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MASTER

**NUCLEAR SHUTTLE
SYSTEM DEFINITION STUDY, PHASE III
FINAL REPORT**

Program Support Requirements

VOLUME III

PART C

**Test Program Analyses
and SRT Requirements**

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

COPY NO.

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FOREWORD

This document contains the program support requirements portion of the final report for the Phase III Nuclear Shuttle System Definition Study. This segment (Part C) of the program support requirements treats the supplementary test program analyses and SRT requirements for both RNS concepts, while other concept-peculiar program support requirements are contained in Parts A and B of this volume for the Class 1 Hybrid and Class 3 RNS concepts, respectively. 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 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:

C. B. Boehmer—Test Program Analyses

K. P. Johnson—Supporting Research and Technology Requirements

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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

Test program analyses and the supporting research and technology portion of the RNS program support requirements are contained in this document. The material was generated in performing Tasks 2 and 7 of the Phase III Study. This document, in combination with Parts A and B for the Class 1 Hybrid and Class 3 RNS, respectively, comprises the total RNS program support requirements defined during the study effort.

The test program analyses are contained in Section 2. Test item work sheets and system test work sheets which were formulated as part of Task 2 are included here as Section 2.1 and 2.2, respectively. These work sheets were used in performing a bottom-up approach to test program definition.

The supporting research and technology requirements, as well as an estimate of the schedules and cost estimates associated with developing the technology to support the RNS development, are presented in Section 3. This effort was done as Task 7 of the study. The major area treated includes structures, thermal/meteoroid protection systems, propulsion, and astrionics. The SRT requirements and recommended programs are delineated in each area, including requirements for orbital experiments, as appropriate.

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Section 2

TEST PROGRAM ANALYSES

The supplementary test program analyses which were developed as part of the test requirements effort (Task 2) during the Phase III study, but omitted from Parts A and B of this volume are contained in this Section. The test item work sheets and system test work sheets follow.

2.1 TEST ITEM WORK SHEETS

The test item work sheets which are displayed here discuss a total of 209 components which are grouped into 108 test items. The test items which are common to both RNS concepts are contained in Section 2.1.1, whereas those test items peculiar to the Class 1 Hybrid and Class 3 RNS concepts are contained in Sections 2.1.2 and 2.1.3, respectively. A prime reason for the differences in test item work sheets between RNS concepts is the difference in reliability allocations for the components between Class 1 Hybrid and Class 3 systems, which results in differences in reliability testing. Additionally, there are five components which are peculiar to the Class 1 Hybrid RNS only, and one component that is peculiar to Class 3.

2.1.1 Test Item Work Sheets Common to Both RNS Concepts

The test items common to both concepts are presented in the following pages. The nomenclature on the work sheets denotes only Class 3; however, the data in Section 2.1.1 are applicable to either RNS.

TEST ITEM WORK SHEET

TEST ITEM NO. 2 LH₂ MALE DISCONNECT
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15.05.04	B-3	N/A	N/A	used as a final design verification or as an input to the final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The LH ₂ feed system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.
No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.				3. QUALIFICATION TEST
2. DEVELOPMENT TESTING				3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure, axial load, shear, bending moment, spring rate and deflection) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions, axial load, shear, bending moment, spring rate and deflection, and structural degradation under radiation fluences. Functional (docking) tests will be conducted in a special docking simulator (SDS) fabricated to study and verify docking techniques and components. Functional (flow) testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).				3.1 (Alternate). The above component qualification tests could be performed at the subsystem (LH ₂ fill) level.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3.2 Subsystem. Structural and functional qualification test on the complete LH ₂ fill in the PIL.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. A test item will be mated with the remainder of the LH ₂ feed components to form a LH ₂ feed subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.				3.2 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the propulsion system and the propellant module LH ₂ tank in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the LH ₂ feed system (high pressure, high flow, high impedance, etc.). Data from this test will be				3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH ₂ tanks on the all-systems test under "hot" NERVA firing.
				3.3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTS
				There will be no reliability test program on this test item. The reliability (probability of no failure) will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 5 GH_2 FEMALE DISCONNECT
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.06.06	B-3	N/A	N/A

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology

2. DEVELOPMENT TESTING

2.1 Component. A smaller number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions, axial load, shear, bending moment, spring rate and deflection, and structural degradation under radiation fluences. Functional (docking) testing will be conducted in a special docking simulator (SDS) fabricated to study and verify docking techniques and components. Functional (flow) testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. A test item will be mated with the remainder of the pressurization components to form a pressurization subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the propellant module LH_2 tank in a system-level test at NRDS in ESTS-2. Battleship tanks will be used to allow extended parameter testing on the pressurization

system (high pressure, high flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The pressurization system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated

3. QUALIFICATION TEST

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure, axial load, shear, bending moment, spring rate and deflection) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (pressurization) level.

3.2 Subsystem. Structural and functional qualification test on the complete flight pressurization in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH_2 tanks on the all-systems test under "hot" NERVA firing

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTS

There will be no reliability test program on this test item. The reliability (probability of no failure) will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 9 LH₂ FLIGHT DISCONNECT
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15.09.01	B-1	N/A	N/A	test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The flight fill system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions, axial load, shear, bending moment, spring rate and deflection, and structural degradation under radiation fluences. Functional (docking) tests will be conducted in a special docking simulator (SDS) fabricated to study and verify docking techniques and components. Functional (flow) testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be mated with the remainder of the flight fill components to form a flight fill subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the propulsion system and the propellant module LH₂ tank in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the pressurization system (high pressure, high flow, high impedance, etc.). Data from this</p>				<p>2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure, axial load, shear, bending moment, spring rate, and deflection) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem (flight fill) level.</p> <p>3.2 Subsystem. Structural and functional qualification test on the complete flight fill in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>There will be no reliability test program on this test item. The reliability (probability of no failure) will be determined by material properties and analysis.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 10 FLOW METER
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15.09.03	C	NA	NA	
25.09.10	C	NA	NA	
1. RESEARCH TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate) The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the PIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished. Two test units will be installed in the PIL for integrated testing with the remainder of the LH ₂ fill system.				3.3 System. The test item will be integrated with the remainder of the propulsion system, the astrionics system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the LH ₂ fill system in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 12 CHECK VALVE, RESUPPLY, LH₂
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15.09.05	C	NA	NA	
25.09.11	C	NA	NA	
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing. Data from the RNS SRT testing on radiation effects and long-life technology will also be used.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the components to form a LH₂ resupply subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2. Battleship tanks will be used to allow extended parameter testing on the LH₂ transfer system (high pressure, low pressure, high flow, low flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The LH₂ transfer system will be subjected to a full range of</p>				<p>testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.</p> <p>2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional test (leakage, flow) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem (LH₂ transfer) level.</p> <p>3.2 Subsystem. Structural and functional qualification test on the complete LH₂ transfer system in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>None.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 13 LH₂ SPRAY NOZZLE
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.09.06	C	N/A	N/A
25.09.12	C	N/A	N/A

1. RESEARCH AND TECHNOLOGY TESTING

This item is a part of the zero-g flight LH₂ transfer system which requires a research and technology flight test to develop and verify techniques to accomplish propellant transfer under zero-g conditions.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions. Functional (flow) testing will be conducted at cryogenic conditions. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4)

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the flight fill components to form a flight fill subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the flight fill system (high pressure, low pressure, high flow, low flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The flight fill system will be subjected to a full range of testing under cold-flow conditions.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure) will be conducted under ambient and cryogenic conditions.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (flight fill) level.

3.2 Subsystem. Structural and functional qualification test on the complete flight fill in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

There is no reliability test program for this test item. The probability of structural failure will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 16 CH₂ VENT AND RELIEF VALVE
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15.10.02	B-1G	N/A	N/A	
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Utilize previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, response times, and crack and reseal points. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional test item will be mated with the remainder of the ground vent components to form a ground vent subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the propulsion system and the propellant module LH₂ tank in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the ground vent</p>				<p>system (high pressure, high flow, high back-pressure, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The flight vent system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.</p> <p>2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response, crack, and reseal pressure) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem (ground vent) level.</p> <p>3.2 Subsystem. Structural and functional qualification test on the complete ground vent system in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>There will be no reliability test program on this test item. This valve is only used on the ground prior to Earth launch. The only failure mode applicable to the flight is the leak failure mode. The probability of occurrence of this failure mode will be determined by material properties and analysis.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 17 GH₂ VENT VALVE
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15.10.03	B-1G	N/A	N/A	
1. RESEARCH AND TECHNOLOGY TESTING				modifications to ensure component adequacy and compliance with requirements. The ground vent system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.
No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.				
2. DEVELOPMENT TESTING				2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).				3. QUALIFICATION TESTING
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electro-mechanical and ground pneumatic interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional test item will be mated with the remainder of the ground vent components to form a ground vent subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.				3.1 (Alternate). The above component qualification tests could be performed at the subsystem (ground vent) level.
2.3 System. The test item will be integrated with the remainder of the propulsion system and the propulsion module LH ₂ tank in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the ground vent system (high pressure, high flow, high back-pressure, etc.). Data from this test will be used as a final design verification or as an input to the final design				3.2 Subsystem. Structural and functional qualification test on the complete ground vent system in the PIL.
				3.2 (Alternate). This test could be eliminated.
				3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH ₂ tanks on the all-systems test under "hot" NERVA firing.
				3.3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTING
				There will be no reliability testing on this test item. This valve is only used on the ground prior to Earth launch. The only failure mode applicable to flight is the leak failure mode. The probability of occurrence of this failure mode will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 18 VENT AND RELIEF DISCONNECT
SYSTEM DISCONNECT

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15.10.05	B-1G	N/A	N/A	
1. RESEARCH AND TECHNOLOGY TESTING				subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.
No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.				
2. DEVELOPMENT TESTING				2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions, axial load, shear, bending moment, spring rate and deflection, and structural degradation under radiation fluences. Functional (docking) testing will be conducted in a special docking simulator (SDS) fabricated to study and verify docking techniques and components. Functional (flow) testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).				3. QUALIFICATION TESTING
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure, axial load, shear, bending moment, spring rate, and deflection) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be mated with the remainder of the ground vent components to form a ground vent subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.				3.1 (Alternate). The above component qualification tests could be performed at the subsystem (ground vent) level.
2.3 System. The test item will be integrated with the remainder of the propulsion system and the propellant module LH ₂ tank in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the ground vent system (high pressure, high flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The ground vent system will be				3.2 Subsystem. Structural and functional qualification test on the complete ground vent in the PIL.
				3.2 (Alternate). This test could be eliminated.
				3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH ₂ tanks on the all-systems test under "hot" NERVA firing.
				3.3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTING
				There will be no reliability test program on this test item. The reliability (probability of no failure) will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 20 GH₂ VENT NOZZLE
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.11.03	B-1	N/A	N/A
15.11.04	B-1	N/A	N/A
25.11.06	B-3	N/A	N/A
25.11.07	B-3	N/A	N/A

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions. Functional (flow) testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the flight vent components to form a flight vent subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the propulsion module LH₂ tank in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the flight vent system (high pressure, high flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to

ensure component adequacy and compliance with requirements. The flight vent system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under 'hot' NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (flight vent) level.

3.2 Subsystem. Structural and functional qualification test on the complete flight vent in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under 'hot' NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

There is no reliability test program on this item. The structural capability will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 21 GH₂ FLIGHT VENT QUAD VALVE ASSEMBLY

CLASS 3

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
25.05.01	C	0.98	90	
25.05.02	C	0.98	90	
25.09.05	C	0.98	90	
25.09.06	C	0.98	90	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH ₂ tankage in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the flight vent system (high pressure, high flow, high back-pressure, etc). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The flight vent system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.
No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.				2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC) or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated
2. DEVELOPMENT TESTING				3. QUALIFICATION TESTING
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, response times, and pump head requirements. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				3.1 Component Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3.1 (Alternate). The above component qualification tests could be performed at the subsystem chilldown level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional four test items will be mated with the remainder of the chilldown components to form a chilldown subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.				3.2 Subsystem. Structural and functional qualification test on the complete chilldown system in the PIL.
				3.2 (Alternate). This test could be eliminated.
				3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH ₂ tanks on the all-systems test under "hot" NERVA firing.
				3.3 (Alternate). This test could be eliminated
				4. RELIABILITY TESTING
				All of the test data developed in the above test program will be credited to the reliability test program. The remainder of the test required to verify the reliability allocation (0.98) at the required confidence level (90 percent) will be conducted with 10 components. A total of successful testing equivalent to 140 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 22 LH₂ CHECK VALVE
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
25.05.03	C	NA	NA	<p>2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2. Battleship tanks will be used to allow extended parameter testing on the flight LH₂ transfer system (high pressure, low pressure, high flow, low flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The chilldown system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.</p> <p>2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem (chilldown) level.</p> <p>3.2 Subsystem. Structural and functional qualification test on the complete chilldown system in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>None</p>
25.05.04	C	NA	NA	
25.05.05	C	NA	NA	
25.05.06	C	NA	NA	
25.05.07	C	NA	NA	
25.09.07	C	NA	NA	
25.09.08	C	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING				
No specific testing. Data from the RNS SRT testing on radiation effects and long-life technology will be used.				
2. DEVELOPMENT TESTING				
<p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the chill-down components to form a chilldown subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 23 CHILLDOWN QUAD VALVE ASSEMBLY
SYSTEM PROPULSION

CLASS

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
25, 05, 08	C	0, 988 each	90	<p>Battleship tanks will be used to allow extended paramete testing on the flight LH₂ transfer system (high pressure, low pressure, high flow, low flow, high impedance, etc.) Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The chilldown system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot NERVA firings.</p> <p>2, 3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3, 1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum</p> <p>3, 1 (Alternate). The above component qualification tests could be performed at the subsystem chilldown level.</p> <p>3, 2 Subsystem. Structural and functional qualification test on the complete chilldown system in the PIL.</p> <p>3, 2 (Alternate). This test could be eliminated.</p> <p>3, 3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.</p> <p>3, 3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>All test data accumulated in the above test program will be credited to the reliability test program. Applicable test data from the Saturn S-IVB program will also be used. S-IVB test data on the chilldown shutoff valves resulted from a total 60,926 ambitized test hours. The remainder of the test time required to verify the reliability statistically (0,988) at the required confidence level (90 percent) will be performed with 10 components. The total successful test time must be equivalent to 190 lunar missions.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>This test item is a part of the zero-g flight LH₂ chilldown system that requires research and technology to develop and verify techniques to accomplish chilldown under zero-g conditions. Data from the RNS SRT testing on radiation effects and long-life technology will also be used.</p> <p>2. DEVELOPMENT TESTING</p> <p>2, 1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2, 1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2, 2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional four test items will be mated with the remainder of the chilldown transfer components to form a chilldown subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2, 3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2.</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 24 GH₂ MALE DISCONNECT
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
25.06.05	B-3	N/A	N/A	<p>system (high pressure, high flow, high impedance, etc). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The pressurization system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under 'hot' NERVA firings.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.</p>				<p>2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites, (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.</p>
<p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions, axial load, shear, bending moment, spring rate and deflection, and structural degradation under radiation fluences. Functional (docking) testing will be conducted in a special docking simulator (SDS) fabricated to study and verify docking techniques and components. Functional (flow) testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. A test item will be mated with the remainder of the pressurization components to form a pressurization subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems</p> <p>2.3 System. The test item will be integrated with the remainder of the propulsion system and the propulsion module LH₂ tank in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the pressurization</p>				<p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure, axial load, shear, bending moment, spring rate, and deflection) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem (pressurization) level.</p> <p>3.2 Subsystem. Structural and functional qualification tests on the complete flight pressurization in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under 'hot' NERVA firing.</p> <p>3.3 (Alternate). This test could be eliminated.</p>
<p>4 RELIABILITY TESTING</p> <p>There will be no reliability test program on this item. The reliability (probability of no failure) will be determined by material properties and analysis.</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 25 LH₂ DISCONNECT
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
25.09.01	B-3	N/A	N/A	<p>be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The pressurization system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.</p>				<p>2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.</p>
<p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions, axial load, shear, bending moment, spring rate and deflection, and structural degradation under radiation fluences. Functional (docking) testing will be conducted in a special docking simulator (SDS) fabricated to study and verify docking techniques and components. Functional (flow) testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be mated with the remainder of the LH₂ fill components to form a LH₂ fill subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the LH₂ fill system and the propulsion module LH₂ tank in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the LH₂ fill system (high pressure, high flow, high impedance, etc.). Data from this test will</p>				<p>3. QUALIFICATION TESTING</p> <p>3.1 Component Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure, axial load, shear, bending moment, spring rate, and deflection) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem (LH₂ fill) level.</p> <p>3.2 Subsystem. Structural and functional qualification test on the complete LH₂ fill in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>There will be no reliability test program on this item. The reliability (probability of no failure) will be determined from material properties and analysis.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 26 FLOW CONTROL VALVES
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
25.09.03	C	0.99	90
25.09.04	C	0.99	90

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing; also, RNS SRT testing on radiation effects and long life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, power requirements, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (See Section 4).

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional two test items will be mated with the remainder of the fill system components to form a fill subsystem to be used in the PIL for structural, functional, and stability testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural, functional, and control stability interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion module propulsion system and the propellant module in a system-level test at NRDS in ESTS-2. Battleship tanks will be used to allow extended parameter testing on the fill system (high pressure, low pressure, high flow, low flow, high impedance, etc). Data

from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The fill system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold flow testing or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate) The above component qualification tests could be performed at the subsystem (fill) level.

3.2 Subsystem. Structural and functional qualification test on the complete system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

All of the data obtained from the above test program will be credited to the reliability program. The remainder of the testing required to verify the reliability allocation (0.99) at the required confidence level (90 percent) will be accomplished with 25 components. The total successful test time must be equivalent to 225 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 28 GH₂ QUAD VALVE ASSEMBLY

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
26.01.01	B-3	NA	NA
26.01.18	B-3	NA	NA
26.01.19	B-3	NA	NA

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4)

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Six test items will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional six test items will be mated with the remainder of the APS components to form an APS subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the APS (high

pressure, low pressure, high flow, low flow, high back pressure, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The APS will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites, (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (APS) level.

3.2 Subsystem. Structural and functional qualification test on the complete APS system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

There will be no reliability testing on this item. These valves are not required for mission success. The only failure mode that could cause loss of the mission is the leak failure mode and the probability of failure in this mode will be determined by material property and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 29 GH₂ STORAGE VESSEL
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
26, 01, 05	B-3	NA	NA	or could be conducted partially at two sites, (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.
1. RESEARCH AND TECHNOLOGY TESTING				3. QUALIFICATION TESTING
No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects.				3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure) tests will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.
2. DEVELOPMENT TESTING				3.1 (Alternate). The above component qualification tests could be performed at the subsystem level.
2.1 Component. A small number (2) of components will be subjected to structural testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements.				3.2 Subsystem. Structural and functional qualification test on the complete APS subsystem in the PIL.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3.2 (Alternate). This test could be eliminated.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogen conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.				3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH ₂ tanks on the all-systems test under "hot" NERVA firing.
2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH ₂ tankage in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the APS (high pressure, high flow, high back-pressure, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The APS will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.				3.3 (Alternate). This test could be eliminated.
2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC),				4. RELIABILITY TESTING
				There is no reliability testing on this item. The probability of failure will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 30 GH_2 RELIEF VALVE

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
26.01.07	B-3	NA	NA	<p>2,3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites, (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.</p>
1. RESEARCH AND TECHNOLOGY TESTING				3. QUALIFICATION TESTING
No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.				3,1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response, crack and reseal pressure) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.
2. DEVELOPMENT TESTING				3,1 (Alternate). The above component qualification tests could be performed at the subsystem level.
2,1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, crack and reseal points, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4)				3,2 Subsystem. Structural and functional qualification test on the complete APS in the PIL.
2,1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3,2 (Alternate). This test could be eliminated.
2,2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be mated with the remainder of the APS components to form an APS subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.				3,3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH_2 tanks on the all-systems test under 'hot' NERVA firing
2,3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH_2 tankage in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the APS (high pressure, high flow, high back-pressure, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The APS will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under 'hot' NERVA firings.				3,3 (Alternate) This test could be eliminated
				4 RELIABILITY TESTING
				There is no reliability testing on this item. Failure of this item will not affect success of the mission.

TEST ITEM WORK SHEET

TEST ITEM NO. 31 CONTROL VALVES GH_2
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
26 01 12	B 3	NA	NA	
26 01 13	B 3	NA	NA	
1 RESEARCH AND TECHNOLOGY TESTING				2 3 System The test item will be integrated with the remainder of the APS and the propulsion module hardware in a system-level test where actual thrust generation will be accomplished This test will be accomplished at a suitable test facility and will supplement and extend the PIL system testing Extended parameter testing on the APS (high pressure high flow rates extended pulse duration firing etc) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements
No specific testing Use previous design technology and testing also RNS SRT testing on radiation effects and long life technology				2 3 (Alternate) This level of testing could be conducted at other test sites (MTF NRDS etc) could be conducted at other levels or could be eliminated
2 DEVELOPMENT TESTING				3 QUALIFICATION TEST
2 1 Component A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences Functional testing will be conducted at room temperature and elevated temperature conditions under vibration and shock conditions and in a vacuum and will include leakage testing flow rate (impedance) determination and response times Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long life requirements Extended environment testing will be performed to delineate dominant failure modes				3 1 Component Qualification testing will be conducted on a small number (2) of components Structural testing (proof and burst pressure) tests and functional tests (leakage flow response) will be conducted under ambient conditions high-temperature conditions vibration shock and vacuum
2 1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL				4 RELIABILITY TESTING
2 2 Subsystem Subsystem testing will be conducted on this test items Four test items will be installed in the SIL for electromechanical interface and functional testing These data will supplement the component test data in the specific area of electrical interface design and problems An additional four test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed Subsystem functional testing will also involve ambient and cryogenic conditions but will not include actual engine firing These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems				None

TEST ITEM WORK SHEET

TEST ITEM NO. 35 HORIZON SENSOR AND ELECTRONICS
SYSTEM NAVIGATION, GUIDANCE, AND CONTROL

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
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37.01.14	A	NA	NA
37.01.15	A	NA	NA

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astronics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astronics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astronics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 36 LANDMARK TRACKER AND ELECTRONICS
SYSTEM NAVIGATION, GUIDANCE, AND CONTROL

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
37.01.16	A	NA	NA
37.01.17	A	NA	NA

1 RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions,

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 37 STAR TRACKER AND ELECTRONICS
SYSTEM NAVIGATION, GUIDANCE, AND CONTROL

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.01.18	A	NA	NA	
37.01.19	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component Testing. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electro-mechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astronics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astronics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astronics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 38 COMMAND LOGIC UNIT
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.03.08	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on one unit in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 39 TRACKING SYSTEM
SYSTEM COMMAND AND CONTROL

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	3. QUALIFICATION TESTING
37.03.09	A	NA	NA	<p>3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.</p> <p>3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.</p> <p>3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.</p> <p>3.2 (Alternate). The above test could be conducted at the system level.</p> <p>3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.</p> <p>3.3 (Alternate). This test could be eliminated.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.</p> <p>Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.</p> <p>2.2 (Alternate). This testing could be conducted at the system level.</p> <p>2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.</p> <p>2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.</p>				<p>4. RELIABILITY TESTING</p> <p>The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 40 MICROWAVE ANTENNA SYSTEM
SYSTEM COMMAND AND CONTROL

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.03.10	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING				3. QUALIFICATION TESTING
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2. DEVELOPMENT TESTING				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test and communicate with the facility during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. This test item will be used for microwave communication between the test article and the facility. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 41 POWER AMPLIFIER/TRANSMITTER ASSEMBLY

CLASS 3

SYSTEM COMMAND AND CONTROL

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37, 03, 11	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING 3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions. 3.1 (Alternate). The entire component qualification could be accomplished by the component contractor. 3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions. 3.2 (Alternate). The above test could be conducted at the system level. 3.3 System. The test item will be integrated with the remainder of the astronics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astronics will be required to control the operation of the test and communicate with the facility during a simulated lunar mission under cold-flow and "hot" firing conditions. 3.3 (Alternate). This test could be eliminated.
2. DEVELOPMENT TESTING 2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions. 2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer. 2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished. 2.2 (Alternate). This testing could be conducted at the system level. 2.3 System. The test item will be integrated with the remainder of the astronics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. This test item will be used to communicate with the facility during the test series. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment. 2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.				4. RELIABILITY TESTING The reliability test program on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 42 RECEIVER/UPLINK SYSTEM
SYSTEM COMMAND AND CONTROL

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.03.12	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING				3. QUALIFICATION TESTING
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2. DEVELOPMENT TESTING				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test with this test item used to reserve ground commands during a simulated lunar mission under cold-flow and 'hot' firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. This test item will be used to reserve ground commands from the facility. Cold-flow and 'hot' NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 43 SIGNAL CONDITIONER
SYSTEM COMMAND AND CONTROL

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.03.13	A	NA	NA	<p>3. QUALIFICATION TESTING</p> <p>3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.</p> <p>3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.</p> <p>3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.</p> <p>3.2 (Alternate). The above test could be conducted at the system level.</p> <p>3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions. This test item will be employed to condition uplink commands from the facility.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.</p> <p>2.2 (Alternate). This testing could be conducted at the system level.</p> <p>2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. This test item will be employed during the tests to condition up-link commands from the facility. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.</p> <p>2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 44 SIGNAL PROCESSOR ASSEMBLY
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.03.14	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
2. DEVELOPMENT TESTING 2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions. 2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer. 2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electro-mechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished. 2.2 (Alternate). This testing could be conducted at the system level. 2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. This test unit will be to process the uplink command from the facility. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic radiation, and electromagnetic environment.				3. QUALIFICATION TESTING 3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions. 3.1 (Alternate). The entire component qualification could be accomplished by the component contractor 3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions 3.2 (Alternate). The above test could be conducted at the system level 3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions. This test item will be to process the uplink commands from the facility. 3.3 (Alternate). This test could be eliminated
4. RELIABILITY TESTING The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program				

TEST ITEM WORK SHEET

TEST ITEM NO. 45 HYDROGEN ASSEMBLY

CLASS 3

SYSTEM ASTRIONICS ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37. 04. 01	A	NA	NA	
37. 04. 02	A	NA	NA	
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.</p> <p>2. DEVELOPMENT TESTING</p> <p>2. 1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.</p> <p>Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.</p> <p>2. 1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.</p> <p>2. 2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.</p> <p>2. 2 (Alternate). This testing could be conducted at the system level.</p> <p>2. 3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.</p>				<p>2. 3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3. 1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.</p> <p>3. 1 (Alternate). The entire component qualification could be accomplished by the component contractor.</p> <p>3. 2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.</p> <p>3. 2 (Alternate). The above test could be conducted at the system level.</p> <p>3. 3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.</p> <p>3. 3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 46 OXYGEN ASSEMBLY

CLASS 3

SYSTEM ASTRIONICS ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.03	A	NA	NA	
37.04.04	A	NA	NA	
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.</p> <p>2. Development Testing</p> <p>2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.</p> <p>Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.</p> <p>2.2 (Alternate). This testing could be conducted at the system level.</p> <p>2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full scale stage operation. Cold-flow and "hot" NERVA engine firings will be</p>				<p>accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.</p> <p>2.3 (Alternate). This test could be conducted under cold flow-conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.</p> <p>3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.</p> <p>3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.</p> <p>3.2 (Alternate). The above test could be conducted at the system level.</p> <p>3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 48 HYDROGEN CONTROL ASSEMBLY

CLASS 3

SYSTEM ASTRIONICS ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.06	A	0.99	50	
37.04.09	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long life technology testing.				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
2. DEVELOPMENT TESTING 2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including the structural testing under vibration and shock conditions. 2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer. 2.2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished. 2.2 (Alternate). This testing could be conducted at the system level. 2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				3. QUALIFICATION TESTING 3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions. 3.1 (Alternate). The entire component qualification could be accomplished by the component contractor. 3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions. 3.2 (Alternate). The above test could be conducted at the system level. 3.3 System The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions. 3.3 (Alternate) This test could be eliminated.
4. RELIABILITY TESTING The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.				

