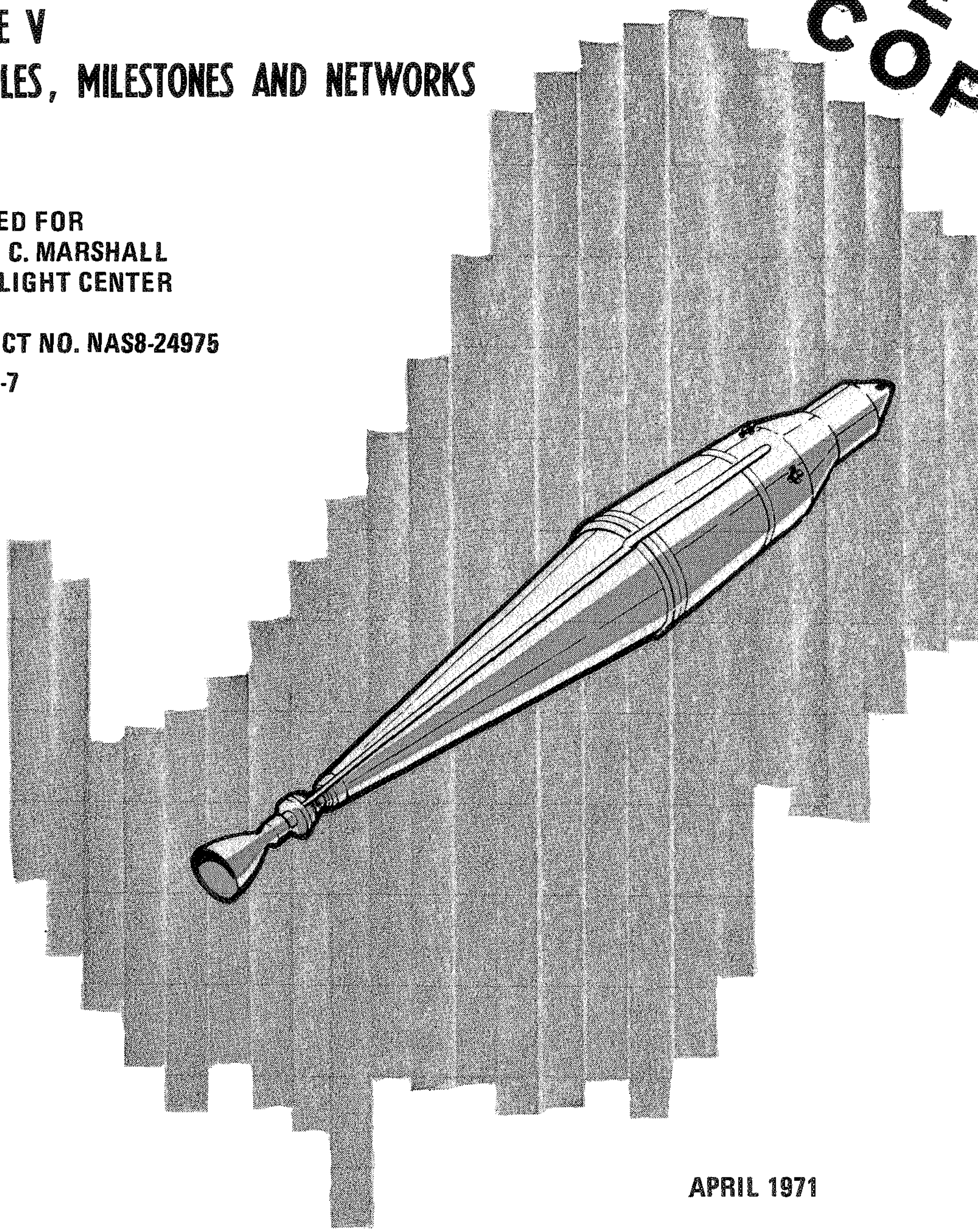
NUCLEAR FLIGHT SYSTEM DEFINITION STUDY

PHASE III FINAL REPORT

VOLUME V
SCHEDULES, MILESTONES AND NETWORKS



PREPARED FOR
GEORGE C. MARSHALL
SPACE FLIGHT CENTER

CONTRACT NO. NAS8-24975

SD71-466-7

APRIL 1971

Space Division
North American Rockwell

SD 71-466 - 7

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Volume V - Schedules, Milestones, and Networks

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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Advanced Programs and Systems Engineering

Approved By

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Advanced Programs

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 requirements, 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.		(SD 71-466-1)	Executive Summary
II.			Concept and Feasibility Analysis
	A.	(SD 71-466-2)	System Evaluation and Capability
	B.	(SD 71-466-3)	Baseline System Definition
	C.	(SD 71-466-4)	System Engineering Documentation
III.		(SD 71-466-5)	Program Support Requirements
IV.		(SD 71-466-6)	Cost Data (Limited Distribution)
V.		(SD 71-466-7)	Schedules, Milestones, and Networks
VI.		(SD 71-466-8)	Reliability and Safety Analysis

This volume presents individual schedules covering SR&T, Test, Manufacturing, and Facilities activities as well as alternate integrated RNS program schedules. Additionally, logic networks were prepared covering the essential elements of Phases B, C, and D showing tasks, sequencing, and interfaces.

ACKNOWLEDGEMENTS

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

D. M. Brooks	Integrated Program Schedules
C. B. Brown	Integrated Program Schedules
H. P. Dobrow	Integrated Program Schedules

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.

CONTENTS

ILLUSTRATIONS

1.0 INTRODUCTION

The program development schedule is a graphical display or timeline of the principal activities and milestones which comprise the development program. It represents one of the resource requirements, and has a significant effect on time, cost, expenditure rate, manpower, facilities, etc. Although the objective of schedule development is definition of realistic time requirements and activity phasing, there is necessarily considerable uncertainty in both requirements and optimal phasing at the present Phase A state of program development. Hardware and time requirements are based on the best available estimates and criteria which will be discussed below. To assure consideration of all of the most promising test program alternatives, schedules have been prepared based on four alternate configurations.

The alternates differ primarily in the configurations employed for the hot and cold flow test article (RNS-TA-1). Although the other test articles are almost the same for all programs, the effect of the different manufacturing time spans for RNS-TA-1 and the variations in allocation of test requirements among the available test articles, is to produce significantly different schedules.

2.0 APPROACH

Preparation of a program development schedule is essentially a synthesis process. It involves determination of the required activities and events, the ground rules and constraints, synthesizing an integrated set of activities, and major milestones that satisfy the ground rules and constraints, and evaluating to determine the optimal schedule. The procedure used in this study, involved the following steps:

1. Consideration of NASA furnished guidelines and program objectives.
2. Establishment of ground rules and assumptions.
3. Consideration of historical schedule data from the NASA Apollo and Saturn programs.
4. Application of schedule data from the contractor's Saturn S-II hardware program.
5. Extraction of applicable data from technical analysis conducted during reusable nuclear shuttle Phase III and previous studies.
6. Preparation of a list of major program milestones arranged in chronological order.
7. Analyses of the previous information and translation of the system and subsystem requirements into development requirements.
8. Construction of alternate program development schedules through an iterative process which takes into account all of the preceding factors.

3.0 GROUND RULES AND ASSUMPTIONS

The following ground rules and assumptions were used in developing the alternate schedules. They are derived from NASA-MSFC guidelines and the results of technical analyses.

1. The schedules cover all development phases from the state of Phase A-IV (Analysis/Definition) through the completion of flight testing and establishment of an initial operational capability (IOC).

2. The schedules define an orderly economical evolution of activities and events leading to the realization of NASA program objectives. NASA dates for first flight (mid-CY 1979) and IOC (CY 1981) are treated as guidelines but not as constraints.

3. Launch will be from KSC using Saturn V-INT-21 booster vehicles.

4. Existing contractor and government facilities will be used; requirements for additional or modified facilities and related equipment will be minimized.

5. The next program phase will be Phase A-IV (Analysis/Definition) starting on July 1, 1971. This will be followed by a normal sequence of Phases B, C, and D.

6. A 12-month spacing for Phases A-IV and B was assumed. This time includes both contract performance and NASA review and is consistent with recent experience on major NASA programs.

7. A 9-month period is assumed for Phase C. This period represents a reduction of 3 months from the 12 month per phase spacing. The rationale for this reduction is the assumption that Phase D would commence immediately at the conclusion of Phase C, with continuous NASA review throughout the program rather than a 3 month gap between phases.

8. For a program in which all test articles are made of flight hardware/configuration, it will take 36 months to fabricate a complete tank including installation and checkout of all systems. This time span was determined from analysis of the actual manufacturing flow taking into account S-II experience as well as the expected learning from the structural test article.

9. The maximum time span to fabricate a complete test stage is 40 months for program alternatives employing mixed flight/non-flight subsystems.

10. A combined production rate for both RNS and S-II of three per year was assumed during DDT&E. Earlier studies on S-II manufacturing showed a rate of four stages per year to be optimal from a unit cost for manufacturing only. A maximum of three RNS tanks per year can be produced with a single set of tooling. Preliminary analysis indicates a number of potential problems connected with prolonged in-production storage, in addition to cost. A rate of two articles per year is considered the minimum economical production rate, due to utilization of manpower and maintenance of key skills. This rate was used for the operational period (one S-II plus one RNS at the same facility).

11. The earliest availability of a NERVA engine at NRDS is July 1, 1977. (Date supplied by engine developer.)

12. Minimum time requirements for major subsystem tests derived in the test planning analysis are as follows:

Cold Flow	9 months
Dynamic Test	12 months
Hot Test	24 months
Facilities C/O	6 months
Flight Test	18 months

13. The launch of the flight test vehicle is scheduled for 6 months prior to the completion of the 24 month hot test program.

14. The IOC date coincides with the completion of the 18-month flight test program.

4.0 PHASING SCHEDULES AND MILESTONES

The calendar date phasing for the RNS Program is similar for the four alternate program development schedules, and will be described in detail in this section of the report.

1. A nine-month Phase A-IV Analysis/Definition Study is scheduled to start on July 1, 1971. The completion of this study will be followed by a three-month customer review, proposal and evaluation period.

2. Phase B - Definition Study will start on July 1, 1972, and lasts for nine months to March 31, 1972. During this study period, the major accomplishments will include:

   - Preliminary system requirements review (SRR)
   - System requirements baseline (SRB) established
   - Mission objective established
   - System and subsystem functional specifications and specification tree established
   - Preliminary design of selected RNS concept
   - Updated preliminary program plans and schedules
   - Updated program cost estimates
   - Prepare trade study reports
   - Phase C recommendations

The completion of the Phase B - Definition Study will be followed by a three month customer review, proposal and evaluation period.

3. Phase C - Design Study will start on July 1, 1973, and lasts for nine months. Major accomplishments during the Design Study will include:

   - Systems design review (SDR)
   - CEI Part I performance specifications
   - Preliminary design of subsystems
   - Preliminary design review (PDR)
   - Updated program plans and schedules
   - Detailed cost estimates
   - Phase D recommendations

4. Phase D - Development/Operations will commence immediately following the completion of the Phase C - Design Study, April 1, 1974. The length of Phase D varies with each alternate Program development schedule, and will be discussed separately in each alternate schedule description.

The program development schedule shows activity bars with some of the key milestones for the following program support functions: Procurement, Facilities, Ground Support Equipment and Logistic Support. Detail program plans and supporting schedules for these program support functions will be prepared during the Phase A-IV or Phase B - Definition Study.

The schedule also depicts a supporting research and technology activity bar reflecting new technology requirements to support the reusable nuclear shuttle program. Key supporting technology studies shown on the schedule include:

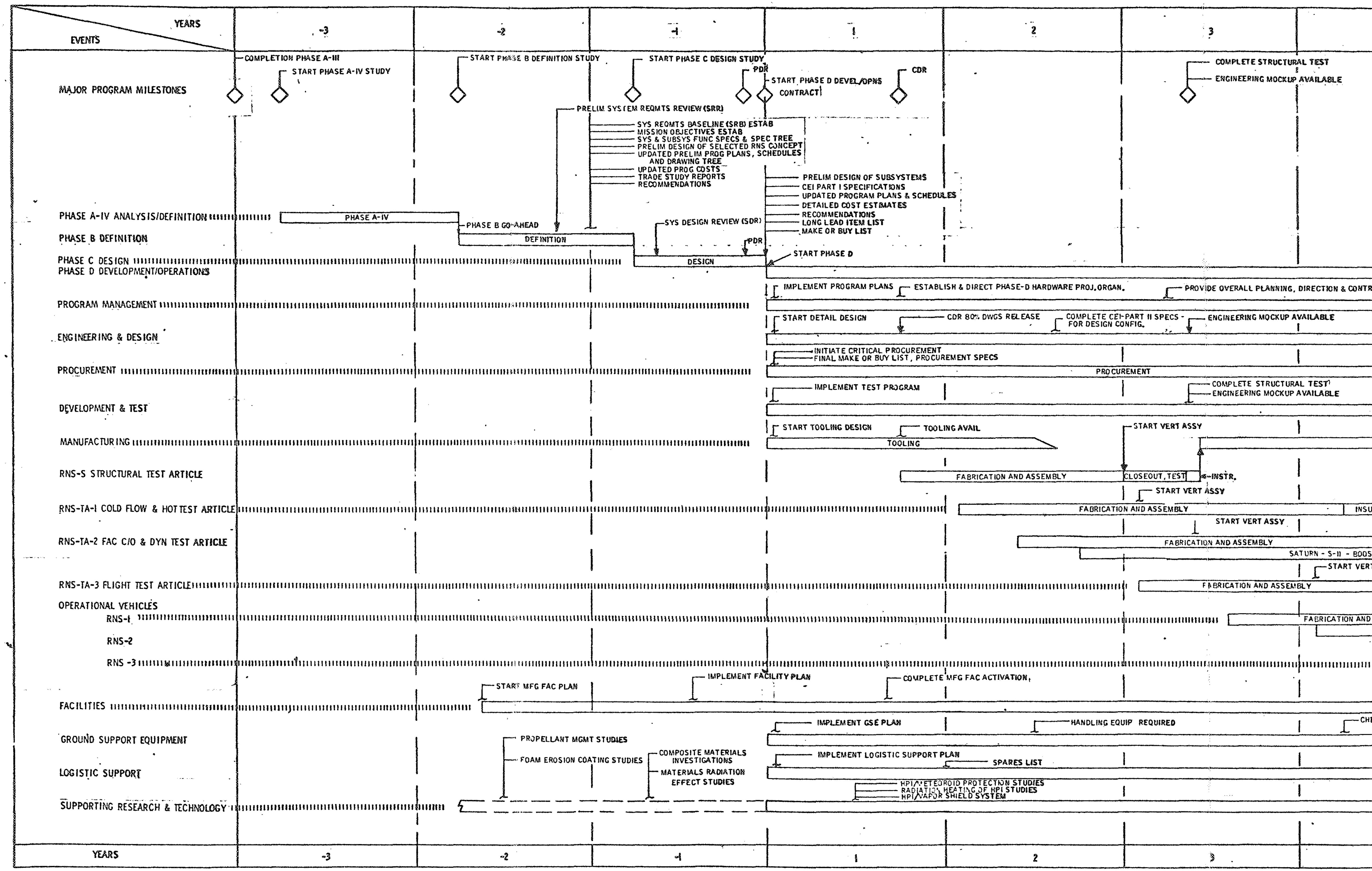
- Propellant management
- Composite materials
- Material radiation effects
- HPI/meteoroid protection
- Radiation heating of HPI
- HPI/vapor shield system

SCHEDULE HIGHLIGHTS

Baseline and Boilerplate Configurations (Alternate 1)

The description of the baseline program schedule is also applicable to the boilerplate configuration. The only difference between the two concepts is that the baseline uses a full flight configuration test article (RNS-TA-1) for the cold flow and hot test programs while the boilerplate concept utilizes a flight configuration geometry with heavier gauge material. Since the manufacturing time requirements and other program elements are the same, both concepts are shown in the same schedule. For simplification, baseline and boilerplate configurations will be referred to as baseline schedule. However, two baseline schedules are considered and are referred to as Alternate 1 (Figure 4-1) and Alternate 2 (Figure 4-2).

The baseline (Alternate 1) schedule depicts the major milestones for each of the principal program functions during Phase D. Program plans will be updated and implemented as soon as possible after Phase D go-ahead. Project management will implement the project organization, schedule and cost control, and technical performance functions. Detail development and production design effort will begin at the start of Phase D with the critical design review (CDR) scheduled nine months later. Eighty percent



