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ABSTRACT

This Quarterly Reliability Status Report is submitted in fulfillment of the requirements of Paragraph 7.3 of Reference (a), and is the ninth in a series of reports to be submitted as part of the Reliability Plan.

1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

This report covers the period from 15 March to 15 June 1965. During this report period major effort has been devoted to:

1. Preparation for presentation of LEM development status to the Presidential Scientific Advisory Committee (PSAC) on 5 and 6 May 1965.

2. A continuation of the implementation of the new test logic in most subsystems.

3. A continuation of coordination with GAEC design groups and vendors in developing LTA, early LEM and final LEM configuration equipment.

4. Participation in working group meetings of the Parts and Materials Program Management Panel (PMPMP).

5. Participation in working group meetings of the Spacecraft Reliability Analysis Management Panel (SRAMP).

The updated reliability estimates based on the Design Reference Mission (DRM) shown in the following table.

	Reliability Estimate		Reliability
	This Quarter	Last Quarter	Goal
Mission Success	0.866	0.884	0.984
Crew Safety	0.9968	0.99717	0.9995

The differences in both mission success and crew safety can be attribured to a further decrease in RCS propellant tank reliability. During this quarter there has been a significant increase in mission success and crew safety reliability in the ECS due a refinement in detail of the math model which more realistically treated the ECS functional paths.

1.2 SUMMARY

On 5 and 6 May 1965 GAEC presented to PSAC an updated status of LEM Development. The theme of the presentation was to show where the subsystem redundancies were and how they evolved. The presentation included updated subsystem reliability estimates, critical failure modes and the compensating provisions which were implemented to alleviate these conditions.

In the EPS the all battery power generation section is undergoing early development. Research of every applicable avenue is continuing to increase knowledge and confidence in the all battery system. In conjunction with the above, a change is in process in the ECS Heat Transport Section to keep battery cell case temperature below 100°F for normal operation, and a cell and battery development test program has been initiated which will evaluate battery high temperature performance.

In an effort to improve the reliability of the RCS propellant tanks, reliability has suggested the following:

1. Bladder leakage detection which is essential during lunar stay.

2. Limiting the amount of pre-launch cycling of the bladders.

3. More stringent quality control procedures during fabrication and assembly.

The RCS bladders, which are a common technology item (with NAA) are under development and it is felt that as development and testing procedes reliability improvement will become evident.

During this period effort continued in updating and completing Failure Mode and Effect Analysis to determine single point failures which would result in loss of crew. Among those under investigation is premature actuation of the cable cutter (umbilical) of ascent-descent stage separation system which would result in inability to pressurize the ascent propulsion system.

2.0 PROGRAM MANAGEMENT

During this quarter there have been extensive changes in end-item schedules as a result of incorporating schedule 37. End-item reliability milestone charts, normally in Section 3, have not been updated. This will be performed during the next quarter.

3.0 SYSTEM ANALYSIS

This section describes the LEM System status as of June 15, 1965 and the system level studies and tasks performed during this reporting period. System Milestones Section 3.1 have not as yet been updated to reflect the latest schedule.

3.1 Systems (Contracted End-Item) Milestone Charts

No effort during this report period.

3.2 RELIABILITY MISSION PROFILE

3.2.1 Overall Mission Profile

The contract specification for LEM (LSP-470-1) requires the use of the Design Reference Mission (DRM) developed by the Apollo Mission Planning Task Force as the base profile for the reporting of reliability estimates. The DRM was presented in the previous quarterly report (LPR-550-8, Section 3.2.1).

3.2.2 LEM Developmental Missions

Reliability has been engaged in a joint systems effort with LEM System Analysis and Integration, EPS, and other cognizant groups to establish preliminary equipment operating profiles to support the LEM-1/206A mission analysis. These profiles will be completed during the next quarter contingent upon the receipt and detailed analysis of the new LEM-1/206A mission outline and trajectory.

Reliability continued to supply inputs to support the LEM-2/207B mission analysis.

3.3 RELIABILITY APPORTIONMENTS AND ESTIMATES

Mission Success and Crew Safety apportionments and estimates for each of the LEM subsystems are presented in Tables 3.3.1 and 3.3.2. The reliability

3.3 RELIABILITY APPORTIONMENTS AND ESTIMATES (continued)

estimates are based on the Design Reference Mission. The apportionments that are shown in the table are based on the "Mission Profile for Reliability Estimates", described in previous reliability quarterly reports. A study is underway to evaluate the impact of using the Design Reference Mission as a basis of a complete LEM system reapportionment. This study should be completed early in the next reporting period. Discussed below are the major changes which have occurred in the reliability estimates for the ECS and RCS and possible future modifications of other major subsystem estimates.

3.3.1 Electrical Power Subsystem

There has been no change in the EPS equipment configuration (math model) or the equipment operating profile.

3.3.2 Propulsion

Descent

The ambient versus supercritical helium pressurization configuration decision still remains unresolved. Since the last report a reliability math model was generated and a mission success of .999330 was estimated for the ambient tankage subsystem. This is an increase of .000008 over the supercritical configuration.

Direction has been given to STL to use the DRM profile and GAEC "K" factors. A computation based on this profile is expected early in the next reporting period.

Ascent

During this report period there have been no changes to the reliability estimates of the Ascent Propulsion System. However, several configuration studies were initiated to prevent propellant leakage past the engine solenoid valves from earth launch until pressurization is effected just prior to lunar lift-off.

TABLE 3.3.1

Mission Success Reliability Apportionments and Estimates

Subsystem	Apportionment	8th Quarter Report Estimate	9th Quarter Report Estimate	Remarks
Navigation & Guidance and Stabilization & Control	.990700	.988205	.988205	
Descent Propulsion	.999075	.998764	.998764	Supercritical Helium in 8th & 9th Reports.
Ascent Propulsion	.999961	.998300	.998300	
Reaction Control	.999804	.944117	.919600	Latest Bladder Failure Rate in 9th Report.
Electrical Power	.998600	.963896	.963896	
Environmental Control	.999446	.988865	.994760	Passive ECS During Translunar Coast in 9th Report.
Communications	.99991	.997680	.997680	
Instrumentation & Displays	.999500	.999378	.999378	Estimate Does Not Include Sensors, Signal Conditioners & Displays
Structures	.999950	.999978	.999978	
Explosive Devices	.999980	.999924	.999924	
Crew Provisions	.99999	*	*	* No Estimate Available
TOTAL	.987	.884	.866	

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TABLE 3.3.2

Crew Safety Reliability Estimates

Subsystem	8th Quarterly Report Estimate	9th Quarterly Report Estimate	Remarks
Navigation & Guidance and Stabilization & Control and Communications	.999651	.999651	With Integrated Guidance ATCA
Descent Propulsion Ascent Propulsion	.999399	.999399	
Reaction Control	.999274	.997807	Updated Bladder Failure Rate in 9th Report.
Electrical Power	.999993	.999993	
Environmental Control	.998896	.999994	9th Report Estimate was Based on a Very Detailed & Comprehensive Math Model.
Explosive Devices	.999954	.999954	
Structures	.999999	.999999	
TOTALS	.99717	.99680	

3.3.3 Reaction Control Subsystem

The revised failure rate for the propellant tank bladders has significantly affected the reliability of this subsystem. The failure rate is based on the current Bell estimate of 8400 failures per 10^6 cycles with one operating cycle for a 5.4 hour (Kt) equivalent mission.

Effort was directed towards evaluation of the common usage RCS engine assembly with respect to NAA reliability requirements and their compatibility to LEM apportionment requirements for the engine. Incorporating the NAA apportioned goal of .997 for 1000 seconds of operation per engine assembly into our present math model results in an estimated RCS reliability of .9557 for mission success.

3.3.4 Navigation and Guidance - Stabilization and Control

No change during this report period.

3.3.5 Environmental Control

The reliability estimate for this subsystem has increased from the previous report. This is due to the change in the ECS equipment configuration and equipment operating profiles (i.e., ECS is passive from earth launch to CSM/LEM pre-separation checkout). The present ECS estimate is based on an all GOX configuration. It is expected that the ECS reliability estimates generated during the next quarter may be significantly changed by the expected changes and modifications in the functional equipment configuration (i.e., Heat Transport Section and Oxygen Module).

3.3.6 Instrumentation and Communications

The status of reliability estimates for both the Instrumentation and Communication subsystems has remained constant during the last quarter. Studies have continued in the evaluation of Sensors and Signal Conditions and their impact on success criteria. A reevaluation of the Communications subsystem reliability estimate is necessary in view of the recent configuration change which deletes the C VHF channel and provided additional LEM/CSM range capability

3.3.6 Instrumentation and Communications (continued)

for the B VHF channel. The impact of the possible ascent trajectory change on the S-Band equipments criticality will be evaluated during the next quarter.

3.3.7 Explosive Device

The reliability estimates for this subsystem have not changed from the previous report. The mission success model still considers the landing gear actuation, ascent-descent stage separation, ascent and descent propulsion pressurization and reaction control pressurization mechanisms as serial assemblies. Only the ascent-descent separation and the ascent propulsion pressurization from mechanisms are considered for crew safety.

A squib actuated valve to pressurize the descent engine with supercritical helium is being investigated. One of the problems associated with the supercritical helium system is the temperature initiation of the explosives, the squibs are specified at -260°F and supercritical helium is at -460°F.

Apollo specification and qualification testing for the electrical initiator (MC453-009) are being reviewed for consistency with the LEM environment profile and reliability.

3.4 RELIABILITY MODELING

3.4.1 Mission Success Models

Mission Success reliability models have been developed in detail for the Environmental Control and the Descent Propulsion Ambient Tankage Subsystems. Previously developed models have been reviewed and updated where required on the Navigation and Guidance, Stabilization and Control, Reaction Control,

3.4.1 Mission Success Models (continued)

Electrical Power, Propulsion, Communication, Instrumentation and Structures Subsystems. Studies are continuing on all subsystems in an effort to describe their models at lower assembly levels. The present models reflect subsystem configurations most indicative of current status as of 15 June 1965. The LEM vehicle level three diagrams were used as a basis for the models and where they were not used as in the Electrical Power, Environmental Control, and the Descent Propulsion Ambient Tankage Subsystems, the most up-to-date subsystem configurations were used. The Design Reference Mission, dated 1 November 1964, was considered as a base profile for the description of mission phases in the modeling.

Reliability modeling and estimation techniques have been thoroughly described in previous quarterly reports. The format or procedure used in evaluating and modeling each subsystem consisted basically of three parts: (1) definition of Success Ground Rules, Assumptions, and Abort Criteria, (2) description of the Success Paths and Minimal Cuts and/or Reliability Block Diagrams, and (3) use of Reliability Estimation Techniques such as Computer Programs. The level of detail described in the models has varied with the availability of design detail; i.e., from the level of parts such as valves in propulsion subsystems to the large assembly levels of the Landing Gear Assembly or Caution and Warning Equipment Assembly which still remain to be clearly defined.

3.4.2 Crew Safety Model

A Crew Safety model has been developed in detail for the Environmental Control Subsystem. Previously developed crew safety models have been reviewed and updated when applicable on the other LEM Subsystems. The detailed LEM subsystem crew safety models were not integrated into an over-all LEM system crew safety model during the current reporting period. The Over-all LEM System Crew Safety Model will be generated during a future reporting period.

3.4.3 Computer Programs

The new version of the Lower Bound Reliability Computer Program and other recently generated supporting programs have been used extensively in the reporting period. These programs have been used to generate and update configuration and subsystem reliability estimates utilized in trade-off studies, mission success estimates, crew safety estimates, and reliability apportionment.

The new version of the Lower Bound Reliability Computer Program was described in the previous quarterly report. During the current and future reporting periods the new program will be modified for more efficient and versatile operation.

3.5 CONFIGURATION ANALYSIS AND RELIABILITY TRADE-OFF STUDIES

3.5.1 General

During this report period, five (5) studies requiring systems level analysis, wholly or in part, were completed. They are listed below:

1. Probability of LEM Requiring CSM Rescue
2. Circuit Breaker Allotment-Power Distribution System
3. Sequential Stage Separation - Elimination of Single Point Failures.
4. Checkout and Flight Performance Requirements
5. Early Pressurization of Ascent Propulsion System

3.5.2 Probability of LEM Requiring CSM Rescue

A study was performed to determine what single point failures and associated probabilities during various phases of the nominal LEM mission which would require the initiation of CSM rescue at a 50,000 ft. parking orbit. The single failure conditions requiring initiation of CSM rescue for crew safety and the probabilities associated with these failure modes are detailed in LMO-550-609. Copies of this study have been sent to North American Aviation.

3.5.3 Circuit Breaker Allotment

Effort has been coordinated with Crew Systems, EPS and the subsystems to allocate equipment circuit breakers such that crew safety will be maintained in case of a bus failure without providing a total redundant distribution system. This was accomplished by making use of the functional redundancy of LEM equipments and the split bus arrangement used by EPS. This recommendation was originally initiated by Reliability. Level III Schematics incorporating this plan are presently being reviewed.

3.5.4 Sequential Stage Separation

The design of the Ascent Engine Latching Device (AELD) allows for the criterion that in the event of the need for an immediate abort (using the ascent engine) that the only crew action required would be pushing the "abort stage" button. The pyro batteries are "enabled" by this action and the ascent engine on signal from the AELD initiates the descent stage separation - wiring deadface - cable cutting sequence. The descent staging signal occurs simultaneously with the ascent engine firing. The signal is then delayed for about 60 milliseconds before firing the deadface squib and an additional 100 milliseconds before firing the cable cutting squib. By the time the sequence is completed the ascent engine has developed close to 90% of its nominal thrust. In the event of a single failure in the delay circuitry (or due to some external source) it is possible for the cable cutting to occur before descent stage separation. While this

3.5.4 Sequential Stage Separation (continued)

would constitute a second failure in the abort stage mode (at least one failure was required to elect that mode) it would be a potential single point failure during the nominal lunar lift-off.

Consideration should be given to using the "Stage" button during the nominal mission for separating and deadfacing leaving the cable cutting only to be initiated by the AELD output. Furthermore it is recommended that indication of "Separation" be provided for the crew. The decision to fire the ascent engine will be dependent upon definite separation.

Circuitry configuration minimizing this contingency has been implemented. However, the effects of late deadfacing still exist.

3.5.5 Checkout and Flight Performance Measurements

The study of measurements to be implemented as part of the Telemetry, caution and warning and operational display requirements was continued during the past quarter. Preliminary measurements lists have been developed for a number of the early LEM vehicles and the LEM-10 vehicle. The reliability input to these measurement studies has consisted of an evaluation of the criticality of each measured function so as to determine a ranking of the necessary candidate measurements. Efforts will continue in this area during the next quarter in coordination with System Analysis and Instrumentation groups in order to arrive at optimum measurement lists for each LEM vehicle.

3.5.6 Early Pressurization of the Ascent Propulsion System

A study was undertaken to determine whether there is a need from the point of crew safety to pressurize the Ascent Propulsion System (APS) prior to LEM-CSM Separation. The preliminary findings of this study reveal that pressurization of the APS during LEM-CSM Pre-Separation Checkout would result in a gain in crew safety and the elimination of 3 potential single point failures which could cause loss of crew. These advantages can be achieved at the cost of a small reduction in mission success. The three single point failures eliminated are:

1. Premature firing of cable cutter or deadface squibs after 250 seconds of powered descent. This would prevent pressurization of the APS which would be required for a successful abort.

2. Either isolation squib valve fails to open on the lunar surface or during an abort stage condition. This is a single functional failure caused by a double squib failures.

3.5.6 Early Pressurization of the Ascent Propulsion System (continued)

3. A leak or rupture occurring anywhere between the isolation squib valves and the quad check valves would go undetected from earth launch until pressurization is effected just prior to lunar lift-off or an abort condition.

This study will be continued in detail and the results will be published during the next reporting period.

3.6 LEM FAILURE MODE AND EFFECT ANALYSIS

3.6.1 FMEA Status

During this reporting period two FMEA's were completed, one covering the Descent Propulsion System and the other the Explosive Devices Subsystem. Neither has been released as yet. A few problem areas were brought to light as a result of performing these FMEA's. These problem areas are:

1. Descent Propulsion System (DPS)

   a. During the pre-separation phase the LEM is completely inactive. If the Gaseous Pressurant System is subject to overpressurization rupture due to heat transfer problems, without the ability to monitor system status, there would be no indication of such an impending failure to the crew. For the supercritical helium system, where a precise heat transfer state is required the necessity for active monitoring of the subsystem is obviously more critical.

   b. In general the instrumentation available for the DPS is inadequate in that instrumentation transducer failures will usually generate conditions that will cause unnecessary abort actions.

3.6.1 FMEA Status (continued)

2. Explosive Devices - There exists potential single failure points (inadvertent firing of one squib) on LEM which could cause loss of the crew. These are:

a. Stage Separation Structural - The contingency of snapping opposing bolt due to tension on landing, causing toppling or deforming of remaining bolts, thus precluding proper separation. At present no failure detection method is available.

b. Deadfacer - Deadfacing umbilical AS/DS. Interruption of electrical connections resulting in loss of descent and ascent engine control. Can not cut umbilical cable; can not abort. Loss of crew.

c. Umbilical Cable Cutter - Umbilical cable cut causing total interruption of electrical connections resulting in loss of ascent and descent engine control. Can not separate AS/DS structure; can not abort. Loss of crew.

3.6.2 Previous Reported Problem/Study Areas

A particular problem area uncovered in the performance of the FMEA for the Ascent Propulsion System reported in the last reporting period was the hazard of a potential pressurization leak path occurring and going undetected. This was a potential single point failure which could result in the loss of crew. A study was performed and some methods were found for alleviating this condition, see Section 3.5.6 of this report.

The previous report, LPR-550-8, suggested a study in Section 3.6.2.1.2.a which would determine if the ECS primary glycol cooling loop is required prior to the LEM/CSM Pre-Separation Checkout. During the

3.6.2 Previous Reported Problem/Study Areas (continued)

present reporting period, it was determined that the ECS would be passive (no active cooling supplied) for the last 10 hours of pre-earth launch checkout to LEM/CSM pre-separation checkout.

The previous report, LPR-550-8 suggested a study in Section 3.6.2.1.2.g which would determine if the Primary Navigation and Guidance could be included in the secondary heat transport loop by adding an interconnect between the redundant cooling loop and the portion of the primary loop which contains the primary N&G equipment. The suggested study was not performed during this reporting period due to the change in the ECS configuration and heat transport requirements. It is anticipated that the suggested study will be performed during a future reporting period.

3.7 SYSTEM MAINTENANCE AND CHECKOUT

3.7.1 General

During this reporting period a technique was developed to evaluate the maintainability of each LEM Replaceable Assembly as related to its installation in the LEM vehicle. A form was developed (Assembly Design Analysis) to assist the Maintainability Engineer in investigating all facets of the vehicle installation, checkout, and logistic support. The analysis will evaluate the probability of replacement, replaceability, prelaunch reliability, and spares recycle requirements. Problems uncovered during the analysis will be brought to the attention of the cognizant engineers.

3.7.2 Checkout

Maintainability engineers participated in the review of the LEM Ground Operations Requirements Plan (LPL-610-3C) and the LEM-1 Ground Operations Requirements Plan (LPL-610-4)

3.7.2 Checkout (continued)

Maintainability engineers also participated in the Checkout Working Group meetings for Guidance and Navigation, Radar, and Stabilization and Control.

Investigation was made of prelaunch cooling requirements for certain assemblies which are not in the ECS loop. These assemblies, whose thermal characteristics have been determined by mission profiles, present a checkout problem due to overheating. Attempts are being made to alleviate the ground cooling problem by modification of test procedure, by provision of auxiliary cooling apparatus, or by modification of thermal characteristics.

A study of the considerations of hypergolic loading relative to prelaunch time lines was made to determine the possibility of causing launch delay in the event of failure in this equipment.

3.7.3 Demonstrations

Maintainability engineers observed and/or participated on the following demonstrations:

1. Removal of IMU, PTA and ASA in stacked configuration (M-5).

2. M-3/M-18 demonstration at the Design Interface Meetings at NAA.

3. Descent engine installation in M-4.

A AVO was written (LAV-550-1268) recommending battery installation demonstrations in M-5.

A memorandum (LMO-550-661) was also written recommending demonstration of removal of certain components in the engine well of the descent stage utilizing M-4.

The M-3/M-18 Phase I schedule was evaluated and comments made during a schedule review meeting. A memorandum will be written recommending extending

3.7.3 Demonstrations (continued)

the use of M-3/M-18 by demonstrating certain unscheduled maintenance tasks as part of Phase II of the M-3/M-18 evaluation.

3.7.4 GSE Maintainability

Grumman Maintainability personnel met with NAA Maintainability personnel at Downey, California on May 20, 1965 to discuss the Maintainability and Operational Readiness Programs and the techniques used. Discussions included the subjects of Design Review, Data Collection and Output Data. Grumman Maintainability is currently refining its program to be compatible with the NAA Program.

A visit was made to WSO, on May 21, 1965 to review the maintainability problem areas on the test equipment. The basic problem was accessibility to failed components for replacement. In some cases this was augmented by improper preparation which created hazardous conditions for the maintenance technicians.

Maintainability Analyses are being performed on MEE end items on a preliminary basis. Only equipment layout drawings and schematics are available at this time. Design recommendations based on these drawings will be followed up as the formal drawings are developed.

3.7.5 Operational Readiness

A technique is being developed which will determine the probability of success for the Mission Essential Equipment for (0) to a maximum of (5) failure occurrences. It is based on the checkout test operating times, countdown sequence interval, and failure rate. This will enable maintainability to determine the equipments which are most critical to launch success.

3.7.5 Operational Readiness (continued)

GSE Maintainability personnel discussed Operational Readiness with NAA personnel as mentioned in Section 3.7.4. The Grumman program is being revised to incorporate refinements in technique which resulted from the discussions. The Operational Readiness Analysis will be primarily concerned with equipment replacement times. Component replacement time requirements will be considered when they are less than those for equipment replacement. These maintainability factors will be computed with the times available at ($\frac{1}{2}$) hour intervals from T-72 to T-0. The results will be a probability of Operational Readiness success during the prelaunch countdown.

A letter has been sent to NASA (LLR-550-87) listing the estimated times to replace the Mission Essential Equipment on the launch pad during countdown. In order to meet a ($2\frac{1}{2}$) hour launch window the majority of the equipment was recommended to be placed in Category 2, Near-Place Redundant. The equipment that can not be replaced in (12) hours or less was recommended to be placed in Category 1, In-Place Redundant. The time estimates are of a preliminary nature and further study will be conducted to verify these figures.

3.8 RELIABILITY ASSESSMENT

A reliability assessment plan (Quantitative Success Index) has been developed by MSC and submitted to GAEC Reliability for review. This plan includes method and ground rules use of data criteria, implementation explanation of derating factors (configuration and environmental) and the failure criteria to be used for the assessment. This plan has been reviewed and listed below are the major GAEC comments submitted to MSC.

1. Success Index (SI) system distorts assessment at DVT which is a most important time for comparision decisions. SI system results in very

3.8 RELIABILITY ASSESSMENT (continued)

1. (continued)

   optimistic estimates at a point in the program where over optimism is not desirable.

2. There is no tie-in between qualitative and quantitative assessment.

3. Unresolved failures needs considerably more clarification.

4. Criteria for inclusion or exclusion of failures and time needs further details and specifics.

5. GAEC prefers upper and lower estimates rather than point estimate. Upper would include only unresolved failures; lower includes all failures.

6. A study should be performed to determine the appropriate configuration and environment derating factors.

3.9 LEM RELIABILITY COMPUTER PROGRAM

The development and operation of the LEM Reliability Computer Program (LRCP) continued as described and planned in previous quarterly reports. Production efforts continued mainly in the failure data recording area and development and checkout procedures were carried out for the parts, testing, maintainability and operating time data collection programs.

The development of an operational program to store data which could be retrieved for a Qualification Status Test (QSL) did not follow the pattern presented in the last Quarterly Report LPR-550-8. A series of meetings were held with MSC-ASPO to determine the final field contents and relative locations for the QSL format. A decision was made to proceed with a TID input format as shown in Figure 1. The intent of this

3.9 LEM RELIABILITY COMPUTER PROGRAM (continued)

program is to present a QSL that contains both LEM parts and equipments. This, of course, changed the existing plans to generate a separate QSL from the Parts Control Program (PCP) and another from the Test Identification Program (TID) and it also created a dual data submittal requirement for the LEM reliability parts group. Nevertheless, as the input format shows, it will be possible to get from the TID program either a composite QSL or separate parts and equipment lists. The scope of the reprogramming effort to modify the TID program is indicated by a comparison of the format shown in Figure 1 and the input transmittal sheet previously submitted in Quarterly Report LPR-550-6 MSC data codes will be used where required for specific field entries. It is planned to resolve the encoding problem in the manner now employed for the failure data system. As data is transcribed from LEM Test Plans to the computer transmittal sheets, appropriate encoding will be done by the reliability test assurance group and the reliability parts group. All inputs will be retained in the data files in coded form and look-up tables will be referenced to provide decoded data for LEM internal format requirements. Data sent to MSC will be in coded form. Furthermore, it is possible to stipulate the inclusion of a specific item on the QSL even though the test it is undergoing is not strictly defined as a qualification test. This capability was provided after discussions with the LEM Reliability Assurance Test group and MSC indicated that such versatility would be desirable.

The programming task to incorporate the input format of Figure 1 in the LRCP has commenced. It remains to decide how the QSL will be sent to MSC i.e., via computer magnetic tapes or as an output format. The submission schedule for the QSL also must be established.

The failure data computer programs have continued to function in an operational mode. Failure data tapes have been sent to the Apollo Failure Information

Card	Card Column	Field Name	Field Width	Remarks
1	7-26	Part Number	20	
	27-46	Part Name	20	
	47-66	Test Plan Number	20	
	67-72	Test Plan Date	6	
2	7-26	Vendor Part Number	20	
	27-31	Vendor	5	Code H4-1
	32	Part or Equipment Code	1	
	33-37	Test Responsibility	5	
	38-39	Overall Test Status	2	Code Ø
	40-45	Scheduled Test Start Date	6	
	46-51	Scheduled Test Completion Date	6	
	52-57	Actual Test Start Date	6	
	58-63	Actual Test Completion Date	6	
	64-69	Required Date	6	
3	7-26	Equipment Number	20	
	27-46	Equipment Name	20	
	47-49	Test Type	3	Code Ø
	50	Type Qualification	1	
	51	Data Source	1	Code J
	52-54	Criticality	3	Code B
	55-58	Number of Units Being Tested	4	
	59	QSL Item	1	
	60	GSE/Flight Indicator	1	
4	7	Index of Test Report	1	
	8-27	Test Report Number	20	
	28-33	Test Report Date	6	
	34-35	Index of Effectivity	2	
	36-51	Effectivity	16	
	52-72	Test Locations	21	Code A, Groups of 3
5	7-69	Serial Numbers	63	Groups of 7
6	7-72	Sub Test and Status	66	Code F1, Groups of 3

FIGURE 1

Test Identification Input Format

Card	Column	Field Name	Field Width	Remarks
7	7	Multiple SS Indicator	1	
	8-70	Subsystem Names	63	Groups of 3
8	7-66	Failure Reports	60	Groups of 10
9	7-66	Associated Test Plan Number	60	Groups of 20
10	7-72	Narrative	66	From 1 to 4 Cards

FIGURE 1 (continued)

Test Identification Input Format

3.9 LEM RELIABILITY COMPUTER PROGRAM (continued)

Bank each time that the LEM central failure files have been updated. The system of failure data processing described in previous quarterly reports, has been operating in a satisfactory manner. This has served as a successful trial procedure for other sections of the LRCP whose production requirements will require a similar processing system. It has been found expeditions to revise the transmittal form for the failure data program as shown in Figure 2. This revision has not affected the integrity of the computer program and was intended only to facilitate the data processing activity. To date, no unusual difficulties have been encountered by the Apollo Failure Data Bank in the updating of their records with LEM failure data. Every attempt has been made at GAEC to assure the validity of the data sent to MSC both in form and in content. The regular data processing checks have been complemented by the updating of the LEM failure data files and a final search of the files for checking purposes before this information group is forwarded to MSC.

It was noted that some of the original field sizes for the failure data program could be expanded to ease present and future constraints. For example, the field size for all report numbers in the failure programs preferably should be expanded to eighteen characters. The preliminary list of proposed field size changes which was presented to MSC for consideration was composed of the following items:

Field Name	Field Size (cc) Present	Proposed
Part Number	20	24
Failure Report Number	10	18
Part Lot or Serial Number	7	12
NHA Lot or Serial Number	7	12
Associated Failure Report No.	10	18
Failure Analysis Report No.	12	18
Corrective Action Report No.	12	18

GAEC was requested to delay program modifications of this type until MSC has had an opportunity to evaluate the effects of our proposed changes on the MSC central failure data system. It is expected that the requested changes will be acted upon during the coming quarter.

KEYPUNCHING INSTRUCTIONS: Keypunch Card Only When There Is Information Between Col. 5 & 79

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
LEM RELIABILITY COMPUTER PROGRAM
FAILURE DATA TRANSMITTAL SHEET

FIGURE 2

PREPARED BY: F. R. F. A. C. A.

DATE & EXT: X X X

FAILURE REPORT

CODES

NUMBER 1 CARD (1 2): PART NUMBER | PART NAME | FAILURE REPORT NUMBER | EVENT DATE YR. MO. DA. | REPORT DATE YR. MO. DA. | # ASSOC. F. R. CARDS ■ | N. C. | SEQUENCING

NUMBER 2 CARD (2 2): PART VENDOR Ⓧ | PART LOT OR SERIAL NUMBER | PART REFERENCE DESIGNATOR | GSE FLT. | VENDOR PART NUMBER | FAILURE SITE *A | F. REP'T SOURCE Ⓧ

NUMBER 3 CARD (3 2): NEXT HIGHER ASSEMBLY NUMBER | NEXT HIGHER ASSEMBLY NAME | NEXT HIGHER ASSEMBLY REFERENCE DESIGNATOR | NHA LOT OR SERIAL NUMBER

NUMBER 4 CARD (4 2): SUBSYSTEM NUMBER | SUBSYS. NAME *R | SYSTEM NAME

ASSOCIATED FAILURE REPORT NUMBERS (10 COLUMNS PER FAILURE REPORT NUMBER)

NUMBER 5 CARD (5 2)

NARRATIVE CARDS (6 2 / 6 2 / 6 2 / 6 2): 1 2 3 4

FAILURE ANALYSIS

NUMBER 1 CARD (1 3): PART NUMBER | PART NAME | FAILURE ANALYSIS REPORT NUMBER | F.A. REPORT DATE YR. MO. DA. | N. C.

NUMBER 2 CARD (2 3): TEST TYPE * S | ENVIR TYPE *F | ENVIRONMENT DEGREE | TEST PLAN NUMBER | TEST REPORT NUMBER | FAILURE REPORT NUMBER

NUMBER 3 CARD (3 3): FAILURE DURING * S | FAILURE SYMPTOM *H | FAILURE MODE * M | FAILURE CAUSE * G | FAILURE DISP * D | ELAPSED TIME FAILED PART * L | CORRECTIVE ACTION REQUEST NUMBER | FAILURE CLASS * B | ACTION TAKEN * D | FAILURE ANALYSIS REPORT SOURCE Ⓧ | ◆ F.A. REC COR ACT. * U | HUMAN FACT.1 * HF 1 | HUMAN FACT.2 * HF 2 | HUMAN FACT.3 * HF 3

NARRATIVE CARDS (4 3 / 4 3 / 4 3 / 4 3): 1 2 3 4

CORRECTIVE ACTION

NUMBER 1 CARD (1 4): PART NUMBER | PART NAME | CORRECTIVE ACTION REPORT NUMBER | C.A. REPORT DATE YR. MO. DA. | # ASSOC. F. R. CARDS ■ | N. C.

NUMBER 2 CARD (2 4): C.A. RESPONSIBILITY ● | C.A. REQUEST DATE YR. MO. DA. | C.A. DUE DATE YR. MO. DA. | C.A. COMPLETION DATE YR. MO. DA. | C.A. EFFECTIVE DATE YR. MO. DA. | CORRECTIVE ACTION EFFECTIVITY | CORRECTIVE ACTION STATUS

ASSOCIATED FAILURE REPORT NUMBERS (10 COLUMNS PER FAILURE REPORT NUMBER)

NUMBER 3 CARD (3 4)

NARRATIVE CARDS (4 4 / 4 4 / 4 4 / 4 4): 1 2 3 4

CODING INSTRUCTIONS

1. Alphabetical characters are written as follows: A B C D E F G H I J K L M N Ø P Q R $ T U V W X Y Z
2. Numerical characters are written as follows: 1 2 3 4 5 6 7 8 9 0
3. Write clearly so that a minimum of deciphering is required at keypunching and verifying time.
4. Column 1 — Card Number
5. Column 3 — Program I.D. Codes
   2 — Failure Reporting
   3 — Failure Analysis
   4 — Corrective Action
6. Column 5 — Transaction Codes
   1 — Addition
   2 — Deletion
   5 — Change
7. NC — Number of Narrative Cards to be read
8. ■ # Assoc. F. R. Cards — Number of Associated Failure Report Cards
9. Ⓧ — See H4-1
10. GSE/FLT — Ground Support Equipment/Flight Indicator For GSE enter G. for Flt. enter F. for both enter B.
11. * — MSC Codes
12. ◆F.A. Rec. Cor. Action — Failure Analysis Recommended Corrective Action
13. ● H4-1/GAEC Dept. Code

ENG 375.1A 4-65

3.9 LEM RELIABILITY COMPUTER PROGRAM (continued)

A program also is underway to revise the input formats for the parts control program. The limited version of the program, which has been in operation for some time, has served its intended purpose of validating programming techniques, storing and retrieving limited quantities of parts data, and permitting cursory evaluation of data output formats. The same basic concepts will be retained in the operational PCP including the processing of data in a manner amenable to the production of selective where-used lists, top-down breakdowns and reliability parts listings. However, although the present PCP formats reflect the periodic requirements that have existed for a separate parts qualification listing, the input revisions will be made with the latest definitions concerning the QSL in mind. The implication here is that in addition to supplying input directly to the PCP, the LEM parts group will prepare test data on transmittal sheets for the TID program. The integrated characteristics of the LRCP will permit the amplification of parts test data with desired parametric data.

Several meetings were held with MSC to discuss the requirements, design, and input contents for the LEM operating time data recording program (OT). A presentation was made at the second meeting of the Data Systems and Use History working group (PMPMP) of the OT computer program requirements and design. The significant points made during this presentation were:

1. The OT computer program has a design compatibility requirement with the LEM operating time data recording system.

2. The programming for the OT program has been completed.

3. The OT input format exists in the form shown in Figure 3.

4. The integrated character of the LRCP will allow tests, failure, or maintainability data associated retrieved and correlated.

Card	Card Column	Field Name	Field Width	Remarks
1	7-26	Part Number	20	
	27-46	Part Name	20	
	47-50	Equipment Log Number	4	
	57-62	Log Entry Date	6	
2	7-13	Part Serial Number	7	
	14-25	Part Reference Designator	12	
	26-32	Time/Cycle Indicator Serial No.	7	
	38-42	Application Life	5	Code L
	43-47	Present Reading	5	Code L
	48-52	Limited Life	5	Code L
	53-55	Subsystem Name	3	Code R
	56-67	Subsystem Serial Number	12	

FIGURE 3

Elapsed Time Input Format

3.9 LEM RELIABILITY COMPUTER PROGRAM (continued)

Further discussions with MSC revolved around the possible expansion of the number of fields in the OT program to include details concerning environments and test conditions encountered during the recording of the operating times. MSC also expressed a desire to relate properly factored operating times to piece parts in the equipments for which operating time records are kept. However, these discussions have not reached a definitive state and direction for program revisions have not been received. The most efficient way of sending elapsed time data to MSC and the schedule for submittal of this information remain to be determined.

The transmittal sheet for the maintainability section of the LRCP is being completed so that a proper program shakedown can be initiated. The program design, as part of the LRCP has been completed. The input format for this program is shown in Figure 4.

In conjunction with the development and operation of the LRCP, the effort to establish an automated interface with subcontractors for the exchange of parts approval data has been continued. The approval task involving more than six thousand parts which was begun at the end of the last reporting period was completed by supplementing the tape returned to the vendor with a complete parts list grouped by approval status. The intent is to process all such data directly into the PCP via an intermediate transposition program.

3.10 SPECIAL EFFORTS AND REPORTS

During this reporting period, Reliability supported and made contributions to some general LEM efforts not reviewed in Sections 3.1 through 3.9. For example, there was participation in a meeting held at MSC pertaining to the Spacecraft Analysis Reliability Panel and in another meeting at North American Aviation, Downey, California which was concerned with

Card	Column	Field Name	Field Width	Remarks
1	7-26	Part Number	20	
	27-46	Part Name	20	
	47-58	Maintainability Analysis Report Number	12	
	59-64	Number of MA Narrative Cards to be Read	1	
2	7-18	Part Reference Designator	12	
	19-28	Equipment Log Number	10	
	29-33	Part Elapsed Time	5	
	34-38	Diagnostic Time	5	
	39-43	Repair Time	5	
	44-48	Verification Time	5	
	49-55	Replacement Part Serial/Lot Number	7	
	56-60	Replacement Part Vendor	5	Code H4-1
	61	Maintainability Environment	1	
	62	Maintainability Action Vehicle	1	
	63	Verification of Complaint	1	
	64-66	Insp. M/H Verification	3	
	67-70	Insp. M/H Repair/Test	4	
3	7-72	Maintainability Analysis Narrative	66	From 1 to 4 Cards

FIGURE 4

Maintainability Analysis Report Input Format

3.10 SPECIAL EFFORTS AND REPORTS (continued)

negotiating the relative Interface Control Documentation (ICD). These matters as well as the analysis of and reply to the MSC review of the Potential Single Point Failure Analysis, LED-550-40 are discussed below.

3.10.1 Interface Control Documentation (ICD)

Reliability has the responsibility for reviewing all ICD's concerning any interface between the CSM of North American Aviation (NAA) and LEM of GAEC. (Other interfaces such as those between GAEC and Hamilton Standard are also reviewed). Upon direction of NASA an ICD negotiation meeting was held at NAA throughout the week starting June 14, 1965, and at GAEC on June 24 and 25, 1965. These meetings were attended by reliability personnel and wherever necessary reliability considerations were discussed and when applicable incorporated into the governing documents. In particular, discussions relative to definitions of such terms as "Mission Success" and "abort" pertaining to the "Mission" ICD were held.

