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NUCLEAR SHUTTLE SYSTEM DEFINITION STUDY, PHASE III FINAL REPORT

PREPARED FOR NASA-MSFC
UNDER CONTRACT NAS8-24714
DRL NO. MSFC-DRL-196,
LINE ITEM 3

VOLUME VI RELIABILITY AND SAFETY ANALYSIS

31

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PHASE III FINAL REPORT

VOLUME VI
Reliability and Safety Analysis

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MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
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FOREWORD

This document contains the results of the reliability and safety analysis effort performed during the Phase III Nuclear Shuttle System Definition Study. Reliability and safety considerations for both the Class 1 Hybrid and Class 3 Reusable Nuclear Shuttle (RNS) concepts are treated here. This work was accomplished for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama, under Contract NAS8-24714. The final report was generated to fulfill the requirements of DRL No. MSFC-DRL-196, Line Item 3, and it covers the period from 1 May 1970 to 1 May 1971.

The study efforts described in this volume were performed under the direction of R. G. Riedesel and C. B. Boehmer, with responsibility for specific activities as follows:

R. S. Cowls—Mission Analysis

R. V. Hauver—Performance Analysis

R. Luna—System Reliability Analysis

PREFACE

The material contained in this document represents a portion of the final report documentation for the Phase III Nuclear Shuttle System Definition Study. The study effort was performed as a 12-month extension to the existing Nuclear Flight System Definition Study Contract (NAS8-24714), with the objective of establishing Phase A conceptual definition for two classes of reusable nuclear shuttle concepts. The first concept class is characterized as a 33-ft-diameter configuration that is launched integrally to orbit by a Saturn V INT-21 vehicle. The second concept class is characterized as a modular configuration which is assembled in earth orbit from modules carried to orbit in a space shuttle.

The final report documentation has been organized to provide separable information for the two concepts, where appropriate, and to combine report material common to both concepts in singular documents. The total documentation for the study is listed below, with this document identified in the left margin.

- Volume I: Executive Summary

Volume II: Concept and Feasibility Analysis
Part A—Class 1 Hybrid RNS
- Book 1—System Analysis and Operations
- Book 2—System Definition

Part B—Class 3 RNS
- Book 1—System Analysis and Operations
- Book 2—System Definition

Volume III: Program Support Requirements
- Part A—Class 1 Hybrid RNS
- Part B—Class 3 RNS
- Part C—Test Program Analyses and SRT Requirements

Volume IV: Cost Data
- Part A—Class 1 Hybrid RNS
- Part B—Class 3 RNS

- Volume V: Schedules, Milestones, and Networks

- Volume VI: Reliability and Safety Analysis

- Volume VII: RNS Project Requirements

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Section 1
INTRODUCTION

This volume contains the results of the realibility and safety analyses, which were performed for the Phase III Study as an integrated effort using the philosophy that the key to safety is reliability. The premise here is that if a properly designed system performs in the manner it was intended, it will not create a safety problem.

The reliability analysis investigated every failure mode of every component of major subsystems, except structures, on the RNS system to determine the effect of a failure. The items that could cause loss of the RNS were identified as flight critical items and were quantified in a single failure analysis. These items were then ranked in order of decreasing criticalities, and a reliability prediction of the RNS was made.

The safety analysis extended this reliability analysis by an investigation of the flight critical items and definition of a series of recommendations for elimination of the flight critical status, or reduction in its probability of occurrence. Multiple failures were investigated in a top-down fault tree analysis. An abort analysis was performed to determine the operational problems caused by failures during the mission. The abort analysis and the failures were then combined to produce a contingency plan, i.e., a plan of action to follow if a failure occurs.

The safety effort during this phase of the study was concentrated on the elimination or reduction of specific failures and thus the reduction of the overall probability of failure (and creation of safety problems) to a minimum. It is felt that this should be the primary concern at this time. The reliability and safety analyses and subsequent recommendations and inputs must be available at an early date in sufficient time to affect the design effort. The

specific results of safety incidents (e.g., radiobiological effects of impact of radioactive portions of NERVA) can be determined at a later date to formulate the environment statements.

The results of the reliability analysis, including the failure mode effects analysis (FMEA) and criticality analysis, are contained in Section 2. The contingency planning work sheets (CPWS), fault trees, abort analysis, and contingency plan comprising the total safety analysis effort are contained in Section 3.

Section 2
RELIABILITY ANALYSIS

A preliminary reliability analysis was performed on the initial RNS design (primarily the results from Phase II) and specific recommendations were made to improve the design reliability and safety. The designs which resulted from these recommendations and from newly incorporated Phase III design modifications were then subjected to a formal reliability analysis consisting of the failure mode and effects analysis (Section 2.3) and a criticality analysis (Section 2.4). The failure mode effects analysis (FMEA) is a qualitative analysis which is used to delineate flight critical items (FCI) which could cause loss of the RNS. The criticality analysis quantifies and ranks the FCI to produce the probability of stage loss as a function of the applicable failure modes of the flight critical items.

These data were then utilized in the safety analysis (Section 3). A contingency planning worksheet (CPWS) (Section 3.1) was prepared for each flight critical item to further analyze the results of failure, the causes of failures, the possible corrective actions, and the emergency detection requirements. The current reliability analysis is therefore a single failure analysis. A fault tree analysis (FTA) (Section 3.2) was also initiated to study the effects of multiple failures. A contingency plan (Section 3.4) was then developed utilizing the data from the FMEA, CPWS, and an abort analysis (Section 3.3) to delineate the operational requirements placed on the RNS by the safety constraints.

2.1 SUMMARY OF RESULTS

Reliability analyses for the Class 1 Hybrid RNS and the Class 3 RNS were performed during the study period. The analyses are identical in many areas and thus both are presented together. The reliability allocations and predictions shown in this section are based on the active portions of a single

lunar shuttle mission, i.e., from startup in earth orbit (Phase F) to the completion of cooldown in lunar orbit (Phase M) and the startup in lunar orbit (Phase O) to the completion of cooldown in earth orbit (Phase V). The times in earth and lunar orbit are considered separately. The FMEA's presented in Section 2.3 are applicable to both concepts with the following exceptions: 15.06-04, Pre-Pressurization Quad Valve; 15.06-08, Ground Pressurization Valve; 15.06-10, Ground Pressurization Disconnect; 15.09-07, Ground Fill and Drain Valve; and 15.09-08, Ground Fill and Drain Disconnect are only applicable to the Class 1 Hybrid RNS and Item 15.05-05 Blocking Valve is only applicable to the Class 3 RNS.

The reliability allocations for the two concepts are given in Tables 2-1 and 2-2. The reliability predictions are given in two forms—with and without the inclusion of the external leakage failure mode. The leakage failure mode, while significant in terms of historical failure rate data, is more conducive to elimination or reduction by design techniques. The dominant leakage failure mode in the RNS designs (external leakage) can be reduced or eliminated by providing multiple static seals and/or welded connections. The reliability predictions without considering the external leakage are given in Tables 2-3 and 2-4 and are reported in the reliability diagrams in Section 2.5. The effect of external leakage, utilizing historical failure rate data and current designs (Saturn and Skylab), is shown in Tables 2-5 and 2-6. In all cases, a single mission reliability of 0.995 was used for NERVA. For other systems as noted, the allocations were used as the reliability predictions in this analysis.

The detail reliability predictions and criticalities (the definitions of these terms are given in Section 2.2) are presented in Sections 2.4 and 2.5) along with a ranking of the flight critical items. The flight critical item list is presented for the Class 1 Hybrid concept. The equivalent list for the Class 3 RNS would have several changes—Items 15.06-04, 15.06-08, and 15.09-07 would be eliminated and Item 15.05-05 would be added as Item Number 11 with a criticality of 815 units. The criticalities shown in Section 2.5 represent an RNS with one propellant module, one propulsion module, and

Table 2-1

RELIABILITY ALLOCATION—CLASS 1 HYBRID RNS

System	System Totals	C&C Module	Propellant Module	Propulsion Module
2.0 Structure	0.9987	0.9998	0.9992	0.9997
3.0 Meteoroid Protection	0.9975	0.9999	0.9978	0.9998
5.0 Main Propulsion	0.9893	-	0.9970	0.9923
5.01 NERVA	0.9950	-	-	0.9950
5.05 Propellant Feed	0.9981	-	0.9988	0.9993
5.06 Pressurization	0.9979	-	0.9988	0.9991
5.09 Fill	0.9991	-	0.9998	0.9992
5.10 Ground Vent	0.9998	-	0.9998	-
5.11 Flight Vent	0.9994	-	0.9997	0.9997
6.0 Auxiliary Propulsion	0.9970	0.9971	-	0.9999
7.0 Astrionics	0.9927	0.9934	0.9997	0.9996
7.01 Guid, Nav, and Control	0.9990	0.9992	0.9999	0.9999
7.04 Electrical Power	0.9967	0.9967	-	-
7.05 Electrical Networks	0.9985	0.9990	0.9998	0.9997
7.09 Data Management	0.9985	0.9985	-	-
8.0 Safety	0.9998	0.9999	0.99995	0.99995
Totals	0.9750	0.9901	0.99365	0.99125

Table 2-2

RELIABILITY ALLOCATION—CLASS 3 RNS

System	System Totals	C&C Module	Propellant Module	Propulsion Module
	(1-8-1)			
2.0 Structure	0.9987	0.99996	0.99986	0.99986
3.0 Meteoroid Protection	0.9975	0.9999	0.999725	0.9998
5.0 Main Propulsion	0.9848	- -	0.99891	0.99352
5.01 NERVA	0.9950	-	-	0.9950
5.05 Propellant Feed	0.99598	-	0.99956	0.9995
5.06 Pressurization	0.9955	-	0.9995	0.9995
5.09 Fill	0.9993	-	0.99996	0.99962
5.10 Ground Vent	0.99992	-	0.99999	-
5.11 Flight Vent	0.9991	-	0.9999	0.9999
6.0 Auxiliary Propulsion	0.9982	0.9983	-	0.9999
7.0 Astrionics	0.9960	0.9967	0.99993	0.99986
7.01 Guid, Nav, and Control	0.9992	0.9994	0.99998	0.99996
7.04 Electrical Power	0.9985	0.9985	-	-
7.05 Electrical Networks	0.9993	0.9998	0.99995	0.9999
7.09 Data Management	0.9990	0.9990	-	-
8.0 Safety	0.9998	0.9999	0.99999	0.99998
Totals 1-1-1	-	0.99476	0.998415	0.99292
1-8-1	0.9750	0.99476	0.98732	0.99292

Table 2-3

RELIABILITY PREDICTION—CLASS 1 RNS (WITHOUT LEAKAGE)

System	System Totals	C&C Module	Propellant Module	Propulsion Module
2.0 Structure*	0.9987	0.9998	0.9992	0.9997
3.0 Meteoroid Protection	0.9974	0.999999	0.9975	0.9999
5.0 Main Propulsion	0.9936	-	0.9999	0.9937
5.01 NERVA*	0.9950			0.9950
5.05 Propellant Feed	0.999998		0.999998	NSF
5.06 Pressurization	NSF**		NSF	NSF
5.09 Fill	0.99871		0.999994	0.99872
5.10 Ground Vent	0.99998		0.99998	--
5.11 Flight Vent	NSF		NSF	NSF
6.0 Auxiliary Propulsion	0.9721	0.9722	--	0.9999
7.0 Astrionics	0.9955	0.9962	0.9997	0.9996
7.01 Guid, Nav, and Control	0.9990	0.9992	0.9999	0.9999
7.04 Electrical Power	0.9995	0.9995	--	--
7.05 Electrical Networks*	0.9985	0.9990	0.9998	0.9997
7.09 Data Management*	0.9985	0.9985	--	--
8.0 Safety*	0.9998	0.9999	0.99995	0.99995
Totals	0.9576	0.9682	0.9963	0.9927

*The allocations were used as predictions for these systems

**No single failure

Table 2-4

RELIABILITY PREDICTION—CLASS 3 RNS (WITHOUT LEAKAGE)

System		System Totals	C&C Module	Propellant Module	Propulsion Module
		(1-8-1)			
2.0 Structure*		0.9987	0.99996	0.99986	0.99986
3.0 Meteoroid Protection		0.9950	0.999999	0.99939	0.9999
5.0 Main Propulsion		0.9895	-	0.9992	0.9937
5.01 NERVA*		0.9950		-	0.9950
5.05 Propellant		0.99587		0.99918	NSF
5.06 Pressurization		NSF		NSF	NSF
5.09 Fill		0.99872		NSF	0.99872
5.10 Ground Vent		0.99998		0.99998	-
5.11 Flight Vent		NSF**		NSF	NSF
6.0 Auxiliary Propulsion		0.9721	0.9722	-	0.9999
7.0 Astrionics		0.9970	0.9977	0.99993	0.99986
7.01 Guid, Nav, and Control		0.9992	0.9994	0.99998	0.99996
7.04 Electrical Power		0.9995	0.9995	-	-
7.05 Electrical Networks*		0.9993	0.9998	0.99995	0.9999
7.09 Data Management*		0.9990	0.9990	-	-
8.0 Safety*		0.9998	0.9999	0.99999	0.99998
Totals	1-1-1	-	0.9698	0.99837	0.9932
	1-8-1	0.9527	0.9698	-	0.9932

*The allocations were used as predictions for these systems
**No single failure

Table 2-5

RELIABILITY PREDICTION—CLASS 1 HYBRID RNS (WITH LEAKAGE)

System	System Totals	C&C Module	Propellant Module	Propulsion Module
2.0 Structure*	0.9987	0.9998	0.9992	0.9997
3.0 Meteoroid Protection	0.9974	0.999999	0.9975	0.9999
5.0 Main Propulsion	0.9854	-	0.9952	0.9902
5.01 NERVA*	0.9950		-	0.9950
5.05 Propellant Feed	0.99893		0.99988	0.99905
5.06 Pressurization	0.99583		0.99728	0.99855
5.09 Fill	0.99759		0.99914	0.99845
5.10 Ground Vent	0.99971		0.99971	-
5.11 Flight Vent	0.99834		0.99917	0.99917
6.0 Auxiliary Propulsion	0.9479	0.9480	-	0.9999
7.0 Astrionics	0.9955	0.9962	0.9997	0.9996
7.01 Guid, Nav, and Control	0.9990	0.9992	0.9999	0.9999
7.04 Electrical Power	0.9995	0.9995	-	-
7.05 Electrical Networks*	0.9985	0.9990	0.9998	0.9997
7.09 Data Management*	0.9985	0.9985	-	-
8.0 Safety*	0.9998	0.9999	0.99995	0.99995
Totals	0.9260	0.9441	0.9916	0.9893

*The allocations were used as predictions for these systems

Table 2-6

RELIABILITY PREDICTION—CLASS 3 RNS (WITH LEAKAGE)

System	System Totals	C&C Module	Propellant Module	Propulsion Module
	(1-8-1)			
2.0 Structure*	0.9987	0.99996	0.99986	0.99986
3.0 Meteoroid Protection	0.9950	0.999999	0.99939	0.9999
5.0 Main Propulsion	0.9758	-	0.9959	0.9902
5.01 NERVA*	0.9950		-	0.9950
5.05 Propellant Feed	0.99290		0.99907	0.99905
5.06 Pressurization	0.99470		0.99856	0.99855
5.09 Fill	0.99682		0.99939	0.99845
5.10 Ground Vent	0.99920		0.99971	-
5.11 Flight Vent	0.99696		0.99917	0.99917
6.0 Auxiliary Propulsion	0.9479	0.9480	-	0.9999
7.0 Astrionics	0.9970	0.9977	0.99993	0.99986
7.01 Guid, Nav, and Control	0.9992	0.9994	0.99998	0.99996
7.04 Electrical Power	0.9995	0.9995	-	-
7.05 Electrical Networks*	0.9993	0.9998	0.99995	0.9999
7.09 Data Management*	0.9990	0.9990	-	-
8.0 Safety*	0.9998	0.9999	0.99999	0.99998
Totals 1-1-1	-	0.9456	0.99507	0.9897
1-8-1	0.9160	0.9456	-	0.9897

*The allocations were used as predictions for these systems

one command and control module. Therefore, the criticalities shown are for the Class 1 Hybrid or the Class 3 Propulsion Module, Command and Control Module and one Propellant Module. The Class 3 RNS contains eight propellant modules and they are operative for different lengths of time and during different operational phases. These factors have been considered in applying the criticalities shown in Section 2.5 in calculating the reliability predictions in Tables 2-4 and 2-6.

The results indicate that the reliability goal of 0.975 for a single lunar shuttle mission is possible. If the external leakage problem is solved, the reliability predictions based on Saturn V failure rate data are 0.958 and 0.953 for the Class 1 Hybrid and the Class 3 RNS, respectively. An improvement of approximately 50 percent (a reduction of failure rate by a factor of two) can be expected for 1975 state of the art. This would give reliability predictions of 0.979 and 0.977 for the two concepts.

2.2 APPROACH

2.2.1 Ground Rules and Assumptions

The ground rules and assumptions used in these analyses are presented below. The methodology used in this analysis and summarized in Section 2.2.2 is in accordance with the requirements set forth in NASA MSFC Drawing No. 10M30111, Revision A, Procedure for Performing Systems Design Analysis.

The factors used in calculating the criticality of an item are based on similar Saturn S-IVB Stage and Skylab item values and engineering judgment.

This report gives an estimate on the probability of the RNS satisfactorily performing its function for a given time under a given environment. The reliability prediction analysis considers only the mission portion of the operation cycle—the period of time from the beginning of the translunar injection burn (Phase F) in earth orbit to the completion of the cooldown in lunar orbit injection burn (Phase M) and the time from the beginning of the first lunar burn (Phase O) to the completion of the cooldown of the

earth orbit injection burn (Phase V). The times in earth orbit (Phase W) and lunar orbit (Phase N) are considered and discussed in the failure mode effects analysis.

2.2.2 Methodology

2.2.2.1 Failure Mode Effects Analysis

The FMEA is a systematic study of the effects of an independent single item failure on subsystem, system, and RNS performance with the primary purpose of identifying potential problem areas. The general method used in preparing the FMEA is to select a block from the applicable reliability diagram and establish it as an "item" to be analyzed in detail. The four basic modes of failures considered during determination and evaluation of the effects of a given failure are:

A. Premature operation of an item.
B. Failure of an item to operate at prescribed time.
C. Failure of an item during operation.
D. Failure of an item to cease operation at a prescribed time.

Each block is evaluated for the failure modes that are applicable. Descriptions of failure types such as "Leakage at connections," "Output when not required," or "No output when required," may be used to cover the failure effect analysis of several failure modes.

Format

The FMEA is presented in a format arranged in columns and headings so the effect of a given failure can be studied by reading from left to right. For each item the applicable failure is indicated and the effect of this failure on the subsystem, RNS, and mission are identified.

Mission time periods are identified in the "Phase" column with capital letters F, G, H, I, J, K, etc. The first, or lefthand, letter indicates the phase in

which the failure occurs; the second letter indicates the phase in which the effect of the failure is being evaluated. For example, the letters "F" and "G" (FG) indicate consideration of the failure as having occurred in Phase "F" and the evaluation of the effect on the RNS and mission during Phase "G." If only one letter is used, it signifies the phase in which the failure occurs.

Evaluation of Effects

The entry which appears in the column concerning effects of the given failure conveys (1) a loss statement, and (2) the supporting words. The loss statement reflects the evaluation of the failure effect, and the supporting words provide the rationale for the statement. The effects of each single failure are classified into one of four groups as shown in the following table:

Effect of Single Item Failure	Probability of Loss (β)
Actual Loss	$\beta = 100\%$
Probable Loss	$10\% < \beta < 100\%$
Possible Loss	$0\% < \beta \leq 10\%$
None	$\beta = 0\%$

The word "None" as used above does not mean there is no effect. It means the probability of loss from the failure has been evaluated to be zero.

Calculating Procedure

Figure 2-1 illustrates the G-323 computer program calculating procedure for RNS loss probability of an item with respect to a designated failure mode over a number of mission phases. The procedure accounts for earlier phase failures contributing to RNS loss probability during the earlier phase and also to the RNS loss probability for later phases.

This accounting is accomplished through double subscripted β factors, β_{ij}. The "i" identified the phase when the failure is considered to have occurred, and the "j" identified the phase when the RNS loss is being considered.

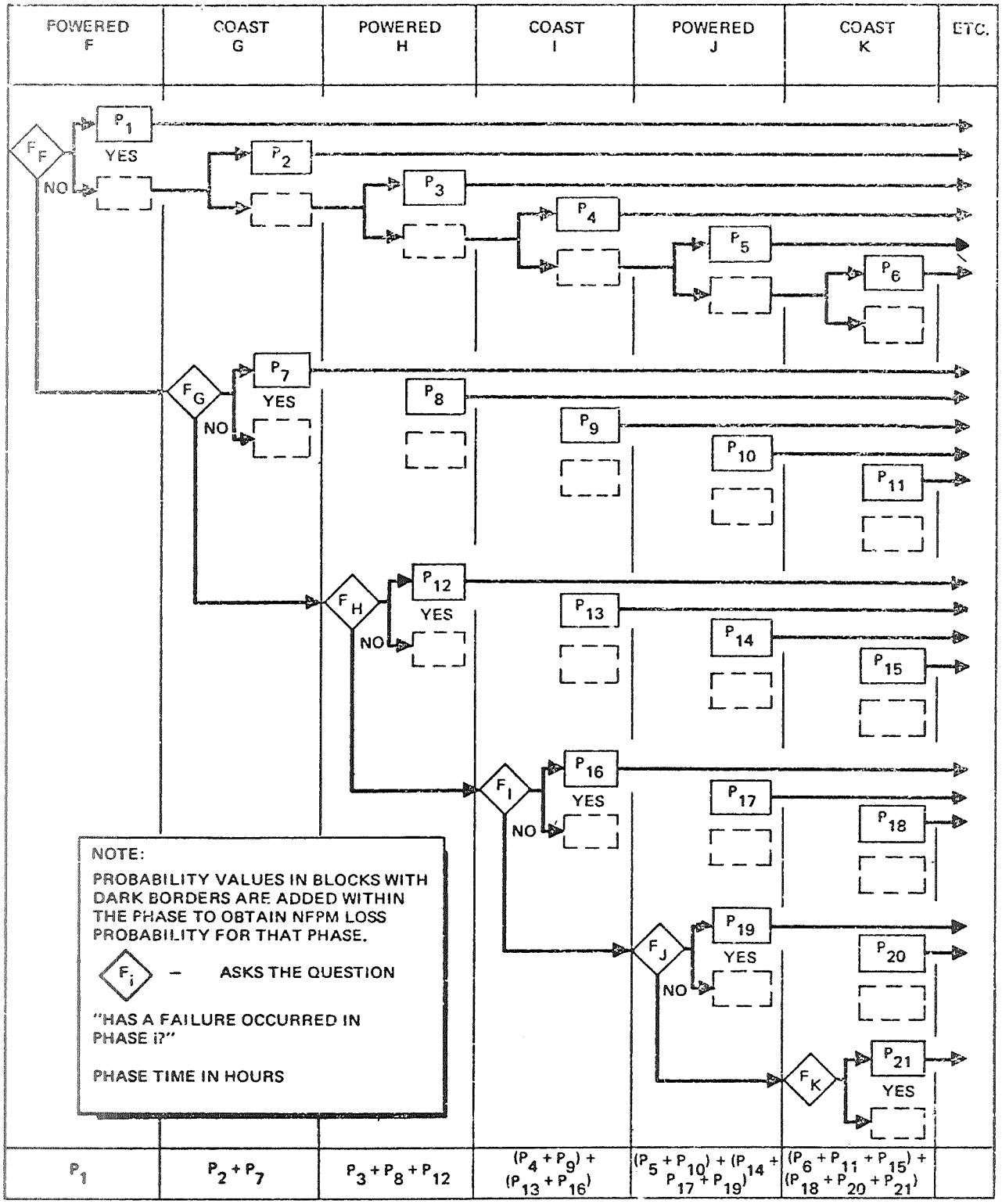


Figure 2-1 PROPAGATION OF LOSS PROBABILITIES

The $K_i t_i \alpha \lambda$ product approximates the failure probability of an item in a designated failure mode during the "ith" phase. This relationship is based on the exponential distribution and the approximation: probability of no failure = $e^{-K_i t_i \alpha \lambda} \simeq 1 - K_i t_i \alpha \lambda$ which applies when the failure probability $K_i t_i \alpha \lambda$ is small. A proportion of this failure probability equal to β_{ii} contributes directly to RNS loss probability during the "ith" phase when failure occurs and a remaining proportion $(1-\beta_{ii})$ is carried over to the next phase. If RNS loss does not occur in the next phase as a result of the "ith" phase failure, a proportion of the yet remaining failure probability equal to $(1-\beta_{ii})(1-\beta_{i,\,i+1})$ is carried over to the next succeeding phase. This process continues in a step wise manner to the last mission phase. The formula for RNS loss probability associated with phase F, G, H, I, J, etc., developed for a single failure mode, can be written for any general phase P as follows:

$$U_p = \sum_{\substack{i = \text{initial} \\ \text{mission} \\ \text{phase}}}^{P-1} \left[\beta_{ip} \left(\prod_{j=1}^{P-1} (1 - \beta_{ij}) \right) K_i t_i \alpha \lambda \right] + \beta_{pp} K_p t_p \alpha \lambda$$

To obtain total RNS loss probability for an item during a phase, a summation over all failure modes is performed. This RNS loss probability for the item is then given as follows:

$$\text{RNS Loss Probability}_{(\text{Item considered})} = \sum_{\substack{\text{All Mission} \\ \text{Phases}}} \; \sum_{\substack{\text{Failure} \\ \text{Modes}}} U_p$$

Ranking

Ranking provides a convenient comparison of all FCI as to their respective contribution toward RNS loss. In this comparison it is more important to treat the criticality number as an index of relative importance rather than an actual quantitative value. With the identity and relative importance of the items in the foreground, the criticality ranking can be used as an aid in determining where to concentrate efforts toward reduction of RNS loss probability.

Because ranking is based on a single-failure effect analysis it should not be used as the sole guide for design improvement efforts. There may be parts designed into the RNS with redundancy and these parts, because of embryonic

design or newness of the state-of-the-art, have a probability of multiple failures as high as the probability of single failure of an FCI. These redundant parts do not appear on the single-failure FCI list.

2.2.3 Glossary of Terms and Symbols

Definition of terms and symbols used in the FMEA are listed below.

Conditional Probability of RNS Loss (β)—The conditional probability of RNS loss given that a failure in the designated failure mode has occurred.

Criticality—That portion of unreliability, associated with failure of a flight critical item, leading to RNS loss.

Criticality Number—The RNS loss rate resulting from the failure susceptibility of an item expressed as the number of RNS losses per million missions.

Criticality Ranking—The ranking of items in decreasing order of the item criticality number.

Environmental Adjustment Factor (k)—A factor by which a given generic failure rate is multiplied to obtain a resulting rate which reflects the mission phase environment.

Failure—A cessation of ability to perform a specified function or functions within previously established limits on the area of interest. This requires that measurable limits be established to define satisfactory performance of the function.

Failure Mode—One of four classes or groups into which the failure of items may be divided for analytical purposes. These four failure modes are: (1) premature operation of an item, (2) failure of an item to operate at prescribed times, (3) failure of an item during operation, and (4) failure of an item to cease operation at a prescribed time.

Failure Mode Frequency Factor (α)—The expected proportion of the total failures of an item chargeable to the designated failure mode.

Failure Probability—Probability that an item will not operate as required for a specified mission time and mission operating environment; the inherent item unreliability for the mission intended.

Failure Type—A general class or group into which the failures of some items may be divided for analytical purposes.

Flight Critical Item (FCI)—A flight critical item describes the functional element for which the portion of unreliability associated with loss of the RNS during the mission can be traced to either:

1. The failure of a single identifiable piece of hardware, such as a relay or valve.
2. The failure in the functioning of a group of components and parts, such as subsystem wiring or piping.

Generic Failure Rate (λ)—Number of failures chargeable to the inherent unreliability per unit-time, cycles, or trials, under laboratory conditions (unstressed-room ambient).

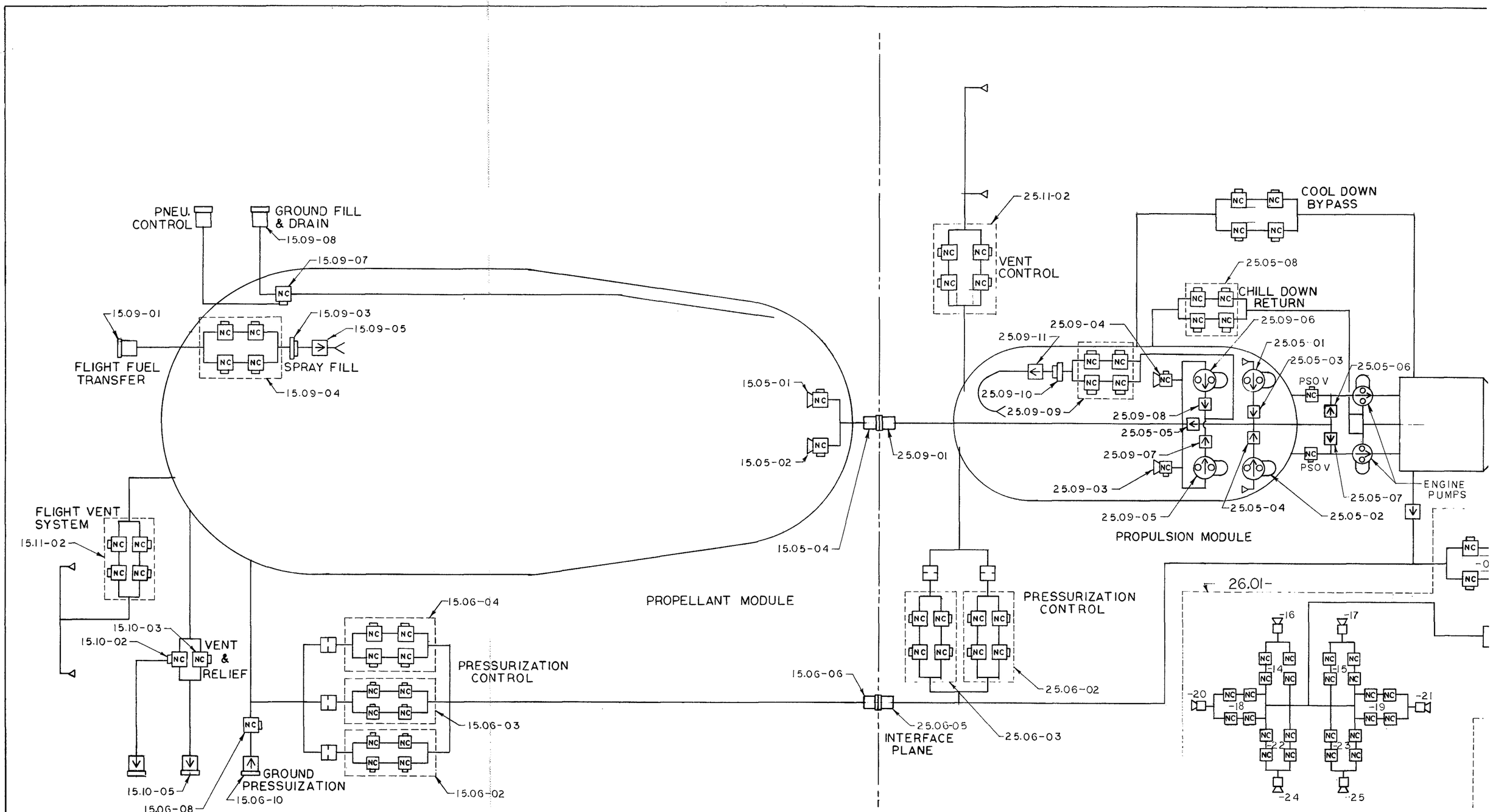
Redundancy—The existence of more than one means of accomplishing a given task, where all of these means must fail before there is an overall failure of the system.

Reliability—The probability of an item performing its function for the time required under the environment specified (see also RNS Reliability).

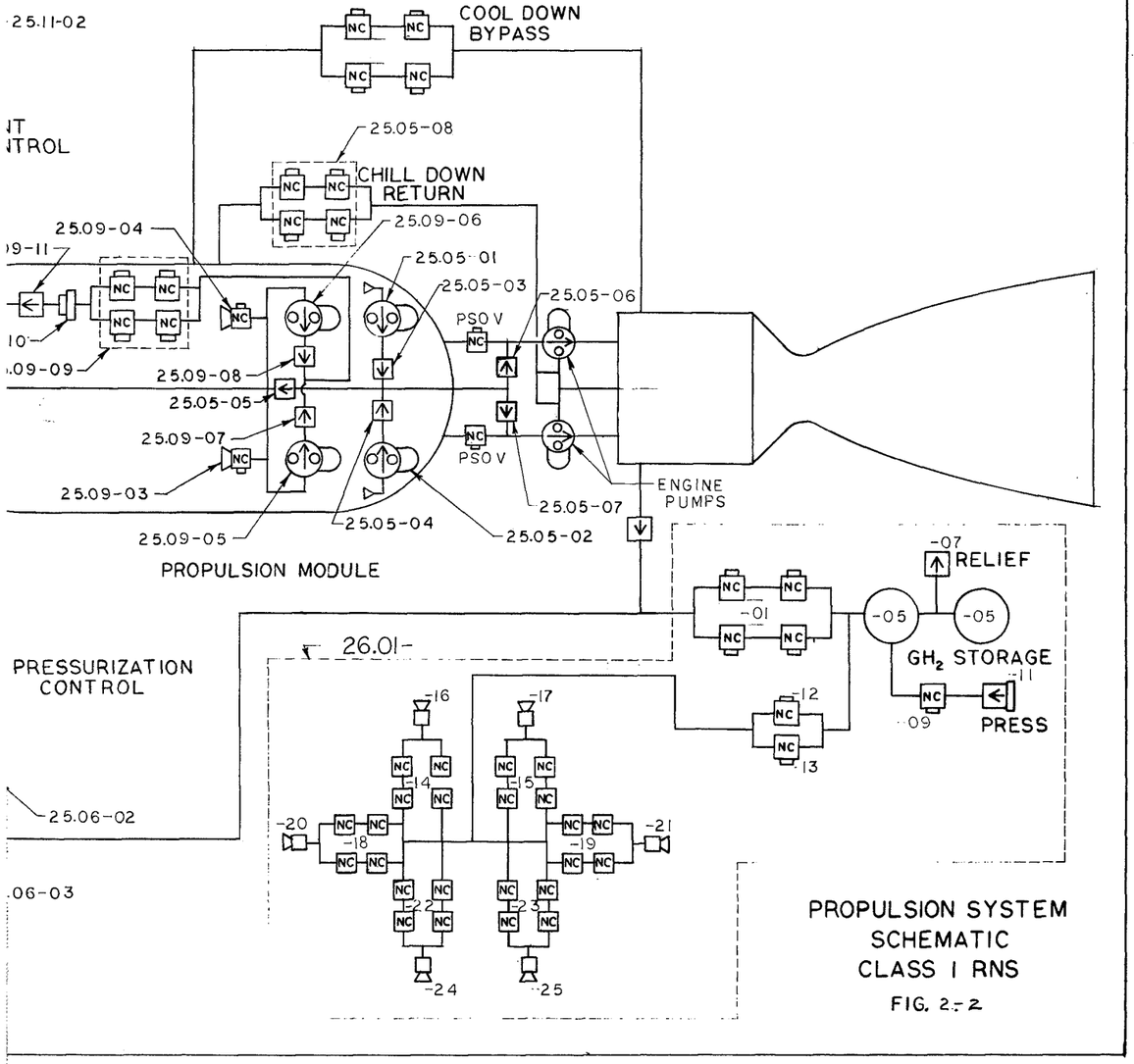
RNS Reliability—Probability that RNS loss will not occur.

2.3 FAILURE MODE EFFECTS ANALYSIS

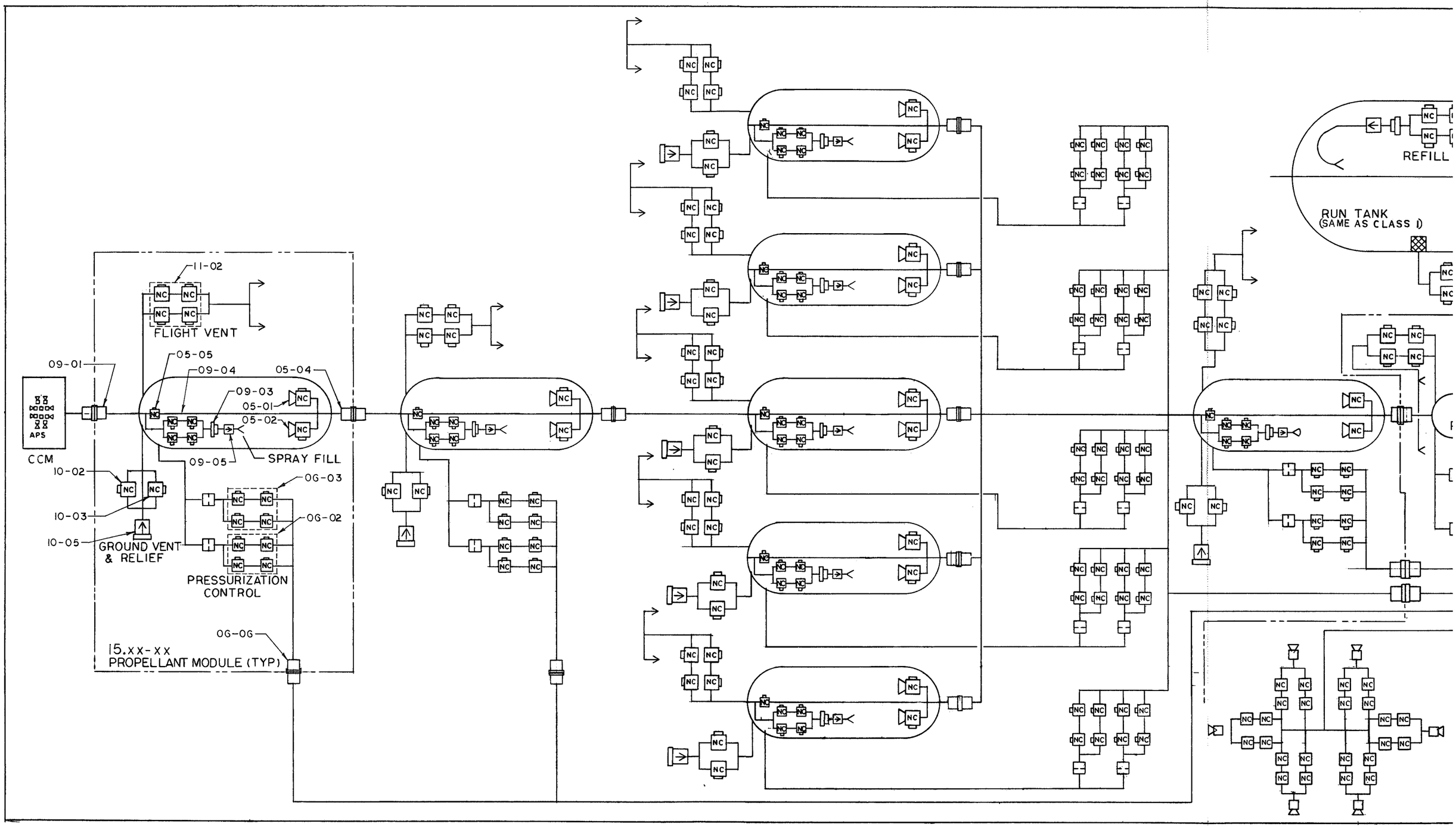
This section contains the individual FMEA work sheets. The systems analyzed are shown in Figures 2-2, 2-3 and 2-4. Figure 2-2 is the Class 1 Hybrid propulsion system, Figure 2-3 is the Class 3 propulsion system and Figure 2-4 is the auxiliary propulsion system which is common to both concepts. These system schematics reflect the current design definition.


PNEU. CONTROL
GROUND FILL & DRAIN
15.09-08
15.09-07
15.09-01
15.09-03
15.09-05
FLIGHT FUEL TRANSFER
SPRAY FILL
15.09-04
FLIGHT VENT SYSTEM
15.11-02
15.10-03
15.10-02
VENT & RELIEF
15.10-05
15.06-08
GROUND PRESSUIZATION
15.06-10
15.06-04
PRESSURIZATION CONTROL
15.06-03
15.06-02
PROPELLANT MODULE
15.05-01
15.05-02
15.05-04
25.09-01
25.11-02
VENT CONTROL
COOL DOWN BYPASS
25.05-08
CHILL DOWN RETURN
25.09-04
25.09-11
25.09-10
25.09-09
25.05-01
25.05-03
25.05-06
PSO V
25.09-08
25.05-05
25.09-07
25.09-03
25.09-05
25.05-04
25.05-02
25.05-07
ENGINE PUMPS
PROPULSION MODULE
26.01
PRESSURIZATION CONTROL
25.06-02
15.06-06
25.06-05
INTERFACE PLANE
25.06-03
-16
-17
-14
-15
-20
-18
-19
-21
-22
-23
-24
-25

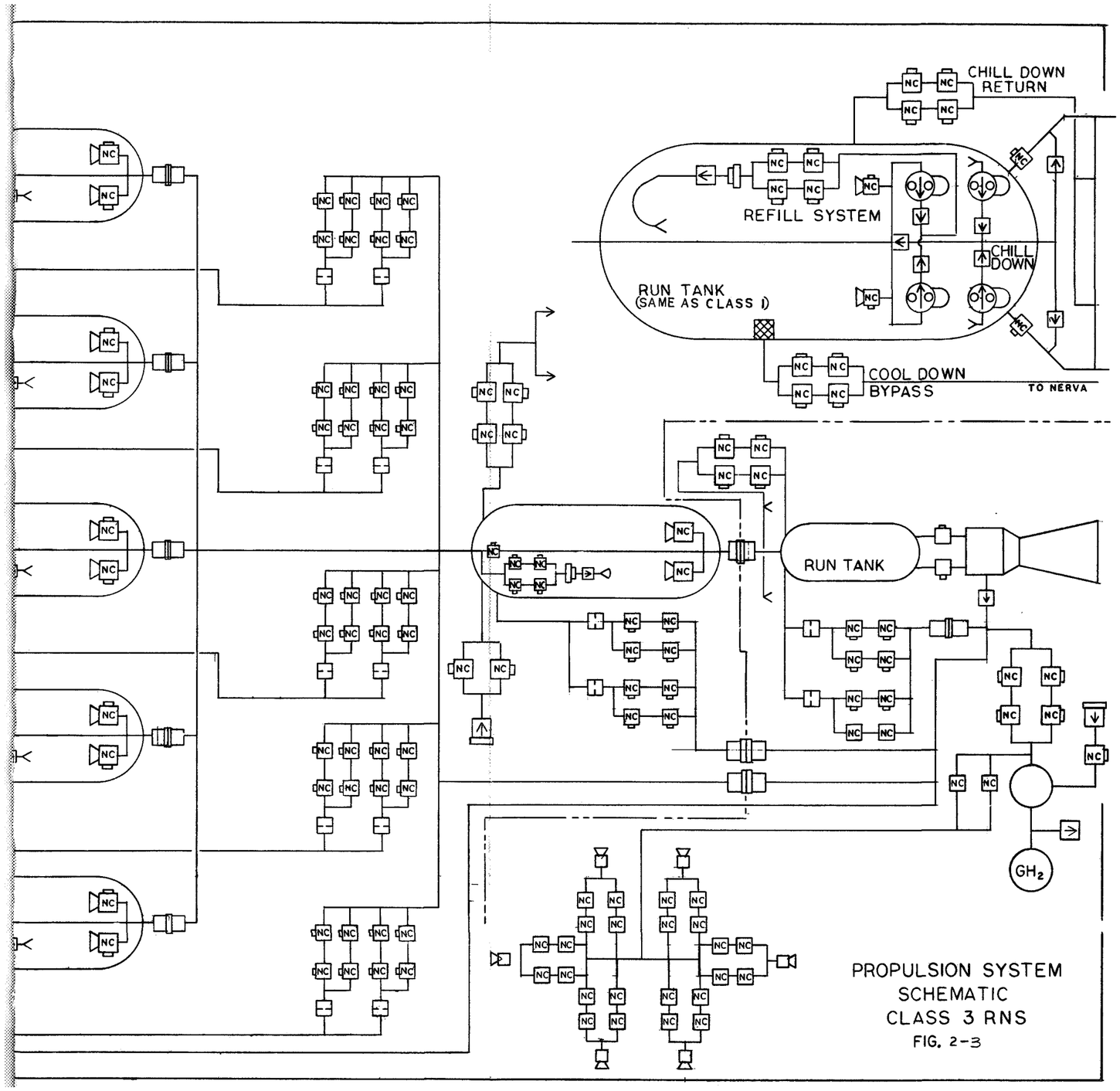
FOLD-OUT #1


25.11-02
COOL DOWN
BYPASS
NT
NTROL
25.05-08
CHILL DOWN
RETURN
25.09-04
25.09-06
25.05-01
25.05-03
25.05-06
PSOV
25.09-08
25.05-05
25.09-07
PSOV
25.09-03
ENGINE
PUMPS
25.05-07
25.09-05
25.05-04
25.05-02
PROPULSION MODULE
-07
RELIEF
-05
-05
GH2 STORAGE
-11
PRESS
-09
26.01-
PRESSURIZATION
CONTROL
-16
-17
-12
-13
-14
-15
-20
-18
-19
-21
-22
-23
-24
-25
25.06-02
06-03
PROPULSION SYSTEM
SCHEMATIC
CLASS I RNS
FIG. 2-2

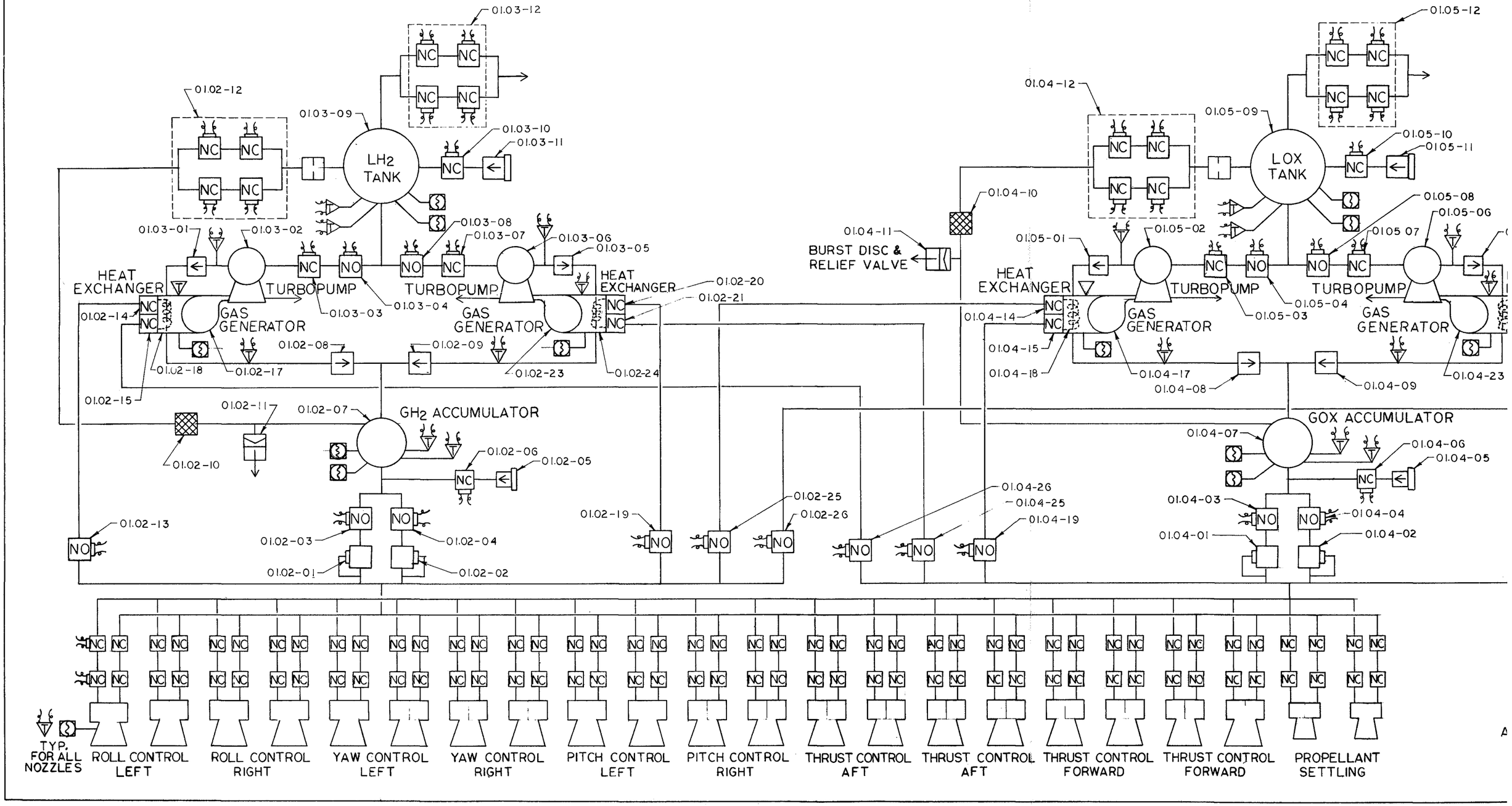
FOLD-OUT #2


11-02
FLIGHT VENT
09-01
05-05
09-04
05-04
09-03
05-01
05-02
09-05
SPRAY FILL
CCM
APS
10-02
10-03
10-05
GROUND VENT
& RELIEF
06-03
06-02
PRESSURIZATION
CONTROL
06-06
15.xx-xx
PROPELLANT MODULE (TYP)
REFILL
RUN TANK
(SAME AS CLASS I)

FOLD-OUT #1

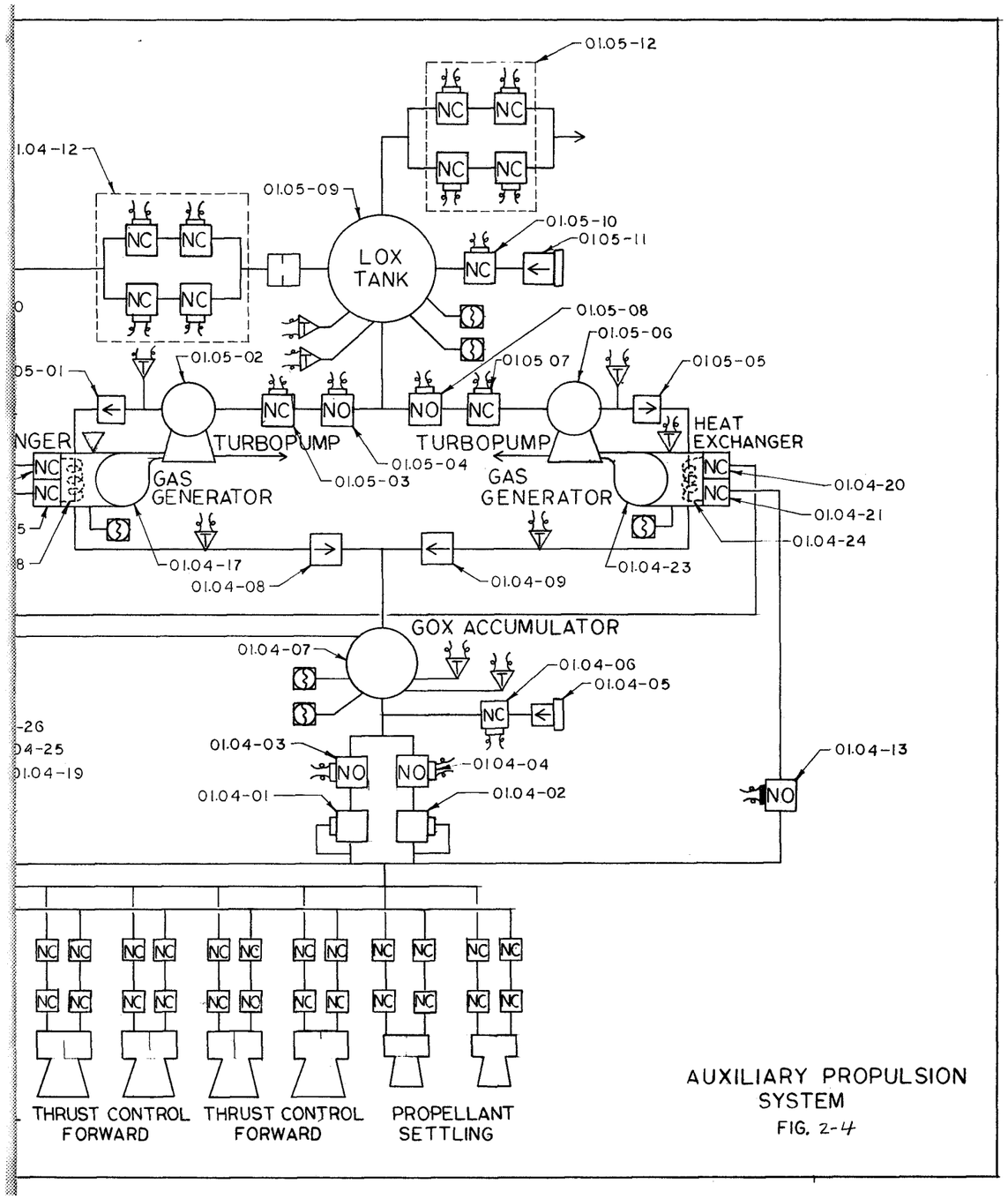

CHILL DOWN RETURN
REFILL SYSTEM
CHILL DOWN
RUN TANK (SAME AS CLASS I)
COOL DOWN BYPASS
TO NERVA
RUN TANK
GH_2
PROPULSION SYSTEM SCHEMATIC CLASS 3 RNS
FIG. 2-3

FOLD-OUT #2



FOLD-OUT #1

FOLD-O


01.05-12
NC
NC
NC
NC
1.04-12
NC
NC
NC
NC
01.05-09
LOX
TANK
01.05-10
0105-11
NC
0
01.05-08
01.05-06
01.05-02
0105 07
0105-05
05-01
NC
NO
NO
NC
NGER
TURBOPUMP
TURBOPUMP
HEAT
EXCHANGER
NC
NC
GAS
GENERATOR
GAS
GENERATOR
NC
NC
01.05-04
01.05-03
01.04-20
01.04-21
01.04-24
5
8
01.04-17
01.04-08
01.04-09
01.04-23
GOX ACCUMULATOR
01.04-07
01.04-06
01.04-05
NC
-26
04-25
01.04-19
01.04-03
NO
NO
-0104-04
01.04-01
01.04-02
01.04-13
NO
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
NC
THRUST CONTROL
FORWARD
THRUST CONTROL
FORWARD
PROPELLANT
SETTLING
AUXILIARY PROPULSION
SYSTEM
FIG. 2-4

FOLD-OUT #2

These systems and the astrionics system are described in Volume II, Parts A and B. All of the FMEA are applicable to both concepts except items:

15.06.04 Prepressurization Valve (Quad)
15.06.08 Ground Pressurization Valve
15.06.10 Ground Pressurization Disconnect
15.09.07 Ground Fill and Drain Valve
15.09.08 Ground Fill and Drain Disconnect

The numbering system used in this analysis and the test requirements task follows the numbering system set up for the weight reporting in the Guidelines and Constraints Document, except an additional number was added—the first digit refers to the module which contains the component. The number 1 was used for the propellant module, 2 is used for propulsion module components, and the prefix 3 is used for the command and control module. Thus, component 15.05.04 is on the propellant module (1), is part of the propulsion system (5), is part of the pressurization subsystem (05), and is the fourth component analyzed (04).

This numbering system applies to both concepts and is graphically illustrated in the reliability diagrams in Section 2.5 along with the reliability allocation and prediction for each subsystem, system, module and the complete RNS. The FMEA sheets are placed in the numerical order of the components analyzed.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FEED, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.05-01,-02 ISOLATION VALVES, LH_2	PROVIDE SHUTOFF CAPABILITY BETWEEN PROPELLANT MODULE AND LH_2 TRANSFER LINE TO PROPULSION MODULE. CLOSED DURING PROPELLANT MODULE FILL AND FEED SYSTEM CHILL-DOWN OPERATIONS. OPEN DURING MISSION POWER PHASES.	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN	NONE THE ISOLATION VALVES ARE PARALLEL TO EACH OTHER AND IN SERIES TO THE -03 TRANSFER LINE.			NONE	NONE
		3. FAILURE TO CLOSE	ACTUAL LOSS EARTH ORBIT PROPELLANT MODULE FILL OPERATIONS COULD NOT BE PERFORMED.	W	W	ACTUAL LOSS LOSS OF PROPELLANT MODULE FILL CAPABILITY DURING EARTH ORBIT (PHASE W). FAILURE MODE DOES NOT APPLY DURING OTHER FLIGHT PHASES.	ACTUAL LOSS RNS NOT AVAILABLE FOR MISSION
		4. FAILURE TO REMAIN CLOSED	PROBABLE LOSS EARTH ORBIT PROPELLANT MODULE FILL OPERATION COULD NOT BE COMPLETED. CONTINUOUS LH_2 BOILOFF IN TRANSFER LINE (-03) DURING LONG MISSION COAST TIMES COULD DEPLETE LH_2 SUPPLY BELOW MINIMUM MISSION REQUIREMENTS.	W	W	PROBABLE LOSS EARTH ORBIT PROPELLANT MODULE FILL OPERATION MAY NOT BE COMPLETED	PROBABLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION
				G I K M P R T	H I J K L M O P Q R S T U V	PROBABLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING DURING COAST PERIODS COULD RESULT IN ENGINE DESTRUCTION	PROBABLE LOSS
		5. LEAKAGE	POSSIBLE LOSS SAME EFFECT AS "FAILURE TO REMAIN CLOSED" MODE	W	W	POSSIBLE LOSS EARTH ORBIT PROPELLANT MODULE FILL MAY NOT BE POSSIBLE.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FEED, LH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.05-01,-02 ISOLATION VALVES LH_2 (CONTINUED)				G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING DURING COAST PERIODS MAY RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FEED, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.05-03 DUCTING, LH_2 TRANSFER	TRANSFER LH_2 FROM PROPELLANT MODULE ISOLATION VALVES (-01,-02) TO RNS PROPULSION MODULE	1. LEAKAGE	POSSIBLE LOSS LOSS OF LH_2 DURING TRANSFER MODE (ALL POWER PHASES) COULD DEPLETE LH_2 SUPPLY BELOW MINIMUM MISSION REQUIREMENTS. EARTH ORBIT RNS REFILL OPERATION MAY NOT BE POSSIBLE	F H J L O Q S U	G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING DURING COAST PERIODS COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W	W	POSSIBLE LOSS INABILITY TO COMPLETE RNS LH_2 FILL OPERATION	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FEED, LH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.05-04 DISCONNECT, LH_2 TRANSFER TO PROPULSION MODULE	MATES WITH 25.09-01 DISCONNECT OF PROPULSION MODULE TO PROVIDE CONNECTION FOR LH_2 TRANSFER FROM PROPELLANT MODULE.	1. LEAKAGE	POSSIBLE LOSS SAME EFFECT AS "LEAKAGE" OF -03 TRANSFER LINE.	F G H I J K L M O P Q R S T U V W W	POSSIBLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING DURING COAST PERIODS COULD RESULT IN ENGINE DESTRUCTION. POSSIBLE LOSS INABILITY TO COMPLETE RNS LH_2 FILL OPERATION	POSSIBLE LOSS POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PRESSURIZATION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.06-01,-05,-09 DUCTING, PRESSURIZATION CONTROL, GH_2	PROVIDE FLOW PATH FOR PRESSURANT GAS FROM PROPULSION MODULE PRESS. SYSTEM TO RNS PROPELLANT MODULE ULLAGE	1. LEAKAGE	POSSIBLE LOSS ABILITY TO CONTROL ULLAGE PRESSURE MAY BE LOST, RESULTING IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE. LOSS OF SUFFICIENT LH_2 COULD CAUSE INABILITY TO PERFORM ENGINE COOLDOWN.	F G H I J K M O P Q R S T U V	F G H I J K M O P Q R S T U V	POSSIBLE LOSS LOSS OF THRUST DURING POWER PHASES. NERVA PUMP FAILURE COULD CAUSE STRUCTURAL DAMAGE TO STAGE. INABILITY TO PERFORM ADEQUATE PULSED AFTERCOOLING DURING COAST PHASES COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W	W	POSSIBLE LOSS INABILITY TO MAINTAIN LH_2 IN PROPELLANT MODULE.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PRESSURIZATION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.06-02 QUAD VALVES (1 set), EXPULSION, GH_2	CONTROL FLOW OF GH_2 TO PROPELLANT MODULE FROM NERVA ENGINE VIA PROPULSION MODULE PRESS DUCTING (25.06-04) DURING POWER PHASES.	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN. 3. FAILURE TO CLOSE 4. FAILURE TO REMAIN CLOSED	NONE THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER		NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS ABILITY TO CONTROL ULLAGE PRESSURE MAY BE LOST, RESULTING IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE. LOSS OF SUFFICIENT LH_2 COULD CAUSE INABILITY TO PERFORM ENGINE COOLDOWN	F F G G H H I I J J K K L L M M O O P P Q Q R R S S T T U U V V	POSSIBLE LOSS THRUST CAPABILITY MAY BE LOST. INABILITY TO PERFORM ADEQUATE PULSED AFTERCOOLING DURING COAST PHASES COULD RESULT IN ENGINE DESTRUCTION	POSSIBLE LOSS
				W W	POSSIBLE LOSS INABILITY TO MAINTAIN LH_2 IN PROPELLANT MODULE	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PRESSURIZATION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.06-03 QUAD VALVES (1 set), GH_2 CONTROL	CONTROL FLOW OF GH_2 TO PROPELLANT MODULE FROM NERVA ENGINE VIA PROPULSION MODULE PRESS DUCTING (25.06-04) DURING POWER PHASES.	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE 4. FAILURE TO REMAIN CLOSED	NONE THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER			NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS ABILITY TO CONTROL ULLAGE PRESSURE MAY BE LOST, RESULTING IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE. LOSS OF SUFFICIENT LH_2 COULD CAUSE INABILITY TO PERFORM ENGINE COOLDOWN	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS THRUST CAPABILITY MAY BE LOST. INABILITY TO PERFORM ADEQUATE PULSED AFTERCOOLING DURING COAST PHASES COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W	W	POSSIBLE LOSS INABILITY TO MAINTAIN LH_2 IN PROPELLANT MODULE.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PRESSURIZATION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.06-04 QUAD VALVES (1 set), PREPRESS, GH_2	CONTROL FLOW OF GH_2 TO PROPELLANT MODULE FROM NERVA ENGINE VIA PROPULSION MODULE PRESS DUCTING (25.06-04) DURING PREPRESSURIZATION OF PROPELLANT MODULE.	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE 4. FAILURE TO REMAIN CLOSED.	NONE THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER		NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS ABILITY TO CONTROL ULLAGE PRESSURE MAY BE LOST, RESULTING IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE. LOSS OF SUFFICIENT LH_2 COULD CAUSE INABILITY TO PERFORM ENGINE COOLDOWN.	F F G G H H I I J J K K L L M M O O P P Q Q R R S S T T U U V V	POSSIBLE LOSS THRUST CAPABILITY MAY BE LOST. INABILITY TO PERFORM ADEQUATE PULSED AFTERCOOLING DURING COAST PHASES COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W W	POSSIBLE LOSS INABILITY TO MAINTAIN LH_2 IN PROPELLANT MODULE	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PRESSURIZATION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.06-06 DISCONNECT, PRESSURIZATION CONTROL, GH_2	CONNECT PROPELLANT (15.06) AND PROPULSION (25.06) MODULE PRESSURIZATION SYSTEMS. PROPELLANT MODULE HALF OF DISCONNECT AT END OF 15.06-05 DUCTING.	1. LEAKAGE	POSSIBLE LOSS ABILITY TO CONTROL ULLAGE PRESSURE MAY BE LOST, RESULTING IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE.	F H J L O Q S U	F H J L O Q S U	POSSIBLE LOSS THRUST CAPABILITY MAY BE LOST	POSSIBLE LOSS
				W	W	NONE DISCONNECT LEAKAGE HAS NO EFFECT DURING EARTH ORBIT OPERATIONS	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PRESSURIZATION

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.06-07 PRESSURE SWITCHES (1 set), LH_2 FLOW CONTROL	SENSE ULLAGE PRESSURE IN PROPELLANT MODULE AND SEND COMMAND SIGNALS THAT ENERGIZE GH_2 CONTROL VALVES (-02,-03) DURING POWER PHASES.	1. OUTPUT WHEN NOT REQUIRED 2. NO OUTPUT WHEN REQUIRED	NONE REDUNDANCY IS PROVIDED		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PRESSURIZATION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.06-08 GROUND FILL VALVE, GH_2 (PRESSURIZATION)	PROVIDE SHUTOFF VALVE BETWEEN RNS PROPELLANT MODULE ULLAGE AND GROUND FILL DISCONNECT. VALVE IS ENERGIZED ONLY DURING GH_2 GROUND FILL OPERATIONS.	1. FAILURE TO OPEN. 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE	ACTUAL LOSS TRANSFER OF GH_2 TO RNS PRESS SYSTEM CANNOT TAKE PLACE (OR BE COMPLETED) DURING GROUND LOADING OPERATIONS.			NONE FAILURE MODES DO NOT APPLY DURING FLIGHT PHASES.	NONE
		4. FAILURE TO REMAIN CLOSED	NONE REDUNDANCY IS PROVIDED BY THE -09 CHECK DISCONNECT.			NONE FAILURE MODE DOES NOT APPLY.	NONE
		5. LEAKAGE	POSSIBLE LOSS ABILITY TO CONTROL ULLAGE PRESSURE MAY BE LOST, RESULTING IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE. LOSS OF SUFFICIENT LH_2 COULD CAUSE INABILITY TO PERFORM ENGINE COOLDOWN	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS CAVITATION OF NERVA PUMP IN POWER PHASES COULD LEAD TO RNS STRUCTURAL DAMAGE. INADEQUATE PULSED AFTERCOOLING DURING COAST PHASES COULD LEAD TO ENGINE DESTRUCTION.	POSSIBLE LOSS
				W	W	POSSIBLE LOSS PROPELLANT REFILL OPERATIONS COULD NOT BE COMPLETED.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PRESSURIZATION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.06-10 GROUND FILL CHECK DISCONNECT, GH_2 (PRESSURIZATION)	CONNECT GH_2 GROUND SUPPLY TO RNS PROPELLANT MODULE PRESSURIZATION SYSTEM	1. LEAKAGE	NONE DISCONNECT IS IN SERIES WITH -07 GROUND FILL VALVE		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FILL, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.09-01 DISCONNECT, LH_2 TRANSFER MODULE, IN-ORBIT	PROVIDE CONNECTION TO EXOGENOUS SOURCE TO REPLENISH LH_2 PROPELLANT MODULE SUPPLY.	1. LEAKAGE	POSSIBLE LOSS EARTH ORBIT REFILL OPERATION MAY NOT BE POSSIBLE. FAILURE MODE HAS NO EFFECT IN OTHER MISSION PHASES.	W	W	POSSIBLE LOSS INABILITY TO COMPLETE PROPELLANT MODULE REFILL OPERATION.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FILL, LH_2

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.09-02 DUCTING, LH_2 FILL, IN-ORBIT	PROVIDE PATH FOR LH_2 REPLENISHMENT FROM -01 DISCONNECT TO PROPELLANT MODULE	1. LEAKAGE	POSSIBLE LOSS EARTH ORBIT REFILL OPERATION MAY NOT BE POSSIBLE. FAILURE MODE WILL HAVE NO EFFECT IN OTHER MISSION PHASES.	W	W	POSSIBLE LOSS INABILITY TO COMPLETE PROPELLANT MODULE REFILL OPERATION	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FILL, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.09-03 FLOW METER, LH_2, PROPELLANT FILL	SENSE LH_2 FLOW RATE DURING PROPELLANT RESUPPLY	1. CLOGGED	1. ACTUAL LOSS RESUPPLY OF PROPELLANT MODULE WOULD NOT BE POSSIBLE	W	W	ACTUAL LOSS LOSS OF PROPELLANT MODULE RESUPPLY CAPABILITY	ACTUAL LOSS RNS NOT AVAILABLE FOR MISSION.