YEARS
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MAJOR PROGRAM MILESTONES
COMPLETION PHASE A-III
START PHASE A-IV STUDY
START PHASE B DEFINITION STUDY
START PHASE C DESIGN STUDY
PDR
START PHASE D DEVEL/OPNS CONTRACT
CDR
COMPLETE STRUCTURAL TEST & ENGINEERING MOCKUP AVAILABLE
PRELIM SYSTEM REQMTS REVIEW (SRR)
SYS REQMTS BASELINE (SRB) ESTAB
MISSION OBJECTIVES ESTAB
SYS & SUBSYS FUNC SPECS & SPEC TREE
PRELIM DESIGN OF SELECTED RNS CONCEPT
UPDATED PRELIM PROG PLANS, SCHEDULES AND DRAWING TREE
UPDATED PROG COSTS
TRADE STUDY REPORTS
RECOMMENDATIONS
PRELIM DESIGN OF SUBSYSTEMS
CEI PART I SPECIFICATIONS
UPDATED PROGRAM PLANS & SCHEDULES
DETAILED COST ESTIMATES
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LONG LEAD ITEM LIST
MAKE OR BUY LIST
PHASE A-IV ANALYSIS/DEFINITION
PHASE A-IV
PHASE B GO-AHEAD
SYS DESIGN REVIEW (SDR)
PHASE B DEFINITION
DEFINITION
PDR
START PHASE D
PHASE C DESIGN
PHASE D DEVELOPMENT/OPERATIONS
DESIGN
PROGRAM MANAGEMENT
IMPLEMENT PROGRAM PLANS
ESTABLISH & DIRECT PHASE-D HARDWARE PROJ.ORGAN.
PROVIDE OVERALL PLANNING, DIRECTION & CONTROL
ENGINEERING & DESIGN
START DETAIL DESIGN
CDR 80% DWGS RELEASE
COMPLETE CEI-PART II SPECS - FOR DESIGN CONFIG.
ENGINEERING MOCKUP AVAILABLE
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START MFG FAC PLAN
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COMPLETE MFG FAC ACTIVATION
GROUND SUPPORT EQUIPMENT
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HANDLING EQUIP REQUIRED
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LOGISTIC SUPPORT
PROPELLANT MGMT STUDIES
FOAM EROSION COATING STUDIES
COMPOSITE MATERIALS INVESTIGATIONS
MATERIALS RADIATION EFFECT STUDIES
IMPLEMENT LOGISTIC SUPPORT PLAN
SPARES LIST
SUPPORTING RESEARCH & TECHNOLOGY
HPI/METEOROID PROTECTION STUDIES
RADIATION HEATING OF HPI STUDIES
HPI/VAPOR SHIELD SYSTEM
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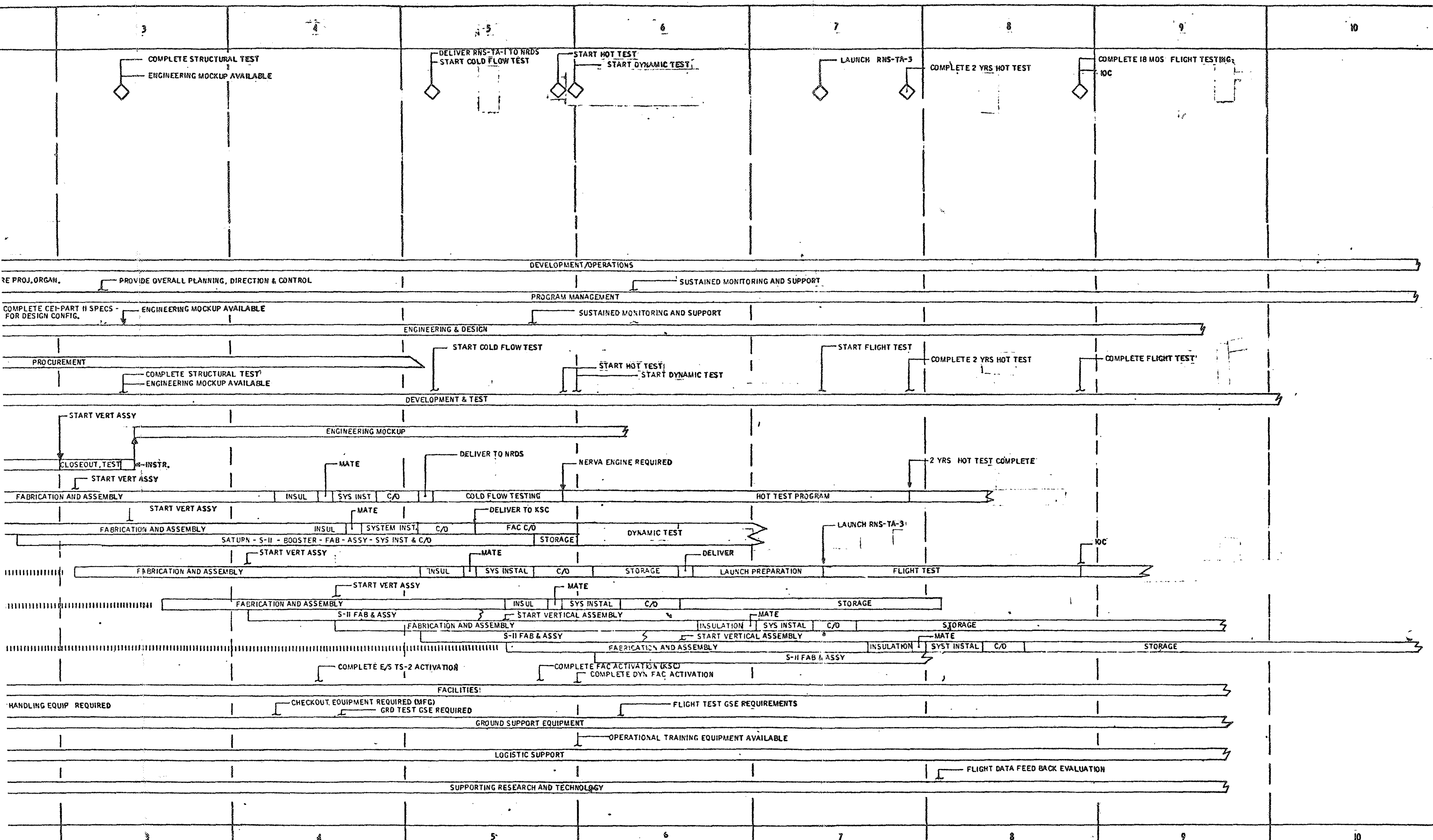


FIGURE 4-1. PRELIMINARY RNS PROGRAM DEVELOPMENT SCHEDULE ALTERNATE I

BASELINE CONFIGURATION
BOILERPLATE CONFIGURATION

4-3, 4-4

2

3

of the detail drawings are scheduled for release by CDR, with the remaining 20 percent scheduled for release within the next three months to assure meeting manufacturing scheduling requirements. The initial operational capability (IOC) date is concurrent with the completion of eighteen months of successful flight testing. The IOC date for the baseline schedule (Alternate 1) is 95 months after the start of Phase D.

The schedule is based on a combined S-II and RNS production rate of three per year. Fabrication of the initial article is scheduled to start nine months after Phase D go-ahead. To allow early verification of structural design, the structural test article (RNS-S) will be fabricated first. Although the full fabrication period of a flight stage is 36 months, the structural test article can be completed in 20 months since non-structural subsystems are not required. By the use of this phasing, structural tests will be completed 2.5 years after Phase D go-ahead, and prior to completing fabrication of the flight test article (RNS-TA-3).

Upon completion of structural tests, RNS-S will be converted to an engineering mockup to support the development and operational programs.

Fabrication of the cold flow/hot test article (RNS-TA-1) will commence four months after the start of RNS-S. The full 36-month fabrication period is required, regardless of whether it is the flight configuration (baseline) or a boilerplate configuration. On completion, RNS-TA-1 will be shipped to NRDS for cold flow testing, followed by the hot test program. Cold flow tests will be completed 59 months after Phase D go-ahead, which is just prior to the start of systems installation on the flight test article (RNS-TA-3). Completion of two years of hot tests occurs 83 months after Phase D go-ahead.

The facility checkout and dynamic test article (RNS-TA-2) is scheduled to start four months after the start of RNS-TA-1 with a scheduled manufacturing time period of thirty-six months. Upon completion of this test article, it will be shipped to KSC for a six-month facility checkout period; then it will be shipped to MSFC for the dynamic test.

An S-II stage is scheduled to start six months after the start of RNS-TA-2, followed four months later by the fabrication of the flight test article (RNS-TA-3). As depicted on the schedule, the RNS-TA-3 will require a short storage period prior to shipment to KSC for the start of launch preparation and launch. The sequence of manufacturing and tests shown with the time assumed above, yields a total time requirement from Phase D go-ahead to IOC date of 7 years and 11 months. Three operational vehicles, RNS-TA-1, RNS-TA-2, and RNS-TA-3, are depicted on the schedule with start dates at one-year intervals. The assumption is that S-II stages required to support the RNS operation flights, will be started at one-year intervals. The operational schedule then reflects a production start rate of one article every six months. A breakdown of the manufacturing techniques, processes, and manufacturing sequence are found in the detailed manufacturing schedules.

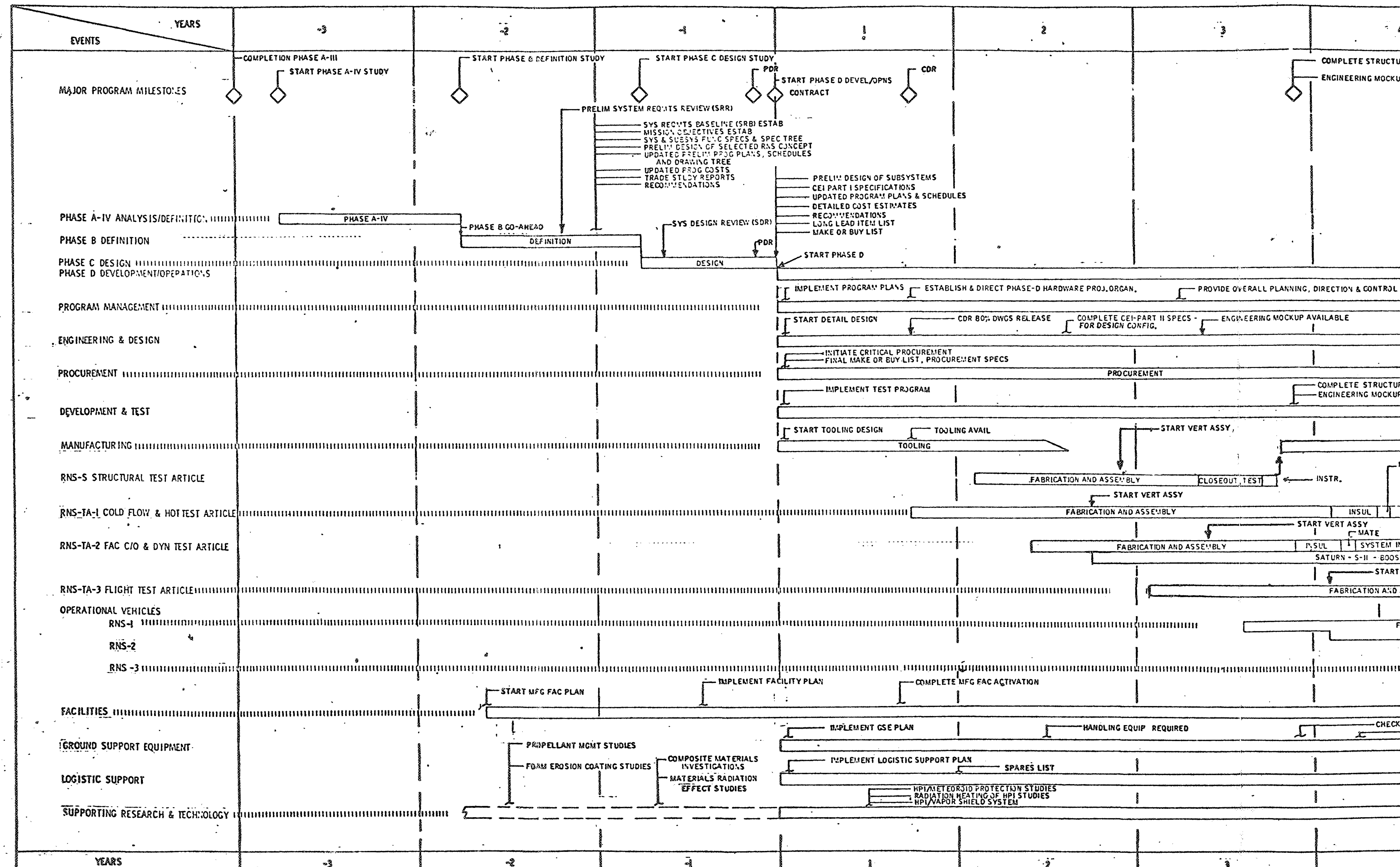
An evaluation of the overall reusable nuclear shuttle program development schedule for the baseline and boilerplate configuration (Figure 4-1) indicates that the phasing of manufacturing and test activities and the sequence of program milestones will lead to a total time span which meets the IOC date.

Baseline and Boilerplate Configurations (Alternate 2)

Figure 4-2 represents an alternate phasing plan applicable either to the baseline or boilerplate configurations. The number and type of development and flight articles are the same, but a variation in time phasing sequence is considered. In this alternate, the cold flow and hot test article (RNS-TA-1) is fabricated first, followed by the structural test article , RNS-S. As in the previous case, the phasing activities and milestones were made with concurrence of all groups involved, specifically, design, test and manufacturing.

The preliminary program phases, A-IV through C, are the same as in Alternate 1 schedule (Figure 4-1). Thus, Phase D commences April 1, 1974. Fabrication of the initial test article will still start nine months after Phase D go-ahead, but in this case it will be RNS-TA-1 instead of RNS-S. This phasing will allow the cold flow and hot tests to be completed earlier. Also, by advancing completion of hot testing, it is possible to advance the flight test and IOC dates.

Fabrication of the structural test article (RNS-S) is delayed six months (Figure 4-2) as compared to Alternate 1 (Figure 4-1). This delay is reflected in the timing of structural tests. However, these tests are still completed prior to the start of cold flow tests or final assembly of subsequent articles. Availability of the engineering mockup will also be delayed six months. RNS-TA-2, the facility checkout and dynamic test article, is fabricated next. This article is on the same timing as in schedule Alternate 1 so that both facility checkout and dynamic tests are completed at the same time and ahead of launch requirements.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MAJOR PROGRAM MILESTONES
COMPLETION PHASE A-III
START PHASE A-IV STUDY
START PHASE B DEFINITION STUDY
START PHASE C DESIGN STUDY
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START PHASE D DEVEL/OPNS CONTRACT
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SYS REQMTS BASELINE (SRB) ESTAB
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MATERIALS RADIATION EFFECT STUDIES
IMPLEMENT LOGISTIC SUPPORT PLAN
SPARES LIST
LOGISTIC SUPPORT
HPI/METEOROID PROTECTION STUDIES
RADIATION HEATING OF HPI STUDIES
HPI/VAPOR SHIELD SYSTEM
SUPPORTING RESEARCH & TECHNOLOGY
YEARS

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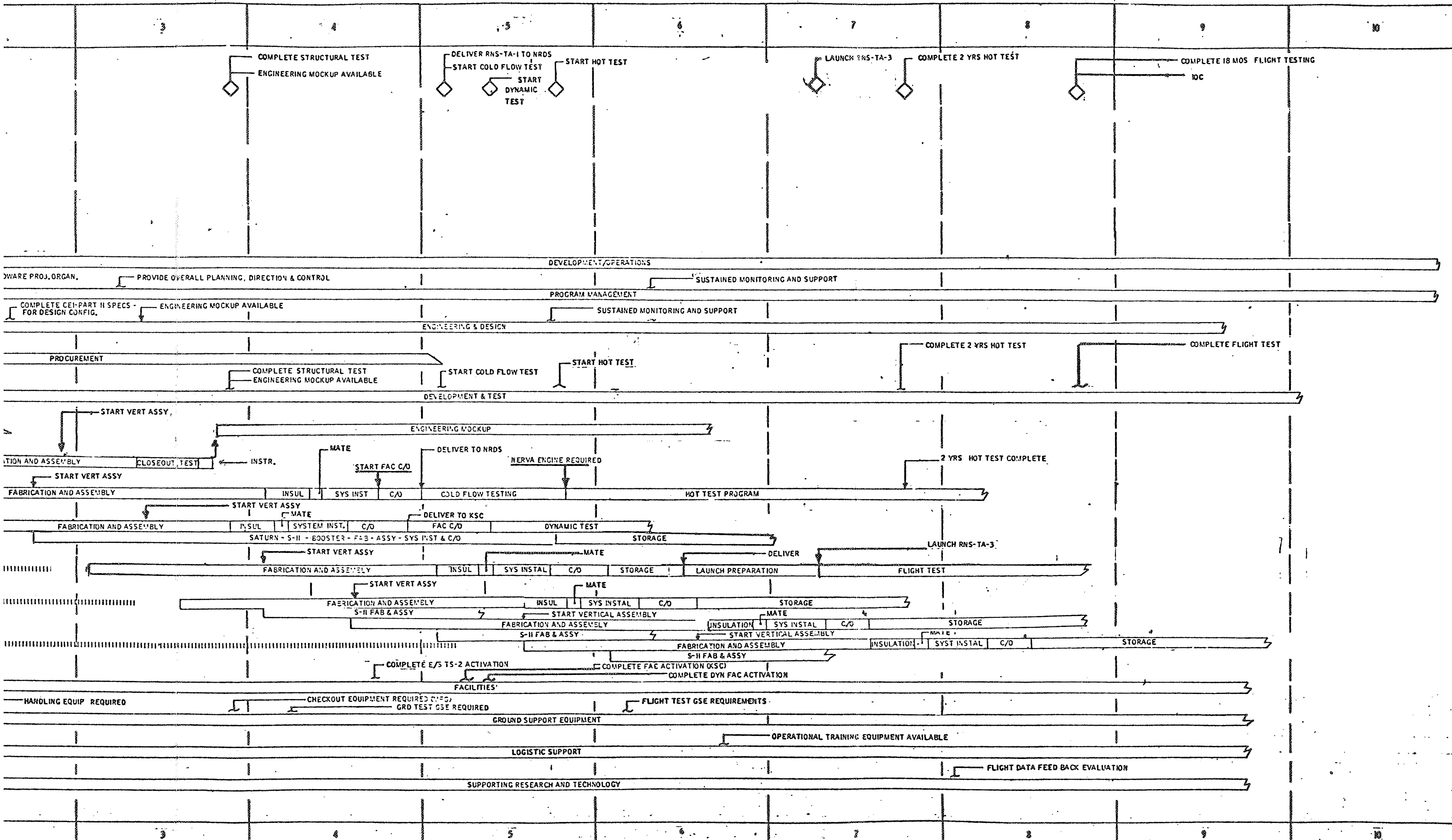


FIGURE 4-2 PRELIMINARY RNS PROGRAM DEVELOPMENT SCHEDULE

ALTERNATE 2 BASELINE CONFIGURATION
BOILERPLATE CONFIGURATION

4-7, 4-8

2 3

Production of the flight test article (RNS-TA-3), is scheduled next and will be completed in advance of launch preparation requirements. The flight test article (RNS-TA-3) will be launched six months prior to completion of two years hot test program. This can be accomplished as a result of experience gained during 1-1/2 years of hot testing. An S-II stage is scheduled for production next, thus, keeping the total production between RNS tanks and S-II stages on four month intervals. RNS-TA-3 will have a brief manufacturing storage period since it is completed about six months prior to the time it is required at the launch site. Launch of RNS-TA-3 occurs five years, ten months after Phase D go-ahead.

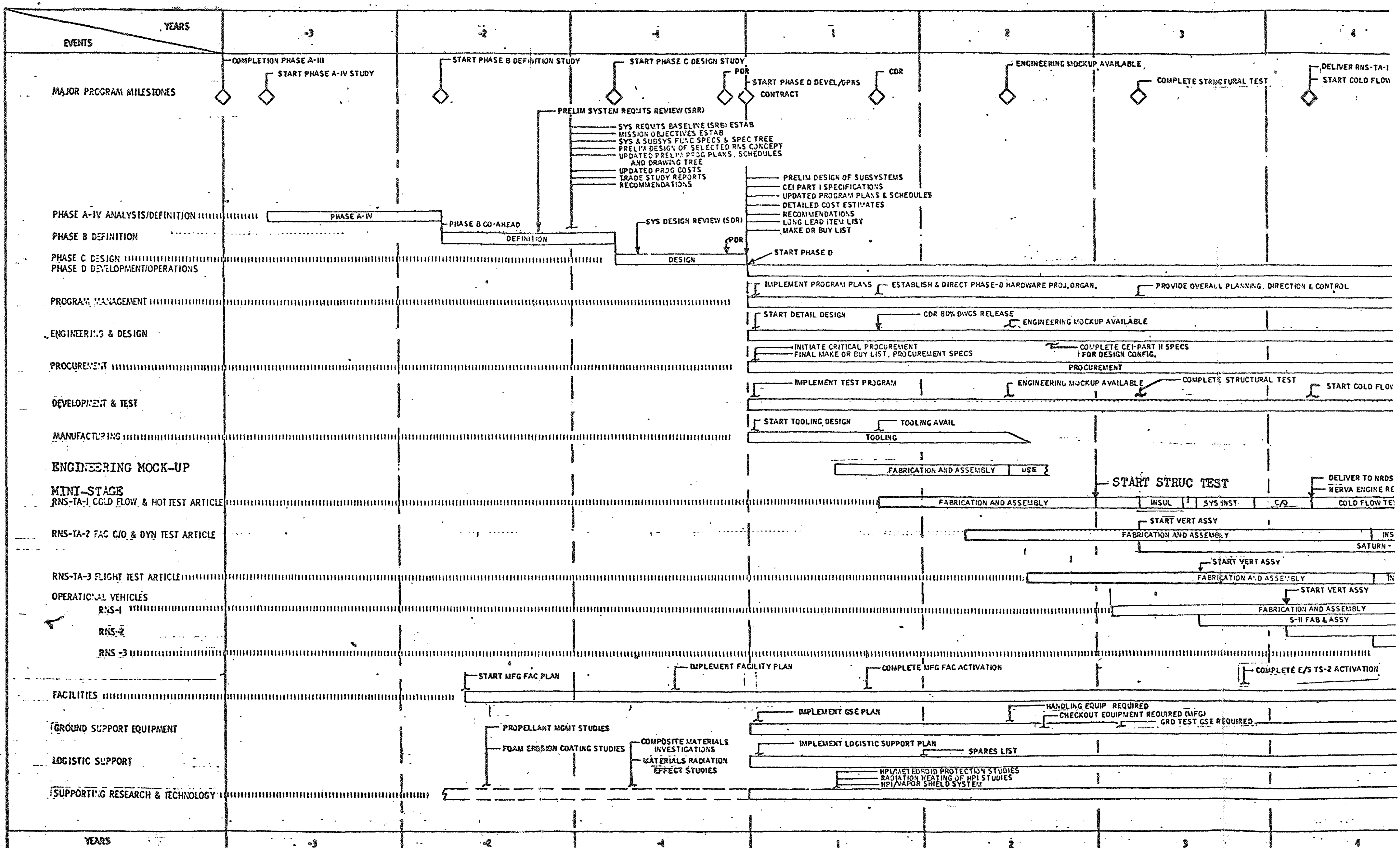
Similarly, the IOC date occurs seven years, nine months after Phase D go-ahead, and after completion of 18 months flight testing. Production of operational hardware proceeds on the same phasing schedule presented in Alternate 1 (Figure 4-1).