3.10.2 Summary of Single Point Failures

The "Potential Single Point Failure Analysis", LED-550-40, dated 12-1-1964 was reviewed by MSC and their comments and criticisms were received by GAEC Reliability on May 19, 1965. The most often repeated criticism by the individual subsystem reviewers at MSC was the suggestion that the hardware level used in the report was too gross. In addition, a format which includes the probability of occurrence of the single point failure as a column entry was recommended. The MSC document, Reference PR-23-65-402 also reviewed each subsystem from the point of view of single point failure potential.

3.10.2 Summary of Single Point Failures (continued)

It is acknowledged that the level of schematic diagrams used in the LED-550-40 report was gross. However, no more detailed information was available at the time. Updating of that document is continuing and a revised report will be released during the following reporting period. (Greater detailed schematics will be used wherever available.)

4.0 SUBSYSTEM - GENERAL

4.0.1 Elapsed Time Indicators

During this period the program for the use of elapsed time indicators was further implemented. Table 4.0.1 presents the updated list of LRE's upon which operating times will be recorded by ETI's. Electro-chemical type ETI's will be permanently installed on the listed LRE's while electro-mechanical ETI's will be mounted on the GSE handling fixtures for more accurate reading of operating times prior to installation of the equipment in LEM's or LTA's. The qualification tests on the electro-chemical ETI's is currently in progress at the Curtis Instrument Inc.

Preliminary procedures and related forms have been developed in coordination with Quality Control for logging the operating time on the ETI's and transmitting the data to the Reliability EDP area. A trial run of the program is anticipated during the next period.

4.0.2 LEM Failure Rates

During this period a report (LED-550-58) was issued listing failure rates which have been coordinated with vendors, or are being presented to vendors for use on the LEM equipments. The use of failure rates which are consistent provides a tool for reviewing the LEM subsystems on a compatible basis.

The failure rate data will be revised as additional or more accurate information becomes available. It is anticipated that a revision of the report will be prepared during the next period.

4.0.3 Derating ("K") Factors

The rationale for the "K" factors used in reliability estimate calculations for the LEM subsystems has been discussed in numerous meetings with vendors. It was also reviewed during one of the meetings with the Presidential Scientific Advisory Committee (PSAC). A memo explaining the basis for the "K" factors is being prepared and will be issued during the next period.

TABLE 4.0.1

ELAPSED TIME INDICATOR INSTALLATION LIST

Specifications	Equipments
Stabilization & Control	
LSC-300-13	Descent Engine Control Assembly
LSC-300-14	Attitude & Translation Control Assembly
LSC-300-33	Abort Electronics Assembly
LSC-300-37	Abort Sensor Assembly
LSC-300-11	Rate Gyro Assembly
LSC-300-71	Program Coupler Assembly
LSC-300-72	Program Reader Assembly
LSC-300-39	Data Entry & Display Assembly
Reaction Control	
LSC-310-5	Quantity Gaging
Environmental Control	
LSC-330-118	Suit Circuit Fans
LSC-330-201	Coolant Pumps
Displays and Controls	
LSC-350-301	Attitude Indicator
LSC-350-302	Gimbal Angle Sequence Transformation Assembly
Instrumentation	
LSC-360-2	PCM/TEA
LSC-360-5	Signal Conditioning Electronics Assembly
LSC-360-8	Caution & Warning Electronic Assembly
Navigation and Guidance	
LSC-370-2-7	Rendezvous Radar ERA
LSC-370-2-10	Rendezvous Radar Antenna Assembly
LSC-370-2-8	Transponder ERA
LSC-370-2-9	Landing Radar ERA
LSC-370-2-11	Landing Radar Antenna Assembly

TABLE 4.0.1 (continued)

ELAPSED TIME INDICATOR INSTALLATION LIST

Specifications	Equipments
Communications	
LSC-380-2-1	S-Band Transponder ERA
LSC-380-2-5	VHF ERA
LSC-380-2-7	Signal Processor ERA
LSC-380-203	S-Band Power Amplifier & Diplexer ERA
(Part of Antenna)	Steerable Antenna ERA
Electrical Power	
LSC-390-6	Inverter
LSC-390-25	ECA (Ascent)
LSC-390-26	ECA (Descent)

4.1 PROPULSION SUBSYSTEMS

4.1.1 Subcontractor Status and Milestones

Tables 4.1.1.1 and 4.1.1.2 indicate the program status and milestones for LEM main propulsion engine contractors.

4.1.2 Propulsion Subsystems Summary

4.1.2.1 Summary of Effort for Period

Monitoring of engine subcontractors, and pressurization and feed system vendors continued during the period. A great number of Type I and II documents were received from feed and pressurization system component vendors.

Compilation of data to provide reliability support during the GAEC/NASA negotiations conducted at GAEC during March and preparation for and participation in the redirected program negotiations with engine vendors comprised the major reliability effort during this report period.

In addition, the problem of fuel loss through the solenoid control valves for the bi-propellant isolation and shut-off valves, has been the subject of considerable study regarding both main propulsion engines.

A reliability estimate of the ambient helium storage configuration has been prepared and is listed in Table 4.1.3.

4.1.2.1 Summary of Effort For Period (continued)

A study of valve designs employed in all applicable LEM subsystems was initiated during this report period.

STL Reliability Report 8438-SC000 (dated March 10, 1965) was received and reviewed during the period. This report is a complete updating of the reliability estimate for the descent engine computed to the

4.1.2.1 Summary of Effort For Period (continued)

specification duty cycle. Contract negotiations were completed in April with Stewart Warner (heat exchanger) and Titeflex (flexible hose).

4.1.2.2 Projected Effort For Next Period

During the next reporting period, the study of valve designs utilized in the LEM Propulsion subsystems will continue.

Increased emphasis will be placed on the area of failure reporting and corrective action, as well as design problem follow-up.

Update Ascent and Descent Propulsion system FMEA's as necessary.

A complete reliability evaluation of the control electronics on the descent engine is planned.

4.1.3 Reliability Apportionments and Estimates

A reliability estimate for the ambient helium storage configuration of the descent propulsion subsystem was prepared utilizing the AMPTF Design Reference Mission (Reference LED-540-12, dated 30 October 1964) and is now included in Table 4.1.3.

STL Reliability Report 8438-SC000 (dated 10 March 1965) was received and reviewed. This analysis is a complete updating of the descent engine reliability estimate; however, it was computed using the engine duty cycle rather than the Reliability Mission Profile. In addition, the GAEC prescribed K Factors were not used. A recomputation to the prescribed mission profile and K Factors is expected in the next period.

4.1.4 Reliability Mathematical Models

4.1.4.1 GAEC Models

The GAEC mathematical models of the propulsion propellant feed systems have not been revised during this report period.

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.1.1.1

BELL AEROSYSTEMS COMPANY ASCENT ENGINE

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan			◪		○															
Reliability Status Report			●	●	●	●	○	○	○	○	○	○	○	○	○	○				
Apportionments and Estimate			●	●	●	●	○	○	○	○	○	○	○	○	○	○				
Math Model			◪	○	◪	○	○	○	○	○	○	○	○	○	○	○				
Configuration Analysis			○	○	◐	●	○	○	○	○										
Failure Mode and Prediction Analysis			◪	○	○	○	○	○	○	○										
Failure Effect Analysis			●	●	●	●	○	○	○	○										
Maintainability Analysis			●	●	●	●	○	○	○	○										
Design Review			NOT FORMALLY SCHEDULED																	
Design Review Documentation			- SEE ABOVE -																	
Circuit Analysis			○		●	○	○	○	○	○										
Reliability Data List			◪		◪		○	○	○	○	○	○	○	○	○					
NPPAR			◪																	
Reliability Test Plan			DELETED																	
Reliability Assessment																				
Failure Reports and Corrective Action			●	●	●	●	○	○	○	○	○	○	○	○	○					
Failure Analysis			●	●	●	●	○	○	○	○	○	○	○	○	○					
Reliability Indoctrination and Training																				

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABULATION FORM

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.1.1.2

SPACE TECHNOLOGY LABORATORIES, INC./VARIABLE INJECTOR DESCENT ENGINE

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan	◐	●																		
Reliability Status Report		●	●	●	●	●	○	○	○	○	○	○	○	○	○					
Apportionments and Estimate		●	●	●	◪	●	○	○	○	○	○	○	○	○	○					
Math Model		●	●	●	●	●	○	○	○	○	○	○	○	○	○					
Configuration Analysis		●	●	●	○	●	○	○	○											
Failure Mode and Prediction Analysis			●	●	○	○	○	○	○											
Failure Effect Analysis			●	●	●	◐	○	○	○											
Maintainability Analysis		●	●	●	●	○	○	○	○											
Design Review	NOT FORMALLY SCHEDULED																			
Design Review Documentation			- SEE ABOVE -																	
Circuit Analysis		●	●	●	●	●	○	○	○											
Reliability Data List		●	●	●	○	○	○	○	○	○	○	○	○	○	○					
NPPAR																				
Reliability Test Plan	DELETED																			
Reliability Assessment																				
Failure Reports and Corrective Action		●	●	●	●	●	○	○	○	○	○	○	○	○	○					
Failure Analysis		●	●	●	●	●	○	○	○	○	○	○	○	○	○					
Reliability Indoctrination and Training																				

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABULATION FORM

TABLE 4.1.3

Reliability Apportionments and Estimates

Equipment	Apportioned	Estimated
Ascent Propulsion Subsystem	.999961	.998300
Ascent Engine	.999982	.999128
Propellant Pressurization and Feed Subsystem	.999979	.999172
Descent Propulsion Subsystem (Supercritical Helium)	.999075	.998764
Descent Engine, Variable Injector, (STL)	.9991	.999442
Propellant Pressurization and Feed Subsystem	.999975	.999322
Descent Propulsion Subsystem (Ambient Helium)	.999075	.998772
Descent Engine, Variable Injector, (STL)	.99991	.999442
Propellant Pressurization and Feed Subsystem	.999975	.999330

4.1.4.2 Vendor Models

Revision of the ascent engine mathematical model by Bell Aerosystems Company expected during this reporting period was not received. This revision has been delayed pending a decision regarding a proposed design change for the problem of leakage through the engine solenoid valves. (Reference Para. 4.1.5.2).

The reliability meeting held at BAC at the close of the previous reporting period had the desirable effect of focusing attention on a design deficiency having considerable effect on engine reliability. Examination of the engine mathematical model clearly shows the large unreliability contribution of the engine solenoid valves, when exposed to propellant at tank storage pressure for the entire LEM mission.

4.1.5 Configuration Analysis

4.1.5.1 Configuration Analysis - GAEC

There has been no formal documentation of pressurization feed system configuration analyses completed during this period.

The problem of engine solenoid valve fuel leakage is still under study.

4.1.5.2 Configuration Analysis - Vendors

Bell Aerosystems Company - Results of configuration analyses performed involving five different configurations providing isolation between the engine solenoid valves and the fuel actuation force were presented in the April Reliability Status Report 8258-932072. Trade-off considerations involved reliability, development time, cost, electrical power, electrical power sequence switching, weight, and possible contingency modes of operation.

Space Technology Laboratories - A configuration analysis of the Throttle Actuator was presented in Report 8438-6242-SU000 dated April 10, 1965. Four different configurations were studied in connection with redesign of electronic dircuitry. The redesign greatly reduces the probability that two or more

4.1.5.2 Configuration Analysis - Vendors (continued)

Space Technology Laboratories (continued)

motors could develop counteracting torques. In addition, the motor drive bridge circuits were redesigned to prevent inadvertent application of driving voltage to any motor as a result of a single component part failure. The configuration selected for further development has three motors and three amplifiers with benefits of decrease in weight, volume and power consumption.

Engine shut-off valve solenoids have been under study by STL. Means are being considered for eliminating the single point leakage path of fuel past the solenoid valve to the overboard vent by use of a plenum chamber or a plenum chamber with a sized orifice.

4.1.6 Failure Mode and Effect Analysis

Revisions to accomplish updating of main engine vendor Failure Effect Analyses have been received from Bell Aerosystems and Space Technology Laboratories. In addition, Failure Effect Analyses have been received from several of the pressurization and feed subsystem component vendors. The GAEC effortduring this period has been limited to review of vendor submittals. The status of these submittals is shown on Tables 4.1.1.1 and 4.1.1.2.

4.1.7 Failure Mode Prediction Analysis

4.1.7.1 Pressurization and Feed System

During the report period seven (7) Failure Mode Prediction Analyses were received and evaluated. Table 4.1.7 summarizes the evaluation status for the seven (7) items.

TABLE 4.1.7

Failure Mode Prediction Analysis

Vendor	Equipment	Evaluation	Status
Schulz Tool	Coupling, Helium LSP-270-813A	LAV-278-104 3-22-1965	Approved
Pelmec	Valve, Helium Explosive LSP-270-714 & -819	LAV-278-179 5-28-1965	Approved
Aircraft Porous Media	Filter, Helium LSP-270-814A	LAV-278-165 5-2-1965	Disapproved
Aircraft Porous Media	Filter, Oxidizer LSP-270-808A	Comments 5-19-1965	Approved
Aircraft Porous Media	Filter, Fuel LSP-270-807A	Comments 5-19-1965	Approved
Sterer	Valve, Helium, Pressure Reducing LSP-270-715A	LAV-550-479 4-12-1965	Disapproved
Sterer	Valve, Helium, Pressure Reducing LSP-270-816A	LAV-550-479 4-12-1965	Disapproved

4.1.8 Maintainability Analysis

4.1.8.1 GAEC Effort

A demonstration is planned to determine the capability of performing maintenance on a LEM vehicle installed in the SLA. Data developed during this demonstration will support the submission of design recommendations to alleviate or eliminate constraints on the performance of maintenance. The time period considered will be from T-68 days (Ascent and Descent Stages mated in the SLA) to launch. Categories of contingencies will include leakage and replacement of failed or suspect components.

LMO-550-621 was submitted to present recommendations which evolved from a maintainability evaluation of the ascent propellant pressurization section. The evaluation was made to review system design features and to highlight weaknesses in design and replacement philosophy which would have adverse effects on the performance of corrective maintenance during prelaunch checkout phases. Recommendations were made to separate the current module into two (2) separate groupings which would lessen the number of interconnections disturbed during replacement, lessen revalidation times and permit removal of each separate grouping rather than a complete module. An additional recommendation was to provide one (1) electrical connector for the module in place of the current three (3) connectors. A study was recommended to determine if the current right and left hand modules can be made physically interchangeable by reorientation of several components.

4.1.8.2 Vendor Effort - Ascent Engine

Follow-up activities were conducted on the test engineer and technician interview program described in LPR-550-8. These activities resulted in submittal of the following recommendations:

1. Establish a special tool requirements list to eliminate assembly or test delays and equipment damage from use of improper tools.

2. Extend the thrust chamber pressure fixture valve stem to provide improved accessibility during use.

3. Clarify acceptance test procedures by standardizing nomenclature and abbreviations, and improving its readability.

4. Redesign Valve Assembly 8258-472225 to extend the fuel outlet manifold flange to a more accessible position. This will provide ease of tube alignment and simplify flange bolt installation.

4.1.9. Design Reviews

A summary of the design review activity during this report period is included on Table 4.1.9.

4.1.10 Circuit Analysis

The STL Descent Engine analysis effort is described in 4.1.5 Configuration Analysis. There has been no other significant activity by vendors during this period. There has been no significant GAEC effort during this reporting period.

4.1.11 Reliability Data Lists

Three (3) component vendor RDL's were received during this period. One (1) was approved and two (2) are in review. There was no significant activity with STL and Bell during this reporting period.

TABLE 4.1.9

Propulsion Subsystem Design Review Status

Item	Specification	Vendor	Design Review Date	Design Review Type	Document
Tank Helium Storage Ascent	LSP-270-711	Airite	4-6-1965	Conceptual	LMN-278-10
Tank Helium Storage Descent	LSP-270-811	Airite	4-7-1965	Conceptual	LMN-278-10
Coupling, Helium Fill & Test Disconnect	LSP-270-813A	Schulz Tool Mfg. Co.	4-8-1965 4-9-1965	Preliminary	LMM-278-9
Hose Assembly Metal, Flexible	LSP-270-809	Titeflex	4-15-1965	Conceptual	LAV-277-104
Hose Assembly Metal, Flexible	LSP-270-809	Titeflex	4-19-1965	Negotiation	LAV-277-104
Bi-Propellant Valve, Engine Ascent	LSP-270-5A	BAC	5-3-1965 5-14-1965	Tech. Mtg.	LMO-550-645
Bi-Propellant Valve, Engine Descent	LSP-270-4A	STL	6-3-1965	Tech. Mtg.	LMM-271-16
Combustion Chamber, Engine Descent	LSP-270-4A	STL	6-2-1965	Tech. Mtg.	LMM-271-16
Combustion Chamber, Engine Descent	LSP-270-4A	STL	6-8-1965 6-9-1965	Tech. Mtg.	LMM-271-16

4.1.12 Non-Preferred Part Approval Request Status

There has been no effort required during this report period.

4.1.13 Reliability Test Program

4.1.13.1 Bell Aerosystems

4.1.13.1.1 HA-2/BA-2 Testing

Phase I testing was completed in April on the Grumman supplied HA-2 feed system rig. The concluding test, a total impulse "blow-down" firing was conducted without incident. The Grumman supplied breadboard pressurization system BA-2 for the HA-2 rig was received at Bell on April 30, 1965. Thirteen short duration engine firings have been conducted with the HA-2/BA-2 rig. All data obtained to date indicates that the rig system is operating satisfactorily.

4.1.13.1.2 Injector Stability Tests

Injector stability testing resumed June 9, 1965. The initial plan was to subject B8-L1B injector with $1\frac{1}{4}$" full Y uncoded baffles to a series of detonator tests at nominal and low O/F mixture ratios. However, the injector failed to recover during the initial nominal firing of the series. Testing was then switched to the B3-L4A injector with the same baffles. The injector was subjected to three detonator tests and it recovered successfully during all three tests. Prior to testing again with the B8-L1B injector, the baffle legs were lengthened to eliminate the gap between the baffles and the chamber wall. The injector with the modified full Y baffles was then subjected to a series of eight detonator tests. The injector recovered in all tests.

4.1.13.2 Space Technology Laboratories

4.1.13.2.1 HATS Engine Firing

Engine DV-001 (Injector 005/L061M28) was installed in the High Altitude Test Stand (HATS) on April 18, 1965. Performance firings utilizing the long ablative chamber were completed. In the only attempt to throttle over the full thrust range, the center body diffuser did not function at the 10% thrust level. Excessive water injection is thought to be the cause.

The P1003 engine (Injector 012/L061M27) was subjected to checkout and calibration firings prior to shipment to AEDC on May 21, 1965.

4.1.13.3 Pressurization and Feed System

During the report period, a total of twenty-one (21) test documents were received and evaluated (2 Program Plans, 14 Detail Test Procedures, and 5 Test Reports). Evaluations and status of these documents are summarized in Table 4.1.13. Program Plans, while containing more than test program information, are included for Liquidometer and MC Manufacturing in order to furnish a complete status. Parker Aircraft and Pelmec have completed their Design Feasibility Test Programs and they have submitted reports as shown in Table 4.1.13. Design Verification Tests are scheduled to start early in the next report period.

4.1.14 Reliability Assessment

There has been no effort expended on reliability assessment during this report period.

TABLE 4.1.13

Reliability Test Program

Vendor	Equipment	Specification	Document	Evaluation	Status
Pelmec	Valve, Helium, Explosive	LSP-270-714A LSP-270-819A	Design Verification Test Plan TP-1200-04	LAV-550-436 3-29-1965	Disapproved
Pelmec	Valve, Helium, Explosive	LSP-270-714A LSP-270-819A	Design Feasibility Preliminary Test Report	LAV-278-139 4-13-1965	Approved
Pelmec	Valve, Helium, Explosive	LSP-270-714A LSP-270-819A	Design Feasibility Test Report	No Comments 5-27-1965	Approved
Pelmec	Valve, Helium, Explosive	LSP-270-714A LSP-270-819A	Design Verification Test Plan TP-1200-04 Revision A	LAV-278-193 6-8-1965	Approved
Pelmec	Valve, Helium, Explosive	LSP-270-714A LSP-270-819A	Failure Investigation & Analysis Report	LAV-550-437 3-30-1965	Disapproved
Aircraft Porous Media	Filter, Helium	LSP-270-814A	Design Verification Test Plan TP 2112 Revision A	LAV-550-449 4-5-1965	Disapproved
Aircraft Porous Media	Filter, Oxidizer	LSP-270-808A	Design Verification Test Plan TP 2107 Revision A	LAV-550-449 4-5-1965	Disapproved
Aircraft Porous Media	Filter, Fuel	LSP-270-807A	Design Verification Test Plan TP 2109	LAV-550-449 4-5-1965	Disapproved
Parker Aircraft	Valve, Helium Pressure Relief	LSP-270-818A	Feasibility Test Report EER-2640043	No Comments 5-28-1965	Approved
Parker Aircraft	Valve, Helium Quad Check	LSP-270-817A	Reliability Assurance Test Procedure IEEP 2640047	LAV-550-1220 5-13-1965	Disapproved
Parker Aircraft	Valve, Helium Quad Check	LSP-270-817A	Design Feasibility Test Report	No Comments 5-18-1965	Approved
Parker Aircraft	Valve, Helium Quad Check	LSP-270-817A	Reliability Assurance Detail Plan IRPR 2640047	No Comments 6-11-1965	Approved
Liquidometer	Detector-Liquid Level	LSP-270-801A	Program Planning Document	LAV-550-1295 6-8-1965	Disapproved

TABLE 4.1.13 (continued)

Reliability Test Program

Vendor	Equipment	Specification	Document	Evaluation	Status
Vacco	Filter, Helium	LSP-270-712A	Design Verification Test Plan	LAV-550-1264 6-10-1965	Disapproved
Sterer	Valve, Helium Pressure Reducing	LSP-270-715A	Development Test Procedure DVTP 27140	LAV-550-466 4-9-1965	Approved
Sterer	Valve, Helium Pressure Reducing	LSP-270-715A	Stress-to-Failure Test Procedure SFP 27140	LAV-550-1253 6-3-1965	Disapproved
Sterer	Valve, Helium Pressure Reducing	LSP-270-715A	Reliability Mission Simulation Test Procedure RTP 27140	LAV-550-490 4-14-1965	Disapproved
Sterer	Valve, Helium Pressure Reducing	LSP-270-715A	Development Test Procedure DVTP 27230	LAV-550-466 4-9-1965	Disapproved
Sterer	Valve, Helium Pressure Reducing	LSP-270-816A	Reliability Mission Simulation Test Procedure RTP 27230	LAV-550-527 5-4-1965	Disapproved
Sterer	Valve, Helium Pressure Reducing	LSP-270-816A	Stress-to-Failure Test Procedure SFP 27230	LAV-550-1252 6-3-1965	Disapproved
M. C. Mfg.	Valve, Helium Pressure Relief	LSP-270-717A	Program Plan MC 6417/6418 Revision A	No Comments 4-20-1965	Approved

4.1.15 Failure Reporting and Corrective Action

4.1.15.1 Bell Aerosystems

During this report period Bell transmitted a total of twenty (20) failure reports. Four (4) of the most recent reports are in an open category pending a satisfactory analysis and corrective action.

4.1.15.2 Space Technology Laboratories (STL)

During this reporting period forty (40) failure reports were received. These failures primarily involved the feasibility and developmental phases. Twenty four (24) failures are in the open category pending a demonstrated corrective action.

4.1.15.3 Pressurization and Feed Systems

There has been no significant activity during this reporting period.

4.2 REACTION CONTROL SUBSYSTEM

4.2.1 General

This report covers the period from 15 March 1965 to 15 June 1965. Updated reliability estimates are shown in Table 4.2.1.

4.2.1.1 Subcontractor Status and Milestones

See Table 4.2.1.1 for the status and milestones of the major GAEC RCS Subcontractors. Component Subcontractors status are available upon request.

4.2.2 Subsystem Summary

4.2.2.1 Summary of Effort For Period

Efforts for this period were directed toward researching RCS component failure rates, conducting reliability coordination meetings with Bell, Parker Giannini and TMC, revision of the Marquardt Program Plan, bladder cycle reduction studies, updating RCS functional failure mode and effect analysis, continued investigation in failure detection schemes for the thrusters and bladders, vendor liaison and RCS component evaluation.

Test effort during the reporting period consisted of reorienting the vendors test program (where applicable), reviewing detailed test plans, participating in technical coordination meetings and witnessing tests at the vendor's facilities. Technical coordination meetings were held with Bell

4.2.2.1 Summary of Effort For Period (continued)

Aerosystems, Airite, Giannini Controls, Parker Aircraft and Purolator. Vibration tests were witnessed at Bell Aerosystems and Airite. The design verification test program for the helium tank has been completed successfully by Airite.

Maintainability activities for the period covered, the Helium Module, propellant feed section components, propellant tanks, helium tanks, the propellant quantity gauging system and engine sub-assemblies. Replacement levels for various components at ETR and WSMR were established. Accessibility studies with regard to the removal and replacement of individual components and sub-assemblies on the LEM vehicle were made and recommendations for improvement were made. Activities also included participation in Pre-Launch Checkout Planning.

4.2.2.1.1 The Marquardt Corporation (TMC)

The revised Program Planning document has been reviewed by GAEC reliability and has been approved, contingent on their resubmittal of an acceptable Maintainability section.

TABLE 4.2.1

SUBSYSTEM ANALYSIS - RCS

Equipment	Reliability				Weight	
	Apportioned *		Estimated **			
	Mission Success	Crew Safety	Mission Success	Crew Safety	Apportioned	Estimated
Helium Pressurization and Controls and Propellant Tankage	.999902	.999959	.965114	.997954	-	-
Thruster Installation A Assembly	.999902	.999976	.954486	.999853	-	-
TOTAL RCS	.999804	.999935	.919600	.997807	-	863.0

* Not updated since last quarterly.

** Details of change will be issued in LED shortly and be explained in more detail in this report.

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.2.1.1

THE MARQUARDT COMPANY - RCS THRUST CHAMBER ASSEMBLY

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan	◪					●														
Reliability Status Report	●	●	●	●	●	◐														
Apportionments and Estimate	○	○	○	◐	◐	○	○	○	○	○	○	○								
Math Model	○				◐															
Configuration Analysis	○																			
Failure Mode and Prediction Analysis	○																			
Failure Effect Analysis	○			◐	●															
Maintainability Analysis	○	●	●	○	◐	◐	○	○	○	○	○	○								
Design Review	○				●	◐														
Design Review Documentation	○				●		○													
Circuit Analysis		NOT APPLICABLE																		
Reliability Data List	○	●	●	●	◐	○	○	○	○	○	○	○								
NPPAR		NOT APPLICABLE																		
Reliability Test Plan		NOT APPLICABLE																		
Reliability Assessment								○												
Failure Reports and Corrective Action	●	●	●	●	●	◐	○	○	○	○	○	○								
Failure Analysis					◐	○	○	○	○	○	○	○								
Reliability Indoctrination and Training												▶								

Due ○
Received ◐
Accepted ●
Unacceptable - Minor Exceptions ◪
Rejected - Major Revision ■

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TABLE 4.2.1.1

BELL - RCS PROPELLANT TANK

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan		○	●																	
Reliability Status Report		●	●	○	●	◐	○	○	○	○	○	○								
Apportionments and Estimate		○	●	●	●	◐	○	○	○	○	○	○								
Math Model	NOT APPLICABLE																			
Configuration Analysis		●																		
Failure Mode and Prediction Analysis		○	◐	●																
Failure Effect Analysis		●	◐	●																
Maintainability Analysis		○	○	●	○	○	○	○	○	○	○	○								
Design Review		●		○																
Design Review Documentation		●		○																
Circuit Analysis	NOT APPLICABLE																			
Reliability Data List			●	○	○	○	○	○	○	○	○	○								
NPPAR	NOT APPLICABLE																			
Reliability Test Plan			●																	
Reliability Assessment								○												
Failure Reports and Corrective Action			◐	○	○	○	○	○	○	○	○	○								
Failure Analysis			◐	○	○	○	○	○	○	○	○	○								
Reliability Indoctrination and Training												▶								

Due ○
Received
Accepted ●
Unacceptable - Minor Exceptions ◪
Rejected - Major Revision ■

Form G 53 8-62

TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.2.1.1

GIANNINI - PROPELLANT QUANTITY GAGING SYSTEM

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan					◐															
Reliability Status Report				●	●	◐	○	○	○	○	○	○								
Apportionments and Estimate						◐	○	○	○	○	○	○								
Math Model							○													
Configuration Analysis						○														
Failure Mode and Prediction Analysis						○														
Failure Effect Analysis						○														
Maintainability Analysis						○	○	○	○	○	○	○								
Design Review							○													
Design Review Documentation							○													
Circuit Analysis							○													
Reliability Data List					●	◐	○	○	○	○	○	○								
NPPAR	NOT APPLICABLE																			
Reliability Test Plan						●														
Reliability Assessment								○	○											
Failure Reports and Corrective Action							○	○	○	○	○	○								
Failure Analysis							○	○	○	○	○	○								
Reliability Indoctrination and Training												▶								

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

TABULATION FORM

4.2.2.1.1 The Marquardt Corporation (TMC) (continued)

A formal Design Review was conducted on the Apollo SM/RCS (Common Usage) thruster engine. A detailed Failure Mode and Effect Analysis was completed for use in conjunction with the noted Design Review.

4.2.2.1.2 Bell

Expulsion cycle testing of the LEM (single ply 6 MIL-Teflon) bladder plexiglass tank was initiated during this reporting period. Monitoring of the tests has continued with analysis of the new failure modes and updating LEM Reliability Estimates.

4.2.2.1.3 Giannini

A preliminary reliability estimate for the propellant quantity gauging system has been initiated based on a comparison of the present knowledge of the LEM PQGS complexity with the Service Module Gauging System presently being built by Giannini Controls Corporation (GCC). Internal design reviews were conducted on the packaging and the electronic design of the control unit, mechanical design and electronic sub-assemblies of the Sensing Unit. A preliminary Reliability Data List has been completed and submitted to GAEC Reliability. Preliminary work on the LEM PQGS failure effect analysis was initiated.

4.2.2.2 Projected Effort for Next Period

4.2.2.2.1 GAEC

During the forthcoming quarter the RCS Functional Failure Mode and Effect Analysis will be updated to include modes of failure revealed in various vendors FMEA received during the past reporting period. Emphasis will be placed on monitoring and analyzing failure data received from the various vendors.

4.2.2.2.1 GAEC (continued)

Test effort for the next reporting period will center mainly on reviewing test plans, reorienting the vendors test program and witnessing selected tests. The design verification testing of the propellant tanks, helium filter, propellant filter, and solenoid latching valve are scheduled to begin during the next reporting period. Qualification testing of the helium tanks will begin during the next reporting period.

4.2.2.2.2 The Marquardt Corporation (TMC)

Major efforts of the TMC reliability group for next reporting period will include updating of the PS/TCA Failure Mode and Effect Analysis and reliability estimates. Failure analysis and investigation will continue on all phases of the test program. TMC Test Plan Report No. A1037C will be revised and submitted to Grumman Reliability group. The Maintainability Analysis Section of the Program Plan will be submitted to GAEC for approval. A LEM S/M Reliability Requirement Comparison Summary will be completed and transmitted to GAEC. The report will be based upon requirements included in Apollo Specification MC901-004 and LEM Specification LSP-310-2B.

A formal LEM Maintainability Assembly Design Analysis will be conducted for all vehicle removable components of the RCS System. This analysis will include maintenance requirements, removal and replacement

4.2.2.2.2 The Marquardt Corporation (TMC) (continued)

data, spares information, and reliability data. Formal Maintainability Analysis by a number of vendors are being prepared. Review and evaluation of the vendor effort will continue.

4.2.2.2.3 Bell

Reliability efforts for the next quarter will be directed toward updating the reliability estimates and failure mode and effect analysis as testing progresses during the LEM Bladder Development Program. The Bell Reliability section will monitor and analyze the results of the planned program described as follows:

1. Objectives

   Bladder Development - To perform the necessary analysis, design and test to insure the bladder cycle life within the limits of the specification LSP-310-405A. The program shall include, but not necessarily be limited to, the following development programs.

2. Scope

   a. Teflon Washer - Design and develop a teflon washer to be inserted inside of the bladder at the top end to reduce bladder displacement during expulsion.

   b. Vent Lines - Design and develop a vent line technique to insure helium gas flow up the side of the teflon bladder during expulsion.

   c. Fill Technique - Design and develop a fill technique using the floatation principle to return the bladder to its correct position during gas expansion. Should include both gas and liquid floatation.

   d. Undersize Bladder - Design and develop an undersized bladder to insure a fit in the hemispherical ends before the cylindrical portion can contact the tank wall.

4.2.2.2.4 Giannini

During the next quarter, efforts on the PQGS failure mode and effect analysis will continue. Efforts will be directed toward completing the maintainability analysis, failure effect analysis, configuration analysis and updating reliability estimates of PQGS. Upon completion of these tasks, a preliminary design review is anticipated.

4.2.3 Reliability Apportionments and Estimates

Reliability estimates for the LEM tank assemblies, based on the test experience of 6 MIL single ply bladders, diffuser tube assemblies, and tank shells from both the Apollo Service and Command Module and LEM tank programs, have been prepared. The failure rate for the bladder assembly was calculated on a total of 237 bladder expulsion cycles, on eleven tank assemblies with two failures. The estimated failure rate for the tank assembly is:

Bladder Assembly	$8,438 \times 10^{-6}$
Diffuser Assembly	1×10^{-6}
Tank Shell	1×10^{-6}
Total Failure Rate	$8,440 \times 10^{-6}$

Therefore, the mission failure rate for the tank assembly based on current data is estimated to be:

$$R = e^{-.008440} = \underline{0.9916}$$

4.2.3 Reliability Apportionments and Estimates (continued)

The reliability estimates for this period are as follows:

	Apportionments	This Quarter Estimate	Last Quarter Estimate
Mission Success	.999804	.9196	.944117
Crew Safety	.999935	.997807	.999274

Improvement in the reliability of the RCS can be achieved only if the inherent reliability of each component in the subsystem is upgraded. Reevaluation of the failure rate estimates, scrutinizing of test data, advising of new operating procedures, constant surveillance of vendor activities and attendance at all design reviews are being performed in those areas where the greatest gain in reliability can be realized. These areas include:

1. Propellant Tank Bladders
2. TCA Injector Valves
3. Propellant Combustion Chamber
4. The Regulator Valves

4.2.4 Reliability Mathematical Model

A Mathematical Model of the RCS has been completed and will be issued shortly in LED-550-28A.

4.2.5 Configuration Analysis

A study was conducted to evaluate the incorporation of a failure detection system into the propellant bladders. It was determined that the high bladder failure rate plus the long lunar stay time makes the bladders a most critical component in the LEM reliability model, especially since bladder failures are not detectable. The three-ply bladder, originally selected, showed merit from a reliability point of view since there was redundancy between plys and failures in one or two plys did not mean a catastrophic failure, but possibly only a small loss in expulsion efficiency.

Detection of bladder failure now comes to the forefront with the selection of the single-ply bladder. A single-ply failure would: lose availability of propellant which goes to the gas side of the bladder subject helium components to liquid propellants or a higher then normal concentration of propellant fumes and may cause erratic operation or explosion of the TCA's if helium gas and propellants intermix during later phase zero "g" maneuvers.

Some possible methods of bladder failure detection are:

1. Liquid Level (Point) Sensors - Incorporated on the helium side of the propellant tank bladders. Bladder rupture would immerse these sensors in propellant and a suitable indicator would be activated. The sensors would be located at the bottom of the propellant tanks and would detect failures during the descent, lunar stay and ascent phases of the mission when the propellants are affected by lunar gravity.

2. Phase Detection Systems - Sensors located in the propellant manifolds. Optical infra-red, magnetostrictive, acoustic, capacitance or other types of sensors would be installed in the manifolds and would indicate the presence of entrained helium in the propellants during all mission

4.2.5 Configuration Analysis (continued)

phases. A system of this type could be expanded to include sensors in the ascent-RCS interconnect lines. Helium entrapment in the ascent propellant may occur when transferring at low ascent tank propellant levels.

4.2.6 Failure Mode and Effect Analysis

4.2.6.1 GAEC

The RCS Functional FMEA will be updated to incorporate various modes of failure revealed by vendor FMEA documents received during the last reporting period. These include the Bell Propellant Tank Bladder, the Parker Latching Solenoid Valve, the Purolator and Vacco inline filters and the Apollo SM/TCA Common Usage Engine FMEA. (The subject FMEA document designation will be LED-550-14, Revision A)

4.2.6.2 The Marquardt Corporation (TMC)

The FMEA tasks for the RCS/TCA has been completed and approved by GAEC Reliability. The document will be updated periodically to reflect any new modes of failure that may occur during current DVT tests and the ensuing Qualification Test Program. An analysis of the current modes appears in Section 4.2.16.

4.2.6.3 Bell

The propellant tank assembly FMEA has been updated periodically and has reflected new modes of failure that have occurred during DFT testing of the redesigned single-ply Teflon Bladder. Revisions to the present FMEA may also be required in the event that components are added to improve bladder expulsion performance.

4.2.6.4 Giannini

Preliminary work is progressing on this analysis for both the Sensing and Control Units. Until recently, the effort had been delayed awaiting the decision to employ the common technology scintillator rod/photomultiplier tube assembly instead of "solid-state sensor blanket" concept.

4.2.7 Failure Mode Prediction Analysis

4.2.7.1 GAEC

No effort during this period.

4.2.7.2 The Marquardt Corporation (TMC)

No effort during this period.

4.2.7.3 Bell

No effort during this period.

4.2.7.4 Giannini

No effort during this period.

4.2.7.5 Component Vendors

Purolator - Vacco - Parker

No effort during this period. An FMEA is expected during the next reporting period from these vendors.

4.2.8 Maintainability Analysis

4.2.8.1 GAEC

Maintainability activities for this reporting period covered: the re-routed propellant lines leading to the cluster mounts and the RCS engines, electrical hook-ups for the engine injector valves, propellant tanks, the main shut-off valves, the helium module, the helium tanks, and the propellant quantity gauging system. A reliability meeting was held at GAEC with the Marquardt Corporation. The subjects discussed were replacement levels for the engines and cluster mounts at ETR and WSMR. The replacement levels for ETR are:

1. Individual engines
2. Propellant line filters.

The replacement levels for WSMR are:

1. Individual engines (if necessary)
2. Injector head and valve assemblies
3. Thruster chamber assemblies (combustors)
4. Bell sections (nozzles)
5. Propellant line filters
6. Transducers

All repair is to be performed at the vendor's facility.