FORM 630-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FILL, LH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.09-04 QUAD VALVES (1 set), LH_2 PROPELLANT FILL	FILL TRANSFER VALVES BETWEEN PROPELLANT MODULE AND LH_2 IN-ORBIT SUPPLY SOURCE	1. FAILURE TO OPEN 2. FAILURE TO CLOSE	NONE THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER.		NONE REDUNDANCY IS PROVIDED	NONE
		3. LEAKAGE	POSSIBLE LOSS ABILITY TO CONTROL ULLAGE PRESSURE MAY BE LOST, RESULTING IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE. LOSS OF SUFFICIENT LH_2 COULD CAUSE INABILITY TO PERFORM ENGINE COOLDOWN.	F G G H H I I J J K K L L M M O O P P Q Q R R S S T T U U V V V	POSSIBLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING COULD RESULT IN ENGINE DESTRUCTION DURING COAST PERIODS.	POSSIBLE LOSS
				W W	POSSIBLE LOSS INABILITY TO COMPLETE LH_2 RESUPPLY	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FILL, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.09-05 CHECK VALVE, LH_2, RESUPPLY	PROVIDE UNDIRECTIONAL FLOW DURING PROPELLANT RESUPPLY	1. FAILURE TO OPEN	ACTUAL LOSS RESUPPLY OF PROPELLANT MODULE WOULD NOT BE POSSIBLE	W	W	ACTUAL LOSS LOSS OF PROPELLANT MODULE RESUPPLY CAPABILITY	ACTUAL LOSS RNS NOT AVAILABLE FOR MISSION
		2. FAILURE TO CLOSE 3. LEAKAGE	NONE - CHECK VALVE IS IN SERIES WITH -04 QUAD VALVE SET			NONE - REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FILL, LH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
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T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.09-06 SPRAY NOZZLE, LH_2 FILL	TRANSFORM LH_2 INTO FINE MIST SPRAY DURING PROPELLANT MODULE RESUPPLY IN EARTH ORBIT (MISSION PHASE W)	1. CLOGGED	ACTUAL LOSS ABILITY TO RESUPPLY PROPELLANT MODULE MAY BE LOST	W	W	ACTUAL LOSS INABILITY TO PERFORM LH_2 RESUPPLY	ACTUAL LOSS RNS NOT AVAILABLE FOR MISSION

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FILL, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.09-07 GROUND FILL VALVE, LH_2	PROVIDE SHUTOFF VALVE BETWEEN PROPELLANT MODULE AND LH_2 GROUND SUPPLY SOURCE	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE	ACTUAL LOSS PROPELLANT MODULE GROUND FILL OPERATION CANNOT BE PERFORMED			NONE FAILURES DO NOT APPLY DURING FLIGHT PHASES AS MODULE IS SERVICED VIA -03 FILL VALVE IN EARTH ORBIT	NONE
		4. FAILURE TO REMAIN CLOSED	PROBABLE LOSS ABILITY TO CONTROL ULLAGE PRESSURE MAY BE LOST, RESULTING IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE. LOSS OF SUFFICIENT LH_2 COULD CAUSE INABILITY TO PERFORM ENGINE COOLDOWN. LH_2 RESUPPLY IN EARTH ORBIT MAY NOT BE COMPLETED	F G H I J K L M O P Q R S T U V	G H I J K L M O P Q R S T U V V	PROBABLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING COULD RESULT IN ENGINE DESTRUCTION DURING COAST PHASES.	PROBABLE LOSS
				W	W	PROBABLE LOSS INABILITY TO COMPLETE LH_2 RESUPPLY	PROBABLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FILL, LH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
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T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.09-07 GROUND FILL VALVE, LH_2 (CONTINUED)		5. LEAKAGE	POSSIBLE LOSS SAME EFFECT AS "FAILURE TO REMAIN CLOSED" MODE.	F G H I J K L M O P Q R S T U V	G H I J K L M O P Q R S T U V V	POSSIBLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING DURING COAST PHASES COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W	W	POSSIBLE LOSS INABILITY TO COMPLETE LH_2 RESUPPLY	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: PROPELLANT FILL, LH_2

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.09-08 DISCONNECT, GROUND FILL, LH_2	PROVIDE CONNECTION TO LH_2 GROUND SUPPLY DURING MODULE GROUND LOADING OPERATIONS.	1. LEAKAGE	POSSIBLE LOSS DELAY IN MODULE GROUND FILL OPERATIONS		NONE THE DISCONNECT IS IN SERIES TO THE -06 GROUND FILL VALVE	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: VENT AND RELIEF, GH_2

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING.
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.10-01 DUCTING, VENT & RELIEF, GH_2	PROVIDE GH_2 FLOW PATH DURING PROPELLANT MODULE VENT AND RELIEF OPERATIONS	1. LEAKAGE	POSSIBLE LOSS ABILITY TO CONTROL ULLAGE PRESSURE MAY BE LOST, RESULTING IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE. LOSS OF SUFFICIENT LH_2 COULD CAUSE INABILITY TO PERFORM ENGINE COOLDOWN. EXCESSIVE LEAKAGE COULD PRECLUDE COMPLETION OF IN-ORBIT LH_2 RESUPPLY.	F G H I J K L M O P Q R S T U V	G H I J K L M O P Q R S T U V V	POSSIBLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W	W	POSSIBLE LOSS INABILITY TO COMPLETE LH_2 RESUPPLY IN EARTH ORBIT (MISSION PHASE W).	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: VENT AND RELIEF, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
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K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.10-02 VALVE, VENT & RELIEF, GH_2	PROVIDE OPEN PATH TO VENT PROPELLANT MODULE DURING GROUND FILL OPERATION.	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE	ACTUAL LOSS PROPELLANT MODULE GROUND FILL OPERATION COULD NOT BE PERFORMED.		NONE FAILURE MODES DO NOT APPLY DURING FLIGHT PHASES	NONE
		4. FAILURE TO REMAIN CLOSED	ACTUAL LOSS DEPLETION OF ULLAGE PRESSURE COULD RESULT IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE. SUFFICIENT LOSS OF LH_2 COULD RESULT IN INABILITY TO PERFORM ENGINE COOLDOWN. OPEN VALVE COULD PRECLUDE COMPLETION OF IN-ORBIT LH_2 RESUPPLY OPERATION.	F F G G H H I I J J K K L L M M O O P P Q Q R R S S T T U U V V	ACTUAL LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING COULD RESULT IN ENGINE DESTRUCTION.	ACTUAL LOSS RNS NOT AVAILABLE FOR MISSION
				W W	ACTUAL LOSS INABILITY TO COMPLETE LH_2 RESUPPLY	ACTUAL LOSS RNS NOT AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: VENT AND RELIEF, LH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
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U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.10-02 VALVE, VENT & RELIEF, GH_2 (CONTINUED)		5. LEAKAGE	POSSIBLE LOSS SAME EFFECT AS "FAILURE TO REMAIN CLOSED" MODE.	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING COULD RESULT IN ENGINE DESTRUCTION	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.
				W	W	POSSIBLE LOSS INABILITY TO COMPLETE LH_2 RESUPPLY	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: VENT AND RELIEF, LH_2

F = TRANSLUNAR INJECTION
G = PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H = INSERTION INTO ELLIPTICAL LUNAR ORBIT
I = PULSED AFTERCOOLING
J = APOLUNE PLANE CHANGE
K = PULSED AFTERCOOLING
L = CIRCULARIZE AT TARGET ALTITUDE
M = PULSED AFTERCOOLING
N = LUNAR ORBIT OPERATIONS
O = INSERTION INTO ELLIPTICAL LUNAR ORBIT
P = PULSED AFTERCOOLING
Q = APOLUNE PLANE CHANGE
R = PULSED AFTERCOOLING
S = TRANSEARTH INJECTION
T = PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U = EARTH ORBIT CAPTURE
V = PULSED AFTERCOOLING
W = ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.10-03 VALVE, RELIEF, GH_2	PROVIDE REDUNDANCY WITH -02 VALVE TO PREVENT OVERPRESS-URIZATION OF MODULE DURING GROUND FILL.	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN	NONE REDUNDANCY IS PROVIDED BY -02 VALVE		NONE REDUNDANCY IS PROVIDED	NONE
		3. FAILURE TO CLOSE	ACTUAL LOSS PROPELLANT MODULE GROUND FILL OPERATION COULD NOT BE PERFORMED		NONE FAILURE MODE DOES NOT APPLY DURING FLIGHT PHASES	NONE
		4. FAILURE TO REMAIN CLOSED	ACTUAL LOSS SAME EFFECT AS "FAILURE TO REMAIN CLOSED," -02 ITEM.	F G H J K L M O P Q R S T U V	ACTUAL LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING COULD RESULT IN ENGINE DESTRUCTION.	ACTUAL LOSS RNS NOT AVAILABLE FOR MISSION.
				W	ACTUAL LOSS INABILITY TO COMPLETE LH_2 RESUPPLY	ACTUAL LOSS RNS NOT AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: VENT AND RELIEF, LH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
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S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.10-03 VALVE, RELIEF, GH_2 (CONTINUED)		5. LEAKAGE	POSSIBLE LOSS SAME EFFECT AS "FAILURE TO REMAIN CLOSED" MODE.	F F G G H H I I J J K K L L M M O O P P Q Q R R S S T T U U V V	POSSIBLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION
				W W	POSSIBLE LOSS INABILITY TO COMPLETE LH_2 RESUPPLY	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: VENT AND RELIEF, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
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P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.10-05 DISCONNECT, VENT AND RELIEF, GH_2	PROVIDE OVERBOARD DUMP FOR VENT AND RELIEF MODES DURING GROUND FILL	1. LEAKAGE	NONE DISCONNECT IS IN SERIES WITH -02 AND -03 VALVES.		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: FLIGHT VENT

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.11-01 DUCTING, FLIGHT VENT, GH_2	PROVIDE PATH FOR GH_2 DURING FLIGHT VENT OPERATIONS	1. LEAKAGE	POSSIBLE LOSS SUFFICIENT LOSS OF ULLAGE PRESSURE COULD RESULT IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE. LH_2 LOSS COULD RESULT IN UNSATISFACTORY ENGINE COOLDOWN DURING COAST PHASES. EXCESSIVE LEAKAGE COULD PRECLUDE COMPLETION OF IN-ORBIT LH_2 RESUPPLY.	F F G G H H I I J J K K L L M M O O P P Q Q R R S S T T U U V V	POSSIBLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W W	POSSIBLE LOSS INABILITY TO COMPLETE LH_2 RESUPPLY	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: FLIGHT VENT

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.11-02 QUAD VALVES (1 set), FLIGHT VENT, GH_2	CONTROL GH_2 VENTING OF RNS PROPELLANT MODULE	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE 4. FAILURE TO REMAIN CLOSED	NONE THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER.		NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS INSUFFICIENT ULLAGE PRESSURE COULD RESULT IN INABILITY TO TRANSFER PROPELLANT TO PROPULSION MODULE. LOSS OF ULLAGE PRESSURE DURING COAST PHASES COULD DEGRADE ENGINE COOLDOWN PERFORMANCE	F F G G H H I I J J K K L L M M O O P P Q Q R R S S T T U U V V	POSSIBLE LOSS THRUST CAPABILITY MAY BE LOST. INABILITY TO PERFORM ADEQUATE PULSED AFTER-COOLING DURING COAST PHASES COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W W	POSSIBLE LOSS INABILITY TO COMPLETE LH_2 TRANSFER OPERATION IN EARTH ORBIT	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPELLANT
SYSTEM: FLIGHT VENT, GH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
15.11-03 NOZZLES, FLIGHT VENT, GH_2	IMPART A PROPULSIVE FORCE WHEN GH_2 IS VENTED FROM THE PROPELLANT MODULE	NONE	NONE		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FEED

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
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U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.05-01,-02 PUMP, LH_2 MOTOR DRIVEN, CHILLDOWN (2)	FORCE LH_2 FROM PROPULSION MODULE TO THE STAGE FEED AND NERVA ENGINE FEED DUCTING DURING PRESTART CHILLDOWN OF BOTH PROPELLANT FEED SYSTEMS.	1. FAILURE TO START 2. FAILURE TO DELIVER AS REQUIRED	NONE - EACH PUMP IS SIZED FOR FULL SYSTEM CHILLDOWN CAPACITY			NONE - REDUNDANCY IS PROVIDED BY EITHER PUMP	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FEED

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L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
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T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.05-03,04 CHECK VALVES, ANTI-BACKFLOW, LH_2	PREVENT LH_2 BACKFLOW FROM OUTLET PORT OF CHILLDOWN PUMPS 25.05-01 AND 25.05-02	1. FAILURE TO OPEN 2. FAILURE TO CLOSE 3. LEAKAGE	NONE - EACH OF THE TWO PUMP OUTLET PORTS DISCHARGE VIA A CHECK VALVE (-03,-04) AND EACH IS SIZED FOR FULL SYSTEM CHILLDOWN OPERATIONS.		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FEED

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T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25,05-05 CHECK VALVE, LH_2 CHILL SYSTEM, STAGE FEED DUCT	PROVIDE UNIDIRECTIONAL FLOW IN STAGE FEED DUCTING DURING CHILLDOWN	1. FAILURE TO OPEN 2. LEAKAGE	PARTIAL LOSS ABILITY TO ACCOMPLISH CHILLDOWN OF THE STAGE FEED DUCTING IS LOST	F H J L O Q S U F H J L O Q S U	POSSIBLE LOSS INADEQUATE CONDITIONING OF STAGE FEED DUCTING COULD PRECLUDE ATTAINMENT OF REQUIRED LH_2 FLOW RATE AND CAUSE[C] A DEGRADATION OF STAGE THRUST	POSSIBLE LOSS
		3. FAILURE TO CLOSE	NONE - FAILURE HAS NO EFFECT		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FEED

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
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K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
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V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.05-06,-07 CHECK VALVE, LH_2, CHILL SYSTEM NERVA ENGINE FEED DUCTING (2)	EACH CHECK VALVE PROVIDES UNIDIRECTIONAL FLOW TO THE INLET DUCTING OF EACH NERVA TURBO-PUMP DURING CHILLDOWN.	1. FAILURE TO OPEN	PARTIAL LOSS ABILITY TO ACCOMPLISH CHILLDOWN OF THE NERVA ENGINE FEED DUCTING IS LOST AND COULD RESULT IN CAVITATION OF THE NERVA TURBOPUMP(S) DURING THE POWER PHASES	F H J L O Q S U	F H J L O Q S U	PROBABLE LOSS LOSS OF THRUST DUE TO LH_2 PUMP CAVITATION	PROBABLE LOSS
		2. FAILURE TO CLOSE 3. LEAKAGE	PARTIAL LOSS ADEQUATE LH_2 CONDITIONING OF THE NERVA ENGINE FEED DUCTING MAY NOT BE ATTAINED, RESULTING IN NERVA TURBO-PUMP(S) CAVITATION DURING THE POWER PHASES.	F H J L O Q S U	F H J L O Q S U	POSSIBLE LOSS LOSS OF THRUST DUE TO LH_2 PUMP CAVITATION.	POSSIBLE LOSS

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FEED

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.05-08 QUAD VALVES (1 set), SHUT-OFF, CHILLDOWN, LH_2	PROVIDE SHUTOFF IN LH_2 CHILLDOWN RETURN LINE FROM NERVA ENGINE FEED DUCTING TO PROPULSION MODULE	1. FAILURE TO OPEN 2. FAILURE TO CLOSE	NONE THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER.			NONE REDUNDANCY IS PROVIDED	NONE
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF LH_2 SUPPLY BELOW AMOUNT REQUIRED FOR NERVA STARTUP AND COOLDOWN OPERATIONS.	F G H J K L M O P Q R S T U V	F G H J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF THRUST DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING DURING MISSION COAST PHASES COULD RESULT IN ENGINE DESTRUCTION	POSSIBLE LOSS
				W	W	POSSIBLE LOSS INABILITY TO MAINTAIN LH_2 IN PROPULSION MODULE	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FEED

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.05-09 DUCTING, LH_2 CHILLDOWN	PROVIDE LH_2 FLOW PATH DURING PRESTART CHILLDOWN OF STAGE AND NERVA ENGINE FEED DUCTING	1. LEAKAGE	POSSIBLE LOSS ABILITY TO ACCOMPLISH CHILLDOWN IS LOST	F H J L O Q S U	F H J L O Q S U	POSSIBLE LOSS INADEQUATE CONDITIONING OF STAGE AND/OR NERVA ENGINE FEED DUCTING COULD PRECLUDE ATTAINMENT OF REQUIRED LH_2 FLOW RATE AND CAUSE A DEGRADATION OF STAGE THRUST.	POSSIBLE LOSS

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PRESSURIZATION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.06-01,-04 DUCTING, PRESSURIZATION CONTROL, GH_2	PROVIDE FLOW PATH FOR GH_2 FROM NERVE ENGINE TO RNS PROPULSION MODULE ULLAGE.	1. LEAKAGE	POSSIBLE LOSS POSSIBLE LOSS OF ULLAGE OR LH_2 COULD CAUSE NERVE PUMP TO CAVITATE IN POWER PHASES. LOSS OF LH_2 COULD CAUSE INABILITY TO COMPLETE MISSION. LOSS OF LH_2 COULD CAUSE INABILITY TO PERFORM ENGINE COOLDOWN. POSSIBLE LOSS OF ABILITY TO RETAIN LH_2 IN PROPULSION MODULE DURING REFILL OPERATION IN EARTH ORBIT.	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF THRUST DUE TO NERVA PUMP CAVITATION OR DEPLETION of LH_2. NERVA PUMP FAILURE COULD CAUSE STRUCTURAL DAMAGE TO STAGE. INABILITY TO PERFORM ENGINE COOLDOWN WILL RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W	W	POSSIBLE LOSS INBILITY TO MAINTAIN LH_2 IN PROPULSION MODULE	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PRESSURIZATION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.06-02 QUAD VALVES (1 set) EXPULSION, GH_2	CONTROL FLOW OF GH_2 TO PROPULSION MODULE FROM NERVA ENGINE DURING POWER PHASES.	1. FAILURE TO OPEN 2. FAILURE TO CLOSE 4. FAILURE TO REMAIN CLOSED	NONE THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER.		NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS LOW ULLAGE PRESSURE COULD CAUSE NERVA PUMP TO CAVITATE DURING POWER PHASES AND COULD RESULT IN RNS STRUCTURAL DAMAGE. LOSS OF ULLAGE PRESSURE DURING COAST PHASES COULD CAUSE INABILITY TO PERFORM ENGINE COOLDOWN. ABILITY TO REFILL PROPULSION MODULE DURING EARTH ORBIT COULD BE LOST.	F F G G H H I I J J K K L L M M O O P P Q Q R R S S T T U U V V	POSSIBLE LOSS THRUST CAPABILITY MAY BE LOST. INABILITY TO PERFORM ADEQUATE PULSED AFTERCOOLING DURING COAST PHASES COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W W	POSSIBLE LOSS INABILITY TO MAINTAIN LH_2 IN PROPULSION MODULE.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PRESSURIZATION

F ⊙ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊙ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊙ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊙ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊙ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊙ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊙ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊙ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.06-03 QUAD VALVES (1 set) CONTROL GH_2	CONTROL FLOW OF GH_2 TO PROPULSION MODULE FROM NERVA ENGINE DURING POWER PHASES	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE 4. FAILURE TO REMAIN CLOSED	NONE THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER.		NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS LOW ULLAGE PRESSURE COULD CAUSE NERVA PUMP TO CAVITATE DURING POWER PHASES AND COULD RESULT IN RNS STRUCTURAL DAMAGE. LOSS OF ULLAGE PRESSURE DURING COAST PHASES COULD CAUSE INABILITY TO PERFORM ENGINE COOLDOWN. ABILITY TO REFILL PROPULSION MODULE DURING EARTH ORBIT COULD BE LOST.	F F G G H H I I J J K K L L M M O O P P Q Q R R S S T T U U V V	POSSIBLE LOSS THRUST CAPABILITY MAY BE LOST. INABILITY TO PERFORM ADEQUATE PULSED AFTERCOOLING DURING COAST PHASES COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W W	POSSIBLE LOSS INABILITY TO MAINTAIN LH_2 IN PROPULSION MODULE	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PRESSURIZATION

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.06-05 DISCONNECT, PRESSURIZATION CONTROL, GH_2	CONNECT PROPULSION (25.06) AND PROPELLANT (15.06) MODULE PRESSURIZATION SYSTEMS. PROPULSION MODULE HALF OF DISCONNECT AT END OF 25.06-04 DUCTING.	1. LEAKAGE	POSSIBLE LOSS ABILITY TO CONTROL ULLAGE PRESSURE MAY BE LOST. INSUFFICIENT ULLAGE PRESSURE COULD CAUSE NERVA PUMP TO CAVITATE DURING POWER PHASES.	F H J L O Q S U	F H J L O Q S U	POSSIBLE LOSS THRUST CAPABILITY MAY BE LOST.	POSSIBLE LOSS
				W	W	NONE DISCONNECT LEAKAGE HAS NO EFFECT DURING EARTH ORBIT OPERATIONS.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PRESSURIZATION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.05-06 PRESSURE SWITCHES (1 set) LH_2 FLOW CONTROL	SENSE ULLAGE PRESSURE IN PROPULSION MODULE AND SEND COMMAND SIGNALS THAT ENERGIZE GH_2 CONTROL VALVES (-02,-03) DURING POWER PHASES.	1. OUTPUT WHEN NOT REQUIRED. 2. NO OUTPUT WHEN REQUIRED	NONE REDUNDANCY IS PROVIDED		NONE	NONE

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FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FILL, LH_2

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.09-01 DISCONNECT, LH_2 TRANSFER	PROVIDE CONNECTION FOR LH_2 TRANSFER FROM PROPELLANT TO PROPULSION RNS MODULES. MATES WITH 15.05-04 DISCONNECT OF PROPELLANT MODULE	1. LEAKAGE	POSSIBLE LOSS ABILITY TO TRANSFER LH_2 TO PROPULSION MODULE WOULD BE DEGRADED AND COULD CAUSE LH_2 SUPPLY TO DECREASE BELOW MINIMUM MISSION REQUIREMENTS.	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS DEPLETION OF LH_2 SUPPLY COULD RESULT IN LH_2 PUMP CAVITATION OF NERVA ENGINE DURING POWER PHASES. PUMP CAVITATION COULD RESULT IN ENGINE STRUCTURAL FAILURE. INABILITY TO PERFORM ADEQUATE PULSED AFTERCOOLING DURING MISSION COAST PHASES COULD ALSO RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W W	POSSIBLE LOSS INABILITY TO TRANSFER LH_2 TO PROPULSION MODULE DURING REFILL OPERATIONS.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FILL, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.09-02 DUCTING, LH_2 TRANSFER	PROVIDES LH_2 FLOW PATH DURING FILL OF THE RNS PROPULSION MODULE.	1. LEAKAGE	POSSIBLE LOSS SAME EFFECT AS ITEM 25.09-01," DISCONNECT LEAKAGE."	F G H H I J J K L L M O O P Q Q R S S T U U V	POSSIBLE LOSS SAME EFFECT AS ITEM 25.09-01, "DISCONNECT LEAKAGE."	POSSIBLE LOSS
				W W	POSSIBLE LOSS INABILITY TO TRANSFER LH_2 TO PROPULSION MODULE DURING REFILL OPERATIONS.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FILL, LH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.09-03,-04 CONTROL VALVES, LH_2 FILL	CONTROL FLOW OF LH_2 FROM THE PROPELLANT MODULE TO THE PROPULSION MODULE DURING POWER PHASES	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN	NONE THE CONTROL VALVES ARE REDUNDANT IN THE OPEN MODE			NONE	NONE
		3. FAILURE TO CLOSE	POSSIBLE LOSS LH_2 WILL ENTER TRANSFER LINE FROM CONTROL VALVES TO THE RNS PROPELLANT MODULE. SUBSEQUENT BOIL-OFF OF LH_2 IN TRANSFER LINE DURING COAST PERIODS COULD DEPLETE THE LH_2 SUPPLY BELOW AMOUNT REQUIRED FOR PROPER NERVA STARTUP.	F H J L O Q S U	G I K M P R T V	POSSIBLE LOSS EXCLUDING TRANSLUNAR INJECTION PHASE, DEPLETION OF LH_2 SUPPLY COULD CAUSE CAVITATION OF NERVA LH_2 PUMP DURING POWER PHASES. INABILITY TO PERFORM ADEQUATE PULSED AFTERCOOLING DURING MISSION COAST PHASES COULD ALSO RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
		4. FAILURE TO REMAIN CLOSED	POSSIBLE LOSS SAME EFFECT AS MODE 3, "FAILURE TO CLOSE."	G I K M P R T	H J L O Q S U V	POSSIBLE LOSS LH_2 SUPPLY DEPLETION COULD CAUSE NERVA LH_2 PUMP CAVITATION DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING DURING MISSION COAST PHASES COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS:
MODULE:
SYSTEM:

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.09-03,-04 CONTROL VALVES, LH_2 FILL (CONTINUED)		5.. LEAKAGE	POSSIBLE LOSS SAME EFFECT AS MODE 4, "FAILURE TO REMAIN CLOSED."	G H I J K L M O P Q R S T U V	POSSIBLE LOSS LH_2 SUPPLY DEPLETION COULD CAUSE NERVA LH_2 PUMP CAVITATION DURING POWER PHASES. INADEQUATE PULSED AFTERCOOLING DURING MISSION COAST PHASES COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
			DURING EARTH ORBIT OPERATIONS, THE "FAILURE TO REMAIN CLOSED" AND "LEAKAGE" MODES COULD DEGRADE LH_2 TRANSFER OPERATIONS. MODES 1, 2 AND 3 DO NOT APPLY DURING EARTH ORBIT.	W	W POSSIBLE LOSS INABILITY TO MAINTAIN LH_2 IN PROPULSION MODULE.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FILL, LH_2

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.09-05,-06 PUMP, LH_2, MOTOR DRIVEN, PRESTART REFILL (2)	FORCE LH_2 FROM PROPELLANT MODULE TO PROPULSION MODULE DURING PRESTART RUN TANK REFILL OPERATION.	1. FAILURE TO START 2. FAILURE TO DELIVER AS REQUIRED.	NONE - EXTENDED LH_2 TRANSFER TIME IS NOT SIGNIFICANT			NONE - SATISFACTORY RUN TANK REFILL IS PROVIDED BY EITHER PUMP	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FILL, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.09,-07-08 CHECK VALVES, ANTI-BACKFLOW, LH_2	PREVENT LH_2 BACKFLOW INTO LH_2 PUMPS DURING RUN TANK REFILL	1. FAILURE TO OPEN 2. FAILURE TO CLOSE 3. LEAKAGE	NONE - EACH OF THE TWO PUMP OUTLET PORTS DISCHARGE VIA A CHECK VALVE (-07,-08) AND SATISFACTORY REFILL OPERATIONS CAN BE PROVIDED BY EITHER PUMP		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FILL, LH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.09-09 QUAD VALVES (1 set) LH2 PRESTART REFILL	CONTROL FLOW OF LH_2 FROM THE PROPELLANT MODULE TO THE PROPULSION MODULE DURING PRESTART RUN TANK REFILL OPERATION.	1. FAILURE TO OPEN 2. FAILURE TO CLOSE	NONE THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER.			NONE	NONE
		3. LEAKAGE	NONE - FAILURE HAS NO EFFECT			NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FILL, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
				F H J L O Q S U	F H J L O Q S U		
25.09-10 FLOW METER, LH_2, PRESTART REFILL	SENSE LH_2 FLOW RATE DURING RUN TANK REFILL	1. CLOGGED	ACTUAL LOSS RESUPPLY OF RUN TANK WOULD NOT BE POSSIBLE			ACTUAL LOSS LOSS OF THRUST DUE TO NERVA PUMP CAVITATION	ACTUAL LOSS

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FILL, LH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.09-11 CHECK VALVE, LH_2 PRESTART REFILL	PROVIDE UNIDIRECTIONAL FLOW IN FILL DUCTING DURING RUN TANK REFILL	1. FAILURE TO OPEN	ACTUAL LOSS RESUPPLY OF RUN TANK WOULD NOT BE POSSIBLE	F H J L O Q S U	F H J L O Q S U	ACTUAL LOSS LOSS OF THRUST DUE TO NERVA PUMP CAVITATION	ACTUAL LOSS
		2. FAILURE TO CLOSE 3. LEAKAGE	NONE - FAILURE(S) NOT CONSIDERED SIGNIFICANT			NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FILL, LH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.09-12 SPRAY NOZZLE, LH_2, PRESTART REFILL	TRANSFORM LH_2 INTO FINE MIST SPRAY DURING RUN TANK REFILL	1. CLOGGED	ACTUAL LOSS ABILITY TO FILL PROPULSION MODULE WOULD BE LOST	F H J L O Q S U	F H J L O Q S U	ACTUAL LOSS LOSS OF THRUST DUE TO NERVA PUMP CAVITATION	ACTUAL LOSS

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: PROPELLANT FILL, LH_2

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
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L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.09-13 LEVEL SENSORS, LH_2	SENSE LH_2 LEVEL IN PROPULSION MODULE AND SEND COMMAND SIGNALS THAT ENERGIZE FLOW CONTROL VALVES (-03,-04) DURING POWER PHASES.	1. OUTPUT WHEN NOT REQUIRED 2. NO OUTPUT WHEN REQUIRED	NONE REDUNDANCY IS PROVIDED		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: FLIGHT VENT, GH_2

F ⊛ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊛ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊛ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊛ CIRCULARIZE AT TARGET ALTITUDE
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N LUNAR ORBIT OPERATIONS
O ⊛ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊛ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊛ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊛ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.11-01,-03,-04,-05 DUCTING, FLIGHT VENT, GH_2	PROVIDE VENT LINE FROM PROPULSION MODULE ULLAGE TO OVERBOARD VENT NOZZLES	1. LEAKAGE	POSSIBLE LOSS INSUFFICIENT ULLAGE PRESSURE COULD CAUSE NERVA PUMP TO CAVITATE DURING POWER PHASES. LOSS OF ULLAGE PRESSURE DURING COAST PHASES COULD DEGRADE ENGINE COOLDOWN PERFORMANCE.	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS THRUST CAPABILITY MAY BE LOST. INABILITY TO PERFORM ADEQUATE PULSED AFTERCOOLING DURING COAST PHASES COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W	W	POSSIBLE LOSS INABILITY TO COMPLETE LH_2 TRANSFER OPERATION IN EARTH ORBIT	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: FLIGHT VENT, GH_2

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
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S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.11-02 QUAD VALVES (1 set) FLIGHT VENT GH_2	CONTROL GH_2 VENTING OF RNS PROPULSION MODULE.	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE 4. FAILURE TO REMAIN CLOSED	NONE THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER.			NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS INSUFFICIENT ULLAGE PRESSURE COULD CAUSE NERVA PUMP TO CAVITATE DURING POWER PHASES. LOSS OF ULLAGE PRESSURE DURING COAST PHASES COULD DEGRADE ENGINE COOLDOWN PERFORMANCE.	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS THRUST CAPABILITY MAY BE LOST INABILITY TO PERFORM ADEQUATE PULSED AFTER-COOLING DURING COAST PHASES COULD RESULT IN ENGINE DESTRUCTION.	POSSIBLE LOSS
				W	W	POSSIBLE LOSS INABILITY TO COMPLETE LH_2 TRANSFER OPERATION IN EARTH ORBIT.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: FLIGHT VENT, GH_2

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
25.11-06,-07 NOZZLES, FLIGHT VENT, GH_2	TO IMPART A PROPULSIVE FORCE WHEN GH_2 IS VENTED FROM THE PROPULSION MODULE	NONE	NONE		NONE	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: APS

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
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S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
26.01-01 QUAD VALVES (1 set) GH_2	PROVIDE SHUTOFF CAPABILITY BETWEEN PROPULSION MODULE PRESSURIZATION SYSTEM AND APS.	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE 4. FAILURE TO REMAIN CLOSED	NONE THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER.			NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS ABILITY TO CONTROL ULLAGE PRESSURE MAY BE LOST. INSUFFICIENT ULLAGE PRESSURE COULD CAUSE NERVA PUMP TO CAVITATE DURING POWER PHASES. LEAKAGE DURING EARTH ORBIT MANEUVERS COULD DEPLETE APS GH_2 SUPPLY	F H J L O Q S U	F H J L O Q S U	POSSIBLE LOSS THRUST CAPABILITY MAY BE LOST.	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF RNS ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS (PHASE W).	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: APS

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
26.01-02,-03,-04 -06,-08,-10 DUCTING, GH_2 PROPELLANT, APS	PROVIDE FLOW PATH FOR APS GH_2 PROPELLANT	1. LEAKAGE	POSSIBLE LOSS ABILITY TO PROVIDE SUFFICIENT GASEOUS HYDROGEN TO APS ENGINE(S) COULD BE DEGRADED.	U V W W	POSSIBLE LOSS LOSS OF RNS ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS (PHASE W). SINCE APS SYSTEM IS PRESSURIZED DURING PHASE U, LINE LEAKAGE CAN ONLY OCCUR DURING THE LAST THREE MISSION PHASES (U, V, W).	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: APS

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
26.01-05 STORAGE SPHERE(S), GH_2, APS	PROVIDE STORAGE FOR GH_2 PROPELLANT TO BE USED DURING EARTH ORBIT APS OPERATIONS.	1. LEAKAGE	POSSIBLE LOSS ABILITY TO PROVIDE SUFFICIENT GASEOUS HYDROGEN TO APS ENGINE(S) COULD BE DEGRADED.	U W V W W W	POSSIBLE LOSS LOSS OF RNS ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS (PHASE W). STORAGE SPHERE(S) ARE LOADED DURING INSERTION INTO CIRCULAR EARTH ORBIT (PHASE U) - CONSEQUENTLY, FAILURE MODE CAN ONLY OCCUR DURING PHASES U, V, AND W.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: APS

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
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L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
26.01-07 RELIEF VALVE, GH_2 STORAGE, APS	PREVENT OVERPRESS-URIZATION OF APS GH_2 STORAGE SPHERE(S)	1. FAILURE TO OPEN 2. FAILURE TO R. OPEN 3. FAILURE TO CLOSE	NONE - NOT APPLICABLE TO A SINGLE FAILURE ANALYSIS AS THESE MODES OF FAILURE ARE DEPENDENT ON THE INITIAL OCCURRENCE OF THOSE SYSTEM FAILURE(S) THAT CAUSE SYSTEM OVERPRESSURIZATION.		NONE	NONE
		4. FAILURE TO REMAIN CLOSED	ACTUAL LOSS SUPPLY OF GH_2 PROPELLANT FOR EARTH ORBIT APS USAGE WOULD BE DEPLETED.	W G H I J K L M O P Q R S T U V	ACTUAL LOSS LOSS OF RNS ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS (PHASE W). THE RELIEF MODE CAN FAIL TO REMAIN CLOSED DURING ANY MISSION PHASE BUT WILL ONLY HAVE AN EFFECT DURING EARTH ORBIT (PHASE W).	ACTUAL LOSS LOSS OF RNS
		5. LEAKAGE	POSSIBLE LOSS SUPPLY OF GH_2 PROPELLANT FOR EARTH ORBIT APS USAGE WOULD BE DIMINISHED	U W V W W W	POSSIBLE LOSS LOSS OF RNS ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS (PHASE W). SINCE GH_2 IS STORED IN SPHERES DURING PHASE U, VALVE LEAKAGE CAN ONLY OCCUR DURING AND AFTER INSERTION INTO CIRCULAR EARTH ORBIT.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: APS

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
26.01-09 GROUND FILL VALVE, GH_2 STORAGE, APS	FILL VALVE IS USED TO LOAD APS GH_2 STORAGE SPHERE(S) DURING GROUND OPERATIONS.	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE	NONE - VALVE IS REQUIRED TO OPERATE DURING GROUND OPERATIONS ONLY			NONE	NONE
		4. FAILURE TO REMAIN CLOSED	NONE - VALVE IS IN SERIES WITH -11 CHECK DISCONNECT			NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS SUPPLY OF GH_2 PROPELLANT FOR EARTH ORBIT APS USAGE WOULD BE DIMINISHED	U V W	W W W	POSSIBLE LOSS LOSS OF RNS ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS (PHASE W). SINCE GH_2 IS STORED IN SPHERES DURING PHASE U, FILL VALVE IS SUSCEPTIBLE TO LEAK MODE DURING U, V AND W MISSION PHASES ONLY.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: APS

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
26.01-11 GROUND FILL CHECK DISCONNECT, GH_2 STORAGE, APS	CONNECTS RNS GH_2 STORAGE TO GROUND DURING APS FILL	1. LEAKAGE	NONE - DISCONNECT IS IN SERIES WITH -09 FILL VALVE		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: APS

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
26.01-12,-13 CONTROL VALVES, GH_2 STORAGE, APS	ISOLATE AND CONTROL FLOW OF GH_2 BETWEEN GH_2 STORAGE SPHERES AND APS ENGINE(S) QUAD VALVE SETS.	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN	NONE ABILITY TO PROVIDE GH_2 PROPELLANT TO APS ENGINES CAN BE ACHIEVED BY OPENING THE -12 OR -13 VALVE.		NONE	NONE
		3. FAILURE TO CLOSE 4. FAILURE TO REMAIN CLOSED	NONE GH_2 PROPELLANT WILL NOT BE LOST AS CONTROL VALVES ARE IN SERIES WITH APS ENGINE(S) QUAD VALVE SETS.		NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS ABILITY TO PROVIDE SUFFICIENT GASEOUS HYDROGEN TO APS ENGINE(S) COULD BE DEGRADED	U W V W W W	POSSIBLE LOSS LOSS OF RNS ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS (PHASE W). SINCE APS SYSTEM IS PRESSURIZED DURING PHASE U, VALVE LEAKAGE CAN ONLY OCCUR DURING THE LAST THREE MISSION PHASES (U, V, W).	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: APS

F = TRANSLUNAR INJECTION
G = PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H = INSERTION INTO ELLIPTICAL LUNAR ORBIT
I = PULSED AFTERCOOLING
J = APOLUNE PLANE CHANGE
K = PULSED AFTERCOOLING
L = CIRCULARIZE AT TARGET ALTITUDE
M = PULSED AFTERCOOLING
N = LUNAR ORBIT OPERATIONS
O = INSERTION INTO ELLIPTICAL LUNAR ORBIT
P = PULSED AFTERCOOLING
Q = APOLUNE PLANE CHANGE
R = PULSED AFTERCOOLING
S = TRANSEARTH INJECTION
T = PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U = EARTH ORBIT CAPTURE
V = PULSED AFTERCOOLING
W = ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
26.01-18-19 QUAD VALVES (2 sets), GH_2 FEED, APS PITCH CONTROL	REGULATES THE FLOW OF PROPELLANT TO THE PITCH CONTROL ENGINES, -20 AND -21	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE 4. FAILURE TO REMAIN CLOSED	NONE EACH QUAD VALVE SET (-18 and -19) CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER.			NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS ABILITY TO PROVIDE SUFFICIENT GASEOUS HYDROGEN TO APS PITCH CONTROL ENGINES COULD BE DEGRADED.	W	W	POSSIBLE LOSS LOSS OF RNS PITCH CONTROL DURING EARTH ORBIT OPERATIONS (PHASE W). EVEN THOUGH APS PROPELLANT IS STORED DURING INSERTION INTO EARTH ORBIT (PHASE U), QUAD VALVE LEAKAGE CANNOT OCCUR UNTIL MISSION PHASE W WHEN THE UPSTREAM APS CONTROL VALVE (-12 or -13) IS COMMANDED OPEN.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: APS

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
26.01-14,-15,-22, -23 QUAD VALVES (4 sets), GH_2 FEED, APS YAW AND ROLL CONTROL	REGULATES THE FLOW OF PROPELLANT TO THE YAW AND ROLL CONTROL ENGINES, -16,-17,-24 AND -25.	1. FAILURE TO OPEN 2. FAILURE TO REMAIN OPEN 3. FAILURE TO CLOSE 4. FAILURE TO REMAIN CLOSED	NONE EACH QUAD VALVE SET (-14, -15, -22 and -23) CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER			NONE	NONE
		5. LEAKAGE	POSSIBLE LOSS ABILITY TO PROVIDE SUFFICIENT GASEOUS HYDROGEN TO APS YAW AND ROLL CONTROL ENGINES COULD BE DEGRADED.	W	W	POSSIBLE LOSS LOSS OF RNS YAW AND ROLL CONTROL DURING EARTH ORBIT OPERATIONS (PHASE W). EVEN THOUGH APS PROPELLANT IS STORED DURING INSERTION INTO EARTH ORBIT (PHASE U), QUAD VALVE LEAKAGE CANNOT OCCUR UNTIL MISSION PHASE W WHEN THE UPSTREAM APS CONTROL VALVE (-12 OR -13) IS COMMANDED OPEN.	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: PROPULSION
SYSTEM: APS

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
26.01-20,-21 ENGINES (2), APS, PITCH CONTROL	PROVIDE THRUST FOR PITCH CONTROL DURING EARTH ORBIT OPERATIONS	NONE	NONE		NONE	NONE
26-01-16,-17, -24, -25 ENGINES (4), APS, YAW AND ROLL CONTROL	PROVIDE THRUST FOR YAW AND ROLL CONTROL DURING EARTH ORBIT OPERATIONS.	NONE	NONE		NONE	NONE

FORM 830-378

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.01-01 ENGINES (20), APS	TO MIX AND IGNITE THE PROPELLANTS AND EJECT THE COMBUSTION PRODUCTS THROUGH A CONVERGENT/ DIVERGENT NOZZLE. EACH ATTITUDE CONTROL COMMAND (i.e., ROLL CONTROL LEFT) MAY BE PERFORMED BY ONE OF TWO ENGINES REDUNDANT TO EACH OTHER.	1. BURN THROUGH	ACTUAL LOSS HOT GAS WILL ESCAPE IN UNCONTROLLED CONDITION RESULTING IN FIRE AND EXPLOSION LEADING TO LOSS OF THE RNS.	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V ACTUAL LOSS STRUCTURAL DAMAGE DUE TO FIRE	ACTUAL LOSS
				W	W ACTUAL LOSS STRUCTURAL DAMAGE DUE TO FIRE	ACTUAL LOSS LOSS OF RNS

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.01-02 IGNITER(20), APS	PROVIDE IGNITION SOURCE FOR O2H2 MIXTURE	1. FAILURE TO ENERGIZE	NONE EACH ENGINE SUBSYSTEM CONTAINS REDUNDANT IGNITERS		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
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L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.01-03 ENGINE CONTROL VALVES, NORMALLY (20) OPEN GH2	NORMALLY OPEN SOLENOID VALVES WHICH DIRECT THE GH2 FROM THE REGULATORS TO THE FUEL SIDE OF THE ENGINE SUBSYSTEM	1. FAILURE TO OPEN 2. FAILURE TO CLOSE 3. LEAKAGE	NONE EACH ENGINE SUBSYSTEM CONTAINS REDUNDANT VALVES		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.01-04 ENGINE CONTROL VALVES, NORMALLY CLOSED, GH2 (20)	NORMALLY CLOSED SOLENOID VALVES WHICH DIRECT THE GH_2 FROM THE REGULATORS TO THE FUEL SIDE OF THE ENGINE SUBSYSTEM	1. FAILURE TO OPEN 2. FAILURE TO CLOSE 3. LEAKAGE	NONE EACH ENGINE SUBSYSTEM CONTAINS REDUNDANT VALVES		NONE REDUNDANCY IS PROVIDED	NONE
			POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				F G H I J K L M O P Q R S T U V W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.01-05 ENGINE CONTROL VALVES, NORMALLY OPEN, GO2 (20)	NORMALLY CLOSED SOLENOID VALVES WHICH DIRECT THE GO2 FROM THE REGULATORS TO THE OXIDIZER SIDE OF THE ENGINE SUBSYSTEM	1. FAILURE TO OPEN 2. FAILURE TO CLOSE 3. LEAKAGE	NONE EACH ENGINE SUBSYSTEM CONTAINS REDUNDANT VALVES		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.01-06 ENGINE CONTROL VALVES, NORMALLY CLOSED, GO2 (20)	NORMALLY CLOSED SOLENOID VALVES WHICH DIRECT THE GO2 FROM THE REGULATORS TO THE OXIDIZER SIDE OF THE ENGINE SUBSYSTEM	1. FAILURE TO OPEN 2. FAILURE TO CLOSE 3. LEAKAGE	NONE EACH ENGINE SUBSYSTEM CONTAINS REDUNDANT VALVES POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V W	NONE REDUNDANCY IS PROVIDED POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	NONE POSSIBLE LOSS
				F G H I J K L M O P Q R S T U V W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
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M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.01-07 DUCTING, GH2, APS	CONNECT ALL COMPONENTS OF THE 36.01.01 GH2 SYSTEM	1. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
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N LUNAR ORBIT OPERATIONS
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P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.01-08 DUCTING, GO2, APS	CONNECT ALL COMPONENTS OF THE 36.01.01 GO2 SYSTEM	1. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
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R PULSED AFTERCOOLING
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U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-01,-02 REGULATORS, GH2 (2)	REGULATES THE GH2 PRESSURANT GAS TO THE APS ENGINES AND HEAT EXCHANGERS	1. EXCESSIVE PRESSURE	NONE THE REGULATORS ARE IN SERIES WITH THE 36.01.02-03,-04 VALVES		NONE REDUNDANCY IS PROVIDED	NONE
		2. INADEQUATE PRESSURE	NONE THE REGULATORS ARE PARALLEL TO EACH OTHER AND ONLY ONE IS REQUIRED FOR SATISFACTORY OPERATION.			

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-03,-04 VALVES, GH_2	NORMALLY OPEN SOLENOID VALVES WHICH DIRECT THE GH2 PRESSURANT GAS TO THE -01 and -02 REGULATORS	1. FAILURE TO OPEN	NONE THE VALVES ARE REDUNDANT IN THE OPEN MODE			NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	NONE THE VALVES ARE IN SERIES TO THE -01, -02 REGULATORS				
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-05 DISCONNECT, GH2 GROUND FILL	PROVIDE INTERFACE WITH GROUND SUPPORT EQUIPMENT TO APS GH2 ACCUMULATOR	1. LEAKAGE	NONE DISCONNECT IS IN SERIES WITH THE 36.01.02-06 FILL VALVE		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
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Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-06 VALVE, GH2 GROUND FILL	FILL VALVE USED TO REPLENISH GH2 SUPPLY DURING GROUND FILL	1. FAILURE TO OPEN	NONE		NONE	NONE
		2. FAILURE TO CLOSE	VALVE IS REQUIRED TO OPERATE DURING GROUND OPERATIONS ONLY			
		3. FAILURE TO REMAIN CLOSED	NONE VALVE IS IN SERIES WITH 36.01.02-05 CHECK DISCONNECT		NONE REDUNDANCY IS PROVIDED	NONE
		4. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F F G G H H I I J J K K L L M M O O P P Q Q R R S S T T U U V V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH CO/
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-07 ACCUMULATOR, GH2	STORE THE CONDITIONED GH2 PRESSURANT GAS	1. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-08,-09 CHECK VALVES, GH2 (2)	PROVIDE UNIDIRECTIONAL FLOW OF THE CONDITIONED GH2 PRESSURANT GAS FROM THE HEAT EXCHANGERS TO THE GH2 ACCUMULATOR	1. FAILURE TO OPEN	NONE THE TWO VALVES (-08,-09) ARE REDUNDANT		NONE	NONE
		2. FAILURE TO CLOSE	NONE FAILURE HAS NO EFFECT		NONE	NONE
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.10.02-10 RELIEF VALVE, GH_2	RELIEVE EXCESSIVE PRESSURE BUILDUP IN GH_2 PRESSURANT SUPPLY	1. FAILURE TO OPEN 2. FAILURE TO CLOSE 3. LEAKAGE	NOT APPLICABLE TO SINGLE FAILURE ANALYSIS			NONE	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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V PULSED AFTERCOOLING
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-11 FILTER, GH2	FILTER THE GH2 PRESSURANT GAS USED TO PRESSURIZE THE LH2 STORAGE TANK	1. CLOGGED	ACTUAL LOSS INABILITY TO PRESSURIZE LH2 SUPPLY TANK WILL RESULT IN INABILITY TO FORCE LH2 TO TURBOPUMPS AND PRECLUDE PROPER "CONDITIONING" OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	ACTUAL LOSS LOSS OF ATTITUDE CONTROL	ACTUAL LOSS
				W	W	ACTUAL LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	ACTUAL LOSS RNS NOT AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
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U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-12							
QUAD VALVES (1 SET)	CONTROL PRESSURANT GAS TO	1. FAILURE TO OPEN	NONE			NONE	NONE
PRESSURIZATION,	LH2 SUPPLY TANK	2. FAILURE TO CLOSE	THE QUAD VALVE SET CONTAINS TWO				
LH2 TANK			SUBSETS OF VALVES IN SERIES AND				
			PARALLEL TO EACH OTHER				
		3. LEAKAGE	POSSIBLE LOSS	F	F	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS FUEL SUPPLY	G H I J K L M O P Q R S T U V	G H I J K L M O P Q R S T U V	LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-13 VALVE, GH2	NORMALLY OPEN SOLENOID VALVE DIVERTS FLOW FROM GH2 REGULATOR(S) TO 36.01.02 -14 HEAT EXCHANGER N. C. VALVE	1. FAILURE TO OPEN	NONE VALVE IS IN PARALLEL TO 36.01.02-19 VALVE			NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	NONE VALVE IS IN SERIES TO 36.01.04-14 VALVE				
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: SYSTEM AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-14							
VALVE, GH2	NORMALLY CLOSED	1. FAILURE TO OPEN	NONE			NONE	NONE
	SOLENOID VALVE CONTROLS		VALVE IS PARALLEL TO			REDUNDANCY IS PROVIDED	
	GH2 FLOW TO		36.01.02-20 VALVE				
	HEAT EXCHANGER	2. FAILURE TO CLOSE	NONE				
			VALVE IS IN SERIES TO				
			36.01.04-13 VALVE				
		3. LEAKAGE	POSSIBLE LOSS	F	F	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS FUEL SUPPLY	G H I J K L M O P Q R S T U V	G H I J K L M O P Q R S T U V	LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-15 VALVE, GO2	NORMALLY CLOSED SOLENOID VALVE CONTROLS GO2 FLOW TO HEAT EXCHANGER	1. FAILURE TO OPEN.	NONE VALVE IS PARALLEL TO 36.01.02-21 VALVE			NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	NONE VALVE IS IN SERIES TO 36.01.04-19 VALVE				
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-16 IGNITER	PROVIDE IGNITION SOURCE FOR O2H2 MIXTURE	1. FAILURE TO ENERGIZE	NONE REDUNDANCY IS PROVIDED BY 36.01.02-22 IGNITER			NONE	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-17 GAS GENERATOR	PROVIDE THERMO ENERGY FOR USE IN HEAT EXCHANGERS TO CONDITION PROPELLANTS	1. FAILURE TO IGNITE	NONE REDUNDANCY IS PROVIDED BY 36.01.02-23 GAS GENERATOR			NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: COMMAND AND CONTROL
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-18							
HEAT EXCHANGER	CONDITIONS THE HYDROGEN PROPELLANT BY RAISING ITS TEMPERATURE TO TBD °R	1. CLOGGED	NONE HEAT EXCHANGER IS PARALLEL TO 36.01.02-24 HEAT EXCHANGER			NONE REDUNDANCY IS PROVIDED	NONE
		2. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
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W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-19 VALVE, GH2	NORMALLY OPEN SOLENOID VALVE DIVERTS FLOW FROM GH2 REGULATOR(S) TO 36.01.02-20 HEAT EXCHANGER N.C. VALVE	1. FAILURE TO OPEN	NONE VALVE IS IN PARALLEL TO 36.01.02-13 VALVE		NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	NONE VALVE IS IN SERIES TO 36.01.02-20 VALVE			
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-20 VALVE, GH2	NORMALLY CLOSED SOLENOID VALVE CONTROLS GH2 FLOW TO HEAT EXCHANGER	1. FAILURE TO OPEN	NONE VALVE IS PARALLEL TO 36.01.02-15 VALVE			NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	NONE VALVE IS IN SERIES TO 36.01.04-19 VALVE				
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
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R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-21 VALVE, GO2	NORMALLY CLOSED SOLENOID VALVE CONTROLS GO2 FLOW TO HEAT EXCHANGER	1. FAILURE TO OPEN	NONE VALVE IS PARALLEL TO 36.01.02-15 VALVE		NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	NONE VALVE IS IN SERIES TO 36.01.04-25 VALVE			
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-22 IGNITER	PROVIDE IGNITION SOURCE FOR O2H2 MIXTURE	1. FAILURE TO ENERGIZE	NONE REDUNDANCY IS PROVIDED BY 36.01.02-16 IGNITER		NONE	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: SYSTEM AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
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T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-23 GAS GENERATOR	PROVIDE THERMO ENERGY FOR USE IN HEAT EXCHANGERS TO CONDITION PROPELLANTS	1. FAILURE TO IGNITE	NONE REDUNDANCY IS PROVIDED BY 36.01.02-17 GAS GENERATOR			NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
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MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-24							
HEAT EXCHANGER	CONDITIONS THE HYDROGEN PROPELLANT BY RAISING ITS TEMPERATURE TO TBD °R	1. CLOSED	NONE HEAT EXCHANGER IS PARALLEL TO 36.01.02-18 HEAT EXCHANGER			NONE REDUNDANCY IS PROVIDED	NONE
		2. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: SYSTEM AUXILIARY PROPULSION

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W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-25						
VALVE, GH2	NORMALLY OPEN SOLENOID VALVE	1. FAILURE TO OPEN	NONE		NONE	NONE
	DIVERTS FLOW FROM GH2		VALVE IS IN PARALLEL TO		REDUNDANCY IS PROVIDED	
	REGULATORS TO 36.01.04-15		36.01.02-26 VALVE			
	HEAT EXCHANGER N.C. VALVE	2. FAILURE TO CLOSE	NONE			
			VALVE IS IN SERIES TO 36.01.04-15			
			VALVE			
		3. LEAKAGE	POSSIBLE LOSS	F G I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
			DEPLETION OF APS FUEL SUPPLY			
				W	POSSIBLE LOSS	POSSIBLE LOSS
					LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
					DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-26							
VALVE, GH2	NORMALLY OPEN SOLENOID VALVE	1. FAILURE TO OPEN	NONE			NONE	NONE
	DIVERTS FLOW FROM GH2		VALVE IS IN PARALLEL TO 36.01.02-25			REDUNDANCY IS PROVIDED	
	REGULATOR(S) TO 36.01.04-20		VALVE				
	HEAT EXCHANGER N.C. VALVE	2. FAILURE TO CLOSE	NONE				
			VALVE IS IN SERIES TO 36.01.04-20				
			VALVE				
		3. LEAKAGE	POSSIBLE LOSS	F	F	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS FUEL SUPPLY	G H I J K L M O P Q R S T U V	G H I J K L M O P Q R S T U V	LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.02-27 DUCTING, GH2	CONNECT ALL COMPONENTS OF THE 36.01.02 GH2 PRESSURANT SYSTEM	1. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-01							
CHECK VALVE, LH2	PROVIDE UNIDIRECTIONAL FLOW FROM TURBOPUMP TO HEAT EXCHANGER	1. FAILURE TO OPEN	NONE			NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	VALVE IS IN PARALLEL WITH THE 36.01.03-05 CHECK VALVE				
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
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U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-02 TURBOPUMP	PUMP LH2 TO HEAT EXCHANGER TO PROVIDE GH2 FUEL FOR APS ENGINES, HEAT EXCHANGERS AND PROVIDE PRESSURANT GAS FOR LH2 SUPPLY SYSTEM.	1. FAILURE TO START 2. FAILURE TO DELIVER AS REQUIRED	NONE TURBOPUMP IS IN PARALLEL WITH THE 36.01.03-06 TURBOPUMP.			NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-03 VALVE, LH2	NORMALLY CLOSED (N.C.) SOLENOID VALVE CONTROLS FLOW FROM LH2 SUPPLY TO 36.01.03-02 TURBOPUMP	1. FAILURE TO OPEN	NONE		NONE	NONE
		2. FAILURE TO CLOSE	THIS VALVE IS IN PARALLEL WITH THE 36.01.03-07 N. C. VALVE		REDUNDANCY IS PROVIDED	
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F F G G H H I I J J K K L L M M O O P P Q Q R R S S T T U U V V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
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U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-04							
VALVE, LH2	NORMALLY OPEN (N.O.)	1. FAILURE TO OPEN	NONE			NONE	NONE
	SOLENOID VALVE DIRECTS	2. FAILURE TO CLOSE	THIS VALVE IS IN PARALLEL WITH			REDUNDANCY IS PROVIDED	
	FLOW FROM LH2 SUPPLY TO		THE 36.01.03-08 N.O. VALVE				
	36.01.03-02 TURBOPUMP VIA	3. LEAKAGE	POSSIBLE LOSS	F	F	POSSIBLE LOSS	POSSIBLE LOSS
	36.01.03-03 VALVE		DEPLETION OF APS FUEL SUPPLY	G H I J K L M O P Q R S T U V	G H I J K L M O P Q R S T U V		
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-05							
CHECK VALVE, LH2	PROVIDE UNIDIRECTIONAL. FLOW FROM TURBOPUMP TO HEAT EXCHANGER	1. FAILURE TO OPEN	NONE			NONE	NONE
		2. FAILURE TO CLOSE	VALVE IS IN PARALLEL WITH THE 36.01.03-01 CHECK VALVE			REDUNDANCY IS PROVIDED	
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
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S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-06 TURBOPUMP	PUMP LH2 TO HEAT EXCHANGER TO PROVIDE GH2 FUEL FOR APS ENGINES, HEAT EXCHANGERS AND PROVIDE PRESSURANT GAS FOR LH2 SUPPLY SYSTEM	1. FAILURE TO START 2. FAILURE TO DELIVER AS REQUIRED	NONE TURBOPUMP IS IN PARALLEL WITH THE 36.01.03-02 TURBOPUMP		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1-HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-07							
VALVE, LH2	NORMALLY CLOSED (N.C.)	1. FAILURE TO OPEN	NONE			NONE	NONE
	SOLENOID VALVE CONTROLS	2. FAILURE TO CLOSE	THIS VALVE IS IN PARALLEL			REDUNDANCY IS PROVIDED	
	FLOW FROM LH2 SUPPLY TO		WITH THE 36.01.03-03 N.C. VALVE				
	36.01.03-06 TURBOPUMP	3. LEAKAGE	POSSIBLE LOSS	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS FUEL SUPPLY				
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
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U ⊛ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-08							
VALVE, LH2	NORMALLY OPEN (N.O.) SOLE-NOID VALVE DIRECTS FLOW FROM LH2 SUPPLY TO 36.01.03-06 TURBOPUMP VIA 36.01.03-05 VALVE	1. FAILURE TO OPEN	NONE			NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	THIS VALVE IS IN PARALLEL WITH THE 36.01.03-04				
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-09 LH2 TANK	STORE LH2 SUPPLY	1. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
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T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
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W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-10						
VALVE, LH2	FILL VALVE USED TO REPLENISH	1. FAILURE TO OPEN	NONE		NONE	NONE
GROUND FILL	LH2 SUPPLY DURING GROUND	2. FAILURE TO REMAIN	VALVE IS REQUIRED TO OPERATE			
	FILL	OPEN	DURING GROUND OPERATIONS ONLY			
		3. FAILURE TO CLOSE				
		4. FAILURE TO	NONE - VALVE IS IN SERIES WITH		NONE	NONE
		REMAIN CLOSED	36.01.03-11 CHECK DISCONNECT		REDUNDANCY IS PROVIDED	
		5. LEAKAGE	POSSIBLE LOSS	F F	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS FUEL SUPPLY	G G H H	LOSS OF ATTITUDE CONTROL	
				I I J J K K L L M M O O P P Q Q R R S S T T U U V V		
				W W	POSSIBLE LOSS	POSSIBLE LOSS
					LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
					DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
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W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-11 DISCONNECT, LH2 GROUND FILL	PROVIDE INTERFACE WITH GROUND SUPPORT EQUIPMENT TO APS LH2 SUPPLY SYSTEM.	1. LEAKAGE	NONE - DISCONNECT IS IN SERIES WITH THE 36.01.03-10 FILL VALVE		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-12							
QUAD VALVES (1 SET),	QUAD VALVE SET USED TO	1. FAILURE TO OPEN	NONE			NONE	NONE
LH2 TANK VENT	RELIEVE EXCESSIVE PRESSURE	2. FAILURE TO CLOSE	THE QUAD VALVE SET CONTAINS TWO				
	BUILDUP IN LH2 TANK		SUBSETS OF VALVES IN SERIES AND				
			PARALLEL TO EACH OTHER				
		3. LEAKAGE	POSSIBLE LOSS	F	F	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS FUEL SUPPLY	G	G		
				H	H	LOSS OF ATTITUDE CONTROL	
				I	I		
				J	J		
				K	K		
				L	L		
				M	M		
				O	O		
				P	P		
				Q	Q		
				R	R		
				S	S		
				T	T		
				U	U		
				V	V		
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.03-13 DUCTING, LH2	CONNECT ALL COMPONENTS OF THE 36.01.03 LH2 STORAGE SYSTEM	1. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
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V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-03,-04						
VALVES, GO2	NORMALLY OPEN SOLENOID VALVES WHICH DIRECT THE GO2 PRESSURANT GAS TO THE -01 AND -02 REGULATORS	1. FAILURE TO OPEN	NONE THE VALVES ARE REDUNDANT IN THE OPEN MODE		NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	NONE THE VALVES ARE IN SERIES TO THE -01, -02 REGULATORS			
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
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V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-05 DISCONNECT, GO2 GROUND FILL	PROVIDE INTERFACE WITH SECOND SUPPORT EQUIPMENT TO APS GO2 ACCUMULATOR	1. LEAKAGE	NONE DISCONNECT IS IN SERIES WITH THE 36.01.04-06 FILL VALVE		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

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N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
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R PULSED AFTERCOOLING
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T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-06							
VALVE, GO2	FILL VALVE USED TO REPLENISH	1. FAILURE TO OPEN	NONE			NONE	NONE
GROUND FILL	GO2 SUPPLY DURING GROUND	2. FAILURE TO CLOSE	VALVE IS REQUIRED TO OPERATE				
	FILL		DURING GROUND OPERATIONS ONLY				
		3. FAILURE TO REMAIN	NONE			NONE	
		CLOSED	VALVE IS IN SERIES WITH			REDUNDANCY IS PROVIDED	
			36.01.04-05 CHECK DISCONNECT				
		4. LEAKAGE	POSSIBLE LOSS	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY			LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
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V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-07							
ACCUMULATOR, GO2	STORE THE CONDITIONED GO2 PRESSURANT GAS	1. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
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T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
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W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-08,-09							
CHECK VALVES,	PROVIDE UNIDIRECTIONAL	1. FAILURE TO OPEN	NONE			NONE	NONE
GO2 (2)	FLOW OF THE CONDITIONED		THE TWO VALVES (-08,-09) ARE				
	GO2 PRESSURANT GAS FROM		REDUNDANT				
	THE HEAT EXCHANGERS TO THE	2. FAILURE TO CLOSE	NONE			NONE	NONE
	GO2 ACCUMULATOR		FAILURE HAS NO EFFECT				
		3. LEAKAGE	POSSIBLE LOSS	F	F	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY	G	G		
				H	H	LOSS OF ATTITUDE CONTROL	
				I	I		
				J	J		
				K	K		
				L	L		
				M	M		
				O	O		
				P	P		
				Q	Q		
				R	R		
				S	S		
				T	T		
				U	U		
				V	V		
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
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ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-10 RELIEF VALVE, GO2	RELIEVE EXCESSIVE PRESSURE BUILDUP IN GO2 PRESSURANT SUPPLY	1. FAILURE TO OPEN 2. FAILURE TO CLOSE 3. LEAKAGE	NOT APPLICABLE TO SINGLE FAILURE ANALYSIS			NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
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M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-11							
FILTER, GO2	FILTER THE GO2 PRESSURANT GAS USED TO PRESSURIZE THE LO2 STORAGE TANK	1. CLOGGED	ACTUAL LOSS INABILITY TO PRESSURIZE LO2 SUPPLY TANK WILL RESULT IN INABILITY TO FORCE LO2 TO TURBOPUMPS AND PRECLUDE PROPER "CONDITIONING" OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	ACTUAL LOSS LOSS OF ATTITUDE CONTROL	ACTUAL LOSS
				W	W	ACTUAL LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	ACTUAL LOSS RNS NOT AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-12 QUAD VALVES (1 Set), PRESSURIZATION, LO2 TANK	CONTROL PRESSURANT GAS TO LO2 TANK	1. FAILURE TO OPEN	NONE			NONE	NONE
		2. FAILURE TO CLOSE	THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER				
		3. LEAKAGE	POSSIBLE LOSS	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY			LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-13							
VALVE, GO2	NORMALLY OPEN SOLENOID	1. FAILURE TO OPEN	NONE			NONE	NONE
	VALVE DIVERTS FLOW FROM GO2		VALVE IS IN PARALLEL TO			REDUNDANCY IS PROVIDED	
	REGULATOR(S) TO 36.01.04-14		36.01.04-19 VALVE				
	HEAT EXCHANGER N.C. VALVE	2. FAILURE TO CLOSE	NONE				
			VALVE IS IN SERIES TO 36.01.04-14				
			VALVE				
		3. LEAKAGE	POSSIBLE LOSS	F	F	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY	G	G		
				H	H	LOSS OF ATTITUDE CONTROL	
				I	I		
				J	J		
				K	K		
				L	L		
				M	M		
				O	O		
				P	P		
				Q	Q		
				R	R		
				S	S		
				T	T		
				U	U		
				V	V		
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-14							
VALVE, GO2	NORMALLY CLOSES	1. FAILURE TO OPEN	NONE			NONE	NONE
	SOLENOID VALVE CONTROLS		VALVE IS PARALLEL TO 36.01.04-20			REDUNDANCY IS PROVIDED	
	GO2 FLOW TO HEAT EXCHANGER		VALVE				
		2. FAILURE TO CLOSE	NONE				
			VALVE IS IN SERIES TO				
			36.01.02-13 VALVE				
		3. LEAKAGE	POSSIBLE LOSS			POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-15						
VALVE, GH2	NORMALLY CLOSED SOLENOID VALVE CONTROLS GH2 FLOW TO HEAT EXCHANGER	1. FAILURE TO OPEN	NONE VALVE IS PARALLEL TO 36.01.02-21 VALVE		NONE	NONE
		2. FAILURE TO CLOSE	NONE VALVE IS IN SERIES TO 36.01.02-19 VALVE			
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-16 IGNITER	PROVIDE IGNITION SOURCE FOR O2H2 MIXTURE	1. FAILURE TO ENERGIZE	NONE REDUNDANCY IS PROVIDED BY 36.01.04-22 IGNITER			NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-17 GAS GENERATOR	PROVIDE THERMO ENERGY FOR USE IN HEAT EXCHANGERS TO CONDITION PROPELLANTS	1. FAILURE TO IGNITE	NONE REDUNDANCY IS PROVIDED BY 36.01.04-23 GAS GENERATOR		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-18							
HEAT EXCHANGER	CONDITIONS THE OXYGEN PROPELLANT BY RAISING ITS TEMPERATURE TO TBD °R	1. CLOSED	NONE HEAT EXCHANGER IS PARALLEL TO 36.01.04-24 HEAT EXCHANGER			NONE REDUNDANCY IS PROVIDED	NONE
		2. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-19							
VALVE, GO2	NORMALLY OPEN SOLENOID VALVE	1. FAILURE TO OPEN	NONE			NONE	NONE
	DIVERTS FLOW FROM GO2		VALVE IS IN PARALLEL TO 36.01.04-13			REDUNDANCY IS PROVIDED	
	REGULATOR(S) TO 36.01.04-20		VALVE				
	HEAT EXCHANGER N.C.VALVE	2. FAILURE TO CLOSE	NONE				
			VALVE IS IN SERIES TO 36.01.04-20				
			VALVE				
		3. LEAKAGE	POSSIBLE LOSS	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY			LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-20							
VALVE, GO2	NORMALLY CLOSED SOLENOID VALVE CONTROLS GO2 FLOW TO HEAT EXCHANGER	1. FAILURE TO OPEN	NONE VALVE IS PARALLEL TO 36.01.04-15 VALVE			NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	NONE VALVE IS IN SERIES TO 36.01.02-19 VALVE				
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-21 VALVE, GH2	NORMALLY CLOSED SOLENOID VALVE CONTROLS GH2 FLOW TO HEAT EXCHANGER	1. FAILURE TO OPEN	NONE VALVE IS PARALLEL TO 36.01.04-15 VALVE			NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	NONE VALVE IS IN SERIES TO 36.01.02-25 VALVE				
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS FUEL SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 3 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-22	PROVIDE IGNITION SOURCE FOR O2H2 MIXTURE	1. FAILURE TO ENERGIZE	NONE REDUNDANCY IS PROVIDED BY 36.01.04-16			NONE	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-23 GAS GENERATOR	PROVIDE THERMC ENERGY FOR USE IN HEAT EXCHANGERS TO CONDITION PROPELLANTS	1. FAILURE TO IGNITE	NONE REDUNDANCY IS PROVIDED BY 36.01.04-17 GAS GENERATOR		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-24 HEAT EXCHANGER	CONDITIONS THE OXYGEN PROPELLANT BY RAISING ITS TEMPERATURE TO TBD °R	1. CLOGGED	NONE HEAT EXCHANGER IS PARALLEL TO 36.01.04-18 HEAT EXCHANGER		NONE REDUNDANCY IS PROVIDED	NONE
		2. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01-04-25							
VALVE, GO2	NORMALLY OPEN SOLENOID VALVE	1. FAILURE TO OPEN	NONE			NONE	NONE
	DIVERTS FLOW FROM GO2		VALVE IS IN PARALLEL TO			REDUNDANCY IS PROVIDED	
	REGULATOR(S) to 36.01.02-15		36.01.04-26 VALVE				
	HEAT EXCHANGER N.C. VALVE	2. FAILURE TO CLOSE	NONE				
			VALVE IS IN SERIES TO 36.01.02-15				
			VALVE				
		3. LEAKAGE	POSSIBLE LOSS	F G H I J K L M O P Q S T U V	F G H I J K L M O P Q S T U V	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY			LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-26							
VALVE, GO2	NORMALLY OPEN SOLENOID VALVE DIVERTS FLOW FROM GO2 REGULATOR(S) TO 36.01.02-20 HEAT EXCHANGER N.C. VALVE	1. FAILURE TO OPEN	NONE VALVE IS IN PARALLEL TO 36.01.04-25 VALVE			NONE REDUNDANCY IS PROVIDED	NONE
		2. FAILURE TO CLOSE	NONE VALVE IS IN SERIES TO 36.01.02-20				
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U	F G H I J K L M O P Q R S T U	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-378

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.04-27 DUCTING, GO2	CONNECT ALL COMPONENTS OF THE 36.01.04 GO2 PRESSURANT SYSTEM	1. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-01 CHECK VALVE, LO2	PROVIDE UNIDIRECTIONAL FLOW FROM TURBOPUMP TO HEAT EXCHANGER	1. FAILURE TO OPEN	NONE			NONE	NONE
		2. FAILURE TO CLOSE	VALVE IS IN PARALLEL WITH THE 36.01.05-05 CHECK VALVE			REDUNDANCY IS PROVIDED	
		3. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-02 TURBOPUMP	PUMP LO2 TO HEAT EXCHANGER TO PROVIDE GO2 FOR APS ENGINES, HEAT EXCHANGERS AND PROVIDE PRESSURANT GAS FOR LO2 SUPPLY SYSTEM	1. FAILURE TO START 2. FAILURE TO DELIVER AS REQUIRED	NONE TURBOPUMP IS IN PARALLEL WITH THE 36.01.05-06 TURBOPUMP		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-03							
VALVE, LO2	NORMALLY CLOSED (N.C.)	1. FAILURE TO OPEN	NONE			NONE	NONE
	SOLENOID VALVE CONTROLS	2. FAILURE TO CLOSE	THIS VALVE IS IN PARALLEL WITH			REDUNDANCY IS PROVIDED	
	FLOW FROM LO2 SUPPLY TO		THE 36.01.05-07 N. C. VALVE				
	36.01.05-02 TURBOPUMP	3. LEAKAGE	POSSIBLE LOSS	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY			LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-04							
VALVE, LO2	NORMALLY OPEN (N.O.)	1. FAILURE TO OPEN	NONE			NONE	NONE
	SOLENOID VALVE DIRECTS FLOW	2. FAILURE TO CLOSE	THIS VALVE IS IN PARALLEL WITH			REDUNDANCY IS PROVIDED	
	LO2 SUPPLY TO 36.01.05-02		THE 36.01.05-08 N. O. VALVE				
	TURBOPUMP VIA 36.01.05-03	3. LEAKAGE	POSSIBLE LOSS	F	F	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY	G	G	LOSS OF ATTITUDE CONTROL	
				H	H		
				I	I		
				J	J		
				K	K		
				L	L		
				M	M		
				O	O		
				P	P		
				Q	Q		
				R	R		
				S	S		
				T	T		
				U	U		
				V	V		
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-05							
CHECK VALVE, LO2	PROVIDE UNIDIRECTIONAL FLOW FROM TURBOPUMP TO HEAT EXCHANGER	1. FAILURE TO OPEN	NONE			NONE	NONE
		2. FAILURE TO CLOSE	VALVE IS IN PARALLEL WITH THE 36.01.05-01 CHECK VALVE			REDUNDANCY IS PROVIDED	
		3. LEAKAGE	POSSIBLE LOSS	F	F	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY	G H I J K L M O P Q R S T U V	G H I J K L M O P Q R S T U V	LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-06 TURBOPUMP	PUMP LO2 TO HEAT EXCHANGER TO PROVIDE GO2 FUEL FOR APS ENGINES, HEAT EXCHANGERS AND PROVIDE PRESSURANT GAS FOR LO2 SUPPLY SYSTEM.	1. FAILURE TO START 2. FAILURE TO DELIVER AS REQUIRED	NONE TURBOPUMP IS IN PARALLEL WITH THE 36.01.05-02 TURBOPUMP		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-07 VALVE, LO2	NORMALLY CLOSED (N.C.) SOLENOID VALVE CONTROLS FLOW FROM LO2 SUPPLY TO 36.01.05-06 TURBOPUMP	1. FAILURE TO OPEN 2. FAILURE TO CLOSE 3. LEAKAGE	NONE THIS VALVE IS IN PARALLEL WITH THE 36.01.05-03 N. C. VALVE POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	NONE REDUNDANCY IS PROVIDED POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	NONE POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
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J ⊕ APOLUNE PLANE CHANGE
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L ⊕ CIRCULARIZE AT TARGET ALTITUDE
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N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-08							
VALVE, LO2	NORMALLY OPEN (N.O.)	1. FAILURE TO OPEN	NONE			NONE	NONE
	SOLENOID VALVE DIRECTS	2. FAILURE TO CLOSE	THIS VALVE IS IN PARALLEL WITH			REDUNDANCY IS PROVIDED	
	FLOW FROM LO2 SUPPLY TO		THE 36.01.05-04 N.O. VALVE				
	36.01.05-06 TURBOPUMP VIA	3. LEAKAGE	POSSIBLE LOSS	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS	POSSIBLE LOSS
	36.01.05-07 VALVE		DEPLETION OF APS OXIDIZER SUPPLY			LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-09 LO2 TANK	STORE LO2 SUPPLY	1. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-10							
VALVE, LO2	FILL VALVE USED TO	1. FAILURE TO OPEN	NONE			NONE	NONE
GROUND FILL	REPLENISH LO2 SUPPLY	2. FAILURE TO	VALVE IS REQUIRED TO OPERATE				
	DURING GROUND FILL	REMAIN OPEN	DURING GROUND OPERATIONS ONLY				
		3. FAILURE TO CLOSE					
		4. FAILURE TO	NONE - VALVE IS IN SERIES WITH			NONE	NONE
		REMAIN CLOSED	36.01.05-11 CHECK DISCONNECT			REDUNDANCY IS PROVIDED	
		5. LEAKAGE	POSSIBLE LOSS	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY			LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-11 DISCONNECT, LO2 GROUND FILL	PROVIDE INTERFACE WITH GROUND SUPPORT EQUIPMENT TO APS LO2 SUPPLY SYSTEM	1. LEAKAGE	NONE - DISCONNECT IS IN SERIES WITH THE 36.01.05-10 FILL VALVE		NONE REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F = TRANSLUNAR INJECTION
G = PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H = INSERTION INTO ELLIPTICAL LUNAR ORBIT
I = PULSED AFTERCOOLING
J = APOLUNE PLANE CHANGE
K = PULSED AFTERCOOLING
L = CIRCULARIZE AT TARGET ALTITUDE
M = PULSED AFTERCOOLING
N = LUNAR ORBIT OPERATIONS
O = INSERTION INTO ELLIPTICAL LUNAR ORBIT
P = PULSED AFTERCOOLING
Q = APOLUNE PLANE CHANGE
R = PULSED AFTERCOOLING
S = TRANSEARTH INJECTION
T = PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U = EARTH ORBIT CAPTURE
V = PULSED AFTERCOOLING
W = ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-12							
QUAD VALVES (1 set), LO2 TANK VENT	QUAD VALVE SET USED TO RELIEVE EXCESSIVE PRESSURE BUILDUP IN LO2 TANK	1. FAILURE TO OPEN	NONE			NONE	NONE
		2. FAILURE TO CLOSE	THE QUAD VALVE SET CONTAINS TWO SUBSETS OF VALVES IN SERIES AND PARALLEL TO EACH OTHER				
		3. LEAKAGE	POSSIBLE LOSS	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS	POSSIBLE LOSS
			DEPLETION OF APS OXIDIZER SUPPLY			LOSS OF ATTITUDE CONTROL	
				W	W	POSSIBLE LOSS-	POSSIBLE LOSS
						LOSS OF ATTITUDE CONTROL	RNS MAY NOT BE
						DURING EARTH ORBIT OPERATIONS	AVAILABLE FOR MISSION

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1 - HYBRID
MODULE: COMMAND AND CONTROL
SYSTEM: AUXILIARY PROPULSION

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
36.01.05-13 DUCTING, LO2	CONNECT ALL COMPONENTS OF THE 36.01.05 LO2 STORAGE SYSTEM	1. LEAKAGE	POSSIBLE LOSS DEPLETION OF APS OXIDIZER SUPPLY	F G H I J K L M O P Q R S T U V	F G H I J K L M O P Q R S T U V	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL	POSSIBLE LOSS
				W	W	POSSIBLE LOSS LOSS OF ATTITUDE CONTROL DURING EARTH ORBIT OPERATIONS	POSSIBLE LOSS RNS MAY NOT BE AVAILABLE FOR MISSION

FORM 830-378

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE NAVIGATION AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.01 PITCH GYRO AND ELECTRONICS	PROVIDE PITCH RATE AND ATTITUDE SIGNAL FOR FLIGHT CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANCY IS PROVIDED BY PITCH GYROS 37.01.02 AND 37.01.03.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY PITCH GYROS 37.01.02 AND 37.01.03	NONE
		2. ERRONEOUS OUTPUT	ACTUAL LOSS COMPUTER WILL RECEIVE THREE OUTPUTS FROM GYROS 37.01.01, 37,01.02 AND 37.01.03 AND WILL USE A 2/3 LOGIC TO ELIMINATE A FAILED GYRO.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE NAVIGATION AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.02 PITCH GYRO AND ELECTRONICS	PROVIDES PITCH RATE AND ATTITUDE SIGNAL FOR FLIGHT CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANCY IS PROVIDED BY PITCH GYROS 37.01.01 AND 37.01.03	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY PITCH GYROS 37.01.01 AND 37.01.03	NONE
		2. ERRONEOUS OUTPUT	ACTUAL LOSS COMPUTER WILL RECEIVE THREE OUTPUTS FROM GYROS 37.01.01, 37.01.02 AND 37.01.03 AND WILL USE A 2/3 LOGIC TO ELIMINATE A FAILED GYRO.	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND CONTROL
SYSTEM: GUIDANCE NAVIGATION AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.03 PITCH GYRO AND ELECTRONICS	PROVIDES PITCH RATE AND ATTITUDE SIGNAL FOR FLIGHT CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANCY IS PROVIDED BY PITCH GYROS 37.01.02 AND 37.01.01.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY PITCH GYROS 37.01.02 AND 37.01.01	NONE
		2. ERRONEOUS OUTPUT	ACTUAL LOSS COMPUTER WILL RECEIVE THREE OUTPUTS FROM GYROS 37.01.01, 37.01.02 AND 37.01.03 AND WILL USE A 2/3 LOGIC TO ELIMINATE A FAILED GYRO.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 830-378

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE NAVIGATION AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.04 YAW GYRO AND ELECTRONICS	PROVIDES YAW RATE AND ATTITUDE SIGNAL FOR FLIGHT CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANCY IS PROVIDED BY YAW GYROS 37.01.05 AND 37.01.06.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY YAW GYROS 37.01.05 AND 37.01.06.	NONE
		2. ERRONEOUS OUTPUT.	ACTUAL LOSS COMPUTER WILL RECEIVE THREE OUTPUTS FROM GYROS 37.01.04, 37,01.05 AND 37.01.06 AND WILL USE A 2/3 LOGIC TO ELIMINATE A FAILED GYRO.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 830-378