The basic differences between the two alternate schedules (Figures 4-1 and 4-2) are that the structural testing and engineering mockup utilization occur earlier in Alternate 1, but cold flow and hot testing are delayed. By advancing these dates in Alternate 2, the flight test and IOC dates are also advanced and the overall schedule is shortened. The effect of this change is a delay in structural design verification and availability of the engineering mockup.

Mini-Stage Configuration (Alternate 3)

The description of program phasing and major program functions for the mini-stage configuration schedule (Figure 4-3) is the same as that described for the baseline schedule except for the discussion that follows.

The initial operational capability (IOC) date depicted on this schedule is January 1, 1981, or nine months earlier than that shown on the baseline configuration schedule (Alternate 2). The reason for the earlier IOC date is that the mini-stage version of RNS-TA-1 can be manufactured in less time than the full flight configuration used in the baseline schedule. The mini-stage (RNS-TA-1) test article uses the S-II forward bulkhead and existing cylinder rings. However, the RNS conical section will be fabricated to design specifications, thus creating an RNS mini-stage configuration. As shown in the schedule, an engineering mockup is built early in the program, with a start date of six months after Phase D go-ahead, and is therefore available earlier than in the other schedules.



EVENTS
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MAJOR PROGRAM MILESTONES
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START PHASE A-IV STUDY
START PHASE B DEFINITION STUDY
START PHASE C DESIGN STUDY
PDR
START PHASE D DEVEL/OPNS CONTRACT
CDR
ENGINEERING MOCKUP AVAILABLE
COMPLETE STRUCTURAL TEST
DELIVER RNS-TA-I
START COLD FLOW
PRELIM SYSTEM REQMTS REVIEW (SRR)
SYS REQMTS BASELINE (SRB) ESTAB
MISSION OBJECTIVES ESTAB
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START COLD FLOW
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MINI-STAGE
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FACILITIES
START MFG FAC PLAN
IMPLEMENT FACILITY PLAN
COMPLETE MFG FAC ACTIVATION
COMPLETE E/S TS-2 ACTIVATION
GROUND SUPPORT EQUIPMENT
PROPELLANT MGMT STUDIES
IMPLEMENT GSE PLAN
HANDLING EQUIP REQUIRED
CHECKOUT EQUIPMENT REQUIRED (MFG)
GRD TEST GSE REQUIRED
LOGISTIC SUPPORT
FOAM EROSION COATING STUDIES
COMPOSITE MATERIALS INVESTIGATIONS
MATERIALS RADIATION EFFECT STUDIES
IMPLEMENT LOGISTIC SUPPORT PLAN
SPARES LIST
SUPPORTING RESEARCH & TECHNOLOGY
HPI/METEOROID PROTECTION STUDIES
RADIATION HEATING OF HPI STUDIES
HPI/VAPOR SHIELD SYSTEM

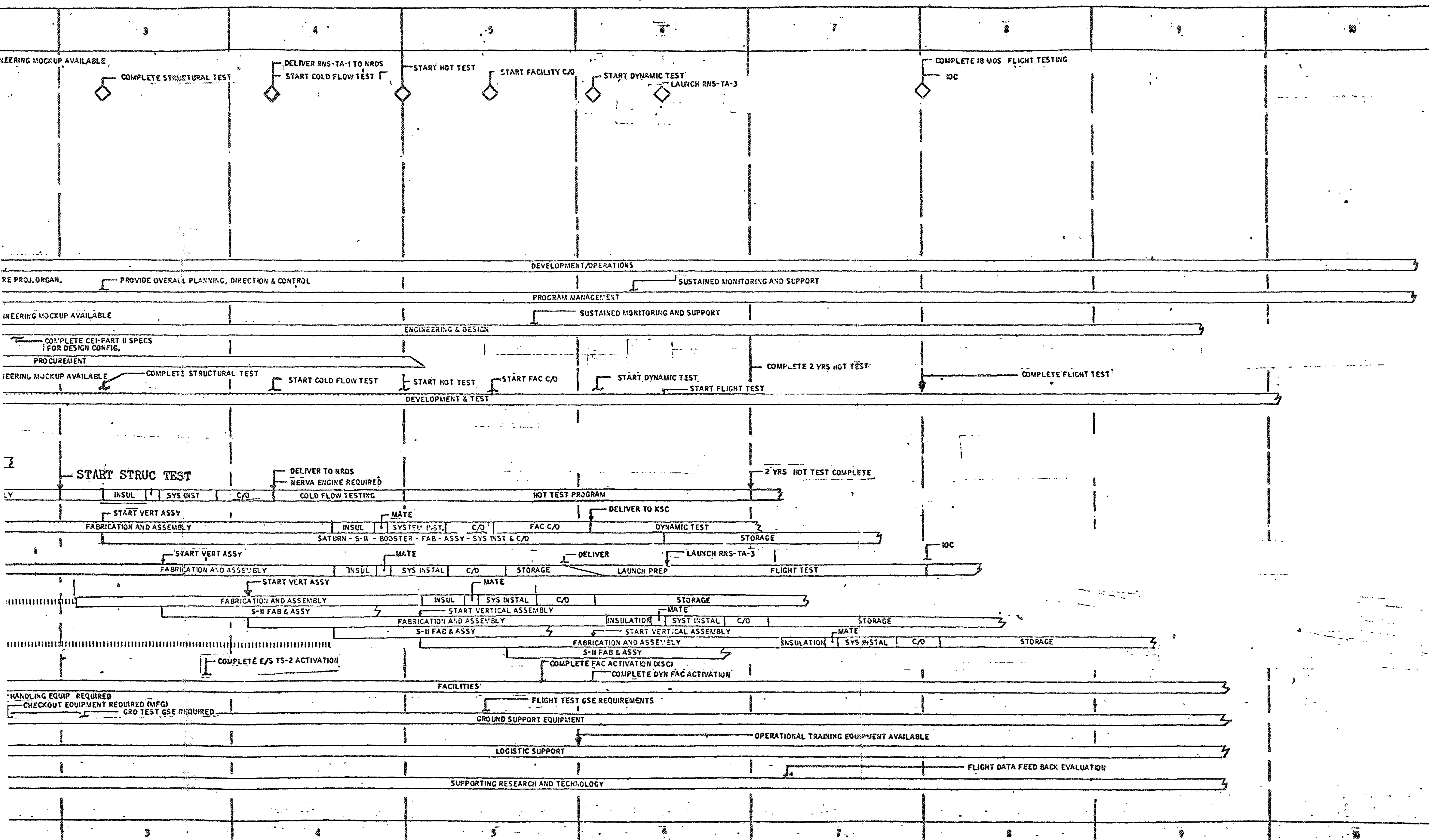

FIGURE 4-3 PRELIMINARY RNS PROGRAM DEVELOPMENT SCHEDULE

Alternate 3 Mini-Stage Configuration

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2

3

The mini-stage structural/cold flow/hot test article (RNS-TA-1) starts nine months after the start of Phase D. The manufacturing time span for this test article is thirty months or six months shorter than RNS-TA-2. This thirty-month time span includes the structural test period. The reason for the shorter manufacturing time span is that the mini-stage utilizes Saturn S-II hardware and is shorter in length than the baseline configuration, thus requiring less fabrication and assembly time. At the completion of structural tests, all required systems will be installed and the RNS-TA-1 would then be delivered to NRDS for cold flow and hot testing. The NERVA engine will be required in March of 1977.

The facility checkout and dynamic test article (RNS-TA-2) is scheduled for start of fabrication six months after the start of RNS-TA-1, with a projected forty months manufacturing period. Upon completion of RNS-TA-2, it will be delivered to KSC for six months of facility checkout, followed by delivery to MSFC for the dynamic test.

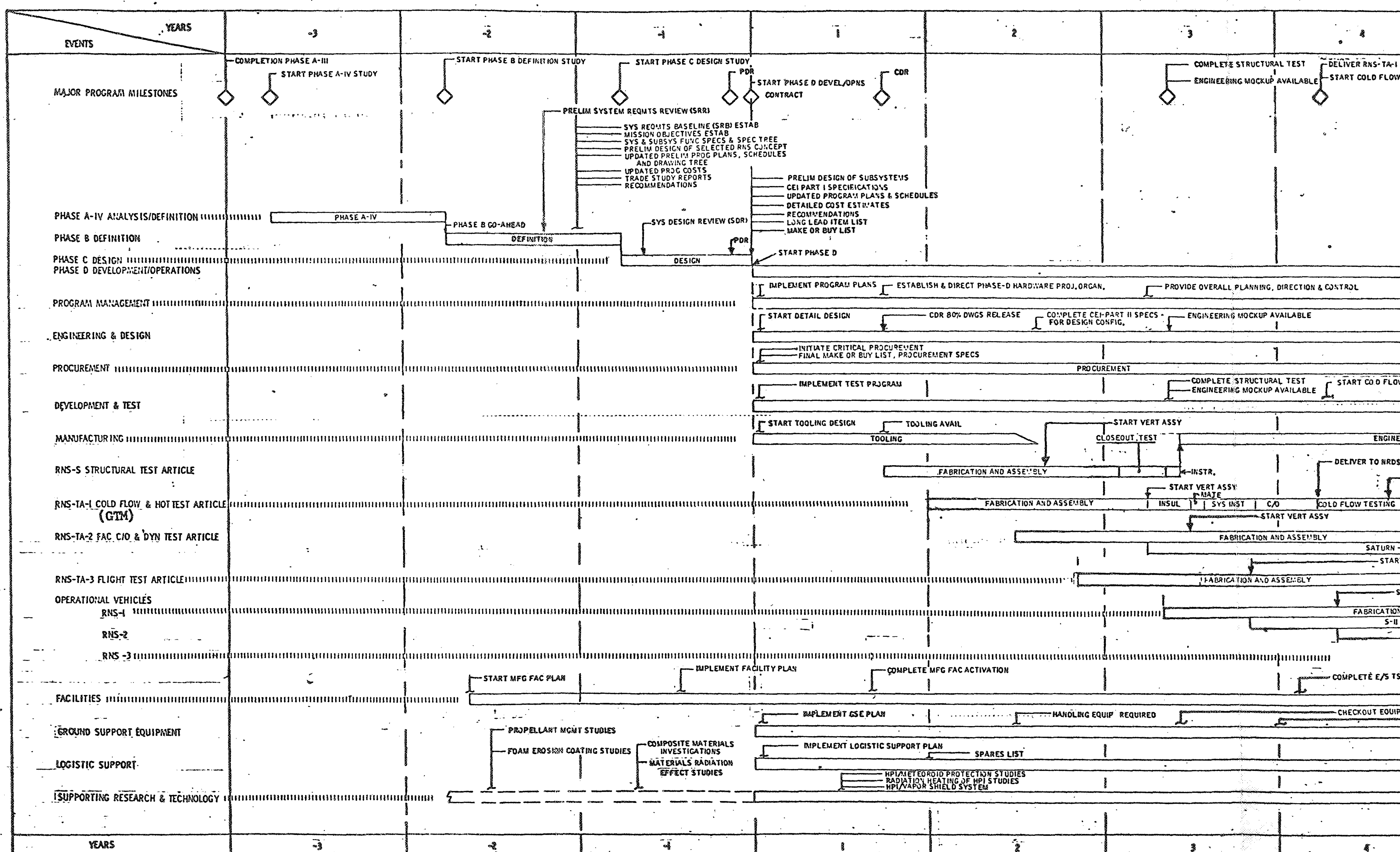
The flight test article (RNS-TA-3) is scheduled to start fabrication four months after the start of RNS-TA-2. Normal manufacturing time span for this flight test article is thirty-six months after which it will be delivered to KSC. As before, the initial S-II is not started until after the flight test article. This schedule gives a time span from Phase D go-ahead to IOC date of 7.0 years which will meet the NASA guidelines.

Detail manufacturing and testing descriptions, procedures, processes, and schedules are found in the manufacturing and program test plans. A description of remaining functional activity bars found in the schedule are the same as those described in the previous sections of Alternates 1 and 2.

An analysis of the reusable nuclear shuttle program schedule for the mini-stage configuration (Alternate 3) indicates that the major sequencing requirements are satisfied, e.g., facility checkout is completed before launch preparations of RNS-TA-3 start. However, one less test article is required for this schedule as compared with the baseline schedule, but a separate engineering mockup is required, possibly constructed of wood.

Ground Test Module (GTM) Configuration (Alternate 4)

The description of program phasing and major program functions for the ground test module (GTM) configuration program schedule (Figure 4-4) is the same as that described previously for the baseline schedule except for the description that follows.



YEARS
EVENTS
-3
-2
-1
1
2
3
4
MAJOR PROGRAM MILESTONES
COMPLETION PHASE A-III
START PHASE A-IV STUDY
START PHASE B DEFINITION STUDY
START PHASE C DESIGN STUDY
PDR
START PHASE D DEVEL/OPNS CONTRACT
CDR
COMPLETE STRUCTURAL TEST
ENGINEERING MOCKUP AVAILABLE
DELIVER RNS-TA-1
START COLD FLOW
PRELIM SYSTEM REQMTS REVIEW (SRR)
SYS REQMTS BASELINE (SRB) ESTAB
MISSION OBJECTIVES ESTAB
SYS & SUBSYS FUNC SPECS & SPEC TREE
PRELIM DESIGN OF SELECTED RNS CONCEPT
UPDATED PRELIM PROG PLANS, SCHEDULES AND DRAWING TREE
UPDATED PROG COSTS
TRADE STUDY REPORTS
RECOMMENDATIONS
PRELIM DESIGN OF SUBSYSTEMS
CEI PART I SPECIFICATIONS
UPDATED PROGRAM PLANS & SCHEDULES
DETAILED COST ESTIMATES
RECOMMENDATIONS
LONG LEAD ITEM LIST
MAKE OR BUY LIST
PHASE A-IV ANALYSIS/DEFINITION
PHASE A-IV
PHASE B GO-AHEAD
PHASE B DEFINITION
DEFINITION
SYS DESIGN REVIEW (SDR)
PDR
START PHASE D
PHASE C DESIGN
PHASE D DEVELOPMENT/OPERATIONS
DESIGN
IMPLEMENT PROGRAM PLANS
ESTABLISH & DIRECT PHASE-D HARDWARE PROJ. ORGAN.
PROVIDE OVERALL PLANNING, DIRECTION & CONTROL
PROGRAM MANAGEMENT
START DETAIL DESIGN
CDR 80% DWGS RELEASE
COMPLETE CEI-PART II SPECS - FOR DESIGN CONFIG.
ENGINEERING MOCKUP AVAILABLE
ENGINEERING & DESIGN
INITIATE CRITICAL PROCUREMENT
FINAL MAKE OR BUY LIST, PROCUREMENT SPECS
PROCUREMENT
PROCUREMENT
IMPLEMENT TEST PROGRAM
COMPLETE STRUCTURAL TEST
ENGINEERING MOCKUP AVAILABLE
START COLD FLOW
DEVELOPMENT & TEST
START TOOLING DESIGN
TOOLING AVAIL
START VERT ASSY
MANUFACTURING
TOOLING
CLOSEOUT TEST
ENGINEE
RNS-S STRUCTURAL TEST ARTICLE
FABRICATION AND ASSEMBLY
INSTR.
DELIVER TO NRDS
START VERT ASSY
MATE
RNS-TA-1 COLD FLOW & HOT TEST ARTICLE (GTM)
FABRICATION AND ASSEMBLY
INSUL
SYS INST
C/O
COLD FLOW TESTING
START VERT ASSY
RNS-TA-2 FAC C/O & DYN TEST ARTICLE
FABRICATION AND ASSEMBLY
SATURN - S
START V
RNS-TA-3 FLIGHT TEST ARTICLE
FABRICATION AND ASSEMBLY
OPERATIONAL VEHICLES
STA
RNS-1
FABRICATION A
RNS-2
S-II FA
RNS-3
START MFG FAC PLAN
IMPLEMENT FACILITY PLAN
COMPLETE MFG FAC ACTIVATION
COMPLETE E/S TS-2
FACILITIES
IMPLEMENT GSE PLAN
HANDLING EQUIP REQUIRED
CHECKOUT EQUIPME
GROUND SUPPORT EQUIPMENT
PROPELLANT MGMT STUDIES
FOAM EROSION COATING STUDIES
COMPOSITE MATERIALS INVESTIGATIONS
MATERIALS RADIATION EFFECT STUDIES
IMPLEMENT LOGISTIC SUPPORT PLAN
SPARES LIST
LOGISTIC SUPPORT
HPI/METEOROID PROTECTION STUDIES
RADIATION HEATING OF HPI STUDIES
HPI/VAPOR SHIELD SYSTEM
SUPPORTING RESEARCH & TECHNOLOGY
YEARS
-3
-2
-1
1
2
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4