4.2.8.1 GAEC (continued)

A meeting with Giannini Corporation was held at GAEC. The required maintainability input by Giannini covering the Propellant Quantity Gauging System was discussed, with special attention to problems pertaining to the removal and replacement of the sensor blankets on the propellant tanks and possible radiation hazards to maintenance personnel.

A meeting was held with the Bell Aerosystems Company at GAEC. Contents of the preliminary Service Manual for the propellant tank assemblies were discussed. GAEC requested that Bell furnish additional information on bladder installation.

The replacement levels for WSMR are:

1. Propellant Tank Assembly (if necessary)

2. Helium Port Inlet Tube and Seals

3. Mounting Flange Nut Plate.

All other tank assembly service and repair is to be performed at the Bell plant.

The accessibility of RCS LEM vehicle replacable components has been investigated. It was found on the

4.2.8.1 GAEC (continued)

LEM M-5 mock-up that the arrangement of valves and propellant lines in the aft equipment bay does not meet maintainability standards, inasmuch as a number of items, such as tanks, would require removal prior to removal of the applicable RCS items. This is being changed for subsequent LEM vehicle configurations.

Recommendations to settle the sensor blanket (PQGS) replacement problem have been made, including the replacement of No. 4 Screws (for joining the sensor blanket halves) by Latches as used on the NAA PQG project. This will permit comparitively easy replacement of the blankets at a minimum of time and correspondingly less radiation dosage to the installers. In addition, the Latches can absorb tank expansion and resist vibration effects better than screws. A LEM Vendor Change Notice is being prepared.

There have been a number of RCS working group meetings where RCS prelaunch checkout plans and procedures were developed. Revision C of the LEM prelaunch checkout plan has been issued. Tests are constantly being changed in compliance with requirements, changes in assigned GSE Units etc.

Halogen will be used instead of Helium for leak detection. In a number of tests helium will be used instead of propellants for valve activation. All test points designated for the RCS prelaunch checkout will be mechanical, except for one electrical test point (for each RCS engine), where induced voltage will be applied to the injector valves. Ten of the thirteen test ports on the RCS Helium Module will be closed (brazed) before leaving the Vertical Assembly Building, in order to reduce weight. After this time the Helium Module can be checked out only by end-to-end testing.

4.2.8.2 The Marquardt Corporation (TMC)

The design of the cluster mount has been finalized. A plain heavy wall drawn tube was selected for the body. The 2219 sheet aluminum alloy legs will be

4.2.8.2 The Marquardt Corporation (TMC)(continued)

attached by fusion welding. The production cluster assembly concept has been analyzed to determine the anticipated maintenance tasks of trouble detection, trouble isolation, and the associated remedial action. The results of this analysis are being finalized. The TMC Support and Maintenance Plan is being revised. It will reflect the field maintenance level as specified by GAEC. Bench and specialized maintenance tasks are being updated. TMC furnished suggestions for engine purge procedures.

4.2.8.3 Bell

Bell published a preliminary support manual for the RCS propellant tanks, Report No. 8339-954001, including sections on Checkout and Trouble Analysis, Repair Instructions, Cleaning Procedures and Transportation. They also furnished information on pre-assembly inspection and on the assembly of the propellant tanks with all components. These operations are covered in Bell Report No. 8339-928002, Assembly and Acceptance Test Procedures for Model 8339.

4.2.8.4 Giannini

Giannini is preparing input data for the Maintainability Analysis. A study on radiation hazards to maintenance personnel is presently being conducted. The electronic packaging layout for the control circuit is almost completed. There will be three cordwood type modules within the Control Unit.

4.2.8.5 Component Vendors

The J. C. Carter Company - Carter issued a Support Manual for the manual propellant disconnect couplings Part No. 6907, including information on Operating procedures, repair instructions, checkout and trouble analysis, etc.

4.2.8.5 Component Vendors (continued)

Parker Aircraft Company - Parker is presently preparing a Maintainability Analysis covering the RCS shut-off valves, including Main shut-off valves, TCA. Isolation valves, cross-feed valves, and Ascent Interconnect valves.

4.2.9 Design Reviews

4.2.9.1 GAEC

No effort during this period.

4.2.9.2 The Marquardt Corporation (TMC).

A formal TMC Design Review was attended by Grumman Reliability personnel at TMC with regard to the SM/RCS Thruster Engine. The objective of the meeting was to review all aspects of the LEM/Apollo common usage engine design, evaluation tests, fabrication methods and performance data to ascertain that the basic design evidences a high level of inherent reliability before the final design freeze and start of qualification tests. For further details on the subject design review, a report will be issued in the next report period.

4.2.9.3 Bell

No effort during this period.

4.2.9.4 Giannini

No effort during this period.

4.2.9.5 Airite Division of Electrada

A final Design Review of the RCS helium tanks was conducted at GAEC. The subject tank assembly meets

4.2.9.5 Airite Division of Electrada (continued)

all the requirements of the design specification. Test specimens show positive evidence of meeting burst pressure safety factor of 2. Tank specimen S/N 007 failed burst pressure test at 7350 PSI and a second specimen S/N 008 burst at 7650 which is well beyond the allowable 7000 PSI burst pressure requirement.

Burst failures were ductile which is a characteristic of titanium pressure vessels. There was no detectible creep at operating pressure levels. Satisfactory vibration tests have been conducted at 120% of qual levels. There are no exotic shipping and storage requirements. The tank does not require pressurization during transit or storage due to the wall thickness of .132". Caution will be required in the mounting of the tank in the LEM vehicle, however, to prevent transfer of over-stresses into the tank due to the rigidity of the vessel.

4.2.10 Circuit Analysis

No circuit analysis performed during this period.

4.2.11 Reliability Data Lists

4.2.11.1 The Marquardt Corporation (TMC)

No activity in this area during this report period.

4.2.11.2 Bell

No activity in this area during this report period.

4.2.11.3 Giannini

Giannini submitted data lists on the Control Unit. All parts have been approved with the exception of nine. (Eight parts have been classified "Approval Withheld" pending receipt of substantiating data. One part has been disapproved.)

4.2.11.3 Giannini (continued)

Ten of the eighteen procurement specifications submitted for review have been classified as "Approval Withheld"; one has been given a disposition of "No Action".

Nine of the thirty-four specification control drawings submitted have been approved.

The procurement documents not accounted for (nine procurement specifications and twenty-five specification control drawings) are still in the review cycle at GAEC.

4.2.12 Non-Preferred Part Approval Request Status

No action required by Parts Group during this report period.

4.2.13 Test Program

4.2.13.1 RCS Helium and Propellant Components - GAEC

4.2.13.2 The Marquardt Corporation (TMC)

Propellant System/Thrust Chamber Assembly (PS/TCA)

Breadboard system testing has been concluded at Magic Mountain. Review of the data has revealed the following:

1. Pressure changes induced by valve opening excitation and valve closing excitation generate disturbances in the fluid system.

2. Firing a steady state engine while another engine is pulsing has a stabilizing effect on the pulsing engines performance.

4.2.13.2 The Marquardt Corporation (TMC)(continued)

PS/TCA (continued)

3. When a steady state and a pulsing engine are paired the impulse of the pulsing engine is lowered by more than 10%.

4. There is no noticeable change in engine performance with off time if there are other engines in the system firing steady state.

During the breadboard system testing at Magic Mountain an engine of the current engine design (pre-igniter type engine) was installed in the engine #13 (vertical up) position. The system was activated and immediately the engine gave evidence of an apparent failure. The engine was removed and disassembled. An internal explosion had damaged the seat on the oxidizer valve. The engine was refurbished with a hard seat on the oxidizer valve and reinstalled in the vertical up position. The engine failed again on the very first series of pulses. Examination revealed that an internal explosion had blown out the teflon seal. The engine was refurbished again and installed in the horizontal position with the fuel valve up. The engine failed again on the first series of pulses. Examination revealed damaged to the oxidizer valve.

The mechanism of failure is described as fuel finding its way back into the oxidizer dribble volume passages and mixing with the oxidizer prematurely when the oxidizer valve is opened causing an internal explosion. These explosions have been occurring during sea level testing. There are differences of opinion as to whether this type of failure could occur in a vacuum environment. Grumman is presently discussing a test program with TMC in which this can be demonstrated. A joint meeting between GAEC/TMC/NASA has been scheduled to review this problem and present possible areas of solution. The results of this meeting will be reported in the next reporting period.

4.2.13.3 Bell

DVT testing on the propellant tanks has been rescheduled pending the results of the bladder development tests. Because of the bladder failures on the LEM oxidizer bladder, a bladder development program has been instituted. Four possible alternatives have been decided upon to solve bladder failure problems. See Section 4.2.2.2.3 for detailed scope of program.

Testing of the undersized bladder has begun but no results have been received to date.

4.2.13.4 Giannini - PQGS

Test effort on the PQGS consisted of review and acceptance of the General Test Plan and participation in technical coordination meetings with Giannini. Testing at the vendor is in the feasibility stage.

4.2.13.5 Component Vendors

Airite - Helium Tanks - The design verification testing on the helium tank was completed successfully during the reporting period. Two tanks were subjected to the following tests:

	S/N-7	S/N-8
1. Acceptance Test	1	1
2. Cycle	2	2
3. Creep	3	3
4. Proof	4	4
5. Shock	5	5
6. Vibration	6	6
7. Overstress (Vib.)	-	7
8. Burst	7	8

Qualification testing on the tanks will begin during the next reporting period.

4.2.13.5 Component Vendors (continued)

Parker - The Latching Solenoid Valve specification section III has been revised to reflect the latest NASA redirection. A trip to Parker Aircraft was made to coordinate the changes. No test planning documents reflecting the specification revision have been received this period.

Purolator - The Inline Propellant filter specification section IV has been revised to reflect the latest NASA redirection. A trip to Purolator was made to coordinate the change and to make recommendations to correct the DVT, Qual and Acceptance test plans. The sinusoidal vibration test requirements were removed from all tests as requested by NASA letter.

4.2.14 Reliability Assessment

No reliability assessment has been performed this period.

4.2.15 Failure Reporting and Corrective Action

Four failure reports were received from Marquardt in the last quarter, three are still pending failure analysis and corrective action. The last two failures #329-017 and #329-018, were phoned to GAEC within 24 hours of occurrence. A compatable telephone reporting form X-144 was employed which was developed by GAEC LEM Reliability Control, and proved very satisfactory.

During a meeting at GAEC, summarized by LMC-550-26, Marquardt was apprised of the updated failure report requirements and several gray areas were clarified. It was re-iterated by Grumman that TMC should adhere to the basic purchase order commitments for failure reporting.

4.2.16 Failure Analysis

Analysis of the failure reports received from TMC during this reporting period indicate the presence of a persistent valve leakage problem which occurs after shutdown of engine firing test at the Magic Mountain TMC test facility. The recent valve leakage reports (Reference Report Nos. 329-017 and 329-018) show a characteristic increase in oxidizer manifold pressure at time of ignition. The suspected cause is entrapment of fuel in the oxidizer passages downstream of the oxidizer valve at the time of ignition causing a (hypergolic) rise in manifold pressure with subsequent valve damage and leakage. The problem is presently being investigated by TMC/TCA Engineering Section. GAEC is concerned that all vertical-up engines will be susceptable to this problem when thrusters are fired on lunar surface, powered phases and during a prelaunch checkout which may be required after a cluster change.

4.2.17 Reliability Training and Indoctrination

There has been no increase in scope of effort reported by major RCS vendors over previous quarterly. Most vendors assume this as a continuous effort.

4.3 GUIDANCE AND CONTROL

4.3.1 General

4.3.1.1 Subcontract Status and Milestones

Tables 4.3.1.1.1 through 4.3.1.1.11 indicate the program status and milestones for each subcontractor in the Guidance and Control area.

4.3.2 Subsystem Summary

4.3.2.1 Summary of Effort for Period

During the report period the major reliability effort has been expended in the following areas:

1. Review of all subcontractor documentation in order to assess the subcontractor's compliance to GAEC reliability requirements. Those documents which are submitted periodically for review and comment are:

   a. Failure Effect Analysis

   b. Failure Reports and Corrective Action Summaries

   c. Reliability Data Lists

   d. Monthly Progress Reports

   e. Quarterly Design Reports

   f. Equipment Specifications

   g. Detail Test Plans and Procedures

   h. Maintainability Plans

2. Participate in meetings with NASA/MSC, subcontractors or associate contractors as required to support GAEC presentations, clarify reliability contractual obligations and/or as contributors to specific working groups.

4.3.2.1 Summary of Effort for Period (continued)

3. Participated in renegotiations with subcontractors as required.

4. Participated in the review and revisions of Interface Control Documents between associate contractors for the NG&C Subsystem.

5. Attended design reviews for constituent units of the NG&C Subsystem.

6. Continued the in-house system Failure Effect Analysis to supplement the subcontractor's hardware Failure Effect Analysis.

7. Performed various configuration (trade-off) studies in an effort to improve the over all Guidance function reliability.

8. Actively supported the in-house design and fabrication of the Program Coupler Assembly for the LEM Mission Programmer.

9. Continued the survey of available data for determination of applicable failure rates.

4.3.2.2 Projected Effort for Next Period

In addition to the continuation of a majority of the tasks delineated in Para. 4.3.2.1, there are specific tasks which will be initiated and/or completed during the next report period.

1. A Failure Effect Analysis for the NG&C Subsystem will be completed.

2. Reliability will participate in renegotiations for the Attitude and Translational Control Assembly, Descent Engine Control Assembly, Rendezvous Radar/Transponder and Landing Radar, Abort Guidance System, Rate Gyro Assembly.

3. Reliability will participate in all design reviews held on any of the subcontracted equipment.

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.3.1.1.1

RCA - RENDEZVOUS RADAR/TRANSPONDER

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan	◪																			
Reliability Status Report	●	●	●	●	●	●	○	○	○	○	○	○	○	○						
Apportionments and Estimate	●	●	●	●	●	●	○	○	○	○	○	○	○	○						
Math Model	●	○	○	○	○	●	○	○	○	○	○	○	○	○						
Configuration Analysis		●				○	○													
Failure Mode and Prediction Analysis		○				○	○													
Failure Effect Analysis		○	◐		◐	◐	○													
Maintainability Analysis	○	●	●	●	◐	◐	○	○	○	○	○	○	○	○						
Design Review			●			◐	○													
Design Review Documentation			●			◐	○													
Circuit Analysis			○			○	○													
Reliability Data List	●	●	●	●	●	■	○	○	○	○	○	○	○	○						
NPPAR		◐	◐	◐	◐	◐	○	○	○	○	○	○	○	○						
Reliability Test Plan						◐	○													
Reliability Assessment								○												
Failure Reports and Corrective Action		●	●	●	◐	◐			○											
Failure Analysis		◐	◐	◐	◐	◐			○											
Reliability Indoctrination and Training	●	●	●	●	●	●	○	○	○	○	○	○	○	○						

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABULATION FORM

TABLE 4.3.1.1.2

RCA/RYAN - LANDING RADAR

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan	◪																			
Reliability Status Report	●	●	●	●	●	●	○	○	○											
Apportionments and Estimate	●	●	●	●	●	●	○	○	○											
Math Model	●	●	●	●	●	●	○	○	○											
Configuration Analysis		●					○	○												
Failure Mode and Prediction Analysis		○					○	○												
Failure Effect Analysis					◐		○	○												
Maintainability Analysis	○	○	◪	○	○	●	○	○	○											
Design Review			○			◐	○	○												
Design Review Documentation		○	◐			◐	○	○												
Circuit Analysis		○					○	○												
Reliability Data List		●			●	●	○	○	○											
NPPAR		◐	◐	◐	◐	◐														
Reliability Test Plan						◐	○													
Reliability Assessment								○												
Failure Reports and Corrective Action				●	●	◐	○	○	○											
Failure Analysis				●	●	◐	○	○	○											
Reliability Indoctrination and Training	○	○	○	○	○	○	○	○	○	○	○	○	○	○						

○ Due
◐ Received
● Accepted
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■ Rejected - Major Revision

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.3.1.1.3

RCA - ATTITUDE AND TRANSLATION CONTROL ASSEMBLY

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan			●																	
Reliability Status Report		●	●	●	●	●	○	○	○	○	○	○								
Apportionments and Estimate		●	●	●	●	●	○	○	○	○	○	○								
Math Model		●				●														
Configuration Analysis		●		●		○	○													
Failure Mode and Prediction Analysis							○													
Failure Effect Analysis				●		○	○													
Maintainability Analysis		●	○	○	○	○	○	○	○											
Design Review				●		◪	○													
Design Review Documentation				●		◪	○													
Circuit Analysis			●			◪	○													
Reliability Data List			●	●	●	■														
NPPAR			■			●														
Reliability Test Plan					●	●			○											
Reliability Assessment																				
Failure Reports and Corrective Action					●	●	○	○	○	○	○									
Failure Analysis						◐	○	○	○	○	○									
Reliability Indoctrination and Training																				

○ Due
● Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.3.1.1.4

RCA - DESCENT ENGINE CONTROL ASSEMBLY

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan				●																
Reliability Status Report				●	●	●	○	○	○	○	○	○								
Apportionments and Estimate				●	●	●	○	○	○	○	○	○								
Math Model				●																
Configuration Analysis						●	○													
Failure Mode and Prediction Analysis							○													
Failure Effect Analysis						○	○													
Maintainability Analysis					○	○	○	○	○											
Design Review				●		○	○													
Design Review Documentation						○	○													
Circuit Analysis						○	○													
Reliability Data List				○	○	◪	○	○	○	○										
NPPAR						●														
Reliability Test Plan					○	●			○											
Reliability Assessment																				
Failure Reports and Corrective Action						●														
Failure Analysis						●														
Reliability Indoctrination and Training																				

○ Due
● Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.3.1.1.5

AIRESEARCH - GIMBAL DRIVE ACTUATOR

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan				●																
Reliability Status Report				●	●	●	○	○	○	○	○	○								
Apportionments and Estimate				●	●	○	○	○	○	○	○	○								
Math Model				●																
Configuration Analysis				●		○	○													
Failure Mode and Prediction Analysis							○													
Failure Effect Analysis				●		○	○													
Maintainability Analysis						◐	○	○	○											
Design Review				●		○	○													
Design Review Documentation				●		○	○													
Circuit Analysis				●		○	○													
Reliability Data List				○	○	○	○	○	○	○										
NPPAR																				
Reliability Test Plan				◪	○	●		○												
Reliability Assessment																				
Failure Reports and Corrective Action																				
Failure Analysis																				
Reliability Indoctrination and Training					●	○	○	○	○	○	○									

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.3.1.1.6

HONEYWELL - ATTITUDE CONTROLLER ASSEMBLY

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan							○													
Reliability Status Report							○	○	○	○	○	○	○	○	○	○				
Apportionments and Estimate							○	○	○	○										
Math Model							○	○	○	○										
Configuration Analysis								○	○	○										
Failure Mode and Prediction Analysis								○	○	○										
Failure Effect Analysis								○	○	○										
Maintainability Analysis								○	○	○										
Design Review								○		○										
Design Review Documentation								○		○										
Circuit Analysis								○	○	○										
Reliability Data List								○	○	○										
NPPAR																				
Reliability Test Plan								○												
Reliability Assessment																				
Failure Reports and Corrective Action																				
Failure Analysis																				
Reliability Indoctrination and Training																				

○ Due
● Received
Accepted
Unacceptable - Minor Exceptions
Rejected - Major Revision

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.3.1.1.7

GAEC - TRANSLATION CONTROLLER ASSEMBLY

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan							○													
Reliability Status Report							○	○	○	○	○	○	○	○	○	○				
Apportionments and Estimate							○	○	○	○										
Math Model							○	○	○	○										
Configuration Analysis								○	○	○										
Failure Mode and Prediction Analysis								○	○	○										
Failure Effect Analysis								○	○	○										
Maintainability Analysis								○	○	○										
Design Review								○		○										
Design Review Documentation								○		○										
Circuit Analysis								○	○	○										
Reliability Data List								○	○	○										
NPPAR																				
Reliability Test Plan								○												
Reliability Assessment																				
Failure Reports and Corrective Action																				
Failure Analysis																				
Reliability Indoctrination and Training																				

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.3.1.1.8

STL - ABORT GUIDANCE SECTION

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan				●																
Reliability Status Report				●	●	●	○	○	○	○	○	○								
Apportionments and Estimate				●	●	◪	○	○	○	○	○	○								
Math Model				●	●															
Configuration Analysis					●	●	○		○											
Failure Mode and Prediction Analysis								○												
Failure Effect Analysis					●															
Maintainability Analysis						◪	○	○	○	○										
Design Review					●		○		○											
Design Review Documentation					●		○		○											
Circuit Analysis						○	○													
Reliability Data List					●	◪														
NPPAR						◪														
Reliability Test Plan					●	●		○	○											
Reliability Assessment																				
Failure Reports and Corrective Action																				
Failure Analysis																				
Reliability Indoctrination and Training						○	○	○	○	○	○									

○ Due
● Received
◪ Accepted - Minor Exceptions
■ Unacceptable - Rejected - Major Revision

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.3.1.1.9

GAEC - PROGRAM COUPLER ASSEMBLY

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan				●																
Reliability Status Report					●	●	○	○	○											
Apportionments and Estimate					●	●	○													
Math Model					●	●	○													
Configuration Analysis					●	●	○													
Failure Mode and Prediction Analysis						○	○	○												
Failure Effect Analysis						○	○	○												
Maintainability Analysis						○	○	○												
Design Review					●		○													
Design Review Documentation					●		○													
Circuit Analysis						○														
Reliability Data List						◪	○	○	○											
NPPAR						●	○													
Reliability Test Plan																				
Reliability Assessment																				
Failure Reports and Corrective Action																				
Failure Analysis																				
Reliability Indoctrination and Training				●																

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.3.1.1.10

FAIRCHILD - PROGRAM READER ASSEMBLY

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan						●														
Reliability Status Report						●	○	○	○											
Apportionments and Estimate						●	○	○												
Math Model						●	○	○												
Configuration Analysis						●	○	○												
Failure Mode and Prediction Analysis						○	○	○												
Failure Effect Analysis						○	○	○												
Maintainability Analysis						○	○	○												
Design Review						●	○													
Design Review Documentation						●	○													
Circuit Analysis						○	○	○												
Reliability Data List						●	○	○												
NPPAR																				
Reliability Test Plan						○	○													
Reliability Assessment																				
Failure Reports and Corrective Action																				
Failure Analysis																				
Reliability Indoctrination and Training																				

○ Due
● Received
Accepted
Unacceptable - Minor Exceptions
Rejected - Major Revision

TABULATION FORM

Form G 63 6-62

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.3.1.1.11

KEARFOTT - RATE GYRO ASSEMBLY

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan		●																		
Reliability Status Report		●	●	●	●	●	○	○	○	○	○	○								
Apportionments and Estimate			●	●	●	◪	○	○	○	○	○	○								
Math Model		●				●														
Configuration Analysis			●	●	●	○	○	○												
Failure Mode and Prediction Analysis			●				○													
Failure Effect Analysis			●		○	○		○												
Maintainability Analysis		●	○	○	○	○	○	○	○											
Design Review		●			○	○	○	○												
Design Review Documentation			●	●		○		○												
Circuit Analysis			●	●	○	○		○												
Reliability Data List			■	○	○	◪														
NPPAR						●														
Reliability Test Plan					●	○			○											
Reliability Assessment		●	○	○	○	○	○	○	○	○										
Failure Reports and Corrective Action						●														
Failure Analysis						●														
Reliability Indoctrination and Training																				

Due ○
Received
Accepted ●
Unacceptable - Minor Exceptions ◪
Rejected - Major Revision ■

4.3.3 Reliability Apportionments and Estimates

The present GAEC estimates and the present apportionments of the units in the Guidance Navigation and Control Subsystem are shown in Table 4.3.3. The estimates are based on part populations delineated in the respective subcontractor reports.

4.3.3.1 Rendezvous Radar/Transponder and Landing Radar

The probability of failure or unreliability of the rendezvous radar/transponder has increased since the last report because of the inclusion in the estimate of the internal connections for each ERA and the interface cabling between the Electronic Assembly and the Antenna Assembly. Inasmuch as the estimates for the RR/T do not meet the present apportionments, RCA and GAEC are continuing efforts in the areas of applicable failure rates, hardware utilization reliability modeling etc., in order to realize compatibility between the two figures.

At the present time, the Landing Radar, including the pedestal subassembly, is meeting its apportionment. If this continues to be the case, adjustments in the apportionments of other radar units (RR/T) may be justifiable as long as the over all radar section goal remains unchanged. This, however, is still under study and no adjustments will be made until such time as the over all vehicle reliability aspects are assessed.

TABLE 4.3.3

Comparison of Reliability Apportionments and Estimates

Equipment	Failure Rate	Equivalent Operating Time	Reliability	Apportionment
RR	278.9	3.07	.999143	.999326
T	61.4	3.07	.999812	
LR	186.129	1.64	.999645	.999541
ATCA	107.430	6.03	.999353	.999
DECA	56.555	1.77	.999900	.9999816
GDA	83.94	1.77	.999851	.9999184
RGA	101.8	6.03	.999387	.999
PRA *	25.73	N/A	N/A	.999
PCA	166.4	N/A	N/A	.995
TCA	30.5	9.802	.999701	.999
ACA	33.4	9.802	.999673	.999
AEA	937.71	8.27	.992245	.99945
ASA	427.06	8.27	.996468	.99910
DEDA	143.49	8.27	.998813	.99995

* LEM 1 Equipment and therefore Design Reference Mission is not applicable.

4.3.3.2 Control Electronics Section (CES)

4.3.3.2.1 Attitude and Translation Control Assembly

The failure rate estimate for ATCA has increased over that reported during the last quarter due to the addition of failure rates for solder connections in the computations. All of RCA's serially configured failure rates for the three (3) modes of ATCA operation are less than the total parts count failure rate noted above and shown in Table 4.3.3. RCA has been requested to include the failure rate for wire wrap connections in future failure rate submitals (LAV-550-1291).

4.3.3.2.2 Descent Engine Control Assembly

The serially configured, failure rate for DECA exhibited a significant increase over that reported during the previous reporting period due to re-direction, LVC-300-13 -11, which requires increased functional and design complexity, and the addition of solder connections to the computations. RCA has been requested to add failure rates for wire wrap connection to future failure rate estimates and also submit recommendations directed toward a realization of the reliability goal.

4.3.3.2.3 Rate Gyro Assembly

The failure rate for the RGA is presented in Kearfott Document No. KDR 4-65-8 dated April 20, 1965. The vendor has been requested (LAV-550-1259) to submit substantiating data for the gyro failure rate since the gyros comprise approximately 95% of the total RGA failure rate.

4.3.3.2.4 Gimbal Drive Actuator

Vendor Progress Report dated December 31, 1964 indicates that the failure rate estimate for the GDA is well within the reliability goal specified

4.3.3.2.4 Gimbal Drive Actuator (continued)

in LSP-300-17. However, since the GDA components are largely mechanical in nature, discussions with the vendor are planned during the next reporting period for the purpose of obtaining substantiating data and/or calculations for the failure rates given.

4.3.3.2.5 Attitude Controller Assembly

Inasmuch as the contract for the ACA has only recently been negotiated, the subcontractor has not sufficiently progressed in the design to evolve a failure rate estimate. Therefore, the reliability estimate for the ACA in Table 4.3.3 is a preliminary GAEC estimates.

4.3.3.2.6 Translational Controller Assembly

The TCA is also in the earliest stages of design and therefore, the estimates must be considered preliminary at this time.

4.3.3.3 Abort Guidance System (AGS)-STL

The reliability estimates of the Abort Guidance Section are based on data from STL's monthly progress report #6. These estimates will be subject to further refinement as the design changes of LVC-300-33-4 are defined and integrated into the AGS configuration. It should also be noted that the estimate of ASA reliability is based on the STL proposed failure rates for the ASA inertial sensors. These have not yet been accepted by GAEC pending the submission of more detailed justification by STL.

4.3.3.4 LEM Mission Programmer

4.3.3.4.1 Program Coupler Assembly

The individual subassemblies were apportioned and new reliability estimates, on all the subassemblies were made during this quarter. The new estimates will appear in the PCA Design Report which is due next month.

4.3.3.4.2 Program Reader Assembly

A preliminary reliability estimate was performed on the PRA by Fairchild and appeared in their pre STM Design Report. GAEC reviewed this estimate and found certain discrepancies which were transmitted to Fairchild who will correct them in the next Monthly Progress Report.

4.3.4 Reliability Mathematical Model

4.3.4.1 Rendezvous Radar/Transponder and Landing Radar

The mission success math models for both radars have remained unchanged from the last report. However, both RCA and GAEC are in the process of developing a radar reliability math model which would differentiate between alternate modes of operation of the radars in various phases of the mission.

4.3.4.2 Control Electronics Section

4.3.4.2.1 Attitude and Translation Control Assembly

RCA's First Monthly Report, dated May 1964, contains the serial Math Model which continues to be used for estimating ATCA failure rate. In compliance with a GAEC request, the vendor has also prepared and submitted (Monthly Report for April 1965) the Math Models for the various modes of ATCA

4.3.4.2.1 Attitude and Translation Control Assembly (continued)

operation. It should be noted that none of these modes require 100% ATCA operation. Further liaison between GAEC and RCA during this report period will be necessary to finalize these models.

4.3.4.2.2 Descent Engine Control Assembly

No formal Reliability Math Model has been received to date since the vendor has assumed a completely serial configuration, (i.e., failure rate based on total parts count method). However, RCA is being directed to rectify this since the failure logic is not serially configured.

4.3.4.2.3 Rate Gyro Assembly

Kearfott submitted a comprehensive serial Math Model as per Document No. KDR 4-65-8 dated April 20, 1965. This model is subdivided to the component level.

4.3.4.2.4 Gimbal Drive Actuator

There have been no changes to the Math Model for the GDA since the last reporting period.

4.3.4.3 Abort Guidance System

As indicated in the last report, the math model for the AGS is serially configured. There has been no change during this report period.

4.3.4.4 LEM Mission Programmer

4.3.4.4.1 Program Coupler Assembly

The mathematical model for the PCA, considers all the electronic circuits including the power supply in a serial configuration. The relays which do not have ground backup capability are all required to function. The relays which have ground backup capability are considered redundant.

4.3.4.4.2 Program Reader Assembly

The PRA mathematical model considers the entire unit as a series model. This is not exactly true since one or two lamp failures will not disable the system. This detail will be incorporated in the revised mathematical model of the PRA.

4.3.5 Configuration Analysis

4.3.5.1 Rendezvous Radar/Transponder and Landing Radar

The major configuration analysis on the RR/T and LR which were in process at the end of the last report period or which were initiated during this report period are as follows:

1. The trade-off study involving the use of the rotary actuator as opposed to the linear actuator for the Landing Radar was completed. Based on reliability, proven performance, weight delivery and cost the linear actuator was chosen and incorporated into the design.

2. The studies involving the use of non-preferred parts for purposes of part count reduction with the attendent weight savings are continuing. RCA and Ryan are continuously forwarding NPPAR's to GAEC for review and approval.

3. As a result of a configuration analysis, the optimum technique used for mode switching in the rendezvous radar was chosen to be the zero sensing method whereby the trunnion resolvers sense the antenna position and switch to mode #2 operation for overhead tracking under all possible design orientations of the LEM vehicle on the lunar surface.

4. Modification of the Threshhold Detector circuit in the Transponder. The newly adopted method which utilizes analog integrated circuits detects signal to noise ratio based on a very narrow band signal and provides better noise

4.3.5.1 Rendezvous Radar/Transponder and Landing Radar (continued)

4. (continued)

protection. As a result of the implementation of the IC's, there was an attendant weight and power savings.

5. A passive network is being investigated by RCA for the B+ line ripple filter in the Frequency Multiplier Chain. The results of this analysis will be reported during the next period.

The effort to optimize the Landing Radar system design configuration analysis on components, subsections and specific areas is continuing. Several of these studies are listed below:

1. The cordwood packaging technique has been chosen in lieu of conventional printed circuit boards, encapsulated circuitry, and micro balloon-filled cordwood due to the fact that this method proved to be the optimum for maintaining the required temperature within the weight limitations specified.

2. A study of several conformal coating materials showed Hysol to be the most desirable. The thermal design was based on this material. The material is presently in a disapproved category, but tests are being conducted at Ryan to prove the acceptability of Hysol. Investigation of other materials is continuing, particularly to improve the thermal conductivity.

3. Becon connectors were specified in early design, but were disapproved by GAEC. Wire wrap terminations were specified. Available wire wrap connectors did not meet Ryan requirements, so several suppliers were asked to develop a connector from Ryan design. A Viking connector was finally selected. Use of phosphor bronze or berylium copper terminals is still under study.

4.3.5.1 Rendezvous Radar/Transponder and Landing Radar (continued)

4. A review of several materials for fabrication or structural support members resulted in selecting K1A and M1A magnesium. The final selection of magnesium over aluminum was based on its superior damping characteristics and lighter weight.

5. A review of several solder plating processes resulted in the selection of the fused solder method as being the most desirable.

6. Ryan developed a special handling and packaging device for integrated circuits. The device eliminates handling problems, permits automatic testing and provides an adapter which greatly improves solderability.

7. Pancake-type transistors were selected for several power applications to reduce weight and provide improved thermal stability.

8. Addition of a crystal discriminator to the modulator improved performance and decreased the parts count, as a result the modulator reliability improved.

4.3.5.2 Control Electronics Section

4.3.5.2.1 Attitude and Translational Control Assembly

No effort during this report period.

4.3.5.2.2 Descent Engine Control Assembly

No effort during this report period.

4.3.5.2.3 Rate Gyro Assembly

No effort during this report period.

4.3.5.2.4 Gimbal Drive Actuator

No effort during this report period.

4.3.5.2.5 Attitude Controller Assembly

Three separate configuration analysis were performed on the Attitude Controller during this quarter. One analysis (LMO-550-641 May 25, 1965), investigated providing redundancy on the detent switches because a certain mode of failure of this switch could disable both controllers. Redundancy was not recommended because of the low probability of occurrence of this failure mechanism. Another analysis (LMO-550-660 June 15, 1965) investigated two methods of mechanization of the attitude controllers into the CES. The third analysis (LMO-550-659 June 15, 1965), examined the problem of a short in one of the three transducers of each controller which would thereby disable the power supply. It was recommended that each controller be provided with its own circuit breaker.

4.3.5.2.6 Translational Controller Assembly

The present design of the Translation Controller was reviewed. No revisions to the design were suggested.

4.3.5.3 Abort Guidance Section

Several configuration analyses are presently being performed by the contractor to effect weight savings in both the AEA and the ASA. Additional trade-off studies are underway to determine the optimum design necessary to meet the revised configuration and performance requirements delineated in LVC-300-33-4. These studies will be reviewed by Reliability when submitted.

4.3.5.4 LEM Mission Programmer

4.3.5.4.1 Program Coupler Assembly

During this report period, a configuration study was performed on two alternate circuits for use in the LGC-PCA interface. As a result of this study, one particular circuit with the attendant weight and volume savings and reliability improvement was recommended. At the present time, the Interface Control Document between GAEC and MIT is being revised to incorporate this circuit.

4.3.5.4.2 Program Reader Assembly

Several trade-off studies were performed on the PRA. One trade-off analyzed the implementation of different methods of arranging the lamps in the light source (series parallel, parallel, constant brightness schemes). Other trade-off studies investigated various interface circuits and the need for a mechanical backup for end of tape sensing. The mechanical backup has been eliminated. All these studies are contained in the Fairchild pre-STM Design Report and Addendum (SME-AK-9, 4 May 1965).

4.3.6 Failure Effect Analysis

4.3.6.1 Rendezvous Radar/Transponder and Landing Radar

The FEA's received from RCA during this report period contained particular discrepancies which were noted by GAEC Reliability. The comments to the FEA's on both the Frequency Multiplier Chain and the Electronic Assembly are incorporated in LAV-550-1242 and LAV-550-1266, respectively.

4.3.6.1 Rendezvous Radar/Transponder and Landing Radar (continued)

GAEC Reliability in this period has initiated the radar system failure effect analysis. The latter analysis shall supplement the vendor's lower level analyses in order that one complete integrated FEA is prepared. Basically, the methodology for the preparation of this analysis will be to analyze each of the output signals of each of the ERA's as they appear on the GAEC level III drawings. The tie in with the vendor's will usually appear in the "Failure Cause" column where the vendor's FEA will be referenced. Some of the objectives of this analysis are as follows:

1. Uncover critical reliability design areas.

2. Determine whether adequate detection methods exist for those critical areas.

3. Define the existing and/or proposed compensating provisions.

4. Assist in the determinator of optimum abort criteria and decisions.

The above effort is also being carried out on the Landing Radar with the exception that comments on Ryan's FEA have not been formalized inasmuch as the analysis had not been submitted until late in the report period.

4.3.6.2 Control Electronics Section

4.3.6.2.1 Attitude and Translation Control Assembly

GAEC has partially completed a functional system FEA for the ATCA during this reporting period. A final draft and review should be completed during the next reporting period. No subcontractor effort has been received during this reporting period, but with the imminent design review, additional subcontractor inputs are expected.

4.3.6.2.2 Descent Engine Control Assembly

GAEC has partially completed a functional system FEA for the DECA during this reporting period. A DECA assembly FEA is due to be submitted during the next reporting period.

4.3.6.3 Abort Guidance System

GAEC has completed a preliminary FEA on the AGS which will be revised during the next report period as a result of modification to the equipment requirements. TRW/STL has not submitted their FEA to GAEC yet.

4.3.6.4 LEM Mission Programmer

4.3.6.4.1 Program Coupler Assembly

A preliminary failure effect analysis has been completed on the PCA at the circuit level. This analysis will appear in the next PCA Design Report.

4.3.7 Failure Mode Prediction Analysis

As indicated in the Subsystem Status and Milestone Charts only the Rendezvous Radar/Transponder Failure Mode Prediction Analysis was due this quarter.

4.3.7.1 Rendezvous Radar/Transponder

RCA has submitted a first cut Failure Mode Prediction Analysis for the Rendezvous Radar Antenna and Electronic Assemblies. Review of the submitted charts indicate compliance with the GAEC requirements to identify the anticipated failure modes with an associated performance parameter and/or an environment. However, the required ranking process was not clear, as some terms and symbols used in the equations were not defined. Therefore, RCA was requested to define these terms and symbols and resubmit for further GAEC evaluation.

4.3.8 Maintainability Analysis

Stabilization and Control checkout work group meetings held on 7 April and 14 June were attended by Maintainability personnel who participated in discussions of checkout philosophy.

