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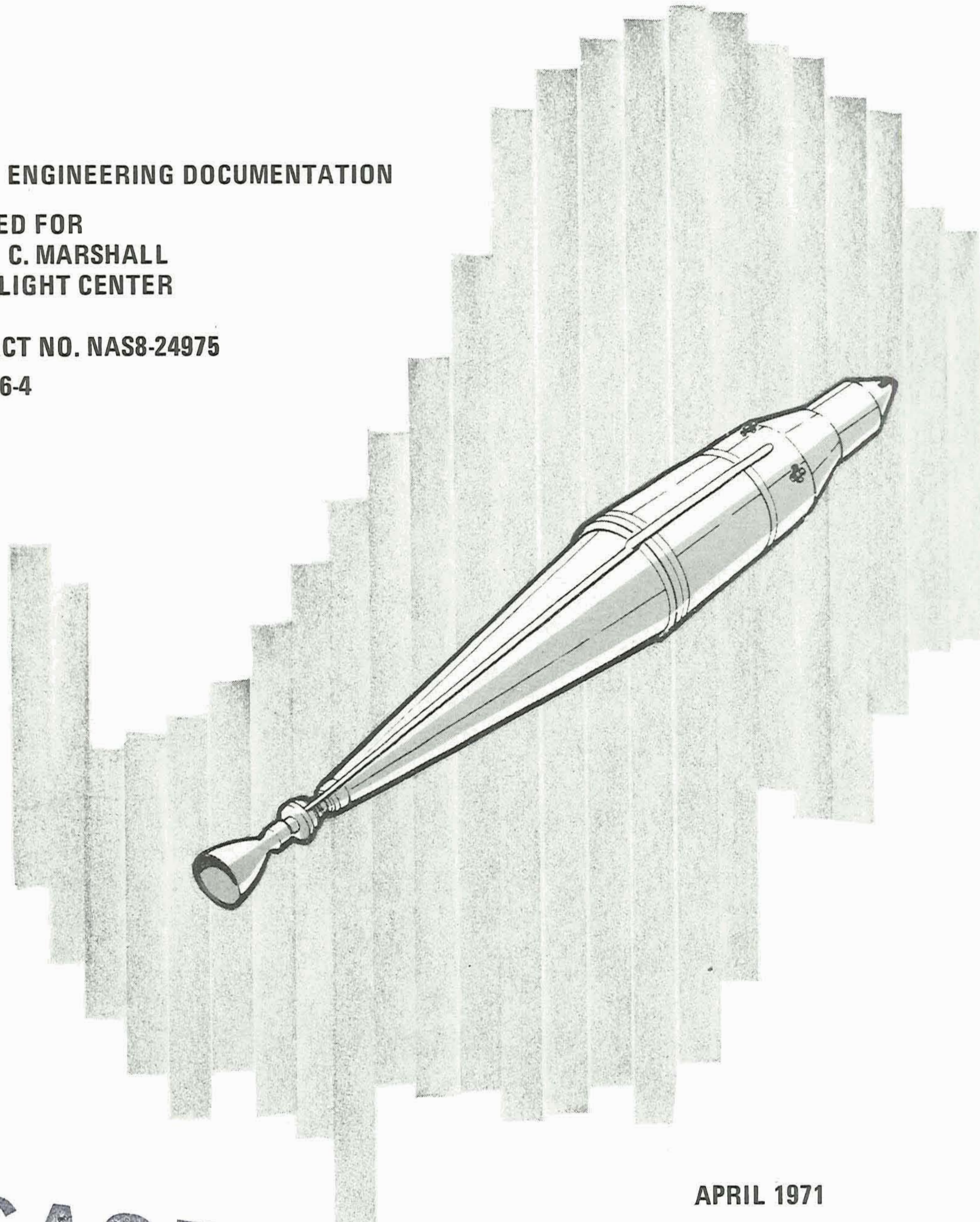
NUCLEAR FLIGHT SYSTEM DEFINITION STUDY

PHASE III FINAL REPORT

PART C.
SYSTEM ENGINEERING DOCUMENTATION

PREPARED FOR
GEORGE C. MARSHALL
SPACE FLIGHT CENTER

CONTRACT NO. NAS8-24975
SD71-466-4



APRIL 1971

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NUCLEAR FLIGHT SYSTEM DEFINITION STUDY

PHASE III FINAL REPORT

Volume II - Concept and Feasibility Analysis

Part C. System Engineering Documentation

Prepared For

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
under Contract NAS8-24975

April 1971

Prepared By

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Approved By

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FOREWORD

The final report on the Phase III Reusable Nuclear Shuttle (RNS) study was prepared by the North American Rockwell Corporation through its Space Division for the National Aeronautics and Space Administration's George C. Marshall Space Flight Center in accordance with Appendix A of contract NAS8-24975. The contract directed a study of mission requirement, design concepts and definition, performance, operations, facilities, and development activities for the RNS with associated funding and scheduling requirements.

This report is submitted in six volumes with Volume II consisting of three separate books:

I.	(SD71-466-1)		Executive Summary
II.			Concept and Feasibility Analysis
	A.	(SD71-466-2)	System Evaluation and Capability
	B.	(SD71-466-3)	Baseline System Definition
	C.	(SD71-466-4)	System Engineering Documentation
III.	(SD71-466-5)		Program Support Requirements
IV.	(SD71-466-6)		Cost Data (Limited Distribution)
V.	(SD71-466-7)		Schedules, Milestones, and Networks
VI.	(SD71-466-8)		Reliability and Safety Analysis

This book of Volume II addresses itself to System Engineering documentation which is an end product of the System Engineering process. The process methodically considers the total system in approaching the problem of utilizing the RNS in performing its missions. Gross system requirements for the three mission classes are identified in the system specification. These requirements are translated to functions and documented in Functional Flow Diagrams. The functions in turn are translated into Design Requirements and are documented in Requirements Allocation Sheets. Timelines for major functions are also provided as part of the documentation.

Recommended changes to the NERVA requirements are presented with the reasons for each proposed change.

ACKNOWLEDGEMENTS

The following NR individuals provided the major contributions for this volume:

W. G. Antypas	Time Lines and Functional Flow Diagrams
A. R. Jusak	System Specification, Functional Flow Diagrams and Requirements Allocation Sheets
A. G. Lane	Recommended changes to NERVA Requirements

C. C. Priest, the NASA-MSFC contracting officer's representative, provided valuable guidance and direction throughout the Phase III study The assistance of D. R. Saxton and other MSFC personnel is also gratefully acknowledged.

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10.0 SYSTEM SPECIFICATION

The System Specification is a general specification which documents system requirements in a form suitable for further technical development and in a form suitable for segregating contract responsibilities. A complete System Specification is a prime product among several products initiated early in a program (in preliminary form in the concept phase) and completed at the end of the design phase. In essence it contains those conclusions of a system analysis which may be specified in quantitative physical terms with tolerances and that may later be verified by performance testing of the system. It organizes this knowledge in a form suitable for technical and contractual management of a development program. Detail specifications, contract end items (CEI's), are derived from requirements in the System Specification. All specifications and the system engineering documentation which provides an analytical substantiation of specified requirements must be within and traceable to the mission requirements for the system as documented in the System Specification.

The System Specification is presented here in the format anticipated for the final product at the end of the design phase.

Space Division
North American Rockwell

Specification No. ____________

Date: ____________________

REUSABLE NUCLEAR SHUTTLE
SYSTEM SPECIFICATION

APPROVED BY: ____________________ Preparing Activity

APPROVED BY ____________________ (NASA Office)

DATE ______________

DATE ______________

CONTRACT NUMBER NAS8-24975

Specification No. ________
Date: ________________

1.0 SCOPE

1.1 This specification defines the system performance and design requirements for the Reusable Nuclear Shuttle System Program. It establishes system requirements for design, development, test, ground and flight operations, and is the single authoritative document stating the contract technical requirements. All elements and contract end items of the Reusable Nuclear Shuttle System Program shall comply with the requirements delineated herein.

1.2 Mission

The Reusable Nuclear Shuttle shall provide a means of delivering men and material between earth and lunar orbit, injection unmanned payloads on a planet intercept trajectory. The RNS will evolve for use in manned planetary missions.

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents

The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced here and other detail content of Sections 3, 4, 5, and 10 to follow, the detail content of Sections 3, 4, 5, and 10 shall be considered a superseding requirement.

SPECIFICATIONS

Military

MIL-B-5087A Amendment 1 29 January 1958	Bonding; Electrical (for Aircraft)
MIL-D-70327 Amendment 1 1 July 1959	Drawings, Engineering and Associated Lists

MIL-E-6051C 17 June 1960	Electrical-Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystems and Aircraft
MIL-I-6181D 25 November 1959	Interference Control Requirements, Aircraft Equipment
MIL-I-8500B 10 October 1960	Interchangeability and Replaceability of Component Parts for Aircraft and Missiles
MIL-P-27407 Amendment 1 8 January 1965	Propellant Pressurizing Agent, Helium
MIL-P-27401B 19 September 1962	Propellant Pressurizing Agent, Nitrogen
MIL-N-6011 14 March 1950	Nitrogen, Liquid and Gas
MIL-M-38310A	Mass Properties Control Requirements for Missile and Space Vehicles
MIL-M-8090D 21 February 1961	Mobility Requirements, Ground Support Equipment, General Specification
MIL-P-27201 21 May 1959	Propellant, Hydrogen
MIL-N-52334 12 November 1963	Nuclear Power Plant Control and Instrumentation Equipment, General Specification for
MIL-S-38/30A	General Requirements for Systems Safety Engineering of Systems and Associated Subsystems and Equipment

NASA

MSFC-PROC-158A	Soldering Electrical Connectors (High Reliability) Procedure for

AEC

TBD

STANDARDS

Military

MIL-STD-130B 24 April 1962	Identification Marking of U.S. Military Property
MIL-STD-143A 14 May 1963	Specifications and Standards Order of Precedence for Selection of
MIL-STD-171A 11 October 1960	Finishing of Metal and Wood Surface
MIL-STD-810 14 June 1962	Environmental Test Methods for Aerospace and Ground Equipment
MIL-STD-129C 11 July 1960	Marking for Shipment and Storage
MIL-STD-1247 12 March 1964	Identification of Pipes, Hoses, Tubes, Lines for Aircraft Missiles, Space Vehicles and Associated Support Equipment and Facilities
MIL-STD-803A 27 January 1964	Human Engineering Design Criteria for Aerospace Systems and Equipment
ABMA-STD-428B 8 April 1960	Printed Circuit Design and Construction Standard
MIL-STD-882	General Requirements for Systems Safety Program for Systems and Associated Sub-Systems and Equipment

Federal

FED-STD-595 1 March 1956	Colors

NASA

MSFC-STD-162 26 July 1961	Mechanical Symbols

DRAWINGS

George C. Marshall Space Flight Center

MSFC-DWG-10M01071 6 March 1961	Environmental Protection When Using Electrical Equipment Within the Areas of Saturn Complexes where Hazardous Areas Exist, Procedure for
MSFC-DWG-10509318 9 July 1960	Hose Assemblies Flex High Pressure Specification for

OTHER PUBLICATIONS

Military

MIL-HDBK-5 March 1959	Strength of Metal Aircraft Elements

NR Space Division

SID 62-128 20 April 1964	Saturn S-II Reliability Plan
SID TBD	General Test Plan for Reusable Nuclear Shuttle
MAQ303-1032C 11 May 1965	Electrical and Electronic Reference Designation Standards for

National Aeronautics and Space Administration

NPC-200-2 April 1962	Quality Program Provisions for Space Systems Contractors
MSFC-PROC-252 19 September 1962	Weight and Balance Requirements Procedure for
NHB 1700.1 (Vol. 1)	NASA Safety Manual, Basic Safety Requirements
NHB 6000.1 (1A)	Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems Equipment and Associated Components

OTHER PUBLICATIONS - Continued

NASA - Continued

NHB 1700.1 (Vol. 3)	NASA Safety Manual, System Safety
NHB 5300.4 (1A)	Reliability Program Provisions for Aeronautical and Space System Contractors
NHB 5300.4 (1B)	Quality Program Provision for Aeronautical and Space System Contractors
NHB 5300.5	Apollo Applications Reliability and Quality Assurance Program Plan
NHB 2330.1	Program Scheduling and Review Handbook
NASA TMX-53957	Space Environment Criteria Guidelines for Use in Space Vehicle Development (1969 Revision)
NASA TMX-53872	Terrestrial Environment (Climatic) Criteria Guidelines for Use in Space Vehicle Development, 1969 Revision (Second Printing)
NASA TMX-53865	Natural Environment Criteria for the NASA Space Station (Second Printing)

Astro-Nuclear Space Company

ANSC Report S-130	NERVA Reference Data (Full Flow Engine)
AGC Report RN-S-0551	Full-Flow Flight-Engine Common Radiation Analysis Model
AGC Report RN-S-0526	NERVA Reference Data
AGC Report RN-S-0533	Reference Mission Data Book for NERVA Design

OTHER PUBLICATIONS - Continued

Space Nuclear Propulsion Office (SNPO)

SNPO-NPRD-1	NERVA Program Requirements Document (Latest Revision)

3.0 REQUIREMENTS

3.1 System Definition

3.1.1 General Description

The Reusable Nuclear Shuttle is a major, new low-cost transportation system proposed in a NASA Integrated Space Program Plan. The RNS is comprised of a propellant tank with a tank capacity for 300,000 pounds of LH_2, a 75,000-pound thrust nuclear engine, and associated subsystems to permit autonomous mission operation. The primary mission is the delivery of men and material between lunar/geosynchronous and earth orbit. The second mission is the injection of unmanned payloads on planetary intercept trajectories after which the RNS returns to its earth operational orbit. Ultimately, through evolutionary growth, the RNS will provide the propulsive requirements for manned planetary missions.

3.1.1.1 System Functional Area

The system functional areas and their major elements specified below form the total Reusable Nuclear Shuttle System.

3.1.1.1.1 RNS Vehicle Functional Area

The RNS vehicle functional area shall consist of the following major elements:

a. RNS tank with associated subsystems

b. NERVA

3.1.1.1.2 Launch Operations and Services Functional Area

The launch operations and service functional area shall consist of the following major elements:

a. Launch pad facility and GSE

b. RNS earth operational orbit with replenishment and maintenance elements

c. Disposal orbit of spent NERVA or RNS stage

3.1.1.1.3 Payload Module Functional Area

The payload module functional area shall consist of the following major elements:

a. Orbiting Lunar Station

b. Space Tug

c. Propellant Module

d. Crew Module

e. Cargo Module

3.1.1.2 Intended Operational Capability (IOC)

The RNS system IOC shall be 1981.

3.1.2 RNS System Missions

The RNS system shall be capable of performing the Design Reference Missions defined in 3.1.2.1. In addition, the system will be capable of performing the missions defined in 3.1.2.2.

3.1.2.1 RNS System Design Reference Missions

3.1.2.1.1 Design Reference Missions

The design reference missions shall be:

a. Class I Mission - The delivery of manned and unmanned payloads between RNS operations orbit and lunar/geosynchronous orbit

b. Class II Mission - The injection of unmanned payloads on planetary intercept trajectories then return to RNS operations orbit

c. Class III Mission - Based on evolutionary growth of RNS - Delivery of manned payloads to planetary orbit and return manned payload to earth orbit

3.1.2.1.2 Design Reference Mission Profiles

The design reference mission profiles shall be as illustrated in Figures 10-1 and 10-2.

3.1.2.1.3 RNS Operations Orbit

The design reference earth RNS operations orbit shall be 260 n mi circular with a 31.5-degree inclination.

3.1.2.1.4 Mission Duration

The RNS mission duration shall be:

a. 28 days thermal cycle for Class I and Class II missions

b. 1040 days thermal cycle for Class III missions. Meteoroid protection shall be provided for the RNS vehicle space operational life of three years.

3.1.2.1.5 Rendezvous with Target Vehicle

The RNS shall have automated rendezvous and docking capability.

3.1.2.2 RNS System Mission Characteristics

The RNS system shall be designed in consideration of the mission characteristics summarized in Tables 10-1, 10-2, 10-3, and 10-4.

3.1.3 System Level Functional Diagrams

The system level functional diagrams, specified below, shall be used for identifying all system functions. The system level functional diagrams establish the general relationship of functional areas and the major elements within the systems.

3.1.3.1 Top-Level Functional Flow Block Diagram (FFBD)

The top-level FFBD, shown in Figure 10-3, portrays the RNS system operations at the system level. The top-level FFBD shall be used for developing lower levels of functional flow diagrams and the subsequent definition of system and

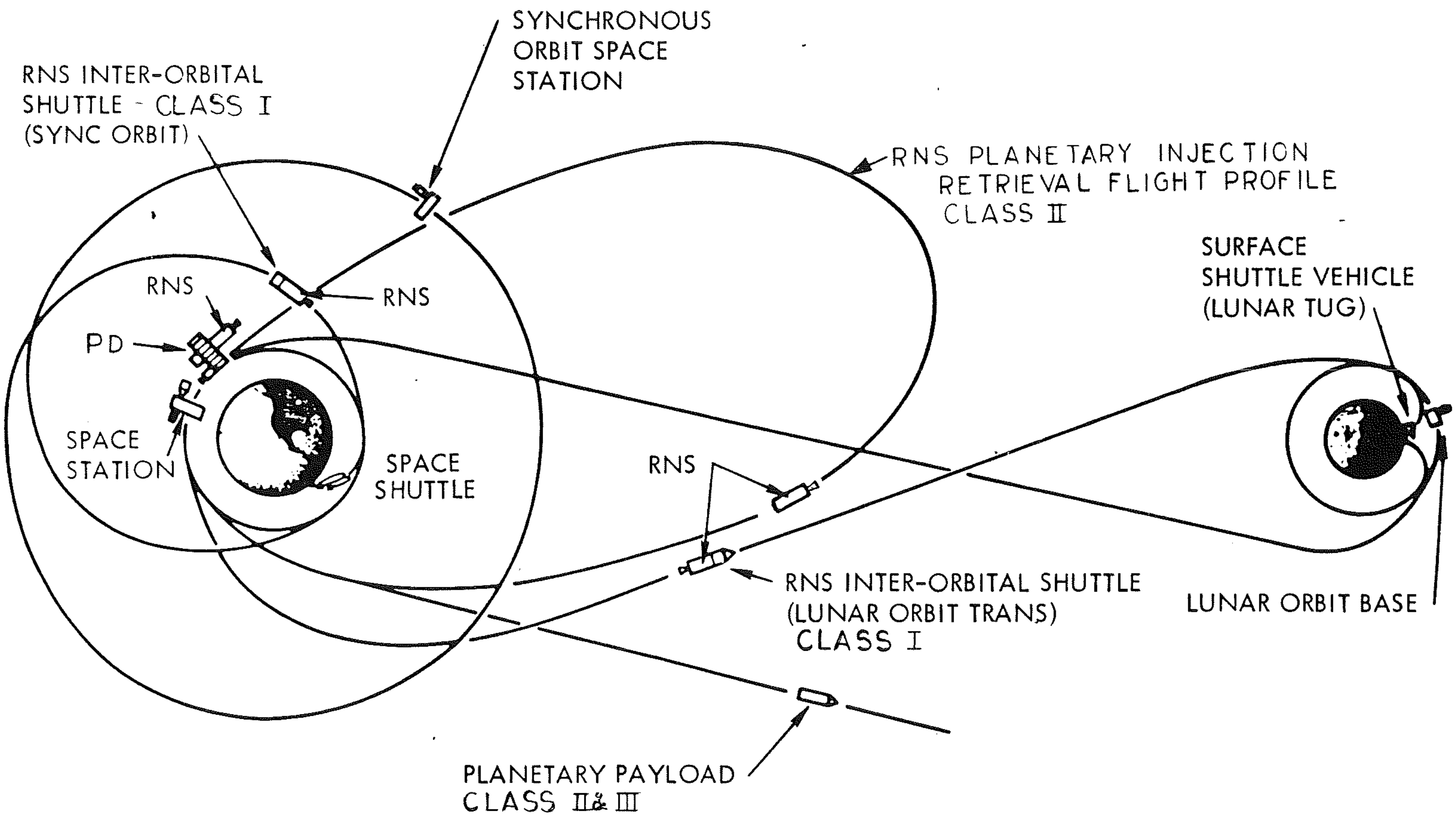


Figure 10-1. Class I/II Mission Profiles

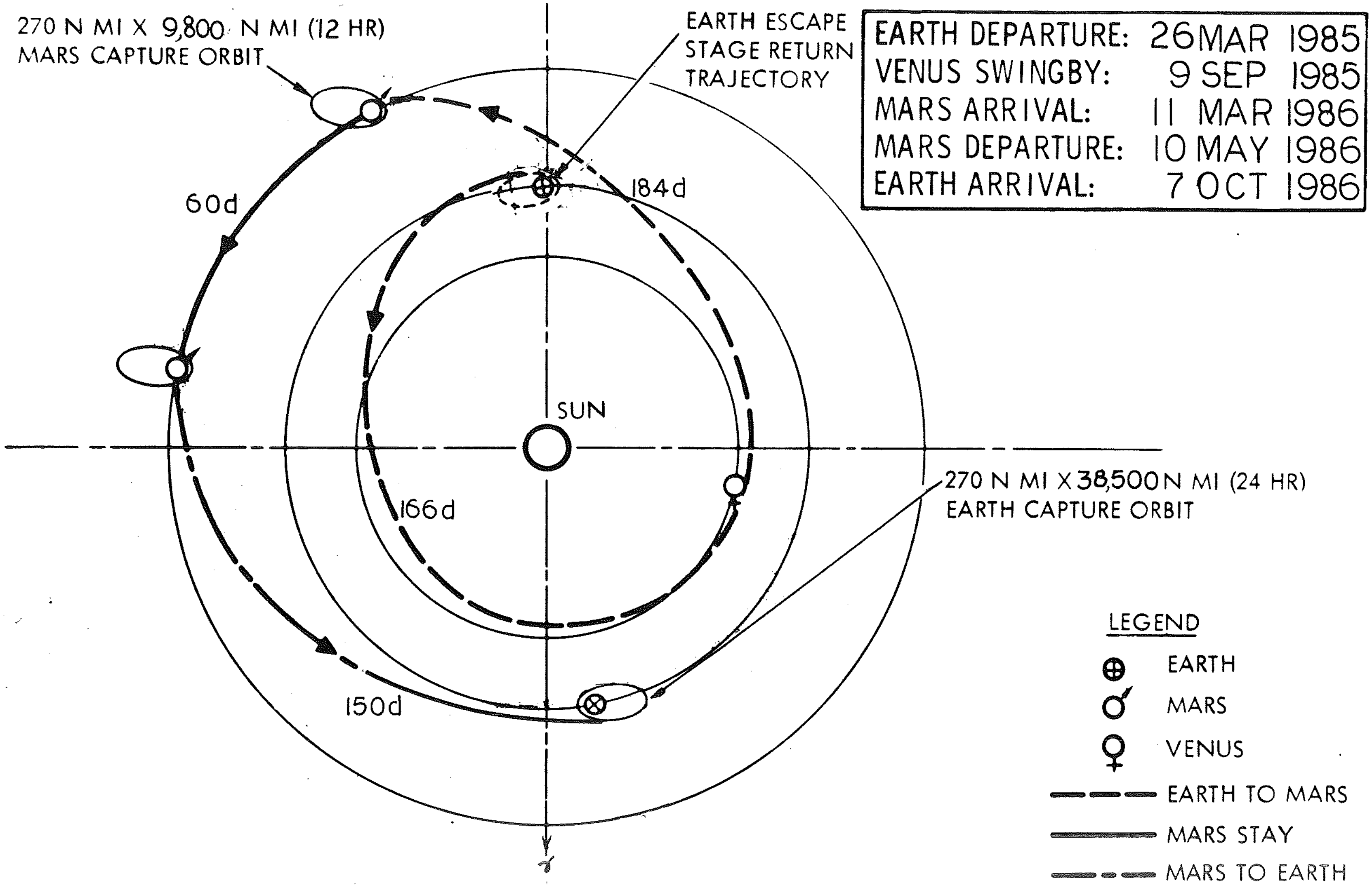


Figure 10-2. 1986 Mars Opposition Mission Profile -- Stage 3 + Payload Operations

Table 10-1.

Nominal RNS Lunar Mission

CHARACTERISTICS / MISSION		CLASS I LUNAR
Earth Departure/Arrival Orbit Altitude		260 N. Mi.
Earth Departure/Arrival Orbit Inclination		31.5 Degrees
Lunar Arrival/Departure Orbit Altitude		60 N. Mi.
Lunar Arrival/Departure Orbit Inclination		90 Degrees
Earth to Moon Coast Time		92 Hours
Moon to Earth Coast Time		83 Hours
Lunar Orbit Insertion Plane Change		0 Degrees
Transearth Injection Plane Change		22 Degrees
Lunar Orbit Stay Time		17.5 Days
Delta-Vs (FPS)	Burns	
Translunar Injection (TLI)	1/2	5000/5040 FPS
Lunar Orbit Insertion (LOI)	1/2/3	2730/0/0 FPS
Transearth Injection (TEI)	1/2/3	1850/330/1010 FPS
Earth Orbit Insertion (EOI)	1	10050 FPS
Midcourse ΔV (Per Mission Leg)		50 FPS
Flight Performance Reserve (FPR)		0.75% ΔV

Table 10-2.

Reference RNS Geosynchronous Mission

CHARACTERISTICS / MISSION	Burns	CLASS I GEOSYNCHRONOUS
Earth Departure/Arrival Orbit Altitude		260 N. Mi.
Earth Departure/Arrival Orbit Inclination		31.5 Degrees
Geosynchronous Arrival/Departure Orbit Inclination		0 Degrees
Low Orbit to Geosynchronous Orbit Coast Time		8.5 Hours
Synchronous Orbit Insertion Adjust		24 Hours
Synchronous Orbit Stay Time		120 Hours
Departure Transfer to Descent Ellipse Insertion		24 Hours
Geosynchronous to Low Orbit Coast		8.5 Hours
Delta-Vs (FPS)	Burns	
Inject to Geosynchronous Orbit	1/2	4230/3636 FPS
Geosynchronous Orbit Insertion	1	5911 FPS
Inject to Low Earth Orbit	1	6011 FPS
Low Earth Orbit Insertion	1/2	3636/4140 FPS
Midcourse ΔV (Per Mission Leg)		50 FPS
Synchronous Orbit Adjust		20 FPS
Flight Performance Reserve		0 .75% ΔV

Table 10-3.

Reference Unmanned Planetary Mission

CHARACTERISTICS	MISSION	CLASS II UNMANNED PLANETARY
Earth Departure/Arrival Orbit Altitude		260 N. Mi.
Earth Departure/Arrival Orbit Inclination		31.5 Degrees
Earth Orbit Escape Time		TBD
Return to RNS Operations Orbit Time		TBD
Delta Vs (FPS)	Burns	
Escape Injection	1/2/3	TBD/TBD/TBD FPS
Retro Thrust	1/2/3	" " " FPS
Return Orbit - Perige Altitude		270 N. Mi.
- Elliptic Orbit Period		TBD
Midcourse Correction (Per Mission Leg)		TBD
Flight Performance Reserve		0.75% ΔV

Table 10-4.

Reference Manned Planetary Mission

CHARACTERISTICS \ MISSION		CLASS III MANNED PLANETARY	
Earth Assembly/Departure Orbit Altitude		260	N. Mi.
Earth Assembly/Departure Orbit Inclination		31.5	Degrees
Earth Assembly/Departure Orbit Eccentricity		0	Degrees
Mars Parking Orbit	- Periapsi Altitude	270	N. Mi.
	- Elliptic Orbit Period	12	Hours
Earth Arrival Orbit	- Periapsis Altitude	270	N. Mi.
	- Elliptic Orbit Period	24	Hours
Midcourse Correction ΔV (Allow. per Mission Leg)		500	FPS
Mars Orbit Trim ΔV		150	FPS

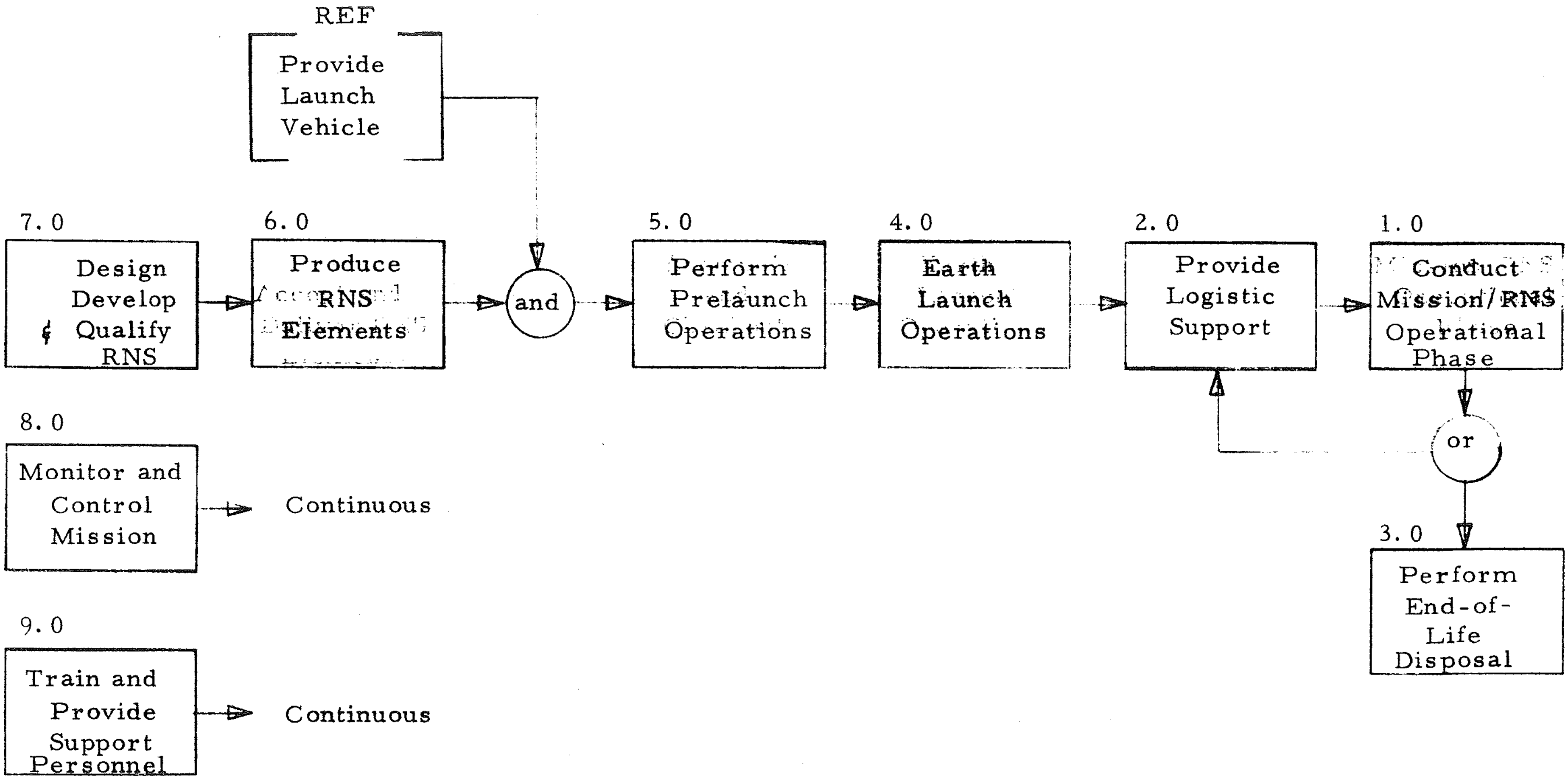


Figure 10-3

Reusable Nuclear Shuttle (RNS)
Top Level Functional Flow Diagram

subsystem design requirements, mission timelines, and to establish the need for air vehicle equipment (AVE), ground support equipment (GSE), operating personnel, and training programs for the development of an operational RNS system. The subparagraphs below specify activity and event coverage of FFBD items 1.0 through 9.0 of Figure 10-3.

3.1.3.1.1 Mission/RNS Operational Phase (1.0) - Shall cover all activities from RNS operations orbit departure through payload delivery, transfer and return to RNS operations orbit.

3.1.3.1.2 Provide Logistic Support (2.0) - Shall begin with delivery of RNS tank and NERVA to operations orbit for assembly and continue through performance of maintenance, expendables replenishment, payload mating, and final RNS payload checkout prior to departure from RNS operations orbit.

3.1.3.1.3 Perform End-of-Life Disposal (3.0) - Shall cover disposal activities commencing with removal of spent or irreparable NERVA from RNS, placing spent NERVA in disposal orbit and returning transporting vehicle (Tug) to operations orbit. The alternative of disposing the entire RNS stage to disposal orbit will also be covered in this functional block.

3.1.3.1.4 Earth Launch Operations (4.0) - Shall include launch planning, launch support, launch vehicle RNS element integration, countdown and boost to RNS operations orbit.

3.1.3.1.5 Assemble and Checkout (5.0) - Shall include receiving and inspection of RNS elements at the launch site; mate NERVA and RNS tank, perform interface tests, demate NERVA and RNS tank, erect RNS tank for mating to launch vehicle, mate RNS tank and INT-21 launch vehicle, and load NERVA in space shuttle.

3.1.3.1.6 Provide, Accept, and Deliver RNS Elements (6.0) - Shall include fabrication of RNS subsystem, assembly of subsystems into RNS tank element, acceptance testing, preparation for shipment, and delivery of RNS element to launch site.

3.1.3.1.7 Design, Develop, and Qualify RNS (7.0) - Shall include final design of RNS element, development of subsystem, and qualification testing of components and subsystems.

3.1.3.1.8 Monitor and Control Mission (8.0) - Shall include all support activities, both on ground and in orbit, to provide vehicle status data required for mission control, as well as data transmission to the RNS vehicle required for achieving mission objectives.

3.1.3.1.9 Train and Provide Support Personnel (9.0) - Shall include identification of training requirements, including passengers, flight crew, and maintenance crew. Training sylibus, mock-ups, and facilities will be established in this functional area.

3.1.3.2 Top-Level Schematic Block Diagram (SBD)

The top-level SBD, shown in Figure 10-4, specifies the functional areas described under 3.1.1.1. The top-level SBD identifies interfaces between functional areas.

3.1.4 System Level Layout Drawings

The RNS inboard profile is shown in Figure 10-5.

3.1.5 Interface Definition

The functional, physical, procedural, and environmental interface requirements between this system and other systems (e.g., Space Tug, OLS, EOS) and between functional areas (e.g., RNS Stage, Launch Operations and Services, and Payload Module) within the RNS system are specified in 3.7. The following list shall comprise the major elements of the System Interface Control Documents which shall define all functional, physical, procedural and environmental interfaces between major elements of the system:

(1) ICD No. RNS Tank Element and NERVA (See 3.7.1.2.3.1)

(2) ICD No. RNS Tank Elements and INT-21 (See 3.7.1.2.3.2)

(3) ICD No. RNS Tank Element and Facilities (See 3.7.1.2.3.3)

(4) ICD No. NERVA and EOS (See 3.7.1.2.3.4)

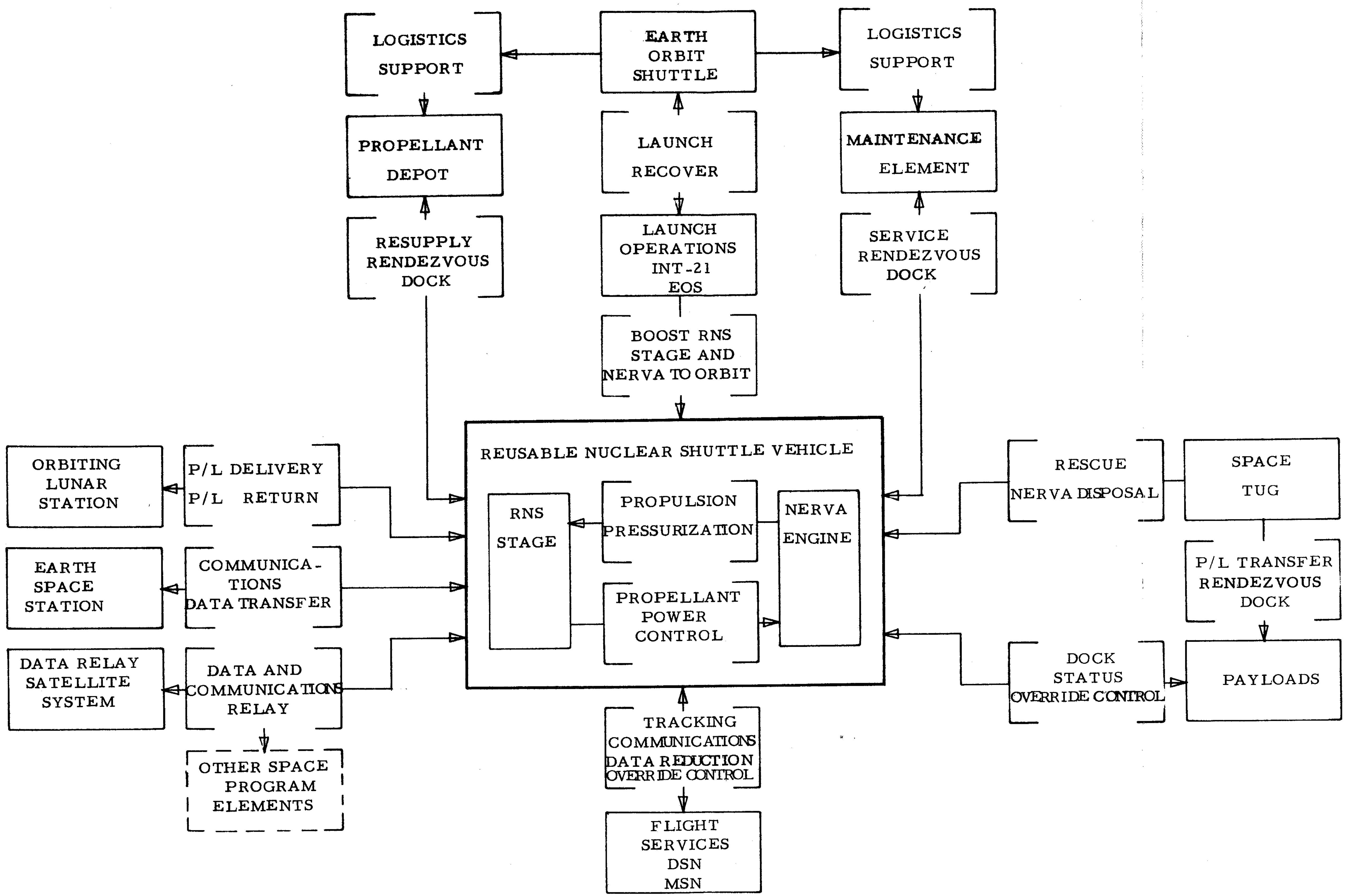


Figure 10-4.Top Level Schematic Block Diagram Reusable Nuclear Shuttle System

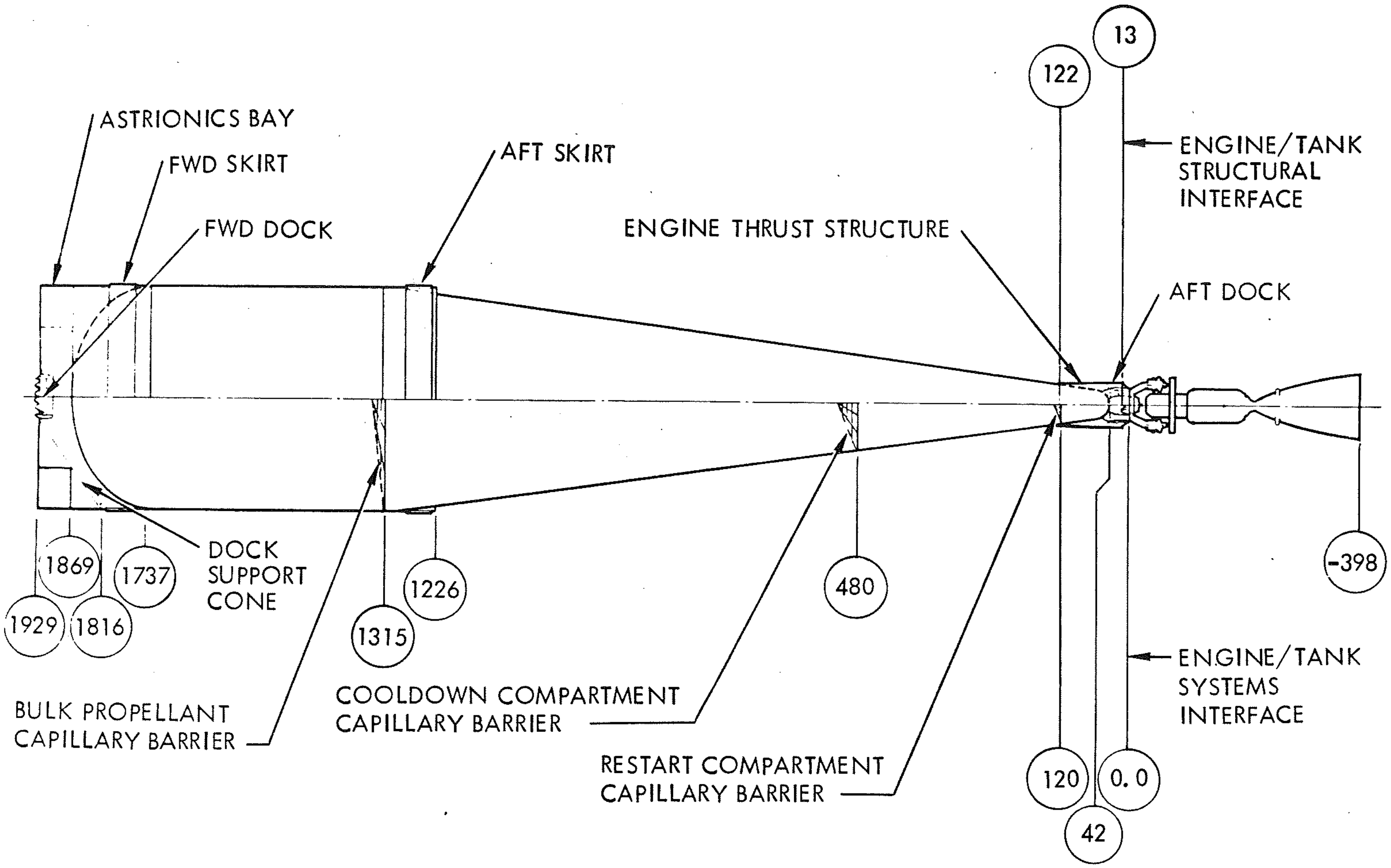


Figure 10-5 Selected RNS Baseline Layout

(5)	ICD No.	TBD	RNS Stage and Payload (See 3.7.1.2.3.8)
(6)	ICD No.	TBD	RNS Stage and Propellant Depot (See 3.7.1.2.3.6)
(7)	ICD No.	TBD	RNS Stage and Maintenance Element (See 3.7.1.2.3.7)
(8)	ICD No.	TBD	RNS Stage and EOS (See 3.7.1.2.3.4)
(9)	ICD No.	TBD	RNS Stage and Space Tug (See 3.7.1.2.3.5)
(10)	ICD No.	TBD	RNS Stage and Orbiting Lunar Station (See 3.7.1.2.3.10)
(11)	ICD No.	TBD	RNS Stage and Space Station (See 3.7.1.2.3.9)
(12)	ICD No.	TBD	RNS Stage and Data Relay Satellite System (See 3.7.1.2.3.11)

3.1.6 Government Furnished Property List

The equipment specified in the following list shall be supplied by the Government for installation and/or integration into or with the major elements of the RNS system.

Item No.	Nomenclature	Spec. and/or Part No.
(1)	NERVA 75,000 lb thrust	
(2)	TBD	
(3)	TBD	
(4)	TBD	
(5)	TBD	

3.1.7 Operational Concept

3.1.7.1 Launch Site

3.1.7.1.1 Launch Site Facilities - The following facilities shall be provided at the launch site or in the same general location:

a. Assembly Building

b. Launch Pad

3.1.7.1.2 Launch Site - The RNS tank element shall be launched by INT-21 from a launch site located at KSC. The NERVA shall be launched by Space Shuttle from a launch site at KSC or alternate Space Shuttle Launch site.

3.1.7.2 RNS Operations Orbit

The RNS operations orbit is defined as 260 n mi circular with an inclination of 31.5 degrees. All RNS missions will originate from and terminate at the operations orbit. Assembly, checkout, maintenance, expendables replenishment, payload mating, and final RNS/payload checkout will be accomplished in the operations orbit.

3.1.7.3 Main NERVA Burn Orbit

The orbit for initiating main NERVA departure burn is defined as 270 n mi (10 n mi above operations orbit) circular inclined 31.5 degrees. This orbit provides safe separation distance between IPP elements in operations orbit and RNS during main burn of NERVA.

3.1.7.4 Earth Orbital Launch Reaction Time - Design Reference Mission

The RNS design shall be based on the following concepts for the launch reaction time for the design reference mission.

a. The RNS shall be capable of launch from a standby status (Sec. 6) within TBD hours.

b. The RNS will nominally be launched at the next acceptable in-plane opportunity.

c. The RNS shall be capable of staying in a launch status (Sec. 6) until the TBD in-plane launch opportunity.

3.1.7.5 Lunar Orbit Launch Reaction Time - Design Reference Mission

The RNS design shall be based on the following concepts for the launch reaction time for departing from lunar orbit.

a. The RNS shall be capable of launch from a standby status (Sec. 6) within TBD hours.

b. The RNS will be capable of launch from lunar orbit at any time with a minimum return payload capability of TBD pounds or 20,000 pounds at the next optimum earth return opportunity.

c. The RNS shall be capable of staying in a dormant status until the TBD optimum earth return opportunity.

3.1.7.6 Rendezvous

The RNS shall be capable of rendezvous to a station keeping position as well as rendezvous to a dock with other program elements (e.g., maintenance element, propellant depot). The RNS will be the active element in rendezvous with the propellant depot or maintenance element, and will require a cooperative target. It will be the passive element holding attitude while the payload is being docked to it.

3.2 Characteristics

3.2.1 Performance

The following performance requirements are arranged in conformance with the functional flow diagram shown in Figure 10-3.

3.2.1.1 Orbital Assembly and Launch - The RNS system shall be capable of achieving launch rates specified in 3.7.3.5.1 for Class I mission traffic models with a turnaround time not to exceed TBD days.

3.2.1.1.1 Vehicle Preparation - RNS tank and NERVA orbital assembly equipment shall be provided to support the requirements of

3.2.1.1. Vehicle design shall be based on the RNS tank and NERVA being mated after RNS system elements are delivered to the operations orbit.

3.2.1.1.2 Propellant Loading - Loading of RNS propellant shall be performed after RNS stage checkout and prior to mating of the payload to the RNS.

3.2.1.1.3 Payload Mating - Payload handling provisions shall be provided to permit mating procedures consistent with the turnaround time specified in 3.2.1.1.

3.2.1.2 Mission Operation

3.2.1.2.1 RNS System Characteristics

3.2.1.2.1.1 Payload Delivery - The RNS system shall be capable of delivering the payload size and weights specified in paragraph 3.2.2.5.

3.2.1.2.1.2 RNS Vehicle Configuration - The RNS vehicle shall consist of a RNS tank and NERVA. The RNS vehicle shall have the following characteristics:

a. The vehicle shall be fully reusable.

b. The vehicle shall be capable of delivering payloads from earth orbit and returning to the earth operations orbit.

c. The RNS vehicle shall be capable of being serviced and maintained in earth orbit.

3.2.1.2.2 RNS Guidance and Navigation

The RNS stage on-board guidance and navigation system shall be capable of performing an automatic rendezvous and docking with other integrated space program elements. It shall also be capable of rendezvous to an orbital station keeping position and holding this position.

3.2.1.2.2.1 Targeting Guidance for Rendezvous - The RNS guidance and navigation system shall be self-targeting for rendezvous.

a. The G&N shall compute maneuvers, times, and steering commands to rendezvous with a passive target.

b. Steering information shall be computed on-board with knowledge of present state of RNS and ephemeris of the target.

3.2.1.2.3 Flight Control

3.2.1.2.3.1 RNS Rotational and Translational Control - The RNS shall be provided with the capability for three axes rotational and translational control.

3.2.1.2.3.2 RNS Flight Control Automatic Hold Capability - The RNS flight control system shall be provided with an automatic attitude hold capability for all mission phases.

3.2.1.2.4 On-Board Checkout - The RNS shall be provided with an on-board checkout capability which can be initiated remotely, or by crew of a manned payload.

3.2.1.2.5 Telecommunications - Voice and data communications shall be provided between the following Integrated Space Program Elements: RNS and Payload, RNS and Ground, RNS and Space Stations, RNS and EOS, and RNS and Tug. Except for link between RNS and payload, the RNS may use either a direct link or relay link through data relay satellite system.

3.2.1.2.6 Electrical Power - Electrical power shall be provided for RNS system and for manned payloads.

3.2.1.2.7 Information Management System - All data flow within the RNS system as well as between the RNS system and Integrated Space Program Elements will be controlled by the Information Management System. The heart of the IMS is the computer and its software.

3.2.1.3 Useful Life

The RNS shall be capable of performing 10 shuttle missions with normal orbital maintenance and servicing, and shall have a minimum three-year service life.

3.2.1.4 Maintenance and Servicing

The RNS system shall provide the capability of accomplishing orbital maintenance and servicing in TBD days or less.

3.2.1.4.1 Safing - The RNS system shall provide for safing within the RNS vehicle without requirement for support equipment.

3.2.1.4.2 Payload Demating - Equipment shall be provided in the operations orbit to demate and transfer returned payload from the RNS to its ultimate destination.

3.2.1.4.3 Post Flight Inspection - Payload demating shall be accomplished prior to performing post flight inspection by the servicing vehicle.

3.2.1.4.4 Data - Data processing equipment shall be provided to process inflight and orbital checkout data following return of RNS to the operations orbit. Data analysis shall be formated to allow for identification and initiation of maintenance and repair (M&R) actions.

3.2.1.4.5 Repair - The appropriate access equipment shall be provided in the operations orbit to perform inspection, scheduled, and unscheduled maintenance.

3.2.1.4.6 RNS System and Subsystem Checkout - The RNS shall be capable of performing its own system and subsystem checkout following M&R action, by utilizing the vehicle on-board checkout capability.

3.2.1.4.7 Expendables Replenishment - The RNS system shall be capable of receiving LH_2 propellant and other expendables transferred to it by other program elements.

3.2.1.4.8 Payload Mating - Equipment shall be provided in the operations orbit to deliver and mate the payload to the RNS. During payload mating, the RNS will maintain an attitude hold position.

3.2.1.4.9 Mated RNS/Payload Checkout - A final automatic checkout of the RNS/payload combination shall be performed by the RNS on-board checkout system prior to departing the operations orbit.

3.2.1.5 Transfer to NERVA Run Orbit

A safe separation distance shall be provided between the RNS and other orbiting space program elements prior to NERVA startup and run. The RNS flight control (RCS) shall be used to provide the separation distance.

3.2.2 Physical Characteristics

The following physical characteristics are identified to assure physical compatibility between major RNS system elements.

3.2.2.1 Engine

The engine for the RNS system is the 75,000-pound thrust NERVA. The engine shall comply with the specification of the NERVA Program Requirements Document, SNPO Document No. SNPO-NPRD-1.

3.2.2.1.1 Engine Propellant - The engines in the RNS are designed to use LH_2 propellant.

3.2.2.2 Tank Configuration - The basic RNS will be configured to a 33-foot diameter single tank geometry that is launched integrally to orbit by a Saturn V INT-21 vehicle.