TEST ITEM WORK SHEET

TEST ITEM NO. 49 OXYGEN CONTROL ASSEMBLY
SYSTEM ASTRIONICS ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.07	A	0.99	50	
37.04.10	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 50 LH₂ SHUTOFF VALVE
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL test where
37.04.11	A	0.99	50
37.04.12	A	0.99	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient, cryogenic, and high-temperature conditions and structural degradation under radiation fluences. Functional testing will be conducted at room and cryogenic, temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the SIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for the electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional two test items will be mated with the remainder of the components to form an electrical fuel cell system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient, high-temperature, and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient, high-temperature, and cryogenic conditions but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the electrical system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be part of the battleship test at MRDS.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, etc.) or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (electrical system) or the system level.

3.2 Subsystem. Structural and functional (nonfiring) qualification test on the item in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete electrical system is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

A reliability test program will be conducted on this test item. A total of 7 test components will be used in a program to verify the reliability allocation (0.99) of the required confidence level (50 percent). A total of 70 successful equivalent lunar missions is required. Data accumulated in the regular test program will be used in the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 51 LOX SHUTOFF VALVE
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.13	A	0.99	50	
37.04.14	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.				2.3 System. The test item will be integrated with the remainder of the Electrical system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be part of the battleship test at NRDS.
2. DEVELOPMENT TESTING 2.1 Component. A small number 2 of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient, cryogenic, and high-temperature conditions and structural degradation under radiation fluences. Functional testing will be conducted at room, and cryogenic, temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, etc.) or could be eliminated.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the SIL.				3. QUALIFICATION TESTING
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for the electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional two test items will be mated with the remainder of the components to form an Electrical Fuel Cell system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient, high-temperature, and cryogen conditions will be performed. Subsystem functional testing will also involve ambient, high-temperature, and cryogenic conditions but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				3.1 Component. Qualification testing will be conducted on a small number 2 of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.
				3.1 (Alternate). The above component qualification tests could be performed at the subsystem (Electrical System) or the system level.
				3.2 Subsystem Structural and functional (nonfiring) qualification test on the item in the PIL.
				3.2 (Alternate). This test could be eliminated.
				3.3 System. The final functional qualification of the complete Electrical System is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.
				3.3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTING A reliability test program will be conducted on this test item. A total of 7 test components will be used in a program to verify the reliability allocation (0.99) of the required confidence level (50 percent). A total of 70 successful equivalent lunar missions is required. Data accumulated in the regular test program will be used in the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 54 VOLTAGE LIMITER SENSOR

CLASS 3

SYSTEM ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	3. QUALIFICATION TESTING
37.04.19	A	0.999	50	3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
37.04.20	A	0.999	50	3.1 (Alternate) The entire component qualification could be accomplished by the component contractor.
1. RESEARCH AND TECHNOLOGY TESTING				3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3.2 (Alternate). The above test could be conducted at the system level.
2. DEVELOPMENT TESTING				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.3 (Alternate). This test could be eliminated.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				4. RELIABILITY TESTING
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				
2.2 (Alternate). This testing could be conducted at the system level.				
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				
2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.				

TEST ITEM WORK SHEET

TEST ITEM NO. 55 VOLTAGE LIMITER CONTROL ASSEMBLY
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.21	A	0.99	50	
37.04.22	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system and the remainder of the appropriate RNS systems in an all-systems test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and 'hot' firing conditions. This test unit will be integrated with the remainder of the power system to provide electrical power to the test article.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. This test unit will be required to operate with the remainder of the power system to provide electrical power for the test article. Cold-flow and 'hot' NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program

TEST ITEM WORK SHEET

TEST ITEM NO. 56 COMMAND SYSTEM INVERTER SWITCH
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.23	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				
2. DEVELOPMENT TESTING				3. QUALIFICATION TESTING
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on one unit in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.2 (Alternate). This testing could be conducted at the system level.				
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				3.2 (Alternate). The above test could be conducted at the system level.
				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
				3.3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 57 START-UP CONTROLS
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04 24	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
2 DEVELOPMENT TESTING 2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions. 2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer. 2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One set of this test item will be installed in the SIL for electro-mechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished. 2.2 (Alternate). This testing could be conducted at the system level. 2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				3. QUALIFICATION TESTING 3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions. 3.1 (Alternate). The entire component qualification could be accomplished by the component contractor. 3.2 Subsystem. Functional subsystem qualification testing will be conducted on one set of this item in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions. 3.2 (Alternate). The above test could be conducted at the system level. 3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions. 3.3 (Alternate). This test could be eliminated.
4. RELIABILITY TESTING The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.				

TEST ITEM WORK SHEET

TEST ITEM NO. 58 MAIN BUS

CLASS 3

SYSTEM ASTRIONICS ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.25	A	NA	NA	<p>2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.</p> <p>3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.</p> <p>3.2 Subsystem. Functional subsystem qualification testing will be conducted on one unit in the SIL. The unit will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.</p> <p>3.2 (Alternate). The above test could be conducted at the system level.</p> <p>3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.</p> <p>Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.</p> <p>2.2 (Alternate) This testing could be conducted at the system level.</p> <p>2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 59 MAIN FEED CONTACTOR
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.04.26	A	NA	NA	
36.04.27	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. These component will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
2. DEVELOPMENT TESTING 2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3. QUALIFICATION TESTING 3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subject to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on one unit in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.2 (Alternate). The above test could be conducted at the system level.
2.3 System. The test item will be integrated with the remainder of the electrical system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				3.3 System. The test item will be integrated with the remainder of the electrical system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
				3.3 (Alternate). This test could be eliminated.
				4.4 RELIABILITY TESTING None.

TEST ITEM WORK SHEET

TEST ITEM NO. 60 AUXILIARY BUS

CLASS 3

SYSTEM ASTRIONICS ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
37.04.28	A	NA	NA

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One set of the test items will be installed in the SIL for electro-mechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operation parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on one set of the test units in the SIL. The unit will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 61 LOW VOLTAGE SENSOR

CLASS 3

SYSTEM ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.29	A	0.9999	50	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
2. DEVELOPMENT TESTING 2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3. QUALIFICATION TESTING 3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on one unit in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.2 (Alternate). The above test could be conducted at the system level.
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
				3.3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTING The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 62 BUSS TRANSFER RELAY

CLASS 3

SYSTEM

ELECTRICAL POWER

COMPONENT

**MAINTENANCE
CATEGORY**

**RELIABILITY
ALLOCATION**

CONFIDENCE LEVEL

37.04.30

A

0.9999

50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on one unit in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 63 CURRENT SENSOR
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.31	A	0.999	50	
37.04.32	A	0.999	50	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astronautics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astronautics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astronautics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 64 REVERSE CURRENT SENSOR

CLASS 3

SYSTEM ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
37.04.33	A	0.999	50
37.04.34	A	0.999	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 65 REVERSE CURRENT SWITCH
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.35	A	0.99	50	
37.04.36	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING 3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions. 3.1 (Alternate). The entire component qualification could be accomplished by the component contractor. 3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions. 3.2 (Alternate). The above test could be conducted at the system level. 3.3 System. The test item will be integrated with the remainder of the astronics system, the propulsion system and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astronics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions. 3.3 (Alternate). This test could be eliminated.
2. DEVELOPMENT TESTING 2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions. 2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer. 2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished. 2.2 (Alternate). This testing could be conducted at the system level. 2.3 System. The test item will be integrated with the remainder of the astronics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment. 2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site or could be eliminated.				4. RELIABILITY TESTING The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 66 LOW VOLTAGE RELAY
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.37	A	0.9999	50	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				2, 3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
2. DEVELOPMENT TESTING 2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions. 2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer. 2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished. 2.2 (Alternate). This testing could be conducted at the system level. 2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				3. QUALIFICATION TESTING 3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions. 3.1 (Alternate). The entire component qualification could be accomplished by the component contractor. 3.2 Subsystem. Functional subsystem qualification testing will be conducted on one unit in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions. 3.2 (Alternate). The above test could be conducted at the system level. 3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS system in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and and "hot" firing conditions. 3.3 (Alternate). This test could be eliminated.
4. RELIABILITY TESTING The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.				

TEST ITEM WORK SHEET

TEST ITEM NO. 67 BATTERY

CLASS 3

SYSTEM ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.38	A	0.99	50	
37.04.39	A	0.99	50	
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.</p> <p>Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.</p> <p>2.1 (Alternate) The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.</p> <p>2.2 (Alternate). This testing could be conducted at the system level.</p> <p>2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.</p>				<p>3. QUALIFICATION TESTING</p> <p>3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.</p> <p>3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.</p> <p>3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.</p> <p>3.2 (Alternate). The above test could be conducted at the system level.</p> <p>3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 68 REVERSE CURRENT ASSEMBLY
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.40	A	0.99	50	
37.04.41	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 69 BATTERY CHARGER

CLASS 3

SYSTEM ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.42	A	0.99	50	
37.04.43	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 71 COMPUTER SUBSYSTEM CONTROLLER
SYSTEM DATA MANAGEMENT

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
37.09.04	A	0.99	50
37.09.05	A	0.99	50
37.09.06	A	0.99	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Three test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on three units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 72 AUXILIARY MEMORY
SYSTEM NAVIGATION, GUIDANCE, AND CONTROL

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.09.07	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING				3. QUALIFICATION TESTING
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2. DEVELOPMENT TESTING				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 (Alternate). The above test could be conducted at the system level.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subject to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 (Alternate). This test could be eliminated.
2.2 (Alternate). This testing could be conducted at the system level.				4. RELIABILITY TESTING
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				Reliability testing on this item will be conducted by the supplier.
2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.				

TEST ITEM WORK SHEET

TEST ITEM NO. 73 APS ENGINE

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.01.01	A	NA	NA	failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated
No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and high-temperature conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				3.1 (Alternate). The above component qualification tests could be performed at the subsystem (APS engine subsystem) or the system level.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be mated with the remainder of the APS components to form an APS system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and high-temperature conditions will be performed. Subsystem functional testing will also involve ambient and high-temperature conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				3.2 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible				3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.
				3.3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTING
				There will be no reliability testing on this item. The reliability (probability of no failure) will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 74 Igniters

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.01.02	A	0.99	50	in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.
36.01.02.16	A	0.99	50	
36.01.02.22	A	0.99	50	
36.01.04.16	A	0.99	50	
36.01.04.22	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING				
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				
2. DEVELOPMENT TESTING				
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Six test items will be installed in the APS in the PIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				
2.2 (Alternate). This testing could be conducted at the system level.				
2.3 System. The test item will be integrated with the remainder of the APS system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item				
2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.				
3. QUALIFICATION TESTING				
3.1 Component Test. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.				
3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.				
3.2 Subsystem Test. Functional subsystem qualification testing will be conducted on six units in the APS in the PIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.				
3.2 (Alternate). The above test could be conducted at the system level.				
3.3 System Test. The test item will be integrated with the remainder of the APS system, the propulsion system and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astronautics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.				
3.3 (Alternate). This test could be eliminated.				
4. RELIABILITY TESTING				
The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.				

TEST ITEM WORK SHEET

TEST ITEM NO. 75 ENGINE GH₂ FEED VALVES

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01.01.03	A	0.9946	50
36.01.01.04	A	0.9946	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and high-temperature conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional four test items will be mated with the remainder of the APS components to form an APS system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and high-temperature conditions will be performed. Subsystem functional testing will also involve ambient and high-temperature conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a

suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural test (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (APS engine subsystem) or the system level.

3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

Reliability testing will be conducted on this test item. A total of 15 test items will be utilized in a program to demonstrate the reliability allocation (0.9946) at the confidence level (50 percent). A total of 130 successful equivalent lunar missions is required. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 76 ENGINE GOX QUAD FEED VALVES
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.01.05	A	0.9946	50	
36.01.01.06	A	0.9946	50	
1. RESEARCH AND TECHNOLOGY TESTING				test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.
No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.				2, 3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.
2. DEVELOPMENT TESTING				3. QUALIFICATION TESTING
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and high-temperature conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).				3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3.1 (Alternate). The above component qualification tests could be performed at the subsystem (APS engine subsystem) or the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional four test items will be mated with the remainder of the APS components to form an APS system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and high-temperature conditions will be performed. Subsystem functional testing will also involve ambient and high-temperature conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.
2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system level test where actual engine firings will be accomplished. This test will be accomplished at a suitable				3.2 (Alternate). This test could be eliminated.
				3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.
				3.3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTING
				Reliability testing will be performed on this test item. A total of 15 test components will be used in a program to verify the reliability allocation (0.9946) at the required confidence level (50 percent). A total of 130 successful equivalent lunar missions is required. Data accumulated in the regular test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 79 GH₂ CHECK VALVE DISCONNECT
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36 01 02 05	A	NA	NA	modifications to insure component adequacy and compliance with requirements.
1 RESEARCH AND TECHNOLOGY TESTING				2 3 (Alternate) This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated
No specific testing Use previous design technology and testing also RNS SRT testing on radiation effects and long-life technology				3 QUALIFICATION TESTING
2 DEVELOPMENT TESTING				3 1 Component Qualification testing will be conducted on a small number (8) of components Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration shock and vacuum
2 1 Component A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions, axial load, shear, bending moment, spring rate and deflection and structural degradation under radiation fluences Functional testing will be conducted at room temperature and cryogenic temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements Extended environment testing will be performed to delineate dominant failure modes				3 1 (Alternate) The above component qualification tests could be performed at the subsystem or the system level
2 1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL				3 2 Subsystem Structural and functional (nonfiring) qualification test on the complete APS in the PIL
2 2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items Six test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed Subsystem functional testing will also involve ambient and cryogenic conditions These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems				3 2 (Alternate) This test could be eliminated
2 3 System The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing Extended parameter testing on the APS system (high pressure, high flow rates extended pulse duration firing, etc) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design				3 3 System The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility
				3 3 (Alternate) This test could be eliminated
				4 RELIABILITY TESTING
				There will be no reliability testing on this item The reliability (probability of no failure) will be determined by material properties and analysis

TEST ITEM WORK SHEET

TEST ITEM NO. 80 GH₂ STORAGE SPHERE
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36 01 02 07	A	NA	NA	<p>2 3 (Alternate) This level of testing could be conducted at other test sites (MTF, KSC NRDS, etc) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated</p> <p>3 QUALIFICATION TESTING</p> <p>3 1 Component Qualification testing will be conducted on a small number (1) of components Structural tests (proof and burst pressure) and functional tests (leakage) will be conducted under ambient conditions cryogenic conditions vibration, shock, and vacuum</p> <p>3 1 (Alternate) The above component qualification tests could be performed at the subsystem or the system level</p> <p>3 2 Subsystem Structural and functional (nonfiring) qualification test on the complete APS in the PIL</p> <p>3 2 (Alternate) This test could be eliminated</p> <p>3 3 System The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility</p> <p>3 3 (Alternate) This test could be eliminated</p> <p>4 RELIABILITY TESTING</p> <p>There will be no reliability testing on this item The reliability (probability of no failure) will be determined by material properties and analysis</p>
<p>1 RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing Use previous design technology and testing, also RNS SRT testing on radiation effects</p> <p>2 DEVELOPMENT TESTING</p> <p>2 1 Component A small number (2) of components will be subjected to structural testing to obtain design and design verification information These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements Extended environment testing will be performed to delineate dominant failure modes</p> <p>2 1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL</p> <p>2 2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed Subsystem functional testing will also involve ambient and cryogenic conditions but will not include actual engine firing These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems</p> <p>2 3 System The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished This test will be accomplished at a suitable test facility Douglas-Sacramento and will supplement and extend the PIL system testing Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing etc) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to insure component adequacy and compliance with requirements</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 81 GH₂ CHECK VALVE

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.02.08	A	NA	NA	
36.01.02.09	A	NA	NA	
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.</p>				<p>2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.</p> <p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.</p> <p>4. RELIABILITY TESTING</p> <p>None</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 83 FILTER

CLASS 3

SYSTEM

AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.02.11	A	NA	NA	<p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure) tests and functional tests (leakage, flow) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.</p> <p>4. RELIABILITY TESTING</p> <p>None.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 85 GOX SHUTOFF VALVE
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.02.15	A	0.99	50	APS system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient, high-temperature, and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient, high-temperature, and cryogenic conditions but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems. 2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements 2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be eliminated. 3. QUALIFICATION TESTING 3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum. 3.1 (Alternate). The above component qualification tests could be performed at the subsystem (APS engine subsystem) or the system level. 3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL. 3.2 (Alternate). This test could be eliminated. 3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility. 3.3 (Alternate). This test could be eliminated. 4. RELIABILITY TESTING A reliability test program will be conducted on this test item. A total of 10 test components will be used in a program to verify the reliability allocation (0.99) of the required confidence level (50 percent). A total of 70 successful equivalent lunar missions is required. Data accumulated in the regular test program will be used in the reliability test program.
36.01.02.21	A	0.99	50	
36.01.04.03	A	0.99	50	
36.01.04.04	A	0.99	50	
36.01.04.06	A	0.99	50	
36.01.04.13	A	0.99	50	
36.01.04.14	A	0.99	50	
36.01.04.19	A	0.99	50	
36.01.04.20	A	0.99	50	
36.01.04.25	A	0.99	50	
36.01.04.26	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING				
No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.				
2. DEVELOPMENT TESTING				
2.1 Component. A small number (4) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient, cryogenic, and high-temperature conditions and structural degradation under radiation fluences. Functional testing will be conducted at room, cryogenic, and elevated temperature conditions, under vibration and shock conditions; and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Fourteen test items will be installed in the SIL for the electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional fourteen test items will be mated with the remainder of the APS components to form an				

TEST ITEM WORK SHEET

TEST ITEM NO. 86 GAS GENERATOR

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36 01 02 17	A	NA	NA	suitable test facility Douglas-Sacramento and will supplement and extend the PIL system testing Extended parameter testing on the APS system (high pressure high flow rates extended pulse duration firing etc) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to insure component adequacy and compliance with requirements
36 01 02 23	A	NA	NA	
36 01 04 17	A	NA	NA	2 3 (Alternate) This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated
36 01 04 23	A	NA	NA	3 QUALIFICATION TESTING
1 RESEARCH AND TECHNOLOGY TESTING				3 1 Component Qualification testing will be conducted on a small number (8) of components Structural tests (proof and burst pressure) and functional tests (leakage flow response) will be conducted under ambient conditions high-temperature conditions vibration, shock and vacuum
No specific testing Utilize previous design technology testing and RNS SRT testing on radiation effects				3 1 (Alternate) The above component qualification tests could be performed at the subsystem or the system level
2 DEVELOPMENT TESTING				3 2 Subsystem Structural and functional (nonfiring) qualification test on the complete APS in the PIL
2 1 Component A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use Structural testing will include proof and burst pressure tests under ambient and high-temperature conditions and structural degradation under radiation fluences Functional testing will be conducted at room temperature and elevated temperature conditions under vibration and shock conditions and in a vacuum and will include leakage testing flow-rate (impedance) determination response times and heat transfer characteristics Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements Extended environment testing will be performed to delineate dominant failure modes				3 2 (Alternate) This test could be eliminated
2 1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL				3 3 System The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility
2 2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items Two test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing Structural testing of the ducting and connections under ambient and high-temperature conditions will be performed Subsystem functional testing will also involve ambient and high-temperature conditions These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems				3 3 (Alternate) This test could be eliminated
2 3 System The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished This test will be accomplished at a				4 RELIABILITY TESTING
				There will be no reliability testing on this item The reliability (probability of no failure) will be determined by material properties and analysis

TEST ITEM WORK SHEET

TEST ITEM NO. 87 HEAT EXCHANGER

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.02.18	A	NA	NA	
36.01.02.24	A	NA	NA	
36.01.04.18	A	NA	NA	
36.01.04.24	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING				system testing. Extended parameter testing on the APS system (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.
No specific testing. Utilize previous design technology, testing and RNS SRT testing on radiation effects.				2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.
2. DEVELOPMENT TESTING				3. QUALIFICATION TESTING
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient, cryogenic, and high-temperature conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, response times and heat transfer characteristics. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic and high-temperature conditions, vibration, shock, and vacuum.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3.1 (Alternate). The above component qualification tests could be performed at the subsystem or the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient, cryogenic, and high temperature conditions will be performed. Subsystem functional testing will also involve ambient, high-temperature, and cryogenic conditions. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.
2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL.				3.2 (Alternate). This test could be eliminated.
				3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.
				3.3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTING
				There will be no reliability testing on this item. The reliability (probability of no failure) will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 88 LH₂ CHECK VALVE
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.03.01	A	NA	NA	
36.01.03.05	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING				
No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.				
2. DEVELOPMENT TESTING				
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				
2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure, high flow				
				rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or an input to the final design modifications to ensure component adequacy and compliance with requirements.
				2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.
				3. QUALIFICATION TESTING
				3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.
				4. RELIABILITY TESTING
				None

TEST ITEM WORK SHEET

TEST ITEM NO. 91 LH₂ STORAGE SPHERE
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01.03.09	A	NA	NA

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to insure component adequacy and compliance with requirements.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem or the system level.

3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

There will be no reliability testing on this item. The reliability (probability of no failure) will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 92 LH₂ CHECK VALVE DISCONNECT
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.03.11	A	NA	NA	modifications to ensure component adequacy and compliance with requirements.
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.
No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions, axial load, shear, bending moment, spring rate and deflection, and structural degradation under radiation influences. Functional testing will be conducted at room temperature and cryogenic temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				3.1 (Alternate). The above component qualification tests could be performed at the subsystem or the system level.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Six test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				3.2 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design.				3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.
				3.3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTING
				There will be no reliability testing on this item. The reliability (probability of no failure) will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 95 GOX CHECK VALVE DISCONNECT
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.04.05	A	NA	NA	<p>modifications to ensure component adequacy and compliance with requirements.</p> <p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem or the system level.</p> <p>3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>There will be no reliability testing on this item. The reliability (probability of no failure) will be determined by material properties and analysis.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions; axial load, shear, bending moment, spring rate and deflection; and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Six test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 96 GOX STORAGE SPHERE
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.04.07	A	NA	NA	<p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (1) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem or the system level.</p> <p>3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTING</p> <p>There will be no reliability testing on this item. The reliability (probability of no failure) will be determined by material properties and analysis.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient cryogenic conditions and structural degradation under radiation fluences. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to insure component adequacy and compliance with requirements.</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 97 GOX CHECK VALVE

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.04.08	A	NA	NA	
36.01.04.09	A	NA	NA	
1. RESEARCH AND TECHNOLOGY TESTING				as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.
No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.				2 3 (Alternate) This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.
2. DEVELOPMENT TESTING				3. QUALIFICATION TESTING
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) tests and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.
2 1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL				4. RELIABILITY TESTING
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				None.
2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve				

TEST ITEM WORK SHEET

TEST ITEM NO. 99 GOX FILTER

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.04.11	A	NA	NA	<p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.</p> <p>4. RELIABILITY TESTS</p> <p>None.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 101 LOX CHECK VALVE
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01.05.01	A	NA	NA
36.01.05.05	A	NA	NA

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a

suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.

4. RELIABILITY TESTING

There is no reliability testing on this item. The probability of failure will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 104 LOX STORAGE SPHERE

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (ARS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36 01 05 09	A	NA	NA	
1 RESEARCH AND TECHNOLOGY TESTING				2 3 (Alternate) This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated
No specific testing Use previous design technology and testing, also RNS SRT testing on radiation effects				3 QUALIFICATION TEST
2 DEVELOPMENT TESTING				3 1 Component Qualification testing will be conducted on a small number (1) of components Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions cryogenic conditions, vibration, shock and vacuum
2 1 Component A small number (2) of components will be subjected to structural testing to obtain design and design verification information These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements Extended environment testing will be performed to delineate dominant failure modes				3 1 (Alternate) The above component qualification tests could be performed at the subsystem or the system level
2 1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL				3 2 Subsystem Structural and functional (nonfiring) qualification test on the complete APS in the PIL
2 2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed Subsystem functional testing will also involve ambient and cryogenic conditions but will not include actual engine firing These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems				3 2 (Alternate) This test could be eliminated
2 3 System The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to insure component adequacy and compliance with requirements				3 3 System The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility
				3 3 (Alternate) This test could be eliminated
				4 RELIABILITY TESTING
				There will be no reliability testing on this item The reliability (probability of no failure) will be determined by material properties and analysis

TEST ITEM WORK SHEET

TEST ITEM NO. 105 GOX CHECK VALVE DISCONNECT

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36 01.05 11	A	NA	NA	modifications to ensure component adequacy and compliance with requirements
1. RESEARCH AND TECHNOLOGY TESTING				2 3 (Alternate) This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem engine system level), or could be eliminated
No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology				3 QUALIFICATION TESTING
2 DEVELOPMENT TESTING				3 1 Component Qualification testing will be conducted on a small number (8) of components Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum
2.1 Component A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions, axial load, shear bending moment, spring rate and deflection, and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements Extended environment testing will be performed to delineate dominant failure modes				3 1 (Alternate). The above component qualification tests could be performed at the subsystem or the system level
2 1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL				3 2 Subsystem Structural and functional (nonfiring) qualification test on the complete APS in the PIL
2 2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Six test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems				3 2 (Alternate). This test could be eliminated
2 3 System The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing Extended parameter testing on the APS system (high pressure, high flow rates, extended pulse duration firing, etc) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design				3 3 System The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility
				3 3 (Alternate) This test could be eliminated
				4 RELIABILITY TESTING
				There will be no reliability testing on this item The reliability (probability of no failure) will be determined by material properties and analysis

TEST ITEM WORK SHEET

TEST ITEM NO. 107 PROPELLANT TANK
SYSTEM STRUCTURES

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
12, 01	NA	NA	NA	
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous research and technology testing from other programs.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. Tests will be conducted on integrally-stiffened panels representing propellant tank walls. Configurations incorporating conventional and modified waffle-rib sections will be investigated to select the most efficient pattern. Axial, shear, and bending moment forces will be applied at room temperature. Tests will be conducted to determine the loads required to cause compressive buckling of spherical segments in the hoop direction. Axial and bending loads will be applied to the spherical segments with and without internal pressure.</p> <p>2.2 Subsystem. Propellant tanks will be subjected to hydrostatic testing with proof and burst pressure under room temperature.</p> <p>2.3 System. None</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. An axial compression test will be conducted on cylinders incorporating the full-scale waffle pattern to verify panel test results and to serve as a quantitative check on waffle-stiffening strength.</p> <p>3.2 Subsystem. The propellant tank will be subjected to hydrostatic testing under proof and burst pressure and room temperature.</p> <p>3.3 System. The propellant tank will be part of the all-system test article which will be tested at NRDS under "hot" firing conditions.</p> <p>4. RELIABILITY TESTING</p> <p>None.</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 108 PROPELLANT TANK

CLASS

SYSTEM STRUCTURES

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
22.01	NA	NA	NA

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous research and technology testing from other programs.