At these meetings specific areas of discussion were AGS vehicle level checkout, GSE requirements for prelaunch checkout, stimuli requirements, ATCA jet logic verification, and propulsion and RCS firing via the Stabilization and Control Subsystem.

Maintainability participated in the review of the LTA-1, Level 3 Stabilization and Control Subsystem drawings.

A review was performed and subsequent Review Meetings attended for the Guidance and Control Section of the Ground Operation Requirements Plan LPL-610-3C.

Meetings for the review of the Flight Control System Checkout Concept and of FCS checkout requirements (abort path) were attended.

4.3.8.1 Rendezvous Radar/Transponder and Landing Radar

Radar Monthly Progress Reports, Quarterly Design Reports, Design Review Reports and other vendor documentation submitted during the period were reviewed by Maintainability and pertinent comments direction and requests forwarded to RCA. The Landing Radar First Design Review Data Package included a Maintainability Analysis prepared by Ryan Aeronautical Company which indicates an intent and maintenance philosophy consistent with the RCA Maintainability Plan LRR-2560-1. The March Radar Monthly Progress Report stated that the fault isolation capability of the Rendezvous Radar/Transponder (RR/T) was being evaluated by RCA and that the results would be forthcoming. The report also presented a list of limited life items for the RR/T

4.3.8.1 Rendezvous Radar/Transponder and Landing Radar (continued)

however, the report did not define the required maintenance or replacement interval for these items. At the Design Review Meeting on the RR, April 29 and 30 RCA was directed to supply the additional information required on limited life items.

4.3.8.2 Control Electronics Section

Maintainability has performed a review of all subcontractor documentation submitted during the period so as to keep apprised of and provide direction to the maintainability aspects of the equipment design. Maintainability personnel participated in pre-issuance review of the Ground Operation Requirements Plan LPL-610-3C, as it pertains to the Control Electronics Se ction.

DECA ground cooling and access problems were investigated with respect to requirements for prelaunch checkout and maintenance. Maintenance concepts submitted by AiResearch for the Gimbal Drive Actuator were reviewed and comments were prepared requesting additional justification for maintenance requirements which are not consistent with present operational planning.

4.3.8.3 Abort Guidance System (AGS)

GAEC participated in a joint subsystem Reliability evaluation of Space Technology Laboratory proposal on LVC-300-33-4, which implemented a major revision to the AGS Purchase Order. Maintainability subsequently participated in the GAEC/STL negotiations on LVC-300-33-4 for both the Abort Sensor Assembly (ASA) and the Abort Electronics Assembly (AEA). As a result of these negotiations the ASA is to provide 120 day performance capability, without retrimming of those parameters which are anticipated to exhibit stability problems.

4.3.8.3 Abort Guidance System (AGS)

At the S&C checkout work group meeting alternate schemes for checking the AGS accelerometer scale factors on the launch pad were considered in terms of maintainability and reliability aspects and their value toward accomplishing a valid functional verification. The addition of 3 mutually perpendicular test accelerometers to the ASA for direct comparison with the output of internal accelerometers was discussed as a possible solution. Further study is being given to this method. If a satisfactory on-board check of the AGS can be devised, removal of the AGS from the vehicle can be avoided, thus avoiding reliability degradation due to handling, and also the conservation of prelaunch checkout time.

The in-house test programs of STL, United Aircraft and Bell were reviewed at a meeting held at Grumman on the 8 and 9 of April. Grumman evaluated the subcontractor programs to verify that adequate testing was being performed to verify design capability, performance and environmental capability.

4.3.8.4 LEM Mission Programmer

Maintainability performed an analysis of the PCA design and subsequently prepared a Maintainability Analysis which was submitted to GAEC, Peconic for inclusion into the PCA Design Report. The analysis assessed the PCA's maintenance requirements, self list feature, replaceability and provided recommendations regarding the implementation of test points. The possible limited storage life characteristics of relays and tantalum capacitors in the PCA has been an issue of some concern and investigation are in process to determine the shelf life characteristics of these parts. It has been established that the relays comply with the 5 year storage requirements and preliminary information received from tantalum capacitor manufacturers are that the capacitors exhibit no special problem however, GAEC awaits receipt of formal data.

4.3.8.4 LEM Mission Programmer (continued)

LTA-1, Level 3 LEM Mission Programmer Review meetings were attended and discussions were participated in regarding interface problems and fault isolation procedures of the LMP.

4.3.8.5 Primary Guidance and Navigation Subsystem

Interface Control documentation between MIT/IL and GAEC is continually being reviewed and assistance is being given to the resolution of problems associated with the installation of the prime Navigation and Guidance Subsystem in the LEM vehicle. Drawings have been studied to determine accessibility and to verify that adequate clearances exist for the removal and installation of components. Suggested wire routing changes have been made to reduce the possibility of wire chafing on bulkheads.

The previously reported study of the probability of IMU/PTA failure during prelaunch operations helped to substantiate the need for a demonstration of the ability to remove these items when the spacecraft is in a stacked configuration. A demonstration was authorized and performed with maintainability participation. To support the demonstration a mockup of the SPS engine bell was constructed and positioned over the LEM so as to accurately simulate the restricted access which occurs after LEM/CSM mating. Removal and replacement operations were performed employing various handling techniques and engine bell positions. Removal of the IMU and PTA was shown to be feasible, and could be performed with satisfactory safety to the equipment with the aid of a detachable handling fixture to facilitate lifting of the IMU. Coordination with MIT resulted in the addition of bosses on the IMU case to which the handling fixture may be mounted when IMU installation or removal is required.

4.3.8.5 Primary Guidance and Navigation Subsystem (continued)

Maintainability personnel attended the meetings of the Guidance and Navigation Checkout work group and participated in discussions of alignment of the Navigation Base, prelaunch checkout flows and test content, component removal requirements and replacement times, fault isolation capability, and content of LGC test ropes. Material was provided at these meetings to support the prelaunch contingency analysis planning of MIT and GAEC.

Prelaunch contingency analysis planning is continuing at MIT and Grumman, although the in-house effort in this area has been greatly curtailed as a result of recent negotiations.

Grumman maintainability personnel met with a counter part from MIT/IL to discuss mutual aims in maintainability design. Grumman offered methods employed in conducting an effective maintainability program and in controlling vendor and subcontractor maintainability efforts.

4.3.9 Design Reviews

4.3.9.1 Rendezvous Radar/Transponder and Landing Radar

During this report period four major radar design reviews were participated in by GAEC Reliability. The following list of memos describes the major reliability aspects of these reviews:

1. LAV-550-1232 - Reliability Review of LEM Fifth Quarterly Design Report RR/T. RCA was advised of specific discrepancies in their failure reporting and analysis procedures and their lack of specific details on various configuration analysis performed by them. They were also directed to provide more information on the external adjustments provided for boresighting the rendezvous radar antenna.

4.3.9.1 Rendezvous Radar/Transponder and Landing Radar (continued)

2. LMO-550-638 - Trip Report - Rendezvous Radar Design Review at RCA-ASD-B on April 29, 30, 1965. GAEC indicated to RCA the inconsistencies of the total power dissipations shown on the Reliability Data List and those totals listed in the body of the report.

3. LMO-550-643 - Trip Report - Radar Frequency Multiplier Design Review at RCA/ECD, Harrison on 29-30 April 1965. Deficiencies in the RCA submitted RDL's and circuit analyses were pointed out to RCA. GAEC also apprised RCA of their concern about the modification of the 2N3375 transistor (cutting off part of the mounting stud) and its possible detrimental affect on the reliability of the device.

4. LAV-550-1242 - Comments to Multiplier Chain Failure Effect Analysis (part of Design Review Report); discrepancies were noted in the RCA FEA and were noted in the memo, however, the analysis as a whole was considered acceptable.

5. LAV-550-1266 - Review of RR/T Failure Effect Analysis (part of Design Review Report). The inadequacy of RCA's effort on the RR/T FEA in specific areas, are outlined in the reference memo which is to be transmitted to the subcontractor.

6. LMO-550-654 - Design Review Meeting on LEM Landing Radar at Ryan. The reliability apportionment and estimate was discussed at the LR design review meeting. GAEC indicated to Ryan/RCA the delinquency of the submission of Reliability portions of the Design Review package (e.g., Reliability Data Lists, Circuit Analysis, Failure Effect Analysis). Several of these items were in route to GAEC at the time of the meeting. Agreement was made between GAEC and RCA/Ryan that the remaining data would be submitted on an as- available basis.

4.3.9.1 Rendezvous Radar/Transponder and Landing Radar (continued)

7. LAV-550-1285 - Reliability Comments to RR/T First Design Review Report LDR-(P)-3100-1. This report contains more detailed comments to the Design Review than does LMO-550-638.

8. LAV-550-1288 - Reliability Comments to LEM Antenna Assembly Design Review Report LDR-(M)-3320-1A. This memo basically takes exception to the RCA thermal design limits for specific components and lists the GAEC Reliability maximum and minimum temperature limits for operating and non-operating conditions.

4.3.9.2 Control Electronics Section

4.3.9.2.1 Attitude and Translation Control Assembly

GAEC Reliability personnel attended the ATCA pre-production design review held at RCA-ASD-B on April 20 and 21 at which RCA presented their detailed circuit analysis. During the discussion it became apparent that errors existed in the Design Report. RCA agreed to correct these and resubmit a completely revised Design Report. At this meeting RCA was requested to submit their failure reports more rapidly and also to improve their failure analysis submittals from a technical content standpoint.

4.3.9.3 Abort Guidance System

There were no formal design reviews held during the report period on the AGS, but GAEC reliability personnel did participate in a weight justification meeting held at UACSC.

4.3.9.4 LEM Mission Programmer

4.3.9.4.1 Program Coupler Assembly

During this quarter, continuous liaison has been established with the Peconic facility to review the PCA design. GAEC Reliability has assigned a reliability engineer at Peconic to support the design effort more effectively.

4.3.9.4.2 Program Reader Assembly

A design review was held at Fairchild to review the pre STM design. Comments on the design review by GAEC reliability, are contained in LMO-550-663, dated 25 June 1965.

4.3.10 Circuit Analysis

4.3.10.1 Rendezvous Radar/Transponder and Landing Radar

The circuit analysis effort of the radar subcontractors to date has been somewhat less than desirable. GAEC has expressed dissatisfaction, with RCA's and Ryan's efforts and has stated this in the minutes of the Design Review meetings. Steps are being taken to alleviate certain problems of clarification of intent and content of future submittals.

4.3.10.2 Control Electronics Section

4.3.10.2.1 Attitude and Translation Control Assembly

The ATCA Pre-Production Model Design Report (RCA Document LDR-(P)-6100-1 Volumes I and II), containing the circuit analysis, was submitted by the vendor prior to the Pre-Production Model Design Review Meeting held at RCA, Burlington, Mass., April 20 and 21, 1965. (RCA Document LDR-(P)-6100-14 Design Review Report). GAEC approval of the Design Report was withheld pending the incorporation of extensive correction and/or additions to the circuit analyses (LAV-300-436), contained therein.

4.3.10.3 Abort Guidance Section (AGS)-STL

Design of the AGS has not progressed to the point where detailed circuit analysis is practicable due primarily to the significant impact of LVC-300-33-4 on the mission and performance requirements of the AGS.

4.3.10.4 LEM Mission Programmer

4.3.10.4.1 Program Coupler Assembly

Many of the circuits in the PCA, have had circuit analyses performed on them. These analyses have considered parameter value variations and input transients, and will be completely delineated in the forthcoming Design Report.

4.3.11 Reliability Data List

4.3.11.1 Rendezvous Radar/Transponder and Landing Radar

GAEC has received the latest updated versions of the RR/T and LR RDL's. These RDL's represent the entire RR/T and LR section. The RDL's have been generally acceptable to GAEC however, in specific cases the vendor was advised to correct certain discrepancies.

These RDL's are the major documents utilized by GAEC in granting part application approval. This effort is currently in process.

4.3.11.2 Control Electronics Section

4.3.11.2.1 Attitude and Translation Control Assembly

RCA submitted one (1) preliminary Reliability Data List, RDL-6100-4, which was reviewed and approved with certain comments. These comments are contained in LAV-550-1255.

4.3.11.2.2 Descent Engine Control Assembly

RCA submitted one (1) preliminary Reliability Data List for the DECA this quarter, RDL-6200-1. This document was reviewed by Reliability and rejected because several parts were overstressed and NPPAR's hadn't been submitted on others (Ref. LAV-550-512).

4.3.11.2.3 Rate Gyro Assembly

One Reliability Data List was submitted by Kearfott for the RGA this quarter. It was disapproved by Reliability for lack of NPPAR submittals on several parts and for use of unapproved procurements on other parts (Ref. LAV-550-1302).

4.3.11.3 Abort Guidance Section (AGS)-STL

Two Reliability Data Lists for the AGS have been received and reviewed during the current reporting period. Both submittals were preliminary and were approved subject to the comments made in LAV-550-489 and LAV-550-1306.

4.3.11.4 LEM Mission Programmer

4.3.11.4.1 Program Coupler Assembly

Three preliminary RDL's have been submitted on the PCA as of this date. In general, these RDL's have been incomplete and have only considered the power supply and decoder subassembly. Major effort will be devoted to completion of the RDL for the entire PCA during the next quarter.

4.3.12 Non Preferred Part Approval Request Status

4.3.12.1 Rendezvous Radar/Transponder and Landing Radar

During this report period, 126 NPPAR's were submitted to GAEC on the radar contract. The status of these is as follows:

4.3.12.1 Rendezvous Radar/Transponder and Landing Radar (continued)

46	Approved
30	Approval Withheld
7	Disapproved
41	Pending
2	Returned Without Review

4.3.12.2 Control Electronics Section

4.3.12.2.1 Attitude and Translation Control Assembly

Thirty six (36) NPPAR's were submitted by RCA for the ATCA. The status of these is as follows:

24	Approved
6	Approval Withheld
1	Disapproved
5	Pending

4.3.12.2.2 Descent Engine Control Assembly

Twenty three (23) NPPAR's were submitted by RCA for DECA. The status of these is as follows:

17	Approved
3	Approval Withheld
1	Disapproved
2	Pending

4.3.12.2.3 Rate Gyro Assembly

Two (2) NPPAR's were submitted by Kearfott for the RGA. One was approved and the other is approval withheld.

4.3.12.3 Abort Guidance Section (AGS)-STL

During the current report period a total of 46 NPPAR forms have been submitted by the contractor

4.3.12.3 Abort Guidance Section (AGS)-STL (continued)

for the AGS. The status of these is as follows:

14	Approved
28	Approval Withheld
3	Disapproved
1	Pending

4.3.12.4 LEM Mission Programmer

4.3.12.4.1 Program Coupler Assembly

There have been 18 NPPAR's submitted during this quarter. The status is as follows:

9	Approved
6	Approval Withheld
3	Disapproved

4.3.12.4.2 Program Reader Assembly

There have been 35 NPPAR's received on the PRA. The status is as follows:

2	Approved
10	Approval Withheld
9	Disapproved
14	Pending

4.3.13 Test Program

4.3.13.1 Rendezvous Radar/Transponder and Landing Radar

Approximately 18 RCA and Ryan Test Plans (LTP), Detail Test Plan (LDTP) and Test Procedures (LTP) were reviewed this period. Levels of these test documents include no only the assembly (end item deliverable) but subassembly and section categories as well (per Para. 5.2, Table A of LVC-372-035).

4.3.13.1 Rendezvous Radar/Transponder and Landing Radar (continued)

RCA is presently performing tests on two (2) experimental computer interface units. These units, after acceptance tests, are to be shipped to MIT for Radar (RR/T and LR) and Computer Interface Tests. Circuit-wise this item represents the input and output stages of the RR/T and LR assemblies. Significant pieces of hardware include digital integrated circuits.

GAEC has initiated Phase I integration testing in Plant #14 at Bethpage. Hardware to be fired up will be Ryan Landing Radar preproduction model (PP2L). To insure compatibility of tests and repeatability of results, Ryan is also supplying VATE (Vendor Acceptance Test Equipment) for the initial checkout and early Phase I effort. Projected integration test plans are to include power supply and pulse transients to evaluate the Radar equipments ability to withstand overstressed voltages and current signals.

4.3.13.2 Control Electronics Section

4.3.13.2.1 Attitude and Translation Control Assembly

RCA submitted a Design Feasibility Test Plan, and an End Item Test Plan for the pre-production model of the ATCA. Since the basic content of these documents was the same a meeting was held with RCA at which comments to each were discussed. Following this meeting RCA revised both test plans which were then reviewed by Reliability and subsequently approved.

Toward the end of this quarter RCA shipped the first ATCA pre-production model to GAEC. This unit is presently undergoing in-house functional tests.

4.3.13.2.2 Descent Engine Control Assembly

Similarly RCA submitted a Design Feasibility Test Plan and an End Item Test Plan for the pre-production model of DECA which was reviewed and discussed at a meeting between RCA and GAEC. Revisions to these test plans are presently in process and submission of them to GAEC is expected early next quarter.

4.3.13.2.3 Rate Gyro Assembly

During this quarter Kearfott has submitted approximately forty (40) preliminary test reports covering the design feasibility tests of the RGA. However, most of these reports were submitted quite late with the result that Kearfott was directed (via. LAV-550-521) to submit these test reports in accordance with their purchase order.

An end item narrative report was received from Kearfott for experimental model E-001 indicating gyro hysteresis was out-of-specification . Kearfott indicated that modifications to their quality control procedures will correct this problem in future gyros. Kearfott was informed (via. LAV-550-1224) that this is considered a failure and a failure report must be submitted, followed up by details of the recommended corrective action which must be approved by GAEC.

4.3.13.2.4 Gimbal Drive Actuator

AiResearch submitted a Reliability Assurance Test Plan which was rejected for the following reasons:

1. Improper hardware was proposed for these tests.

2. Ultra-High Vacuum requirements were not being met.

3. Proposed Stress-to-Failure Tests were unacceptable.

4.3.13.3 Abort Guidance Section

A revised General Test Plan has been prepared by STL for the AGS, based on the program redefinition. This plan is presently being reviewed by STL and is scheduled for submission to GAEC early next quarter.

4.3.14 Reliability Assessment

Inasmuch as there has been no design verification testing to date, there has been no effort expended in the assessment area.

4.3.15 Failure Reports

4.3.15.1 Rendezvous Radar/Transponder and Landing Radar

There have been 62 failure reports submitted during this reporting period for the RR/T. All but seventeen of these failures have been closed out with satisfactory analysis and corrective actions.

Ryan Aeronautical Company who is a subcontractor to RCA has forwarded eighty two reports during this period with fourteen still in the open category (e.g., no failure analyses have been received on these fourteen failure reports).

Meetings have been held with the subcontractors to expedite the submittal and completeness of the failure reports.

4.3.15.2 Control Electronics Section

4.3.15.2.1 Attitude and Translational Control Assembly

During this reporting period twelve (12) failure reports have been submitted by the vendor for the

4.3.15.2.1 Attitude and Translational Control Assembly (continued)

ATCA. Five (5) of the most current are still open, pending analysis and corrective action which is expected during the next reporting period.

4.3.15.2.2 Descent Engine Control Assembly

During this reporting period one (1) failure report has been submitted by the vendor for DECA. The status of this failure is considered closed due to satisfactory analysis and corrective action.

4.3.15.2.3 Rate Gyro Assembly

One failure, for the RGA, was reported by the vendor during this period. The status of this failure is still open.

4.3.15.3 Abort Guidance Section

There have been no failure reports submitted during the report period.

4.3.15.4 LEM Mission Programmer

There have been no failure reports submitted during the report period.

4.3.16 Failure Analysis

4.3.16.1 Rendezvous Radar/Transponder and Landing Radar

During this reporting period the analysis reports received from RCA have been indicative of generally good practices and for the most part have been accepted by GAEC. However, it is believed that more specific corrective steps could still be taken by RCA. RCA has been advised of those particular areas in their failure analyses, where specific

4.3.16.1 Rendezvous Radar/Transponder and Landing Radar (continued)

corrective steps should be taken, reference LAV-550-1267. One of the drawbacks of RCA's failure analysis is their continued use of the word "accidental cause". GAEC has told RCA that they must investigate these "accidents" more thoroughly and endeavor to eliminate the cause of these accidents.

Ryan had been delinquent in their submission of the analyses of failure reports on the Landing Radar and was so advised. Recently there has been a large submission of failure analyses. Comments concerning the failure reports and submissions are contained in LAV-550-1257.

4.3.16.2 Control Electronics Section

4.3.16.2.1 Attitude and Translational Control Assembly

There are five (5) failure analysis reports outstanding for ATCA for this reporting period. The vendor was verbally requested, at the Pre-Production Design Review, to expend more effort on corrective action and include a summary of such action in the Failure Analysis Reports. Latest Failure Analysis Reports have shown significant improvement in this area. All failures to date have been attributed to causes other than generic and/or ATCA design; such as workmanship, mishandling, over test, etc.

4.4 COMMUNICATIONS SUBSYSTEM

4.4.1 General

During this quarter, the Communications Subsystem Reliability effort was devoted to the constant analysis of those essential subsystem reliability requirements specified in the GAEC Reliability Program Plan.

4.4.1.1 Subcontractor Status and Milestones

Tables 4.4.1.2.1 through 4.4.1.2.9 indicate the subcontractor reliability documentation effort.

4.4.2 Subsystem Summary

4.4.2.1 Summary of Effort for This Period

Extensive vendor liaison and coordination took place during this period in the form of technical coordination meetings and design reviews. Numerous vendor specifications, reports and other documents were reviewed and comments forwarded where appropriate.

Comprehensive Communication System studies were completed by RCA covering the design requirements for the inline assembly basis, a link basis, and a modal system basis. This information provided essential knowledge required for the preparation of the Failure Mode and Effect Analysis of the Communication Subsystem. This effort was undertaken to explore the modal capabilities of the communications subsystem and to gain a better insight into the reliability of the Communications

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TABLE 4.4.1.2.1

RCA/COLLINS - SIGNAL PROCESSOR

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks Milestones																				
Program Plan			■																	
Reliability Status Report			●	●	●	●	○	○	○	○	○	○	○	○						
Apportionments and Estimate			●	○	○	○	○	○	○	○	○	○	○	○						
Math Model	Requirement to Be Inserted Into Next Specification Amendment																			
Configuration Analysis				●		◐	○													
Failure Mode and Prediction Analysis							○													
Failure Effect Analysis				●	●	◪	○													
Maintainability Analysis			●	○	○	○	○	○	○	○	○	○	○	○						
Design Review							○													
Design Review Documentation						◪	○													
Circuit Analysis						◪	○													
Reliability Data List			○	●	●	◪	○	○	○	○	○	○	○	○						
NPPAR				◐	◐															
Reliability Test Plan			○	◪	◪															
Reliability Assessment	Requirement to Be Inserted Into Next Specification Amendment																			
Failure Reports and Corrective Action				●																
Failure Analysis				○																
Reliability Indoctrination and Training			○	○	○	○	○	○	○	○	○	○	○	○						

Date:
○ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABLE 4.4.1.2.2

RCA/Motorola - S-Band Transceiver

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks Milestones																				
Program Plan			■																	
Reliability Status Report			●	●	●	◐	○	○	○	○	○	○	○	○						
Apportionments and Estimate			●	○	○	○	○	○	○	○	○	○	○	○						
Math Model				◪																
Configuration Analysis						●														
Failure Mode and Prediction Analysis						○	○													
Failure Effect Analysis				●		●														
Maintainability Analysis			○	○	○	○	○	○	○	○	○	○	○	○						
Design Review						◐														
Design Review Documentation					◐															
Circuit Analysis						◪														
Reliability Data List			○	●	○	◪	○	○	○	○	○	○	○	○						
NPPAR				◐	◐															
Reliability Test Plan			○	◪		◐														
Reliability Assessment	Requirement To Be Inserted Into Next Specification Amendment																			
Failure Reports and Corrective Action				●	●	●														
Failure Analysis				○	●	●														
Reliability Indoctrination and Training			○	○	○	○	○	○	○	○	○	○	○	○						

○ Due
● Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABLE 4.4.1.2.3

RCA/RAYTHEON - S-BAND POWER AMPLIFIER

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks Milestones																				
Program Plan		○																		
Reliability Status Report		●	●	●	●	◐	○	○	○	○	○	○	○	○						
Apportionments and Estimate			○	●	○	○	○	○	○	○	○	○	○	○						
Math Model	Requirement To Be Inserted Into Next Specification Amendment																			
Configuration Analysis		○	○	●		◐	○													
Failure Mode and Prediction Analysis		○	○			◐	○													
Failure Effect Analysis		○	●	●	●	◐	○													
Maintainability Analysis			○	○	○	○	○	○	○	○	○	○	○	○						
Design Review			◪				○													
Design Review Documentation		○		◪	◪		○													
Circuit Analysis		○	○				○													
Reliability Data List			○	●	●	◐														
NPPAR					◐															
Reliability Test Plan		◪			◪	◐														
Reliability Assessment	Requirement To Be Inserted Into Next Specification Amendment																			
Failure Reports and Corrective Action			●	●	●	●														
Failure Analysis				●	●	●														
Reliability Indoctrination and Training		○	○	○	○	○	○	○	○	○	○	○	○	○						

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABLE 4.4.1.2.4

RCA/RANTEC - S-BAND MULTIPLEXER

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan				○																
Reliability Status Report				○	●	○	○	○	○	○	○	○	○	○						
Apportionments and Estimate					○	○	○	○	○	○	○	○	○	○						
Math Model	Requirement To Be Inserted Into Next Specification Amendment																			
Configuration Analysis							○													
Failure Mode and Prediction Analysis							○													
Failure Effect Analysis							○													
Maintainability Analysis					○	○	○	○	○	○	○	○	○	○						
Design Review							○													
Design Review Documentation							○													
Circuit Analysis							○													
Reliability Data List					○	○	○	○	○	○	○	○	○	○						
NPPAR	None																			
Reliability Test Plan				○																
Reliability Assessment	Requirement To Be Inserted Into Next Specification Amendment																			
Failure Reports and Corrective Action	None																			
Failure Analysis	None																			
Reliability Indoctrination and Training				○	○	○	○	○	○	○	○	○	○	○						

Due ○
Received ◐
Accepted ●
Unacceptable - Minor Exceptions ◪
Rejected - Major Revision ■

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TABLE 4.4.1.2.5

RCA/DALMO VICTOR - S-BAND STEERABLE ANTENNA

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan			○																	
Reliability Status Report			○	○	●	◐	○	○	○	○	○	○	○	○						
Apportionments and Estimate				●	○	○	○	○	○	○	○	○	○	○						
Math Model				●																
Configuration Analysis				●	◐	◐	○													
Failure Mode and Prediction Analysis				●			○													
Failure Effect Analysis				○	●	◐	○													
Maintainability Analysis				○	○	○	○	○	○	○	○	○	○	○						
Design Review				◪	◐		○													
Design Review Documentation				◪		◐														
Circuit Analysis				○	○		○													
Reliability Data List				○	●	◐	○	○	○	○	○	○	○	○						
NPPAR	None																			
Reliability Test Plan			○	◪																
Reliability Assessment	Requirement To Be Inserted Into Next Specification Amendment																			
Failure Reports and Corrective Action	None																			
Failure Analysis	None																			
Reliability Indoctrination and Training																				

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABLE 4.4.1.2.6

RCA - S-BAND ERECTABLE ANTENNA

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan		○																		
Reliability Status Report		○	○	●	○	○	○	○	○	○	○	○	○	○						
Apportionments and Estimate		○	○	○	○	○	○	○	○	○	○	○	○	○						
Math Model	Requirement To Be Inserted Into Next Specification Amendment																			
Configuration Analysis			○			◐														
Failure Mode and Prediction Analysis			○			◐	○													
Failure Effect Analysis			●			◐														
Maintainability Analysis		○	○	○	○	○	○	○	○	○	○	○	○	○						
Design Review			◪			◐														
Design Review Documentation			○			◐														
Circuit Analysis	None																			
Reliability Data List		○	○	○	○	○	○	○	○	○	○	○	○	○						
NPPAR	None																			
Reliability Test Plan		○		◪		◐														
Reliability Assessment	Requirement To Be Inserted Into Next Specification Amendment																			
Failure Reports and Corrective Action	None																			
Failure Analysis	None																			
Reliability Indoctrination and Training		○	○	○	○	○	○	○	○	○	○	○	○	○						

Due ○
Received ◐
Accepted ●
Unacceptable - Minor Exceptions ◪
Rejected - Major Revision ■

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.4.1.2.7

RCA - VHF TRANSCEIVER RF SUBASSEMBLY

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan		■																		
Reliability Status Report		○	○	○	●	◐	○	○	○	○	○	○	○	○						
Apportionments and Estimate		○	○	●	○	○	○	○	○	○	○	○	○	○						
Math Model				●																
Configuration Analysis			●				○													
Failure Mode and Prediction Analysis			●				○													
Failure Effect Analysis			●				○													
Maintainability Analysis		○	○	○	○	○	○	○	○	○	○	○	○	○						
Design Review							○													
Design Review Documentation							○													
Circuit Analysis			●				○													
Reliability Data List		○	●	●	●	○	○	○	○	○	○	○	○	○						
MPPAR			◐	◐	◐															
Reliability Test Plan		○																		
Reliability Assessment	Requirement To Be Inserted Into Next Specification Amendment																			
Failure Reports and Corrective Action				●																
Failure Analysis				●	●	●														
Reliability Indoctrination and Training		○	○	○	○	○	○	○	○	○	○	○	○	○						

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABLE 4.4.1.2.8

RANTEC - VHF DIPLEXER

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks Milestones																				
Program Plan			○	◐																
Reliability Status Report			○	●	●	○	○	○	○	○	○	○	○	○						
Apportionments and Estimate				○	○	○	○	○	○	○	○	○	○	○						
Math Model	Requirement To Be Inserted Into Specification Amendment																			
Configuration Analysis				●		○														
Failure Mode and Prediction Analysis				●			○													
Failure Effect Analysis				●		○														
Maintainability Analysis				○	○	○	○	○	○	○	○	○	○	○						
Design Review				◪		◐														
Design Review Documentation				◪		○														
Circuit Analysis				●		○														
Reliability Data List				●	○	○	○	○	○	○	○	○	○	○						
NPPAR	None																			
Reliability Test Plan			○	◐	◐															
Reliability Assessment	Requirement To Be Inserted Into Specification Amendment																			
Failure Reports and Corrective Action	None																			
Failure Analysis	None																			
Reliability Indoctrination and Training																				

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABLE 4.4.1.2.9

QUANTATRON - VHF AND S-BAND RF COAXIAL SWITCH

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks Milestones																				
Program Plan				○		◐														
Reliability Status Report				○	●	●	○	○	○	○	○	○	○	○						
Apportionments and Estimate					○	○	○	○	○	○	○	○	○	○						
Math Model	Requirement To Be Inserted Into Specification Amendment																			
Configuration Analysis	Deleted																			
Failure Mode and Prediction Analysis					○		○													
Failure Effect Analysis	Deleted																			
Maintainability Analysis	Deleted																			
Design Review					◪	◐	○													
Design Review Documentation					◪	◐	○													
Circuit Analysis	Deleted																			
Reliability Data List	Deleted																			
NPPAR	Deleted																			
Reliability Test Plan	None																			
Reliability Assessment	Requirement To Be Inserted Into Specification Amendment																			
Failure Reports and Corrective Action	None																			
Failure Analysis	None																			
Reliability Indoctrination and Training																				

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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4.4.2.1 Summary of Effort For This Period (continued)

Subsystem. The S-Band Section, VHF Section, Signal Processor Section, Personal Communications System and Cabin Inter-Communication were each considered in modal detail.

In the area of the Communications Subsystem antennas, numerous meetings were attended during which the reliability aspects of the inflight antennas, the EVA antenna, the steerable antenna and the lunar stay antenna designs were thoroughly discussed and evaluated.

During this period, the AVCO Digital Command Assembly Program Plan was presented but it was found to be lacking in content. It was accordingly rejected by GAEC Reliability Control. AVCO was directed to significantly expand and elaborate upon the subsystem reliability requirements and their implementation.

Considerable effort was devoted to a comprehensive and detailed review of the reliability status and achievements of each subcontractor to ensure compatibility with the ultimate reliability design. In this connection, the reliability requirements of the RCA and AVCO contracts were expanded and clarified. The subsystem Level III drawings were reviewed and found to be acceptable.

The Communications Subsystem mathematical model was revised and updated. Subsystem reliability estimates and apportionments were reviewed and re-evaluated as a result of this effort.

Considerable effort was expended providing maintainability direction to the subcontractors so as to ensure consistent maintainability disciplines.

Finally, liaison and coordination with the GAEC Communications Subsystem group, and other associated groups on mutual engineering efforts required considerable reliability consultation.

4.4.2.2 Projected Effort For Next Period

During the next quarterly report period, the Communications Subsystem Reliability effort is expected to center about the following areas of activity.

1. It is expected that considerable reliability effort will be expended during this period in updating Reliability Block Diagrams for each Communication link. These diagrams will provide the most meaningful data from which the Complex Subsystem Reliability Apportionments and Estimates can be made.

2. As expected, a significant portion of the reliability effort will be devoted to coordination with the many Communications Subsystem vendors. Documentation, including specifications, reports, proposals, and quarterlies, will be reviewed and disseminated. Technical Coordination meetings, design reviews, conceptual presentations and demonstrations are expected to be numerous. Effort in the area of circuit analysis design review and configuration analysis will continue together with monitoring and evaluating components.

3. The Failure Mode and Effect Analysis should be revised and expanded so as to reflect the latest subsystem configuration and design, thereby ensuring ultimate subsystem reliability.

4. It is expected that much activity will be centered around the maintainability analysis which will be updated during the next period. A significant portion of this activity will be devoted to directing the in-house and vendor efforts to satisfy the LEM Maintainability design requirements. Of particular interest will be the repackaging effort and its impact on maintainability. The study to determine test points requirements for fault isolation failure analysis and operational readiness will be continued.

4.4.2.2 Projected Effort For Next Period (continued)

5. The subsystem mathematical models needed on both a subsystem, link and modal basis will require significant effort during the next quarter. It is anticipated that a large number of mathematical models will be required to completely define and understand the reliability disciplines.

4.4.3 Reliability Apportionments and Estimates

Significant continued effort was devoted during this period to updating and re-evaluating the subsystem reliability estimates and apportionments.

Functional block diagrams, apportionments and estimates were updated by the vendors as the design progressed.

Two comprehensive studies have been completed by RCA: a Prediction of Reliability Bounds (LRR-C-4103-2, 31 March 1965) and "A Translated Mission Profile and Reapportionment of Reliability Goals (LRR-C-4103-5, 6 April 1965). These reports strive to achieve a more realistic understanding of subsystem reliability by defining levels of performance and using realistic estimates of actual operating times. As a result of these and other periodic estimates, it is becoming evident that further application of reliability techniques such as additional redundancy and more hi-rel parts usage would be essential if these goals are to be achieved. The recognition of reduced modal capabilities in later phases of the mission would also aid in approaching reliability apportionments.

GAEC Reliability has devoted considerable time to these efforts in order to ensure overall subsystem compatibility. The effort to reappraise and reapportion the subsystem reliability requirements in order to provide the most realistic presentation was continued. This will allow the vendors to reapportion wherever possible, consistent with current subsystem reliability requirements.

4.4.4 Reliability Mathematical Models

The vendor effort to establish Communication Subsystem mathematical models was continued. In this report quarter, back-up modes based on design changes and efforts towards improvement of system reliability were considered. A comprehensive study, Identification and Preliminary Evaluation of Critical Areas, LPR-C-4103-4, dated 6 April 1965, was performed in an effort to define those portions of the communications subsystem which are most essential.

GAEC Reliability constructed a preliminary mathematical model of the entire Communication Subsystem to determine its mission success reliability. The mathematical model considered the possible back-up operational modes in conjunction with the functional mission requirements. Since the actual subsystem equipments are still undergoing design changes which involve success paths, the modeling must be continuously revised and updated.

The reliability modeling will be continued on both GAEC and vendor levels as additional vendor data is submitted. This data will detail further design changes and/or design freeze through Design Reviews scheduled for the next report quarter.

4.4.5 Configuration Analysis

Several configuration analyses were conducted and evaluated by GAEC Reliability during this report period.

A trade-off study on the Signal Processor Low-Pass Filter Utilization (LMR-(P)-4100-12) was performed by RCA on the relative advantages of using an active or passive low-pass filter in the audio control portion of the SPS. It was concluded that the active filter would be smaller, lighter and more reliable but did require a small amount of power. GAEC is awaiting an RCA decision as to whether these results will be implemented.

4.4.5 Configuration Analysis (continued)

A trade-off study on the Steerable Antenna Infra-Red Tracking versus Radio Frequency Tracking techniques (LMR-(P)-4100-12) was submitted by RCA. This study supported the conceptual design using RF Tracking which was proposed by RCA. The study was accepted by GAEC Reliability.

GAEC Reliability completed a configuration analysis on the relative merits of PCM Transmission on 1.024 M c/s only versus PCM Transmission on either 512 K c/s or 1.024 M c/s. It was conclusively shown that for the slight difference in weight, the significant improvement in reliability more than justifies the use of 1.024 M c/s and 512 K c/s for PCM Transmission (LMO-550-620, dated 21 April 1965).

GAEC Reliability performed a configuration evaluation study of the Communications Subsystem evolved to date. The purpose of the analysis was to demonstrate the impact which the reliability improvement program has had on the subsystem. (LEM Informal Memo, dated 20 April 1965 also presented to PSAC on 5 May 1965).

In conjunction with the presentation prepared for the Presidential Scientific Advisory Committee (PSAC) in April 1965, a configuration analysis comparing the reliability parameters of the Communications Subsystem with and without redundancy, (Contract Change Authorization #61) was prepared. This analysis clearly demonstrated an improvement in Probability of Success for the Communication Subsystem. This came as a result of implementing redundant VHF Transceivers, S-Band Transceivers and Power Amplifiers, etc.

4.4.6 Failure Mode and Effect Analysis

A preliminary Failure Effect Analysis (Cover Letter No. LCC-(P)-2500/260-4100 RCA, Burlington, Mass.)

4.4.6 Failure Mode and Effect Analysis (continued)

for S-Band Transceiver, Signal Processor Assembly, Power Amplifier, and S-Band Steerable Antenna was reviewed and considered general acceptable. The effort will be continued and updated as the design matures.

GAEC Reliability performed a Failure Mode and Effect Analysis for the VHF and S-Band Systems (LEM Informal Memo, dated April 22, 1965). This study was presented to the Presidential Scientific Advisory Committee (PSAC) for approval. It considered all Transmit/Receive Modes required for mission success. Signal loss or degradation was considered, and compensating provisions were utilized (path switching) to correct those malfunctions.