3.2.2.3 Gross Weight

The vehicle dry weight shall not exceed TBD pounds (including external 4,000-pound shield). (Burnout weight $\approx$85,100 pounds)

3.2.2.4 Propellant Capacity

The RNS propellant tank shall be designed to have a maximum capacity of 300,000 pounds of LH_2 propellant with provisions for five percent ullage.

3.2.2.5 Payload Weight

The RNS stage shall be capable of delivering the payload weights defined in paragraphs 3.2.2.5.1 through 3.2.2.5.4.

3.2.2.5.1 Lunar Shuttle Payload - The range of payloads delivered to lunar orbit and returned from lunar orbit are identified as:

a. 200,000 pounds outbound with zero payload return (maximum payload delivered)

b. 166,000 pounds outbound with 20,000 pounds return (nominal logistic payload)

c. Zero pounds outbound with 120,000 pounds return (maximum payload returned).

3.2.2.5.2 Geosynchronous Shuttle Payload - The range of payloads delivered to geosynchronous orbit and returned from geosynchronous orbit are identified as:

a. TBD pounds outbound with zero payload returned (maximum outbound).

b. TBD pounds outbound and 20,000 pounds returned (nominal logistic payload).

c. Zero pound outbound and TBD pounds returned (maximum payload returned).

3.2.2.5.3 Unmanned Planetary Payload - The range of payloads injected on a planetary mission are identified as:

a. Curve (A) of Figure 10-6 defines the range of payload delivery requirements of the RNS departing and returning to the operations orbit.

b. Curve (B) of Figure 10-6 defines the range of payload delivery requirements of the RNS departing the operations orbit, and injecting itself into a heliocentric orbit after payload separation.

3.2.2.5.4 Manned Planetary Payload - The manned planetary payloads are identified as:

a. 293,300 pounds for the 560-day opposition class Mars mission.

b. 425,000 pounds for the 1040-day conjunction class Mars mission.

3.2.3 Reliability

3.2.3.1 Failure Mode and Effects Analysis - (TBD)

3.2.3.2 Redundancy - The following characteristics shall be used as guidelines for all RNS stage design:

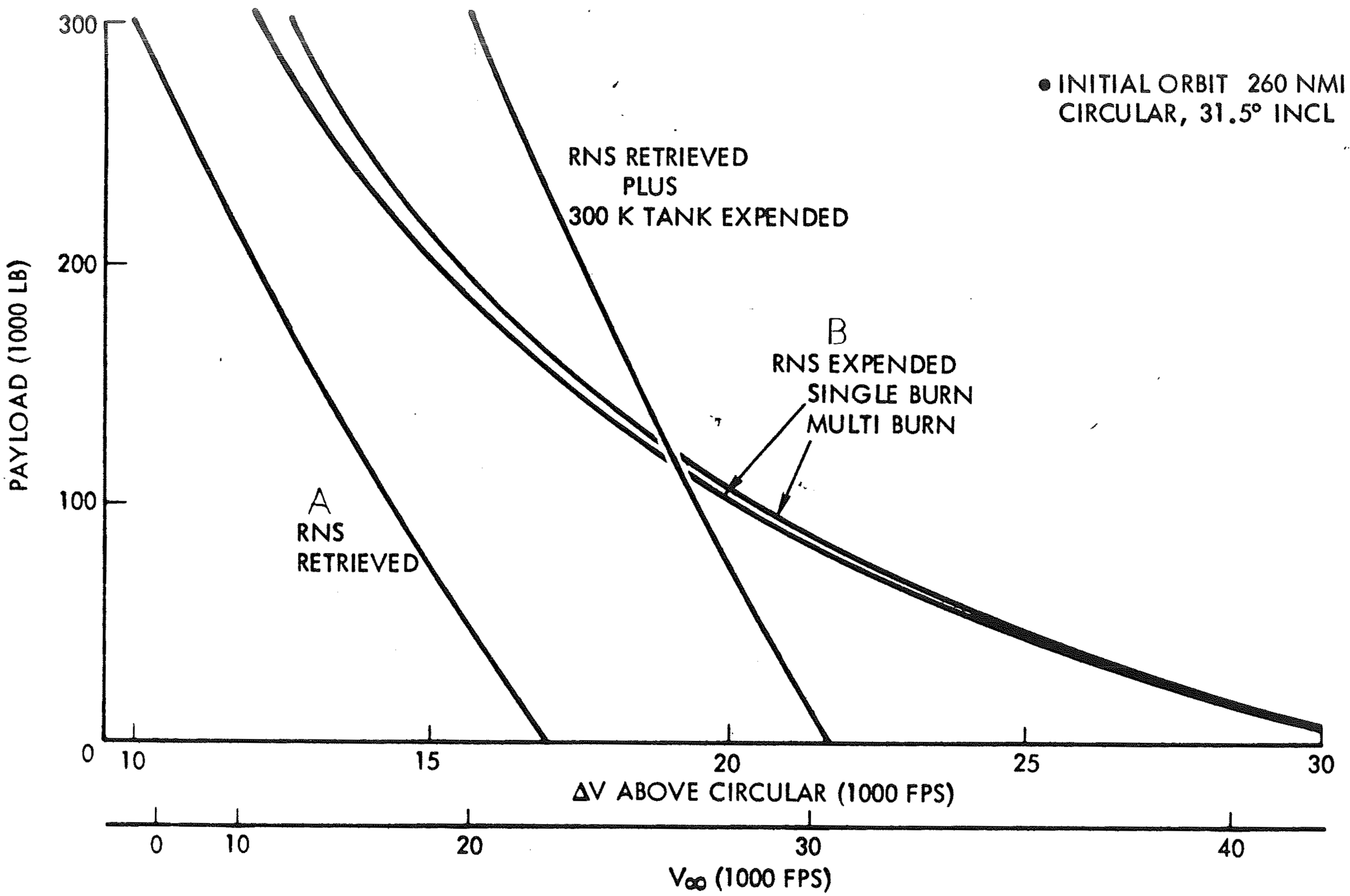


Figure 10-6. Unmanned Planetary Payload Delivery Requirements

a. Where redundancy is needed, full mission capability shall be developed, avoiding minimum requirement, minimum performance backup system concepts for any operational mode. If, after having satisfied the operational requirements defined in item "c" below, additional "fail-safe" modes are inherent in the design; their use is desirable and need not meet the full mission capability requirement.

b. System redundancy techniques shall be selected and implemented such that switching of system functions between redundant elements or paths in the event of a failure in an active functional path do not create a transient condition causing unacceptable system/vehicle performance

c. 1. The vehicle system shall remain operational following any single failure in a nonelectronic system or any two failures in electronic systems. The vehicle system is in operational condition if remaining mission* objectives can be accomplished without compromise.

2. Safe return capability shall be maintained following any two failures in a nonelectronic system, or any three failures in an electronic system. The vehicle system is in a safe condition if (a) the vehicle(s) can be returned to the earth operations orbit, and (b) payload passenger safety is not jeopardized, and (c) attitude hold for payload transfer can be accomplished.

3. Structural components such as rocket engine thrust chamber, vehicle structures, tanks, and fluid lines are not considered to be active elements and need not meet (1) and (2) above but shall have safety factors as specified below:

a. TBD
b. TBD
c.
etc.

*Refers to design reference mission

3.2.4 Maintainability

The RNS vehicle design shall incorporate maintainability features that will permit accomplishment of all necessary maintenance and repair with a minimum expenditure of maintenance resources, particularly with respect to manpower and elapsed time. Special consideration shall be given to provision of maintainability characteristics that will minimize turnaround time.

3.2.4.1 Maintainability Design Requirements - Maintainability (M) design requirements shall be specified in terms of elapsed maintenance time, man-hours, numbers of personnel, or other such measures of maintainability either individually or in combination. Specification of M design requirements is intended to insure "designed-in" M characteristics need to:

a. Achieve short turnaround time through ease of repair action

b. Facilitate accomplishment of unscheduled maintenance under all expected operational and environmental conditions

With respect to unscheduled maintenance, special emphasis shall be placed upon equipment accessibility zero gravity situations, use of the on-board checkout system for fault isolation and post-repair verification, and corrections of malfunctions by replacement of the FRU containing the fault. No orbital maintenance is contemplated on the FRU's. FRU's will be returned to ground for repair or disposal.

3.2.4.2 Mean-Time-To-Repair (MTTR)

The RNS vehicles will have a MTTR of less than TBD days.

3.2.5 Environmental Conditions

3.2.5.1 National Environments - The RNS system shall be designed in accordance with the natural environment criteria specified in NASA TMX-53957 and TMX-53872, and as modified by the requirements of this specification.

3.2.5.2 Induced Environment - The RNS vehicle elements shall be designed in accordance with the induced environmental criteria specified in TBD, with the exception (if any) noted in the following subparagraphs. The GSE shall be designed in accordance with the environmental criteria specified in TBD, with the exception (if any) noted in the following subparagraphs.

3.2.5.2.1 Acceleration Load Factors - The normal mission resultant load factor on the passengers shall not exceed TBD g in any direction; nor shall vector components exceed the following magnitudes:

a. Longitudinal ± g
b. Longitudinal ± g
c. Lateral ± g

3.2.5.2.2 Acoustics, Vibration, and Shock

3.2.5.2.2.1 Acoustics - During boost ascent and major orbital ΔV/s, shall not exceed the following:

a. Acoustics TBD
b. Vibration TBD
c. Shock TBD

3.2.6 Transportability (TBD)

3.3 Design and Construction

3.3.1 Materials, Parts, and Processes

All materials, parts, and processes selected for use in design and construction of the RNS system shall be compatible with the performance and environmental criteria for the end item as specified in the CEI specifications. Materials, parts, and processes used on off-the-shelf hardware or hardware previously developed on other Government contracts shall be acceptable provided the hardware is verified to be compatible with the performance and environmental criteria as specified in this specification.

3.3.1.1 General Design and Construction Standards - Unless otherwise specified herein or in the detail equipment specifications, the requirement of AFSCM 80-series publications listed in 2.1, shall be incorporated as an integral part of the requirements of this specification by reference.

3.3.1.2 Selection of Specifications and Standards - Specifications and standards for necessary commodities and services shall be selected in accordance with MIL-STD-143 except as otherwise specified herein. The DOD Index of (TBD), shall be the source of issues in effect from which selections are to be made.

3.3.1.2.1 Selection of Qualified, Standard and Commercial Parts - Parts selection for use on the shuttle system shall be made from controlled parts with demonstrated adequacy for the intended application and environments. Qualified parts (see 6.0) and preferred standard parts (see 6.0) lists may be used as sources of selection. If commercial grade parts (see 6.0) are used, prior notification shall be given to the procuring agency.

3.3.1.3 Materials, Parts and Processes - Standard, proven and economical parts such as airframe hardware and mechanical, electrical, hydraulic and pneumatic components, shall be specified to the maximum extent consistent with reliability, maintainability and performance requirements thus implementing (TBD). Materials shall be chosen on the basis of suitability for intended use and the availability in this country during national emergency. Noncritical materials shall be used wherever practical under the constraints otherwise specified. Raw materials in mill product form shall be specified in terms of NASA specifications, military specifications, or approved industry association specifications such as the Aeronautical Material Specification (AMS) whenever possible. Only those parts, materials, and processes designated as standard by the government design specifications may be used in the applicable equipment without procuring activity approval.

3.3.1.4 Standard, Commercial and Qualified Parts - The selection of parts shall be made in accordance with the requirements of the government design specification applicable to that equipment. Parts which are in current production and available, as indicated by being on qualified parts lists, shall be used to the maximum extent possible. Those parts which are to be obtained from only certain of the many suppliers listed on the QPL shall be considered as nonstandard (selected) parts. When no general specifications exist, the selection procedure for parts shall follow the order of precedence established in MIL-STD-143. Unless otherwise specified, air vehicle commercial parts covered by ANA Bulletin 147 shall be considered as being within Group I standards as defined by MIL-STD-143.

3.3.1.5 Moisture and Fungus Resistance - System equipment shall be designed so that the materials comprising its makeup are basically not nutrients for fungus. Fungus nutrient materials may be used in permanently hermetically sealed assemblies and other accepted and qualified uses such as paper capacitors and treated transformers. Other necessary fungus nutrient material applications will require treatment by a method which will render the resulting exposed surface fungus resistant. Moisture resistance is considered the property of not degrading in the presence of moisture or absorbing and holding moisture. The criteria for and determination of fungus and moisture resistance shall be in accordance with MIL-E-5272 and MIL-STD-810 as appropriate. Fungus inert materials are listed in MIL-STD-454 requirement 4.

3.3.1.6 Corrosion of Metal Parts - The protective finishes and finish schemes of all ground equipment shall comply with the requirements of MIL-STD-808. Airborne equipment finishes and coatings shall comply with the requirements of TBD. Type II protection classification and the following additional requirements:

a. The organic finishes or finish systems used shall provide the necessary corrosion resistance for the metal being protected and for all materials used in areas subjected to severe corrosive environments.

b. The use of dissimilar metals (as defined in MS 33586) in direct contact is prohibited. When dissimilar metals are required to be joined, their faying surfaces shall be adequately insulated, preferably by (TBD) sealant or an approved sealing compound, to assure protection from electrolytic corrosion. Additional organic finishing or barrier tapes may be used, subject to requirements and restrictions of (TBD).

c. The chemical finishes used shall provide adequate corrosion resistance, however, those parts or surfaces of parts located in corrosion susceptible areas or which form exterior surfaces of the system shall require chemical finishing to provide maximum corrosion resistance.

3.3.1.7 Radiation Resistance

Component and material used on the RNS will be exposed to nuclear radiation during NERVA engine run and, to a lesser degree, after engine shutdown. Components and materials must be capable of withstanding this radiation environment throughout the life of the RNS stage. Neutron flux density and gamma kerma rate for various portions of the RNS stage are given below (8-degree half-cone angle and 25-inch cap radius):

a. Forward skirt area: Neutron flux density, $\approx 1.5 \times 10^9$ N-cm^2-sec^{-1} (E > 0.9 Mev); gamma kerma rate 8×10^3 rad(c)-hr^{-1}

b. Aft skirt area: Neutron flux density, $\approx 3 \times 10^9$ N-cm^{-2}-sec^{-1}; gamma kerma rate, $\approx 2 \times 10^4$ rad(c)-hr^{-1}

c. Aft bulkhead: Neutron flux density, $\approx 2 \times 10^{11}$ N-cm^2-sec^{-1}; gamma kerma rate, $\approx 5 \times 10^5$ rad(c)-hr^{-1}

3.3.1.8 Contamination Control - Cleanliness of the assembled spacecraft shall be to the requirements of (TBD). Fluid cleanliness shall be in accordance with (TBD). All other cleanliness requirements shall be in accordance with (TBD).

3.3.1.9 Storage - The Space Shuttle System hardware shall be designed for a storage life of (TBD) years in the environment defined in (TBD) except that in those cases where age-sensitive materials cannot be avoided, replacement of such materials shall be permitted on a schedule basis during the storage period.

3.3.1.10 Interchangeability and Replaceability - Airborne equipment, components and parts shall be interchangeable and replaceable to the extent required by MIL-I-8500. For those items required to be interchangeable by MIL-I-8500, the interchangeable items of equipment shall be identified for the model designated for the First Article Configuration Inspection.

3.3.1.11 Workmanship - All air vehicle equipment workmanship shall be in accordance with high-grade aircraft practices and of quality to assure safety, proper operation, high reliability, and service life requirements. All facilities, aerospace ground and training equipment workmanship shall be the highest quality commensurate with the use of the item.

3.3.1.12 Electromagnetic Interference - The system shall be designed to the compatibility requirements of MIL-I-6181D.

3.3.1.12.1 Electromagnetic Radiation - Each major element shall be electromagnetically compatible with other elements in the system. Any one element shall not be a source of interference that could adversely affect the operation of other elements or compromise its own operational capabilities.

3.3.1.13 Identification and Marking - The identification and marking of airborne equipment shall be in accordance with (TBD). The designation of the aircraft shall conform to the requirements of (TBD). Serialization markings of new equipment shall conform to the requirements of (TBD).

3.3.2 (Reserved for Future Use)

3.3.3 (Reserved for Future Use)

3.3.4 Safety

3.3.4.1 Range Requirements - The Space Shuttle System shall meet the safety requirements established by the Air Force Eastern Test Range (TBD).

3.3.4.2 Safety Requirements - The System Safety program for the Space Shuttle shall be compatible with the requirements of the OMSF Safety Program.

3.3.4.2.1 Single Failure - All credible single failure modes or credible combinations of failures and errors which result in loss of crew and passengers or unacceptable risk to general population groups will be eliminated by design change and/or mission modification.

3.3.4.2.2 NERVA Emergency Mode - No single failure or credible combination of failures and errors will prevent or preclude operation of the NERVA engine in the emergency mode.

3.3.4.3 Safe Mission Termination - The RNS System shall provide for safe mission termination in the event major malfunctions occur during prelaunch preparations and subsequent NERVA run. The desired safe mission termination shall allow safe crew and passenger transfer prior to NERVA run and for abort subsequent to NERVA run.

3.3.4.4 Radiation Hazards

3.3.4.4.1 Crew and Passenger Radiation Dose - Total radiation dose from the NERVA engine and plume sources will be limited to 10 REM per passenger and 3 REM per crew member per round trip shuttle mission.

3.3.4.4.2 Maintenance Personnel Radiation Dose - RNS maintenance personnel will not receive more than 25 REM per year from the RNS.

3.3.4.4.3 Space Station Radiation Dose - Total integrated radiation dose from the RNS to any manned space station or manned orbital system will not exceed 0.1 REM during any single NERVA engine run.

3.3.4.5 Nonhazardous Material Selection - Materials used shall be selected with ignition, flammability, toxicity, expansion, contraction, and shock sensitivity characteristics that do not present potential hazards due to use in the intended environment.

3.3.5 Human Performance/Human Engineering

3.3.5.1 Human Engineering Criteria - MIL-STD-1472 shall be used as a guide for the application of human engineering principles to the design of the RNS system elements.

3.4 Documentation

The documentation data for the RNS system shall consist of specifications, drawings, and interface control documentation as shown in Figure 10-7.

3.5 Logistics

3.5.1 Maintenance

Three levels of maintenance shall be provided for the Space Shuttle system elements and support equipment.

3.5.1.1 Maintenance Level I - Maintenance Level I shall consist of all maintenance activities accomplished directly on system-installed hardware. Maintenance Level I shall include fault isolation, removal, replacement of components, FRU's, or subsystems, servicing, replenishing, inspection and repair in place.

3.5.1.2 Maintenance Level II - Maintenance Level II shall consist of those maintenance activities performed in direct support of first-level maintenance and involves disposition or repair of hardware removed during first level maintenance activities. Maintenance Level II shall normally be performed at maintenance element or maintenance depot equipped with special test and checkout equipment. Level II maintenance shall provide for the removal, replacement, repair, calibration, adjustment, checkout, test and inspection to the lowest replaceable part.

3.5.1.3 Maintenance Level III - Maintenance Level III shall consist of those maintenance activities performed in direct support of first- and second-level maintenance. Maintenance Level III may also involve disposition or repair of hardware removed during first-, second-, and third-level maintenance activities. Maintenance Level III shall normally be performed at more remote locations such as contractor and vendor factories or government repair and overhaul facilities. Maintenance Level III shall involve major repair or overhaul which is beyond the capabilities of the second-level maintenance facilities.

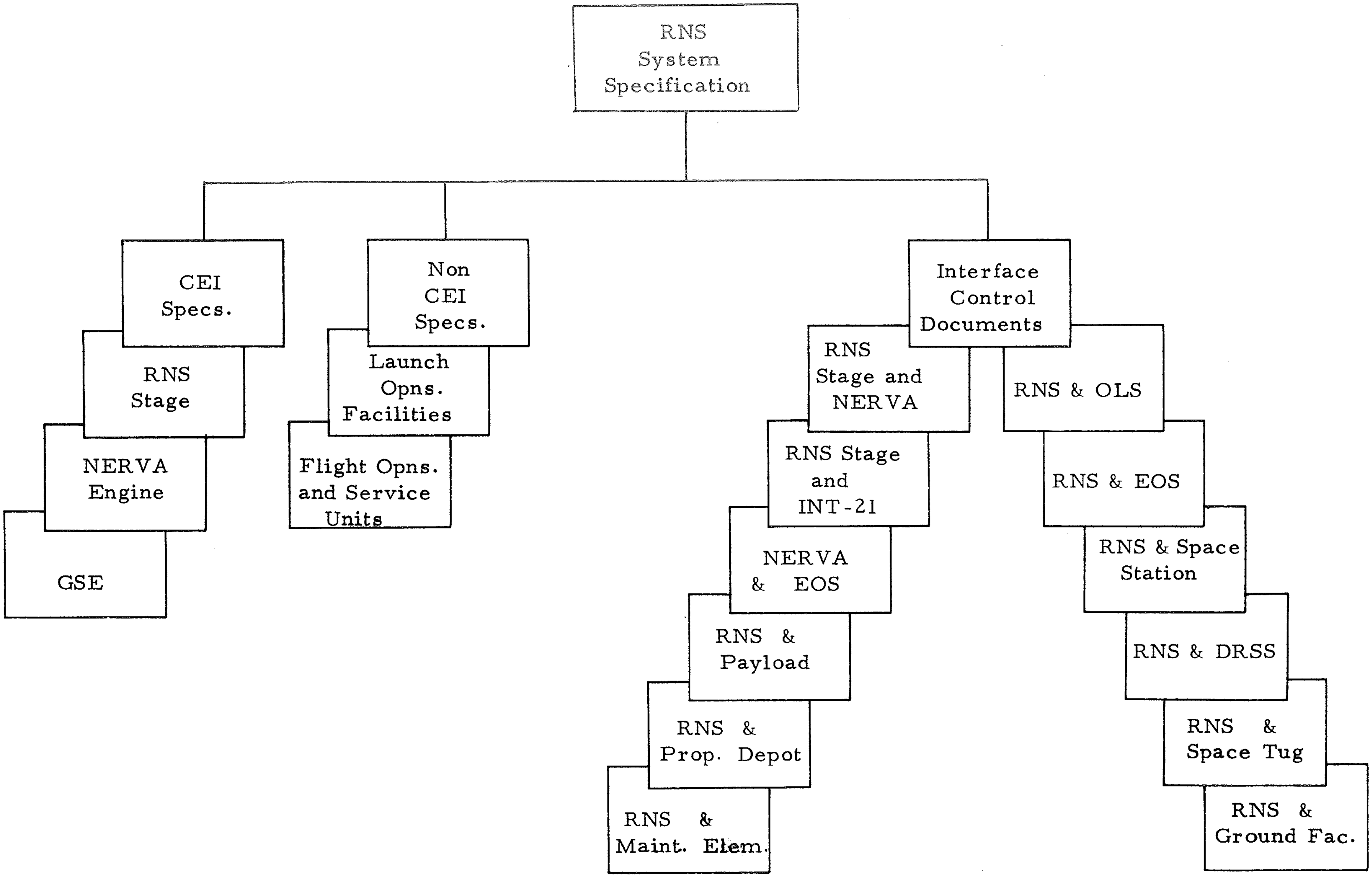


Figure 10-7. Documentation Products

3.5.2 Supply Support

The RNS system shall be designed and constructed to be compatible with the supply support system policy, location and distribution and management system specified below.

3.5.2.1 Sparing Policy - The Space Shuttle program policy for supporting system operations with spare hardware shall be:

a. Electrical and electronic spares shall be maintained to the modular box level.

b. Mechanical, structural, and propulsion spares shall be maintained at the lowest replaceable serialized unit level (FRU).

3.5.2.2 Supply Support Locations - Logistics Support Centers (LSC) shall be established at the prime contractor, associate contractors, and selected major subcontractors facilities, and at the launch operational site. The LSC configuration and support policy shall be consistent with the level of supply support required for equipment, and vehicle hardware, material support.

3.5.2.3 Supply Support Inventory Distribution and Management System - Distribution and control of the RNS program support hardware and materials shall be maintained by an inventory management system. Normal and expedited supply and resupply of support materials and equipment shall be statused at each LSC to support program contract end items consistent with support requirements.

3.5.3 Facilities and Facility Equipment

Nuclear shuttle system facilities and equipment shall be provided to support launch site and orbital operations. Existing facilities and equipment shall be utilized wherever possible. New procurement or modifications shall be held to a minimum.

3.5.3.1 Launch Site Facilities and Equipment - Characteristics of the launch site facilities and GSE shall be as specified in 3.7 and its subparagraphs.

3.6 Personnel and Training

3.6.1 Personnel

Manning support of the nuclear shuttle system and its equipment through all system life cycle phases shall include operational personnel, maintenance crew and systems control personnel.

3.6.1.1 Flight Crew - The RNS flight crew is defined as the manned payload crew making repeated shuttle trips between operations orbit and lunar orbit or between operations orbit and geosynchronous orbit providing mission control and manual override of RNS.

3.6.1.2 Passengers - RNS passengers are defined as those persons making infrequent trips between operations orbit and lunar/geosynchronous orbit in the manned payload. Their prime function is that of performing operations or experiments in lunar/geosynchronous orbit and not performing flight crew functions.

3.6.1.3 Maintenance Personnel - These persons perform the orbital and maintenance and servicing functions while the RNS is in the operations orbit. Maintenance actions are primarily remove and replace operations with repair in place operations being performed on items which cannot be removed for repair.

3.6.2 Training

3.6.2.1 Contractor and Government Training - Training services shall be provided to support the operational use of the Nuclear Shuttle System.

3.6.2.1.1 Place of Training - Training shall be provided at:

a. The contractors facility
b. Operational sites

3.6.2.1.2 Type of Training - The following types of training shall be provided:

a. Classroom presentations

b. Shop demonstrations

c. Practical application on trainers and simulators

3.6.2.1.3 Training Program - The training program shall:

a. Provide training through the (TBD) level

b. Include training on all contractor-furnished equipment

c. Include training on Government-furnished equipment, if the Government does not possess in-house capability.

d. Include interfaces between all Government-furnished subsystems.

3.6.2.2 Training Equipment - Equipment shall be provided for training purposes as specified in 3.6.2. Training equipment shall include:

a. Vehicle interface simulators

b. Vehicle systems simulation trainers

3.6.2.2.1 Training Equipment Maintenance - Training equipment, utilized at contractors facilities shall be updated and refurbished to support the operational training facilities.

3.6.2.3 Training Devices - Training devices shall be provided and shall include:

a. Models

b. Operational parts and assemblies

3.6.2.3.1 Use of Training Devices - Training devices shall be employed to develop skills for individuals, groups, and teams in operations familiarization in:

a. Systems

b. Subsystems

c. Components

3.6.2.3.2 Skill Development - Skills shall be developed to perform the following tasks:

a. Operational sequences
b. Systems and subsystem operation
c. Fault detection and isolation
d. Normal and emergency procedures
e. Servicing
f. Inspection
g. Maintenance

3.6.2.4 Course Materials and Training Aids - Training material shall include:

a. Handbooks

b. Workbooks

c. System and subsystem study guides

d. Training handouts

e. Operational and maintenance documentation

f. Informal documents such as course outlines and lesson plans

g. Wall charts

h. Transparency slides

i. Schematics

j. Systems configurations

3.7 Functional Area Characteristics

3.7.1 Reusable Nuclear Shuttle Vehicle

The RNS vehicle shall consist of an RNS tank element and NERVA engine element. The RNS vehicle shall interface with other functional elements as shown in Figure 10-4. The RNS stage shall be capable of delivering payloads on Class I, II, and III missions as defined in paragraph 3.2.2.5.

3.7.1.1 NERVA Engine

3.7.1.1.1 NERVA Engine Performance Characteristics - Performance characteristics of the engine are summarized in the paragraphs below and in Table 10-5.

3.7.1.1.1.1 Vacuum Performance Rating - The vacuum performance rating of the engine, based on a nozzle ration of 100:1 and using hydrogen propellant as specified in MFSC Specification 356 is as follows:

a. Thrust: 75,000 ± 2000 pounds including a controllability tolerance (thrust considered parallel to the pressure vessel axis)

b. Specific impulse: Nominal 825 seconds ± 0.75 percent including a controllability tolerance (does not include allowable operating hydrogen leakage nor hydrogen required for tank pressurization)

c. Nominal chamber (P_c): 450 psia (nominal thrust-chamber pressure is the stagnation pressure)

d. Nominal chamber temperature (T_c): 4250 R (nominal thrust-chamber temperature is the stagnation temperature)

e. Normal mode endurance: 600 minutes (10 hours) at rated temperature (including throttling), accumulated in up to 60 cycles of varying duration. The duration capability at rated conditions (P_c = 450 psia, T_c = 4250 R) for single burns is 1 hour.

3.7.1.1.1.2 Operating Modes - The engine has three operating modes as follows:

a. Normal mode - engine operation with all subsystems and components capable of being operated as designed.

Table 10-5

Summary of Engine Performance Characteristics for NERVA Engine

Rated Vacuum Performance	
Thrust (in vacuum)	75,000 lb nominal
Chamber Temperature (T_c)	4250°R nominal
Chamber Pressure (P_c)	450 psia nominal
Vacuum Specific Impulse (I_{sp})	825 sec nominal
Duration	
At rated Chamber Temperature	600 minutes (minimum) 60 cycles
Startup	
Temperature transient, bootstrap to throttle point T_c (measured) °R/sec:	150 nominal
Pressure transient, throttle point to rated conditions P_c (measured) psi/sec:	50 nominal
Throttleability	
Pressure transient, rated conditions to throttle point P_c (measured) psi/sec:	50 nominal
Shutdown	
Shutdown transients (includes throttling)	
T_c (measured) °R/sec	150 nominal
P_c (measured) psi/sec:	50 nominal
($P_c \geq$ 293 psia)	

b. Malfunction mode - single turbopump operation. Engine operation at 80-percent thrust with one leg of the propellant feed system inoperative.

c. Emergency mode - engine operation at a level to effect safe crew return or to prevent danger to earth's population. Only one operating cycle in emergency mode will be required.

3.7.1.1.2 Physical Characteristics

3.7.1.1.2.1 Weight - Engine weight, excluding external shield is 27,728 pounds (this includes a projected weight allocation of 500 pounds for the stage-mounted portion of the NERVA digital instrumentation and control electronics, located forward of the primary engine stage interface).

3.7.1.1.2.2 Dimensions - The overall NERVA engine dimensional envelope is shown in Figure 10-8.

3.7.1.1.2.3 NERVA Interface - The physical interface between NERVA engine and RNS stage is shown in Figures 10-9, 10-10, and 10-11. The electrical connector layout is shown in Figures 10-9 and 10-10, whereas the mechanical connection is shown in Figure 10-11.

3.7.1.2 RNS Stage Tank

3.7.1.2.1 Performance

3.7.1.2.1.1 RNS Stage Tank - The RNS Stage Tank shall be capable of delivering LH_2 propellant to the NERVA engine in accordance with the propellant conditioning requirements of Table 10-6.

3.7.1.2.1.2 Meteoroid/Thermal Protection - Meteoroid protection will be provided for the RNS propellant tank for no penetration with a probability of no impact penetration of .995 for three years of space exposure.

The thermal cycle for Class I and Class II missions is 28 days, based upon the reference Lunar Shuttle Mission with a 17-day lunar stay time. The RNS will evolve to meet the requirements of the Class III thermal cycle requirements which can extend to approximately three years.

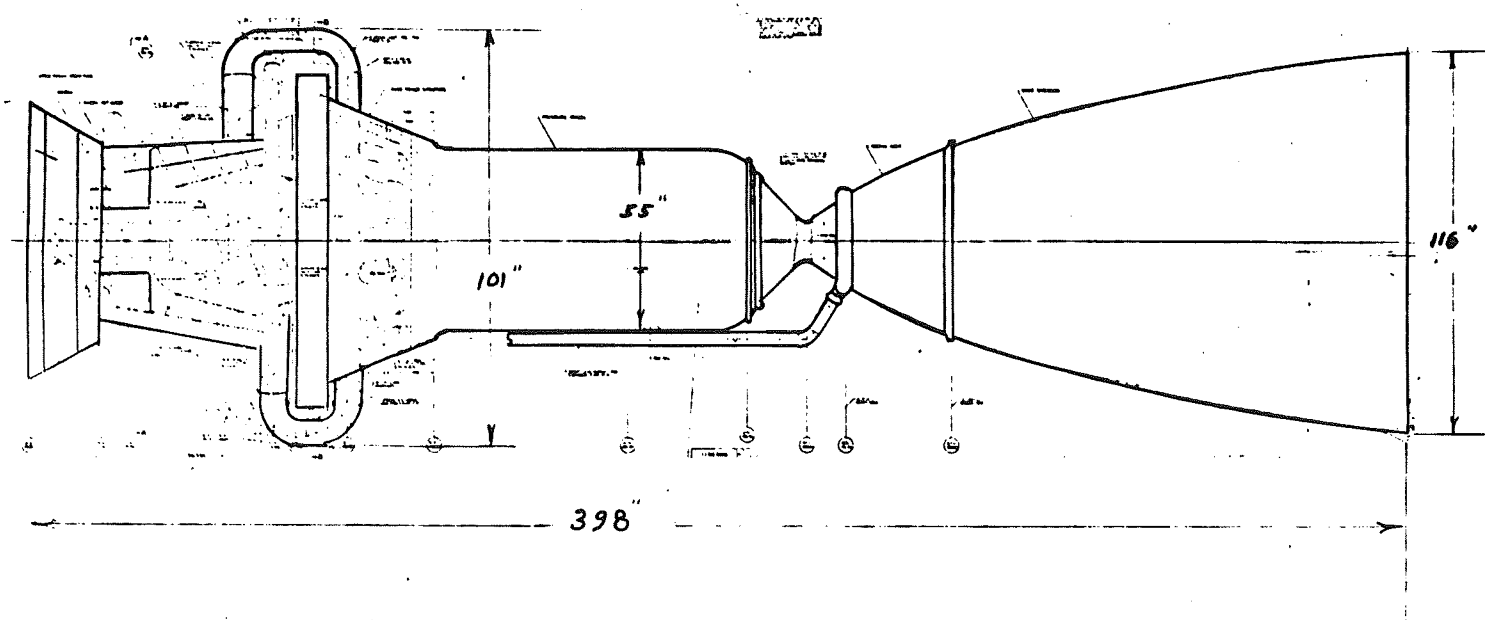


Figure 10-8. NERVA Engine Dimensional Envelope

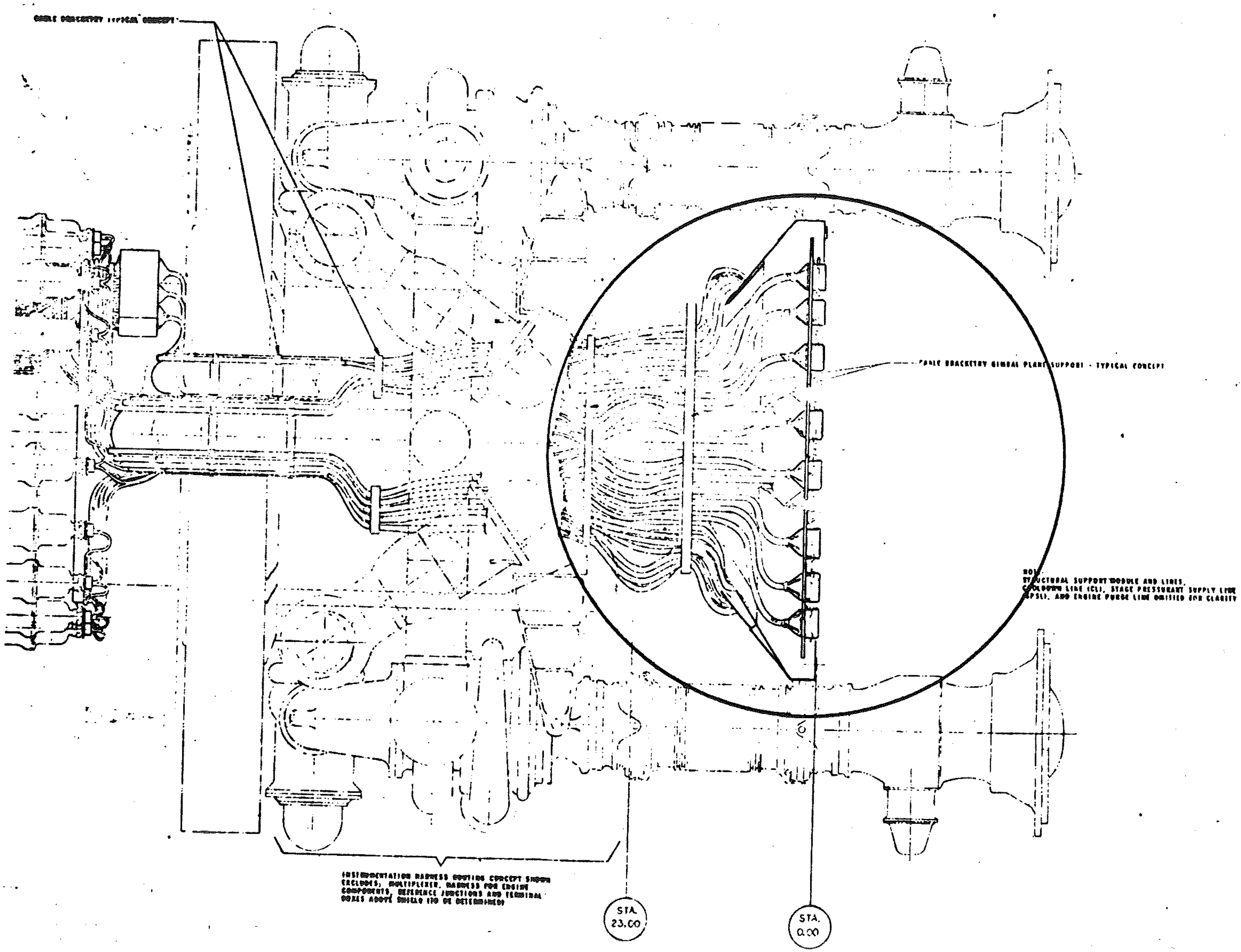


Figure 10-9. Electrical Connector Interface

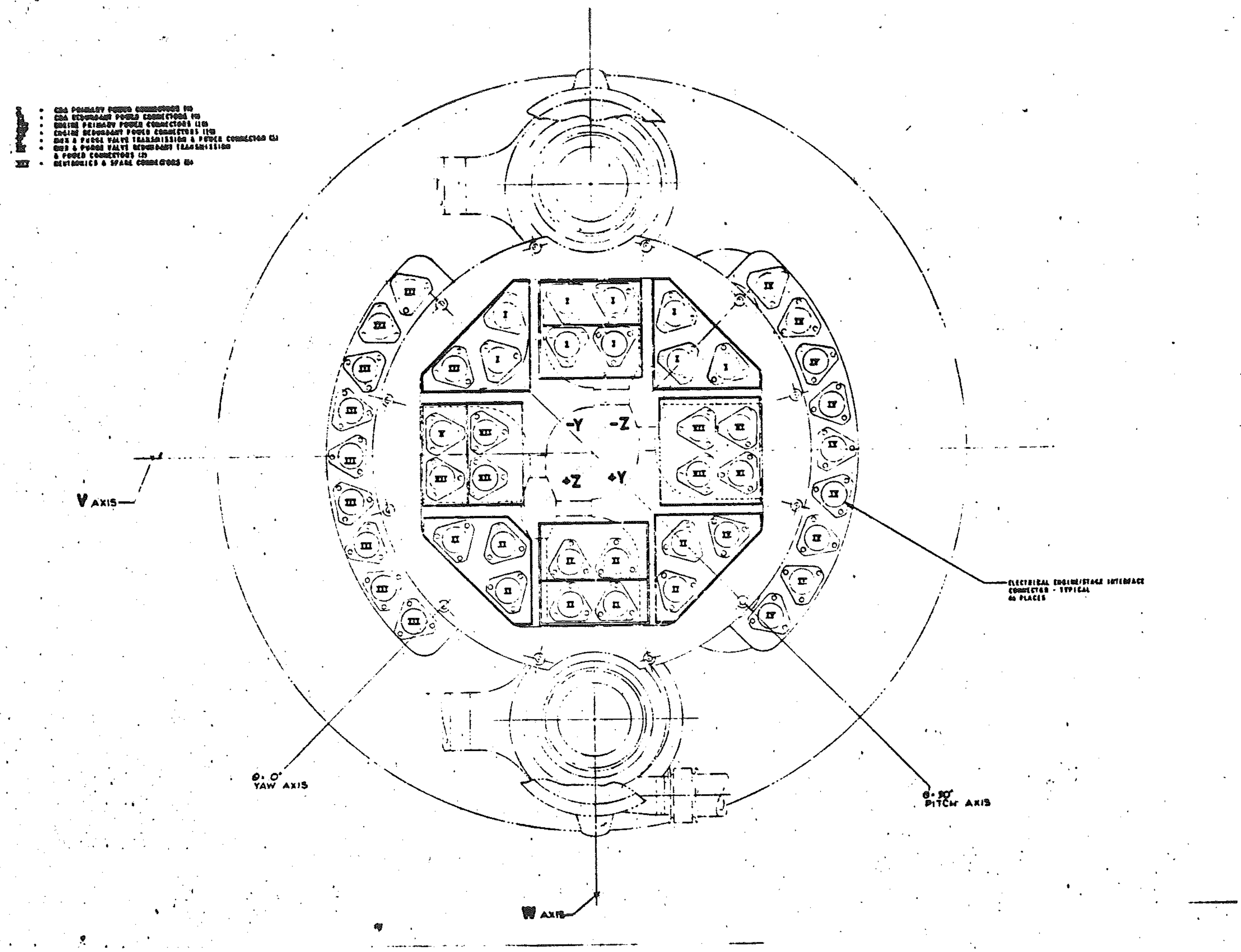


Figure 10-10 Electrical Connector Arrangement

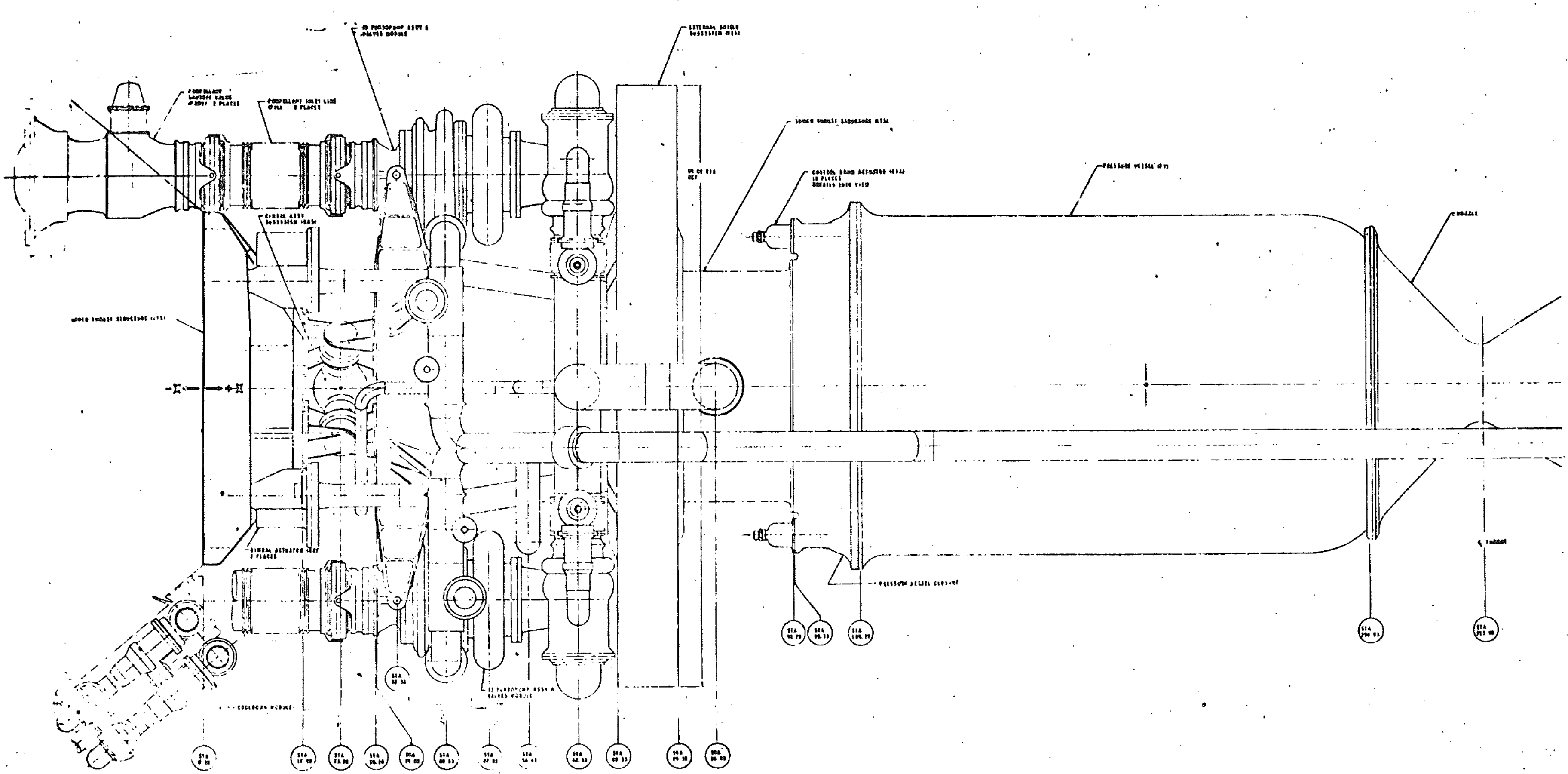


Figure 10-11. NERVA Mechanical Interface

Table 10-6

PROPELLANT CONDITIONING REQUIREMENTS

	Tank Pressure (PSIA)	Saturation Pressure (PSIA)	Vapor %
Normal Operation			
Startup	TBD to 30	TBD	0
Rated Condition	28	28	0
Cooldown	TBD	TBD	TBD
Single Turbopump Operation			
Startup	TBD to 30	TBD	0
Rated Condition	30	28	0
Cooldown	TBD	TBD	TBD
Component Malfunction			
Startup	Same as Normal Operation		
Rated Condition	Same as Normal Operation		
Cooldown	TBD	TBD	TBD
Emergency Operation			
Startup	TBD to 30	TBD	0
Rated Condition	30	28	0
Cooldown	TBD	TBD	TBD

3.7.1.2.1.3 Docking/Clustering - The RNS will be capable of docking with other Space Program Elements through use of a neuter docking system. The RNS will be capable of being either the active or passive element in the docking maneuver. The following docking position and impact parameters shall not be exceeded for RNS to Space Program Element docking.

a. Centerline miss distance ± TBD inches

b. Miss angle ± TBD degrees

c. Longitudinal velocity TBD FPS (max)

d. Lateral velocity TBD FPS (max)

e. Angular velocity TBD FPS (max)

The RNS will have the active neuter docking system at the forward skirt.

Provisions will be made for clustering advanced RNS stages into a Planetary Nuclear Propulsive System (PNPS) for Class II missions.

3.7.1.2.1.4 Auxiliary Propulsion - An Auxiliary Propulsion System will provide RNS attitude orientation and attitude control during powered and unpowered phases of the mission. Translational maneuvers will also be provided by the Auxiliary Propulsion System so that safe separation distance between RNS and Space Program Element can be maintained or acquired prior to NERVA engine startup.

The Auxiliary Propulsion System shall be capable of performing the following RNS maneuvers.

Pitch TBD degree(s) per minute

Yaw TBD degree(s) per minute

Roll TBD degree(s) per minute

Translational ΔV TBD FPS (max) with payload and RNS tank full of propellant

3.7.1.2.1.5 Astrionics - The astrionics includes all of the electrical and electronic equipment on board the RNS stage. Functions performed by the astrionics equipment include: generation of electrical power, distribution of electrical power, and information management which includes data handling, communications and control.

3.7.1.2.1.5.1 Communications - Communications will provide for information flow on-board the RNS, between the RNS and other space vehicles, and between the RNS and other space vehicles, and between the RNS and ground. Tracking information provides range and/or pointing information with respect to other vehicles. Bandwidth requirements for the communication and tracking links are detailed in Table 10-7.

3.7.1.2.1.5.2 Guidance and Navigation - The RNS shall have an autonomous guidance system utilizing NSFN and DSN for backup orbit determination. The on-board G&N system shall guide the vehicle in establishing orbits and rendezvousing with space program elements. The G&N system shall operate satisfactorily in any vehicle attitude. The system shall be capable of being reprogrammed to accommodate mission re-planning. This capability shall be utilized to generate nominal and alternative targeting and rendezvous plans.

3.7.1.2.1.5.3 Electrical Power - The electrical power system shall be self-sufficient in being able to generate power for a period of 55 days for Class I and II missions. Basic power requirements are to satisfy the needs of the NERVA engine and RNS stage subsystems. Class III missions will require development of an electrical power system to generate electrical power for periods up to three years.

3.7.1.2.2 Physical Characteristics

3.7.1.2.2.1 RNS Stage Geometry - The RNS stage shall be of the "single tank" configuration, 33 feet in diameter with a 300,000-pound LH_2 propellant capacity that is launched integrally to orbit by a Saturn V INT-21 launch vehicle. Figure 10-5 depicts an inboard profile of the selected RNS baseline configuration.

Table 10-7. Bandwidth Requirements for RNS Communication & Tracking Links

Channel Transmits \ Communication Link From RNS	To Ground		To Logistics Vehicles		To PD	
	Up Link	Down Link	Up Link	Down Link	Up Link	Down Link
Digital data (telemetry)	12.5 KBPS for 100 KHz	6 x 10^5 BPS for 4.8 MHz	12.5 KBPS for 100 KHz	12.5 KBPS for 100 KHz	12.5 KBPS for 100 KHz	12.5 KBPS for 100 KHz
Voice	1 at 4 KHz	1 at 4 KHz	1 at 4 KHz	1 at 4 KHz	1 at 4 KHz	1 at 4 KHz
Video (TV)	None	1 at 4.5 MHz	1 at 4.5 MHz	1 at 4.5MHz	1 at 4.5 MHz	1 at 4.5 MHz
Tracking Data	PRN ranging at 1 MBPS for 8 MHz	PRN ranging at 1 MBPS for 8 MHz	PRN ranging at 1 MBPS for 8 MHz	PRN ranging at 1 MBPS for 8 MHz	PRN ranging at 1 MBPS for 8 MHz	PRN ranging at 1 MBPS for 8 MHz

3.7.1.2.2.2 RNS Stage Weight - The RNS stage weight less NERVA engine shall not exceed TBD pounds.

3.7.1.2.3 RNS Interfaces

3.7.1.2.3.1 RNS NERVA Engine - Paragraph 3.7.1.1.2.3 is incorporated herein by reference

3.7.1.2.3.2 RNS and INT-21 Launch Vehicle - The RNS shall have mechanical and electrical interface features compatible with INT-21 mating interface.

3.7.1.2.3.3 Launch Pad Facility and GSE Interface - The RNS shall have mechanical and electrical interface features compatible with:

a. Propellant loading line fittings
b. Propellant tank vent line fittings
c. Ground power umbilical connectors
d. Communication umbilical connector fittings
e. Grounding cable attach fittings
f. Purge and ventilating line fittings

3.7.1.2.3.4 Earth Orbit Shuttle (EOS) Orbiter Interface - The EOS Orbiter will be utilized for delivery of the NERVA engine to RNS operations orbit for initial assembly of the NERVA engine to the RNS stage. All logistics support for RNS missions will be provided to the RNS orbit by the EOS.

3.7.1.2.3.5 Space Tug Interface - The space tug will be utilized to transfer and mate the payload to the RNS. The space tug will be the active element in the rendezvous and docking operation while the RNS maintains an attitude hole orientation. The space tug also will be utilized for engine disposal.