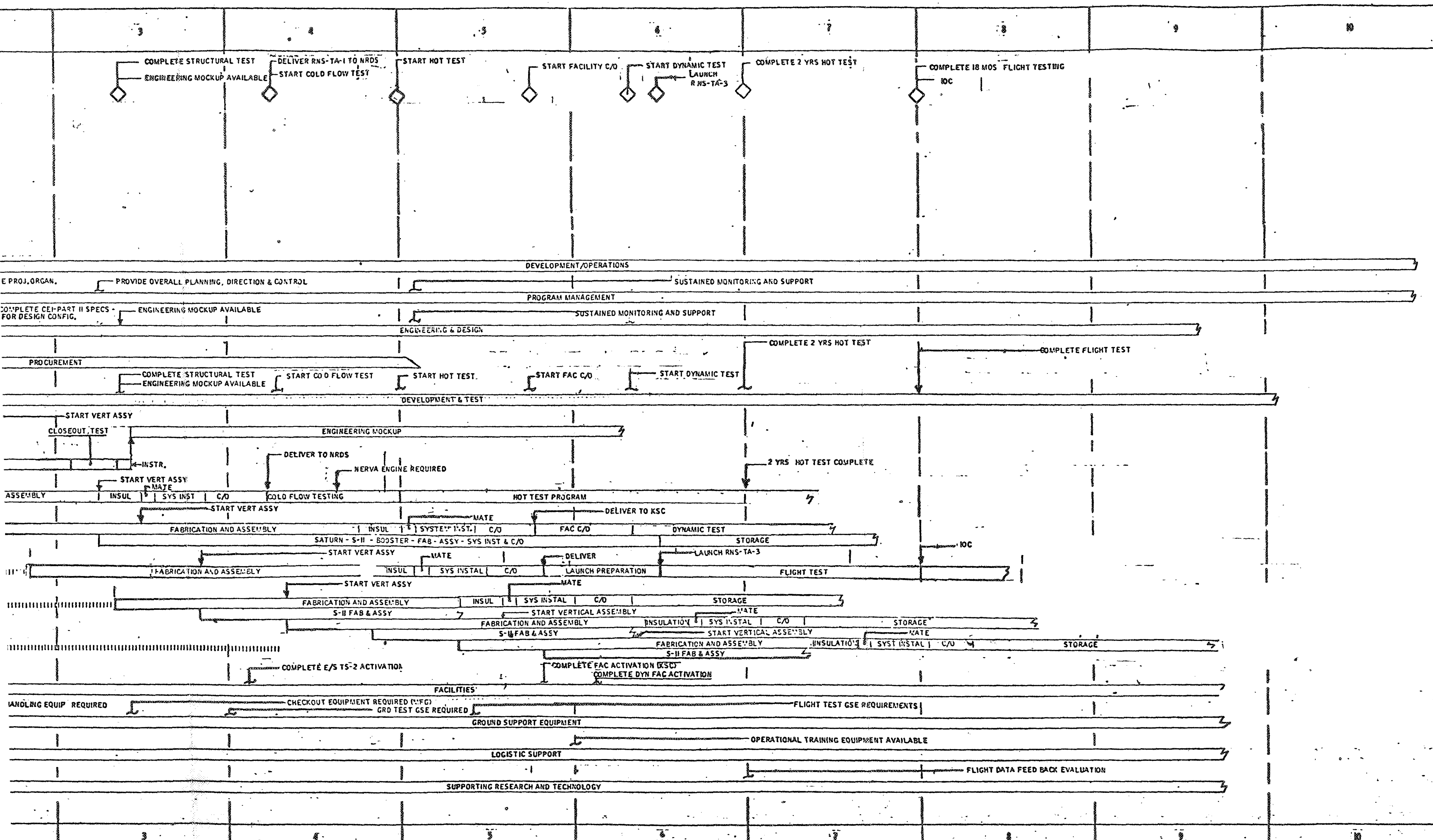

FIGURE 4-4 PRELIMINARY RNS PROGRAM DEVELOPMENT SCHEDULE ALTERNATE 4 GTM Configuration

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The initial operational capability (IOC) date shown on the schedule is nine months earlier than depicted on the baseline program schedule (Alternate 2). An earlier IOC date can be realized by using surplus available S-II hardware, i. e., forward bulkhead, and cylinder sections in the RNS-TA-1 construction, thus reducing the manufacturing time from forty months to twenty-seven months.

As shown in the schedule (Figure 4-4), the structural test article (RNS-S) will start nine months after Phase D go-ahead. Manufacturing and structural testing will require twenty months after which this test article will be used as an engineering mockup.

Fabrication of the cold flow/hot test article (RNS-TA-1) will be initiated three months after the start of RNS-S. Availability of Saturn S-II hardware makes this spacing feasible. After manufacture of RNS-TA-1, the test article will be delivered to NRDS to start nine months of cold flow testing, followed by two years of hot testing. The NERVA engine will be required in August of 1977.

The facility checkout and dynamic test article RNS-TA-2 is scheduled to start fabrication six months after RNS-TA-1. This article is manufactured to flight configuration and will require a forty-month manufacturing period, after which it will be shipped to KSC for a six-month facility checkout period, followed by delivery to MSFC for the dynamic test.

Flight test article (RNS-TA-3) is scheduled to start fabrication four months after the start of RNS-TA-2. Normal manufacturing time span of thirty-six months is shown in the schedule after which it will be shipped to KSC for launch. The time required from Phase D go-ahead to IOC date is 7.0 years.

Detail manufacturing and testing descriptions, procedures, processes and schedules are found in the manufacturing and program test plans. A description of phasing and milestones for the remaining functional activity bars found in the schedule are the same as described in the previous sections of Alternates 1 and 2.

Schedules Summary Evaluation

An evaluation of the four alternate program development schedules indicates each of the schedules is feasible, although none is ideal in all respects. Each schedule has some dificiencies either in IOC date (based on MSFC study guidelines) or in the testing phase logic. However, the schedules contain a certain amount of flexibility with a reasonable amount of time slack allowed for unforeseeable program delays or test failures. Phase A-IV through Phase C have the same calendar start dates and associated time for the four schedules. IOC dates differ by eleven months, with the earliest IOC date related to the mini-stage and ground test module configurations. IOC date differences of the schedules are attributed to the following factors:

1. Number of test articles used in the program schedules
2. Number of tests scheduled for each test article
3. Differences in test article fabrication start dates
4. Use of available Saturn S-II hardware and tooling
5. Differences in fabrication and assembly time spans when available S-II hardware is used

The baseline configuration program development schedules reflect the desired manufacturing time spans and testing sequences within the program constraints used in the development of this schedule. An earlier IOC date could be realized by modifying or changing any of the following ground rules and assumptions, e.g., shortening the length of the hot test period or the flight test period; starting the flight test prior to the completion of the hot test; or shortening study Phases A-IV or B. However, the time spans used are the best estimates of realistic requirements. The above comments and remarks are applicable to the baseline, as well as the boilerplate configurations. The baseline configuration schedule has a distinct advantage over the other alternates because of the increase in the level of confidence if the ground test article RNS-TA-1 is fabricated as a full flight configuration vehicle.

An analysis of the mini-stage program schedule indicates the different testing conditions are not as desirable as the testing program portrayed on the baseline configuration schedule. The cold flow and hot test would be conducted on a smaller than flight size configuration test article and manufacturing would encounter a problem of manpower utilization in the manufacturing sequence of the test articles. Additionally, there is a measure of uncertainty of the availability and condition of S-II hardware.

The ground test module (GTM) schedule is well sequenced in that there is little overlapping of the major tests. No storage time is required for any of the test articles. Manufacturing time spans represent optimal periods for each of the manufacturing processes. The primary uncertainty in evaluating this schedule is the assumption that S-II hardware will be available and suitable for use in the manufacture of test article RNS-TA-1. This question needs further investigation.

Assuming NASA's IOC date is not firmly fixed and the difference between Alternates 1 and 2 is not critical, it is recommended that Alternate 1 schedule be adopted. The rationale for this recommendation is that baseline/boilerplate configurations (Alternate 2) require that the cold flow/hot test article (RNS-TA-1) be fabricated prior to the structural test article. Although this is feasible, it is not a practical approach. The fabrication of the structural article after the RNS-TA-1 would delay the resolution and incorporation of structural design changes. Consequently, the delayed incorporation of required changes into the completed CF/HT article could result in a major structural modification. Additionally, the possibility exists that the magnitude of the change would preclude the incorporation of these changes into completed structural systems or articles. This would result in performing tests on an article which is not representative of the flight stage configuration.

In conclusion, the fabrication of RNS-TA-1 (Alternate 1) after the structural article (RNS-S), will permit early resolution of structural changes, as well as permit the majority of these changes to be incorporated on an in-line basis, thus keeping modification and change costs to a minimum.

5.0 PROGRAM SCHEDULES

The program schedules are a breakdown of the integrated schedules discussed in Section 4.0. The program schedules section incorporates the individual schedules of major programs such as SR&T, Development Test, Manufacturing, Facilities, Launch Operations, and a representative lunar mission. The schedules presented in this section are discussed in greater detail in Volumes II and III.

SYSTEM ENGINEERING AND DESIGN SCHEDULES

The System Engineering and Design schedule presented in Figure 5-1 depicts the phasing of the different tasks and functions (discussed in the detailed System Engineering plan) to produce the specific engineering outputs in a timely manner within allocated time and funding. The functions shown are based on procedures, controls, and management systems of NR/SD.

The schedule reflects the planned periods of accomplishments for each of the major tasks; program milestones, requirements milestones, planning and control, integration and design, etc.

SUPPORTING RESEARCH AND TECHNOLOGY PROGRAM SCHEDULE

The RNS Supporting Research and Technology (SR&T) program schedule presented in Figure 5-2 represents an evolutionary stage development approach which addresses itself to two technology design periods. These are established by the initiation of the Phase D effort of the RNS program (Development/Operations Phase). The plan is to produce an initial RNS for the 1974 technology period, and then improve the design in judicious steps beneficial to the lunar shuttle mission while evolving an advanced system for manned planetary missions operation. In this manner, the benefits derived from normal technology development, as well as programmed activities by other space elements will be maximized. Additionally, expenditures and development risk will be minimized.

The significant tasks and schedules are shown in the figure. Some of the more significant efforts beneficial to an advanced reusable nuclear stage, applicable to both lunar and manned Mars missions, include the

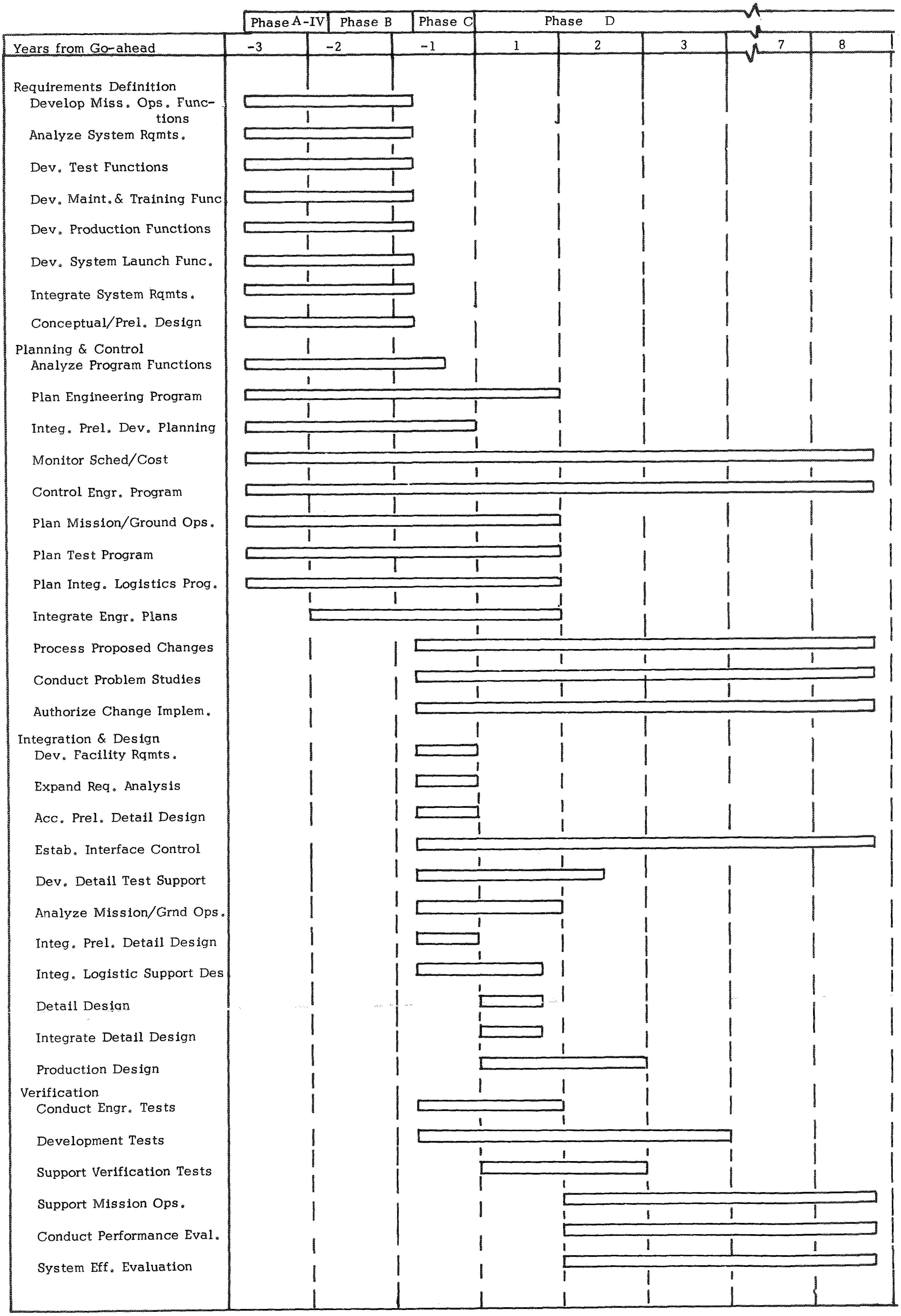


Figure 5-1 System Engineering and Design Schedule

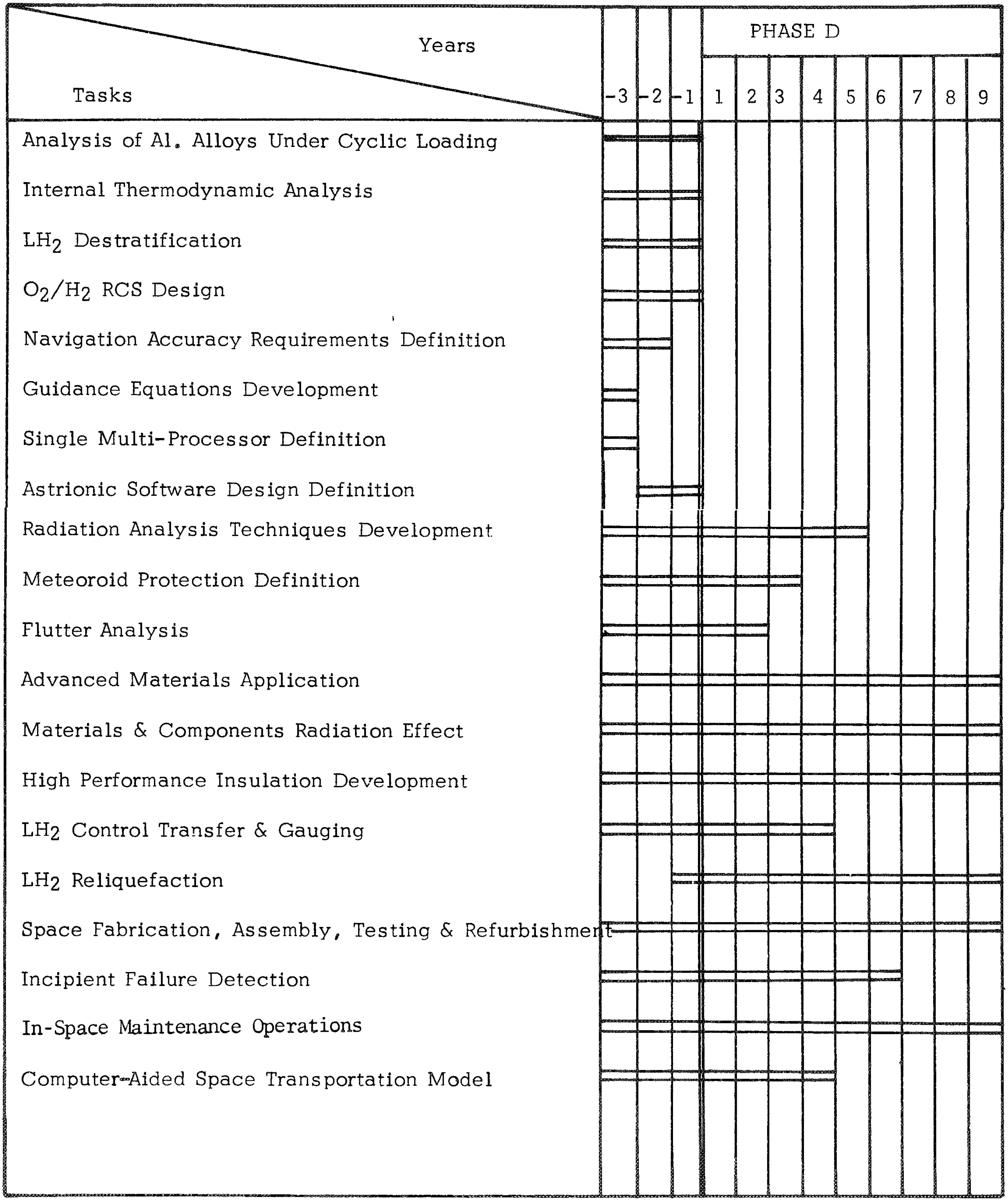


Figure 5-2. Supporting Research and Technology Program Schedule

development of boron-epoxy for application to major structural components. Also, a continuing improvement on high performance insulation, taking into consideration ease of manufacturing, installation, inspection and repair, would be beneficial to both programs. Additionally, developments in space fabrication, assembly, testing, and refurbishment could be of a significant benefit to all future space systems.

LH_2 reliquefaction (partial or total) has not shown to improve significantly the payload performance of the RNS for the reference lunar mission. On the other hand, it shows large payload performance gains for missions of extended duration, such as manned Mars exploration, and is therefore scheduled in that context.

TEST DEVELOPMENT PROGRAM

The test development program is divided into four major categories:

1. Subsystem tests
2. Cold flow tests
3. Hot tests
4. Flight tests

This section presents the schedules of each of the test programs which are discussed in detail in Volume III, Section 2.0.

Subsystem Test Schedule

The anticipated long life of the reusable nuclear stage (RNS) dictates the selection of proven materials, components, and development techniques to effect the program mission with high confidence level. The primary testing requirement is to integrate and optimize the equipment and software. This will be accomplished by an extensive subsystem test development program. Figure 5-3 is a typical schedule showing the major subsystems and their related time phasing.

Cold Flow and Hot Test Schedules

Detailed analysis of the cold and hot test programs are discussed in Volume III, Section 2.0. However, this section presents a summary of the overall baseline configuration schedule required to accomplish the cold flow and hot test programs.