2. DEVELOPMENT TESTING

2.1 Component. Tests will be conducted on integrally-stiffened panels representing propellant tank walls. Configurations incorporating conventional and modified waffle-rib sections will be investigated to select the most efficient pattern. Axial, shear, and bending moment forces will be applied at room temperature. Tests will be conducted to determine the loads required to cause compressive buckling of spherical segments in the hoop direction. Axial and bending loads will be applied to the spherical segments with and without internal pressure.

2.2 Subsystem. Propellant tanks will be subjected to hydrostatic testing with proof and burst pressure under room temperature.

2.3 System. None

3. QUALIFICATION TESTING

3.1 Component. An axial compression test will be conducted on cylinders incorporating the full-scale waffle pattern to verify panel test results and to serve as a quantitative check on waffle-stiffening strength.

3.2 Subsystem. The propellant tank will be subjected to hydrostatic testing under proof and burst pressure and room temperature.

3.3 System. The propellant tank will be part of the all-system test article which will be tested at NRDS under "hot" firing conditions

4. RELIABILITY TESTING

None.

2.1.2 Test Item Work Sheets—Class 1 Hybrid Only

The test items peculiar to the Class 1 Hybrid RNS are treated on the following pages.

TEST ITEM WORK SHEET

TEST ITEM NO. 1 PROPELLANT ISOLATION VALVES
SYSTEM PROPULSION

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.05.01	C	0.965	90
15.05.02	C	0.965	90

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (See Section 4).

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Two additional test items will be mated with the remainder of the LH₂ feed components to form a LH₂ feed subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the propellant module LH₂ tank in a system-level test at NRDS in ESTS-2.

A battleship tank will be used to allow extended parameter testing on the LH₂ fill system (high pressure, high flow, high back-pressure, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The LH₂ fill system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) tests and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (LH₂ fill) level.

3.2 Subsystem. Structural and functional qualification test on the complete LH₂ fill system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTS

All data accumulated in the above test program will be credited to the reliability test program. Data on the Saturn S-IVB prevalue is also applicable (88,701 ambientized hours) and will be factored into the reliability calculations either as a direct substitute for test time or in a Bayesian manner. The remainder of the test time required to demonstrate the reliability (0.965) at a confidence level of 90 percent will be conducted at the component level with approximately 10 components. The total successful test time must be equivalent to 65 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 3 GH₂ PRESSURIZATION VALVE (1/2 IN.)

CLASS 1 HYBRID

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.06.02	B-1	0.988	60
15.06.03	B-1	0.988	60
25.06.02	B-3	0.988	80
25.06.03	B-3	0.988	80

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Four additional test items will be mated with the remainder of the pressurization components to form a pressurization subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2. Battleship tanks will be used to allow extended parameter testing on the flight vent system (high pressure, low pressure, high flow, low flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The pressurization system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (pressurization) level.

3.2 Subsystem. Structural and functional qualification test on the complete pressurization system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ on the all-systems test under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

All of the test data accumulated in the above program will be credited to the reliability test program. Applicable test data from the Saturn S-IVB program will also be used. S-IVB data on the pressurization control module and the repressurization control module total 35,578 and 8,912 ambient hours, respectively. The remainder of the test time required to verify the reliability allocation statistically (0.988) at the required confidence level (60 percent) will be performed with 10 components. The total successful test time must be equivalent to 75 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 4 GH_2 PRESSURIZATION VALVE (1-1/4 IN)

CLASS 1 HYBRID

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15 06 04	B 1	0 988	60	Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The pressurization system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under hot NERVA firings.
1 RESEARCH AND TECHNOLOGY TESTING				2 3 (Alternate) This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.
No specific testing. Use previous design technology and testing also RNS SRT testing on radiation effects and long-life technology.				
2 DEVELOPMENT TESTING				3 QUALIFICATION TESTING
2 1 Component A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				3 1 Component Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.
2 1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL.				3 1 (Alternate) The above component qualification tests could be performed at the subsystem (pressurization) level.
2 2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Four additional test items will be mated with the remainder of the pressurization components to form a pressurization subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.				3 2 Subsystem Structural and functional qualification test on the complete pressurization system in the PIL.
2 3 System The test item will be integrated with the remainder of the propulsion system and the appropriate LH_2 tankage in a system-level test at NRDS in ESTS-2 Battleship tanks will be used to allow extended parameter testing on the flight vent system (high pressure, low pressure, high flow, low flow, high impedance, etc.).				3 2 (Alternate) This test could be eliminated.
				3 3 System The final functional qualification of the complete propulsion system is accomplished with flight-weight LH_2 on the all-systems test under "hot" NERVA firing.
				3 3 (Alternate) This test could be eliminated.
				4 RELIABILITY TESTS
				All of the test data accumulated in the above program will be credited to the reliability test program. Applicable test data from the Saturn S-IVB program will also be used. S-IVB data on the pressurization control module and the repressurization control module total 35,578 and 8,912 ambient hours, respectively. The remainder of the test time required to verify the reliability allocation statistically (0.988) at the required confidence level (60 percent) will be performed with 10 components. The total successful test time must be equivalent to 75 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 6 PRESSURE SWITCH ASSEMBLY (3)
SYSTEM PROPULSION

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.06.07	C	0.99 each	90
25.06.06	C	0.99 each	90

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Six test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished. Six test items will be installed in the PIL for integrated testing with the remainder of the pressurization system.

2.2 (Alternate) This testing could be conducted at the system level

2.3 System. The test item will be integrated with the remainder of the propulsion system in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor

3.2 Subsystem. Functional subsystem qualification testing will be conducted on six units in the PIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the propulsion system, the astronics system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The pressure switches will be required to control the operation of the pressurization system during a simulated lunar mission under cold-flow and 'hot' firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 7 GH₂ GROUND PRESSURIZATION VALVE
SYSTEM PROPULSION

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.06.08	B-1G	N/A	N/A
26.01.09	B-3	N/A	N/A

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also, and RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional test item will be mated with the remainder of the ground pressurization components to form a ground pressurization subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the ground

pressurization system (high pressure, high flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The ground pressurization system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.

3. QUALIFICATION TEST

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (ground pressurization) level.

3.2 Subsystem. Structural and functional qualification test on the complete ground pressurization system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on all the systems tested under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTS

There will be no reliability testing on this test item. The test item is only used prior to Earth launch. The only failure mode applicable to space operations is the leak mode. The probability of occurrence of this failure mode will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO 8 CH₂ GROUND FILL DISCONNECT
SYSTEM PROPULSION

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15 06 10	B-1	N/A	N/A	an input to the final design modifications to ensure component adequacy and compliance with requirements. The pressurization system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot NERVA firings
1 RESEARCH AND TECHNOLOGY TESTING				2 3 (Alternate) This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated
No specific testing Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology				
2 DEVELOPMENT TESTING				3 QUALIFICATION TESTING
2 1 Component A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions, axial load, shear, bending moment, spring rate and deflection, and structural degradation under radiation fluences. Functional (flow) testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				3 1 Component Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure, axial load, shear, bending moment, spring rate and deflection) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.
2 1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL.				3 1 (Alternate) The above component qualification tests could be performed at the subsystem pressurization level.
2 2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items. A test item will be mated with the remainder of the pressurization components to form a pressurization subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.				3 2 Subsystem Structural and functional qualification test on the complete pressurization system in the PIL.
2 3 System The test item will be integrated with the remainder of the propulsion system and the propellant module LH ₂ tank in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the LH ₂ feed system (high pressure, high flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design verification or as				3 2 (Alternate) This test could be eliminated.
				3 3 System The final functional qualification of the complete propulsion system is accomplished with flight-weight LH ₂ tanks on the all-systems test under "hot NERVA firing.
				3 3 (Alternate) This test could be eliminated.
				4 RELIABILITY TESTS
				There will be no reliability test program on this test item. The reliability (probability of no failure) will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 11 PROPELLANT FILL QUAD VALVE ASSEMBLY

CLASS 1 HYBRID

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.09.04	C	0.988 each	90
25.09.09	C	0.988 each	90

1. RESEARCH AND TECHNOLOGY TESTING

This test item is a part of the zero-g flight LH₂ transfer system that requires a research and technology flight test to develop and verify techniques to accomplish propellant transfer under zero-g conditions. Data from the RNS SRT testing on radiation effects and long-life technology will also be used.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional four test items will be mated with the remainder of the flight LH₂ transfer components to form a LH₂ transfer subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2. Battleship tanks will be used to allow extended parameter testing on the flight LH₂ transfer system (high pressure, low pressure, high flow, low flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The flight LH₂ transfer system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (flight transfer) level.

3.2 Subsystem. Structural and functional qualification test on the complete flight LH₂ transfer system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

All test data accumulated in the above test program will be credited to the reliability test program. Applicable test data from the Saturn S-IVB program will also be used. S-IVB test data on the chilldown shutoff valves resulted from a total 60,926 ambientized test hours. The remainder of the test time required to verify the reliability statistically (0.988) at the required confidence level (90 percent) will be performed with 20 components. The total successful test time must be equivalent to 190 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 14 LH₂ GROUND FILL VALVE
SYSTEM PROPULSION

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15.09.07	B-1G	N/A	N/A	
1. RESEARCH AND TECHNOLOGY TESTING				to ensure component adequacy and compliance with requirements. The ground fill system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.
No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.				
2. DEVELOPMENT TESTING				2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).				3. QUALIFICATION TESTING
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electro-mechanical and ground pneumatic interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional test item will be mated with the remainder of the ground fill components to form a ground fill subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.				3.1 (Alternate). The above component qualification tests could be performed at the subsystem (ground fill) level.
2.3 System. The test item will be integrated with the remainder of the propulsion system and the propellant module LH ₂ tank in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the ground fill system (high pressure, high flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications				3.2 Subsystem. Structural and functional qualification test on the complete ground fill system in the PIL.
				3.2 (Alternate). This test could be eliminated.
				3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH ₂ tanks on the all-systems test under "hot" NERVA firing.
				3 3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTING
				There will be no reliability test program on this test item. This valve is only used on the ground prior to Earth launch. The only failure mode applicable to flight operations is the leak mode. The probability of occurrence of this failure mode will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 15 GROUND FILL DISCONNECT

CLASS 1 HYBRID

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15.09.08	B-1	N/A	N/A	an input to the final design modifications to ensure component adequacy and compliance with requirements. The LH ₂ fill system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.
No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.				3 QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural testing (proof and burst pressure, axial load, shear, bending moment, spring rate and deflection) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions, axial load, shear, bending moment, spring rate and deflection, and structural degradation under radiation fluences. Functional (flow) testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing and flow-rate (impedance) determination. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				3.1 (Alternate). The above component qualification tests could be performed at the subsystem (LH ₂ fill) level.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3.2 Subsystem. Structural and functional qualification test on the complete LH ₂ fill in the PIL
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. A test item will be mated with the remainder of the LH ₂ components to form a LH ₂ fill subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems				3.2 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the propulsion system and the propellant module LH ₂ tank in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the LH ₂ feed system (high pressure, high flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design verification or as				3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH ₂ tanks on the all-systems test under "hot" NERVA firing.
				3.3 (Alternate). This test could be eliminated
				4. RELIABILITY TESTS
				There will be no reliability test program on this test item. The reliability (probability of no failure) will be determined by material properties and analysis.

TEST ITEM WORK SHEET

TEST ITEM NO. 19 GH₂ FLIGHT VENT QUAD VALVE ASSEMBLY

CLASS 1 HYBRID

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.11.02	B-1	0.988 each	60
25.11.02	B-3	0.988 each	80

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).

2.1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional four test items will be mated with the remainder of the flight vent components to form a flight vent subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2.

A battleship tank will be used to allow extended parameter testing on the flight vent system (high pressure, high flow, high back-pressure, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The flight vent system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (flight vent) level.

3.2 Subsystem. Structural and functional qualification test on the complete flight vent system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

All of the test data developed in the above test program will be credited to the reliability test program. The remainder of the test required to verify the reliability allocation (0.988) at the required confidence level (80 percent) will be conducted with 15 components. A total of successful testing equivalent to 140 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 27 LIQUID LEVEL SENSOR (3)

CLASS 1 HYBRID

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
25.09.13	C	0.99 each	90	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
2. DEVELOPMENT TESTING 2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions. 2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer. 2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Three test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished. Three units will be installed in the PIL for integrated testing with the remainder of the propellant fill system. 2.2 (Alternate). This testing could be conducted at the system level. 2.3 System. The test item will be integrated with the remainder of the propulsion system in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				3. QUALIFICATION TEST 3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions. 3.1 (Alternate) The entire component qualification could be accomplished by the component contractor. 3.2 Subsystem. Functional subsystem qualification testing will be conducted on three units in the PIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions. 3.2 (Alternate). The above test could be conducted at the system level. 3.3 System. The test item will be integrated with the remainder of the propulsion system, the astrionics system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The level sensors will be required to control the operation of the fill system during a simulated lunar mission under cold-flow and "hot" firing conditions. 3.3 (Alternate). This test could be eliminated.
4. RELIABILITY TESTING The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.				

TEST ITEM WORK SHEET

TEST ITEM NO. 32 GYRO ASSEMBLY

CLASS 1 HYBRID

SYSTEM NAVIGATION, GUIDANCE, AND CONTROL

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
37.01.01	A	0.995	50
37.01.02	A	0.995	50
37.01.03	A	0.995	50
37.01.04	A	0.995	50
37.01.05	A	0.995	50
37.01.06	A	0.995	50
37.01.07	A	0.995	50
37.01.08	A	0.995	50
37.01.09	A	0.995	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subject to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level

test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate) The entire component qualification could be accomplished by the component contractor.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

Reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 33 POWER SUPPLY AND REGULATOR
SYSTEM NAVIGATION, GUIDANCE, AND CONTROL

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.01.10	A	0.98	50	
37.01.11	A	0.98	50	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electro-mechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 34 REVERSE CURRENT RELAY

CLASS 1 HYBRID

SYSTEM ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
37.01.12	A	0.987	50
37.01.13	A	0.987	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2. Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 47 FUEL CELL

CLASS 1 HYBRID

SYSTEM

ASTRIONICS ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
37.04.05	A	0.96	50
37.04.08	A	0.96	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor

3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level

3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program

TEST ITEM WORK SHEET

TEST ITEM NO. 52 INVERTER ASSEMBLY
SYSTEM ELECTRICAL POWER

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	3. QUALIFICATION TESTING
04. 15	A	0.98	50	3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
04. 16	A	0.98	50	3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
1. RESEARCH AND TECHNOLOGY TESTING				3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3.2 (Alternate). The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions. This test item will be used to provide ac electrical power to the test facility.
2. DEVELOPMENT TESTING				3.3 (Alternate). This test could be eliminated.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				4. RELIABILITY TESTING
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				The reliability testing on the above item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electro-mechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				
2.2 (Alternate). This testing could be conducted at the system level.				
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full scale stage operation. This test item will be used to provide AC electrical power to the test article. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				
2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.				

TEST ITEM WORK SHEET

TEST ITEM NO. 53 INVERTER CONTROL RELAY

CLASS 1 HYBRID

SYSTEM ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.15	A	0.98	50	
37.04.16	A	0.98	50	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate) This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 70 DIGITAL COMPUTER
SYSTEM DATA MANAGEMENT

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
37.09.01	A	0.98	50
37.09.02	A	0.98	50
37.09.03	A	0.98	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Three test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 77 GH₂ PRESSURE REGULATOR
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01 02.01	A	0 99	50
36.01.02 02	A	0 99	50

1 RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, pressure regulation performance, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the APS components to form an APS system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a

suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to insure component adequacy and compliance with requirements.

2.3 (Alternate) This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels, or could be eliminated.

3 QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, pressure regulation, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate) The above component qualification tests could be performed at the subsystem or the system level.

3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.

3.3 (Alternate) This test could be eliminated.

4. RELIABILITY TESTING

A reliability test program will be conducted on this item. A total of 10 test items will be used in a test program to verify the reliability allocation (0.99) at the required confidence level (50 percent). A total of 70 successful equivalent lunar missions is required. Data from the regular test program (above) will be used in the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 78 GH₂ SHUTOFF VALVE

CLASS 1 HYBRID

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.02.03	A	0.99	50	<p>cryogen conditions will be performed. Subsystem functional testing will also involve ambient, high-temperature, and cryogenic conditions but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to insure component adequacy and compliance with requirements.</p> <p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc) or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage flow, response) will be conducted under ambient conditions, high-temperature conditions vibration, shock, and vacuum.</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem (APS engine subsystem) or the system level.</p> <p>3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4 RELIABILITY TESTING</p> <p>A reliability test program will be conducted on this test item. A total of 10 test components will be used in a program to verify the reliability allocation (0.99) of the required confidence level (50 percent). A total of 70 successful equivalent lunar missions is required. Data accumulated in the regular test program will be used in the reliability test program.</p>
36.01.02.04	A	0.99	50	
36.01.02.06	A	0.99	50	
36.01.02.13	A	0.99	50	
36.01.02.14	A	0.99	50	
36.01.02.19	A	0.99	50	
36.01.02.20	A	0.99	50	
36.01.02.25	A	0.99	50	
36.01.02.26	A	0.99	50	
36.01.04.15	A	0.99	50	
36.01.04.21	A	0.99	50	
1 RESEARCH AND TECHNOLOGY TESTING				
No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.				
2. DEVELOPMENT TESTING				
2.1 Component. A small number (4) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient, cryogenic and high-temperature conditions and structural degradation under radiation fluences. Functional testing will be conducted at room, cryogenic, and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Fourteen test items will be installed in the SIL for the electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional fourteen test items will be mated with the remainder of the APS components to form an APS system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient, high-temperature, and				

TEST ITEM WORK SHEET

TEST ITEM NO. 82 GH₂ RELIEF VALVE

CLASS 1 HYBRID

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01.02.10	A	0.9999	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room and cryogenic temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination and crack and reseal pressure settings. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Six test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient, high-temperature, and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient, high-temperature, and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure with planned relief valve operation, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification

or as an input to the final design modifications to ensure component adequacy and compliance with requirements.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response, crack, and reseal pressure) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem or the system level.

3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

There will only be a partial reliability verification on this test item. The number of equivalent lunar missions required (7,000) precludes a full reliability verification program. The reliability (probability of no failure) will be determined by material properties analysis and results of previous testing on relief valves. (Saturn S-IVB testing on the LH₂ relief valve totaled 103,086 ambitized hours.) A small reliability test program using Bayes techniques will then be employed.

TEST ITEM WORK SHEET

TEST ITEM NO. 84 CH₂ PRESSURIZATION QUAD VALVES
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.02.12	A	0.9946 each	50	<p>Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements</p> <p>2.3 (Alternate) This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum</p> <p>4. RELIABILITY TESTING</p> <p>All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.9946) at the required confidence level (50 percent) will be performed with 10 components. The total successful test time must be equivalent to 130 lunar missions.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Four additional test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing.</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 89 LH₂ TURBOPUMP

CLASS 1 HYBRID

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.03.02	A	0.99	50	duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.
36.01.03.06	A	0.99	50	2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine] system level), or could be eliminated
1. RESEARCH AND TECHNOLOGY TESTING				3. QUALIFICATION TESTING
No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.				3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.
2. DEVELOPMENT TESTING				4. RELIABILITY TESTING
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage, pressure rise, NPSH, efficiency turbine and pump flow rate, and dynamic performance testing. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.99) at the required confidence level (50 percent) will be performed with 5 components. The total successful test time must be equivalent to 70 lunar missions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				
2.2 Subsystem. Subsystem testing will be conducted on the test item in conjunction with other test items. Four test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				
2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse				

TEST ITEM WORK SHEET

TEST ITEM NO. 90 GH₂ SHUTOFF VALVE

CLASS 1 HYBRID

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01.03.03	A	0.99	50
36.01.03.04	A	0.99	50
36.01.03.07	A	0.99	50
36.01.03.08	A	0.99	50
36.01.03.10	A	0.99	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Five test items will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Five additional test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.

4. RELIABILITY TESTING

All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.99) at the required confidence level (50 percent) will be performed with 7 components. The total successful test time must be equivalent to 70 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 93 GH₂ VENT/RELIEF QUAD VALVES

CLASS 1 HYBRID

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36. 01. 03. 12	A	0. 9946 each	50	
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific. Use previous design technology and testing; also RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2. 1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2. 1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2. 2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Four additional test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.</p>				<p>2. 3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.</p> <p>2. 3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3. 1 Component. Qualification testing will be conducted on a small (8) number of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock and vacuum.</p> <p>4. RELIABILITY TESTS</p> <p>All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0. 9946) at the required confidence level (50 percent) will be performed with 10 components. The total successful test time must be equivalent to 130 lunar missions.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 94 GOX PRESSURE REGULATOR

CLASS 1 HYBRID

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.04.01	A	0.99	50	
36.01.04.02	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING				
No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.				
2. DEVELOPMENT TESTING				
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, pressure regulation performance, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the APS components to form an APS system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				
2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a				
				<p>suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.</p> <p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels, or could be eliminated.</p>
3. QUALIFICATION TESTING				
3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, pressure regulation, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.				
3.1 (Alternate). The above component qualification tests could be performed at the subsystem or the system level.				
3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.				
3.2 (Alternate). This test could be eliminated.				
3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.				
3.3 (Alternate). This test could be eliminated.				
4. RELIABILITY TESTING				
A reliability test program will be conducted on this item. A total of 10 test items will be used in a test program to verify the reliability allocation (0.99) at the required confidence level (50 percent). A total of 70 successful equivalent lunar missions is required. Data from the regular test program (above) will be used in the reliability test program.				

TEST ITEM WORK SHEET

TEST ITEM NO. 98 GOX RELIEF VALVE
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01 04 10	A	0 9999	50	or as an input to the final design modifications to ensure component adequacy and compliance with requirements
1 RESEARCH AND TECHNOLOGY TESTING				2 3 (Alternate) This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc) or could be conducted at other levels, or could be eliminated
No specific testing Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology				3 QUALIFICATION TESTING
2 DEVELOPMENT TESTING				3 1 Component Qualification testing will be conducted on a small number (2) of components Structural tests (proof and burst pressure) and functional tests (leakage, flow, response, crack, and reseal pressure) will be conducted under ambient conditions, cryogenic conditions, vibration, shock and vacuum
2.1 Component A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences Functional testing will be conducted at room and cryogenic temperature conditions under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination and crack and reseal pressure settings Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements Extended environment testing will be performed to delineate dominant failure modes				3 1 (Alternate) The above component qualification tests could be performed at the subsystem or the system level
2.1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL.				3 2 Subsystem Structural and functional (nonfiring) qualification test on the complete APS system in the PIL
2.2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items Six test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing Structural testing of the ducting and connections under ambient, high-temperature, and cryogenic conditions will be performed Subsystem functional testing will also involve ambient, high-temperature, and cryogenic conditions, but will not include actual engine firing These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems				3 2 (Alternate) This test could be eliminated
2 3 System The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing Extended parameter testing on the APS system (high pressure with planned relief valve operation, high flow rates, extended pulse duration firing, etc) will be employed to delineate possible failure modes and to serve as a final design verification				3 3 System The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility
				3 3 (Alternate) This test could be eliminated
				4 RELIABILITY TESTING
				There will only be a partial reliability verification on this test item The number of equivalent lunar missions required (7,000) precludes a full reliability verification program The reliability (probability of no failure) will be determined by material properties analysis and results of previous testing on relief valves (Saturn S-IVB testing on the LH ₂ relief valve totaled 103,086 ambient hours) A small reliability test program using Bayes techniques will then be employed

TEST ITEM WORK SHEET

TEST ITEM NO. 102 LOX TURBOPUMP

CLASS 1 HYBRID

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.05.02	A	0.99	50	
36.01.05.06	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING				Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.
No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects and long-life technology.				2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.
2. DEVELOPMENT TESTING				3. QUALIFICATION TESTING
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage, pressure rise, NPSH, efficiency, turbine and flow rate, and dynamic performance testing. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				4. RELIABILITY TESTS
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide information on possible structural or functional interface problems.				All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.99) at the required confidence level (50 percent) will be performed with five components. The total successful test time must be equivalent to 70 lunar missions.
2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing.				

TEST ITEM WORK SHEET

TEST ITEM NO. 103 LOX SHUTOFF VALVE

CLASS 1 HYBRID

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01.05.03	A	0.99	50
36.01.05.04	A	0.99	50
36.01.05.07	A	0.99	50
36.01.05.08	A	0.99	50
36.01.05.10	A	0.99	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Five test items will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Five additional test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem engine system level), or could be eliminated

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.

4. RELIABILITY TESTS

All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.99) at the required confidence level (50 percent) will be performed with 7 components. The total successful test time must be equivalent to 70 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 106 GOX VENT/RELIEF QUAD VALVES
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 1 HYBRID

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.05.12	A	0.9946 each	50	<p>engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.</p> <p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small (2) number of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.</p> <p>4. RELIABILITY TESTS</p> <p>All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.9946) at the required confidence level (50 percent) will be performed with 10 components. The total successful test time must be equivalent to 130 lunar missions.</p>
<p>1. RESEARCH AND TECHNOLOGY</p> <p>No specific. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Four additional test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual</p>				

2.1.3 Test Item Work Sheets—Class 3 Only

The test items peculiar to the Class 3 RNS are treated on the following pages.