4.4.7 Failure Mode Prediction Analysis

Reliability Control continued the evaluation of approaches for making Failure Mode Predictions for subsystem equipments. Transmittal of design information from vendors has made it possible to commence Failure Mode Prediction during this report period.

Raytheon submitted an initial Failure Mode Prediction Analysis on the S-Band Power Amplifier, Pre-Production Model, dated 1 April 1965, which considered the possibility of certain electrical and mechanical failures induced by excessive temperature, vibration and acceleration. The amplitron was considered as a newly designed component with a high likelihood of failure occurrence. Several other items which showed need for corrective action were uncovered. Worthy of mention are two fixed wirewound resistors, R13 and R14 (Part No. 125054 in modules A2 and A6) and connector J1 (Part No. 125087) which are lacking in vibration data history. Because the state of packaging was not finalized at the date of the document release, further analysis will be performed as more information becomes available.

4.4.8 Maintainability Analysis

4.4.8.1 VHF RF Subassembly

A preliminary analysis to the component level was accomplished during the last reporting period and the effort was continued to determine if improved maintainability can be obtained without significantly compromising reliability or equipment performance. Results of this study should be available during the next reporting period.

4.4.8.2 Signal Processor

During this period the continuation of the effort which would determine the thoroughness of the vendor's analysis was deferred until the extent of anticipated circuit redesign was learned.

4.4.8.3 S-Band Power Amplifier

Comments about the analysis reported during the last report period have been brought to the attention of the vendor for implementation. Additional information is expected to be available during the next report period.

4.4.8.4 C-Band Transponder

The investigation to find a way for removing the antenna "hat" has continued. As yet no solution can be reported. The effort will be continued during the next reporting period.

4.4.9. Design Reviews and Technical Coordination Meetings

The following Communications Subsystem Design Reviews and Technical Coordination Meetings were attended by GAEC Reliability.

4.4.9.1 Monthly Technical Coordination Meeting for LEM VHF Transceiver at RCA, CSD, Camden, New Jersey

An important facet of this meeting was a proposed switching arrangement to disable the receiver during the transmitting function (i.e., decrease operating time) in order to increase reliability. This would place power consumption and operating time at the astronaut's discretion.

4.4.9.2 Monthly Technical Meeting For S-Band Erectable Antenna at RCA, MSRD, Moorestown, New Jersey

The items of importance to reliability follow:

1. RCA will derive procedures for arriving at reliability numerics for the subject antenna.

2. Membrane fastening study showed no hazards to reliability and this will be reflected in future failure mode analyses and maintainability studies.

3. Metal-to-plastic sliding contact will be used in the tripod design to alleviate sizing . For metal-to-metal gear trains, etc., in the Azimuth Elevation Assembly suitable lubricant will be used.

4.4.9.3 Technical Coordination Meeting With RCA for LEM Communications Subsystem Reliability at GAEC, Bethpage, New York

Details of this reliability meeting may be found in GAEC meeting minutes, LMM-550-24, dated 14 April 1965. The purpose of the meeting was to discuss methods and progress of the Communication System Reliability Math Modeling. The final results of RCA's studies appeared in documents mentioned in Paragraphs 4.4.3 and 4.4.4 of this report.

4.4.9.4 Design Review I of S-Band Transponder at Motorola Phoenix, Arizona

The following important action items and comments of interest to reliability were presented at this review.

1. Dip-brazed attachment lugs had a questionable reliability history and reliability data is scanty for this process. Motorola was asked to investigate alternate methods of clamping the transponder modules in place.

2. The adequacy of the thermal path between modular interfaces is questionable. Motorola was asked to present conceptual inspection procedures which assured intimate mechanical contact at the interface after each assembly action. As the design progresses Motorola was also asked to present test evidence of interface integrity.

3. The adequacy of the epoxy bond alone fastening modules to the chassis was questioned. Analysis and test data was requested justifying such an approach.

4. RF components such as the Power Combiner, which could develop partial pressures should be either positively sealed or vented to prevent such degradation possibilities.

5. Sensitivity analysis should be made on components such as isolators, which contain securely fastened materials having different coefficients of expansion.

6. A vast number of intermodular coaxial connections are made. They are very closely positioned in many instances so that accessibility and possible transposes are problematical. Motorola should study ways of improving accessibility and of marking and arranging the "coax" to avoid transpositions.

4.4.9.4 Design Review I of S-Band Transponder at Motorola Phoenix, Arizona (continued)

7. It was strongly requested that Motorola clarify and further analyze their 2N3375 and similar transistor failures. Emphasis was placed on investigation of possible spike problems.

   In general Motorola had made very little coneptual progress in (a) maintainability studies or design, (b) wiring harness concepts and wiring restraint techniques. They were requested to formulate these concepts and submit them for design approval.

4.4.9.5 Design Review of RF Switch at Quantatron, Santa Monica, California

The following summarized action items of importance to reliability were generated at this review:

1. The switch bellows is to be investigated and discussed in Failure Mode Analysis for binding and degraded pressure conditions in an O_2 atmosphere.

2. The mechanics of RF contact action is to be studied and discussed in Failure Mode Analysis.

3. Vibration test procedures shall be devised which show RF performance during test and oscilloscope and chatter detectors shall be used during vibration tests to demonstrate feasibility of the design.

4. A mechanical and electrical analysis of the contact crossbar at minimum and maximum forces shall be made.

4.4.9.6 Design Review of S-Band Erectable Antenna Held at RCA, MSRD, Moorestown, New Jersey

Noteworthy reliability facets of this meeting follow:

4.4.9.6 Design Review of S-Band Erectable Antenna Held at RCA, MSRD, Moorestown, New Jersey (continued)

1. RCA will study Azimuth Elevation gear train for gear simplification and elimination by coaxially aligning the gears. Three spur gears and associated shafts and bearings could be eliminated.

2. Limit staps will be investigated for lessening gear teeth strain in the elevation assembly.

3. Cold welding of leaf springs will be studied.

4. Detented effects (several stable open positions) of rib positions have been evidenced on some models. This is under study.

5. Folding procedures for this antenna are to be definitized, formally written and submitted to GAEC.

6. A stability analysis under asymmetric opening conditions is to be made.

Further details of this review may be found in the RCA MSRD Design Review Report for the LEM Erectable Antenna dated 23 June 1965.

4.4.10 Circuit Analysis

Preliminary circuit analyses were continued on the Signal Processor, the S-Band Transceiver and Power Amplifiers and the VHF Transceiver by the subcontractors. These preliminary analysis were generally acceptable and comments were made known during technical coordination meetings.

In conjunction with these circuits and reviews, Reliability Data Lists RDL-4100-11 through RDL-4100-14 were reviewed by GAEC Reliability.

4.4.11 Reliability Data List

During this reporting period, reliability data lists for the S-Band Steerable Antenna, S-Band Power Amplifier, Signal Processor Assembly, and S-Band Transceiver, RDL-4100-11 thru RDL-4100-14 respectively, were completed and/or revised and reviewed by GAEC Reliability. While it is understood that non-approved parts are acceptable on the breadboard models, the vendors were cautioned against the continued use of su h parts in flyable equipment. Many components were electrically overstressed and many portions of the submittals were incomplete. Corrective action was requested. In general, most lists were conditionally accepted. GAEC Reliability comments were forwarded to RCA and coordinated during meetings with the vendors.

4.4.12 Non-Preferred Parts Approval Request (NPPAR) Status

In accordance with the requirements of the contract, RCA is required to forward NPPAR forms to GAEC as evidence of the adequacy of non-standard parts in both performance and reliability for the specific application.

During this report period, 58 NPPAR reports have been received on the Communications Subsystem, 26 of which were approved, 2 were disapproved, 9 had approval withheld, 21 are pending GAEC action and 2 were withdrawn by RCA.

4.4.13 Reliability Test Program

4.4.13.1 Steerable Antenna

Dalmo Victor for the development test program has proposed the following environmental tests.

1. Bearings and gears - vibration, vacuum high and low temperatures.

2. Electrical windup units - vibration and life testing.

4.4.13.1 Steerable Antenna (continued)

3. Electrical breadboards - high and low temperature.

4. Microwave transmission hardware - high power operation in a vacuum.

5. Reflector - vibration and shock.

6. Motors and pick offs - low temperature operation, high temperature in a vacuum vibration, humidity, fungus, salt fog.

Some of the tests that are presently in process are the RF Feed subassembly, Servo Drives and Electronics, Bearings and Lubricating materials and Processes.

Effort is underway to have the vendor specify levels and durations on the above proposed tests.

4.4.13.2 Erectable Antenna

RCA is finalizing a CET (Critical Environmental Test) plan which will include vibration, vacuum, shock and ultra high vacuum testing.

Membrane feasibility tests in process or completed are flexures (fold and unfold) and emissivity, absorbtivity and ultra violet effects respectively. The flexure test requires 100 cycles of operation with no more than 0.1 db of reflectivity degradation change.

4.4.13.3 Vendor Redirection

A revised tabulation chart of the redirection requirements imposed on the LEM program. as presented in the last quarterly report, is as shown in Table 4.4.13.1.

TABLE 4.4.13.1

Subcontractors Status

Item	Equipment	LSC 300-	Spec. Input Generated	Negotiations in Process	Negotiations Complete
1	Communication Subsystem	2	X	X	
2	VHF Diplexer	3	X	X	
3	Inflight & EVA Antennas	5	X	N/A	N/A
4	RF Coaxial Cables	601	X		
5	RF Coaxial Connectors	602	X	X	
6	RF Coaxial Switch	7	X	X	
7	Digital Command Assembly	11	X	X	X
8	VHF Multiplexers	12	X	X	
9	C-Band Transponder Antenna	14	X	X	
10	Telemetry Switch	16	X	X	

4.4.14 Reliability Assessment

In as much as the reliability assessment for the Communications Subsystem is to be derived as a function of the Reliability Test Program data defined in Para. 4.4.13 and since no test data is as yet available, no significant effort was devoted to reliability assessment during this period.

4.4.15 Failure Reporting and Corrective Action

Failure reports received against the Communication system during the last quarter (March 15 to June 15) numbered twelve. Only one of these failures was from RCA, our prime contractor. This failure was recently received and the analysis and corrective action is still pending.

Failure reports are being received via RCA from their subcontractors, namely Collins, Motorola and Raytheon. Collins has submitted one failure report, Motorola eight and Raytheon two failures. Collins has its failure still in the open status, Motorola has one open and Raytheon's are closed out with satisfactory failure analysis and corrective action.

4.4.16 Failure Analysis

During this report period Grumman has maintained cognizance over the vendors failure analysis efforts. Most of the failures which have occurred to date have not been attributed to faulty design and/or reliability techniques. Most are being satisfactorily investigated and closed out.

The S-Band Power Amplifier Discovery and Elimination of Failure Modes FR-65-130 dated 29 March 1965, was submitted and found acceptable. The report detailed the failure analysis and corrective actions undertaken to eliminate high-voltage arcing and circuit failures.

4.5 ENVIRONMENTAL CONTROL SUBSYSTEM

4.5.1 General

The Presidential Scientific Advisory Committee Space Technology Subpanel reviewed the LEM-ECS Reliability Program and had no disagreements with its status. Presentations were made at GAEC and at Hamilton Standard. The presentation to the subpanel on the LEM-ECS at HSD consisted of a general review of the over all programs on the space suit and ECS including detailed review of basic logic, present status and goals.

4.5.1.1 Subcontractor Status and Milestones

Table 4.5.1 shows the ECS Subcontractor Status and Milestones.

4.5.2 Subsystem Summary

4.5.2.1 Summary of Efforts For This Period

For PSAC briefing at GAEC, Reliability had prepared a critical failure mode analysis to supplement the required "Failure Mode and Effect Analysis" (LMO-550-37).

The program briefing material, Pages 74, 81 and 82 of this meeting held at GAEC on 5 May 1962 contain this analysis.

Design Feasibility Testing has resulted in a number of outstanding failure reports (RDR's) which now is a sisyphean task at HSD to resolve the necessary corrective action.

Maintainability tasks are achieving success as the design effort is achieving momentum.

Configuration Analysis are being performed as a result the LEM Battery Configuration. ECS changes are required in the heat transport, water management and oxygen supply system resulting in 3 out of the 4 sections the ECS being investigated for possible change.

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

SUBCONTRACTOR: HAMILTON STANDARD

TABLE 4.5.1.

EQUIPMENT: ENVIRONMENTAL CONTROL

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan				●																
Reliability Status Report				●		●	○	○	○	○	○	○								
Apportionments and Estimate				●		●	○	○	○	○	○	○								
Math Model				●		●	○	○	○	○	○	○								
Configuration Analysis				●		●	○	○	○	○	○	○								
Failure Mode and Prediction Analysis				●		●	○	○	○	○	○	○								
Failure Effect Analysis				●		●	○	○	○	○	○	○								
Maintainability Analysis				●		●	○	○	○	○	○	○								
Design Review						◐														
Design Review Documentation						◐														
Circuit Analysis		Not Applicable																		
Reliability Data List	●					●														
NPPAR		Not Applicable																		
Reliability Test Plan				●																
Reliability Assessment			●		●	●	○	○	○	○	○	○								
Failure Reports and Corrective Action				●	●	●	○	○	○	○	○	○								
Failure Analysis																				
Reliability Indoctrination and Training	●																			

Due ○
Received ◐
Accepted ●
Unacceptable - Minor Exceptions
Rejected - Major Revision

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TABULATION FORM

4.5.2.1 Summary of Efforts For This Period (continued)

PLSS as a back up for LEM ECS is in a general state of flux. This item will be clarified during the MSC Data Verification and Review Team Visit to GAEC on June 22, 1965. The development status of the brushless DC motor is of great concern to Reliability. The results of testing to date indicate a relative weakness in the electronic design of the Suit Fan Motor. HSD has recognized this problem and is investigating a second source.

The failures to date on Brushless DC Motors are:

Item No. 118 Suit Fan Motor

RDR	Test	Failure
118M1	Low Temperature End	Bearing Failure
118M2	Rig Check Out	Directional Transistor Short
118M3	Simulated Design	Directional Transistor Short
118M4	Vibration Test at Simulated Design	Capacitor Sheared Printed Circuit Board
118M5	Vibration Test at Simulated Design	Capacitor Sheared Printed Circuit Board
118M6	Vibration Test	Electrical Connector Sheared

Item No. 290 Pump Coolant

RDR	Test	Failure
290-1	DFT Calibration	Electronic Portion Malfunctioned
290-1	DFT Operational Test	Over Torquing of Retaining Plate (Leakage)

4.5.2.1.1 Summary Vendor Co-ordination

Co-ordination meetings were held with HSD covering the following subjects:

Review of Reliability Data Report	LAV-550-491 LVM-1150-56
Review & Discussion of FMEA of ECS Item 290	LAV-550-491 LVM-1150-56
Evaluation & Discussion of Oustanding Items	LAV-550-491 LVM-1150-56
Review of Prelaunch Operation Items for Math Model	LAV-550-491 LVM-1150-56
Review of Failure Rates	LMM-550-25 LMM-1150-53 LMM-550-28
HSD Proprietary Items	LMM-550-25
Mission Time Lines	LMM-550-25 LMM-1150-53
Design Review Programs at HSD Vendors	LMM-550-25
Deliquent Submittal of Data from HSD Vendors	LMM-550-28
ECS Reliability Improvement	LMM-550-28
Corrective Action	LAV-550-1260

4.5.2.1.2 CO_2 Sensor

During this period it was decided by NASA that initial delivery of CO_2 Sensors was to be GFE.

4.5.2.2 Projected Effort For Next Period

4.5.2.2.1 Heat Rejection Study

Complete Reliability Analysis on LTV and GAEC Thermo heat rejection schemes.

4.5.2.2.2 GOX Configuration Study

Complete Reliability Analysis on GOX Configuration Study.

4.5.2.2.3 NASA Data Verification & Survey Team

Prepare for NASA Data Verification and Survey Team Visit on ECS Reliability modeling.

4.5.2.2.4 Brushless DC Motors

Review all current data on Brushless Motor to determine if Reliability improvement can be accomplished.

4.5.2.2.5 Thermal Control - Water Management

Complete reliability analysis on new thermal control requirements necessitated by battery temperature requirements.

4.5.2.2.6 Gamah Fittings

Investigate the use of Gamah fittings of ECS installations.

4.5.2.2.7 Reliability Improvements

Investigate in conjunction with HSD the Reliability of the following items.

Item 113	Valve, Check
Item 119	Valve, Check Fan
Item 210	Accumulator, Glycol

[redacted]

4.5.2.2.7 Reliability Improvements (continued)

Item 312 Disconnect Oxygen

Item 222 Filter, Glycol

Item 290 Pump, Glycol

4.5.2.2.8 Ground Operations Requirement Plan LPL-610-3C

A review of this document indicates that the last checkout for LEM ECS components is approximately eight weeks prior to launch.

4.5.2.2.9 Heat Rejection Study (Radiation Program)

Finalized configurations were arrived at during this reporting period. Reliability estimates will be completed during the next reporting period.

4.5.2.2.10 Design Review Program

Continue Design Review Program on all items as they complete design feasibility testing.

4.5.3 Reliability Apportionments and Estimates

	Apportionments	Estimate HSD*	Estimate GAEC(DRM)
Mission Success	.999446	.996154	.994740
Crew Safety	.99982	.999897	.999994**

* The HSD estimate is presently based on the original mission profile which appear in its Purchase Order.

** Based on Ascent Phase's only.

[redacted]

4.5.3.1 Equipment Breakdown

	Contractor	Apportionment Mission Success	Apportionment Crew Safety
4 Section's of ECS	HSD	.999500	.999911
CO_2 Sensor	Perkin-Elmer	MTBF 100,000 hrs.	
Cold Plates	To be selected	.999995	

4.5.4 Reliability Math Model

During the reporting period Hamilton Standard has calculated the reliability of the four sections of the ECS (Ref. HSD Report SVHSER 280). The total mission success reliability for these sections is .996154 as compared with the goal of .9995 and the crew safety reliability is .999897 as compared with the goal of .9999.

4.5.5 Configuration Analysis

4.5.5.1 Space Radiation Design

The LEM Radiation Design Review was held in conjunction with LTV GAEC on April 21 and 22 at GAEC. The items reviewed were:

1. Panel Design and Mounting Deployment Mechanism
2. Lock and Gimbal Release Design
3. Line Runs
4. Criteria for Structural Loading
5. Materials, Coatings, Compatibility
6. Crew Systems Tasks
   a. Unlocking, deploying and orienting panel
   b. Start up provisions
7. Reliability Criteria
   a. System Evaluation
   b. Meteorite Hazards

4.5.5.1 Space Radiation Design (continued)

The configuration analysis has not been completed on this item.

4.5.5.2 Battery - Heat Transport -Water Module Configuration Study

The overriding factor in changing the ECS Thermal Control System was based in minimizing the Battery Cell Case. Temperature based on reliability considerations maximum battery temperatures were set at 100°F for normal operation and 140°F for a one-ascent battery abort condition.

A number of design's were eliminated from further consideration on the basis of single point failures that were discovered during the configuration analysis.

This study is now under current evaluation and will be reported to NASA on or about July 25, 1965.

4.5.5.3 Space Suit Failure Study

LMO-550-631 presented the analysis of the space suit failure study. Reliability recommended the Retractable Flow Limiter Concept be utilized.

4.5.6 Failure Mode and Effect Analysis

Failure Effect Analysis have thus far been performed by HSD on many of their components. GAEC evaluation of these FEA's are reported in the various meeting minutes. GAEC Function Failure Mode and Effect Analysis LED-550-37 is now being revised to reflect latest released schematic changes.

4.5.7 Failure Mode Prediction Analysis

No effort in this period.

4.5.8 Maintainability

4.5.8.1 Vendor Co-ordination

GAEC has directed the vendor HSD to use pigtails and splices in lieu of pin connectors for the electrical wiring of the 190D (Heat Transport Pump Package). This directive does provide some degree of reliability improvement with resultant problems in the maintainability area. The problems involved with the use of splices are currently under investigation by reliability. The application of splices will be considered on an individual basis.

4.5.8.2 Accessibility of ECS Component in Aft Equipment Bay

LMO-550-628 studied the accessibility of ECS components in the aft equipment bay. Recommendations were made to enhance maintainability. The summary of recommendations is:

1. Relocate ECS components per Figure 4.5.1.
2. Redesign Coolant Accumulator 210
3. Install an access panel in a size sufficiently adequate to permit maintenance on Squib Valve Item No. 417, and Coolant Accumulator Item No. 210.

4.5.9 Design Reviews

Implementation of formal design reviews was initiated during the period (Ref. GAEC Memo LVM-331-739, dated 3 June 1965). Grumman now requires that a design review be held for each item after completion of Design Feasibility Testing.

The ECS items that have completed Design Feasibility Testing are:

Item	Completed Test
111	3/12
204	4/14
208	4/20
214	3/12
221	4/19
223	3/12

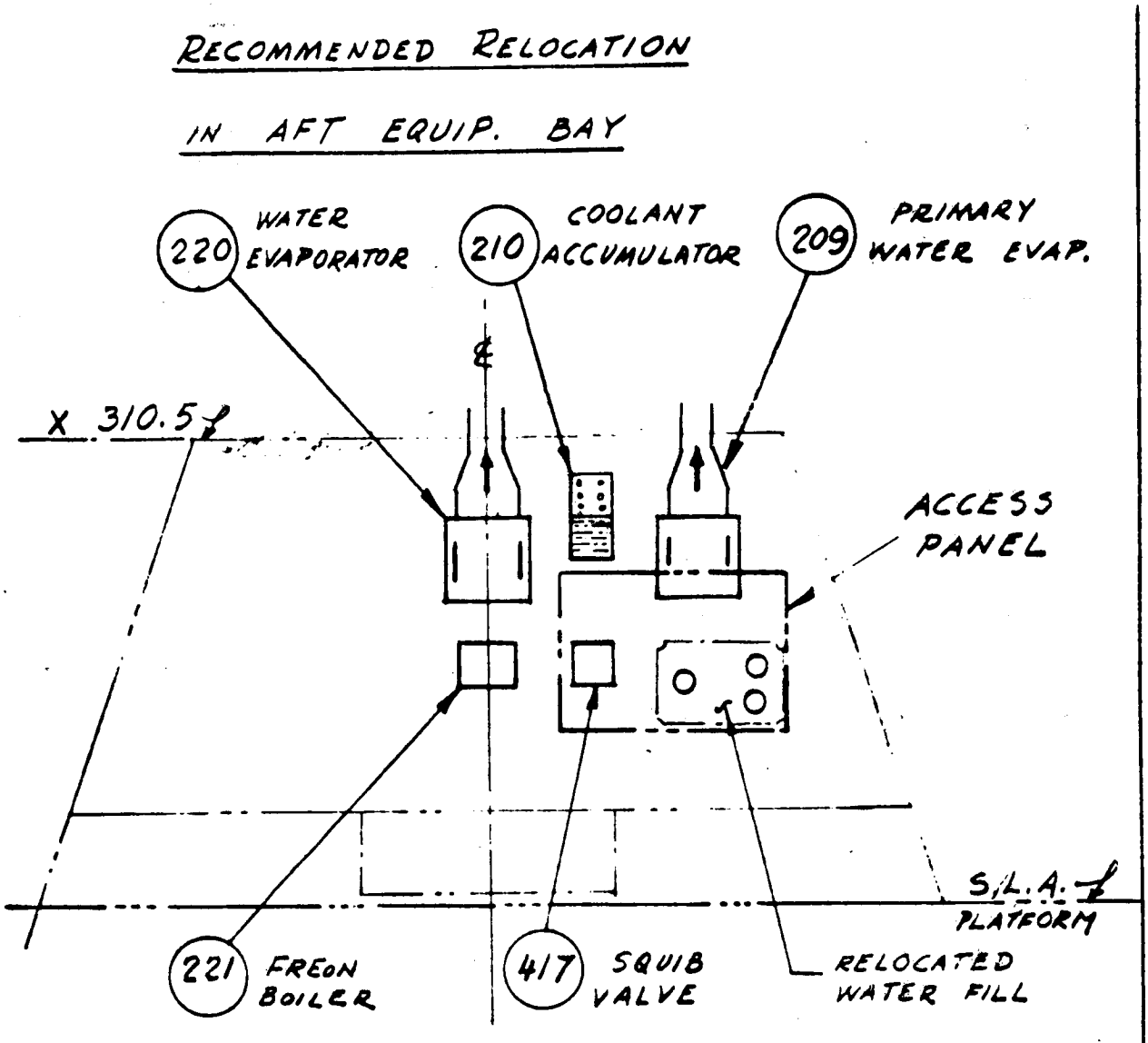
RECOMMENDED RELOCATION
IN AFT EQUIP. BAY
220 WATER EVAPORATOR
210 COOLANT ACCUMULATOR
209 PRIMARY WATER EVAP.
X 310.5
ACCESS PANEL
S.L.A. PLATFORM
221 FREON BOILER
417 SQUIB VALVE
RELOCATED WATER FILL
VIEW LOOKING FWD
AFT EQUIP. BAY -Z 27

FIGURE 4.5.1

4.5.9.1 Common Usage Item

These problems are documented in LMM-550-25 for the LEM ECS Item 403 Water Fill and Drain Connection. They are:

1. The female half of the disconnect can be disarmed by shock resulting in loss of function.

2. A wire snap ring is used without a locking device, failure of wire results in loss of function.

3. Poppet springs are weak and inadvertant force can break this connection.

4.5.10 Circuit Analysis

No effort to report for this period.

4.5.11 Reliability Data List

Reliability Data List were prepared by the Subcontractor. For status see Figure 4.5.1.2.

4.5.12 NPPAR

No effort for this period.

4.5.13 Reliability Test Program

4.5.13.1 Contract Status

Amendments to LSP-330-2A were completed and reviewed in preparation for contract re-negotiation. The amendments as of 15 June 1965 include the following:

1. The reoriented test logic resulting from the MSC-GAEC test program redefinition of 25 November 1964 and

4.5.13.1 Contract Status (continued)

2. The change in equipment requirements (e.g., deletion of the cryogenic heat exchanges, gaseous oxygen accumulator, etc.) resulting from the decision to use an all battery power generating source for the LEM.

In addition, the reliability tasks and documentation requirements of the contract were updated to reflect the test program redefinition.

4.5.13.2 Test Program Progress

The first phase of the Development Test Program (Component Design Feasibility Tests DFT) at HSD is proceeding at a rate for too slow to meet the Program Schedule of LED-260-330-01, Revision B "LEM Ground Test Logic, LEM ECS, Sections 1, 2, 3 and 4", dated December 9, 1964. Whereas component DFT was scheduled to be completed by the 4th week of May 1965, the test status on 30 May 1965 was as follows:

1. Component DFT completed - 18
2. Component DFT in progress - 17
3. Component DFT not started - 23

The "completed" tests are subject to Grumman approval, based upon the evaluation of the HSD test reports which are in the process of preparation. The first Design Review for Production Release is to be held on 7 July 1965, the results of which will be reported in the next Reliability Quarterly.

4.5.13.3 Oxygen Storage and Supply Section

No test activity in progress due to redefined section design (Ref. CCA #103).

4.5.14 Failure Reporting and Corrective Action and Failure Analysis

The following is a cumulative listing of failures, and status of corrective action from Hamilton Standard:

RDT and Item No	Date of Failure	Failure Analysis	Status Of Corrective Action
107-1	5/20/1965	Oxygen Leak	Closed
118M-1	3/2/1965	Bearing Failure	Open
118M-3	4/1/1965	Transistor Fail.	Open
119-1	3/20/1965	Leakage	Open
222-1	4/2/1965	Leakage	Open
401-1	4/1/1965	Leakage	Open
203-1	4/31/1965	Leakage	Open
204-1	3/11/1965	Low Glycol Flow	Open
208-3	12/15/1965	Flow Rate Varies out of Spec.	Open
210-1	2/4/1965	Primability of Diaphram	Open
220-1	2/16/1965	Leakage	Closed
290-1	4/14/1965	Electronics Malfunction	Open
402-1	4/5/1965	Leakage	Open
406-1	4/9/1965	Leakage	Open
414-1	6/9/1965	Leakage	Open
118M-2	4/23/1965	Electronics Fail.	Closed
118M-4	4/9/1965	Electronics Fail.	Closed
118M-5	4/16/1965	Electronics Fail.	Closed
118M-6	4/16/1965	Electronics Fail.	Closed
210-1	3/3/1965	Vibration Failure	Closed
305-1	3/19/1965	Leakage	Closed
309-1	3/12/1965	Leakage	Closed
406-1	4/5/1965	Flow Rate	Closed

4.6 ELECTRICAL POWER SUBSYSTEM

4.6.1 General

The report covers the reliability status of the Electrical Power Subsystem from March 15, 1965 to June 15, 1965. The Electrical Power Subsystem (EPS) contains the Power Generation Subsystem (PGS) and the DC and AC distribution systems. This quarter covers the progress and status of the new all-battery system.

4.6.1.1 Subcontractor Status and Milestones

Table 4.6.1.1.1 lists the major assemblies, contractors, and associated P.O. and specification numbers.

Table 4.6.1.1.2 is a milestone chart showing the status of the program and documentation.

TABLE 4.6.1.1.1

Equipment/Contractor Summary

Equipment	Contractor	P.O. No.	Spec. No.
General Purpose Inverter	Hamilton Standard	2-24494	LSP-390-6A
Electronic Control Assemblies	General Electric	Not Issued	LSP-390-25,26
Batteries (Main Power)	Eagle Pitcher	Not Issued	LSP-390-21,22
Junction Box, Relay	General Electric	Not Issued	LSP-390-23
Bus Tie Contactor	General Electric	Not Issued	LSP-390-24

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TABLE 4.6.1.1.2

HAMILTON STANDARD - GENERAL PURPOSE INVERTER

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks Milestones																				
Program Plan				●																
Reliability Status Report				●	●	●	○	○	○	○	○	○	○	○	○	○				
Apportionments and Estimate				●																
Math Model				●			○		○											
Configuration Analysis				●			○		○											
Failure Mode and Prediction Analysis					○		○		○											
Failure Effect Analysis				●			○		○											
Maintainability Analysis				○	○	○	○	○	○											
Design Review				●			○		○											
Design Review Documentation				●			○		○											
Circuit Analysis				●			○		○											
Reliability Data List					●	●	○	○	○	○	○	○	○	○	○	○				
NPPAR					◐	◪	○		○											
Reliability Test Plan				◐	◪	○														
Reliability Assessment					●		○		○											
Failure Reports and Corrective Action						○	○	○	○	○	○	○	○	○	○	○				
Failure Analysis						○	○	○	○	○	○	○	○	○	○	○				
Reliability Indoctrination and Training																				

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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4.6.2 Subsystem Summary

4.6.2.1 Summary of Effort for This Period

1. Power Distribution Subsystem - A reliability analysis was made of the new schematic generated for the All-Battery System (LDW-390-21000) and it was determined that a split-buss system (a bus on the Commander's side of LEM and another one on the Systems Engineer's side, each one electrically connected to the other) will be used, rather than the Primary Transfer and Peak busses required for the fuel cell.

   It was decided that 4 batteries will be stored in the descent stage and be used to power the mission until just before Lunar Launch. Two batteries will be positioned in the ascent stage and be used for the final phases of the mission, or in the event of an emergency abort, will be used for LEM power upon staging the descent stage.

   The descent batteries are connected in parallel and are sized so that the mission may continue, with a limited lunar stay, upon the failure of one of the four. Upon the failure of the second battery in the descent stage, the logic of the ECA senses this, and gives signals for transferring ascent battery power to the busses and for an abort procedure to commence.

   The ascent batteries are 100% redundant in as much as a successful lunar launch can be accomplished with only one of the two batteries.

   Battery temperature significantly influences ECS sizing and reliability. The problem was studied by the Environmental Control and Reliability engineers. The design now calls for the temperature to be held at + 100°F at normal operation and approximately + 140°F during an emergency abort.

4.6.2.1 Summary of Effort For This Period (continued)

2. Batteries For PGS (LSP-390-21,22) - Eagle Pitcher has been selected to develop the batteries for the PGS. The descent battery capacity will be approximately 500 ampere-hours and the ascent batteries about 450 ampere-hours. Inquiries have been sent to various battery manufacturers and reliability engineers have visited the facilities of the larger space system manufacturers such as J.P.L Convair and Locheed in California and many others throughout the country, in an effort to gather reliability or test information on high capacity silver-oxide zinc batteries.

3. Electronic Control Assembly (LSP-390-23) - The Electronic Control Assembly (ECA) for the all-battery system is approximately as complex as the ECA for the fuel cells. In addition, a Relay Junction Box has been included in the present ECA for the purpose of switching power either from the Command Module or from the Ascent or Descent Batteries to the buss.

   There will be one ECA (electrically) for each battery. It will contain a Main Feed Contactor which will connect each battery to the buss or, in the event of a fault, remove the battery from the buss. The ECA will sense temperature changes in the battery, over current and over and under voltage conditions in the feed wire and assist in the "dead facing" operations of the descent stage.

   General Electric has been selected as the vendor and was notified on 25 June 1965.

4. General Purpose Inverter (LSP-390-6A) - The inverter converts twenty-eight volts DC into one hundred fifteen volts four hundred cycle power.

4.6.2.1 Summary of Effort For This Period (continued)

4. General Purpose Inverter (continued)

Hamilton Standard is in the design and development testing phase of the program. A monthly progress report LVM-1151-095 has been received and reviewed. The report reveals a problem in staying within the thermal boundaries for the cold rail. HSD indicates it may be necessary to increase the total length of the heat flange from 31.5 to 35.0 linear inches. Circuit problems have delayed the scheduled delivery on modules one through eight. A number of circuits were redesigned in order to keep the electrical stress on the parts within the limitations of the derating policy.

5. DC Distribution Subsystem (LDW-390-60000-4) - The DC Distribution Subsystem consists of the circuit breakers for protection of the 28 VDC Main Power Feed, cables, connectors, distribution busses, and interconnecting circuit breakers for the individual loads.

The distribution system logic has changed with the change of fuel cells to batteries. Loads have been redistributed on each half of the distribution buss so that in the event of an emergency, degraded, abort may be successfully accomplished with the loss of one buss. Non-redundant crew safety equipment will be dual fed, with each feeder connected to separate busses.

6. AC Distribution Subsystem (LDW-390-60000-5) - The AC Distribution Subsection consists of two circuit breakers for the outputs of two Inverters, cables, connectors, and the distribution busses. An external power input is coupled to the buss through a circuit breaker.

4.6.2.1 Summary of Effort For This Period (continued)

6. AC Distribution Subsystem (continued)

In the initial circuit configuration, the outputs of the inverters and the external power input were connected to a single rotary switch. A reliability analysis revealed that a single switch in series with all the inputs to the AC bus would negate the advantages of redundant inverters. Failure of the switch would prevent the use of the other inverter. Separate switches will be incorporated.

7. Lighting Control Assemblies (LSP-390-9)-There are five different lighting controls. Three of the assemblies are of the mag-amp or reactor type control and are used to reduce the main power to a variable voltage for lighting control. Two of the units are DC to DC converters One is a DC to AC converter. A fourth type of control is a variable auto-transformer. The fifth type is a variable potentiometer.

Four proposals have been received and are being evaluated.

4.6.2.2 Projected Effort for Next Period

1. A Reliability test program is being prepared by GAEC in order to obtain the necessary test data to provide an indication of realistic failure rates for 550 AH batteries operating at 100°F. This will be done in conjunction with continuing effort to ferret out all existing, applicable reliability data on comparable batteries.

2. Specifications are being completed for Power Connector, Bulkhead, Feed-thru, LSP-390-19. Two proposals have been received and will be evaluated.

3. The initial progress report has been received from Deutsch on the circular connector, LSC-390-8, and will be evaluated during the next period.

4.6.2.2 Projected Effort for Next Period (continued)

3. (continued)

Specification and procurement drawings for the LSC-390-8 connectors have been submitted for approval.

4. Specification and procurement drawings for the Lighting Control Assemblies LSP-390-9, has been submitted for approval.

5. Development tests are scheduled to begin on the General Purpose Inverter (LSP-390-6A) during the next quarter. As problems are discovered by the various tests, a report of the malfunction will be sent to Grumman. The Failure Reports will be analyzed by Reliability. If corrective action is required, recommendations will be sent to the approrpriate departments.

A visit to Hamilton Standard is planned for the next quarter.

6. Effort will continue with the maintainability analysis of the Power Generation Section.

4.6.3 Reliability Apportionments and Estimates

1. Electrical Power Subsystem - The Reliability estimates are based on the mission time of the Design Reference Mission profile and on the reliability model shown in LED-550-44, dated 27 February 1965.

Estimates for the Electrical Power Subsystem are tabulated below:

	8th Quarterly	9th Quarterly
Mission Success	0.963896	0.963896
Crew Safety	0.999993	0.999993

2. Batteries (Main Power) - A test program is being initiated and a data research is being conducted for the purpose of establishing a

[redacted]

4.6.3 Reliability Apportionments and Estimates (continued)

2. Batteries (continued)

realistic battery failure rate. Maximum nominal operating temperature has been established at about 100°F.

3. General Purpose Inverter(LSP-390-6A) - Changes in the original design of the Inverter has resulted in a decrease in the reliability estimate. The results are tabulated below.

Apportionment	0.999700
8th Quarterly	0.994510
9th Quarterly	0.993226

In order to improve reliability the following changes are being incorporated.

The voltage control circuit has been changed from a full boost system to a ringing choke type circuit. The original circuit required doubling the input voltage which the revised circuit required an increase of only 20%. This reduced the size and weight of the transformers and reduced the electrical stress on the semi-conductors.

The control circuit has been revised to regulate the output voltage, constrain overload current, and constrain voltage applied to the power stages.

The tap changer used push pull input to a toroidal transformer. Differential loading by the SCR's subjected the transformer to a DC component. The circuit was changed using four separate transformers.

The inverter input voltage was reduced 50% Current sensing for overload was removed from the output circuit to the inverter stage. Semi-conductors now operate within limits of derating policy.

[redacted]

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4.6.3 Reliability Apportionments and Estimates (continued)

3. General Purpose Inverter (continued)

The oscillator and synchronizing circuit input sensitivity was increased from seven milliamperes to one milliampere. Circuit complexity was reduced by one transistor, two diodes, and two resistors.

The logic circuit was changed to a countdown flip-flop, two synchronized two stage ring counters, and a second countdown flip-flop. This circuit eliminates the unwanted pulses caused by propogation delays.

These modifications have reduced the weight and power dissipation of the GPI. Reducing control voltage levels and power consumption has resulted in a decrease in electrical stress levels on electrical parts.