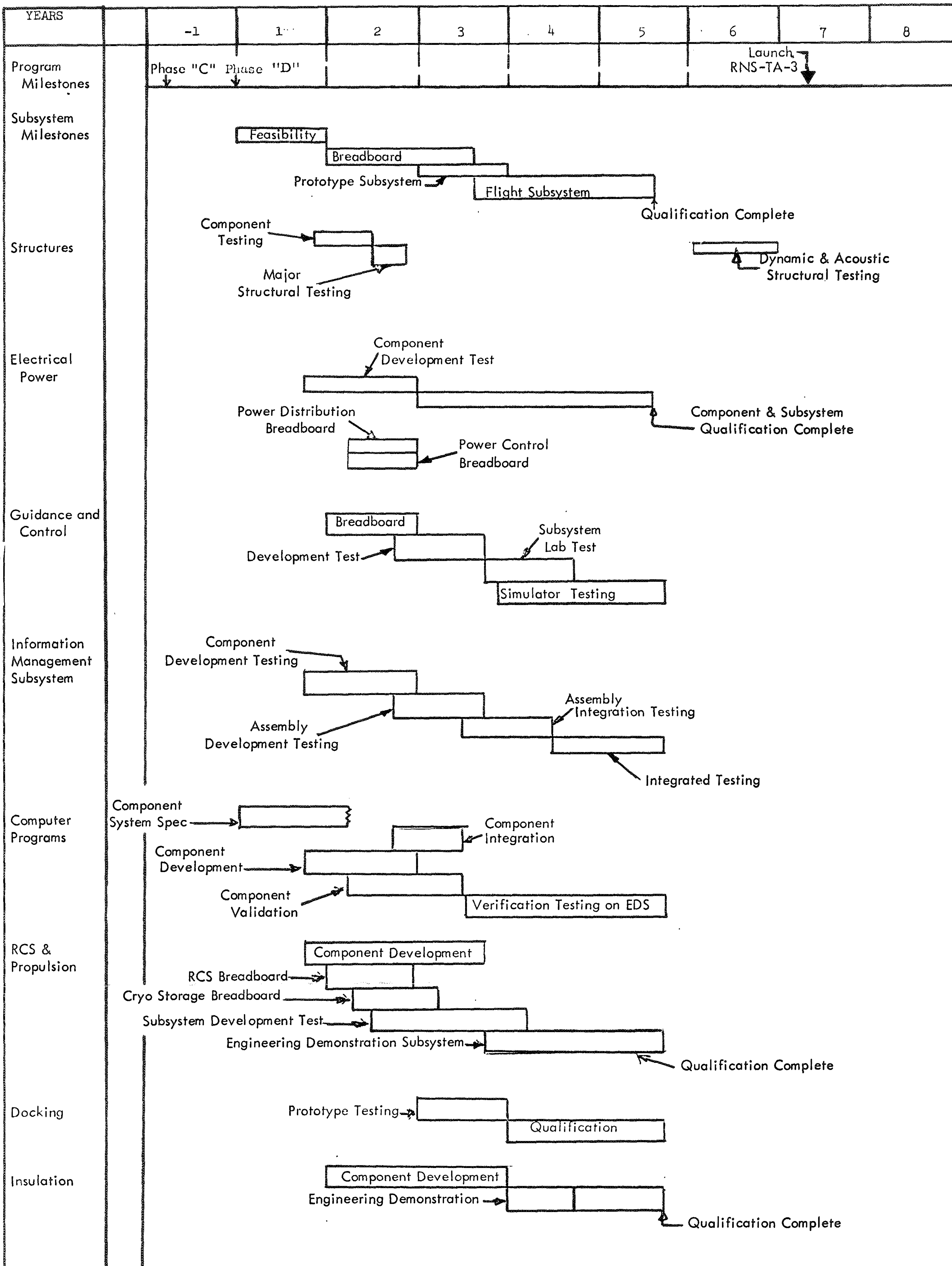


Figure 5-3. Subsystem Test Program

Cold Flow Test Schedule

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:

- Facility and tank activation and tanking
- Tanking and low propellant feed tests
- Tanking and propellant feed tests to full rated flow
- Integrated propulsion and system testing
- Operational and modification support

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

The cold flow test schedule which is estimated to last approximately nine months is shown in Figure 5-4. The cold flow test program will provide:

- Early verification of the design, manufacturing process, test procedures, and performance of the prototype systems under cryogenic environment.
- Confidence in hot testing operations at NRDS through cold flow test operations.
- 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.

Hot Test Schedule

At the completion of the cold flow test program, the cold flow test article will be utilized for the hot test program. Figure 5-5 depicts the hot test schedule which is estimated to run approximately two years.

FUNCTION	WEEK DAY
1. Receive and Inspect: a) RNS Tank b) Dummy or Unfueled Engine	
2. RNS Tank Preparation	
3. Transport RNS Tank to E/STS-2	
4. Prepare RNS Tank for Erection	
5. Erect RNS Tank on E/S TS-2	
6. Complete RNS Tank/Fac. Hook-Up	
7. Conduct Activation Tests a) Cryogenic System b) Facilities c) GSE d) C/O Systems, etc.	
8. Transport Unfueled Engine or Dummy Engine to E/STS-2	
9. Mate Engine to RNS Tank and Align	
10. Complete Interface Hook-Up	
11. Perform RNS/Fac. /GSE and Systems Interface C/O - Umbilicals, Instrumentations, Elect. Syst. Etc. and Make Necessary Modifications	
12. Tanking and Low Flow Propellant Feed Test	
13. Evaluate and Verify Prel. Fluid Dynamics on Prop. Feed and Turbo Pump Coupling	
14. Tanking and Prop. Feed Rated Flow Tests	
15. Evaluate and Verify Item 14 Results	
16. Integrated Propulsion System Testing, (a) Verify Automatic C/O System, Evaluation and Verification of Eng/Stage Control Systems and Instrumentations, End to End C/O, and Simulation of Countdown	
17. Data Analysis	
18. Operational and Modification Support	

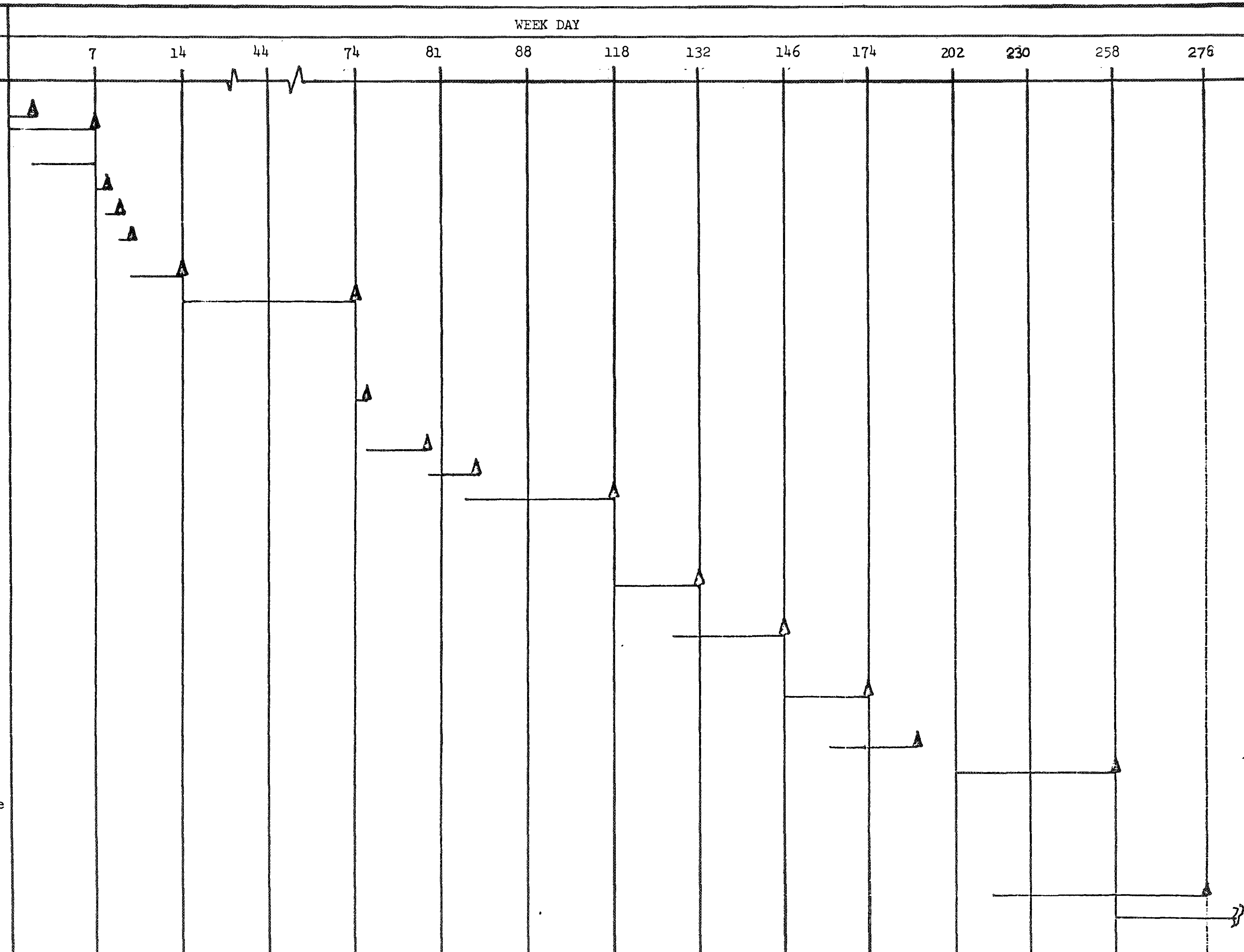


Figure 5-4 Cold Flow Test Cycle

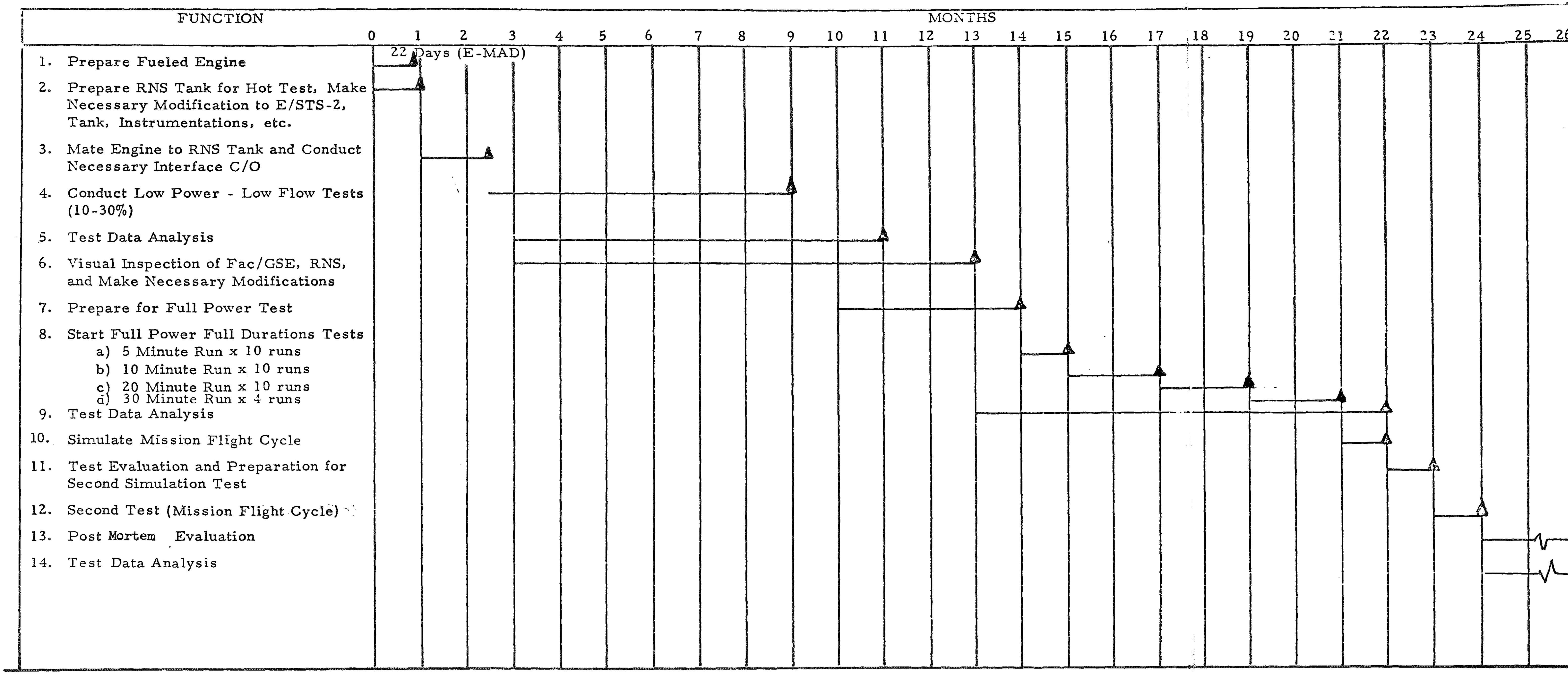


Figure 5-5 Hot Test Cycle

The hot test program, as envisioned, will yield data that will allow evaluation and verification of the integrated RNS tank design interfaced with NERVA engine. For example, a typical full-power full-duration test series is outlined in Item 8 (Figure 5-5).

The mission flight profile cannot be simulated completely because of extensive facility requirements associated with the vacuum environment. Emphasis will 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.

Flight Test Schedule

The flight test schedule is presented in Figure 5-6. The test will be initiated with the launch of RNS-TA-3, which is fully configured and instrumented, to obtain all the required flight test data. The basic objective is to demonstrate the flight worthiness and operational capability of the vehicle as a shuttle vehicle. Detailed discussion of the flight test program is presented in Volume III, Section 2.0.

Manufacturing Schedules

The manufacturing schedules are presented in three figures. Figure 5-7 represents an overall schedule for the manufacture of the required RNS tanks. Figures 5-8 and 5-9 represent the sequence of events and the flow time for the production of the structural test article and the cold flow/hot test article, respectively. The schedules are based on similar operations experienced during S-II program, and follow the manufacturing technique discussed in detail in Volume III, Section 3.0. The manufacturing schedule has been developed to make maximum utilization of existing facilities, tooling, and technical skills.

Integrated Facilities Schedule

The integrated facilities schedule shown in Figure 5-10 represents the time phasing of the major facilities required in support of the RNS program. The major facilities considered are: (1) manufacturing, (2) cold flow/hot test, (3) dynamic test, and (4) operational (KSC). Although the modification requirements for the dynamic test facility is yet to be determined (TBD), it is included only to show its utilization date. The preparation of criteria, design, construction, and activation period of all facilities are based on the start of their utilization period. Detailed description of the facilities is discussed in Volume III, Section 4.0.

Program Operations

Schedules 5-11 through 5-20 are presented for the program operations. These operations commence with the assembly and checkout in the vertical assembly building (VAB) at KSC, proceeding through launch vehicle build-up and RNS mating with INT-21, pad checkout operations, RNS orbital assembly, turnaround operations, and lunar and synchronous orbit flight operations.

Figure 5-21 represents the production/operations schedule for the baseline RNS program. The schedule was developed employing the following ground rules: (1) fabrication of one RNS plus one S-II per year, (2) ten-year operational program, (3) requirement for six flight stages (baseline), and (4) ten flights per stage, evenly spaced. The schedule shows the time periods required for each stage covering production and checkout, storage, and flight operations. It is evident that storage times for the RNS tank can be quite lengthy. RNS tank storage requirements are discussed in Volume III, Section 2.0.