TEST ITEM WORK SHEET

TEST ITEM NO. 1 PROPELLANT ISOLATION VALVES

CLASS 3

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.05.01	C	0.979	90
15.05.02	C	0.979	90
15.05.05	C	0.979	90

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (See Section 4).

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Two additional test items will be mated with the remainder of the LH₂ feed components to form a LH₂ feed subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the propellant module LH₂ tank in a system-level test at NRDS in ESTS-2.

A battleship tank will be used to allow extended parameter testing on the LH₂ fill system (high pressure, high flow, high back-pressure, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The LH₂ fill system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) tests and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (LH₂ fill) level.

3.2 Subsystem. Structural and functional qualification test on the complete LH₂ fill system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTS

All data accumulated in the above test program will be credited to the reliability test program. Data on the Saturn S-IVB prevalue is also applicable (88,701 ambientized hours) and will be factored into the reliability calculations either as a direct substitute for test time or in a Bayesian manner. The remainder of the test time required to demonstrate the reliability (0.979) at a confidence level of 90 percent will be conducted at the component level with approximately 10 components. The total successful test time must be equivalent to 110 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 3 GH₂ PRESSURIZATION VALVE (1/2 IN.)

CLASS 3

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.06.02	B-1	0.992	60
15.06.03	B-1	0.992	60
25.06.02	B-3	0.992	80
25.06.03	B-3	0.992	80

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Four additional test items will be mated with the remainder of the pressurization components to form a pressurization subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2. Battleship tanks will be used to allow extended parameter testing on the flight vent system (high pressure, low pressure, high flow, low flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The pressurization system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (pressurization) level.

3.2 Subsystem. Structural and functional qualification test on the complete pressurization system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ on the all-systems test under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

All of the test data accumulated in the above program will be credited to the reliability test program. Applicable test data from the Saturn S-IVB program will also be used. S-IVB data on the pressurization control module and the repressurization control module total 35,578 and 8,912 ambitized hours, respectively. The remainder of the test time required to verify the reliability allocation statistically (0.992) at the required confidence level (60 percent) will be performed with 10 components. The total successful test time must be equivalent to 110 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 6 PRESSURE SWITCH ASSEMBLY (3)

CLASS 3

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
15.06.07	C	0.993 each	90	
25.06.06	C	0.993 each	90	
1. RESEARCH AND TECHNOLOGY TESTING				2,3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on six units in the PIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Six test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished. Six test items will be installed in the PIL for integrated testing with the remainder of the pressurization system.				3.3 System. The test item will be integrated with the remainder of the propulsion system, the astrionics system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The pressure switches will be required to control the operation of the pressurization system during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the propulsion system in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 7 GH_2 GROUND PRESSURIZATION VALVE
SYSTEM PROPULSION

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
26.01.09	B-3	N/A	N/A	<p>pressurization system (high pressure, high flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The ground pressurization system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.</p>
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing, also, and RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. One test item will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional test item will be mated with the remainder of the ground pressurization components to form a ground pressurization subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH_2 tankage in a system-level test at NRDS in ESTS-2. A battleship tank will be used to allow extended parameter testing on the ground</p>				<p>2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated</p> <p>3. QUALIFICATION TEST</p> <p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem (ground pressurization) level.</p> <p>3.2 Subsystem. Structural and functional qualification test on the complete ground pressurization system in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH_2 tanks on all the systems tested under "hot" NERVA firing.</p> <p>3.3 (Alternate). This test could be eliminated.</p> <p>4. RELIABILITY TESTS</p> <p>There will be no reliability testing on this test item. The test item is only used prior to Earth launch. The only failure mode applicable to space operations is the leak mode. The probability of occurrence of this failure mode will be determined by material properties and analysis.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 11 PROPELLANT FILL QUAD VALVE ASSEMBLY

CLASS 3

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15.09 04	C	0.992 each	90
25.09.09	C	0.992 each	90

1. RESEARCH AND TECHNOLOGY TESTING

This test item is a part of the zero-g flight LH₂ transfer system that requires a research and technology flight test to develop and verify techniques to accomplish propellant transfer under zero-g conditions. Data from the RNS SRT testing on radiation effects and long-life technology will also be used.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature, cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional four test items will be mated with the remainder of the flight LH₂ transfer components to form a LH₂ transfer subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2. Battleship tanks will be used to allow extended parameter testing on the flight LH₂ transfer system (high pressure, low pressure, high flow, low flow, high impedance, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The flight LH₂ transfer system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under "hot" NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (flight transfer) level.

3.2 Subsystem. Structural and functional qualification test on the complete flight LH₂ transfer system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

All test data accumulated in the above test program will be credited to the reliability test program. Applicable test data from the Saturn S-IVB program will also be used. S-IVB test data on the chutdown shutoff valves resulted from a total 60,926 ambientized test hours. The remainder of the test time required to verify the reliability statistically (0.992) at the required confidence level (90 percent) will be performed with 30 components. The total successful test time must be equivalent to 280 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 19 GH₂ FLIGHT VENT QUAD VALVE ASSEMBLY

CLASS 3

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
15. 11. 02	B-1	0.992 each	60
25. 11. 02	B-3	0.992 each	80

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes (see section 4).

2.1 (Alternate) The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional four test items will be mated with the remainder of the flight vent components to form a flight vent subsystem to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions. These data are required to verify that the component design is compatible with the required subsystem design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the propulsion system and the appropriate LH₂ tankage in a system-level test at NRDS in ESTS-2

A battleship tank will be used to allow extended parameter testing on the flight vent system (high pressure, high flow, high back-pressure, etc.). Data from this test will be used as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements. The flight vent system will be subjected to a full range of testing under cold-flow conditions and then subjected to functional verification under 'hot' NERVA firings.

2.3 (Alternate). This level of testing could be conducted under cold-flow conditions at other test sites (MTF, KSC), or could be conducted at more than one site (propulsion module cold-flow testing at Sacto, MTF, KSC, MSFC, propellant module at MTF, KSC), or could be conducted partially at two sites (cold-flow testing at MTF, hot firings at NRDS), or could be limited to cold-flow testing or be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (flight vent) level.

3.2 Subsystem. Structural and functional qualification test on the complete flight vent system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete propulsion system is accomplished with flight-weight LH₂ tanks on the all-systems test under "hot" NERVA firing.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

All of the test data developed in the above test program will be credited to the reliability test program. The remainder of the test required to verify the reliability allocation (0.992) at the required confidence level (80 percent) will be conducted with 20 components. A total of successful testing equivalent to 200 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 27 LIQUID LEVEL SENSOR (3)

CLASS 3

SYSTEM PROPULSION

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
25.09.13	C	0.993 each	90	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
2. DEVELOPMENT TESTING 2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions. 2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer. 2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Three test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished. Three units will be installed in the PIL for integrated testing with the remainder of the propellant fill system. 2.2 (Alternate). This testing could be conducted at the system level. 2.3 System. The test item will be integrated with the remainder of the propulsion system in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				3. QUALIFICATION TEST 3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions. 3.1 (Alternate). The entire component qualification could be accomplished by the component contractor 3.2 Subsystem. Functional subsystem qualification testing will be conducted on three units in the PIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions. 3.2 (Alternate) The above test could be conducted at the system level 3.3 System. The test item will be integrated with the remainder of the propulsion system, the astronics system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The level sensors will be required to control the operation of the fill system during a simulated lunar mission under cold-flow and "hot" firing conditions 3.3 (Alternate). This test could be eliminated
4. RELIABILITY TESTING The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.				

TEST ITEM WORK SHEET

TEST ITEM NO. 32 GYRO ASSEMBLY

CLASS 3

SYSTEM NAVIGATION, GUIDANCE, AND CONTROL

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
37.01.01	A	0.996	50
37.01.02	A	0.996	50
37.01.03	A	0.996	50
37.01.04	A	0.996	50
37.01.05	A	0.996	50
37.01.06	A	0.996	50
37.01.07	A	0.996	50
37.01.08	A	0.996	50
37.01.09	A	0.996	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subject to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level

test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

Reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 33 POWER SUPPLY AND REGULATOR
SYSTEM NAVIGATION, GUIDANCE, AND CONTROL

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
37.01.10	A	0.99	50
37.01.11	A	0.99	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.

2. DEVELOPMENT TESTING

2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.

Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.

2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electro-mechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.

2.2 (Alternate). This testing could be conducted at the system level.

2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 34 REVERSE CURRENT RELAY

CLASS 3

SYSTEM ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
37.01.12	A	0.99	50
37.01.13	A	0.99	50
1. RESEARCH AND TECHNOLOGY TESTING			
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.			
2. DEVELOPMENT TESTING			
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.			
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.			
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.			
2.2. Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.			
2.2 (Alternate). This testing could be conducted at the system level.			
2.3 System. The test item will be integrated with the remainder of the astronics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.			

2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.

3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.

3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.

3.2 (Alternate). The above test could be conducted at the system level.

3.3 System. The test item will be integrated with the remainder of the astronics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astronics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 47 FUEL CELL

CLASS 3

SYSTEM ASTRIONICS ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.05	A	0.98	50	
37.04.08	A	0.98	50	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions				3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3 3 System The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4 RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 52 INVERTER ASSEMBLY
SYSTEM ELECTRICAL POWER

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	3. QUALIFICATION TESTING
37.04.15	A	0.99	50	3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
37.04.16	A	0.99	50	
1. RESEARCH AND TECHNOLOGY TESTING				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				
2. DEVELOPMENT TESTING				3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The test item will be integrated with the remainder of the astronautics system, the propulsion system and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astronautics will be required to control the operation of the test during a simulated lunar mission under cold-flow and 'hot' firing conditions. This test item will be used to provide ac electrical power to the test facility
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Nine test items will be installed in the SIL for electro-mechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astronautics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full scale stage operation. This test item will be used to provide AC electrical power to the test article. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				
2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.				4. RELIABILITY TESTING
				The reliability testing on the above item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 53 INVERTER CONTROL RELAY

CLASS 3

SYSTEM ELECTRICAL POWER

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.04.17	A	0.999	50	
37.04.18	A	0.999	50	
1. RESEARCH AND TECHNOLOGY TESTING No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				2.3 (Alternate) This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
2. DEVELOPMENT TESTING 2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors. Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3. QUALIFICATION TESTING 3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on two units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.2 (Alternate). The above test could be conducted at the system level.
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system, and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
				3.3 (Alternate). This test could be eliminated.
				4. RELIABILITY TESTING The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 70 DIGITAL COMPUTER
SYSTEM DATA MANAGEMENT

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
37.09.01	A	0.985	50	
37.09.02	A	0.985	50	
37.09.03	A	0.985	50	
1. RESEARCH AND TECHNOLOGY TESTING				2.3 (Alternate). This test could be conducted under cold-flow conditions at other test sites (MTF, KSC) or could be conducted at more than one test site, or could be eliminated.
No specific testing. These units will be designed and developed by outside contractors, therefore the research and technology testing will be conducted outside the scope of this test plan. The research and technology testing, however, must include radiation effects and long-life technology testing.				3. QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3.1 Component. It is assumed that the test item will be provided by other contractors and therefore the component qualification testing will be accomplished by the component contractor. Qualification testing will be accomplished on the installation under vibration and shock conditions.
2.1 Component. It is assumed that this test item will be provided as developed hardware and that the component development testing will be performed by other contractors.				3.1 (Alternate). The entire component qualification could be accomplished by the component contractor.
Development testing by the RNS contractor will be limited to installation aspects including structural testing under vibration and shock conditions.				3.2 Subsystem. Functional subsystem qualification testing will be conducted on nine units in the SIL. The units will be subjected to normal and extended electrical parameters to demonstrate adequate performance under normal and malfunction conditions.
2.1 (Alternate). The above component testing could be conducted at the subsystem level or could be conducted by the component manufacturer.				3.2 (Alternate). The above test could be conducted at the system level.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Three test items will be installed in the SIL for electromechanical interface and functional testing. Circuit and component redundancy will be investigated, effects of electrical loading and supply voltage variations will be examined, and the test item will be subjected to normal operating parameters, extended parameter operation, and malfunction operations. Normal operating limits for proper subsystem operation will be determined. Electromagnetic interference testing will be accomplished.				3.3 System. The test item will be integrated with the remainder of the astrionics system, the propulsion system and the remainder of the appropriate RNS systems in an all-system test in ESTS-2 at NRDS to demonstrate system performance under conditions as close to an actual flight test as possible. The astrionics will be required to control the operation of the test during a simulated lunar mission under cold-flow and "hot" firing conditions.
2.2 (Alternate). This testing could be conducted at the system level.				3.3 (Alternate). This test could be eliminated.
2.3 System. The test item will be integrated with the remainder of the astrionics system and appropriate portions of the command and control module in a system-level test in ESTS-2 at NRDS. This test will be part of the Battleship Test Program and will provide design verification and/or redesign information on the operation of the test item in full-scale stage operation. Cold-flow and "hot" NERVA engine firings will be accomplished to delineate possible design problems in the vibration, acoustic, radiation, and electromagnetic environment.				4. RELIABILITY TESTING
				The reliability testing on this item will be conducted by the supplier. The results of the above test program will be credited to the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 77 GH₂ PRESSURE REGULATOR

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.02.01	A	0.993	50	
36.01.02.02	A	0.993	50	
1. RESEARCH AND TECHNOLOGY TESTING				<p>suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to insure component adequacy and compliance with requirements.</p> <p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels, or could be eliminated.</p>
2. DEVELOPMENT TESTING				3. QUALIFICATION TESTING
<p>No specific testing. Use previous design technology and testing; also, RNS SRT testing on radiation effects and long-life technology.</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, pressure regulation performance, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the APS components to form an APS system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a</p>				<p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, pressure regulation, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem or the system level.</p> <p>3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.</p> <p>3.3 (Alternate). This test could be eliminated.</p>
4. RELIABILITY TESTING				<p>A reliability test program will be conducted on this item. A total of 10 test items will be used in a test program to verify the reliability allocation (0.993) at the required confidence level (50 percent). A total of 100 successful equivalent lunar missions is required. Data from the regular test program (above) will be used in the reliability test program.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 78 CH₂ SHUTOFF VALVE

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01.02.03	A	0.993	50
36.01.02.04	A	0.993	50
36.01.02.06	A	0.993	50
36.01.02.13	A	0.993	50
36.01.02.14	A	0.993	50
36.01.02.19	A	0.993	50
36.01.02.20	A	0.993	50
36.01.02.25	A	0.993	50
36.01.02.26	A	0.993	50
36.01.04.15	A	0.993	50
36.01.04.21	A	0.993	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (4) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient, cryogenic, and high-temperature conditions and structural degradation under radiation fluences. Functional testing will be conducted at room, cryogenic, and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Fourteen test items will be installed in the SIL for the electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. An additional fourteen test items will be mated with the remainder of the APS components to form an APS system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient, high-temperature, and

cryogen conditions will be performed. Subsystem functional testing will also involve ambient, high-temperature, and cryogenic conditions but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to insure component adequacy and compliance with requirements.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem (APS engine subsystem) or the system level.

3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

A reliability test program will be conducted on this test item. A total of 10 test components will be used in a program to verify the reliability allocation (0.993) of the required confidence level (50 percent). A total of 100 successful equivalent lunar missions is required. Data accumulated in the regular test program will be used in the reliability test program.

TEST ITEM WORK SHEET

TEST ITEM NO. 82 GH₂ RELIEF VALVE

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01.02.10	A	0.99995	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room and cryogenic temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination and crack and reseal pressure settings. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Six test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient, high-temperature, and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient, high-temperature, and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure with planned relief valve operation, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification

or as an input to the final design modifications to ensure component adequacy and compliance with requirements.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels, or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response, crack, and reseal pressure) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum.

3.1 (Alternate). The above component qualification tests could be performed at the subsystem or the system level.

3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS system in the PIL.

3.2 (Alternate). This test could be eliminated.

3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.

3.3 (Alternate). This test could be eliminated.

4. RELIABILITY TESTING

There will only be a partial reliability verification on this test item. The number of equivalent lunar missions required (14,000) precludes a full reliability verification program. The reliability (probability of no failure) will be determined by material properties analysis and results of previous testing on relief valves. (Saturn S-IVB testing on the LH₂ relief valve totaled 103,086 ambient hours.) A small reliability test program using Bayes techniques will then be employed.

TEST ITEM WORK SHEET

TEST ITEM NO. 84 GH₂ PRESSURIZATION QUAD VALVES
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.02.12	A	0.995 each	50	Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to insure component adequacy and compliance with requirements
1. RESEARCH AND TECHNOLOGY TESTING				2 3 (Alternate) This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated
No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.				3 QUALIFICATION TESTING
2. DEVELOPMENT TESTING				3 1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				4. RELIABILITY TESTING
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.995) at the required confidence level (50 percent) will be performed with 10 components. The total successful test time must be equivalent to 140 lunar missions.
2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Four additional test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				
2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing.				

TEST ITEM WORK SHEET

TEST ITEM NO. 89 LH₂ TURBOPUMP
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.03.02	A	0.993	50	
36.01.03.06	A	0.993	50	
1. RESEARCH AND TECHNOLOGY TESTING				duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.
No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.				2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine]system level), or could be eliminated
2. DEVELOPMENT TESTING				3. QUALIFICATION TESTING
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage, pressure rise, NPSH, efficiency turbine and pump flow rate, and dynamic performance testing. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.				3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				4. RELIABILITY TESTING
2.2 Subsystem. Subsystem testing will be conducted on the test item in conjunction with other test items. Four test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.993) at the required confidence level (50 percent) will be performed with 10 components. The total successful test time must be equivalent to 100 lunar missions.
2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse				

TEST ITEM WORK SHEET

TEST ITEM NO. 90 CH₂ SHUTOFF VALVE

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01.03.03	A	0.993	50
36.01.03.04	A	0.993	50
36.01.03.07	A	0.993	50
36.01.03.08	A	0.993	50
36.01.03.10	A	0.993	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Five test items will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Five additional test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.

4. RELIABILITY TESTING

All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.993) at the required confidence level (50 percent) will be performed with 10 components. The total successful test time must be equivalent to 100 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 93 GH₂ VENT/RELIEF QUAD VALVES

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.03.12	A	0.995 each	50	
1. RESEARCH AND TECHNOLOGY TESTING No specific. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.				2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.
2. DEVELOPMENT TESTING 2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes. 2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL. 2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Four additional test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.				2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.
3. QUALIFICATION TESTING 3.1 Component. Qualification testing will be conducted on a small (8) number of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock and vacuum.				4. RELIABILITY TESTS All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.995) at the required confidence level (50 percent) will be performed with 10 components. The total successful test time must be equivalent to 140 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 94 GOX PRESSURE REGULATOR

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.04.01	A	0.993	50	
36.01.04.02	A	0.993	50	
1. RESEARCH AND TECHNOLOGY TESTING				<p>suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure, high flow rates, extended pulse duration firing, etc) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements</p> <p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels, or could be eliminated</p>
2. DEVELOPMENT TESTING				3. QUALIFICATION TESTING
<p>No specific testing. Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology.</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and cryogenic temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, pressure regulation performance, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Two test items will be mated with the remainder of the APS components to form an APS system to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a</p>				<p>3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, pressure regulation, response) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum</p> <p>3.1 (Alternate). The above component qualification tests could be performed at the subsystem or the system level.</p> <p>3.2 Subsystem. Structural and functional (nonfiring) qualification test on the complete APS in the PIL.</p> <p>3.2 (Alternate). This test could be eliminated.</p> <p>3.3 System. The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility.</p> <p>3.3 (Alternate). This test could be eliminated</p>
4. RELIABILITY TESTING				<p>A reliability test program will be conducted on this item. A total of 10 test items will be used in a test program to verify the reliability allocation (0.993) at the required confidence level (50 percent) A total of 100 successful equivalent lunar missions is required Data from the regular test program (above) will be used in the reliability test program.</p>

TEST ITEM WORK SHEET

TEST ITEM NO. 98 GOX RELIEF VALVE
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01 04 10	A	0 99995	50	
1 RESEARCH AND TECHNOLOGY TESTING				or as an input to the final design modifications to ensure component adequacy and compliance with requirements
No specific testing Use previous design technology and testing, also, RNS SRT testing on radiation effects and long-life technology				2 3 (Alternate) This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc) or could be conducted at other levels, or could be eliminated
2 DEVELOPMENT TESTING				3 QUALIFICATION TESTING
2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room and cryogenic temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination and crack and reseal pressure settings Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements Extended environment testing will be performed to delineate dominant failure modes				3 1 Component Qualification testing will be conducted on a small number (2) of components Structural tests (proof and burst pressure) and functional tests (leakage, flow, response, crack, and reseal pressure) will be conducted under ambient conditions, cryogenic conditions, vibration, shock, and vacuum
2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.				3 1 (Alternate) The above component qualification tests could be performed at the subsystem or the system level
2.2 Subsystem Subsystem testing will be conducted on this test item in conjunction with other test items. Six test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing Structural testing of the ducting and connections under ambient, high-temperature, and cryogenic conditions will be performed Subsystem functional testing will also involve ambient, high-temperature, and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems				3 2 Subsystem Structural and functional (nonfiring) qualification test on the complete APS system in the PIL
2.3 System The test item will be integrated with the remainder of the APS system and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS system (high pressure with planned relief valve operation, high flow rates, extended pulse duration firing, etc) will be employed to delineate possible failure modes and to serve as a final design verification				3 2 (Alternate) This test could be eliminated
				3 3 System The final functional qualification of the complete APS is accomplished with flight components on a command and control module at the Douglas-Sacramento Test Facility
				3 3 (Alternate) This test could be eliminated
				4 RELIABILITY TESTING
				There will only be a partial reliability verification on this test item The number of equivalent lunar missions required (14,000) precludes a full reliability verification program The reliability (probability of no failure) will be determined by material properties analysis and results of previous testing on relief valves (Saturn S-IVB testing on the LH ₂ relief valve totaled 103,086 ambient hours) A small reliability test program using Bayes techniques will then be employed

TEST ITEM WORK SHEET

TEST ITEM NO. 100 GOX PRESSURIZATION QUAD VALVES

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01.04.12	A	0.995 each	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electro-mechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Four additional test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small (2) number of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.

4. RELIABILITY TESTS

All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.995) at the required confidence level (50 percent) will be performed with 10 components. The total successful test time must be equivalent to 140 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 102 LOX TURBOPUMP
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.05.02	A	0.993	50	<p>Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.</p> <p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small number (8) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.</p> <p>4. RELIABILITY TESTS</p> <p>All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.993) at the required confidence level (50 percent) will be performed with 10 components. The total successful test time must be equivalent to 100 lunar missions.</p>
36.01.05.06	A	0.993	50	
<p>1. RESEARCH AND TECHNOLOGY TESTING</p> <p>No specific testing. Use previous design technology and testing; also RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at cryogenic conditions, under vibration and shock conditions, and in a vacuum and will include leakage, pressure rise, NPSH, efficiency, turbine and flow rate, and dynamic performance testing. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing.</p>				

TEST ITEM WORK SHEET

TEST ITEM NO. 103 LOX SHUTOFF VALVE

CLASS 3

SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL
36.01.05.03	A	0.993	50
36.01.05.04	A	0.993	50
36.01.05.07	A	0.993	50
36.01.05.08	A	0.993	50
36.01.05.10	A	0.993	50

1. RESEARCH AND TECHNOLOGY TESTING

No specific testing. Use previous design technology and testing, also RNS SRT testing on radiation effects and long life technology.

2. DEVELOPMENT TESTING

2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.

2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.

2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Five test items will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Five additional test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide design information on possible structural or functional interface problems.

2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.

2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem engine system level), or could be eliminated.

3. QUALIFICATION TESTING

3.1 Component. Qualification testing will be conducted on a small number (2) of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.

4. RELIABILITY TESTS

All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.993) at the required confidence level (50 percent) will be performed with 10 components. The total successful test time must be equivalent to 100 lunar missions.

TEST ITEM WORK SHEET

TEST ITEM NO. 106 GOX VENT/RELIEF QUAD VALVES
SYSTEM AUXILIARY PROPULSION SYSTEM (APS)

CLASS 3

COMPONENT	MAINTENANCE CATEGORY	RELIABILITY ALLOCATION	CONFIDENCE LEVEL	
36.01.05.12	A	0.995 each	50	<p>engine firings will be accomplished. This test will be accomplished at a suitable test facility, Douglas-Sacramento, and will supplement and extend the PIL system testing. Extended parameter testing on the APS (high pressure, high flow rates, extended pulse duration firing, etc.) will be employed to delineate possible failure modes and to serve as a final design verification or as an input to the final design modifications to ensure component adequacy and compliance with requirements.</p>
<p>1. RESEARCH AND TECHNOLOGY</p> <p>No specific. Use previous design technology and testing, also RNS SRT testing on radiation effects and long-life technology.</p> <p>2. DEVELOPMENT TESTING</p> <p>2.1 Component. A small number (2) of components will be subjected to structural and functional testing to obtain design and design verification information. These data are required to aid in the design and possible redesign of components and to provide verification that the design techniques are adequate for the proposed use. Structural testing will include proof and burst pressure tests under ambient and cryogenic conditions and structural degradation under radiation fluences. Functional testing will be conducted at room temperature and elevated temperature conditions, under vibration and shock conditions, and in a vacuum and will include leakage testing, flow-rate (impedance) determination, and response times. Nonoperational and repeated cycle testing will be conducted to assure ability to satisfy dormant and long-life requirements. Extended environment testing will be performed to delineate dominant failure modes.</p> <p>2.1 (Alternate). The above component testing could be conducted at the subsystem level in the PIL.</p> <p>2.2 Subsystem. Subsystem testing will be conducted on this test item in conjunction with other test items. Four test items will be installed in the SIL for electromechanical interface and functional testing. These data will supplement the component test data in the specific area of electrical interface design and problems. Four additional test items will be mated with the remainder of the APS components to form an APS to be used in the PIL for structural and functional testing. Structural testing of the ducting and connections under ambient and cryogenic conditions will be performed. Subsystem functional testing will also involve ambient and cryogenic conditions, but will not include actual engine firing. These data are required to verify that the component design is compatible with the required system design requirements and to provide information on possible structural or functional interface problems.</p> <p>2.3 System. The test item will be integrated with the remainder of the APS and the appropriate command and control module hardware in a system-level test where actual</p>				<p>2.3 (Alternate). This level of testing could be conducted at other test sites (MTF, KSC, NRDS, etc.) or could be conducted at other levels (engines could be test fired at a component level or at a subsystem [engine system] level), or could be eliminated.</p> <p>3. QUALIFICATION TESTING</p> <p>3.1 Component. Qualification testing will be conducted on a small (2) number of components. Structural tests (proof and burst pressure) and functional tests (leakage, flow, response) will be conducted under ambient conditions, high-temperature conditions, vibration, shock, and vacuum.</p> <p>4. RELIABILITY TESTS</p> <p>All of the test data accumulated in the above test program will be credited to the reliability test program. The remainder of the test time required to verify the reliability allocation statistically (0.995) at the required confidence level (50 percent) will be performed with 10 components. The total successful test time must be equivalent to 140 lunar missions.</p>

2.2 SYSTEM TEST WORK SHEETS

A total of 87 candidate system tests were defined during the Phase III study effort as part of Subtask 2.2, Test Definition. The tests were initially constructed to treat each test hardware item independently and to consider categories of development, qualification, and acceptance testing for each. The results of this approach were then summarized to form a total of 14 systems test series which were test hardware independent, with test levels combined wherever practical. The work sheets were constructed in a format which posed a total of eight questions for each test, including the nature of the test, support requirements, expected worth of the test, etc. The series of systems tests, including recommendation for each, are presented in the following pages. The information is applicable to both RNS concepts.