3.7.1.2.3.6 Propellant Depot (PD) Interface - The propellant depot will serve as the LH_2 storage and transfer system for the RNS as well as other program elements. RNS will be the active element in the rendezvous and docking with the PD while the propellant depot will maintain attitude hold orientation. Override control of the RNS will be provided to the propellant depot through RF link. Direct wired controls will be provided to the PD for control of the RNS fill and vent system through a connector attached to the neuter docking system. Propellant line fittings will be provided at the docking interface for orbital transfer of the LH_2 propellant. Propellant location control and attitude orientation will be provided by the PD after the RNS has docked to it.

3.7.1.2.3.7 Maintenance Element Interface - The Maintenance Element (ME) will be utilized to perform orbital maintenance and servicing operations in the RNS. It will be physically docked to the RNS while maintenance operations are being performed on the RNS.

3.7.1.2.3.8 Payload Interface

3.7.1.2.3.8.1 Mechanical Interface - The RNS stage docking subsystem shall contain the necessary mechanical mechanisms to dock, hold, and deploy the payload module. The payload module interfacing device must be adaptable to various size payload modules while maintaining a common interface with the RNS stage.

3.7.1.2.3.8.2 Electrical Interface - An electrical connector interface shall be provided between the payload module and the RNS such that the RNS status can be monitored at all times and such that override control of the RNS is available to the manned payload module.

3.7.1.2.3.9 Earth Orbit Space Station Interface - A functional interface will exist between the Earth Orbit Space Station and RNS to: provide a communication link with RNS payload crew, provide ephemeris data, and provide override control of RNS with unmanned payloads.

3.7.1.2.3.10 Orbiting Lunar Station (OLS) Interface - Only a functional interface will exist between the RNS and the OLS. Communications tracking and RNS override control (through RF link) functions will be between RNS and OLS.

3.7.1.2.3.11 Data Relay Satellite System (DRSS) Interface - The DRSS will serve to relay communications and data between RNS and other space program elements.

3.7.1.2.3.12 Ground Communication and Tracking Interface - The MSFN and DSN will be utilized to transmit and receive data between RNS and ground stations as well as providing backup tracking data.

3.7.2 Launch Operations

The Launch Operations Complex shall consist of the following:

3.7.2.1 INT-21 Prelaunch Area - A prelaunch operations area and appropriate GSE shall be provided to check out and service the INT-21 launch vehicle and RNS stage.

3.7.2.1.1 Electrical Power - TBD

3.7.2.1.2 Environmental Control - TBD

3.7.2.1.3 Gas Storage Supply and Lines - TBD

3.7.2.1.4 Ground Support Equipment - TBD

3.7.2.2 EOS Prelaunch Area - A prelaunch operations area with appropriate GSE shall be provided to check out and service the EOS launch vehicle and NERVA engine.

3.7.2.2.1 Electrical Power - TBD

3.7.2.2.2 Environmental Control - TBD

3.7.2.2.3 Gas Storage and Supply Lines - TBD

3.7.2.2.4 Ground Support Equipment - TBD

3.7.2.3 INT-21 Launch Area - A launch area with appropriate launch support equipment tied to the Launch Control Center will be provided to launch the RNS on the INT-21 vehicle.

3.7.2.3.1 Propellant Storage and Supply Lines - TBD

3.7.2.3.2 Gas Storage and Supply Lines - TBD

3.7.2.3.3 Electrical Power - TBD

3.7.2.3.4 Environmental Control - TBD

3.7.2.4 EOS Launch Area - A launch area with the appropriate launch support equipment tied to the Launch Control Center will be provided to launch the RNS on the INT-21 launch vehicle.

3.7.2.4.1 Propellant Storage and Supply Lines - TBD

3.7.2.4.2 Gas Storage and Supply Lines - TBD

3.7.2.4.3 Electrical Power - TBD

3.7.2.4.4 Environmental Control - TBD

3.7.3 Orbital Operations

3.7.3.1 RNS Stage/NERVA Orbital Assembly - The RNS stage and NERVA engine will be delivered to the RNS operations orbit for assembly.

3.7.3.1.1 RNS Stage Assembly Operations - TBD

3.7.3.1.2 NERVA Engine Assembly Operations - TBD

3.7.3.2 RNS Maintenance Operations - Scheduled and unscheduled maintenance operations will be performed in RNS operations orbit utilizing a Maintenance Element and maintenance crew. On-board checkout capability will be utilized to determine stage status prior to and following maintenance operations.

3.7.3.2.1 Forward Skirt Area Maintenance Operations - TBD

3.7.3.2.2 Tank Area Maintenance Operations - TBD

3.7.3.2.3 Engine Area Maintenance Operations - TBD

3.7.3.3 Propellant Transfer - Propellant transfer shall be accomplished either by EOS Orbiter or a propellant depot.

3.7.3.3.1 Propellant Transfer Rate - TBD

3.7.3.3.2 Propellant Condition During Transfer - TBD

3.7.3.4 Payload Mating and Demating - The payload will be delivered to and mated to the RNS by Space Tug. The Tug will be the active element during rendezvous and docking while the RNS maintains an attitude hold orientation. As in the case of the mating operation, the Space Tug will be the active element and the RNS/payload the passive vehicle during rendezvous and dock of the demating operation.

3.7.3.5 Mission Flight Operations

3.7.3.5.1 Class I Shuttle Mission - A launch rate ot TBD flights per year.

3.7.3.5.1.1 Lunar Shuttle Mission - The nominal Lunar Shuttle Mission profile is made up of:

Two translunar injection (TLI) burns (ΔVs = 5000 and 5010 FPS), a midcourse correction (MCC) burn (ΔV = 50 FPS), a single lunar orbit insertion (LOI) burn (ΔV = 2680 FPS), orbit adjust burns (by RCS) (ΔVs = 20 + 27 FPS), a three-burn transearth injection (TLI) (ΔVs = 1850, 330 and 985 FPS), a midcourse correction burn (ΔV = 50 FPS), and a single earth orbit insertion (EOI) burn (ΔV = 10050 FPS).

3.7.3.5.1.2 Synchronous Orbit Shuttle Mission - The reference geosynchronous orbit shuttle mission profile is made up of: a phasing ellipse injection (PEI) burn (ΔV = 4230 FPS), an ascent ellipse injection (AEI) burn (ΔV = 3636 FPS), midcourse correction (MCC) burn (ΔV = 50 FPS), synchronous orbit insertion (SOI) burn (ΔV = 5911 FPS), orbit adjust burns (by RCS) (ΔV = 10 + 10 FPS), descent ellipse injection (DEI) burn (ΔV = 6011 FPS), midcourse correction (MCC) burn (ΔV = 50 FPS), phasing ellipse injection (PEI) burn (ΔV = 3636 FPS), and return orbit insertion (ROI) burn (ΔV = 4140 FPS).

3.7.3.5.2 Class II Unmanned Planetary Mission

3.7.3.5.2.1 Planetary Injection RNS Returned - TBD

3.7.3.5.2.2 Planetary Injection RNS Expended - TBD

3.7.3.5.3 Class III Manned Planetary Mission - TBD

4.0 QUALITY ASSURANCE

The following paragraphs establish the requirements for formal tests/verifications of the Reusable Nuclear Shuttle System functional performance, design characteristics and operability. Formal verification shall establish acceptance of design and development engineering. Each requirement in Section 3.0 is associated with one or more subparagraphs of Section 4.0, which defines the verification method(s) and the test category. A Verification Cross Index provides for accountability of each Section 3.0 requirement. The index follows paragraph 4.2.5.8, and identifies all paragraphs in Section 3.0. Only those requirements identified as Type A have a test requirement in the system specification. Those requirements which can be verified by testing at the Contract End Item level or below are allocated to the appropriate CEI specification for definition of the test requirement and are identified as Type B requirements.

4.1 General

The basic philosophy for performing the quality assurance provisions is based on progressive, incremental testing. The flight elements will be tested as individual items first at test facilities and then at the operational facility. The severity of the flight environment will be progressively increased by increments until the maximum performance attainable by the prime item is achieved. The final phase of development flight testing will involve TBD launches from the RNS operational orbit to demonstrate the Design Reference Mission Capability. The requirements associated with this final mated launch phase are covered as a part of this System Specification. All design requirements which can be verified by tests at the Prime Item or lower level are covered as part of the Prime and Critical Item Development Specifications.

4.1.1 Responsibility for Tests

4.1.1.1 System Development Contractor Responsibility (TBD)

4.1.1.2 Prime Item Contractor Responsibility (TBD)

4.1.1.3 Associate Contractor Responsibility (TBD)

4.1.1.4 Customer Responsibility (TBD)

4.1.2 Special Tests and Examinations (TBD)

4.2 Quality Conformance Inspections

The following paragraphs cover the test/verification requirements necessary to verify the requirements of Section 3.0 have been achieved. The Section 3.0 requirements paragraph number to which the Section 4.0 paragraph addresses itself is shown in parentheses following the Section 4.0 paragraph number. Any given Section 4.0 paragraph may provide verification requirements for all or part of the referenced Section 3.0 paragraph. Insofar as is practical, the tests are listed in a logical sequence. Contractor quality assurance criteria shall be in general accordance with NASA Publication, NHB 5300.4 (1B).

4.2.1 Reliability Testing

Test data collection and recording requirements will be reviewed for all system level tests. Test data which will be used as a part of the reliability analysis will be collected and recorded as required for system reliability verification purposes. Testing with the primary objective of obtaining reliability data will not be done unless these data cannot be obtained in the Engineering Tests and Evaluations, the Qualification Tests, the Installation Tests, or Formal Performance Verification Tests and Demonstrations. Tests identified for reliability analysis only are listed in the following paragraphs.

4.2.1.1 Reliability Tests (TBD)

4.2.2 Engineering Test and Evaluation

The test requirements specified in the following paragraphs are limited to those tests which are required for direct support of the design and development activity, but which cannot be accomplished by testing performed at the Contract End Item level. In general, these are tests associated with the mated NERVA and RNS Stage launch and/or prelaunch activities conducted at KSC. They also include the post flight activities.

4.2.2.1 Evaluation of RNS System Prelaunch Procedures and Equipment

(3.2.1.1.1) Vehicle Preparation (TBD)

(3.2.1.1.2) Propellant Load-ons (TBD)

(3.2.1.1.3) Payload Mating (TBD)

(3.2.1.2.1.1) Payload Delivery (TBD)

4.2.3 Qualification Testing of Contract End Items and Critical Items

Qualification testing of Contract End Items and Critical Items will be done at the System Test level only when these tests cannot be completed at the Contract End Item or Critical Item level. Tests identified for System level qualification of Contract End Item or Critical Items are listed in the following paragraphs.

4.2.3.1 Qualification Tests (TBD)

4.2.4 Installation Testing

Installation testing of the Reusable Nuclear Shuttle vehicle at the system level will be accomplished as a part of the Engineering Test and Evaluation requirements of paragraph 4.2.2 and/or the Formal Performance Verification Test and Demonstration requirements of paragraph 4.2.5 to the greatest extent possible. Installation tests that cannot be met under these referenced paragraphs are listed in the following paragraphs.

4.2.4.1 Installation Tests (TBD)

4.2.5 Formal Performance Verification Tests and Demonstrations

The test requirements specified in the following paragraphs are intended to demonstrate that the Reusable Nuclear Shuttle vehicle satisfies the system performance and design requirements of Section 3.0. The test vehicle(s) used for these demonstrations shall be of the operational configuration.

4.2.5.1 (3.2.1.1.1) Vehicle Preparation - The operations necessary to show compliance with Section 3.0 requirements for mission planning, RNS stage and NERVA engine delivery to the operations orbit, mating of NERVA engine to RNS stage, and checkout of the assembled stage, shall be demonstrated.

4.2.5.2 (3.2.1.1.2) Propellant Loading - The ability to transfer propellants from the EOS orbiter or propellant depot shall be demonstrated in the RNS operations orbit.

4.2.5.3 (3.2.1.1.3) Payload Mating - The space tug shall be utilized with a representative payload to perform rendezvous and docking operations associated with mating and demating operations to demonstrate operational capability.

4.2.5.4 (3.2.1.2.1.1) Payload Delivery - Test flight of the representative lunar shuttle mission shall be performed to demonstrate capability of satisfying the requirements set forth in paragraph 3.2.5.

4.2.5.5 (3.2.1.2.1) Provide In-Flight Support - The support equipment procedures and facilities necessary to support the mission operations shall be demonstrated to show compliance with the Section 3.0 requirements. The functions to be demonstrated are listed below (not necessarily in the order listed):

a. Communications with the Reusable Nuclear Shuttle vehicle and with the space program elements

b. Command and control of the RNS system, if required

c. Tracking, including the processing and analysis of in-flight data

4.2.5.6 Perform Inspection Maintenance and Repair Operations - The support equipment, procedures and facilities required for postflight operations shall be demonstrated to show satisfactory compliance with the requirements of Section 3.0. Completion of the postflight test operations listed below are intended to demonstrate this capability (not necessarily in the order listed).

a. Demating of payload from RNS

b. Mate maintenance element with RNS

c. Perform checkout, maintenance and servicing as required. Demonstrate the capability to perform the operations in a manner to support launch rates of TBD missions per year.

4.2.5.7 Perform End-Of-Life Disposal - The RNS stage and/or NERVA engine shall be disposed of in long-life orbit after reaching its end-of-life or inoperative condition.

4.2.5.8 Perform Orbital Dormant Mode Storage Operations (TBD)

VERIFICATION CROSS REFERENCE INDEX

METHOD LEGEND:

- N/A Not Applicable
- 1. Inspection
- 2. Review of Analytical Data
- 3. Demonstration
- 4. Test

TEST CATEGORY:

- Type A System Level Test
- Type B Contract End Item Level Test

TEST LEGEND:

- a. Engineering Test and Evaluation
- b. Preliminary Qualification
- c. Formal Qualification
- d. Reliability Test and Analysis
- e. Engineering Critical Component Qualification

SECTION 3 REQUIREMENT REFERENCE	VERIFICATION METHOD					TEST CATEGORY		TEST LEGEND					SECTION 4 VERIFICATION REQUIREMENT
	N/A	1	2	3	4	A	B	a	b	c	d	e	
3.	X												
3.1	X												
3.1.1	X												
3.1.1.1	X												
3.1.1.1.2	X												
3.1.1.1.3	X												
3.1.1.2	X												
3.1.2	X												
3.1.2.1	X												
3.1.2.1.1				X		X				X			
3.1.2.1.2	X												
3.1.2.1.3	X												
3.1.2.1.4				X		X		X					
3.1.2.1.5				X		X				X			
3.1.2.2													
3.1.3	X												
3.1.3.1	X												
3.1.3.1.1				X		X				X			4.2.5.3, .4
3.1.3.1.2				X		X				X			4.2.5.1, .2, .7
3.1.3.1.3				X		X				X			4.2.5.8

SECTION 3 REQUIREMENT REFERENCE	VERIFICATION METHOD					TEST CATEGORY		TEST LEGEND					SECTION 4 VERIFICATION REQUIREMENT
	N/A	1	2	3	4	A	B	a	b	c	d	e	
3.1.3.1.4				X			X			X			4.2.5.1
3.1.3.1.5				X			X			X			4.2.5.1
3.1.3.1.6					X		X	X					4.2.5.1
3.1.3.1.7					X		X	X					4.2.5.1
3.1.3.1.8	X												
3.1.3.1.9	X												
3.1.3.2	X												
3.1.4		X				X							4.2
3.1.5	X												
3.1.6		X					X			X			4.2.5.1
3.1.7	X												
3.1.7.1	X												
3.1.7.1.1	X												
3.1.7.1.2				X			X			X			4.2.5.1
3.1.7.2	X												
3.1.7.3	X												
3.1.7.4				X		X				X			4.2.5.4
3.1.7.5				X		X				X			4.2.5.4
3.1.7.6				X		X				X			4.2.5.5
3.2	X												
3.2.1	X												
3.2.1.1				X		X				X			4.2.5.4
3.2.1.1.1	X												
3.2.1.1.2				X		X				X			4.2.5.2
3.2.1.1.3				X		X				X			4.2.5.3
3.2.1.2	X												
3.2.1.2.1	X												
3.2.1.2.1.1				X		X				X			4.2.5.4
3.2.1.2.1.2				X		X				X			4.2.5.4, 6
3.2.1.2.2						X							TBD
3.2.1.2.2.1						X							TBD
3.2.1.2.3	X												

SECTION 3 REQUIREMENT REFERENCE	VERIFICATION METHOD					TEST CATEGORY		TEST LEGEND					SECTION 4 VERIFICATION REQUIREMENT
	N/A	1	2	3	4	A	B	a	b	c	d	e	
3.2.1.2.3.1						X							TBD
3.2.1.2.3.2						X							TBD
3.2.1.2.4							X	X					TBD
3.2.1.2.5							X	X					TBD
3.2.1.2.6							X	X					TBD
3.2.1.2.7							X	X					TBD
3.2.1.3						X				X			4.2.5
3.2.1.4						X				X			4.2.5.6
3.2.1.4.1				X		X				X			4.2.5.6
3.2.1.4.2				X		X				X			4.2.5.3
3.2.1.4.3				X		X				X			4.2.5.6
3.2.1.4.4				X		X				X			4.2.5.5
3.2.1.4.5				X		X				X			4.2.5.6
3.2.1.4.6				X		X				X			4.2.5.6
3.2.1.4.7				X		X				X			4.2.5.2
3.2.1.4.8				X		X				X			4.2.5.3
3.2.1.4.9				X		X				X			4.2.5.6
3.2.1.5				X		X				X			4.2.5.4
3.2.2	X												
3.2.2.1		3.2.2.1 thru 3.6.2.4											TBD
3.7	X												
3.7.1					X	X							
3.7.1.1	X												
3.7.1.1.1					X		X	X					4.2.2
3.7.1.1.1.1					X		X	X					4.2.2
3.7.1.1.1.2					X		X	X					4.2.2
3.7.1.1.2	X												
3.7.1.1.2.1					X		X	X					4.2
3.7.1.1.2.2		X					X						4.2
3.7.1.1.2.3					X	X							4.2.4.1
3.7.1.2	X												
3.7.1.2.1													
3.7.1.2.1.1					X			X					4.2.2

SECTION 3 REQUIREMENT REFERENCE	VERIFICATION METHOD					TEST CATEGORY		TEST LEGEND					SECTION 4 VERIFICATION REQUIREMENT
	N/A	1	2	3	4	A	B	a	b	c	d	e	
3.7.1.2.1.2		X				X							4.2.2
3.7.1.2.1.3				X		X				X			4.2.2.1
3.7.1.2.1.4				X		X				X			4.2.5.3
3.7.1.2.1.5				X		X				X			4.2.5.5
3.7.1.2.1.5.1				X		X				X			4.2.5.5
3.7.1.2.1.5.2				X		X				X			4.2.5.5
3.7.1.2.1.5.3				X		X				X			4.2.5.5
3.7.1.2.2	X												
3.7.1.2.2.1		X					X						4.2.4.1
3.7.1.2.2.2		X					X						4.2.4.1
3.7.1.2.3				3.7.1.2.3 thru 3.7.3.5.2.3									TBD

5.0 PREPARATION FOR DELIVERY

5.1 Packaging, Handling, and Transportation

5.1.1 General Requirements

General requirements for packaging, handling, and transportation for the system elements shall be in accordance with the requirements of NASA Publications NHB 6000.1 (1A) and the requirements of this specification.

Requirements herein shall define packaging, handling and transportation methods, equipment and practices which will prevent hardware damage and assure retention of hardware reliability during delivery and storage.

Requirements for packaging, handling, and transportation shall cover the following system elements:

a. Flight vehicles, major subsystems and components

b. Ground operations equipment

c. Orbital launch, recovery, and refurbishment equipment

d. Spares

5.1.2 Protective Methods

5.1.2.1 Levels of Protection - Levels of preservation, packaging and packing, as outlined below, and as further defined in NHB 6000.1 (1A), shall be established for each category of hardware.

a. Preservation and Packaging Level

Level A - Storage for indefinitely long time

Level B - Storage not exceeding one year

Level C - Immediate use by first receiver

b. Packing Level

Level A - Multiple world-wide (overseas) shipment

Level B - Multiple domestic shipment, covered storage

Level C - Immediate use by first receiver

5.1.2.2 Selection of Levels - Selection of levels shall depend on destination, modes of transport, conditions of environmental control during shipment and storage, duration of storage, and anticipated requirements for trans-shipment or redistribution.

5.1.2.3 Environmental Analysis - Specific methods of preservation, packaging, packing, and specific transport requirements and methods shall insure protection of the system hardware against the natural and induced environments to which it will be exposed. Analysis and consideration of the hazards associated with these environments shall be performed prior to hardware design and prior to development of protective packaging methods and transport equipment. The hazards analysis shall cover all phases of the hardware production and delivery cycle including in-plant storage and handling; local transportation at point of origin; transportation to destination; and receiving, redistribution, handling, and storage at the destination facility.

5.1.3 Packaging and Transport Data

Necessary packaging and transport design and procedural data shall be prepared in sufficient detail to permit customer review and to fully implement all applicable requirements for items requiring specially designed packaging or transport methods due to special sensitivity to shock, vibration, contamination, corrosion, or temperature, or due to physical characteristics such as size, weight, or configuration.

6.0 NOTES

6.1 Definitions

6.1.1 Launch Status

A state of readiness from which the RNS can depart from the operations orbit within TBD minutes. The vehicle configuration is:

a. Vehicle propellant tanks are full

b. Payload is mated to the RNS

c. Crew and passengers are on board

d. Mated payload and RNS are in the process of checkout for RNS operations orbit departure

6.1.2 Standby Status

The RNS vehicle is said to be in a standby condition for accepting the payload when the following conditions are met:

a. Scheduled and unscheduled maintenance operations have been performed

b. Checkout of the vehicle verifies operational readiness of the vehicle

c. The propellant tanks are full

d. The on-board computer has been programmed for the mission

6.1.3 Qualified Parts

This category consists of parts and components controlled by military specifications and compatible with the defined Reusable Nuclear Shuttle usage environments. In all cases, these parts shall undergo 100 percent screening tests prior to their installation in the RNS vehicle.

6.1.4 Commercial Grade Parts

This category consists of noncontrolled parts which may be normal inventory of manufacturers or suppliers.

6.2 Abbreviations

AEI	-	Ascent Ellipse Insertion
DEI	-	Descent Ellipse Insertion
DRSS	-	Data Relay Satellite System
EI	-	Escape Injection
EOI	-	Earth Orbit Injection
EOS	-	Earth Orbit Shuttle
FRU	-	Flight Replaceable Unit
GOS	-	Geosynchronous Orbit Station
GSE	-	Ground Support Equipment
LOI	-	Lunar Orbit Insertion
LOT	-	Low Orbit Transfer
MCC	-	Midcourse Correction
ME	-	Maintenance Element
MEM	-	Manned Excursion Module
M&R	-	Maintain and Repair
OLS	-	Orbiting Lunar Station
OBCO	-	On-Board Checkout
PD	-	Propellant Depot
PEI	-	Phasing Ellipse Insertion
PMM	-	Planetary Mission Module

PMSC - Planetary Mission Spacecraft

POI - Planetary Orbit Insertion

PNPS - Planetary Nuclear Propulsion System

RNS - Reusable Nuclear Shuttle

ROI - Return Orbit Insertion

R&R - Remove and Replace

SOI - Synchronous Orbit Insertion

SOT - Synchronous Orbit Transfer

TE - Transearth

TEI - Transearth Injection

TL - Translunar

TLI - Translunar Injection

TPI - Transplanetary Injection

7.0 (Reserved for Future Use)

8.0 (Reserved for Future Use)

9.0 (Reserved for Future Use)

10.0 APPENDIX

10.1 Deviations to Government Documents (TBD)

11.0 FUNCTIONAL FLOW DIAGRAMS

ASSUMPTIONS

Functional flow diagrams developed in the Phase II study were updated and expanded to the level necessary to identify system design criteria and are oriented to the numerical format defined in the MSFC Guidelines of Reference (11.1) and include functions from RNS production through end-of-life disposal. Primary emphasis was placed on Class I Lunar/Synchronous Orbit Shuttle Mission and Class II Unmanned Planetary Mission. Class III Manned Planetary Mission analysis was limited to the level necessary to identify requirements over and above those of Class I and II missions. Mission classes redefined in Reference (11.1) form the basis on which the expanded functional flow diagrams were developed. The RNS stage defined in Reference (11.2) which requires separate launch of the RNS tank by the INT-21 launch vehicle and NERVA engine by the Space Shuttle, served as the baseline for Earth orbit operation functions. Prior to launch, the NERVA engine and RNS tank will be mated and demated in the high bay aisle at KSC. The shroud will be assembled while the RNS tank is in a horizontal attitude before stacking the RNS in an inverted position on the INT-21 launch vehicle. Due to potential traffic problems associated with replenishment of a propellant and maintenance depot as well as the RNS radiation environment, a separate maintenance element (ME) and propellant depot (PD) was assumed to be in the RNS operations orbit. Propellant transfer from the propellant depot to the RNS is assumed to be accomplished in a single transfer operation. Replenishment of the depot propellant would be accomplished by the Space Shuttle.

The NR reference lunar shuttle mission identified in Reference (11.3) is used in the Class I mission analysis. This reference mission uses a two-burn translunar injection, use of NERVA engine for mid-course correction, a single burn lunar orbit insertion, 12-hour lunar orbit adjustment, 17-day lunar stay time, a trans-Earth injection using three burns, and a single burn Earth orbit insertion. The RNS is allowed to cooldown for 24 hours following Earth orbit insertion before initiating any maintenance operations. While the RNS is waiting in lunar orbit for the trans-Earth injection opportunity (without a payload), it is cycled to a dormant mode to conserve consumables required to generate electrical energy.

No NERVA engine burns are made in the vicinity of any space program element. Prior to departing RNS operations orbit, lunar orbit, or synchronous orbit, separation distance (altitude and orbit phasing) between the RNS and space program element (propellant depot, lunar orbit space station or synchronous orbit space station) is achieved through use of the Reaction Control System (RCS).

The Class II unmanned planetary mission assumes a three-burn maneuver to place the payload on an escape injection trajectory. An option is shown on the functional flow diagrams for using the retro burn or apogee burn for setting the RNS return perigee altitude.

A number of options are open for the method by which the spent RNS stage may be disposed. Selection of the specific method of RNS end-of-life disposal is subject for further trade study which will be influenced by stage life, engine removal capability, phasing of space tug end-of-life, and other space program considerations. This analysis considered disposal of the total RNS stage, i.e., tank and engine mated. Two disposal locations, geocentric orbit and heliocentric orbit, are shown in Functions 3.1 and 3.2 (Figure 11-45 and 11-46 respectively) in the functional flow diagrams.

Only 33-foot diameter stages were considered for the planetary nuclear propulsion system (PNPS) to be utilized in the Class III manned planetary mission. This was done in compliance with the direction of paragraph 3.401 of Reference (11.1), which states NR will study only the 33-foot diameter RNS concept. Two potential PNPS configurations identified in Reference (11.4) are shown in Figure 11-1 and were used in developing the functional flow diagrams for the Class III mission.

The functional flow diagrams, Figures 11-2 through 11-49 serve as the basis for developing RNS design requirements to be documented in Requirement Allocation Sheets.

ABBREVIATIONS

The abbreviations used in the functional flow diagrams and the associated Requirement Allocation Sheets in the following section are listed below.

RNS	Reusable Nuclear Shuttle
RNS Tank	Reusable Nuclear Shuttle tank (w/o engine)
GSE	Ground Support Equipment
HPI	High Performance Insulation
KSC	Kennedy Space Center
OAT	Overall tests
OPS	Operations
C/O	Checkout
DDAS	Digital Data Acquisition System
RF	Radio Frequency
TLM	Telemetry
FLT	Flight
EBW	Explosive Bridge Wire
GN&C	Guidance, Navigation & Control
CALIB	Calibration

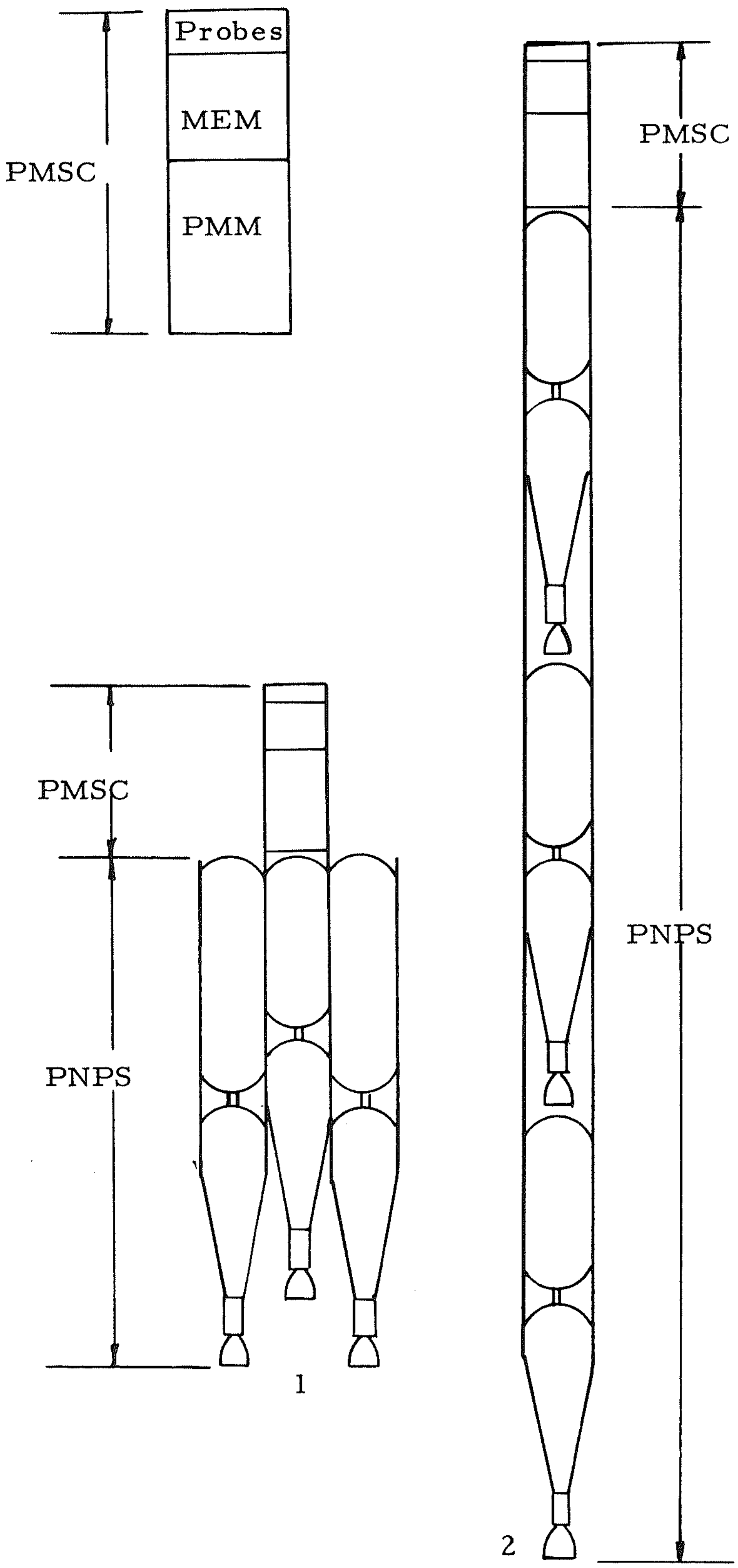


Figure 11-1 Planetary Nuclear Propulsion System Concepts

L/V	Launch Vehicle (INT-21)
EDST	Emergency Detection System Test
INT-21	S-IC/S-II Stages
ML	Mobile Launcher
VAB	Vehicle Assembly Building
ACE	Acceptance Checkout Equipment
MSS	Mobile Service Structure
LO_2	Liquid Oxygen
LH_2	Liquid Hydrogen
C/A	Corrective Action
CDDT	Countdown Demonstration Test
EOS	Earth to Orbit Shuttle (Space Shuttle)
EI	Escape Injection
TLI	Translunar Injection
PEI	Phasing Ellipse Insertion
SOT	Synchronous Orbit Transfer
AEI	Ascent Ellipse Insertion
OLS	Orbiting Lunar Station
GOS	Geosynchronous Orbit Station
TE	Trans-Earth
TL	Translunar
TEI	Trans-Earth Injection
DEI	Descent Ellipse Insertion
LOT	Low Orbit Transfer
OBCO	On-board Checkout
LOI	Lunar Orbit Insertion
ME	Maintenance Element
EOI	Earth Orbit Insertion
PD	Propellant Depot
SOI	Synchronous Orbit Insertion
ROI	Return Orbit Insertion
MCC	Midcourse Correction
PNPS	Planetary Nuclear Propulsion System
TPI	Transplanetary Injection
POI	Planetary Orbit Insertion
PMM	Planetary Mission Module
MEM	Manned Excursion Module
PMSC	Planetary Mission Spacecraft

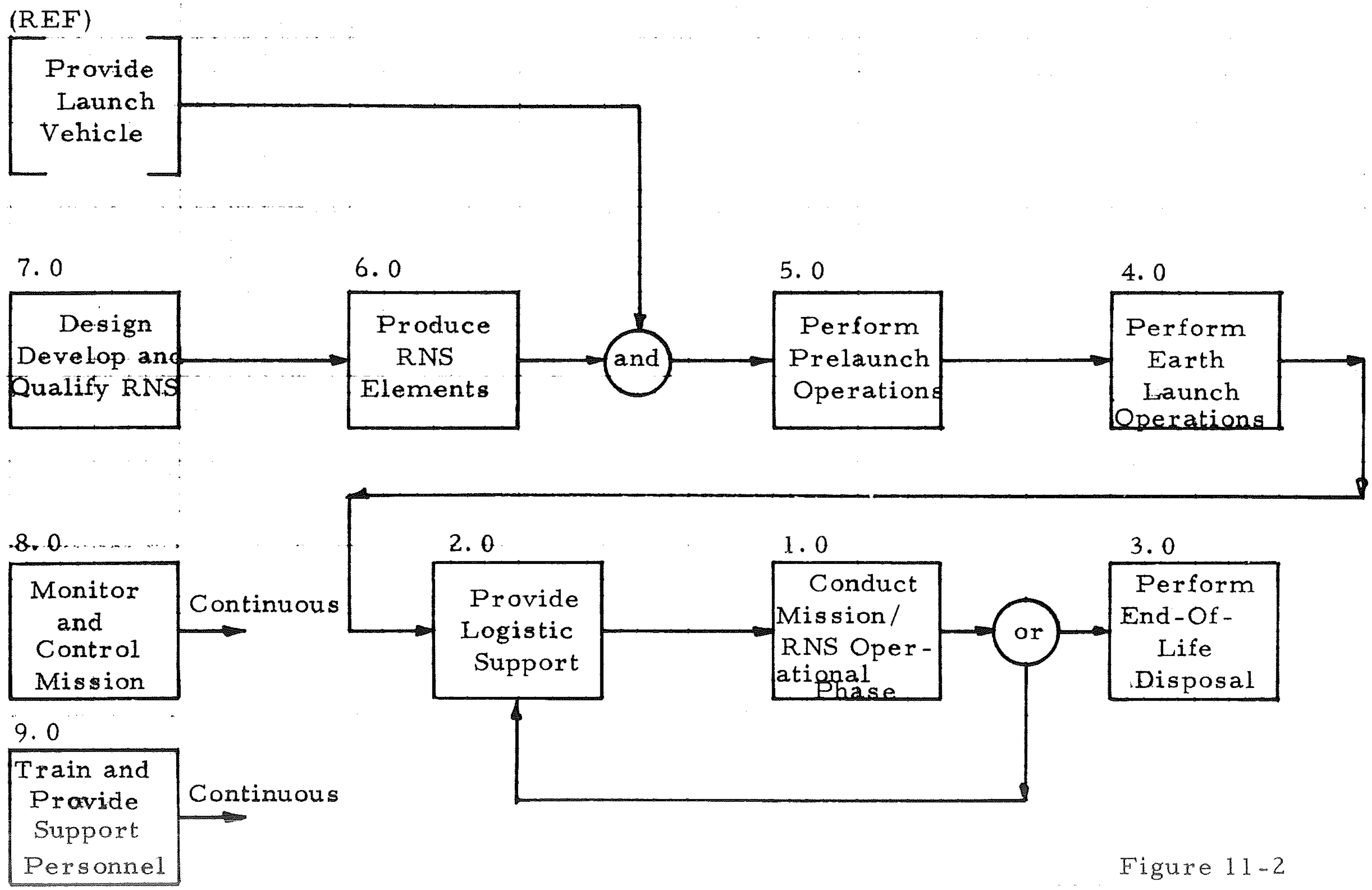


Figure 11-2

Reusable Nuclear Shuttle Top Level Functional Flow Diagram

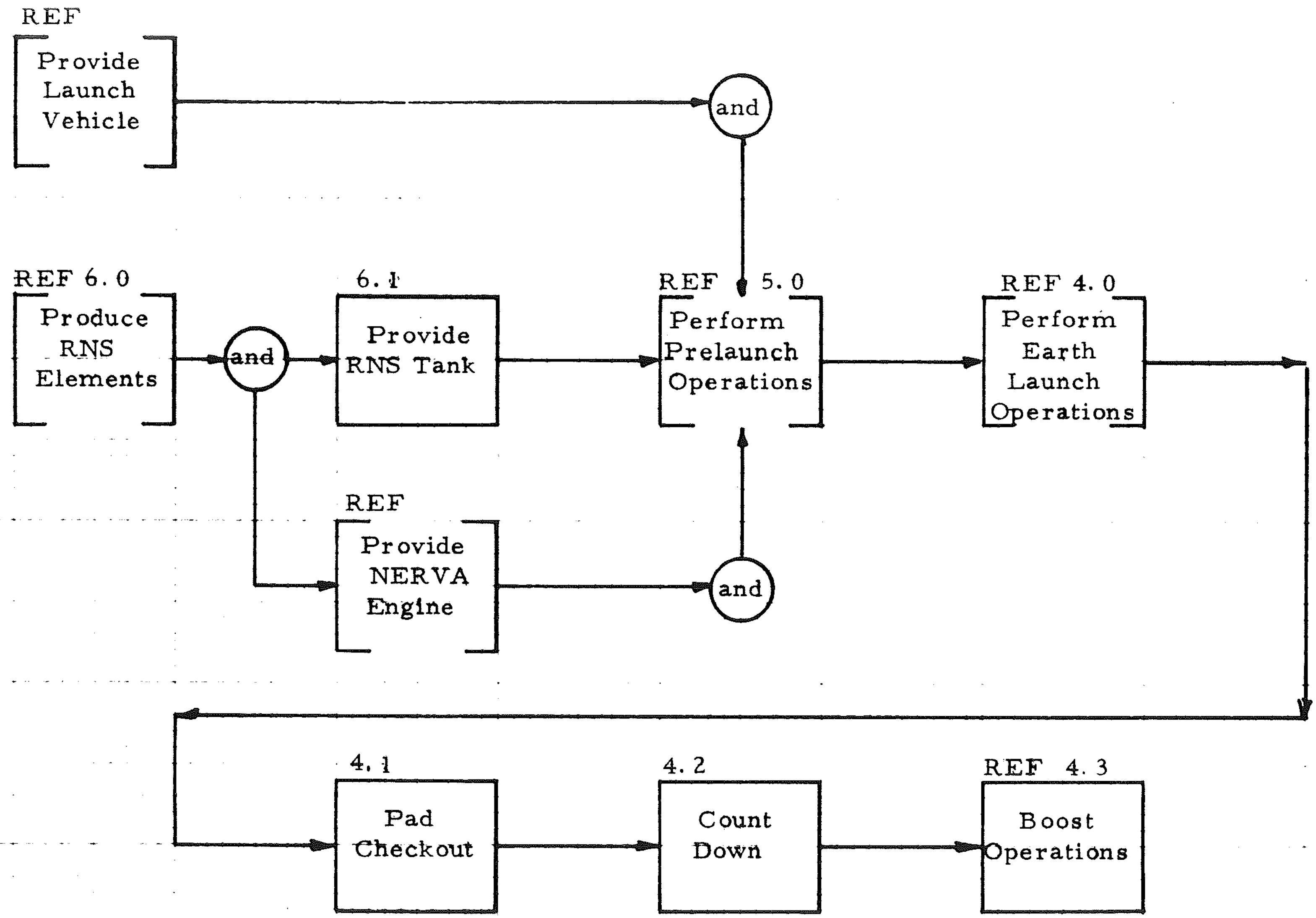


Figure 11-3
6.0 Produce RNS Elements First Level FFD

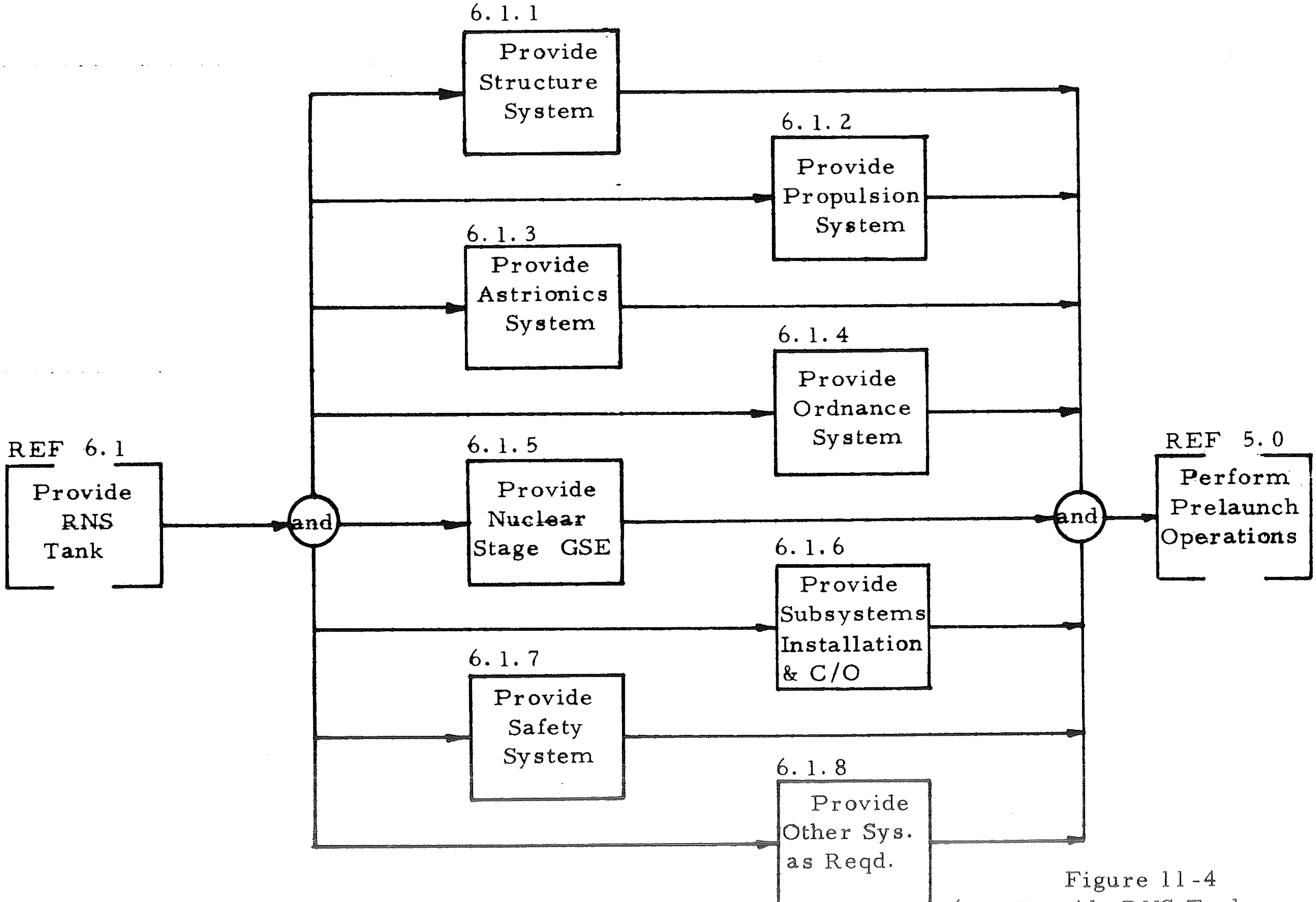


Figure 11-4
6.1 Provide RNS Tank
Second Level FFD

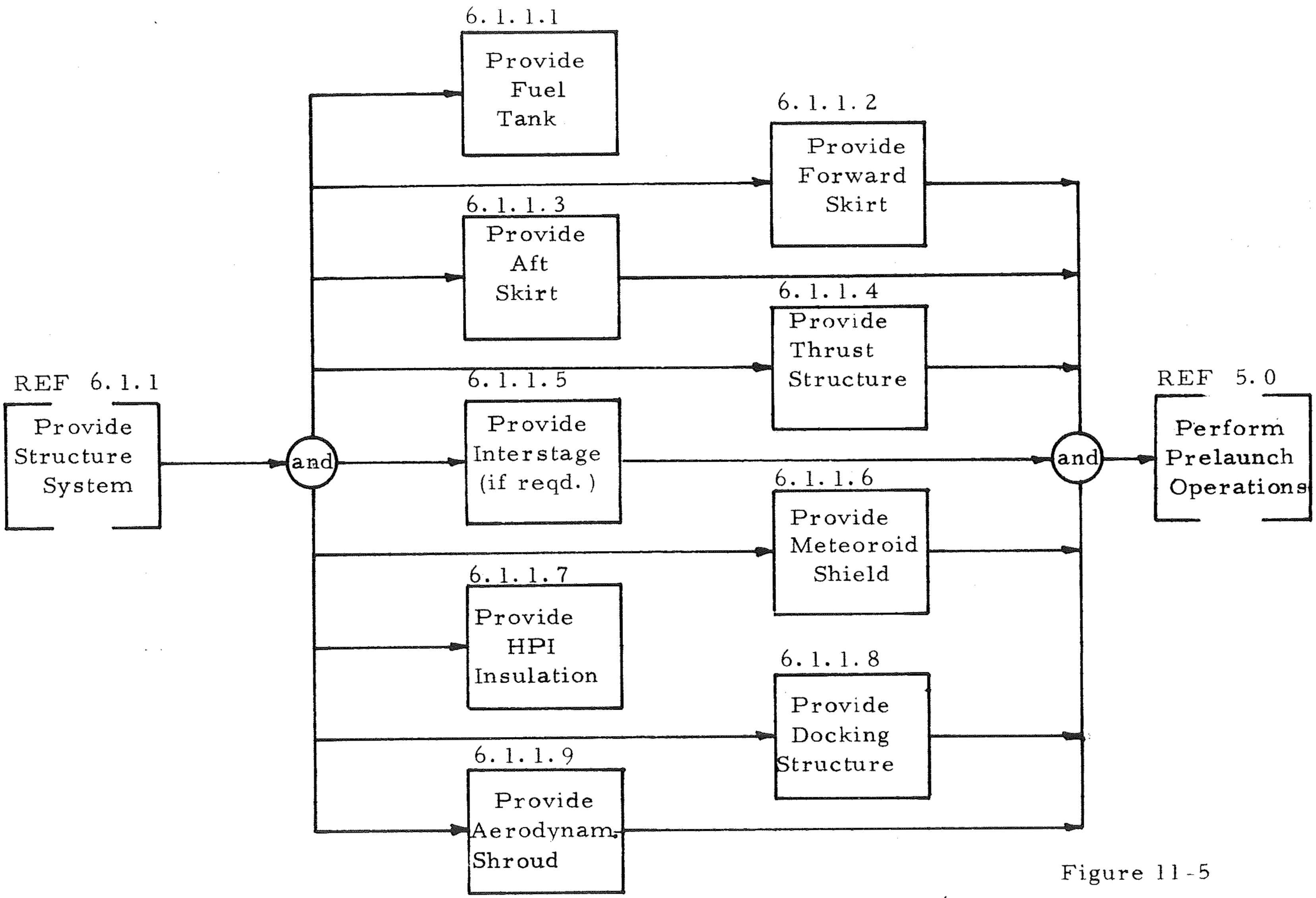


Figure 11-5

6.1.1 Provide Structures System Third Level FFD

10 X 10 PER INCH NO PRINT

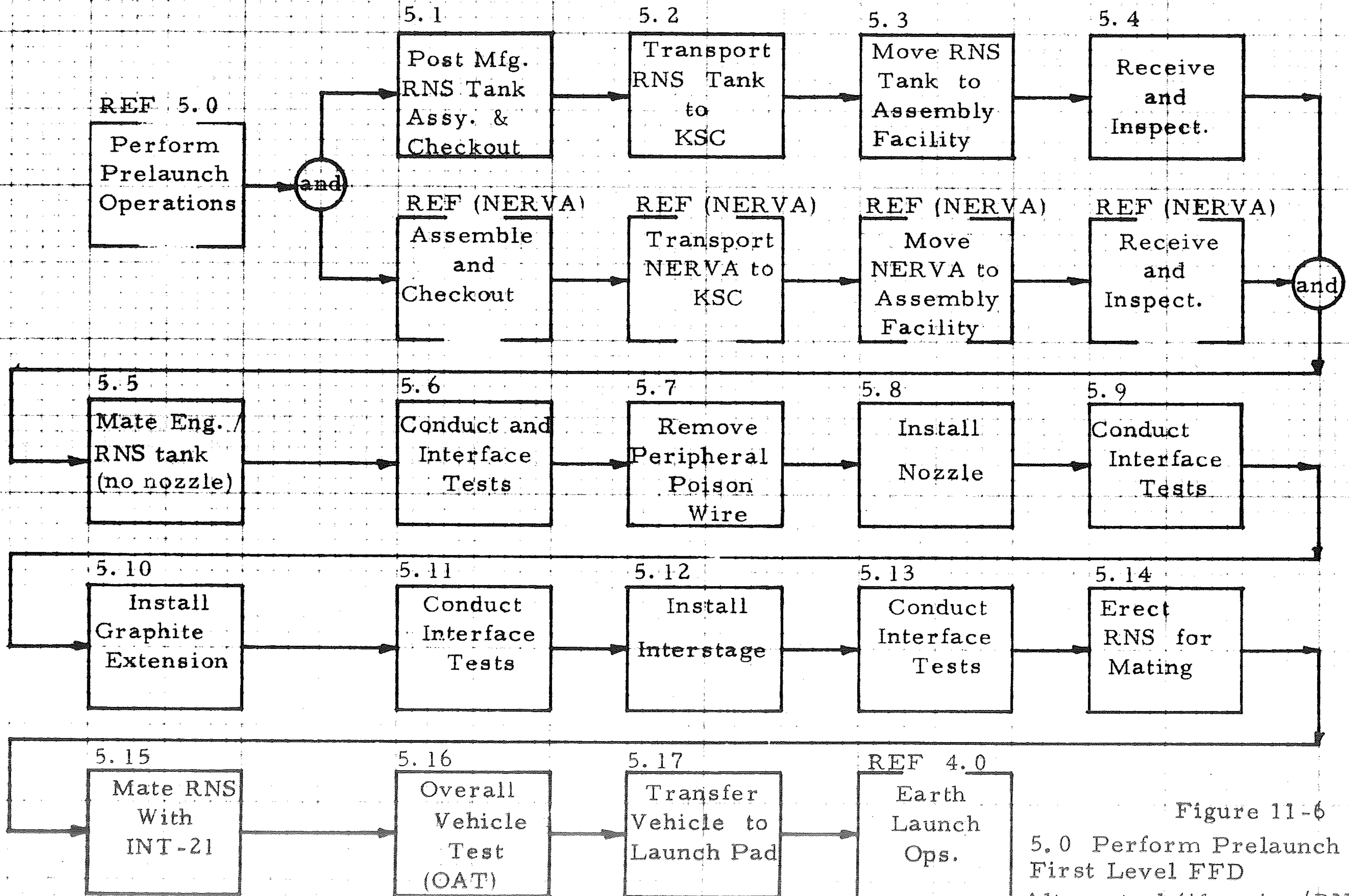


Figure 11-6
5.0 Perform Prelaunch Ops.
First Level FFD
Alternate 1 (if engine/RNS tank launched mated) integral launch)