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE NAVIGATION AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.05 YAW GYRO AND ELECTRONICS	PROVIDES YAW RATE AND ATTITUDE SIGNAL FOR FLIGHT CONTROL.	1. FAILURE TO OPERATE.	ACTUAL LOSS REDUNDANCY IS PROVIDED BY YAW GYROS 37.01.04 AND 37.01.06	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY YAW GYROS 37.01.04 and 37.01.05.	NONE
		2. ERRONEOUS OUTPUT	ACTUAL LOSS COMPUTER WILL RECEIVE THREE OUTPUTS FROM GYROS 37.01.04, 37.01.05 AND 37.01.06 AND WILL USE A 2/3 LOGIC TO ELIMINATE A FAILED GYRO.	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE NAVIGATION AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.06 YAW GYRO AND ELECTRONICS	PROVIDES YAW RATE AND ATTITUDE SIGNAL FOR FLIGHT CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANCY IS PROGIDED BY YAW GYROS 37.01.04 AND 37.01.05	F		NONE FOR F AND SUBSEQUENT PHASE. REDUNDANCY IS PROVIDED BY YAW GYROS 37.01.04 AND 37.01.05	NONE
		2. ERRONEOUS OUTPUT.	ACTUAL LOSS COMPUTER WILL RECEIVE THREE OUTPUTS FOR GYROS 37.01.04, 37.01.05 AND 37.01.06 AND WILL USE A 2/3 LOGIC TO ELIMINATE A FAILED GYRO.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED	NONE

FORM 630-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE NAVIGATION AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.07 ROLL GYRO AND ELECTRONICS	PROVIDES ROLL RATE AND ATTITUDE SIGNAL FOR FLIGHT CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANCY IS PROVIDED BY ROLL GYROS 37.01.08 and 37.01.09	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY ROLL GYROS 37.01.08 and 37.01.09.	NONE
		2. ERRONEOUS OUTPUT	ACTUAL LOSS COMPUTER WILL RECEIVE THREE OUTPUTS FROM GYROS 37.01.07, 37.01.08 and 37.01.09 AND WILL USE A 2/3 LOGIC TO ELIMINATE A FAILED GYRO.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE, NAVIGATION & CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.08 ROLL GYRO AND ELECTRONICS	PROVIDES ROLL RATE AND ATTITUDE SIGNAL FOR FLIGHT CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANCY IS PROVIDED BY ROLL GYROS 37.01.07 AND 37.01.09	F	NONE FOR F AND SUBSEQUENT PHASES REDUNDANCY IS PROVIDED BY ROLL GYROS 37.01.07 AND 37.01.09	NONE
		2. ERRONEOUS OUTPUT	ACTUAL LOSS COMPUTER WILL RECEIVE THREE OUTPUTS FROM GYROS 37.01.07, 37,01.08 AND 37.01.09 AND WILL USE A 2/3 LOGIC TO ELIMINATE A FAILED GYRO.		NONE FOR F AND SUBSEQUENT PHASES REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE, NAVIGATION AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.09 ROLL GYRO AND ELECTRONICS	PROVIDES ROLL RATE AND ATTITUDE SIGNAL FOR FLIGHT CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANCY IS PROVIDED BY ROLL GYROS 37.01.07 AND 37.01.08	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY ROLL GYROS 37.01.07 AND 37.01.08	NONE
		2. ERRONEOUS OUTPUT	ACTUAL LOSS COMPUTER WILL RECEIVE THREE OUTPUTS FROM GYROS 37.01.07, 37.01.08 AND 37.01.09 AND WILL USE A 2/3 LOGIC TO ELIMINATE A FAILED GYRO.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE NAVIGATION AND CONTROL

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.10 POWER SUPPLY AND REGULATORS	CONVERT RAW ELECTRICAL POWER TO APPROPRIATE VOLTAGE REQUIRED FOR ASTRIONICS SYSTEM COMPONENTS	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANT POWER SUPPLY 37.01.11 WILL PROVIDE REQUIRED ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY POWER SUPPLY 37.01.11.	NONE
		2. SHORT	ACTUAL LOSS ABILITY OF POWER SUPPLY TO CONVERT ELECTRICAL POWER IS LOST. REDUNDANT POWER SUPPLY 37.01.11 WILL PROVIDE REQUIRED POWER. REVERSE CURRENT RELAY 37.01.12 WILL REMOVE POWER SUPPLY FROM SYSTEM.	F		NONE FOR F AND SUBSEQUENT SYSTEM. REDUNDANCY IS PROVIDED.	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE NAVIGATION AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.11 POWER SUPPLY AND REGULATORS	CONVERT RAW ELECTRICAL POWER TO APPROPRIATE VOLTAGE REQUIRED FOR ASTRIONICS SYSTEM COMPONENTS	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANT POWER SUPPLY 37.01.10 WILL PROVIDE REQUIRED ELECTRICAL POWER	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS POWERED BY POWER SUPPLY 37.01.10.	NONE
		2. SHORT	ACTUAL LOSS ABILITY OF POWER SUPPLY TO CONVERT ELECTRICAL POWER IS LOST. REDUNDANT POWER SUPPLY 37.01.10 WILL PROVIDE REQUIRED POWER. REVERSE CURRENT RELAY 37.01.13 WILL REMOVE POWER SUPPLY FROM SYSTEM.	F		NONE FOR F AND SUBSEQUENT SYSTEM. REDUNDANCY IS PROVIDED.	NONE

FORM 630-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE NAVIGATION AND CONTROL

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.12 REVERSE CURRENT RELAY ASSEMBLY	MONITOR THE DIRECTION OF CURRENT OUT OF THE POWER SUPPLY 37.01.10 AND DISCONNECT THE SUPPLY IF THE SUPPLY DRAWN CURRENT FROM THE SYSTEM	1. FAILURE TO OPERATE	NONE. FAILURE DOES NOT APPLY TO A SINGLE FAILURE ANALYSIS			NONE	NONE
		2. OPERATES WHEN NOT REQUIRED.	ACTUAL LOSS POWER SUPPLY 37.01.10 IS REMOVED FROM THE SYSTEM. REDUNDANT POWER SUPPLY 37.01.11 WILL PROVIDE THE REQUIRED ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE NAVIGATION AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.13 REVERSE CURRENT RELAY ASSEMBLY	MONITOR THE DIRECTION OF CURRENT OUT OF THE POWER SUPPLY 37.01.11 AND DISCONNECT THE SUPPLY IF THE SUPPLY DRAWN CURRENT FROM THE SYSTEM.	1. FAILURE TO OPERATE	NONE. FAILURE DOES NOT APPLY TO A SINGLE FAILURE ANALYSIS			NONE	NONE
		2. OPERATES WHEN NOT REQUIRED	ACTUAL LOSS POWER SUPPLY 37.01.11 IS REMOVED FROM THE SYSTEM. REDUNDANT POWER SUPPLY 37.01.10 WILL PROVIDE THE REQUIRED ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE, NAVIGATION AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.14 HORIZON SENSOR	PROVIDES ROLL AND PITCH RATES AND ATTITUDE SIGNALS	1. FAILURE TO OPERATE	ACTUAL LOSS THIS IS NOT REQUIRED FOR SYSTEM OPERATION, APPROPRIATE SIGNALS CAN BE OBTAINED FROM OTHER SENSORS INCLUDING THE REDUNDANT HORIZON SENSOR 37.01.15	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE
		2. ERRONEOUS OUTPUT	SAME AS ABOVE.	F		NONE FOR F AND SUBSEQUENT PHASES.	NONE

FORM 830-378

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE, NAVIGATION AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.15 HORIZON SENSOR	PROVIDE ROLL AND PITCH RATES AND ATTITUDE SIGNALS	1. FAILURE TO OPERATE	ACTUAL LOSS THIS ITEM IS NOT REQUIRED FOR SYSTEM OPERATION, APPROPRIATE SIGNALS CAN BE OBTAINED FROM OTHER SENSORS INCLUDING THE REDUNDANT HORIZON, SENSOR 37.01.14.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE
		2. ERRONEOUS OUTPUT	SAME AS ABOVE	F		NONE FOR F AND SUBSEQUENT PHASES.	NONE

FORM 880-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE, NAVIGATION AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.16 LANDMARK TRACKER	PROVIDES POSITION INFORMATION FOR THE GUIDANCE, NAVIGATION AND CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS THIS ITEM IS NOT REQUIRED FOR SYSTEM OPERATION, APPROPRIATE SIGNALS CAN BE OBTAINED FROM OTHER SENSORS INCLUDING THE REDUNDANT LANDMARK TRACKER 37.01.17	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	
		2. ERRONEOUS OUTPUT	SAME AS ABOVE	F		NONE FOR F AND SUBSEQUENT PHASES.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE, NAVIGATION AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.17							
LANDMARK TRACKER	PROVIDES POSITION INFORMATION FOR THE GUIDANCE, NAVIGATION AND CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS THIS ITEM IS NOT REQUIRED FOR SYSTEM OPERATION, APPROPRIATE SIGNALS CAN BE OBTAINED FROM OTHER SENSORS INCLUDING THE REDUNDANT LANDMARK TRACKER 37.01.16	F		NONE FOR F AND SUBSEQUENT PHASES.	
		2. ERRONEOUS OUTPUT	SAME AS ABOVE	F		NONE FOR F AND SUBSEQUENT PHASES.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE, NAVIGATION AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.18 STAR TRACKER	PROVIDES POSITION INFORMATION FOR THE GUIDANCE, NAVIGATION AND CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS THIS ITEM IS NOT REQUIRED FOR SYSTEM OPERATION, APPROPRIATE SIGNALS CAN BE OBTAINED FROM OTHER SENSORS INCLUDING THE REDUNDANT STAR TRACKER 37.01.19	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	
		2. ERRONEOUS OUTPUT	SAME AS ABOVE	F		NONE FOR F AND SUBSEQUENT PHASES.	NONE

FORM 830-378

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: GUIDANCE, NAVIGATION AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.01.19 STAR TRACKER	PROVIDE POSITION INFORMATION FOR THE GUIDANCE, NAVIGATION AND CONTROL	1. FAILURE TO OPERATE	ACTUAL LOSS THIS ITEM IS NOT REQUIRED FOR SYSTEM OPERATION, APPROPRIATE SIGNALS CAN BE OBTAINED FROM OTHER SENSORS INCLUDING THE REDUNDANT STAR TRACKER 37.01.18	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED	
		2. ERRONEOUS OUTPUT	SAME AS ABOVE	F		NONE FOR F AND SUBSEQUENT PHASES.	NONE

FORM 888-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.21 VOLTAGE LIMITER CONTROL	CONTROL VOLTAGE OUTPUT OF FUEL CELL 37.04.05	1. FAILURE TO OPERATE	ACTUAL LOSS. LOSS OF ABILITY OF FUEL CELL 37.04.05 TO SUPPLY ELECTRIC POWER. REDUNDANT FUEL CELL 37.04.08 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		2. FAILURE TO OPERATE CORRECTLY	POSSIBLE LOSS. INCORRECT VOLTAGE OUTPUT MAY CAUSE DEGRADED PERFORMANCE OF ELECTRICAL SYSTEM.	F G H I J K L M N O P Q R S T U V W	F G H I J K L M N O P Q R S T U V W	POSSIBLE LOSS. POSSIBLE LOSS OF ELECTRICAL SYSTEM.	POSSIBLE LOSS

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: *COMMAND AND CONTROL*
SYSTEM: ELECTRICAL

F ⊛ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊛ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊛ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊛ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊛ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊛ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊛ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊛ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.22 VOLTAGE LIMITER CONTROL	CONTROL VOLTAGE OUTPUT OF FUEL CELL 37.04.08	1. FAILURE TO OPERATE	ACTUAL LOSS LOSS OF ABILITY OF FUEL CELL 37.04.08 TO SUPPLY ELECTRIC POWER. REDUNDANT FUEL CELL 37.04.05 WILL PROVIDE ELECTRICAL POWER	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE
		2. FAILURE TO OPERATE CORRECTLY	POSSIBLE LOSS INCORRECT VOLTAGE OUTPUT MAY CAUSE DEGRADED PERFORMANCE OF ELECTRICAL SYSTEM	F G H I J K L M N O P Q R S T U V W	F G H I J K L M N O P Q R S T U V W	POSSIBLE LOSS POSSIBLE LOSS OF ELECTRICAL SYSTEM.	POSSIBLE LOSS

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.03.08 COMMAND LOGIC UNIT	PERFORM UPLINK COMMAND ROUTING	1. FAILURE TO OPERATE	ACTUAL LOSS UPLINK COMMAND SYSTEM WILL BE INOPERATIVE. UPLINK COMMAND SYSTEM IS NOT REQUIRED FOR MISSION SUCCESS.	F		NONE FOR F AND SUBSEQUENT PHASES. COMPONENT IS NOT REQUIRED FOR MISSION SUCCESS.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.03.09 TRACKING SYSTEM	RECEIVES AND TRANSMITS TRACKING SIGNALS	1. FAILURE TO OPERATE	ACTUAL LOSS TRACKING CAPABILITY IS LOST. TRACKING CAPABILITY IS NOT REQUIRED FOR MISSION SUCCESS.	F		NONE FOR F AND SUGSEQUENT PHASES. SYSTEM IS NOT REQUIRED FOR MISSION SUCCESS.	NONE

FORM 620-978

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.03.10 ANTENNA SYSTEM	RECEIVE UPLINK SIGNALS AND TRANSMIT DOWNLINK SIGNALS	1. FAILURE TO OPERATE	ACTUAL LOSS UPLINK COMMAND AND DOWNLINK DATA CHANNELS WILL BE LOST. THESE SYSTEMS ARE NOT REQUIRED FOR MISSION SUCCESS.	F		NONE FOR F AND SUBSEQUENT PHASES. SYSTEMS ARE NOT REQUIRED FOR MISSION SUCCESS.	NONE

FORM 638-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.03.11 POWER AMPLIFIER ASSEMBLY	AMPLIFIER DOWNLINK SIGNALS	1. FAILURE TO OPERATE	ACTUAL LOSS DOWNLINK DATA SYSTEM IS LOST. THIS SYSTEM IS NOT REQUIRED FOR MISSION SUCCESS.	F	NONE FOR F AND SUBSEQUENT PHASES. SYSTEM IS NOT REQUIRED FOR MISSION SUCCESS.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.03.12 RECEIVER	RECEIVES UPLINK SIGNALS	1. FAILURE TO OPERATE	ACTUAL LOSS THE UPLINK COMMAND SYSTEM IS INOPERATIVE. THIS SYSTEM IS NOT REQUIRED FOR MISSION SUCCESS.	F		NONE FOR F AND SUBSEQUENT PHASES. THIS SYSTEM IS NOT REQUIRED FOR MISSION SUCCESS.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.03.13 SIGNAL CONDITIONER	DEMODULATES UPLINK SIGNALS	1. FAILURE TO OPERATE	ACTUAL LOSS THE UPLINK SYSTEM IS LOST. THIS SYSTEM IS *NOT* REQUIRED FOR MISSION SUCCESS.	F	NONE FOR F AND SUBSEQUENT PHASES. THIS SYSTEM IS NOT REQUIRED FOR MISSION SUCCESS.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.03.14 SIGNAL PROCESSOR ASSEMBLY	PROCESSES UPLINK AND DOWNLINK SIGNALS	1. FAILURE TO OPERATE	ACTUAL LOSS UPLINK AND DOWNLINK CAPABILITY IS LOST. THESE SYSTEMS ARE NOT REQUIRED FOR MISSION SUCCESS.	F	NONE FOR F AND SUBSEQUENT PHASES. SYSTEMS ARE NOT REQUIRED FOR MISSION SUCCESS.	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F = TRANSLUNAR INJECTION
G = PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H = INSERTION INTO ELLIPTICAL LUNAR ORBIT
I = PULSED AFTERCOOLING
J = APOLUNE PLANE CHANGE
K = PULSED AFTERCOOLING
L = CIRCULARIZE AT TARGET ALTITUDE
M = PULSED AFTERCOOLING
N = LUNAR ORBIT OPERATIONS
O = INSERTION INTO ELLIPTICAL LUNAR ORBIT
P = PULSED AFTERCOOLING
Q = APOLUNE PLANE CHANGE
R = PULSED AFTERCOOLING
S = TRANSEARTH INJECTION
T = PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U = EARTH ORBIT CAPTURE
V = PULSED AFTERCOOLING
W = ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.01							
HYDROGEN ASSEMBLY	PROVIDE LIQUID HYDROGEN FOR FUEL CELL 37.04.05	1. LEAK	POSSIBLE LOSS. LOSS OF LH_2 FOR FUEL CELL 37.04.05 MAY PREVENT GENERATION OF ELECTRICAL POWER. FUEL CELL 37.04.08 WITH SEPARATE LH_2 SUPPLY WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		2. BURST	POSSIBLE LOSS POSSIBLE DAMAGE TO OTHER COMPONENTS IN THE SUBSYSTEM.	F G H I J K L M N O P Q R S T U V W	F G H I J K L M N O P Q R S T U V W	POSSIBLE LOSS POSSIBLE DAMAGE TO OTHER COMPONENTS IN THE COMMAND AND CONTROL MODULE.	POSSIBLE LOSS

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.02 HYDROGEN ASSEMBLY	PROVIDE LIQUID HYDROGEN FOR FUEL CELL 37.04.08	1. LEAK	POSSIBLE LOSS. LOSS OF LH_2 FOR FUEL CELL 37.04.08 MAY PREVENT GENERATION OF ELECTRICAL POWER. FUEL CELL 37.04.05 WITH SEPARATE LH_2 SUPPLY WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE
		1. BURST	POSSIBLE LOSS POSSIBLE DAMAGE TO OTHER COMPONENTS IN THE SUBSYSTEM	F G H I J K L M N O P Q R S T U V W	F G H I J K L M N O P Q R S T U V W	POSSIBLE LOSS POSSIBLE DAMAGE TO OTHER COMPONENTS IN THE COMMAND AND CONTROL MODULE.	POSSIBLE LOSS

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.03 OXYGEN ASSEMBLY	PROVIDE LIQUID OXYGEN FOR FUEL CELL 37.04.05	1. LEAK	POSSIBLE LOSS. LOSS OF LO_2 FOR FUEL CELL 37.04.05 MAY PREVENT GENERATION OF ELECTRICAL POWER. FUEL CELL 37.04.08 WITH SEPARATE LO_2 SUPPLY WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		2. BURST	POSSIBLE LOSS. POSSIBLE DAMAGE TO OTHER COMPONENTS IN THE SUBSYSTEM.	F G H I J K L M N O P Q R S T U V W	F G H I J K L M N O P Q R S T U V W	POSSIBLE LOSS. POSSIBLE DAMAGE TO OTHER COMPONENTS IN THE COMMAND AND CONTROL MODULE.	POSSIBLE LOSS

FORM 888-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.04							
OXYGEN ASSEMBLY	PROVIDE LIQUID OXYGEN FOR FUEL CELL 37.04.08	1. LEAK	POSSIBLE LOSS LOSS OF LO_2 FOR FUEL CELL 37.04.08 MAY PREVENT GENERATION OF ELECTRICAL POWER. FUEL CELL 37.04.05 WITH SEPARATE LO_2 SUPPLY WILL PROVIDE ELECTRICAL POWER.	F	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05	NONE
		2. BURST	POSSIBLE LOSS POSSIBLE DAMAGE TO OTHER COMPONENTS IN THE SUBSYSTEM	F G H I J K L M N O P Q R S T U V W	F G H I J K L M N O P Q R S T U V W	POSSIBLE LOSS. POSSIBLE DAMAGE TO OTHER COMPONENTS IN THE COMMAND AND CONTROL MODULE.	POSSIBLE LOSS

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.05 FUEL CELL	GENERATES ELECTRICAL POWER FOR RNS SYSTEMS.	1. FAILURE TO OPERATE	ACTUAL LOSS BUT REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		2. LEAK	ACTUAL LOSS. SHUTOFF VALVES 37.04.11 AND 37.04.13 PROVIDE SHUTOFF CAPABILITY BUT LOSS OF LH_2 AND LO_2 PREVENT GENERATION OF ELECTRICAL POWER. ELECTRICAL POWER WILL BE PROVIDED BY REDUNDANT FUEL CELL 37.04.08.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.06 HYDROGEN CONTROL ASSEMBLY	CONTROLS FLOW OF LIQUID HYDROGEN TO FUEL CELL 37.04.05	1. FAILURE TO OPERATE.	ACTUAL LOSS. LIQUID HYDROGEN WILL NOT BE DELIVERED TO FUEL CELL 37.04.05, HOWEVER, FUEL CELL 37.04.08 WITH ITS SEPARATE LH_2 CONTROL PROVIDES REDUNDANCY.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		2. FAILURE TO CEASE CPERATION.	ACTUAL LOSS. SHUTOFF VALVE WILL PREVENT ADDITIONAL LOSS OF LH_2. FUEL CELL 37.04.08 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		3. LEAK	POSSIBLE LOSS. LOSS OF LH_2 MAY CAUSE LOSS OF ABILITY OF FUEL CELL 37.04.05 TO PROVIDE ELECTRICAL POWER. FUEL CELL 37.04.08 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.07 OXYGEN CONTROL ASSEMBLY	CONTROL, FLOW OF LIQUID OXYGEN TO FUEL CELL 37.04.05	1. FAILURE TO OPERATE.	ACTUAL LOSS. LIQUID OXYGEN WILL NOT BE DELIVERED TO FUEL CELL 37.04.05, HOWEVER, FUEL CELL 37.04.08 WITH ITS SEPARATE LO_2 CONTROL PROVIDES REDUNDANCY.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		2. FAILURE TO CEASE OPERATION	ACTUAL LOSS. SHUTOFF VALVE WILL PREVENT ADDITIONAL LOSS OF LO_2. FUEL CELL 37.04.08 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		3. LEAK	POSSIBLE LOSS. LOSS OF LO_2 MAY CAUSE LOSS OF ABILITY OF FUEL CELL 37.04.05 TO PROVIDE ELECTRICAL POWER. FUEL CELL 37.04.05 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE

FORM 639-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.08 FUEL CELL	GENERATES ELECTRICAL POWER FOR RNS SYSTEMS.	1. FAILURE TO OPERATE.	ACTUAL LOSS BUT REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE
		2. LEAK	ACTUAL LOSS. SHUTOFF VALVES 37.04.12 AND 37.04.14 PROVIDE SHUTOFF CAPABILITY BUT LOSS OF LH_2 AND LO_2 PREVENT GENERATION OF ELECTRICAL POWER. ELECTRICAL POWER WILL BE PROVIDED BY REDUNDANT FUEL CELL 37.04.05.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F = TRANSLUNAR INJECTION
G = PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H = INSERTION INTO ELLIPTICAL LUNAR ORBIT
I = PULSED AFTERCOOLING
J = APOLUNE PLANE CHANGE
K = PULSED AFTERCOOLING
L = CIRCULARIZE AT TARGET ALTITUDE
M = PULSED AFTERCOOLING
N = LUNAR ORBIT OPERATIONS
O = INSERTION INTO ELLIPTICAL LUNAR ORBIT
P = PULSED AFTERCOOLING
Q = APOLUNE PLANE CHANGE
R = PULSED AFTERCOOLING
S = TRANSEARTH INJECTION
T = PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U = EARTH ORBIT CAPTURE
V = PULSED AFTERCOOLING
W = ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.09							
HYDROGEN CONTROL ASSEMBLY	CONTROLS FLOW OF LIQUID HYDROGEN TO FUEL CELL 37.04.08	1. FAILURE TO OPERATE	ACTUAL LOSS. LIQUID HYDROGEN WILL NOT BE DELIVERED TO FUEL CELL 37.04.08, HOWEVER, FUEL CELL 37.04.05 WITH ITS SEPARATE LH_2 CONTROL PROVIDES REDUNDANCY.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE
		2. FAILURE TO *CEASE OPERATION*	ACTUAL LOSS. SHUTOFF VALVE WILL PREVENT ADDITIONAL LOSS OF LH_2. FUEL CELL 37.04.05 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE
		3. LEAK	POSSIBLE LOSS. LOSS OF LH_2 MAY CAUSE LOSS OF ABILITY OF FUEL CELL 37.04.08 TO PROVIDE ELECTRICAL POWER. FUEL CELL 37.04.05 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.10 OXYGEN CONTROL ASSEMBLY	CONTROLS FLOW OF LIQUID OXYGEN TO FUEL CELL 37.04.05	1. FAILURE TO OPERATE.	ACTUAL LOSS. LIQUID OXYGEN WILL NOT BE DELIVERED TO FUEL CELL 37.04.08, HOWEVER, FUEL CELL 37.04.05 WITH ITS SEPARATE LO_2 CONTROL PROVIDES REDUNDANCY.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE
		2. FAILURE TO CEASE OPERATION	ACTUAL LOSS. SHUTOFF VALVE WILL PREVENT ADDITIONAL LOSS OF LO_2. FUEL CELL 37.04.05 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE
		3. LEAK	POSSIBLE LOSS. LOSS OF LO_2 MAY CAUSE LOSS OF ABILITY OF FUEL CELL 37.04.08 TO PROVIDE ELECTRICAL POWER. FUEL CELL 37.04.05 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.11 SHUTOFF VALVE LIQUID HYDROGEN	PROVIDES SHUTOFF CAPABILITY BETWEEN THE LIQUID HYDROGEN CONTROL ASSEMBLY 37.04.06 AND FUEL CELL 37.01.05	1. FAILURE TO OPEN	ACTUAL LOSS. LIQUID HYDROGEN WILL NOT BE DELIVERED TO FUEL CELL 37.04.05 CAUSING LOSS OF ABILITY TO GENERATE ELECTRICAL POWER. REDUNDANT FUEL CELL 37.04.08 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		2. FAILURE TO REMAIN OPEN	SAME AS ABOVE	F		NONE	NONE
		3. FAILURE TO CLOSE	NONE. HYDROGEN CONTROL MODULE 37.04.06 PROVIDES REDUNDANCY.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE
		4. FAILURE TO REMAIN CLOSED	NONE. HYDROGEN CONTROL MODULE 37.04.06 PROVIDES REDUNDANCY.	F		NONE	NONE
		5. LEAK	NONE. HYDROGEN CONTROL MODULE 37.04.06 PROVIDES REDUNDANCY	F		NONE	NONE

FORM 839-378

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.12 SHUTOFF VALVE LIQUID HYDROGEN	PROVIDES SHUTOFF CAPABILITY BETWEEN THE LIQUID HYDROGEN CONTROL ASSEMBLY 37.04.09 AND FUEL CELL 37.01.08	1. FAILURE TO OPEN	ACTUAL LOSS. LIQUID HYDROGEN WILL NOT BE DELIVERED TO FUEL CELL 37.04.08 CAUSING LOSS OF ABILITY TO GENERATE ELECTRICAL POWER. REDUNDANT FUEL CELL 37.04.05 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL DELL 37.04.05.	NONE
		2. FAILURE TO REMAIN OPEN	SAME AS ABOVE	F		NONE	NONE
		3. FAILURE TO CLOSE	NONE. HYDROGEN CONTROL MODULE 37.04.09 PROVIDES REDUNDANCY	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE
		4. FAILURE TO REMAIN CLOSED	NONE. HYDROGEN CONTROL MODULE 37.04.09 PROVIDES REDUNDANCY	F		NONE	NONE
		5. LEAK	NONE. HYDROGEN CONTROL MODULE 37.04.09 PROVIDES REDUNDANCY	F		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL MODULE
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.13 SHUTOFF VALVE LIQUID OXYGEN	PROVIDES SHUTOFF CAPABILITY BETWEEN THE LIQUID OXYGEN CONTROL ASSEMBLY 37.04.07 AND FUEL CELL 37.01.05	1. FAILURE TO OPEN	ACTUAL LOSS. LIQUID OXYGEN WILL NOT BE DELIVERED TO FUEL CELL 37.04.05 CAUSING LOSS OF ABILITY TO GENERATE ELECTRICAL POWER. REDUNDANT FUEL CELL 37.04.08 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		2. FAILURE TO REMAIN OPEN	SAME AS ABOVE	F		NONE	NONE
		3. FAILURE TO CLOSE	NONE. OXYGEN CONTROL MODULE 37.04.07 PROVIDES REDUNDANCY	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE
		4. FAILURE TO REMAIN CLOSED	NONE. OXYGEN CONTROL MODULE 37.04.07 PROVIDES REDUNDANCY	F		NONE	NONE
		5. LEAK	NONE. OXYGEN CONTROL MODULE 37.04.07 PROVIDES REDUNDANCY.	F		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.14 SHUTOFF VALVE LIQUID OXYGEN	PROVIDES SHUTOFF CAPABILITY BETWEEN THE LIQUID OXYGEN CONTROL ASSEMBLY 37.04.10 AND FUEL CELL 37.01.08	1. FAILURE TO OPEN	ACTUAL LOSS. LIQUID OXYGEN WILL NOT BE DELIVERED TO FUEL CELL 37.04.08 CAUSING LOSS OF ABILITY TO GENERATE ELECTRICAL POWER. REDUNDANT FUEL CELL 37.04.05 WILL PROVIDE ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE
		2. FAILURE TO REMAIN OPEN	SAME AS ABOVE	F		NONE	NONE
		3. FAILURE TO CLOSE	NONE. OXYGEN CONTROL MODULE 37.04.10 PROVIDES REDUNDANCY	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE
		4. FAILURE TO REMAIN CLOSED	NONE. OXYGEN CONTROL MODULE 37.04.10 PROVIDES REDUNDANCY	F		NONE	NONE
		5. LEAK	NONE. OXYGEN CONTROL MODULE 37.04.10 PROVIDES REDUNDANCY	F		NONE	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.15 INVERTER ASSEMBLY	CONVERTS THE DIRECT CURRENT ELECTRICAL POWER FROM THE FUEL CELLS TO ALTERNATING CURRENT ELECTRICAL POWER.	1. FAILURE TO OPERATE	ACTUAL LOSS. CONVERSION OF ELECTRICAL POWER WILL NOT BE ACCOMPLISHED. REDUNDANT INVERTER ASSEMBLY 37.04.16 WILL PROVIDE THIS CAPABILITY	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY INVERTER ASSEMBLY 37.04.16	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.16 INVERTER ASSEMBLY	CONVERTS THE DIRECT CURRENT ELECTRICAL POWER FROM THE FUEL CELLS TO ALTERNATING CURRENT ELECTRICAL POWER.	1. FAILURE TO OPERATE	ACTUAL LOSS. CONVERSION OF ELECTRICAL POWER WILL NOT BE ACCOMPLISHED. REDUNDANT INVERTER ASSEMBLY 37.04.15 WILL PROVIDE THIS CAPABILITY	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY INVERTER ASSEMBLY 37.04.15	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.17 INVERTER CONTROL RELAY	CONTROL INVERTER ASSEMBLY 37.04.15	1. FAILURE TO OPERATE	ACTUAL LOSS. INVERTER ASSEMBLY 37.04.15 WILL BE INOPERABLE. REDUNDANT INVERTER ASSEMBLY 37.04.16 WILL PROVIDE THE ELECTRICAL CONVERSION FUNCTION.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY INVERTER ASSEMBLY 37.04.16	

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.18 INVERTER CONTROL RELAY	CONTROL INVERTER ASSEMBLY 37.04.16	FAILURE TO OPERATE	ACTUAL LOSS. INVERTER ASSEMBLY 37.04.16 WILL BE INOPERABLE. REDUNDANT INVERTER ASSEMBLY 37.04.15 WILL PROVIDE THE ELECTRICAL CONVERSION FUNCTION.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY INVERTER ASSEMBLY 37.04.15	

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.19 VOLTAGE LIMITER SENSOR	MONITORS OUTPUT OF FUEL CELL 37.04.05	1. FAILURE TO OPERATE	ACTUAL LOSS. FUEL CELL 37.04.05 WILL BE INOPERATIVE. REDUNDANT FUEL CELL 37.01.08 WILL PROVIDE REQUIRED ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		2. ERRONEOUS OUTPUT	POSSIBLE LOSS ERRONEOUS OUTPUT MAY CAUSE OUTPUT OF TWO FUEL CELLS TO BE DIFFERENT CAUSING DEGRADED PERFORMANCE.	F G H I J K L M N O P Q R S T U V W	F G H I J K L M N O P Q R S T U V W	POSSIBLE LOSS. POSSIBLE LOSS OF ELECTRICAL SYSTEM.	POSSIBLE LOSS.

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.20 VOLTAGE LIMITOR SENSOR	MONITORS OUTPUT OF FUEL CELL 37.04.08	1. FAILURE TO OPERATE	ACTUAL LOSS. FUELL CELL 37.04.08 WILL BE INOPERATIVE. REDUNDANT FUEL CELL 37.01.05 WILL PROVIDE REQUIRED ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE
		2. ERRONEOUS OUTPUT	POSSIBLE LOSS. ERRONEOUS OUTPUT MAY CAUSE OUTPUT OF TWO FUEL CELLS TO BE DIFFERENT CAUSING DEGRADED PERFORMANCE.	F G H I J K L M N O P Q R S T U V W	F G H I J K L M N O P Q R S T U V W	POSSIBLE LOSS. POSSIBLE LOSS OF ELECTRICAL SYSTEM.	POSSIBLE LOSS

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.23 COMMAND SYSTEM INVERTER SWITCH	PROVIDE MANUAL CONTROL OF INVERTERS	FAILURE TO OPERATE	ACTUAL LOSS LOSS OF MANUAL CONTROL OF INVERTERS. AUTOMATIC CONTROL SHOULD PROVIDE ADEQUATE CONTROL. FAILURE NOT APPLICABLE TO A SINGLE FAILURE ANALYSIS.	F	NONE FOR F AND SUBSEQUENT PHASES.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
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N LUNAR ORBIT OPERATIONS
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P PULSED AFTERCOOLING
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R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.24 START-UP CONTROLS	PROVIDE COMPONENTS AND CONTROL REQUIRED TO START-UP THE ELECTRICAL SYSTEM	FAILURE TO OPERATE	ACTUAL LOSS ABILITY TO START-UP ELECTRICAL SYSTEM IS LOST.	W		ACTUAL LOSS	MISSION WILL BE DELAYED

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.25 MAIN BUSS	TRANSMIT ELECTRICAL CURRENT	1. SHORT	ACTUAL LOSS BUS TRANSFER RELAY 37.04.29, AND MAIN FEED CONTACTORS WILL OPERATE AND REMOVE MAIN BUSS FROM SYSTEM AND TRANSFER FUEL CELLS TO AUXILIARY BUSSES 37.04.28.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANT OPERATION IS PROVIDED BY AUXILIARY BUSSES 37.04.28.	NONE
		2. OPEN	SAME AS ABOVE.	F		SAME AS ABOVE.	NONE
		3. HIGH RESISTANCE	SAME AS ABOVE.	F		SAME AS ABOVE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.26 MAIN FEED CONTACTORS	CONNECT FUEL CELL 37.04.05 TO MAIN BUSS	1. FAILURE TO CLOSE	ACTUAL LOSS. ELECTRICAL POWER FROM FUEL CELL 37.04.05 CANNOT REACH MAIN BUSS REDUNDANT FUEL CELL 37.04.08 WITH MAIN FEED CONTACTOR 37.04.27 WILL PROVIDE REQUIRED ELECTRICAL POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE
		2. FAILURE TO REMAIN CLOSED	SAME AS ABOVE	F		SAME AS ABOVE	NONE
		3. FAILURE TO OPEN	CONTACTOR SHOULD NOT BE REQUIRED TO OPEN UNLESS FAILURES EXIST IN OTHER COMPONENTS.	F		NONE FOR F AND SUBSEQUENT PHASES. FAILURE NOT APPLICABLE TO SINGLE FAILURE ANALYSIS.	NONE
		4. FAILURE TO REMAIN OPEN	SAME AS FAILURE TYPE NO. 3	F		SAME AS FAILURE TYPE NO. 3	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.27 MAIN FEED CONTACTORS	CONNECT FUEL CELL 37.04.08 TO MAIN BUSS	1. FAILURE TO CLOSE	ACTUAL LOSS. ELECTRICAL POWER FROM FUEL CELL 37.04.08 CANNOT REACH MAIN BUSS REDUNDANT FUEL CELL 37.04.05 WITH MAIN FEED CONTACTOR 37.04.26 WILL PROVIDE REQUIRED ELECTRICAL POWER.	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE
		2. FAILURE TO REMAIN CLOSED	SAME AS ABOVE	F	SAME AS ABOVE	NONE
		3. FAILURE TO OPEN	CONTACTOR SHOULD NOT BE REQUIRED TO OPEN UNLESS FAILURE EXISTS IN OTHER COMPONENTS	F	NONE FOR F AND SUBSEQUENT PHASES. FAILURE NOT APPLICABLE TO SINGLE FAILURE ANALYSIS.	NONE
		4. FAILURE TO REMAIN OPEN	SAME AS FAILURE TYPE NO. 3	F	SAME AS FAILURE TYPE NO. 3	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
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Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.28 AUXILIARY BUSSES (NUMBER TO BE DETERMINED)	TRANSMIT ELECTRICAL CURRENT TO REDUNDANT SYSTEMS. SYSTEM WILL BE DESIGNED TO OPERATE SATISFACTORILY WITH ONE BUSS FAILURE.	1. SHORT	NONE. NOT APPLICABLE TO SINGLE FAILURE ANALYSIS.	F		NONE	NONE
		2. OPEN	SAME AS ABOVE	F		NONE	NONE
		3. HIGH RESISTANCE	SAME AS ABOVE	F		NONE	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION–IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.29 LOW VOLTAGE SENSOR	MONITORS VOLTAGE ON MAIN BUSS 37.04.25. PROVIDES SIGNAL TO LOW VOLTAGE RELAY 37.04.37 WHEN BUSS VOLTAGE IS LOW	1. FAILURE TO OPERATE	NONE. FAILURE DOES NOT APPLY TO SINGLE FAILURE ANALYSIS	F		NONE	NONE
		2. OPERATES WHEN NOT REQUIRED	ACTUAL. MAIN BUSS WILL BE REMOVED FROM THE FUEL CELLS. AUXILIARY BUSSES 37.04.28 WILL PROVIDE ELECTRIC POWER TO SYSTEMS.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.30 BUSS TRANSFER RELAY ASSEMBLY	TRANSFERS ELECTRICAL POWER TO AUXILIARY BUSSES IF FAILURE TO MAIN BUSS OCCURS.	1. FAILURE TO OPERATE	NONE. NOT APPLICABLE TO SINGLE FAILURE ANALYSIS.	F		NONE	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.31 CURRENT SENSOR	MONITORS CURRENT DRAWN FROM FUEL CELL 37.04.05 DIAGNOSTIC ONLY.	FAILURE TO OPERATE	NONE FAILURE OF THIS ITEM WILL NOT EFFECT SYSTEM PERFORMANCE.	F	NONE FOR F AND SUBSEQUENT PHASES.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING
MIDCOURSE CORRECTION–IDLE MODE
TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING
MIDCOURSE CORRECTION–IDLE MODE
TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.32 CURRENT SENSOR	MONITORS CURRENT DRAWN FROM FUEL CELL 37.04.08 DIAGNOSTIC ONLY.	FAILURE TO OPERATE	NONE FAILURE OF THIS ITEM WILL NOT EFFECT SYSTEM PERFORMANCE	F	NONE FOR F AND SUBSEQUENT PHASES	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.33 REVERSE CURRENT SENSOR	MONITORS DIRECTION OF CURRENT OUT OF FUEL CELL 37.04.05, SENDS SIGNAL TO REVERSE CURRENT SWITCH 37.04.35 WHEN FUEL CELL IS DRAWING CURRENT FROM MAIN BUSS 37.04.25	1. FAILURE TO OPERATE	NONE. FAILURE NOT APPLICABLE TO SINGLE FAILURE ANALYSIS.	F	NONE	NONE
		2. OPERATES WHEN NOT REQUIRED	ACTUAL LOSS. FUEL CELL 37.04.05 IS REMOVED FROM THE SYSTEM. FUEL CELL 37.04.08 WILL PROVIDE ELECTRIC POWER.	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.08.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.34 REVERSE CURRENT SENSOR	MONITORS DIRECTION IF CURRENT OUT OF FUEL CELL 37.04.08, SENDS SIGNAL TO REVERSE CURRENT SWITCH 37.04.36 WHEN FUEL CELL IS DRAWING CURRENT FROM MAIN BUSS 37.04.25	1. FAILURE TO OPERATE	NONE. FAILURE NOT APPLICABLE TO SINGLE FAILURE ANALYSIS.	F		NONE	NONE
		2. OPERATES WHEN NOT REQUIRED	ACTUAL LOSS. FUEL CELL 37.04.08 IS REMOVED FROM THE SYSTEM. FUEL CELL 37.04.05 WILL PROVIDE ELECTRIC POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL 37.04.05.	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.35 REVERSE CURRENT SWITCH	TRANSMITS SIGNAL FROM REVERSE CURRENT SENSOR 37.04.33 TO MAIN FEED CONTACTOR 37.04.26 TO OPEN WHEN FUEL CELL 37.04.05 TO DRAWING CURRENT FROM MAIN BUSS 37.04.25 SWITCH IS CLOSED FOR NOMINAL OPERATION.	1. FAILURE TO CLOSE	ACTUAL LOSS. FUEL CELL 37.04.05 IS NOT CONNECTED TO THE MAIN BUSS 37.04.25 REDUNDANT FUEL CELL 37.04.08 WILL PROVIDE REQUIRED ELECTRIC POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL SYSTEM 37.04.08.	NONE
		2. FAILURE TO REMAIN CLOSED	SAME AS ABOVE	F		NONE	NONE
		3. FAILURE TO OPEN	NONE. FAILURE NOT APPLICABLE TO SINGLE FAILURE ANALYSIS.	F		NONE	NONE
		4. FAILURE TO REMAIN OPEN	SAME AS FAILURE TYPE NO. 3	F		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.36 REVERSE CURRENT SWITCH	TRANSMITS SIGNAL FROM REVERSE CURRENT SENSOR 37.04.34 TO MAIN FEED CONTACTOR 37.04.27 TO OPEN WHEN FUEL CELL 37.04.08 TO DRAWING CURRENT FROM MAIN BUSS 37.04.25. SWITCH IS CLOSED FOR NORMAL OPERATION	1. FAILURE TO CLOSE	ACTUAL LOSS FUEL CELL 37.04.08 IS NOT CONNECTED TO THE MAIN BUSS 37.04.25. REDUNDANT FUEL CELL 37.04.05 WILL PROVIDE REQUIRED ELECTRIC POWER.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY FUEL CELL SYSTEM 37.04.05	NONE
		2. FAILURE TO REMAIN CLOSED	SAME AS ABOVE	F		NONE	NONE
		3. FAILURE TO OPEN	NONE. FAILURE NOT APPLICABLE TO SINGLE FAILURE ANALYSIS.	F		NONE	NONE
		4. FAILURE TO REMAIN OPEN	SAME AS FAILURE TYPE NO. 3	F		NONE	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.37 LOW VOLTAGE RELAY	TRANSMITS SIGNAL FROM LOW VOLTAGE SENSOR 37.04.29 TO BUSS TRANSFER RELAY 37.04.30 AND MAIN CONTRACTORS 37.04.26 AND 37.04.27 TO REMOVE MAIN BUSS 37.04.25 FROM FUEL CELLS AND CONNECT AUXILIARY BUSSES 37.04.28	1. FAILURE TO CLOSE	NONE. FAILURE DOES NOT APPLY TO SINGLE FAILURE ANALYSIS.		NONE	NONE
		2. FAILURE TO REMAIN CLOSED	NONE. FAILURE DOES NOT APPLY TO SINGLE FAILURE ANALYSIS.		NONE	NONE
		3. FAILURE TO OPEN	NONE. FAILURE DOES NOT APPLY TO SINGLE FAILURE ANALYSIS.		NONE	NONE
		4. FAILURE TO REMAIN OPEN	ACTUAL LOSS MAIN BUSS 37.04.25 WILL BE REMOVED FROM FUEL CELLS. AUXILIARY BUSSES 37.04.28 WILL PROVIDE ELECTRICAL POWER.	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY AUXILIARY BUSSES 37.04.28.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE			FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.38 BATTERY	PROVIDES PEAK LOAD CURRENT	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANCY BATTERY 37.04.39 WILL PROVIDE REQUIRED ELECTRICAL POWER.	F			NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY BATTERY 37.04.39	NONE
		2. SHORT	ACTUAL LOSS ABILITY TO PRODUCE POWER IS LOST. REDUNDANCY IS PROVIDED BY BATTERY 37.04.39. REVERSE CURRENT PROTECTION IS PROVIDED BY REVERSE CURRENT ASSEMBLY 37.04.40	F			NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.39 BATTERY	PROVIDES PEAK LOAD CURRENT	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANCY BATTERY 37.04.38 WILL PROVIDE REQUIRED ELECTRICAL POWER	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY BATTERY 37.04.38.	NONE
		2. SHORT	ACTUAL LOSS ABILITY TO PRODUCE POWER IS LOST. REDUNDANCY IS PROVIDED BY BATTERY 37.04.38. REVERSE CURRENT PROTECTION IS PROVIDED BY REVERSE CURRENT ASSEMBLY 37.04.41.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.40 REVERSE CURRENT ASSEMBLY	SENSE CURRENT DIRECTION OUT OF BATTERY 37.04.38 AND PREVENT BATTERY FROM DRAWING CURRENT FROM MAIN BUSS 37.04.25.	1. FAILURE TO OPERATE	NONE. FAILURE DOES NOT APPLY TO SINGLE FAILURE ANALYSIS.		NONE	NONE
		2. OPERATES WHEN NOT REQUIRED	ACTUAL LOSS BATTERY 37.04.38 IS REMOVED FROM ELECTRICAL SYSTEM. REDUNDANT BATTERY 37.04.39 WILL PROVIDE REQUIRED ELECTRICAL POWER.	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION--IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.41 REVERSE CURRENT ASSEMBLY	SENSE CURRENT DIRECTION OUT OF BATTERY 37.04.39 AND PREVENT BATTERY FROM DRAWING CURRENT FROM MAIN BUSS 37.04.25.	1. FAILURE TO OPERATE	NONE. FAILURE DOES NOT APPLY TO SINGLE FAILURE ANALYSIS.		NONE	NONE
		2. OPERATES WHEN NOT REQUIRED	ACTUAL LOSS BATTERY 37.04.39 IS REMOVED FROM ELECTRICAL SYSTEM. REDUNDANT BATTERY 37.04.38 WILL PROVIDE REQUIRED ELECTRICAL POWER.	F	NONE FOR F AND SUBSEQUENT PHASES, REDUNDANCY IS PROVIDED.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.42 BATTERY CHARGER	RECHARGE REUSABLE BATTERIES	1. FAILURE TO OPERATE	ACTUAL LOSS BATTERY 37.04.38 WILL NOT BE RECHARGED. REDUNDANCY IS PROVIDED BY BATTERY 37.04.39	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY BATTERY 37.04.39 AND BATTERY CHARGER 37.04.43	

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: ELECTRICAL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.04.43 BATTERY CHARGER	RECHARGE REUSABLE BATTERIES	1. FAILURE TO OPERATE	ACTUAL LOSS BATTERY 37.04.39 WILL NOT BE RECHARGED. REDUNDANCY IS PROVIDED BY BATTERY 37.04.38	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY BATTERY 37.04.38 AND BATTERY CHARGER 37.04.42.	

FORM 888-378

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.09.01 COMPUTER DIGITAL	PROVIDES THE COMPUTATION CAPABILITY FOR THE NAVIGATION, CONTROL, COMMAND AND DATA ACQUISITION SYSTEM	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANT COMPUTERS 37.09.02 AND 37.09.03 PROVIDE REQUIRED COMPUTATIONAL CAPABILITY.	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY COMPUTERS 37.09.02 AND 37.09.03.	NONE
		2. ERRONEOUS OUTPUT	ACTUAL LOSS THREE COMPUTERS ARE PROVIDED TO ALLOW A VOTING LOGIC WHERE A NON-CONFORMING OUTPUT WILL BE REJECTED.	F	NONE FOR F AND SUBSEQUENT PHASES. THREE COMPUTERS ARE PROVIDED.	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F = TRANSLUNAR INJECTION
G = PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H = INSERTION INTO ELLIPTICAL LUNAR ORBIT
I = PULSED AFTERCOOLING
J = APOLUNE PLANE CHANGE
K = PULSED AFTERCOOLING
L = CIRCULARIZE AT TARGET ALTITUDE
M = PULSED AFTERCOOLING
N = LUNAR ORBIT OPERATIONS
O = INSERTION INTO ELLIPTICAL LUNAR ORBIT
P = PULSED AFTERCOOLING
Q = APOLUNE PLANE CHANGE
R = PULSED AFTERCOOLING
S = TRANSEARTH INJECTION
T = PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U = EARTH ORBIT CAPTURE
V = PULSED AFTERCOOLING
W = ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.09.02 COMPUTER DIGITAL	PROVIDES THE COMPUTATION CAPABILITY FOR THE NAVIGATION, CONTROL, COMMAND AND DATA ACQUISITION SYSTEMS.	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANT COMPUTERS 37.09,01 AND 37.09.03 PROVIDE REQUIRED COMPUTATIONAL CAPABILITY.	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY COMPUTERS 37.09.01 AND 37.09.03	NONE
		2. ERRONEOUS OUTPUT	ACTUAL LOSS THREE COMPUTERS ARE PROVIDED TO ALLOW A VOTING LOGIC WHERE A NON-CONFORMING OUTPUT WILL BE REJECTED.	F	NONE FOR F AND SUBSEQUENT PHASES. THREE COMPUTERS ARE PROVIDED.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F ● TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ● APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ● CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ● INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ● APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ● TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ● EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.09.03 COMPUTER DIGITAL	PROVIDES THE COMPUTATION CAPABILITY FOR THE NAVIGATION, CONTROL, COMMAND AND DATA ACQUISITION SYSTEMS.	1. FAILURE TO OPERATE	ACTUAL LOSS REDUNDANT COMPUTERS 37.09.02 AND 37.09.01 PROVIDE REQUIRED COMPUTATIONAL CAPABILITY.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED BY COMPUTERS 37.09.02 AND 37.09.01.	NONE
		2. ERRONEOUS OUTPUT	ACTUAL LOSS THREE COMPUTERS ARE PROVIDED TO ALLOW A VOTING LOGIC WHERE A NON-CONFORMING OUTPUT WILL BE REJECTED.	F		NONE FOR F AND SUBSEQUENT PHASES. THREE COMPUTERS ARE PROVIDED.	NONE

FORM 830-375

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F ⊕ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊕ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊕ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊕ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊕ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊕ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊕ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.09.04 COMPUTER SUBSYSTEM CONTROLLER	CONTROLS COMPUTER 37.09.01	1. FAILURE TO OPERATE	ACTUAL LOSS COMPUTER 37.09.01 WILL BE INOPERATIVE. REDUNDANT COMPUTERS 37.09.02 AND 37.09.03 WILL PROVIDE REQUIRED COMPUTATIONAL CAPABILITY.	F	NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 880-378

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.09.05 COMPUTER SUBSYSTEM CONTROLLER	CONTROLS COMPUTER 37.09.02	1. FAILURE TO OPERATE	ACTUAL LOSS COMPUTER 37.09.02 WILL BE INOPERATIVE. REDUNDANT COMPUTERS 37.09.01 AND 37.09.03 WILL PROVIDE REQUIRED COMPUTATIONAL CAPABILITY.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 830-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND COMMAND AND CONTROL

F ⊙ TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H ⊙ INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J ⊙ APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L ⊙ CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O ⊙ INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q ⊙ APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S ⊙ TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U ⊙ EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE		FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.09.06 COMPUTER SUBSYSTEM CONTROLLER	CONTROLS COMPUTER 37.09.03	1. FAILURE TO OPERATE	ACTUAL LOSS COMPUTER 37.09.03 WILL BE INOPERATIVE. REDUNDANT COMPUTERS 37.09.02 AND 37.09.01 WILL PROVIDE REQUIRED COMPUTATIONAL CAPABILITY.	F		NONE FOR F AND SUBSEQUENT PHASES. REDUNDANCY IS PROVIDED.	NONE

FORM 650-376

RELIABILITY FAILURE EFFECT ANALYSIS

MISSION: LUNAR SHUTTLE
CLASS: 1H
MODULE: COMMAND AND CONTROL
SYSTEM: COMMAND AND CONTROL

F • TRANSLUNAR INJECTION
G PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSLUNAR COAST
H • INSERTION INTO ELLIPTICAL LUNAR ORBIT
I PULSED AFTERCOOLING
J • APOLUNE PLANE CHANGE
K PULSED AFTERCOOLING
L • CIRCULARIZE AT TARGET ALTITUDE
M PULSED AFTERCOOLING
N LUNAR ORBIT OPERATIONS
O • INSERTION INTO ELLIPTICAL LUNAR ORBIT
P PULSED AFTERCOOLING
Q • APOLUNE PLANE CHANGE
R PULSED AFTERCOOLING
S • TRANSEARTH INJECTION
T PULSED AFTERCOOLING MIDCOURSE CORRECTION—IDLE MODE TRANSEARTH COAST
U • EARTH ORBIT CAPTURE
V PULSED AFTERCOOLING
W ORBIT RESUPPLY AND C/O OPERATIONS

ITEM	FUNCTION	FAILURE TYPE/MODE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	PHASE	FAILURE EFFECT ON RNS	FAILURE EFFECT ON MISSION OR SPACECRAFT
37.09.07 AUXILIARY MEMORY	STORE DATA FOR DIGITAL COMPUTER SYSTEM	1. FAILURE TO OPERATE	ACTUAL LOSS THE DATA STORED IN THE AUXILIARY MEMORY WILL NOT BE AVAILABLE TO THE DIGITAL COMPUTERS. UNDER CURRENT GROUND RULES THERE WILL NOT BE ANY FLIGHT CRITICAL DATA STORED IN THE AUXILIARY MEMORY.	F	NONE FOR F AND SUBSEQUENT PHASES. DATA IN AUXILIARY MEMORY IS NOT REQUIRED FOR MISSION SUCCESS.	NONE

2.4 CRITICALITY ANALYSIS

The criticality analysis computer printout sheets are presented in this section. The methodology and method of computation are discussed in Section 2.2. Each item listed in the FMEA sheets in Section 2.3 as an actual, probable, or possible loss item is analyzed in the analysis and quantified.

The computer printout sheets displayed in this section considered a Class 1 Hybrid design and treated external leakage as a viable failure mode. The criticality ranking list for a Class 1 Hybrid RNS and a Class 3 without leakage is shown in Table 2-7. The units of criticality are failures per million missions. The results for a Class 1 Hybrid RNS with leakage are given in the computer printout criticality ranking list tabulated in Table 2-8. A Class 3 RNS criticality ranking list would appear the same as Table 2-8 with Items 15.06-04, 15.06-08, and 15.09-07 removed and Item 15.05.05 added with a criticality of 815 units.

Table 2-7

CRITICALITY RANKING
(Without Leakage)

Rank	Criticality	Name	Number
1	10073	Engines, APS (20)	36.01.01.01
2	8399	Gas Generator (2)	36.01.02.17
3	8399	Gas Generator (2)	36.01.04.17
4	1021	Engines, Propellant Settling (2)	36.03.01.01
5	815	Valve, Block	15.05.05*
6	653	Check Valve, Resupply	25.09.11
7	199	Fill Valve	25.09.03
8	199	Fill Valve	25.09.04
9	152	Nozzle, Resupply	25.09.12
10	152	Flow Meter	25.09.10
11	144	Voltage Limiter Sensor	37.04.19
12	144	Voltage Limiter Sensor	37.04.20
13	109	Filter	36.01.02.11
14	109	Filter	36.01.04.11
15	54	Voltage Limiter Control	37.04.21
16	54	Voltage Limiter Control	37.04.22
17	42	Valve, Vent and Relief	15.10.02
18	29	Valve, Relief	15.10.03

*Class 3 only.

Table 2-8. CLASS 1 HYBRID RNS

CRITICALITY RANKING LIST

RANK	CRIT. NO.	NAME	REM NO.
1	10072.3	ENGINES,APS(20)	36.01.01-01
2	8399.0	GAS GENERATOR,LH2,APS(2)	36.01.02-17
3	8399.0	GAS GENERATOR,GO2,APS(2)	36.01.04-17
4	2592.5	QUAD VALVES,PRESS LO2APS	36.01.04-12
5	2592.5	QUAD VALVES,PRESS LH2APS	36.01.02-12
6	1425.9	CNTRL VALVES,GH2,NC22APS	36.01.01-04
7	1425.9	CNTRL VALVES,GO2,NC22APS	36.01.01-06
8	1296.3	QUAD VALVES,LH2 VENT,APS	36.01.03-12
9	1296.3	QUAD VALVES,LO2 VENT,APS	36.01.05-12
10	1021.4	ENGINES,PROP SETTLING(2)	36.03.01-01
11	657.5	GROUND PRESS VALVE,GH2	15.06-08
12	653.4	CK VALVE,RESUPPLY LH2	25.09-11
13	648.1	VALVE,LH2,NCAPS	36.01.03-07
14	648.1	VALVE,LH2,NOAPS	36.01.03-08
15	648.1	VALVE,LH2,GRD FILL,APS	36.01.03-10
16	648.1	VALVE,GH2,GRD FILL,APS	36.01.02-06
17	648.1	VALVE,GO2,NOAPS	36.01.04-03
18	648.1	VALVE,GO2,NOAPS	36.01.04-04
19	648.1	VALVE,GO2,GRD FILL,APS	36.01.04-06
20	648.1	VALVE,GH2,NOAPS	36.01.02-03
21	648.1	VALVE,GH2,NOAPS	36.01.02-04
22	648.1	VALVE,LO2,NCAPS	36.01.05-03
23	648.1	VALVE,LO2,NOAPS	36.01.05-04
24	648.1	VALVE,LO2,NCAPS	36.01.05-07
25	648.1	VALVE,LO2,NOAPS	36.01.05-08
26	648.1	VALVE,LO2,GRD FILL,APS	36.01.05-10
27	648.1	VALVE,LH2,NCAPS	36.01.03-03
28	648.1	VALVE,LH2,NOAPS	36.01.03-04
29	612.5	QUAD VALVES,XPULSION GH2	15.06-02
30	612.5	QUAD VALVES,CONTROL GH2	15.06-03
31	612.5	QUAD VALVES,PREPRESS GH2	15.06-04
32	612.5	QUAD VALVES,RESUPPLY LH2	15.09-04
33	612.5	QUAD VALVES,FLT VENT,GH2	15.11-02
34	612.5	QUAD VALVES,CHILLDOWN	25.05-08
35	612.5	QUAD VALVES,XPULSION GH2	25.06-02
36	612.5	QUAD VALVES,CONTROL GH2	25.06-03
37	612.5	QUAD VALVES,FLT VENT GH2	25.11-02
38	457.5	DUCTING,FUEL,APS	36.01.01-07
39	457.5	DUCTING,OXIDIZER,APS	36.01.01-08
40	350.8	CHECK VALVE,GH2,APS	36.01.02-08
41	350.8	CHECK VALVE,GH2,APS	36.01.02-09
42	350.8	CHECK VALVE,GO2,APS	36.01.04-08
43	350.8	CHECK VALVE,FO2,APS	36.01.04-09
44	251.1	VALVE,GRD FILL,DRAIN LH2	15.09-07
45	216.2	DUCTING,GH2	15.06-01
46	216.2	DUCTING,VENT+RELIEF,GH2	15.10-01
47	216.2	DUCTING,FLT VENT,GH2	15.11-01
48	216.2	DUCTING,GH2	25.06-01
49	216.2	DUCTING,GH2	25.11-01
50	199.1	FILL VALVE,INFLT XFER	25.09-04
51	199.1	FILL VALVE,INFLT XFER	25.09-03
52	189.4	DUCTING,LH2 FILL	25.09-02
53	151.5	NOZZLE,RESUPPLY LH2	25.09-12
54	151.5	FLOW METER,RESUPPLY LH2	25.09-10
55	144.1	VOLTAGE LIMITER SENSOR	37.04-19
56	144.1	VOLTAGE LIMITER SENSOR	37.04-20
57	109.0	FILTER,GH2,APS	36.01.02-11
58	109.0	FILTER,GO2,APS	36.01.04-11
59	101.2	DUCTING,FEED LH2	25.05-09
60	91.5	DUCTING,LH2,APS	36.01.03-13
61	91.5	DUCTING,LO2,APS	36.01.05-13
62	77.6	CK VALVE,CHILL NERVAFEED	25.05-07
63	77.6	CK VALVE,CHILL STAGEFEED	25.05-05
64	77.6	CK VALVE,CHILL NERVAFEED	25.05-06
65	64.8	VALVE,GH2,NOAPS	36.01.02-19
66	64.8	SO VALVE,GH2,HTEXCH,APS	36.01.02-20
67	64.8	SO VALVE GO2,HTEXCH,APS	36.01.02-21
68	64.8	VALVE,GH2,NOAPS	36.01.02-25
69	64.8	VALVE,GH2,NOAPS	36.01.02-26
70	64.8	VALVE,GH2,NOAPS	36.01.02-13
71	64.8	SO VALVE,GH2,HTEXCH,APS	36.01.02-14
72	64.8	VALVE,GO2,NOAPS	36.01.04-13

73	64.8	SO VALVE,GO2,HTEXCH,APS	36.01.04-14
74	64.8	SO VALVE,GH2,HTEXCH,APS	36.01.04-15
75	64.8	VALVE,GO2,NOAPS	36.01.04-19
76	64.8	SL VALVE,GO2',HTEXCH,APS	36.01.04-20
77	64.8	SO VALVE,GH2,HTEXCH,APS	36.01.04-21
78	64.8	VALVE,GO2,NOAPS	36.01.04-25
79	64.8	VALVE,GO2,NOAPS	36.01.04-26
80	64.8	SO VALVE,GO2,HTEXCH,APS	36.01.02-15
81	61.0	ACCUMULATOR,GH2,APS	36.01.02-07
82	61.0	ACCUMULATOR,GO2,APS	36.01.04-07
83	61.0	TANK,LO2 STORAGE,APS	36.01.05-09
84	61.0	TANK,LH2 STORAGE,APS	36.01.03-09
85	54.0	VOLTAGE LIMITER CNTRL	37.04-21
86	54.0	VOLTAGE LIMITER CNTRL	37.04-22
87	41.6	VALVE,VENT+RELIEF,GH2	15.10-02
88	38.0	ISOLATION VALVE,LH2	15.05-02
89	38.0	ISOLATION VALVE,LH2	15.05-01
90	37.9	DUCTING,LH2 TRANSFER	15.05-03

91	35.1	CHECK VALVE,LO2,APS	36.01.05-01
92	35.1	CHECK VALVE,LO2,APS	36.01.05-05
93	35.1	CHECK VALVE,LH2,APS	36.01.03-01
94	35.1	CHECK VALVE,LH2,APS	36.01.03-05
95	28.8	O2 ASSY,FUEL CELL(S)	37.04-03
96	28.8	O2 ASSY,FUEL CELL(S)	37.04-04
97	28.8	H2 ASSY,FUEL CELL(S)	37.04-01
98	28.8	H2 ASSY,FUEL CELL(S)	37.04-02
99	28.6	VALVE,RELIEF,GH2	15.10-03
*0	9.2	HEAT EXCHANGER,LH2,APS	36.01.02-18
*1	9.2	HEAT EXCHANGER,LH2,APS	36.01.02-24
*2	9.2	HEAT EXCHANGER,LO2,APS	36.01.04-18
*3	9.2	HEAT EXCHANGER,LO2,APS	36.01.04-24
*4	5.4	DISCONNECT,GH2 PRESS	15.06-06
*5	5.4	CHECK DISCONNECT,PRESS	25.06-05
*6	4.7	DISCONNECT,LH2 TRANSFER	15.05-04
*7	4.7	DISCONNECT,LH2 FILL	25.09-01
*8	.0	RELIEF VALVE,GH2,APS	36.01.02-10
*9	.0	RELIEF VALVE,GO2,APS	36.01.04-10

CLASS 1 HYBRID RNS

PROPELLANT FEED,15.05

1	ISOLATION VALVE,LH2	15.05-01		
	(2962)FAIL TO REMAIN CLOSED		1	
	(2002)	LEAKAGE	37	
		ITOTAL		38
2	ISOLATION VALVE,LH2	15.05-02		
	(2962)FAIL TO REMAIN CLOSED		1	
	(2002)	LEAKAGE	37	
		ITOTAL		38
3	DUCTING,LH2 TRANSFER	15.05-03		
	(2002)	LEAKAGE	38	
		ITOTAL		38
4	DISCONNECT,LH2 TRANSFER	15.05-04		
	(2002)	LEAKAGE	5	
		ITOTAL		5

SUBSYSTEM PROPELLANT FEED,15.05
CRITICALITY 118.7
RELIABILITY .999881

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	2.0	6.0	6.0	6.2	6.3	6.6	6.7	7.3
FAILURE CRITICALITY	28.0	48.7	3.3	4.8	2.9	4.1	2.5	5.5

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	7.4	7.7	7.8	8.1	8.2	10.7	11.0	10.7
FAILURE CRITICALITY	2.0	3.2	1.5	2.0	1.0	7.6	1.3	.0

CLASS 1 HYBRID RNS

PRESSURIZATION,15.06

1	DUCTING,GH2	15.06-01		
	(2002)	LEAKAGE	216	
		ITOTAL		216
2	QUAD VALVES,XPULSION GH2	15.06-02		
	(2002)	LEAKAGE	613	
		ITOTAL		613
3	QUAD VALVES,CONTROL GH2	15.06-03		
	(2002)	LEAKAGE	613	
		ITOTAL		613
4	QUAD VALVES,PREPRESS GH2	15.06-04		
	(2002)	LEAKAGE	613	
		ITOTAL		613
5	DISCONNECT,GH2 PRESS	15.06-06		
	(2002)	LEAKAGE	5	
		ITOTAL		5
6	GROUND PRESS VALVE,GH2	15.06-08		
	(2002)	LEAKAGE	658	
		ITOTAL		658

SUBSYSTEM PRESSURIZATION,15.06
CRITICALITY 2716.7
RELIABILITY .997283

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	113.1	127.1	139.7	138.7	151.0	149.8	161.9	161.5
FAILURE CRITICALITY	1561.9	212.9	185.8	20.9	162.3	18.0	137.9	23.8

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	173.3	172.0	183.6	181.8	193.2	200.2	233.9	236.0
FAILURE CRITICALITY	112.5	13.9	86.1	8.7	58.5	31.9	74.6	6.8

CLASS-1 HYBRID RNS

FILL AND DRAIN/ORBIT REFUELING 15.09

1 QUAD VALVES,RESUPPLY LH2 15.09-04

(2002)	LEAKAGE	613	
	ITOTAL		613

2 VALVE,GRD FILL,DRAIN LH2 15.09-07

(2962)	FAIL TO REMAIN CLOSED	6	
(2002)	LEAKAGE	245	
	ITOTAL		251

SUBSYSTEM FILL AND DRAIN/ORBIT REFUELING 15.09
CRITICALITY 863.6
RELIABILITY .999136

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	37.8	40.9	44.7	44.1	48.0	47.5	51.4	51.1
FAILURE CRITICALITY	495.6	67.6	59.0	6.6	51.6	5.7	43.9	7.6

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	55.8	54.4	58.2	57.5	61.2	63.4	74.4	74.8
FAILURE CRITICALITY	35.9	4.4	27.5	2.8	18.8	10.3	24.2	2.2

CLASS 1 HYBRID RNS

VENT AND RELIEF,GH2,15-10

1	DUCTING,VENT+RELIEF,GH2 15.10-01			
	(2002)	LEAKAGE	216	
		ITOTAL		216
2	VALVE,VENT+RELIEF,GH2 15.10-02			
	(2962)FAIL TO REMAIN CLOSED		11	
	(2002)	LEAKAGE	31	
		ITOTAL		42
3	VALVE,RELIEF,GH2 15.10-03			
	(2962)FAIL TO REMAIN CLOSED		7	
	(2002)	LEAKAGE	21	
		ITOTAL		29

SUBSYSTEM VENT AND RELIEF,GH2,15-10
CRITICALITY 286.4
RELIABILITY .999714

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	18.4	13.6	14.7	13.8	15.9	14.9	16.9	16.1
FAILURE CRITICALITY	161.4	22.1	19.3	2.2	17.0	1.9	14.6	2.5

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	18.1	17.1	19.1	18.1	20.0	20.5	25.5	23.7
FAILURE CRITICALITY	12.1	1.5	9.5	1.0	6.7	3.8	9.8	1.1

CLASS 1 HYBRID RNS

FLIGHT VENT,15.11

1 DUCTING,FLT VENT,GH2 15.11-01
(2002) LEAKAGE 216
ITOTAL 216

2 QUAD VALVES,FLT VENT,GH2 15.11-02
(2002) LEAKAGE 613
ITOTAL 613

SUBSYSTEM FLIGHT VENT,15.11
CRITICALITY 828.7
RELIABILITY .999171

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	34.5	38.8	42.6	42.3	46.1	45.7	49.4	49.3
FAILURE CRITICALITY	476.4	64.9	56.7	6.4	49.5	5.5	42.1	7.3

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	52.9	52.5	56.0	55.4	58.9	61.1	71.3	72.0
FAILURE CRITICALITY	34.3	4.2	26.3	2.7	17.9	9.7	22.8	2.1

CLASS 1 HYBRID RNS

PROPELLANT FEED,25.05

1	CK VALVE,CHILL STAGEFEED 25.05-05			
	(2002)	LEAKAGE	78	
		ITOTAL		78
2	CK VALVE,CHILL NERVAFEED 25.05-06			
	(2002)	LEAKAGE	78	
		ITOTAL		78
3	CK VALVE,CHILL NERVAFEED 25.05-07			
	(2002)	LEAKAGE	78	
		ITOTAL		78
4	QUAD VALVES,CHILLDOWN 25.05-08			
	(2002)	LEAKAGE	613	
		ITOTAL		613
5	DUCTING,FEED LH2 25.05-09			
	(2002)	LEAKAGE	101	
		ITOTAL		101

SUBSYSTEM PROPELLANT FEED,25.05
CRITICALITY 946.6
RELIABILITY .999053

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	55.2	28.7	64.6	31.3	70.4	33.8	76.1	36.4
FAILURE CRITICALITY	573.8	48.0	68.0	4.7	59.2	4.1	50.1	5.4

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	81.8	38.8	87.3	41.0	92.5	45.1	110.6	53.2
FAILURE CRITICALITY	40.7	3.1	31.1	2.0	21.0	7.2	26.7	1.5

CLASS 1 HYBRID RNS

PRESSURIZATION,25.06

1	DUCTING,GH2	25.06-01		
	(2002)	LEAKAGE	216	
		ITOTAL		216
2	QUAD VALVES,XPULSION GH2	25.06-02		
	(2002)	LEAKAGE	613	
		ITOTAL		613
3	QUAD VALVES,CONTROL GH2	25.06-03		
	(2002)	LEAKAGE	613	
		ITOTAL		613
4	CHECK DISCONNECT,PRESS	25.06-05		
	(2002)	LEAKAGE	5	
		ITOTAL		5

SUBSYSTEM PRESSURIZATION,25.06
CRITICALITY 1446.6
RELIABILITY .998553

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	60.2	67.7	74.4	73.8	80.4	79.8	86.2	86.0
FAILURE CRITICALITY	831.7	113.4	98.9	11.1	86.4	9.6	73.4	12.7

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	92.3	91.6	97.8	96.8	102.9	106.6	124.5	125.7
FAILURE CRITICALITY	59.9	7.4	45.8	4.6	31.2	17.0	39.7	3.6

CLASS 1 HYBRID RNS

FILL AND DRAIN/ORBIT REFUELING,25.09

1	DISCONNECT,LH2 FILL	25.09-01		
	(2002)	LEAKAGE	5	
		ITOTAL		5
2	DUCTING,LH2 FILL	25.09-02		
	(2002)	LEAKAGE	189	
		ITOTAL		189
3	FILL VALVE,INFLT XFER	25.09-03		
	(1236)	FAIL TO CLOSE	161	
	(2962)	FAIL TO REMAIN CLOSED	0	
	(2002)	LEAKAGE	38	
		ITOTAL		199
4	FILL VALVE,INFLT XFER	25.09-04		
	(1236)	FAIL TO CLOSE	161	
	(2962)	FAIL TO REMAIN CLOSED	0	
	(2002)	LEAKAGE	38	
		ITOTAL		199
5	FLOW METER,RESUPPLY LH2	25.09-10		
	(2024)	CLOGGED	152	
		ITOTAL		152
6	CK VALVE,RESUPPLY LH2	25.09-11		
	(1221)	FAIL TO OPEN	653	
		ITOTAL		653
7	NOZZLE,RESUPPLY LH2	25.09-12		
	(2024)	CLOGGED	152	
		ITOTAL		152

SUBSYSTEM FILL AND DRAIN/ORBIT REFUELING,25.09
CRITICALITY 1548.8
RELIABILITY .998451

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	403.3	82.3	80.9	36.3	83.4	38.7	85.8	44.8
FAILURE CRITICALITY	717.4	102.7	90.8	10.8	85.7	10.1	80.4	15.0

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	88.3	44.6	90.5	45.7	92.6	80.1	177.3	74.3
FAILURE CRITICALITY	74.9	10.2	69.2	8.0	63.2	43.6	142.4	24.3

CLASS 1 HYBRID RNS

FLIGHT VENT,25.11

1 DUCTING,GH2 25.11-01
(2002) LEAKAGE 216
ITOTAL 216

2 QUAD VALVES,FLT VENT GH2 25.11-02
(2002) LEAKAGE 613
ITOTAL 613

SUBSYSTEM FLIGHT VENT,25.11
CRITICALITY 828.7
RELIABILITY .999171

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	34.5	38.8	42.6	42.3	46.1	45.7	49.4	49.3
FAILURE CRITICALITY	476.4	64.9	56.7	6.4	49.5	5.5	42.1	7.3

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	52.9	52.5	56.0	55.4	58.9	61.1	71.3	72.0
FAILURE CRITICALITY	34.3	4.2	26.3	2.7	17.9	9.7	22.8	2.1

CLASS 1 HYBRID RNS

ENGINE,APS36.01.01

1 ENGINES,APS(20) 36.01.01-01
(812) BURNTHROUGH 10072
ITOTAL 10072

SUBSYSTEM ENGINE,APS36.01.01
CRITICALITY 10072.3
RELIABILITY .989928

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	504.1	576.4	572.0	581.1	576.6	584.2	579.6	663.2
FAILURE CRITICALITY	6961.7	1076.6	87.5	237.8	76.4	191.0	64.9	790.9

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	657.0	650.3	644.4	637.2	631.5	628.1	785.9	800.8
FAILURE CRITICALITY	53.0	42.1	40.5	27.3	27.6	27.1	337.4	30.5

CLASS 1 HYBRID RNS

ENGINE S/S APS 36.01.01

1 CNTRL VALVES,GH2,NC22APS 36.01.01-04
(2002) LEAKAGE 1426
ITOTAL 1426

2 CNTRL VALVES,GO2,NC22APS 36.01.01-06
(2002) LEAKAGE 1426
ITOTAL 1426

3 DUCTING,FUEL,APS 36.01.01-07
(2002) LEAKAGE 458
ITOTAL 458

4 DUCTING,OXIDIZER,APS 36.01.01-08
(2002) LEAKAGE 458
ITOTAL 458

SUBSYSTEM ENGINE S/S APS 36.01.01
CRITICALITY 3766.8
RELIABILITY .996233

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	74.1	179.3	185.6	193.8	199.8	207.6	213.4	227.9
FAILURE CRITICALITY	1023.3	1394.8	121.7	136.9	106.3	118.1	90.4	156.0