4.6.4 Reliability Mathematical Model

1. Power Generation Subsystem - The All Battery EPS will contain four batteries in the descent stage and two batteries in the ascent stage. Ground rules for "Mission Success" consider all six batteries and associated electrical control assemblies in series from Earth Launch through Lunar Stay. The loss of any one of the six batteries negates the possibility of achieving a thirty-five hour lunar stay. Loss of a descent battery shortens the lunar stay time, since the remaining three batteries will be discharged at an accelerated rate. An abort would be initiated if either ascent battery malfunctions. Crew safety criteria requires at least one of the two ascent batteries to operate during normal ascent or abort phases. This configuration has improved the PGS reliability to .963896 in comparison to the Fuel Cell configuration which had a reliability of 0.938750.

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4.6.5 Configuration Analysis

1. Power Generation Section - No effort to report during this period since contracts have only recently been awarded.

2. DC Distribution System (LDW-390-60000-4) - A configuration analysis was performed on a preliminary schematic of theDC Distribution System, as reported in Para. 4.6.2.1 (5).

3. AC Distribution System (LDW-390-60000-5) - The AC Distribution system consists of the circuit breakers and feeder lines to two General Purpose Inverters. The two inverters are for redundancy. One inverter will be inoperative while on standby. The outputs will go through circuit breakers to the AC Buss.

   A failure mode and effects analysis indicated that a single failure of the series switch in the inverter output would prevent either inverter from supplying AC to the bus. Reliability's recommendation to install a separate circuit breaker for each AC power input to the bus has been incorporated.

4. General Purpose Inverter (LSP-390-6A) - Analysis indicated there is no redundancy in the inverter circuitry. Because of the nature of the design, the use of redundant circuits became impractical. The problem has been offset by using redundant inverters in the AC Distribution system.

   Basic circuit functions have been changed to improve the operation and efficiency of the unit. Parts are being selected that will operate within the limits of the derating policy. The reliability of the GPF is expected to improve as a result of this redesign.

5. LEM Lighting Control System (LSP-390-9) - The lighting control systems have been revised. A preliminary configuration analysis is being prepared for the new system.

4.6.6 Failure Mode and Effect Analysis

Effort is continuing to improve reliability through a Failure Mode and Effect Analysis program.

As the various analyses are received from the vendors, they are reviewed, and the information is used to develop a Subsystem level Failure Mode and Effect Analysis.

The analysis will detect such things as critical circuits in series, where a single part failure will cause an equipment failure. Recommendations are developed to correct the problem, based on the GMEA. Corrective action requests are sent to the cognizant persons. Follow-up procedures are then established to observe the effects of the corrective action.

The data accumulated through the FMEA program will be used to train LEM personnel to identify a malfunction indication, and to outline the proper procedures to correct or circumvent the malfunction. Hamilton Standard has submitted a revised FEA based on the redesigned inverter, LSP-390-6A. There have been no other inputs due from vendors during this quarter.

4.6.7 Failure Mode Prediction Analysis

The FMPA is associated with the overstress portion of the test program. Vendor inputs are not due during this quarter.

4.6.8 Maintainability

1. Descent Stage Battery Installation - The effort for this reporting period included detailed task inputs for a battery installation demonstration soon to be conducted at this facility. The tasks will among other things exhibit the maintainability characteristics planned for this portion of the subsystem. The primary maintainability interest in this demonstration is the susceptability of human induced maintenance damage to the cold rails in the descent stage.

4.6.8 Maintainability (continued)

2. Battery Cover Design - Eagle-Picher has agreed to alter the original battery cover design and submit a new one. The original design did not allow sufficient clearance between adjacent batteries for installing the battery mounting hardware. This problem will be closely monitored at the coming design review meetings.

3. General Purpose Inverter - An assembly design analysis has been prepared on the inverter presenting the latest equipment status. Subject form will be continuously updated to the design freeze date. Any problems noted on the form will be resolved prior to the freeze date.

4.6.9 Design Reviews

There were no design reviews held during this quarter.

4.6.10 Circuit Analysis

1. General Purpose Inverter - A previous analysis by Hamilton Standard indicated that a number of parts were electrically overstressed since they exceed the limits of GAEC's Derating Policy. (LED-550-25A, dated 11 November 1965). In order to utilize the maximum number of parts listed in the Approved Parts List LED-550-25A Hamilton Standard found it necessary to redesign the circuits. An updated analysis has been received in their Monthly Report LVM-1151-091, dated 21 April 1965.

4.6.11 Reliability Data List

1. General Purpose Inverter - An updated RDL has been submitted by Hamilton Standard in the Monthly Report, LVM-1151-095, dated 23 April 1965, the list is being reviewed by Reliability.

4.6.12 NPPAR Status

1. General Purpose Inverter - Hamilton Standard has submitted a list of parts to GAEC for approval. The present status is as follows:

Approved	54%
Approval Withheld	20%
Disapproved	6%
Open	20%
TOTAL	20%

Part Specification Drawings were submitted for approval. The present status is as follows:

Approved	0%
Disapproved	80%
Open	20%
TOTAL	100%

4.6.13 Test Program

1. Batteries - The contract was awarded to Eagle-Picher on 22 June 1965. The test plan is due in ninety days.

2. Electrical Control Assembly & Relay Junction Box The contract was awarded to General Electric on 25 June 1965. The test plan is due in ninety days.

3. General Purpose Inverter - Hamilton Standard has not resubmitted the general test plan as required.

   To date, development testing has been performed at the engineering breadboard model level of assembly. It is anticipated, that design feasibility testing on the preproduction model (S/N 1) will commence during the next reporting period.

4. Circular Connectors - Qualification testing is planned to commence during next reporting period.

4.6.14 Reliability Assessment

No effort during this reporting period.

4.6.15 Failure Reporting and Corrective Action

Due to the redirection from fuel cells to batteries in the EPS, most of the associated equipment has been deleted or changed. As a result there has been no testing.

4.6.16 Failure Analysis

No effort during this reporting period.

4.7 STRUCTURAL AND MECHANICAL DESIGN

4.7.1 General

Most significant and fruitful contribution from Reliability during this quarter was in the configuration analysis performed on the various pyrotechnic components and systems. These analysis are detailed within this report.

4.7.1.1 Subcontractor Status and Milestones

Present subcontractor status and milestones reached to date are presented in Tables 4.7.1.1 and 4.7.1.2 for the ascent stage propellant tanks (Aerojet) and for the descent stage propellant tanks (Allison).

4.7.2 Subsystem Summary

4.7.2.1 Summary of Effort For This Period

1. A configuration analysis was performed on the LTA-1 landing gear down lock indicator system.

2. A configuration analysis has been started on a guillotine versus mechanical disconnect.

3. A configuration analysis on the pyrotechnic stage separation system solid state sequencing timers has been performed.

4. Configuration analysis on pyrotechnic valves versus solenoid operated valves has been performed.

5. A Maintainability analysis on the interstage explosive bolt and nut has been performed.

6. Monitoring of the tankage subcontractors continued this period. An increase in the volume of documentation for review was noted.

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TABLE 4.7.1.1.1

ASCENT STAGE PROPELLANT TANK - AEROJET GENERAL

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks Milestones																				
Program Plan			◪	●																
Reliability Status Report				●	●	●	○	○												
Apportionments and Estimate				●	●	●	○	○												
Math Model		NOT APPLICABLE																		
Configuration Analysis				●	●	●	○	○												
Failure Mode and Prediction Analysis				●	●	●	○	○												
Failure Effect Analysis				●	●	●	○	○												
Maintainability Analysis				○	○	○	○	○												
Design Review			●				○	○												
Design Review Documentation			●				○	○												
Circuit Analysis		NOT APPLICABLE																		
Reliability Data List				●	●	●	○	○												
NPPAR		NOT APPLICABLE																		
Reliability Test Plan				●																
Reliability Assessment							○	○	○	○	○									
Failure Reports and Corrective Action						●	○	○	○	○	○									
Failure Analysis						●	○	○	○	○	○									
Reliability Indoctrination and Training											▶									

○ Due
● Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABLE 4.7.1.1.2

DESCENT STAGE PROPELLANT TANK - ALLISON

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan	◪	●																		
Reliability Status Report	●	●	●	●	●	●	○	○												
Apportionments and Estimate	●	●	●	●	●	●	○	○												
Math Model	NOT APPLICABLE																			
Configuration Analysis	◪	○	○	◐	●	●	○	○												
Failure Mode and Prediction Analysis	●			●	●		○	○												
Failure Effect Analysis	●	●	●	●	●	●	○	○												
Maintainability Analysis	●	●	●	●	●	●	○	○												
Design Review	●						○	○												
Design Review Documentation	●						○	○												
Circuit Analysis	NOT APPLICABLE																			
Reliability Data List																				
NPPAR	○	○	◐	●																
Reliability Test Plan																				
Reliability Assessment							○	○												
Failure Reports and Corrective Action					○	●	○	○	○	○	○	○								
Failure Analysis					○	●	○	○	○	○	○	○								
Reliability Indoctrination and Training												►								

Due ○
Received ◐
Accepted ●
Unacceptable - Minor Exceptions ◪
Rejected - Major Revision ■

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4.7.2.1 Summary of Effort For This Period (continued)

7. Vibration tests on the Allison feasibility tank was completed.

8. The failure analysis on the Allison P-009 tank was completed.

9. A preliminary leak test on the simulated Aerojet Tankage was successfully completed.

10. Pyrotechnic design studies were conducted concerning the initiators, physical separation of components, explosive bolt and nut, MDF Guillotine, mechanical disconnect and the LTA-1 pyro system.

11. A configuration analysis is being performed to improve pyro component reliability (i.e., umbilical cutter and interupter).

4.7.2.2 Projected Effort For Next Quarter

1. Configuration analysis guillotine versus mechanical disconnect.

2. Continue FMEA

3. Continue review of vendor documentation.

4. Start verification testing on the Descent Propellant tankage.

5. Start feasibility testing on the Ascent Propellant tankage.

6. Follow up interstage explosive bolt and nut installation and accessibility problem into the mockup phase.

7. Continue extensive study of the entire pyro system.

4.7.3 Reliability Apportionment and Estimates

1. Pyrotechnic Subsystem

The reliability apportionment and estimates

4.7.3 Reliability Apportionment and Estimates (continued)

1. Pyrotechnic Subsystem (continued)

are the same as last quarter and are shown in the Table below. Component redesign is currently being conducted to increase the reliability (see Para. 4.7.5.1)

2. Structural

No change in status during this quarter.

Subsystem	Reliability			
	Apportionment		Estimated	
	Mission Success	Crew Safety	Mission Success	Crew Safety
Pyrotechnic Ascent-Descent Stage Separation Systems (only)	.999999	.999999	.9995 *.99996	.9995 *.99996

* These reliability estimates are determined using the NAA initiator reliability estimate of .999.

4.7.4 Reliability Mathematical Models

1. Pyrotechnic

No change in status during this quarter.

2. Structural

No change in status during this quarter.

4.7.5 Configuration Analysis

4.7.5.1 GAEC Effort

1. The landing gear down lock indicator system for LTA-1 reference pyrotechnic drawing LDW-320-21000 was reviewed. In accordance with

4.7.5.1 GAEC Effort (continued)

1. (continued)

   Reliability's recommendations the original system was replaced with a system the same as that used in the LEM-10. This system was discussed in the last quarterly report.

2. A configuration analysis has been started for the guillotine umbilical cutter versus a mechanical disconnect cutter.

3. Redesign of the umbilical cutter is being investigated in an effort to increase the reliability. Formerly, the device was an initiator powered guillotine. A initiator operated shaped charge was used as a back-up system. In the redesign either of the initiators can now operate eith of the two MDF powered guillotine cutters. Evaluation of such configurations and variations thereof is a continuing process.

4. Reduction in the quantity of interupter initiators is being investigated.

5. Re-evaluation of the solid state timers controlling the sequencing of the bolt, interupter and umbilical cutter initiators was conducted. To have proper sequencing the system was revised to ensure that Timer #2 can not start until Timer #1 is finished. Previously, both timers were started from one signal. Proper sequencing, which is critical, was dependant upon part quality and variations in their tolerances.

6. Analysis on pyrotechnic versus solenoid operated valves which are used in the ECS and Propulsion areas were and are being conducted. While reliability differences exist between the above valves, it was system reliability requirements that dictated the choice. For ECS the solenoid valve was chosen.

4.7.5.2 Vendor Effort

1. Aerojet General

No change in status during this quarter.

2. Allison

No change in status during this quarter.

4.7.6 Failure Mode and Effect Analysis

No change in status during this quarter.

4.7.7 Failure Mode Prediction Analysis

No changes or additions to the subject analysis was reported during this quarter from either Aerojet General or Allison.

4.7.8 Maintainability

1. Pyrotechnics

Explosive Bolts - The maintainability group is currently investigating the accessibility and installation of the interstage explosive bolts and nuts. The installation is required to be performed in an extremely tight area. Difficulties are anticipated in applying the required torque and safetying the explosive bolts. Maintainability will look into and possibly suggest the use of pre-load washers to achieve the required torque and ease this portion of the installation.

Pyro Batteries - A review has been conducted on the preliminary drawings depicting the installation of the Pyro Batteries. It has not been firmly established if the batteries will be cold railed. In any event the proposed location in the descent stage quad IV area will present no problems for installation or accessibility.

4.7.8 Maintainability (continued)

2. Structure

Maintainability recommended a demonstration of selected maintenance tasks on a LEM Descent Stage. This was a result of the PD-1 DE1 which raised questions with respect to access thru the lower heat shield. The study is concerned with the configuration as it exists and varies from T-68 days until launch. A summary of expected contingencies, affected components, a summary of data to be determined and a listing of resources required were presented. (Ref. LMO-550-661).

A concurrent effort is being studied with respect to the entire LEM vehicle. This begins by extending the capability of the M3/M18 mockup to include specified access tasks consistent with a limited rework of the M3 mockup. Later stages of the study will be conducted on the M5 mockup, assuming that the vehicle is updated to a suitable configuration.

3. Vendor

No change in status during this quarter.

4.7.9 Design Review

4.7.9.1 GAEC Effort

1. The need for physical separation of redundant pyrotechnic functions was stressed and whenever possible this is being accomplished e.g., LMO-540-26.

2. Since the last reporting period 747 drawings, drawing changes and specifications were reviewed and approved by Reliability as part of the Design Review effort.

4.7.9.1 GAEC Effort (continued)

3. Design reviews and tests on the MDF guillotine have taken place (See Para. 4.7.5.1.3).

4. Conduced preliminary design review on a mechanical disconnect (See Para. 4.7.5.1.2).

5. Design review conducted on the LTA-1 Level 3 Schematic LDW-320-21000. Action items are contained in LMO-540-26, dated 1 June 1965.

4.7.9.2 Vendor Effort

Design reviews were conducted on the explosive bolts and explosive nuts.

NAA and Space Ordanence Systems were contacted on the design and testing of the Apollo standard initiator its failure modes, and its failure rates.

4.7.10 Circuit Analysis

No effort for this period.

4.7.11 Reliability Data List

No change in status during this quarter.

4.7.12 NPPAR Status

No effort for this period.

4.7.13 Reliability Test

1. Pyrotechnic

Explosive Nut and Bolt Assembly - It is anticipated that the first stage of DFT will commence during the next report period.

4.7.13 Reliability Test (continued)

1. Pyrotechnic (continued)

Landing Gear Uplock Release Mechanism - This program is presently in the Design Feasibility phase. Two release techniques are currently under investigation. They are:

a. Initiator - Pressure release mechanism

b. Detonation - Guillotine release mechanism

2. Aerojet General

No change in status during this quarter.

3. Allison

During this report period, the test effort at Allison was still in the feasibility stage. A total of 11 hours 44 minutes of random and sinusoidal time was completed on the tank. This time includes both empty and full conditions.

Preliminary wear tests on the Teflon bumper that are located inside the tank are continuing. It was found that under severe vibration conditions the flaking of the teflon occurred.

4.7.14 Failure Reporting and Corrective Action

See Para. 4.7.15.

4.7.15 Failure Analysis

The analysis of the failure of Allison tank S/N - P-009 which failed on March 9, 1965 at 74% of the required proof pressure of 360 psig is given in Allison report #65 FA8-6 dated 19 April 1965. Following is a summary of the report and GAEC comments.

4.7.15 Failure Analysis (continued)

The premature failure of the Ti-6AL-4V LEM propellant tank during proof test was attributed to a localized microstructural abnormality consisting of embrittled massive alpha. Stabilization of alpha phase in titanium is generally attributed to an excessive amount of nitrogen, oxygen, and/or aluminum. However, since an electron microprobe analysis of the failure revealed a normal aluminum content in the massive alpha structure, it is assumed that the alpha stabilization was a result of either oxygen or nitrogen. From comparisons of photomicrographs, the stabilization of alpha is attributed to oxygen.

Since the abnormal structure was encapsulated in the LEM forging, it is assumed it was present in the melt. Possible sources of oxygen, as the stabilizing agent, are titanium oxides entrapped during the melt and/or high oxygen content scrap used in the melt. Should an oxide become entrapped in the melt, it is possible it might diffuse completely during melting and never show up as a low density inclusion during subsequent radiographic inspection.

The occurrence of this abnormal structure, at least in quantities or sizes that cause premature failure, can be seen from the following: to the date of the failure, 1375 second stage minuteman rocket motor case components, 264 Apollo tank components and 39 LEM propellant tank components have been fabricated from Ti-6AL-4V and proof tested by Allison Division of General Motors. The dome of Serial No. P-009 is the first of 1678 components to fail prematurely because of this abnormal massive alpha structure.

To date there has been three (3) known premature failures - two at Aerojet General Corp. on Minuteman Wing II Aft Closures and one at Allison on P-009 LEM Propellant tank. All three failed for the same reason during the first proof pressure loading test.

On the basis of the above it is felt by GAEC that deliverable end items would be free from injurious massive alpha structure, since all LEM propellant tanks are proof pressure tested prior to delivery.

4.7.16 Vendor Reliability Training and Indoctrination

No change in status during this quarter.

4.8 CREW PROVISIONS

4.8.1 General

4.8.1.1 Subcontractor Status and Milestones

Analysis and comparisons of vendors proposals are currently being made on various components of the lighting system. Negotiations are also being conducted with Lundy Electronics for the purchase of a waste management system for the LEM. Otherwise no subcontractors have been selected and there is no status or milestones to report during this quarter.

4.8.2 Subsystem Summary

4.8.2.1 Summary of Efforts During this Quarter

1. The configuration analysis for the Waste Management System was completed.
2. A review of GAEC and vendor drawings is in progress.
3. Discussions with designers took place on the advisability of using berylium for various LEM components.
4. Inputs were provided and specifications were reviewed for crew provision subsystems.
5. Failure effect analyses were continued wherever design had progressed far enough to make such an analysis meaningful.
6. Held design review meeting on use of velcro and pip-pins on back-pack.
7. Reviewed energy-absorption features of crew support and restraint system.
8. Reviewed NAA interface drawing LID-340-11104 on emergency O_2 storage.

4.8.2.2 Projected Effort For Next Quarter

1. Vendors reliability inputs for the Waste Management System will be evaluated.
2. Continue participation of in-house design reviews.
3. Continue reliability review of GAEC and vendor drawings.
4. Continue Failure Mode and Effect Analysis

4.8.3 Reliability Apportionment and Estimate

No effort during this period.

4.8.4 Reliability Mathematical Model

No effort during this period.

4.8.5 Configuration Analysis

4.8.5.1 Crew Support and Restraint

A tentative satisfactory compromise between adequate support and ease of mobility has been reached and is currently being tested in a KC-135 Tanker. Reference GAEC Drawing: LSK-340-1241.

4.8.5.2 Vomitus Management

The requirement for this equipment is presently under study by NASA.

4.8.5.3 Waste Management

The Lundy Electronics and Systems Company has been selected to supply the Urine Waste Management System. Negotiations between GAEC and Lundy are currently in progress. No provisions are being or will be made for feces removal unless NASA later so directs.

4.8.6 Failure Mode and Effect Analysis

Failure mode and effect analyses are being made and modified as the designs are improved and potential failures eliminated. This is being done for all crew provision subsystems. Reference GAEC Drawing: LDW-340-60,000 entitled Level III Schematic-Crew Provision Subsystem

4.8.7 Failure Mode Prediction Analysis

No effort reported in this period since no subcontractor have submitted test plans yet.

4.8.8 Maintainability Analysis

No effor for this period.

4.8.9 Design Review

Informal design reviews for all the crew provision subsystems are continually being made as the design progresses.

1. For the ascent-descent subsystem (ladder) berylium is being studied as a weight saving substitute for aluminum. Berylium has a better strength-weight ratio.

2. For the PLSS Back-Pack velcro is being considered as a simple restraining device for the astronaut performing navigational sightings. The back-pack with the velcro attached is pinned to the cabin floor with the velcro surface upward. When the astronaut wishes to take a navigational sighting he stands upon the back pack. This raises his eyes to the proper height for the sighting while the velcro on his shoes meshes with the velcro on the pack to keep him from floating around in the zero gravity condition.

4.8.10 Circuit Analysis

Not applicable.

4.8.11 Reliability Data List

No change in status.

4.8.12 NPPAR

No change in status.

4.8.13 Test Program

No change in status.

4.8.14 Failure Reporting and Corrective Action

No failures were reported during this quarter.

4.8.15 Failure Analysis

Since there were no reported failures, there were no analysis efforts during this quarter.

4.9 INSTRUMENTATION

This report covers the period from 15 March 1965 to 15 June 1965.

4.9.1 General

During this reporting period a detailed measurement requirement study to determine the most likely candidates for low-bit rate telemetry was initiated and will be continued during the next quarter. The status, results and reference documentation of the reliability improvement studies carried out in the Instrumentation area during this reporting period are described in the following subsections.

4.9.1.1 Subcontractor Status and Milestones

Subcontractor status for Radiation, Arma, and Leach is given in Table 4.9.1.1-2 through -6, respectively.

4.9.2 Summary of Efforts for Period

Efforts were expended in the following areas:

1. Measurement selection criteria for low-bit rate telemetry.

2. Reliability estimate of the helium tank pressure instrumentation to confirm that majority voting is unnecessary.

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.9.1.1-2

RADIATION - PCM

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan																				
Reliability Status Report						○	○	○	○	○	○	○	○							
Apportionments and Estimate						●	○	○	○											
Math Model																				
Configuration Analysis							○													
Failure Mode and Prediction Analysis							○													
Failure Effect Analysis						◐														
Maintainability Analysis						◪	○													
Design Review							○													
Design Review Documentation							○													
Circuit Analysis																				
Reliability Data List						◐														
NPPAR																				
Reliability Test Plan							○													
Reliability Assessment								○	○	○	○	○	○							
Failure Reports and Corrective Action						○	○	○	○	○	○	○	○							
Failure Analysis						○	○	○	○	○	○	○	○							
Reliability Indoctrination and Training																				

○ Due
● Received
◐ Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.9.1.1-3

RADIATION - GT - TE

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan																				
Reliability Status Report						◐	○	○	○	○	○	○	○							
Apportionments and Estimate						●	○	○	○											
Math Model																				
Configuration Analysis							○													
Failure Mode and Prediction Analysis							○													
Failure Effect Analysis						●														
Maintainability Analysis						◪	○													
Design Review							○													
Design Review Documentation							○													
Circuit Analysis																				
Reliability Data List						◐														
NPPAR																				
Reliability Test Plan							○													
Reliability Assessment								○	○	○	○	○	○							
Failure Reports and Corrective Action						○	○	○	○	○	○	○	○							
Failure Analysis						○	○	○	○	○	○	○	○							
Reliability Indoctrination and Training																				

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.9.1.1-4

ARMA - CWEA

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan																				
Reliability Status Report						●	○	○	○	○	○	○	○							
Apportionments and Estimate						●	○	○	○											
Math Model																				
Configuration Analysis						◐	○													
Failure Mode and Prediction Analysis							○													
Failure Effect Analysis							○													
Maintainability Analysis							○													
Design Review							○													
Design Review Documentation							○													
Circuit Analysis					◐															
Reliability Data List						○														
NPPAR						◐														
Reliability Test Plan							○													
Reliability Assessment							○	○	○	○	○	○	○							
Failure Reports and Corrective Action						○	○	○	○	○	○	○	○							
Failure Analysis						○	○	○	○	○	○	○	○							
Reliability Indoctrination and Training																				

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.9.1.1-5

ARMA - SGEA

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan						◪														
Reliability Status Report						◐														
Apportionments and Estimate						◐														
Math Model							○													
Configuration Analysis						◐														
Failure Mode and Prediction Analysis								○												
Failure Effect Analysis							○													
Maintainability Analysis							○													
Design Review							○													
Design Review Documentation							○													
Circuit Analysis							○													
Reliability Data List							○													
NPPAR							○													
Reliability Test Plan							○													
Reliability Assessment								○												
Failure Reports and Corrective Action						◐	○	○	○	○	○	○	○							
Failure Analysis						○	○	○	○	○	○	○	○							
Reliability Indoctrination and Training																				

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE 4.9.1.1-6

LEACH - DSEA

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan						◐														
Reliability Status Report						◐	○	○	○	○	○	○	○							
Apportionments and Estimate						◪	○	○	○											
Math Model																				
Configuration Analysis						◐														
Failure Mode and Prediction Analysis							○													
Failure Effect Analysis							○													
Maintainability Analysis							○													
Design Review							○													
Design Review Documentation							○													
Circuit Analysis						○														
Reliability Data List							○													
NPPAR						◐														
Reliability Test Plan						◪														
Reliability Assessment							○	○	○	○	○	○	○							
Failure Reports and Corrective Action							○	○	○	○	○	○	○							
Failure Analysis							○	○	○	○	○	○	○							
Reliability Indoctrination and Training																				

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Accepted
Unacceptable - Minor Exceptions
Rejected - Major Revision

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4.9.2 Summary of Efforts for Period (continued)

3. Review of monthly failure report summary for failures related to the Displays and Controls Subsystem and Instrumentation Subsystem.

4. Additional C&WEA requirements for abort guidance detection.

5. Bio-medical power supply voltage change from 28 vdc to 16.8 vdc (CCA No. 104).

6. Apportionment requirement study for RCS R&D insturmentation.

7. DSEA ETI requirement study.

8. C&WEA additional parameter detection weight study (circuit breakers, etc.).

9. PCMTEA Preliminary Design Review "Action Item" followup.

10. Warning channel and relay distribution arrangement study.

11. Classification of measurements as to crew safety or mission success.

12. Fused versus non-fused 28 vdc measurements instrumentation study.

13. Fail-safe detection (measurement) design study.

14. Attend Design Review and followup vendor activities.

15. Preparation of a critical FMEA for Instrumentation Subsystem and estimate comparison lists.

4.9.2 Summary of Effort for Period (continued)

16. Effort has also been expended in performing a preliminary maintainability analysis on the Signal Conditioner (SCEA) ERA, and to find solutions for outstanding PCMTEA design problems that effect maintainability. (See 8th Quarterly Report.)

17. A study of all subsystems has been initiated to identify the in-house maintainability effort for the sensors.

4.9.2.1 Measurements

Mission success classification of LEM measurements has been completed for those subsystems where detailed instrumentation implementation information is available. The measurements considered are those listed on the 3 May 1965 measurement list. The present implementation of operational measurements were reviewed in an effort to update the Instrumentation reliability block diagrams. Measurement classifications (crew safety or mission success) were updated on the basis of the revised Manned LEM measurement list.

Their grouping, in accordance with their destination points, were reviewed and modified to depict the present configuration. An investigation in the displays areas continues in order to accumulate information of possible methods of backup to the measurements.

4.9.2.1 Measurements (continued)

Additional requirements for parameters to be detected by the C&WEA are under study. Such parameters as from Abort Guidance Section circuit breakers, and others which will increase the already overloaded C&WEA capability. Increasing the detection capability will tend to reduce the reliability of C&WEA and increase the gap between its present reliability estimate and its goal.

A coordination meeting which was attended by all subsystem engineers, was held to discuss low-bit rate telemetry. Details of the meeting are contained in LMM-360-30, dated 19 June 1965. Measurement optimization efforts for high and low bit rates will continue. Subsystem measurement implementation was reviewed and commented on in the area of Propulsion, RCS, and ECS.

4.9.2.1.2 Sensors

Reliability participated in several Instrumentation equipment vendor negotiations. Details are as follows:

1. Reviewed and commented on reliability apportionments and Mission Profile Table Specifications, LSP-360-23, Multi-current, LSP-360-616-1, Discrete Transducer, LSP-360-605, Resistance Thermocouple, LSP-360-619, Angular Velocity, LSP-360-604, Thermocouple Ref. Function, LSP-360-18, Speed and STL Pressure Transducers and Flight Fibration System, (See LAV-550-510). Reviewed and rejected HSD specification SVHS-3118 for the "Sensor, Temperature Resistive Element" for incorrect reliability apportionments.

2. Evaluated three proposals for the Thermocouple Reference Junction and three for Separation Distance Transducer.

4.9.2.1.2 Sensors (continued)

3. Reviewed the Propellant Quantity Gaging change test description (PQGS) (See LAV-255-113), Test Procedures for PQGS.

4. Attended Ascent Engine Instrumentation meetings on 7 April 1965 to discuss the reliability requirements for the supercritical helium tank pressure measurement to determine whether majority voting was necessary.

5. Attended GAEC Giannini meeting on 16 June 1965 to discuss the reasons of selecting the phototube configuration for the Sensing Unit Electronic Module (SUEM) versus the solid state pn-junction diode-lithium drift configuration.

6. Attended vendor negotiations meeting to discuss Discrete Transducers reliability requirements. A meeting was held between GAEC-Lockheed to discuss Separation Distance Transducers and vendor requirements.

4.9.2.1.3 Signal Conditioning Units (SCU)

Reliability reviewed SCU changes generated during this period such as addition of a dual step output buffer (See LVC-365-003) and modified SCU specifications by adding Mission Profile Tables in the SCEA specifications.

Reliability reviewed documentation submitted by Arma. The Program Plan was reviewed and found to be satisfactory. The first and second monthly program reports were reviewed, where the design approach is thoroughly presented and a complete circuit and configuration analyses is given. Circuit design and breadboard application have been initiated. The packaging design is progressing without serious problems at the present. A gain adjust potentiometer is affected by vibration, however, Arma feels that this will be resolved.

Attended vendor negotiations where reliability and maintainability requirements were fully covered and clarified.

4.9.2.1.4 SCEA/Electronic Replaceable Assembly (ERA)

Efforts were expended for the in-house design and fabrication of the SCEA chassis. Meetings were attended to discuss the technical and documentation aspects of the design.

A GAEC/Arma meeting was held to discuss SCEA/ERA reliability design requirements. The reliability apportionment goal was set to be .99999, which reflects the requirements of the SCEA chassis only. The remainder of SCEA, i.e., the interior that is comprised of 48 modules, is reflected in the SCU's individual specifications. Vendor negotiations for this plan are expected in the near future. Specification LSP-360-5 was reviewed and reliability inputs were prepared for the SCEA assembly.

4.9.2.1.5 C&WEA

During this period vendor and in-house documentation were reviewed and commented on (See LAV-550-1247). Possible changes of Table IX of C&WEA specification were examined jointly by reliability and subsystem engineering. The size, weight, power and design of the C&WEA configuration depend on the Table IX changes, e.g., the change of a 40 light requirement to a 5 light requirement. Abort guidance detected parameter increase from one to 20 (See LVC-360-006) and possible circuit breakers detection (lights) requirements (See LMO-480-269). Parts problems were examined such as component characteristics which change with the five year storage. Arma Engineering, however, released parts for pre-production of three units.

4.9.2.1.5 C&WEA (continued)

Relay Components Thermal Analysis (LCW-R-40) showed the possibility of significant improvement in weight due to the cooler running of C&WEA, which will allow lighter and thinner structure. A meeting was held at Arma to discuss in detail the reliability requirements of the Program Plan stated in the Purchase Order. The meeting was held in an effort to cut cost without affecting the reliability status of the C&WEA.

Failure Analysis reporting forms and procedures were reviewed and commented on. It was decided at the meeting that failure effect analysis would be limited to the level of a functional element, i.e., OR-AND gates, comparators, etc..

4.9.2.1.6 PCMTEA

Reliability reviewed LEM Engineering memorandums concerning PCMTEA, followed vendor activity in the area of the preload relaxation study, test of boot strapped cable and the incorporation of SCP's 24-28 in the preproduction units M-1 and M-2.

A preliminary Design Review at Radiation, Incorporated was attended. The entire design was covered and reliability aspects examined and were evaluated. Action items were generated, for details see LMM-361-005. Action items No. 2, 19, 20, 21, 22 have been resolved (Radiation Letter No. 1811-0670-1480). An in-house packaging meeting was attended to investigate the thermal profile (TE Power Supply hot spots), the foam compression change, the weight increase from 32 to 40 pounds due to SCP's generated, the material and to see if repackaging was necessary. It was felt that problems did exist and that further investigation is needed. Results for the foam compression tests are expected. It was expressed that if an initial 30 psi, instead of the present 20 psi, were applied the compression relaxation problem will be greatly, if not completely, reduced.

4.9.2.1.6 PCMTEA (continued)

The redundant mode of operation pre-flight checkout for this assembly was studied. In reply to LAV-361-3, Radiation, Incorporated stated in TWX 1811-062301480/4-26-65 that this checkout applies only to the TE oscillator and the TE redundant power supply and that Radiation would like GAEC continuation. A study was initiated to check if tests of the TE redundancies and majority voting sections were satisfactory. A memorandum was generated expressing the opinion of Reliability Control.

In general, it was expressed that the points of test available at present for TE were satisfactory. The 5,000 hour operating time considered for the reliability estimate of the quad amplifiers, the inspection and testing performed during the manufacturing process (See GT (General Time, Test Procedure No. 6007403, 6007052)), and the weight and complexity increase, did not warrant justification for further testing points.

CCA No. 109 modifies TE Mission Operational Profile, (Greenwich Mean Time was changed to Elapsed Time requirement) all changes created by this direction have been incorporated in the TE specification. Also changes due to CCA No. 61 in the section of PCM have been prepared.

4.9.2.1.7 DSEA

Reviewed and commented on in-house and vendor documentation such as Program Plan and Cost Proposal (LAV-550-522) monthly reports, DSEA Motor Qualification Test, Reliability Estimate, Leach Parts Approval/Qualification Program-Schedule.

Meetings were attended in an effort to clarify the Program Plan and the Parts Approval/Quality Program Schedule requirements (See Leach/TWX No. 211200-24/4-22-65).

4.9.2.1.7 DSEA (continued)

Inputs to Instrumentation Subsystem for the DSEA Concept Design Review were given. Component procurement and vendor evaluation are in process. The delivery schedule has been modified due to LVC-362-001 and -005. The vendor was directed to submit a reliability block diagram, failure rate (FR) sources and FR substantiating test data. Also, the vendor was instructed to use GAEC supplied failure rates. Initiated DSEA/ETI requirement study in an effort to eliminate this requirement since the time log requirement can be satisfied via the ETI of the DSEA handling fixture; for details see LAV-550-1299.

4.9.2.1.8 LTA's and LEM's Reliability Requirement Study

Efforts have been initiated in this area last quarter to analyze R&D Insturmentations used in LEM's 1 through 9. The purpose of this study is to determine the degree of adequacy, and implementation design excellence of R&D Instrumentations.

4.9.2.2 Projected Effort For Next Period

Future effort in Instrumentation Subsystem Reliability will be concentrated in the following areas:

1. FMEA for instrumentation assemblies and subsystem interfaces.

2. Determine hardware involved for each subsystem interface (sensors and signal conditioners).

3. Review and update detailed reliability block diagrams for all subsystem interfaces.

4. Update reliability apportionment requirements for each measurement and the sensors, SCU's and C&WEA electronics within each channel.

4.9.2.2 Project Effort For Next Period (continued)

5. Continue in-flight measurements analysis to determine importance and complexity.

6. Study design requirements versus proposed configurations. Review specifications, LVR's and evaluate vendor proposals.

7. Review vendor documentation, in-house documentation, and participate in activities on all instrumentation assemblies and all subsystem instrumentation interfaces.

8. Attend GAEC/Vendor Subsystem interface meetings.

9. Attend concept and preliminary Design Reviews. Vendor liaison activity follow-up.

10. Measurement selection, selection criteria for low-bit telemetry.

11. Review failure reports and participate in vendor corrective action activities.

12. Apportionment requirement study for RCS-R&D Instrumentation.

13. C&WEA additional parameter detection requirement study-abort guidance detection, circuit breaker detection, etc..

14. PCMTEA Preliminary Design Review action items follow-up.

15. Study warning channels and relays distribution arrangement to achieve optimum reliability.

16. Study R&D Instrumentation reliability requirement.

17. Continue to update measurements as to crew safety and mission success.

4.9.2.2 Project Effort for Next Period (continued)

18. RCS-fuel and oxidizer temperature measurement study; delete if supercritical. Extend efforts to the other instrumentation interfaces.

19. Participate in the activity of implementing fuses for measurement QC distribution.

20. Study fail safe detection designs in the area of measurements and C&WEA channels.

21. Participate in "Apollo Checkout and Measurement Criteria" activities.

22. LGC (S&C) oscillator and TE oscillator possibility of backup study.

23. Reliability design efforts for measurements that have high reliability requirements.

24. Continue study to determine fault isolation capabilities for the various instrumentation configurations.

25. Continue study to determine the optimum for location of the various sensors. Special considerations will be given to those devices where reliability, test and checkout requirements indicate the need for good accessibility and ease of replacement.

4.9.3 Reliability Apportionment and Estimate

The apportioned reliability goals for all Instrumentation equipments have remained constant during the reporting period.

4.9.3 Reliability Apportionment and Estimate (continued)

Reliability estimates of major equipments have not changed since the last report. The effort to make a reliability estimate for all signal conditioners and transducers has continued but is dependent on NASA/MSC approval of the success criteria used in preparing the system level reliability block diagrams for these units.

4.9.3.1 SEA

Preliminary results have been obtained for sensors from the preliminary subsystem interface block diagrams, which take into account all findings concerning importance, complexity, and redundancy provided by similar measurements or by D&C subsystem. Reliability estimates, which define sensor complexity, were generated and are based on the best designs presented in the respective submitted proposals.

In most cases the estimated and apportioned sensor reliabilities are very close or equal. However, the absolute pressure sensor, thermocouple wire sensor, and the discrete miniature switch are devices that have an apportioned reliability that is considerably higher than the estimated reliability. The design of these sensors will be analyzed further in an effort to improve the design of the device or the measurement implementation scheme in order to meet the required reliability.