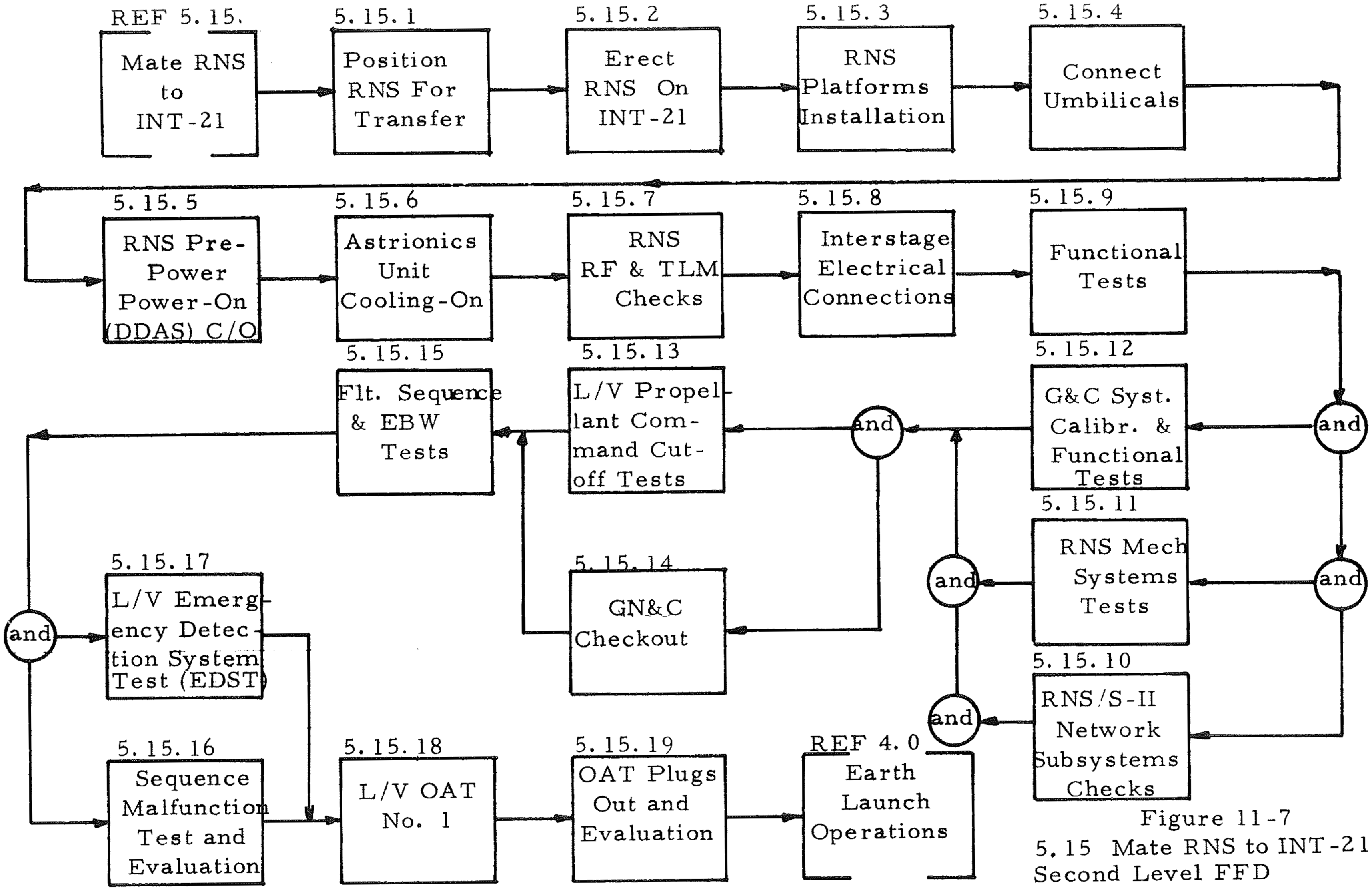


Figure 11-7
5.15 Mate RNS to INT-21
Second Level FFD

Alternate 1 (if engine/tank launched mated, integral launch)

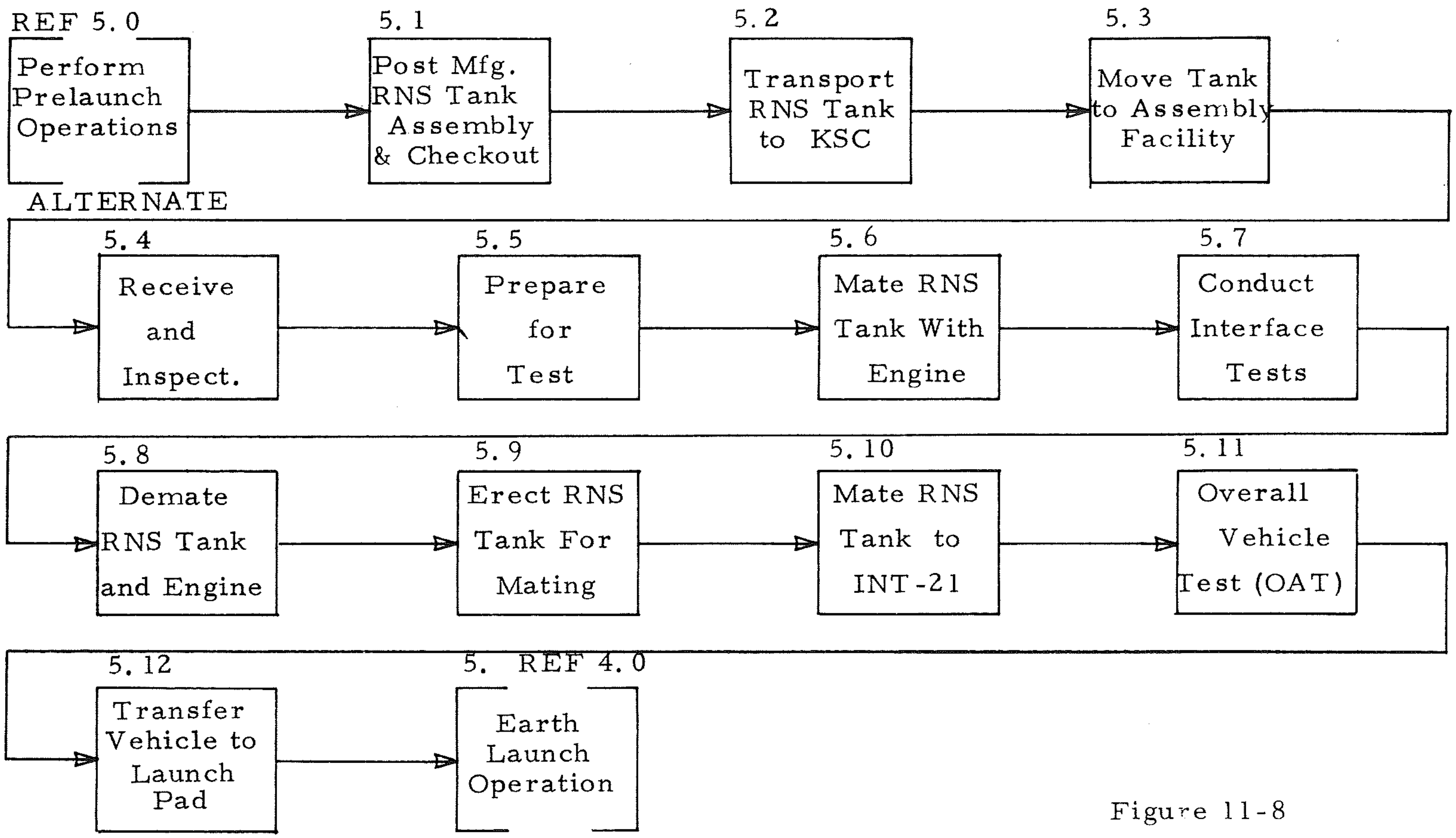


Figure 11-8

5.0 Perform Prelaunch Ops.
First Level FFD
Alternate 2 (if engine and tank launched separately)

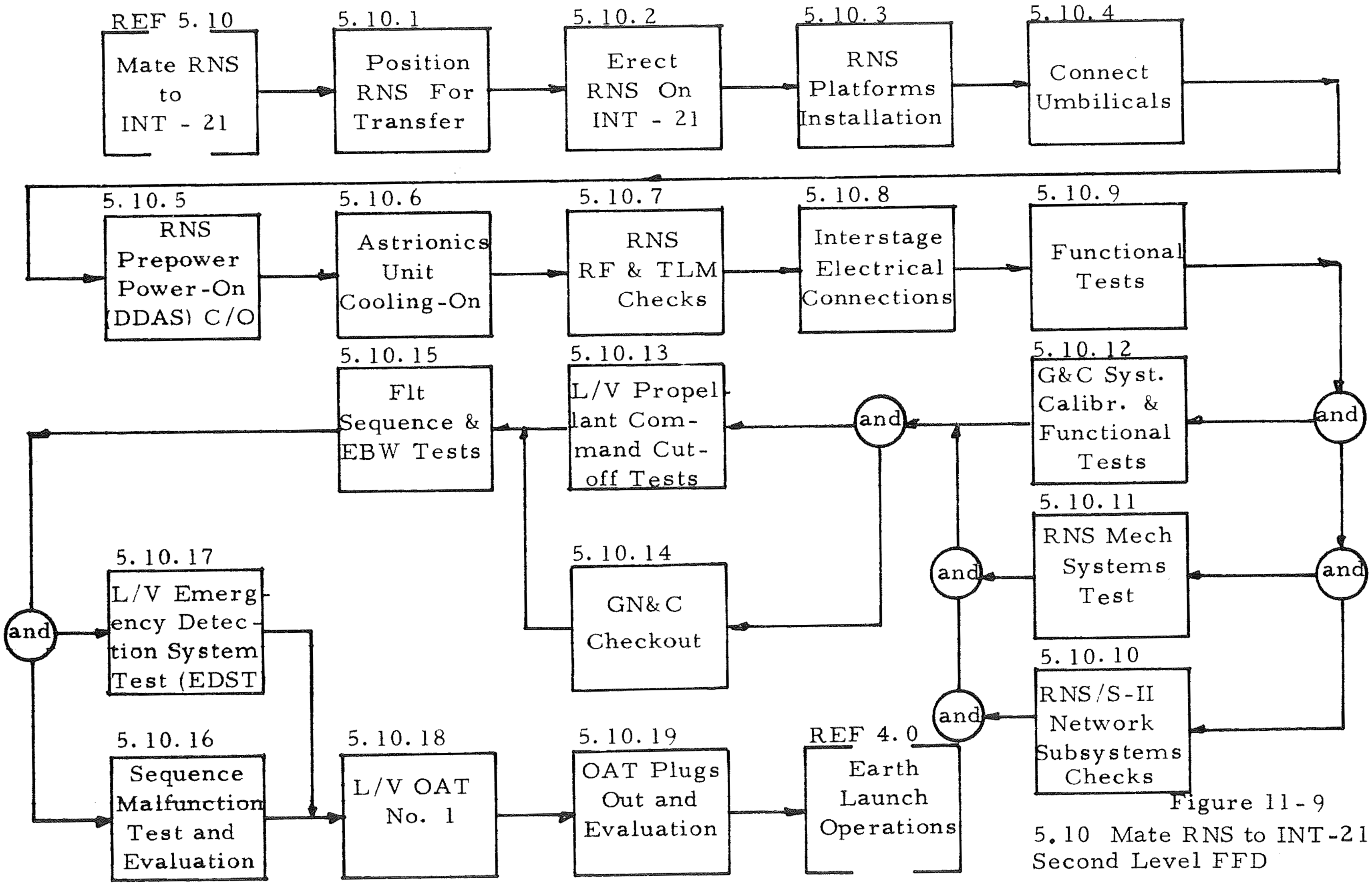


Figure 11-9

5.10 Mate RNS to INT-21
Second Level FFD

Alternate 2 (if engine/tank launched separately; integral launch)

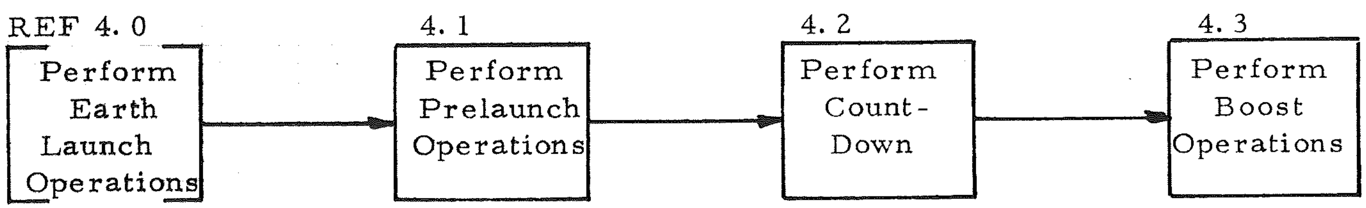


Figure 11-10

4.0 Pre-Earth Launch Operations
First Level FFD

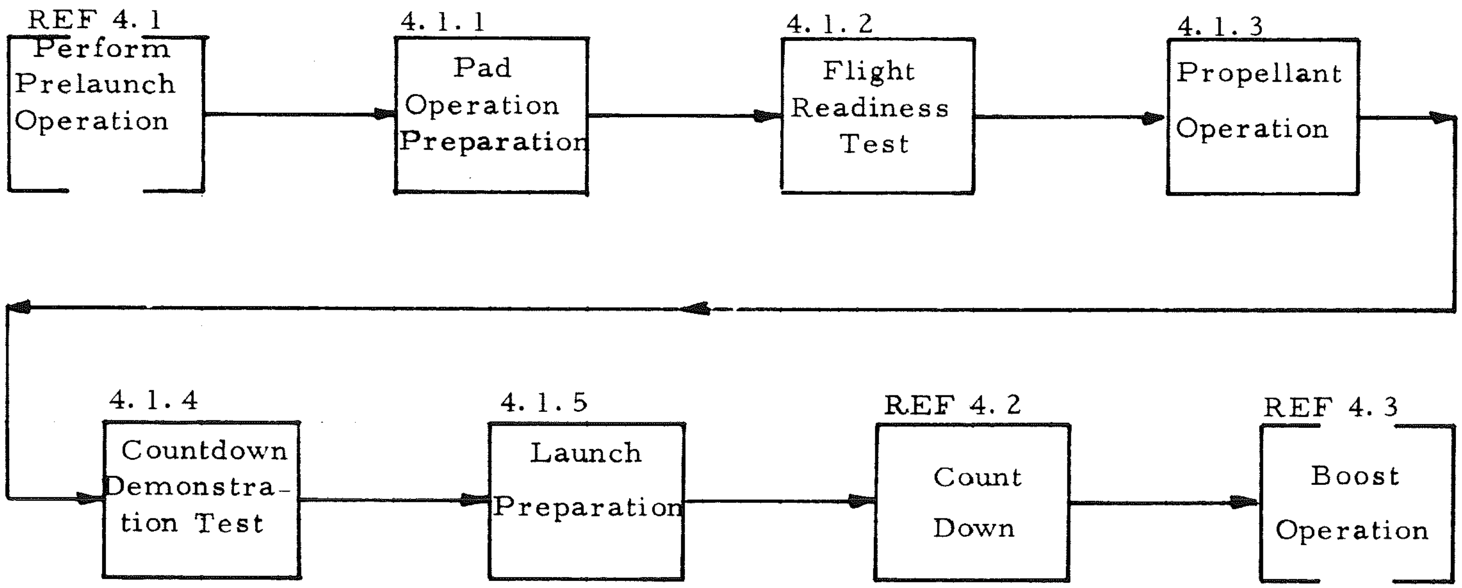


Figure 11-11
4.1 Prelaunch Operation
Second Level FFD

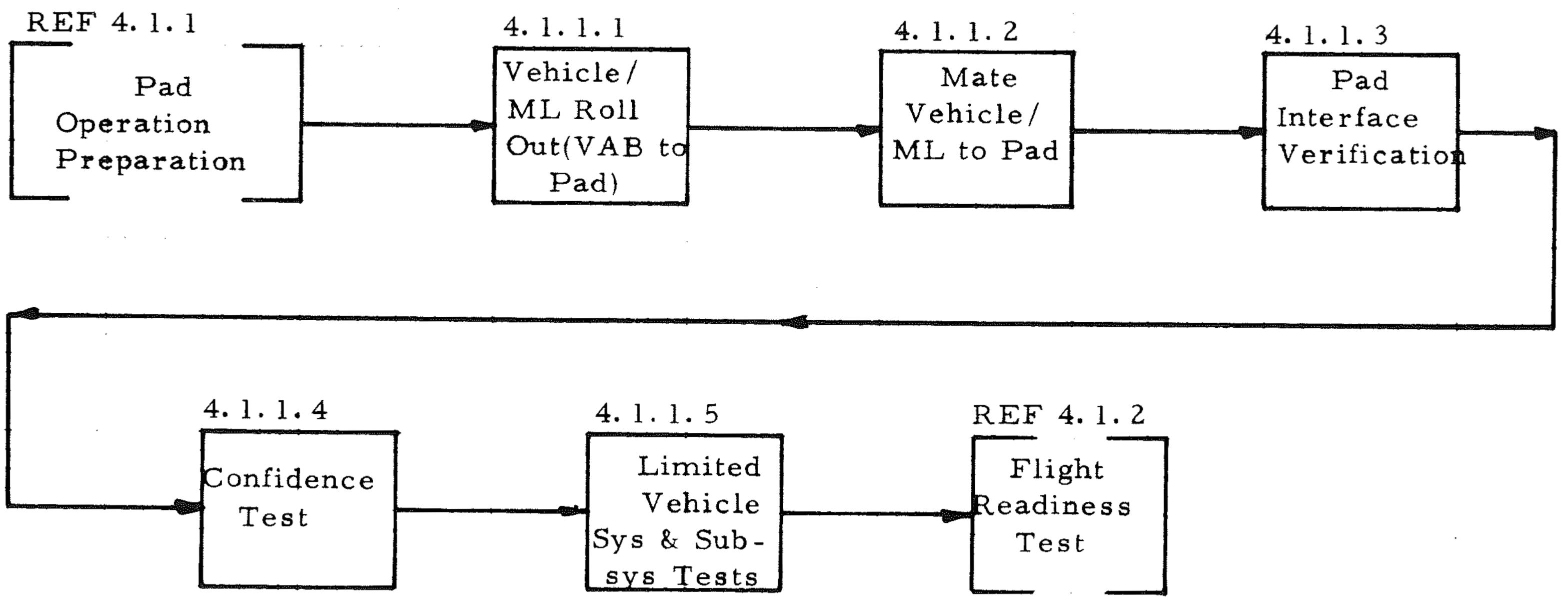


Figure 11-12
4.1.1 Pad Operation Preparation
Third Level FFD

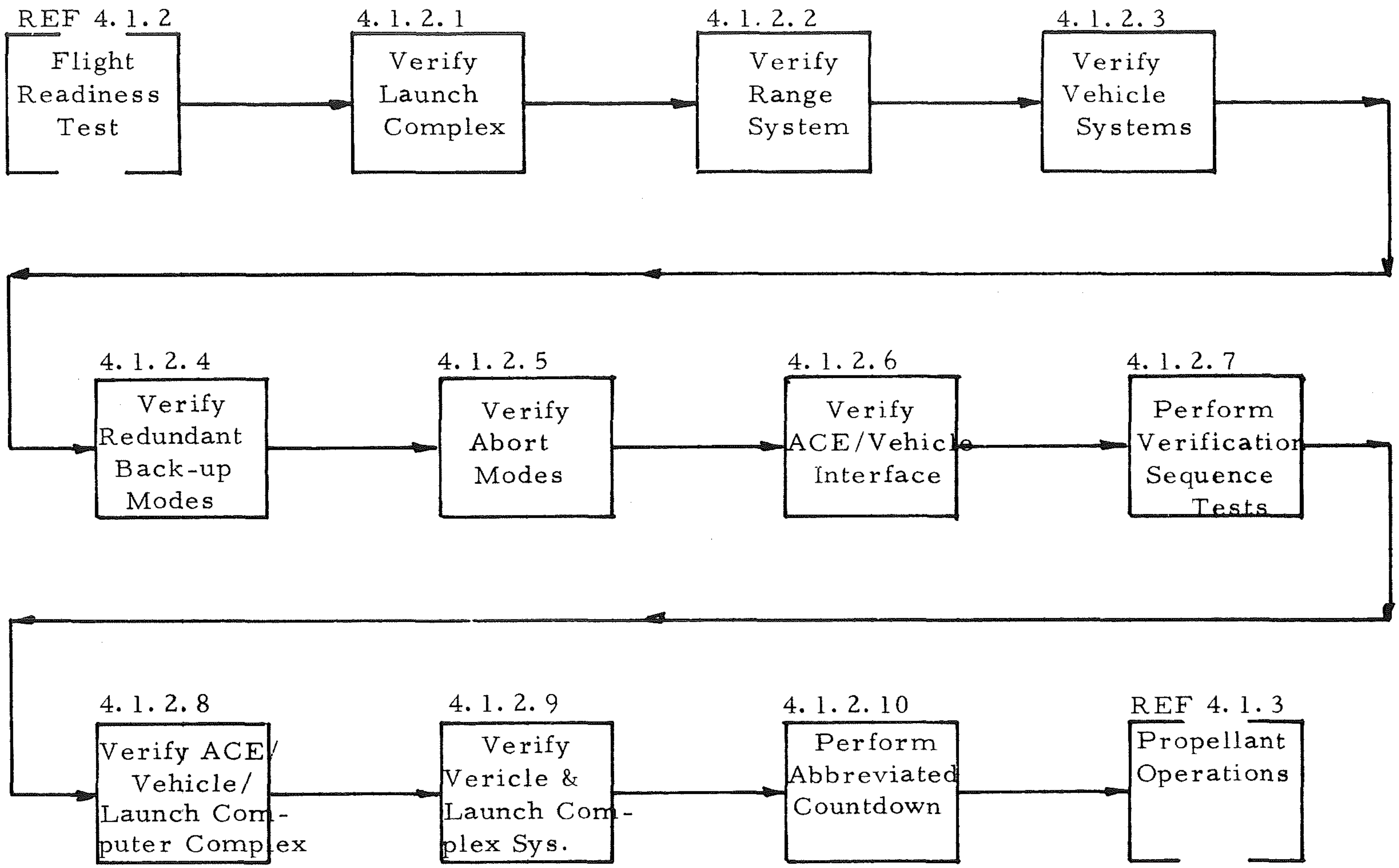


Figure 11-13
4.1.2 Flight Readiness Test
Third Level FFD

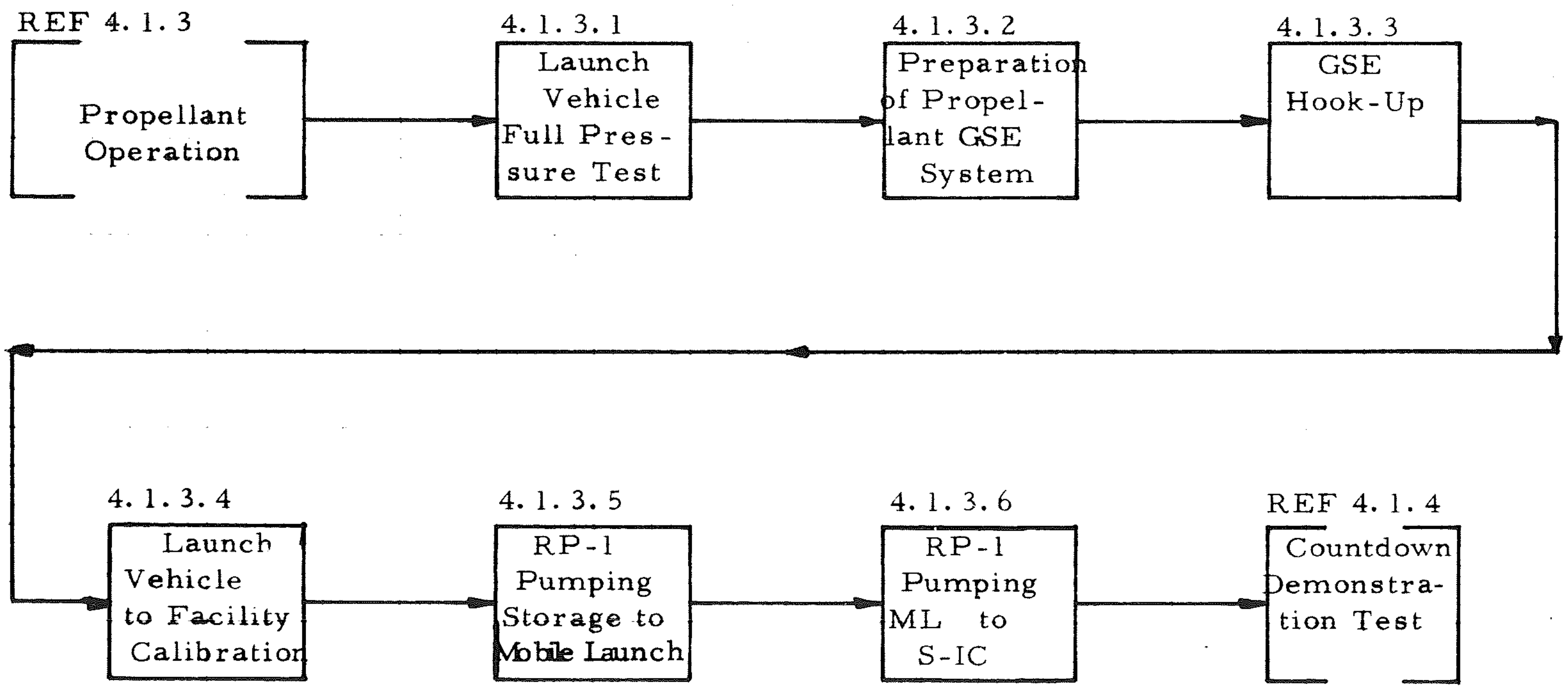


Figure 11-14
4.1.3 Propellant Operation
Third Level FFD

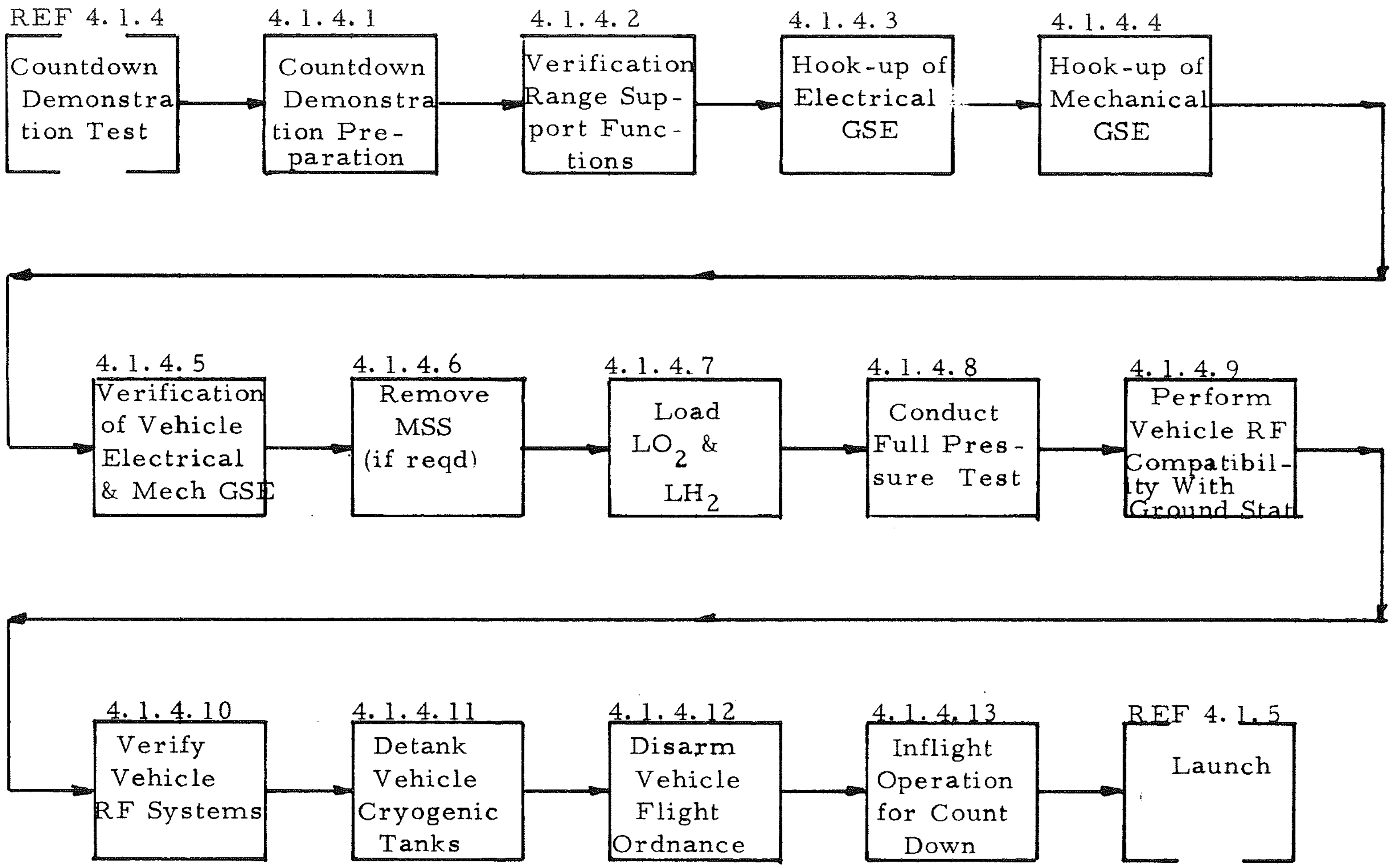


Figure 11-15
4.1.4 Countdown Demonstration Test
Third Level FFD

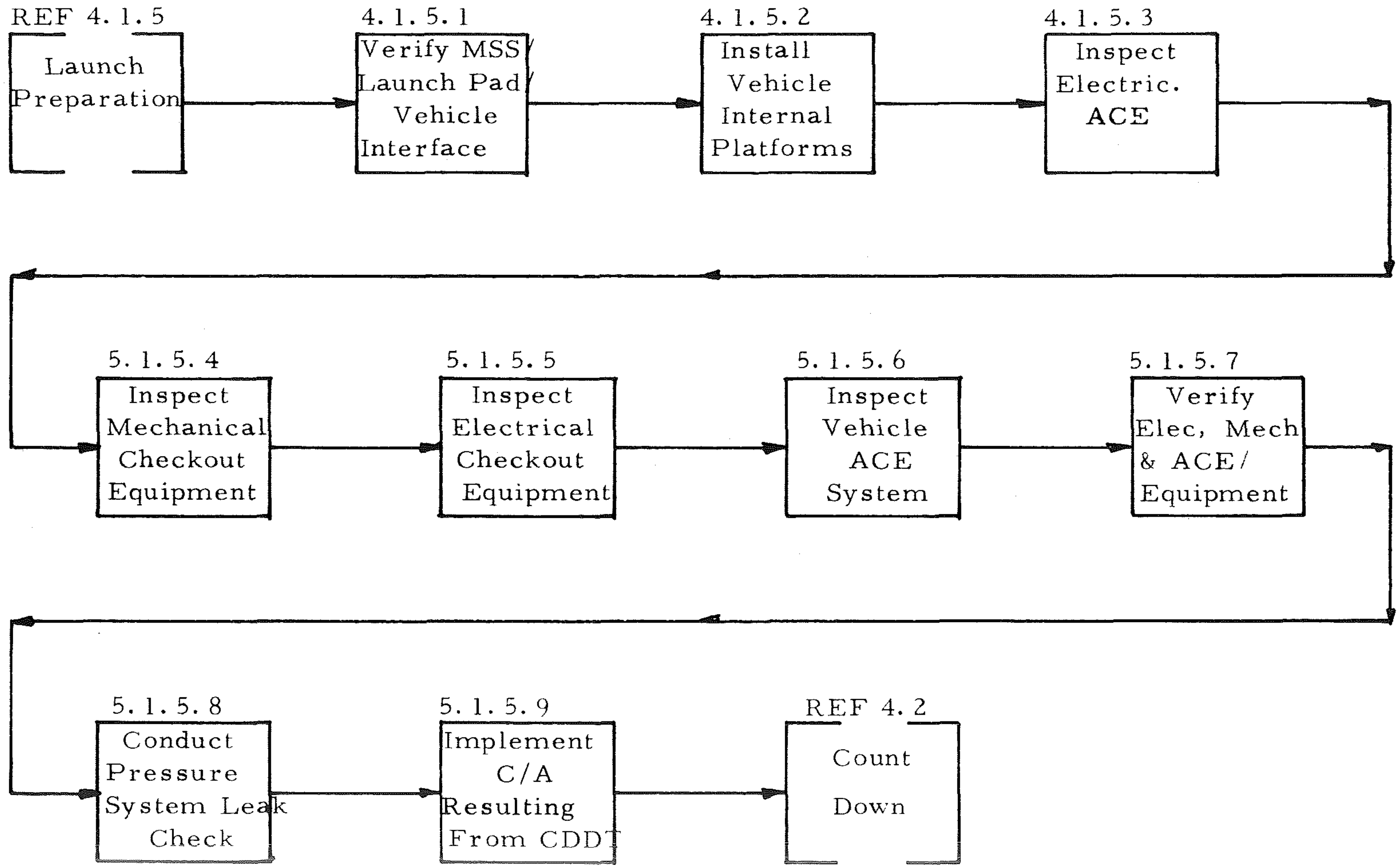


Figure 11-16
4.1.5 Launch Preparation
Third Level FFD

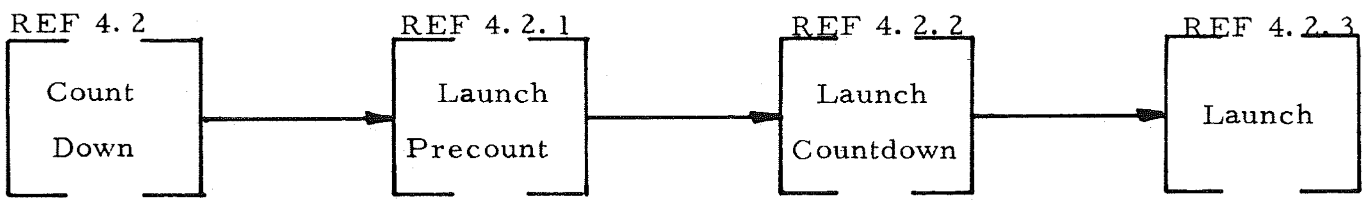
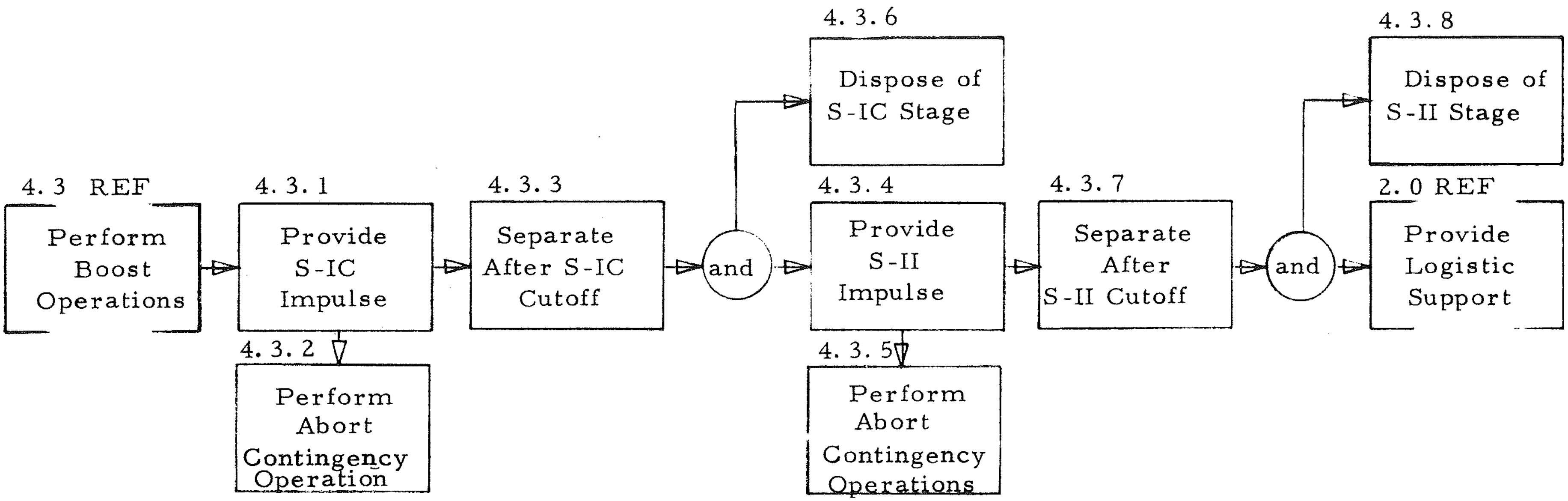
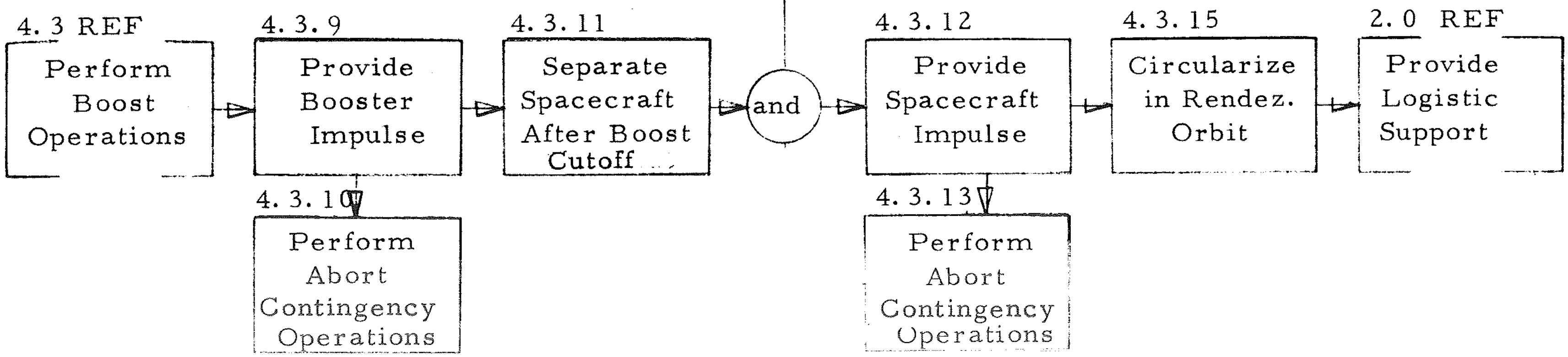


Figure 11-17
4.2 Countdown
Second Level FFD



NOTE: Boost RNS Tank via INT-21 Launch Vehicle



NOTE: Boost RNS Engine Module Separately via Space Shuttle

Figure 11-18
4.3 Perform Boost Operations
Second Level Functional Flow Diagram

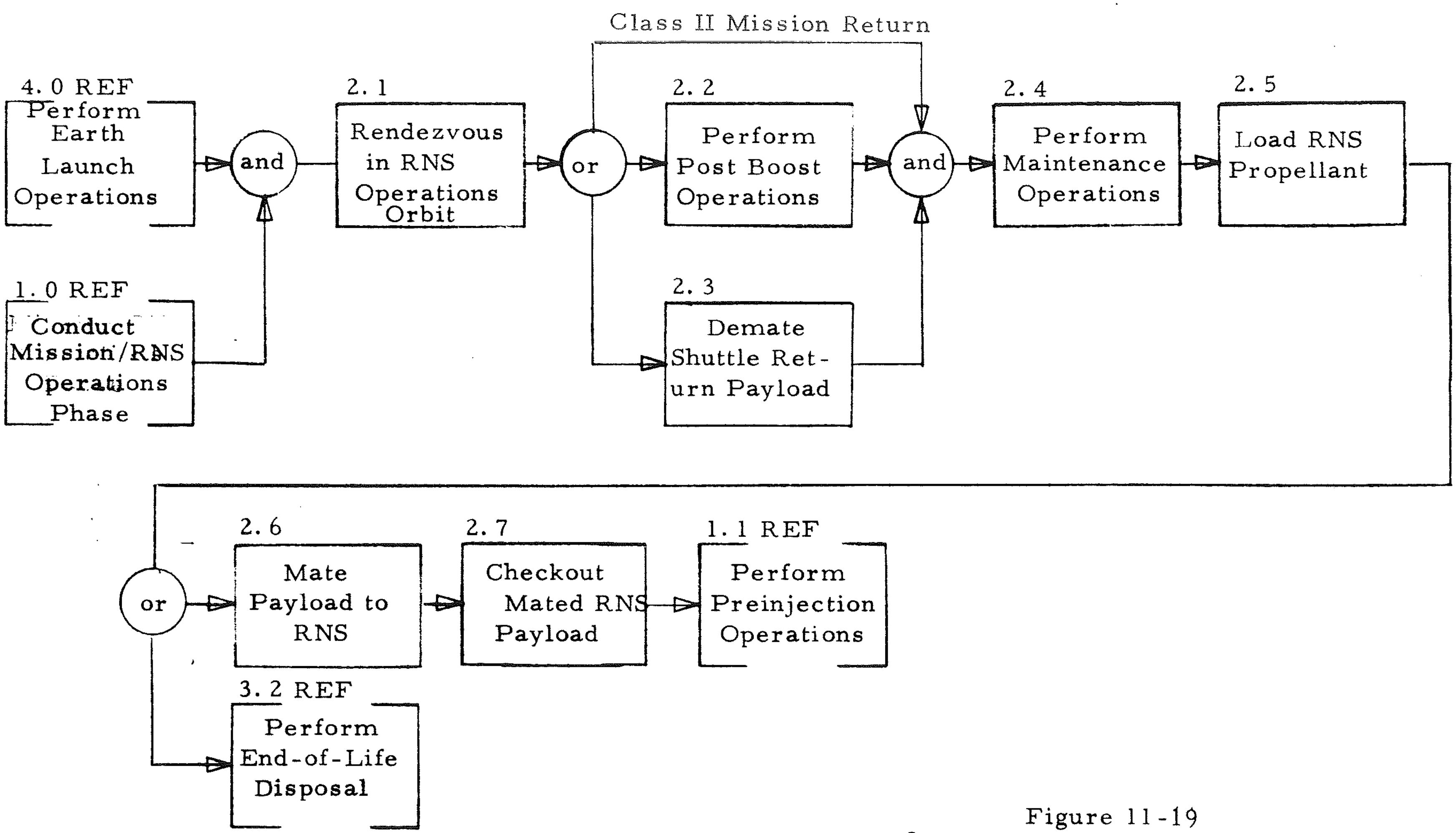


Figure 11-19
2.0 Provide Logistics Support
Class I and II Missions
First Level FFD

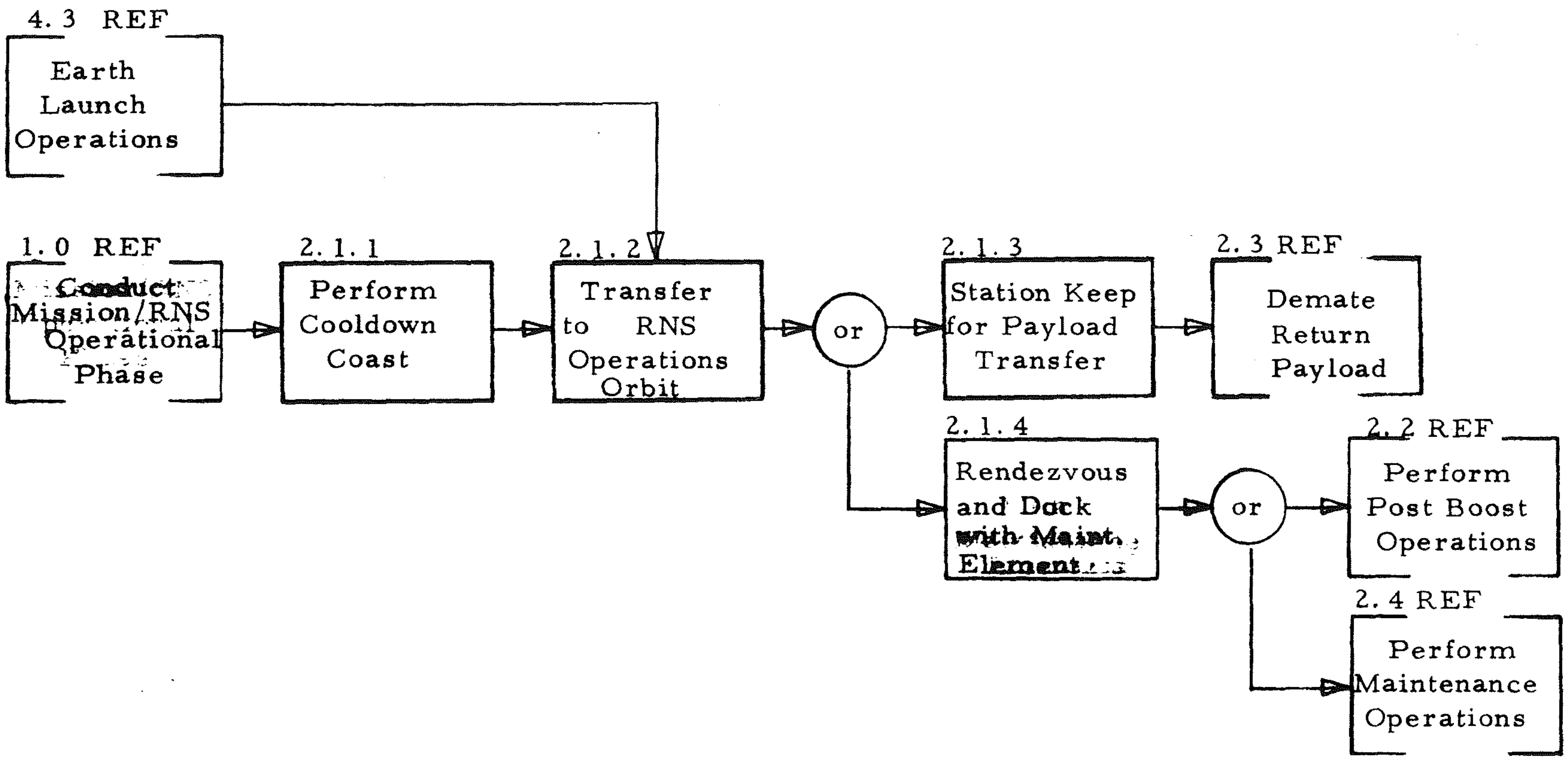


Figure 11-20
2.1 Rendezvous in RNS Operations Orbit
Class I and II Missions
Second Level FFD

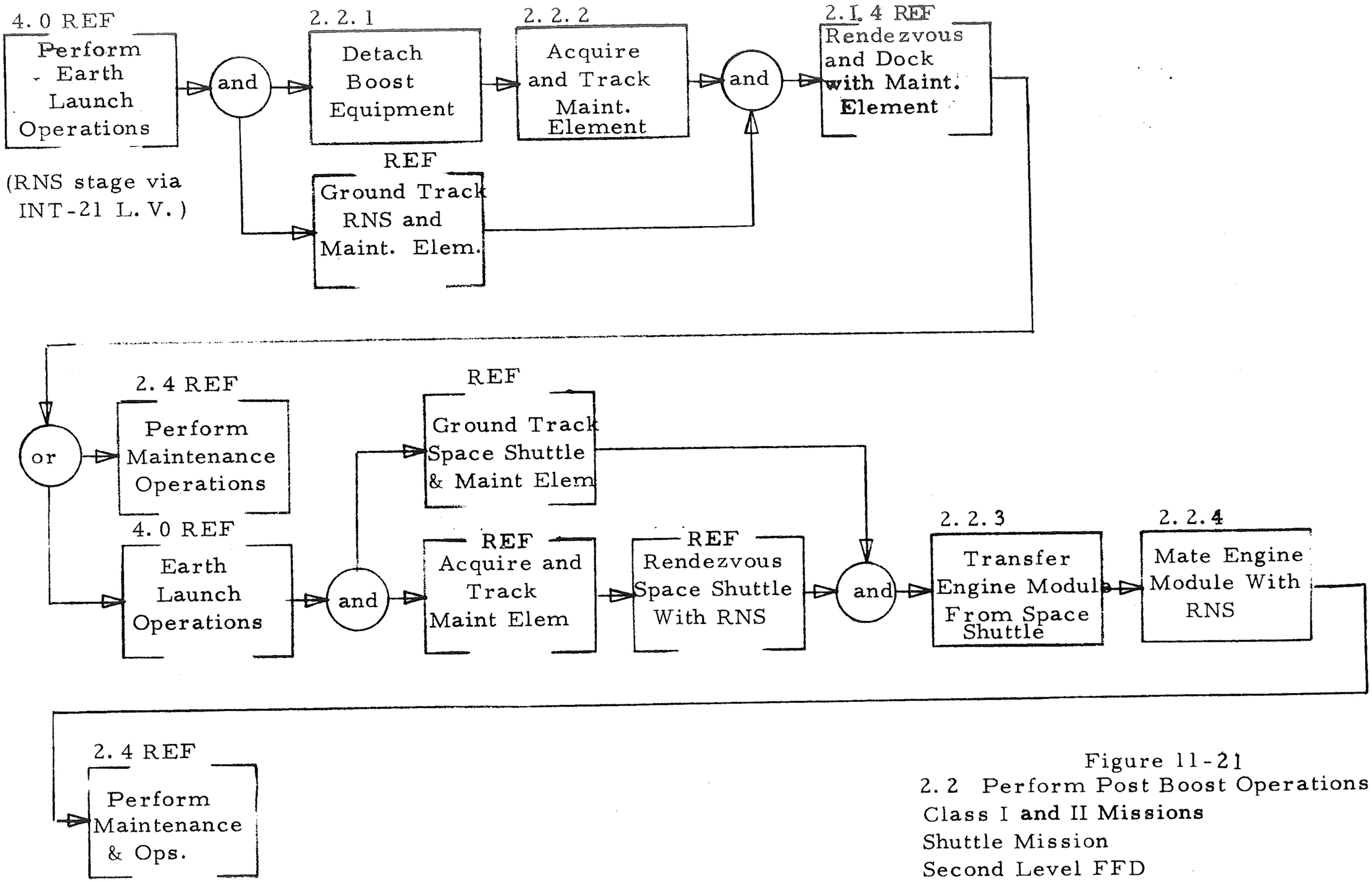


Figure 11-21
2.2 Perform Post Boost Operations
Class I and II Missions
Shuttle Mission
Second Level FFD