System Test No. 1—Systems Integration Laboratory

What is the test?

This test is an active electromechanical mockup of the propulsion, astrionics, safety, etc. subsystems.

What does the test do?

This test will investigate, develop, and qualify the electrical interfaces between various components which comprise the subsystems, between the subsystems which comprise the RNS modules, between the several RNS modules, between the RNS system and the NERVA digital instrumentation and control electronics (NDICE), and between the RNS system and the ground/aerospace support equipment. Normal operation and extended parameter operation will be employed.

Why is the test required?

This test is required to provide the opportunity to verify that the electrical interface between the components, subsystems, modules, NDICE, and the ground/aerospace support equipment is adequate to meet the system requirements or to determine that interface problems exist, and to provide the design information required for component, subsystem, module, NDICE or support equipment redesign. This test is also required to develop onboard checkout and ground automatic checkout system software procedures.

What are the facility/hardware requirements?

The facility requirements involve primarily a suitable area and some sort of mounting fixture where the various components can be mounted in an arrangement similar to the physical arrangement on the RNS. A source of electrical power and thermal conditioning will be required. A computerized checkout system to insert command signals and analyze responses will be utilized during the early portions of the test series to perform a portion of the testing and to provide design data for the onboard checkout system and the ground automatic checkout systems.

The hardware requirements would involve a complete set of RNS electro-mechanical hardware plus the NDICE and electrical ground/aerospace support equipment. This set of hardware will reflect the continuous increase in the level of design—i. e., the initial development level components will be replaced with redesigned components and eventually with qualification level components. Therefore, the equivalent of two complete sets of hardware is required.

What is the estimated worth of the test?

The data from this test should provide accurate information on the electrical interfaces under ambient environment conditions and normal and abnormal operations. This data should reveal any problem areas or verify conformity with the RNS requirements. The data should provide design information useful or required in the redesign of the components, subsystem, module, NDICE or support equipment. The test should provide information useful or required in the design of the onboard checkout system and the ground checkout systems.

What are the alternatives to be considered?

The alternative to be considered is to eliminate this test and perform the electrical interface testing at a higher level. The data cannot be obtained at the component level. The required data for the development phase of the program could be obtained in System Test 6, the dry checkout phase of the battleship test program. The required data for the qualification phase of the program could be obtained during System Test 9, the dry checkout phase of the all-systems test program. The required data for the acceptance phase of the program could be obtained during System Test 12, the manufacturing acceptance test.

Elimination of this test and the incorporation of this test with Systems Tests 6 and 9 would extend the time before design verification and/or redesign requirements are obtained and thus delay the design process. The risk of delay of the battleship and all-systems test program is also increased.

What is the impact of alternatives on cost and schedule?

The elimination of this test would reduce facility costs by \$27,500. Schedule implications would be that the design and qualification data will be available at a later date.

What is the final decision regarding this system test?

This test will be incorporated into the development and qualification portions of the test plan. This test will not be included as part of the acceptance test program.

System Test No. 2—Propulsion Integration Laboratory

What is the test?

This test is an active electrical, mechanical, and fluid mockup of the propulsion components.

What does the test do?

This test will investigate, develop, and qualify the mechanical and fluid interfaces between propulsion system components, between modules of the RNS and between the RNS and the NERVA. This test will investigate the fluid conditions and performance in the propulsion system under normal and abnormal conditions.

Why is the test required?

This test is required to investigate and verify the mechanical and fluid interfaces and to investigate the fluid dynamics in the propulsion system. The mechanical interface between the various propulsion systems must be verified and/or design information obtained for use in the redesign effort. The performance of the propulsion system as a unit must be verified and/or design information obtained to permit redesign and subsequent verification prior to the time that the system is either subject to higher level testing or the design is considered to be adequate and further design is terminated.

What are the facility/hardware requirements?

A facility is required where the propulsion system components can be mounted in a physical arrangement similar to their arrangement in the flight vehicle. The facility must have capability to supply and safely handle liquid and gaseous hydrogen liquid and gaseous oxygen, and purge gaseous (GN_2 , GHe) and must be qualified for high-pressure operation. Electrical power equal to the RNS electrical power system must be supplied along with an automatic checkout system to insert commands and analyze response. The hardware requirements involve a complete set of propulsion components including ducting. This set of hardware will reflect the continuous increase in the level of design,—i. e., the initial development level components will be replaced with redesigned components and eventually with qualification level components. Therefore the equivalent of two complete sets of hardware is required. A simulator of the Nerva interface is required.

What is the estimated worth of the test?

The data from this test should provide accurate information on the mechanical interfaces under ambient and cryogenic conditions and normal and abnormal operations. The data should reveal any mechanical interface problems and supply the required redesign information or verify conformity with requirements. The data on the performance of the system—flow dynamics, chilldown,

etc.—must be adjusted to account for the lack of space conditions—zero gravity, space temperatures, vacuum, etc. However, the data will be invaluable in the design and analysis process as an experimental verification of the analytical techniques used in the performance analysis and design.

What are the alternatives to be considered?

The alternative to be considered is to eliminate this test and perform the mechanical and fluid interface testing on the propulsion systems at a higher level. The data cannot be obtained at the component level. The required data for the development phase of the program could be obtained in System Test 7, the cold flow portion of the battleship test program. The required data for the qualification phase of the test program could be obtained in Systems Test 10, the cold flow portion of the all-systems test series. The required data for the acceptance phase of the program could be obtained in System Test 13, the cold flow portion of the acceptance test series.

Elimination of this test would extend the time before design verification and/or redesign requirements are obtained and thus will delay the design process. The risk of delay of the battleship and all-systems test programs is also increased.

What is the impact of alternatives on cost and schedule?

The elimination of this test would reduce facility cost for the Class 1 Hybrid by \$110,000 and by \$500,000 for the Class 3 RNS. Schedule implications would be minimal because other tests (8 and 10) would be expanded to obtain the required data. The design data would be available at a later date however, which would introduce the possibility of schedule delays.

What is the final decision regarding this system test?

This test is selected to be incorporated into the development and qualification portions of the test plan. This test will not be included as part of the acceptance test program.

System Test No. 3—Special Docking Simulator

What is the test?

This test is an active mockup of the docking and disconnect components of the RNS.

What does the test do?

This test will investigate, develop, and verify, the static and dynamic mechanical, electrical, and optical/laser operation and interfaces of the various docking mechanisms and disconnects between the modules of the RNS, between the RNS and the payload and between the RNS and other space facilities under normal and abnormal conditions.

Why is the test required?

This test is required to investigate and qualify the static and dynamic operation of the docking system and disconnect components. The static mechanical interfaces between the various RNS modules must be verified and/or redesign information obtained. The ability of the docking mechanisms and the disconnects to withstand the static and dynamic loadings during the docking operation and the remainder of the RNS operating cycle during normal operation and extended parameter operation must be verified and/or redesign information obtained. The operation of the electrical and fluid disconnects during the docking operation must be verified and/or design information obtained. The operation of these disconnects during the RNS operations will be investigated in the systems integration and propulsion integration laboratory test (System Tests 1 and 2). The terminal operation of the rendezvous and docking astrionics must be verified and/or redesign information obtained. The performance of the docking system as a unit working with the docking system of other units (other RNS modules, payload, etc.) must be verified and/or redesign information before the design of this system can be considered to be adequate and the design is terminated.

What are the facility/hardware requirements?

A facility is required that is capable of suspending entire RNS modules or mockups of the modules with attached docking systems and disconnects and simulating the docking operation. The mockups and the facility must be designed to provide the actual loading, accelerations, momentum, etc. to simulate actual docking operations under zero-gravity conditions. A complete set of docking system hardware and disconnects including components from the payload and other space facilities is required. This set of hardware will reflect the continuous increase in the level of design by continuous replacement of components. The equivalent of two complete sets of hardware is required.

What is the estimated worth of the test?

The data from this test should provide accurate information on the dynamics involved in the docking operation and the capabilities of the components to perform the required operations under normal and abnormal conditions. The data should reveal any mechanical, electrical or optical/laser problem areas and supply the required redesign information or verify conformity with requirements. The data on the performance of the systems must be adjusted to account for the lack of zero gravity or the lack of ability to completely simulated zero gravity. The data will be invaluable in the design and analysis process as an experimental verification of the analytical techniques used in the performance analysis and design.

What are the alternatives to be considered?

This test could be eliminated and replaced with individual component test with a corresponding reduction in the value of the data.

What is the impact of alternatives on cost and schedules?

Elimination of this test would reduce the facility costs by \$500,000.

What is the final decision regarding this system test?

This test is selected to be incorporated into the development and qualification portions of the test plan. This test will not be included as part of the acceptance test program.

System Test No. 4—Space Chamber—RNS Module

What is the test?

This is a test of the various RNS modules under space vacuum conditions.

What does the test do?

This test will investigate and partially confirm the effectiveness of the high performance insulation, the extent of outgassing of materials in the space environment, and the extent of vacuum welding of components in the space environment.

Why is the test required?

This test or the equivalent is required to provide test data on the validity of the design of the components of the test item to operate in the vacuum environment of space for long periods of time.

What are the facility/hardware requirements?

The facility requirement is a space chamber large enough to receive the test items. The hardware requirements are represented by the test item.

What is the estimated worth of the test?

The data from this test should provide accurate information on the ability of the components of the test article to exist and operate in the space vacuum environment. The test should provide data on the effectiveness of the high-performance insulation on a full-scale basis.

What are the alternatives to be considered?

This test could be eliminated. The required data could be obtained in smaller space chambers with component level testing.

What is the impact of alternatives on cost and schedule?

The cost of the facility (not estimated) would be eliminated. The cost of a development flight-weight insulated test article would be eliminated. The schedule should not be significantly affected if the data are obtained during component testing instead of full-scale module testing.

What is the final decision regarding this system test?

This test will not be included in the test plan.

Systems Test No. 5—Vehicle Dynamic Test

What is the test?

This test is a dynamic vibration test on the complete RNS vehicle.

What does the test do?

This test will determine the critical frequencies of the assembled vehicle and the response of the vehicle to induced vibrations.

Why is the test required?

This test will provide information on the response of the vehicle to induced vibration. This information is required as design verification and design data for the vehicle dynamics analysis.

What are the facility/hardware requirements?

The facility requirements include a facility capable of suspending a complete RNS and subjecting the RNS to a range of induced vibrations. The hardware requirements include the module propellant tanks and mass mockups of the components.

What is the estimated worth of the test?

The data from this test will confirm analytical predictions of the dynamic response.

What are the alternatives to be considered?

The alternative is to eliminate the test and use the analytical predictions.

What is the impact of alternatives on cost and schedule?

If this test is eliminated the dynamic test facility is eliminated.

What is the final decision regarding this test?

This test is not included in the test plan.

System Test No. 6—Battleship—Dry Checkout

What is the test?

This test is a static and dynamic checkout of the battleship version of the individual RNS modules and the assembled battleship configuration.

What does the test do?

This test will test the electromechanical components of the specific modules, including all valves, motors, pumps, disconnects, cables multiplexers, signal conditioners, etc. Leak and pressure testing of the LH₂ tank, ducting and storage spheres will be accomplished by the use of gaseous helium.

Why is the test required?

This test or its equivalent is required to demonstrate the correct assembly of the several components which comprise the battleship version of the specific RNS module assembly, prior to shipment to the test site or prior to initiation of the cold flow test.

What are the facility/hardware requirements?

The facility requirements for this test depend on the test article. If the test article is a propulsion module without the NERVA or a Class 3 propellant module, the dry checkout can be performed in a horizontal position at the assembly point or in a suitable test tower. If the test article is a propulsion module with NERVA, the dry checkout should be performed in the mating facility. If the test article is the Class 1 Hybrid propellant module, which will be fabricated at the test site, the facility will be the cold flow and/or hot firing test facility (E/STS-2). The cold flow/hot firing test facility would also be used if the test article is a complete battleship RNS.

All of the test articles described above should experience a dry checkout prior to movement to the test site; therefore, all of these facility requirements are applicable.

A checkout system should be provided at each dry checkout facility. This checkout system should include an automatic system and a supply of high pressure helium. The checkout system should be capable of generating and transmitting command signals to the test article, receiving responses, analyzing the results and presenting the results in a suitable manner.

What is the estimated worth of the test?

The data from this test should provide accurate information on the accuracy of the assembly operations and the ability of the battleship assembly to perform the subsequent operations.

What are the alternatives to be considered?

This test could be eliminated and combined with system test candidates 7 and 8, where the dry checkout would be accomplished prior to the cold flow and hot firing.

What is the impact of alternatives on cost and schedules?

The facilities that would be required for this test will be required at a later date for System Tests 9 and 12. If the test is conducted as part of tests 7 or 8, no additional facilities are required. This test would be repeated during the cold flow and hot firing tests.

What is the final decision regarding this system test?

This test is selected for incorporation into the test plan.

System Test No. 7—Battleship—Cold Flow

What is the test?

This test is a development test of the several battleship test articles under liquid hydrogen conditions.

What does the test do?

The test will investigate and partially confirm the design of the battleship version of the RNS. The assembly will be subjected to LH₂ fill, LH₂ drain, GH₂ pressurization, and GH₂ venting operations under normal conditions and extended parameter operations under normal conditions and extended parameter operations.

Why is the test required?

The test or the equivalent is required to provide test data on the validity of the design of the component and systems of the propulsion and astrionics system or to provide data sufficient to provide the basis for component or system redesign.

What are the facility/hardware requirements?

A test stand capable of receiving the several RNS modules and/or the complete battleship assembly and performing the required LH₂ operations is required. A suitable control and monitoring system is also required. The test article will consist of a complete set of development level propulsion system, astrionics system, etc., heavy-wall LH₂ tanks with insulation, and a NERVA.

What is the estimated worth of the test?

The data from this test should provide accurate information on the performance of the battleship assembly under cryogenic conditions and under normal and extended parameter operations. These data should reveal any design deficiencies and provide data for any redesign activities. The data on the performance of the system—flow dynamics, chilldown, etc.—must be adjusted to account for the lack of space conditions—zero gravity, space temperatures, vacuum etc. However, the data will be invaluable in the design and analysis process as a verification of the analytical techniques used in the performance analysis and design.

Which are the alternatives to be considered?

This test could be eliminated. The required data could be obtained in an expanded PIL test (System Test 2) or could be obtained as part of System Test 8.

What is the impact of alternatives on cost and schedule?

None. This test could be conducted in the same facility as System Test 8 and with the same hardware. This test could be conducted prior to System Test 8.

What is the final decision regarding this test?

This test will be included in the test plan.

System Test No. 8 — Battleship Hot Firing

What is the test?

This test is a complete development level test of the battleship RNS, including the NERVA, under hot firing conditions.

What does the test do?

The test will subject the battleship version of the RNS to operations and environments which will provide data on the adequacy of the design and/or data for component or system redesign. The operations will include LH₂ fill, LH₂ feed, GH₂ pressurization, GH₂ venting under normal, abnormal, emergency, and extended parameter conditions. The NERVA generated environments (radiation, thermal, vibration, etc.) will be present and the NERVA/RNS interface will be included in the system under test.

Why is the test required?

This test or the equivalent is required to provide timely data on the adequacy of the design or provide timely redesign information. All of the required data cannot be obtained at the component or the subsystem level.

What are the facility/hardware requirements?

A test stand capable of receiving the battleship RNS and conducting a hot firing of a nuclear engine is required (ETS-1 or E/STS-2 at the Nuclear Rocket Development Station). A suitable control and instrumentation system is required. The test hardware is a complete propulsion module in a battleship configuration (thick wall tank-prototype hardware) is required.

What is the estimated worth of the test?

This test will provide the most realistic test possible on the operation of the battleship RNS. The data must be corrected for the lack of space environments (total vacuum, space temperature, low or zero gravity) and the presence of a test cell (scatter radiation, damped vibration, etc.).

What are the alternatives to be considered?

This test could be eliminated with a reduction in design confidence. Some of the required data could be obtained in component test, the systems integration laboratory (Test 1), an expanded propulsion integration laboratory (System Test 2) and System Test 7.

What is the impact of alternatives on cost and schedule?

If this test and system Tests 11 and 14 are eliminated the requirement for E/STS-2 is eliminated at a saving of \$52 million. The schedule would not be affected.

What is the final decision regarding this test?

This test is included in the test plan.

System Test No. 9 — All Systems Dry Checkout

What is the test?

This test is a functional checkout of the all systems vehicle including a propellant module, a command and control module and a propulsion module with an engine.

What does the test do?

This test will test the electromechanical components of the assembly, including all valves, motors, pumps, disconnects, cables, multiplexers, signal conditioners, etc. Leak and pressure testing of the LH₂ tank, ducting and storage spheres will be accomplished by the use of gaseous helium.

Why is the test required?

This test, or the equivalent, is required to demonstrate the correct assembly of the several components which comprise the all systems vehicle.

What are the facility/hardware requirements?

The facility requirements will depend on the test article involved. If the test article is a propellant module, a command and control module, or a propulsion module without the NERVA the facility requirements could be the assembly area or a suitable test tower. The propulsion module with the NERVA will experience the dry checkout at the mating site, either in the mating area or in a test tower. If the test article is a combination of modules or the complete all-system test vehicle the dry checkout will be conducted in the cold flow/hot firing test facility (E/STS-2).

The checkout facility should contain a checkout system, preferably an automatic system, and a supply of high pressure helium. The checkout system should be capable of generating and transmitting command signals to the test article, viewing responses, analyzing the results and presenting the results in a suitable manner.

What is the estimated worth of the test?

The data from this test should provide accurate information on the accuracy of the assembly operations and the ability of the all-systems vehicle to perform the subsequent operations.

What are the alternatives to be considered?

This test could be eliminated and combined with System Test 10 where the dry checkout will be performed prior to the cold flow test.

What is the impact of alternatives on cost and schedule?

If this test is conducted independently of System Test 10 a new facility is required, but this is unnecessary. The individual modules can be tested individually and the combination can be tested prior to test 10. No effect on hardware or schedule.

What is the final decision regarding this test?

This test is included in the test plan as dry checkout tests on the individual RNS modules and also as part of System Test 10.

System Test No. 10 — All Systems Cold Flow

What is the test?

This test is a qualification test of the various modules of the RNS under LH₂ conditions.

What does the test do?

The test will investigate and confirm the design of the propulsion system and the astrionics system of the propulsion module, the propellant module and the command and control module. The individual modules and the complete assembly will be subjected to LH₂ fill, LH₂ drain, GH₂ pressurization, and GH₂ venting operations under normal conditions and extended parameter operations.

Why is the test required?

The test or the equivalent is required to provide test data on the validity of the design of the component and systems of the test item.

What are the facility/hardware requirements?

A test stand capable of receiving the propulsion module, a propellant module and the command and control module individually and collectively and performing the required LH₂ operations is required. A suitable control and monitoring system is also required. The test article will consist of a complete set of qualification level propulsion module (with NERVA), a propellant module and a command and control module including the propulsion system, astrionics systems, etc., and flight weight LH₂ tanks with suitable insulation.

What is the estimated worth of the test?

The data from this test should provide accurate information on the performance of the propulsion module, the propellant module and the command and control module under cryogenic conditions and under normal and extended parameter operations. This data should reveal any design deficiencies and provide data for any redesign activities. The data on the performance of the system — flow dynamics, chilldown, etc., — must be adjusted to account for the lack of space conditions — zero gravity, space temperatures, vacuum, etc.). However, the data will be invaluable as verification of the analytical techniques used in the performance analysis and design.

Which are the alternatives to be considered?

This test could be eliminated. The required data could be obtained in an expanded PIL test (System Test 2) or as a part of System Test 11.

What is the impact of alternatives on cost and schedule?

None. This test will be conducted prior to the hot firing test and in the same facility. The test hardware and the schedule would not be affected. If this test plus all other cold flow and hot firing tests are eliminated, the requirement for the E/STS-2 facility is eliminated with a savings of \$52 million.

What is the final decision regarding this test?

This test will be included in the test plan.

System Test No. 11 — All Systems Hot Firing

What is the test?

This test is a complete qualification level test of the all systems test article including the NERVA, under hot firing conditions.

What does the test do?

The test will subject a complete production version of the RNS to operations and environments which will provide data on the adequacy of the design. The operations will include LH₂ fill, LH₂ feed, GH₂ pressurization, GH₂ venting under normal, abnormal, emergency, and extended parameter conditions. The NERVA generated environments (radiation, thermal, vibration, etc.) will be present and the NERVA/RNS interface will be included in the system under test.

Why is the test required?

This test or the equivalent is required to provide data on the adequacy of the design. All of the required data cannot be obtained at the component or the subsystem level.

What are the facility/hardware requirements?

A test stand capable of receiving the complete all systems test article and conducting a hot firing of a nuclear engine is required (E/STS-2 at NRDS). A suitable control and instrumentation system is required. The test hardware is a complete production propulsion module, command and control module, and a propellant module.

What is the estimated worth of the test?

This test will provide the most realistic test possible on the operation of the production version of the RNS. The data must be corrected for the lack of space environments (total vacuum, space temperature, low or zero gravity) and the presence of a test cell (scatter radiation, damped vibration, etc.).

What are the alternatives to be considered?

This test could be eliminated with a reduction in design confidence. Some of the required data could be obtained on component test, the systems integration laboratory (Test 1), and an expanded propulsion integration laboratory (System Test 2), or in the cold flow test (System Test 10).

What is the impact of alternatives on cost and schedule?

If this test, the all system cold flow test and the battleship cold flow and hot firing tests are eliminated, the requirement for E/STS-2 is eliminated with a savings of \$52 million. If this test is eliminated, the requirement for one set of hardware is eliminated. No effect on schedule.

What is the final decision regarding this test?

This test is included in the test plan.

System Test No. 12 — Manufacturing Acceptance - RNS Modules

What is the test?

This test is a static and dynamic checkout of the completed RNS modules.

What does the test do?

This test will test the electromechanical components of the assembly, including all valves, motors, pumps, disconnects, cables, multiplexers, signal conditioners, etc. Leak and pressure testing of the LH₂ tank, ducting, and storage spheres will be accomplished by the use of gaseous helium.

Why is the test required?

This test is required to demonstrate the correct assembly of the several components which comprise the several RNS modules.

What are the facility/hardware requirements?

The facility requirements include a test tower - a facility capable of erecting the specific module, a checkout system (preferably an automatic system) and a supply of high pressure helium. The checkout system should be capable of generating and transmitting command signals to the assembly, receiving responses, analyzing the results and presenting the results in a suitable manner. The hardware is the assembly under test.

What is the estimated worth of the test?

The data from this test should provide accurate information on the accuracy of the assembly operations and the ability of the specific module to perform the subsequent operations. This test, along with the component level test and the subsequent cold flow test (System Test 13) will constitute the acceptance test of this assembly.

What are the alternatives to be considered?

This test could be eliminated and the test data could be obtained in a dry checkout prior to the cold flow acceptance test 13.

What is the impact of alternatives on cost and schedule?

This test will be conducted in existing facilities. No effect on hardware or schedule.

What is the final decision regarding this test?

This test is included in the test plan.

System Test 13 — Acceptance Cold Flow

What is the test?

This test is an acceptance test of the several RNS modules under LH₂ conditions.

What does the test do?

The test will confirm the assembly of the propulsion system and the astrionics system of the specific module. The assembly will be subjected to LH₂ fill, LH₂ drain, GH₂ pressurization, and GH₂ venting operations under normal conditions and extended parameter operations.

Why is the test required?

The test or the equivalent is required to provide acceptance test data on the systems of the specific module under cryogenic conditions.

What are the facility/hardware requirements?

A test stand capable of receiving the specific module and performing the required LH₂ operations is required. A suitable control and monitoring system is also required. The test article will consist of a completed module including the propulsion system, astrionics system, etc. and a flight-weight LH₂ tank with suitable insulation.

What is the estimated worth of the test?

The data from this test should provide accurate information on the performance of the specific module under cryogenic conditions. This data should reveal any assembly deficiencies. The data on the performance of the system - flow dynamics, chilldown, etc. - must be adjusted to account for the lack of space conditions - zero gravity, space temperatures, vacuum, etc.

What are the alternatives to be considered?

This test could be eliminated. The acceptance test could be completed with the dry checkout (Test 12.)

What is the impact of alternatives on cost and schedule?

If this test is eliminated the requirement for an acceptance test cold flow facility is eliminated. The schedule will not be significantly affected by the alternative.

What is the final decision regarding this test?

This test will be included in the test plan.

System Test No. 14 — Acceptance Hot Firing

What is the test?

This test is a static firing of the RNS propulsion module.

What does the test do?

This test provides assurance that the propulsion module will be capable of performing the required space operations.

Why is the test required?

This test is not required. Component testing and dry checkout testing on the module and a cold flow test on the propulsion module run tank will suffice as an acceptance test procedure.

What are the facility/hardware requirements?

This test requires a facility capable of conducting a hot nuclear engine firing (ETS-1 or E/STS-2 at NRDS) and capable of receiving the test article. The hardware requirements are represented by the test article.

What is the estimated worth of the test?

This test would increase the confidence level in the production items but at a cost of increasing the transportation and launch problem. The test would be conducted to minimize the amount of residual radiation in the core but any residual radiation will complicate the transportation and launch problems and increase the safety problems.

What are the alternatives to be considered?

This test can be eliminated and the acceptance based on component tests, dry checkout and cold flow tests.

What is the impact of alternatives on cost and schedule?

There will be no increase in facility requirements for this test. The schedule would have to reflect the additional time required for this test.

What is the final decision regarding this test?

This test is not included in the test plan.

Section 3

SUPPORTING RESEARCH AND TECHNOLOGY

3.1 SRT REQUIREMENTS

The SRT requirements for the RNS which were identified and documented in the Phase II final report (MDC G0585, Volume III, May 1970) were reviewed considering Phase III design requirements and the current RNS design concept to quantify the magnitude of their potential impacts on the design. Also, additional significant items have been added to the list as a result of the evaluation of RNS operations during the current study.