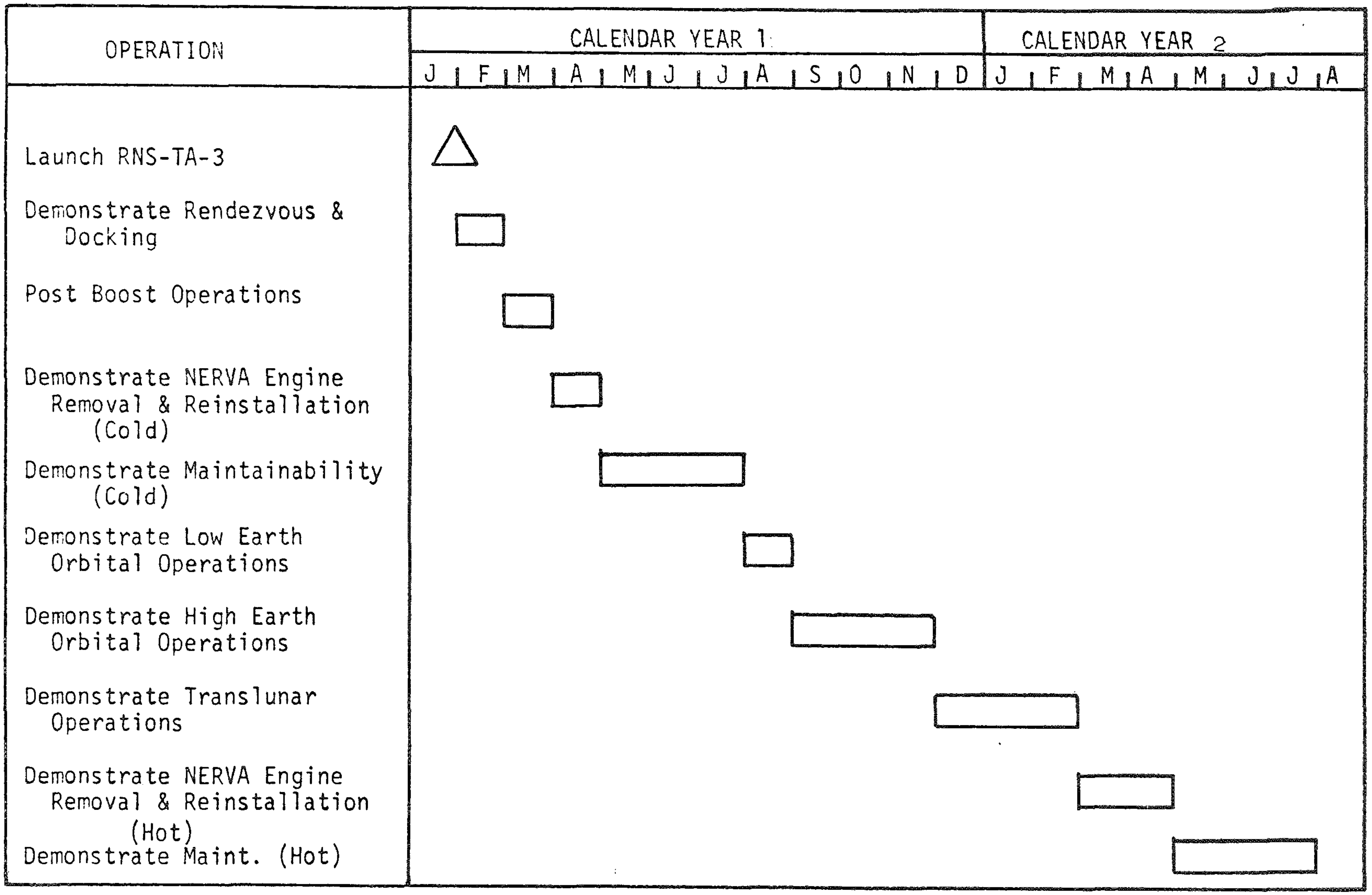


Figure 5-6 Flight Test Program Schedule

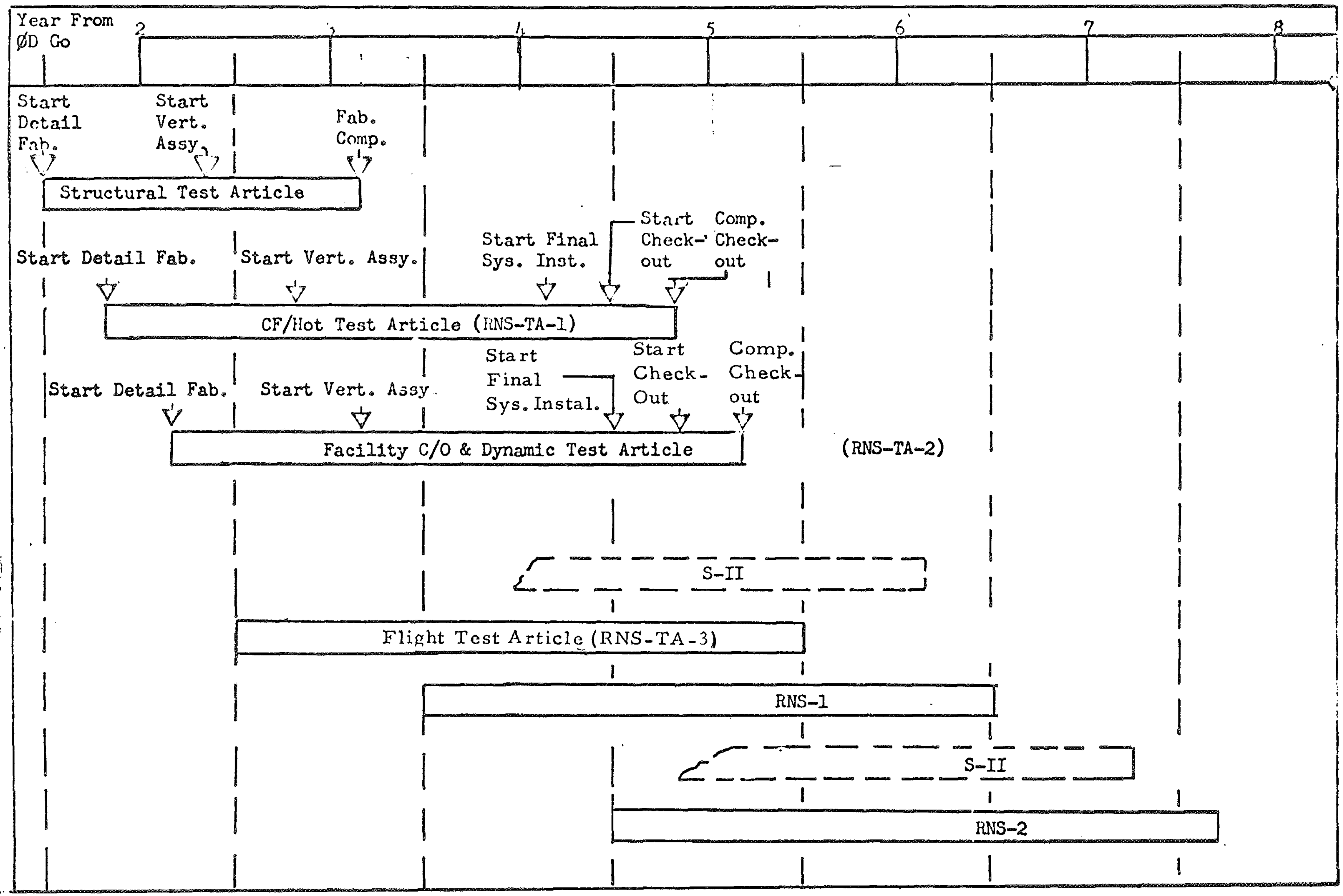


Figure 5-7 RNS Manufacturing Schedule

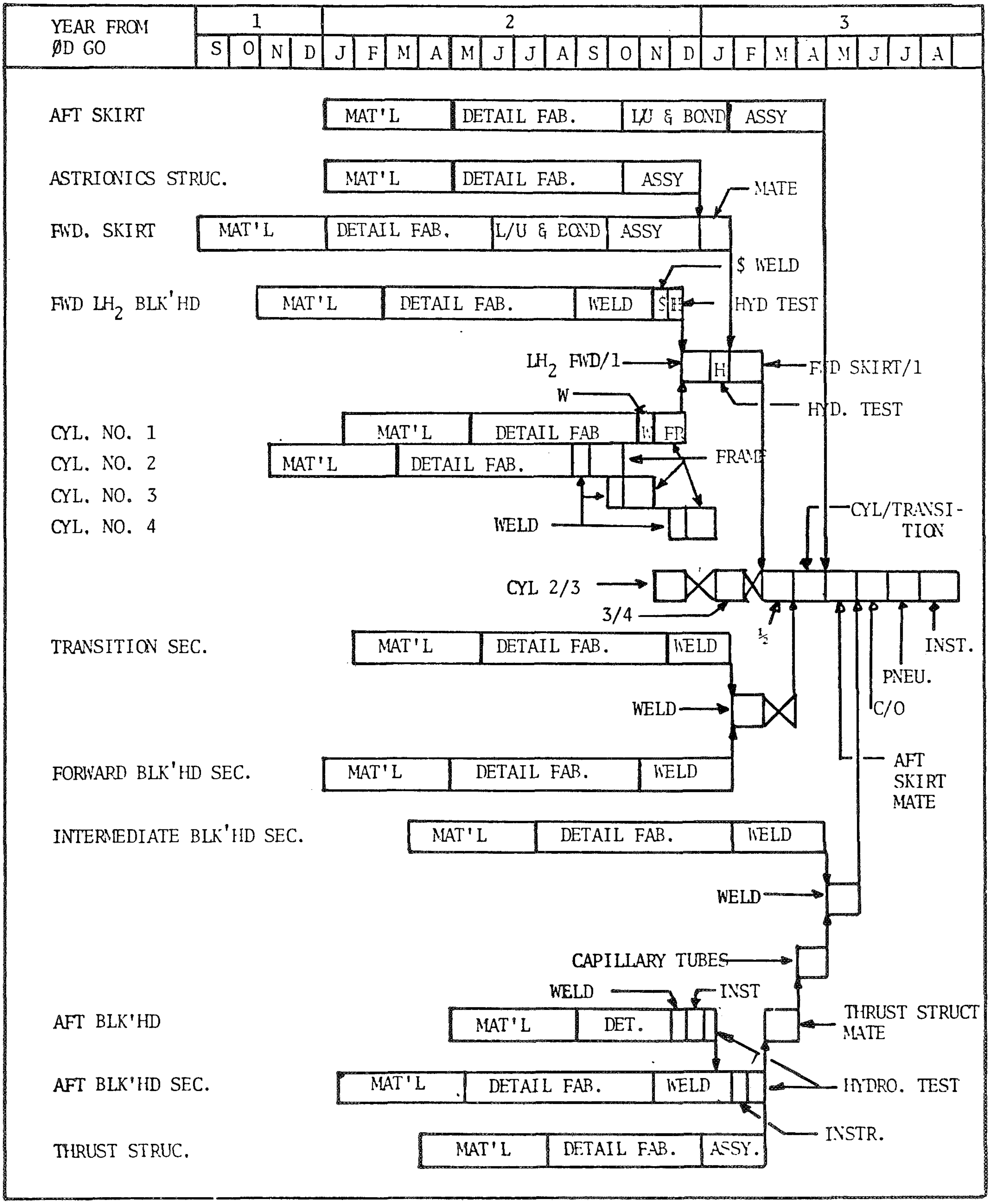


Figure 5-8 RNS Structural Test Article Manufacturing Schedule

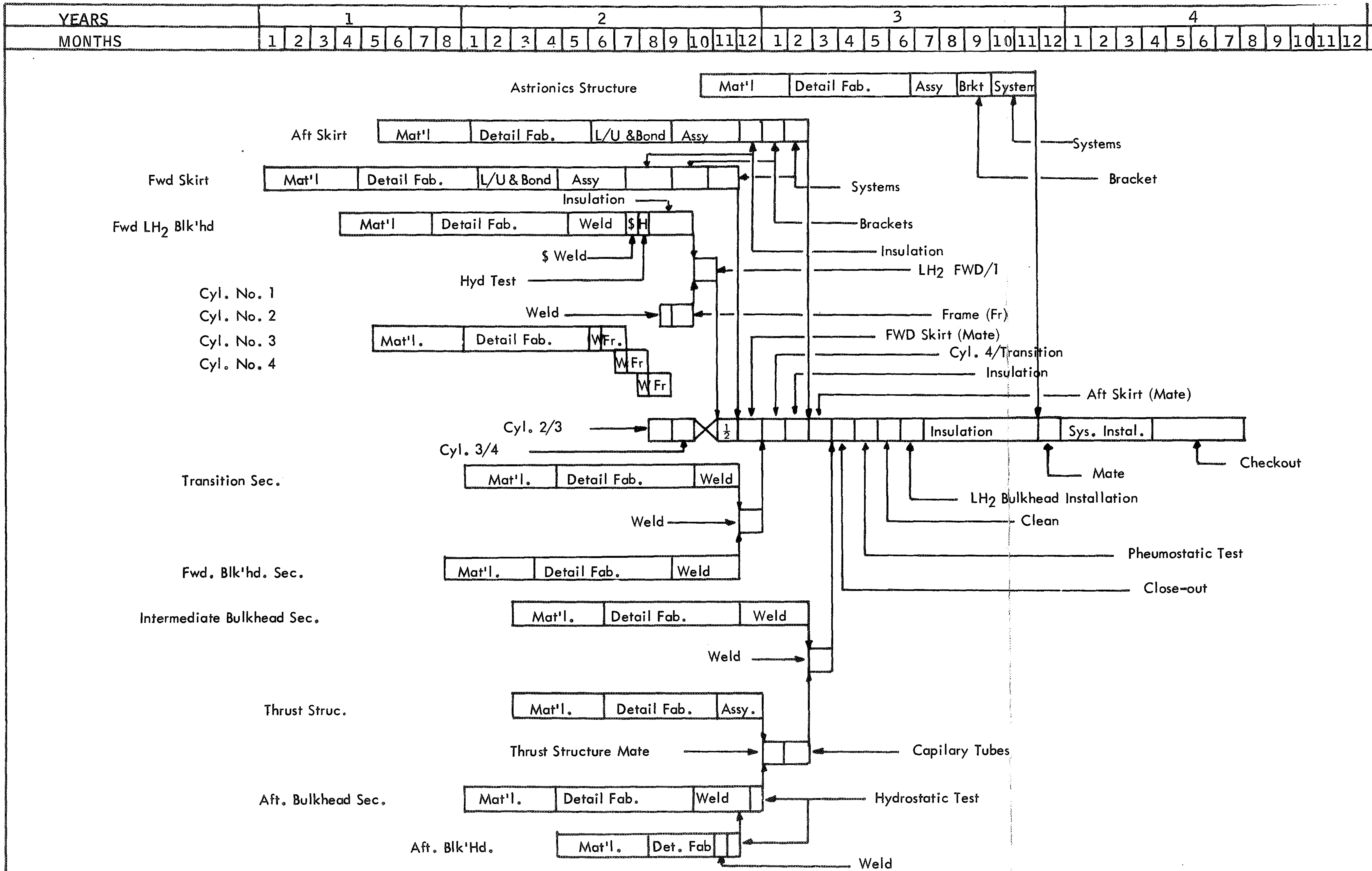
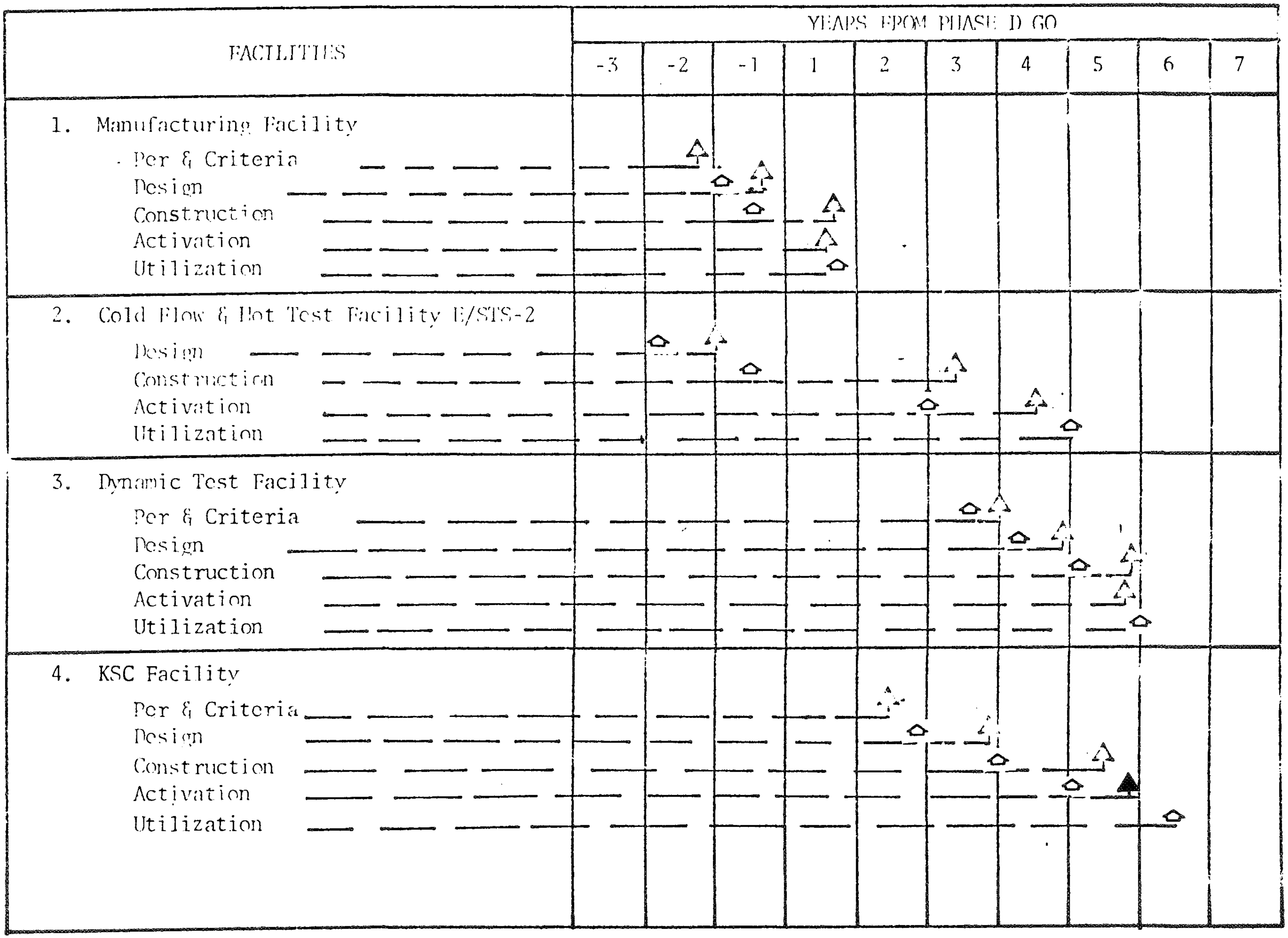


Figure 5-9. RNS Cold Flow/Hot Test Article (RNS-TA-1)



Work (completed)