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	233.2	242.3	247.4	254.3	259.1	325.0	343.2	380.8
FAILURE CRITICALITY	73.7	91.2	56.4	57.0	38.4	209.2	48.9	44.5

CLASS 1 HYBRID RNS

GH2 PRESSURANT APS 36.01.02

1	VALVE,GH2,NOAPS	36.01.02-03		
	(2002)	LEAKAGE	648	
		ITOTAL		648
2	VALVE,GH2,NOAPS	36.01.02-04		
	(2002)	LEAKAGE	648	
		ITOTAL		648
3	VALVE,GH2,GRD FILL,APS	36.01.02-06		
	(2002)	LEAKAGE	648	
		ITOTAL		648
4	ACCUMULATOR,GH2,APS	36.01.02-07		
	(2002)	LEAKAGE	61	
		ITOTAL		61
5	CHECK VALVE,GH2,APS	36.01.02-08		
	(2002)	LEAKAGE	351	
		ITOTAL		351
6	CHECK VALVE,GH2,APS	36.01.02-09		
	(2002)	LEAKAGE	351	
		ITOTAL		351
7	RELIEF VALVE,GH2,APS	36.01.02-10		
	(2362)FAIL TO REMAIN CLOSED		0	
	(2002)	LEAKAGE	0	
		ITOTAL		0
8	FILTER,GH2,APS	36.01.02-11		
	(2024)	CLOGGED	109	
		ITOTAL		109
9	QUAD VALVES,PRESS LH2APS	36.01.02-12		
	(2002)	LEAKAGE	2593	
		ITOTAL		2593
10	VALVE,GH2,NOAPS	36.01.02-13		
	(2002)	LEAKAGE	65	
		ITOTAL		65
11	SO VALVE,GH2,HTEXCH,APS	36.01.02-14		
	(2002)	LEAKAGE	65	
		ITOTAL		65

12	SO VALVE,GO2,HTEXCH,APS 36.01.02-15			
	(2002)	LEAKAGE	65	
		ITOTAL		65
13	HEAT EXCHANGER,LH2,APS 36.01.02-18			
	(2002)	LEAKAGE	9	
		ITOTAL		9
14	VALVE,GH2,NOAPS 36.01.02-19			
	(2002)	LEAKAGE	65	
		ITOTAL		65
15	SO VALVE,GH2,HTEXCH,APS 36.01.02-20			
	(2002)	LEAKAGE	65	
		ITOTAL		65
16	SO VALVE GO2,HTEXCH,APS 36.01.02-21			
	(2002)	LEAKAGE	65	
		ITOTAL		65
17	HEAT EXCHANGER,LH2,APS 36.01.02-24			
	(2002)	LEAKAGE	9	
		ITOTAL		9
18	VALVE,GH2,NOAPS 36.01.02-25			
	(2002)	LEAKAGE	65	
		ITOTAL		65
19	VALVE,GH2,NOAPS 36.01.02-26			
	(2002)	LEAKAGE	65	
		ITOTAL		65
20	GAS GENERATOR,LH2,APS(2) 36.01.02-17			
	(812)	BURNTHROUGH	8399	
		ITOTAL		8399

SUBSYSTEM GH2 PRESSURANT APS 36.01.02
CRITICALITY 14344.2
RELIABILITY .985656

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	1520.3	2301.8	475.0	525.1	496.9	546.6	518.0	709.1
FAILURE CRITICALITY	2991.0	4185.0	376.0	437.0	352.2	407.9	327.4	597.8

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	548.7	637.9	570.7	618.9	588.8	1852.9	1000.3	1433.4
FAILURE CRITICALITY	301.6	403.7	274.8	313.1	246.8	1673.4	544.3	912.2

CLASS 1 HYBRID RNS

LH2 SUPPLY APS 36.01.03

1	CHECK VALVE,LH2,APS	36.01.03-01		
	(2002)	LEAKAGE	35	
		ITOTAL		35
2	VALVE,LH2,NCAPS	36.01.03-03		
	(2002)	LEAKAGE	648	
		ITOTAL		648
3	VALVE,LH2,NOAPS	36.01.03-04		
	(2002)	LEAKAGE	648	
		ITOTAL		648
4	CHECK VALVE,LH2,APS	36.01.03-05		
	(2002)	LEAKAGE	35	
		ITOTAL		35
5	VALVE,LH2,NCAPS	36.01.03-07		
	(2002)	LEAKAGE	648	
		ITOTAL		648
6	VALVE,LH2,NOAPS	36.01.03-08		
	(2002)	LEAKAGE	648	
		ITOTAL		648
7	TANK,LH2 STORAGE,APS	36.01.03-09		
	(2002)	LEAKAGE	61	
		ITOTAL		61
8	VALVE,LH2,GRD FILL,APS	36.01.03-10		
	(2002)	LEAKAGE	648	
		ITOTAL		648
9	QUAD VALVES,LH2 VENT,APS	36.01.03-12		
	(2002)	LEAKAGE	1296	
		ITOTAL		1296
10	DUCTING,LH2,APS	36.01.03-13		
	(2002)	LEAKAGE	92	
		ITOTAL		92

SUBSYSTEM LH2 SUPPLY APS 36.01.03
CRITICALITY 4759.6
RELIABILITY .995240

	PHASE F	PHASE G	PHASE H	PHASE I	PHASE J	PHASE K	PHASE L	PHASE M
	(.75)	(108.)	(.1)	(12.)	(.1)	(12.)	(.1)	(19.)
PHASE CRITICALITY	93.6	226.6	234.5	244.8	252.4	262.3	269.6	287.9
FAILURE CRITICALITY	1293.0	1762.4	153.8	173.0	134.4	149.3	114.2	197.2

	PHASE O	PHASE P	PHASE Q	PHASE R	PHASE S	PHASE T	PHASE U	PHASE V
	(.1)	(14.)	(.1)	(12.)	(.1)	(72.)	(.25)	(45.)
PHASE CRITICALITY	294.6	306.2	312.6	321.3	327.4	410.7	433.7	481.2
FAILURE CRITICALITY	93.2	115.2	71.3	72.0	48.5	264.3	61.8	56.2

CLASS 1 HYBRID RNS

GO2 PRESSURANT APS 36.01.04

1	VA_VE,GO2,NOAPS	36.01.04-03		
	(2002)	LEAKAGE	648	
		ITOTAL		648
2	VALVE,GO2,NOAPS	36.01.04-04		
	(2002)	LEAKAGE	648	
		ITOTAL		648
3	VALVE,GO2,GRD FILL,APS	36.01.04-06		
	(2002)	LEAKAGE	648	
		ITOTAL		648
4	ACCUMULATOR,GO2,APS	36.01.04-07		
	(2002)	LEAKAGE	61	
		ITOTAL		61
5	CHECK VALVE,GO2,APS	36.01.04-08		
	(2002)	LEAKAGE	351	
		ITOTAL		351
6	CHECK VALVE,FO2,APS	36.01.04-09		
	(2002)	LEAKAGE	351	
		ITOTAL		351
7	RELIEF VALVE,GO2,APS	36.01.04-10		
	(2962)FAIL TO REMAIN CLOSED		0	
	(2002)	LEAKAGE	0	
		ITOTAL		0
8	FILTER,GO2,APS	36.01.04-11		
	(2024)	CLOGGED	109	
		ITOTAL		109
9	QUAD VALVES,PRESS LO2APS	36.01.04-12		
	(2002)	LEAKAGE	2593	
		ITOTAL		2593
10	VALVE,GO2,NOAPS	36.01.04-13		
	(2002)	LEAKAGE	65	
		ITOTAL		65
11	SO VALVE,GO2,HTEXCH,APS	36.01.04-14		
	(2002)	LEAKAGE	65	
		ITOTAL		65

12	SO VALVE,GH2,HTEXCH,APS	36.01.04-15			
	(2002)	LEAKAGE	65		
		ITOTAL		65	
13	HEAT EXCHANGER,LO2,APS	36.01.04-18			
	(2002)	LEAKAGE	9		
		ITOTAL		9	
14	VALVE,GO2,NOAPS	36.01.04-19			
	(2002)	LEAKAGE	65		
		ITOTAL		65	
15	SL VALVE,GO2,HTEXCH,APS	36.01.04-20			
	(2002)	LEAKAGE	65		
		ITOTAL		65	
16	SO VALVE,GH2,HTEXCH,APS	36.01.04-21			
	(2002)	LEAKAGE	65		
		ITOTAL		65	
17	HEAT EXCHANGER,LO2,APS	36.01.04-24			
	(2002)	LEAKAGE	9		
		ITOTAL		9	
18	VALVE,GO2,NOAPS	36.01.04-25			
	(2002)	LEAKAGE	65		
		ITOTAL		65	
19	VALVE,GO2,NOAPS	36.01.04-26			
	(2002)	LEAKAGE	65		
		ITOTAL		65	
20	GAS GENERATOR,GO2,APS(2)	36.01.04-17			
	(312)	BURNTHROUGH	8399		
		ITOTAL		8399	

SUBSYSTEM GO2 PRESSURANT APS 36.01.04
CRITICALITY 14344.2
RELIABILITY .985656

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	1520.3	2301.8	475.0	525.1	496.9	546.6	518.0	709.1
FAILURE CRITICALITY	2991.0	4185.0	376.0	437.0	352.2	407.9	327.4	597.8

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	548.7	637.9	570.7	618.9	588.8	1852.9	1000.3	1433.4
FAILURE CRITICALITY	301.6	403.7	274.8	313.1	246.8	1673.4	544.3	912.2

CLASS 1 HYBRID RNS

LO2 SUPPLY APS 36.01.05

1	CHECK VALVE,LO2,APS	36.01.05-01		
	(2002)	LEAKAGE	35	
		ITOTAL		35
2	VALVE,LO2,NCAPS	36.01.05-03		
	(2002)	LEAKAGE	648	
		ITOTAL		648
3	VALVE,LO2,NOAPS	36.01.05-04		
	(2002)	LEAKAGE	648	
		ITOTAL		648
4	CHECK VALVE,LO2,APS	36.01.05-05		
	(2002)	LEAKAGE	35	
		ITOTAL		35
5	VALVE,LO2,NCAPS	36.01.05-07		
	(2002)	LEAKAGE	648	
		ITOTAL		648
6	VALVE,LO2,NOAPS	36.01.05-08		
	(2002)	LEAKAGE	648	
		ITOTAL		648
7	TANK,LO2 STORAGE,APS	36.01.05-09		
	(2002)	LEAKAGE	61	
		ITOTAL		61
8	VALVE,LO2,GRD FILL,APS	36.01.05-10		
	(2002)	LEAKAGE	648	
		ITOTAL		648
9	QUAD VALVES,LO2 VENT,APS	36.01.05-12		
	(2002)	LEAKAGE	1296	
		ITOTAL		1296
10	DUCTING,LO2,APS	36.01.05-13		
	(2002)	LEAKAGE	92	
		ITOTAL		92

SUBSYSTEM LO2 SUPPLY APS 36.01.05
CRITICALITY 4759.6
RELIABILITY .995240

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	93.6	226.6	234.5	244.8	252.4	262.3	269.6	287.9
FAILURE CRITICALITY	1293.0	1762.4	153.8	173.0	134.4	149.3	114.2	197.2

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	294.6	306.2	312.6	321.3	327.4	410.7	433.7	481.2
FAILURE CRITICALITY	93.2	115.2	71.3	72.0	48.5	264.3	61.8	56.2

CLASS 1 HYBRID PNS

ENGINE,PROP SETTLING 36.03.01

1 ENGINES,PROP SETTLING(2) 36.03.01-01
(812) BURNTHROUGH 1021
ITOTAL 1021

SUBSYSTEM ENGINE,PROP SETTLING 36.03.01
CRITICALITY 1021.4
RELIABILITY .998979

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	51.1	58.4	58.0	58.9	58.5	59.2	58.8	67.3
FAILURE CRITICALITY	706.0	109.2	8.9	24.1	7.8	19.4	6.6	80.2

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	66.6	65.9	65.3	64.6	64.0	63.7	79.7	81.2
FAILURE CRITICALITY	5.4	4.3	4.1	2.8	2.8	2.8	34.2	3.1

CLASS 1 HYBRID RNS

ELECTRICAL POWER,37.04

1	H2 ASSY,FUEL CELL(S)	37.04-01		
	(2002)	LEAKAGE	29	
		ITOTAL		29
2	H2 ASSY,FUEL CELL(S)	37.04-02		
	(2002)	LEAKAGE	29	
		ITOTAL		29
3	O2 ASSY,FUEL CELL(S)	37.04-03		
	(2002)	LEAKAGE	29	
		ITOTAL		29
4	O2 ASSY,FUEL CELL(S)	37.04-04		
	(2002)	LEAKAGE	29	
		ITOTAL		29
5	VOLTAGE LIMITER SENSOR	37.04-19		
	(3864)NO OUTPUT WHEN REQUIRED		72	
	(3763) ERRONEOUS OUTPUT		72	
		ITOTAL		144
6	VOLTAGE LIMITER SENSOR	37.04-20		
	(3864)NO OUTPUT WHEN REQUIRED		72	
	(3763) ERRONEOUS OUTPUT		72	
		ITOTAL		144
7	VOLTAGE LIMITER CNTRL	37.04-21		
	(3864)NO OUTPUT WHEN REQUIRED		27	
	(606)FAIL TO CEASE OPERATION		27	
		ITOTAL		54
8	VOLTAGE LIMITER CNTRL	37.04-22		
	(3864)NO OUTPUT WHEN REQUIRED		27	
	(606)FAIL TO CEASE OPERATION		27	
		ITOTAL		54

SUBSYSTEM ELECTRICAL POWER,37.04
CRITICALITY 511.6
RELIABILITY .999488

	PHASE F (.75)	PHASE G (108.)	PHASE H (.1)	PHASE I (12.)	PHASE J (.1)	PHASE K (12.)	PHASE L (.1)	PHASE M (19.)
PHASE CRITICALITY	21.3	23.9	26.3	26.1	28.4	28.2	30.5	30.4
FAILURE CRITICALITY	294.2	40.1	35.0	3.9	30.6	3.4	26.0	4.5

	PHASE O (.1)	PHASE P (14.)	PHASE Q (.1)	PHASE R (12.)	PHASE S (.1)	PHASE T (72.)	PHASE U (.25)	PHASE V (45.)
PHASE CRITICALITY	32.6	32.4	34.6	34.2	36.4	37.7	44.0	44.4
FAILURE CRITICALITY	21.2	2.6	16.2	1.6	11.0	6.0	14.1	1.3

2.5 RELIABILITY DIAGRAMS

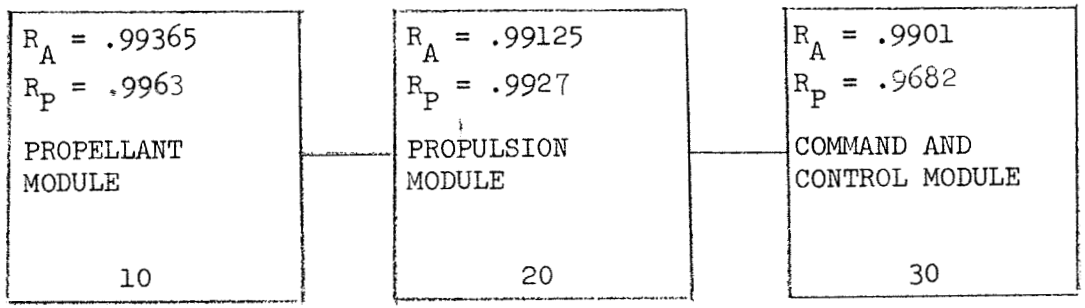
The reliability diagrams are presented here to provide a visual representation of the breakdown of an RNS into modules, a module into systems, and a system into subsystems. The reliability allocations and predictions are printed for each item. The predictions in this section do not consider external leakage and therefore are consistent with Tables 2-3 and 2-4. Both concepts are displayed, with the Class 1 Hybrid RNS first and then the Class 3.

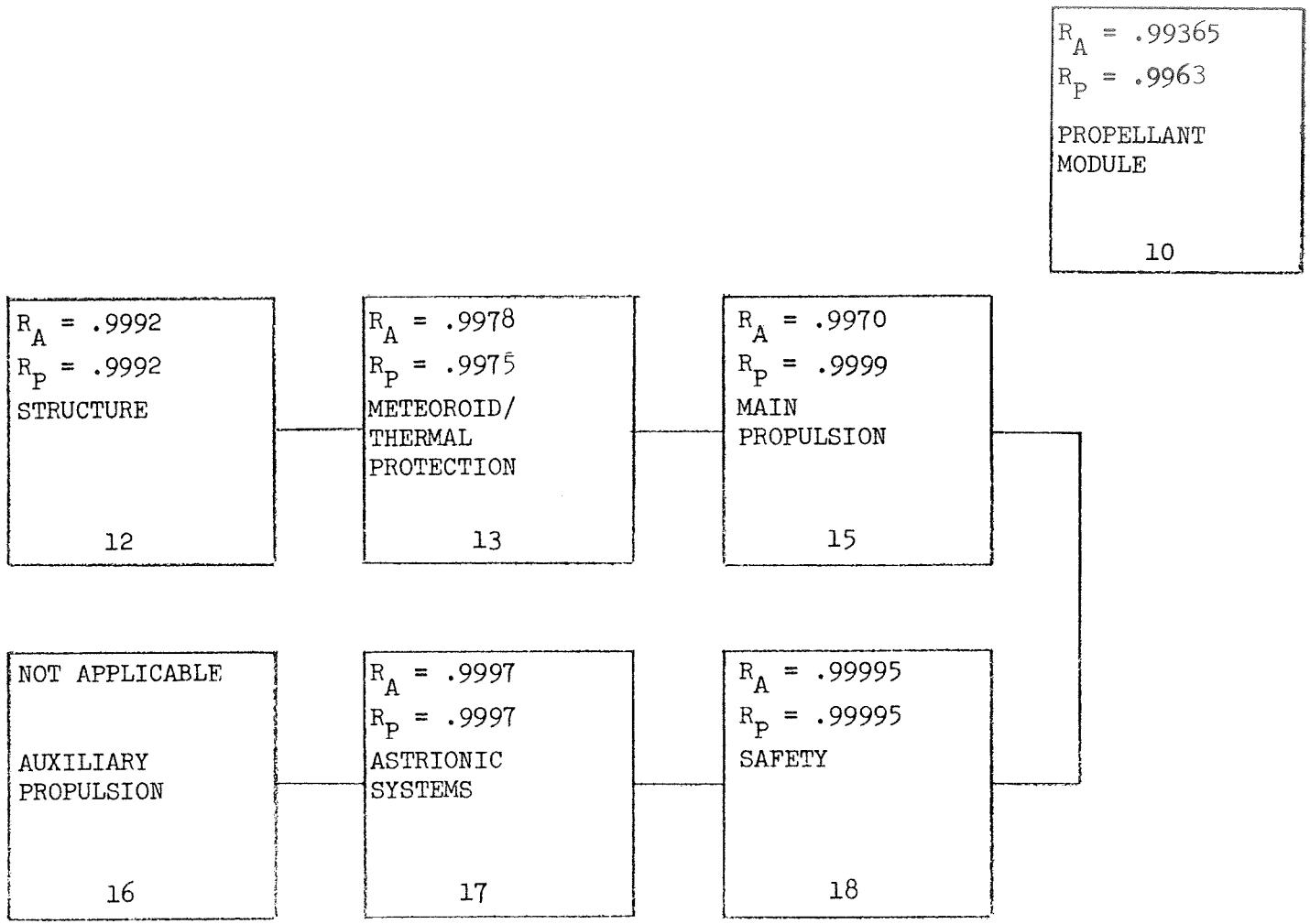
2.6 RELIABILITY RECOMMENDATIONS

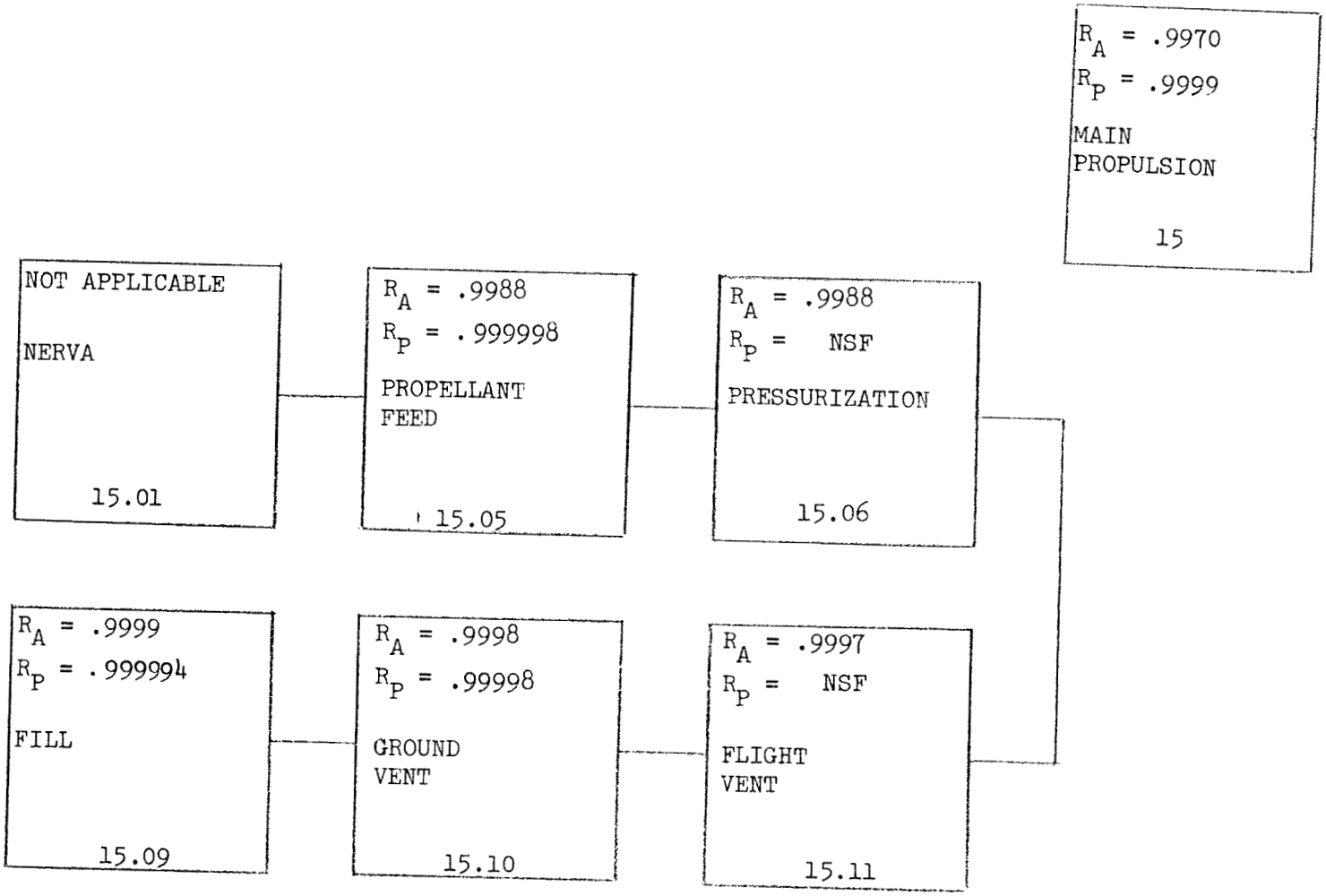
A reliability improvement trade study was active during the entire Phase III study. Early in the study period a series of preliminary reliability analyses were conducted which resulted in reliability improvement recommendations in the propulsion, astrionics and auxiliary propulsion system. These recommendations plus additional design changes resulted in the design depicted in Figures 2-2, 2-3, and 2-4. As these figures show, most of the functional failure modes (failure to operate, etc.) have been made nonflight critical (no single failure) by means of redundancy. Only the structural failure modes (burst, leakage, etc.) remain as single failure items. In general, these failure modes will be handled analytically. These analyses will have to show that the probability of occurrence of these failure modes has been reduced to an acceptable level. A few single failure items will always remain, e.g., meteoroid penetration of the propellant tank, primarily due to the cost of reduction or elimination being prohibitive.

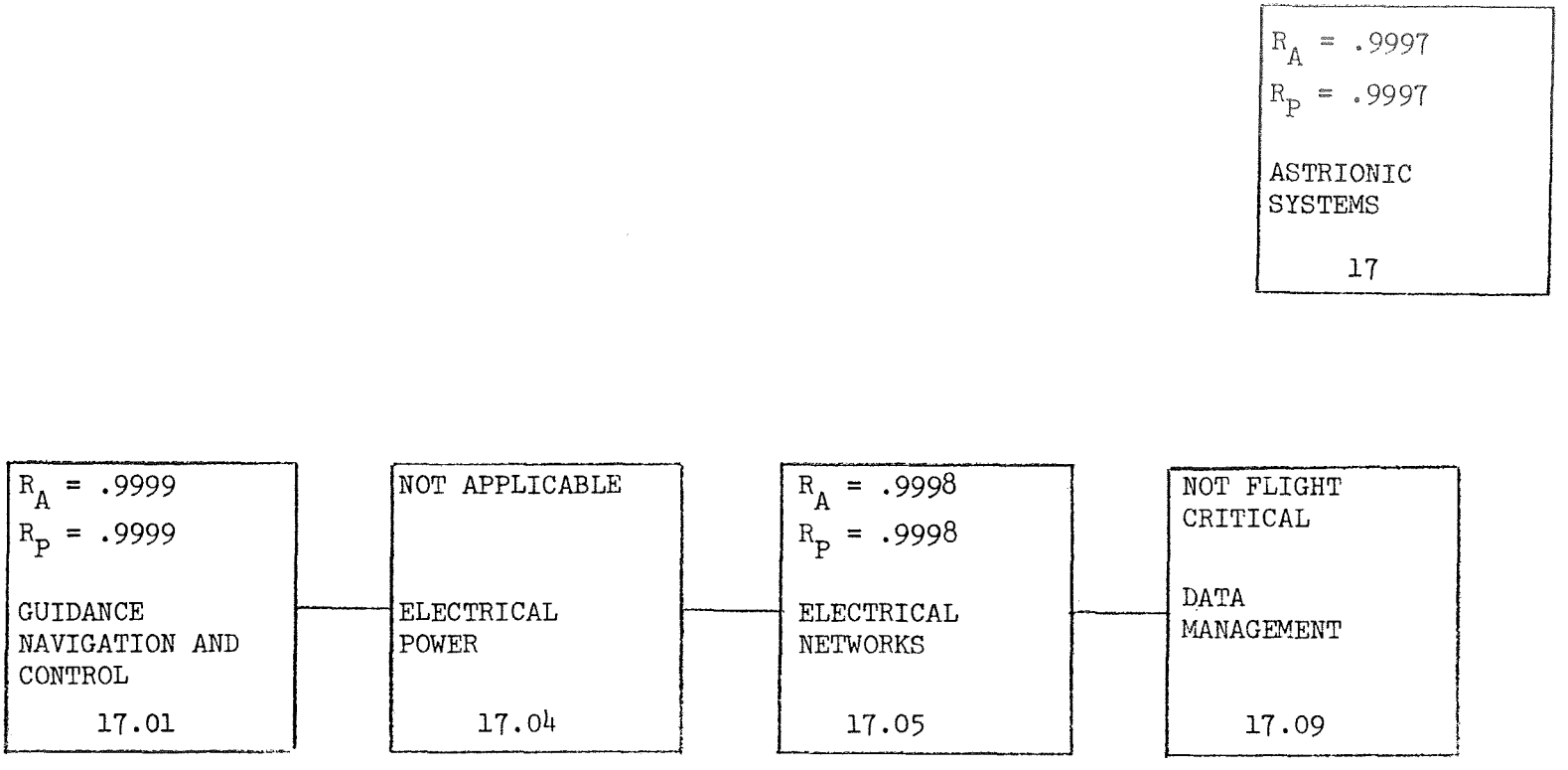
Specific reliability/safety recommendations are made for each flight critical item on the contingency planning worksheets contained in Section 3.1.

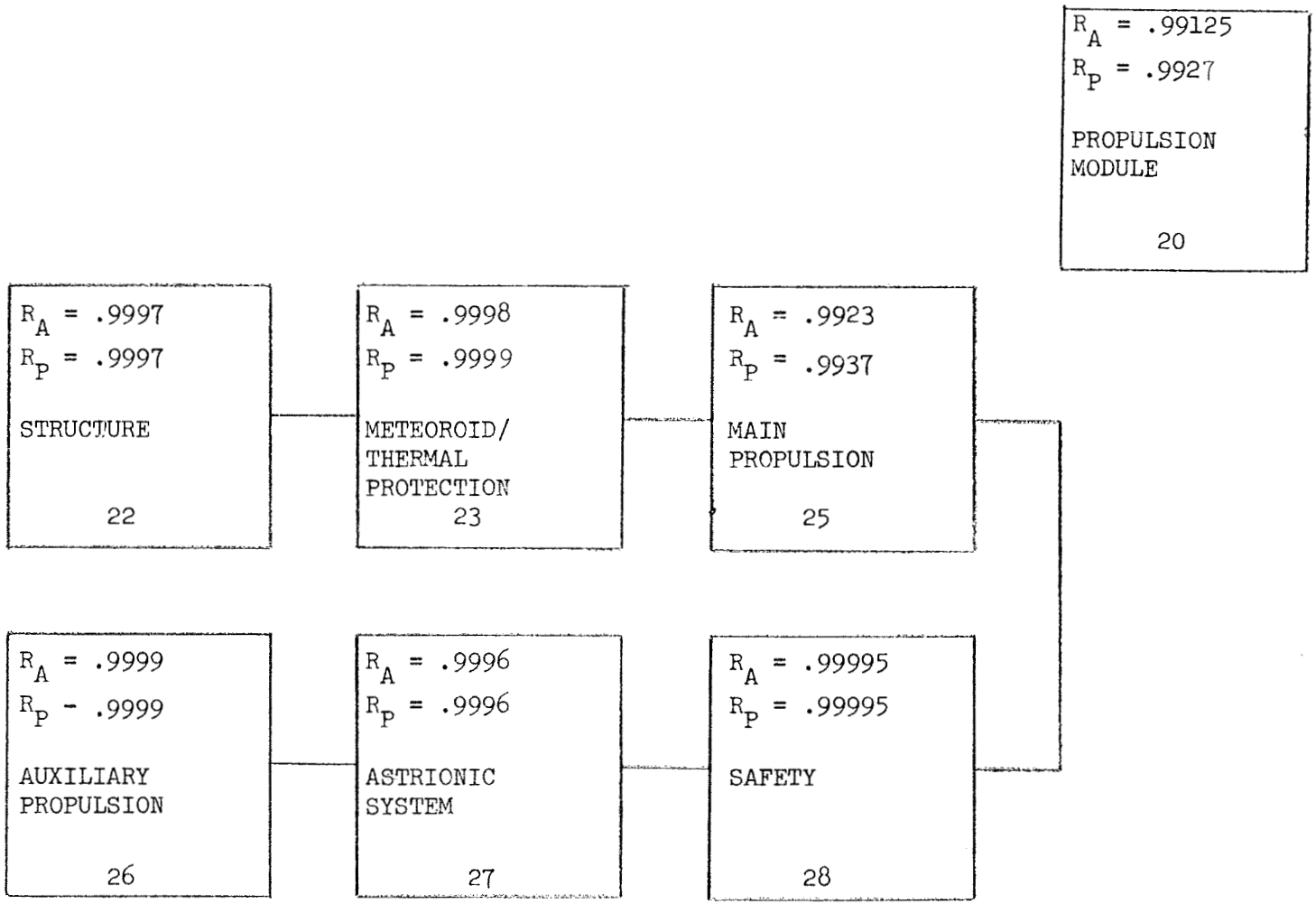
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R_P = .9576
CLASS 1 H
REUSABLE
NUCLEAR SHUTTLE

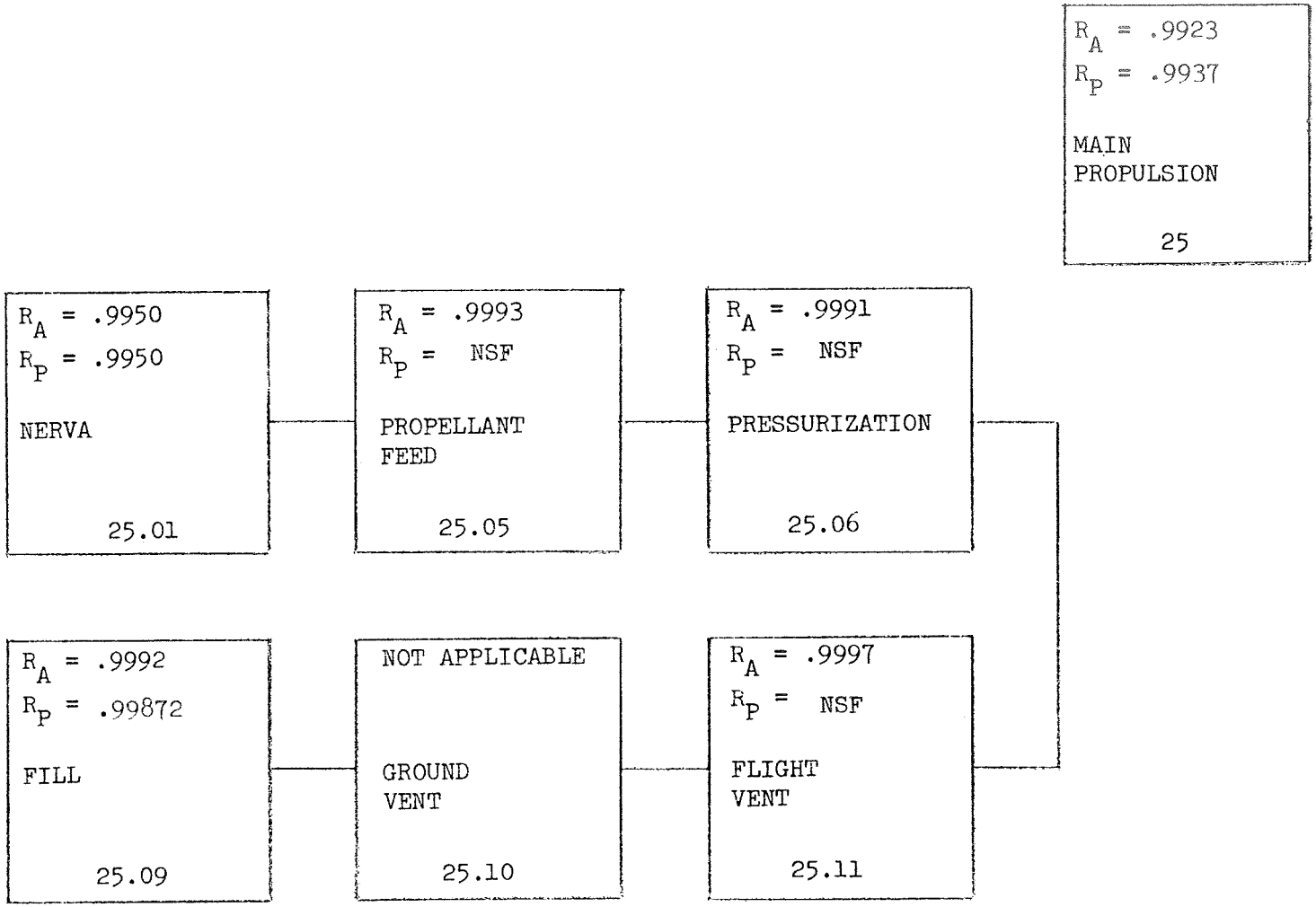


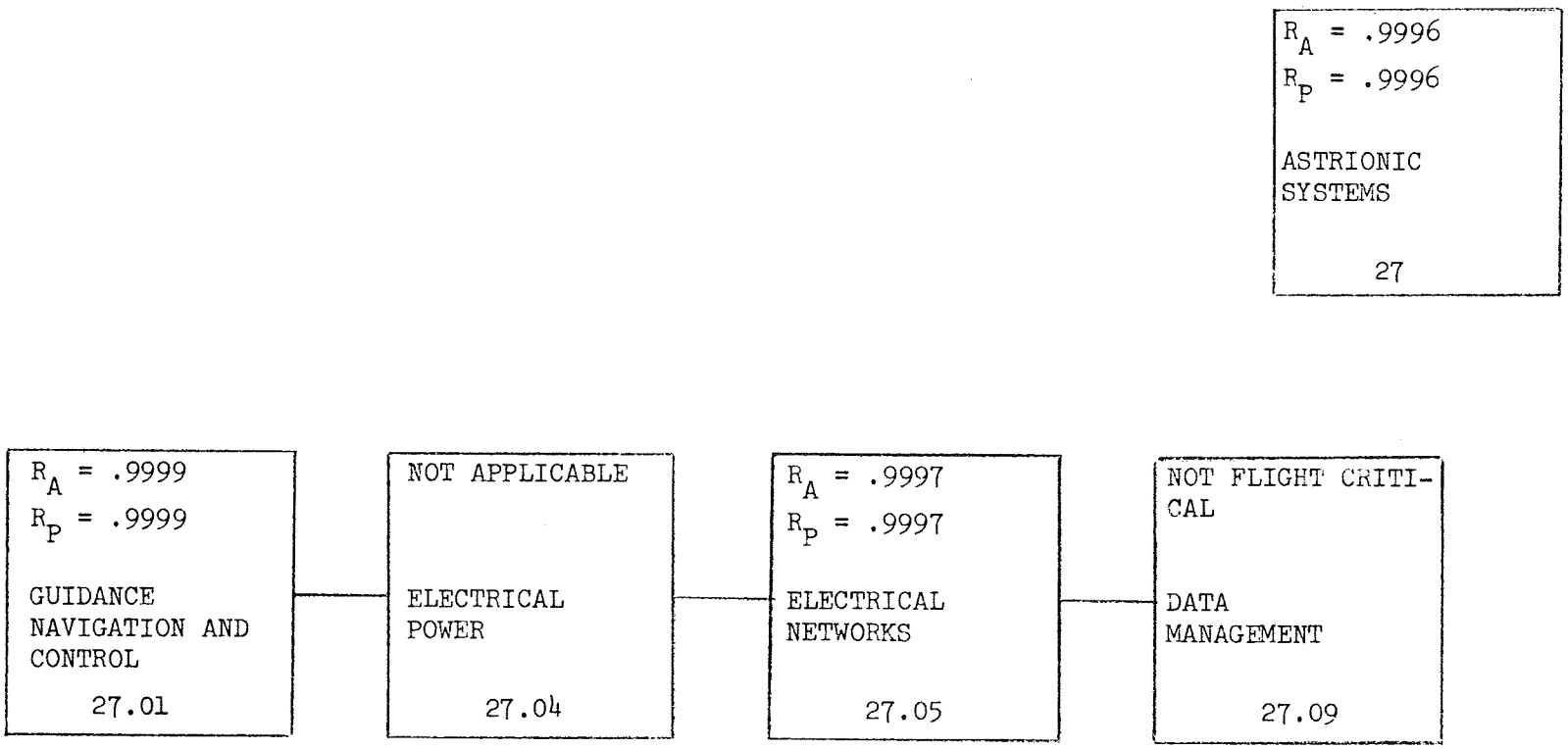

R_A = .99365
R_P = .9963
PROPELLANT MODULE
10
R_A = .9992
R_P = .9992
STRUCTURE
12
R_A = .9978
R_P = .9975
METEOROID/ THERMAL PROTECTION
13
R_A = .9970
R_P = .9999
MAIN PROPULSION
15
NOT APPLICABLE
AUXILIARY PROPULSION
16
R_A = .9997
R_P = .9997
ASTRIONIC SYSTEMS
17
R_A = .99995
R_P = .99995
SAFETY
18

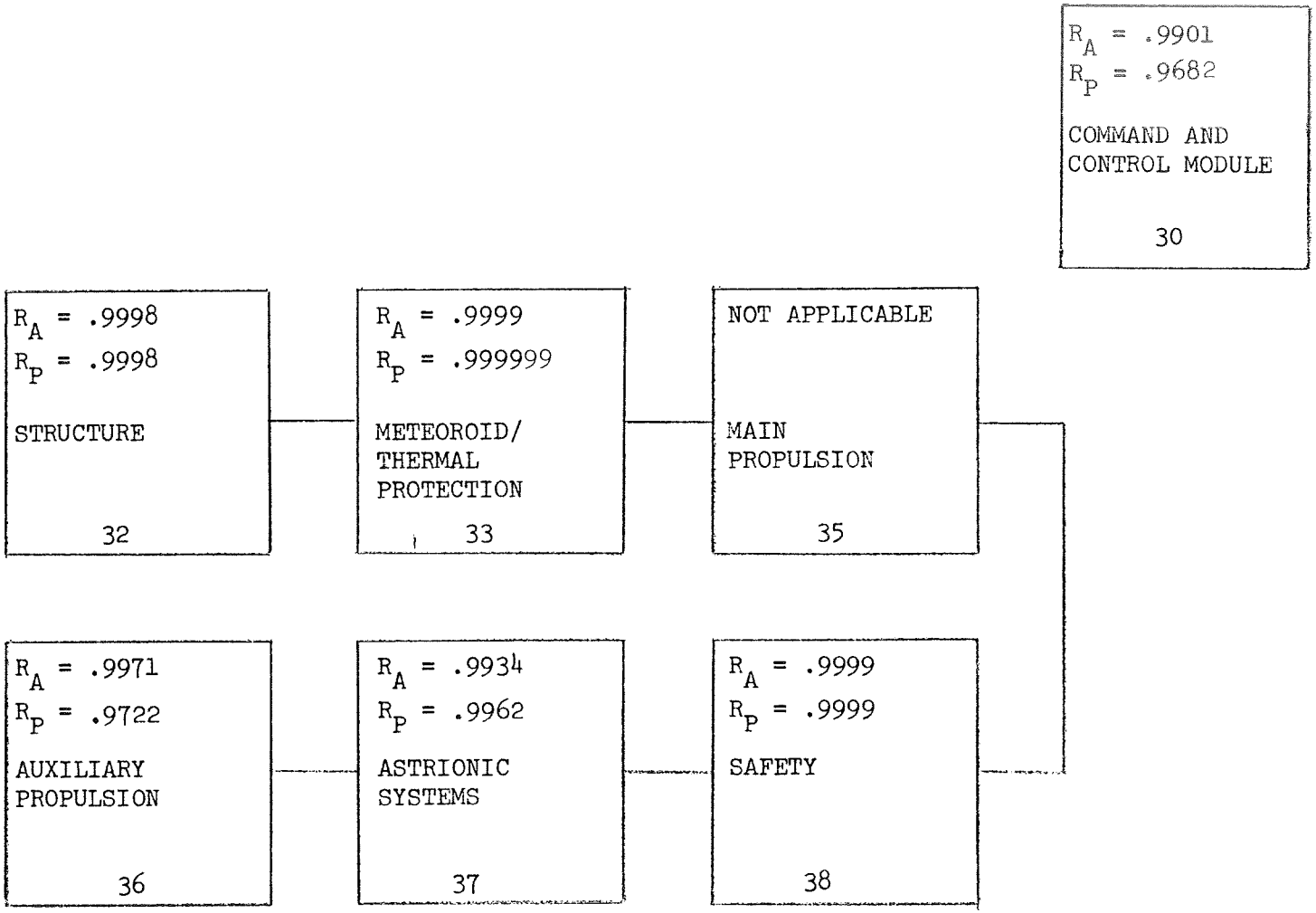

R_A = .9970
R_P = .9999
MAIN PROPULSION
15
NOT APPLICABLE
NERVA
15.01
R_A = .9988
R_P = .999998
PROPELLANT FEED
15.05
R_A = .9988
R_P = NSF
PRESSURIZATION
15.06
R_A = .9999
R_P = .999994
FILL
15.09
R_A = .9998
R_P = .99998
GROUND VENT
15.10
R_A = .9997
R_P = NSF
FLIGHT VENT
15.11

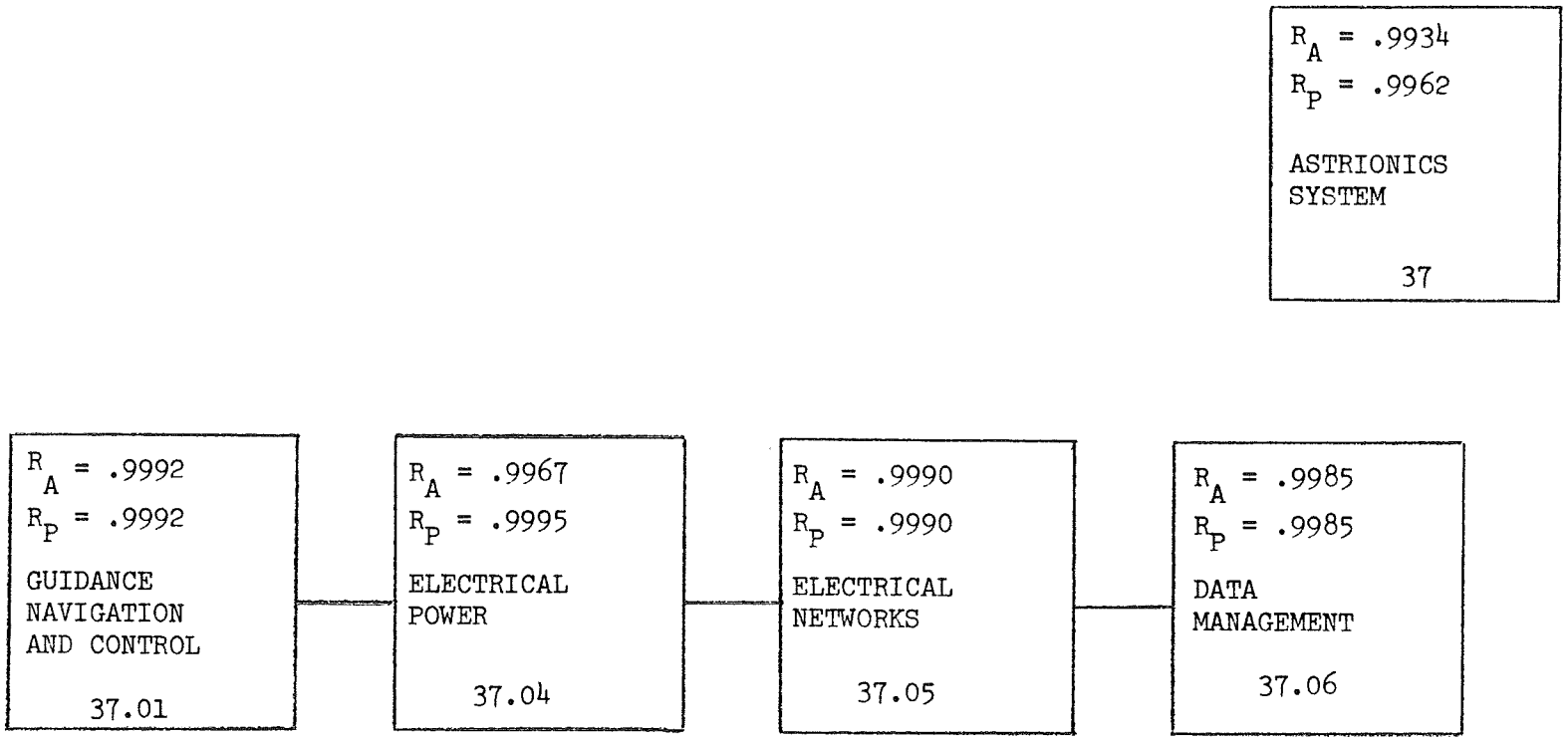

R_A = .9997
R_P = .9997
ASTRIONIC SYSTEMS
17
R_A = .9999
R_P = .9999
GUIDANCE NAVIGATION AND CONTROL
17.01
NOT APPLICABLE
ELECTRICAL POWER
17.04
R_A = .9998
R_P = .9998
ELECTRICAL NETWORKS
17.05
NOT FLIGHT CRITICAL
DATA MANAGEMENT
17.09


R_A = .99125
R_P = .9927
PROPULSION MODULE
20
R_A = .9997
R_P = .9997
STRUCTURE
22
R_A = .9998
R_P = .9999
METEOROID/ THERMAL PROTECTION
23
R_A = .9923
R_P = .9937
MAIN PROPULSION
25
R_A = .9999
R_P - .9999
AUXILIARY PROPULSION
26
R_A = .9996
R_P = .9996
ASTRIONIC SYSTEM
27
R_A = .99995
R_P = .99995
SAFETY
28


R_A = .9923
R_P = .9937
MAIN PROPULSION
25
R_A = .9950
R_P = .9950
NERVA
25.01
R_A = .9993
R_P = NSF
PROPELLANT FEED
25.05
R_A = .9991
R_P = NSF
PRESSURIZATION
25.06
R_A = .9992
R_P = .99872
FILL
25.09
NOT APPLICABLE
GROUND VENT
25.10
R_A = .9997
R_P = NSF
FLIGHT VENT
25.11

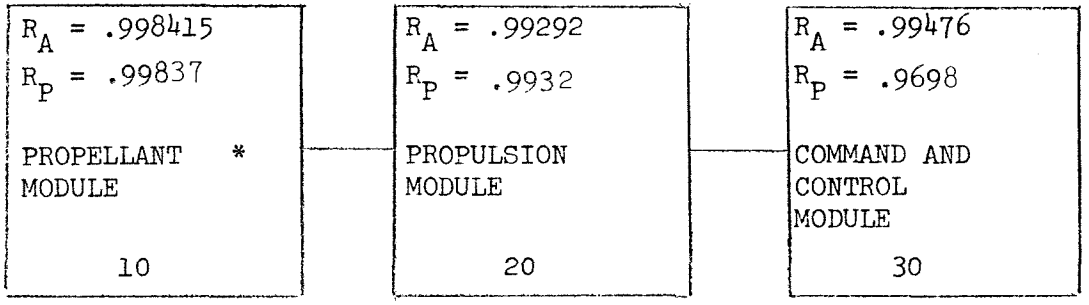

R_A = .9996
R_P = .9996
ASTRIONIC SYSTEMS
27
R_A = .9999
R_P = .9999
GUIDANCE NAVIGATION AND CONTROL
27.01
NOT APPLICABLE
ELECTRICAL POWER
27.04
R_A = .9997
R_P = .9997
ELECTRICAL NETWORKS
27.05
NOT FLIGHT CRITI-CAL
DATA MANAGEMENT
27.09


R_A = .9901
R_P = .9682
COMMAND AND CONTROL MODULE
30
R_A = .9998
R_P = .9998
STRUCTURE
32
R_A = .9999
R_P = .999999
METEOROID/ THERMAL PROTECTION
33
NOT APPLICABLE
MAIN PROPULSION
35
R_A = .9971
R_P = .9722
AUXILIARY PROPULSION
36
R_A = .9934
R_P = .9962
ASTRIONIC SYSTEMS
37
R_A = .9999
R_P = .9999
SAFETY
38

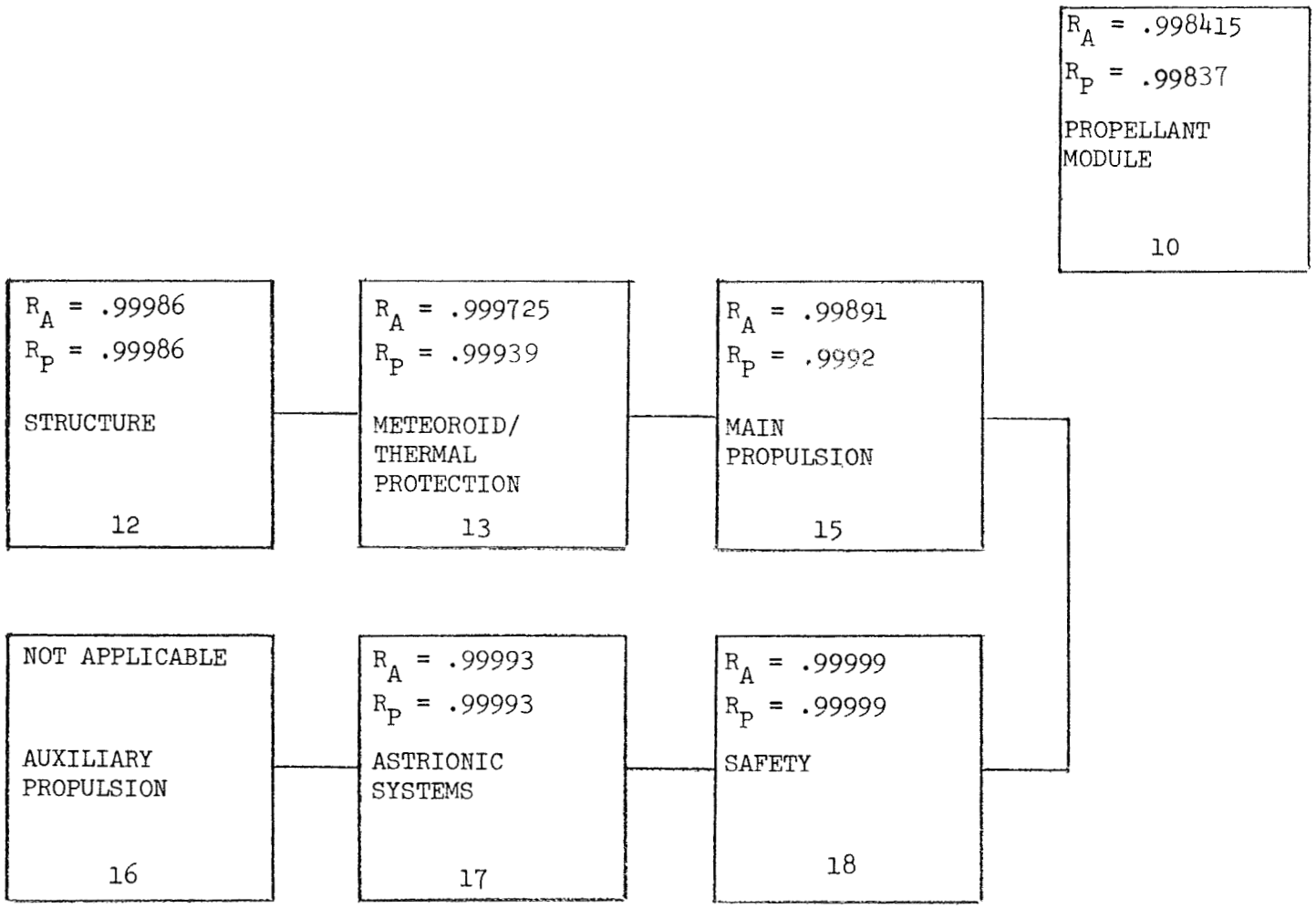

R_A = .9934
R_P = .9962
ASTRIONICS SYSTEM
37
R_A = .9992
R_P = .9992
GUIDANCE NAVIGATION AND CONTROL
37.01
R_A = .9967
R_P = .9995
ELECTRICAL POWER
37.04
R_A = .9990
R_P = .9990
ELECTRICAL NETWORKS
37.05
R_A = .9985
R_P = .9985
DATA MANAGEMENT
37.06

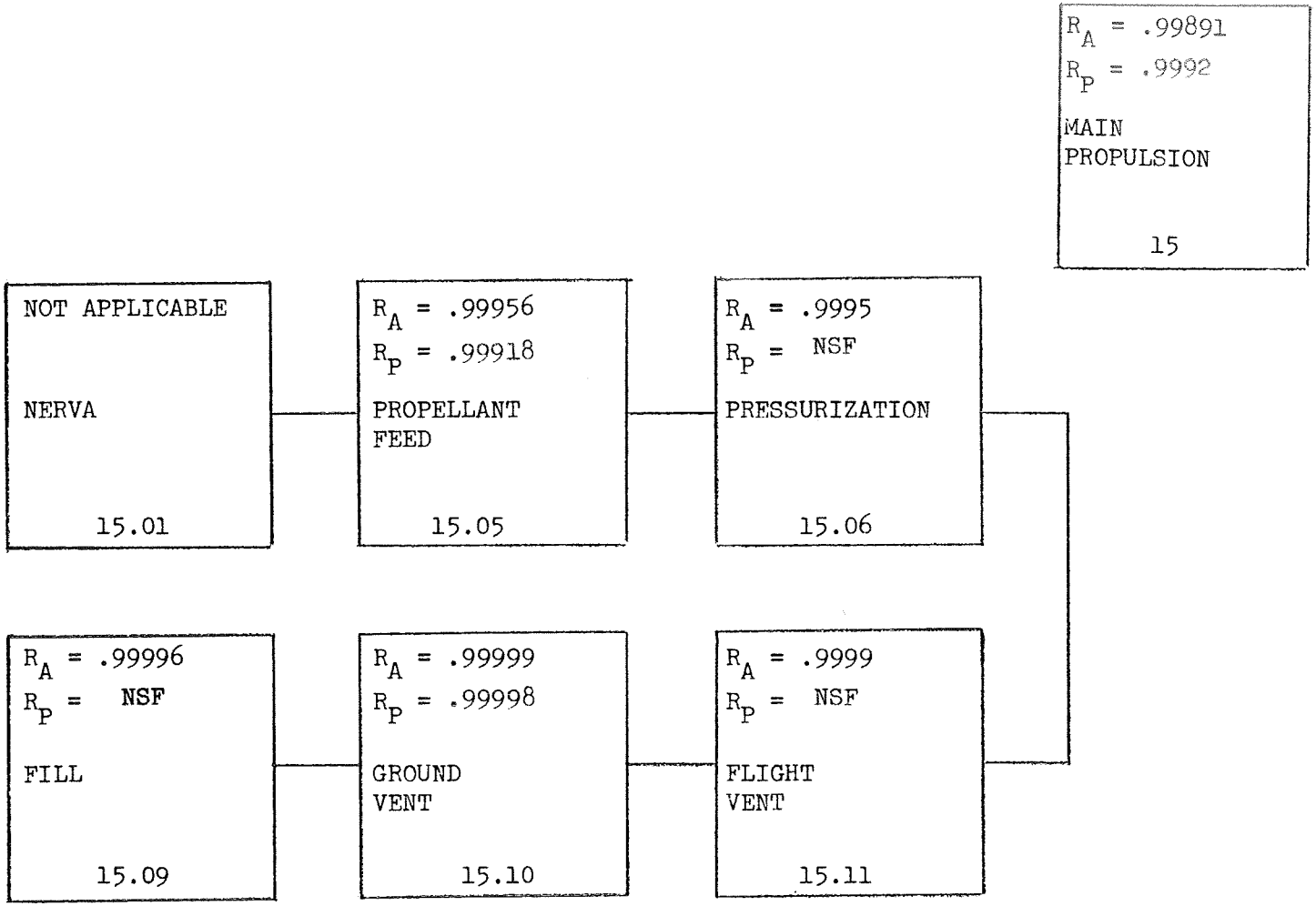
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$R_P = .9527$

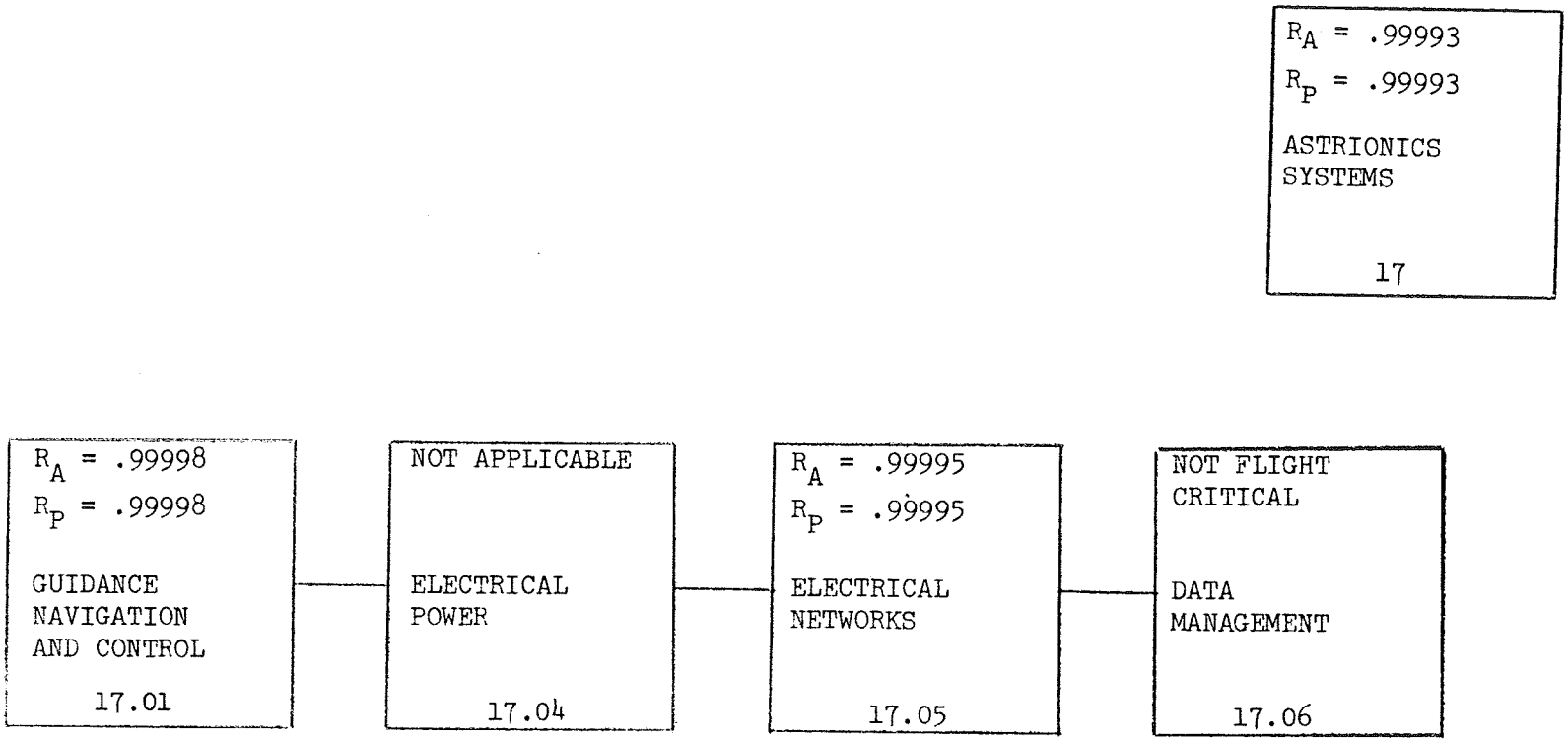
CLASS 3
REUSABLE
NUCLEAR
SHUTTLE

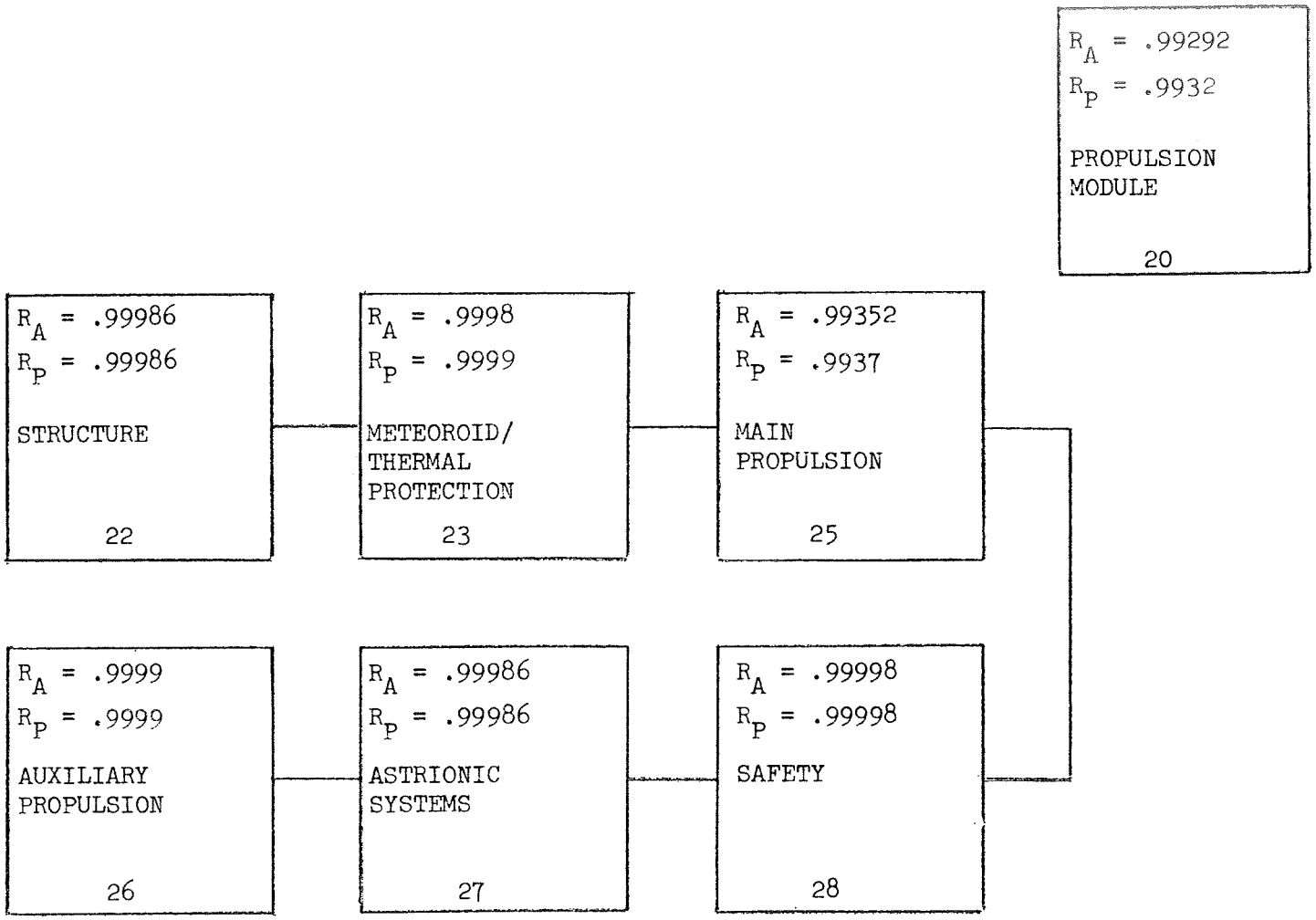


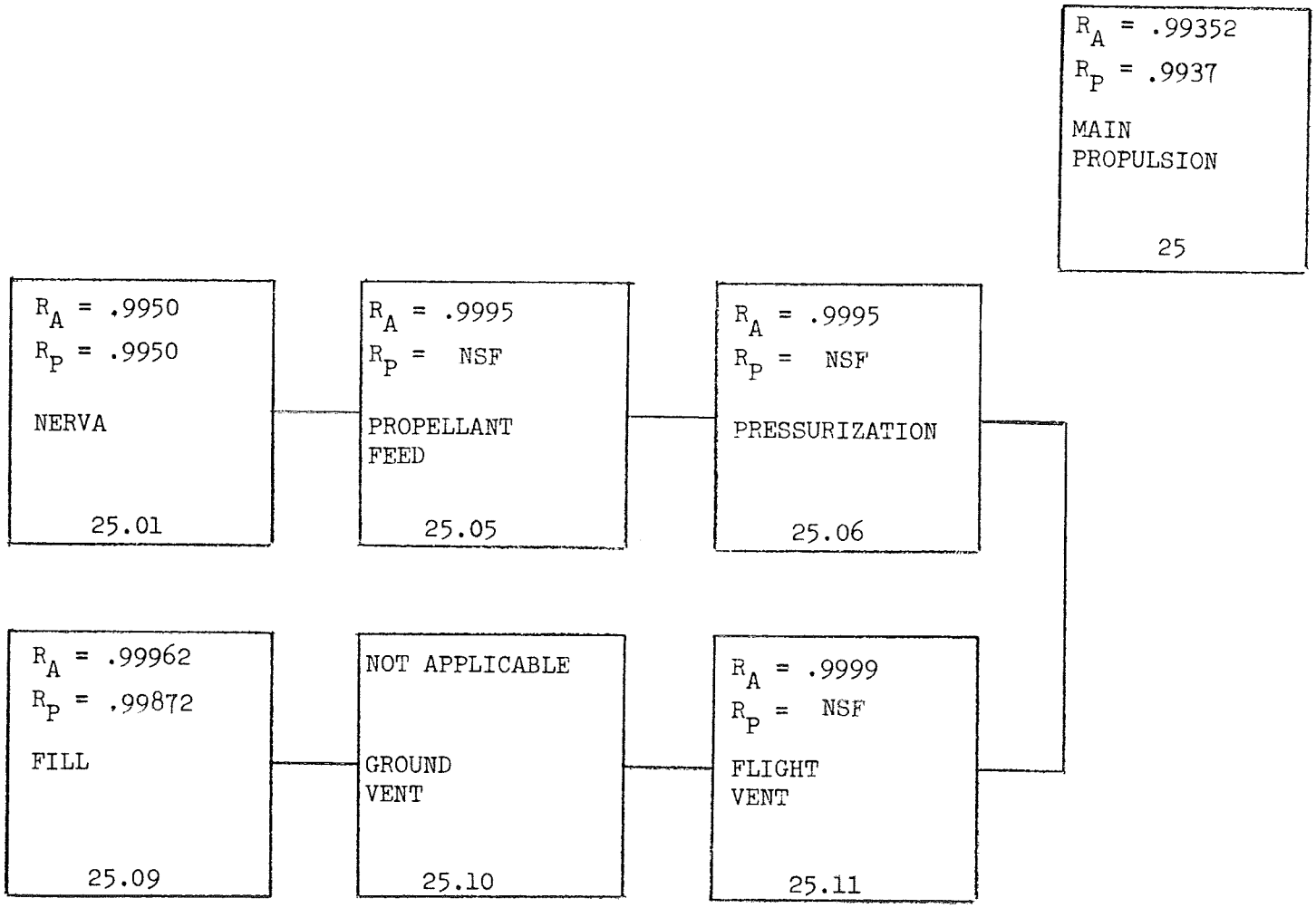
* A complete Class 3 RNS will contain eight propellant modules, one propulsion module and one command and control module.