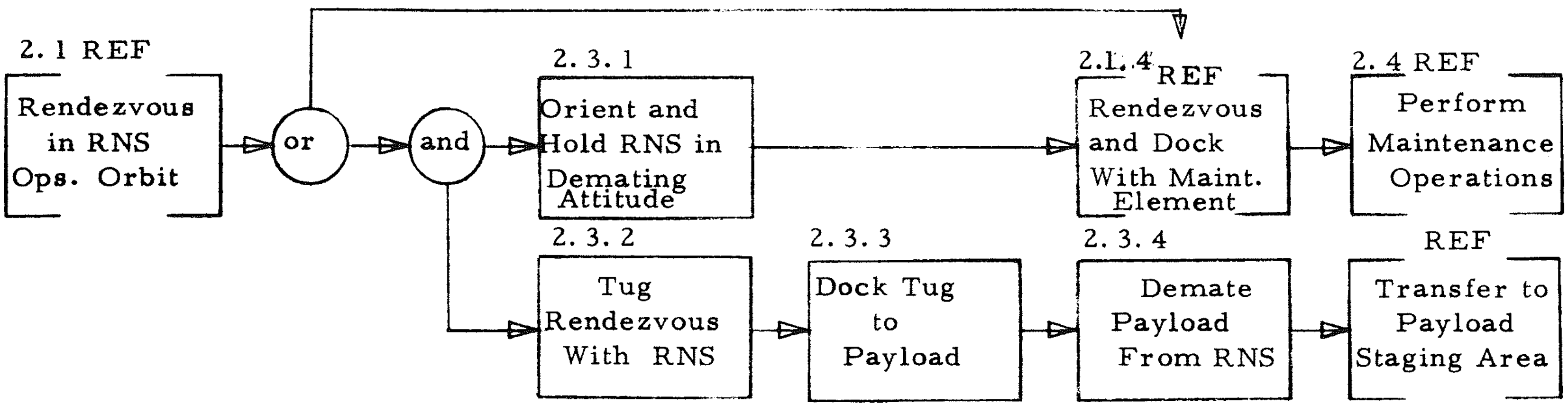


Figure 11-22
2.3 Demate Shuttle Return Payload
Class I and II Missions
Second Level FFD

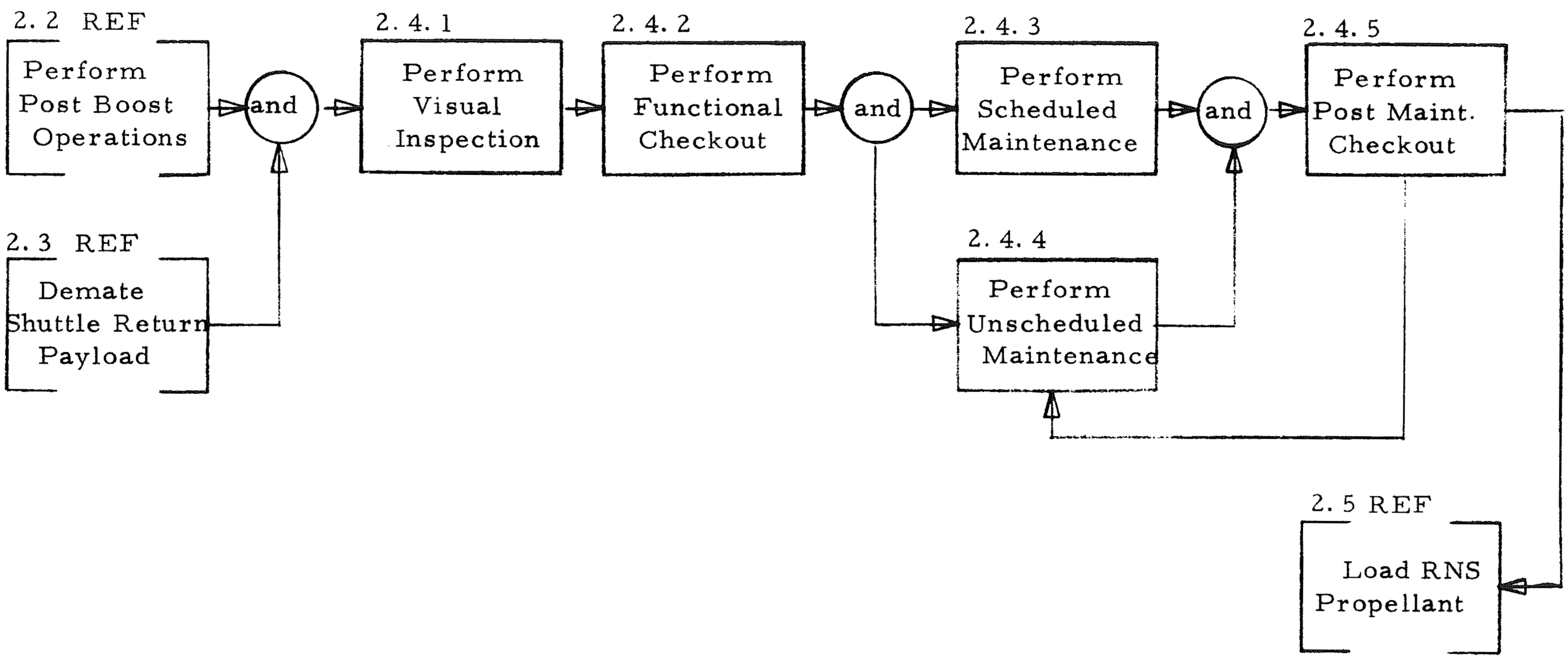


Figure 11-23
2.4 Perform Maintenance Operations
Class I and II Mission
Second Level FFD

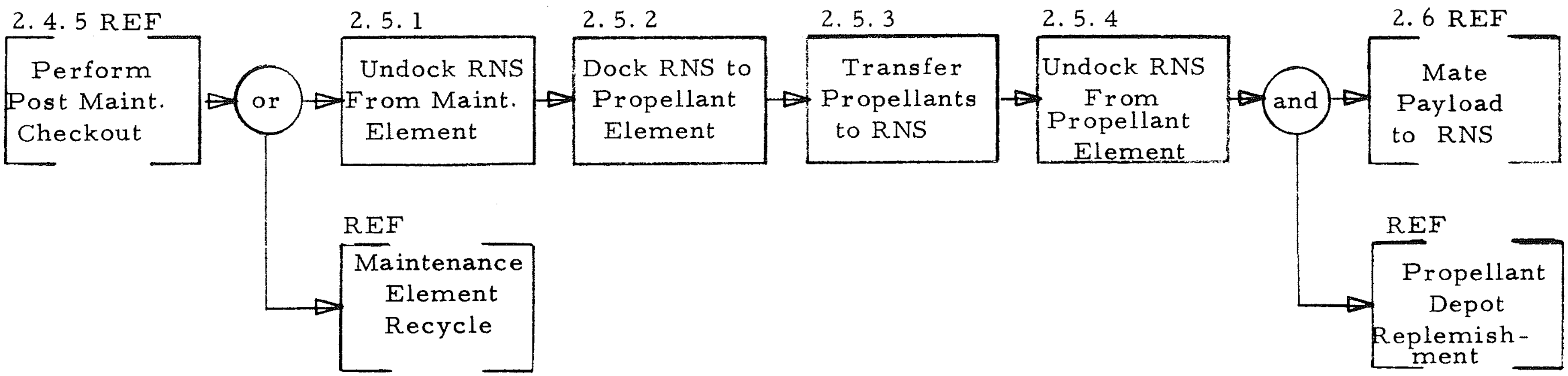


Figure 11-24
2.5 Load RNS Propellant
Class I and II Missions
Second Level FFD

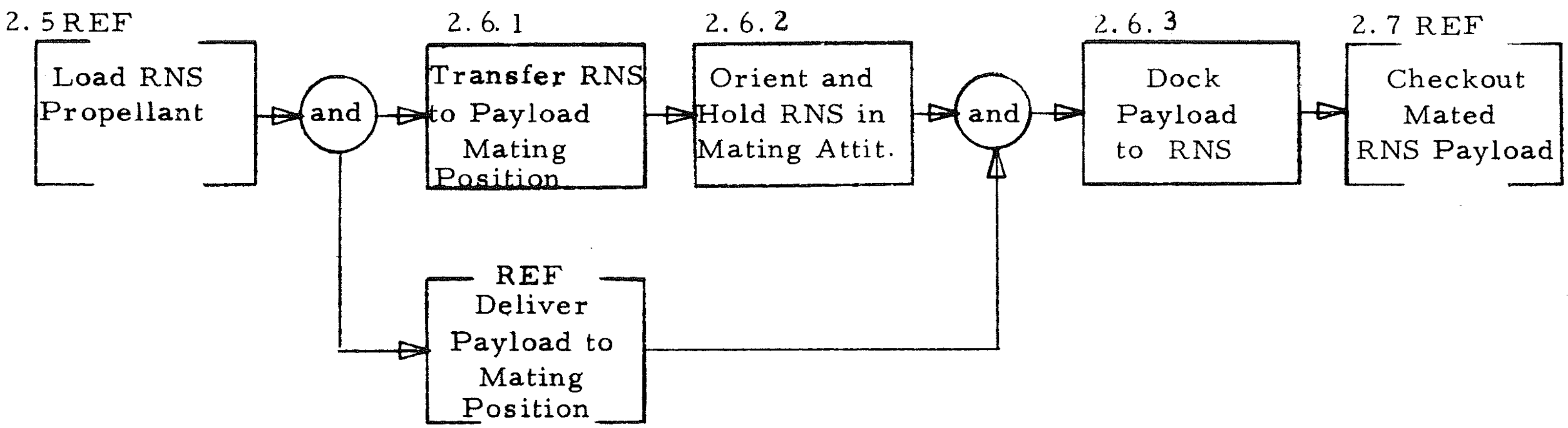


Figure 11-25
2.6 Mate Payload to RNS
Class I and II Missions
Second Level FFD

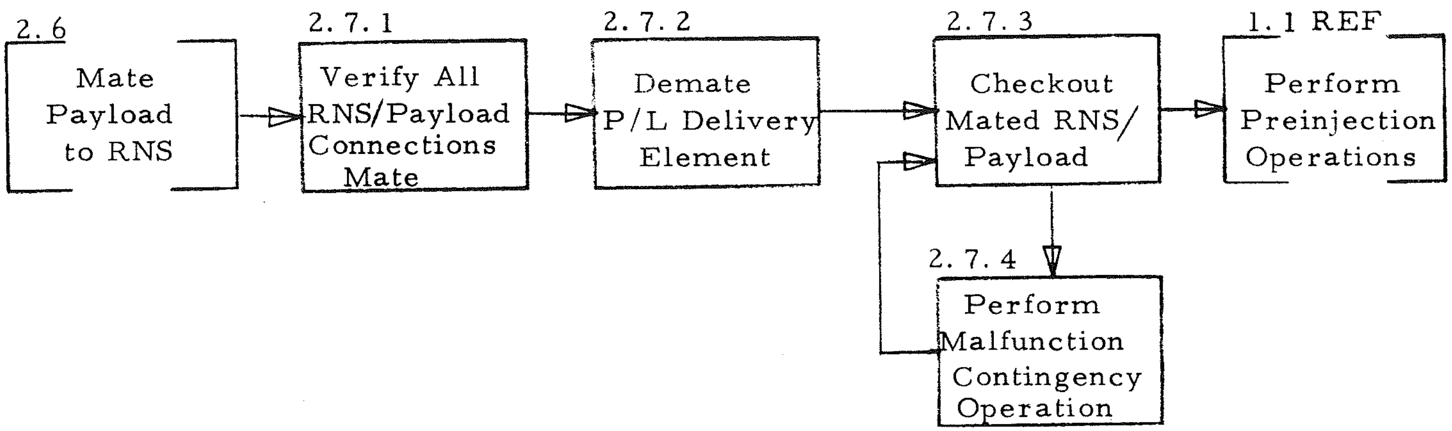


Figure 11-26
2.7 Checkout Mated RNS/Payload
Class I and II Missions
Second Level FFD

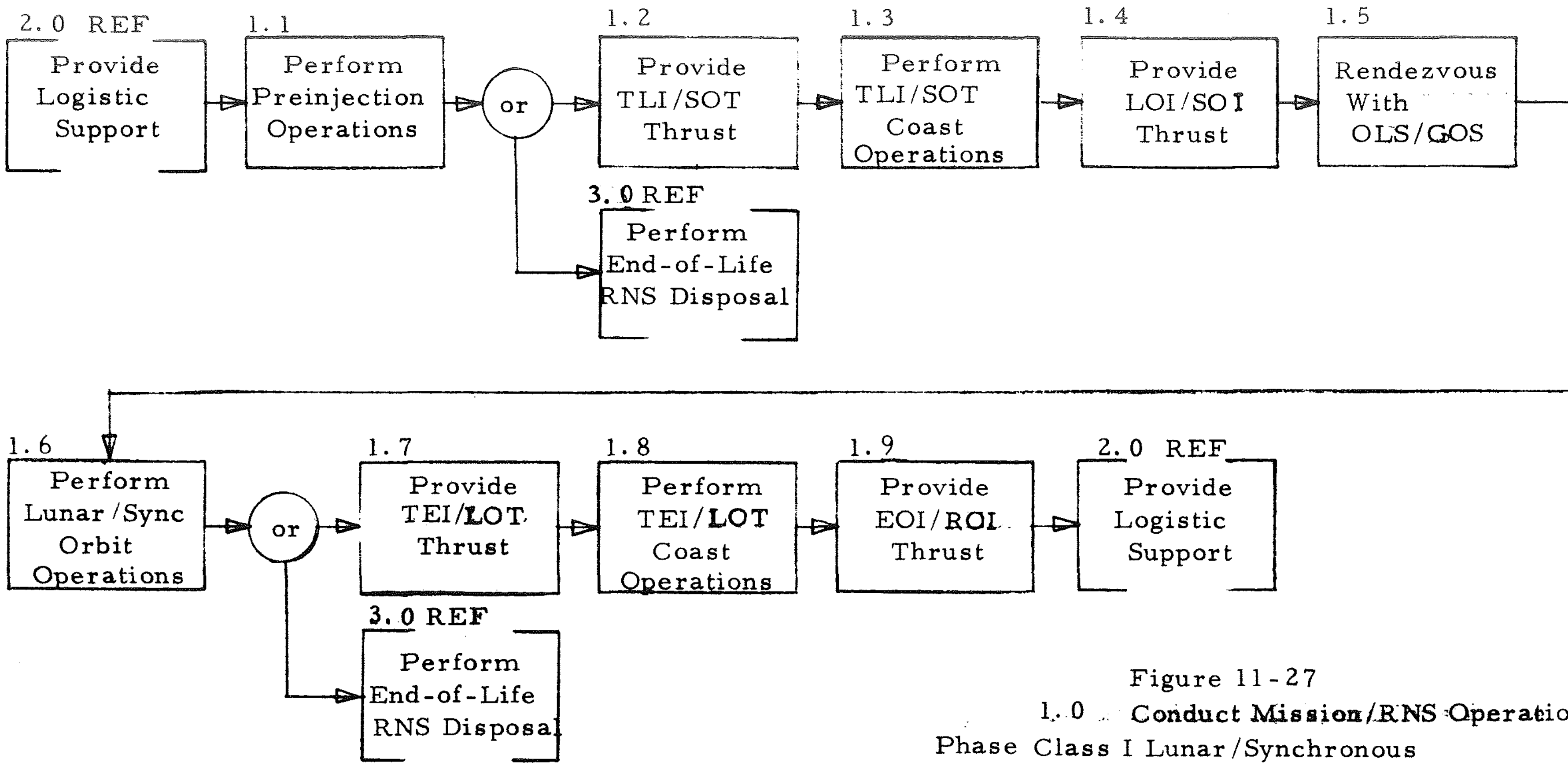


Figure 11-27
1.0 Conduct Mission/RNS Operations
Phase Class I Lunar/Synchronous
Orbit Shuttle Mission
First Level FFD

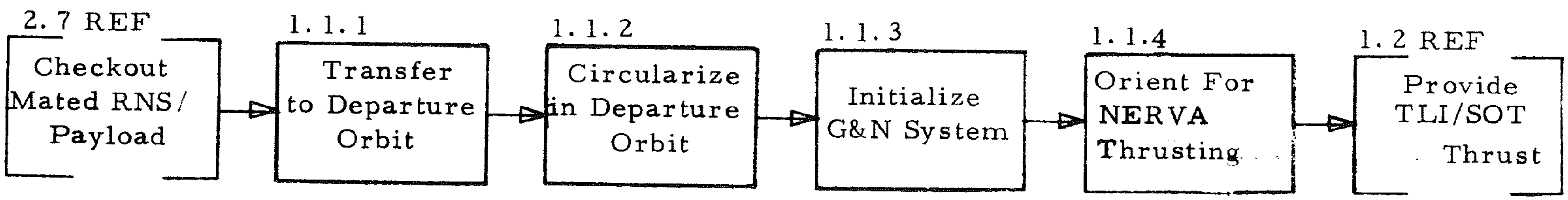


Figure 11-28
1.1 Perform Preinjection Operations
Class I Lunar/Synchronous Orbit Shuttle Mission
Second Level FFD

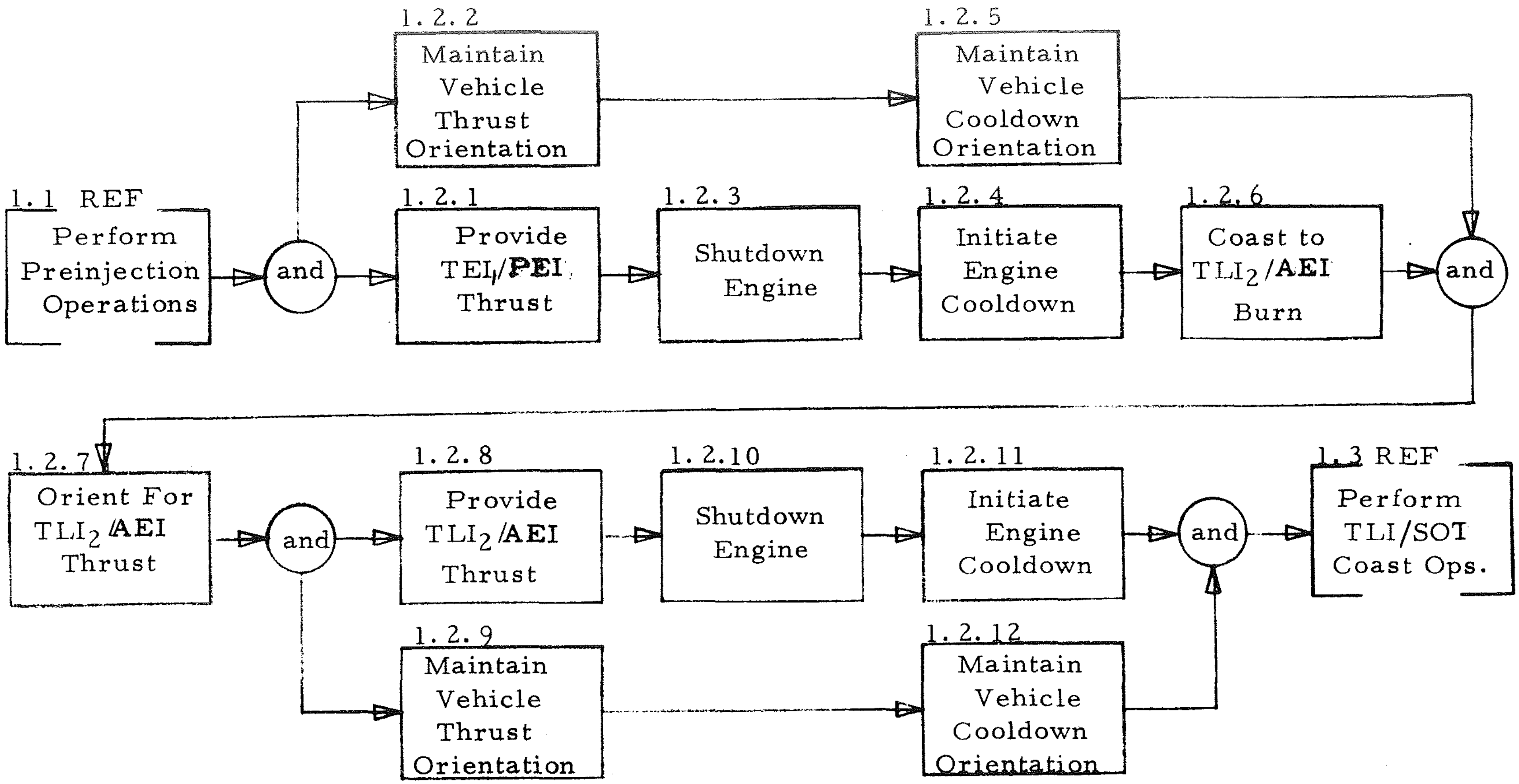


Figure 11-29
1.2 Provide TLI/SOT Thrust
Class I Lunar/Synchronous
Orbit Shuttle Mission
Second Level FFD

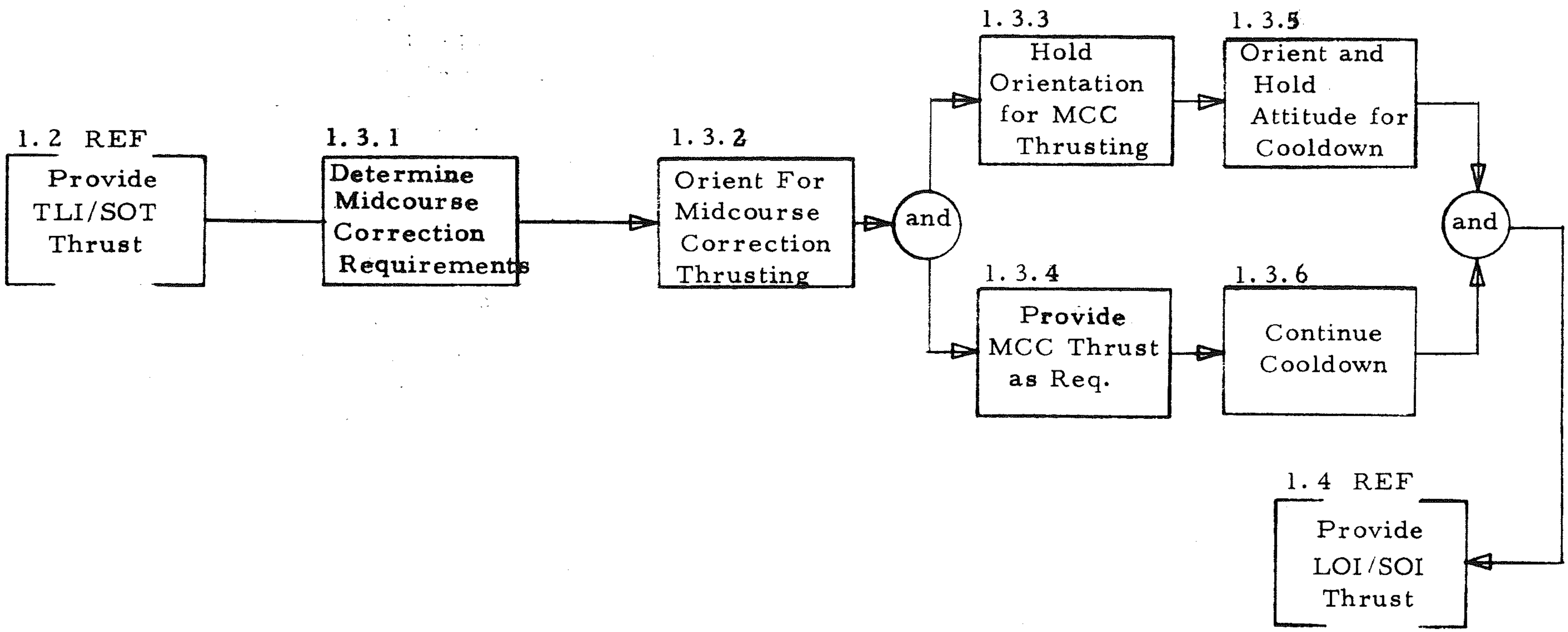


Figure 11-30
1.3 Perform TLI/SOT Coast Operations
Class I Lunar/Synchronous
Orbit Shuttle Mission
Second Level FFD

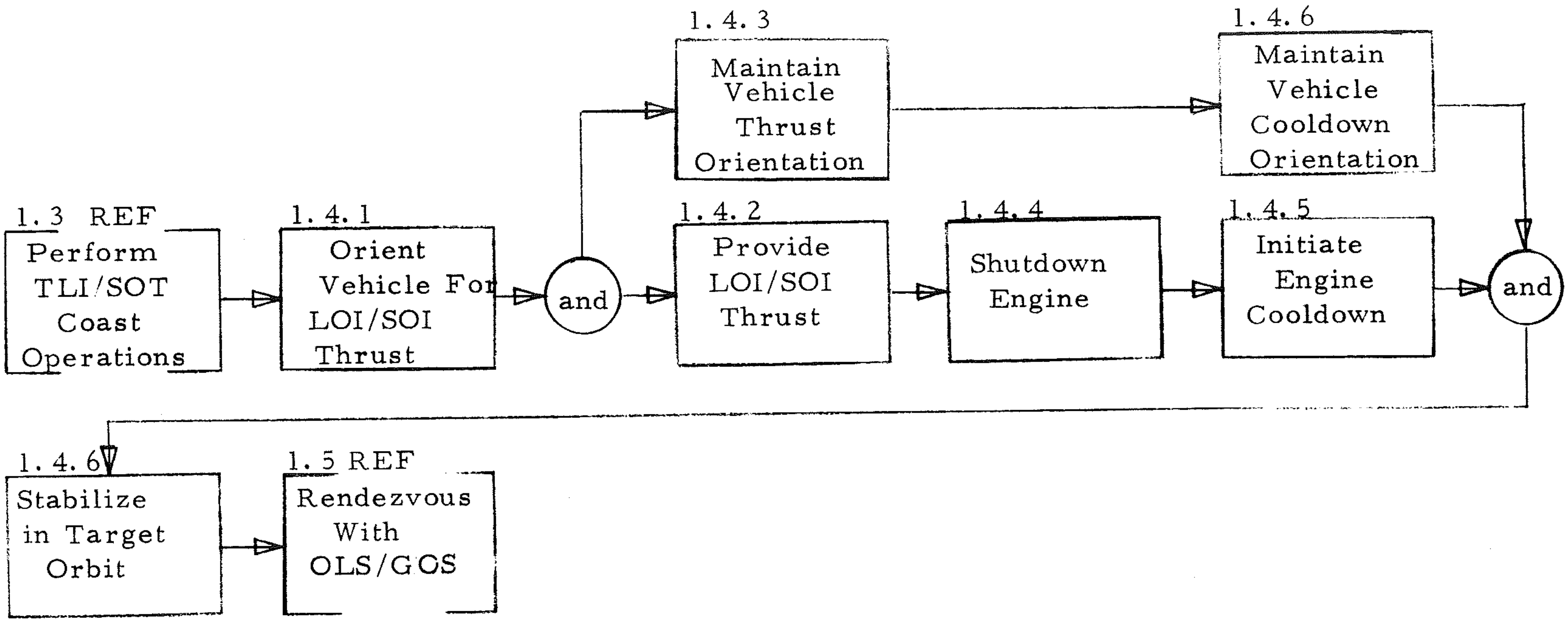


Figure 11-31
1.4 Provide LOI/SOI Thrust
Class I Lunar/Synchronous
Orbit Shuttle Mission
Second Level Functional Diagram

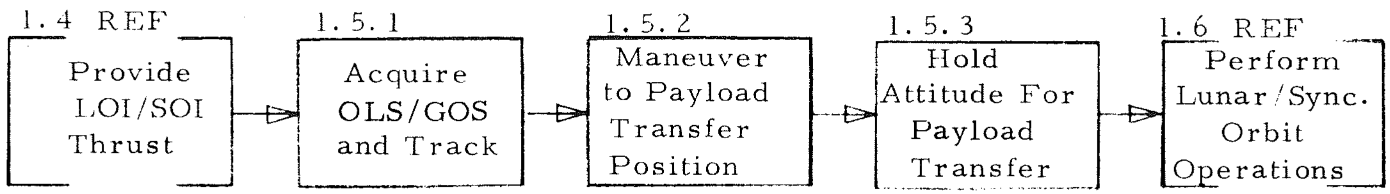


Figure 11-32
1.5 Rendezvous With OLS/GOS
Class I Lunar/Synchronous
Orbit Shuttle Mission
Second Level Functional Diagram

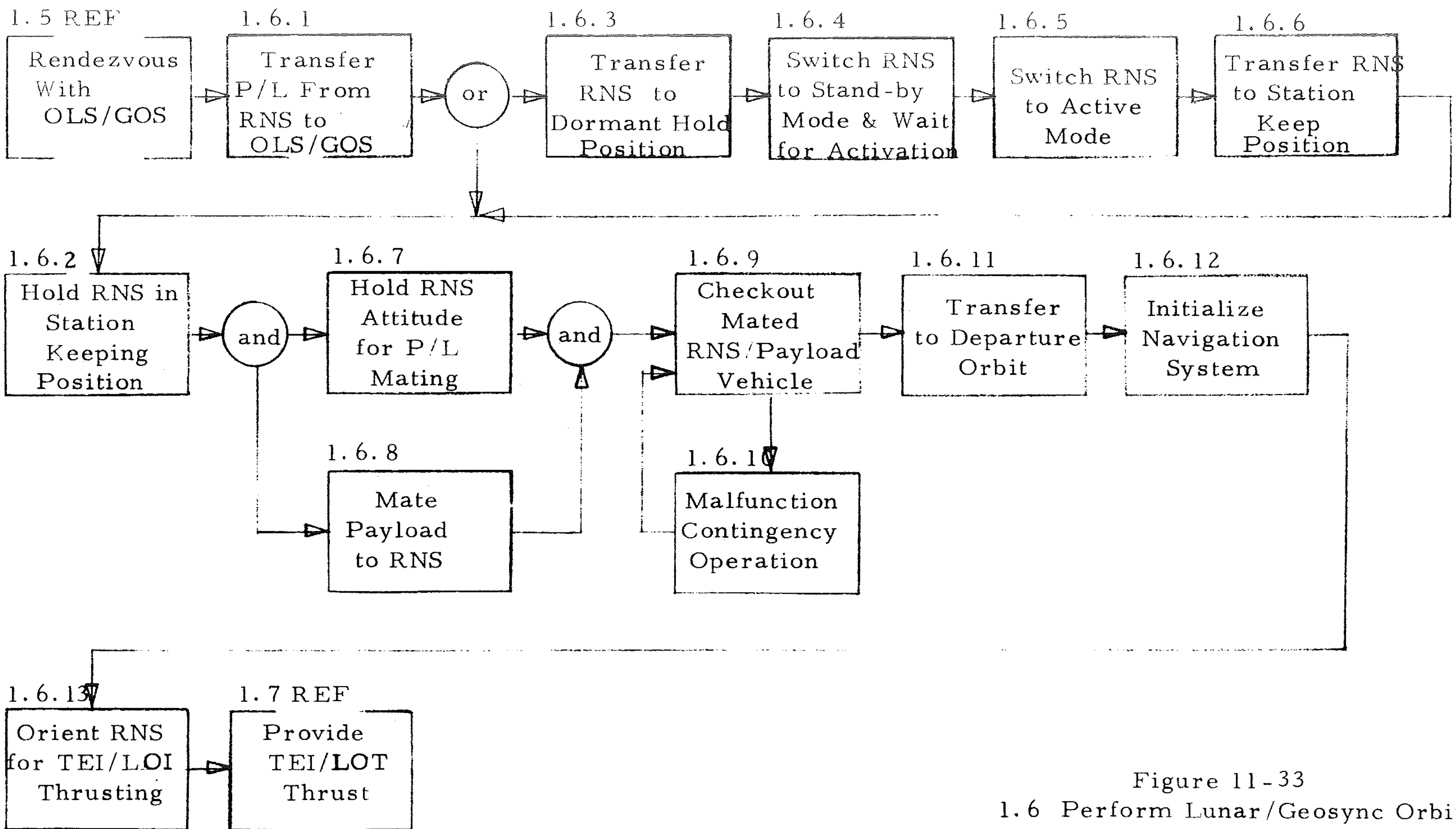


Figure 11-33
1.6 Perform Lunar/Geosync Orbit Operations
Class I Lunar/Geosynchronous Orbit
Shuttle Mission
Second Level FFD

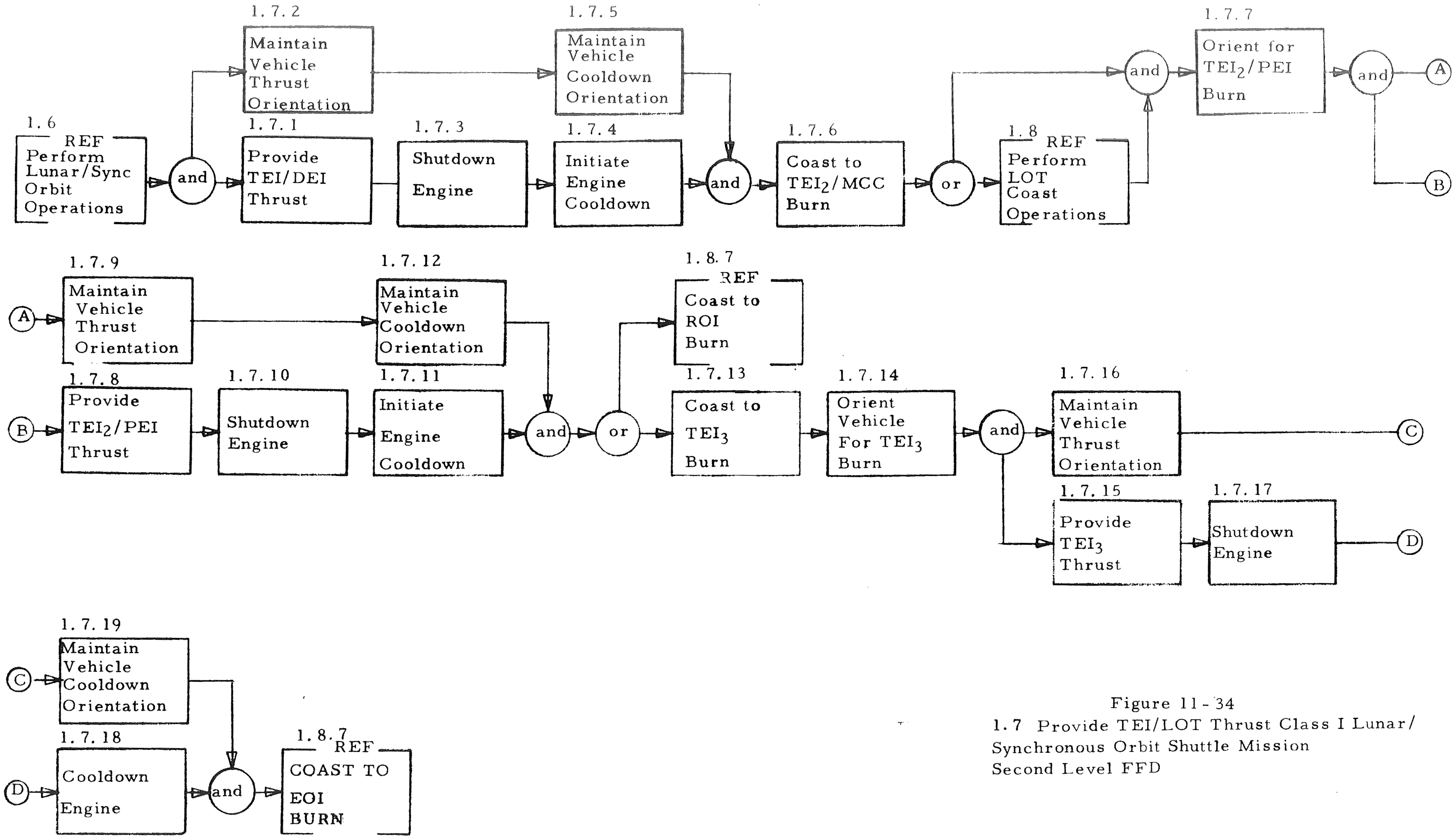


Figure 11-34
1.7 Provide TEI/LOT Thrust Class I Lunar/ Synchronous Orbit Shuttle Mission Second Level FFD

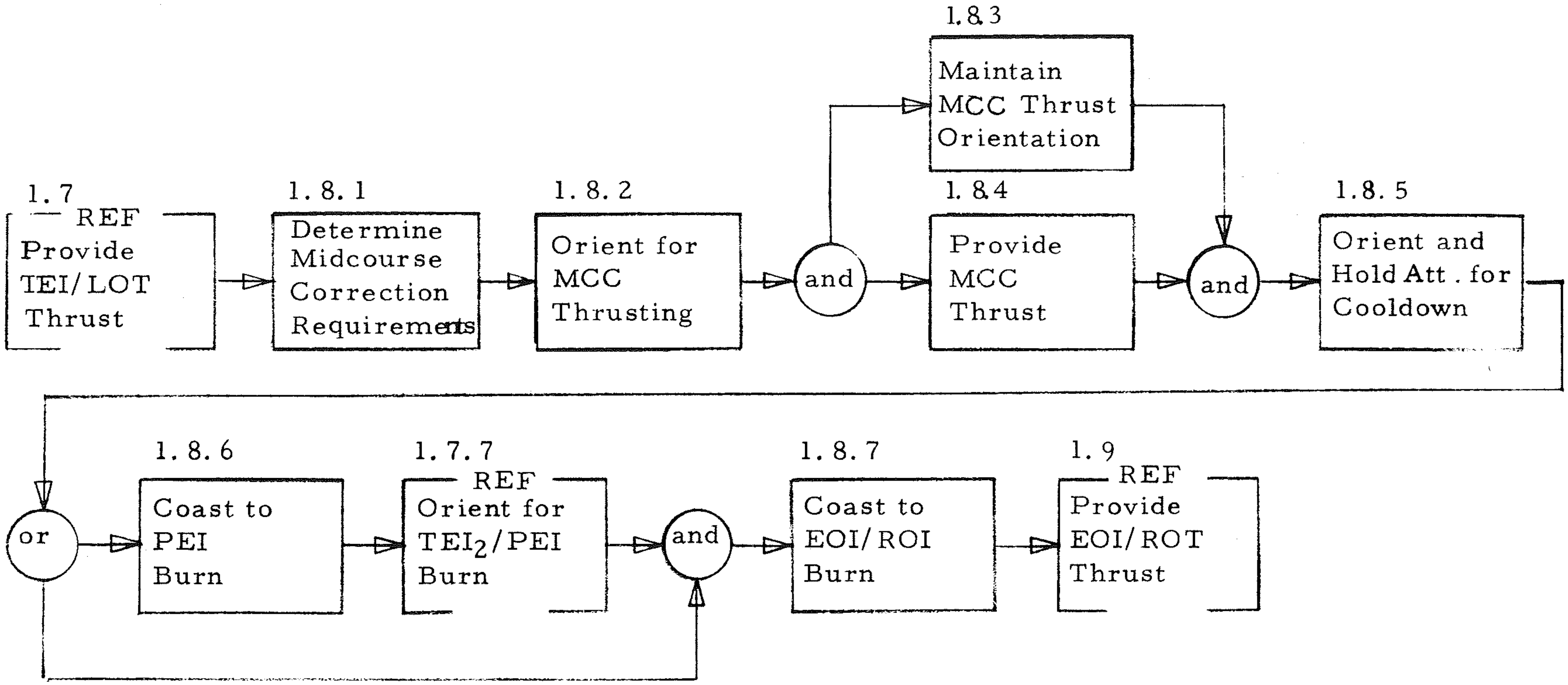


Figure 11-35
1.8 Perform TEI/LOT Coast Operations
Class I Lunar/Synchronous Orbit Shuttle
Mission Second Level F.F.D.

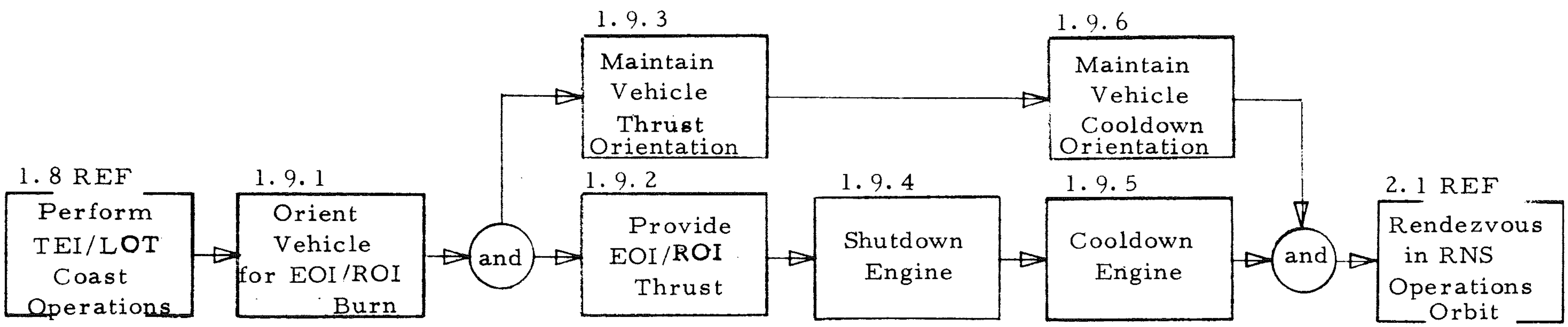


Figure 11-36
1.9 Provide EOI/ROI Thrust
Class I Lunar/Synchronous
Orbit Shuttle Mission
Second Level FFD

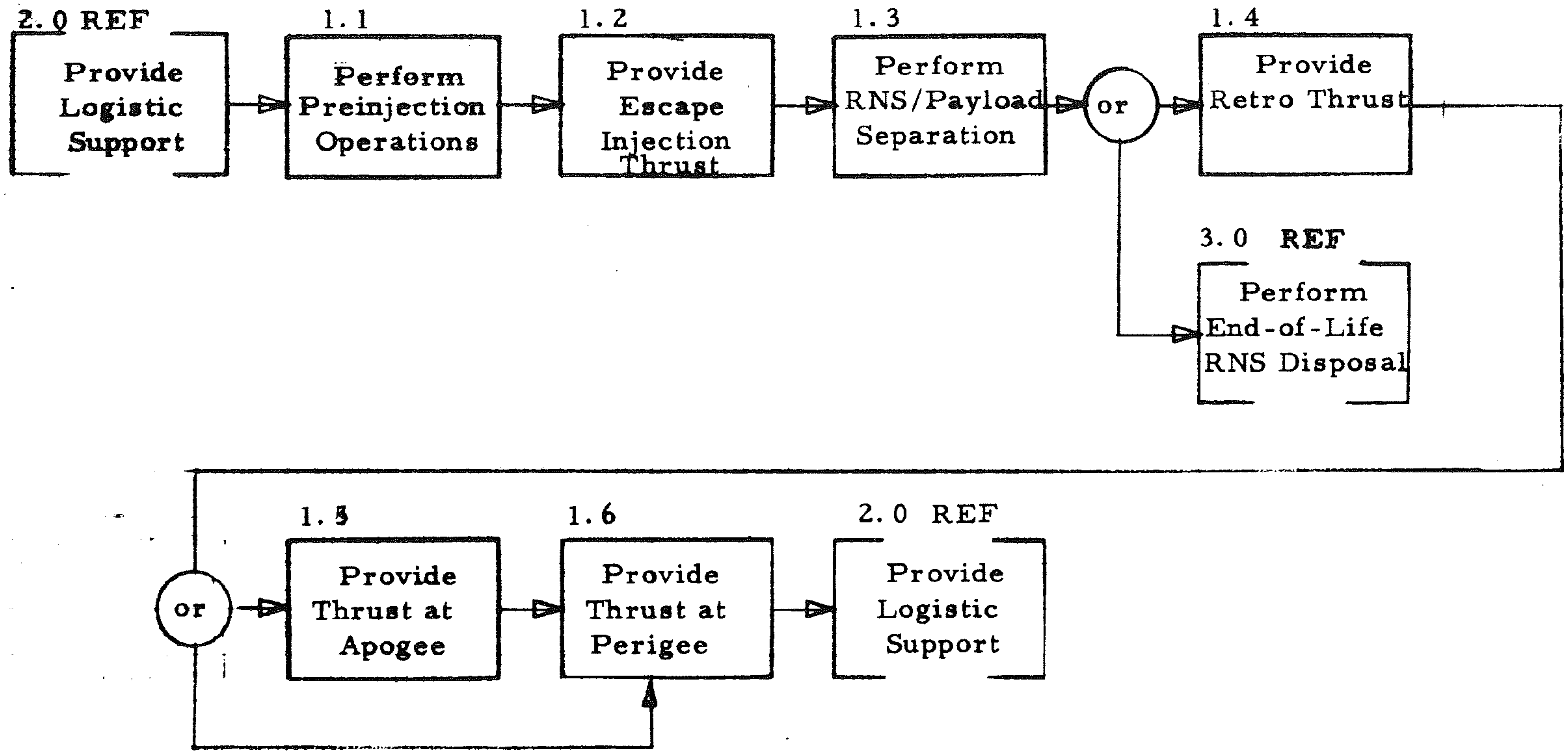


Figure 11-37
1.0 Conduct Mission/RNS Operations
Phase Class II Unmanned Planetary Mission
First Level Functional Diagram

Same as 1.1 Class I

Figure 11-38
1.1 Perform Preinjection Operations
Class II Unmanned Planetary Mission
Second Level FFD

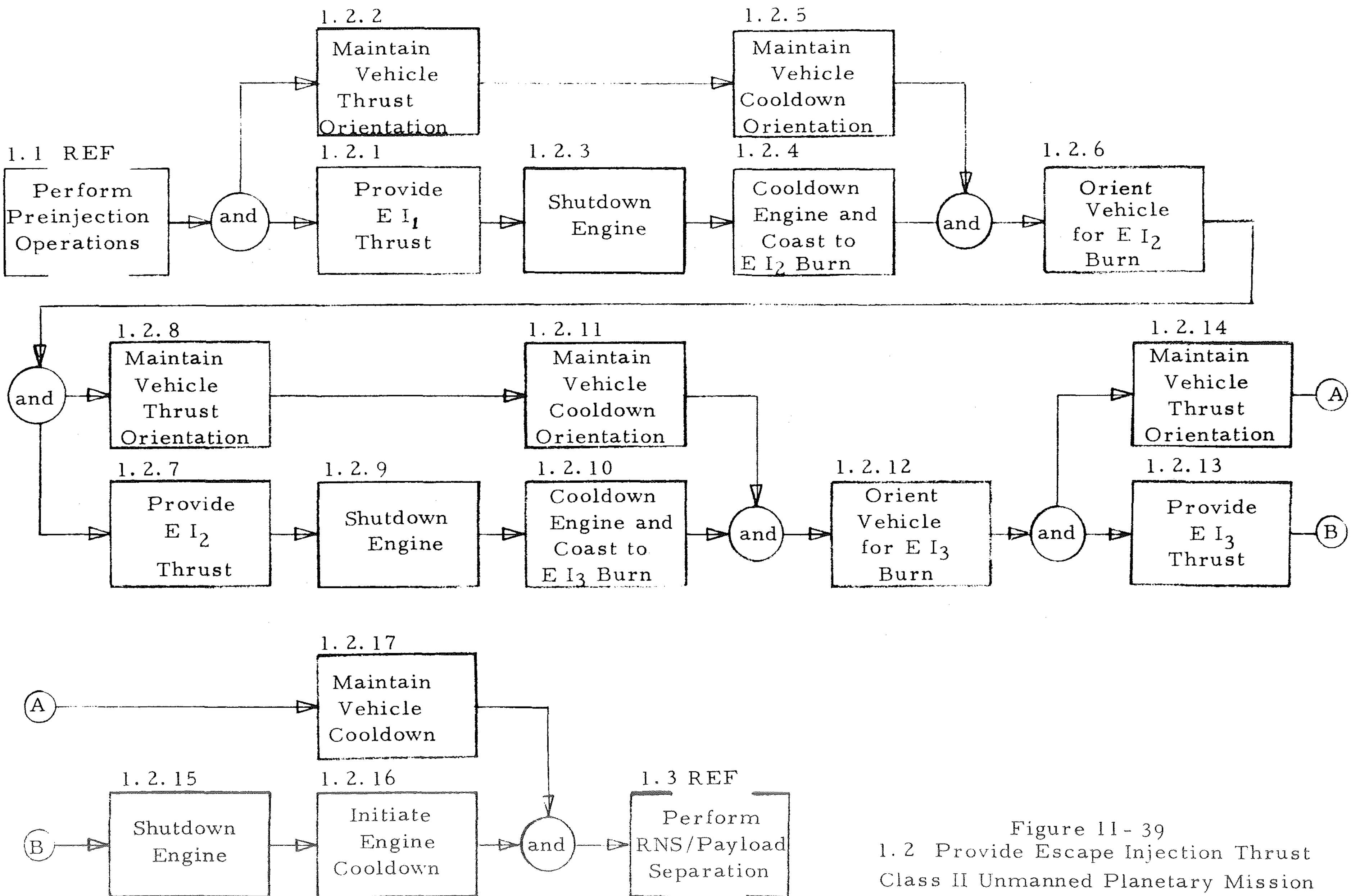


Figure II-39
1.2 Provide Escape Injection Thrust
Class II Unmanned Planetary Mission
Second Level FFD

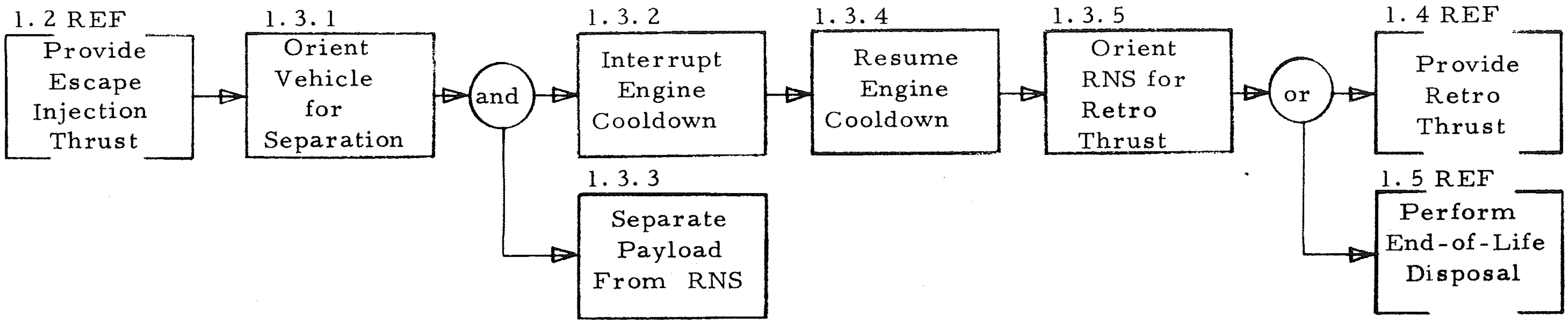


Figure 11-40
1.3 Perform RNS/Payload Separation
Class II Unmanned Planetary Mission
Second Level FFD