No feasibility problems have been found which would prevent a commitment to development of the RNS. However, there are SRT questions concerning some baseline subsystem features. An assessment of these is summarized in Tables 3-1 and 3-2 for the two candidate RNS concepts. The nature of the required SRT is identified for various items together with their impact on the RNS. Most of these can be classified as uncertainties in the design criteria which are applied. They will be discussed in subsequent sections together with additional items not assessed in terms of weight. Although best judgements of these have been applied conservatively for the RNS, experimental data are required to verify and refine the applicable criteria. The estimated weight penalties are indicated on the basis of the anticipated design alternative or a more conservative criterion.

Caution should be used in attempting to rank cited SRT tasks according to the weights in Tables 3-1 and 3-2, since the degree of uncertainty or risk is not comparable in each case. All are required to achieve an efficient design and enable hardware development with a high degree of confidence. A promising prospect for RNS weight improvement is identified as titanium tankage. Improved HPI performance could also yield significant weight improvement.

Table 3-1

SRT IMPACT ON RNS DESIGN—CLASS 1 HYBRID

Item	Required SRT	Impact on RNS	Estimated Weight Savings (or Penalty) (lb)	Design Alternative
Titanium tankage	Fracture toughness, manufacturing	Weight improvement	5,100	Aluminum (current baseline)
Fiberglass tank supports	Properties and fatigue at cryogenic temperatures	Feasibility	(1,500 B. O.)	Titanium
Meteoroid protection	Damage criteria	Uncertainty	(1,000)	Increase armor weight
High-performance insulation	Verify performance and design criteria	Uncertainty	(2,400)	Increase insulation thickness
Propellant dynamics	a) Prestart settling criteria	a) Uncertainty	a) (900)	a) Higher thrust and no benefit from NERVA ramp
	b) Aftercoolant acquisition	b) Uncertainty	b) (3,500)	b) Settle for pulses
Chiltdown	Boiling heat transfer criteria for feed system chiltdown	Uncertainty	(1,500 B. O.)	Vent boiloff
Propellant stratification	Criteria and destratification	Uncertainty	(1,200 B. O.)	-----
Nuclear heating of propellant	Mixing mode	Uncertainty	(300 B. O.)	Vent boiloff
Computer system	Reliability enhancement of factor of 5 from present technology	Reliability	(500)	Redundancy
B. O. = Boiloff				

Table 3-2
SRT IMPACT ON RNS DESIGN-CLASS 3

Item	Required SRT	Impact on RNS	Estimated Weight Savings (or Penalty) (lb)	Design Alternative
Titanium tankage	Fracture toughness, manufacturing	Weight improvement	7,200	Aluminum (current baseline)
Fiberglass tank supports	Properties and fatigue at cryogenic temperatures	Feasibility	(6,400 B. O.)	Titanium
Meteoroid protection	Damage criteria	Uncertainty	(2,100)	Increase armor weight
High-performance insulation	Verify performance and design criteria	Uncertainty	4,000	Increase insulation thickness
Propellant dynamics	a) Prestart settling criteria	a) Uncertainty	a) (1,400)	a) Higher thrust and no benefit from NERVA ramp
	b) Aftercoolant acquisition criteria	b) Uncertainty	b) (3,500)	b) Settle for pulses
Chiltdown	Boiling heat transfer criteria			
	a) Feed system chill-down	a) Uncertainty	(2,200 B. O.)	Vent boiloff
	b) Propellant resupply	b) Uncertainty		
Propellant stratification	Criteria and destratification	Uncertainty	(1,400 B. O.)	-----
Nuclear heating of propellant	Mixing mode	Uncertainty	(300 B. O.)	Vent boiloff
Computer system	Reliability enhancement of factor of 5 from present technology	Reliability	(500)	Redundancy
B. O. = Boiloff				

In addition to weight improvement, increase of stage lifetime and reliability and reduction of manufacturing cost are also significant SRT goals. However, a meaningful quantification of these factors is not consistent with the current status of stage development.

The program for SRT is discussed in Section 3.2 in terms of current state-of-the-art and proposed future effort. The schedules for proposed SRT are presented in Figures 3-1 and 3-2. The program is subdivided into two categories: (1) top-priority items, and (2) product improvement items. The top-priority items, indicated in Figure 3-1, are unique to the RNS. These consist of all the items evaluated in Table 3-1, and also include radiation effects programs and the in-orbit experiments required for the propellant management technologies. The product improvement items, shown in Figure 3-2, also affect RNS quality, lifetime, and performance. However, these items are also significant for other leading NASA programs such as Skylab and space shuttle. Therefore, it is anticipated that much pertinent technology will be available for application to the RNS. No further distinction will be made between these categories in describing the requirements and programs.

3.1.1 Structure

Titanium tankage offers the potential of major RNS weight improvement compared to the current baseline material of 2014-T6 aluminum. The established weight savings shown in the table are based on an allowable stress of 186,000 psi at -225°F for 6 Al-4V titanium alloy. The minimal requirement to achieve this weight improvement would consist of conducting SRT in the areas of fracture toughness and large-scale manufacturing. Additional weight savings not indicated here could be obtained through providing texture strengthening of titanium.

Fiber glass tank supports have been selected for the RNS, but data are lacking on the mechanical properties and fatigue of these structures in a radiation environment and in vacuum at cryogenic temperatures. Thus, it could be considered that there is a feasibility question concerning these which must

*Program described in cited section of Volume III, Appendix C

Figure 3-1 RNS SUPPORTING RESEARCH AND TECHNOLOGY PROGRAM - TOP PRIORITY ITEMS

<u>Item</u>	<u>Program*</u>	
1. Fracture Mechanics	3.2.1.3	200 K
2. Welding Techniques	3.2.1.4	200 K
3. Surface Coatings	3.2.2.3	100 K
4. Propellant Transfer	3.2.3.5	200 K
5. Failure Prediction	3.2.5.2	500 K
6. Dormant Failure Rates	3.2.7.1	200 K
7. Long Life Characteristics	3.2.7.2	300 K

*Program described in cited section of Volume III, Appendix C

Figure 3-2

RNS SUPPORTING RESEARCH AND TECHNOLOGY PROGRAM -
PRODUCT IMPROVEMENT ITEMS

be resolved by performing further SRT. The estimated weight penalty is attributed to boiloff in this case if the alternative of titanium tank supports were utilized.

SRT requirements are minimal for primary structures using established aluminum alloys, such as 2014-T6 and 7075-T73. Fracture mechanics development is warranted to assure reliable proof testing. The most beneficial SRT for improving the quality of the finished product, particularly propellant tankage and interstages, would be in improving weld joints to reduce porosity and developing techniques for minimizing the heat-affected zones adjacent to the welds. This affects welding techniques, welding positions, weld materials, and equipment.

3.1.2 Meteoroid/Thermal Protection

An integral armor concept has been selected for the RNS, using low-density polyurethane foam and a fiber glass primary bumper. Additional effort is required to establish precise damage criteria for meteoroid protection. It is estimated that the uncertainty related to this factor could amount to an increased armor density of as much as 0.1 psf (about a one-third increase).

Performing additional SRT in the area of HPI has a major impact on the RNS. There is uncertainty concerning the present design criteria and performance values which are applied for the stage design. An evaluation was made of the current technology development program for DAM/Dacron net HPI to permit utilizing the limited amount of available MSFC and MDAC test data on system performance. A design value was adopted for the RNS study as 2×10^{-5} Btu/ft-hr $^{\circ}$ R adjusted to the design temperature range of 400/40 $^{\circ}$ R. This includes provisions for studs, joints, and typical installations considered for the RNS. However, it is reasonable to attribute an uncertainty in these data, considering values as high as 4.5×10^{-5} . The additional insulation weight which would be incurred at this inferior insulation performance is indicated in the table. However, it is desirable to seek improvements beyond the current baseline HPI performance. The RNS thermal protection design avoids boiloff during the mission by venting and topping off propellant in orbit prior to starting the mission. Reduction of the conductivity significantly below 10^{-5} Btu/ft-hr $^{\circ}$ R could eliminate this penalty.

Another thermal protection system uncertainty is the surface coating absorptivity, which is degraded by prolonged exposure to the space environment. Since a conservative value was used for design ($x = 0.32$), coating absorptivity improvement could possibly provide a small weight reduction (100 to 200 lb).

3.1.3 Main Propulsion

Two major areas are indicated under propellant dynamics. The first is the propellant settling criteria which apply to the prestart settling for the RNS. Uncertainty concerning these criteria could result in the requirement for a high APS settling thrust and longer dissipative settling times and possibly eliminate the benefit from integration of the prestart settling with the NERVA thrust ramp. The estimated penalty for a more conservative criterion in these areas is indicated based on applying a Bond number of 100 for both inviscid and dissipative phases of settling, instead of the current baseline of 10 for the inviscid phase. The aftercooling propellant acquisition criteria assume that no propellant settling is required to provide aftercooling pulses, but that surface tension device performance would be adequate. The estimated weight penalty shown on the table is based on the premise of requiring settling for each aftercooling pulse, applying a conservative Bond number criterion of 100.

A lack of data on boiling heat transfer in low-gravity conditions provides uncertainty concerning chilldown processes for two situations: prestart feed system chilldown and propellant resupply. The weight penalty indicated for feed system chilldown is based on the alternative of an overboard dump of all feed system chilldown propellant. A chilldown penalty to condition a warm propellant tank for propellant resupply is not assessed, since the thermal protection concept is based on venting this propellant. The major concern is the pressure surges during the initial portion of the chilldown.

Potential amounts of boiloff which would require venting because of uncertainty in stratification phenomena from either sidewall heating or nuclear heating are also indicated in Tables 3-1 and 3-2. The propellant stratification work should include assessment of the implications of non-equilibrium heating of the ullage gas.

It should be noted that all of the technology issues in some of the items in Tables 3-1 and 3-2 would be the subject of orbital experiments on propellant fluid dynamics and thermodynamics. Various such experiments have been proposed in the past (Project Thermo) and further consideration of such experiments should include RNS requirements. These technologies will also apply to any other advanced space propulsion systems.

Specific weight penalties for suction dip phenomena and propellant venting have not been assessed in the table, since problems were not anticipated for RNS operation. However, this does not eliminate unforeseen phenomena which also would be assessed in the context of orbital experiments. However, the suction dip criteria will significantly affect RNS transportation costs through the efficiency of propellant delivery by the tanker vehicle.

3.1.4 Auxiliary Propulsion

A cryogenic APS system utilizing a turbopump-fed propellant conditioning system and film-cooled thrusters has been selected. Although RNS thrust level requirements are lower, the basic technology for the APS system should be provided by the space shuttle development program.

3.1.5 Astrionics

The major astrionics SRT requirement is a space-resident computer system which would achieve a substantial increase in the mean time between failures (MTBF) from approximately 10,000 hours at current technology to 50,000 hours for RNS requirement. The estimated weight penalty in Tables 3-1 and 3-2 is based on providing system redundancy. Additional SRT activities on failure prediction techniques should improve the economics of RNS maintenance.

3.1.6 Radiation Environment

SRT requirements have been identified for the long-term behavior of materials and equipment in the nuclear radiation environment of NERVA. These include the fiber glass honeycomb and fiber glass struts, DAM, polyurethane foam, surface coatings, organic valve seals, electrical insulators, fuel cell materials, and transducers. Where uncertainty exists for lack of data, the concern is not feasibility but achieving the desired RNS operational lifetime.

3.1.7 Reliability

Dormant failure rate data on candidate electronic and propulsion system hardware are necessary to establish system design requirements. Also, evaluation of long-life characteristics will be important to select candidate hardware configurations and make reliability predictions.

3.2 SRT PROGRAM

This section presents the SRT state of the art and proposed further activity in light of the requirements discussed in Section 3.1.

3.2.1 Structure

3.2.1.1 Titanium Tankage

Because of its superior strength-to-weight characteristics, titanium has been considered as a growth candidate for the RNS propellant tanks. However, there are still many characteristics of the material which prevent its use for large cryogenic tankage. For this application, the titanium tank will experience temperatures between -423°F and -100°F while under load. The tank pressure will cycle 60 times over a period of 1 to 3 years, and the titanium will be exposed to hydrogen gas at -100°F . Current limitations on titanium sheet size dictate much larger weld lengths than for aluminum, and the thin gages of the material will be difficult to handle.

State of the Art

Partial-thickness crack coupons have been used to evaluate materials for pressure vessel performance. Typical fracture toughness data have been obtained for commercially available alloys (Ti-6Al-4V and Ti-5Al-2.5Sn) in both the parent and weld metals, and they indicate that very small flaws can lead to failures.

Recent studies (Reference 1) have shown that control of metallurgical variables can improve the fracture toughness of a given alloy and that improvements may be possible by varying alloy composition. Figure 3-3 shows that heating titanium to the beta region can cause a change in the microstructure which gives the material better fracture toughness characteristics without a significant loss of strength.

Figure 3-3

EFFECT OF FLAW SIZE ON FRACTURE STRESS

Another potential problem in using titanium as an LH_2 tank is the possibility of enhanced flaw growth. At temperatures above $-100^\circ F$, the fatigue life is reduced (Reference 2) when hydrogen is present. The results of other studies showed that a diffusion-controlled mechanism is responsible for this reduction (Reference 3) indicating that for longer times, the effect may be found at even lower temperatures.

Test results have indicated that higher biaxial strengths could be realized for pressure vessel applications at these temperatures by using texture-strengthened titanium. The relation between uniaxial and biaxial tensile strength properties of 0.050-in. annealed 6Al-4V titanium is shown in Figure 3-4, and shows biaxial strengths which are 50 percent greater than uniaxial tensile strengths (Reference 4).

Program

Variations on present alloys (such as a very low oxygen-content Ti-6Al-4V) and new compositions should be studied to improve toughness and maintain strength. To define the limitations for preventing hydrogen attack, it will

Figure 3-4 BIAxIAL STRENGTH PROPERTIES AS A FUNCTION OF TEMPERATURE

be necessary to study (1) flaw growth under both fatigue and sustained load and (2) the influence of stress, time, temperature, and alloy type.

If these tests are successful, then a subscale test tank should be fabricated and tested to demonstrate titanium as a material for large scale tankage. In particular, the handling of large thin-gage sheets and the making of good quality welds which are crack-free will have to be demonstrated. To utilize texture strengthening in a production application will require developing the processing methods to make sheet product with a uniform and reproducible texture. This processing should also be compatible with the alloy and microstructure requirements for maximum fracture toughness. Consequently, it would need to be done subsequent to the above programs.

3.2.1.2 Fiber Glass Support Structures

Fiber glass, due to its superior low thermal conductivity properties, has been selected for heat blocks, thrust structure, and interstages between propellant modules. Both honeycomb and tubular strut construction are being considered.

State of the Art

Information is available on the strength properties of fiber glass laminates at room temperature. Some fatigue strength data exist for compression and for shear specimens. Very little data are available for strengths at cryogenic temperatures, and no data exist for compression and shear at these temperatures. Fatigue behavior data at cryogenic temperatures are nonexistent. Additionally, the ability of the fiber glass to resist cracking under large differential temperatures (-423° to $+350^{\circ}\text{F}$) and cyclical loading has to be established. The qualities of fiber glass laminates, such as void content, filament orientation, etc., greatly influence all of these strength properties.

Program

It is proposed to subject specimens to cyclical loading at fractions of the ultimate load until failure occurs for temperatures ranging from -423°F to $+350^{\circ}\text{F}$ and including temperature gradients.

3.2.1.3 Fracture Mechanics

The RNS tankage will experience more than 60 pressure cycles during its operating life, thus increasing the role of fracture mechanics. Flaws may exist in any manufactured pressure vessel, and they may grow sufficiently during service (or even proof) to cause failure.

State of the Art

The concepts of fracture mechanics have seriously challenged the validity of conventional proof-testing procedures as an assurance of reliability. Application of fracture mechanics in its present state to select proof and service loads usually means a very heavy structure and, in many cases, represents an unnecessary increase in weight. Not all areas of fracture mechanics are fully formulated, and great care must be exercised in actual applications. One such area which is extremely important is the case of flaws whose sizes approach the thickness of the sheet. Another weak area is sustained-load flaw growth and the concept of a threshold stress intensity. Here, the possibility of environmentally induced crack growth introduces additional complications. Since design requirements cannot wait until the theory is complete, a careful study of proof-testing concepts is needed to incorporate as much of current knowledge as possible without unnecessary penalties.

Program

The following data are required:

- A. Static fracture toughness. Both shallow and deep flaws must be used to develop the stress intensity magnification factors for the thicknesses to be used.
- B. Static threshold fracture toughness for stable crack growth.
- C. Cyclic flaw growth rate.

These data must be obtained for the actual thicknesses, welding procedures, temperatures, and environments, and must reflect the state of the material after any and all processing steps. Where possible, reaction rates should be determined for environmentally induced flaw growth so that long-term behavior may be predicted from short-term tests.

3.2.1.4 Welding

The vertical or stacking approach was employed in the manufacture of the Saturn S-IC and the S-II stages. The large size of the Class 1 Hybrid RNS propellant module also dictates vertical assembly.

State of the Art

The weld porosity and the incidence of rework required for welds made in the horizontal or 3 o'clock out-of-position welding are exceedingly high compared to down hand and inclined welding techniques. The introduction of the pulsed arc in Mig and Tig welding, and of reverse polarity in plasma arc welding are advanced from the previous Saturn state-of-the-art, and may produce good welding criteria for out-of-position welding.

Program

The following data are required:

- A. Preliminary operational stresses for welds and tank parent metal.
- B. Proof stresses to guarantee either a safe-life or leak-before burst at operating pressures.
- C. Fracture stress vs initial flaw size under single load-to-failure conditions. This will establish statistically reliable proof test conditions.
- D. Cyclic flaw growth characteristics at operating stresses and environments in order to set limits for safe-life and leak-before burst margins. This also defines the minimum flaw size that must be screened out by the proof test.
- E. The effect of double-repair welds on static and cyclic weld properties.

Four test approaches are recommended:

- A. Investigate pulsed arc and plasma arc welding methods that will provide finer dendrite cell size with expected improvements in strength and ductility.
- B. Investigate weld wire compositions that have elemental additions that provide finer dendrite cell size, and also allow the weld to age to higher yield strengths than now available (approximately 20 to 28 ksi).

- C. Establish mechanized repair methods that do not degrade weld strength and toughness after two repair cycles.
- D. Examine other techniques to improve weld strength such as cold-gas chilling of welds and local elevated-temperature aging treatments.

3.2.2 Meteoroid/Thermal Protection System

3.2.2.1 Meteoroid Protection

An integral armor concept has been selected for the RNS, using low-density foam and a fiber glass primary bumper. Meteoroid armor is a significant contribution to the stage inert weight. The meteoroid protection subsystem is designed in conjunction with the thermal protection subsystem, because the HPI required for these vehicles provides a portion of the meteoroid armor and some armor concepts (e. g., foam) can provide ground hold insulation.

State of the Art

Three candidate thermal/meteoroid concepts were considered for the nuclear stage. The fixed-shroud concept employed a truss grid core honeycomb sandwich structure spaced away from the insulated propellant tank. The deployable-shroud concept used a meteoroid bumper cinched down on the insulation during launch, but deployed in space to increase its effectiveness. The selected integral armor concept has been described. Test data generated for this study were assessed together with previous test results to evaluate these concepts.

The effectiveness of the armor system in defeating meteoroids of the design mass is a major area of uncertainty, since the bases for velocity and particle density extrapolation from the test conditions to the assumed meteoroid characteristics is open to question. Also, tests conducted with foam (References 5 and 6) have shown vaporific effects where the foam can magnify the impact of the oncoming particles. This has been particularly observed for tests conducted with low melting projectile/bumper combinations. Because the average velocity of particles relative to earth is 20 km/sec and current ballistic ranges are around 8 km/sec, the low melting point systems may reflect actual damage mechanisms more closely.

Program

The objectives are to select the optimum meteoroid armor configuration for the RNS and to reduce the uncertainties in its penetration resistance as much as is possible with laboratory tests. The test program is divided into two phases, as follows.

Phase 1—Evaluate alternative meteoroid armor configurations for the RNS to velocities of about 8 km/sec. Various combinations of bumpers, foam, HPI, and spacing, corresponding to possible armor configurations, will be tested. The ballistic limit (projectile mass which can be defeated) will be determined for the configurations of interest. HPI physical damage will be assessed in conjunction with this evaluation. Approximately 100 impact tests should be performed.

Phase 2—Evaluate the configuration(s) selected in Phase 1 for penetration resistance to meteoroid impact conditions. An assessment will be made of the adequacy of the extrapolation formulae applied to Phase 1 test results. A theoretical basis will be derived to establish laboratory impact conditions which will most closely approximate meteoroid impact for the particular configuration(s) selected. This would consider projectiles such as cadmium which might better approximate the low density of cometary meteoroids. Tests will be performed on the selected configuration(s) for the impact conditions derived above. Modifications will be made to the configuration as indicated by those tests. A final series of tests will be performed for the revised configurations. This combined theoretical and experimental phase would include 40 meteoroid impact tests.

Orbital tests may be required to resolve uncertainties in both the meteoroid environment and penetration phenomenon. These tests would logically follow the tests described here and would be combined with other orbital tests.

3.2.2.2 High-Performance Insulation

The RNS concept employs DAM with a dacron net spacer (DAM/net) as an integral part of the thermal/meteoroid protection system. High-performance insulations consisting of multiple radiation barriers to solar heat have demonstrated 10^{-3} lower thermal conductivities than foam. The use of these

systems in space would make feasible the storage of liquid hydrogen in space for 30 to 300 days without the need for refrigeration, excessive boiloff, or high tank pressures. The development of this system for large-scale tankage is fundamental to effective operation of the RNS.

During its lifetime the insulation will have to protect LH_2 propellants in space for more than 30 days, be purged with inert gases while on the ground, withstand launch loads of 4.4 g's, withstand aerodynamic forces, outgas contaminant gases, evacuate purge gases and gases leaked into the insulation, and perform efficiently with structural penetrations.

The design considers that the insulation will be constrained by a compressive loading of approximately 0.1 to 0.2 psi, thus acting to transmit ascent-phase aerodynamic loads to the tank wall. Once orbital insertion is achieved, this compressive loading is released.

Effect of Mechanical Compression

State of the Art—A major portion of the experimental work to date on compression has been obtained by Lockheed (Reference 7) using a flatplate calorimeter. These data have been reported several times in different forms (References 8 and 9) and have been used by MDAC in its present HPI work (Reference 10). The results of these data are shown in Figure 3-5. The data indicate that the DAM/net system retains its thermal performance satisfactorily under compressive loading. Recently, however, additional experiments have cast doubt on the validity of the compression data that exist. These data reflect the conductivity while the insulation is under compressive loads. However, no data are available on the insulation performance after it has been released and allowed to spring back. These effects are currently under investigation at MDAC.

Program—It is recommended that the following information be obtained:

- A. Sensitivity of thermal conductivity of candidate HPI systems to compressive loads of 0.001 to 0.3 psi.

Figure 3-5

LOADING EFFECT ON INSULATION PERFORMANCE

- B. Percent spring-back as a function of time under compression.
- C. Thermal performance after release of compressive loads.

Two types of tests are recommended:

- A. Structural screening tests to determine spring-back properties of candidate insulation systems.
- B. Thermal performance versus compressive loads for three insulation systems. Samples should be tested on a 15-in.-diameter calorimeter while under compressive load, and after the insulation has been released.

Venting Characteristics

State of the Art — Thermal performance tests of HPI are generally carried out after several days of pumpdown. Outgassing of small amounts of contaminants with low vapor pressure can affect the insulation performance (Reference 10). As a result, serious consideration must be given to the design of composite meteoroid/thermal protection systems to insure that outgassing and evacuation will not be a problem, especially at lower pressure levels, where free molecular flow rather than continuum flow is of primary consideration. In addition, it is necessary to evaluate whether compressive loads will hinder evacuation.

Program — The necessary data on purge and evacuation of the insulation system may be obtained with the following program:

- A. Purging — Hot- and cold-gas purge screening tests of compressed insulation and thermal/meteoroid systems would be performed on a 15-in.-diameter calorimeter with LH₂ capability. After these tests were conducted, similar ones would be made on 5- to 8-ft diameter tanks for the successful candidate.
- B. Evacuation — Initial precursor outgassing tests of foam systems would be conducted for compressed and noncompressed states. Sequential outgassing and evacuation tests to the screening purge (15-in. diameter) and purge tests (5- to 8-ft diameter) would be made on compressed and noncompressed samples. Ascent launch pressure environment would be simulated.

Meteoroid Damage

To assess the capabilities of the foam/DAM/net composite design as meteoroid armor for the RNS, meteoroid penetration tests have been performed concurrent with the present study. These results have been used in the present design philosophy. However, it is felt that additional testing related to thermal degradation following meteoroid impact is necessary.

Leaking Tests and Studies

State of the Art — The difficulties of storing LH₂ in a cryogenic state for long times with minimal leakage are well known. However, the effects of such leakage on the in-space thermal performance characteristics of candidate HPI materials are all but unknown (Reference 11).

Program — It will be necessary to determine the extent of thermal degradation and the amount of degraded surface area as a function of leak rate and insulation thickness and density. In addition, various design concepts for the evacuation of gases from the RNS insulation blanket at low pressure levels should be evaluated.

This problem requires primary analytical investigation, with supporting thermal/vacuum experiments on the 15-in. -diameter calorimeter. A baseline design concept will be evaluated with several leak rates.

Penetrations and Discontinuities

State of the Art — Much conceptual design has been accomplished (References 7, 8, 9, 12, 13) and is being extended and improved at MDAC (Reference 10). Very limited thermal performance data have been obtained for various attachment techniques and blanket joints (Reference 10), and virtually no data exist on blankets designed for sharp or concave corners. The study of penetrations on cryogenic storage vessels to date has consisted primarily of the utilization of computerized thermal models to predict thermal performance, coupled with experimental tests (References 7, 8, and 14).

Program — While analytical techniques may be satisfactory for determining the penetration heat leaks of particular configurations, experimentation will be necessary to determine the superiority of insulation layup techniques around penetrations. In addition, basic design criteria for penetrations, including piping, electrical connections, structural members, etc., need to be developed with special attention being given to manufacturing difficulties imposed by the presence of penetrations. The design requirements imposed by flexible ducting for RNS orbital assembly must be evaluated.

Blanket designs for application to the RNS are now relatively well developed. However, there is a need to develop and define adequately certain design features as elucidated above and perform associated structural and thermal tests.