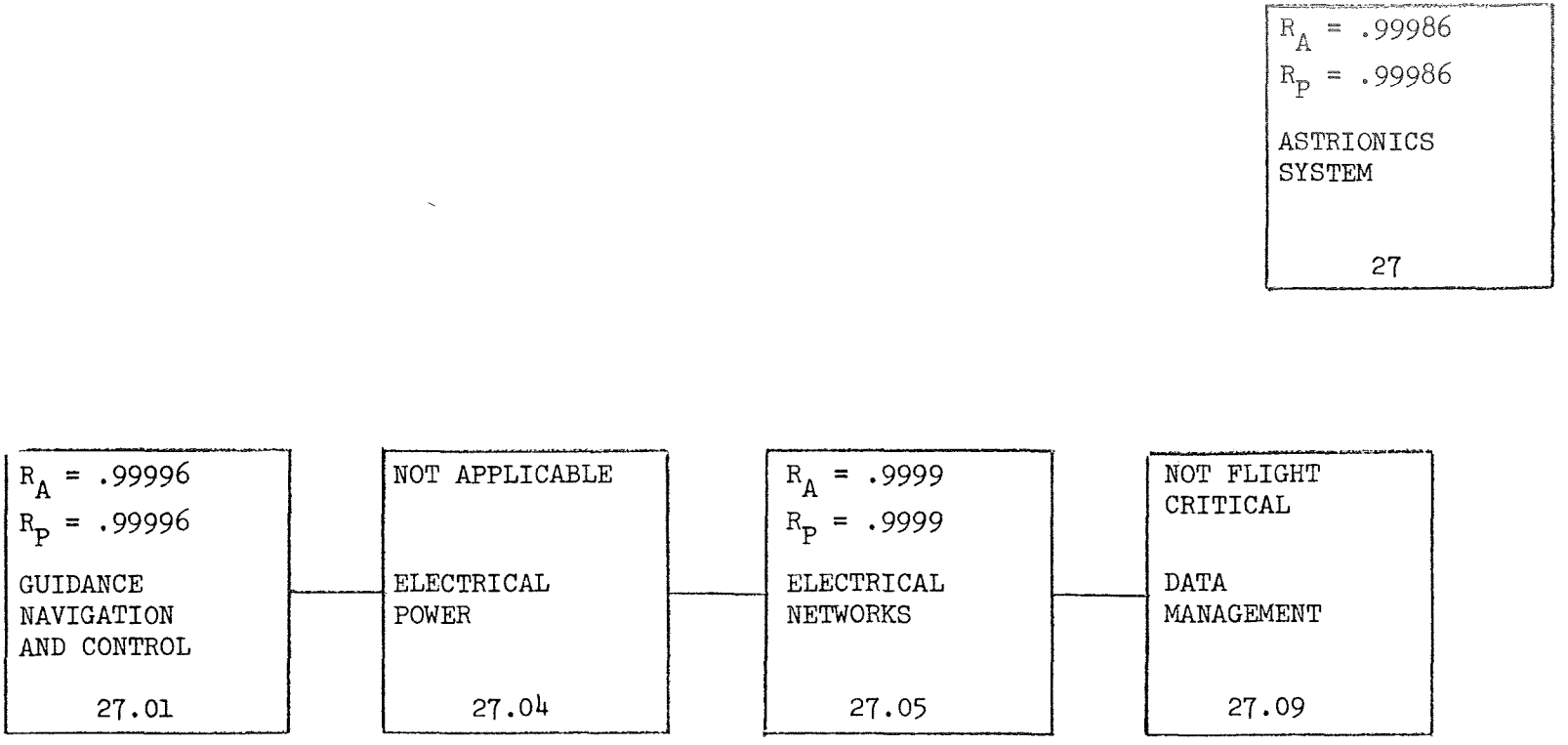

R_A = .998415
R_P = .99837
PROPELLANT MODULE
10
R_A = .99986
R_P = .99986
STRUCTURE
12
R_A = .999725
R_P = .99939
METEOROID/ THERMAL PROTECTION
13
R_A = .99891
R_P = .9992
MAIN PROPULSION
15
NOT APPLICABLE
AUXILIARY PROPULSION
16
R_A = .99993
R_P = .99993
ASTRIONIC SYSTEMS
17
R_A = .99999
R_P = .99999
SAFETY
18

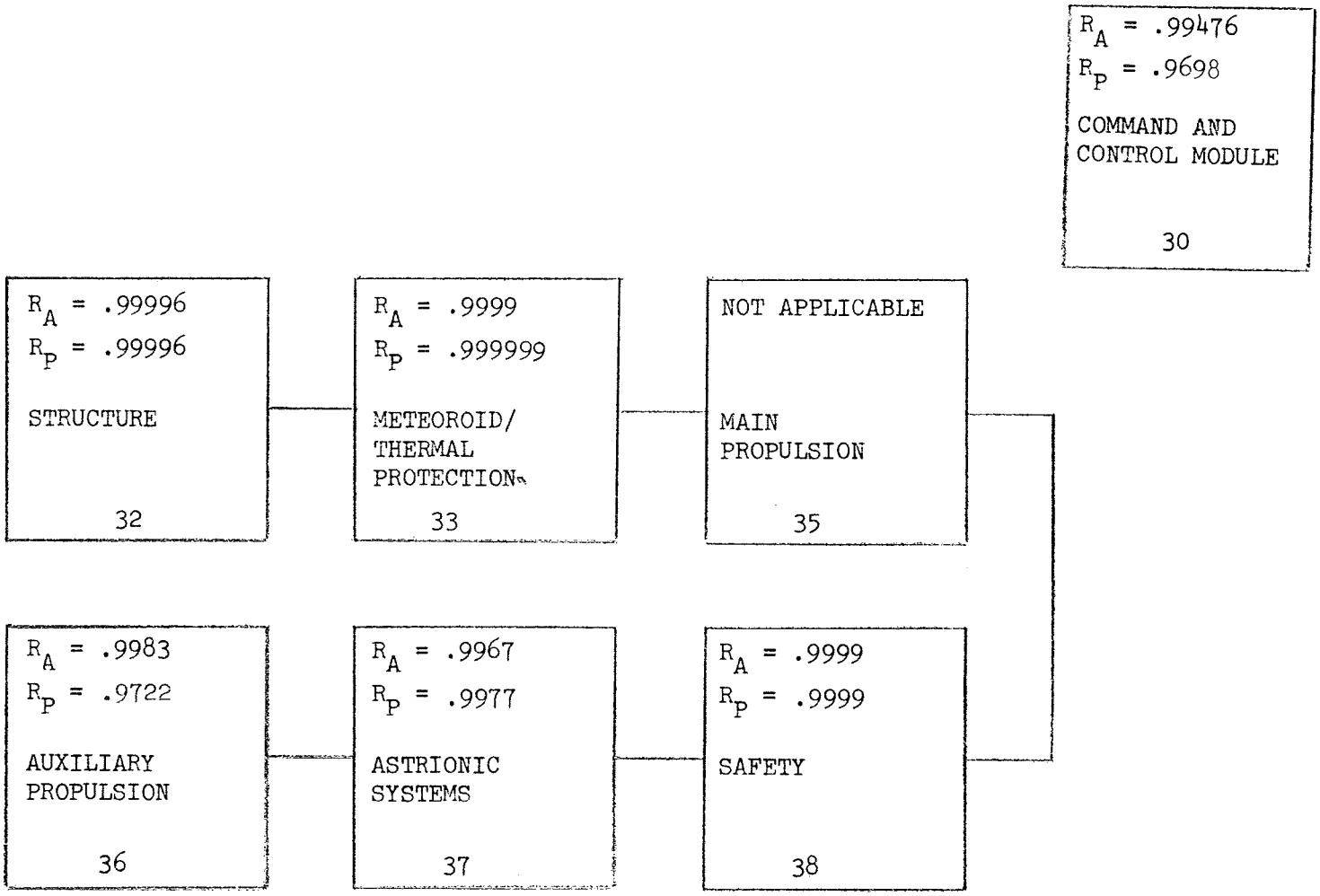

R_A = .99891
R_P = .9992
MAIN PROPULSION
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NOT APPLICABLE
NERVA
15.01
R_A = .99956
R_P = .99918
PROPELLANT FEED
15.05
R_A = .9995
R_P = NSF
PRESSURIZATION
15.06
R_A = .99996
R_P = NSF
FILL
15.09
R_A = .99999
R_P = .99998
GROUND VENT
15.10
R_A = .9999
R_P = NSF
FLIGHT VENT
15.11

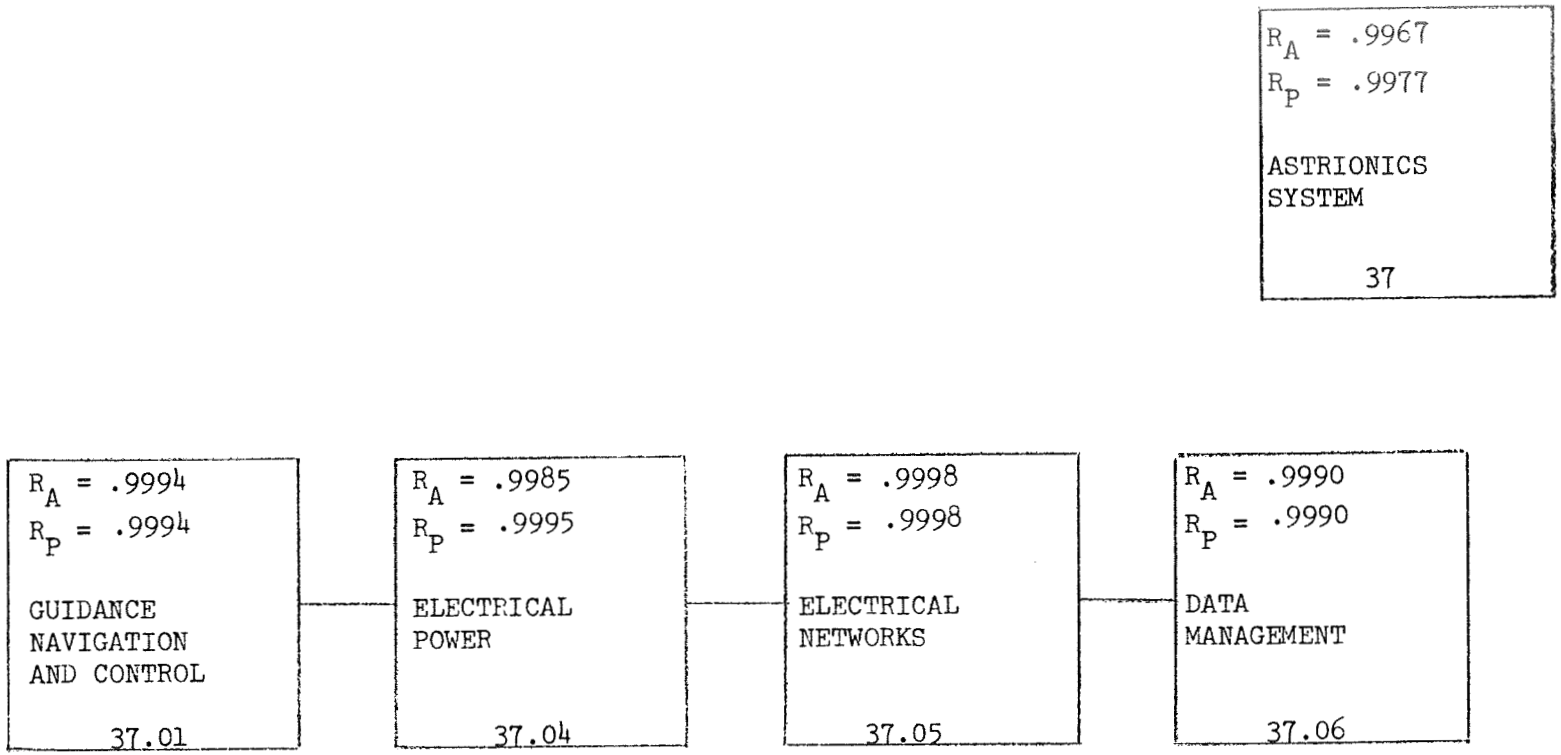

R_A = .99993
R_P = .99993
ASTRIONICS SYSTEMS
17
R_A = .99998
R_P = .99998
GUIDANCE NAVIGATION AND CONTROL
17.01
NOT APPLICABLE
ELECTRICAL POWER
17.04
R_A = .99995
R_P = .99995
ELECTRICAL NETWORKS
17.05
NOT FLIGHT CRITICAL
DATA MANAGEMENT
17.06


R_A = .99292
R_P = .9932
PROPULSION MODULE
20
R_A = .99986
R_P = .99986
STRUCTURE
22
R_A = .9998
R_P = .9999
METEOROID/ THERMAL PROTECTION
23
R_A = .99352
R_P = .9937
MAIN PROPULSION
25
R_A = .9999
R_P = .9999
AUXILIARY PROPULSION
26
R_A = .99986
R_P = .99986
ASTRIONIC SYSTEMS
27
R_A = .99998
R_P = .99998
SAFETY
28


R_A = .99352
R_P = .9937
MAIN PROPULSION
25
R_A = .9950
R_P = .9950
NERVA
25.01
R_A = .9995
R_P = NSF
PROPELLANT FEED
25.05
R_A = .9995
R_P = NSF
PRESSURIZATION
25.06
R_A = .99962
R_P = .99872
FILL
25.09
NOT APPLICABLE
GROUND VENT
25.10
R_A = .9999
R_P = NSF
FLIGHT VENT
25.11


R_A = .99986
R_P = .99986
ASTRIONICS SYSTEM
27
R_A = .99996
R_P = .99996
GUIDANCE NAVIGATION AND CONTROL
27.01
NOT APPLICABLE
ELECTRICAL POWER
27.04
R_A = .9999
R_P = .9999
ELECTRICAL NETWORKS
27.05
NOT FLIGHT CRITICAL
DATA MANAGEMENT
27.09


R_A = .99476
R_P = .9698
COMMAND AND CONTROL MODULE
30
R_A = .99996
R_P = .99996
STRUCTURE
32
R_A = .9999
R_P = .999999
METEOROID/ THERMAL PROTECTION
33
NOT APPLICABLE
MAIN PROPULSION
35
R_A = .9983
R_P = .9722
AUXILIARY PROPULSION
36
R_A = .9967
R_P = .9977
ASTRIONIC SYSTEMS
37
R_A = .9999
R_P = .9999
SAFETY
38


R_A = .9967
R_P = .9977
ASTRIONICS SYSTEM
37
R_A = .9994
R_P = .9994
GUIDANCE NAVIGATION AND CONTROL
37.01
R_A = .9985
R_P = .9995
ELECTRICAL POWER
37.04
R_A = .9998
R_P = .9998
ELECTRICAL NETWORKS
37.05
R_A = .9990
R_P = .9990
DATA MANAGEMENT
37.06

Section 3
SAFETY ANALYSIS

This section contains the flight safety analysis performed during the Phase III study. The safety analysis is primarily a problem definition exercise, consisting of the contingency planning work sheets (Section 3.1), which are a continuation of the reliability analysis described in Section 2, the fault tree analysis (Section 3.2), which approaches the field of problem definition in a different manner than the FMEA, the abort analysis (Section 3.3), which is also a problem definition activity, but one that deals with the operations instead of the hardware, and the contingency plan (Section 3.4), which presents recommendations on the solutions to some of the problems identified in the abort analysis. The philosophy is to attempt to uncover as many of the hardware and operational problem areas as possible that could cause safety problems. Once a problem is identified the solution is usually a matter of engineering. That is the reason for the multi-pronged attack—a problem that does not appear in the failure mode effects analysis (essentially a bottom-up approach) may appear in the fault tree analysis (essentially a top-down approach) and problems that do not appear in either of these (both of which are essentially hardware oriented) may appear in the abort analysis.

Several potential safety problems have been defined, including explosions in earth orbit, earth impact during the translunar coast period, desirability for separate cryogenic storage for essential systems (APS and electric power), etc. A recommendation for inclusion of a NERVA emergency idle mode has been made to permit a wider flexibility in abort operations. Additionally, it is recommended that the 5-hour cooldown period limitation for the emergency operation be eliminated. However, this analysis is not complete and must be continued as the design changes, as the operations change, as ground rules change, and as abort capabilities become more definitive.

3.1 CONTINGENCY PLANNING WORKSHEETS

3.1.1 Introduction

The contingency planning worksheets (CPWS) are a continuation of the reliability analysis discussed in Section 2. The flight critical items, defined in the failure mode effects analysis (Section 2.3) and quantified in the criticality analysis (Section 2.4), are discussed in this section. These flight critical items are also single failure items in the single failure analysis currently used in the reliability analysis. Therefore, these items are components which, if they fail, can cause loss of the mission and perhaps more important, can create a safety problem.

Each flight critical item is identified, the effect on the Reusable Nuclear Shuttle (RNS) is discussed, the applicable mission phase is identified, the failure type is categorized, the probability is listed, any secondary effects are identified, possible corrective action is listed, emergency detection requirements are identified, and the operational mode requirements are identified.

The component identification can be used to identify the specific component under discussion by reference to the system diagrams in Section 2.3. The operational phases are listed in Table 3-1. The failure categories are listed in Table 3-2. The probabilities listed on the CPWS were developed in Section 2.4 and described in Section 2.2. The value given is actually the probability of the failure causing loss of the mission divided by one million. Secondary effect factors are outside influences which could directly or indirectly cause the failure. These factors normally do not appear in a reliability analysis but are important and should be considered. They do normally appear in a fault tree analysis, which is contained in Section 3.2. The possible corrective actions represent the recommendations by the reliability/safety group to the design group for reliability/safety improvements.

Table 3-1

RNS LUNAR MISSION OPERATIONAL PHASES

Mission Phase	Description
● F	Translunar injection
G	Pulsed aftercooling Midcourse correction Translunar coast
● H	Insertion into elliptical orbit
I	Pulsed aftercooling
● J	Apolune plane change
K	Pulsed aftercooling
● L	Circularization at target altitude
M	Pulsed aftercooling
N	Lunar orbit operations
● O	Insertion into elliptical lunar orbit
P	Pulsed aftercooling
● Q	Apolune plane change
R	Pulsed aftercooling
● S	Transearth injection
T	Pulsed aftercooling Midcourse correction Transearth coast
● U	Earth orbit capture
V	Pulsed aftercooling
W	Orbit resupply and checkout operations

● Denotes NERVA thrusting operation

Table 3-2

FAILURE CATEGORIES

I Failures which do not require an abort or significant alteration of the normal mission plan and do not result in the addition of single failure points to the system.

II Failures which allow the stage to continue at normal rated conditions, do not require an immediate abort, but do introduce additional single future points to the system.

- II-A Failures that do not require any action to continue and complete the mission.
- II-B Failures that require some action to allow continued normal operation but completion of the mission is allowed.
- II-C Failures that allow normal operation but at a penalty to consumables thereby creating a situation where mission completion may not be possible.

III Failures that result in the loss of ability to achieve or maintain normal conditions but will allow operation at a reduced level.

IV Failures that result in a prompt loss of RNS control or thrust capability, or prompt destruction of the RNS.

- IV-A Failures which result in loss of control of the flight path.
- IV-B Failures that result in complete loss of engine operation except cooldown.
- IV-C Failures that result in complete loss of engine operation including cooldown.
- IV-D Failures that result in prompt destruction of the RNS.

V Failures that result in inability to perform earth orbit or lunar orbit operations.

The emergency detection requirements represent the recommendations for items on the emergency detection system list, items that will monitor the RNS and warn of impending or actual failures. The operational mode requirements are listed in detail in the several contingency plans contained in Section 3.4.

3.1.2 Discussion of Results

As discussed previously in Section 2.6, a series of reliability and safety recommendations were made to the design groups in the course of the Phase III Study. These, in general, were for the addition of redundant components to eliminate functional single failures. The reliability block diagrams (shown in Section 2.5) represent the inclusion of many of these recommendations. In general, the one failure mode that is difficult, if not impossible to eliminate by redundancy, is external leakage; in fact, the addition of parallel redundant components to eliminate functional single failures (e.g., failure to open) increased the possibility of external leakage. Therefore, most of the items on these sheets are for that type of failure and, in general, the recommendation is for improved design, specifically, multiple seals or better seals and welded connections where possible. Improved propellant contamination requirements (specifications) are also recommended in response to the statistics that this problem is a major[1] cause of seal leakage. For the auxiliary propulsion system (APS) a separate redundant APS is recommended whereby leakage in one system would not affect the other system.

The contingency planning work sheets are therefore displayed in two groups—a group which does not include the external leakage failure mode and is consistent with the reliability predictions of Tables 2-3 and 2-4, and a second group of CPWS which contains the items where the external leakage would be a problem if adequate design solutions are not obtained.

3.1.3 Contingency Planning Work Sheets—Group 1

This section contains the contingency planning work sheets that have viable failure modes other than, or in addition to, leakage.

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Feed

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.05.01 15.05.02 Isolation Valve, LH_2	(1) Failure to remain closed (2) Leakage	Possible Loss Continuous LH_2 boiloff in transfer line during long mission coast times could deplete LH_2 supply below minimum requirements.	G I K M N P R T V	II-C	38	Docking shock	Improved design Leak detection system	LH_2 level Pressure or temperature sensor in transfer line 15.05.03 - 25.09.02 Valve position	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Fill

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.09.07 Shutoff Valve, Ground Fill and Drain, LH_2	(1) Failure to remain closed	Actual Loss Loss of ullage pressurization will cause loss of ability to transfer LH_2 to the propulsion module. Loss of LH_2 could cause loss of ability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U V	IV-C and V	251	Control system failure	Provide redundancy with additional valves. Provide ground power only to prevent valve from coming open during flight. Provide check disconnect	Ullage pressure LH_2 liquid level Valve position	See Contingency Plan
	(2) Leakage	Possible Loss Loss of ullage pressurization will cause loss of ability to transfer LH_2 to the propulsion module. Loss of LH_2 could cause loss of ability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U V	IV-C and V			Provide check disconnect. Improve design	Ullage pressure LH_2 liquid level	

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Ground Vent

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.10.02 Valve, Vent and Relief, GH_2	(1) Failure to remain closed	Actual Loss Loss of ullage pressure will cause loss of ability to transfer LH_2 to the propulsion module. Loss of GH_2 and LH_2 could cause inability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U V	IV-C	42	Docking shock Control system failure	Provide redundancy with additional valves. Provide check disconnect. Provide ground power to vent valve, design relief valve so that it is inoperative in flight.	Ullage pressure LH_2 liquid level Valve position	See Contingency Plan
	(2) Leakage	Possible Loss Loss of ullage pressure will cause loss of ability to transfer LH_2 to the propulsion module. Loss of GH_2 and LH_2 could cause inability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U V	II-C			Improve seal design Provide check disconnect	Ullage pressure LH_2 liquid level	

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Ground Vent

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.10.03 Valve, Relief, GH_2	(1) Failure to remain closed	Actual Loss Loss of ullage pressure will cause loss of ability to transfer LH_2 to the propulsion module. Loss of GH_2 and LH_2 could cause inability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U V	IV-C	29	Docking shock Vibration	Provide redundancy with additional valves. Provide check disconnect. Provide ground power to vent valve, design relief valve so that it is inoperative in flight.	Ullage pressure LH_2 liquid level Valve position	See Contingency Plan
	(2) Leakage	Possible Loss Loss of ullage pressure will cause loss of ability to transfer LH_2 to the propulsion module. Loss of GH_2 and LH_2 could cause inability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U V	IV-C			Improve seal design Provide check disconnect.	Ullage pressure LH_2 liquid level	

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Fill

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.09.03 25.09.04 Control Valves, LH_2 Fill	(1) Failure to close (2) Failure to remain closed (3) Leakage	Possible Loss LH_2 will enter transfer line. Subsequent boiloff could deplete LH_2 supply below amount required to complete mission or cooldown. Pressure buildup could cause structural damage to transfer lines 25.09.02 and 15.05.03.	F G H I J K L M N O P Q R S T U V W	II-C	199	Control system failure	Add redundant series valves	Transfer line pressure sensors Valve position indicators	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Propellant Fill

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.09.10 Flow Meter, LH_2	Clogged (inability to turn)	Actual Loss Resupply of propulsion module is not possible.	F H J L O Q S U	IV B	151	Radiation	Remove	LH_2 level in propulsion module	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Propellant Fill

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.09.11 Valve, Check, Resupply, LH_2	Failure to open	Actual Loss Resupply of propulsion module is not possible	F H J L O Q S U	IV B	653	Command signal failure	Redundant valve	Valve position Propulsion module liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Propellant Fill

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.09.12 Nozzle, Spray, LH_2	Clogged	Actual Loss Ability to fill propulsion module is lost.	F H J L O Q S U	IV B	151	Contamination in propellants	More stringent propellant cleanliness requirements	LH_2 level in propulsion module	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
26.01.05 Relief Valve, GH_2 Storage, APS	Failure to remain closed Leakage	Actual Loss Supply of GH_2 for earth orbit operations will be lost.	U V W	V		Docking shock	Improved design Substitute burst disk Provide redundant GH_2 storage vessel	APS GH_2 storage Vessel pressure sensor Valve position sensor	

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.01.01 36.03.01.01 Engines, APS	Burnthrough	Actual Loss Possible destructive impingement on LH_2 or LOX tanks or other APS nozzles.	All	IV-D	10072		Improved design Separation of engines Blast shields	None identified at the present time	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.02.10 36.01.04.10 Valve, Relief	(1) Fail to remain closed (2) Leakage	Possible Loss Loss of APS propellants may cause loss of attitude control.	All	II-C	<1		Provide separate, redundant accumulator or APS system	Accumulator pressure	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.02.11 36.01.04.11 Filter	Clogged	Actual Loss Inability to pressurize LOX or LH_2 tanks, which prevents transfer of LOX or LH_2 to turbopumps. Loss of attitude control	All	IV-A	109	Contamination in propellants	More stringent propellant cleanliness requirements Redundant filter Provide separate, redundant APS system	LOX and LH_2 tank pressure	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.02.17 36.01.02.23 36.01.04.17 36.01.04.23 Gas Generator	Burnthrough	Probable Loss Burnthrough may cause explosion in the command and control module.	All	IV-D	8399	Improper manufacture and checkout	Improved design	None identified at the present time	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: Electrical

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
37.04.01 37.04.02 Hydrogen Assembly	Burst	Possible Loss Possible damage to other components in the RNS.	F G H I J K L M N O P Q R S T U V W	IV-D	29	External heat Improper manufacture and test	Improved design Physical placement blast shield	Storage sphere pressure	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: Electrical

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
37.04.03 37.04.04 Oxygen Assembly	Burst	Possible Loss Possible damage to other components in the RNS.	F G H I J K L M N O P Q R S T U V W	IV-D	29	External heat Improper manufacture and test	Improved design Physical placement blast shield	Storage sphere pressure	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: Electrical

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
37.04.19 37.04.20 Voltage Limiter Sensor	Erroneous Output	Possible Loss Erroneous output may cause output of two fuel cells to be different causing degraded performance.	F G H I J K L M N O P Q R S T U V W	II-B	144		Provides redundant sensors and a 2/3 logic	Voltage	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: Electrical

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
37.04.21 37.04.22 Voltage Limiter Control	Erroneous Output	Possible Loss Erroneous output may cause output of two fuel cells to be different causing degraded performance.	F G H I J K L M N O P Q R S T U V W	II-B	54	Vibration	Provide redundant controls and a 2/3 logic	Voltage	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 3
MODULE: Propellant
SYSTEM: LH_2 Feed

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.05.05 Blocking Valve	Failure to open. Failure to remain open	Ability to transfer LH_2 to the propulsion module is lost.	I H J L O Q S U	IV-B	815	Control System Command ——— Vibration	Provide redundant valves. ——— Eliminate	Valve position ——— LH_2 level in propulsion module.	See Contingency plan

3.1.4 Contingency Planning Work Sheets - Group 2

This section contains the contingency planning work sheets for the items with external leakage as the only flight critical failure mode.

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Feed

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.05.03 Ducting, LH_2 Transfer	Leakage	Possible Loss Loss of LH_2 during transfer mode (all power phases) could deplete LH_2 supply below minimum mission requirements.	F H J L O Q S U	II-C	38	Radiation damage Vibration	Improved design	LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: LH_2 Feed

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.05.04 Disconnect	Leakage	Possible Loss Ability to transfer LH_2 may be lost.	F H J L O Q S V	II-C	5	Incorrect docking Abnormal bending moments	Improved design	LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Pressurization

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.06.01 Ducting, Pressurization, GH_2	Leakage	Possible Loss Loss of ullage pressure could cause loss of ability to transfer propellant to propulsion module. Loss of LH_2 could cause loss of ability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U V	II-C	216	Vibration	Improved design	Ullage pressure LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Pressurization

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.06.02 15.06.03 15.06.04 Pressurization Valves, GH_2	Leakage	Possible Loss Low ullage pressure could cause loss of ability to transfer LH_2 to propulsion module. Loss of LH_2 could cause loss of ability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U	II-C	613	Radiation	Improved design Leak detection system	Ullage pressure sensor LH_2 level sensor	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Pressurization

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.06.06 Disconnect, Pressurization, GH_2	Leakage	Possible Loss Ability to control ullage pressure in propellant and propulsion module may be lost. Loss of ullage pressure in propellant module may result in inability to transfer LH_2 to propulsion module. Loss of ability to control ullage pressure in propulsion module may result in NERVA pump cavitation. Loss of LH_2 may result in inability to complete mission and/or cooldown.	F H J L O Q S U	II-C	5	Incorrect docking Abnormal bending moment	Improved design	Ullage pressure	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Liquid Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Pressurization

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.06.08 Ground Pressurization Valve, GH_2	Leakage	Possible Loss Loss of ullage could cause inability to transfer LH_2 to propulsion module. Loss of LH_2 could cause inability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U V	II-C	658	Radiation Effects	Improved design Leak detection system	Ullage pressure LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Fill

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.09.04 Fill Valve, Orbital, LH_2	Leakage	Possible Loss Loss of ullage or LH_2 through fill valve could cause inability to transfer LH_2 to propulsion module.	F G H I J K L M N O P Q R S T U V	II-C and V	613	Vibration	Improved design Leak detection system	Ullage pressure LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Ground Vent

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.10.01 Ducting, Ground Vent, GH_2	Leakage	Possible Loss Loss of ullage pressure could cause loss of ability to transfer propellant to propulsion module. Loss of LH_2 could cause loss of ability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U V	II-C	216	Radiation	Improved design	Ullage pressure LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Flight Vent

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.11.01 Ducting, Flight Vent, GH_2	Leakage	Possible Loss Loss of ullage pressure could cause loss of ability to transfer propellant to propulsion module. Loss of LH_2 could cause loss of ability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U V	II-C	216	Vibration	Improved design	Ullage pressure LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propellant
SYSTEM: Flight Vent

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
15.11.02 Quad Valves, Flight Vent, GH_2	Leakage	Possible Loss Insufficient ullage pressure could cause loss of ability to transfer LH_2 to the propulsion module. Loss of LH_2 could cause inability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U	II-C	613	Radiation	Improved design Leak detection system	Ullage pressure LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Propellant Feed

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.05.05 25.05.06 25.05.07	Leakage	Possible Loss Loss of LH_2 may cause loss of ability to complete mission.	All	II C	78	Radiation Contamination in propellant	Improved design More stringent propellant cleanliness requirement	LH_2 level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Propellant Feed

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.05.08 Quad Valve, Chilldown, LH_2	Leakage	Possible Loss Depletion of LH_2 could cause inability to complete mission and/or cooldown.	All	II-C	612	Radiation Contamination in propellant	Improved Design More stringent propellant cleanliness requirements	LH_2 supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Pressurization

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.06.01 Ducting, Pressurization, GH_2	Leakage	Possible Loss Possible loss of ullage or LH_2 could cause NERVA pump to cavitate in power phases. Loss of LH_2 could create inability to complete mission or cooldown.	F G H I J K L M N O P Q R S T U V	II-C	216	Vibration	Improved design	Ullage pressure LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Pressurization

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.06.02 25.06.03 Pressurization Valves, GH_2	Leakage	Possible Loss Low ullage pressure could cause NERVA pump to cavitate. Loss of GH_2 and LH_2 could cause inability to complete mission or cooldown.	F G H I J K L M N O P Q R S T U V W	II-C	613	Radiation	Improved design Leak detection system	Ullage pressure sensor LH_2 level sensor	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Pressurization

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.06.05 Disconnect, Pressurization, GH_2	Leakage	Possible Loss Ability to control ullage pressure in propellant and propulsion module may be lost. Loss of ullage pressure in propellant module may result in inability to transfer LH_2 to propulsion module. Loss of ability to control ullage pressure in propulsion module may result in NERVA pump cavitation. Loss of LH_2 may result in inability to complete mission and/or cooldown.	F H J L O Q S U	II-C	5	Vibration Bending moment	Improved design	Ullage pressure	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: LH_2 Fill

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.09.01 Disconnect, LH_2	Leakage	Possible Loss Ability to transfer LH_2 may be lost.	F H J L O Q S V	IV-B	5	Incorrect docking	Improved design	LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Ground Fill

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.09.02 Ducting, Ground Fill, LH_2	Leakage	Possible Loss Possible loss of ullage or LH_2 could cause NERVA pump to cavitate in power phases. Loss of LH_2 could cause inability to complete mission or cooldown.	F G H I J K L M N O P Q R S T U V	II-C	189	Vibration	Improved design	Ullage pressure LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Flight Vent

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.11.01 Ducting, Flight Vent, GH_2	Leakage	Possible Loss Possible loss of ullage or LH_2 could cause NERVA pump to cavitate in power phases. Loss of LH_2 could cause inability to complete mission or cooldown.	F G H I J K L M N O P Q R S T U V	II-C	216	Vibration	Improved design	Ullage pressure LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Propulsion
SYSTEM: Flight Vent

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
25.11.02 Quad Valves, Flight Vent, GH_2	Leakage	Possible Loss Insufficient ullage pressure could cause NERVA pump to cavitate during power phases. Loss of ullage pressure or LH_2 could cause inability to complete mission and/or cooldown.	F G H I J K L M N O P Q R S T U V	II-C	613	Radiation	Improved design Provide leak detection system	Ullage pressure LH_2 liquid level	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.01.04 36.01.01.06 Control Valves	Leakage	Possible Loss Loss of APS propellants may cause loss of attitude control.	All	II-C	1426	Radiation Contamination in propellants	Improved design More stringent propellant cleanliness requirements Provide separate, redundant APS system	LOX and LH_2 propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.01.07 36.01.01.08 Ducting	Leakage	Possible Loss Loss of APS propellant may cause loss of attitude control.	All	II-C	458	Vibration	Improved design Provide separate, redundant APS system	LOX and LH_2 propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.02.03	Leakage	Possible Loss	All	II-C	648	Radiation	Improved design	LH_2 propellant supply	See Contingency Plan
36.01.02.04		Loss of APS propellants may cause loss of attitude control.			648	Contamination in propellant	More stringent propellant cleanliness requirements		
36.01.02.06					648		Provide separate redundant APS system		
36.01.02.13					65				
36.01.02.14					65				
36.01.02.15					65				
36.01.02.19					65				
36.01.02.20					65				
36.01.02.21					65				
36.01.02.25					65				
36.01.02.26					65				
Valve, Shutoff GH_2									

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.02.07 36.01.04.07 Accumulator	Leakage	Possible Loss Loss of APS propellants may cause loss of attitude control.	All	II-C	61	Vibration Radiation Contamination in propellants	Improved design More stringent propellant cleanliness requirements Provide separate, redundant APS system	LOX and LH_2 propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.02.08 36.01.02.09 Valve, Check, GH_2	Leakage	Possible Loss Loss of APS propellants may cause loss of attitude control.	All	II-C	351	Vibration Radiation Contamination in propellants	Improved design More stringent propellant cleanliness requirements Provide separate redundant APS system	LH_2 propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.02.12 36.01.04.12 Quad Valves, Pressurization	Leakage	Possible Loss Loss of APS propellants may cause loss of attitude control.	All	II-C	2593	Radiation Contamination in propellants	Improved design More stringent propellant cleanliness requirements Provide separate, redundant APS system	LOX and LH_2 propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.02.18 36.01.02.24 36.01.04.18 36.01.04.24 Heat Exchanger	Leakage	Possible Loss Loss of APS propellants may cause loss of attitude control.	All	II-C	9	Vibration	Improved design	LOX and LH_2 propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.03.01 36.01.03.05 Valve, Check, LH_2	Leakage	Possible Loss Loss of LH_2 may cause loss of attitude control.	All	II-C	35	Vibration Contamination in propellants	Improved design More stringent propellant cleanliness requirements Provide separate, redundant APS system	LH_2 propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.03.03 36.01.03.04 36.01.03.07 36.01.03.08 36.01.03.10 Valve, Shutoff, LH_2	Leakage	Possible Loss Loss of APS propellants may cause loss of attitude control.	All	II-C	648	Radiation Contamination in propellants	Improved design More stringent propellant cleanliness requirements Provide separate, redundant APS system	LH_2 propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.03.09 36.01.05.09 Tank, Storage, LOX and LH_2	Leakage	Possible Loss Loss of APS propellants may cause loss of attitude control.	All	II-C	61		Improved design Provide separate, redundant APS system	LOX and LH_2 propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.03.12 36.01.05.12 Quad Valves, Vent	Leakage	Possible Loss Loss of APS propellants may cause loss of attitude control.	All	II-C	1296	Radiation Contamination in propellants	Improved design More stringent propellant cleanliness requirements Provide separate, redundant APS system	LOX and LH_2 propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.03.13 36.01.05.15 Ducting, LH_2 and LOX	Leakage	Possible Loss Loss of APS propellant may cause loss of attitude control.	All	II-C	92	Vibration	Improved design Provide separate redundant APS system	LOX and LH_2 propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.04.03	Leakage	Possible Loss Loss of APS propellants may cause loss of attitude control.	All	II-C	648	Radiation Contamination in propellants	Improved design More stringent propellant cleanliness requirements Provide separate, redundant APS system	LOX propellant supply	See Contingency Plan
36.01.04.04					648				
36.01.04.06					648				
36.01.04.13					65				
36.01.04.15					65				
36.01.04.19					65				
36.01.04.20					65				
36.01.04.21					65				
36.01.04.25					65				
36.01.04.26					65				
Valve, Shutoff, GOX					65				

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.04.08 36.01.04.09 Valve Check, GOX	Leakage	Possible Loss Loss of APS propellants may cause loss of attitude control.	All	II-C	351	Vibration Radiation Contamination in propellants	Improved design More stringent propellant cleanliness requirements Provide separate, redundant APS system	LOX propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.05.01 36.01.05.05 Valve, Check, LOX	Leakage	Possible Loss Loss of LOX may cause loss of attitude control.	All	II-C	35	Vibration Contamination in propellants	Improved design More stringent propellant cleanliness requirements Provide separate, redundant APS system	LOX propellant supply	See Contingency Plan

Form No. *830-380 (11-70)

MISSION: Lunar Shuttle
CLASS: 1 Hybrid and 3
MODULE: Command and Control
SYSTEM: APS

CONTINGENCY PLANNING WORK SHEET

ITEM	CRITICAL FAILURE TYPE/MODE	FAILURE EFFECT ON NUCLEAR STAGE	PHASE	FAILURE CATEGORY	PROBABILITY	SECONDARY EFFECT FACTORS	POSSIBLE CORRECTIVE ACTION	EMERGENCY DETECTION REQUIREMENTS	OPERATIONAL MODE REQUIREMENTS
36.01.05.03 36.01.05.04 36.01.05.07 36.01.05.08 36.01.05.10 Valve, Shutoff, LOX	Leakage	Possible Loss Loss of APS propellant may cause loss of attitude control.	All	II-C	648	Radiation Contamination in propellants	Improved design More stringent propellant cleanliness requirements Provide separate, redundant APS system	LOX propellant supply	See Contingency Plan

3.2 FAULT TREE ANALYSIS

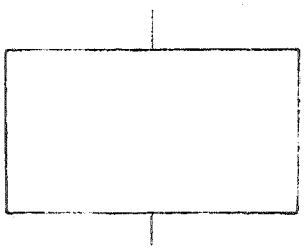
A partial fault tree analysis was performed during the Phase III study as an aid and supplement to the remainder of the reliability and safety work. Definition of the complete fault tree at this time was beyond the available manpower capability. It was felt, however, that the tree should be initiated and continued through subsequent project phases, and it should be performed in such a manner that it would provide visibility in certain critical areas. Three general areas were studied: (1) the top level tree, which delineates the general problem areas in the operation of the RNS; (2) the problem of earth impact of radioactive debris, which would be caused by malfunctions in earth orbit and (3) the problem of loss of tank pressure, which results in the inability to start the NERVA or causes turbopump cavitation during operation.

3.2.1 Fault Tree Methodology

The fault trees which are presented in this section are represented by the following symbols:

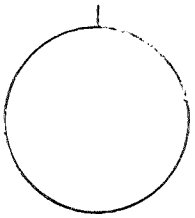
EVENT REPRESENTATIONS

The rectangle identifies an event that results from the combination of fault events through the input logic gate.

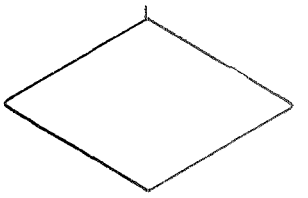


The rectangle is also used to describe a conditional input to an INHIBIT GATE. It indicates a condition that is presumed to exist for the life of the system.

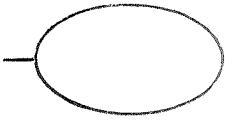
The circle describes a basic fault event that requires no further development. Frequency and mode of failure of items so identified are derived from empirical data.



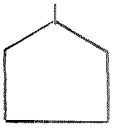
The diamond describes a fault event that is considered basic in a given fault tree. The possible causes of the event are not developed either because the event is of insufficient consequence or the necessary information is unavailable.



The oval is used to record the conditional input to an INHIBIT GATE. It defines the state of the system that permits a fault sequence to occur, and may be either normal to the system or result from failures.



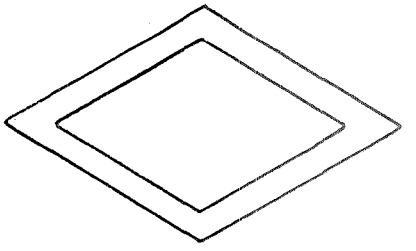
The house indicates an event that is normally expected to occur such as a phase change in a dynamic system.



The triangles are used as transfer symbols. A line from the apex of the triangle indicates a "transfer in" and a line from the side denotes a "transfer out."

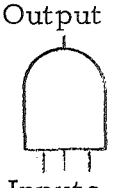


The double diamond is used in the simplification of a fault tree for numerical evaluation. The event described results from the causes that have been identified but are not shown on a particular version of the fault tree.

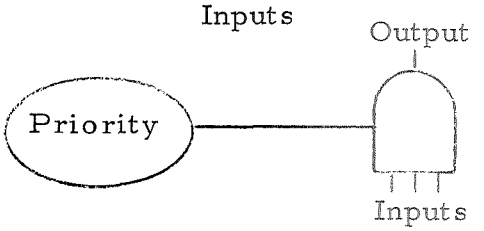


LOGIC OPERATIONS

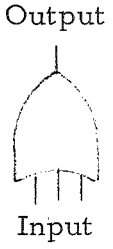
AND GATE describes the logical operation whereby the coexistence of all input events is required to produce the output event.



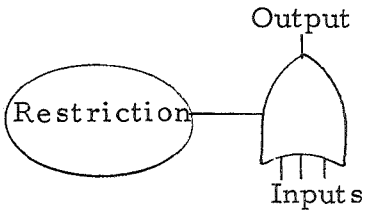
PRIORITY AND GATE performs the same logic function as the AND GATE with the additional stipulation that sequence as well as coexistence is required.



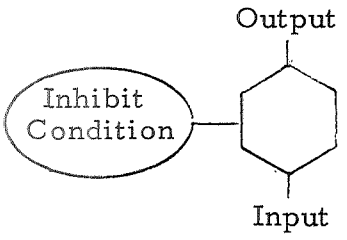
OR GATE defines the situation whereby the output event will exist if one or more of the input events exists.

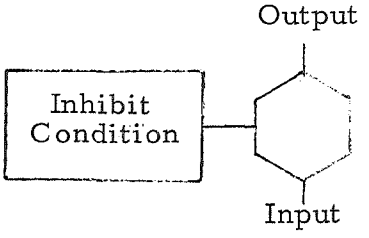


EXCLUSIVE OR GATE functions as an OR GATE with the restriction that specified inputs cannot co-exist.



INHIBIT GATES describe a casual relationship between one fault and another. The input event directly produces the output event if the indicated condition is satisfied. The conditional input defines a state of the system that permits the fault sequence to occur, and may be either normal to the system or result from failures. It is represented by an oval if it describes a specific failure mode and a rectangle if it describes a condition that may exist for the life of the system.





The system used in this analysis is the system represented by the figures contained in Section 2.3.

3.2.2 Discussion of Results

The fault tree is incomplete; therefore, a complete evaluation of the design is not possible. The full value of a fault tree becomes apparent when it is performed simultaneously with the design effort, but then it is in a continuous process of change. Hence, a report at a specific time only shows the state of the tree at that point in the design evolution. For example, the fault tree effort during this phase devoted some time to an examination of the pre-pressurization system which was later eliminated. The tree as it exists now is represented by the sheets in Section 3.2.3 and is devoted to the development of the top level tree, the examination of the failures in earth orbit which could cause reentry of radioactive particles, and the investigation of the failures which cause loss of LH_2 to NERVA or loss of ullage pressure in the propulsion module. The development of the top level event is represented by the top level tree and subtrees 1, 2, 3, 4, K, L, M, N, P, Q, F, and B.

This group of trees delineates general type of failures that will lead to either public exposure to nuclear hazards or injury or death to space personnel.

The failures in earth orbit which could cause earth impact are delineated in subtrees F, F-1, F-3, M-1, B-1J, B-1W, B-1X, B-1T, B-1U, B-1Y, B-1AA, B-1AE, and B-1AD.

The subtrees that investigate the loss of LH_2 to the NERVA include B-1, B-1B, B-1F, B-1Q, B-1R, and B-1H.

A reentry of the RNS or portions of the RNS can be caused by a situation in earth orbit where the RNS has failed and is in a reentry condition. Additionally, a case could exist where the abandoned RNS is not assisted by other space vehicles or cannot be helped because the RNS is not intact. The problem could also be caused by guidance failures in the translunar injection phase, the transearth injection phase, or the earth orbit injection phase. Also, as shown in the abort analysis (Section 3.3), the problem could result from cooldown failure in the translunar coast phase. Subtrees F and M-1 delineate the failures that can cause the first type of failure, i.e., failure in earth orbit. As shown in subtree F, there are a number of items on the RNS which can explode or cause explosions. These include high-pressure bottles on the command and control module and the propulsion module. The probability of occurrence of these failures can be reduced by redundant relief systems. The payload (subtree PL) must also be investigated for this type of failure. One lesson that can be learned from this analysis is to avoid explosions in earth orbit. It will be extremely difficult, if not impossible, to prevent the reentry and earth impact of radioactive debris, and this debris will impact in a time span of less than 1.5 years.

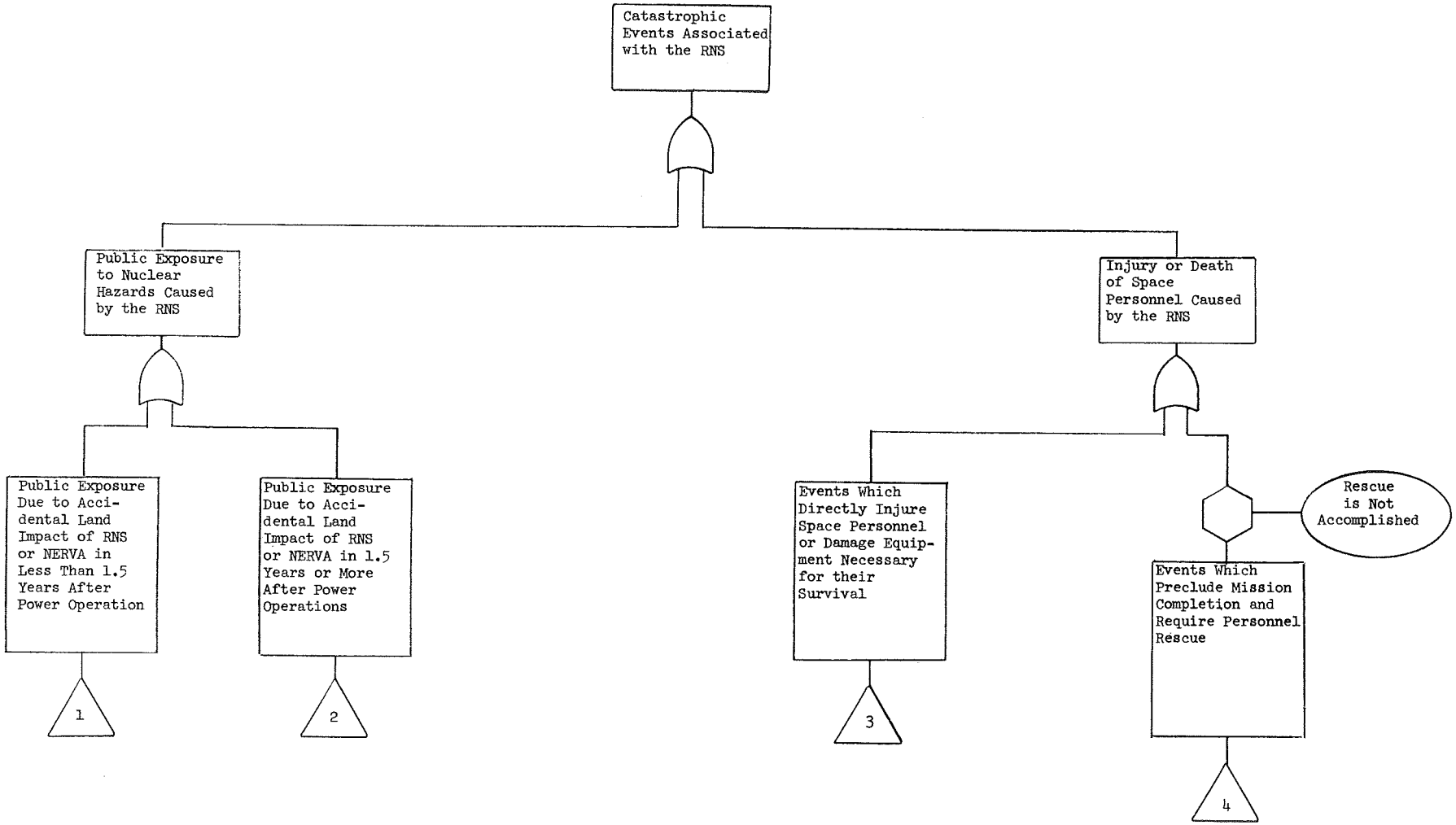
Another failure that can cause reentry of the RNS is the loss of altitude control. As shown on subtree M-1, this can be caused by loss of the command and control module and the propulsion module auxiliary propulsion systems during most of the earth orbit operations, but the loss of the propulsion module APS alone during the changing of the command and control module will cause this to happen. Loss of attitude control could make it

difficult to perform a docking or grabbing maneuver by other space vehicles to prevent reentry. Subtrees M-1 and below investigate this problem.

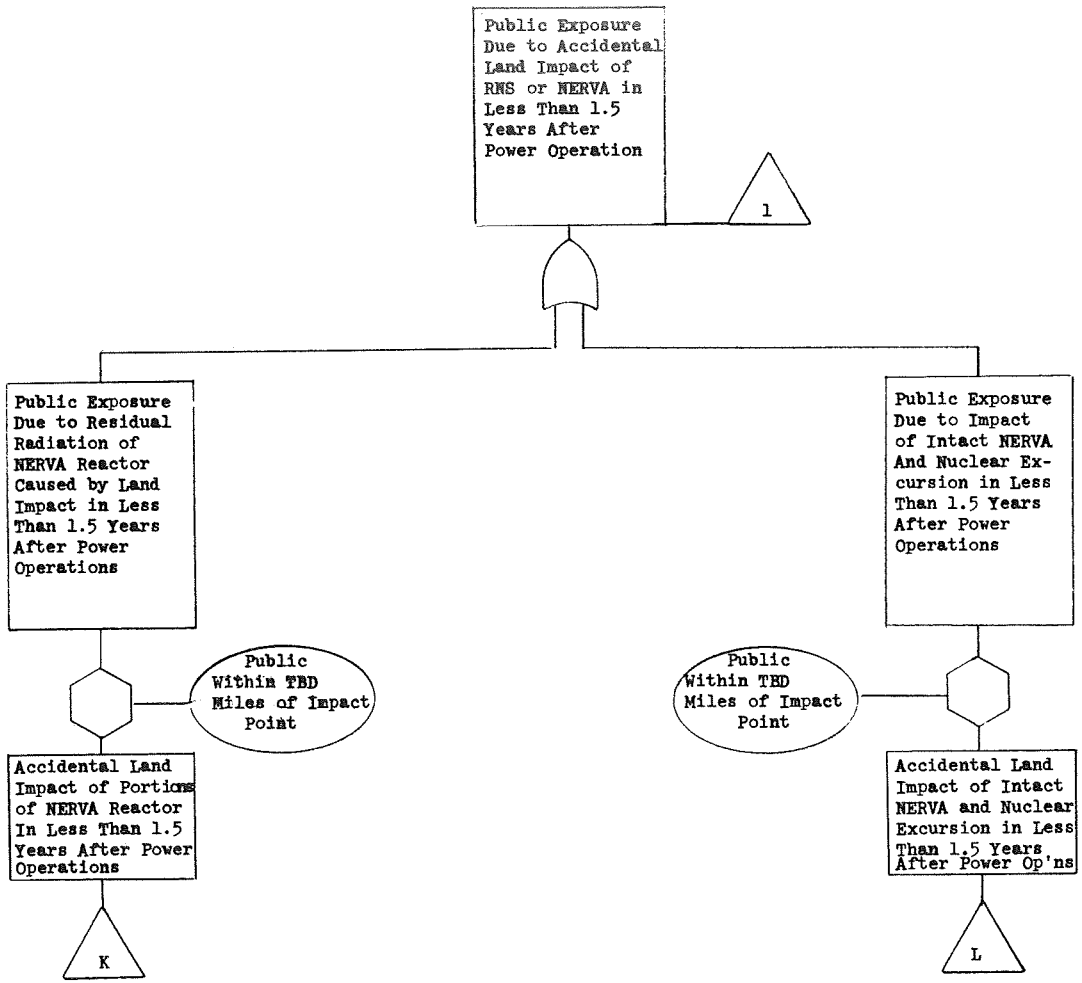
A third failure by which the RNS could experience difficulty in earth orbit is the unavailability of LH_2 to the NERVA turbopumps at the correct pressure during the initial startup for the TLI maneuver. This situation could cause pump cavitation, which is a potentially explosive failure. This situation also exists for other mission phases, but the earth impact implications are not present for those phases. Subtree B-1 investigates the failures which could cause this problem.

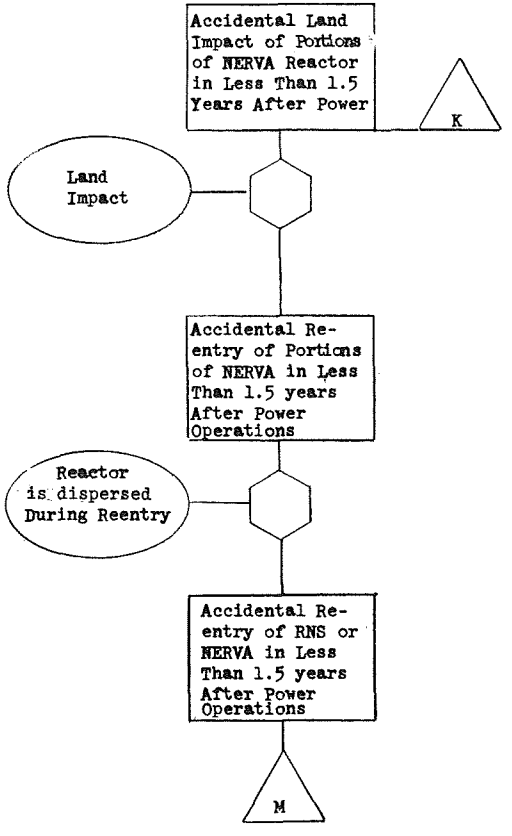
The fault tree analysis should continue in future phases of the RNS project to expand the areas discussed above and to investigate other areas as they become important.

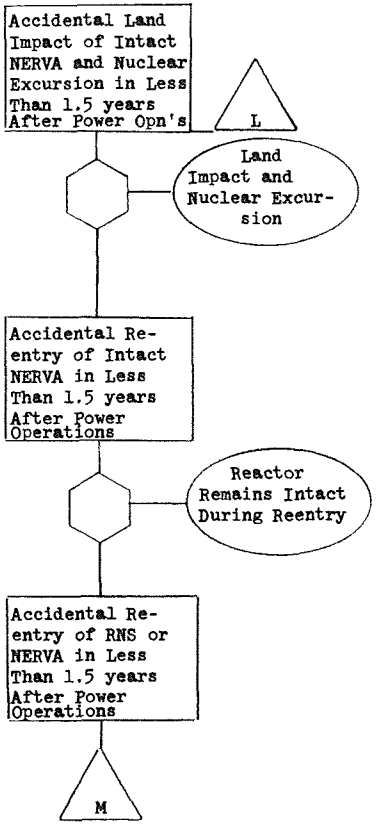
The top-level fault tree and related subtrees which were identified above are contained in the following pages of this section.

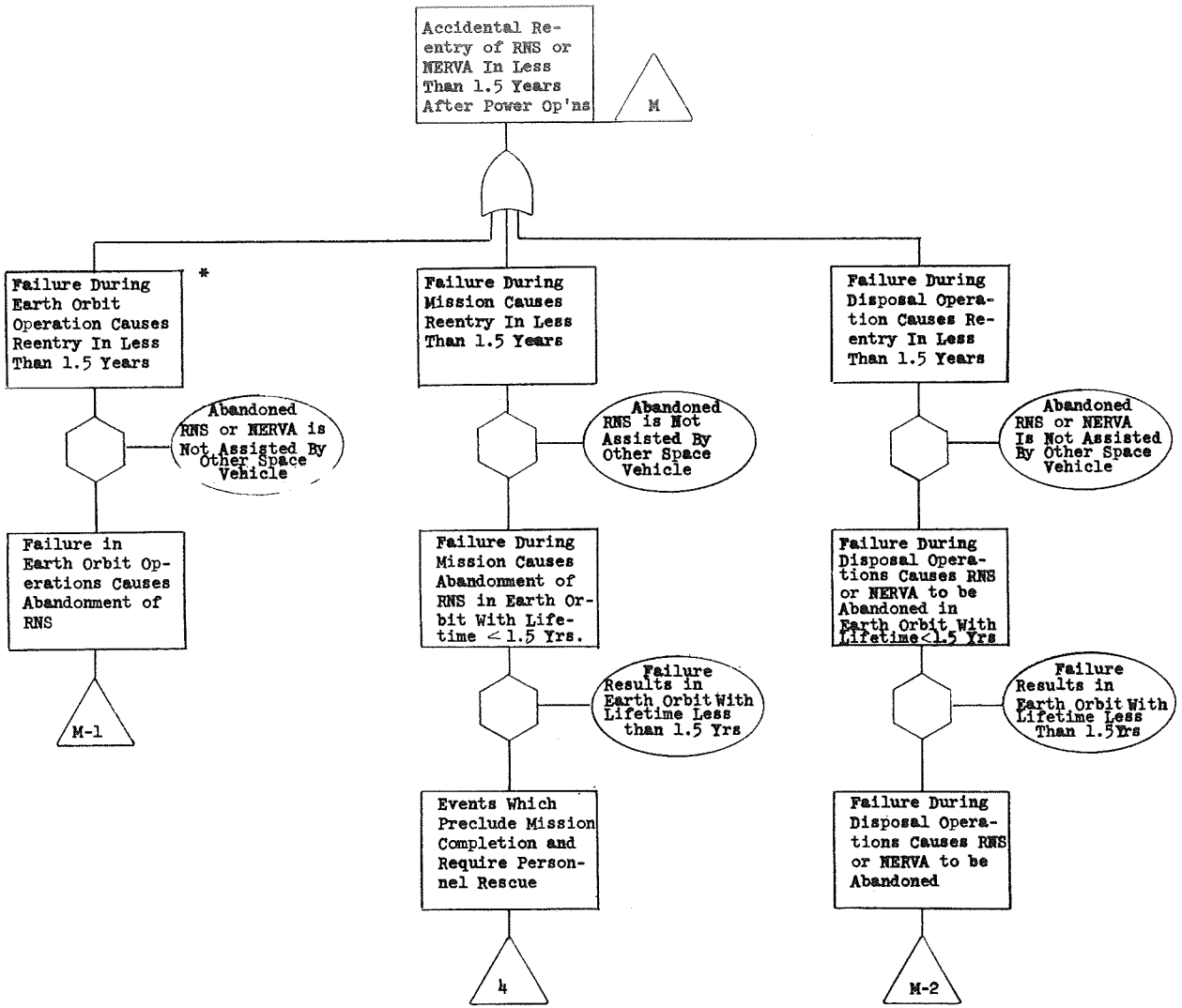


TOP LEVEL FAULT TREE

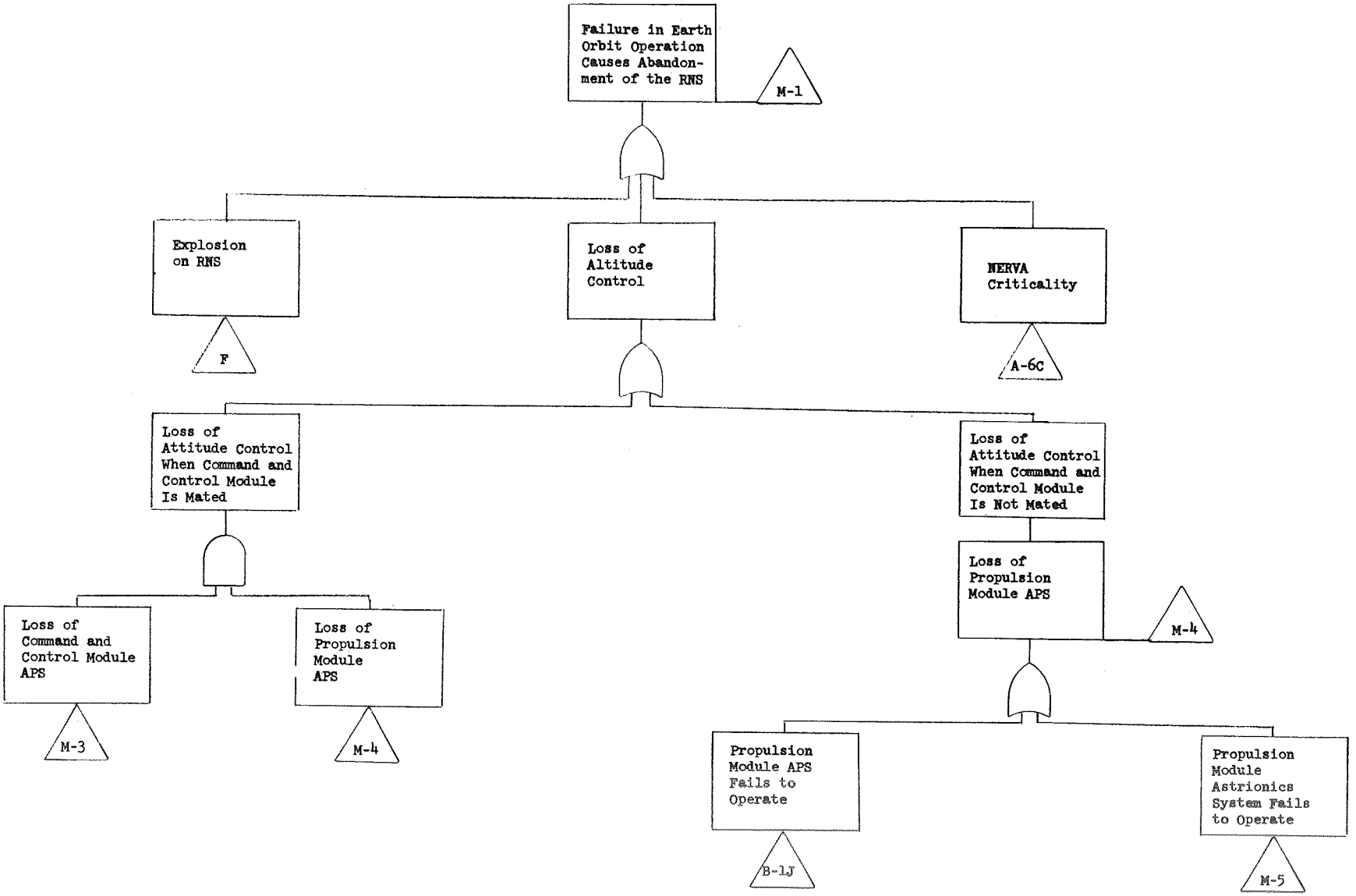

Public Exposure Due to Accidental Land Impact of RNS or NERVA in Less Than 1.5 Years After Power Operation
1
Public Exposure Due to Residual Radiation of NERVA Reactor Caused by Land Impact in Less Than 1.5 Years After Power Operations
Public Within TBD Miles of Impact Point
Accidental Land Impact of Portions of NERVA Reactor In Less Than 1.5 Years After Power Operations
K
Public Exposure Due to Impact of Intact NERVA And Nuclear Excursion in Less Than 1.5 Years After Power Operations
Public Within TBD Miles of Impact Point
Accidental Land Impact of Intact NERVA and Nuclear Excursion in Less Than 1.5 Years After Power Op'ns
L

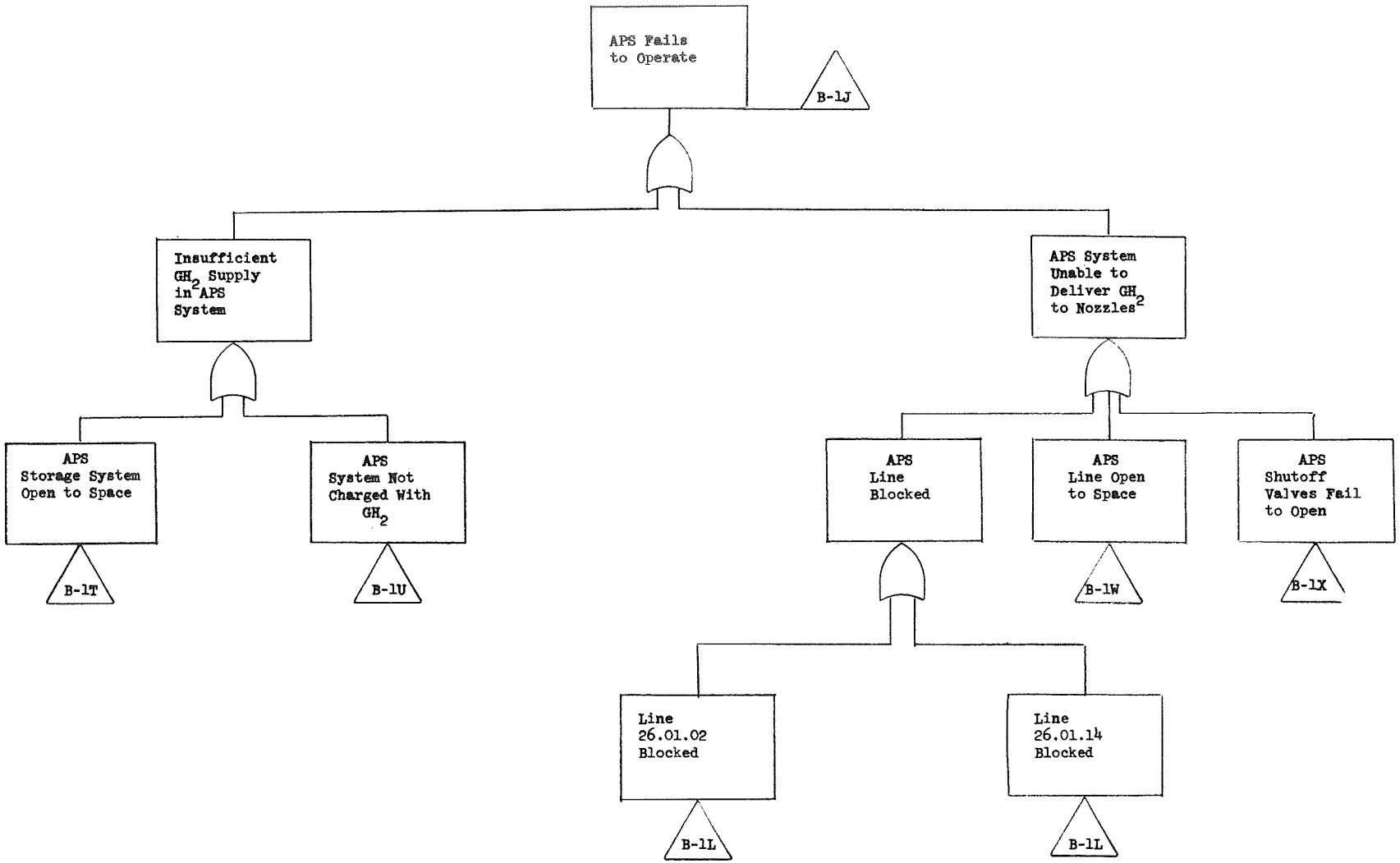

Accidental Land Impact of Portions of NERVA Reactor in Less Than 1.5 Years After Power
K
Land Impact
Accidental Re-entry of Portions of NERVA in Less Than 1.5 years After Power Operations
Reactor is dispersed During Reentry
Accidental Re-entry of RNS or NERVA in Less Than 1.5 years After Power Operations
M

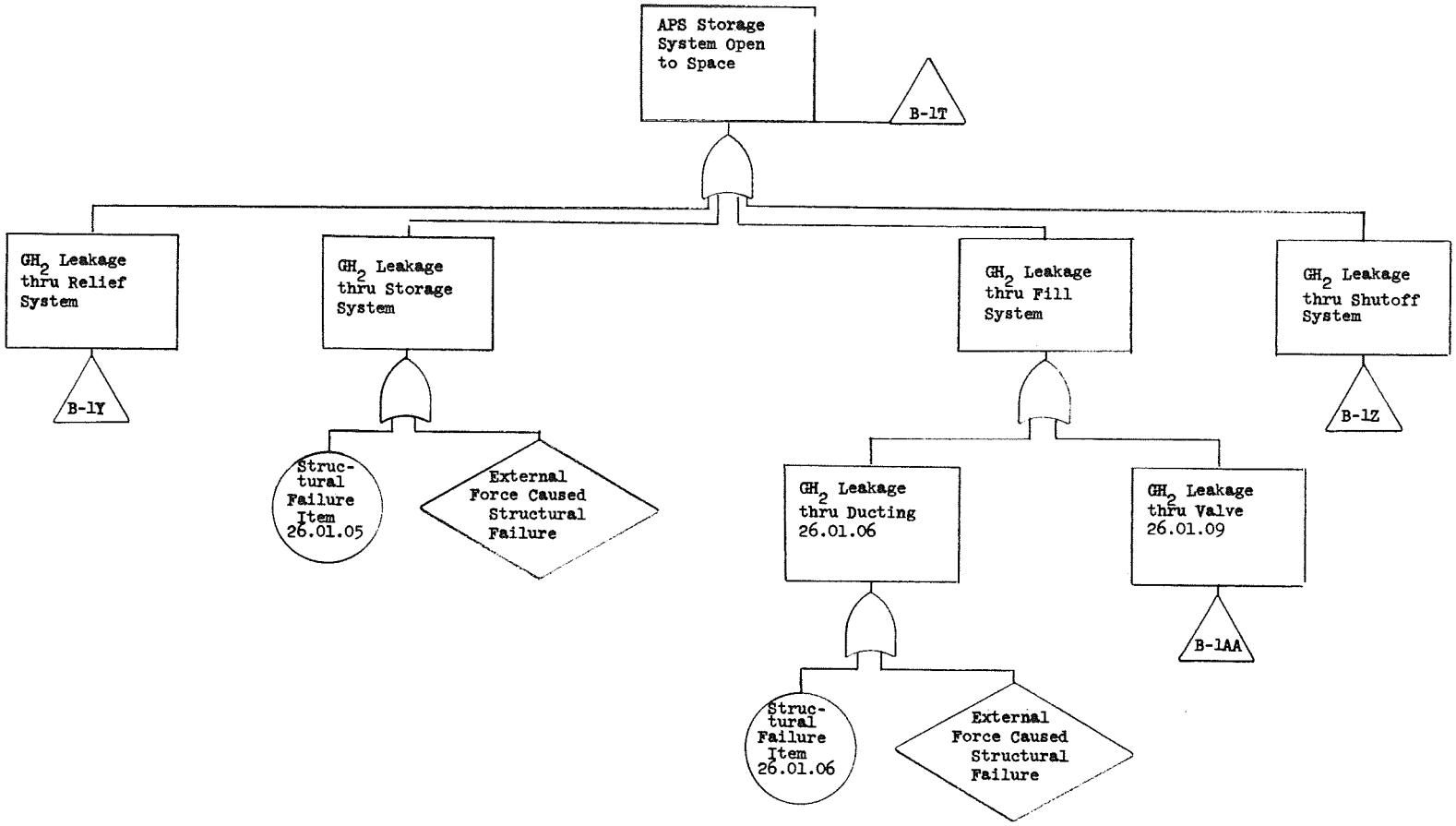

Accidental Land Impact of Intact NERVA and Nuclear Excursion in Less Than 1.5 years After Power Opn's
L
Land Impact and Nuclear Excursion
Accidental Re-entry of Intact NERVA in Less Than 1.5 years After Power Operations
Reactor Remains Intact During Reentry
Accidental Re-entry of RNS or NERVA in Less Than 1.5 years After Power Operations
M



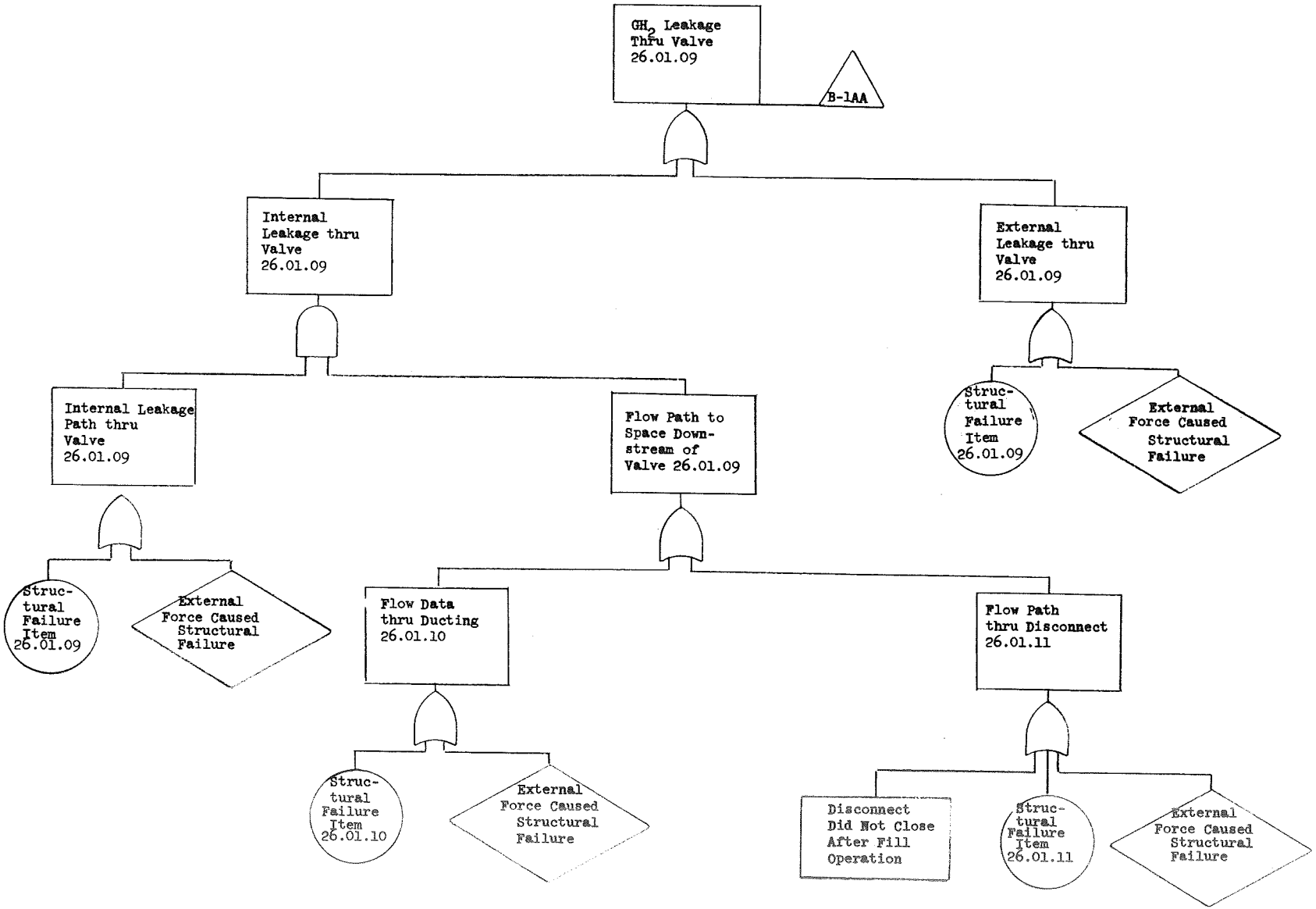
* It is assumed that the lifetime of the Earth Orbit is less than 1.5 years.