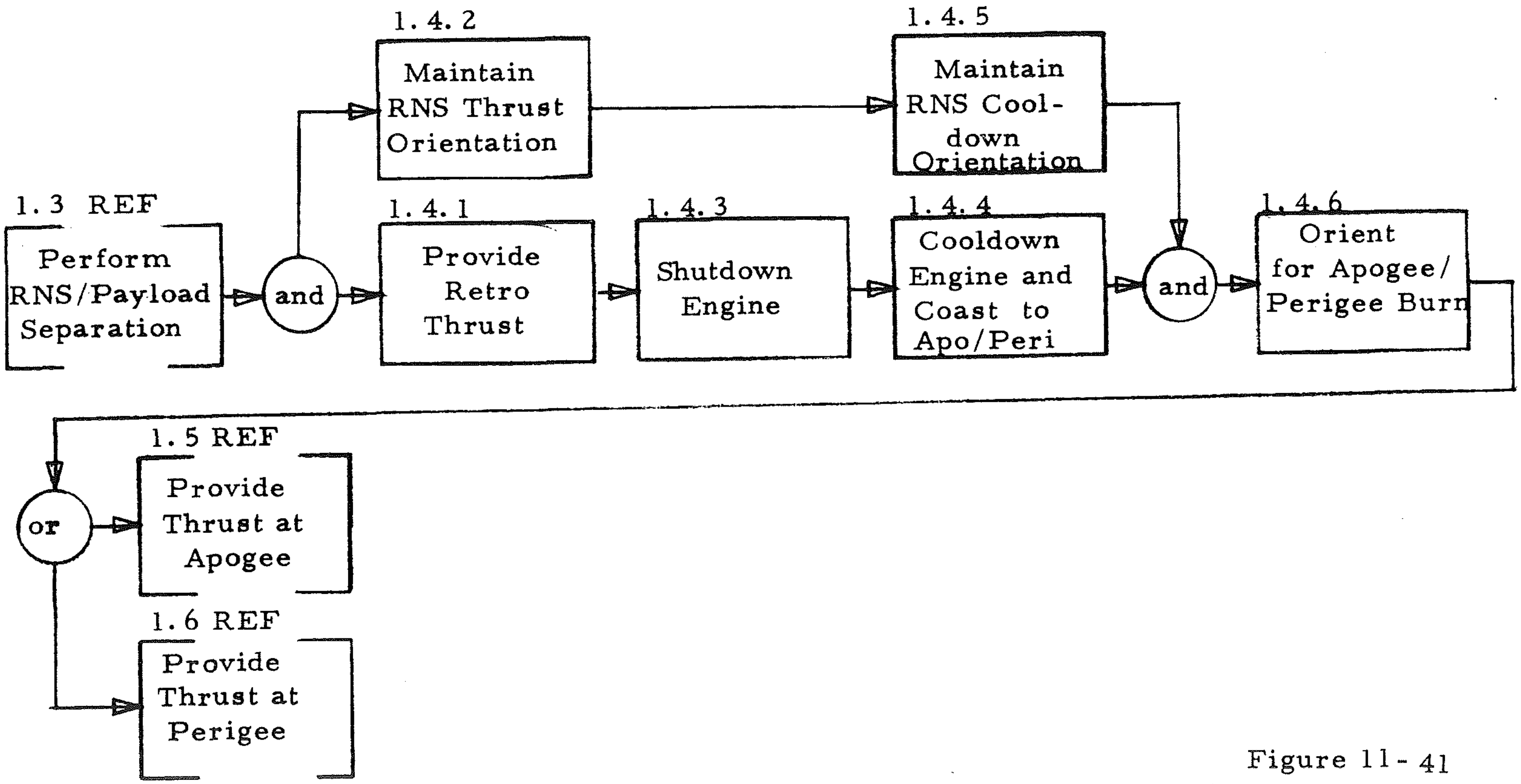


Figure 11-41
1.4 Provide Retro Thrust
Class II Unmanned Planetary Mission
Second Level FFD

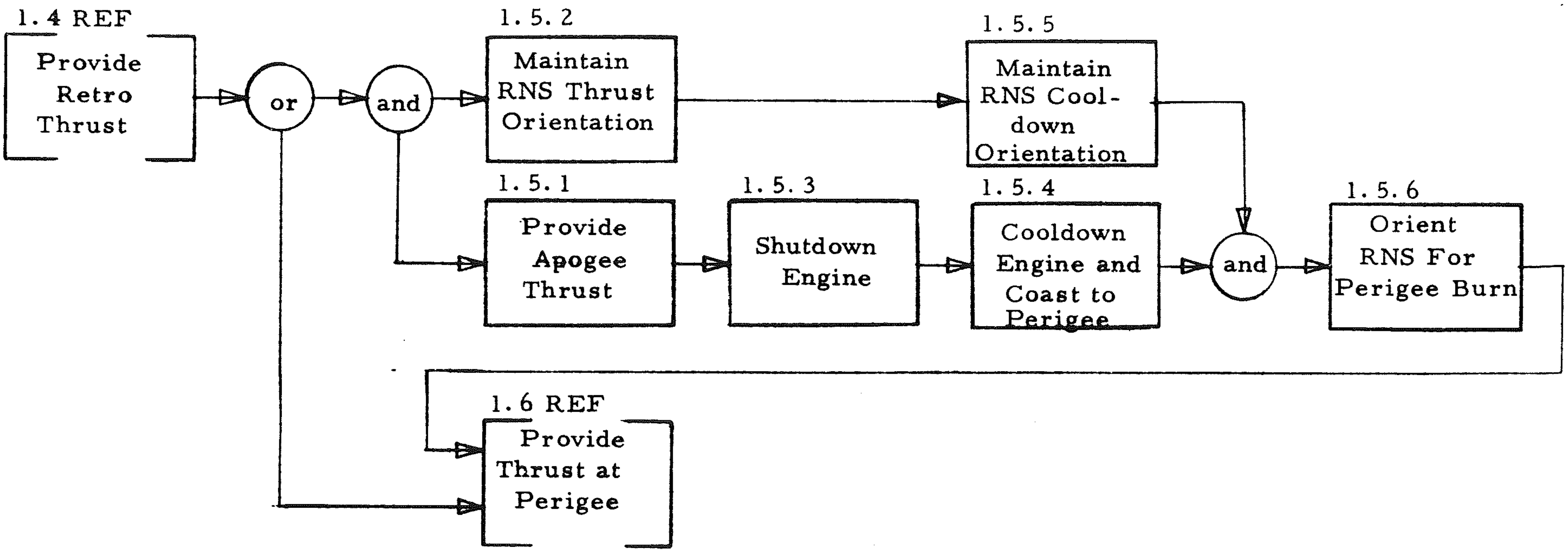


Figure 11-42
1.5 Provide Thrust at Apogee
Class II Unmanned Planetary Mission
Second Level FFD

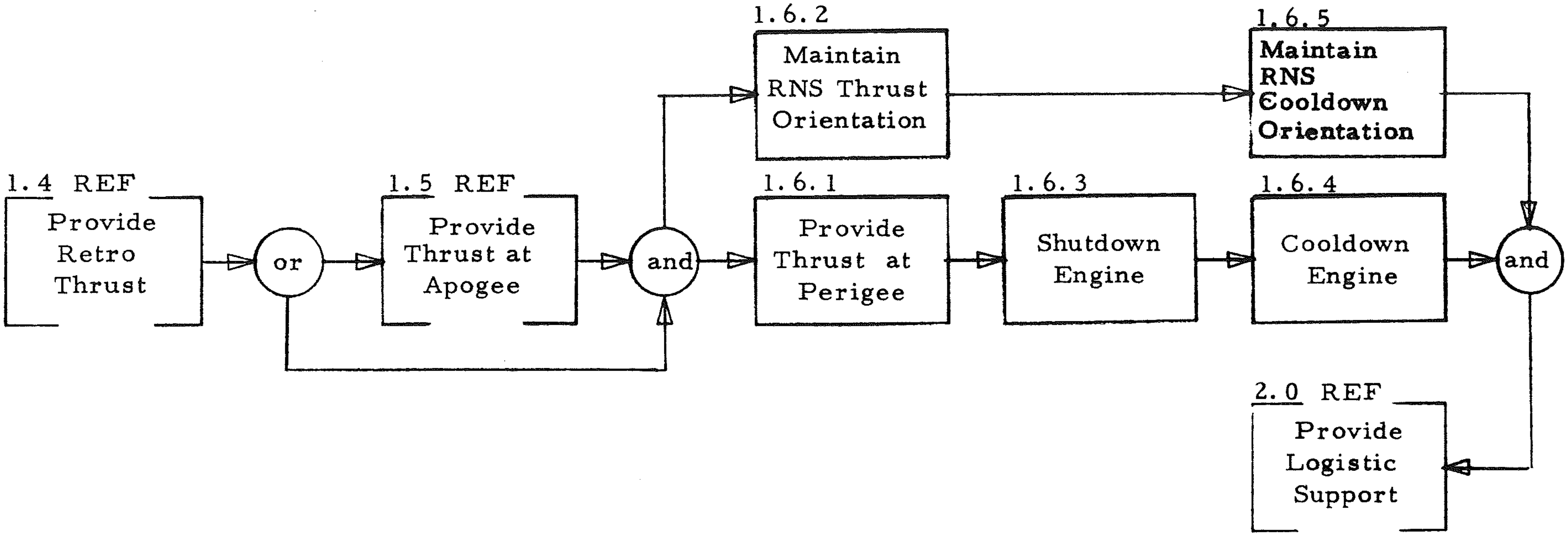


Figure 11-43
1.6 Provide Thrust at Perigee
Class II Unmanned Planetary Mission
Second Level FFD

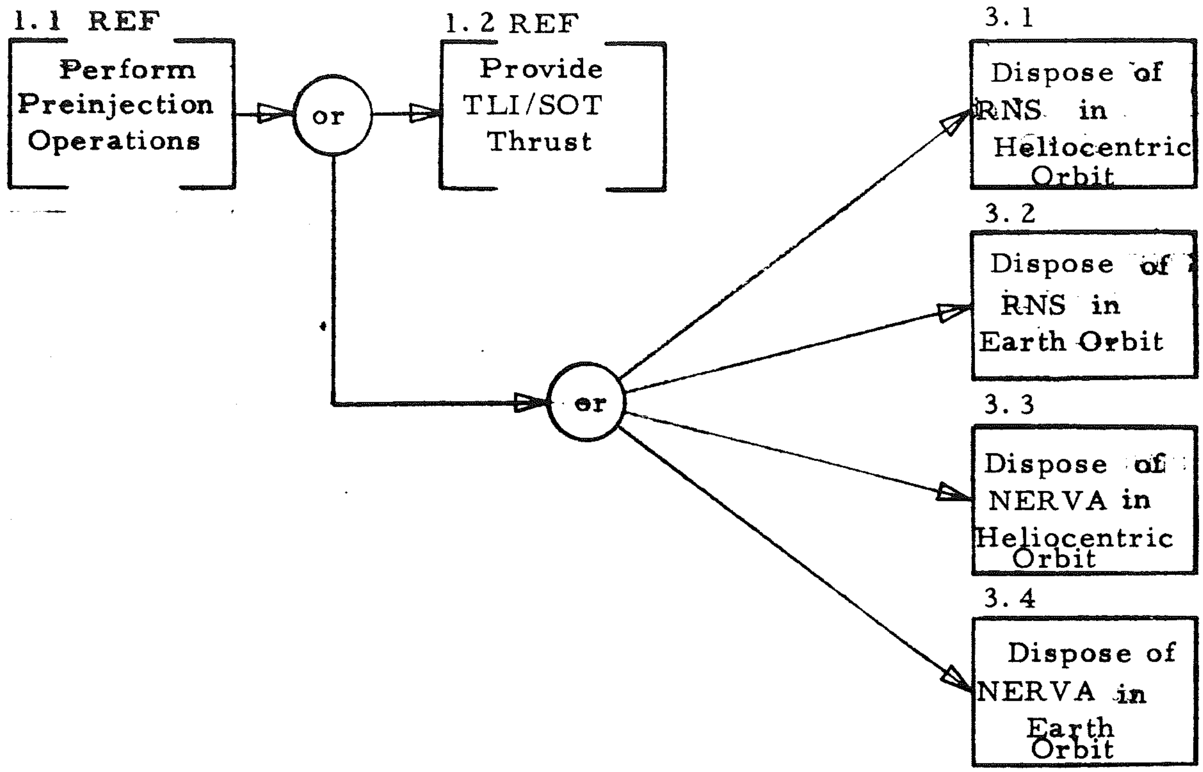


Figure 11-44
3.0 Perform End-of-Life Disposal
Class I and Class II Missions
First Level FFD

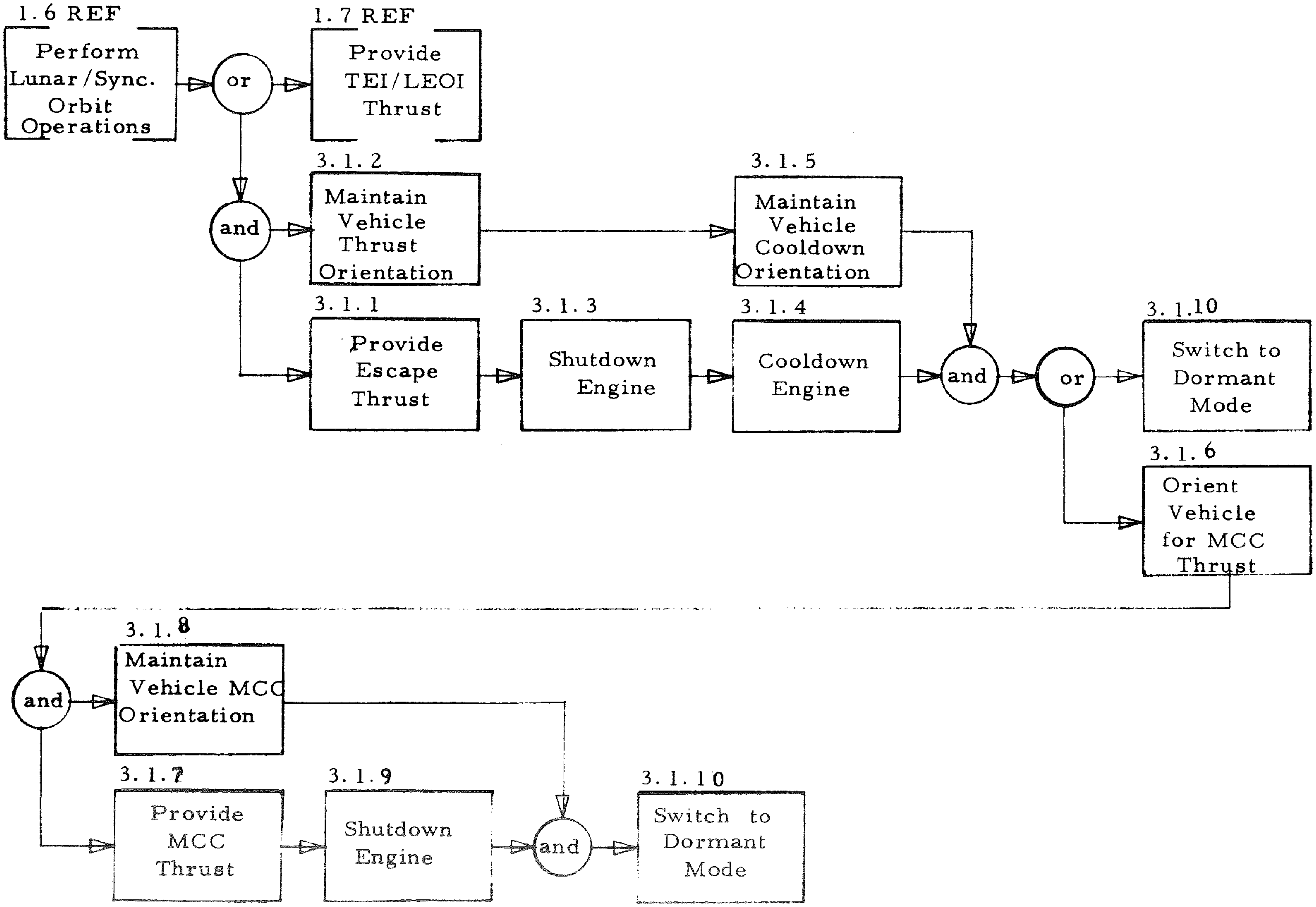


Figure 11-45
3.1 Dispose of RNS in Heliocentric Orbit
Class I Lunar/Synchronous Orbit Shuttle
Mission Second Level FFD

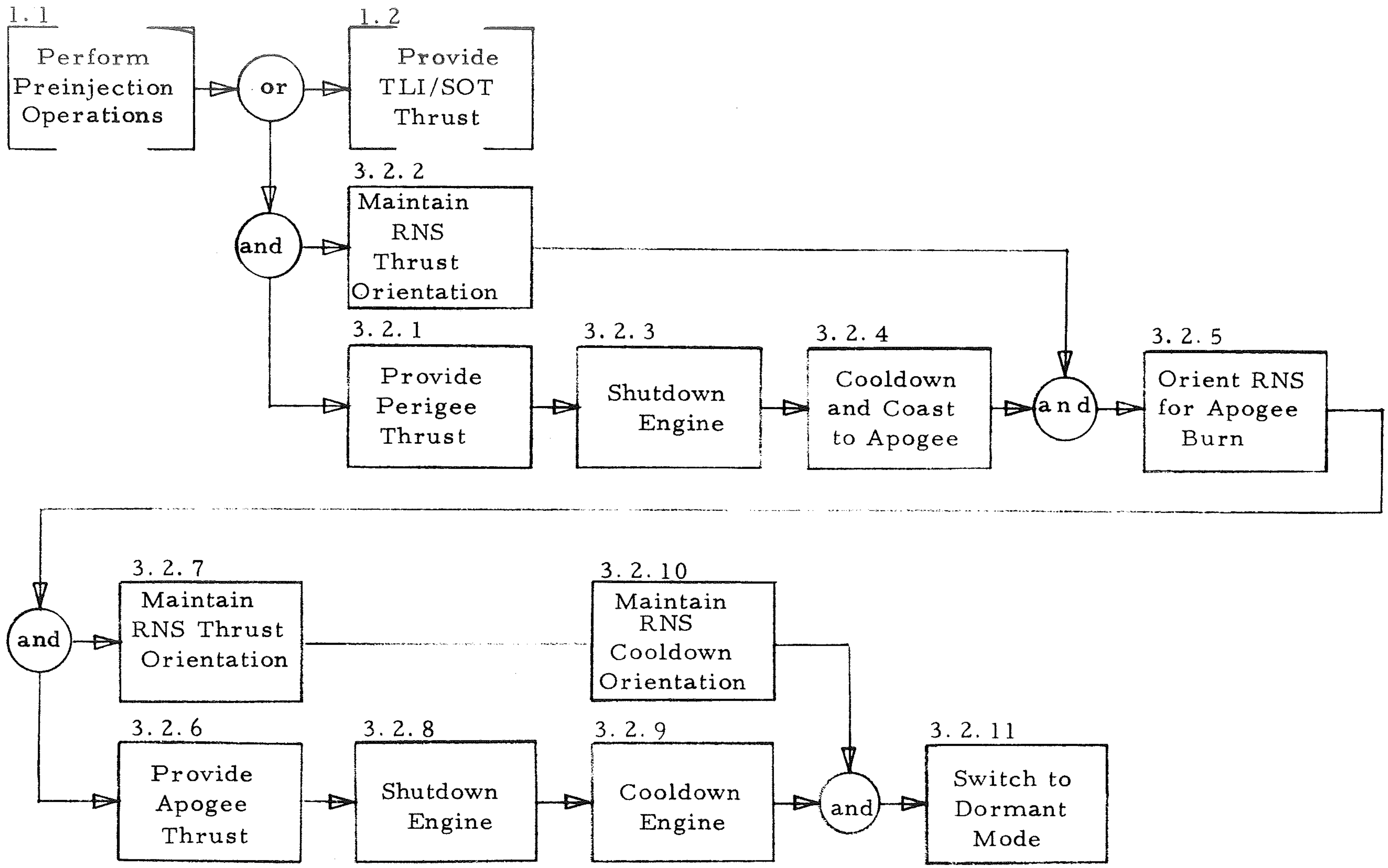


Figure 11-46
3.2 Dispose of RNS in Earth Orbit
Class I Lunar/Synchronous
Orbit Shuttle Mission
Second Level FFD

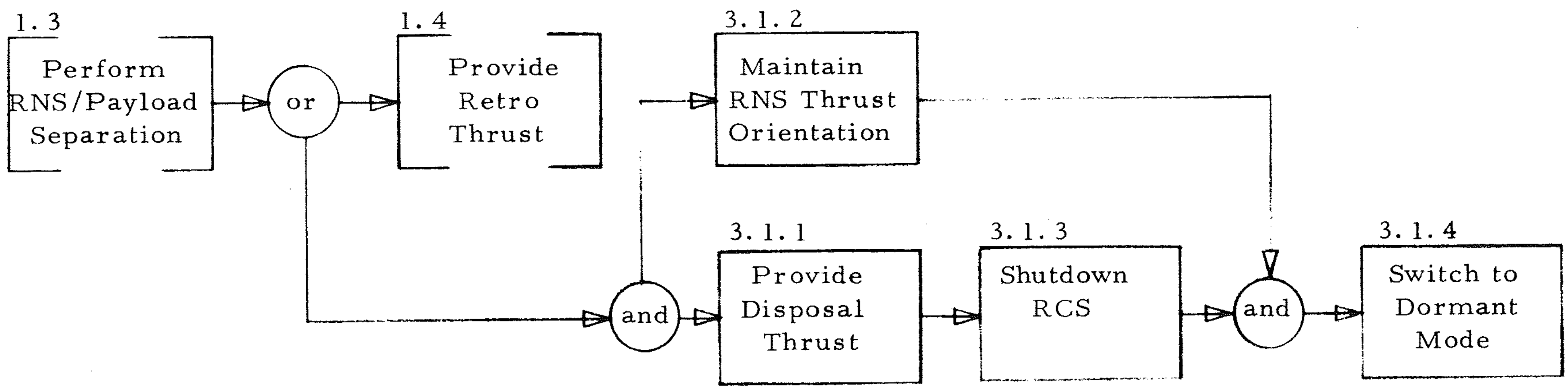


Figure 11-47
3.1 Dispose of RNS in Heliocentric Orbit
Class II Unmanned Planetary Mission
Second Level FFD

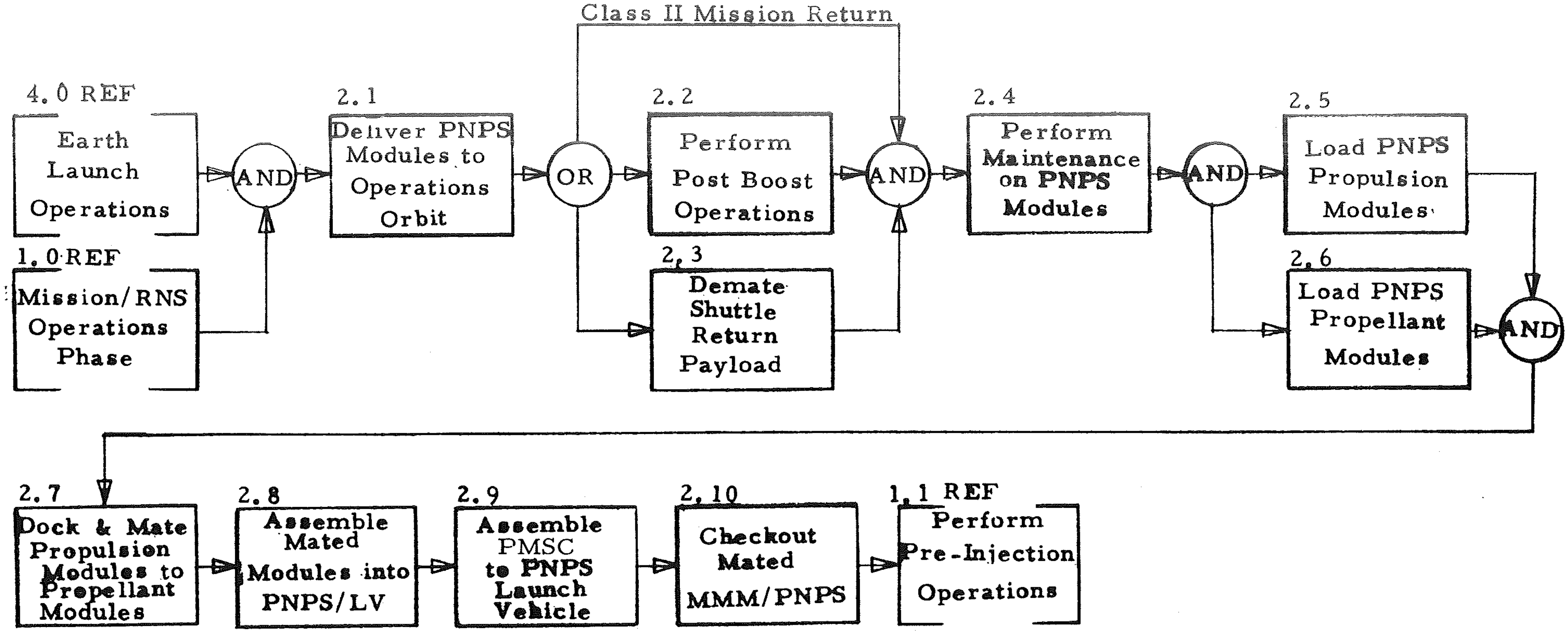


Figure 11-48
2.0 Provide Logistic Support
Class III Missions
First Level FFD

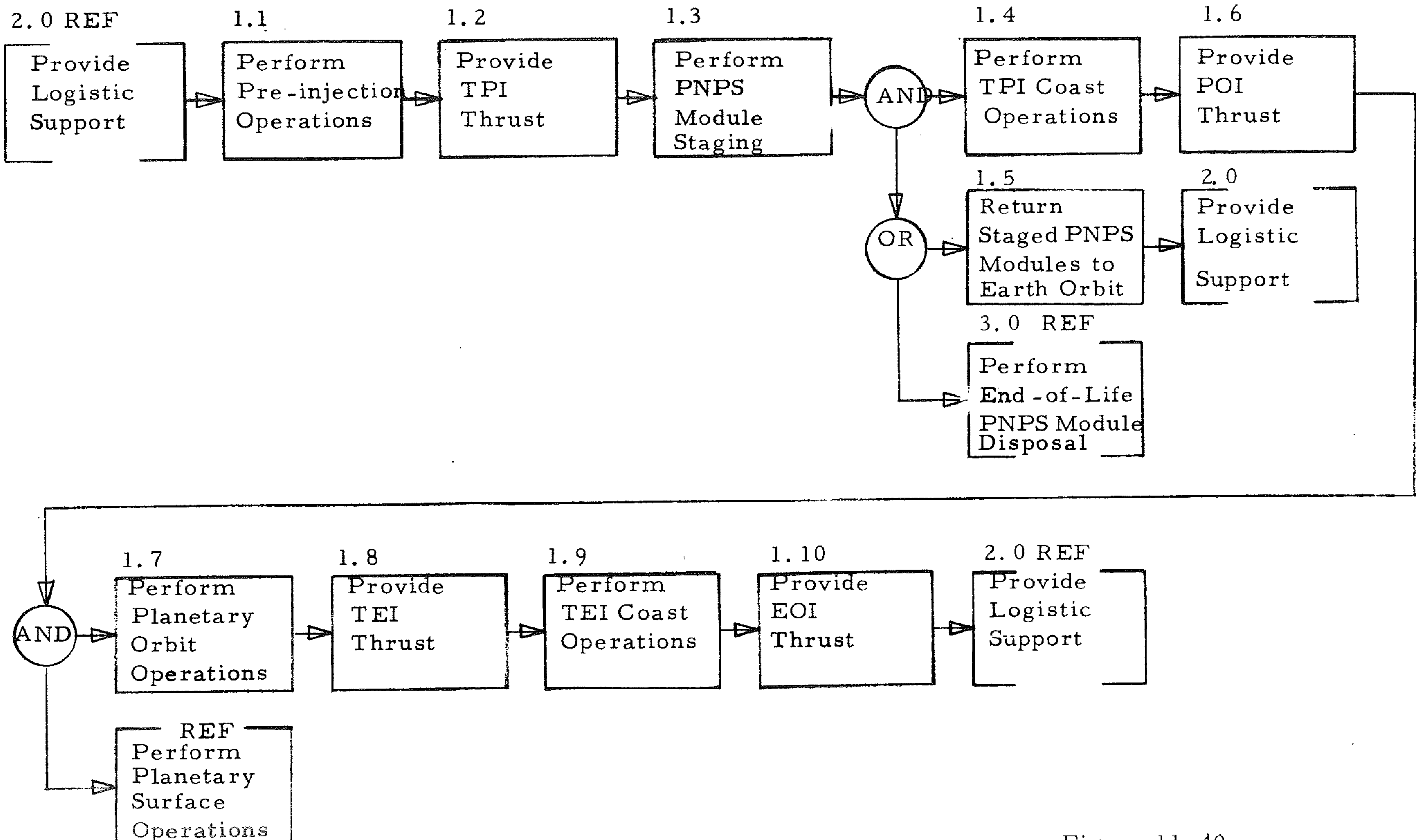


Figure 11-49

1.0 Mission/RNS Operational Phase
Class III Manned Planetary Mission
First Level FFD

REFERENCES

11.1 MSFC Document No. PD-SA-70-63, "Guidelines and Constraints Document Nuclear Shuttle System Definition Study" Phase A, Revision No. 2, Dated October 1, 1970.

11.2 SD70-184-5 "Monthly Progress Report No. 5, Nuclear Shuttle System Definition, Phase III," Dated September 1970.

11.3 SD70-117-3, "Nuclear Flight System Definition Study Phase II Final Report," Dated August 1970.

11.4 SD70-117-2, "Nuclear Flight System Definition Study Phase II Final Report," Dated August 1970.

12.0 REQUIREMENT ALLOCATION SHEET

Requirement Allocation Sheets (RAS) have been prepared for the orbital and flight functions of the Class I missions. These sheets of Table 12-1 contain the results of the analysis of each function of the functional flow diagrams (FFD). The requirements identified on the RAS are coded by function name and number so that they are directly related to specific blocks of the FFD's. The objective of the design requirement entries on the RAS are to (1) establish functional and design requirements which will eventually be included into the design requirements section of the Part I Detail Specification (CEI); (2) initiate recognition of intrasystem and intersystem interface requirements and facility requirements; and (3) initiate recognition of personnel requirements.

Design Requirement entries include: (1) description of the function; (2) specific design characteristics created by the function; i.e., input, output, performance values and allowable quantitative tolerances. Maintenance requirements will be identified where applicable; (3) requirements which constrain or have significant influence on design; and (4) functional and physical interface with other program elements.

Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	PROVIDE LOGISTIC SUPPORT (CLASS I & II) - 2.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
2.0 - Provide Logistic Support	The baseline RNS operations orbit for assembly, Earth orbit operations, and Earth orbit launch of the RNS will be 260 N.Mi circular orbit at an inclination of 31.5°. All logistics operations such as checkout, maintenance, expendables replenishment, etc., will be performed in the RNS operations orbit.	PD-SA-P-70-63 (MSFC)			

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Table 12-1 **REQUIREMENTS ALLOCATION SHEETS**

FUNCTIONAL DIAGRAM TITLE & NO.: RENDEZVOUS IN RNS OPERATIONS ORBIT (CLASS I & II) - 2.0

NOMENCLATURE & NO. OF CEI:

FUNCTION NAME & NO.	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIPMENT IDENT.	
				NAME	CEI NO.
2.1 Rendezvous in RNS Operations Orbit	RNS will rendezvous with the maintenance element and tug for performing post boost operations and/or demating RNS return payload.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO. RENDEZVOUS IN RNS OPERATIONS ORBIT (CLASS I & II) - 2.1

NOMENCLATURE & NO. OF CEI

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
2.1.1 Perform Cool-down Const.	Upon return of the RNS to the 270 n mi Earth orbit, a 24-hour cooldown will be initiated prior to performing any maintenance operations. During latter portion of cooldown, when time between cooldown pulses are TBD minutes and the radiation level at the payload is TBD rad, the payload will be removed from the RNS by the space tug. The tug approach pattern must not exceed a half cone angle of 20 degrees from the longitudinal axis when within 150 feet of the RNS. The RNS will maintain an attitude hold orientation during the rendezvous and payload transfer operation.	SD 70-117-2 (NAR) PDS 70-242 (NAR)			
2.1.2 Transfer to RNS Operations Orbit	All assembly, logistic, and maintenance operations will take place in the RNS operations orbit defined as 260 n mi, 31.5° inclination. The reaction control system is to be utilized in transferring the returning RNS from the 270 to 260 n mi orbit for rendezvous with the maintenance element and/or propellant depot. A delta V of 34 FPS will be required to perform this maneuver. RNS acquisition and tracking requirements prior to transfer are:	PD-SA-P-70-63 (MSFC) SD 70-117-2 (NAR) PDS70-242 (NAR)			

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Table 12-1 **REQUIREMENTS ALLOCATION SHEETS**	
FUNCTIONAL DIAGRAM TITLE & NO.	RENDEZVOUS IN RNS OPERATIONS ORBIT (CLASS I & II) - 2.1
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NO.	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIPMENT IDENT.	
				NAME	CEI NO.
2.1.2 Cont. Transfer to Operations Orbit	Detection (3σ) - 100 N.Mi. Range Accuracy (3σ) ± 0.02% Radar Range Rate Acc. (3σ) ± 6 FPS The passive vehicle must provide a cooperative target.				
2.1.3 Station Keep for Payload Transfer	When the payload transfer is made in the 260 N.Mi, 31.5° inclination orbit, the RNS will take up a station keeping position TBD feet (miles) from the maintenance element and assume an attitude hold orientation until the Space Tug removes the payload and departs the vicinity of the RNS station. The RNS will be the passive element during the rendezvous.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	RENDEZVOUS IN RNS OPERATIONS ORBIT (CLASS I & II) - 2.1
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NO.	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIPMENT IDENT. NAME	EQUIPMENT IDENT. CEI NO.
2.1.4 Rendezvous and Dock with Maint. Element	The RNS is the active vehicle while rendezvousing and docking to the maintenance element. The maintenance element must be cooperative during this maneuver. At ±3.94 inch range accuracy requirement is the 3σ value for the docking maneuver. The 3σ range rate accuracy for a scanning laser radar (SLR) is ± 1% of ± 0.167 inches (whichever is greater). Radar angular accuracy is to be 0.6° and SLR angular accuracy is to be ± 0.02°. Docking position and impact parameters shall not be exceeded for an RNS to maintenance element docking. a. Centerline Miss Distance ± inches b. Miss Angle ± degrees c. Longitudinal velocity FPS (max) d. Lateral velocity FPS (max) e. Angular velocity FPS (max) The RNS will have the active neuter docking system at the forward skirt.	PDS70-242 (NAR)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	PROVIDE LOGISTIC SUPPORT (CLASS I & II) - 2.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NO.	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIPMENT IDENT.	
				NAME	CEI NO.
2.2 Perform Post Boost Operations	RNS post boost operations will include removal of boost protective equipment, rendezvous of RNS tank with maintenance element, assembling NERVA engine to RNS tank, and removal of stage and engine launch safety devices.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	PERFORM POST BOOST OPERATIONS (CLASS I & II) - 2.2
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
2.2.1 Detach Boost Equipment	Boost shrouds used for launch which are not jettisoned during boost must be removed prior to engine mating operations.	SD 70-184-3 (NAR)			
2.2.2 Acquire and Track Maint. Element	RNS is the active vehicle in rendezvous with the maintenance element. Prior to initiating the rendezvous maneuver, the maintenance element must be acquired by the RNS radar and tracked for TBD minutes to establish position relative to the RNS. Acquisition and tracking requirements prior to transfer are: Detection (3σ) n mi Range Accuracy (3σ) ± % Radar Range Rate Acc. (3σ) ± FPS				
2.2.3 Transfer Engine Module From Space Shuttle	Engine module may be transferred directly from the orbiter to the RNS tank after engine deployment from the orbiter cargo bay.				

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Table 12-1 **REQUIREMENTS ALLOCATION SHEETS**

FUNCTIONAL DIAGRAM TITLE & NO.	PERFORMANCE POST BOOST OPERATIONS (CLASS I & II) - 2.2
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NO.	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIPMENT IDENT. NAME	EQUIPMENT IDENT. CEI NO.
2.2.4 Mate Engine Module with RNS	The RNS/maintenance element will be passive during the engine mating operation performing an attitude hold orientation. Position and impact parameters shall not be exceeded for an engine to RNS tank docking. a. Centerline Miss Distance ± inches b. Miss Angle ± degrees c. Longitudinal velocity FPS (max) d. Lateral Velocity FPS (max) e. Angular Velocity FPS (max) Structural linkage shall utilize neuter docking mechanism. Mechanical (lines, tubes) linkage shall utilize TBD fastening devices. Electrical connections shall utilize TBD connectors.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS					
FUNCTIONAL DIAGRAM TITLE & NO.	PROVIDE LOGISTIC SUPPORT (CLASS I & II) - 2.0				
NOMENCLATURE & NO. OF CEI					
FUNCTION NAME & NO.	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIPMENT IDENT.	
				NAME	CEI NO.
2.3 Demate Shuttle Return Payload	Payload transfer may be accomplished by Tug. The RNS will maintain attitude control while the payload is maneuvered and docked to the RNS (or undocked from the RNS).	PD-SA-P-70-63 (MSFC)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	DEMATE SHUTTLE RETURN PAYLOAD (CLASS I & II) - 2.3
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
2.3.1 Orient and Hold RNS in Demating Attitude	RNS will be oriented in line-of-flight attitude and held in this attitude for the tug rendezvous and dock maneuver. This attitude will be held until the tug completes the demating operation and departs the vicinity of the RNS.				
2.3.2 Tug rendezvous With RNS	The RNS will be the passive during the tug rendezvous maneuver providing a target as required by tug.				
2.3.3 Dock Tug to Payload	Position and impact parameters shall not be exceeded for a tug to payload docking: a. Centerline Miss Distance ± TBD in. b. Miss Angle ± TBD degrees c. Longitudinal Velocity TBD FPS (max) d. Lateral Velocity TBD FPS (max) e. Angular Velocity TBD FPS (max)				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	DEMATE SHUTTLE RETURN PAYLOAD (CLASS I & II) - 2.3
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NO.	DESIGN REQUIREMENT	REFERENCE SOURCE OF STUDY	FACILITY REQUIREMENTS	EQUIPMENT IDENT.	
				NAME	CEI NO.
2.3.4 Demate Payload from RNS	Verification of positive tug/payload docking will be made prior to RNS-payload release. This verification signal will be made by means of TBD and the RNS release command made through RF command loop.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	PROVIDE LOGISTIC SUPPORT (CLASS I & II) - 2.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
2.4 Perform Maint. Operations	In-orbit maintenance and propellant refueling of the RNS will be accomplished at the RNS operations orbit. RNS maintenance personnel will not receive more than 25 REM whole body dose per year from the RNS.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	PERFORM MAINTENANCE OPERATIONS (CLASS I & II) - 2.4
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
2.4.1 - Perform Visual Inspection	A visual inspection will be made of the RNS through maintenance element viewing ports and/or by Space Tug. Shielding will be required for visual (via TV cameras) inspection of the engine area. Radiation monitoring will be required preferably by means of both active and passive dosimetry to assure radiation levels TBD RAD - HR^{-1} prior to any scheduled or unscheduled maintenance operations.	SD 70-184-3 (NAR)			
2.4.2 Perform Functional Checkout	The on-board checkout (OBCO) will be utilized to determine status of the RNS subsystems in conjunction with the malfunction detection data stored by the information management system.				
2.4.3 Perform Scheduled Maintenance	Limited life components (such as fuell cells) will be replaced on a periodic cycle. Components reaching operational margins determined by trend data analysis and failure prediction analysis.	SD 70-184-3 (NAR)			
2.4.4 Perform Unscheduled Maintenance	Unscheduled maintenance is defined as that maintenance required as a result of fault detection made during functional checkout or visual inspection on return from a Shuttle flight or following post boost operations. These maintenance operations may fall in the categories of: adjustment, remove and replace, or repair-in-place.	SD 70-184-3 (NAR)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	PERFORM MAINTENANCE OPERATIONS (CLASS I & II) - 2.4
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
2.4.5 - Perform Post Maintenance Checkout	A post maintenance checkout will be made utilizing (OBCO) and maintenance element interfacing equipment to verify system operational readiness. If malfunctions are detected, unscheduled maintenance will be performed followed by another post maintenance checkout. Decision for system readiness with a redundant system out will be mission dependent.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	PROVIDE LOGISTIC SUPPORT (CLASS I & II) - 2.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
2.5 Load RNS Propellant	In-orbit refueling of the RNS will be accomplished in the RNS operations orbit, which is defined as 260 N.Mi. circular inclined at 31.5 degrees.	PD-SA-P-70-63 (MSFC)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	LOAD RNS PROPELLANT (CLASS I & II) - 2.5
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
2.5.1 - Undock RNS from Maint. Elements	Configure RNS subsystems for undocking from maintenance element, rendezvous and dock with propellant depot. Undock and verify RNS/maintenance element undocked by uncouple signal to IMS and visual cue to maintenance crew. Transfer to propellant depot utilizing RNS reaction control system. (Tug may also perform transfer.)				
2.5.2 - Dock RNS to Propellant Depot	The RNS will be the active element in docking to the propellant depot. n γ radiation monitoring will be required prior to propellant transfer operations to assure that radiation level does not exceed TBD RAD - HR^{-1}. Position and impact parameters will not be exceeded for RNS to propellant depot docking. a. Centerline Miss Distance $\pm$ TBD in. b. Miss Angle $\pm$ TBD degrees c. Longitudinal Velocity TBD FPS (max) d. Lateral Velocity TBD FPS (max) e. Angular Velocity TBD FPS (max)				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	LOAD RNS PROPELLANT (CLASS I & II) - 2.5
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
2.5.3 - Transfer Propellant to RNS	Verify docking mechanism locked. Engage propellant transfer line(s). Engage electrical control interfacing connectors. Verify all RNS/propellant interface connections made through interlocking circuit. Prechill fill line(s) until line temperature of TBD °R is reached, and initiate propellant transfer maneuver. Fill RNS tank at TBD GPM under TBD psia. Top RNS stage at TBD GPM under TBD psia. Propellant condition at completion of transfer shall be °R at a pressure between 15.5 to 20 psia. Peak pressure in RNS tank shall not exceed 27.5 psia during filling. Temperature and quantity will be monitored during filling. Secure propellant transfer lines. Verify fill lines secured. Disengage propellant transfer lines. Disengage electrical control connectors. Verify all disengagement completed.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	LOAD RNS PROPELLANT (CLASS I & II) - 2.5
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
2.5.4 Undock RNS from propellant element.	Configure RNS subsystems for undocking from propellant depot. Release and disengage docking mechanism. Separate RNS from propellant depot utilizing RNS reaction control system. Propellant depot will hold attitude and position during undocking operation.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	PROVIDE LOGISTIC SUPPORT (CLASS I & II) - 2.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
2.6 Mate payload to RNS	Payloads for the RNS will be delivered by the logistics vehicle and assembled in the RNS operations orbit. The space tug may be used to maneuver the payload to the RNS.	PD-SA-P-70-63 (MSFC)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	MATE PAYLOAD TO RNS (CLASS I & II) - 2.6
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
2.6.1 Transfer RNS to payload mating position.	Maneuver the RNS to a position TBD feet from the propellant depot for accepting the payload.				
2.6.2 Orient and hold RNS in mating attitude.	The RNS will maintain attitude control while the payload is maneuvered and docked to the RNS. RNS will be oriented in line-of-flight attitude and held in this attitude for tug/payload rendezvous and dock maneuver.	PD-SA-P-70-63 (MSFC)			
2.6.3 Dock payload to RNS.	Position and impact parameters will not be exceeded for payload to RNS docking: Centerline miss distance ± TBD inches Miss angle ± TBD degrees Longitudinal velocity TBD FPS (max) Lateral velocity TBD FPS (max) Angular velocity TBD FPS (max)				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	PROVIDE LOGISTIC SUPPORT (CLASS I & II) - 2.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
2.7 Checkout mated RNS/Payload.	Final automatic checkout of the vehicle occurs after payload docking.	PD-SA-P-70-63 (MSFC)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	CHECKOUT MATED RNS/PAYLOAD (CLASS I & II) - 2.7
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
2.7.1 Verify all RNS/ Payload Connections Made.	Utilizing interlock circuitry and OBCO equipment verify all RNS/Payload connections are made. Unmanned payloads verifications items: mechanical docking TM Data RNS/Cargo module verification items: mechanical docking oxygen water voice communications alarm electrical power override command T/M data RNS/Tug Payload Mechanical docking voice (back up) alarm override command T/M data $n\ \gamma$ Radiation dosimetry and associated monitoring equipment.	SD70-184-6 (NAR)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO. CHECKOUT MATED RNS/PAYLOAD (CLASS I & II) - 2.7

NOMENCLATURE & NO. OF CEI

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
2.7.2 Demate P/L delivery element.	The payload delivery element (space tug or space shuttle orbiter) will undock from the RNS/Payload vehicle and take up a station keeping position TBD feet from the RNS/Payload vehicle. Station keeping position will be held until automatic checkout of RNS/Payload is completed.				
2.7.3 Checkout mated RNS/Payload.	RNS will maintain attitude hold throughout automated checkout of mated vehicle. Automatic checkout performed by OBCO equipment may be initiated by manned payload or other space program through the command link. Status of RNS/Payload vehicle will be transmitted to space program mission control and the manned payload through the RNS information management system.	SD70-184-3 (NAR)			
2.7.3 Perform Malfunction Contingency Operation.	Malfunction contingency operation will be determined by space program mission control and the nature of the malfunction. Assistance may be required from tug in station keeping position or the maintenance element.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATIONS PHASE (CLASS I) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.0 Conduct Mission/ RNS Operations Phase	The baseline RNS operations orbit for assembly, Earth orbit operations, and Earth orbit launch of the RNS will be 260 n mi circular orbit at an inclination of 31.5°. <u>Class I:</u> Lunar/Geosynchronous Orbit Shuttle Missions The RNS will be used to transport manned and unmanned payloads between low Earth orbit and lunar orbit. Lunar arrival/ departure orbit altitude is 60 n mi. Lunar arrival/departure orbit inclination is 90 degrees. Midcourse delta-V is 50 fps per mission leg. The RNS will be used to transport manned and unmanned payloads between low Earth orbit and geosynchronous orbit. Geo-synchronous arrival/departure orbit inclination is 0 degrees. Midcourse correction delta-V is 50 fps per mission leg. Earth orbit arrival/departure orbit is 260 n mi inclined 31.5 degrees. The RNS stage life in space is three years with maintenance in Earth orbit. Meteoroid protection will be provided for the three year stage life.	PD-SA-P-70-63			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATIONS PHASE (CLASS I) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.0 (cont)	Engine operating time shall be utilized in multiple cycles up to 60, of varying lengths totaling a minimum of 600 minutes (10 hours). All operations at rated temperatures shall be considered as part of the 600 minute endurance.	SNPO-NPRD-1 Rev. 8			
	Operational interfaces with other space program elements will include the following: INT-21 launch vehicle, space shuttle, space tug, maintenance element, propellant depot, space stations (Earth and lunar), manned, and unmanned payloads.				
	RNS design shall provide environmental protection both induced and natural, from launch through mission duration (i.e., terrestrial, Earth orbit space, cislunar space, lunar orbit space, cisplanetary space, and planetary space). Electrical power, guidance, navigation, control, and two-way communications will be provided as required throughout the entire mission.	SD70-117-3 (NAR)			
	The RNS will be designed for 28 day thermal cycle in class I and II missions. A payload penalty for boiloff will be taken on round trip missions exceeding 28 days.	SD70-184-6			

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FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATIONS PHASE (CLASS I) - 1.0				
NOMENCLATURE & NO. OF CEI					
FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.1 Perform Pre-injection Operations	The total integrated radiation dose from the RNS to any manned space station or manned orbital system will not exceed 0.1 rem during single NERVA engine burn.	PD-SA-P -70-63 (MSFC)			
	The RNS will maneuver to a 270 n mi orbit utilizing the RNS reaction control system (or space tug) to provide a separation distance between the RNS and manned orbital system prior to starting the NERVA engine. Guidance system data will be verified and updated as required prior to initiating Earth departure thrusting.	SD70-117-2 (NAR)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO. PERFORM PREINJECTION OPERATIONS (CLASS I) - 1.1

NOMENCLATURE & NO. OF CEI

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.1.1 Transfer to Departure Orbit	A delta-V of 17 fps will be provided by the RNS reaction control system (RCS) to transfer to a 270 n mi - 31.5 degree inclined orbit.	SD70-117-2 (NAR)			
1.1.2 Circularize in Departure Orbit	After coast of ≈ 44 minutes, a delta-V of 17 fps will be provided by the RNS RCS to circularize in 270 n mi orbit.	SD70-117-2 (NRA)			
1.1.3 Initialize G&N System	The ephemeris data in the guidance and navigation system will be verified and updated as required prior to initiating Earth departure thrusting. Verification and update shall be accomplished within TBD minutes and TBD minutes prior to starting NERVA engine.				
1.1.4 Orient for NERVA Thrusting	Orient the RNS/payload vehicle for the TLI/SOT thrusting maneuver. Orientation shall be accomplished within TBD minutes and TBD minutes prior to NERVA engine start.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATIONS PHASE (CLASS I) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.2 Provide TLI/SOT Thrust	The NERVA engine will be run for the time duration necessary to impart the required delta-V to the vehicle to inject it on a translunar or synchronous orbit transfer trajectory.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Provide TLI/SOT Thrust (Class I) - 1.2
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.2.1 Provide TLI_1/ PEI Thrust	Configure RNS systems for NERVA engine run. Initiate NERVA engine preconditioning 2.17 minutes prior to engine start TLI, thrust - impart 5000 fps delta-V to vehicle. NERVA start through pump tailoff (PTO) ≈ 1620 seconds.	S130-CP 090290-AF1 Fig. 5.2.2 SD70-184-5			
	PEI thrust - impart 4230 fps delta-V to vehicle. NERVA start thru PTO ≈ 1335 seconds.	SD70-184-6			
1.2.2 Maintain Vehicle Thrust Orientation	Maintain vehicle thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
1.2.3 Shutdown Engine	Initiate engine shutdown upon reaching TLI, delta-V of 4984 fps or PEI delta-V of 2584 fps. Verify thrusting of RNS has terminated.	SD70-184-5			
1.2.4 Initiate Engine Cooldown	NERVA engine cooldown will be initiated at the completion of pump tail off. Cooldown propellant requirements and cooldown time is a function of engine run duration and will be accomplished in accordance with engine interface requirements (NPRD -1 and S-130-CP090290).	S130-CP 090290-AF1 (ANSC)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Provide TLI/SOT Thrust (Class I) - 1.2
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.2.5 Maintain Vehicle Cooldown Orientation	Maintain vehicle cooldown thrust orientation within the following flight path limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree TLI_1 to TLI_2 cooldown = 4 hours PEI to AEI cooldown = 3.2 hours				
1.2.6 Coast to TLI_2/ AEI Burn	TLI_1 to TLI_2 coast duration is approximately 4 hours. Update navigation state vector. PEI to AEI coast duration is approximately 3.2 hours. Update navigation state vector.				
1.2.7 Orient for TLI_2/ AEI Thrust	Orient the RNS/payload vehicle for the TLI_2/AEI thrusting maneuver. Orientation shall be accomplished within TBD minutes and TBD minutes prior to NERVA engine start.				
1.2.8 Provide TLI_2/ AEI Thrust	Configure RNS systems for NERVA engine run. Initiate NERVA engine preconditioning 2.17 minutes prior to engine start. TLI_2 thrust - impart 5010 fps delta-V to vehicle. NERVA start thru PTO $\approx$ 1370 seconds.	S-130-CP 090209-AFI (ANSC) SD70-184-5			

Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Provide TLI/SOT Thrust (Class I) - 1.2
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.2.8 (contd)	AEI thrust - impart 3636 fps delta-V to vehicle. NERVA start thru PTO ≈1370 sec.	SD70-184-6			
1.2.9 Maintain Vehicle Thrust Orientation	Maintain vehicle thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
1.2.10 Shutdown Engine	Initiate engine shutdown upon reaching TLI_2 delta-V of 4996 fps or AEI delta-V of 3608 fps. Verify thrusting of RNS has terminated.				
1.2.11 Initiate Engine Cooldown	NERVA engine cooldown will be initiated at the completion of pump tailoff. Cooldown propellant requirements and cooldown time is a function of engine run duration and will be accomplished in accordance with engine interface requirements (NPRD-1 and S-130-CP090290).	S-130-CP 90209-AF1 (ANSC)			
1.2.12 Maintain Vehicle Cooldown Orientation	Maintain vehicle cooldown thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree TLI_2 to MCC cooldown time 10 hrs AEI to MCC cooldown time 2 hrs				

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FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATIONS PHASE (CLASS I) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.3 Perform TLI/SOT Coast Operations	Engine cooldown will continue during coast period until cooldown is complete or until next engine run. Vehicle position will be determined and updated during coast and midcourse corrections made as required.	SD70-184-5 (NAR)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Perform TLI/SOT Coast Operations (Class I) - 1.3
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.3.1 Determine Mid-course Correction Requirements	Vehicle position will be determined and updated during coast phase of flight. Mid-course corrections requirement will be determined from on-board sensor data and on-board navigation computations. Time of midcourse correction will be made to allow time for vehicle reorientation and engine preconditioning. The navigation sensors will be oriented to sight on predetermined planetary or celestial bodies. Sensors will be capable of the following excersions: Star tracker ± TBD degrees Horizon sensor ± TBD degrees				
1.3.2 Orient for Mid-course Correction Thrusting	Orient vehicle for the midcourse correction thrusting maneuver. Orientation shall be accomplished within TBD minutes and TBD minutes prior to NERVA engine startup.				
1.3.3 Hold Orientation For MCC Thrusting	Vehicle MCC thrust orientation will be maintained within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.: Perform TLI/SOT Coast Operations (Class I) - 1.3

NOMENCLATURE & NO. OF CEI:

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.3.4 Provide MCC Thrust as Req.	Configure RNS system for NERVA engine run. Initiate NERVA preconditioning 2.17 minutes prior to engine start. MCC delta-V 50 fps (max) NERVA start thru PTO ≈ 520 seconds.	S130-CP-090290-AF1 Fig. 5.2.2 SD70-184-5			
1.3.5 Orient and Hold Attitude for Cooldown	Orient vehicle to obtain maximum cooldown thrusting benefit. Maintain vehicle cool-down thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
1.3.6 Continue Cooldown	Continue cooldown to completion on next NERVA engine run. MCC to LOI = 82 hours MCC to SOI = 3.3 hours	 SD70-184-5 SD70-184-6			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATION PHASES (CLASS I) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.4 Provide LOI/ SOI Thrust	The RNS/payload vehicle will be oriented for LOI/SOI thrusting. The NERVA engine will be operated at full power for a time sufficient to impart the required delta-V to the vehicle for lunar orbit insertion or synchronous orbit insertion.				