Work (started

INTEGRATED FACILITIES SCHEDULE

Figure 5-10

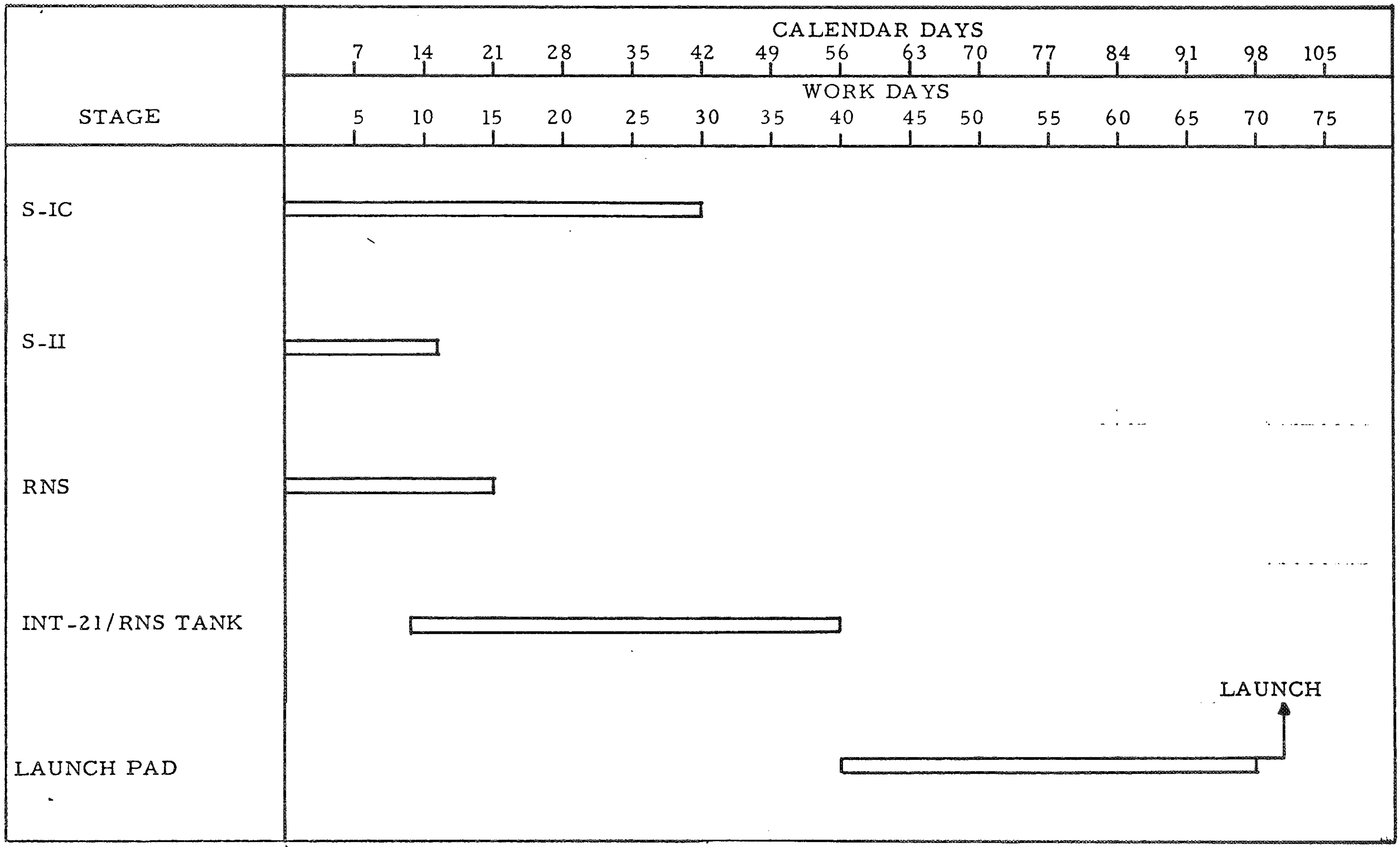


Figure 5-11 KSC Operations Timelines

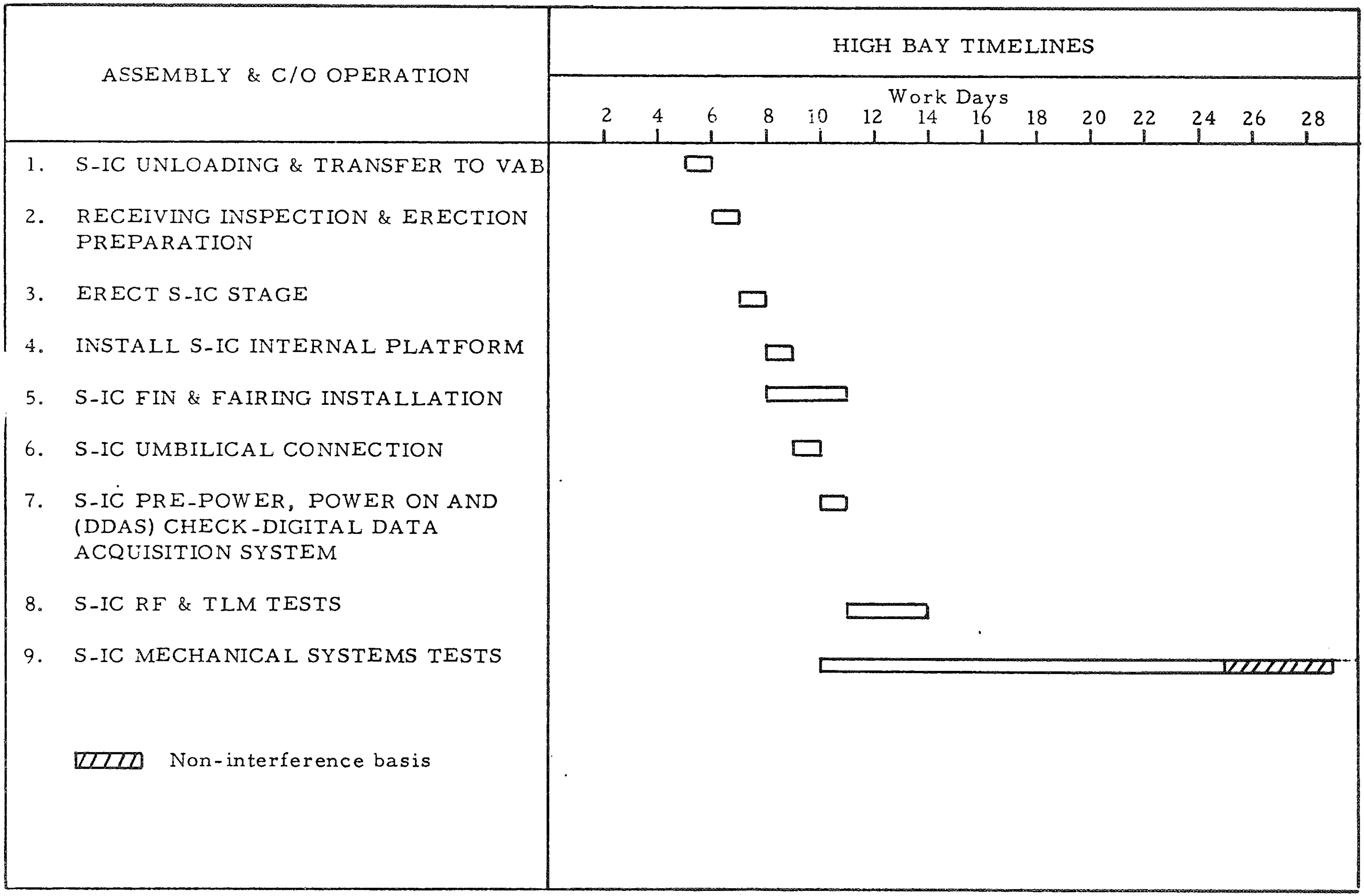


Figure 5-12 S-IC Stage Schedule

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

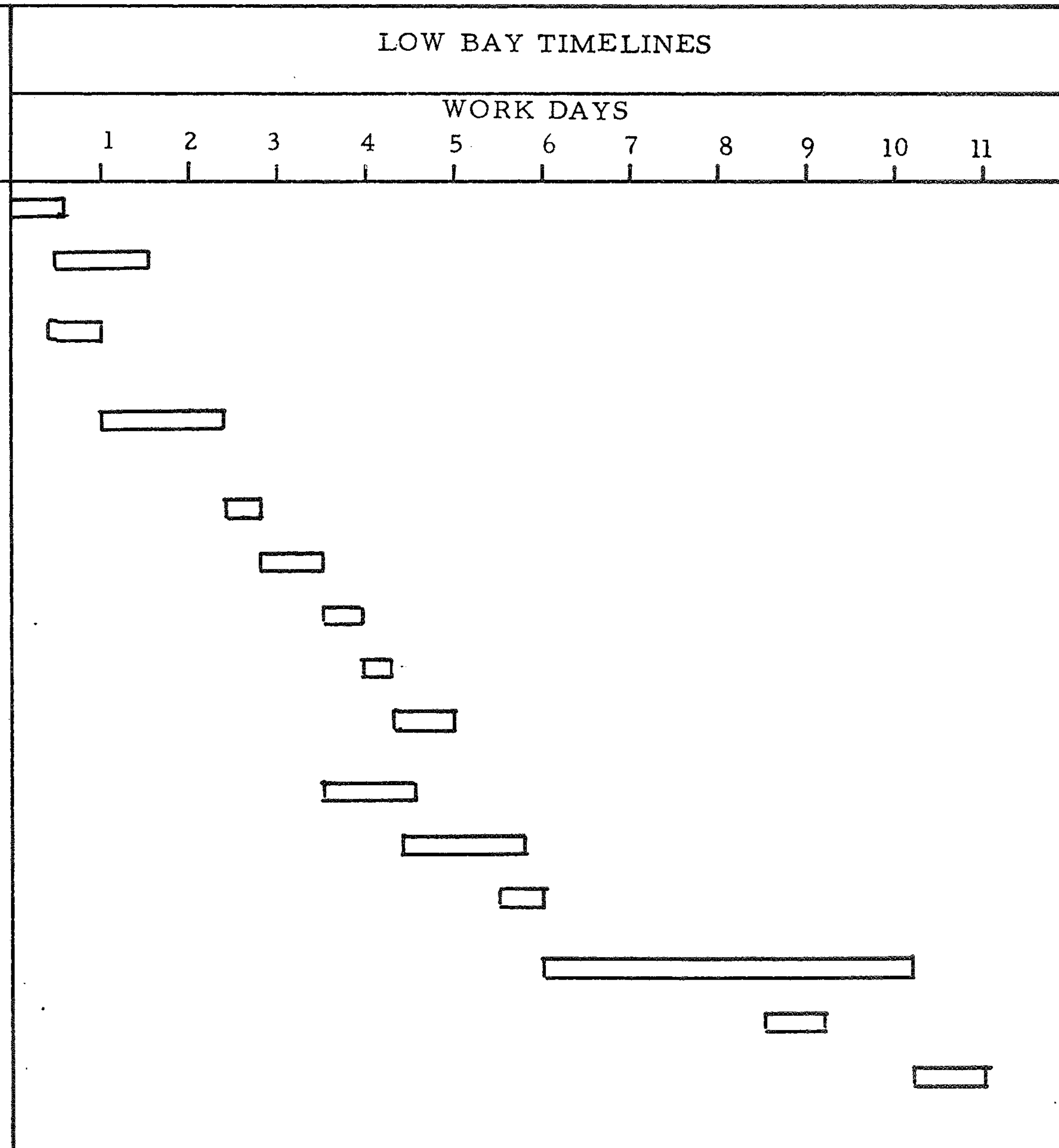


Figure 5-13 S-II Stage Schedule

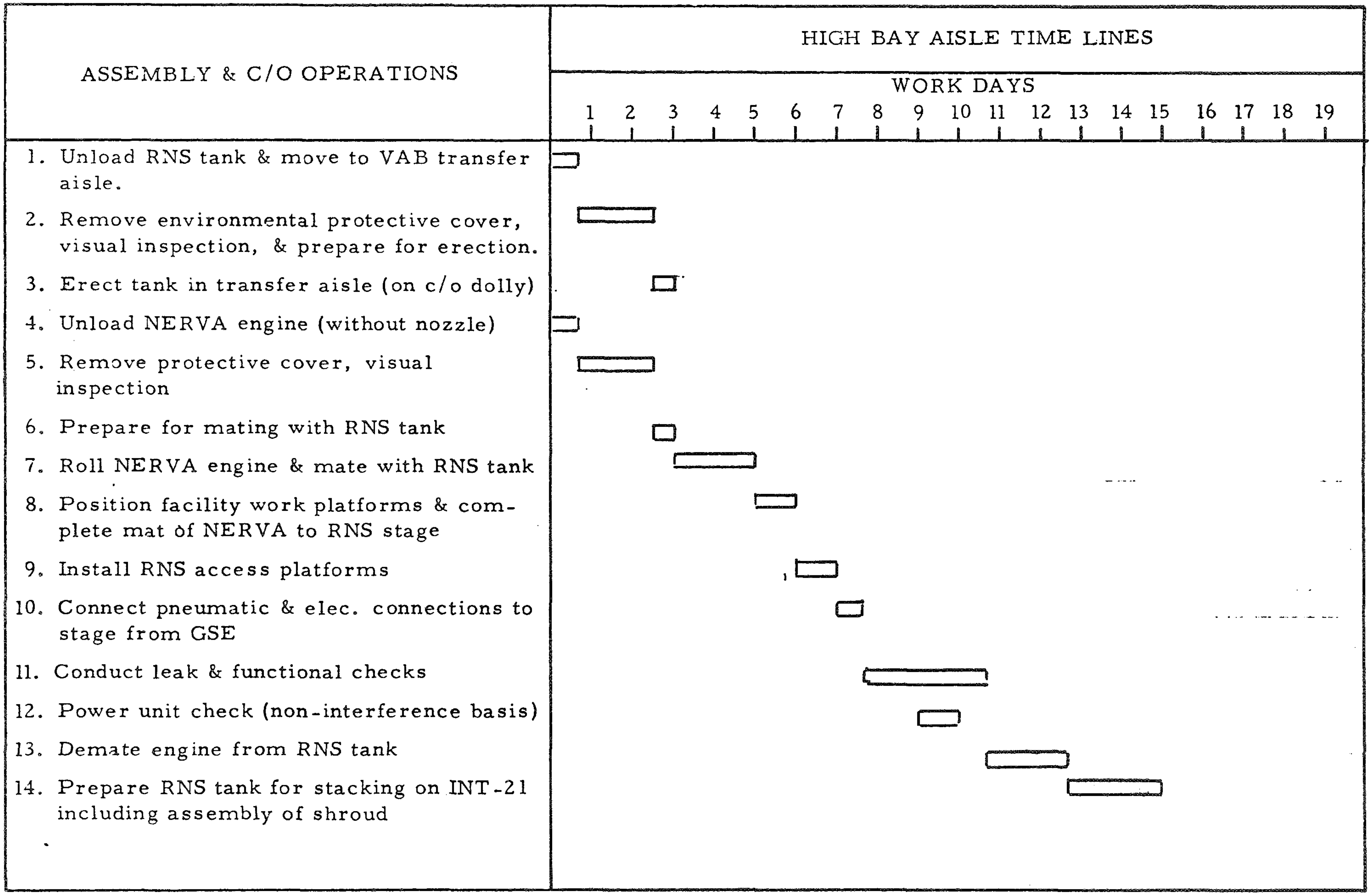


Figure 5-14 RNS Operations Schedule

ASSEMBLY & C/O OPERATIONS

1. Erect S-II on S-IC stage.
2. Erect S-II work platforms
3. S-II Umbilical connections
4. S-II Prepower, power on DDAS Checks
5. S-II RF & TLM tests
6. S-II Mechanical system tests
7. Erect RNS on INT-21
8. Complete installation of RNS platforms
9. Connect RNS umbilical (forward)
10. RNS pre-power, power on & DDAS checks
11. Astrionic unit cooling on
12. RNS RF & TLM
13. Electrical connections
14. Functional test
15. RNS & S-II network subsystem tests
16. RNS mechanical systems tests
17. GN&C system calibration & func. tests
18. L/V propellant disp. & command cutoff tests.
19. GN&C checks
20. Flight sequence & exploding bridge wire (EBW) tests.
21. Sequence malfunction test & evaluation
22. L/V emergency detection system test (EDST)
23. Preparation for L/V OAT No. 1
24. OAT No. 1 Plugs out & evaluation