Orbital Experiment

Data on the performance of an integrated HPI system in an actual mission environment is not available and requires in-space testing, since it is not feasible to simulate simultaneously all of the environmental aspects of an actual flight. Considerable testing has been accomplished in an effort to establish the performance of HPI systems. Examples of the results of this testing are described in previous sections and encompass the areas of thermal insulation, structural, and evacuation performance. In general, the thermal performance and evacuation efficiency investigations have been carried out in vacuum chambers while structural tests have considered the effects of rapid evacuation, high acceleration, acoustics, and vibrational loadings on the insulation. The data obtainable from an orbital experiment of the integral system will be necessary to confirm the vehicle thermal design. The orbital test would be combined with destratification and meteoroid experiments. The Thor/Delta or a piggyback experiment on a space module would be candidate vehicles to be used to place the experiment in orbit.

3.2.2.3 Surface Coatings

The exterior of the RNS will be protected with solar reflector coatings. It will be necessary for the surface coating to adhere and maintain integrity throughout the full RNS lifetime of 10 round trips and 3 years in space.

State of the Art

The principal candidates as surface coatings for the RNS are Z-93 (SP500 ZNO-pigmented potassium silicate paint) and S-13G (silicate treated - ZNO in metal silicone base). Limited data are available concerning the performance of these coatings after extended exposure to the space environment. It has been found that Z-93 exhibits good stability over a period of 1,580 ESH (earth sunshine hours) for the near earth environment and near the moon with a change in α_s/ϵ from a nominal value of 0.20 to 0.21 (References 15 and 16). S-13G shows a more substantial degradation from 0.22 nominal to about 0.32 in 1,600 ESH, although the level apparently stabilizes up to at least 3,000 ESH (References 17 and 18). No flight or laboratory data were available for longer time periods with either coating.

Program

Most of the available data on the performance of surface coatings in space have been obtained from experiments on spacecraft. Since the data requirements for other space systems will be comparable to those of the RNS, a recognition of these needs in on-going spacecraft programs can provide the necessary long duration space environment data which is required. The S-13G coating has been selected for Skylab. This should provide the opportunity to evaluate its performance on a large system.

3.2.3 Main Propulsion

3.2.3.1 Propellant Dynamics

In order to achieve safe and efficient in-orbit engine startup and tank venting, positive design provisions must be made to assure that the liquid propellant is positioned over the tank feed line outlet and remote from the vent outlet. Also, efficient operation of the RNS during aftercooling requires a passive propellant collection system such as the selected surface tension basket.

Propellant Settling

State of the Art — In July 1966 the AS-203 in-orbit experiment, using a partially loaded S-IVB, was flown to demonstrate the adequacy of the initial propellant settling thrust and the continuous vent system (4.4×10^{-4} g and

5.5×10^{-5} g) for maintaining the liquid in a settled condition (Reference 19). Although the AS-203 test did verify the Saturn design adequacy, it was not designed to provide the detailed understanding of the basic fluid mechanics of propellant settling required to evolve efficient reliable designs for other applications.

Analytical and 1-g experimental propellant settling research conducted by MDAC (References 19 and 20) has shown that the flow process occurs in four distinct stages: (1) initial inviscid flow of liquid across the tank; (2) impact and turbulent flow; (3) laminar wave dissipation; and (4) bubble formation and displacement. Analytical expressions have been developed to characterize these flows. The 1-g tests with a Bond number ranging from 87 to 4,150 have been conducted to correlate the equations, and these have been incorporated into a computer code to predict optimum settling times and acceleration levels. Figure 3-6 shows the 1-g test apparatus and typical test results. Tests have been conducted with models ranging in size from 2 to 20 in. in diameter and various fluids including water, DC200, ethyl alcohol, and hexane.

In the past, sloshing has been analyzed by means of a mass-spring analogy (Reference 21) or more recently by linearized inviscid flow theory and although adequate for 1-g problems, the results are highly questionable for low-g conditions. Recently, however, advanced numerical techniques have been developed by MDAC which can predict sloshing and the probable point of wave breakup for applied loads such as ACS thrusting (Reference 22). Also, the marker-and-cell (MAC) program originally developed at Los Alamos and applied by MDAC to propellant feed system problems (Reference 23) has considerable potential in this area. For example, the MAC program was applied to the prediction of sloshing and wave breakup in the Saturn S-IVB tank during docking disturbances for one of the early Apollo flights (Reference 13). The results are shown in Figure 3-7 as separate frames from the MAC-produced movies. The influence of baffles and other control devices can be assessed with such computer codes.

Figure 3-6

PROPELLANT SETTLING RESEARCH

Figure 3-7

SYMMETRIC PROPELLANT UNSETTLING USING MAC PROGRAM

During the MDAC/NASA Project THERMO program, the various problems and critical scaling laws for interface instability were investigated (Reference 24). For example, design criteria analyses and supporting ground based tests were conducted on the interface stability during low-g pressurization (see Paragraph 3.2.3.5). The end result was stability criteria for various inlet diffusers. However, before such data can be confidently applied to design activity, the validity of the criteria at very low-g levels must be established.

Program — Based on this research, the process of propellant acceleration settling has been reasonably well characterized, although certain detailed features of the flow, such as turbulent dissipation and bubble behavior, must be better defined by low-g experiments to establish optimum design. Low Bond number tests (1 to 100) are particularly needed to correlate bubble production and displacement data. Although drop tower and low-g aircraft tests can be informative in this area, the limitations on controlled imposed acceleration and test times limit their usefulness. Also, the theory indicates that a two-level thrust settling mode is optimum, but this has never been experimentally demonstrated. This has a major impact on the RNS, since NERVA thrust is utilized to accomplish the high-thrust energy dissipation phase of settling. Therefore, in-orbit testing is highly recommended. Requirements for such experiments have been defined in References 24 and 25. Cryogenics are not essential in these experiments since fluids such as hexane closely approximate the kinematic viscosity and surface tension of LH_2 . Use of such fluids also permits the use of transparent tanks and good quality photographic instrumentation. Tanks in the 2 to 4 ft diameter range and imposed g-levels of 10^{-2} to 10^{-4} are appropriate. Such an experiment would require an APS for providing settling thrust.

Sophisticated analytical tools are becoming available to solve propellant dynamics problems. These basic analytical concepts must be expanded and refined in order to apply the numerical approaches to real world problems (as real tank shapes) and ground-based experiments should be continued to provide preliminary verification and scaling data. Orbital experiments should be performed to provide final verification of the analytical concepts and computer codes.

Limited scope, small-scale experiments could possibly be conducted on the orbital workshop or integrated with other propellant management experiments on a separate orbital experiment. Noncryogenic fluids (simulants) could be used in these tests with transparent tanks ranging in size from 2 to 4 ft. An APS would be required to provide disturbing forces and photographic coverage would constitute the basic data.

Surface tension devices in the form of sump screens or tank wall liner screens have been used with noncryogenic propellants and have been proposed for use with cryogenics (Reference 26). However, the heat transfer and resulting boiling and vaporization that occur in cryogenic systems impose serious limitations on surface tension systems. For example, tank pressure decay that is normally experienced after engine shutdown in cryogenic systems can result in propellant vaporization and bubble production within the propellant contained in the surface tension device. This precludes the delivery of fluid in a pure liquid phase and can lead to the inability of the screen or surface tension device to retain liquid. There has been relatively little experimental work conducted with surface tension orientation concepts with cryogenics, particularly under representative thermal and reduced gravity conditions. Negative 1-g tests can be used to demonstrate the surface tension concept with LH₂, but because of the very low surface tension of cryogenics, and thus the low heads that can be supported, only very small models (4 to 5 in.) can be used. In earth-based low-g tests, there is insufficient time to establish proper heat transfer and bubble behavior. Thus, an orbital experiment to establish the behavior of cryogenic surface tension orientation systems is required before a design can be committed for a specific system.

3.2.3.2 Chillydown

During an RNS propellant resupply it is necessary to chillydown warm propellant tankage in a controlled manner which will not exceed the tank design pressure. Also, prior to RNS startup it is necessary to chillydown the active portion of the feed system to assure propellant conditions for NERVA and to accomplish a predictable startup operation.

State of the Art

A lack of data on boiling heat transfer in low-gravity conditions provides uncertainty concerning chilldown processes for these RNS design requirements. Low-g boiling experiments were conducted using an Aerocommander aircraft, which indicated that the boiling curves show little, if any, effect of a reduced gravity field on nucleate boiling over a gravity range between 0.01 and 1 g (Reference 27). A model based on the transport of enthalpy similar to that of Han and Griffith (Reference 28) was used to explain the insensitivity of boiling heat transfer to gravity for the range studied. This model utilized the concept of the superheated layer during bubble growth that was removed as superheated liquid by the departing bubbles. An evaluation of boiling heat transfer in hydrogen (Reference 29) indicates that film boiling occupies about 90 percent of duct chilldown time. A film boiling heat transfer correlation for hydrogen was obtained in Reference 30.

Program

In-orbit testing of tank chilldown and boiling heat transfer processes are essential for efficient design of the RNS. The experiment should be conducted with LH₂. A forced convection transfer between two tanks would be utilized containing components in the configuration of the RNS propellant resupply and chilldown system concepts.

3.2.3.3 Stratification/Destratification

Heat entering a cryogenic propellant tank results in a rise in tank pressure which depends on how the added energy is distributed through the tank contents. The RNS has long orbital coast periods in a gravity gradient stabilized attitude which tends to keep the propellant oriented at the end of the tank. This is conducive to temperature stratification, which results in higher pressures than a uniform temperature situation.

State of the Art

Extensive research has been devoted to developing techniques for predicting the degree and characteristics of the stratification (References 31, 32, and 33). Many subscale and full-scale 1-g stratification tests have been conducted. The nature of the stratification is dependent upon the prevailing or dominant mode of heat transfer, as boiling or conduction, and these two processes

cannot be completely divorced. Some very small scale (less than 1 ft) low-g testing has been conducted in this area (References 34 through 37), but there are no data on low-g stratification in large tanks. Ullage heating data for the Saturn AS-203 experiment indicate potential problems from nonequilibrium heating.

To reduce the undesirable effects of stratification, techniques have been studied for eliminating the temperature differences in the system generally by intermittent fluid mixing (Reference 38). These techniques involve some form of pumping using mechanical devices and/or liquid jets. Research now underway at MDAC is investigating the application of EHD principles to destratification (Reference 39). It appears that destratification is feasible and requires very low power levels (Reference 40), but there has been very little low-g experimentation to establish this as a fact.

Program

The two most promising techniques for analytically studying stratification/destratification are a University of Michigan computer code (Reference 41) and the MAC code (Reference 23), both of which are being studied at MDAC. MAC is particularly useful in that it produces movies of the flow and thermal behavior (temperature distributions). Thus, once low-g verification of these numerical methods predictions can be obtained, analytical experiments can be confidently performed on a computer.

Effort should be devoted to extending potential analytical techniques, particularly the MAC program, to handle more complex geometries (spherical coordinates) with improved computational efficiency. Ground-based scaling tests and subsystem development tests (pumps and mixers) should also be conducted.

Laboratory testing should be continued to assess the influence of boiling, vibration, sloshing, concentrated heat leaks, pressurization, venting, etc., on stratification/destratification. An in-orbit experiment on destratification is essential for RNS development.

3.2.3.4 Nuclear Heating of Propellant

Early nuclear stage design concepts caused great concern for the implications of nuclear heating of propellant because the vehicle configuration resulted in a large amount of nonuniform energy deposition in the propellant. However, the design concepts which have been defined during the Phase II and III RNS studies have been motivated by a requirement to minimize the radiation dose to the manned payload at the top of the stage. Accordingly, the stage configuration is confined to a narrow shadow cone provided by the NERVA internal shield. Consequently, the amount of energy deposition in the propellant is reduced substantially. Also the propulsion module configuration which locates a small run tank adjacent to the engine and removed from the main propellant tankage isolates the impact of the nuclear heating.

State of the Art

The effects of nuclear heating of propellant have been simulated by various experiments which give a good indication of the nature of the problem. The approach has been to examine fluid behavior under three circumstances: bottom heating only, sidewall heating only, and a combination of bottom and sidewall heating.

The first such experiments were performed by Tatom, et. al. (Reference 42) using a cylindrical 500-gallon tank with LH_2 . Temperature profiles and Schlieren photographs were obtained during nonexpulsion tests. With bottom heating only, essentially complete mixing occurred. With sidewall heating only, a distinct stratified layer of warm fluid occurred at the top of the liquid fed by the sidewall boundary layer. With combined bottom and sidewall heating, both effects are present, but the degree of stratification is reduced.

Experiments were also performed by Anderson and Kolar (Reference 43). A two-dimensional glass tank with a 45-degree sloping bottom was used. Fluid discharge was permitted during the experiment. Infrared lamps were used for heating and blackened sidewalls simulated uniform wall heating. Temperature profiles and schlieren photographs were obtained. The three heating variations were tested. With bottom heating alone, simulating nuclear heating, complete mixing (with no evident regions of either upflow or down flow) was obtained resulting in a uniform axial temperature profile. Sidewall heating

alone resulted in a stratified layer near the surface. A combination of bottom and sidewall heating resulted in an interaction of the two modes of heating in which the bottom heated fluid was unable to penetrate through the stable stratified layer resulting from sidewall heating. In tests with only bottom heating, the fluid temperature history at the tank exit gave good agreement with that predicted by a complete mixing model.

Another set of experiments was performed by Biesiadny (Reference 44) using the same experimental facility as Anderson and Kolar. These investigated the use of baffles to alleviate stratification. With sidewall heating only, baffles reduce the stratification moderately during early phases but were not significantly effective after an extended test time. With both sidewall and bottom heating, the baffles were less effective than with sidewall heating only.

Early experimental results provided the basis for the first theoretical analysis of nuclear heating of propellant by Vliet, et. al. (Reference 45). In this model bottom heating is distributed through the bulk of the fluid by the complete mixing mode. Sidewall heating produces a boundary layer (assumed to be turbulent) which delivers fluid to the stratified layer. A similarity model is assumed to describe the stratified layer temperature profile. The surface temperature and stratified layer ducts can then be calculated from the region interfaces and boundary conditions. These analyses were refined and incorporated into a general asymmetric propellant heating code.

The experiments and analyses indicated have served to illuminate some of the phenomenological aspects of the propellant heating problem. The HPI system reduces sidewall heating to a negligible amount, so the only propellant heating in question during engine operation is the nuclear heating entering through the tank bottom.

A variety of possible modes of distributing the energy deposited in the propellant by nuclear heating have been identified. Some involve combinations of modes. Of these, the no mixing mode and the complete mixing mode will result in the lowest fluid temperature delivered to the turbopump. In the no-mixing mode the heated propellant at the bottom of the tank is drained from the tank without delivering heat elsewhere within the tank. Thus, once a steady

state is achieved early in the nuclear engine operation propellant is drained at a constant temperature. In the complete mixing mode all the nuclear heating energy is distributed uniformly throughout the tank as rapidly as it is deposited. This could be achieved in a highly turbulent flow condition. The complete mixing mode allows a buildup of energy content in the later portions of the propellant drain period, but this buildup is significantly lost in that which would occur with temperature stratification. Any propellant stratification occurring from boundary layer effects during nuclear heating is deleterious to system performance.

Program

In order to evaluate fluid dynamic phenomena associated with nuclear heating, the experimental techniques and facilities employed must provide authentic simulation of energy deposition by NERVA in LH₂. Flexibility should be provided for evaluating various tank configurations, heat flux distributions, and propellant control concepts. Tank draining during the experiments is required. Investigation of scaling phenomena by MDAC has indicated that a Reynolds number based on the tank draining rate and an effective Grashoff number based on the total heating rate are the dominant fluid dynamic scaling parameters. A prototype program involving both LH₂ and a nuclear reactor is considered essential to simulate the fluid dynamic scaling parameters. A 9-ft-diameter LH₂ tank and a reactor located at General Dynamics, Ft. Worth, should be made available and utilized for such a program. A study is in progress to define such an application of this facility (Reference 46).

3.2.3.5 Propellant Transfer

The efficiency of orbital propellant transfer operations has a major impact on the cost of propellant delivered to the RNS, which is the dominant factor in the economics of the transportation system.

State of the Art

The current understanding of low-g fluid dynamics and thermodynamics is not adequate in many areas to support a highly reliable propellant transfer design effort. (Many of these deficiencies were defined during Project THERMO, Reference 24.) Supporting research and technology is required in this area, culminating with an in-orbit transfer experiment.

In-orbit transfer systems may be divided into two categories: low-g and zero-g (less than 10^{-6} g). In low-g systems, an acceleration (either linear or angular) is applied to the total system to aid in proper propellant positioning. In zero-g systems no force is applied to the total system and other means such as surface tension or electrical forces must be used to properly position the liquid during transfer. In either case, mechanical pumping or pressurization may be used to actually move the liquid between tanks. Linear acceleration was adopted as a baseline for the RNS during Phase II. Efficient propellant draining and maintaining a hot ullage during expulsion are essential to this concept.

In low-g transfer, supply tank residuals, caused by suction-dip and pull-through, result in significant weight penalties. This flow process has been studied with dubious success using linearized inviscid flow theory (Reference 47). More advanced numerical techniques, such as a nonlinearized theory (Reference 22), and a finite difference solution to the Navier-Stokes equations, such as MAC (Reference 23), show promise as realistic analytical tools. Figure 3-8 shows results of both a nonlinearized analysis and a MAC prediction of the vapor pull-through height as compared to test data extrapolated to low-g conditions.

Figure 3-8 CORRELATION OF LINEAR AND NONLINEAR THEORIES TO EXPERIMENTS ON PULL-THROUGH HEIGHT

A potential problem for all transfer systems using tank pressurization is the interface instability and severe pressure collapse that may result from an improperly designed inlet diffuser; these instabilities can be quite severe in low-g experience as compared to normal 1-g. This problem was explored in detail (References 19 and 24). An analysis was performed and 1-g scaling pressurization tests were conducted in a 2-ft-diameter transparent tank using various inlet diffuser designs. The design criteria were developed to establish stable behavior with the various type diffusers.

Program

The low-g suction dip predictions need to be verified by in-orbit transfer tests before the analytical techniques can be confidently applied to actual system design. These tests should be conducted in transparent tanks with cryogen simulants. If successful correlation is achieved, the analytical models must be expanded to handle more complex problems. Also, the pressurization correlations must be extended and checked out for very low-g conditions. Either cryogenic or cryogenic simulant experiments in 2- to 3-ft-diameter tanks can be used in this area.

3.2.3.6 In-Orbit Propellant Management Testing

The preceding discussion has indicated that much of the necessary propellant management research must culminate in some form of in-orbit experiment, since proper low-g simulation is difficult to obtain in earth-based experiments. Areas that have a critical need for in-orbit testing for the RNS include insulation performance characteristics, propellant dynamics, chilldown and boiling, and propellant transfer.

State of the Art

During the past 10 years, there has been extensive drop tower and zero-g aircraft testing, but relatively little long-duration low-g experimentation, particularly with cryogenic fluids and on a useful scale. During the early 1960's, a series of small-scale LH₂ experiments were performed using Aerobee sounding rockets to study basic heat transfer and fluid dynamics (References 34 through 37). In addition to their technical value, these tests brought to light some of the testing problems such as instrumentation and data acquisition.

The largest in-orbit experiment conducted to date was the Saturn AS-203 experiment (Reference 48). This NASA/MDAC experiment was conducted with a partially loaded S-IVB stage and was designed to primarily verify the design of the S-IVB in-orbit venting and propellant control system. The program also provided insight into the basic characteristics of LH₂ in the low-g environment and was a major step forward in developing the technology for the design and operation of such experiments. Also on the same flight a piggyback experiment was flown to demonstrate subcritical storage of cryogenics using a throttling device and heat exchanger concept for guaranteeing all gas phase expulsion (Reference 49).

There has been an extensive effort in planning advanced technology in-orbit experiments both of the single and multipurpose type. The most complete example of this is the NASA/MDAC Project THERMO Program (References 24 and 25).

Program

There are basically two types of in-orbit experiments that may be considered: (1) experiments that are integrated into other orbital systems such as the Saturn workshop, space station, etc.; and (2) separately launched experiments. In the second category, the experiment package may be completely independent or may be tethered and serviced as by a space station. Experiments integrated into another orbiting system are generally limited in size and environment. However, certain basic experiments like low-g boiling may be well suited to such an approach. These integrated experiments may also help in exploring problem areas in order to evolve a more reliable full-range separate experiment.

As a minimum, one single tank experiment using LH_2 should be flown to study insulation performance, stratification and destratification. Such an experiment is illustrated in Figure 3-9. These should be at reasonably large scale (above 3-ft diameter) and with a representative thermal environment (wall heat flux and heat shorts). This test could be combined with an LH_2 storage experiment. Both stratification and destratification using a number of potential concepts could be accomplished in the same test.

A second cryogenic experiment employing a dual insulated tank apparatus should be flown to study propellant transfer problems, including settling, pressurization effects, chilldown receiver tank thermodynamics, and surface tension orientation concepts. Hardware to conduct such a test is illustrated in Figure 3-10.

A third experiment, using simulant fluids in transparent tanks, should be flown to study basic propellant dynamics and interface stability problems such as vapor pull-through, sloshing, and pressurant induced instability.

Studies such as Reference 25 show that such experiments can be launched with available launch vehicles such as Thor-Delta at a cost of about \$7 million per flight, including two experiment packages, vehicle and launch costs. The variations in experiments have a very minor effect on the cost since the bulk of the cost lies in the vehicle and launch operations. It also requires at least

Figure 3-9

STRATIFICATION/DESTRATIFICATION EXPERIMENT

Figure 3-10

PROPELLANT TRANSFER RECEIVER TANKS THERMODYNAMICS EXPERIMENT

2 years for a complete test problem including design, launch, and data analysis.

3.2.4 Auxiliary Propulsion

A cryogenic APS system utilizing a turbopump-fed propellant conditioning system and film-cooled thrusters has been selected for the RNS. Since the APS is located in the command and control module, which is returned to the ground after each mission, the lifetime requirements on APS components will not be excessive. The design implications of cryogenic APS systems are currently being defined for the space shuttle program (Reference 50). The propellant conditioning system selected for the RNS is the same as for space shuttle. The space shuttle engines are 1,000-lb thrust, compared to 50-lb thrust for the RNS. The cryogenic APS technology developed for the space shuttle will apply directly to the RNS. Therefore, a separate SRT program is not envisioned as being required.

3.2.5 Astrionics

3.2.5.1 Computer Systems

The reliability analysis for the RNS utilized data based on two IBM 4 π MOL computers in a redundant configuration. This element represented the weakest link with an MTBF of 4.1×10^3 hours. A requirement exists for development of ultra-reliable computer system elements for space-resident systems.

Reliability Requirements

The reliability requirement for the RNS computer, based on a 45-day mission, is estimated at 38,500 hours. This assumes a 1 + 1 computer configuration and uses dormant failure rates for the standby computer (10 percent of active), and requires a 0.99 sensing and switching probability. The required MTBF is about 1 decade above the present reliability quoted for airborne computers. Additionally, methods to implement a 0.99 switchover probability are presently undeveloped but would likely require that both computers be operational and tracking one another which would further increase the reliability requirement.

Program

A careful review of all resident computer space system requirements and a definition of a family of compatible computers to satisfy these requirements would prove meaningful to RNS and all other long-life programs. Methods of switchover to a redundant computer needs investigation along with other reliability enhancement techniques including self-healing.

3.2.5.2 Failure Prediction Techniques

The use of orbital maintenance to extend the life of the RNS requires that criteria be established for performing maintenance. The nature of most failures is apparently such that evidence of impending failure exists prior to performance degradation beyond acceptable limits. The existence of onboard checkout systems for evaluation of a wide range of data provides a valuable tool to investigate this evidence and identify elements of the RNS that are amenable to maintenance.

Identification of the nature and characteristics of impending failure evidence should be made for the various system elements and instrumentation for monitoring and analyzing these characteristics developed. Four approaches appear attractive. It is necessary to establish the benefits and practicality of implementing these for the RNS.

Quantitative Performance Analysis

State of the Art—Monitoring the performance of a functional system and establishing bands of performance outside which maintenance is required, but performance is adequate is the classical approach to this problem when graceful degradation is the anticipated failure mode. The standard may be fixed at absolute levels or may be comparative as with the analysis of trend data. This basic technique is utilized in checkout and nondestructive testing. Examples of evidence to be monitored for solenoid valves are changes in power demands or heat, possibly using infrared sensing, time of closure or the shape of the back EMF curve. The latter suggests that other electrical signature analysis investigation may be fruitful.

The nature of solid-state electronics failures provides less motivation for identifying evidence of impending failure. End of life or wearout failure phenomena do not apply to these devices, rather, random failure is experienced. Unlike mechanical components, ability to enhance reliability through the use of redundancy is easily implemented.

Trend analysis has been successfully utilized on the Saturn program in at least one area. Relay failures in the reusable S-IVB automatic GSE were found to be highly correlated to changes in the activation times. Automated self-test procedures were developed and utilized successfully to identify relays that required placement in advance of failure. Because little work in the area of fault prediction has been done, no basis for a definitive program recommendation is provided.

Program – Some precursor activities for electrical components should be defined. Included would be identification of potential electrical signature characteristics for various electrical components. Alternatively the investigation of trend analysis algorithms for electronic components could be conducted, based on specific performance characteristics.

Mechanical Signature Analysis

State of the Art – A sensitive accelerometer or transducer attached to the device provides an electrical signal corresponding to the mechanical signature. This signal is processed to reveal the presence of an object or significant deviation from normal. The signature of a defective device may differ from the signature of a normal device in amplitude, frequency content, or periodicity. The frequency range of interest may vary from audible to as high as 1 MHz. The technique offers the advantage of defect detection before performance degradation. Thus, this technique may be used to detect defects which are otherwise undetectable and which have an adverse effect upon the life of the device.

Program – After identification of flight control components on the RNS (electromechanical or mechanical components), establish the mechanical

signatures of functioning devices, especially in the ultrasonic region for mechanical devices. Introduce controlled defects into the components and ascertain the changes in characteristic signatures over a wide frequency spectrum and correlate the results. Define instrumentation to monitor and analyze these characteristics.

Acoustic Emission

State of the Art — The initiation and propagation of cracks in the weldments of RNS cryogenic propellant tanks can cause failure of these tanks during their continued service. Acoustic emission, an advanced nondestructive technique, is used to detect the sounds produced by the formation and growth of cracks. Permanently attached transducers connected to an onboard acoustic emission system can continuously monitor an aluminum cryogenic tank and can indicate when a crack is formed. Acoustic emission can only detect the initiation and propagation of cracks and cannot detect the presence of existing stable cracks. Thus, an onboard acoustic emission monitoring system must be developed for continuous use.

The acoustic emission characteristics of various materials, including graphite, fiber composites, and metals, have been studied at MDAC and in other organizations (References 51 through 53). A program is currently in progress to relate acoustic emission to crack length in aluminum tension and fatigue specimens. In Reference 54 it was found that formation of a crack with area greater than 10^{-5} in.² resulted in emission stress waves. The size of crack detectable depends upon the material and the amount of amplification. The feasibility of acoustic emission monitoring of cryogenic tanks will be established by applying this technique to subscale aluminum tanks, which will be cyclicly proof tested. It is expected that sound will travel better in a cryogenic tank at lower temperatures than at room temperature. Piezoelectric crystals also work well at these temperatures. The only potential problem is coupling the transducer to the tank. It is expected, however, that an adhesive having the necessary properties can be found or

that mechanical fastening can be used. The tanks will be loaded with the aim of producing cracks in the weldments.