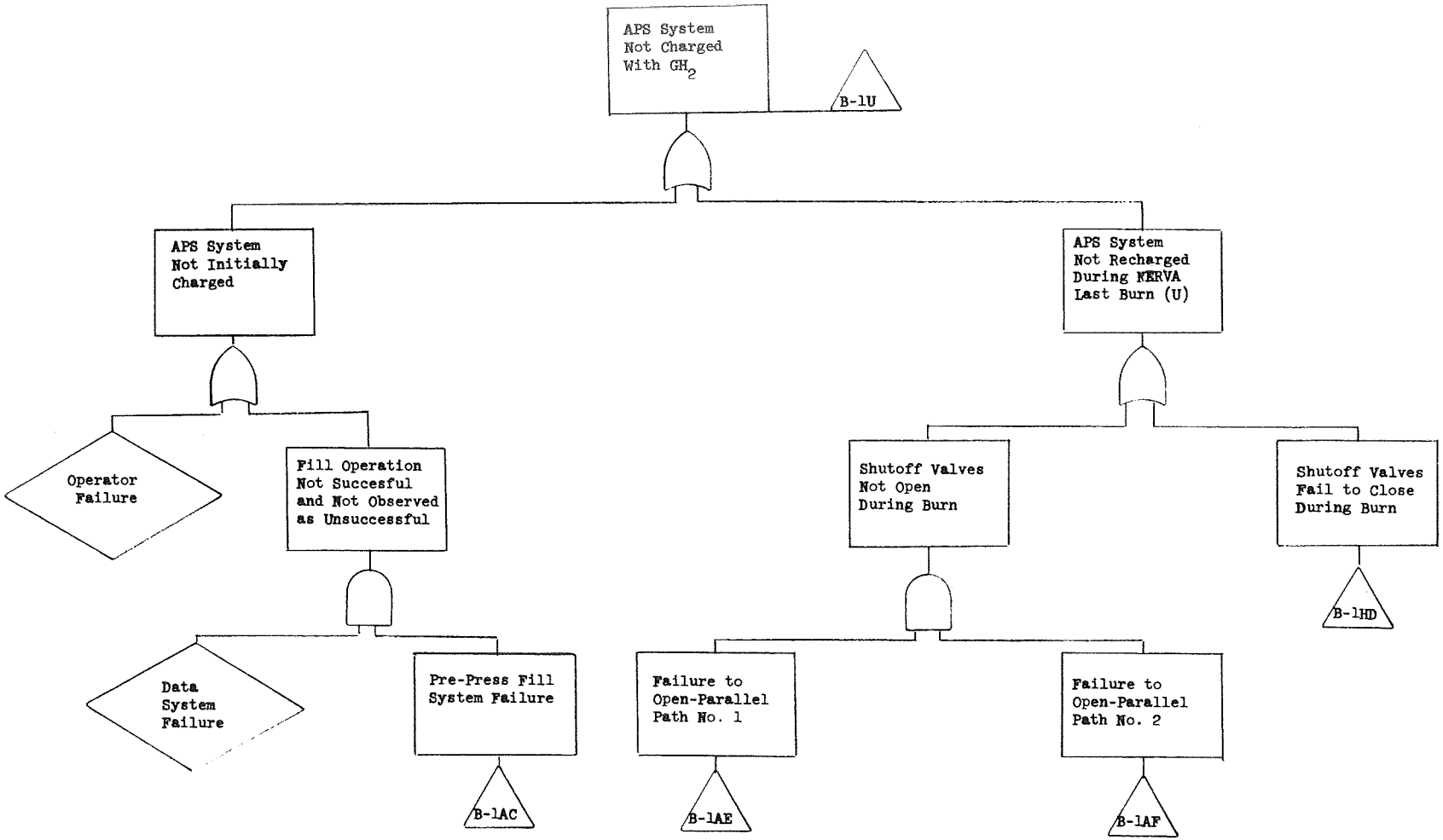

Failure in Earth Orbit Operation Causes Abandonment of the RNS
M-1
Explosion on RNS
F
Loss of Altitude Control
NERVA Criticality
A-6C
Loss of Attitude Control When Command and Control Module Is Mated
Loss of Attitude Control When Command and Control Module Is Not Mated
Loss of Command and Control Module APS
M-3
Loss of Propulsion Module APS
M-4
Loss of Propulsion Module APS
M-4
Propulsion Module APS Fails to Operate
B-1J
Propulsion Module Astrionics System Fails to Operate
M-5

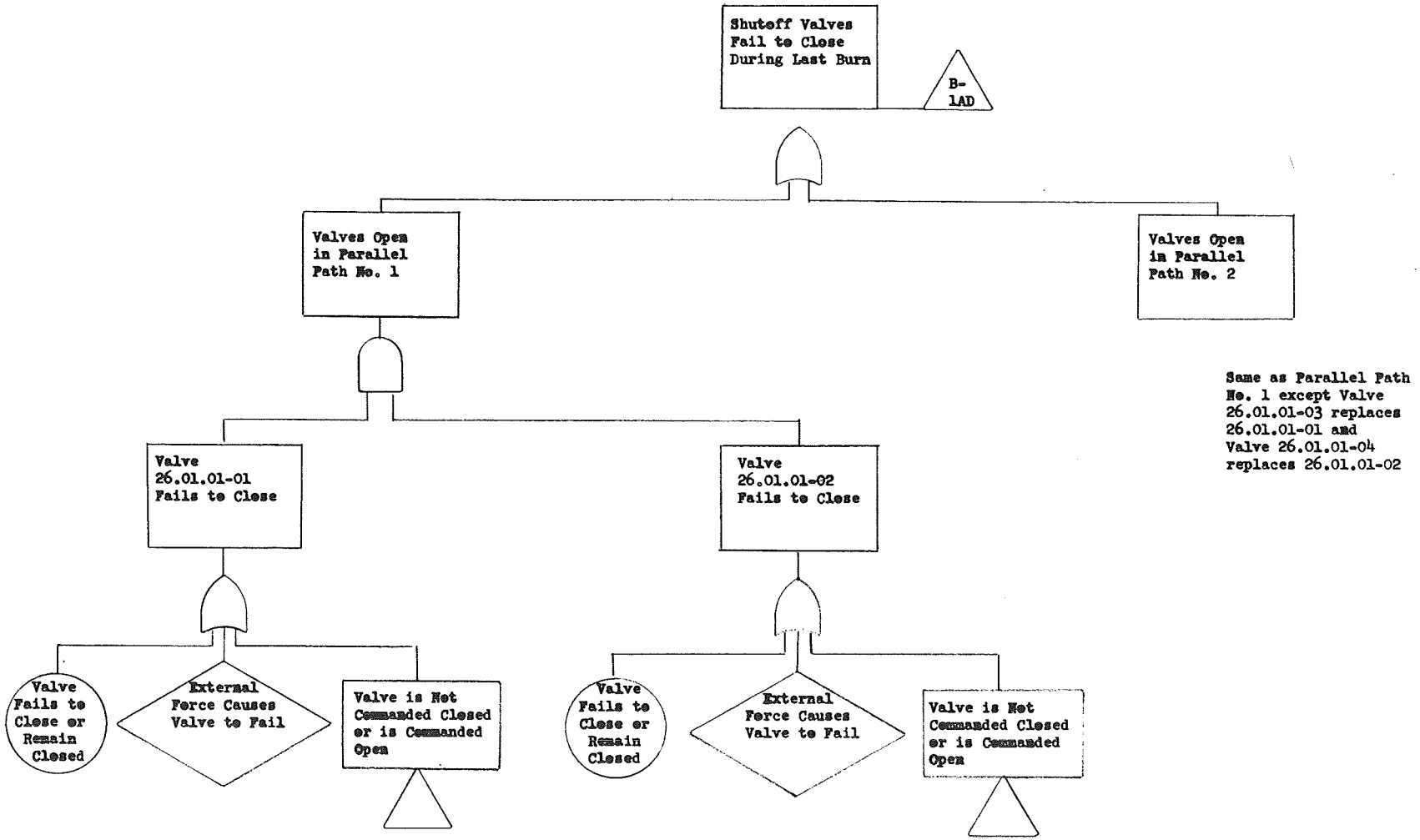

APS Fails to Operate
B-1J
Insufficient GH_2 Supply in APS System
APS System Unable to Deliver GH_2 to Nozzles
APS Storage System Open to Space
APS System Not Charged With GH_2
APS Line Blocked
APS Line Open to Space
APS Shutoff Valves Fail to Open
B-1T
B-1U
B-1W
B-1X
Line 26.01.02 Blocked
Line 26.01.14 Blocked
B-1L
B-1L


APS Storage System Open to Space
B-1T
GH_2 Leakage thru Relief System
B-1Y
GH_2 Leakage thru Storage System
Struc-tural Failure Item 26.01.05
External Force Caused Structural Failure
GH_2 Leakage thru Fill System
GH_2 Leakage thru Ducting 26.01.06
Struc-tural Failure Item 26.01.06
External Force Caused Structural Failure
GH_2 Leakage thru Valve 26.01.09
B-1AA
GH_2 Leakage thru Shutoff System
B-1Z

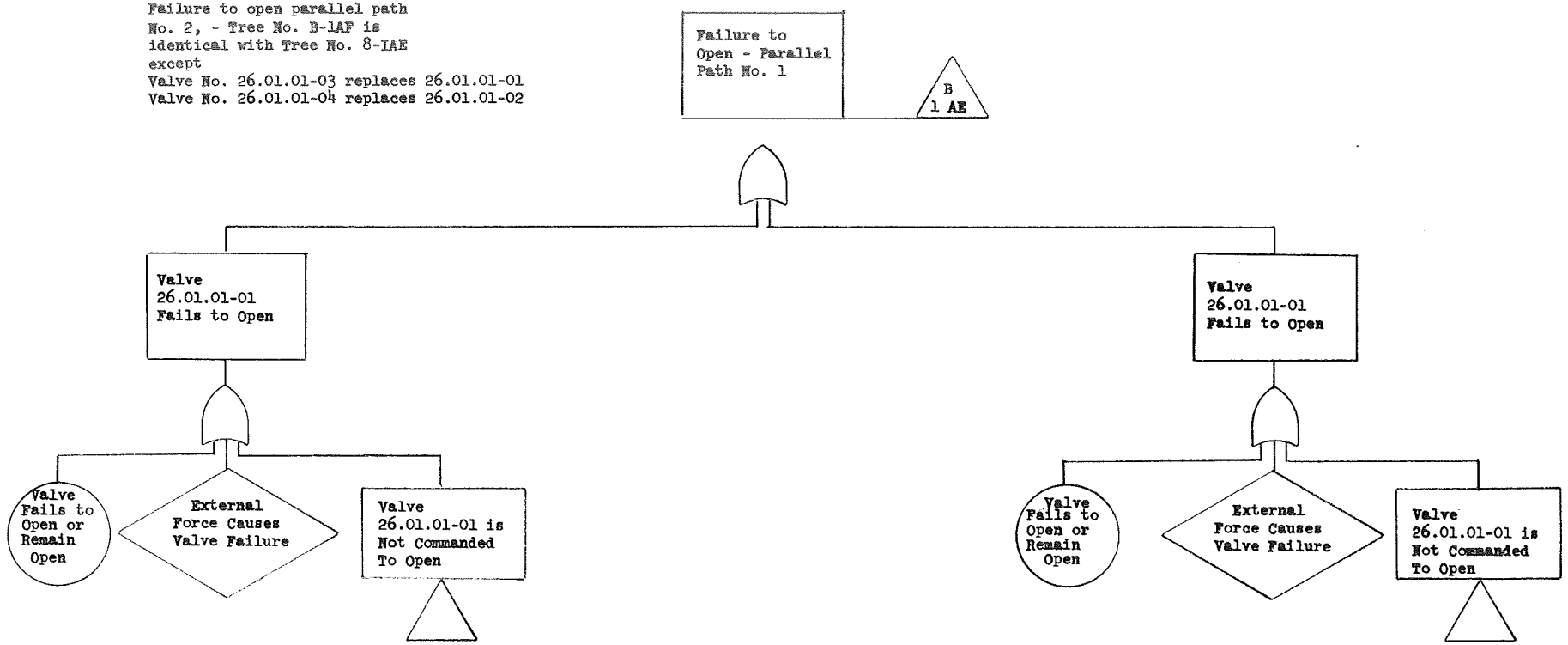
GH_2 Leakage thru Relief System
B-1Y
GH_2 Leakage thru Ducting 26.01.06
GH_2 Leakage thru Relief Valve 26.01.07
Struc-tural Failure Item 26.01.06
External Force Caused Structural Failure
Relief Valve 26.01.07 Failed to Re-main Closed
Relief Valve 26.01.07 Failed in Leakage Mode
Relief Valve Open Due to High Pressure
Valve Failed to Remain Closed
External Force Caused Valve To Open
Struc-tural Failure Item 25.07.10
External Force Caused Structural Failure
B-1AB

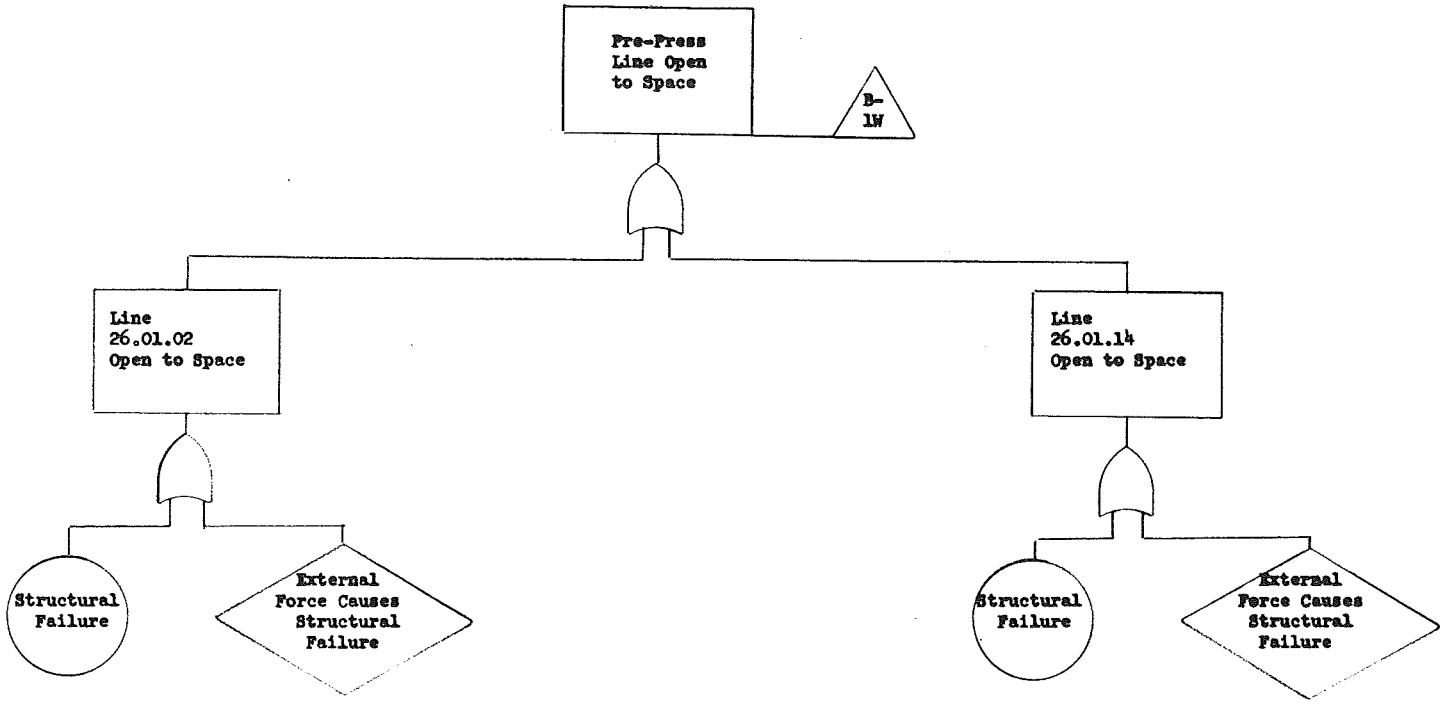

GH_2 Leakage Thru Valve 26.01.09
B-1AA
Internal Leakage thru Valve 26.01.09
External Leakage thru Valve 26.01.09
Internal Leakage Path thru Valve 26.01.09
Flow Path to Space Down-stream of Valve 26.01.09
Struc-tural Failure Item 26.01.09
External Force Caused Structural Failure
Struc-tural Failure Item 26.01.09
External Force Caused Structural Failure
Flow Data thru Ducting 26.01.10
Flow Path thru Disconnect 26.01.11
Struc-tural Failure Item 26.01.10
External Force Caused Structural Failure
Disconnect Did Not Close After Fill Operation
Struc-tural Failure Item 26.01.11
External Force Caused Structural Failure

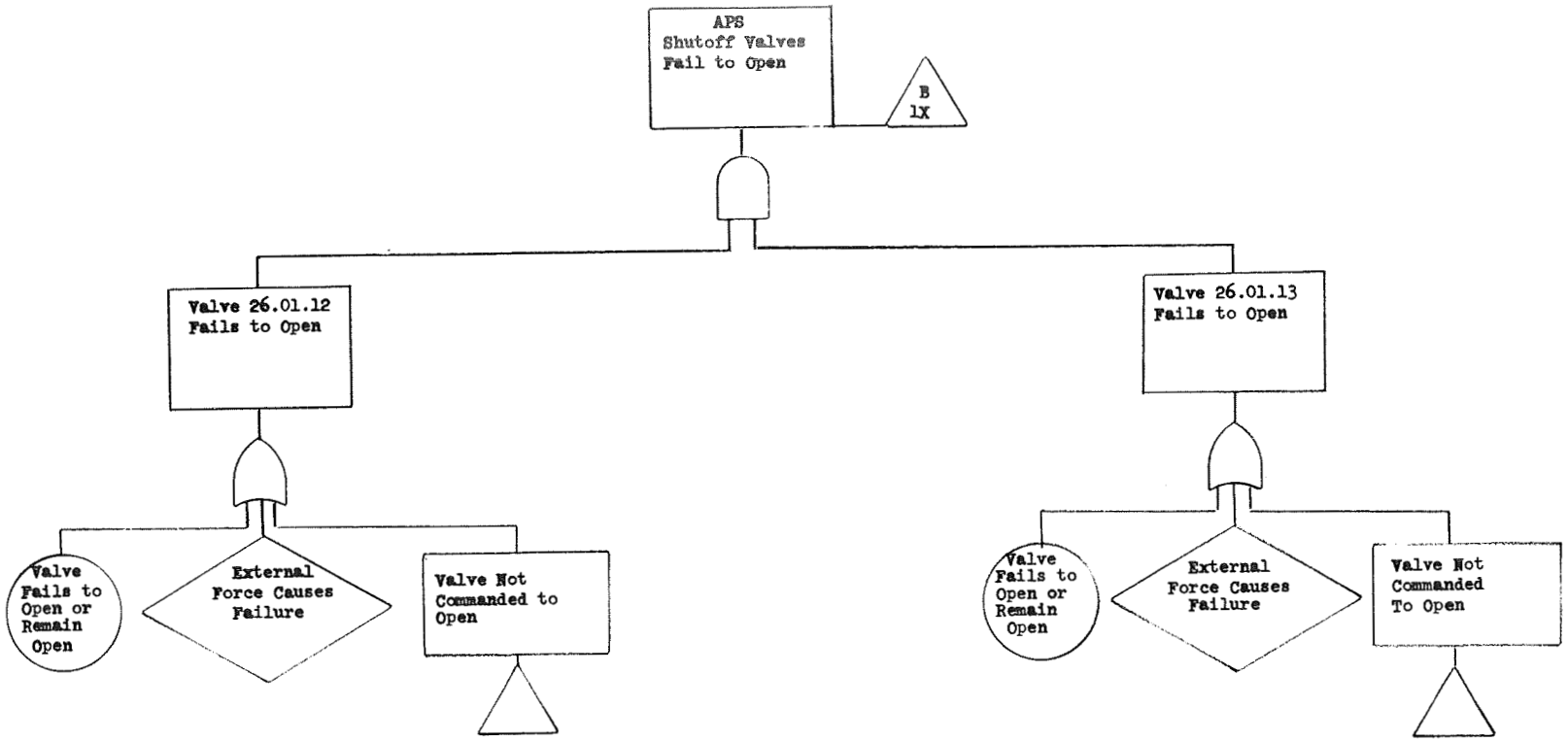

APS System Not Charged With GH_2
B-1U
APS System Not Initially Charged
APS System Not Recharged During MERVA Last Burn (U)
Operator Failure
Fill Operation Not Succesful and Not Observed as Unsuccessful
Shutoff Valves Not Open During Burn
Shutoff Valves Fail to Close During Burn
B-1HD
Data System Failure
Pre-Press Fill System Failure
Failure to Open-Parallel Path No. 1
Failure to Open-Parallel Path No. 2
B-1AC
B-1AE
B-1AF

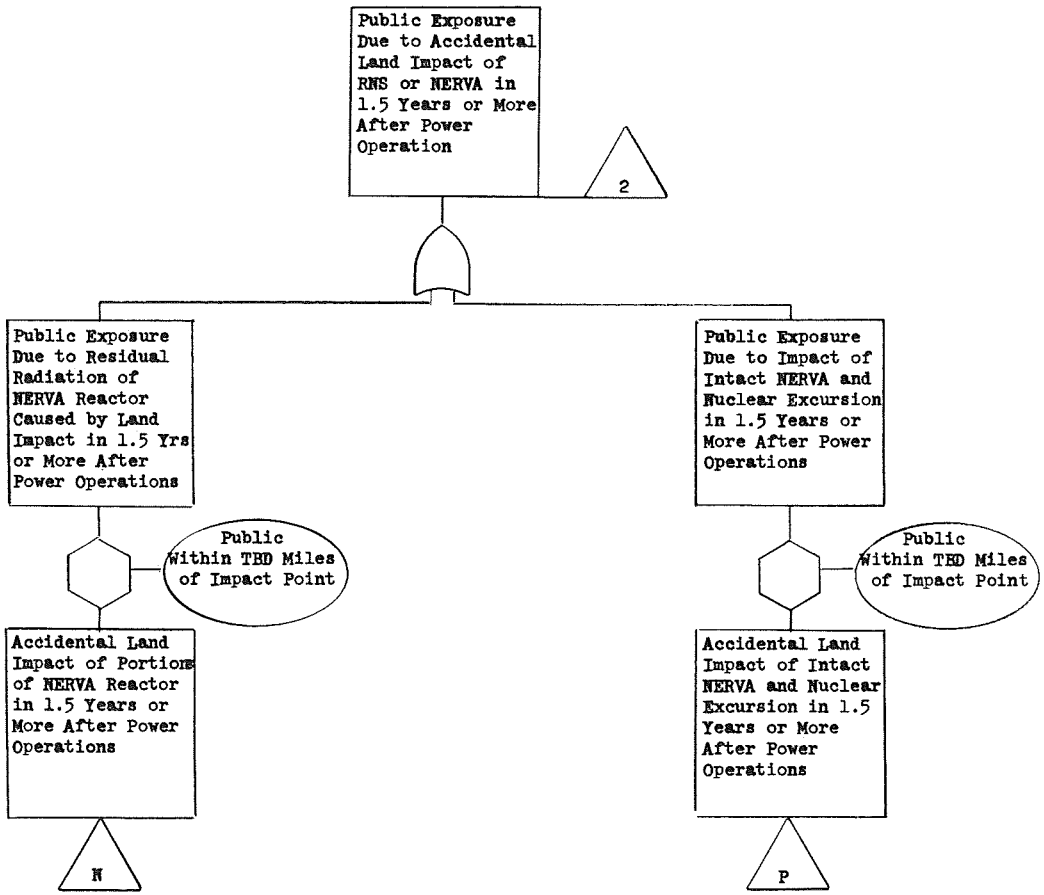

Shutoff Valves Fail to Close During Last Burn
B-1AD
Valves Open in Parallel Path No. 1
Valves Open in Parallel Path No. 2
Valve 26.01.01-01 Fails to Close
Valve 26.01.01-02 Fails to Close
Valve Fails to Close or Remain Closed
External Force Causes Valve to Fail
Valve is Not Commanded Closed or is Commanded Open
Valve Fails to Close or Remain Closed
External Force Causes Valve to Fail
Valve is Not Commanded Closed or is Commanded Open
Same as Parallel Path No. 1 except Valve 26.01.01-03 replaces 26.01.01-01 and Valve 26.01.01-04 replaces 26.01.01-02

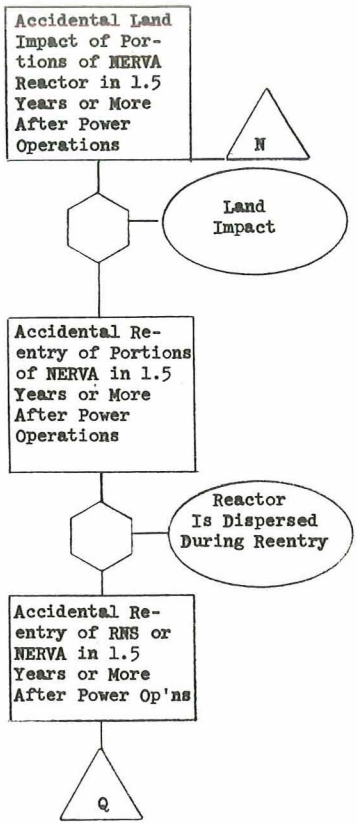
Failure to open parallel path
No. 2, - Tree No. B-1AF is
identical with Tree No. 8-1AE
except
Valve No. 26.01.01-03 replaces 26.01.01-01
Valve No. 26.01.01-04 replaces 26.01.01-02

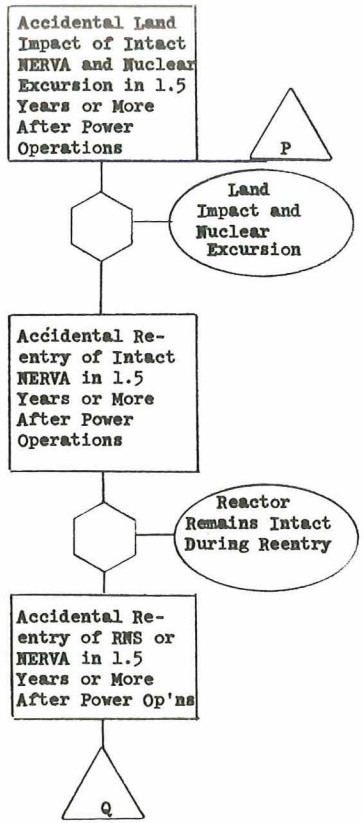


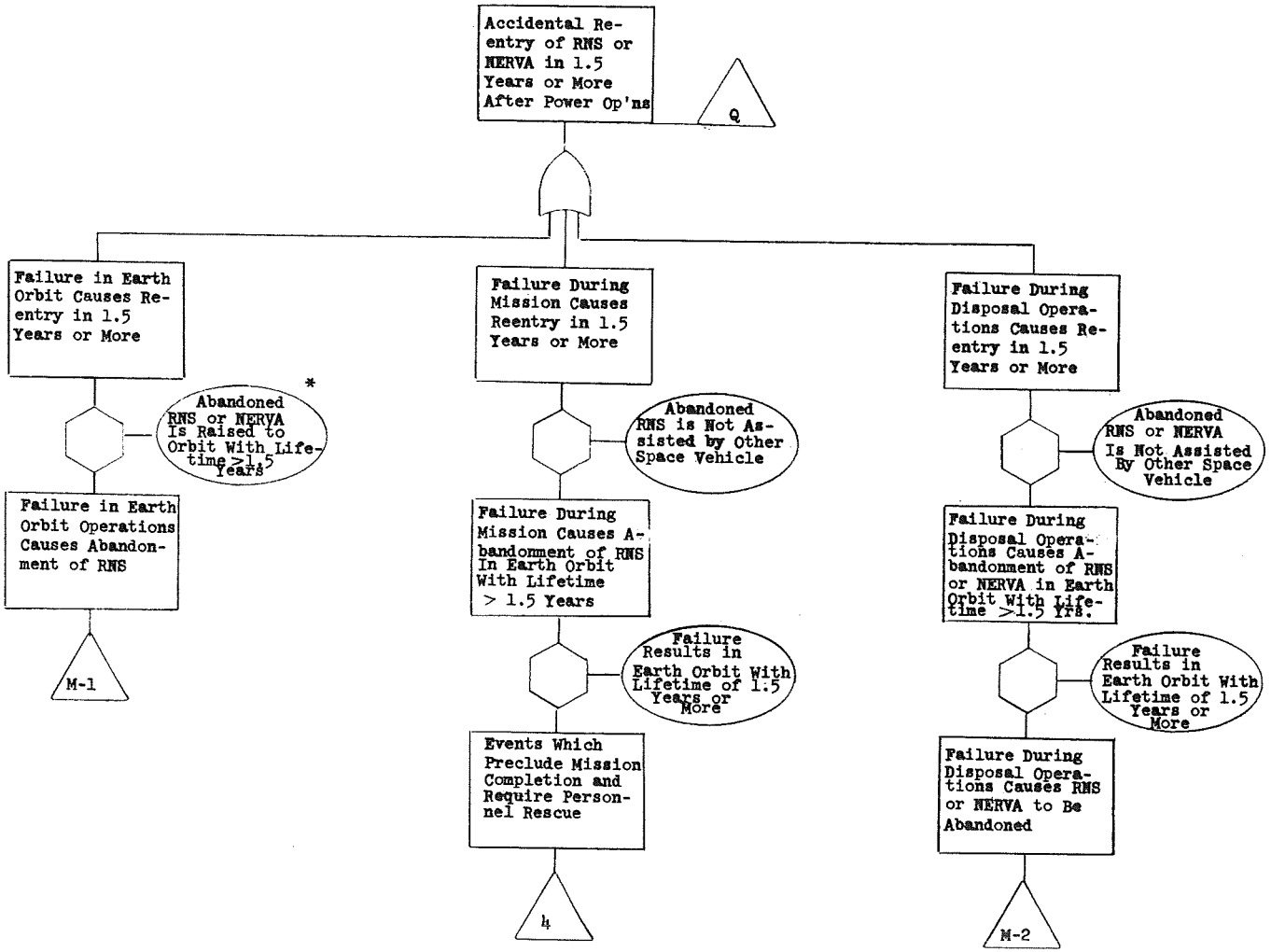

Pre-Press
Line Open
to Space
B-
1W
Line
26.01.02
Open to Space
Line
26.01.14
Open to Space
Structural
Failure
External
Force Causes
Structural
Failure
Structural
Failure
External
Force Causes
Structural
Failure


APS
Shutoff Valves
Fail to Open
B
1X
Valve 26.01.12
Fails to Open
Valve 26.01.13
Fails to Open
Valve
Fails to
Open or
Remain
Open
External
Force Causes
Failure
Valve Not
Commanded to
Open
Valve
Fails to
Open or
Remain
Open
External
Force Causes
Failure
Valve Not
Commanded
To Open

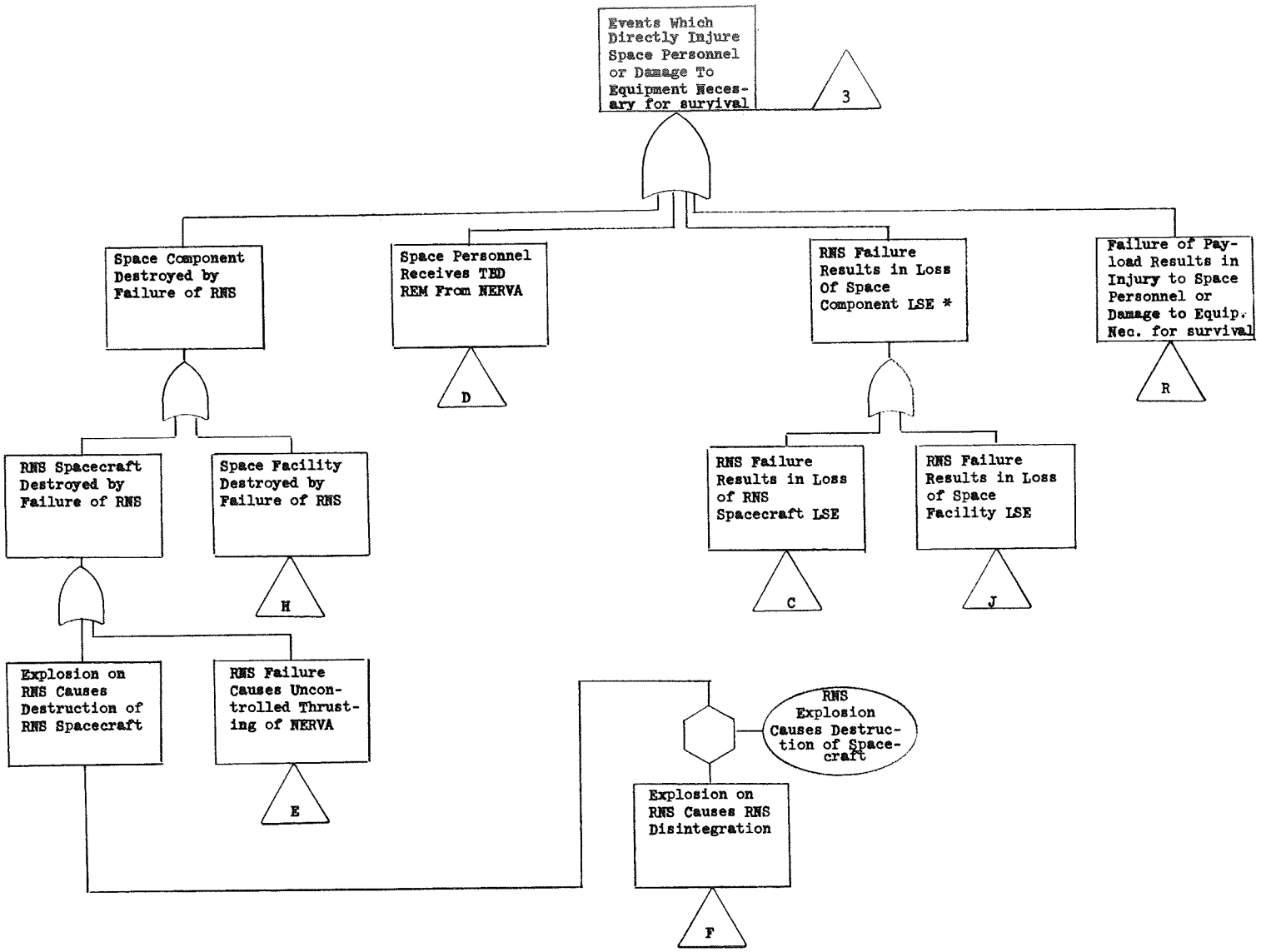

Public Exposure Due to Accidental Land Impact of RNS or NERVA in 1.5 Years or More After Power Operation
2
Public Exposure Due to Residual Radiation of NERVA Reactor Caused by Land Impact in 1.5 Yrs or More After Power Operations
Public Within TBD Miles of Impact Point
Accidental Land Impact of Portions of NERVA Reactor in 1.5 Years or More After Power Operations
N
Public Exposure Due to Impact of Intact NERVA and Nuclear Excursion in 1.5 Years or More After Power Operations
Public Within TBD Miles of Impact Point
Accidental Land Impact of Intact NERVA and Nuclear Excursion in 1.5 Years or More After Power Operations
P


Accidental Land Impact of Portions of NERVA Reactor in 1.5 Years or More After Power Operations
N
Land Impact
Accidental Reentry of Portions of NERVA in 1.5 Years or More After Power Operations
Reactor Is Dispersed During Reentry
Accidental Reentry of RNS or NERVA in 1.5 Years or More After Power Op'ns
Q


Accidental Land Impact of Intact NERVA and Nuclear Excursion in 1.5 Years or More After Power Operations
P
Land Impact and Nuclear Excursion
Accidental Reentry of Intact NERVA in 1.5 Years or More After Power Operations
Reactor Remains Intact During Reentry
Accidental Reentry of RNS or NERVA in 1.5 Years or More After Power Op'ns
Q

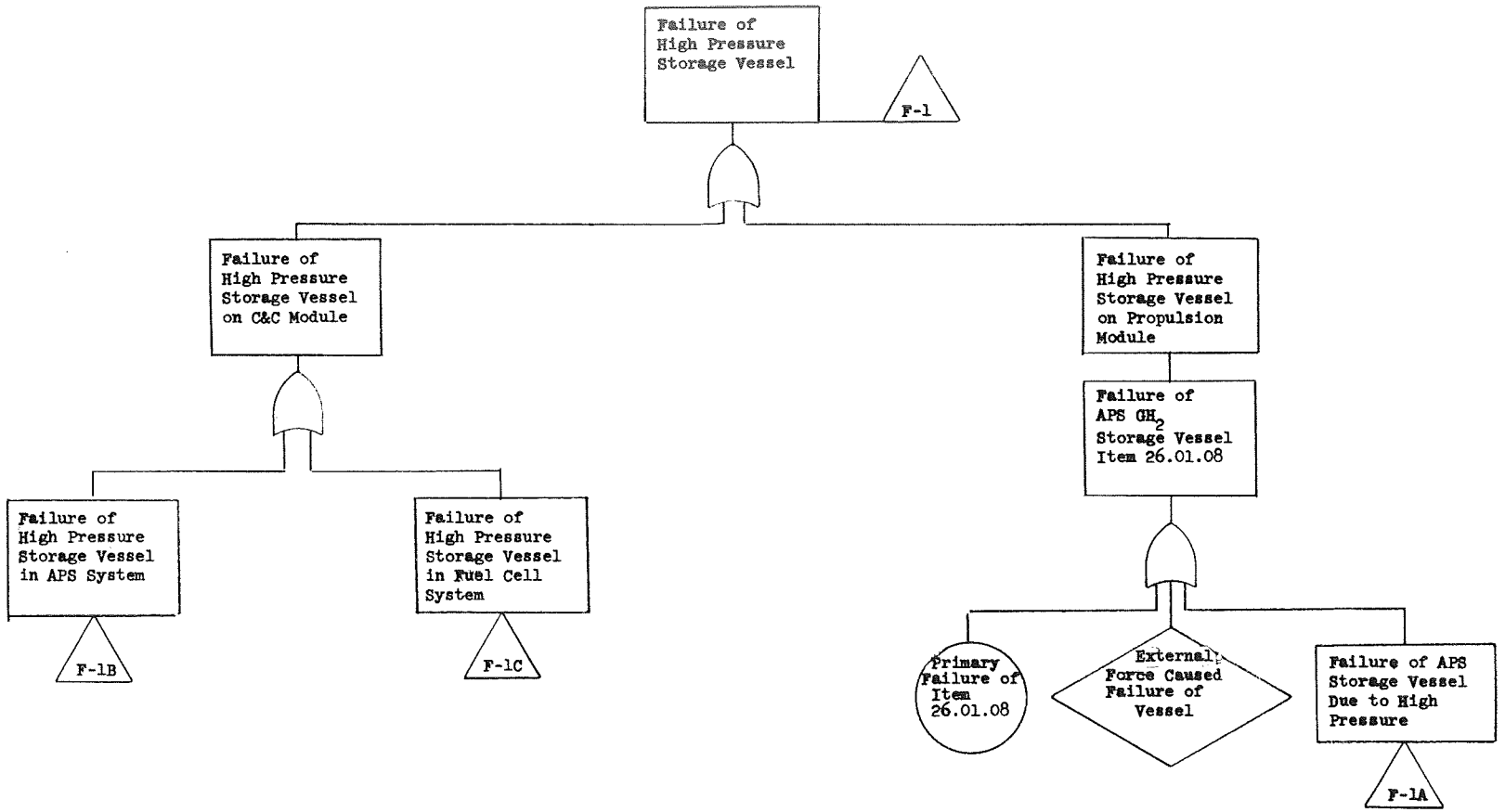


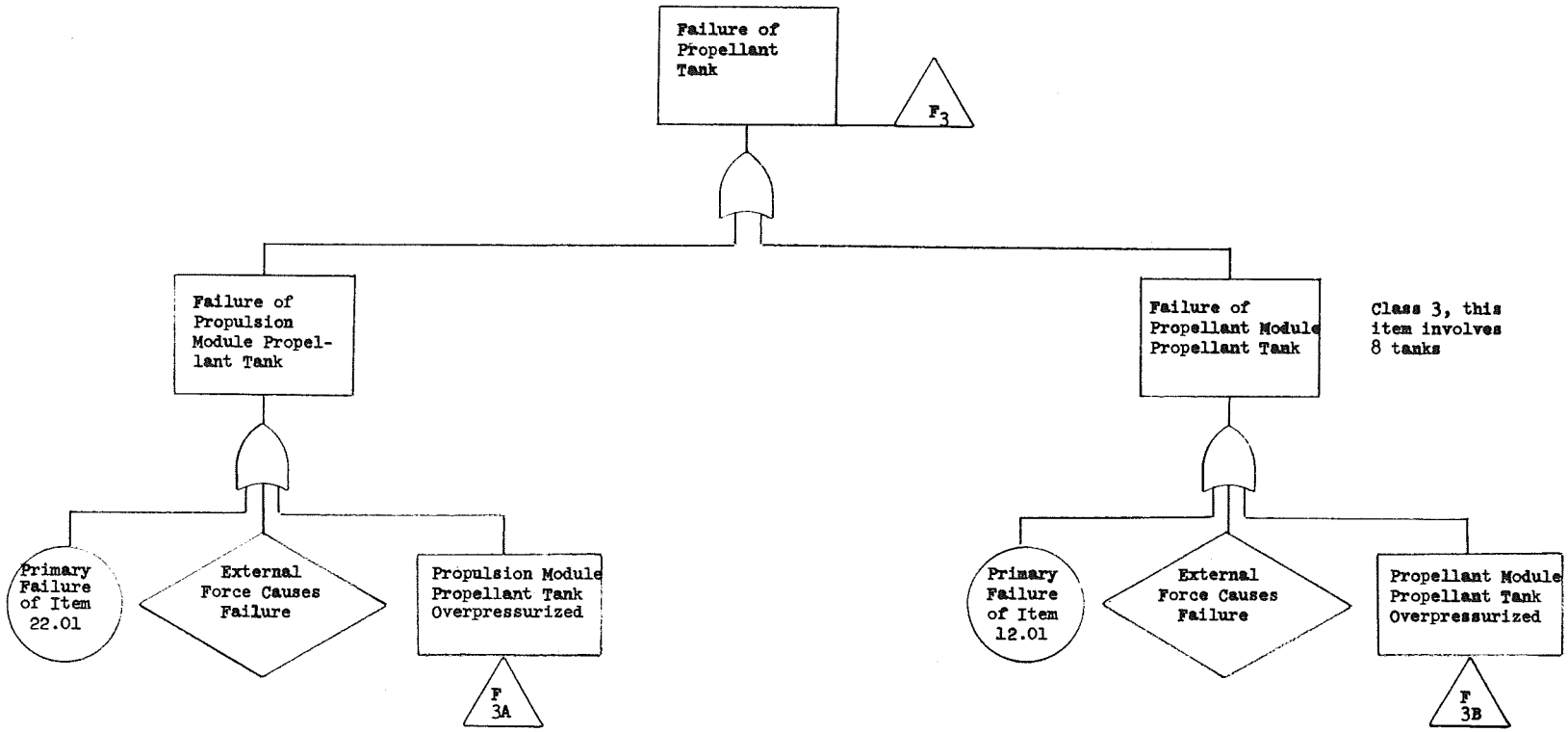
* It is assumed that the lifetime of the Earth Orbit is less than 1.5 years.

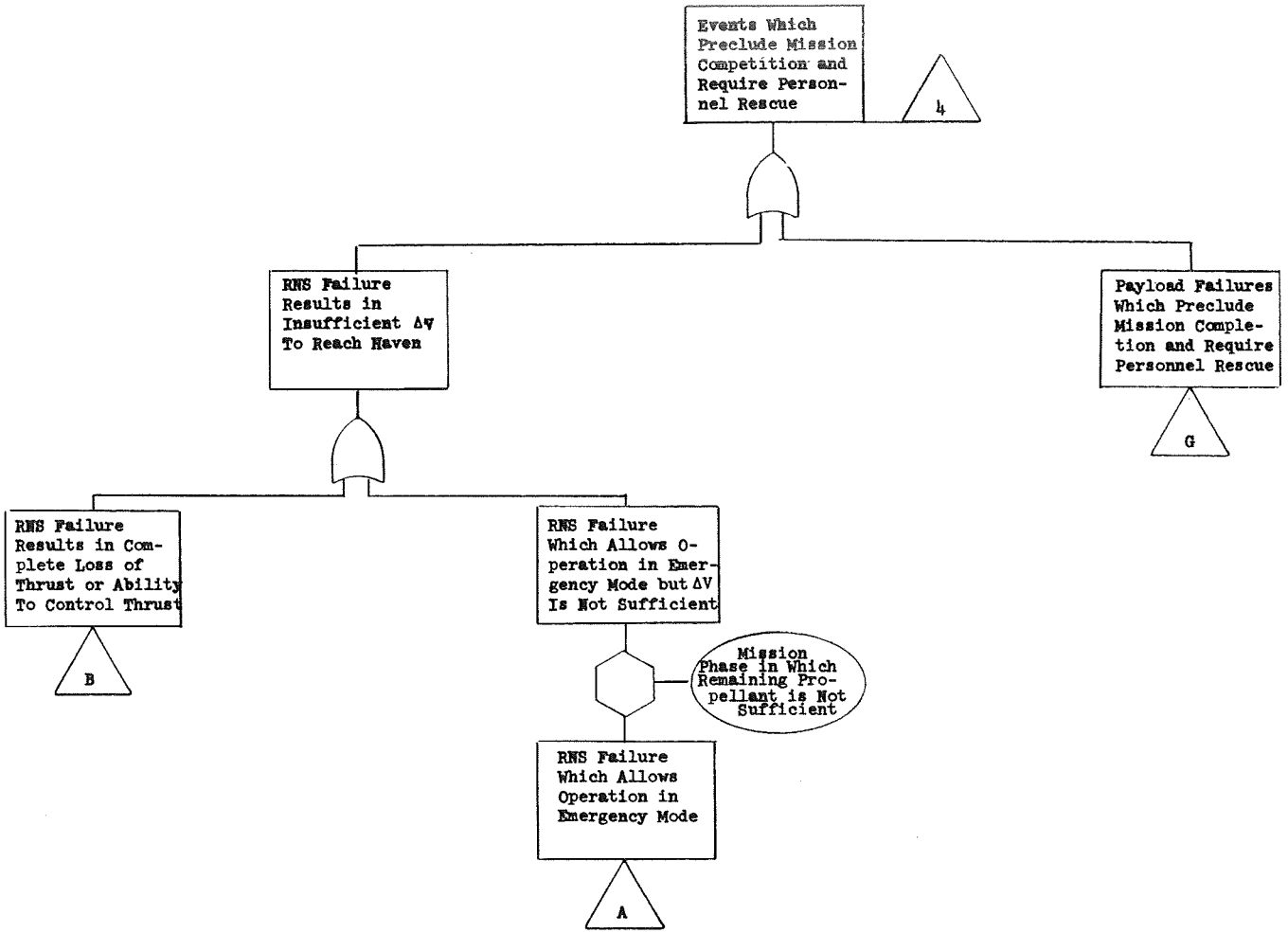


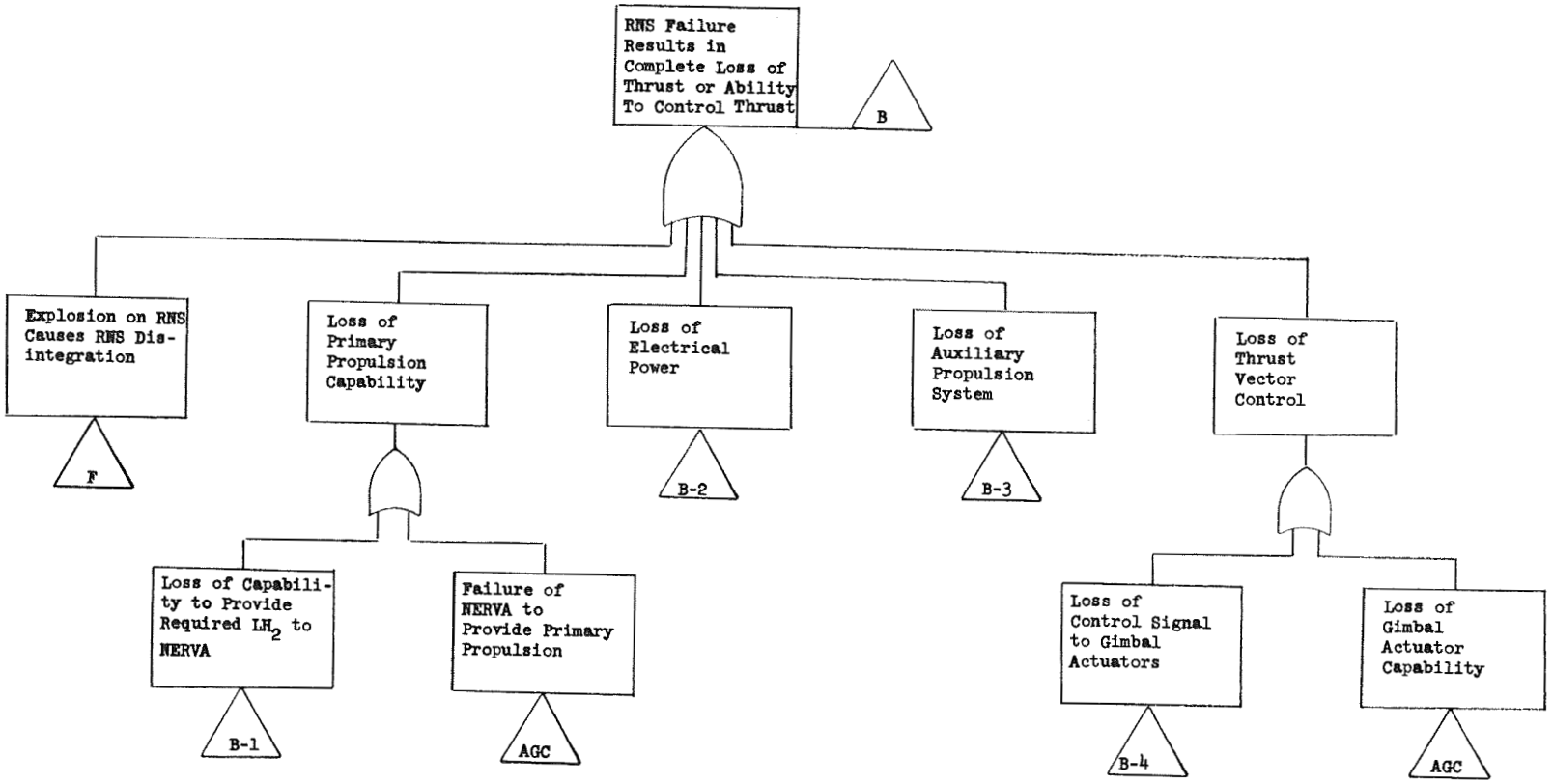
* LSE - Life Support Equipment

Explosion On RNS Causes RNS Disintegration
F
Failure of High Pressure Storage Vessel
F-1
Failure of High Pressure Ducting
F-2
Failure of Propellant Tank
F-3
Failure of APS Nozzle
F-4
Explosion In APS System
F-5
Explosion In Fuel Cell System
F-6
NERVA Pump Cavitation Due To RNS Failure
F-7
Collision During Docking of RNS Components
F-8
Collision With Other Space Components
F-9
Explosion In NERVA
AGC
Explosion In Payload
PL

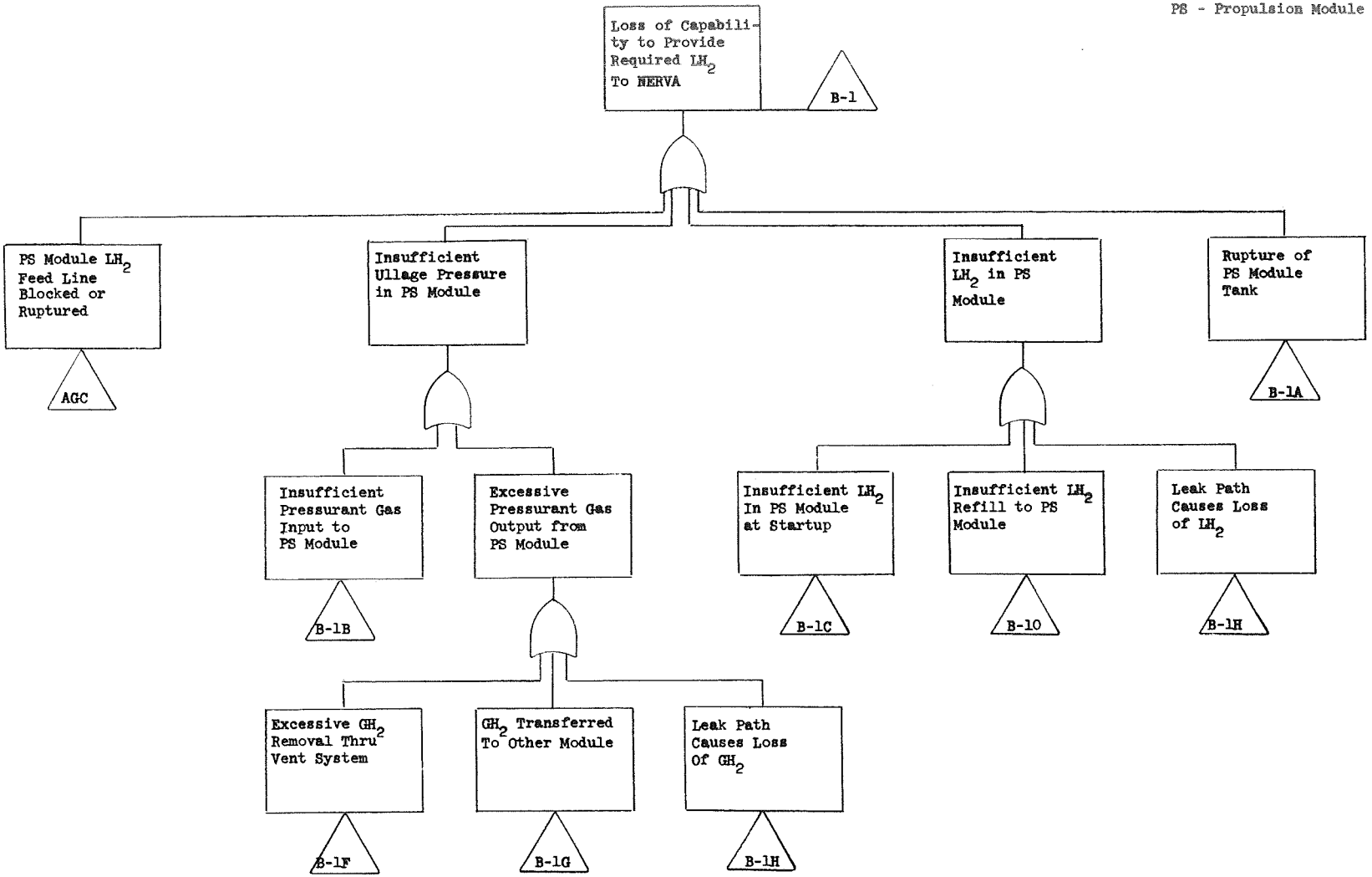

Failure of High Pressure Storage Vessel
F-1
Failure of High Pressure Storage Vessel on C&C Module
Failure of High Pressure Storage Vessel on Propulsion Module
Failure of APS GH_2 Storage Vessel Item 26.01.08
Failure of High Pressure Storage Vessel in APS System
F-1B
Failure of High Pressure Storage Vessel in Fuel Cell System
F-1C
Primary Failure of Item 26.01.08
External Force Caused Failure of Vessel
Failure of APS Storage Vessel Due to High Pressure
F-1A

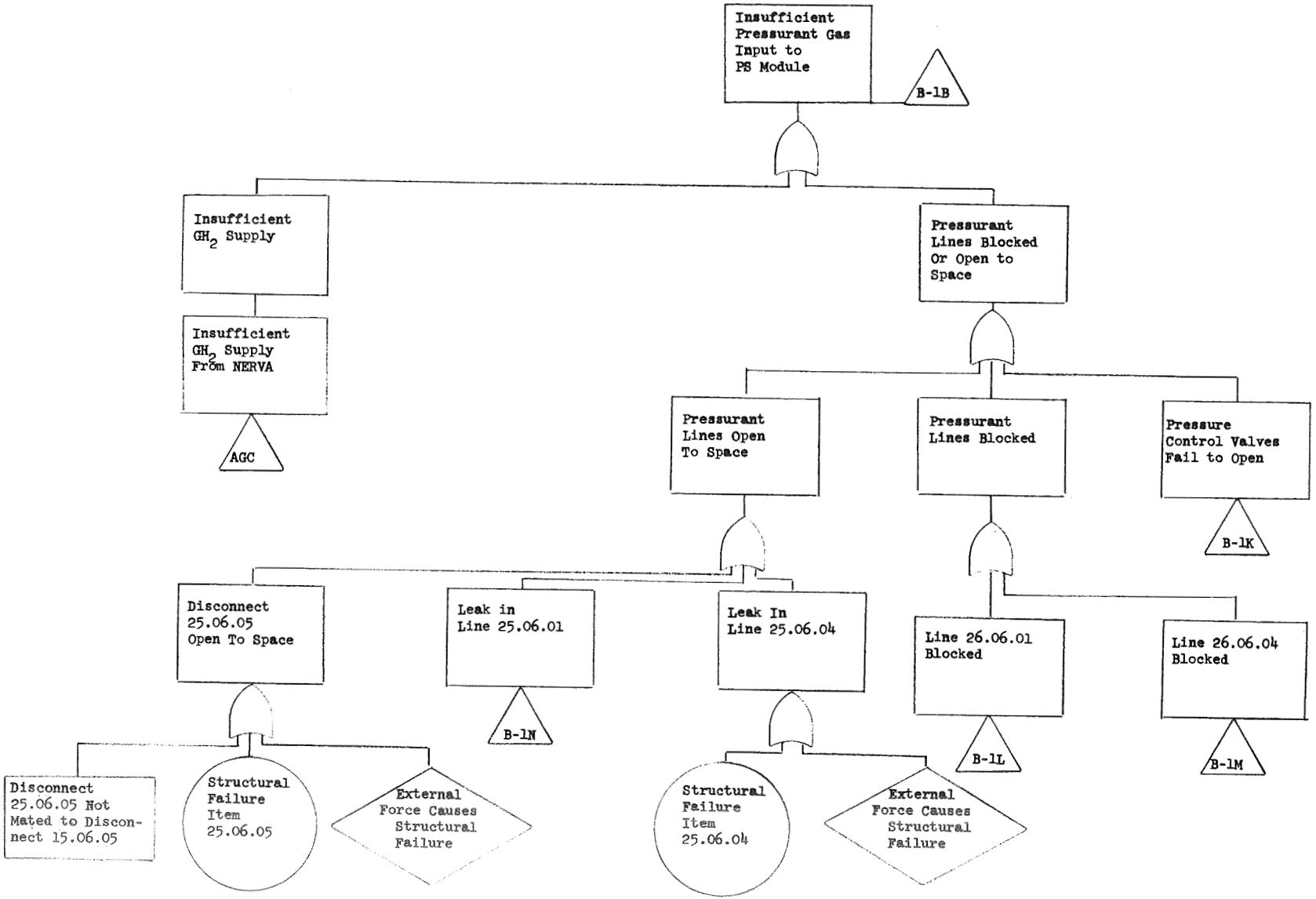

Failure of Propellant Tank
F3
Failure of Propulsion Module Propellant Tank
Failure of Propellant Module Propellant Tank
Class 3, this item involves 8 tanks
Primary Failure of Item 22.01
External Force Causes Failure
Propulsion Module Propellant Tank Overpressurized
F 3A
Primary Failure of Item 12.01
External Force Causes Failure
Propellant Module Propellant Tank Overpressurized
F 3B


Events Which Preclude Mission Competition and Require Personnel Rescue
4
RNS Failure Results in Insufficient Δv To Reach Haven
Payload Failures Which Preclude Mission Completion and Require Personnel Rescue
G
RNS Failure Results in Complete Loss of Thrust or Ability To Control Thrust
B
RNS Failure Which Allows Operation in Emergency Mode but ΔV Is Not Sufficient
Mission Phase in Which Remaining Propellant is Not Sufficient
RNS Failure Which Allows Operation in Emergency Mode
A

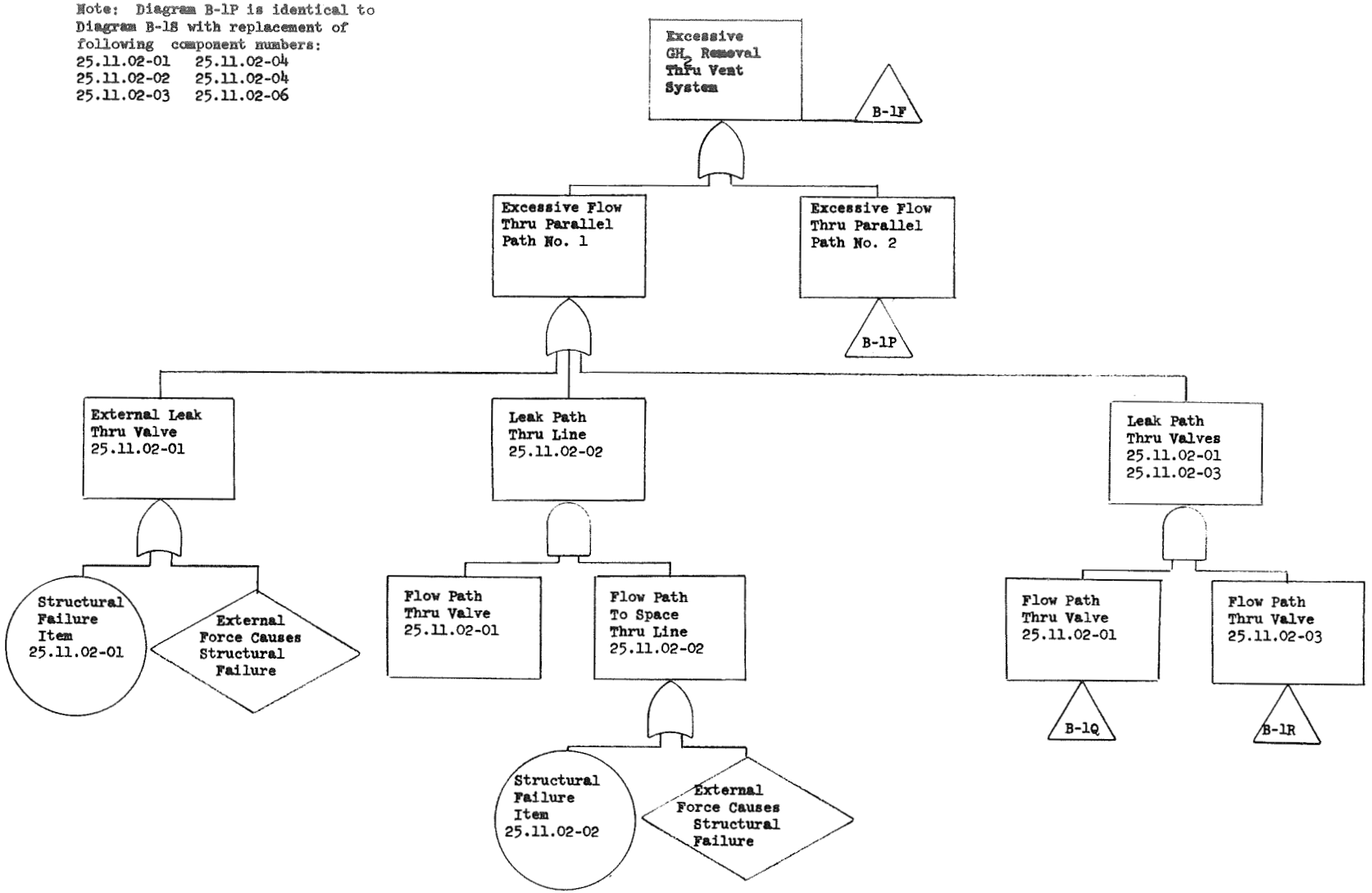

RNS Failure Results in Complete Loss of Thrust or Ability To Control Thrust
B
Explosion on RNS Causes RNS Dis-integration
F
Loss of Primary Propulsion Capability
Loss of Capability to Provide Required LH_2 to NERVA
B-1
Failure of NERVA to Provide Primary Propulsion
AGC
Loss of Electrical Power
B-2
Loss of Auxiliary Propulsion System
B-3
Loss of Thrust Vector Control
Loss of Control Signal to Gimbal Actuators
B-4
Loss of Gimbal Actuator Capability
AGC

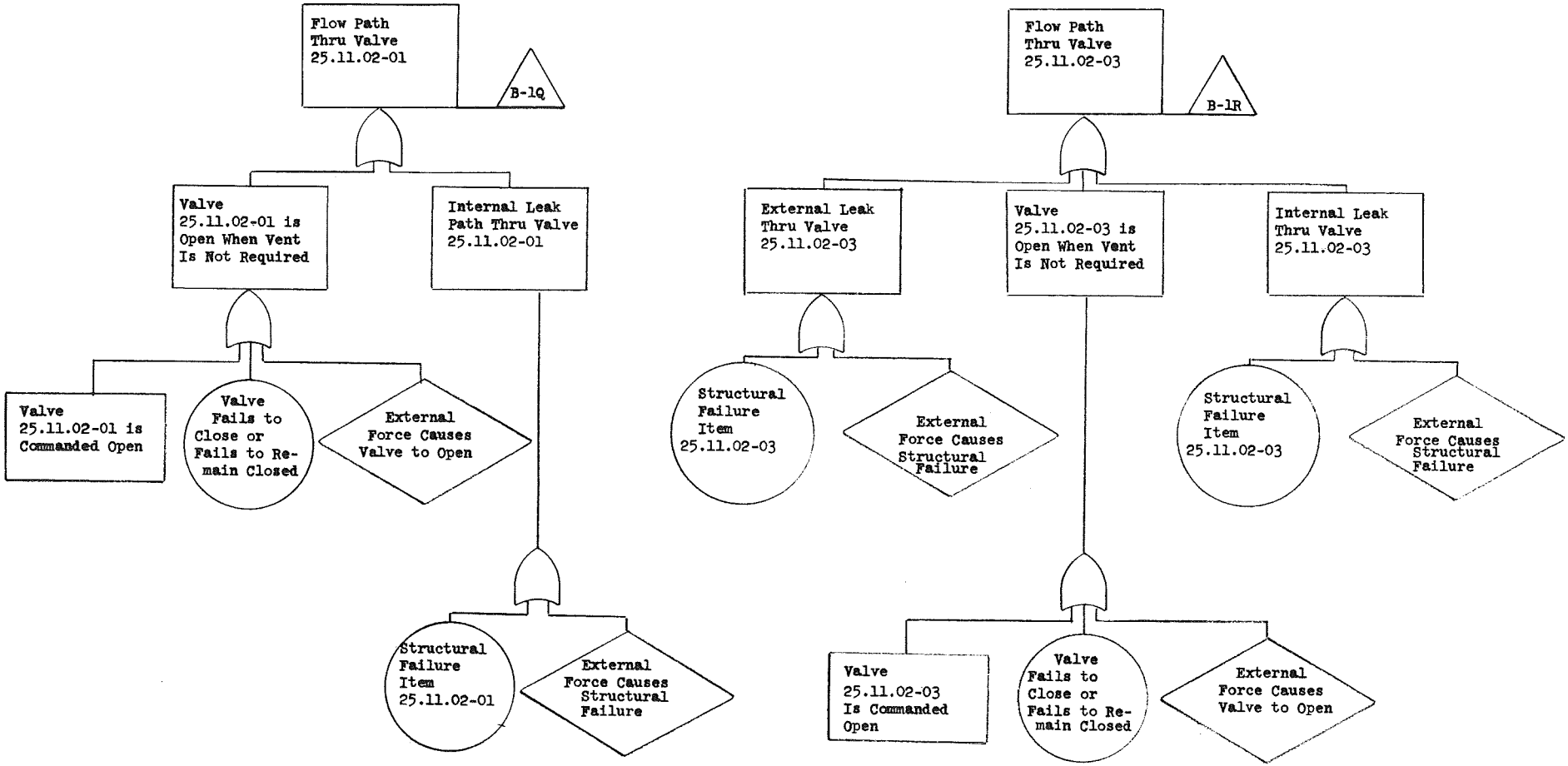
PS - Propulsion Module

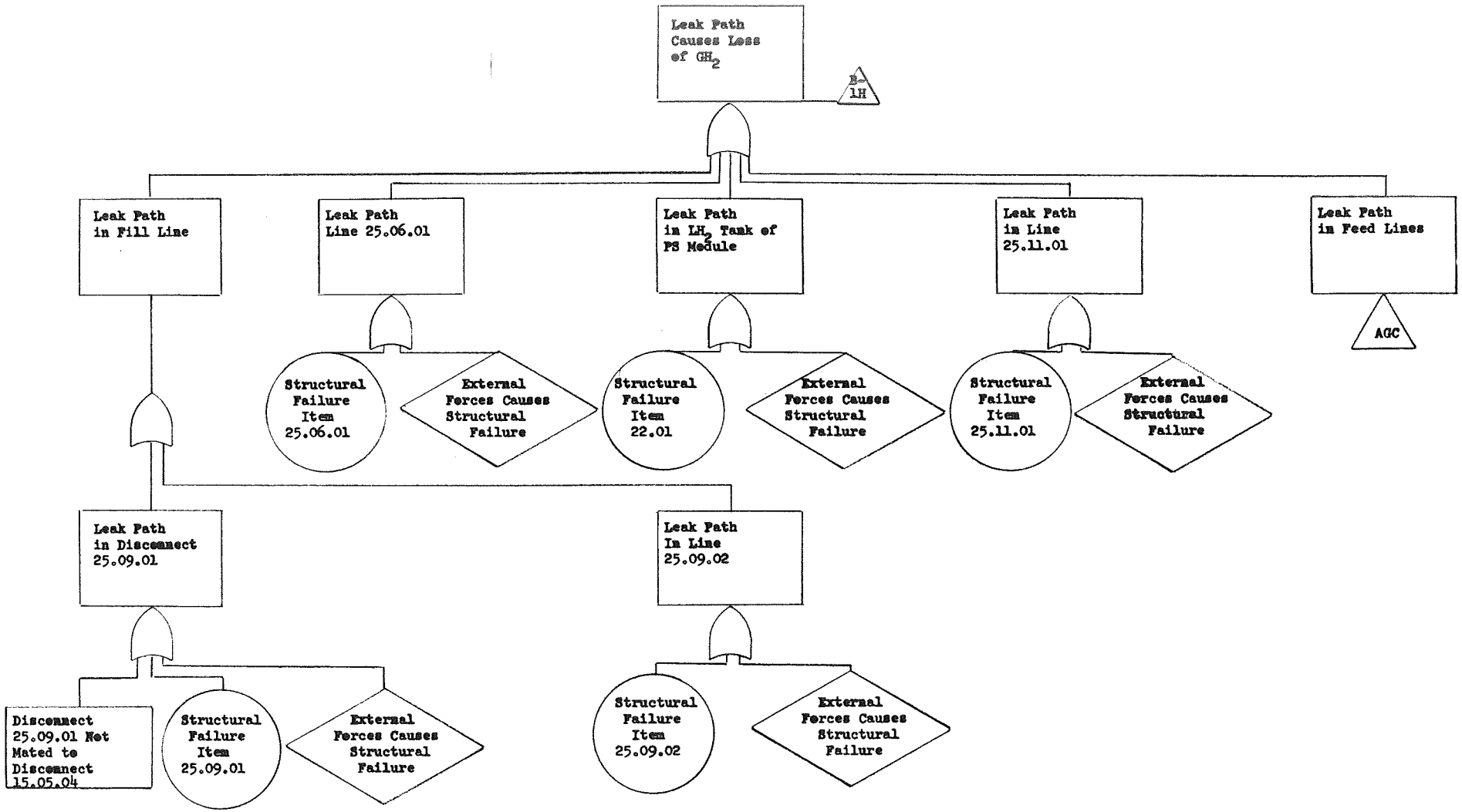



Insufficient Pressurant Gas Input to PS Module
B-1B
Insufficient GH_2 Supply
Insufficient GH_2 Supply From NERVA
AGC
Pressurant Lines Blocked Or Open to Space
Pressurant Lines Open To Space
Pressurant Lines Blocked
Pressure Control Valves Fail to Open
B-1K
Disconnect 25.06.05 Open To Space
Leak in Line 25.06.01
B-1N
Leak In Line 25.06.04
Line 26.06.01 Blocked
B-1L
Line 26.06.04 Blocked
B-1M
Disconnect 25.06.05 Not Mated to Disconnect 15.06.05
Structural Failure Item 25.06.05
External Force Causes Structural Failure
Structural Failure Item 25.06.04
External Force Causes Structural Failure

Note: Diagram B-1P is identical to Diagram B-1S with replacement of following component numbers:
25.11.02-01 25.11.02-04
25.11.02-02 25.11.02-04
25.11.02-03 25.11.02-06




Flow Path
Thru Valve
25.11.02-01
B-1Q
Valve
25.11.02-01 is
Open When Vent
Is Not Required
Internal Leak
Path Thru Valve
25.11.02-01
Valve
25.11.02-01 is
Commanded Open
Valve
Fails to
Close or
Fails to Re-
main Closed
External
Force Causes
Valve to Open
Structural
Failure
Item
25.11.02-01
External
Force Causes
Structural
Failure
Flow Path
Thru Valve
25.11.02-03
B-1R
External Leak
Thru Valve
25.11.02-03
Valve
25.11.02-03 is
Open When Vent
Is Not Required
Internal Leak
Thru Valve
25.11.02-03
Structural
Failure
Item
25.11.02-03
External
Force Causes
Structural
Failure
Structural
Failure
Item
25.11.02-03
External
Force Causes
Structural
Failure
Valve
25.11.02-03
Is Commanded
Open
Valve
Fails to
Close or
Fails to Re-
main Closed
External
Force Causes
Valve to Open


Leak Path Causes Loss of GH_2
B-1H
Leak Path in Fill Line
Leak Path Line 25.06.01
Leak Path in LH_2 Tank of PS Module
Leak Path in Line 25.11.01
Leak Path in Feed Lines
AGC
Structural Failure Item 25.06.01
External Forces Causes Structural Failure
Structural Failure Item 22.01
External Forces Causes Structural Failure
Structural Failure Item 25.11.01
External Forces Causes Structural Failure
Leak Path in Disconnect 25.09.01
Leak Path In Line 25.09.02
Disconnect 25.09.01 Not Mated to Disconnect 15.05.04
Structural Failure Item 25.09.01
External Forces Causes Structural Failure
Structural Failure Item 25.09.02
External Forces Causes Structural Failure

3.3 ABORT ANALYSIS

3.3.1 Introduction

The abort analysis was performed to provide the data necessary to conceive and delineate a contingency plan — a plan of action which is initiated by a failure of the RNS at some point in the mission. The abort analysis answers the questions: (1) what kind of orbit (earth, lunar) will result if the RNS experiences a complete loss of thrust capability, (2) what is the magnitude of the thrust capability available to the RNS from the NERVA emergency mode and from other sources (APS, cooldown) and how should it be used, (3) what is the orbit which results after the application of this additional thrust, and (4) what capability must be available to rescue the personnel aboard the RNS and return them to a safe haven? A corollary question is: can a loss of thrust capability cause the RNS to impact the surface of the earth? It is obvious that a guidance malfunction could cause earth impact during the translunar injection burn (Phase F) and the earth orbit injection burn (Phase U), but the study also revealed that a loss of thrust capability during the translunar coast (Phase G) could also cause earth impact. An identification of the mission phases used in the abort analysis is shown in Table 3-3.

This report presents the results of an analysis to determine the RNS trajectories resulting from early thrust termination. The RNS maneuvers differ from conventional chemical rocket maneuvers in that tail-off and cooldown impulse provide a significant percentage of the required injection energy relatively late in the trajectory. The nominal mission was arbitrarily scheduled for earth departure on January 1, 1980. The launch time and orbit ascending node location were chosen to minimize the TLI velocity requirement and also provide a hyperbolic lunar orbit with an inclination of 90 degrees, a perilune altitude of 60 nmi, and a trip time of 108 hours. There is no guarantee that the trajectories resulting from this analysis will be repeated for other launch dates or target conditions; however, the gross behavior of the trajectories (apogee and perigee altitudes versus time) should be representative.