4.9.3.2 SCEA

As was stated in Para. 4.9.3, result of a lower level apportionment have been obtained from the reliability apportionment study that was completed during this period. The same approach as

4.9.3.2 SCEA (continued)

in Sensors (SEA) was used. The reliability estimates are based on proposed designs and are compatible with the apportionment. Only two signal conditioners, (Active Attenuator, 502-3, and Analog Buffer, 504-1 through -4) have apportionments that are greater than the estimate reliability. Details of the derivation results are presented in the forth-coming reliability apportionment study. Further study will determine the design approach to satisfy this high requirement.

Reliability estimates will be submitted by the vendor in the near future.

4.9.3.3 PCMTEA

1. PCM

The reliability apportionment remains the same for this section. However, the addition of the split-phase output for the low bit rate will modify the reliability estimate. The reliability estimate for the PCM NRZ nominal output will remain the same. The split phase must be differentiated from the NRZ and treated separately. A study will be conducted to define this change and a reliability estimate will be given for the split phase out.

2. TE

The reliability apportionment for this section remains the same. However, the reliability estimate will change due to design changes that occured to modify the "hot-spot" and worse problems, and the addition of the serial time.

4.9.3.4 C&WEA

The reliability apportionment remains the same. The reliability estimate will follow the parts selection activity; however, the vendor has been directed to use GAEC failure rates wherever possible.

4.9.3.5 DSEA

The reliability apportionment remains the same. Reliability estimate results were submitted. The vendor was directed to send FR's substantiating data and wherever possible use specification failure rates.

4.9.4 Reliability Mathematical Model

Efforts continued during this period to complete reliability block diagrams that describe the relationship between subsystem-instrumentation interfaces, measurements within each subsystem, and subassemblies (sensors, SCU's, etc.) within each measurement.

It was expected that all instrumentation information would be available during this period. However, due to the EPS redesign, and N&G and S&C instrumentation implementation considerations, the interface data is still not available. As a result, an estimate of EPS, N&G, and S&C instrumentation complexity was made in order to calculate overall instrumentation reliability.

4.9.5 Configuration Analysis

The existing configuration of measurements was studied and efforts were made to determine their relation to other detection schemes in order to define the overall data acquisition configuration of LEM.

4.9.5.1 SEA

Configuration analysis of hardware in the section is not available at the present.

4.9.5.2 SCEA

Configuration analysis on the level of signal conditioning units was given by the vendor in the area of filters, pre-regulators and transformers in an effort to optimize design (first monthly report).

4.9.5.3 PCMTEA

During this period configuration analysis for the changes due to SCP's and Preliminary Design Review action items was performed. Progress was not made in the critical measurement even distribution over the HSG study; however, efforts will continue in the near future.

4.9.5.4 C&WEA

Configuration analyses were performed by the vendor in the area of connectors, DC/DC Converter, and C&WEA net-work configuration to avoid unnecessary redundancies and yet meet the reliability apportionment requirements.

4.9.5.5 DSEA

The two configurations, Center Latch and Twist Lock Mounting, were examined and the second was selected.

Configuration analysis of networks, packaging and changes of the design will be submitted in the near future.

4.9.6 Failure Mode and Effect Analysis

Effort in this area was limited to PCMTEA. The results will be completed in the forth-coming period.

4.9.6.1 SEA

There is no activity to report at this time.

4.9.6.2 SCEA

There is no activity to report at this time.

4.9.6.3 PCMTEA

1. PCM

The FMEA of this section was reviewed and reported. The same activity at a lower level is carried out by the vendor in order to incorporate in the analysis the design changes and additions imposed by the SCP's, such as design modification in over-coming thermal problems alternate high speed gates configuration and the addition of the split phase to serial time outputs.

2. TE

The same applies to this section as in PCM.

4.9.6.4 C&WEA

The FMEA for this assembly is under preparation.

4.9.6.5 DSEA

The FMEA efforts for this assembly have been started. Status of this activity will be reported in the Leach second monthly report.

4.9.7 Failure Mode Prediction Analysis

No effort to report at this time.

4.9.8 Maintainability Analysis

A preliminary analysis of the Signal Conditioning Electronics Assembly was completed during this period. This effort has resulted in identifying several potential problem areas and the generation of recommendations for improving maintainability.

It has been recommended that the basic concept with respect to the degree of flexibility requirements be thoroughly re-examined and that a weight-reliability/maintainability study be accomplished to include the following as a minimum:

1. Elimination of the "pressurized box" configuration.

2. Encapsulation of the subassembly connectors (moisture protection).

3. Reduction in the number of spare wires in the harness.

4. Effects of configuration changes on down time (taking into consideration the effects on the time line and/or launch window as a result of re-cycling requirements).

5. Number of allowable removals and replacement of subassemblies and the effects on reliability.

4.9.9 Design Reviews

No effort to report during this quarter.

4.9.10 Circuit Analysis

4.9.10.1 PCMTE

Efforts continue by the vendor in the area of split phase, serial time, and/or modifications of the former TE design. Results will be reported on RDL's.

4.9.10.2 C&WEA

This is being performed in parallel with the design efforts. Partial results have been submitted and accepted. No effort to report for the other sections of Instrumentation.

4.9.11 Reliability Data Lists (RDL's)

4.9.11.1 PCMTEA

One RDL was submitted for the PCM/TEA during this report period and is currently in review. The remaining RDL's will be reported and submitted in the next monthly report.

4.9.11.2 C&WEA

Under separation will be submitted in near future.

4.9.11.3 No effort to report for the other sections.

4.9.12 NPPAR Status

4.9.12.1 PCMTEA

NPPAR's are not required of this subcontractor, selection review is made via part procurement specification. During this report period, twenty-two specifications were reviewed; seventeen specifications were approved and five were classified "approval withheld".

4.9.12.2 C&WEA

Four NPPAR's were submitted; three were approved and one has been classified "approval withheld".

4.9.12.3 No other effort to report.

4.9.13 Reliability Test Program

4.9.13.1 General

A major effort during the past quarter has been in providing follow-up on the program redefinition. This has included providing vendor and in-house test requirements interpretation and clarification; review, comment and justification of vendor submitted cost proposals and participation in the subsequent negotiations. This effort is expected to continue through the next quarter and the results will be reported accordingly.

4.9.13.2 Pulse Code Modulation and Timing Electronic Assembly (PCM/TEA): Radiation, Incorporated

Design feasibility testing has continued through the past quarter on both the mechanical and thermal model as well as preproduction models no. 1 and no. 2. Mechanical model testing has been centered on resolving the foam compression study that was initiated as a result of the preliminary design review held during March 1965. Thermal model tests have been concentrated on the codes section which presently indicates excessive element temperatures which may necessitate redesign of the codes. A codes redesign study is under way as well as re-configuring of the subassemblies to redistribute the hot spots.

4.9.13.3 Caution and Warning Electronic Assembly (C&WEA): Arma Corporation

Arma is continuing feasibility testing and has submitted test plans for component parts and the relay subassembly tests. The overall test philosophy for the C&WEA was submitted in Arma document No. LCW-R-G and disapproved by Reliability; the comments are contained in LAV-550-429.

4.9.13.4 Data Storage Electronic Assembly (DSEA): Leach Corporation

During the past quarter Leach submitted their Design Feasibility Test Plan, Leach document No. 105-001. The document was disapproved and comments were forwarded to Leach indicating that the test plan would have to be expanded to include lower level of assembly tests before approval would be given.

4.9.13.5 Signal Conditioner Electronic Assemblies (SCEA): Arma Corporation

The contract for the SCEA was increased in scope during the past quarter to include design and manufacture of the mechanical assembly. This change necessitated invoking the test requirements for a major assembly (ERA) and Arma is presently preparing a subcontractor change proposal for the new requirements. As would be expected, this change has delayed submittal of design feasibility test plans; however, Arma has been performing design feasibility tests on bread-board subassemblies and is reporting via the monthly progress reports.

4.9.13.6 Water Quantity Measuring Device (WQMD): EOS

Effort for this period has been limited to defining the test requirement in preparation for the LVC for program redefinition.

4.9.13.7 Transducers

The effort for the period has been concentrated on proposal review and vendor selection, no purchase orders have been issued as yet.

4.9.14 Reliability Assessment

No effort to report at this time.

4.9.15 Failure Reporting and Corrective Action

Four failure reports that apply to design feasibility tests were received for the C&WEA. The report were reviewed pending receipt of analysis.

No other failures to report for this period.

4.9.16 Failure Analysis

No analysis were received during this period.

4.10 DISPLAYS AND CONTROLS

This covers the Reliability effort between 15 March and 15 June 1965.

4.10.1 General

The majority of the displays are in initial design and consequently the reporting for this period is limited.

4.10.1.1 Subcontractor Status and Milestones

Specifications and vendor requirements have been provided for all the devices associated with the Displays and Controls Subsystem. Vendors have been selected for all the displays and controls except the newly instituted Tone Generator "Caution and Warning". Tables 4.10.1.2 to 4.10.1.5 show the milestones for the devices that have reached a more advanced stage of development.

4.10.2 Subsystem Summary

4.10.2.1 Summary of Effort for Period

1. Reliability has continued the review and evaluation of specifications, vendor requirements, and proposals; participated in the selection of vendors, and attended negotiations and technical coordination meeting for those devices where contracts have been awarded.

   Monitoring of the vendors' effort has been limited to those devices' that are in early design phases. The effort may be seen by referring to the updated Milestone Charts (Tables 4.10.1.2-5) Additional Milestones Charts will be provided as information becomes available.

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

ATTITUDE INDICATOR AND GASTA

LEAR SIEGLER

TABLE 4.10.1.2

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan				●																
Reliability Status Report					●	●	○	○	○	○	○	○	○	○	○					
Apportionments and Estimate					●	●	○	○	○											
Math Model					●															
Configuration Analysis					●	●	○	○	○	○	○	○	○	○	○					
Failure Mode and Prediction Analysis					○	●	○													
Failure Effect Analysis					◪	●	○													
Maintainability Analysis																				
Design Review					●	●		○	○											
Design Review Documentation					●	●		○	○											
Circuit Analysis					●	○	○	○	○	○	○	○	○	○	○					
Reliability Data List					●	●	○	○	○	○	○	○	○	○	○					
NPPAR					◐	◐														
Reliability Test Plan				●																
Reliability Assessment																				
Failure Reports and Corrective Action					○	○														
Failure Analysis					○	○														
Reliability Indoctrination and Training																				

○ Due
● Received
Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

CROSS POINTER METER - D'ARSONVAL

HONEYWELL, INCORPORATED

TABLE 4.10.1.3

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan				■	○	●														
Reliability Status Report					○	○	○	○	○	○	○	○	○	○	○					
Apportionments and Estimate					○	●	○	○	○	○	○	○	○	○	○					
Math Model						●														
Configuration Analysis					○															
Failure Mode and Prediction Analysis					○															
Failure Effect Analysis						■														
Maintainability Analysis																				
Design Review					○															
Design Review Documentation					○															
Circuit Analysis					○	○														
Reliability Data List					◐	◐	○	○	○	○	○	○	○	○	○					
NPPAR						◐														
Reliability Test Plan				●																
Reliability Assessment						○														
Failure Reports and Corrective Action				○		○														
Failure Analysis				○		○														
Reliability Indoctrination and Training																				

* Acceptable - Minor Exceptions

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

INDICATOR THRUST-TO-WEIGHT RATIO

TABLE 4.10.1.4

APPENDIX

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan					◐															
Reliability Status Report						○	○	○	○	○	○	○	○	○						
Apportionments and Estimate					◐	○	○	○	○	○	○	○	○	○						
Math Model																				
Configuration Analysis						○														
Failure Mode and Prediction Analysis					●															
Failure Effect Analysis					●*															
Maintainability Analysis					●*	◐	○	○	○	○	○	○	○	○						
Design Review						○														
Design Review Documentation						○														
Circuit Analysis						○														
Reliability Data List						●*	○	○	○	○	○	○	○	○						
NPPAR						○														
Reliability Test Plan					●															
Reliability Assessment					○															
Failure Reports and Corrective Action						○														
Failure Analysis						○														
Reliability Indoctrination and Training																				

* Acceptable - Minor Exceptions

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

INDICATOR, INCREMENTAL VELOCITY, DISPLAYS

SYLVANIA

TABLE 4.10.1.5

Year	1964				1965				1966				1967				1968			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tasks / Milestones																				
Program Plan				○	●															
Reliability Status Report					○	◐	○	○	○	○	○	○	○	○	○	○				
Apportionments and Estimate					○	◐	○	○	○	○	○	○	○	○	○	○				
Math Model					○	○														
Configuration Analysis					○	○														
Failure Mode and Prediction Analysis					○	◐														
Failure Effect Analysis					○	◐														
Maintainability Analysis					○	◐	○	○	○	○	○	○	○	○	○	○				
Design Review					■	◐														
Design Review Documentation					○	◐														
Circuit Analysis					○	◐														
Reliability Data List					○	◐	○													
NPPAR						◐	○													
Reliability Test Plan				○																
Reliability Assessment																				
Failure Reports and Corrective Action					○															
Failure Analysis					○															
Reliability Indoctrination and Training																				

○ Due
◐ Received
● Accepted
◪ Unacceptable - Minor Exceptions
■ Rejected - Major Revision

TABULATION FORM

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4.10.2.1 Summary of Effort for Period (continued)

2. A study to determine the suitability of the simple D'Arsonval meter versus the more complex servometric D'Arsonval meter to meet LEM requirements has been completed.

3. An investigation of the Caution and Warning Indicator test circuitry has been concluded. (See LAV-550-1258).

4. Preparation of the overall reliability block diagram for the Displays and Controls Subsystem has continued with the development of a preliminary mathematical model. The completion of the mission success reliability block diagrams for measurements associated with the LEM subsystems has been deferred due to insufficient information in the Navigation and Guidance, and Stabilization and Control areas. The reliability block diagrams for Electrical Power subsystem has also been delayed because of redefinition.

5. The reliability effort in the areas of apportionment, configuration and circuit analysis, reliability estimates, maintainability analysis, and evaluation of parts has continued.

6. Each display and control was reviewed to determine if post qualification testing should be imposed. Effort has also been expended on monitoring the vendor design feasibility test results to ascertain that no weak links in the design are overlooked.

7. The investigation for the purpose of evaluating the use of splices in the Displays and Controls Subsystem and the effects of the physical locations has continued. A study to determine the scheduled maintenance cycle for each device was initiated with the primary effort being devoted to electro-luminescent lighting.

4.10.2.1 Summary of Effort for Period (continued)

8. During this reporting period a significant portion of the effort has been devoted to the coordination of the vendors' reliability tasks with respect to their implementation of an effective parts program to assure the required selection and application of electronic parts. Vendors have been or will be directed to utilize the "B" revision of the Grumman Acceptable Parts List (LED-550-25) for parts selection and to employ the failure rates called out for LEM High Reliability Parts in LED-550-58. Procedures have also been implemented for handling part deviation requests.

4.10.2.2 Projected Effort for Next Period

During the next reporting period the Displays and Controls Subsystem Reliability effort is expected to be centered around the following areas of activity:

1. Closely monitor all vendor efforts to insure that all milestones are met.

2. Review and comment on all vendor documentation.

3. Follow-up efforts initiated by the Displays and Controls Subsystem.

4. Participate in Design Reviews.

5. Continue to update the mathematical model of the Displays and Controls Subsystem. This will reflect latest information concerning the criticality of each display and control.

6. Develop mission success reliability block diagrams for measurements in the Navigation and Guidance, Stabilization and Control, and Electrical Power Subsystem systems as pertinent information becomes available. These block diagrams denote the existence of any weak link and determine if a need exists for additional displays and controls.

4.10.2.2 Projected Effort for Next Period (continued)

7. Carry out the Reliability Apportionment .

8. Initiate study of ETI requirements for each device.

9. Continue the evaluation of 6 volts versus 28 volts incandescent lamps.

10. Reliability trade-off studies will be conducted to determine if display requirements in areas such as abort guidance and circuit breakers give rise to the need for additional Caution and Warning Indicators.

11. Effort will be continued to monitoring each vendor's design feasibility and design verification tests to assure that the test results are consistent with the design requirements. Close surveillance will also be provided in monitoring the qualification testing of the Elapsed Time Indicator.

12. The study to determine the optimum replacement cycle for those devices having limited life items will be continued as well as the effort to establish the effects of replacing a failed display, control, or panel segment on the time line.

4.10.3 Reliability Apportionments and Estimates

All displays and controls to which reliability apportionments have been assigned and reliability estimates calculated are listed in Table 4.10.3. Each vendor has been or will be directed to employ GAEC Failure Rates (See LED-550-58) for calculating reliability estimates.

TABLE 4.10.3

Item	Apportioned Reliability	Estimated Reliability
Helium Pressure & Temp. Indicator	0.99999	0.9998
Incremental Velocity Indicator	0.9999	0.999944
Cross Pointer Meter	0.99999	0.99994
Range/Range Ratio Indicator	0.999995	0.9995
S&C Panel Assembly	0.9999	0.99986
Digital Event Timer	0.99999	0.99991
RCS Quantity Gage	0.999995	0.9999572
Mission Elapsed Timer	0.9999	-
Flag Indicator	0.99999	0.999994
Caution Indicator	0.999999	-
Caution & Warning Light	0.9999999	-
Attitude Indicator	0.9999	0.999146
Gimbal Angle Sequence Transformation Assembly (GASTA)	0.9999	0.999486
Tone Generator (Caution and Warning)	0.99999	-
D'Arsonval Meter	0.99999	0.99996

4.10.3.1 D'Arsonval and Cross-Pointer Meters

Reliability estimates have been prepared for the D'Arsonval and Cross-Pointer displays by the vendor. Because these estimates do not reflect latest mission times and GAEC accepted failure rates, the vendor is expected to update his calculation during the next quarter. As a result GAEC Reliability has inserted into Table 4.10.3 more realistic reliability figures than those submitted by Honeywell.

4.10.3.2 Incremental Velocity Indicator

The reliability estimate for the incremental velocity indicator as given in Table 4.10.3 has been calculated using GAEC accepted failure rates. GAEC Reliability has pointed out that the parts derating policy was not employed. Results of the reliability analysis will be submitted by Sylvania in their preliminary design report.

4.10.3.3 GASTA and Attitude Indicator

New reliability estimates have been given for the Attitude Indicator and GASTA using GAEC LEM High Reliability Failure Rates. These new estimates more closely approach the apportionment for these devices.

4.10.4 Reliability Mathematical Model

Efforts were directed during this period toward the development of a preliminary mathematical model for the Displays and Controls Subsystem. Backup modes for all displays and controls were examined by tracing all display and control functional signals from source to termination. The displays and controls were then grouped according to whether their functional signals

4.10.4 Reliability Mathematical Model (continued)

will be picked up by either the C&WEA and/or the PCMTEA. In addition, the controls were separated into those devices that are utilized for the control of the LEM subsystems, and those devices whose only purpose is to control the displays indicating the subsystem status. The mathematical model will be continually updated to reflect new developments involving the complexity and the criticality of each display and control.

4.10.4.1 Attitude Indicator and GASTA

The reliability mathematical model for the GASTA was developed during this period and considered all elements in series, since failure of one element will disable the entire assembly. The three axis of the GASTA are not separable and a failure cannot be isolated to one axis. In the Attitude Indicator, components are considered in series except for the electroluminescent lighting, which is considered redundant. The three axis of the Attitude Indicator are separable. but a failure in one axis will cause difficulty in reading useful information on the other axes. Further study of this problem will be carried out in the next report period.

4.10.5 Configuration Analysis

4.10.5.1 Caution Indicator (Annunicator Light)

A discussion on the Lunar Touchdown requirements was held with Crew Provisions and Displays and Controls. As a result, Reliability initiated a study to determine the relative merits of the 6 volt and 28 volt lamps. Preliminary results indicate that the 6 volt lamp is more reliable. This study will be continued with completion expected before the next quarterly report is released.

4.10.5.2 D'Arsonval Meters

The suitability of the simple D'Arsonval Meter (Weston) versus the more complex servometric D'Arsonval Meter (Honeywell) to meet LEM requirements has been considered. Results indicate that the Weston and Honeywell meters are approximately equivalent in weight and reliability, but the Honeywell meter is far superior in its ability to withstand vibrational shock.

4.10.5.3 Caution and Warning Indicator

An investigation of the Caution and Warning Indicator test circuitry has been completed. See LAV-550-1258. It was noted that the single diode in the test circuit was operating at close to rated current and it was recommended that it be replaced by a series-parallel arrangement of four diodes in order to improve the reliability of the test circuit.

4.10.5.4 Attitude Indicator and GASTA

A trade-off study, performed on the GASTA, compared the use of an 800 cps power supply versus a 400 cps demodulator-modulator mechanization. The 400 cps demod-mod arrangement provided many advantages, in weight, power, accuracy, etc, but its reliability estimate was slightly lower than the estimate for the 800 cps power supply. The demod-mod scheme was selected because of the advantages and qualitative reliability benefits gained over the power supply. This information is delineated in Lear Siegler's Conceptual Design Report for the GASTA, in the meeting minutes LMM-350-2, and in LMO-550-640.

4.10.6 Failure Effect Analysis

4.10.6.1 Attitude Indicator and GASTA

Preliminary Failure Effect Analyses have been performed on both the Attitude Indicator and the GASTA. These analyses were limited in depth and continued effort, in more detail, will be forthcoming in this next quarter.

4.10.6.2 D'Arsonval and Cross Pointer Meters

The FMEA for the meters has been rejected by Reliability because of insufficient information. Honeywell is expected to submit a more detailed FMEA during the next reporting period.

4.10.7 Failure Mode Prediction Analysis

4.10.7.1 Attitude Indicator and GASTA

Lear has submitted initial Failure Mode Prediction Analyses on the Attitude Indicator and the GASTA. During the review of the FMPA several inconsistencies were discovered. Lear Siegler has been directed to take the necessary corrective action.

4.10.8 Maintainability Analysis

The study to establish the maintenance philosophy for the replacement of malfunctioning devices was continued. Several basic concepts were considered (See 8th Quarterly Report). Preliminary findings indicate that in order to assure the inherent reliability of the panel segment on which the malfunctioning device is installed, it is desirable to replace the complete panel segment with a qualified spare. Further study will be carried out during the next reporting period to confirm this concept since this concept may have a significant effect on the time line.

4.10.8 Maintainability Analysis (continued)

The investigation to determine the replacement for devices having limited life items has continued. Prime effort has been placed on the electro-luminescent lighting.

Preliminary investigation has established that displays having electro-luminescent lighting will possibly not meet the design specification operating life requirements (1200 hours). Steps have been initiated to determine the life expectancy under build-up, prelaunch, and flight conditions in order to adequately define the required replacement cycle. (See LAV-550-1249)

4.10.9 Design Review

4.10.9.1 Attitude Indicator and GASTA

A design review was held, on the GASTA at Lear Siegler during this quarter. A GAEC reliability representative was in attendance and certain aspects, of the GASTA program, were discussed. Comments to the meeting and discussions held, are contained in LMM-350-2 and LMO-550-640.

4.10.9.2 Digital Event Timer and Incremental Velocity Indicator

Design review documentation for the Digital Event Timer and Incremental Velocity Indicator is presently being evaluated.

4.10.10 Circuit Analysis

Existing designs are presently under study.

4.10.11 Reliability Data List

During this reporting period the following preliminary reliability data lists have been reviewed and commented on:

4.10.11 Reliability Data List

1. GASTA and Attitude Indicator (See LAV-550-428)

2. D'Arsonval and Cross Pointer Meters (See LAV-550-472)

3. Thrust to Weight Ratio Indicator (See LAV-550-495.

Each vendor has been notified that they will be required to comply with the minimum requirements of the Parts Selection and Application section of the Purchase Order. Each vendor will also be supplied with a revised version of the Grumman Acceptable Parts List (LED-550-25B) as well as the updated version of the Parts Derating Policy (LED-550-60).

Parts deviation requests have been received from Honeywell for the LEM Meters. Each part deviation has been evaluated and a reply to these requests will be released during the early part of the next reporting period. In summary:

1. Honeywell will be denied blanket approval of their deviations.

2. Deviations I and II and possibly III will be granted for equipments prior to LTA-8.

3. Part of deviation I may possibly be granted for LTA-8.

4.10.12 NPPAR Status

In accordance with the requirements of the purchase order(s), all vendors must forward NPPAR forms to Grumman as evidence of the adequacy of non standard parts in both performance and reliability for specific applications.

4.10.12 NPPAR Status (continued)

Thirty six (36) NPPAR's have been received on the Displays Subsystem. Twenty four (24) have been approved, eleven (11) are pending review and two (2) are approval withheld pending submittals of substantiating test data.

4.10.13 Reliability Test Program

The vendor test program has been monitored and the status for the devices in the more advance stages of design as follows:

1. Elapsed Time Indicator (ETI) - Qualification Testing is scheduled to start at this writing. Results of tests will be reported during the next quarter.

2. Incremental Velocity Indicator - Design Feasibility test has been completed for the structures with the electrical portion scheduled for completion during the next reporting period.

3. D'Arsonval and Cross Pointer Meters - Design Feasibility Tests were started. Design Verification tests are to be performed during the next reporting period.

4. Attitude Indicator and GASTA - Design Feasibility Test in progress.

4.10.14 Reliability Assessment

No effort to report at this time.

4.10.15 Failure Reporting

Three failures have been informally reported in the displays subsystem. These failures occurred during development tests. The vendors have been directed to comply with the requirements of the purchase order(s) concerning failure reporting.

4.10.16 Failure Analysis

Inasmuch as no failures were formally submitted to GAEC, no effort has been devoted to this area. Steps have been implemented to direct the vendor's efforts in determining the cause of the failures informally reported.

4.11 GROUND SUPPORT EQUIPMENT (GSE)

4.11.1 General

4.11.1.2 Summary of Effort for the Period

The reliability effort on LEM GSE during the past reporting period has been concentrated in the following areas:

a. Update mission-essential and hazardous equipment listings.

b. Review of vendor proposals, negotiations with vendors, and surveillance of vendors under contract including design reviews.

c. Completion of PSDF/WSO DEI Chit #17 dealing with the effect on GSE of a facility power loss.

d. Analysis of GSE failures at PSDF/WSO.

e. Investigation of backup cooling requirements on the pad after LEM closeout.

f. Review of mechanical parts/components documentation.

g. Active participation in GSE Status, Concepts, and Requirements Review meetings.

h. Meeting with NAA/S&ID to update common-use GSE Reliability Cooperative Plan (MH01-05500-400).

i. Participation in Altitude Simulation Facility Working Group meetings at WSO.

j. Revision of reliability policy memos and LVR "boilerplate" based on the LEM Program redefinition.

k. FMEA on PD-1 Rig.

l. Reliability Test effort on GSE.

4.11.1.2 Summary of Effort for the Period (continued)

m. Review MSC-ASEC, Apollo Program GSE Criteria, with respect to the GSE/Reliability effort.

n. Reliability analysis on in-house GSE designs.

o. GSE hazard proofing and safety requirements.

4.11.1.3 Projected Effort for Next Period

The anticipated effort for the next quarter shall include the following:

a. Complete reliability effort (FMEA) on GSE for use with PD-1; start effort on PA-1 GSE.

b. Continue review of vendor effort and documentation on MEE and hazardous units.

c. Perform FMEA on Altitude Simulation Facility per PSDF/WSO DEI Chits #28 and 37.

d. Participate in Test Stand #1 (PD-1) DEI.

e. Update mission-essential and hazardous equipment listings.

4.11.2 Discussion

4.11.2.1 Mission-Essential & Hazardous GSE Listing

The listings of mission-essential and hazardous GSE have been updated since the last report to reflect the latest changes in GSE requirements. References (a) and (b) were also submitted to NASA/MSC at LEM GSE Management Review Meeting #14 in response to an action item in NASA TWX PH5/G320-14-65-T457. These lists will be periodically updated as GSE requirements change.

It is planned to incorporate these listings as part of the GSE Planning & Requirements List during the next quarter.

4.11.2.2 Reliability Effort on Subcontracted GSE/STE

During this report period, Reliability has continued to evaluate and monitor the various vendor's reliability tasks and documentation, on subcontracted ground support equipment, to assure their compliance with the reliability design requirements for the individual equipments. The general reliability status on subcontracted ground support equipment is indicated in Table 4.11.1.1.

The following are typical vendor monitoring tasks performed during this report period:

1. Review, approval or disapproval of part/component selection, specification control drawings and reliability backup data on the following end-items: (The results of the reviews were forwarded via the noted references.)

430-52120	Gaseous Oxygen Component Test Stand	via Ref.(c)
430-52160	Water Component Test Stand	via Ref.(c)
430-52210	Water-Glycol Component Test Stand	via Ref.(c)
430-54200	Oxygen Transfer Unit	via Ref.(d)
430-54400	Cabin Leakage Test Unit	via Ref.(d)
430-54700	Water-Glycol Trim Control Unit	via Ref.(d)
430-64200	Supercritical Helium Conditioning Unit	via *
430-64260	Helium Storage & Transfer Dewar	via *
440-43100	LEM Mission Simulator	via Ref.(u)

* Vendor Document Traveler (P.O. #3-60816)

2. Evaluation of vendor preliminary analyses, (Failure Mode and Effect Analysis, Reliability Data Lists, Reliability Estimate, Configuration Analysis, Maintainability Analysis) and requested changes as required, for the following end items:

430-54200 Oxygen Transfer Unit

TABLE 4.11.1.1

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
MEE	410-11110-1	M	Cable Set L/C 39 LUT	◐																
	11170-1	B	Cable Set Carry-On		●															
	11180-1	M	Switching Control Unit FDS								⊕									
	11760-1	B	Checkout Station, Radar System	◐																
	11990-1	G	Ground Station ACE S/C																	●
	12731-1	B	Junction Box Carry-On	◐	●															
	32020-1	B	Probe Assembly C-Band Antenna	●	●	●														
	32060-1	M	Adapter Assembly VHF In-Flight Antenna	◐																
	32150-1	M	Rack Signal Switching	◐																
	32200-1	M	Adapter Assembly S-Band Antennas	◐																
	410-32280-5	B	Console, S-Band & Communications	●	●															
	430-51100-1	M	Accumulator H_2O Separator Discharge	●					●											
	54200-1	B	Unit Supply Gaseous O_2	●	●	●	●	●	⊕	◪	◪	◪	●	⊕	●	●	●	●	●	
	54320-1	M	Vacuum Pump H_2O Mangt. Section Serv.	◐																
	54400-1	B	Unit Cabin Leak Test	●	●	●	●	●	⊕	◪	◪	◪	●	⊕	●	●	●	●	●	
	54600-1	B	Unit Supply Freon	●	●	●	●	●												
	54700-11	B	Fluid Trim Subassembly (Local)	●	●	●	●	●	⊕							●	⊕			
	430-54700-13	B	Portable Fill, Reservoir	●	●	●	●	●	⊕							●	⊕			

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
MEE	410-62080-1	B	Test Set RCS Propellant Qty. Gaging	●	●	●	●	●	⊕						●					
	410-64130-1	M	Controller Fuel Dist. System								⊕									
	430-64200-13	B	Conditioning Unit Subassembly, SHe	●	●	●	●	●	⊕	⊕	⊕	⊕	⊕	⊕	●	●	⊕	⊕		
	64200-15	B	Fluid Dist. Unit Subassembly, SHe	●	●	●	●	●	⊕	⊕	⊕	⊕	⊕	⊕	●	●	⊕	⊕		
	64200-17	B	Remote Control Console, SHe	●	●	●	●	●	⊕	⊕	⊕	⊕	⊕	⊕	●	●	⊕	⊕		
	64230-1	M	Trans. Control Assembly RCS Fuel								⊕	●								
	64240-1	M	Trans. Control Assembly RCS Oxidizer								⊕	●								
	64260-1	B	Dewar He Storage Trans.	●	●	●	●	●	⊕	⊕	⊕	⊕	⊕	⊕	●	●	⊕	⊕		
	64500-1	M	Unit Pressure Maint.	◐								●								●
	430-82720-1	G	Detector, Leak He/H_2	◐																
	410-82970-1	B	Test Set Initiator Simulator	◐	●															
	430-94057-1	G	Unit, RCS Oxidizer Servicing								●									
MEE	430-94063-1	G	Unit RCS Fuel Servicing								●									
HAZ MSE	430-52120-1	B	GAS O_2 Comp. Test Stand	●	●	●	●	●	⊕	⊕		◪			●	●	●			●
	62040-1	M	Scavenging Assembly RCS	●																●
	62100-1	B	Test Stand Helium Component	●	●	●	●	●	●	⊕		●					●	●	●	●
	430-62160-1	M	Cart. Ullage Simulator A/D	●								●								

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
HAZ MSE	430-62170-1	M	Assembly Checkout Ascent/Descent Prop. Section	●								●								●
	430-62180-1	M	Cart Checkout Propellant Systems	●								●								
	410-62220-1	M	Console Control Engine Firing	●								●								
	62220-3	M	Console, Control Engine Firing	●								⊕								
	410-62250-1	M	Station Control Thrust Vector	●																
	430-62390-1	M	Set Adapter Test Component	◐																
	430-62390-9	M	Set Adapter Test Component	◐																
	410-62690-1	M	AdapterSet HA-3	◐																
	62690-3	M	Adapter Set PD-1	◐								⊕								
	62690-5	M	Adapter Set PA-1	◐																
	62690-7	M	Adapter Set Prop.	◐																
	62740-1	M	Console, Control RCS	●	●	●	●													
	62850-1	M	Station Checkout, Propellant S/S	●																
	62850-3	M	Station Checkout, Propellant S/S	●																
	62900-1	M	Console, Test Conductor	●								●								
	62920-1	M	Control Station RCS Stand	●																
	410-64018-1	M	Controller Helium Dist. Unit	●								●								

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
HAZ MSE	410-64020-1	M	Controller, Propellant Load Control Assy.	●								●								●
	64020-3	M	Controller, Propellant Load Control Assy.	●								●								●
	64020-9	M	Controller, Propellant Load Control Assy.	●								●								●
	410-64020-15	M	Controller Propellant Load Control Assy.	●								●								●
	430-64220-1	M	Distribution Unit Pressure He	●								●								
	430-64320-1	M	Drip Removal Assy. Fuel	◐																
	430-64330-1	M	Drip Removal Assy. Oxidizer	◐																
	430-64420-1	M	Assy. Loading Control, Fuel	●								●								
	430-64420-3	M	Assy. Loading Control, Oxidizer	●								●								
	430-64420-9	M	Assy. Loading Control, Fuel	●								●								
	430-64420-15	M	Assy. Loading Control, Oxidizer	●								●								
	410-64580-1	M	Control Station He Pressure	◐								●								
	410-64660-1	M	Console, Control Ser. Unit Facility Valve	●								●								
HAZ MSE	410-64660-3	M	Console, Control Ser. Unit Facility Valve	●																

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
HAZ STE	410-1080-1	M	Cons. Liquid Level Remote Control Gauge	◐																
	430-2480-1	M	Test Lines, Fuel Distribution, RCS									⊕								
	430-2490-1	M	Test Lines, Oxidizer Distribution, RCS									⊕								
	450-5506-1	B	Bio-Medical Monitoring Assy.	●	●	●	●	●												
	430-5510-1	M	Simulator, Internal Environment	●	●	●	●	●		●		●					●	●	●	●
	6090-65	M	Ascent Engine Simulator	●																
	6090-69	M	Ascent Engine Simulator	●																
	6150-1	M	Descent Engine Simulator	●								⊕								
	6150-5	M	Descent Engine Simulator	●								⊕								
	6460-1	M	Remote Oper. Liquid Level Gage	●								●								●
	6460-3	M	Remote Oper. Liquid Level Gage	●								●								●
	430-6630-1	M	Propulsion Test Unit HA-3									●								
	410-6640-1	M	Control Station #1 - Pneumatics									●								
	410-6640-3	M	Control Station #2 - Pneumatics									●								
	430-6670-1	M	Nitrogen/Helium Pressurization	●								●								
HAZ STE	430-6710	M	Fluid Distr. Sys. T/S No. 2	●								●								

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan (LTS)
HAZ STE	430-6800-1	M	Descent Ullage Test Unit	◐																
	6819-1	M	Sight Gage Unit Live Propellant	◐																
	6819-3	M	Sight Gage Unit Live Propellant	◐																
	6930-1	M	Fluid Dist. System Alt. Stand #1	●								●								
	430-6940-1	M	Fluid Dist. System Alt. Stand #3																	●
HAZ-STE	410-6949-1	M	Controller N_2/He Pressure Unit	◐								●								
	410-6990-1	M	System Control Cell Pressure									●								
NON-HAZ MSE																				
	410-11020	B	Simulator, Ascent Stage	●	●	●														
	410-11030	B	Simulator, Descent Stage	●	●	●														
	11090	M	Cable Set, GAEC Prod. Test Facility	◐																
	11190	B	Intercom	◐	◐															
(MEE)	11215	B	Pulse Gen. Digital Control	●	●	←								Cancelled						→
	11220	B	Intercom Test Conductor	◐																
	11240	B	Intercom Explosion Proof	◐																
(MEE)	11960	M	Ant. Hat Rendezvous Radar	◐	←									Cancelled						→
NON-HAZ MSE	410-12010	M	Data. Acq. Sys., LEM Prop. Test Fac.	●	←									Cancelled						→
	400-12020	B	Analog & Digital Assy.	●	●	←								Cancelled						→

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan (LTS)
NON-HAZ MSE	400-12030	B	Signal Conditioning Assy.	●	●	←								Cancelled						→
	400-12040	B	Potentiometric Recorder & Ind.	●	●	←								Cancelled						→
MEE	410-12100	B	Cond. Signal Up-Down Counter	●	●	←								Cancelled						→
MEE	410-12110	B	Sig. Cond., Data Register	●	●	←								Cancelled						→
NON-MSE	420-13249	B	Running Gear, Torsion Bar Susp. Trans.	●		●	●	●												
	420-13500	M	Transporter, D/S	◐																
	420-13750	M	Positioner, Cleaning	◐																●
	410-22020	B	Test Station Abort Guid. Sec. Maint.	◐	◐															
	410-22040	M	Test Station Con. Elect. Sec. Maint.	◐																
	410-22055	M	Temp. Monitoring Control Assy.	◐																
	410-22950	B	Test Station Cmd. Con. Sec. Maint.	●	●															
	410-32080	M	Adapter Assy. VHF RD Telem. Ant.	◐																
	410-32100	B	Test Assembly Digit Command	●	●	●	●	●												
	410-32120	B	Test Assembly Ranging	◐	●															
	410-32160	B	Test Station C-Band Transp. Maint.	◐	◐	←								Cancelled						→
	410-32180	M	Adapter Assy. UHF Cmd. Ant.	◐																
NON-HAZ MSE	410-32201	B	Coupler S-Band Steerable Ant.	◐																