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FUNCTIONAL DIAGRAM TITLE & NO.	Provide LOI/SOI Thrust (Class I) - 1.4
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.4.1 Orient Vehicle for LOI/SOI Thrust	Orient vehicle for the LOI/SOI thrusting maneuver. Orientation shall be accomplished within TBD minutes and TBD minutes prior to NERVA engine start.				
1.4.2 Provide LOI/ SOI Thrust	Configure RNS system for NERVA engine run. Initiate NERVA preconditioning 2.17 minutes prior to engine start.	S130-CP 090290-AF1 Fig. 5.2.2			
	LOI thrust - impart 2680 fps delta-V to vehicle. NERVA start thru PTO ≈ 710 seconds.	SD70-184-5			
	SOI thrust - impart 5911 fps delta-V to vehicle. NERVA start thru PTO ≈ 1300 seconds.	SD70-184-6			
1.4.3 Maintain Vehicle Thrust Orientation	Maintain vehicle thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
1.4.4 Shutdown Engine	Initiate engine shutdown upon reaching LOI delta-V of 2630 fps or SOI delta-V of 5876 fps. Verify thrusting of RNS has terminated.				

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FUNCTIONAL DIAGRAM TITLE & NO.	Provide LOI/SOI Thrust (Class I) - 1.4
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.4.5 Initiate Engine Cooldown	NERVA engine cooldown will be initiated at the completion of PTO, cooldown will be accomplished in accordance with engine interface requirements (NPRD-1 and S-130-CP090290).	S-130-CP 090290-AF1 (ANSC)			
1.4.6 Maintain Vehicle Cooldown Orientation	Maintain vehicle cooldown thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
	LOI to orbit adjust 12 hours	SD70-184-5			
	SOI to orbit adjust 24 hours	SD70-184-6			

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FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATIONS PHASE (CLASS I) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.5 Rendezvous With OLS/GOS	The RNS/payload vehicle will rendezvous with the OLS/GOS and take up a station keeping. During lunar or geosynchronous orbit operations, the RNS will remain at a safe distance from and in the same orbit as the lunar or geosynchronous space station. n, γ radiation monitoring will be required to assure radiation level $\leq$ TBD rad-hr^{-1} at the lunar or geosynchronous orbit space station.	PD-SA-P-70-63 (MSFC)			

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FUNCTIONAL DIAGRAM TITLE & NO.	Rendezvous With OLS/GOS (Class I) - 1.5
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.5.1 Acquire OLS/GOS and Track	RNS is the active vehicle in the rendezvous with the OLS/GOS. Prior to initiating the rendezvous maneuver to the OLS/GOS station keeping position, the RNS must acquire and track the OLS TBD minutes or GOS TBD minutes to establish position relative to RNS. OLS acquisition and tracking requirements prior to transfer are: Detection (3σ) TBD n mi Range accuracy (3σ) ± TBD % Radar range rate acc. (3σ) ± TBD fps GOS acquisition and tracking requirements prior to transfer are Detection (3σ) TBD n mi Range accuracy (3σ) ± TBD % Radar range rate acc. (3σ) TBD fps				
1.5.2 Maneuver to Payload Transfer Position	The RNS RCS will be utilized to transfer to the station keeping position 10 n mi from OLS/GOS for payload transfer.	SD70-117-2			
1.5.3 Hold Attitude for Payload Transfer	RNS will be oriented in line-of-flight attitude and held in this attitude for the tug rendezvous and dock maneuver. This attitude will be held until the tug completes the demating operation and departs the vicinity of the RNS.				

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FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATIONS PHASE (CLASS I) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.6 Perform Lunar/ Geosynchronous Orbit Operations	RNS lunar/geosynchronous operations will include payload unloading, station keeping and payload mating operations. For extended lunar stay times the RNS may transfer to a remote station keeping position away from the payload transfer position.				

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FUNCTIONAL DIAGRAM TITLE & NO.	Perform Lunar/Geosynchronous Orbit Operations (Class I) - 1.6
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.6.1 Transfer Payload From RNS to OLS/GOS	The RNS will be passive during the tug rendezvous maneuver providing a TBD target as required by the tug. The following impact parameters shall not be exceeded in the tug payload docking: Longitudinal velocity TBD fps (max) Lateral velocity TBD fps (max) Angular velocity TBD fps (max)				
1.6.2 Hold RNS in Station Keeping Position	After payload is demated from RNS by the tug, the RNS will hold a station keeping position until the time for return payload mating by the tug. RNS orientation attitude during station keeping will be inertially fixed in space with a permissible attitude drift of TBD degrees. Position relative to the OLS/GOS shall not be less than TBD n mi.				
1.6.3 Transfer RNS to Dormant Hold Position	In the event the RNS is to stay in lunar orbit for an extensive period of time it may be necessary to position it TBD n mi or over the horizon from the OLS. At this distance the RNS may be permitted to drift in a dormant mode until such time an Earth return payload is ready to be mated to it. Transfer to this position would be accomplished by RNS RCS or space tug.				

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FUNCTIONAL DIAGRAM TITLE & NO.	Perform Lunar/Geosynchronous Orbit Operations (Class I) - 1.6
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.6.4 Switch RNS to Stand-By Mode and Wait For Activation	After RNS is positioned in the dormant wait mode position or station, selected systems will be deactivated to conserve electrical energy. Only the following subsystems will remain energized during the dormant mode. NERVA engine Pressurization Electrical control Environmental control Communications				
1.6.5 Switch RNS to Active Mode	RNS subsystems turned off to place the stage in a dormant mode will be reactivated by command through the communication system. Activation of subsystems required for transfer to the payload mating station keeping position will be verified.				
1.6.6 Transfer RNS to Station Keeping Position	The RNS will be transferred to the payload mating station keeping position utilizing the RNS RCS or space tug.				

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FUNCTIONAL DIAGRAM TITLE & NO.	Perform Lunar/Geosynchronous Orbit Operations (Class I) - 1.6				
NOMENCLATURE & NO. OF CEI					
FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.6.7 Hold RNS Attitude for P/L Mating	The RNS will maintain attitude control while the payload is maneuvered and docked to the RNS. RNS will be oriented in the line-of-flight attitude and held in this attitude for tug/payload rendezvous and docking maneuver.	PD-SA-P-70-63			
1.6.8 Mate Payload to RNS	Position and Impact parameters will not be exceeded for payload to RNS docking: Centerline miss distance ± TBD inches Longitudinal velocity TBD fps (max) Lateral velocity TBD fps (max) Angular velocity TBD fps (max)				
1.6.9 Checkout Mated RNS/Payload Vehicle	Utilizing interlocking circuitry and OBCO equipment verify all RNS/payload connections are made and the RNS/payload vehicle are operationally ready for TE/LO transit operation. Checkout function may be initiated by crew of; payload, tug, or space station.				
1.6.10 Malfunction Contingency Operation	Malfunction contingency operation will be determined by space program mission control and the nature of the malfunction. Assistance may be required by crew of tug, or space station.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.: Perform Lunar/Synchronous Orbit Operations (Class I) - 1.6

NOMENCLATURE & NO. OF CEI:

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.6.11 Transfer to Departure Orbit	A delta-V of 13.5 fps will be provided by RNS RCS to transfer from OLS 60 n mi to 70 n mi lunar orbit. A delta-V of 13.5 fps will circularize the vehicle in the 70 n mi orbit. Coast time between RCS burns is 3 hours. In the case of departure from GOS, a delta-V of 10 fps provided by RNS RCS will give the required separation between space station and RNS prior to NERVA engine run. Coast time from RCS burn to DEI is 24 hours.				
1.6.12 Initialize Navigation System	The ephemeris data in the guidance and navigation system will be verified and updated as required prior to initiating TEI thrusting. Verification and update shall be accomplished within TBD minutes and TBD minutes prior to starting NERVA engine.				
1.6.13 Orient RNS for TEI/LOT Thrusting	Orient the RNS/payload vehicle for the TEI/LOT thrusting maneuver. Orientation shall be accomplished within TBD minutes and TBD minutes prior to starting NERVA engine.				

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FUNCTIONAL DIAGRAM TITLE & NO.	Conduct Mission/RNS Operations Phase (Class I) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.7 Provide TEI/ LOT Thrust	The NERVA engine will be run for the time duration necessary to impart the required delta-V to the vehicle to inject it on a trans-Earth or low Earth orbit transfer trajectory.				

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FUNCTIONAL DIAGRAM TITLE & NO.	Provide TEI/LOT Thrust (Class I) - 1.7
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.7.1 Provide TEI/ DEI Thrust	Configure RNS systems for NERVA engine run. Initiate NERVA engine preconditioning 2.17 minutes prior to engine start. TEI_1 thrust - impart 1850 fps delta-V to vehicle. NERVA start through pump tail-off (PTO) ≈ 370 seconds.	S-130-CP 090290-AF1 SD70-184-5			
	DEI thrust - impart 6011 fps delta-V to vehicle. NERVA start thru PTO ≈800 seconds.	SD70-184-6			
1.7.2 Maintain Vehicle Thrust Orientation	Maintain vehicle thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
1.7.3 Shutdown Engine	Initiate engine shutdown upon reaching TEI_1 delta-V of 1836 fps or DEI delta-V of 5968 fps. Verify thrusting of RNS has terminated.				
1.7.4 Initiate Engine Cooldown	NERVA engine cooldown will be initiated at the completion of pump tail off. Cooldown propellant requirements and cooldown time is a function of engine run duration and will be accomplished in accordance with engine interface requirements (NPRD-1 and S130-CP090290).	S130-CP 090290-AF1 (ANSC)			

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FUNCTIONAL DIAGRAM TITLE & NO. Provide TEI/LOT Thrust (Class I) - 1.7

NOMENCLATURE & NO. OF CEI

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.7.5 Maintain Vehicle Cooldown Orientation	Maintain vehicle cooldown thrust orientation within the following flight path limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree TEI_1 to TEI_2 cooldown = 12 hours DEI to MCC cooldown = 2 hours				
1.7.6 Coast to TEI_2/MCC	TEI_1 to TEI_2 coast curation is approximately 12 hours. Update navigation state vector DEI to MCC coast duration is approximately 2 hours. Update navigation state vector.				
1.7.7 Orient for TEI_2/MCC Thrust	Orient the RNS/payload vehicle for the TEI_2/MCC thrusting maneuver. Orienttation shall be accomplished within TBD minutes and TBD minutes prior to NERVA engine start.				
1.7.8 Provide TLI_2/PEI Thrust	Configure RNS systems for NERVA engine run. Initiate NERVA engine preconditioning TBD minutes prior to engine start. TEI_2 thrust - impart 330 fps delta-V to vehicle. NERVA start thru PTO ≈190 sec. PEI thrust - impart 3636 fps delta-V to vehicle. NERVA start thru PTO ≈480 sec.	S130-CP 090209-AF1 (ANSC) SD70-184-6			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Provide TLI/LOT Thrust (Class I) - 1.7
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.7.9 Maintain Vehicle Thrust Orientation	Maintain vehicle thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
1.7.10 Shutdown Engine	Initiate engine shutdown upon reaching TEI_2 delta-V of 327 fps or PEI delta-V of 3612 fps. Verify thrusting of RNS has terminated.				
1.7.11 Initiate Engine Cooldown	NERVA engine cooldown will be initiated at the completion of pump tailoff. Cooldown propellant requirements and cooldown time is a function of engine run duration and will be accomplished in accordance with engine interface requirements (NPRD-1 and S130-CP090290).	S130-CP 090209-AFI (ANSC)			
1.7.12 Maintain Vehicle Cooldown Orientation	Maintain vehicle cooldown thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree TEI_2 to TEI_3 cooldown time 12 hrs PEI to ROI cooldown time 3.2 hrs	 SD70-184-5 SD70-184-6			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO. Provide TLI/LOT Thrust (Class I) - 1.7

NOMENCLATURE & NO. OF CEI

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.7.13 Coast to TEI_3 Burn	TEI_2 to TEI_3 coast duration is approximately 12 hours. Update navigation state vector.	SD70-184-5			
1.7.14 Orient Vehicle for TEI_3 Burn	Orient the RNS/payload vehicle for the TEI_3 thrusting maneuver. Orientation shall be accomplished within TBD minutes and TBD minutes prior to NERVA engine start.				
1.7.15 Provide TEI_3 Thrust	Configure RNS systems for NERVA engine run. Initiate NERVA engine preconditioning 2.17 minutes prior to engine start. TLI_3 thrust - impart 985 fps delta-V to vehicle. NERVA start through pump tailoff (PTO) ≈ 260 seconds.	S130-CP 090290-AF1 (ANSC) SD70-184-5			
1.7.16 Maintain Vehicle Thrust Orientation	Maintain vehicle thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
1.7.17 Shutdown Engine	Initiate engine shutdown upon reaching TEI_3 delta-V of 977 fps. Verify thrusting of RNS has terminated.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Provide TEI/LOT Thrust (Class I) - 1.7
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.7.18 Cooldown Engine	NERVA engine cooldown will be initiated at the completion of pump tailoff. Cooldown propellant requirements and cooldown time is a function of engine run duration and will be accomplished in accordance with engine interface requirements (NPRD-1 and S130-CP090290).	S130-CP 090290-AF1 (ANSC)			
1.7.19 Maintain Vehicle Cooldown Orientation	Maintain vehicle cooldown thrust orientation within the following flight path limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree TEI_3 cooldown 9 hours	SD70-184-5			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATIONS PHASE (CLASS I) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.8 Perform TEI/ LOT Coast Operations	Engine cooldown will continue during coast period until cooldown is complete or until next engine run. Vehicle position will be determined and updated during coast and midcourse corrections made as required.	SD70-184-5 (NAR) SD70-184-6 (NAR)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Perform TEI/LOT Coast Operations (Class I) - 1.8
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.8.1 Determine Mid-course Correction Requirements	Vehicle position will be determined and updated during coast phase of flight. Mid-course corrections requirement will be determined from on-board sensor data and on-board navigation computations. Time of midcourse correction will be made to allow time for vehicle reorientation and engine pre-conditioning. The navigation sensors will be oriented to sight on predetermined planetary or celestial bodies. Sensors will be capable of the following excersions: Star tracker ± TBD degrees Horizon sensor ± TBD degrees				
1.8.2 Orient for Mid-course Correction Thrusting	Orient vehicle for the midcourse correction thrusting maneuver. Orientation shall be accomplished within TBD minutes and TBD minutes prior to NERVA engine start-up.				
1.8.3 Maintain MCC Thrust Orientation	Vehicle MCC thrust orientation will be maintained within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				

Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Perform TEI/LOT Coast Operations (Class I) - 1.8
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.8.4 Provide MCC Thrust	Configure RNS system for NERVA engine run. Initiate NERVA preconditioning 2.17 minutes prior to engine start. MCC delta-V 50 fps (max). NERVA startup thru PTO ≈ 250 sec.	S130-CP 090290-AF1 SD70-184-5			
1.8.5 Orient and Hold Attitude for Cooldown	Orient vehicle to obtain maximum cool-down thrusting benefit. Maintain vehicle cooldown thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
1.8.6 Coast to EOI/PEI Burn	Attitude during coast to facilitate navigation function will be maintained within the following flight path limits: Pitch ± TBD degrees Yaw ± TBD degrees Roll ± TBD degrees MCC to EOI coast time 73 hours MCC to PEI coast time 3.3 hours	SD70-184-5 SD70-184-6			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATION PHASES (CLASS I) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.9 Provide EOI/ROI Thrust	The RNS/payload vehicle will be oriented for EOI/ROI thrusting. The NERVA engine will be operated at full power for a time sufficient to impart the required delta-V to the vehicle for Earth orbit insertion or return orbit insertion.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.: Provide EOI/ROI Thrust (Class I) - 1.9

NOMENCLATURE & NO. OF CEI:

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
1.9.1 Orient Vehicle for EOI/ROI Burn	Orient vehicle for the EOI/ROI thrusting maneuver. Orientation shall be accomplished within TBD minutes and TBD minutes prior to NERVA engine start.				
1.9.2 Provide EOI/ROI Thrust	Configure RNS system for NERVA engine run. Initiate NERVA preconditioning 2.17 minutes prior to engine start.	S130-CP 090290-AF1			
	EOI thrust - impart 9850 fps delta-V to vehicle. NERVA start thru PTO ≈990 sec.	SD70-184-5			
	ROI thrust - impart 4140 fps delta-V to vehicle. NERVA start thru PTO ≈470 sec.	SD70-184-6			
1.9.3 Maintain Vehicle Thrust Orientation	Maintain vehicle thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
1.9.4 Shutdown Engine	Initiate engine shutdown upon reaching EOI delta-V of 9650 fps or ROI delta-V of 4117 fps. Verify thrusting of RNS has terminated.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Provide LOI/SOI Thrust (Class I) - 1.9
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.9.5 Initiate Engine Cooldown	NERVA engine cooldown will be initiated at the completion of PTO. Cooldown will be accomplished in accordance with engine interface requirements (NPRD-1 and S130-CP090290).	S130-CP 090290-AFI (ANSC)			
1.9.6 Maintain Vehicle Cooldown Orientation	Maintain vehicle cooldown thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree EOI to hoh. trans. 24 hours ROI to Hoh. trans. 24 hours				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATIONS PHASE (CLASS II) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.0 Conduct Mission/ RNS Operations Phase	The baseline RNS operations orbit for assembly, Earth orbit operations, and Earth orbit launch of the RNS will be 260 n mi circular orbit at an inclination of 31.5°.	PD-SA-P-70-63			
	Class II: Unmanned Planetary Mission				
	The RNS will be used to inject unmanned payloads on planetary intercept trajectories after which the RNS will return to the operations orbit for reuse. The RNS may be disposed of from the injection trajectory if it has reached its end-of-life time. Earth departure/arrival orbit is 260 n mi inclined at 31.5°.				
	The RNS stage life in space is three years with maintenance in Earth orbit. Meteoroid protection will be provided for the three year stage life.				
	Engine operating time shall be utilized in multiple cycles up to 60 of varying lengths totaling a minimum of 600 minutes (10 hrs). All operations at rated temperatures shall be considered as part of the 600 minute endurance.	SNPO-NPRD-1 Rev. 8			
	Operational interfaces with other space program elements will include the following: INT-21 launch vehicle, space shuttle, space tug, maintenance element, propellant depot,				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	CONDUCT MISSION/RNS OPERATIONS PHASE (CLASS II) - 1.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
1.0 cont.	and unmanned payloads.				
	RNS design shall provide environmental protection from launch through mission duration (i.e., terrestrial, Earth orbit space, CIS lunar space, lunar orbit space, CIS planetary space, and planetary space). Electrical power guidance, navigation, control, and two-way communications will be provided as required throughout the entire mission.	SD70-117-3 (NAR)			
	The RNS will be designed for a 28 day thermal cycle for class I and II missions. A payload penalty for boiloff will be taken on round trip missions exceeding 28 days.	SD70-184-6 (NAR)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Perform End-Of-Life Disposal 3.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
3.0 Perform End-Of-Life Disposal	The RNS or NERVA alone will be disposed of in long life geocentric orbit or in heliocentric orbit at the end of vehicle or NERVA life. Disposal modes will vary and be dependent on disposal location as well as disposal configuration (i. e., entire RNS or NERVA alone). Tug assistance will be required for NERVA disposal whereas the RNS may or may not require Tug assistance contingent upon its operational status.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Perform End-Of-Life Disposal (Class I) - 3.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
3.1 Dispose of RNS in Heliocentric Orbit	The spent RNS may be disposed of in heliocentric orbit from RNS operations orbit, synchronous orbit or lunar orbit. The delta-V's listed below are required from the various mission locations. Location — Delta-V RNS operations orbit — 11,000 fps Geosynchronous orbit — 4,500 fps Lunar orbit — 3,500 fps				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Dispose of RNS in Heliocentric Orbit (Class I) - 3.1
NOMENCLATURE & NO. OF CEI	(RNS Self Disposal)

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
3.1.1 Provide Escape Thrust	Configure RNS systems for NERVA run. Initiate NERVA preconditioning 2.17 min. prior to engine start impart 11,000 fps delta-V to RNS. NERVA start thru PTO ≈ 538 sec.				
3.1.2 Maintain Vehicle Thrust Orientation	Maintain RNS thrust orientation within the following limits during NERVA thrusting. Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
3.1.3 Shutdown Engine	Initiate engine shutdown upon reaching escape delta-V of TBD fps.				
3.1.4 Cooldown Engine	NERVA engine cooldown will be initiated at the completion of pump tailoff. Cooldown propellant requirements and cooldown time is a function of engine run duration and will be accomplished in accordance with engine interface requirements (NPRD-1 and S-130-CP090290)	S-130-CP090209 AF1 (ANSC)			

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO. Dispose of RNS in Heliocentric Orbit (Class I) - 3.1

NOMENCLATURE & NO. OF CEI

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
3.1.5 Maintain Vehicle Cooldown Orientation	Maintain vehicle cooldown thrust orientation within the following limits: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree Escape thrust cooldown ≈55 hours.				
3.1.6 Orient Vehicle for MCC Thrust	Orient vehicle for midcourse correction thrusting maneuver. Orientation shall be accomplished within TBD minutes and TBD minutes prior to NERVA startup.				
3.1.7 Provide MCC Thrust	Configure RNS system for NERVA run. Initiate NERVA preconditioning 2.17 min. prior to start. MCC delta-V 50 fps. NERVA startup thru PTO ≈ 250 sec.				
3.1.8 Maintain Vehicle MCC Orientation	RNS MCC thrust orientation will be maintained within the following limits during NERVA thrusting: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
3.1.9 Shutdown Engine	Initiate engine shutdown upon achieving required MCC delta-V.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Dispose of RNS in Heliocentric Orbit (Class I) - 3.1
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
3.1.10 Switch to Dormant Mode	Systems not required for monitoring RNS system status will be de-energized. The following systems will remain activated to depletion of power supply reactants and battery life. NERVA Pressurization Electrical control Communications				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Perform End-Of-Life Disposal (Class I) - 3.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
3.2 Dispose of RNS in Earth Orbit	The spent RNS may be disposed of in long life (1000 year) Earth orbit of 660 n mi or greater. Delta-V required for transfer from RNS operations orbit to 660 n mi orbit (45° inc) is 6,500 fps. Disposal to a 20,325 n mi circular orbit from geosynchronous orbit requires a delta-V of 220 fps.				

Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO. Dispose of RNS in Earth Orbit (Class I) - 3.2

NOMENCLATURE & NO. OF CEI

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
3.2.1 Provide Perigee Thrust	Configure RNS systems for NERVA run. Initiate NERVA preconditioning 2.17 min. prior to engine start. Impart 3250 fps delta-V to RNS. NERVA start thru PTO ≈ TBD sec.	S130-CP090290 (Fig 5.2.2) (ANSC)			
3.2.2 Maintain RNS Thrust Orientation	Maintain RNS thrust orientation within the following limits during NERVA thrusting: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
3.2.3 Shutdown Engine	Initiate engine shutdown upon reaching a delta-V of TBD fps. Verify NERVA thrusting has terminated.				
3.2.4 Cooldown and Coast to Apogee	Initiate cooldown at PTO and hold cooldown attitude to achieve maximum benefit from cooldown thrust. Coast time between perigee and apogee burn is ≈ 50 minutes.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Dispose of RNS in Earth Orbit (Class I) - 3.2
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
3.2.5 Orient RNS for Apogee Burn	Orient RNS stage for apogee the thrusting maneuver. Orientation shall be accomplished within TBD minutes and TBD minutes prior to NERVA start.				
3.2.6 Provide apogee Thrust	Configure RNS systems for NERVA run. Initiate NERVA preconditioning 2.17 min. prior to engine start. Impart 3250 fps delta-V to RNS. NERVA start to PTO ≈ TBD sec.				
3.2.7 Maintain RNS Thrust Orientation	Maintain RNS thrust orientation within the following limits during NERVA thrusting: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
3.2.8 Shutdown Engine	Initiate engine shutdown upon reaching a delta-V of TBD fps.				
3.2.9 Cooldown Engine	Initiate cooldown APTO and hold cooldown attitude to achieve maximum benefit from cooldown thrust.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Dispose of RNS in Earth Orbit (Class I) - 3.2
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT. NAME	EQUIP. IDENT. CEI NO.
3.2.10 Maintain RNS Cooldown Orientation	Maintain RNS cooldown orientation within the following limits during NERVA cooldown: Pitch ± TBD degrees Yaw ± TBD degrees Roll ± TBD degrees				
3.2.11 Switch to Dormant Mode	Systems not required for monitoring RNS system status will be de-energized. The following systems will remain activated to depletion of power supply reactants and battery life: NERVA Pressurization Electrical Control Communications				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Perform End-Of-Life Disposal (Class II) - 3.0
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
3.1 Dispose of RNS in Heliocentric Orbit	The RNS disposal to heliocentric orbit from Class II injection trajectory will require a delta-V of approximately 25 fps.				

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Table 12-1 REQUIREMENTS ALLOCATION SHEETS

FUNCTIONAL DIAGRAM TITLE & NO.	Dispose of RNS in Heliocentric Orbit (Class II) 3.1
NOMENCLATURE & NO. OF CEI	

FUNCTION NAME & NUMBER	DESIGN REQUIREMENT	REFERENCE SOURCE OR STUDY	FACILITY REQUIREMENTS	EQUIP. IDENT.	
				NAME	CEI NO.
3.1.1 Provide Disposal Thrust	Configure RNS system for NERVA run. Initiate NERVA preconditioning 2.17 min. prior to start. Provide disposal delta-V of 25 fps.				
3.1.2 Maintain RNS Thrust Orientation	RNS thrust orientation will be maintained within the following limits during RCS thrusting: Pitch ± TBD degree Yaw ± TBD degree Roll ± TBD degree				
3.1.3 Shutdown RCS	Initiate RCS shutdown upon achieving required delta-V.				
3.1.4 Switch to Dormant Mode	Systems not required for monitoring RNS system status will be de-energized. The following systems will remain activated to depletion of power supply reactants and battery life. NERVA Pressurization Electrical control Communications				

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13.0 TIME LINES

Operational time lines have been prepared for ground and space operations. The ground operations include cold and hot test operations, and KSC Operations whereas the space operation time lines cover orbital assembly, reference lunar mission, turnaround operations and the reference synchronous orbit mission.

COLD FLOW AND HOT TEST TIME LINES

Detailed analysis of the cold and hot test programs are discussed in detail in Volume III, Section 2.0. However, this section presents the overall time lines required to accomplish the cold flow and hot test programs.

Figure 13-1 presents the cold flow test cycle. The cold flow test article configured with prototype flight hardware will be utilized during the cold flow development program. The test program includes no special simulation of propellant heating phenomena. Propellant heat transfer only to the extent of that occurring under extended duration exposure to ambient environment will be considered during cold flow testing.

The cold flow test program consists of five phases:

1. Facility and tank activation and tanking
2. Tanking and low propellant feed tests
3. Tanking and propellant feed tests to full rated flow
4. Integrated propulsion and system testing
5. Operational and modification support

Phases 1, 2, and 3 will be conducted under support equipment manual control mode. Phase 4 and 5 will be conducted utilizing support equipment automatic checkout capability.

The cold flow test program which is estimated to last approximately nine months will provide:

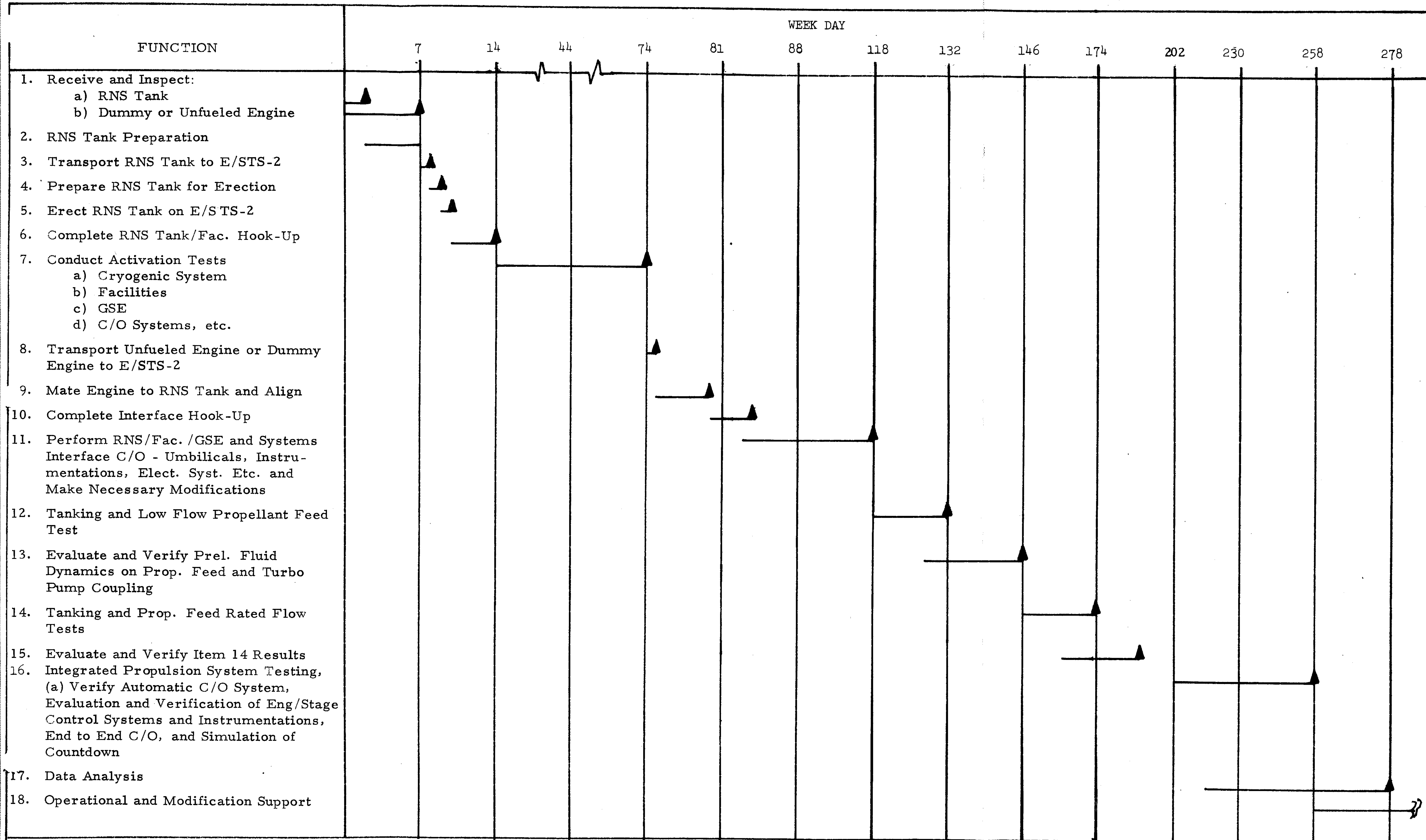


Figure 13-1. Cold Flow Test Cycle

Early verification of the design, manufacturing process, test procedures, and performance of the prototype systems under cryogenic environment.

Confidence for cold flow and hot testing operations at NRDS by maximizing NRDS hot testing through minimizing cold flow problems.

Confidence and verification of propellant transfer procedures and techniques.

Develop operational and emergency procedures.

Train test team personnel prior to involvement with hot testing program.

At the completion of the cold flow test program, the cold flow test article will be utilized for the hot test program. Figure 13-2 depicts the hot test cycle which is estimated to run approximately two years.

The hot test program as envisioned will yield data that will allow for evaluation and verification of the integrated RNS tank design combined with NERVA engine. For example, a typical full power full duration test series is outlined in item 8, Figure 13-2.

The mission flight profile cannot be simulated completely because of extensive facility requirements associated with the vacuum environment. Emphasis should be placed on simulation of the engine burn and subsequent cool-down portion of the cycle. This will afford means of evaluating the effect of the operational mission cycle on the various subsystems, i.e., propellant feed and GN&C.

At present it is estimated that two simulated mission flight cycles will adequately verify the design performance. Each test cycle will last approximately six days. This is the time required for a complete cycle of the RNS from the time it leaves earth orbit, goes to the moon, and returns to earth orbit.

KSC OPERATIONAL TIME LINES

Earth launch operation procedures for the RNS have been developed compatible with the currently accepted S-IC and S-II KSC operations to determine time lines and operational requirements of the total launch vehicle composed of an INT-21 (S-IC and S-II stages) and an RNS tank. Figure 13-3 is a time line representing the KSC launch operations. To provide continuity to the overall operations picture, the figure also includes representative mission and in-orbit turnaround operations. As defined by this

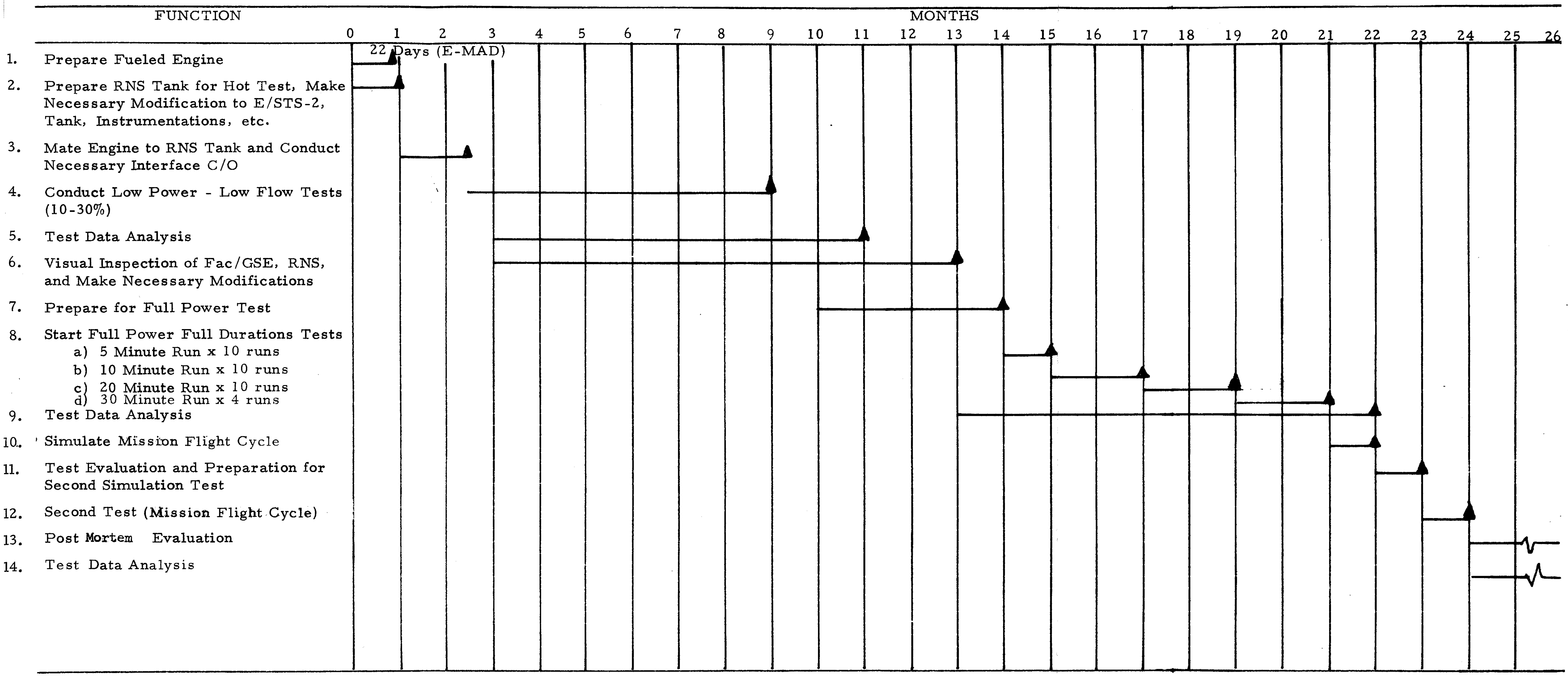
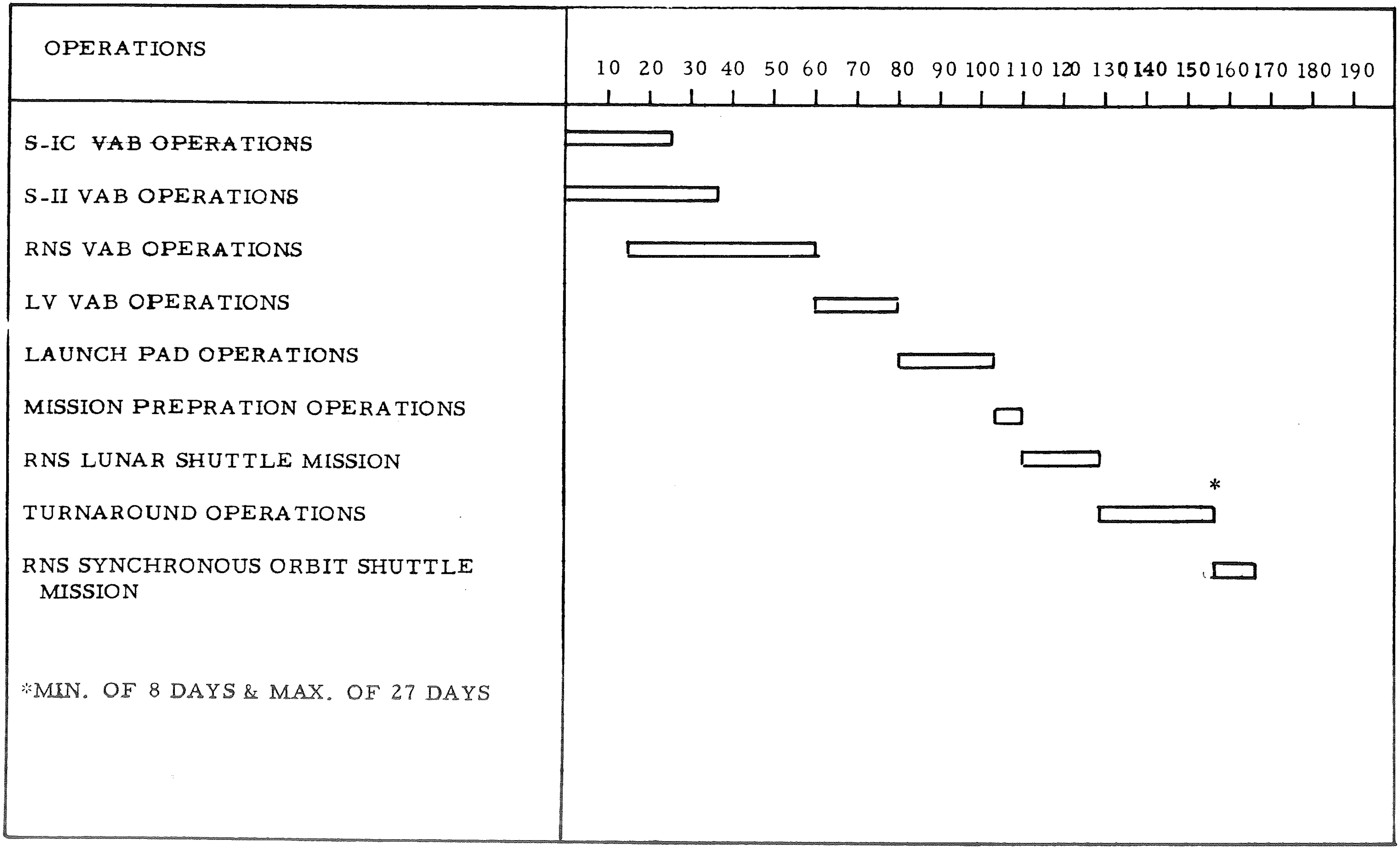


Figure 13-2 Hot Test Cycle


OPERATIONS
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190
S-IC VAB OPERATIONS
S-II VAB OPERATIONS
RNS VAB OPERATIONS
LV VAB OPERATIONS
LAUNCH PAD OPERATIONS
MISSION PREPRATION OPERATIONS
RNS LUNAR SHUTTLE MISSION
TURNAROUND OPERATIONS
RNS SYNCHRONOUS ORBIT SHUTTLE MISSION
*
*MIN. OF 8 DAYS & MAX. OF 27 DAYS

breakdown, the overall mission operations are represented by separate items.

Figure 13-4 represents the total VAB operation from the initial arrival of stages up to the time the mobile launcher leaves the VAB to the pad and launch. The time lines include times required for assembly, mating, and checkout of S-IC, S-II stages, RNS tank, high bay operations (integration of INT-21/RNS tank), and the pad operations. Based on preliminary operational requirements, approximately 75 working days are required from initial operations to launch.

Figures 13-5 and 13-6 represent the KSC operations specifically related to the S-IC and S-II stages, respectively. These include operations from the receipt of the stages at KSC through the conclusion of the mechanical systems tests for each, and are basically unaffected by the replacement of the S-IVB stage with RNS tank. Following receipt and inspection, the S-IC stage is erected on the mobile launcher in one of the VAB high bays. The S-II is erected in the transfer aisle and mated to the aft interstage in one of the low bay checkout cells. After completion of its checkout and functional tests, it is then moved to the high bay and mated with the S-IC stage.

The NERVA engine will be interfaced with the RNS tank. The complete stage will then be subjected to a comprehensive checkout to verify continuity and functional integrity of the interfaces as indicated in Figure 13-7. All fluid interface connections will be subjected to leak and functional verification tests and all electrical connections will receive continuity, resistance, and isolation tests. After individual systems are verified, the RNS stage will be subjected to an integrated onboard computer self status and checkout test and malfunction simulation test. Upon completion of the engine/tank interface test activities, and after the NERVA engine is demated from the RNS tank, the RNS tank will be ready for mating operations with INT-21. The RNS will be launched in a non-integral configuration, that is, launched inverted without NERVA engine.

Testing at KSC before RNS/INT-21 mating operations will be performed to ascertain the flight readiness of critical items which, in the event of failure, would require demating for replacement or would create undesirable conditions after mating. Stage mating activity at KSC involves associate contractor effort and coordination and requires the timely planning of manpower and support equipment. Any malfunction after mating operations would cause a significant schedule impact and a corresponding increase in operations cost. Therefore, it is mandatory to establish system flight readiness prior to mating operations.

Figure 13-8 depicts the INT-21/RNS tank operation in the high bay which is required to complete the assembly and to verify the integrity of the complete vehicle.