Program — Several basic aspects must be investigated. The type of wave propagation associated with the sound created by crack initiation will be analytically and/or experimentally determined. This will provide the basis for selection of the proper type of transducer and operating frequency. A study of the interference noises resulting from the attached structures and the tank itself will be conducted by analyzing their frequency spectrum. The array and the number of transducers will be determined for the subscale tank such that the entire tank can be efficiently and economically monitored. The instrumentation needed for continuously monitoring and recording the acoustic emissions will be defined.

Ultrasonic Crack Detection

State of the Art — Ultrasonic pulse-echo and transmission techniques can be used to detect the existence of cracks in weldments. Crack detection is accomplished by analyzing the reflected signals from flaws. Transducers permanently attached to critical areas of a cryogenic tank can be connected to onboard instrumentation such that the tank can be inspected while docked in earth orbit. The ultrasonic crack detection checkout can be conducted after each orbit-to-orbit flight and can indicate a go or no go condition for the next flight.

Two types of the ultrasonic systems have been evaluated.

- A. Continuous Wave Ultrasonic Flaw Detector — A transmitter produces ultrasonic waves in the wall which are picked up by a receiver. The flaw in the metal between the transducers will produce a drop in the output voltage of the receiver from which the general location of the leak can be determined. The area covered by one transmitter-receiver system is 1 to 2 in. wide; thus, many transducers are needed for a large area. Minimum puncture sizes detectable would be on the order of 0.040-in. diameter at 6 ft and 0.075-in. diameter at 25 ft.

- B. Pulse-Echo Technique — One transducer generates and receives the signal which is displayed on a CRT oscilloscope. This indicates the existence of a defect and its location from the crystal. The amount of reflected energy depends on the relation between the size of the flaw and the wavelength of the signal; the higher this ratio, the more energy reflected.

The upper limit of frequency occurs when grain boundaries in the material attenuate and reflect the ultrasonic sound waves. For aluminum, a 5-MHz frequency is advisable. A low-power (1,000 volts peak to peak, 2- μ sec pulse) pulsed ultrasonic detector would detect flaws in aluminum up to 25 ft away. The minimum flaw size is equivalent to a 0.040-in. hole, 1/8 in. long. It is possible to have each transmitting transducer and associated pickup receiver commutated to a single transmitting and receiving system, providing sequential operation of the system.

Program — The feasibility of ultrasonic crack detection in cryogenic tanks will be established by applying this technique to subscale tanks. A set of standards containing machined cracks of various sizes and orientations will be evaluated using both the pulse-echo and transmission (pulsed or continuous wave) techniques to determine which is more efficient. This technique will then be applied to the flawed subscale tanks to detect the existing cracks. These conventional techniques may not be completely adequate due to small flaws and unfavorable flaw orientations. To aid in data analysis, two techniques, pattern recognition (particularly wave form analysis and matched filtering) and signal extraction, will be investigated. Flaw location can also be determined by triangulation techniques from the phase of a signal received by several transducers. These techniques may be applied while in orbit to detect the initiation, growth, and location of cracks to avoid premature catastrophic failure.

3.2.6 Radiation Effects

During 10 hours of total nuclear engine burn time, the nuclear stage components will be subject to irradiation exposure doses ranging from $\sim 10^4$ rads (C)* and $\sim 10^{10}$ nvt in the forward region to $\sim 10^7$ rads (C) and

*-(C)-CARBON

$\sim 10^{15}$ nvt in the aft region. A study of the irradiation effects on the stage component materials indicated that many of them appeared to be suitable for their designed environment (Reference 55). However, some of the materials appeared questionable for consideration of their respective functions. These materials consist of such items as valve seals, solar cells (semiconductors), batteries, fuel cells, wire insulation, transducers, fiber glass composites, aluminized Mylar, and polyurethane foam. A current study (Reference 46) has consisted of a review of Saturn S-II and S-IVB components and systems to determine the organic materials and their applications. A survey of radiation effects data for these will provide recommended tolerances. Transferring many of stage components from the mid or aft regions to the forward location will reduce the incident radiation levels on these components and may eliminate the necessity of redesign for radiation hardening. Many of the component materials which are sensitive to radiation (Reference 56) and their behavior unknown under the anticipated environments, will require testing in the radiation environment.

3.2.6.1 Structure

Fiber glass-epoxy materials have received consideration for use as a structural load-bearing members (thrust cone, support straps) in the nuclear stage design. Radiation effects data are reviewed in Volume II, Book 1 of this report.

The irradiation effects test data reported for fiber glass-epoxy structures appeared to be relatively meager and insufficient for design applications. A small quantity of test information is available on fiber glass structure made of S-glass and epoxy (Epon 828) which appeared promising. However, no irradiation test data were available for the reference design materials which also contains a different epoxy binder (Epon 1031).

In view of the data lacking, irradiation testing would be required to substantiate the use of fiber glass for structural members. The tests should be conducted on reference design fiber glass structure specimens in duplicate.

The testing environment will include irradiation exposures from $\sim 10^4$ to $\sim 10^8$ rads, at temperatures from -423° F to $+150^\circ$ F in controlled vacuum or operational atmospheres.

3.2.6.2 Meteoroid/Thermal

Aluminized Mylar (aluminum-coated Mylar film) is used in the thermal insulation system. Radiation effects data are presented in Section 4 of Volume II, Book 1. The amount of irradiation test data reported on aluminized Mylar and bare Mylar materials is small and insufficient for design applications. According to the data received, aluminized Mylar appears to be relatively satisfactory where irradiation exposures would not exceed 10^6 rads. For use at higher exposure levels, additional irradiation testing is recommended. The tests should be conducted on reference design aluminized Mylar specimens, for both individual layers and panels of multiple layers. The testing environment will include irradiation exposures from $\sim 10^4$ to $\sim 10^8$ rads, at temperatures from -423° F to $\pm 150^\circ$ F, in a controlled vacuum or operational atmosphere. Pre- and post-irradiation tests will include both mechanical and physical property measurements.

Polyurethane foam has also been designated for use as meteoroid shield on the RNS. Few nuclear irradiation data up to $\sim 10^8$ rads have been reported for similar polyurethane types. For the application intended, the amount of relative test data reported on polyurethane foam material appears insufficient. It is recommended that irradiation tests be conducted on reference-type polyurethane foam specimens in duplicate. The testing environment should include irradiation exposures from $\sim 10^4$ to $\sim 10^8$ rads at temperatures from -250° F to $+50^\circ$ F in a controlled vacuum or operational atmosphere. Pre- and post-irradiation tests will include mechanical property measurements.

The performance of candidate thermal protective coatings such as Z-93 and S-136 under combined space and nuclear radiation environments must also be investigated to establish its adherence, mechanical integrity, and change of optical properties.

3.2.6.3 Main Propulsion System

Several representative valves of the propulsion system were selected for studying the effect of irradiation on the component materials. Whereas the majority of the valve parts were made of aluminum and stainless steel, several were of Teflon and other nonmetallics (Nylon, silicone, rubber, Kel-F). These nonmetallics were primarily used as the seals, gaskets, O-rings, and load-bearing surfaces which took compression loads. Radiation effects data are presented in Section 4 of Volume II, Book 1.

Teflon in each of the valves was regarded as the most susceptible material to irradiation damage when compared with the other nonmetallic materials. Nylon, Teflon, Kel-F, and silicone rubber test coupons were irradiated and tested at ambient conditions. In addition, irradiations were conducted at cryogenic temperatures and their properties were measured at both ambient and cryogenic temperatures. Only sufficient testing of Teflon has been conducted at combined vacuum and cryogenic temperatures to determine the synergistic effects of these variables. In this a property improvement was noted at vacuum conditions. From the previous test data collected and reviewed, Teflon, Nylon, silicone rubber, and Kel-F appeared relatively satisfactory for use in the low exposure regions of the stage forward section. However, in the mid or aft regions of the stage where exposure dose levels are greater than $\sim 10^6$ rads their use may be marginal or intolerable without further irradiation testing of materials and components.

Tests should be conducted on the various nonmetallic materials (coupons) which are employed in each valve as well as the complete valves. Mechanical testing of the sample coupons (in duplicate) should be conducted on each material exposed at each of several irradiation exposure levels while under simulated operational environments. These should include irradiation exposure levels ranging from $\sim 10^5$ to $\sim 10^8$ rads, temperatures from -423°F to room temperature, and controlled vacuum or operational atmospheres. The testing of actual valves containing the above materials is necessary to evaluate actual leakages which will be incurred in the valve assembly which may not be diagnosed quantitatively from coupon tests alone.

3.2.6.4 Astrionics

Radiation effects on electronics are reviewed in Section 4 of Volume II, Book 1.

Batteries and Fuel Cells

The alkaline batteries which have been reviewed and show a potential for application include the nickel-cadmium (Ni-Cd) and the silver-zinc types (Ag-Zn). A relatively small quantity of test data show that test cells of these types have reportedly performed well with less than 10-percent change in capacity after irradiation exposures of 3×10^8 rads for Ni-Cd and 7×10^7 rads for Ag-Zn. No irradiation test data was available for complete alkaline batteries.

No data were available for irradiation effects on the cells. A review of cell components indicated that most of the components are made of stainless steel which present no immediate radiation problem. However, the electrode (separator) materials have not been laboratory qualified for gamma and neutron environments.

The main concern for electric wiring and cables is the effect of radiation on the organic dielectric materials since the metal or ceramic parts are highly resistant to nuclear radiation. In most cases examined, the electrical conductivity properties have showed an increase exponentially in response to ionizing radiations until reaching equilibrium. Following irradiation exposures the induced conductivity had generally decreased. Permanent effects of radiation on organic insulating materials are normally associated with chemical changes, the most important of which are molecular scission and cross-linkage. The latter leads to hardening and embrittlement. Degradation in the advanced stages can be disastrous in that insulating materials may break and crumble thus losing structural integrity. These include Teflon, polyvinylidene-fluoride, polyethylene, and polyimide. From test data collected and reviewed, a combination of either Teflon (FEP), polyethylene, or polyvinylidene-fluoride with polyimide appear to be satisfactory for wiring insulation in various regions of the stage where exposure dose levels are less than 10^7 rads. In regions where exposure dose may be

higher than 10^7 rads further irradiation testing of the materials would be required.

The irradiation effects on the various types of transducers for measuring temperature, pressure, liquid level, fluid flow, strain, and acceleration supplied by vendors have been reviewed. These have been investigated for radiation hardness and tests were conducted at reactor facilities. However, there is a definite scarcity of detailed experimental results on their sensitivity to nuclear environments. Information on transducer tolerance to a combined environment of nuclear radiation, vibration, and temperature, especially cryogenic temperature, was almost completely lacking. Many radiation tolerance listings are appraisals based on estimated tolerance of transducer materials and basic parts.

It is recommended that radiation testing of fuel cells, electrical insulators, and transducers be conducted to meet the required information. The testing environment should include the combination of radiation exposures from 10^4 to 10^7 rads (γ) and from 10^9 to 10^{15} nvt (neutrons), at selected temperatures from -423° F to $+300^\circ$ F for insulators and transducers and up to 600° F for fuel cell materials. The atmosphere should be controlled vacuum or operational atmospheres. Electrical property response measurements will be conducted on the fuel cell samples before, during, and after the experiments to determine their degree of degradation. Pre- and post-irradiation tests will include both mechanical and electrical property measurements. Functional checkout and sensitivity measurements for transducers will be conducted before, during, and after the irradiation experiments to determine their degradation and accuracy.

3.2.7 Reliability

3.2.7.1 Dormant Failure Rates

State of the Art

Recent surveys indicate that little information is available on component nonoperating failure modes and failure rates in the space environment.

References 57 and 58 contain probably the most extensive information available on nonoperating failure rates; however, the data for most parts are for an Earth environment. An earlier report (Reference 59) suggested an operating to nonoperating failure rate ratio of 10 for electronic equipment, and this has been used for all MDAC reliability studies. It is realized, however, that an across-the-board ratio is not valid for mechanical components. In fact, Reference 60 suggests that a much lower ratio may be applicable for certain mechanical components in the space environment. In addition, a recent study on electronic components (Reference 61) recommends an operating to nonoperating failure rate ratio of 100. A reliability study for the manned Mars mission (Class IV) utilizing the NFPM demonstrated the sensitivity of the reliability prediction to the operating to nonoperating failure rate ratio. The prediction for the Mars departure stage of a five-stage vehicle ranged from 0.0610 for a ratio of 1.0 (operating and nonoperation failure rates are equal) to 0.7209 for a ratio of 10 to 0.9842 for the assumption that no failures occur in the nonoperating state. It has been stated (Reference 61) that "in the crusade for mission success, the technology needed for nonoperating survival stands today as the major gap to be closed in the field of reliability."

Program

A survey study should be conducted which will contact all agencies where nonoperating failure rate data is available. This survey will expand the reference studies by requesting and analyzing data for all types of space vehicle components instead of concentrating on electronic components only. The objective of this study would be nonoperating failure rate data for each specific type of component (i. e., solenoid valves, control actuators, pressure regulators, pumps, computer transducers, etc.) as a function of the imposed environment. A typical test program to identify nonoperating failure mechanisms would subject 5 - 10 Saturn components and 5 - 10 advanced state-of-the-art components to an extended period in a nonoperating (but installed in a system) condition. The Saturn components would include solenoid valves, LH₂ pump, relief valves, LH₂ feed valves and pressure switches. The advanced components would primarily include astrionics

components (integrated circuit chip, etc.) but would include a group of data acquisition sensors and could include advanced propulsion components. The imposed environments would include radiation (gamma and neutron), vacuum, cryogenic, and vibration to appropriate levels.

3.2.7.2 Long-Life Characteristics

State of the Art

Most long life programs are concerned with spacecraft system and not specifically oriented to stage requirements, but much of the data generated are applicable to the RNS. Specifically, current studies are in progress or have been completed on batteries, positive expulsion devices, memory core devices, thermal control pumps, pressure regulators, seals, motor driven switches, ordnance valves, and solenoid valves. System tests such as the current program at MDAC which will test two subsystems and be conducted concurrently with the space station simulator test program (NASA Contract NAS1-8997) will identify design flaws, potential weak points in the assembly and selection of materials, wearout mechanisms of components typical of the type that would be used on the RNS (valves, pumps, etc.). This program will also identify types of tests that can be conducted to determine manufacturing flaws and develop signature-analysis techniques for failure prediction purposes.

Program

A long life technology plan should include: (1) establishing a long-life technology data center; (2) developing a method of demonstrating long-life capability based on statistical methods; (3) developing an understanding of life-limiting conditions on systems; (4) developing design guidelines for radiation hardening of materials and components; (5) developing methods to deter wearout; (6) developing a long-life preferred parts list; (7) developing signature test techniques; and, (8) performing long-duration life tests.

This list of objectives is formidable but can be accomplished in cooperation with other programs. For example, a program should be established immediately to develop the long-life data center and develop an understanding

of life-limiting conditions. This could be supplemented by a test program on typical Saturn components and selected advanced state-of-the-art components to provide empirical data for developing methods to deter wearout and developing signature test techniques. The Saturn components would include components of the type that would be used on the RNS. In these tests, however, the components would be operated in the imposed environment (radiation, vacuum, cryogenic, vibration, etc.) until failure to determine specific failure modes. As the design of the RNS progresses, specific RNS components must be subjected to long-life tests as soon as possible. These tests should be initiated as soon as items can be identified as viable candidates for the RNS. For example, several propulsion components (e. g., solenoid valves used in the vent system) could be so identified at the present time and could, therefore, be the subject of a long-life test program beginning immediately.

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REFERENCES

1. S. F. Frederick and W. D. Hanna. Fracture Toughness and Deformation of Titanium Alloys at Low Temperatures. McDonnell Douglas Astronautics Company, MDAC Report DAC 62997, October 1969.
2. G. F. Pittanato. The Reactivity of Hydrogen with Ti-6Al-4V Under Fatigue Cycling at Ambient and Cryogenic Temperatures. Trans. AMS, V62, 1969, P 410-417.
3. G. F. Pittanato. The Effects of a Hydrogen Environment on the Mechanical Properties of Forged Ti-6Al-4V ELI Weldments. McDonnell Douglas Astronautics Company, MDAC Report DAC 62146, November 1969.
4. H. W. Babel and S. F. Frederick. A Review of Texture Strengthening of Titanium Alloys. J. Metals, V20, No. 10, October 1968, P 32-38.
5. J. H. Tillotson. A Theoretical and Experimental Correlation of Hypervelocity Impact on Layered Targets. E. G. and G., Inc., Report S-425-R, May 1968.
6. R. G. Teng. Hypervelocity Impact Testing of Cadmium Spheres in Cadmium Targets. McDonnell Douglas Astronautics Company, AF Contract F29606-69-C-0072 published in 1970.
7. P. V. Hale. Study of Thermal Conductivity Requirements, Vol. I. High Performance Insulation Thermal Conductivity Test Program. Contract NAS8-21347, Interim Report, January 1969, Lockheed Missiles and Space Company, Huntsville Research and Engineering Center, 4800 Bradford Blvd., Huntsville, Alabama.
8. J. J. Brogan. Investigations Regarding Developing of a High Performance Insulation System, Third Quarterly Progress Report. Contract NAS8-20758, 15 April 1968, K-17-68-3, Lockheed Missiles and Space Company, Sunnyvale, California.
9. Investigations Regarding Development of a High Performance Insulation System, Final Report, Contract NAS8-20758, 25 July 1968, Lockheed Missiles and Space Company, Report K17-68-5.
10. Investigation of High Performance Insulation. Contract NAS8-21400, Study in progress by Thermodynamics and Nuclear Effects Department, McDonnell Douglas Astronautics Company, Santa Monica, California.

11. Cryogenic Technology Research at MSFC, Research Achievements Review. NASA TM-X-53670, Volume II, Report No. 7, 1967.
12. R. A. Burkley. Development of Materials and Materials Application Concepts for Joint Use as Cryogenic Insulation and Micro-Meteorite Bumpers. Contracts NAS8-11747 and NAS8-30140, Goodyear Aerospace Corporation, 1210 Massillon Road, Akron, Ohio.
13. Study of Structural-Thermal Insulation - Meteoroid Protection Integration. Contract NAS8-21430, The Boeing Co., Report D5-17525, May 15, 1959.
14. Advanced Studies on Multi-Layer Insulation Systems. Contract NAS3-6283, Final Report, NASA CR-54929, A. D. Little, Inc., June 1, 1966.
15. Charles F. Schafer and Tommy C. Bannister. Thermal Control Coating Degradation Data from the Pegasus Experiment Packages. Progress in Astronautics and Aeronautics. Vol. 20, 1967.
16. Carr B. Neel. The Role of Flight Experiments in the Study of Thermal-Control Coatings for Spacecraft. AIAA Paper 67-329, Thermophysics Specialist Conference, New Orleans, Louisiana/ April 17-20, 1967.
17. P. M. Blair, Jr., G. F. Pezdirtz, and R. A. Jewell. Ultraviolet Stability of Some White Thermal Control Coatings Characterized in Vacuum. AIAA Paper 67-345. Thermophysics Specialist Conference, New Orleans, Louisiana, April 17-20, 1967.
18. John P. Millard. Results from the Thermal Control Coatings Experiment on OSO-III. AIAA Paper 68-794. AIAA Thermophysics Conference, Los Angeles, California. June 24-26, 1968.
19. G. W. Burge, J. B. Blackmon, and R. A. Madsen, Analytical Approaches for the Design of Orbital Refueling Systems. AIAA Paper 69-567, June 1969.
20. J. B. Blackmon, J. N. Castle, and B. R. Heckman. Propellant Settling. McDonnell Douglas Astronautics Company, MDAC Report DAC-62263, May 1968.
21. E. Ring, Rocket Propellant and Pressurization Systems. Prentice-Hall, 1964.
22. C. R. Easton, Nonlinear Free Surface Effects in Tank Draining at Low-Gravity. McDonnell Douglas Astronautics Company, MDAC Paper 10-102, June 1969.

23. C. R. Easton and J. B. Nelson. The MDAC Version of the Marker-and-Cell Program. McDonnell Douglas Astronautics Company, MDAC Report 62426, February 1969.
24. Project THERMO, Final Report. McDonnell Douglas Astronautics Company, MDAC Report DAC 60594, March 1967.
25. Project THERMO - Phase B Prime. McDonnell Douglas Astronautics Company, MDAC Report DAC 60799, September 1967.
26. Low-Gravity Propellant Control Using Capillary Devices in Large Scale Cryogenic Vehicles. Convair Report No. 584-4-269, January 1970.
27. S. H. Schwartz. Saturated Pool Boiling of Water in a Reduced Gravity Environment. PH.D. thesis, University of Southern California, June 1966.
28. C. Y. Han and P. Griffith. The Mechanism of Heat Transfer in Nuclear Pool Boiling. MIT Report No. 7673-19, dated 1962.
29. B. L. Pierce and J. W. H. Chi. An Experimental and Analytical Study of Film Boiling Heat Transfer to Hydrogen. AIAA Paper No. 70-660, June 1970.
30. J. W. H. Chi. Forced Convection Boiling Heat Transfer to Hydrogen. Journal of Spacecraft and Rockets. Vol. III, No. 1, P. 150. January 1966.
31. G. C. Vliet, J. J. Brogen, T. S. Shappard, F. H. Harris, and F. L. Hines. Stratified Layer Flow Model - A Numerical Approach to Temperature Stratification in Liquids Contained in Heated Vessels. AIAA Paper 67-37, January 1964.
32. B. D. Neff. Free Convection in a Container of Cryogenic Fluid. MS Thesis, Denver University, 1965.
33. J. M. Rudes. Stratification in a Pressurized Container with Sidewall Heating. AIAA Journal, Volume 2, No. 1, 1964.
34. R. H. Knoll, G. R. Smolak, and R. Nunamaker. Weightlessness Experiments with LH₂ in Aerobee Sounding Rockets, Flight #1. NASA TM-X-484, 1962.
35. J. G. McArdle, R. C. Dillon, and D. A. Altos. Weightlessness Experiments with LH₂ in Aerobee Sounding Rockets, Flight #2. NASA TM-X-718, 1962.
36. R. Nunamaker, E. L. Corpas, and J. G. McArdle. Weightlessness Experiments with LH₂ in Aerobee Sounding Rockets, Flight #3. NAS TM-X-872, 1963.

37. J.D. Tagetz, M.J. Conroy, and R.G. Jackson. Weightlessness Experiments with LH_2 in Aerobee Sounding Rockets, Flight #4. NASA TM-C-873, 1964.
38. L.J. Poth, et al. A Study of Cryogenic Propellant Mixing Techniques. General Dynamics - Fort Worth Division, Report No. FZA-439-1, 1 November 1968.
39. J.B. Blackmon. A Study of the Initiation of Electroconvection International Symposium of Electrohydrodynamics. April 1969.
40. W.W. Gerberich and C.E. Hartbourr. Some Observations on Stress Wave Emission as a Measure of Grade Growth.
41. E.Z. Barakat, B. Merte, and J.A. Clark. Finite Difference Solution of Stratification and Pressure Rise in Containers. Conference on Long Term Cryogenic Propellant Storage in Space, October 1966.
42. J.W. Tatom, W.H. Brown, L.H. Knight, and E.F. Cox. Analysis of Thermal Stratification of Liquid Hydrogen in Rocket Propellant Tanks. Advances in Cryogenic Engineering, Vol. 9. Plenum Press, N.Y. (1964).
43. B.H. Anderson and M.J. Kolar. Experimental Investigation of the Behavior of a Confined Fluid Subjected to Nonuniform Source and Wall Heating. NASA TND-2079. November 1963.
44. T.J. Biesiadny. Experimental Investigation of Baffle Effectiveness in a Confined Fluid Subjected to Wall and Nonuniform Source Heating. M.S. Thesis, Purdue University. August 1966.
45. G.C. Vliet. Stratified Layer Flow Model - A Numerical Approach to Liquid Temperature Stratification. J. Spacecraft and Rockets 1, 666. 1964.
46. Evaluation of Insulation Materials and Components for Use in a Nuclear Radiation Environment. General Dynamics - Fort Worth, Contract NAS8-25848.
47. P.C. Bhuta and L.R. Koval. Sloshing of a Liquid in a Draining or Filling Tank under Variable-g. June 1965.
48. Evaluation of AS-203 Low-Gravity Orbital Experiment. Space Division, Chrysler Corporation, Huntsville, Alabama, Technical Report HSM-R421-67, 13 January 1967.
49. R.K. Allgeier. Subcritical Cryogenic Storage Development and Flight Test. NASA TND-4293, February 1968.
50. Space Shuttle High Pressure Auxiliary Propulsion Subsystem Definition. McDonnell Douglas Astronautics Company, NAS8-26248.

51. D. O. Harris, H. L. Dunegan, and A. S. Tetelman. Prediction of Fatigue Lifetime by Combined Fracture Mechanics and Acoustic Emission Techniques. Air Force Conference on Fatigue and Fracture of Aircraft Structures and Materials, December 1969.
52. Robert B. Engle and Harold L. Dunegan. Acoustic Emission, Stress Wave Detection as a Tool for Nondestructive Testing and Material Evaluation. International Journal of Nondestructive Testing, Vol. 1, 1969.
53. A. T. Green. Stress Wave Detection Saturn S-II. NASA Report No. CR 61161, December 1966.
54. Dr. G. S. Baker. Acoustic Emission and Prefracture Processes in High Strength Steels. AFML-TR-67-266, March 1968.
55. E. E. Kerlin and E. T. Smith. Measured Effects of the Various Combinations of Nuclear Radiation, Vacuum, and Cryotemperatures on Engineering Materials. General Dynamics, Fort Worth Division, Biennial Report FZK-290, July 1, 1966.
56. MDAC-West, Effect of Radiation on Mylar. Memorandum from A. DelGrosso of A2-253 to R. A. Meyer of A-253, March 2, 1970.
57. Handbook of Long-Life Space Vehicle Investigations. Martin Marietta Corporation M-68-21, 1967 and 1968.
58. D. F. Cottrell. Dormant Operating and Storage Effects on Electronic Equipment and Part Reliability. Martin Marietta Corporation, Final Report, RADC-TR-67-307.
59. Dormant Operating and Storage Effects on Electronic Equipment and Part Reliability, Martin Marietta Corporation, RADC-TR-66-348.
60. Compilation and Analysis of Calendar-Age-Related Data for Hydraulic System Components. Planning Research Corporation, PRC-R-377.
61. S. M. Checkasky. Long Term Storage and System Reliability. Proceedings, 1970 Annual Symposium on Reliability.