Table 3-3

OPERATIONAL PHASES CONSIDERED FOR ABORT ANALYSIS

Mission Phase	Description
● F	Translunar injection
G	Pulsed aftercooling Midcourse correction Translunar coast
● H	Insertion into elliptical orbit
I	Pulsed aftercooling
● J	Apolune plane change
K	Pulsed aftercooling
● L	Circularize at target altitude
M	Pulsed aftercooling
N	Lunar orbit operations
● O	Insertion into elliptical lunar orbit
P	Pulsed aftercooling
● Q	Apolune plane change
R	Pulsed aftercooling
● S	Transearth injection
T	Pulsed aftercooling Midcourse correction Transearth coast
● U	Earth orbit capture
V	Pulsed aftercooling
W	Earth orbit resupply and checkout operations

● Denotes NERVA Thrusting Operation

Data used in this analysis were generated with the MDAC F866 (FLIP) computer program. Due to the significant effects of lunar perturbations, the two-body instantaneous orbit parameters provided as a part of the nominal trajectory printout do not accurately represent abort trajectories that result from thrust termination during tail-off or cooldown. For these conditions, abort trajectories were generated using four-body simulation to obtain accurate results.

3.3.2 Translunar Injection – Phase F

The translunar injection (TLI) burn, as used for this analysis, starts with the initiation of thrust buildup and has a duration of 1759 seconds (end of full thrust). Figure 3-1 shows the apogee altitude of the earth orbit that would result from a premature engine shutdown. Figure 3-2 shows the perigee altitude for this orbit as a function of time of thrust termination. Perigee altitude has been raised from 260 to 574 nmi during the TLI burn (it is raised to the lunar radius during subsequent thrust tail-off and cooldown operations). Two general types of abort maneuvers are available to return the RNS to an acceptable earth orbit: (1) an immediate retrofire utilizing the NERVA

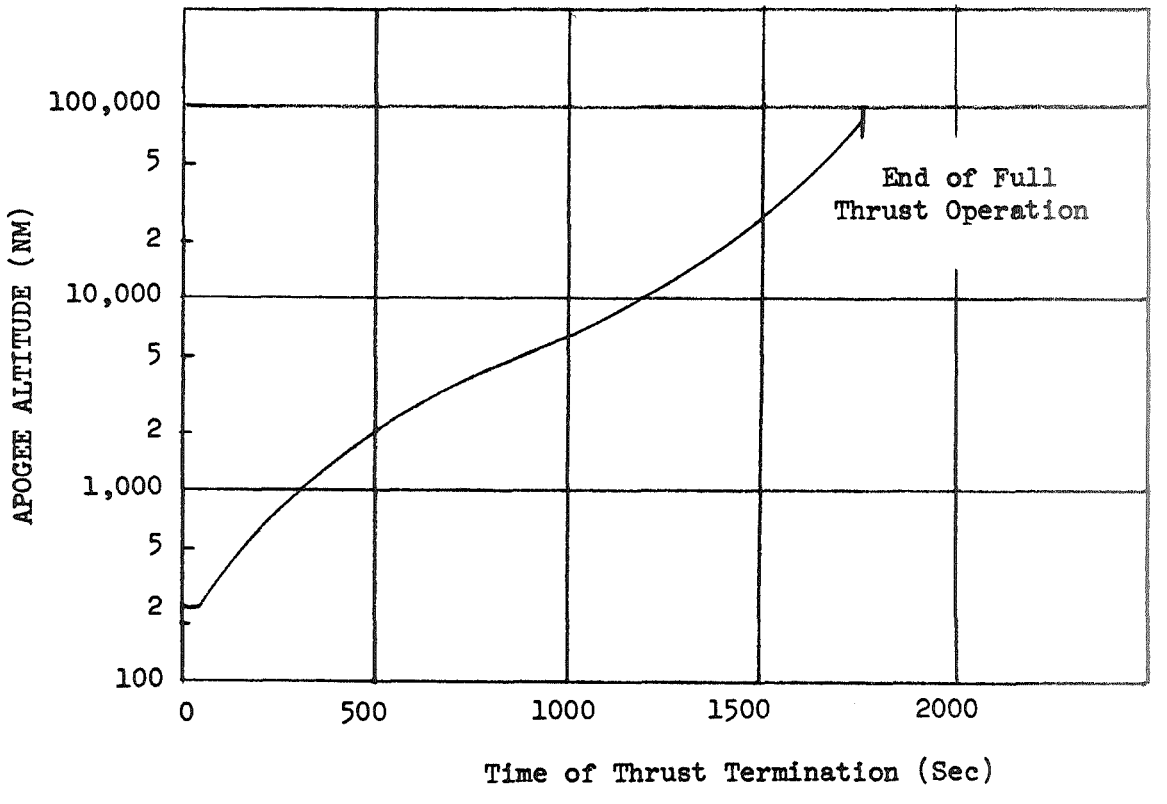


Figure 3-1 APOGEE ALTITUDE HISTORY - PHASE F

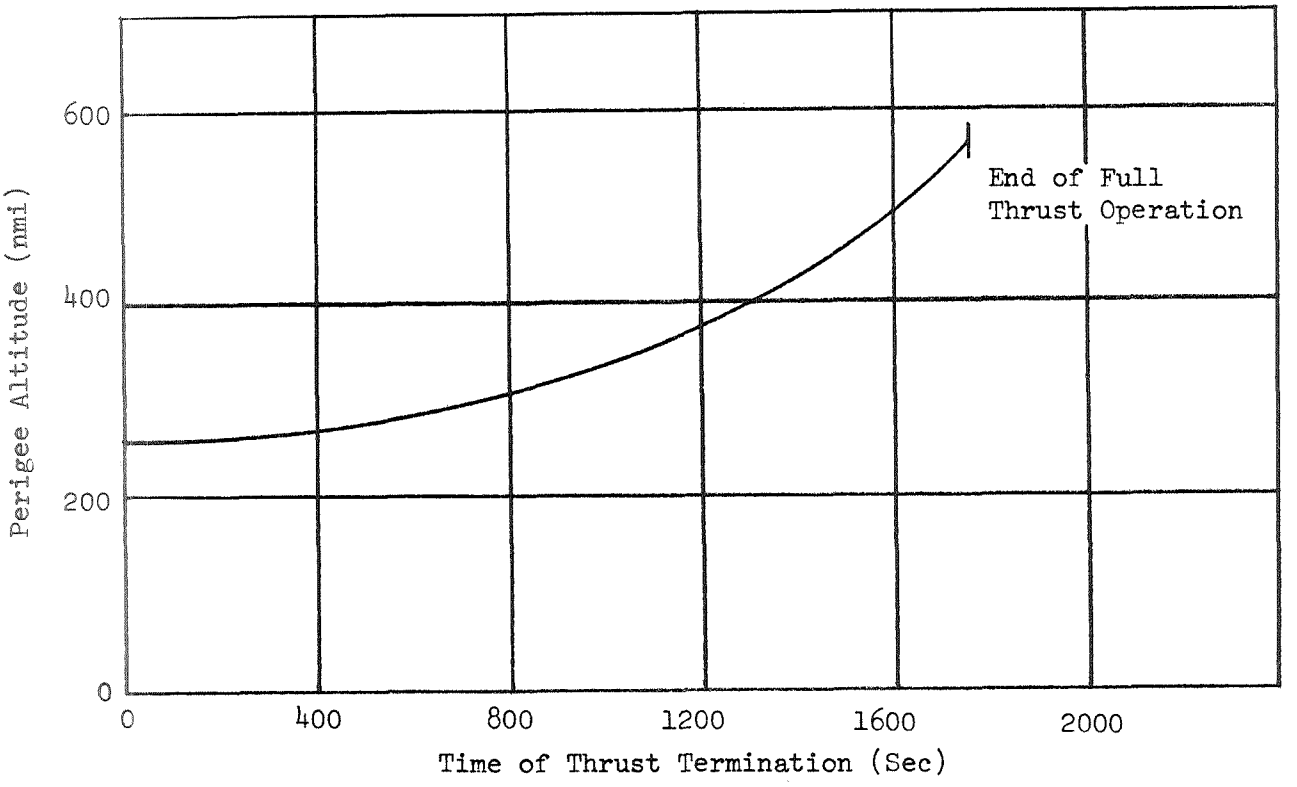


Figure 3 -2 PERIGEE ALTITUDE HISTORY - PHASE F

emergency mode thrust to establish an elliptical orbit with a perigee at 260 nmi and the idle mode to circularize at perigee, and (2) a shutdown and coast to apogee with an idle mode operation at apogee to lower the perigee to 260 nmi, followed by an emergency mode burn at perigee. The apogee of the elliptical orbit resulting from the first option is shown in Figure 3-3. The magnitude of the apogee burn for the second option is shown in Figure 3-4 and the magnitude of the perigee burn is shown in Figure 3-5. The data shown in Figure 3-5 also represent the approximate amount of total velocity required for the first option.

The capability of the NERVA emergency mode during the translunar injection mode is shown in Figure 3-5. The capability during the remainder of the mission, in terms of the velocity increment available at the start and end of a specific mission phase, is shown in Figure 3-6.

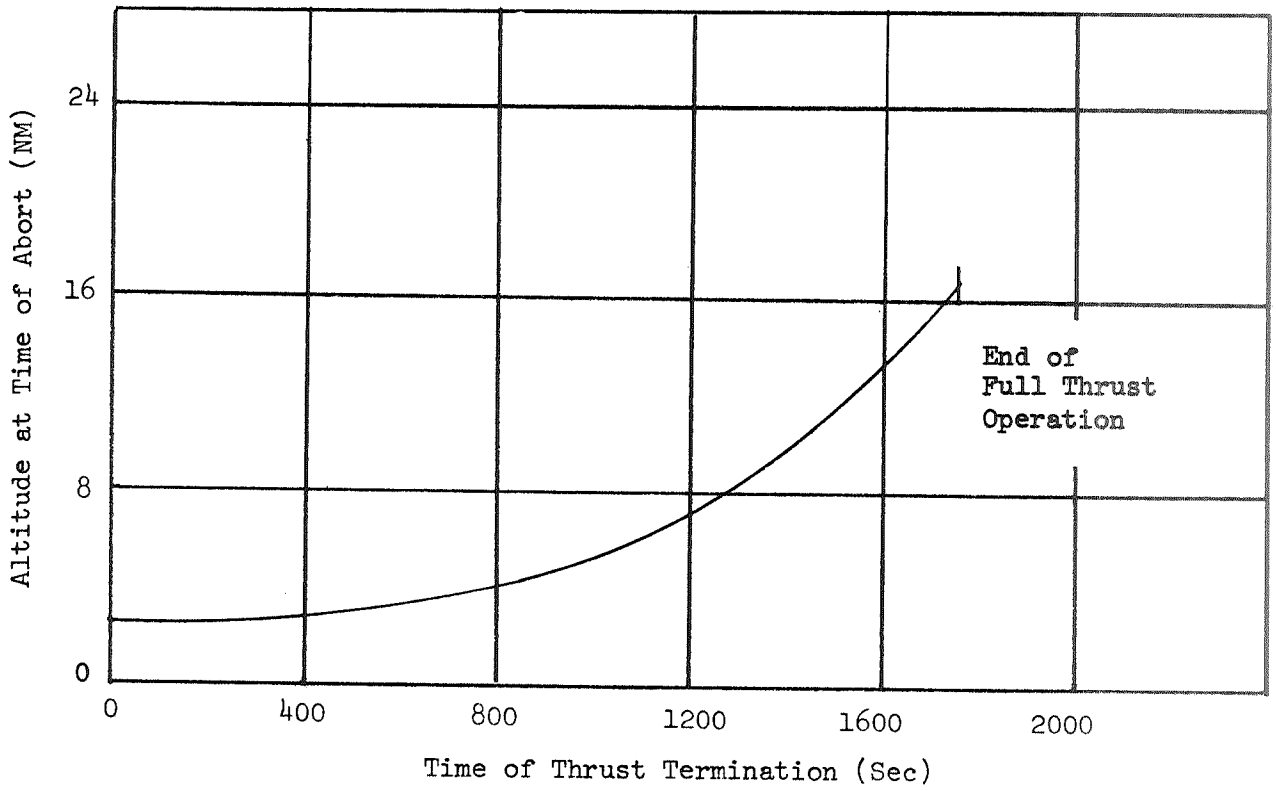


Figure 3- 3 ABORT ALTITUDE HISTORY - PHASE F

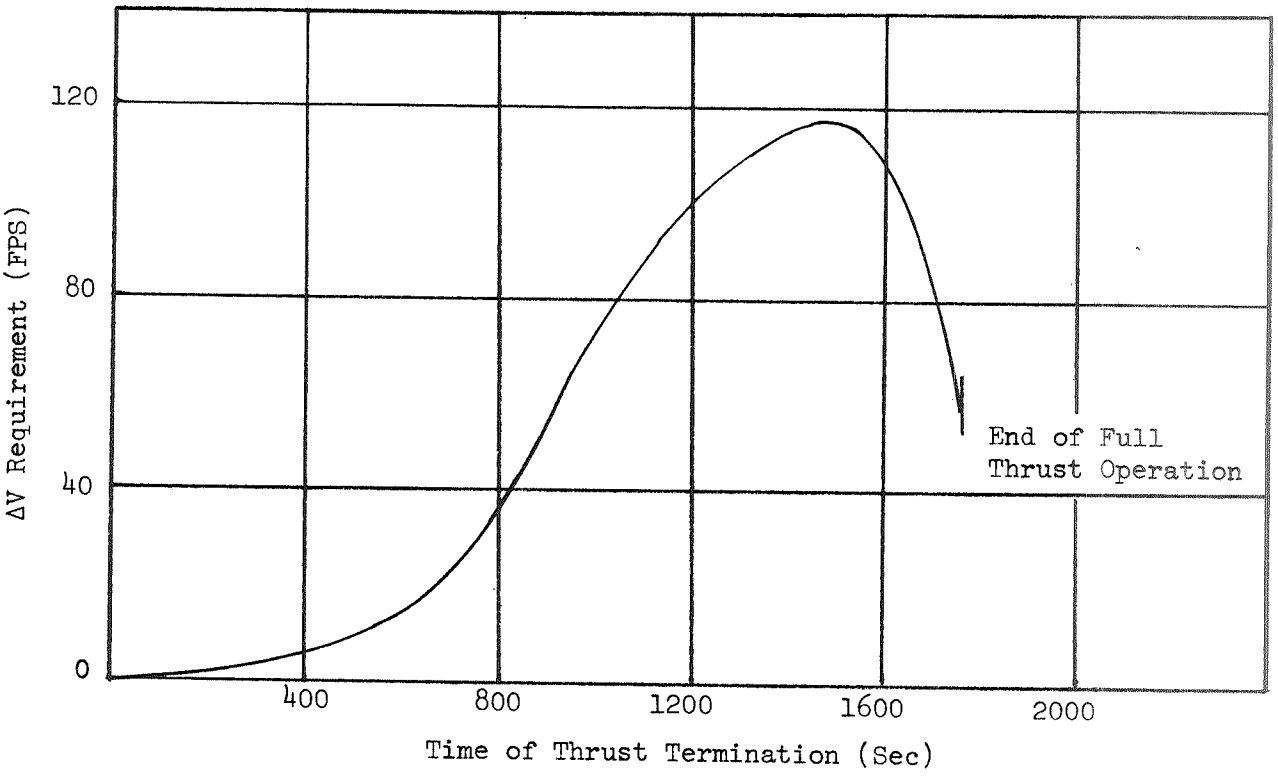


Figure 3-4 APOGEE TRIM REQUIREMENT - PHASE F

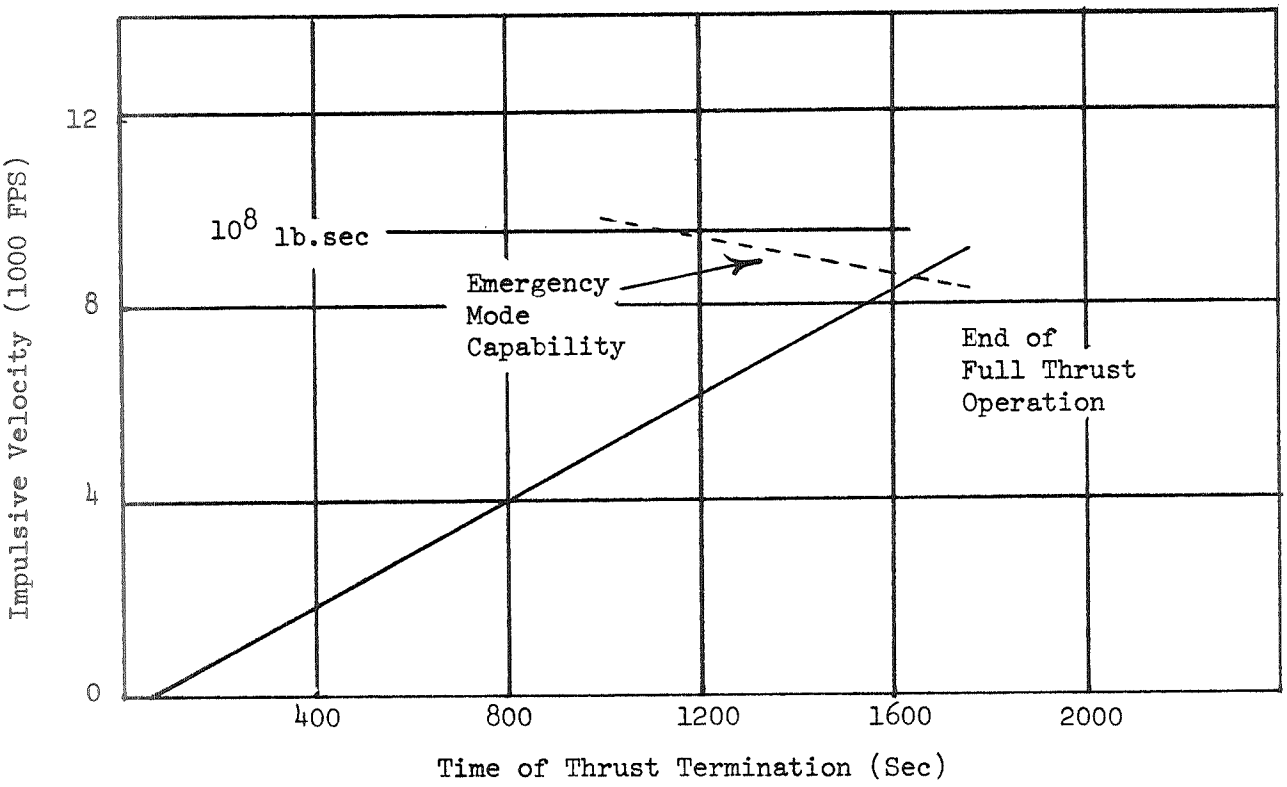


Figure 3-5 IMPULSIVE VELOCITY REQUIREMENT - PHASE F

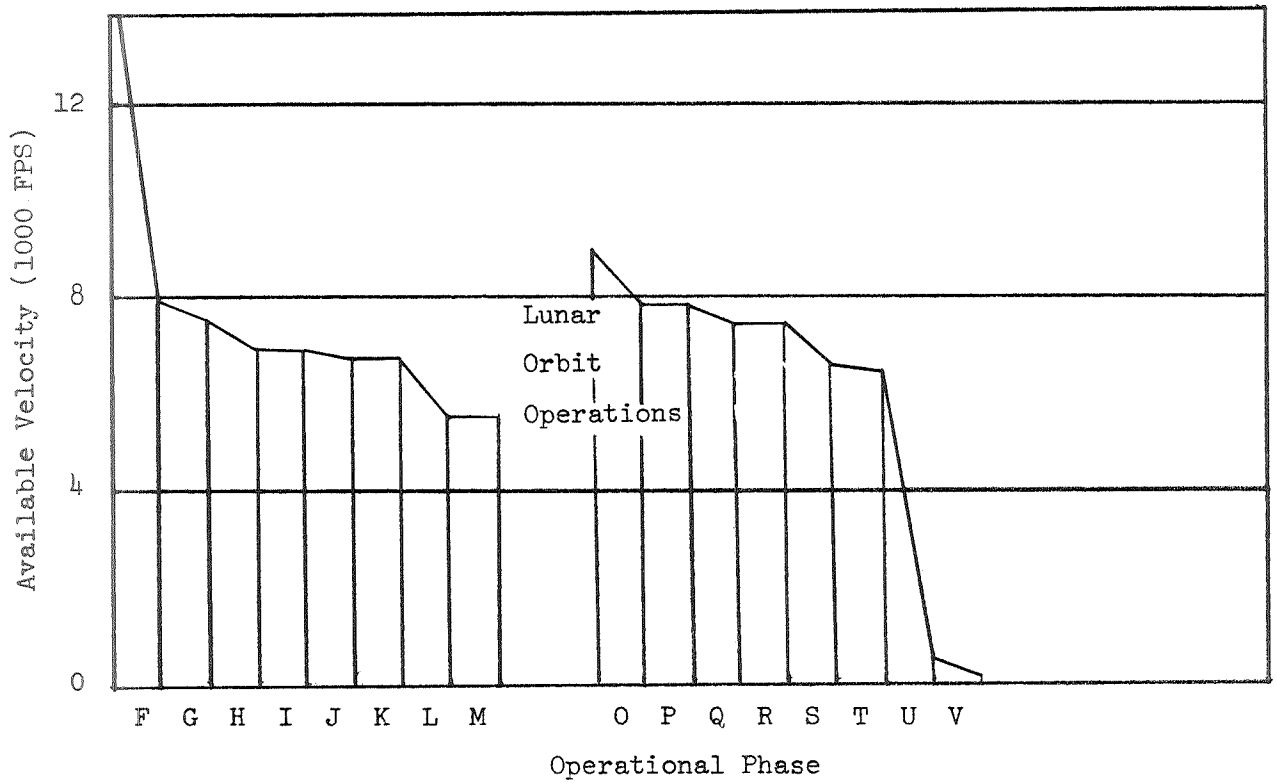


Figure 3-6 EMERGENCY MODE CAPABILITY

As shown in Figure 3-5 the velocity increment required could be as high as 9,200 ft/sec. Therefore, if a failure occurs in the last 200 seconds of burn it would not be possible to circularize. The resultant orbit for both options will be an ellipse with a perigee of 260 nmi and some external propulsion capability will be required for rescue.

An alternate abort mode during this latter part of Phase F would be to use the emergency mode to continue the burn and then abort to the moon. A total of approximately 6,750 ft/sec would be required to accomplish this option. This requirement is within the capability of the emergency/idle mode operation.

3.3.3 Translunar Coast – Phase G

During tail-off and the first few hours of cooldown, the apogee altitude is raised to distances where, if a premature shutdown (loss of cooldown thrust) occurs, the resultant abort ellipse experiences extensive lunar perturbations (see Figure 3-7). These perturbations are best illustrated by the perigee altitude versus thrust termination time graph presented in Figure 3-8. The effect of the lunar perturbations is to initially lower the perigee altitude, with an earth impact resulting if shutdown occurs from 1 to 3 hours into the mission. For later shutdown times, the perigee altitude increases rapidly as discussed below. The velocity requirement to raise the perigee altitude to 260 nmi has been determined for two modes. For the first mode, the RNS is allowed to achieve apogee and the impulsive maneuver is then performed. The cost in impulsive velocity is shown (the solid curve in Figure 3-9) as a function of time of thrust termination. A time period of approximately 70 hours will elapse during the coast to apogee in this case. A maneuver that provides some performance gain is to immediately correct the velocity after the early shutdown is observed. This correction consists of either (1) subtracting velocity (retrofire) so that the apogee altitude of the last acceptable perigee altitude is reached, or (2) adding velocity to increase apogee altitude to that which would be achieved if shutdown did not occur until later than 3 hours into the mission. The cost for this maneuver is spproximated by the dashed line in Figure 3-9. These performance requirements represent a minimum, since the maneuvers are initiated immediately after the malfunction. At this point in the mission the capability of the APS system is

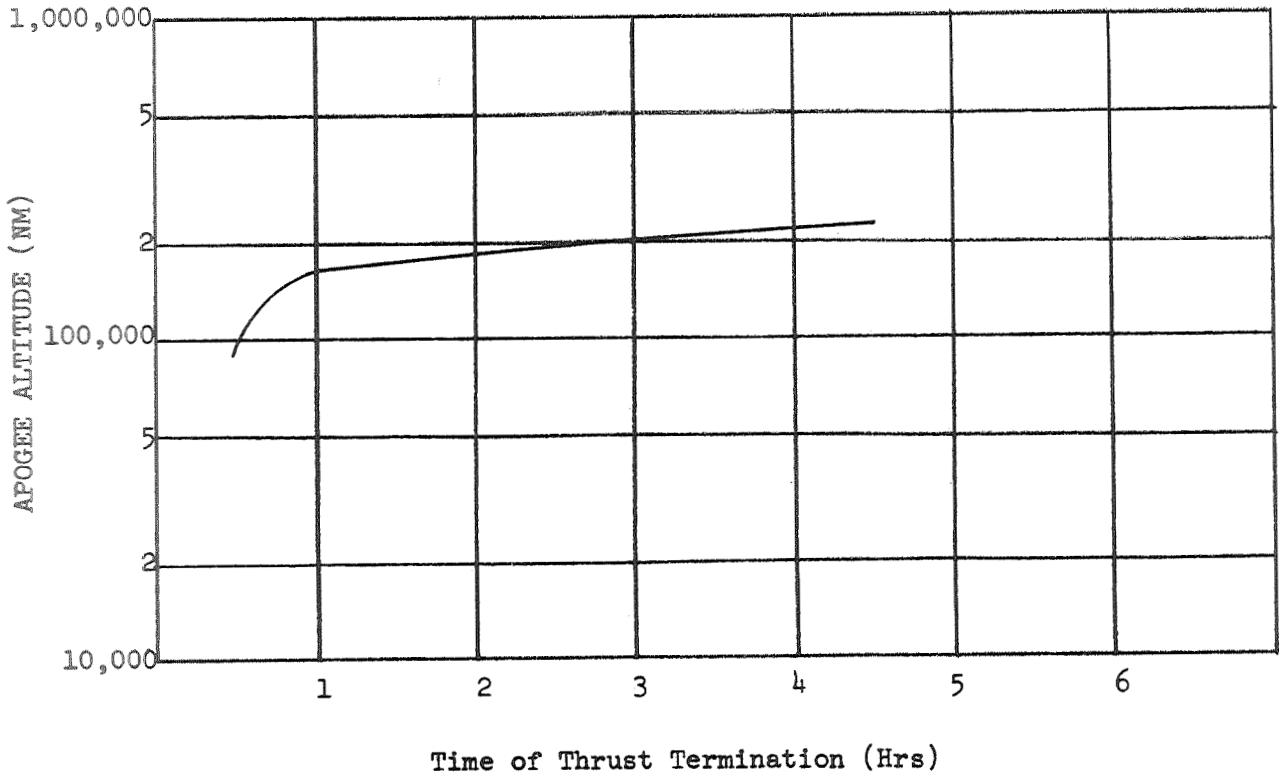


Figure 3-7 APOGEE ALTITUDE HISTORY - PHASE G

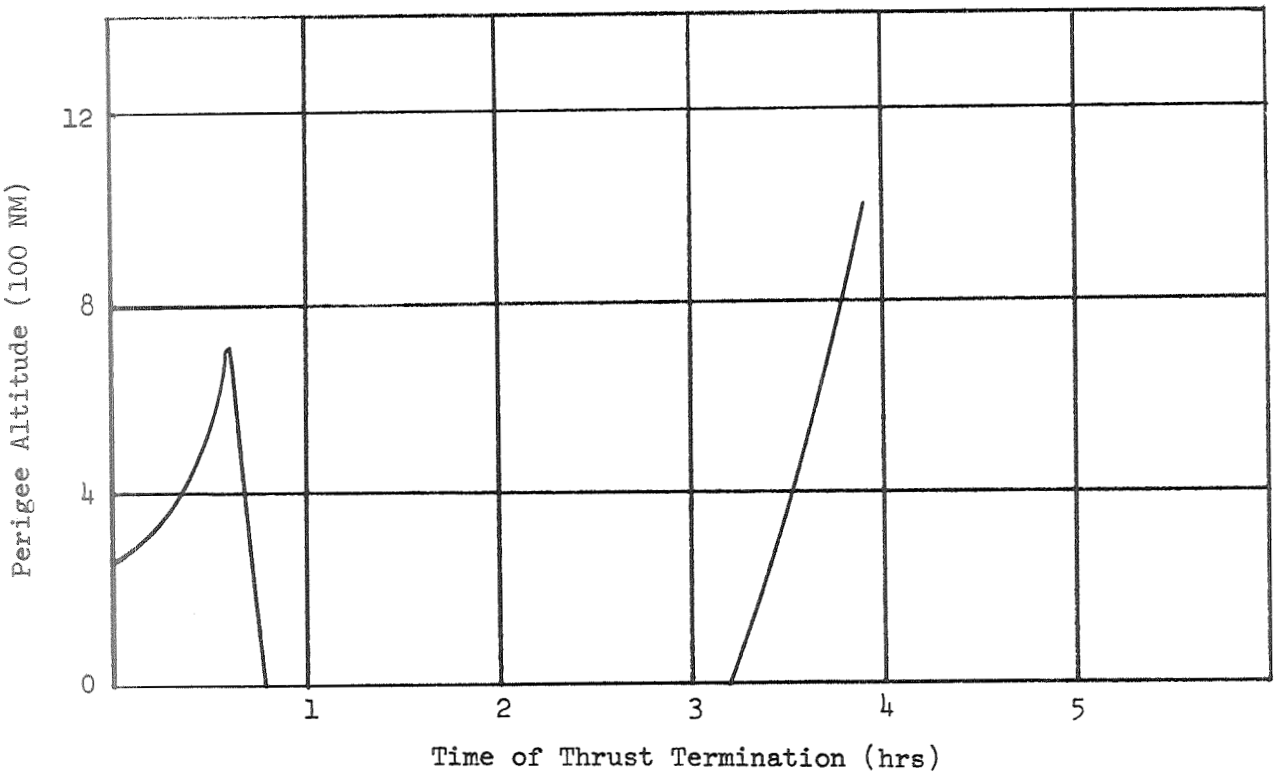


Figure 3-8 PERIGEE ALTITUDE HISTORY - PHASE G

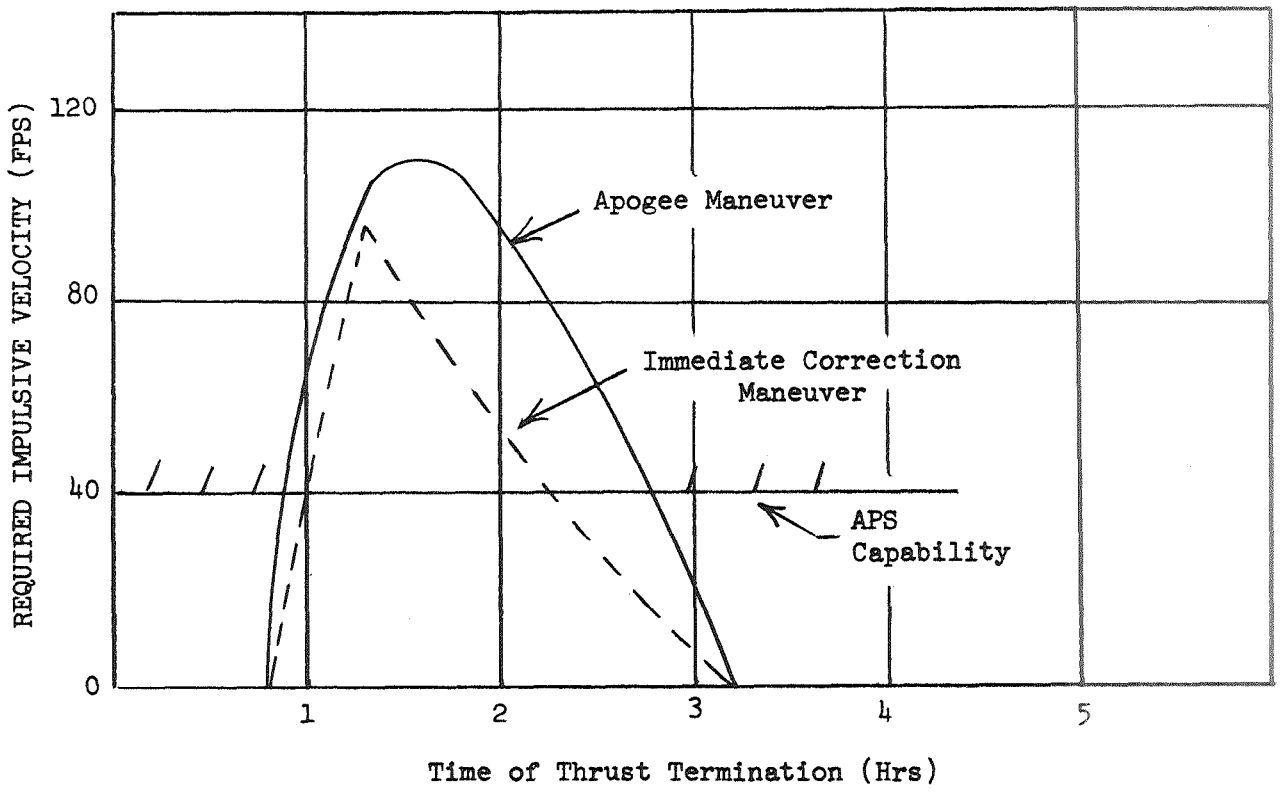


Figure 3-9 REQUIRED IMPULSIVE VELOCITY TO PREVENT EARTH IMPACT - PHASE G

approximately 40 ft/sec. Therefore, even for this latter mode, there exists a time between 1 to 3 hours where the APS propellant is not sufficient to raise the perigee to 260 nmi. Assuming that the APS or some other means of propulsion is used to raise the perigee to 260 nmi, the velocity required to circularize at perigee is plotted as a function of time of abort in Figure 3-10.

During the later phase of cooldown (3 through 102 hours) both apogee and perigee altitudes initially increase and then become relatively stable (see Figures 3-11 and 3-12). The perigees of these orbits reach the lunar distance of 220, 000 nmi and the apogees range from 2, 000, 000 to 8, 000, 000 nmi. It should be pointed out that this post-swingby perigee occurs after a flyby of the moon. An apogee maneuver is impractical for these abort orbits as it would take over a month before it could be executed. Assuming a perigee burn, the impulsive velocity to establish a 260 nmi by the abort perigee altitude orbit has been plotted in Figure 3-13.

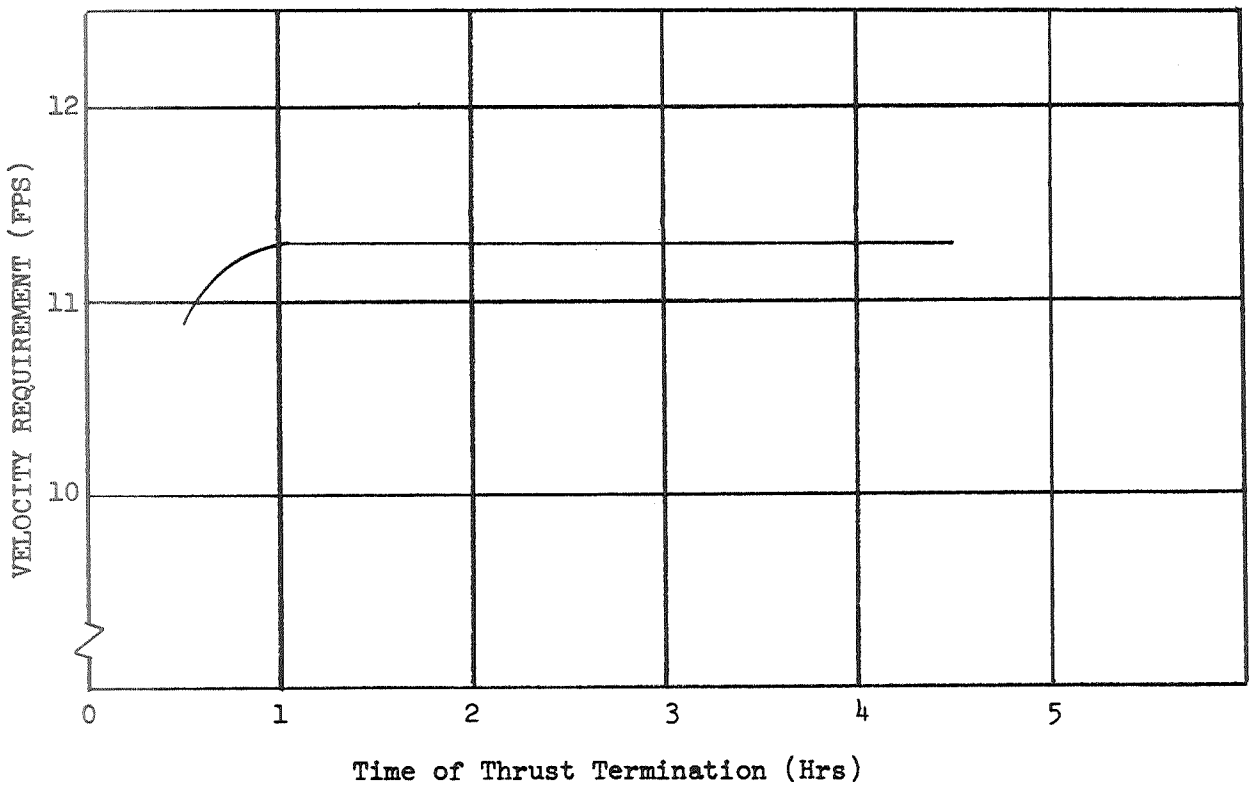


Figure 3-10 VELOCITY REQUIREMENT FOR INJECTION INTO 260 NM CIRCULAR ORBIT - PHASE G

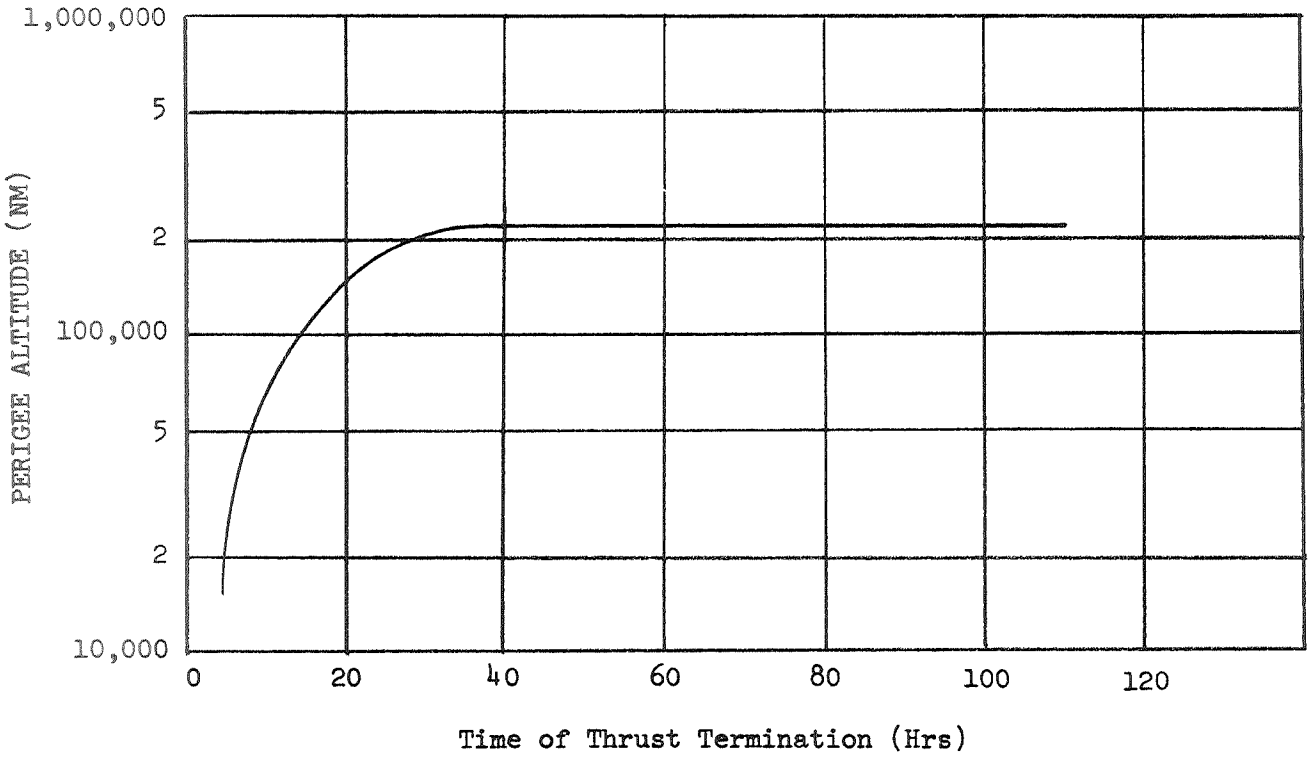


Figure 3-11 PERIGEE ALTITUDE HISTORY - PHASE G

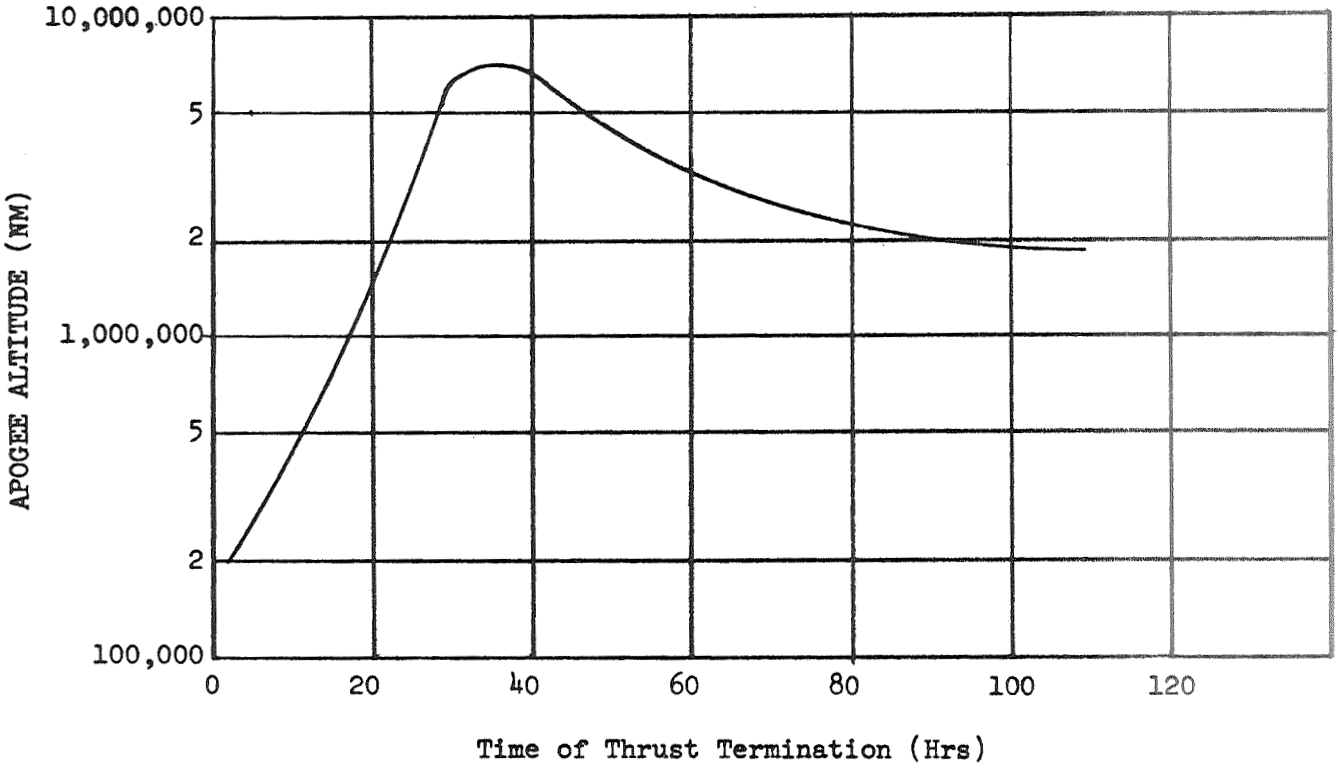


Figure 3-12 APOGEE ALTITUDE HISTORY - PHASE G

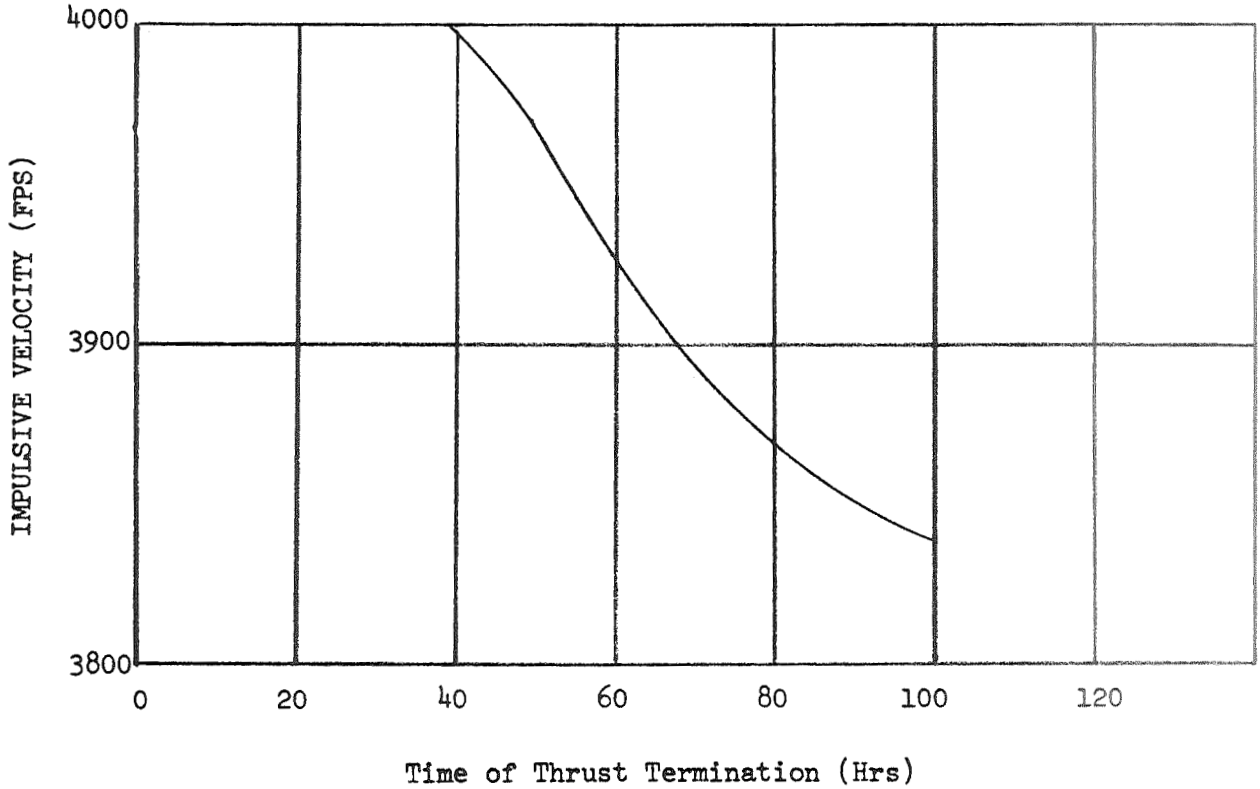


Figure 3-13 IMPULSIVE VELOCITY REQUIREMENT FOR ESTABLISHING A 260 x 220,000 NM ORBIT - PHASE G

If an abort to lunar orbit were an acceptable mode of operation, a more practical final orbit might be achieved. Figure 3-14 the lunar closest approach distances are presented as a function of time of abort. These data also indicate that for the mission selected there is no premature engine shutdown that will cause a lunar impact. Assuming that an out-of-plane (relative to the space station) circular orbit is acceptable, the impulsive velocity required is shown in Figure 3-15 for a perilune burn. A three-burn maneuver would cost a total of 5, 200 ft/sec and would result in a rendezvous with the space station. At this point in the mission, the velocity increment available from the NERVA emergency mode is approximatey 7, 650 ft/sec, more than is required for either the perigee burn to achieve a high earth orbit or either lunar orbit injection option.

The critical point in this phase is the period between 1 and 3 hours where a failure to continue cooldown will result in an earth impact. This could only

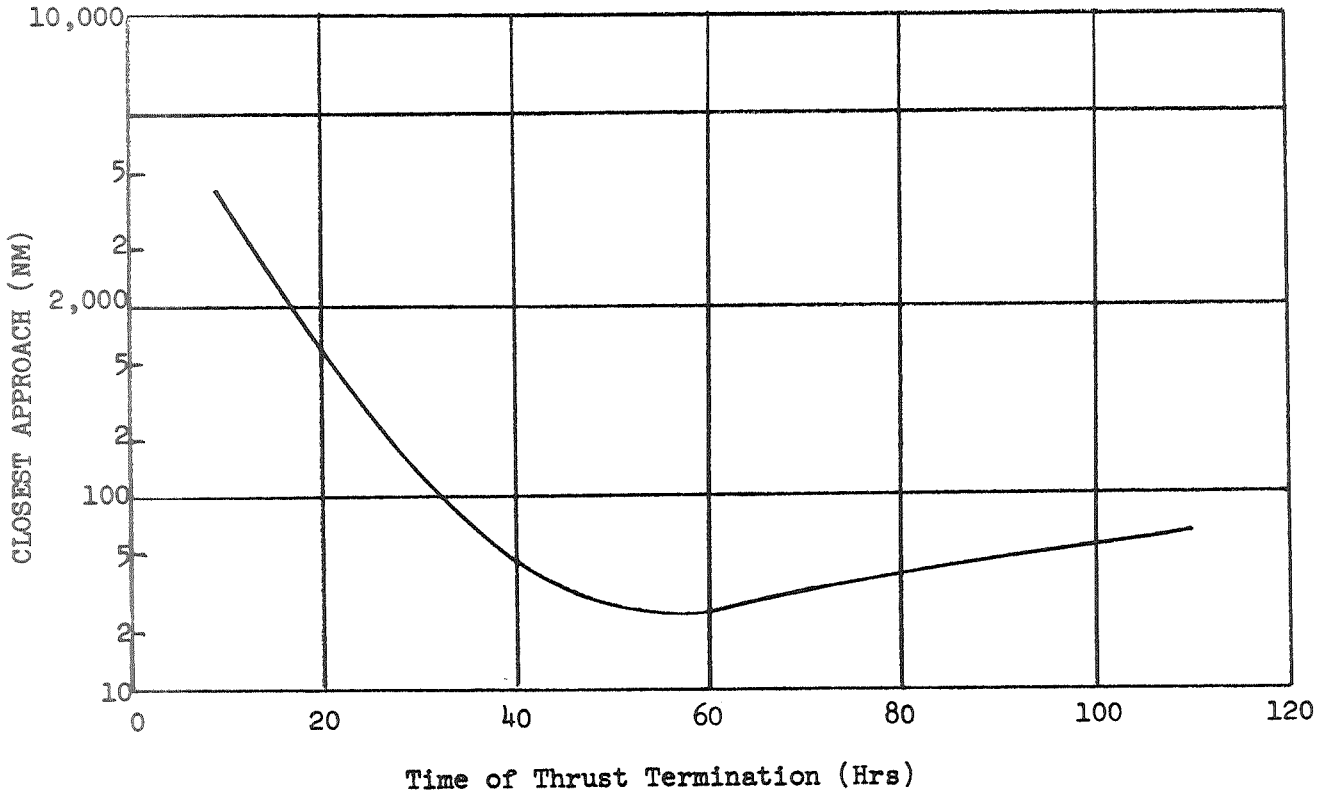


Figure 3-14 CLOSEST APPROACH TO THE MOON - PHASE G

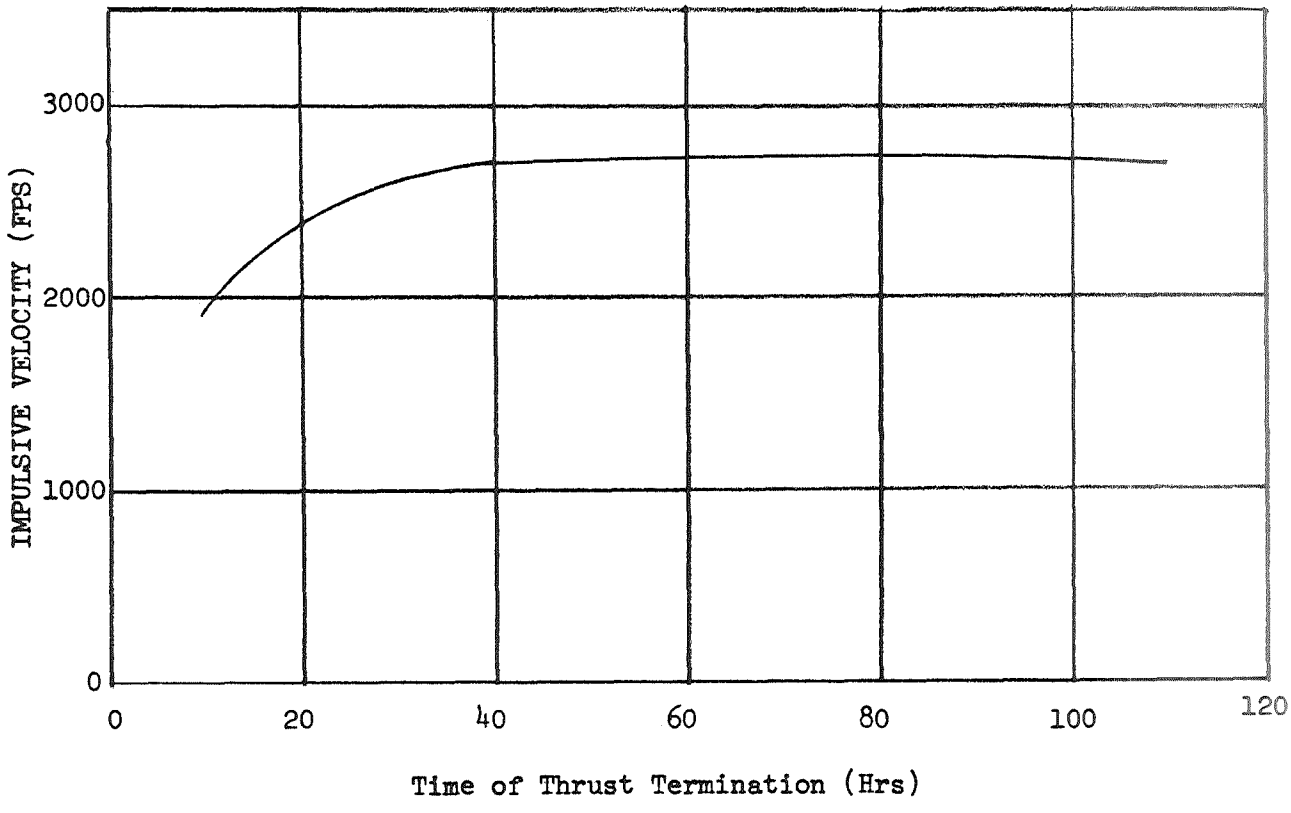


Figure 3-15 IMPULSIVE VELOCITY REQUIREMENTS FOR ATTAINING A CIRCULAR LUNAR ORBIT - PHASE G

be caused by a Class IV-A, IV-C, or IV-D type of failure (see Section 3.1.1 for definition of failure classes). A Class IV-A or IV-D would also rule out any possibility of preventing earth impact caused by inability to control the flight path. A Class IV-C failure would demand another source of propulsive capability — the auxiliary porpulsion system. In the present design the APS capability is inadequate, i.e., up to 115 ft/sec is required, while only 40 ft/sec is available.

3.3.4 Lunar Orbit Injection — Phases H, I, J, K, L, M

The first burn of the lunar injection occurs at perilune of the incoming hyperbolic orbit. Assuming an RNS weight of 316,000 lb, a NERVA specific impulse of 825 seconds and a thrust level of 75,000 lb, the initial injection burn is 109 seconds long and provides an impulsive velocity of 847 ft/sec at a cost of 10,000 lb of propellant. In Figure 3-16, the apogee and apolune

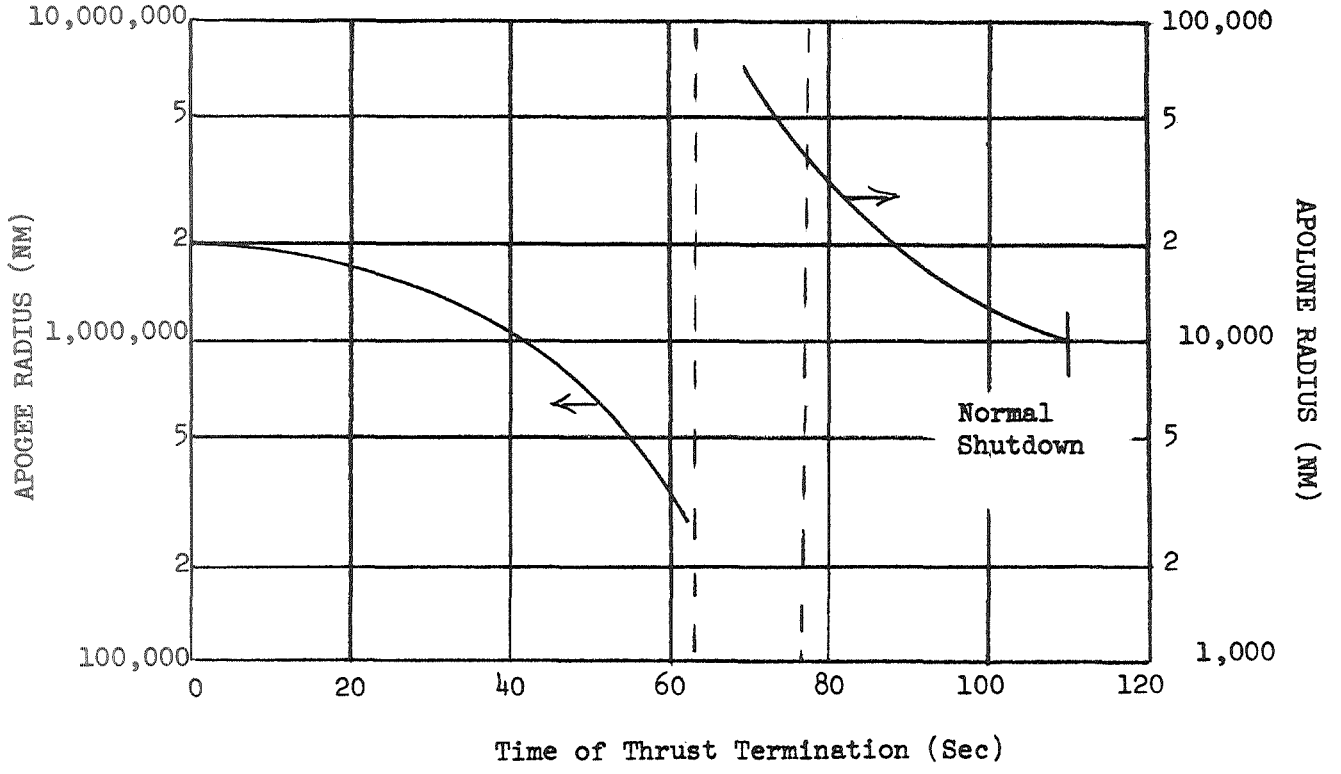


Figure 3-16 INITIAL LUNAR ORBIT INJECTION PARAMETERS - PHASE H

radii are shown as a function of burn time. For the first 60 seconds of the burn an early shutdown will result in the RNS leaving the lunar sphere of influence and orbiting the earth with a perigee at the lunar distance and apogee as shown. For aborts occurring after 80 seconds of burn time, the RNS will be captured by the moon in an orbit with a perilune altitude of 60 nmi and an apolune as illustrated in the figure. If an abort occurs between 60 and 80 seconds, the vehicle motion is not accurately defined by patched conic techniques and should be solved as a three-body problem. This was deemed beyond the scope of the present study and postponed until a later phase of the RNS development.

The problem of how to best use the RNS after an abort has been considered. If one adopts the philosophy of establishing an earth orbit the velocity requirements would be similar to the data of Figure 3-17. For the first 60 seconds, it has been assumed that the injection would occur near perilune, after a lunar flyby, but out of the moon's sphere of influence. If an abort were to occur after 80 seconds in the burn, the RNS would coast in the orbit until the position is reached where the desired earth orbit is obtained with minimum velocity expenditure. On the other hand, if the RNS attempts to establish an out-of-plane 60 nmi circular lunar orbit by a single prograde burn, the velocity requirement is shown in Figure 3-18. A three burn maneuver, including a continuation of the Phase H burn, would cost up to 5, 200 ft/sec. The NERVA emergency mode capability is 7, 050 ft/sec at this point which provides a confortable margin for the required velocity increment for either lunar option.

In the plane change maneuver (Phase J), the orbit plane is rotated about the pole to shift the ascending node. Assuming a weight of 306, 000 lb and the same propulsion parameters previously discussed, a 30-degree node shift costs approximately 963 ft/sec or 11, 300 lb of propellant. The burn time associated with the maneuver is 124 seconds. For the nominal mission the RNS lunar orbit plane is normal to the earth-moon line after 24 hours of orbit. If the ascending node location (~270 degrees at this time) is increased by the plane-change maneuver, an abort during the burn could be handled by waiting until the lunar rotation (13 degrees/day) provides another coplanar opportunity with the plane normal to the earth-moon line. The velocity requirement to establish an earth orbit 260 by 222, 000 nmi is then about 2, 100 ft/sec (6, 760 ft/sec is available from the NERVA emergency mode). Conversely, if the plane change decreases the ascending node location, the orbit waiting requirement for a coplanar condition is extensive and a non-coplanar abort to earth is performed. A more practical abort mode would be to circularize a periline which would cost 1, 780 ft/sec.

However, the final lunar orbit would then be in a different plane than the lunar space station. A prior operation to complete the plane change would be required to place the final orbit in the proper plane. Figure 3-19 gives

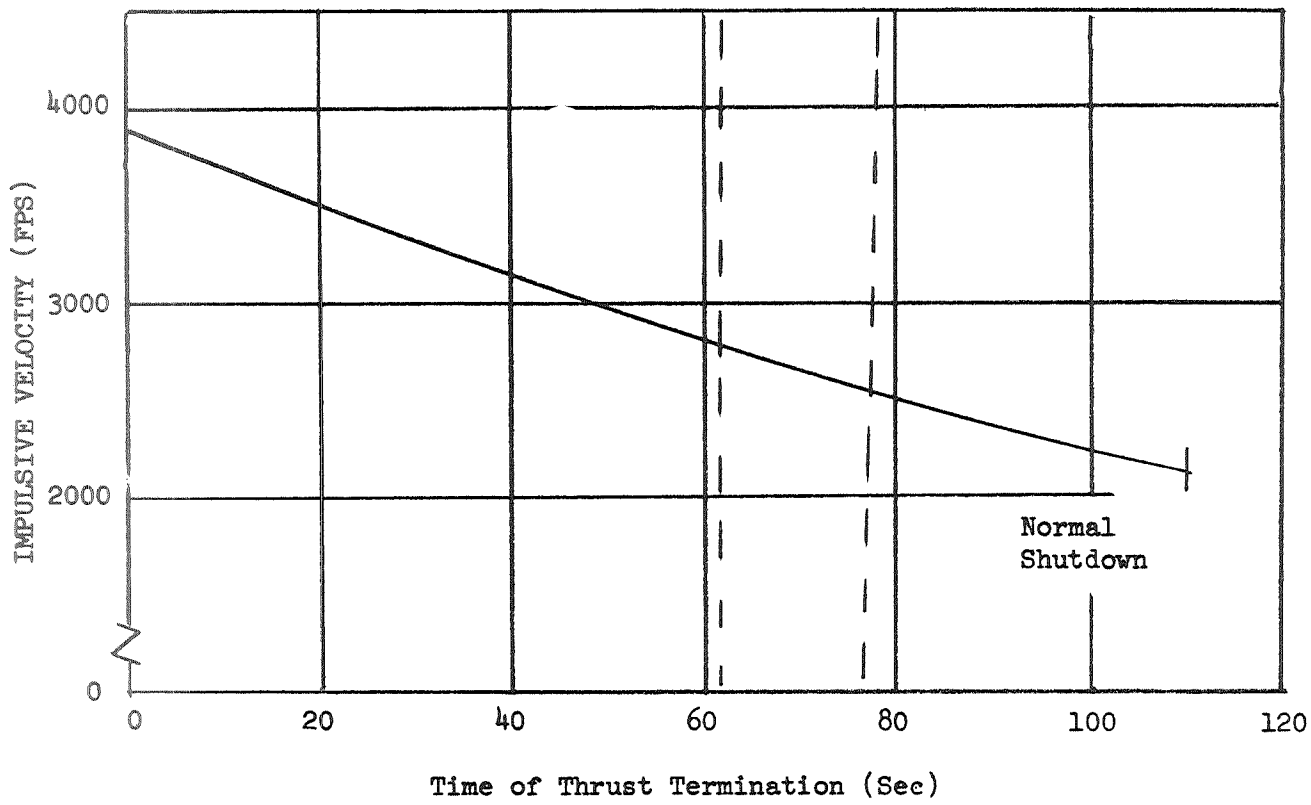


Figure 3-17 IMPULSIVE VELOCITY REQUIREMENT FOR 260 x 220,000 NM EARTH ORBIT - PHASE H

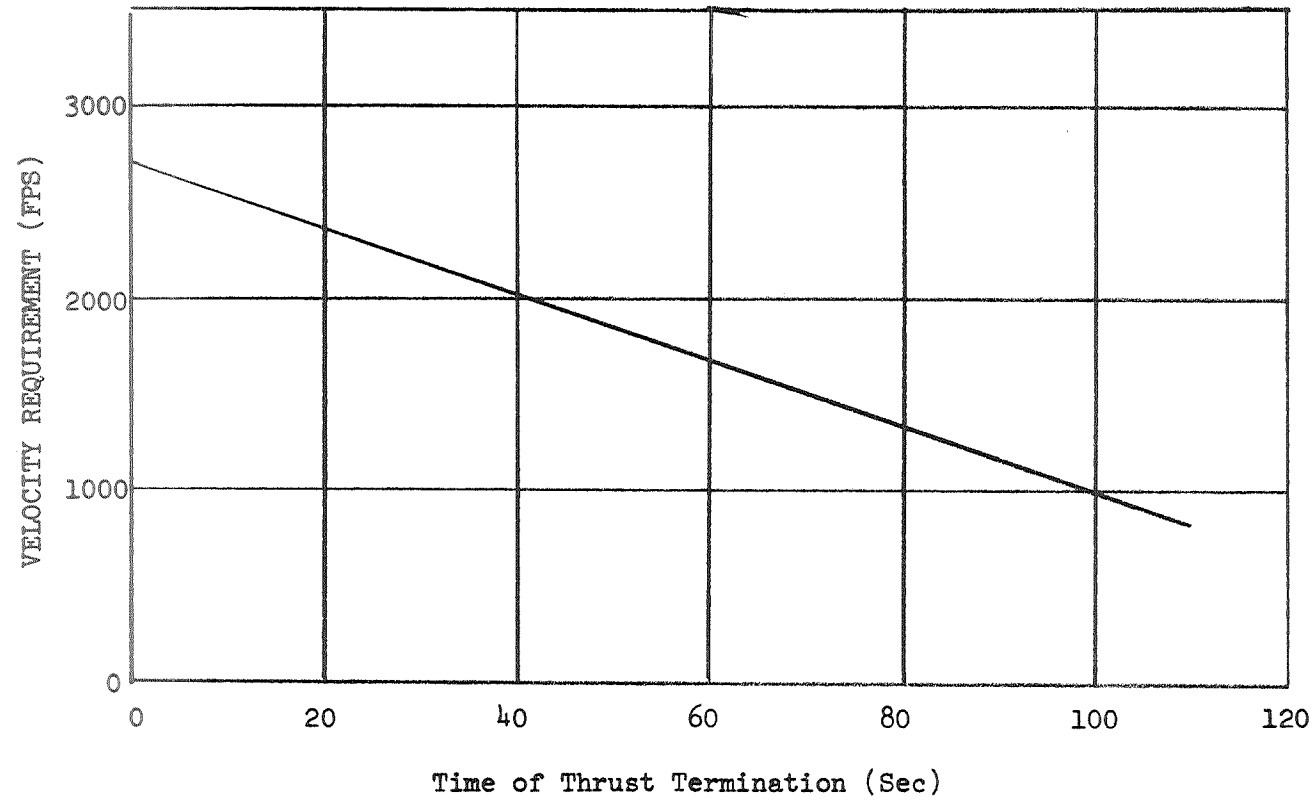


Figure 3-18 VELOCITY REQUIREMENT FOR A 60 NM CIRCULAR LUNAR ORBIT - PHASE H

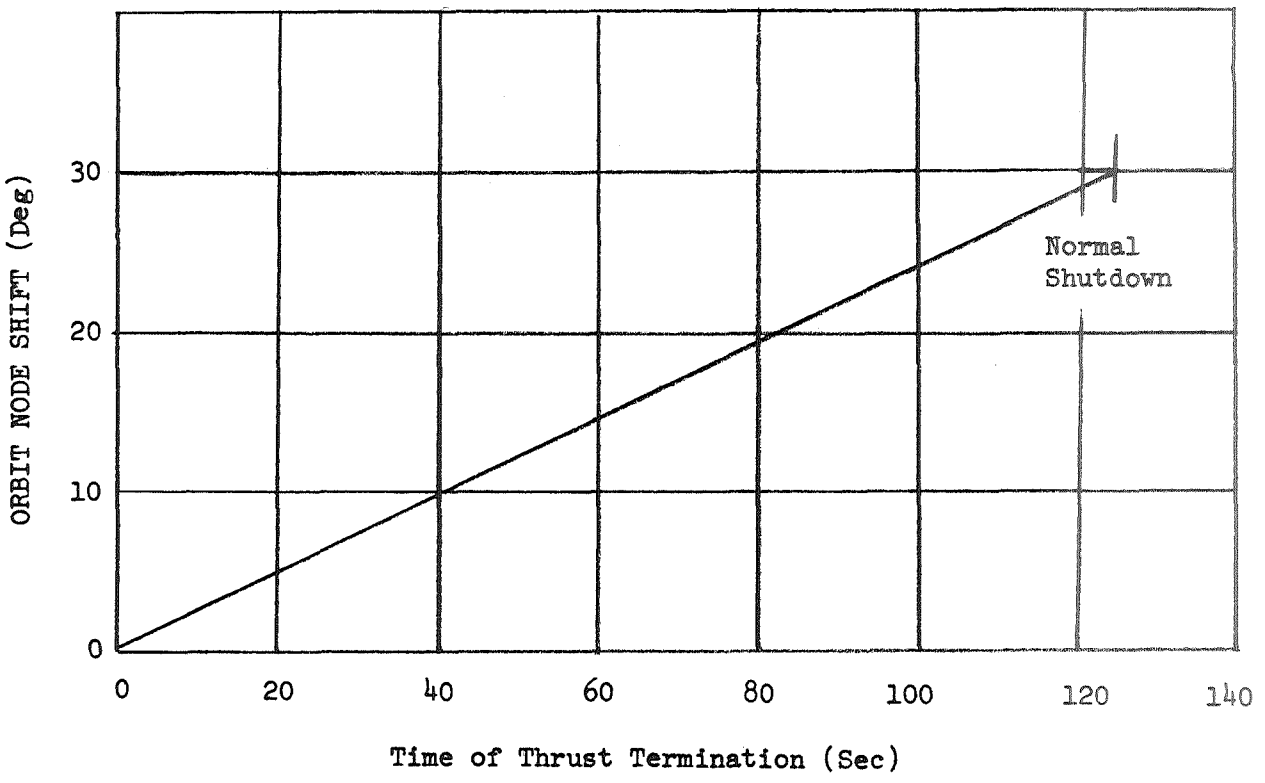


Figure 3-19 LUNAR ORBIT PLANE CHANGE - PHASE J

the amount of required plane change remaining as a function of failure time and Figure 3-20 gives the required velocity requirement. This type of operation requires two thrust maneuvers—only one is allowed for the NERVA emergency mode and the APS capability at this point in the mission (31.4 ft/sec) is inadequate. An emergency idle mode could be utilized if it is available, or external rescue systems could be utilized.

The final lunar injection maneuver (Phase L) occurs at perilune of the rotated 24-hour lunar orbit. For the previously defined propulsion paramerters and a weight of 295,000 lb, the ΔV requirement of 1,860 ft/sec translates to a burn time of 211 seconds and a propellant expenditure of 19,200 lb.