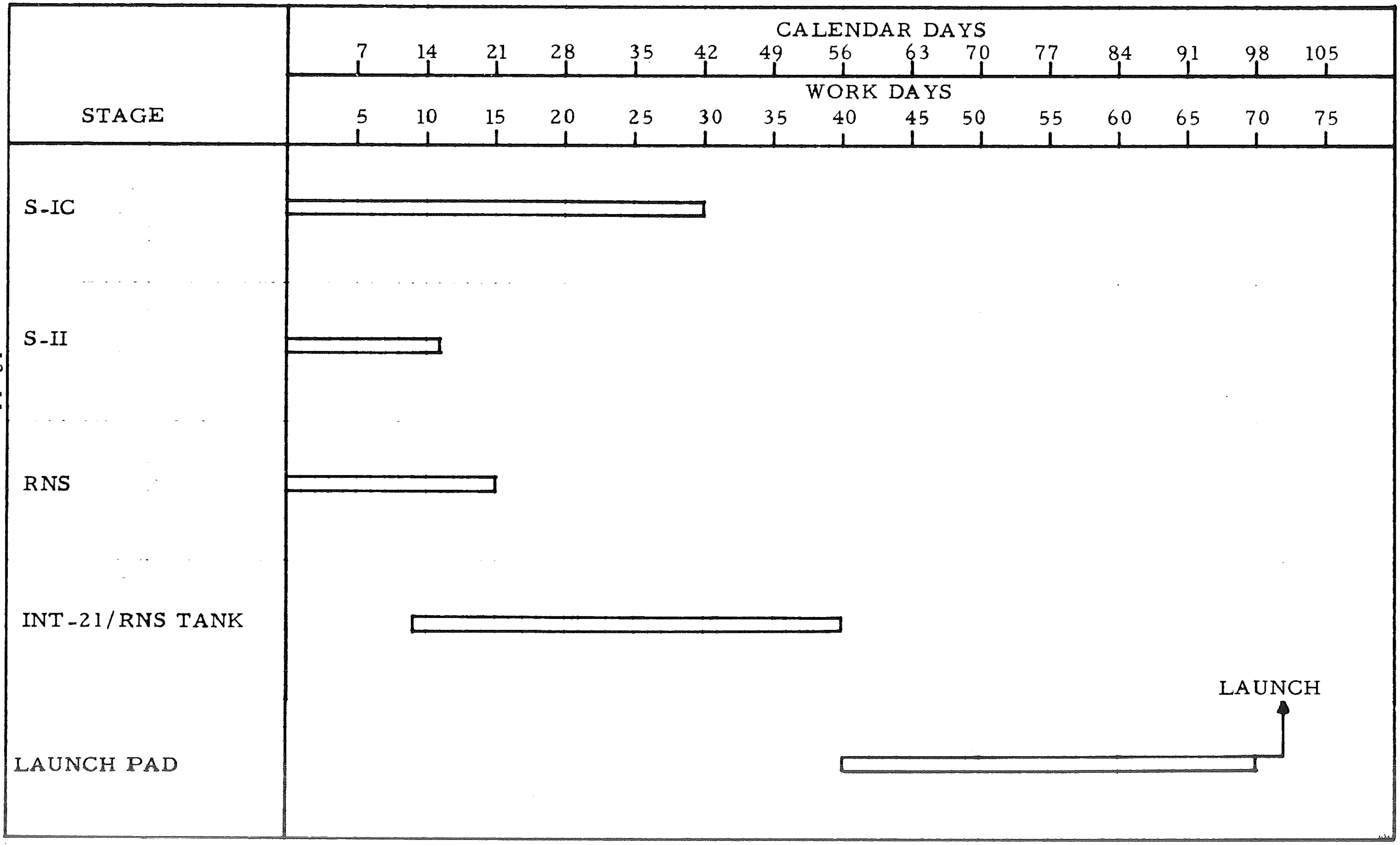


Figure 13-4 KSC Operations Timelines

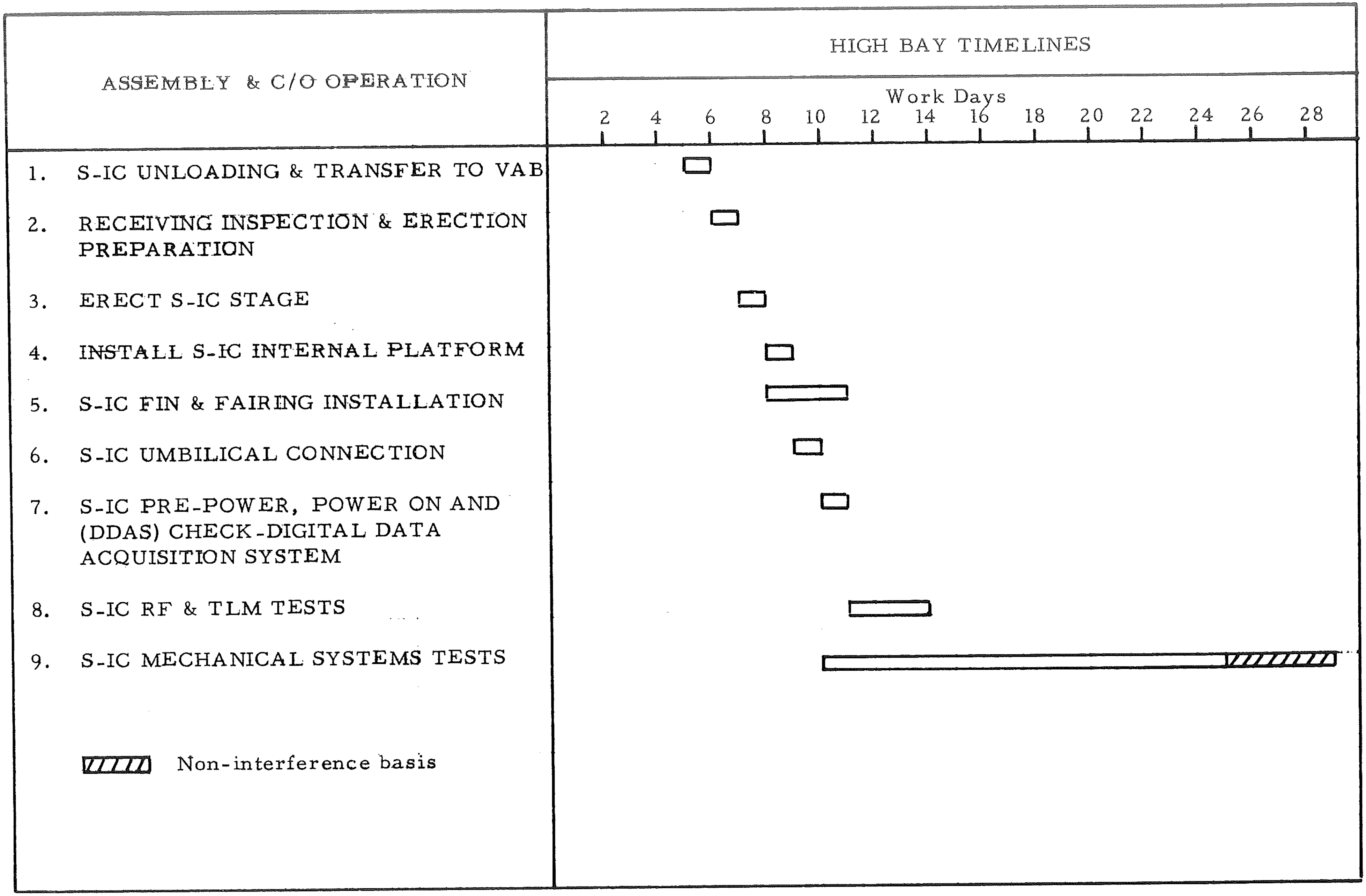


Figure 13-5 S-IC Stage Schedule

ASSEMBLY & C/O OPERATIONS
1. Unload interstage & move to low bay aisle.
2. Remove interstage, install on c/o dolly, remove fwd ring.
3. Unload S-II stage & move to VAB transfer aisle.
4. Remove env. protective covers, visual inspection, prepare for erection
5. Erect stage in transfer aisle.
6. Remove engine protective frame
7. Begin mate S-II to aft interstage.
8. Move c/o dolly into C/O cell.
9. Position Fac. work platforms & complete mate S-II to aft interstage.
10. Install stage access platforms.
11. Assemble & install heat shield.
12. Connect pneumatic & elec connections to stage from GSE
13. Leakage and functional checks
14. Power unit check (non interference basis)
15. Prepare for erection

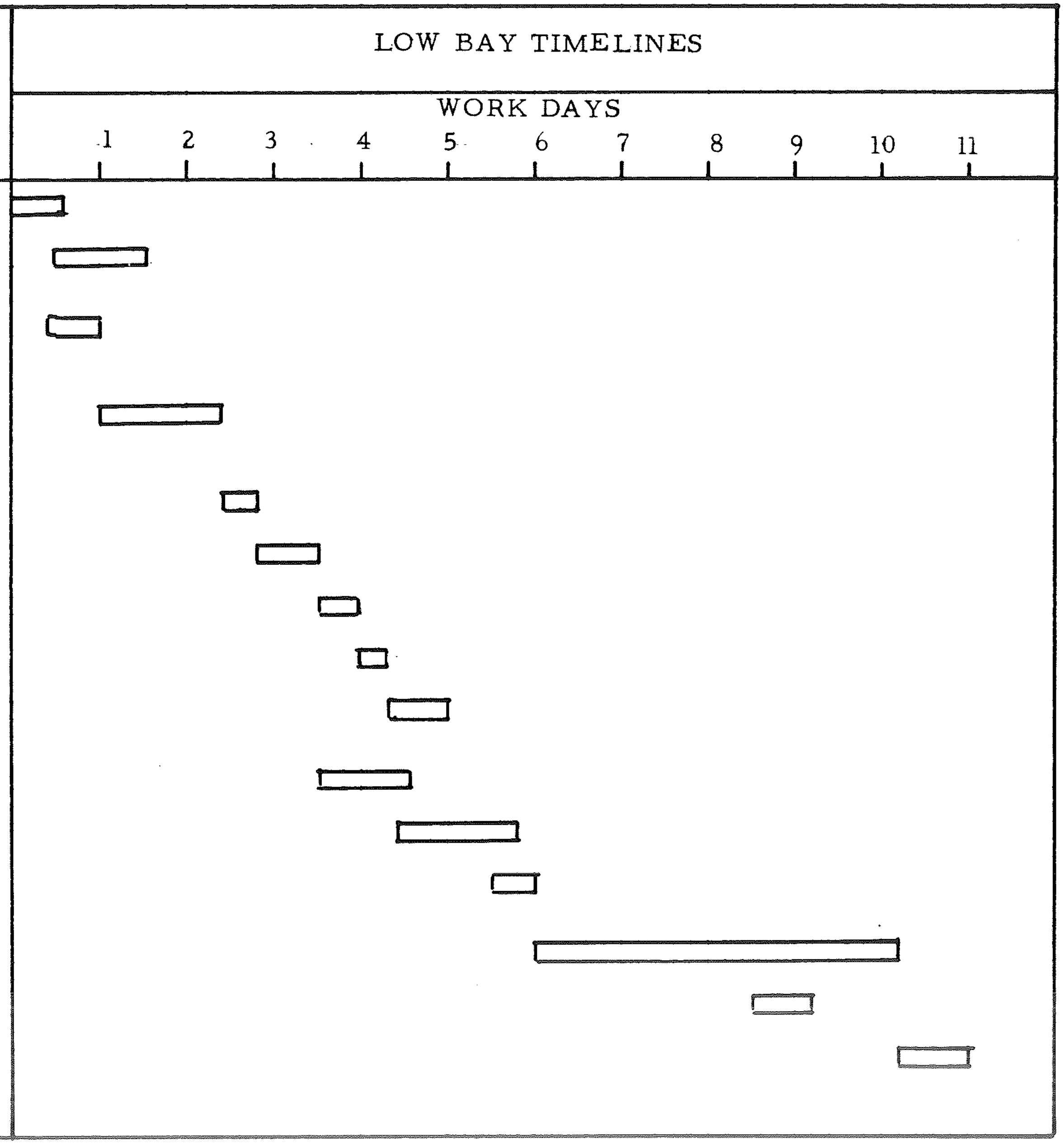


Figure 13-6 S-II Stage Schedule

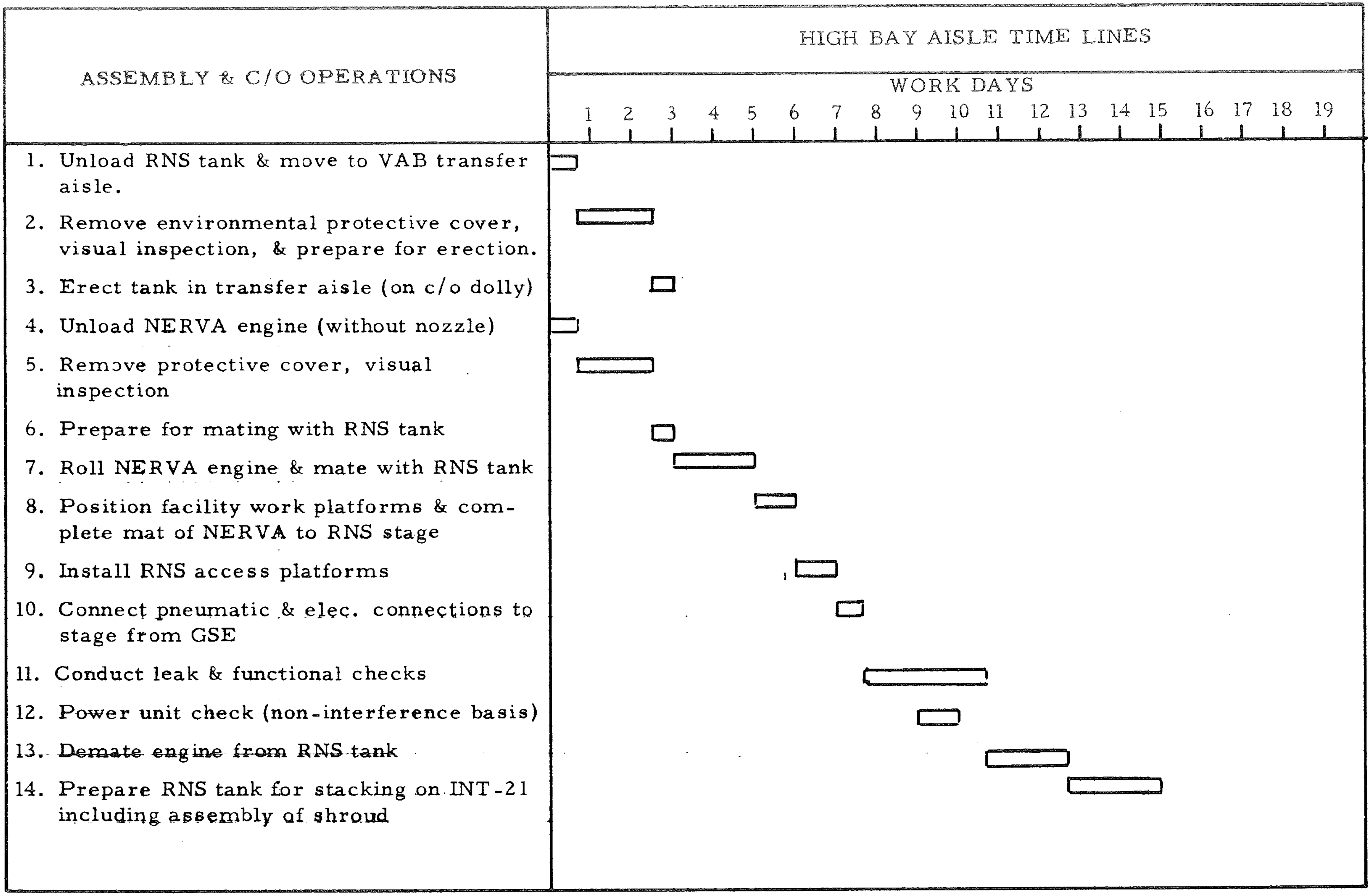


Figure 13-7 RNS Operations Schedule

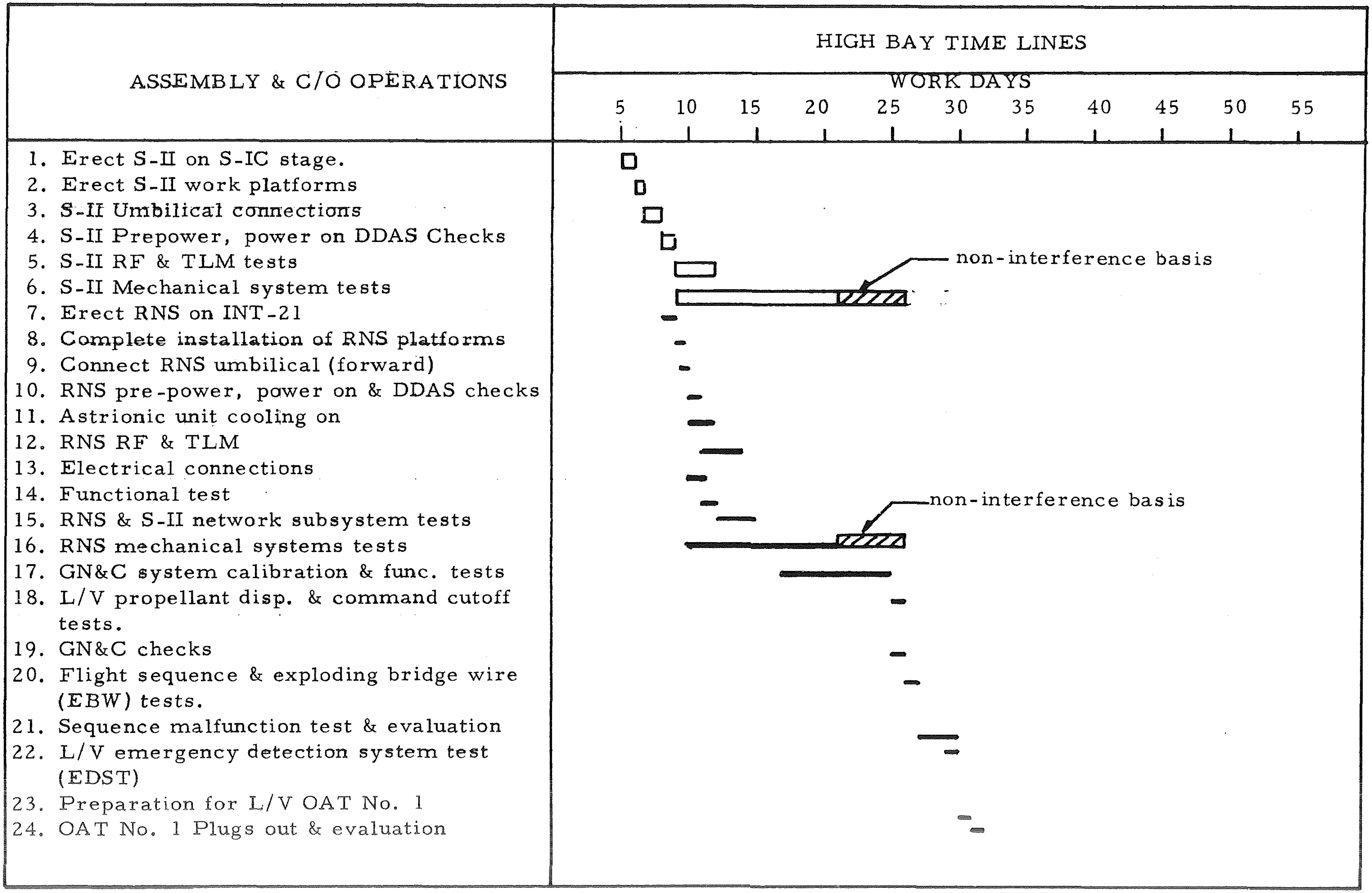


Figure 13-8 INT-21/RNS Tank Schedule

Figure 13-9 includes the launch vehicle operations time lines from the time the mobile launcher (ML) transfers the vehicle to the pad, pad operations, and launch.

Flight test time lines are presented in Figure 13-10 and represent the 18 month flight test program as indicated by the study guidelines.

ORBITAL OPERATIONS

Two sets of time lines are shown in Figures 13-11 and 13-12 which cover initial orbital assembly operations and turnaround operations, respectively. The RNS tank is launched to orbit on the INT-21 launch vehicle whereas the NERVA engine is launched by the EOS for orbital assembly. A propellant depot (PD) is assumed to exist in the RNS operations orbit to permit loading of RNS propellants in a single transfer.

The major functions in the turnaround operations between flights are identified in Figure 13-12. It can be seen from the time line that the turnaround operations can vary from a minimum of eight days to a maximum of 27 days depending on the extent of unscheduled maintainenance to be performed and the assumption that the propellant depot will permit replenishment of RNS propellant in a single transfer. The maximum turnaround time is identified as 27 days for the time between two lunar missions if the next high payload lunar mission opportunity is to be met. The minimum eight-day turnaround is predicated on the fact that unscheduled maintenance activities can be conducted concurrently with scheduled activities on a non-interference basis and within the time span of the scheduled maintenance.

FLIGHT OPERATIONS

Time lines for the nominal lunar and geosynchronous orbit missions are presented in Figures 13-13 and 13-14, respectively. The lunar mission time line presents the nominal mission with a 92-hour trans-lunar trip time, 17.5-day lunar stay and 83-hour transearth trip time. This nominal lunar mission utilizes the second transearth injection opportunity which accounts for the 17.5-day lunar stay time. Also shown on the time lines are the earth departure and earth return operations.

The geosynchronous orbit shuttle mission is not constrained by launch opportunities as is the lunar mission. The ability to reach any point in the geosynchronous orbit and return to the RNS operations orbit is accomplished through the phasing orbit maneuvers. A five-day geosynchronous orbit stay time is considered adequate for performing payload transfer operations. The total geosynchronous orbit mission time is approximately ten days as indicated in the time line of Figure 13-14.

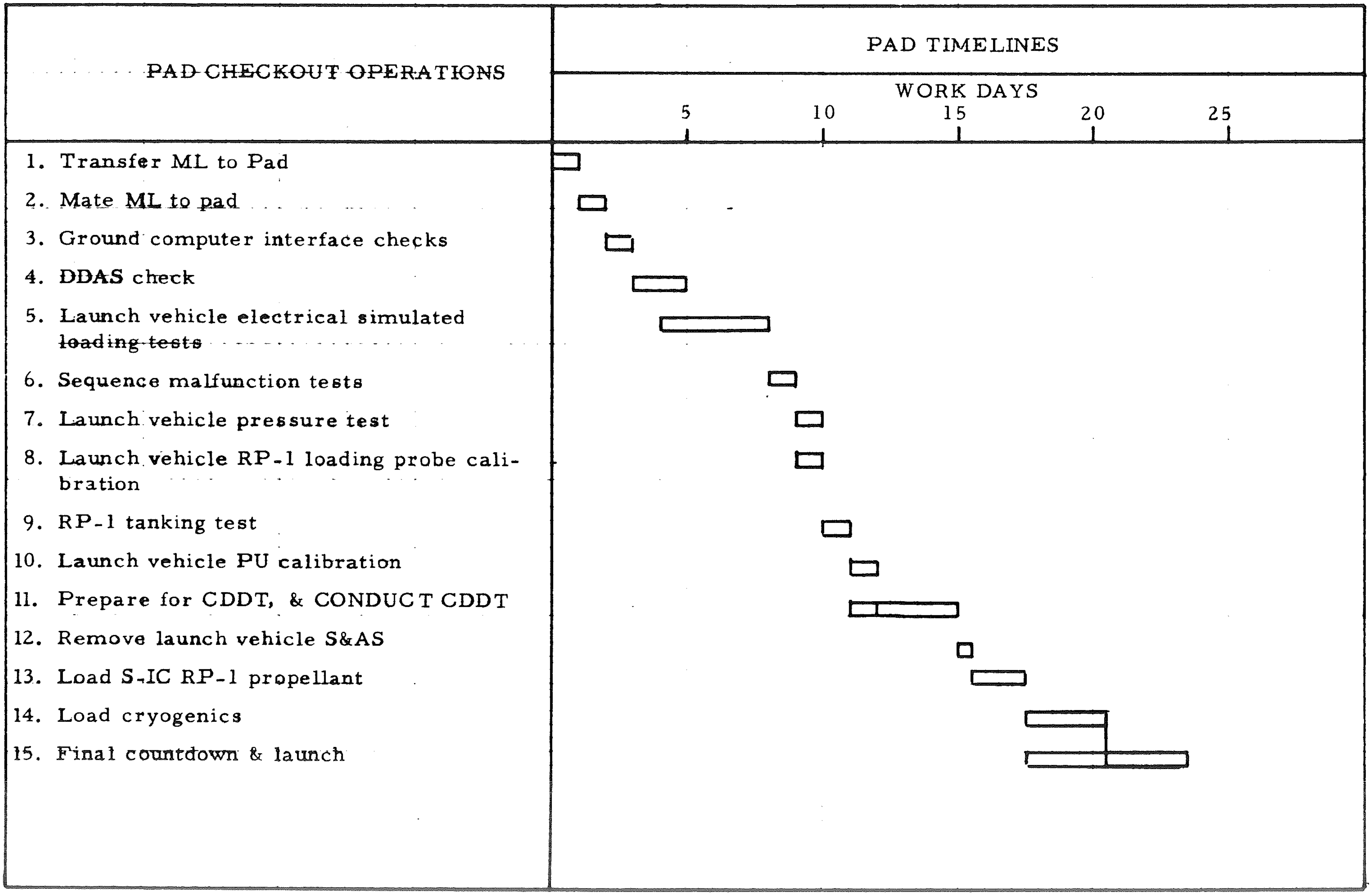


Figure 13-9 PAD Operations Schedule

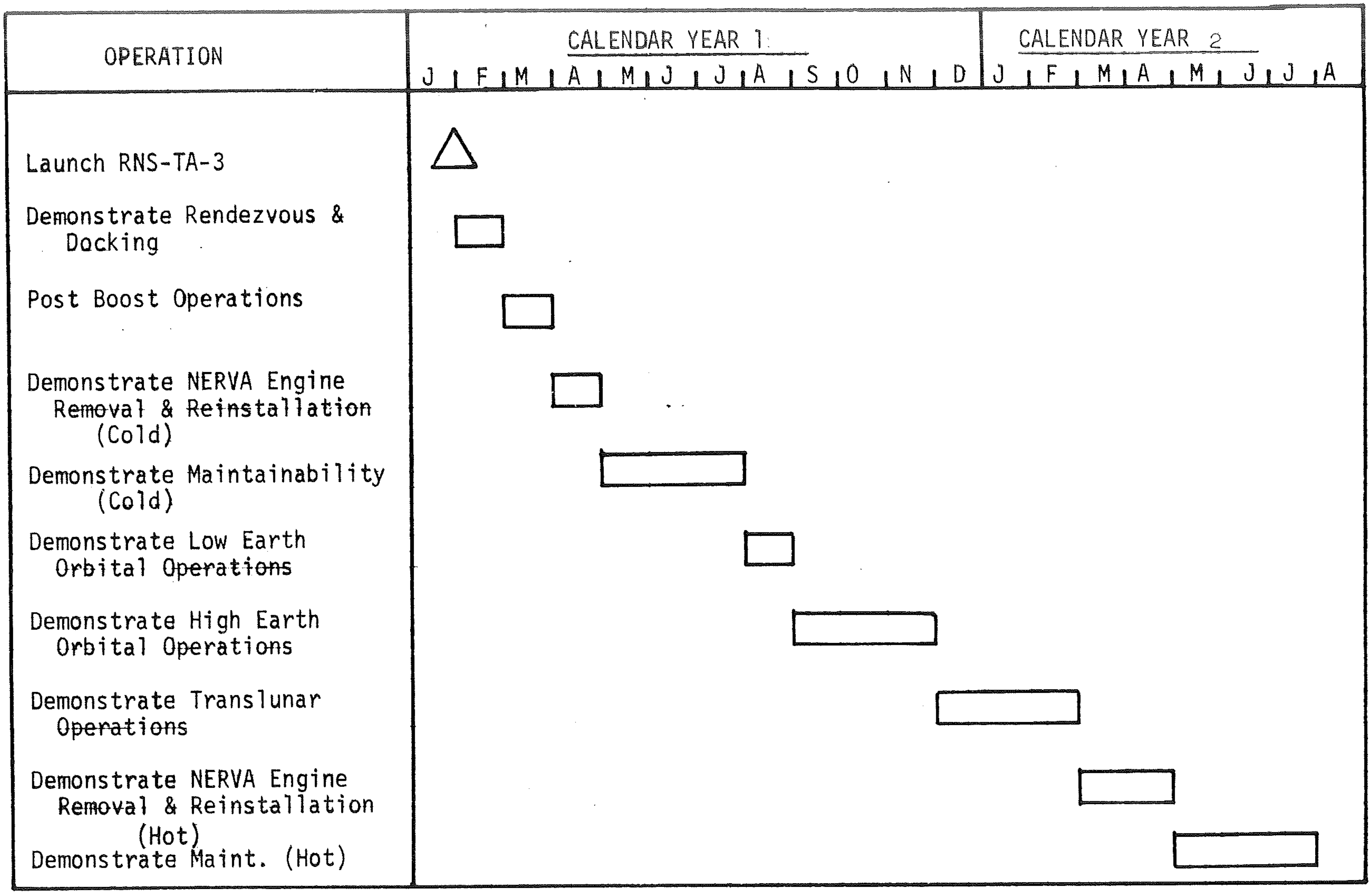


Figure 13-10. Flight Test Program Schedule

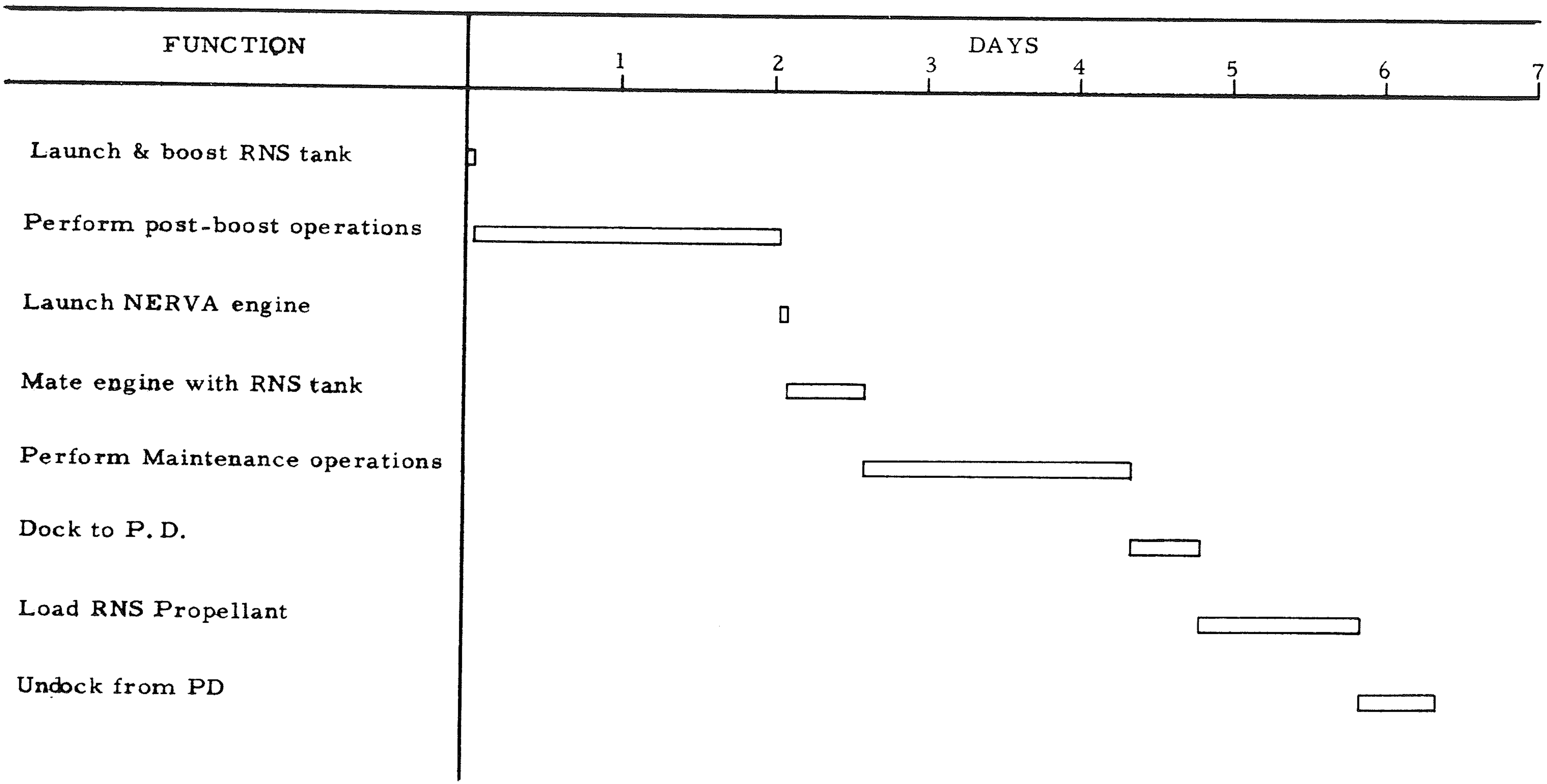


Figure 13-11. RNS Orbital Assembly

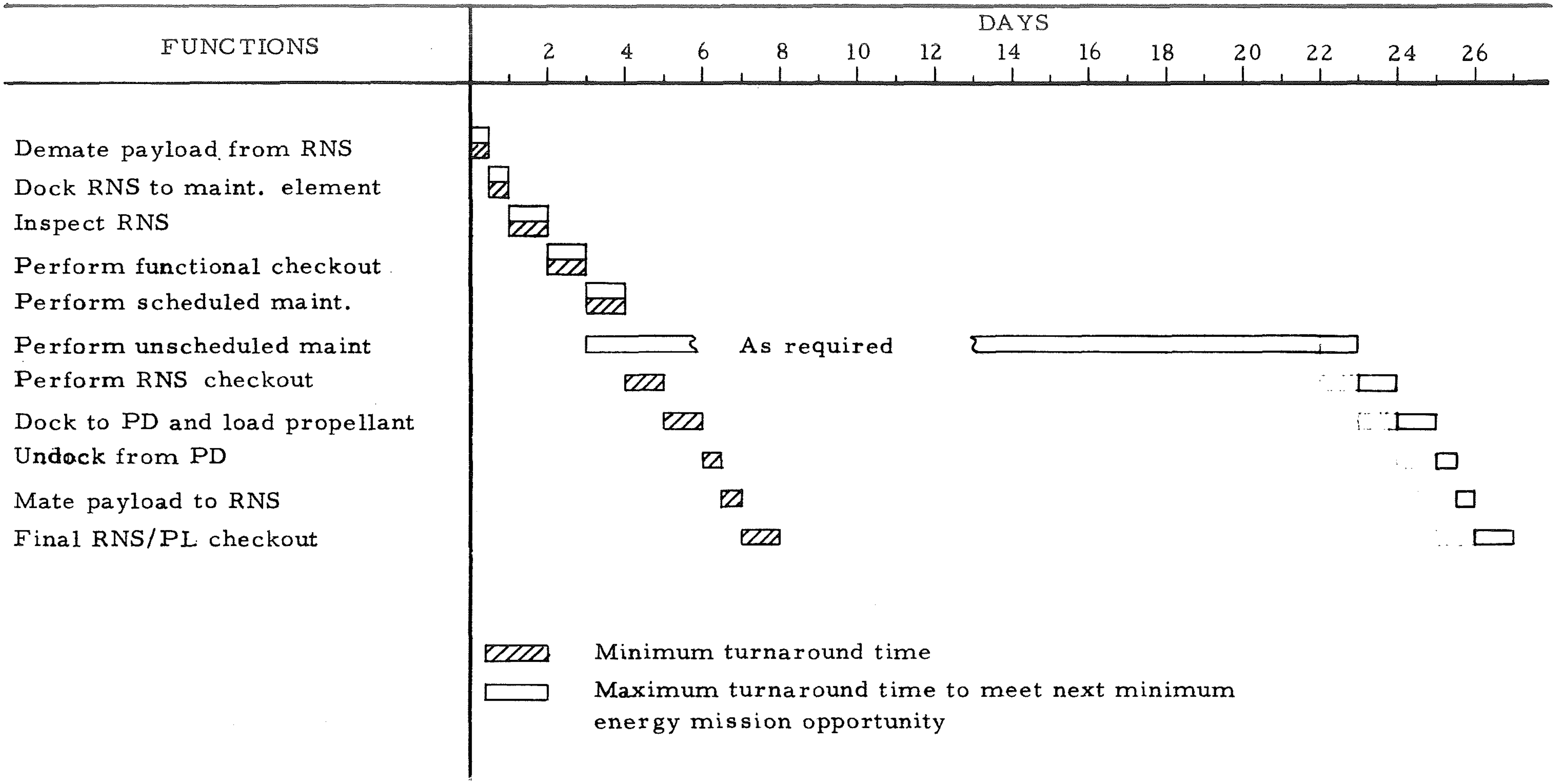


Figure 13-12. Turnaround Operations

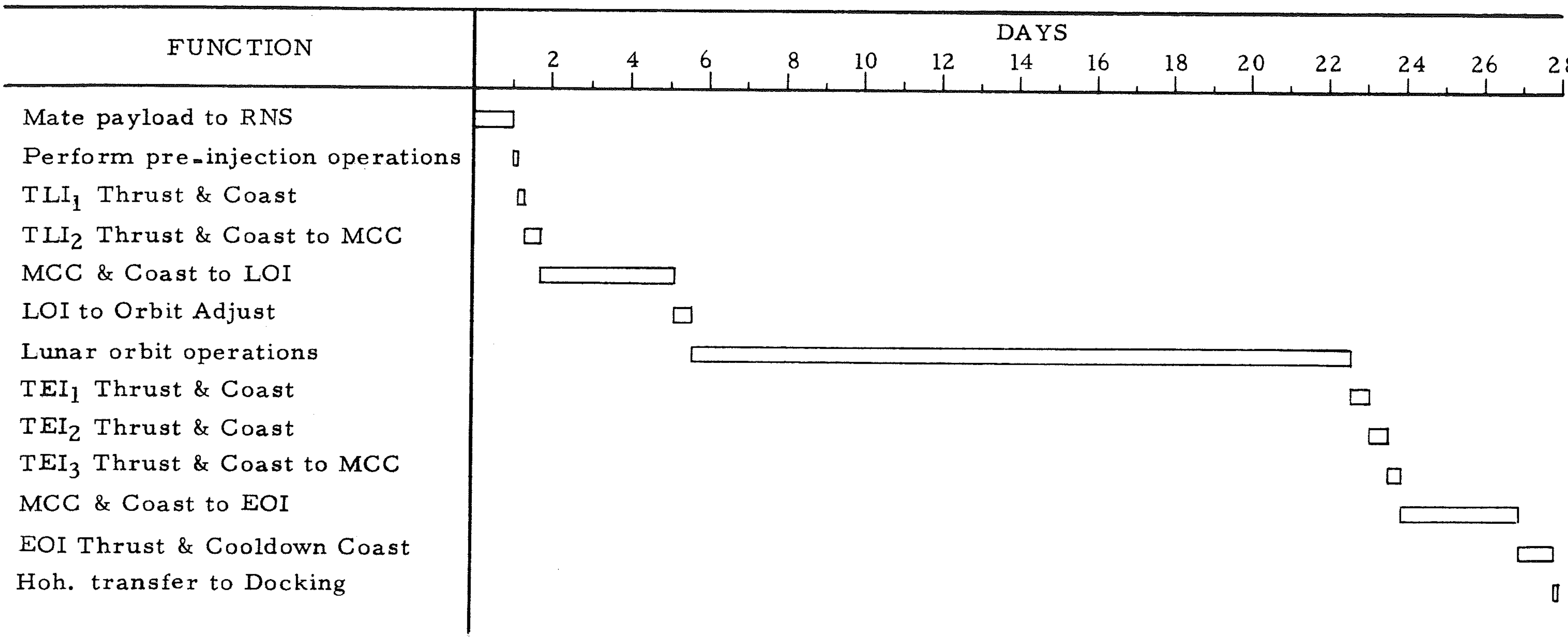


Figure 13-13. Nominal Lunar Shuttle Mission

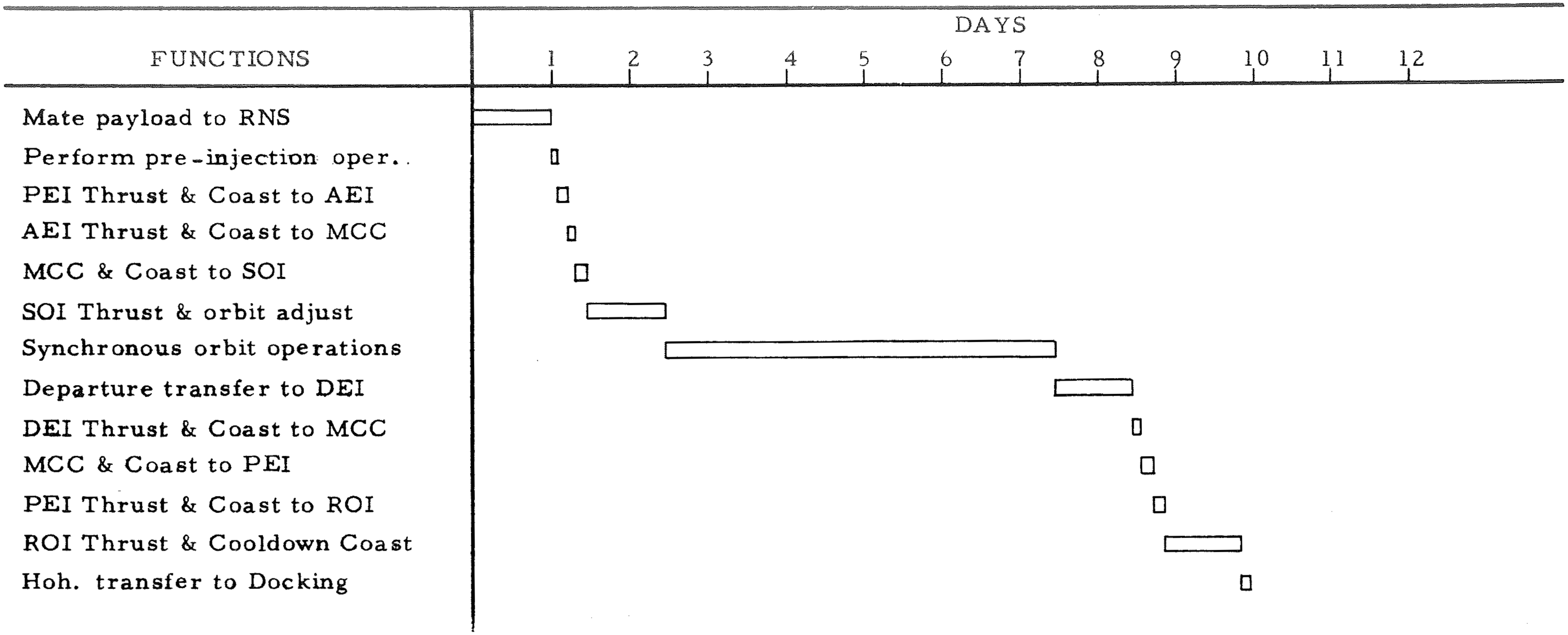


Figure 13-14. Reference Synchronous Orbit Mission

14.0 RECOMMENDED CHANGES TO NERVA REQUIREMENTS

Both standard and modified engine designs were employed during the Phase III study to ascertain a satisfactory interface of the 8-degree half cone angle, 25-inch cap radius tank with the NERVA. For example, the design shown in Figure 14-1 illustrates the feasibility of incorporating a standard neuter docking system in the engine/tank interface for automatic orbital mating of the engine and tank. The latest engine configuration is used, with the following modifications: the main feed lines are joggled inboard to accommodate the docking system geometry and to facilitate connection to the 25-inch radius tank cap; and six large electrical connectors of the same total pin area are employed in place of the 46 smaller connectors as specified in the latest ANSC reports. The active docking assembly is incorporated in the stage thrust structure, and a passive docking ring is attached to the engine forward thrust plate. An actuated coupling plate inside of the active docking section on the stage provides for holdback of the line and electrical connections during structural acquisition and lockup, with subsequent positive alignment and coupling of the subsystems.

The stage thrust structure is a titanium skirt sized to attach to the tank conical aft bulkhead at the same station as the lower propellant retention screen and to integrate with the docking installation. The arrangement permits commonality in the tank features for the thrust structure and screen attachments; affords good path length for minimization of thermal leakage; and fully encloses the system elements of the interface.

If the turns in the main propellant lines at the TPA inlets are objectionable, the TPA's can be rotated to align with the propellant lines without significant effect on the overall configuration. Joggling of the lines has the advantage of bringing them closer to the engine gimbal center, thus, reducing the amount of flexibility required to accommodate the engine gimbal motions.

If access for inspection, etc. of the forward side of the interface is desired, the thrust structure can be constructed as an open truss rather than a monocoque tube.

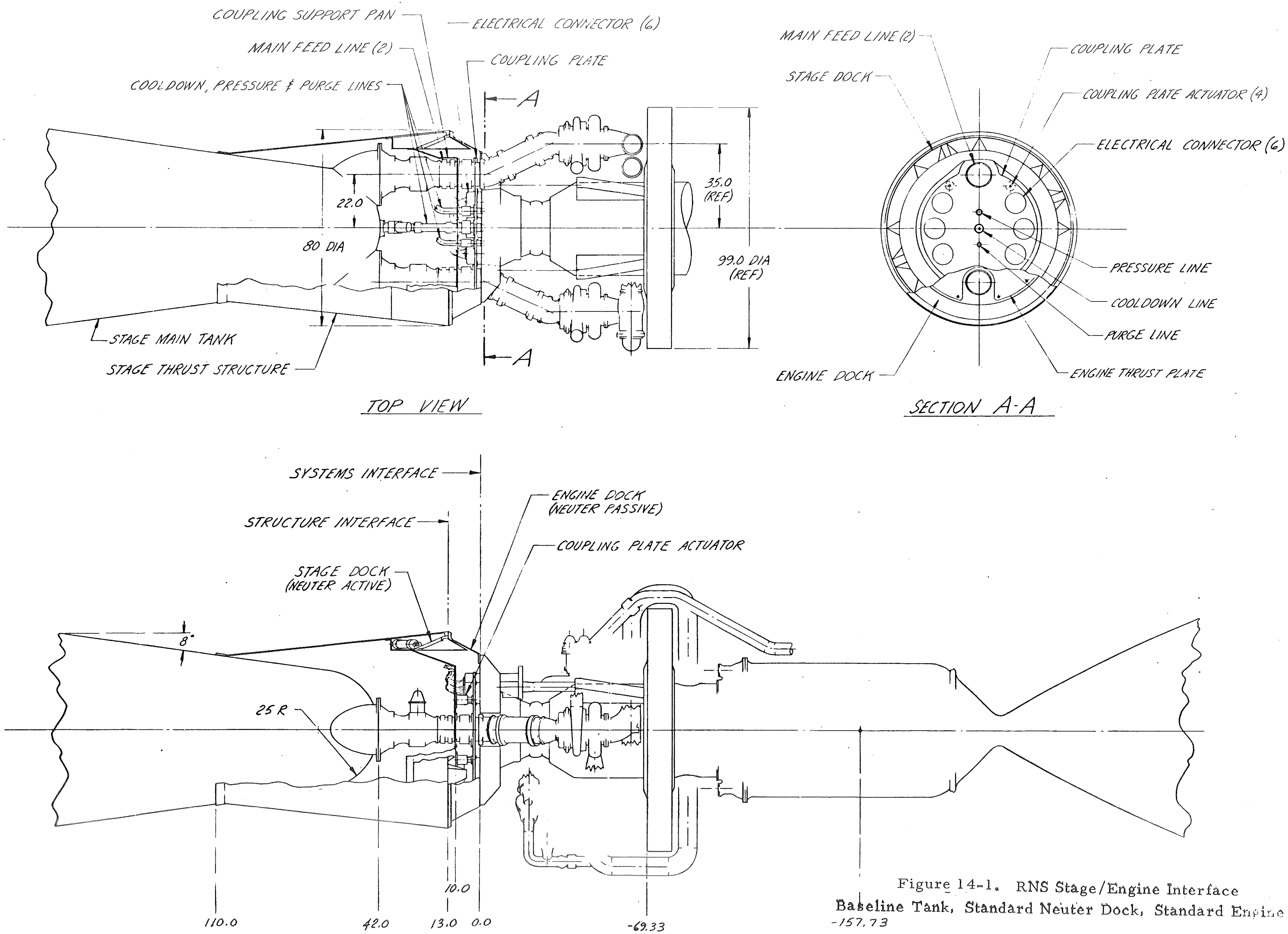


Figure 14-1. RNS Stage/Engine Interface Baseline Tank, Standard Neuter Dock, Standard Engine

In order to maximally exploit the radiation shielding advantages of the small (25 inch) aft cap radius of the baseline tank, it would be desirable to contract the engine accessory systems ahead of the external shield - particularly the TPA's which may be significant secondary scatterers. In the current engine configuration, the TPA's are located 35 inches out from the centerline and the valves/plumbing project beyond the nominal 50-inch external shield radius in many places. The results of preliminary studies presented in Figures 14-2 and 14-3 has indicated that, with a nominal lengthening of the thrust structure ahead of the shield, the TPA's can be pulled in to 22 inches from center and the valves/plumbing contracted to a 38.5-inch radius envelope without otherwise significantly altering the present arrangement and component concepts. The depicted interface design employs this contracted engine configuration.

The stage thrust structure, docking and coupling provisions are the same as for the standard engine configuration with joggled feed lines. The principal difference is that the feed lines do not require joggling. If the engine design can in fact be so modified, additional shield weight savings might be accrued and a simpler interface design accomplished.

Additionally, it is recommended that the engine control subsystem be integrated into the stage GN&C subsystem to minimize both weight and cost. The capability for engine and reactor diagnostic information being fed through the GN&C multiprocessing computer is an essential facet of this design. In this regard, it is also recommended that address, gain select, and bias be transmitted over coaxial calbes using frequency and/or time division multiplexing. The location of the converter from digital to analog for the actuators should be determined as soon as possible since it could have a possible impact on equipment location and cable routing. An output hysteresis constraint in degrees should be included in the specifications for TVC (thrust vector control).

An ECP written by ANSC recommends that "the engine be designed to handle particulate matter with a distribution as specified in MIL-STD-1246A, level 500, throughout its operating life. The level 500 applies only to the distribution of particulate matter as dispersed in the fluid and delivered to the engine so as not to exceed a total weight accumulation of 220 grams (with a density equivalent to aluminum) throughout the engine operating life."

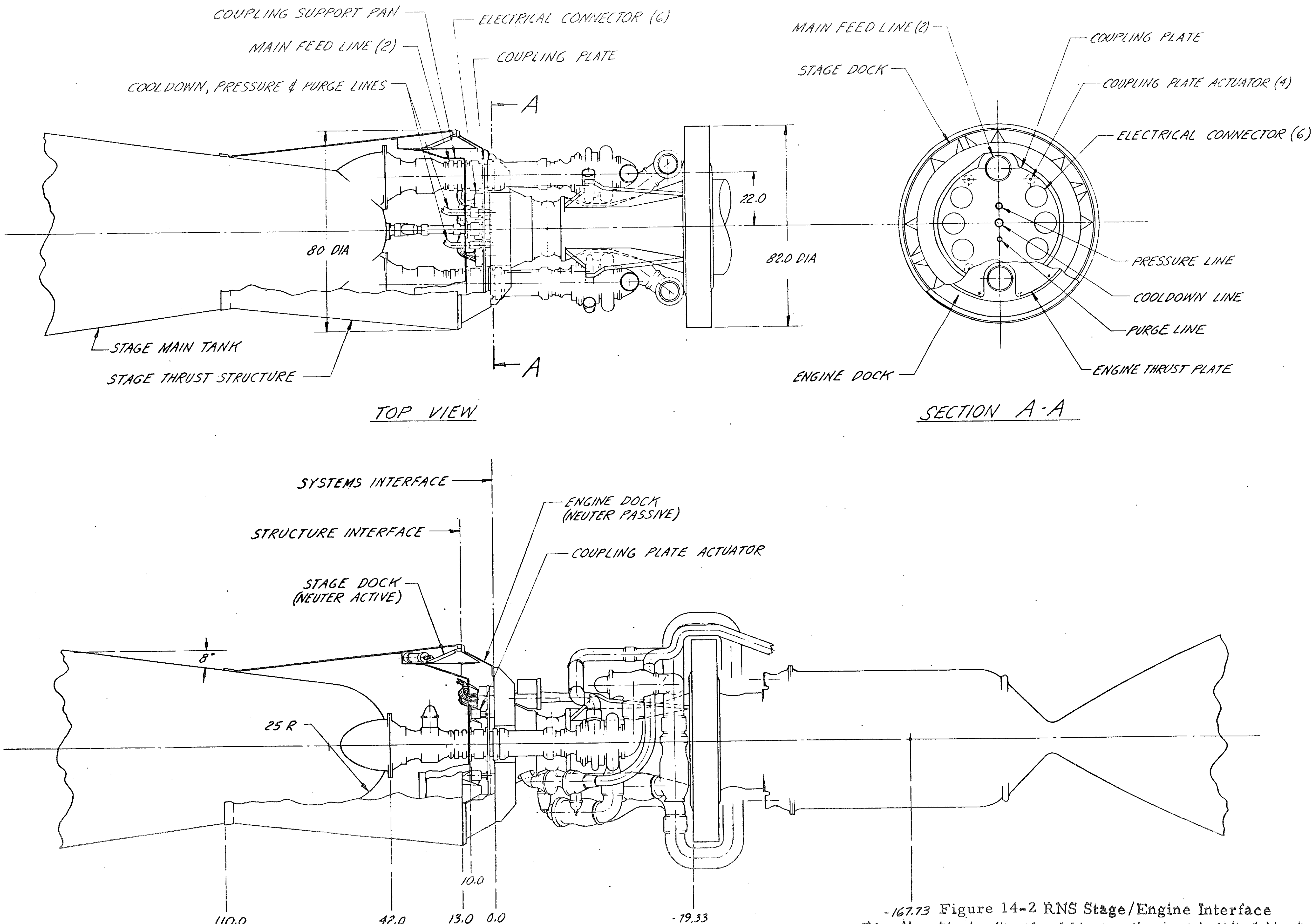


Figure 14-2 RNS Stage/Engine Interface
Baseline Tank, Standard Neuter Dock, Modified Engine

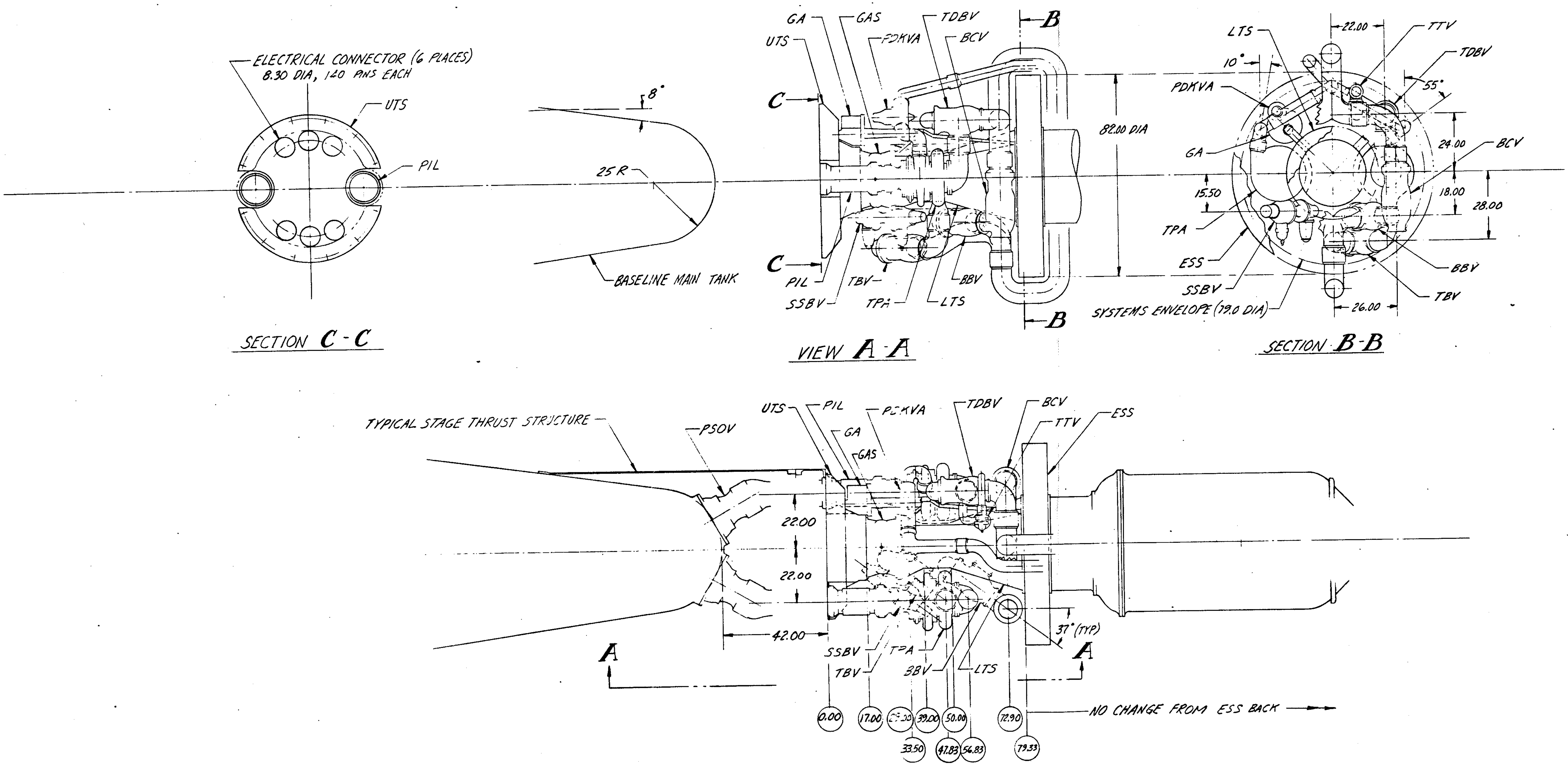


Figure 14-3. **Design Study - NERVA Engine Modified Accessory Envelope**

The proposed specification recommendation that total weight flow to the engine be limited to 220 grams (with a density equivalent to aluminum) throughout the engine operating life appears difficult to implement. While it is felt that the ability to meet such a requirement is desirable, no direct way (i.e., no test program, sampling procedure) is known to prove that the total accumulated flow will be limited to 220 grams. Such a "proof" is likely to be indirect, complex, and costly.