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
NON-HAZ MSE	410-32281	B	Video Simulator Slow Scan	◐																
	410-32300	B	Test Station Commun. Maint.	●	●															
	410-32440	B	Test Station Antenna Maint.	◐	●															
	410-32520	M	Test Station RR/T and LR Maint.	●	◐															
	440-41001	B	External Visual Display Equipment	●	●	●	●	●			●		●		●	●	⊕	⊕		
	410-42100	M	Test Station D&C Maint.	●																
	410-43100	B	EPS/PGS Thermal Vac. Chamber	●	●	●	●	●	⊕						●	●		⊕		
	430-52160	B	Test Stand Water Comp.	●	●	●	●	●	⊕	⊕		◪			●	●	●			●
	430-52210	B	Test Stand Water Glycol Comp.	●	●	●	●	●	⊕	⊕		◪			●	●	●			●
	410-62090	B	Cart, Strip Chart & Event Rcdr.	◐	◐	←								Cancelled						→
	450-62162	B	Transmitter Turbine Tape, Rate of Flow	◐																
	410-62191	M	Strip Chart & Event Rcdr.	●	←									Cancelled						→
	430-62260	M	Port Checkout Unit Prop. Sys.	◐																
	410-62399	B	Module Cards LEM GSE	●				●												
NON-HAZ MSE	410-62470	M	Cart Transducer Checkout	●	←									Cancelled						→
	410-62480	B	Cart, Fuel Flush & Purge RCS	●	◐	←								Cancelled						→
	430-62520	B	Cart, Oxid., Flush & Purge RCS	●	◐	←								Cancelled						→

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
NON-HAZ MSE	410-62800	B	Console RCS Programmer	●	●	●	●													
	410-62858	B	Acquisition Assy. Digital	●																
	420-63320	B	Force Measurement Section	●	●	●														
	420-63840	B	Actuation Subsystem	●	●	●	●	●							●	●	●	●	●	●
	410-64010	M	Controller, Press., He Dist. Unit	◐	←										Cancelled					→
	410-64030	M	Controller RCS Fuel Trans. Unit	◐																
	430-64460	M	Control Unit Prop. Trans. RCS Fuel	●	●	←									Cancelled					→
	410-72060	B	Checkout Assy. DSEA	●	●															
	410-81180	B	Simulator Inverter	●	●	←									Cancelled					→
	410-82140	M	Unit Vehicle Power Supply	●																●
	410-82150	M	Simulator Load	●																
	410-82300	B	Test Std. Gen. Pur. Inver. Maint.	●	●															
	430-82600	B	Test Bench Cryo. & Gas O_2	◐	●	←									Cancelled					→
	430-82620	B	Test Bench Cryo. & Gas H_2	◐	●	←									Cancelled					→
	410-82650	M	Control Unit Serv. Cryo. H_2	◐	←										Cancelled					→
NON-HAZ MSE	410-82670	M	Control Unit Serv. Cryo. O_2	●	←										Cancelled					→
	430-84100	M	Control Unit Fuel Cell Serv.	◐							⊕	●	←		Cancelled					→

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
NON-HAZ MSE	430-84310	M	LH_2 Fill & Vent Cont. Unit								⊕	←			Cancelled					→
	430-84330	M	LO_2 Fill & Vent Cont. Unit								⊕	←			Cancelled					→
NON-HAZ STE	430-1060	M	GN_2 Regulator Unit RCS Test	●																
	430-1150	M	Cart, RCS Vac. Test Fuel	●																
	410-3259	B	Rack Equipment	◐																
	410-3340	B	Test Station S-Band Equip. Devel.	●	←										Cancelled					→
	410-3825	B	Radar, Signal Gen. Equip.	◐																
	410-3900	B	Test Set, Interface & Perf. Radar N&G	◐	●															
	430-6100	M	Unit Calibration Weight Tank	◐																
	430-6168	B	Valve, Selector, 3 Way	●																
	430-6320	B	Stand Stor. Trans. Sub Fuel	●																
	430-6330	B	Stand Stor. Tran. Suboxid.	◐																
	430-6440	B	Cart Trans. & Stur. Sub Prop.	●	●	●														
NON-HAZ STE	430-6480	B	Comp. Test Stand Sub Prop.		●															
	430-6580	B	Cart N_2 Conditioning	●	●															
	410-7100	B	Test Station Devel. SCEA	◐	◐	←									Cancelled					→

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
NON-HAZ STE	410-7500	B	Test Station PCMTEA Dev.	●	●	●	●	●												
	410-7600	B	Test Station C&WEA	●	●	●	●	●												
	410-7700	B	Test Station DSEA	●	●	●	●	●												
	410-7800	B	Test Station SCEA	●	●	●	●	●												
	410-7850	B	Detector SCEA Intermittent	●	●	●	●	●												
	410-7900	B	Test Station ISG	●	●	●	●	●												
	430-8120	B	Supercritical & LO_2 Dev. Bench	●	●	●	●	●	◐	◐		◐	← Cancelled							→
	430-8130	B	Supercritical & LH_2 Dev. Bench	●	●	●	●	●	◐	◐		◐	← Cancelled							→
	430-8140	B	Bench Test Fuel Cell Gas Dev.	●	●	●	●	●	◐	← Cancelled								◐		
	410-8150	B	Load Bank AC.	●	●															
	430-8160	B	PGS Thermal Vacuum Chamber	●	← Cancelled															→
	430-8170	B	Leak Detector He-H_2	●	●	← Cancelled														→
	410-8210	B	Unit - R/C Cryo. H_2 Rig	●	●	← Cancelled														→
	410-8250	B	Unit - R/C Cryo. O_2 Rig		●															
NON-HAZ STE	410-8371	B	Ripple Control Module	◐																
	410-8450	B	C/U Remote LH_2 Trans. & Storage	●	●	← Cancelled														→
	410-8470	B	C/U LO_2 Stor. & Trans.		●															

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
NON-HAZ STE	410-8760	M	Simulator, Fuel Cell	◐	Cancelled →															
	410-9150	B	Test Rack Stimul. & Monitoring		●															
	410-9160	B	Console Control FCL		●															
	410-9161	B	Stimul. & Monitoring Test Rack	◐																
	450-9200	B	Station, LEM Data Reduction	●	●	●	●	●	●	●					●	●	●	●	●	◐
	410-9470	B	Intercom	●	●	●														
	410-9480	B	Intercom. Test Conductor	●	●	●														
	410-9851	B	Pressure Indic. System	◐																
	400-9909	B	Transducer, Absol. Press., Med. Range	●																
	400-9913	B	Transducer, Diff. Press. Bidir. (Wet-Dry)	●																
	400-9914	B	Transducer, Absol. Press. Low Range	●																
	400-9917	B	Transducer, Diff. Press. Bidir. (Wet-Wet)	●																
NON-HAZ STE	400-9923	B	Transducer, Diff. Press. Unidirect.	●																
	400-9926	B	Gage Pressure Medium Range	●																

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

Crit. Class	Part Number	MBG	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
NON-HAZ-STE	450-9938	B	Sensor Simulator Assembly	●																
	450-9952	B	Digital Data Acquisition System	●	●	●														
	450-9953	B	Digital Data Acquisition System	●	●	●													•	
	450-9258	B	Digital Data Acquisition System	●	●	●														
	450-9959	B	Data Acquisition Section	●	●	●														

TABLE 4.11.1.1 (continued)

Reliability Status List For LEM GSE/STE

SYMBOL LEGEND

- ⊕ Preliminary or partially complete
- ◐ Received for review and inputs
- ● Accepted, complete
- ◪ Unacceptable, minor exceptions
- ■ Rejected, major revision

NOTE: "X" Below denotes Reliability task or effort that is not applicable to the respective classifications shown.

Crit. Class	Part Number	M B G	Equipment Name	LSP	LVR	Vendor Evaluations	Vendor Negotiations	P.O. Awarded	Part Selection	RDL	Rel. Estimate	FMEA	Config. Anal.	Maint. Anal.	Program Plan	Spec. Tree	Design Report	Design Review	Design Freeze	Test Plan(LTS)
MEE			(Mission Essential Equipment)																	
HAZ-MSE			(Hazardous Mission Support Equipment)								X		X							
HAZ-STE			(Hazardous Special Test Equipment)								X		X							
NON-HAZ MSE			(Non-Hazardous Mission Support Equip.)						X	X	X	X	X	X	X	X	X	X	X	
NON-HAZ STE			(Non-Hazardous Special Test Equipment)						X	X	X	X	X	X	X	X	X	X	X	
		M	(Make Item)		X	X	X	X							X	X				
		B	(Buy Item)																	
		G	(Government Furnished Item		X	X	X	X							X	X				

4.11.2.2 Reliability Effort on Subcontracted GSE/STE (continued)

2. (continued)

430-54400	Cabin Leakage Test Unit
430-64200	Supercritical Helium Conditioning Unit
430-64260	Helium Storage & Transfer Dewar
440-41001	External Visual Display Equipment

3. Participated in preliminary and/or final design reviews on the following end items:

430-54200	Oxygen Transfer Unit
430-54400	Cabin Leakage Test Unit
430-54700	Water-Glycol Trim Control Unit
430-64200	Supercritical Helium Conditioning Unit
430-64260	Helium Storage & Transfer Dewar
440-43100	LEM Mission Simulator

4.11.2.3 PSDF/WSO DEI Chit #17-FMEA on Facility Electrical Power

The subject chit, which requested an FMEA to be performed on the facility electrical power, has been completed for Ambient Test Stand #402 at PSDF/WSO. The results of this effort are contained in Reference (e). Recommendations for eliminating the possibility of the five (5) potential Class I failures and an FMEA to cover Altitude Test Stands #401 and #403, are presently being worked on.

4.11.2.4 Failure Analysis and Corrective Action

Preliminary failure analyses were completed on approximately 20% (54) of the GSE failures which have occurred at PSDF/WSO and GAEC, Bethpage. Corrective action has been instituted on thirty (30) of the above failures. Reference (f) summarizes a typical analysis and recommended corrective action on a group of failures encountered on GSE.

Fifty-one (51) failures have occurred on common-use GSE at PSDF/WSO. Failure data has been requested from the Apollo Failure Data System and discussions are planned with NAA/S&ID to benefit from any failure analysis and corrective action as instituted by NAA.

4.11.2.5 Investigation of Backup Cooling Requirements for LEM After Closeout

This investigation was conducted as a result of an action item levied on GAEC at Apollo Checkout Panel Meeting #17. Initial consideration was given to the various LEM configurations and their respective checkout plans at ETR to establish the primary cooling requirements. In addition, the study considered various backup configurations. A preliminary report was presented at the 18th Checkout Panel, Reference (g).

Based on the above study, Reliability will recommend "near-place" parallel redundancy for the 430-54600 Freon Supply Unit and the associated freon bottles (430-54330) for use on LEM's 1 thru 3 since no loss in cooling can be tolerated for the R&D instrumentation. Recommendations for backup cooling on LEM's 4-10 will be made at a later date based on the review of the ETR Range Safety Plan (AFMTCP 80-2).

4.11.2.6 Review of Mechanical Parts/Components Documentation

Documentation was reviewed for the selection and application approval for GSE mechanical parts/components during this report period. This effort encompassed a review of Advance Material Notices (AMN) and Specification Control Drawings (LSC) on in-house GSE designs as well as parts lists and Reliability Data Lists (RDL) submitted by LEM GSE vendors.

An in-house procedure is being set up to collect and utilize reliability backup data on commercial parts/components into which the majority of the mechanical parts/components fall.

4.11.2.7 Reliability Participation in Monthly GSE Status Review, Requirements Review and Concepts Review Meetings

Reliability continued its participation in the subject meetings during this report period to discuss and resolve the following problem areas:

4.11.2.7 Reliability Participation in Monthly GSE Status Review, Requirements Review and Concepts Review Meetings (continued)

a. Waiver requests relative to MSC-GSE-1B and hi-rel parts on certain items of MEE which contain a high percentage of off-the-shelf commercial equipment.

b. Mean-Time-Between-Failure (MTBF) requirements for MSE (300 hours).

c. Individual equipment criticality classifications.

d. Apportionments for LEM mission-essential GSE which are in excess of 600 hours.

Reliability was given an action item at Requirements Review #11 to evaluate the necessity of providing a standby or replacement SHe Conditioning and Transfer Assembly (430-64200) as backup in the immediate launch area. The results of this study are contained in Reference (q) and were presented at the 6 April concept review.

4.11.2.8 Common-Use GSE

A meeting was held with NAA/S&ID during this report period to discuss and approve the common-use GSE Reliability Cooperative Plan (MH01-04400-500). Changes to the plan were recommended to reflect applicable documentation where GAEC is the developing contractor. The Plan was approved with confirmation sent to NAA via Reference (i). GAEC also requested data packages from NAA on common-use GSE in order to complete the systems FMEA at PSDF/WSO and ETR (see Reference (n)).

A meeting will be held during the next report period to discuss failure analysis and corrective action particularly with reference to common-use GSE failures at PSDF/WSO. Failure reports on these failures were transmitted to NAA/S&ID via Reference (j).

4.11.2.9 Reliability Participation in Altitude Simulation Facility Working Group

Reliability actively participated in the GSE/Altitude Simulation Working Group, which was established as a result of PSDF/WSO DEI Chit #18, dated 2-10-1965.

4.11.2.10 Further Definition of Reliability Program for GSE

Reference (k) was written to define the GSE/Reliability program resulting from the LEM Program Redefinition in April. In addition, the LVR boilerplate was revised to reflect the program changes. The reliability requirements for GSE parts are covered in Reference (t) which is intended to be used as a guide by GSE engineers and designers in the selection of parts for GSE.

Reference (s), which outlines the in-house reliability program for GSE, was updated and reissued during this period.

4.11.2.11 FMEA for PD-1 Rig

An FMEA on the PD-1 Rig was performed for presentation at the May 26, 1965 DEI. Analysis of this Rig revealed the possibility of no Class I, twenty eight (28) Class II, three (3) Class III and four (4) Class IV type failures. Reference (1) was issued to cover the FMEA on this rig and further details may be found therein.

4.11.2.12 GSE/Reliability Test

During this reporting period Reliability Test Group continued to review various LEM/GSE Design Control Specifications (LSP) and Vendor Requirements documents (LVR) for the imposition of Acceptance Test and Qualification Test requirements (See Table 4.11.1.1 Equipment Status List).

4.11.2.12 GSE/Reliability Test (continued)

In addition, Test Group continued to prepare LEM/GSE Qualification Test Data Sheets for Mission Essential Equipment. These were submitted to NASA for approval via Reference (p). As yet, no approval has been obtained.

The Test Group also participated in review of vendor proposals, negotiations with vendors and surveillance of vendors under contract.

Limited witnessing of Acceptance and/or Qualification Tests was conducted on GSE end items in Mission Essential or Hazardous categories warranting special attention.

4.11.2.13 Review of MSC-ASEC Apollo Program Ground Support Equipment Criteria

This MSC-ASPO document was reviewed by Reliability for its relavence to the LEM Reliability Program requirements for GSE. Comments were made on Section 5.0, "GSE Reliability Program Requirements", that the section be revised to reflect the current GAEC reliability program.

4.11.2.14 Reliability Effort on In-House GSE

Reliability has reviewed various in-house GSE designs primarily in support of the BA4 and PD-1 site activation at PSDF/WSO. The Reliability effort consisted mainly of parts selection and application review and FMEA's. The following units were covered during this report period:

a.	430-6100-1&3	Weight Tank Calibration Unit
b.	430-6460	Liquid Level Gage, Remote Operated
c.	410-6640	Control Station, Pneumatics
d.	430-6930	Fluid Distribution System Altitude Stand #1
e.	410-6949	N_2/He Pressurization Unit Controller

4.11.2.14 Reliability Effect on In-House GSE (continued)

f.	430-6990	Cold Flow, Helium System
g.*	410-11180	FDS Switching Control Unit
h.	430-62160	A/D Ullage Checkout Unit
i.	430-62180	Cart, Checkout, Prop. System
j.	410-62220-1	Engine Firing Control Console
k.	410-62900	Console, Test Conductor
l.	410-64020-1&3 9&15	Controller, Prop. Loading Control Assembly
m.*	410-64130	FDS Valve Box Controller
n.	430-64220-1	Distribution Unit, Helium Pressurization
o.*	410-64230	Transfer Control Assembly RCS, Fuel
	410-64240	Transfer Control Assembly RCS, Oxidizer
p.	430-64500	Pressure Maintenance Unit

Preliminary reliability predictions have been performed on those MEE units denoted (*).

A recommendation was made for a design change on the 410-62220-1&3 to incorporate redundancy in the Emergency Abort Logic Circuit (See Reference(r)). Completion of the PD-1 GSE FMEA's as well as additional predictions for MEE is anticipated during the next report period.

4.11.2.15 GSE Hazard Proofing and Safety Requirements

A meeting was held at MSC-Houston between NASA safety and GAEC GSE personnel to discuss NASA document MSFC 10M01071 as it applies to the electrical design of GSE. Reliability prepared an input for this meeting, the results of which may be found in Reference (y).

4.11.3 References

a.	LED-550-48A	Prelaunch MEE Listing
b.	LED-550-50A	Hazardous GSE Listing
c.	LAV-550-461 511 1281	Parts Approval for ECS Test Stands.
d.	LAV-550-497/ 1243	Parts Review 430-54200
	LAV-550-498/ 519	Parts Review 430-54700
	LAV-550-499/ 1226/ 1244/ 1273	Parts Review 430-54400
e.	LMO-550-639	DEI Chit #17, FMEA
f.	LAV-550-1246	Trip Report on Mesur-Matic Meters
g.	Action Item Response # 17.14.3.1	Apollo Checkout Panel Meeting #17 (Submitted at Meeting #18)
h.	LAV-550-502	Common-Use/GSE
i.	LLR-550-85	Common-Use ICD Approval
j.	LLR-630-151 LLR-630-144 LLR-630-171	CU/GSE Failure Reports
k.	LMO-550-624	Changes to Reliability/GSE Effort due to LEM Program Redefinition.
l.	LMO-550-644	PD-1 Rig DEI, FMEA
m.	LPR-550-8	Quarterly Reliability Status Report.
n.	LLR-550-86	Request for CU/GSE Data
o.	LMO-550-657	Trip Report on 430-64200 and 430-64260.
p.	LLR-400-206	Transmittal of Qual Test Data Sheets for GSE.
q.	LMO-550-614	Preliminary Reliability Study of Supercritical Helium Conditioning and Transfer Assembly 430-64200.

4.11.3 References (continued)

r.	LAV-550-1304	Request for Redundancy in Emergency Abort Logic on Engine Firing Control Station 410-62220.
s.	LMO-550-452A	Outline of the In-House Reliability Program for GSE.
t.	LMO-550-1305	GSE Reliability Parts Program, Instruction for
u.	LAV-550-481	Parts Approval for LMS
	503	Parts Approval for LMS
	1240	Parts Approval for LMS
	1241	Parts Approval for LMS
	1248	Parts Approval for LMS
v.	LAV-550-1215	Transmittal of GAEC's Derating Policy to Link.
w.	LAV-550-485	Approval of Hamilton Standard's Reliability Plan.
x.	Meeting #191	NAA/S&ID GAEC Meeting Minutes
y.		PH4/G-391-14-65-553

4.12 ELECTRONIC PACKAGING

4.12.1 General

4.12.1.1 Major Effort for the Period

The major effort in electronic packaging for this period was devoted to the technical monitoring of designs performed by subcontractors and in-house design groups for the various systems of the LEM. This monitoring was accomplished as follows:

1. Review of and comments on documentation, e.g., progress reports, vendor in-house specifications etc.

2. Attendance at technical coordination meetings, both with vendors and representatives from other GAEC groups.

Effort has also been exerted reviewing proposed revisions to internal packaging specifications and proposed specifications for wire wrap.

4.12.1.2 Technical Monitoring and Assistance Areas

Effort has been expended in a number of subsystem areas and results are discussed in the following sections.

4.12.1.2.1 Communications Subsystem

4.12.1.2.1.1 Signal Processor Assembly

As a result of a meeting held at GAEC on 27 and 28 April 1965, Collins Radio Corporation has agreed to

1. Redesign the package by mounting cordwood assemblies on only one side of a board rather than the present back to back mounting. This

4.12.1.2.1.1 Signal Processor Assembly (continued)

1. (continued)

   scheme would permit a mechanical mount for the cordwoods (as well as adhesive) and provide room to do all interconnecting wiring on the reverse side of the board.

2. Investigate a redesign of this chassis which was found to be weak during vibration tests.

3. Redesign of the special handling kit to comply with GAEC Drawing LLO-420-378.

This information may be found in minutes, LMM-381-15 of 3 May 1965, "LEM SPA Technical Meeting" and in AVO, LAV-381-245 of 17 May 1965, "GAEC Comments on Collins Signal Processor Drawings".

4.12.1.2.1.2 S-Band Transceiver

The design of this ERA is inherently problematical and whatever "fixes" are made to correct design deficiencies will only add to the weight of the package. At present, of the total of 20.2 lbs. of weight, 11 lbs. are attributed to structure. Design inadequacies are listed below:

1. Multiple thermal interfaces whose repeatable integrity in production is questionable.

2. Inadequate clamping of modules to base plate would be cause for excess vibration.

3. Covers attached to base plate are used for EMI purposes only (no multiple use).

4. The necessity of removing several modules to repair another module makes for poor maintainability.

5. RF packaging in only two dimensions led to poor packaging density.

4.12.1.2.1.2 S-Band Transceiver (continued)

6. Lugs which are dip-brazed to chassis are subject to high stress in vibration. No test data is available to attest for reliability of braze.

7. The long through bolts used to bolt the modules together will act as springs under vibration.

Additional objections to this ERA may be found in LMO-490-225 of 13 May 1965 and LMO-510-313 of 17 May 1965.

GAEC Reliability at this date, still objects to this method of packaging. The design problems have evolved from a series of changes (e.g., changing it from a subassembly to a single ERA package). Additional comments may be found in Motorola meeting minutes, LMM-381-17, dated 10 May 1965.

4.12.1.2.1.3 S- Band Power Amplifier

The layout of the electronics packaging has yet to be settled. The close proximity of the two amplitrons has cuased a problem of coaxial interconnection. This has resolved itself into a trade-off between a violation of coasial cable minimum bend radius requirements or the use of rigid coax with attendant loss of reliability, and a larger insertion loss. A larger package could of course, solve such problems but all layout possibilities should be exhausted before this recourse is chosen.

Various investigations have been made into election beam welding, dip brazing etc., in order to effect a strong, light package. However, because of lack of sufficient experience data, the package will probably be "hogged" out of solid stock.

4.12.1.2.1.4 VHF Transceiver

This package has presented a problem in this area of transistor mounting. It was requested that these parts be cemented to the mounting surface as well as providing the spring clips which are presently used. It was feared that spring clips alone would not be sufficient when the package is subjected to vibration. In addition, the cement being heat conductive, would provide an additional heat path for the transistor.

4.12.1.2.1.5 Erectable Antenna

An experimental model antenna was found to have two stable positions when erected, one being paraboloidal, the other distorted. The distorted position was claimed by RCA to have been caused by fabric shrinkage. They stated that the next fabric (a chromel knit) will not be subject to shrinkage. RCA will conduct a study of the fabric tension-rib spring strength relationship for the purpose of precluding the possibility of a distorted stable state.

4.12.1.2.1.6 RF Switch

This switch whose contacts are hermetically sealed, uses four metallic-bellows, which represent a possible hazard if the seals break. Should there be a rupture of any of the bellows, the contacts would be exposed to an atmosphere of oxygen. Should there be any outgassing of non-metallic-materials in the switch, such products together with the oxygen present, might constitute an explosive mixture in the presence of arcing.
A review will be made of outgassing properties of all non-metallic-materials, the possibilities of bellows rupturing and any other conditions tending to aggravate the situation.

4.12.1.2.1.7 Digital Command Assembly

This ERA has been redesigned to approach optimum packaging. Some areas are still not fully defined e.g., cable runs, but the preliminary layout represents a good package with proper regard for reliability, maintainability, heat dissipation, weight and vibration.

Each of the flat packs mounted on cards, has a metallic finger bonded to it which acts as a heat path to the outside shell. The flat packs are cemented to boards and their leads are welded to nickel printed circuitry. Close examination of these boards revealed whiskering of the circuit runs which ere in tight proximity.

The vendor Avco is to furnish the QC procedures used to inspect for these protrusions and submit the methods used for their removal. Additional stiffening of the long side of the box by use of a cross-tie was recommended. Drawings for a handling kit are not complete, nor is the thermal analysis which is awaiting the finalization of the electronic circuitry.

4.12.1.2.2 Guidance Navigation and Control

4.12.1.2.2.1 Radar

4.12.1.2.2.1.1 Frequency Multipliers

The following areas of questionable packaging have been brought to the attention of the communication subsystem vendor, RCA.

1. The press fit of varactors into chucks on the Quadrupler.

2. A staking or conformal coating of resistors to improve heat dissipation to chassis.

4.12.1.2.2.1.1 Frequency Multipliers (continued)

3. Possible RF leakage where cover is mounted to Quadrupler chassis.

4. Failure of support for coils cantilevered from chassis.

5. Fretting action between waveguide and chassis in Hi-Frequency Doubler.

6. Excessive clearance between Frequency Multiplier chassis and cover possibly permitting RF leakage.

7. Better packaging techniques desired for mounting transistors to heat sink.

4.12.1.2.2.1.2 Landing Radar

The following areas of possible packaging deficiencies and areas of insufficient packaging study have been brought to the attention of Ryan Aeronautical Company:

1. The problem of attaching the antenna array to the electronic package and thermally isolating it.

2. The problem of attaching electronic parts to printed circuits in a cordwood subject to vibration.

3. The failure to use mechanical means of attachment of cordwoods cemented to the chassis and the failure to use improved adhesives for better heat transfer.

4. The problem of sealing the cover and chassis interface to preclude the possibility of RF leakage.

5. The use of electron beam welding for chassis structure without sufficient data to substantiate structural integrity.

4.12.1.2.2.1.2 Landing Radar (continued)

6. The lack of a thermal analysis of web mounted electronic parts to substantiate the cordwood layout.

7. The lack of a trade-off of the weight of additional screws to improve heat transfer and the temperature of electronic parts in the cordwood modules being mounted.

8. The lack of an analysis to determine the effect on transmitting and receiving signals on antenna arrays subject to high thermal excursions.

4.12.1.2.2.1.3 Rendezvous Radar

RCA has indicated that certain areas of the package will be transmitting as much as 5 watts/inch to the cold rail. Although thermodynamics has provided for this high input, an effort will be made to redistribute the electronic parts, add heat shunts or use other devices to distribute heat more uniformly.

4.12.1.2.2.2 Control Electronics System

4.12.1.2.2.2.1 Attitude and Translation Control Assembly (ATCA)

RCA has indicated that plate temperatures approaching 158°F can occur during operation. Since 160°F is the limit temperature of electronic parts, either a redesign will be necessary or parts must be coated or packaged in such a way as to keep a temperature differential between the plate and the electronic part below 2°F. RCA will be monitored to insure that the test of relays in vibration will be in the direction of opening and closing of contacts. This will be performed at various "g" levels through an excursion up to 2000 cps.

4.12.1.2.2.2.1 Attitude and Translation Control Assembly (ATCA) (continued)

RCA has been cautioned to use mechanical means as well as adhesives mounting cordwood assemblies.

4.12.1.2.2.2.2 Descent Engine Control Assembly (DECA)

The exact method whereby cordwood modules are mounted onto printed boards has yet to be determined. A mechanical means and an adhesive has been recommended but the electrical connection has not been spelled out.

The potting compound, its heat conducting properties, techniques of encapsulation will all be carefully monitored so as to obtain a structurally sound, reliable cordwood with good heat dissipation.

In stressing the fact that fault isolation at the vehicle will be limited to the assembly level, RCA nevertheless, was cautioned to design the ERA so that any repair may be made with a minimum of disturbance to other components of the assembly.

4.12.1.2.2.3 Non LEM-10 Equipment

4.12.1.2.2.3.1 Program Reader Assembly

Fairchild, in all stress analyses, has always used worst case conditions. Using this concept, Fairchild would undoubtedly develop a safe package but an unduly heavy one. It was requested that a refinement in design take place, i.e., that true end conditions of beams be used instead of just assuming a simple beam.

4.12.1.2.2.3.1 Program Reader Assembly (continued)

Fairchild has failed to meet the 160°F requirement as the maximum temperature of electronic components. It was pointed out that to meet this specification, heat sink plate temperatures should be low enough to systain a differential sufficient to absorb the entire heat emission of all electronic parts.

4.12.1.2.2.3.2 Program Coupler Assembly (PCA)

Because of an increase in the number of relays required (as determine by the design groups) the size of the package has grown from 19 inches to 25 inches. The entire concept of packaging has changed so that the ERA is now composed of about 15 cordwood subassemblies wired together point to point and soldered. This improved some maintainability aspects of the PCA.

4.12.1.2.3 Electrical Power Subsystem

1. General Electric has indicated that the operation of electronic parts at a temperature of 200°F is contemplated. Before this is permitted, GE will have to submit sufficient data to prove the reliability of parts at 200°F.

2. The use of a dip-brazed chassis was discouraged unless sufficient inspection techniques are employed to insure the soundness of the braze.

3. GE was urged to use mechanical means to supplement adhesives in the mounting of subassemblies.

Further amplification of the above may be found in LAV-550-496, dated 20 April 1965.

4.12.1.2.4 Descent Engine (Electronics)

STL has been requested to furnish a thermal analysis of packaged electronic assemblies mounted on the engine.

4.12.1.3 Projected Effort for Next Period

Continued surveillance will be maintained over the packaging of any electronic equipment discussed in previous reports. Additional effort will be expended as the occasion arises, e.g., pyrotechnics is under consideration. Attendance at meetings with vendors, review of documents with comments, review of drawings where applicable will all be part of this effort.

Time will also be spent with the Specification Group in the development of specifications affecting packaging (i.e., wire wrap specifications) and with documents requesting deviations from specifications.

Exothermic reactions during encapsulation and foaming problems are also under study.

5.0 DOCUMENTATION RELEASED DURING THE REPORT PERIOD

5.1 MEMORANDUMS

Number	Date	Title
LMO-550-572	3-8-1965	Trip Report on Design Review of the LEM Data Reduction Station of Astrodata Inc., Analheim, California, 8-9-10 February 1965
LMO-550-573	3-8-1965	Ground Rules for Categorizing GSE/STE as Prelaunch Mission Essential, Hazardous, and Flight Mission Essential
LMO-550-574	3-9-1965	Report on Reliability Meeting of RCA-ECD Harrison, New Jersey, on 11 February 1965, P.O. 2-18856-C, Rendezvous and Landing Radars
LMO-550-575	3-11-1965	Review of Proposed Relays Per LSP-390-11
LMO-550-576	3-11-1965	Reliability Comments on the Raytheon Corp. Thermofit Connector (Splice) Presentation
LMO-550-577	3-15-1965	Reliability Analysis of RCS Instrumentation
LMO-550-578 thru LMO-550-585	PROPRIETARY	
LMO-550-586 thru LMO-550-603	CANCELLED	

5.1 MEMORANDUMS (continued)

Number	Date	Title
LMO-550-604	3-17-1965	Request for Information Related to Tube Brazing
LMO-550-605	3-17-1965	Maintainability Aspects of an All Battery LEM Configuration
LMO-550-606	3-22-1965	Trip Report to Bell Aerosystems, Buffalo 18 February 1965, Design Review of Bi-Propellant Valve and Discussion of Associated Problems
LMO-550-607	3-25-1965	Clarification of Use of Qualified Parts and LSC Drawings for Use on LEM-GSE
LMO-550-608	CANCELLED	
LMO-550-609	3-25-1965	Probability of LEM Requiring CSM Rescue
LMO-550-610	3-29-1965	LEM Ascent Engine, P.O. 2018832-C
LMO-550-611	PROPRIETARY	
LMO-550-612	4-2-1965	Trip Report-NASA, MSC-R&QA Meeting, Parts and Material Program Management Panel, 17 March 1965
LMO-550-613	4-3-1965	Estimate of the Probability of Equipment Failures During an 8 Hour Cold Soak of LEM-1

5.1 MEMORANDUMS (continued)

Number	Date	Title
LMO-550-614	4-8-1965	Preliminary Reliability Study of the Supercritical Helium Conditioning and Transfer Unit Assembly, 430-64200
LMO-550-615	4-8-1965	Design of Umbilical Separation Between Ascent and Descent Stages
LMO-550-616	PROPRIETARY	
LMO-550-617	4-13-1965	Silver Oxide-Zinc Battery FTA 1 & 2 LSP-390-17
LMO-550-618	4-16-1965	Trip Report to MSC, Houston, to Discuss Wire Wrap Test Reports
LMO-550-619	4-20-1965	Manotta Electro-Magnetic Valves (904434-10354 & 904434-10356)
LMO-550-534A	4-12-1965	Electrical Power Supply Load Arrangement Crew Safety
LMO-550-620	4-21-1965	Configuration Analysis & FMEA of PCM Transmission 1.024 M C/S only & PCM Transmission on Either 512 K C/S or 1.024 M C/S
LMO-550-621	4-22-1965	Maintainability Recommendations

5.1 MEMORANDUMS (continued)

Number	Date	Title
LMO-550-622	4-23-1965	Reliability Analysis of R&D Instrumentation Checkout
LMO-550-623	4-26-1965	GAEC-MSC Meeting, 15 April 1965, at MSC, Houston, Texas, LEM Reliability Qualification Status List Format
LMO-550-624	4-28-1965	Changes to Reliability/ GSE Effort Resulting from the LEM Program Redefinition
LMO-550-625	4-29-1965	Crew Safety Reliability Considerations Relating to Pressurization of the Ascent Propulsion System During Pre-Separation Checkout
LMO-550-626	4-30-1965	Equipment Listing for LEM Mission Operating Profiles
LMO-550-627	5-6-1965	Comments on Report of Trip to Sylvania - Design Feasibility Test
LMO-550-628	5-5-1965	Maintainability Recommendations for ECS Component Accessibility in the Aft Equipment Bay
LMO-550-629	PROPRIETARY	
LMO-550-630	5-8-1965	Trip Report - Rendezvous Radar Antenna - Design Review

5.1 MEMORANDUMS (continued)

Number	Date	Title
LMO-550-631		Estimated Reliability for Suit Failure Study for Environmental Control S/S
LMO-550-632	CANCELLED	
LMO-550-633	5-11-1965	GAEC/MIT Interface Connectors
LMO-550-634	5-11-1965	LEM Elapsed Time Indicator Data Philosophy Held at GAEC on April 1965
LMO-550-635	5-13-1965	Use of Split-Pin Wire Wrap Terminals in LEM Electronic Packaging
LMO-550-636	5-13-1965	T/V Test of Instrument Panels
LMO-550-637	5-14-1965	Comments on Review of Test Program for Range Indicator
LMO-550-638	5-15-1965	Trip Report - RR/Design Review at RCA-ASD-B on 29-30 April 1965
LMO-550-639	5-17-1965	DEI Chit Item No. 12, Failure Mode and Effect Analysis on WSMR Facility Power
LMO-550-640	5-17-1965	Comments on GASTA Conceptual Design Report and GASTA Design Review
LMO-550-641	5-25-1965	Detent Switch Mechanization in the Attitude Controller

5.1 MEMORANDUMS (continued)

Number	Date	Title
LMO-550-642	5-20-1965	Reliability Manpower by NASA Tasks for CCA's 28, 34,38,39,43,45,46,47, & 48
LMO-550-643	5-25-1965	Radar Frequency Multiplier Design Review Meetings Held at ECD Harrison and GAEC
LMO-550-644	5-25-1965	Propulsion Descent Rig (PD-1) Design Eng. Insp. (DEI) Failure Mode & Effect Analysis (FMEA) 26 May 1965
LMO-550-645	5-26-1965	Trip Report to Bell Aerosystems Corp. Buffalo 3 May 1965 Design Review of Bi-Propellant Valve and Associated Problems.
LMO-550-646	5-25-1965	Summary of Second PMPMP Data Systems & Use History Working Group Meeting, MSC Houston, Texas 20 May 1965
LMO-550-647	PROPRIETARY	
LMO-550-648	6- 1-1965	Trip Report-Reliability Meeting With Parker Aircraft at Los Angeles, California on 7 May 1965
LMO-550-649	6-3-1965	Reliability Comments on RCS Prediction of Reliability Bounds Report LRR-C-4103-2, 31 March 1965

5.1 MEMORANDUMS (continued)

Number	Date	Title
LMO-550-650	6-3-1965	Reliability Control Review of AiResearch Program Plan for the Supercritical Helium Tanks Assembly
LMO-550-651	6-3-1965	LSP-300-14B, Control Assembly Attitude and Translation Controller
LMO-550-652	6-4-1965	Trip Report PQGS Reliability Meeting with Giannini Controls at Durate, California on 6 May 1965
LMO-550-653	6-7-1965	Equipment Operating Profiles for Reliability Evaluation
LMO-550-654	6-8-1965	Design Review Meeting on LEM Landing Radar Held at Ryan Aeronautical Co. on 19-20 May 1965
LMO-550-655	CANCELLED	
LMO-550-656	6-11-1965	Acting LEM Reliability Manager
LMO-550-657	6-12-1965	Trip Report of the Reliability Conference on the Supercritical Helium Conditioning and Transfer Unit and Duvar Assembly Held at Beech Aircraft Co., Boulder, Colorado, 1 June 1965

5.1 MEMORANDUMS (continued)

Number	Date	Title
LMO-550-658	6-14-1965	RCS Propellant Tank Bladder Cycle Requirement Recommendations for Specification No. LSP-310-405 (Amendment No. 4)

5.2 ENGINEERING DOCUMENTS

Number	Date	Title
LED-550-53	CANCELLED	
LED-550-54	3-5-1965	Maintainability Analysis for the Internal Environmental Simulator
LED-550-55	3-24-1965	Estimated Reliability of Ambient versus Supercritical Oxygen Storage for LEM Environmental Control Subsystem
LED-550-56	4-3-1965	Failure Mode and Effect Analysis of the Transfer Control Unit, RCS Fluids only 430-64460
LED-550-28A	3-30-1965	RCS Ground Rules, Failure Rates & Estimates for the Design Reference Mission
LED-550-57	6-10-1965	LEM Communications Subsystem Math Model and Reliability Estimates