In Figure 3-21 apolune altitude is plotted versus time of abort. In Figure 3-22 the velocity required to complete the circularization maneuver is presented. If the lunar orbit is not acceptable, an earth orbit with a 260-nmi perigee can be established. However, as in the abort during node shift the geometry has shifted and could be as much as 10 degrees out of plane at the first opportunity for establishing the desired earth orbit. The velocity requirement should vary nonlinearly from approximately 2,100 ft/sec for

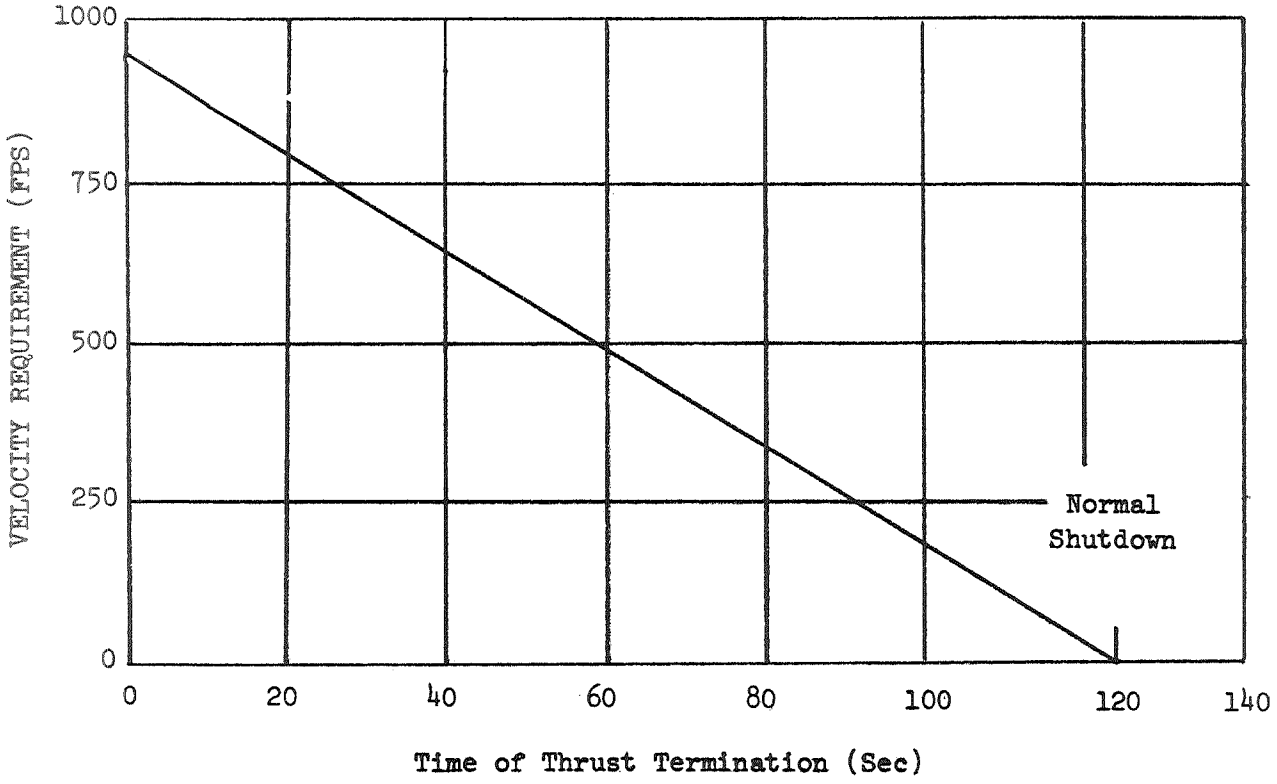


Figure 3-20 VELOCITY REQUIREMENT TO COMPLETE LUNAR ORBIT PLANE CHANGE - PHASE J

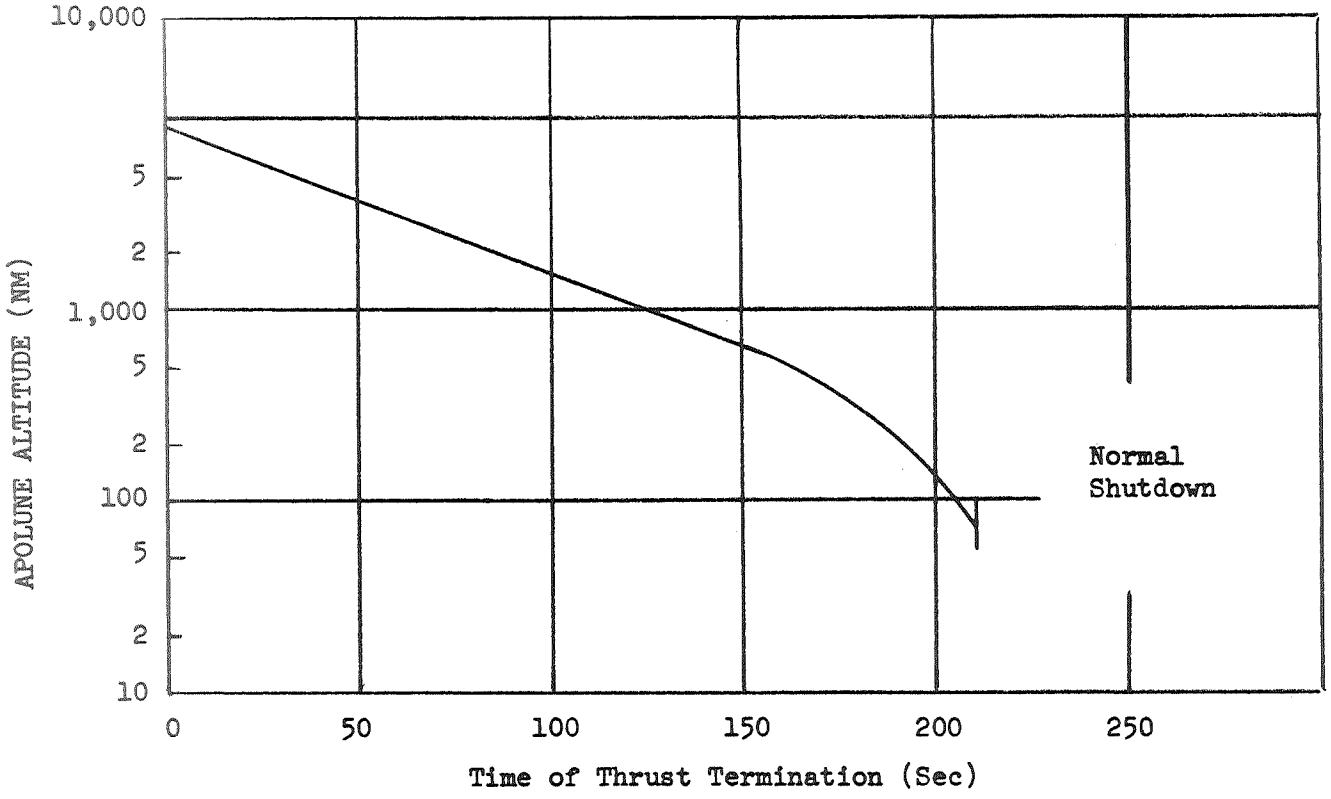


Figure 3-21 APOLUNE ALTITUDE HISTORY - PHASE L

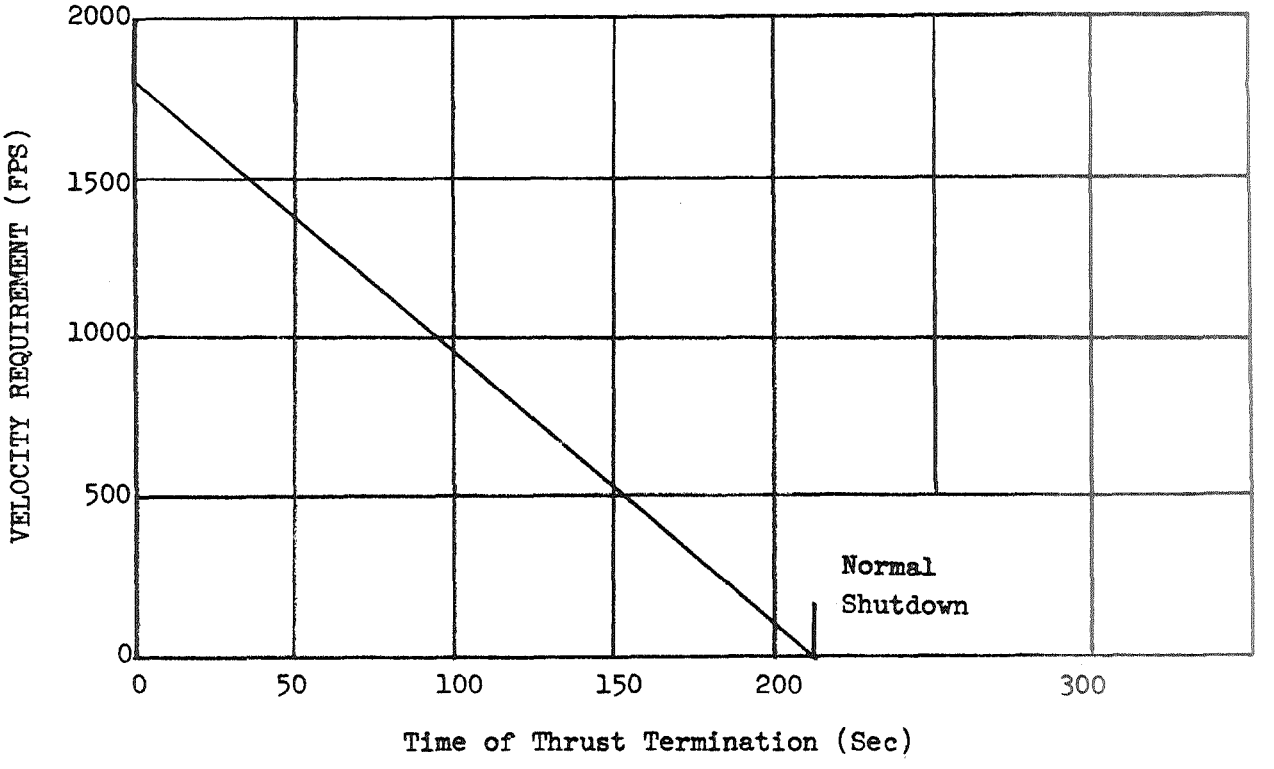


Figure 3-22 VELOCITY REQUIREMENT TO COMPLETE INJECTION MANEUVER - PHASE L

abort at the start of the maneuver to 2, 670 ft/sec near the end of the burn. The capability of the NERVA emergency mode is greater than 5, 600 ft/sec during this maneuver.

3.3.5 Transearth Orbit Injection (Phases O, P, Q, R, S, T)

The transearth orbit injection is similar to the lunar injection in that it also consists of three burns: an injection into a 24-hour elliptical orbit; a node shift maneuver in the 24-hour orbit; and the injection onto the transearth hyperbola at perilune of the 24-hour orbit. For this analysis it has been assumed that the injection onto the hyperbolic orbit is initiated at approximately 12 o'clock on January 30, 1980. The perilune latitude and longitude of the 90-degree inclination, 24-hour ellipse and the full thrust burn time were selected to achieve a 72-hour transit time and 260-nmi earth arrival perigee altitude at an inclination of 31.5 degrees.

RNS weight at the start of the injection into the 24-hour departure ellipse was 174, 000 lb. The injection velocity requirement at 1, 860 ft/sec costs

approximately 12, 000 lb of propellant, assuming a specific impulse of 825 seconds with a thrust level at 75, 000 lb and burn time of 129 seconds. In Figure 3-23 the apolune altitude that would be attained in case of a premature shutdown has been plotted as a function of time at thrust termination. The velocity requirement to establish a circular orbit at the 60-nmi perilune by a retrograde maneuver is shown in Figure 3-24. If escape from the lunar sphere of influence and establishment of an earth orbit is required, the situation becomes complex. Since the reason for establishing the 24-hour ellipse is to achieve the correct departure geometry by rotating the RNS orbit plane into the escape hyperbola, the alignment between the abort ellipse and desired escape hyperbola will be significant. If the node shift to be performed is negative, the RNS can wait in orbit until the regression rate (13 deg/day) provides a coplanar situation that will result in an opportunity to reach earth on a 72-hour transfer. The velocity required for this situation is shown in Figure 3-25. On the other hand, if the desired node shift is positive, the regression rate moves the RNS orbit plane in the opposite direction tending to increase velocity requirements. Unless a relatively long waiting period is acceptable, the velocity requirements will be significantly larger than those shown in Figure 3-25. The resulting earth orbit will have a perigee of 260 nmi and an apogee greater than the lunar distance.

It would appear that the logical abort action for a failure during the insertion into an elliptical lunar orbit (Phase O) would be to perform an immediate retrograde maneuver. The emergency mode capability during this phase is between 7, 900 and 8, 900 ft/sec, again more than enough for this maneuver.

The second burn (Phase Q) takes place over the lunar pole and, assuming a node shift of 30 degrees, costs some 6, 000 lb of propellant to provide the required 963 ft/sec. Assuming a thrust level of 75, 000 lb, this maneuver will take 63 seconds to perform. The velocity requirement to complete the maneuver is shown versus time of shutdown in Figure 3-26. A safe 60-nmi lunar orbit could be achieved by performing a retrograde injection at perilune at a cost of 1, 860 ft/sec. For achieving an earth orbit, the initial node location discussion of the previous paragraph applies with a favorable location

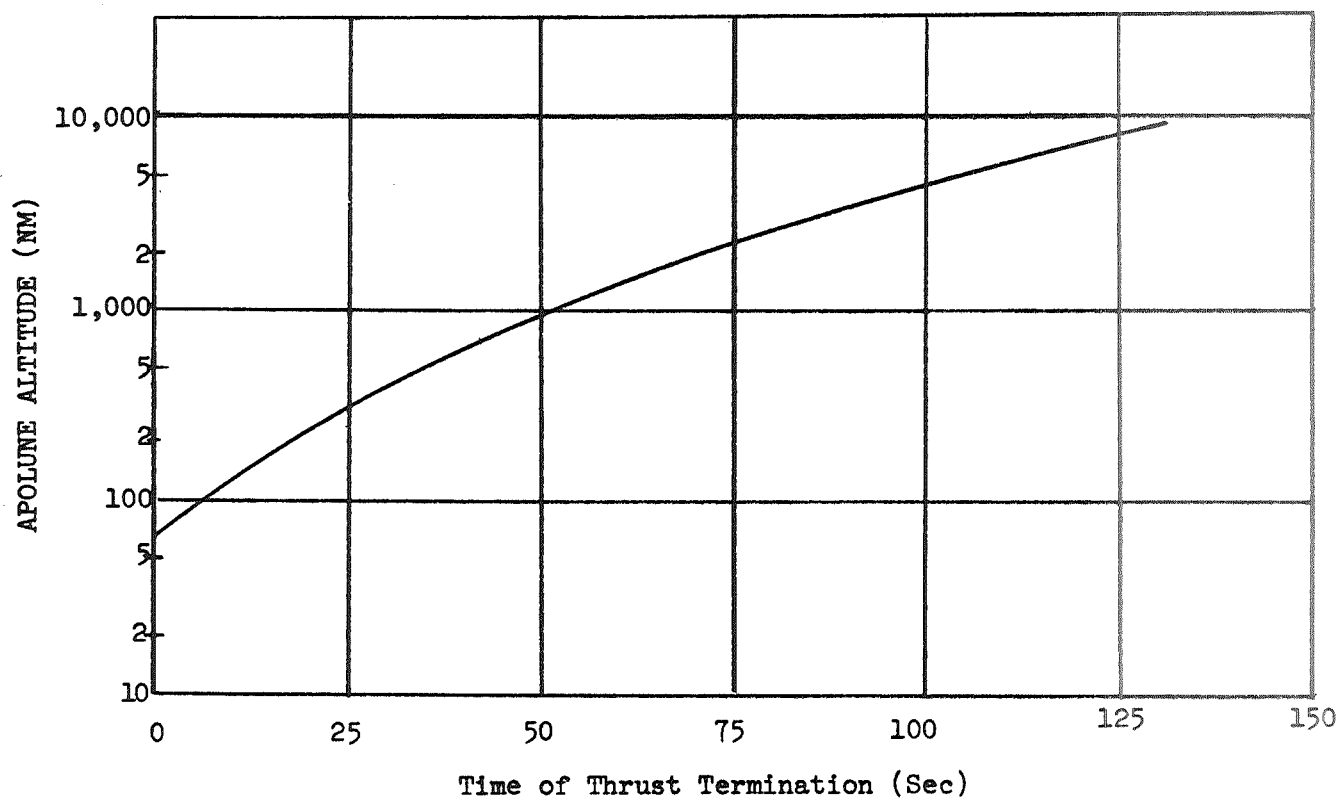


Figure 3-23 APOLUNE ALTITUDE HISTORY - PHASE 0

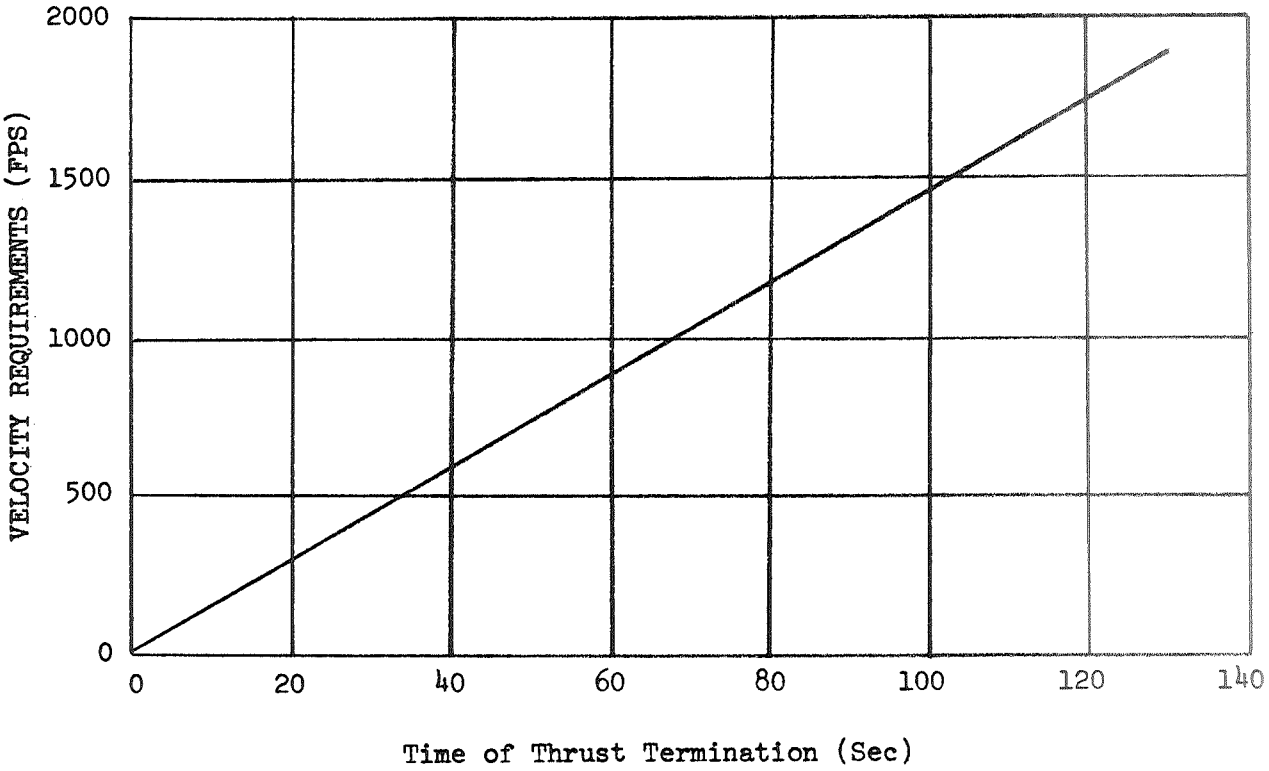


Figure 3-24 VELOCITY REQUIREMENT TO CIRCULARIZE AT PERILUNE - PHASE 0

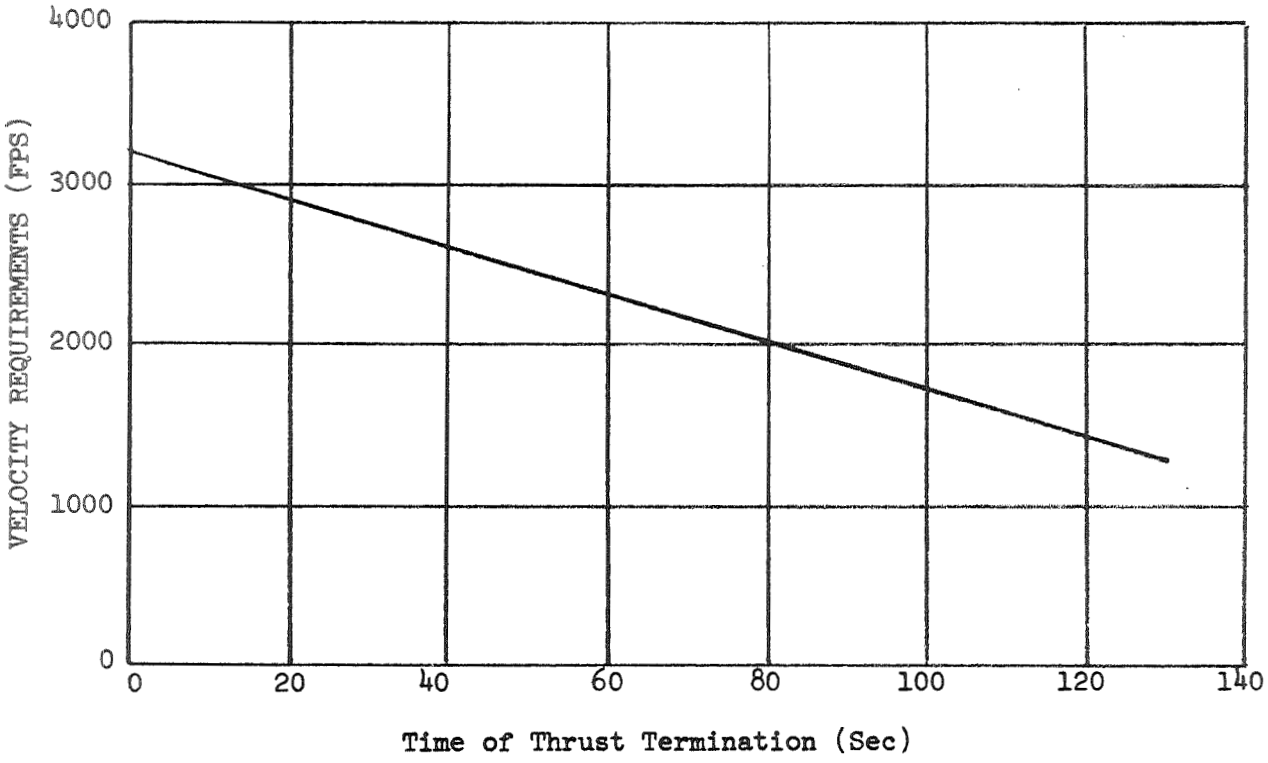


Figure 3-25 VELOCITY REQUIREMENT TO ACHIEVE 260 x 220,000 NM EARTH ORBIT - PHASE O

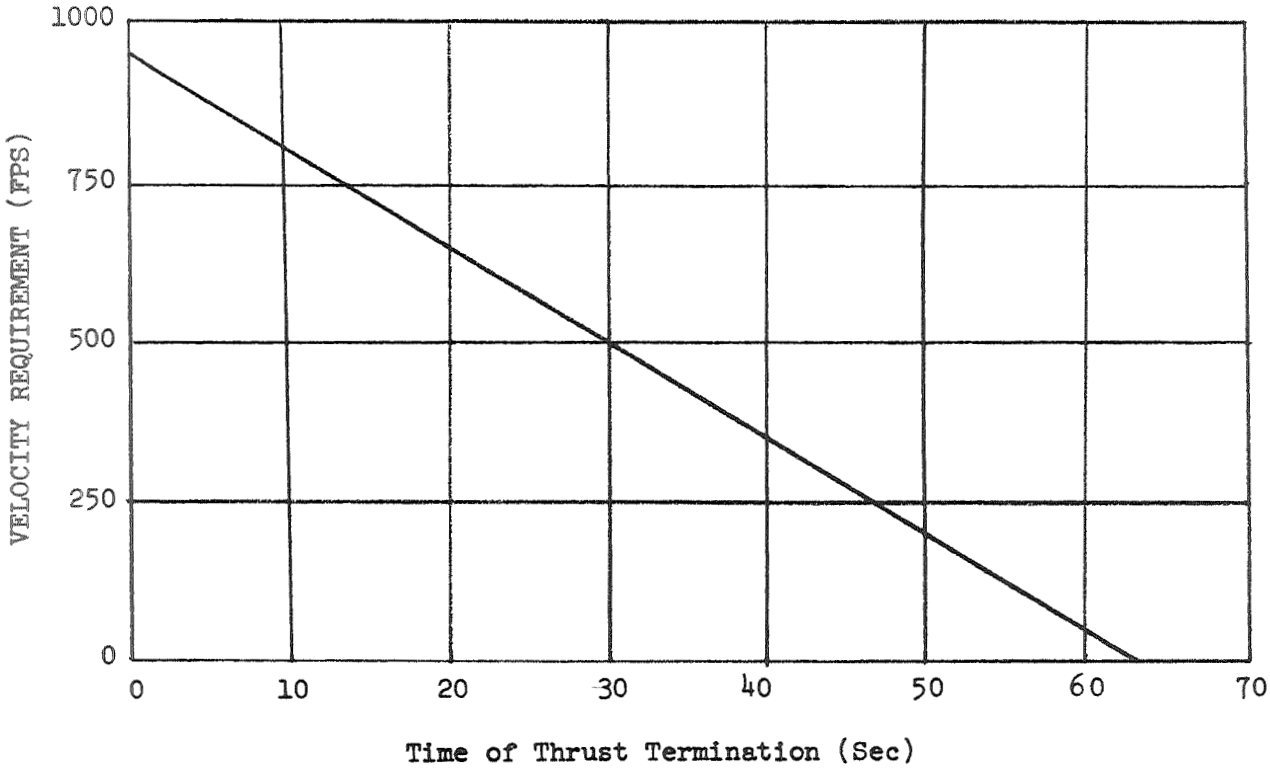


Figure 3-26 VELOCITY REQUIRED TO COMPLETE LUNAR ORBIT PLANE CHANGE - PHASE Q

costing approximately 1, 300 ft/sec and an unfavorable location being more costly. It would appear the most attractive action would be a return to a lunar safe haven. The cost is 1, 860 ft/sec, as compared to the NERVA emergency mode capability of between 7, 500 and 7, 900 ft/sec. A preliminary burn to cancel out the node shift could be attained with the NERVA idle mode.

The third burn (Phase S) places the RNS on the transearth hyperbola. The thrust profile consists of a 56-second buildup, a 32. 5-second full thrust phase, and a 34-second period with a constant 45, 000-lb thrust followed by tail-off, with cooldown terminating at 12. 26 hours. The transearth injection burn and the resulting trajectories are analogous to the situations encountered in premature shutdown aborts for the translunar injection burn. The abort trajectories from the transearth injection burn can be grouped in two categories: (1) those that orbit the moon with shutdown occurring between 0 and 62 seconds into the burn and (2) those which escape the moon when engine shutdown occurs later than 62 seconds. They are discussed in the following paragraphs.

3. 3. 5. 1 Aborts Resulting in Lunar Orbits

Apolune and perilune altitudes have been plotted as a function of time of thrust termination and are presented in Figures 3-27 and 3-28. The slow change in apolune altitude reflects the thrust buildup phase. At approximately 62 seconds into the TEI maneuver the abort trajectory, which is initially an elliptical lunar orbit is perturbed by the earth so that the RNS will escape the lunar gravitation field and be captured by the earth. The perilune altitude history (Figure 3-28) illustrates the effect of earth perturbations on the lunar orbit. At apolune of the abort ellipse the earth's perturbations distort the elliptical trajectory by reducing the perigee radius and increasing the orbit eccentricity. Figure 3-29 illustrates the predicted cost of re-establishing the 60-nmi perilune altitude by (1) an apolune maneuver or (2) by an immediate velocity addition or subtraction to maximize or minimize the earth's influence. The immediate maneuver is the more effective approach, with an impulsive velocity requirement approximately one-half that of the apolune maneuver. The "safe orbit" would be a 60-nmi circular lunar orbit for shutdown occurring before 56 seconds. In Figure 3-30,

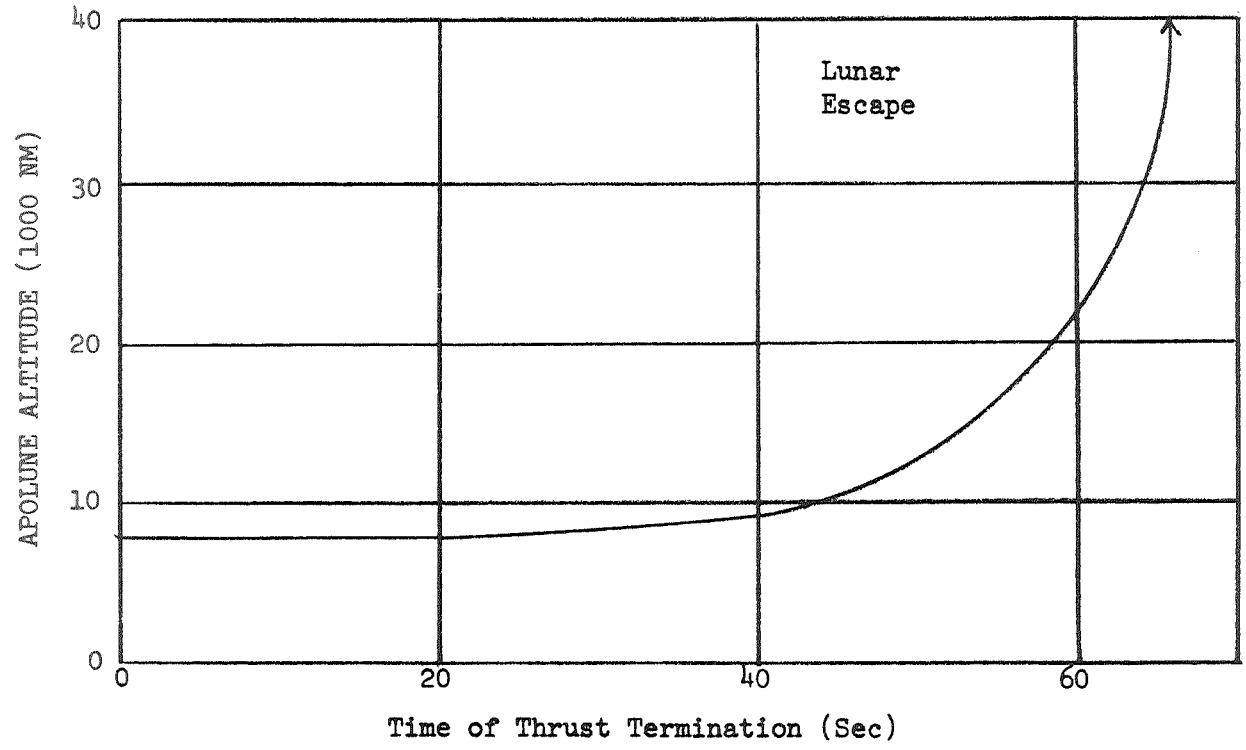


Figure 3-27 APOLUNE ALTITUDE HISTORY - PHASE S

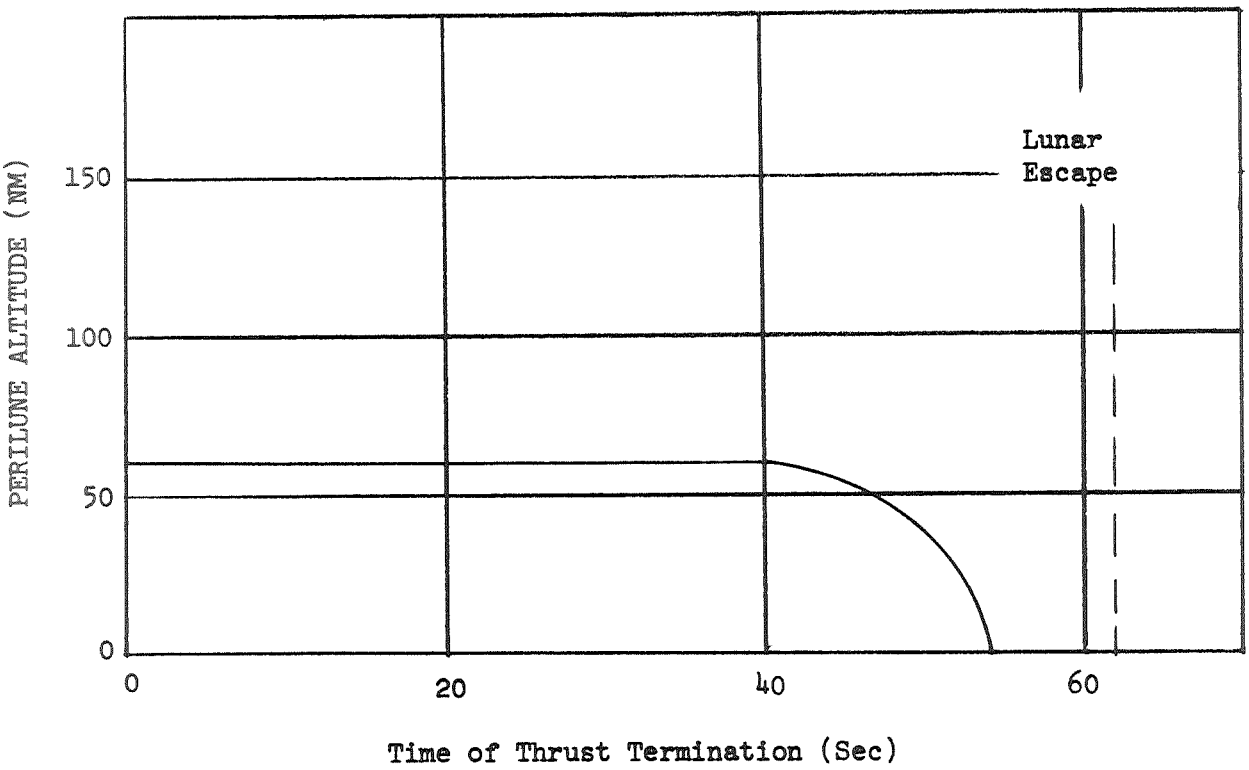


Figure 3-28 PERILUNE ALTITUDE HISTORY - PHASE S

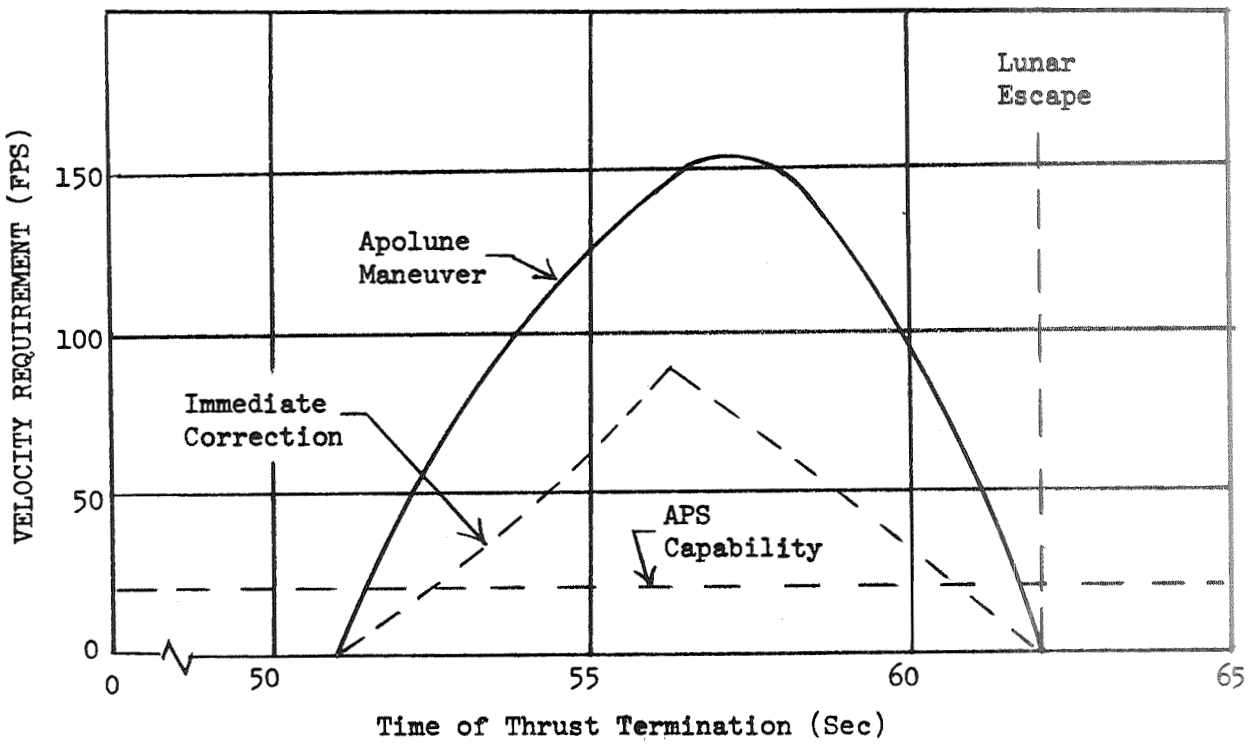


Figure 3-29 VELOCITY REQUIREMENT TO RAISE PERILUNE TO 60 NM - PHASE S

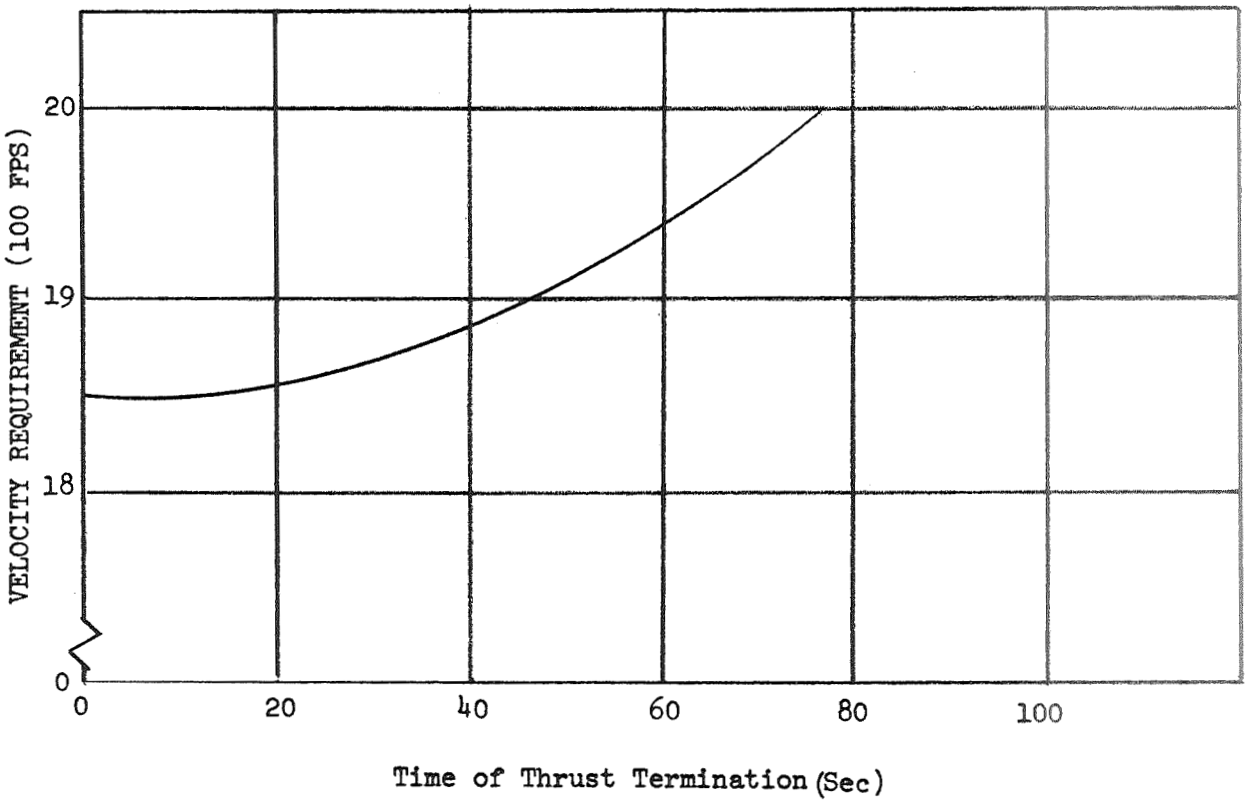


Figure 3-30 VELOCITY REQUIREMENT TO CIRCULARIZE AT 60 NM PERILUNE - PHASE S

the velocity requirement to circularize the lunar orbit at perilune (assuming perilune has been raised to 60 nmi) is shown. Aborts occurring after 56 seconds, with either of the perilune corrections shown in Figure 3-24, results in an earth orbit and will be included in the following discussion.

As shown in Figure 3-29, the APS velocity capability at this time is only 22 ft/sec, which is not nearly enough to accomplish the required maneuver over the full range of the critical time span.

3.3.5.2 Aborts Resulting in Earth Orbits

Apogee and perigee altitudes resulting from engine shutdowns occurring later than 62 seconds into the burn and during the transearth coast (Phase T) are presented in Figures 3-31 and 3-32. Thrust, in this case refers to both normal thrust conditions and thrust generated during cooldown. The velocity requirement to lower perigee altitude to the desired value of 260 nmi is illustrated in Figure 3-33. Assuming that the 260-nmi perigee is attained, the velocity required to circularize a perigee is presented in Figure 3-34.

3.3.6 Earth Orbit Injection – Phase U

The RNS weighs approximately 148,000 lb at the initiation of this maneuver. Assuming an impulsive velocity requirement of 10,200 ft/sec, a thrust level of 75,000 lb and a specific impulse of 825 seconds, the time to perform the maneuver is 525 seconds. The apogee altitude of the abort ellipse with a 260-nmi perigee altitude is shown for premature shutdown in Figure 3-35. If the orbit is circularized at a subsequent perigee, the velocity requirement will be that shown in Figure 3-36. However, as shown in Figure 3-36, the available velocity increment from the NERVA emergency mode is considerably less than the velocity requirement. This is obvious when it is considered that the velocity requirement is predicated on a specific impulse of 825 seconds and the NERVA emergency mode specific impulse is 500 seconds. The external rescue propulsion requirements would be essentially twice the difference between the velocity requirement and the NERVA emergency mode capability (Figure 3-36). The velocity requirements are also based upon an assumption that no plane change maneuvers are required. However, there will be relative nodal regression rates which will have to be accounted for in the actual situation.

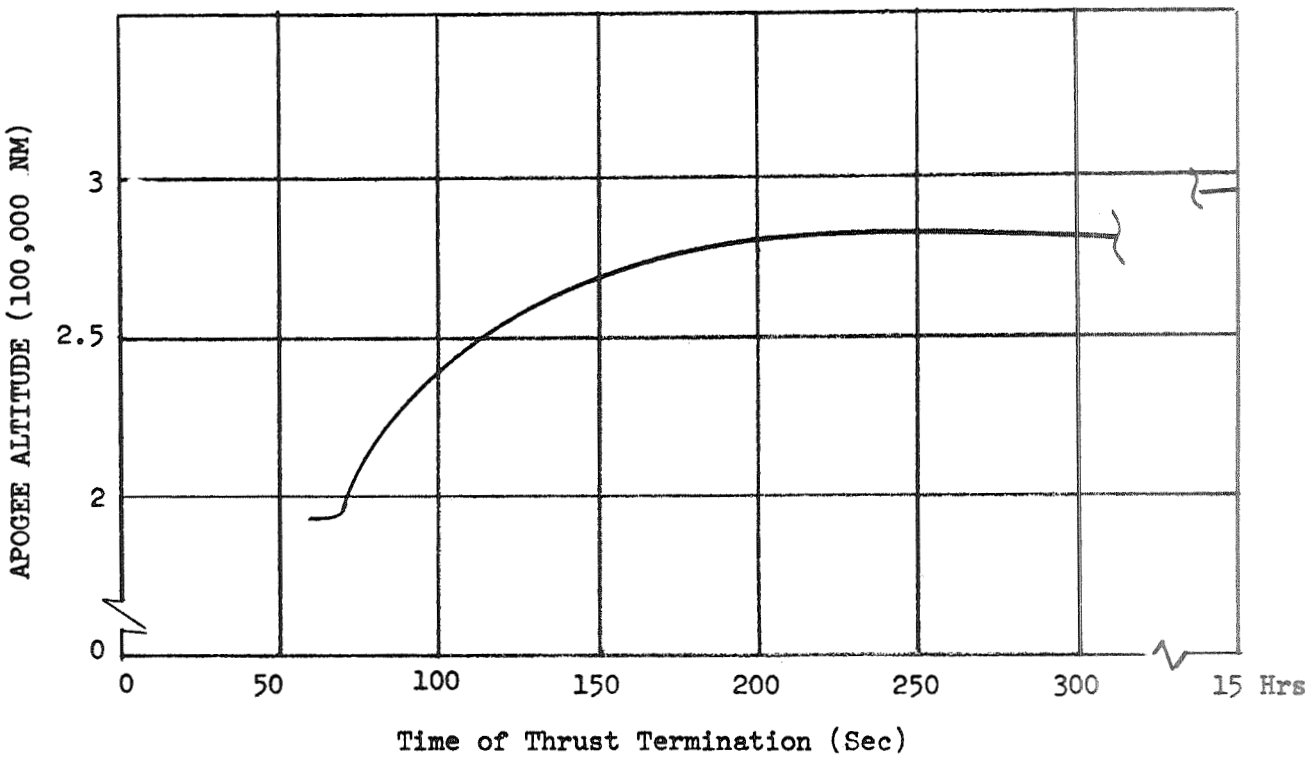


Figure 3-31 APOGEE ALTITUDE HISTORY - PHASES S AND T

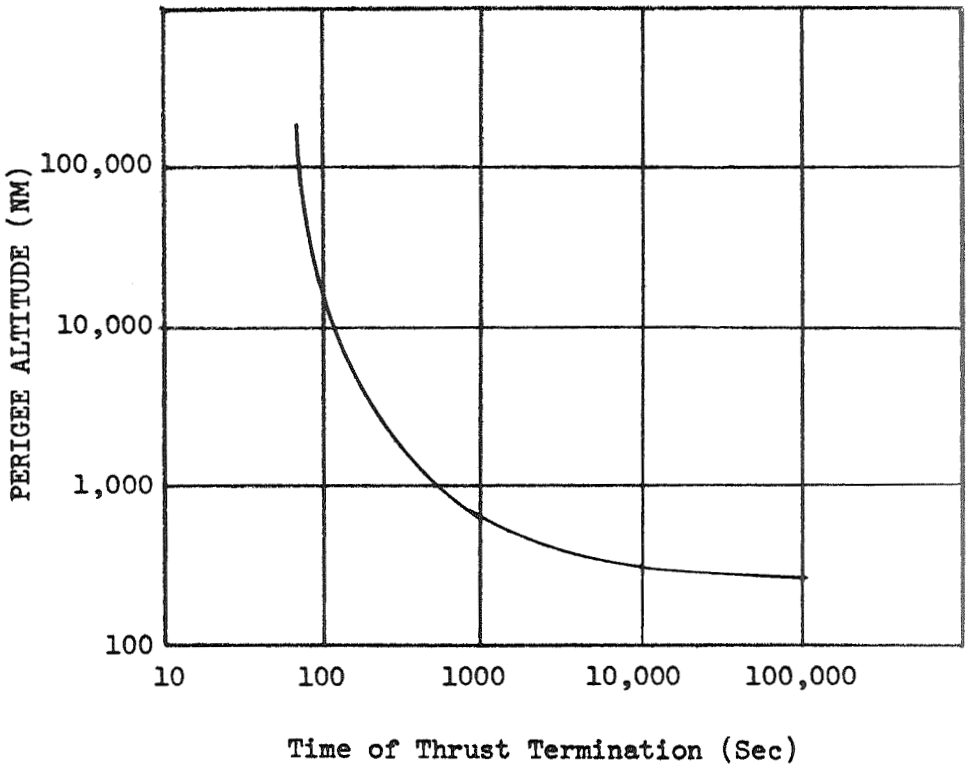


Figure 3-32 PERIGEE ALTITUDE HISTORY - PHASES S AND T

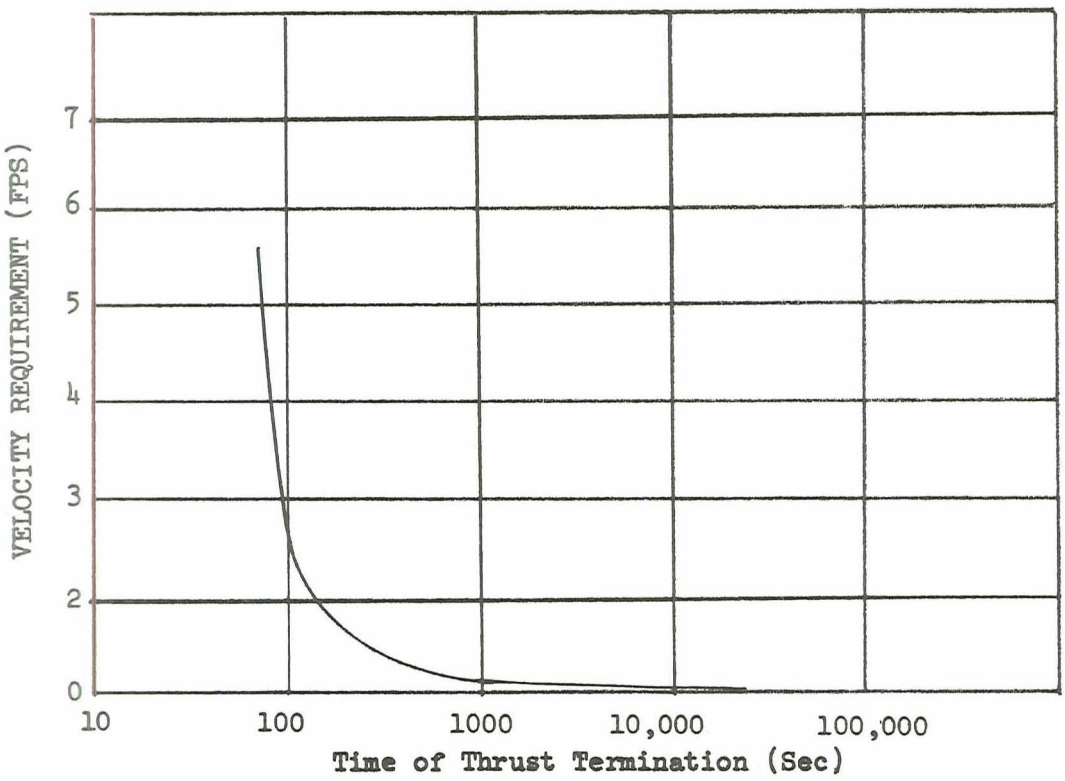


Figure 3-33 VELOCITY REQUIREMENT TO LOWER PERIGEE TO 260 NMI - PHASE T

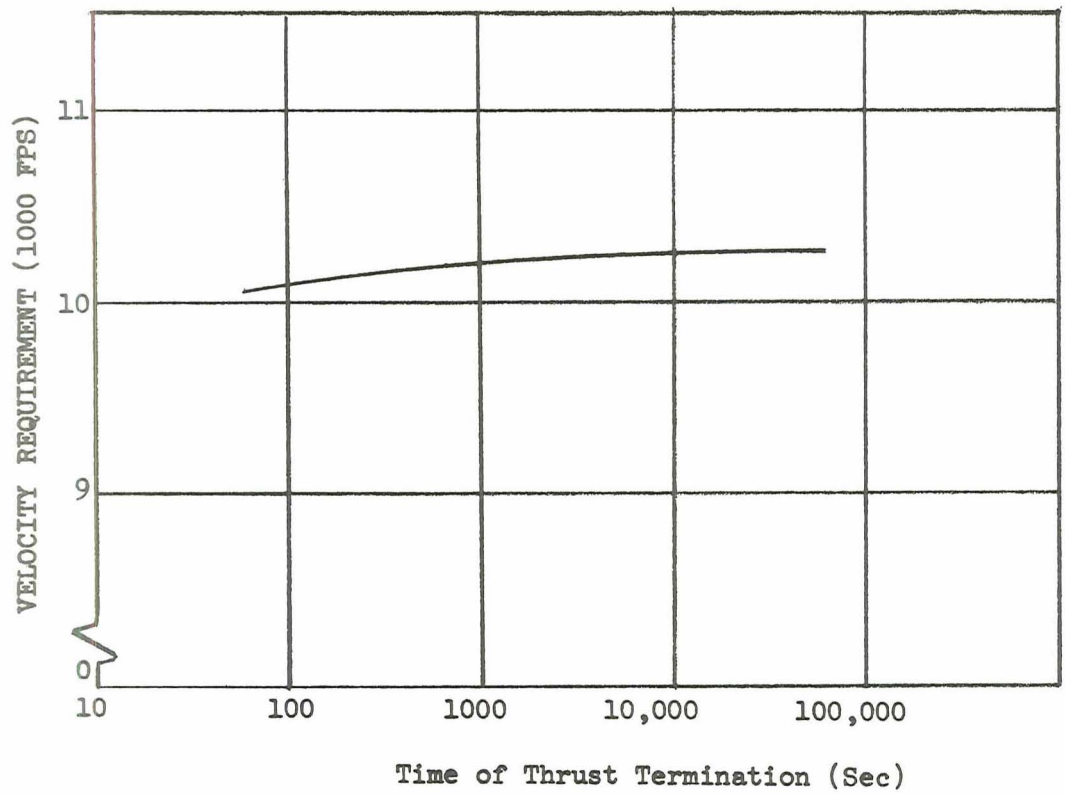


Figure 3-34 VELOCITY REQUIREMENT TO CIRCULARIZE AT 260 NM PERIGEE - PHASE T

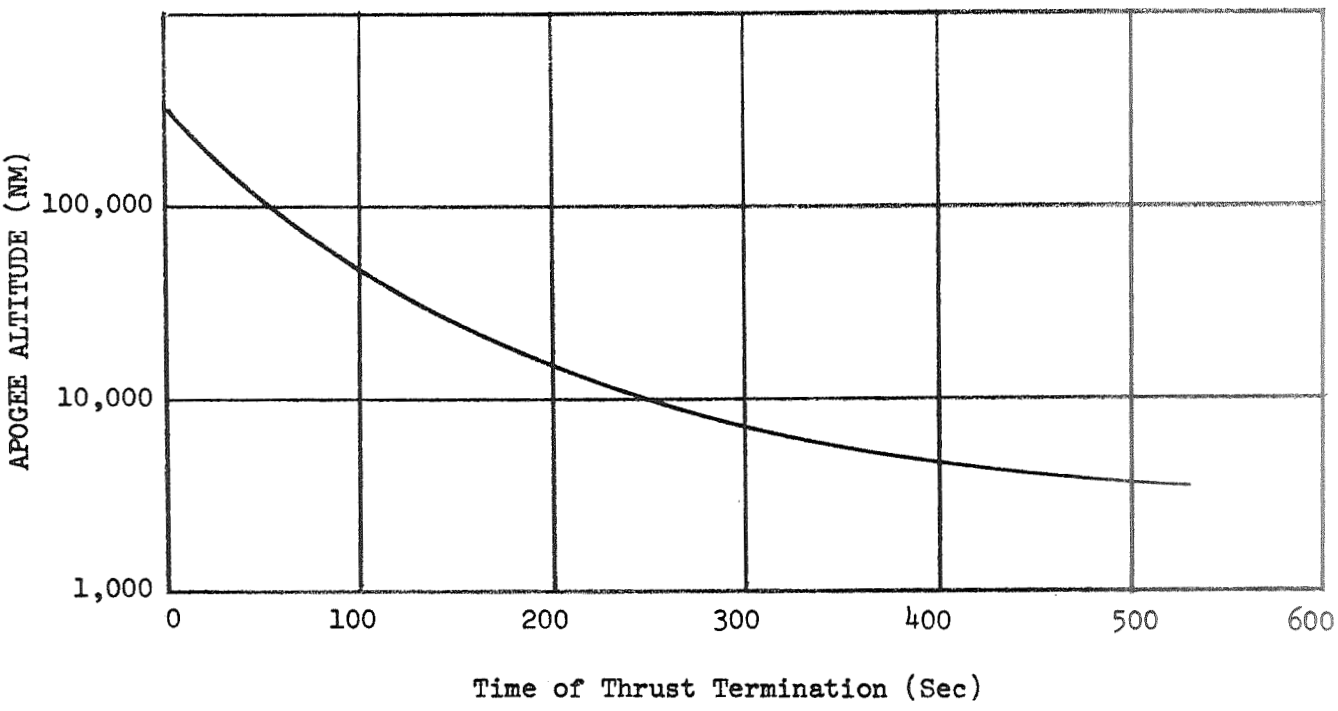


Figure 3-35 APOGEE ALTITUDE HISTORY - PHASE U

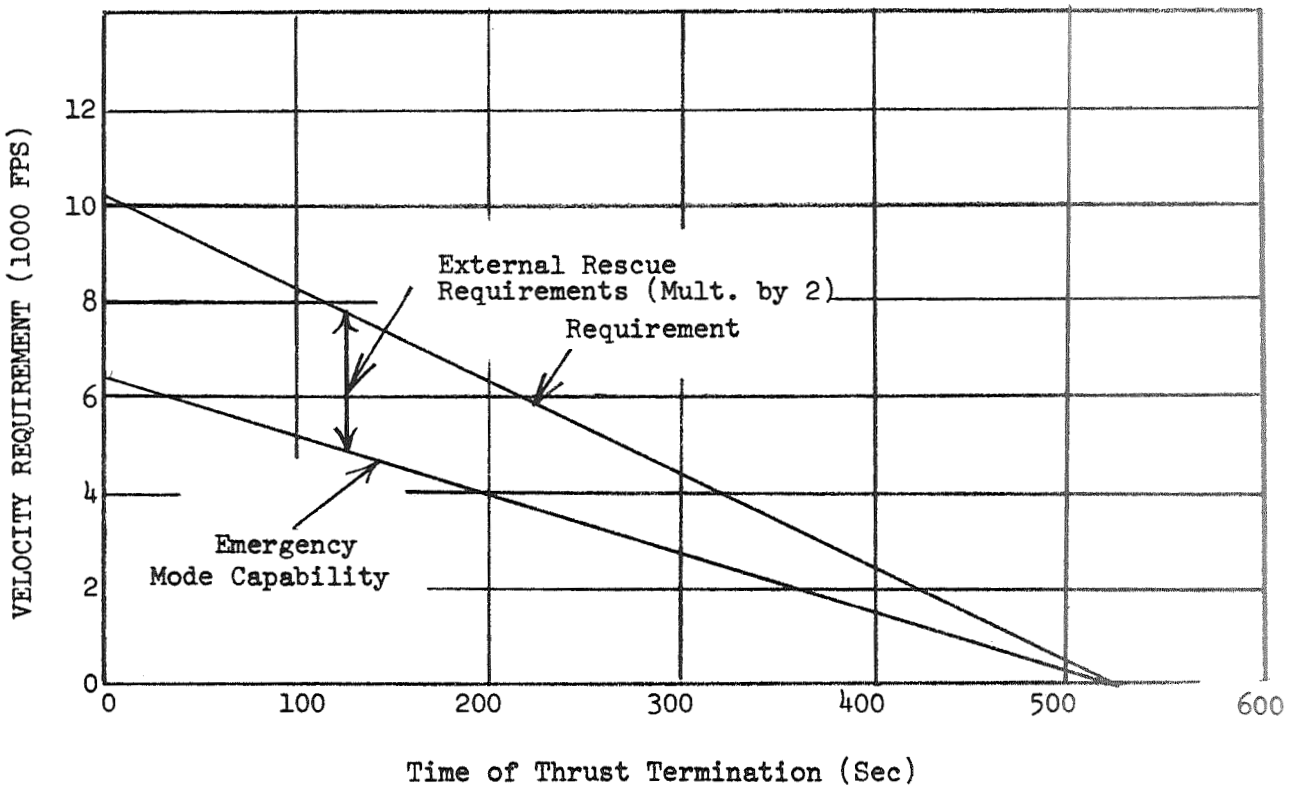


Figure 3-36 ABORT VELOCITY REQUIREMENTS - PHASE U

3.3.7 External Rescue Capability

Postulating an RNS thrust loss at any given point in the lunar shuttle mission identifies a range of conditions over which rescue may be required. Rescue velocity requirements, based on departure from and return to earth or lunar circular orbit, are indicated in Table 3-4.

The rescue orbits are specified in terms of perigee/apogee altitudes, and rescue velocities (total) presume equal-out-equal-back requirements. In accordance with the NASA study guidelines, the tug has the following characteristics, as specified in the NASA guidelines and constraints documents.

Propulsion Module	
Inert (lb)	10,000
Propellant Capacity (lb)	60,000
Specific Impulse (sec)	460
Instrument Module	2,000

The total velocity capability of the tug (ideal, excluding gravity losses) based on no payload out, is 18,100 ft/sec and 19,600 ft/sec for return payloads of 20,000 and 15,000 lb, respecitively. This capability is seen to be more than adequate for rescue out of lunar orbit during the LOI and TEI maneuvers, and sufficient for rescue out of earth orbit for most of the TLI and EOI maneuvers.

Two options are seen during the latter portion of the TLI maneuver: (1) return to an elliptical earth orbit and (2) capture in an elliptical lunar orbit. Then a second tug would complete the operation of returning the RNS to low circular orbits. The latter of the two options is significantly less costly. A third approach could be to return the mission crew to earth following rendezvous of the lunar rescue vehicle.

Table 3-4

RESCUE VELOCITY REQUIREMENTS

Mission Phase	Rescue Orbit (nmi)		Total Retrieval ΔV (ft/sec)	
	Earth	Lunar	Earth Orbit	Lunar Orbit
TLI (0 to ~3 hours) (a)	260/X (260<X<200K)	--	0 to 22, 600	--
(3 to 108 hours) (b)	Perigee to 220K Apogee to 10^7	60/X (220K<X<10^7)	>22, 600	3, 800 to 5, 400 +PC*
LOI	220K/X (220K<X<10^6)	60/X (60<X<10^7)	22, 600	0 to 5, 400 +PC
TEI	220K/220K to 260/300K	60/X (60<X<10^7)	≤20, 400	0 to 6, 100 +PC
EOI	260/X 260<X<300K	--	0 to 20, 400	--

*PC—Plane Change

3.4 CONTINGENCY PLAN

A flight safety contingency plan was developed for the lunar shuttle mission. The plan that is detailed in this section was developed for the Class 1 Hybrid RNS but is also applicable for the Class 3 RNS.

The contingency plan is a continuation of the flight safety analysis discussed previously. The types of aborts were discussed in Section 3.3 and the general abort modes delineated in this section were derived from that analysis. The classes of failures were used in the contingency planning work sheets, which were presented in Section 3.1. The contingency planning work sheets detail the actual component failures that fall into these classifications, while the contingency plan delineates the action that will be taken when one of these failures occur.

It must be pointed out that this is not a final product. As more detail studies are made on the trajectories, more specific ground rules are adopted, and more detail and specific definitions of RNS emergency operational modes are made, this contingency plan will change. However, this is felt to be a viable plan under the current level of mission and system definition and ground rules.

3.4.1 Ground Rules, Assumptions, and Definitions

The ground rules and assumptions used in this analysis are as follows:

A. The NERVA engine has several levels of operations:

1. Rated conditions
2. Throttle mode
3. Malfunction mode
4. Emergency mode
5. Idle mode

The rated condition, throttle mode, and malfunction mode are all at rated specific impulse (825 seconds) but different levels of thrust. The emergency mode and the idle mode are at a reduced specific impulse (500 seconds) and a lower level of thrust. The throttle mode and malfunction mode are not used explicitly in this analysis—the throttle mode is a non-malfunction mode and the malfunction mode is a result of a Class II-C failure. The

emergency mode is defined in the NERVA program requirements Document (NPRD) as a mode with a thrust of 30, 000 lb, a specific impulse of 500 seconds, and a total impulse of 10^8 lb-sec. The emergency mode requirements will be provided in a single engine cycle and must be attainable from all operating modes of the engine cycle. If the malfunction occurs during normal steady-state operation, immediate retreat to an emergency mode will be made. If the malfunction occurs during engine modes following the steady-state power mode, provisions will be made for cooling up to 5 hours before entering an emergency mode.

There are two identified NERVA idle modes, a mode where turbo-pump operation is required and a mode where tank pressure is used for the driving force. It is assumed in this analysis that this latter mode is available as an additional emergency mode. This assumption allows a much greater flexibility in the abort maneuvers at a small cost (if any) in engine design. The only requirement is that one flow path be available (either the normal path through the PSOV valves or the cooldown path through the CSOV/CSCV valves) and that there is sufficient control of the control drums to achieve criticality.

B. Two safe havens are available, a 260-nmi circular earth orbit and a 60-nmi circular lunar orbit. It is assumed that the RNS in a 260-nmi circular earth orbit can rendezvous with a space station, a space tug or a ground based launch vehicle. Any other orbit will require external rescue. It is assumed that any lunar orbit except the 60-nmi circular orbit containing the lunar orbit space station will require external rescue.

C. The crew capsule will remain with the RNS to await rescue if possible. The capsule does not have an earth reentry capability but does have a 21-day life support capability. It is assumed that there is no propulsion capability on the capsule, but a requirement for this capability is indicated in one abort maneuver (Phase S).

D. The priority on an abort maneuver is first to protect the earth population and second to protect the RNS crew. This becomes a problem in Phase G.

E. It is assumed that Class IV-A failures (loss of control of the flight path) will be detected before a substantial change in the flight path is experienced. This assumption must be verified at a later date when the safety system and ground support requirements are defined. The failure categories were listed earlier in Table 3-2.

3.4.2 Abort Actions

The abort action for a Class I failure (failures which do not introduce additional single failures—essentially the loss of equipment which cannot effect mission success) is the same for all mission phases—continue mission as planned.

The abort action for a Class II failure is a function of the subclass of failure and the mission phase. The action for a Class IIA failure (failures which do not require any action to complete the mission—essentially the failure of one of an on-line redundant set of components) is the same for all mission phases—continue mission as planned. The action for a Class IIB failure (failures that require some action to allow completion of the mission—essentially the failure of a component which is backed up by a standby redundant component) is the same for all mission classes—initiate command to perform action required to restore system to normal operations and then continue mission as planned. If a Class IIA or IIB failure occurs on the outbound portion of the trip (on the way to the moon) a question arises—should the RNS be allowed to leave the moon on the return trip if it contains a single failure item? If the answer to this question is "NO", then the action stated above should be further defined to include—abort the mission at the lunar base and repair or discard the RNS.

The Class IIC failures (failures that allow normal operation but a penalty to consumables) were further divided in two subclasses—Class II C-1 where the penalty is a minor one characterized by a reduction to the malfunction mode operation and Class II C-2 where the penalty is a major one characterized by a major, but not catastrophic, leakage failure. The action for a Class II C-1 failure is to continue the mission as planned and add consumables at the lunar base if the failure occurred on the outbound leg. The restriction on leaving the lunar base with a single failure discussed above might apply to this failure classification.

The action for a Class II C-2 failure would be to return to a safe haven as soon as possible. In general the specific actions would be the same as defined in Table 3-5 for the Class III failures except in the later portions of the translunar injection phase and the early portions of the translunar coast the action might be to return to earth and in the early portions of the transearth coast phase the action might be to return to the moon. The detail operations during the other phases might change to decrease the time required to reach a safe haven or an orbit from which rescue can be easily accomplished.

The action for Class III failures (failures that require reduction to operation at the NERVA emergency mode) are outlined in Table 3-5.

The action for Class IV failures is a function of the subclass of failure and specific cases, the mission phase. The action for a Class IV A failure (loss of control of the flight path) is to shut down the NERVA in a rapid but nondestructive manner and then to separate the crew capsule. This recommendation and assumption number 5 (that this type of failure can be detected before a substantial change in the flight path is experienced) should prevent the RNS from impacting the earth on the translunar injection burn and the earth orbit injection burn, the theory being to terminate thrust before an impact trajectory is generated. The exception to this action is in the earth impact portion of the translunar coast phase (see Section 3.3.3). If the failure occurs during this phase, the recommendation is to continue the cool-down thrusting in a manner (directed by the crew and/or ground control) to increase or decrease the velocity to a value (see Figure 3-9) which will remove the possibility of earth impact. The other exception is a similar situation during the transearth injection phase (Phase S) where lunar impact is possible. A similar plan of action, as described above, would apply.

The action for a Class IV B failure (complete loss of engine operation except cooldown) would be to shutdown and cool NERVA or continue cooldown in a normal manner and utilize the cooldown thrust in a manner which will minimize the amount of external rescue requirements. An external rescue will, in general, be required.

Table 3-5

ABORT ACTIONS FOR CLASS III FAILURES

Phase	Action	
	With Emergency Mode	Without Emergency Mode
Translunar injection (F-1) 0 to 1,600 sec	Abort to earth. Immediate retro with emergency mode, circularize at perigee with idle mode.	External rescue with earth space tug
Translunar injection (F-2) ~1,600 to 1,759 sec	Abort to moon, use emergency mode to continue TLI burn, use idle mode for three burns, at moon	External rescue with lunar space tug
Translunar coast (G)	Abort to moon, use emergency mode for first lunar burn, idle mode for plane change, (if required) and for circularization.	External rescue with lunar space tug
Elliptical lunar orbit injection (H)	Abort to moon. Continue with emergency mode, perform remaining two burns with idle mode.	External rescue with lunar space tug.
Coast in lunar elliptical orbit (I) (before plane change)	Abort to moon. Perform plane change burn with idle mode, circularization with emergency mode.	External rescue with lunar space tug.
Plane Change in lunar orbit (J)	Abort to moon. Continue plane change with emergency mode, use idle mode for circularization.	External rescue with lunar space tug.
Coast in elliptical lunar orbit (K), (after plane change)	Abort to moon. Use emergency mode to circularize	External rescue with lunar space tug.
Circularization at 60 nmi (L)	Abort to moon. Continue burn with emergency mode.	External rescue with lunar space tug.
Injection in elliptical lunar orbit (O)	Abort to moon. Retro with emergency mode back to 60-nmi circle.	External rescue with lunar space tug.

Table 3-5 (page 2 of 2)

ABORT ACTIONS FOR CLASS III FAILURES

Phase	Action	
	With Emergency Mode	Without Emergency Mode
Coast in elliptical lunar orbit (P) (before plane change)	Abort to moon. Circularize with emergency mode at perilune.	External rescue with lunar space tug.
Plane change in lunar orbit (Q)	Abort to moon. Null plane change with immediate emergency mode, circularize at perilune with idle mode.	External rescue with lunar space tug.
Coast in elliptical lunar orbit (R) (after plane change)	Abort to moon. Perform plane change with idle mode, circularization with emergency mode.	External rescue with lunar space tug.
Transearth injection (S)	Abort to moon. Retro to elliptical lunar orbit with emergency mode, perform plane change and circularization with idle mode.	External rescue with lunar space tug.
Transearth coast (T)	Abort to earth. Perform partial circularization with emergency mode. External rescue with space tug.	External rescue with earth space tug (two may be required)
Earth orbit injection (U)	Abort to earth. Continue circularization with emergency mode. External rescue with space tug.	External rescue with earth space tug. (Two may be required).

The actions for Class IV C (complete loss of engine operation including cooldown) and Class IV D failures (failure that results in prompt destruction of the RNS) is to separate the crew capsule as rapidly as possible and await rescue from an external source. The requirements for external rescue and the capability of the space tug are discussed in Section 3.4.3.

The action for a Class V failure (failures that occur in earth or lunar orbit) would be to repair or discard the RNS.

3.5 SAFETY RECOMMENDATIONS

One of the results of the flight safety analysis is a series of recommendations for changes to the systems to improve the safety, i.e., decrease the probability of creating safety problems. Many recommendations were made to the design groups during the course of the report period—some were accepted and incorporated into the systems as shown in Figures 2-2, 2-3 and 2-4, resulting in a safer design than the one reported after the Phase II study. The design (and the operations) are not as safe as they must be for the RNS to be acceptable as a space vehicle—but that is due to the fact that the safety analysis is not complete. All of the potential safety problems have not been identified and all that have been identified have not been solved. The following recommendations may provide solutions to some of these problems.

In the hardware areas the following recommendations are made:

A. Eliminate, as far as possible, all items that can cause a catastrophic explosion in earth orbit (or on the mission). This is one method by which radioactive debris can reenter and impact the earth.

B. Provide redundant cryogen storage for critical systems—a loss of the auxiliary propulsion system is in a Class IV A failure.

C. Redundant systems should be physically separated from each other (Reference the Apollo 13 problem) so that a failure on one redundant component does not affect the other APS engines.

D. Add sufficient APS capability (~70 ft/sec) to prevent earth impact with a Class IV C failure during the translunar coast phase.

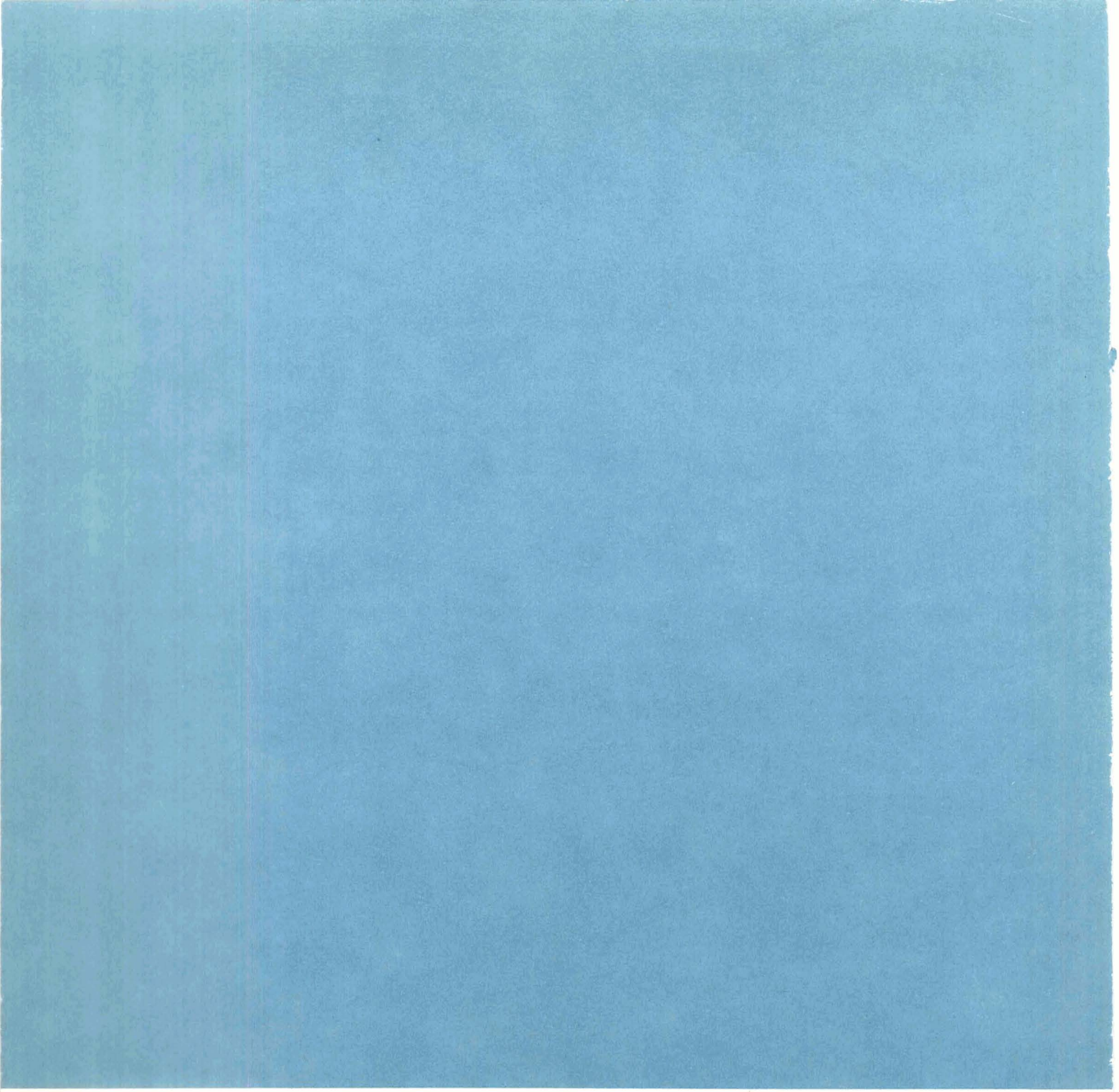
E. Provide an emergency detection system that will be able to detect a loss of flight path control before a substantial change in the flight path has occurred (see assumption 5, Section 3.4).

F. Eliminate the cooldown limitation on the NERVA emergency mode operation. This 5-hour constraint reduces considerably the effectiveness of the emergency mode since many of the abort operations listed in Table 3-5 could not be accomplished if this limitation is not relaxed. Maintaining the 5-hour cooldown limitation would result in increased requirements for external rescue capability.

G. Extend the emergency mode operation to a tank-head idle mode. This will also greatly increase the flexibility of the abort operations. This mode would require a minimum of operable equipment on the NERVA.

H. Establish a space tug at lunar orbit and earth orbit for external rescue.

A recommendation is also made to analyze the lunar shuttle trajectory to determine if the anomaly of earth impact during the translunar coast phase can be eliminated by a trajectory modification.



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