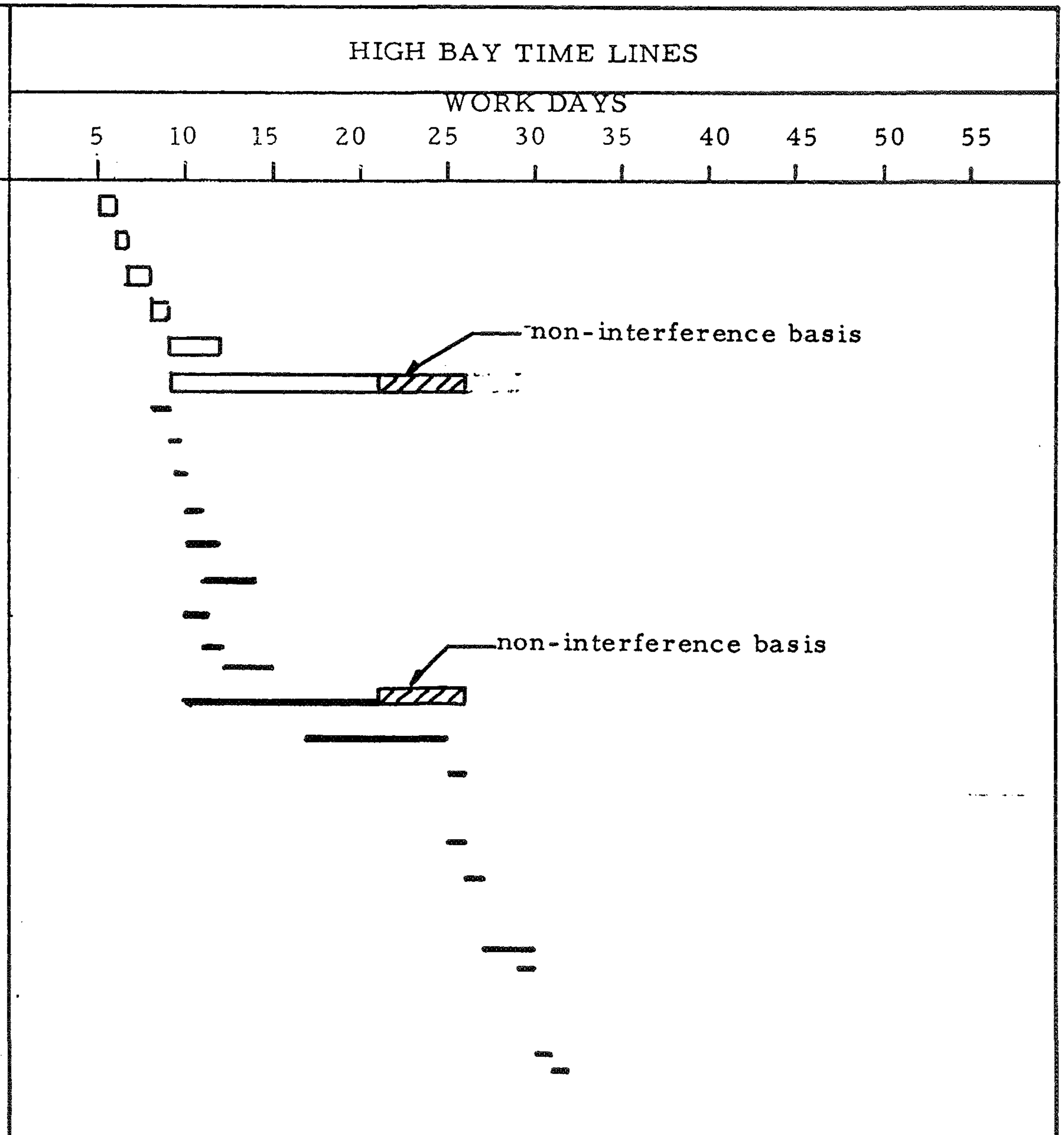


Figure 5-15 INT-21/RNS Tank Schedule

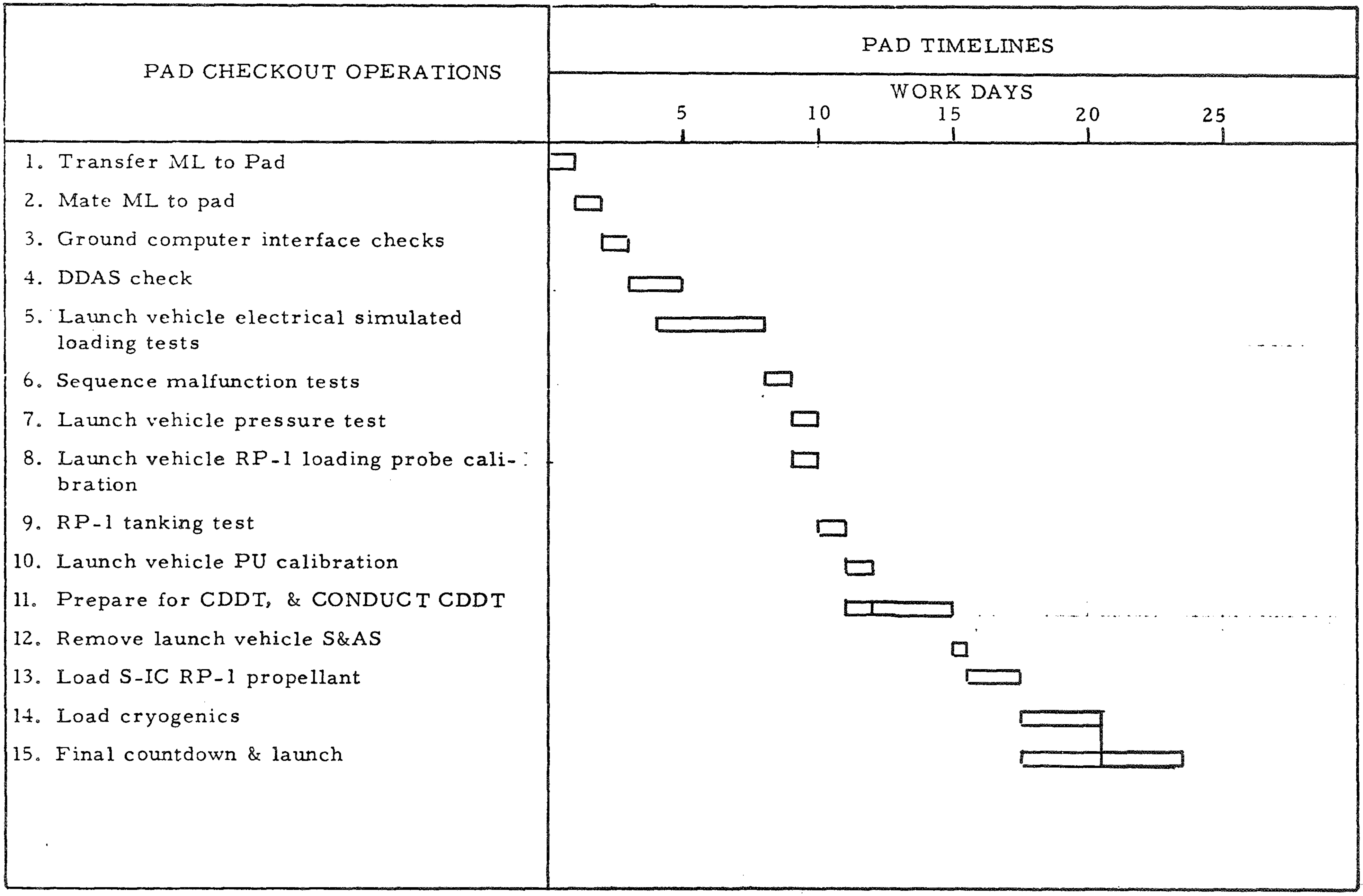


Figure 5-16 PAD Operations Schedule

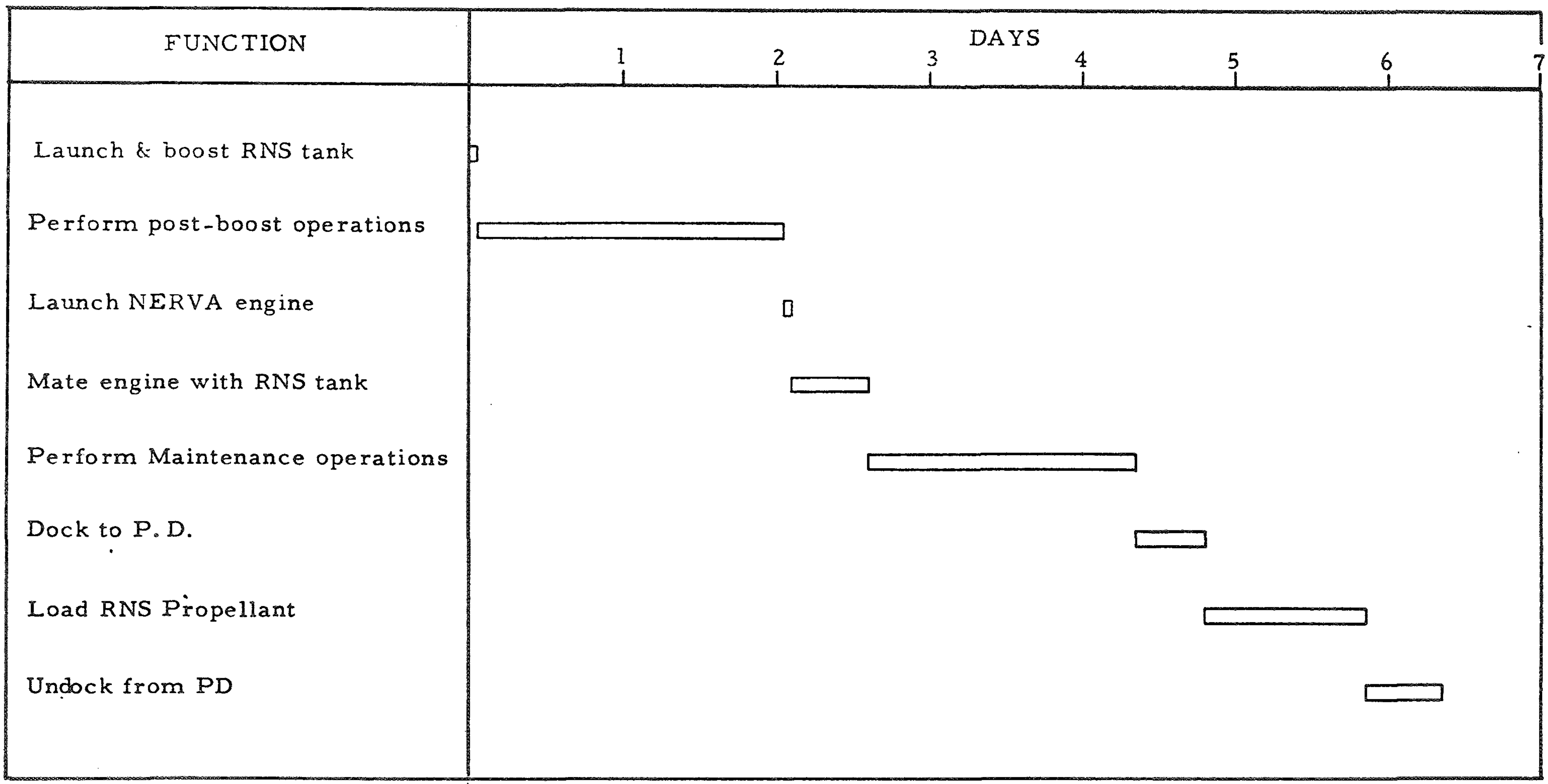


Figure 5-17 RNS Orbital Assembly

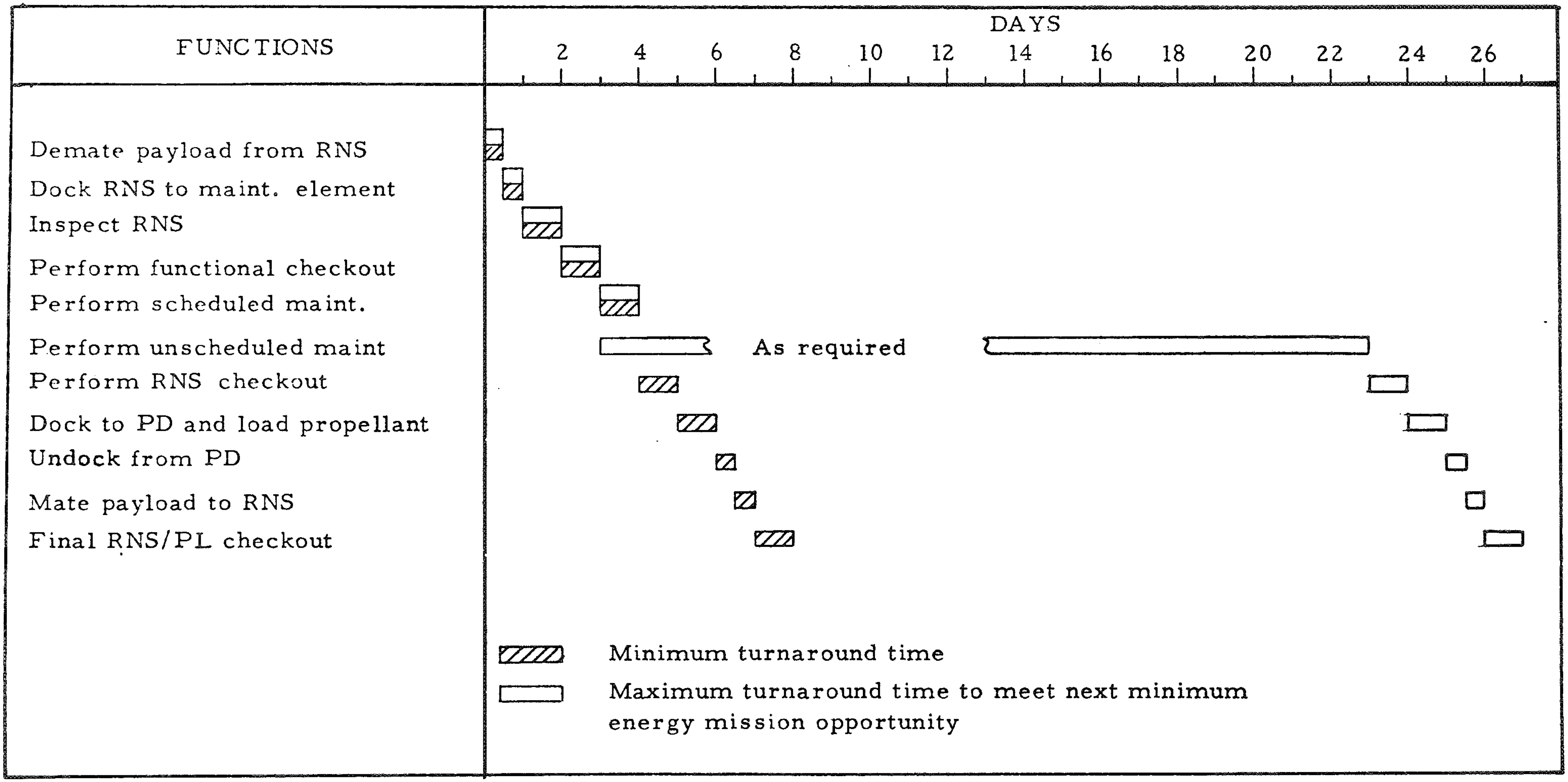


Figure 5-18 Turnaround Operations

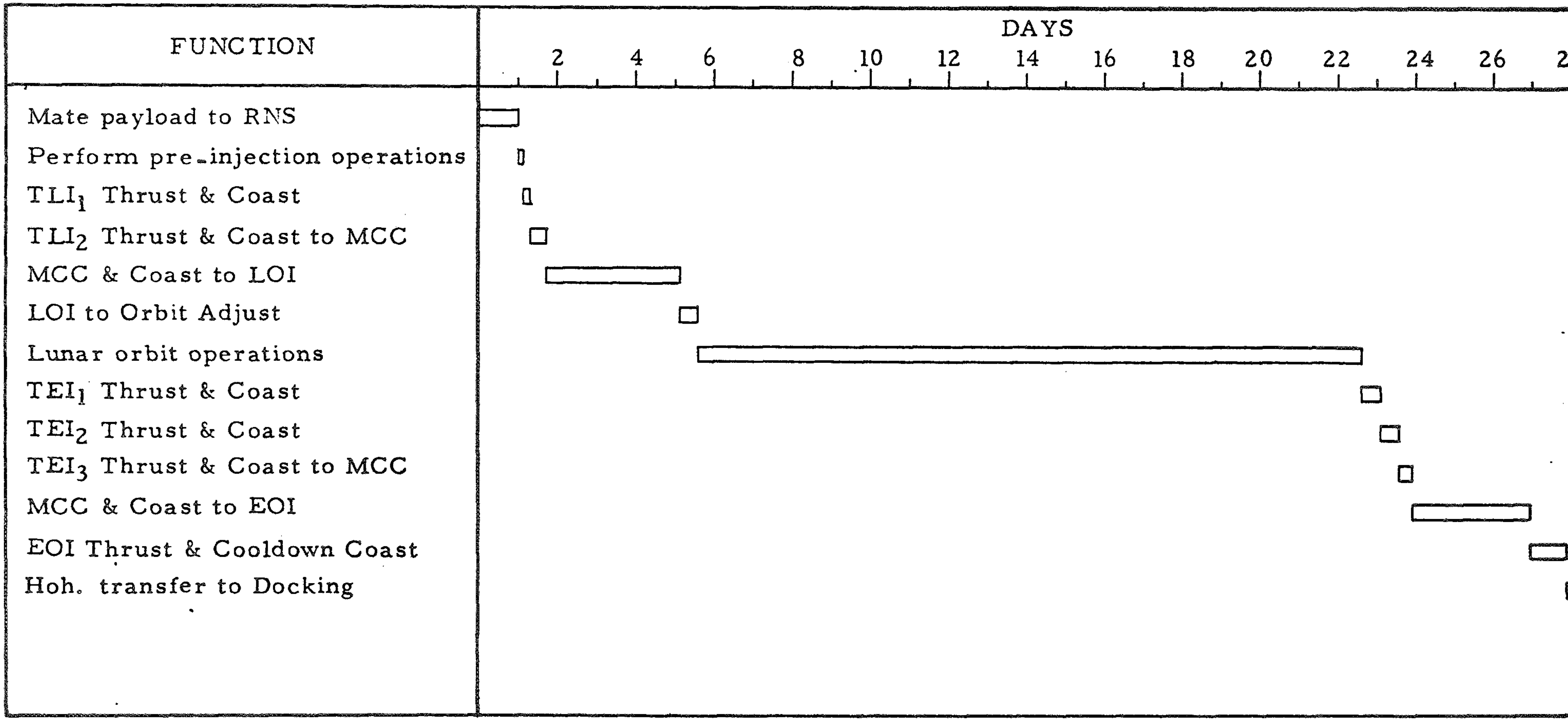


Figure 5-19 Reference Lunar Shuttle Mission

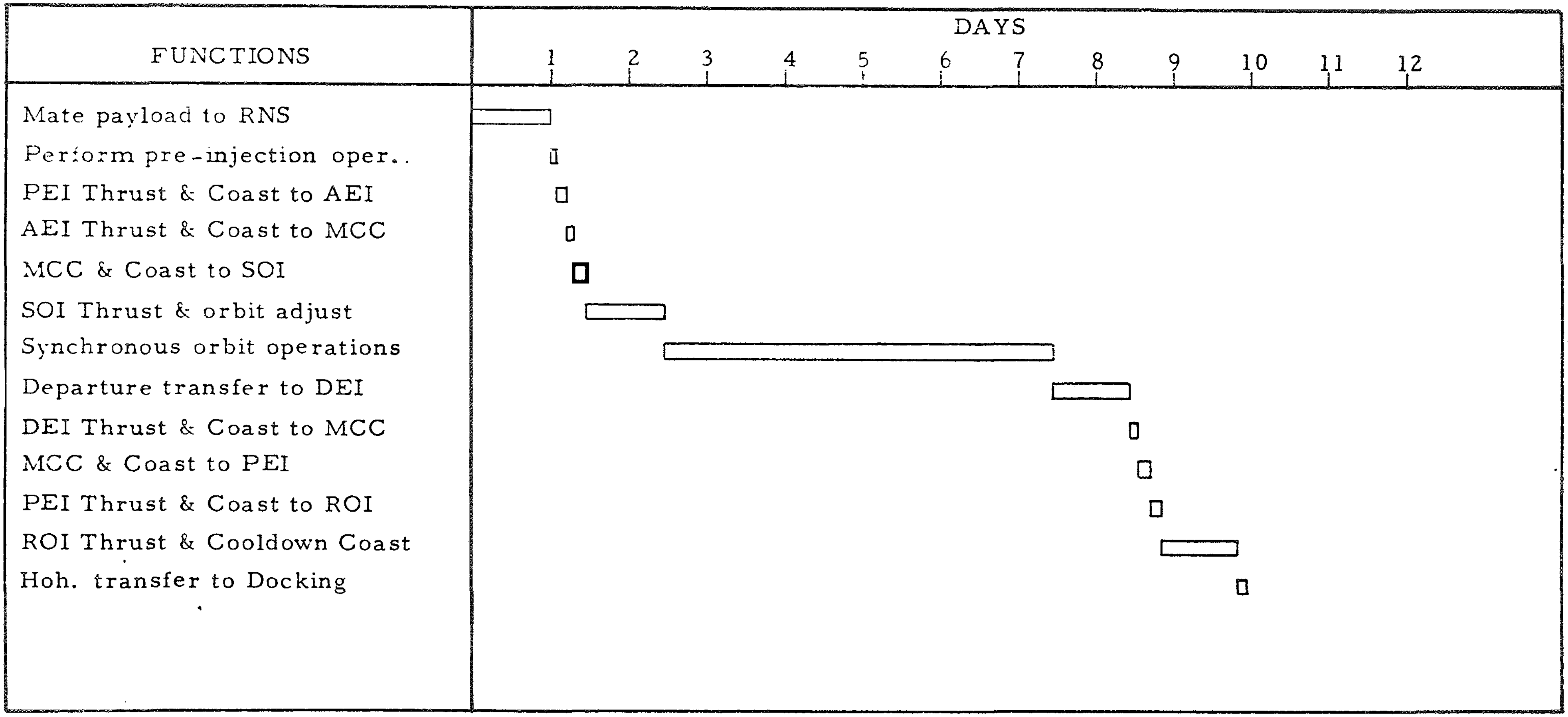


Figure 5-20 **Reference Synchronous Orbit Mission**

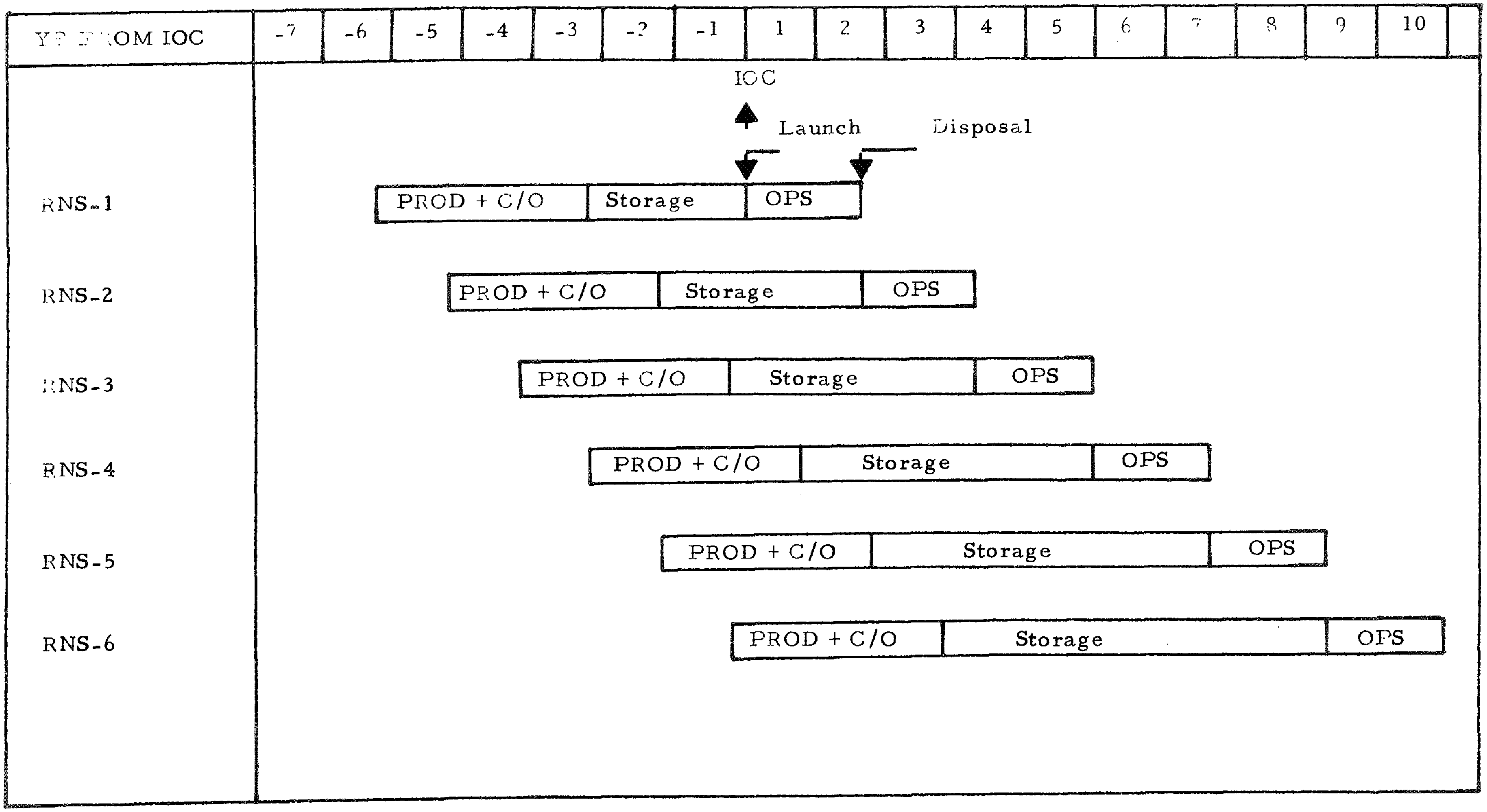
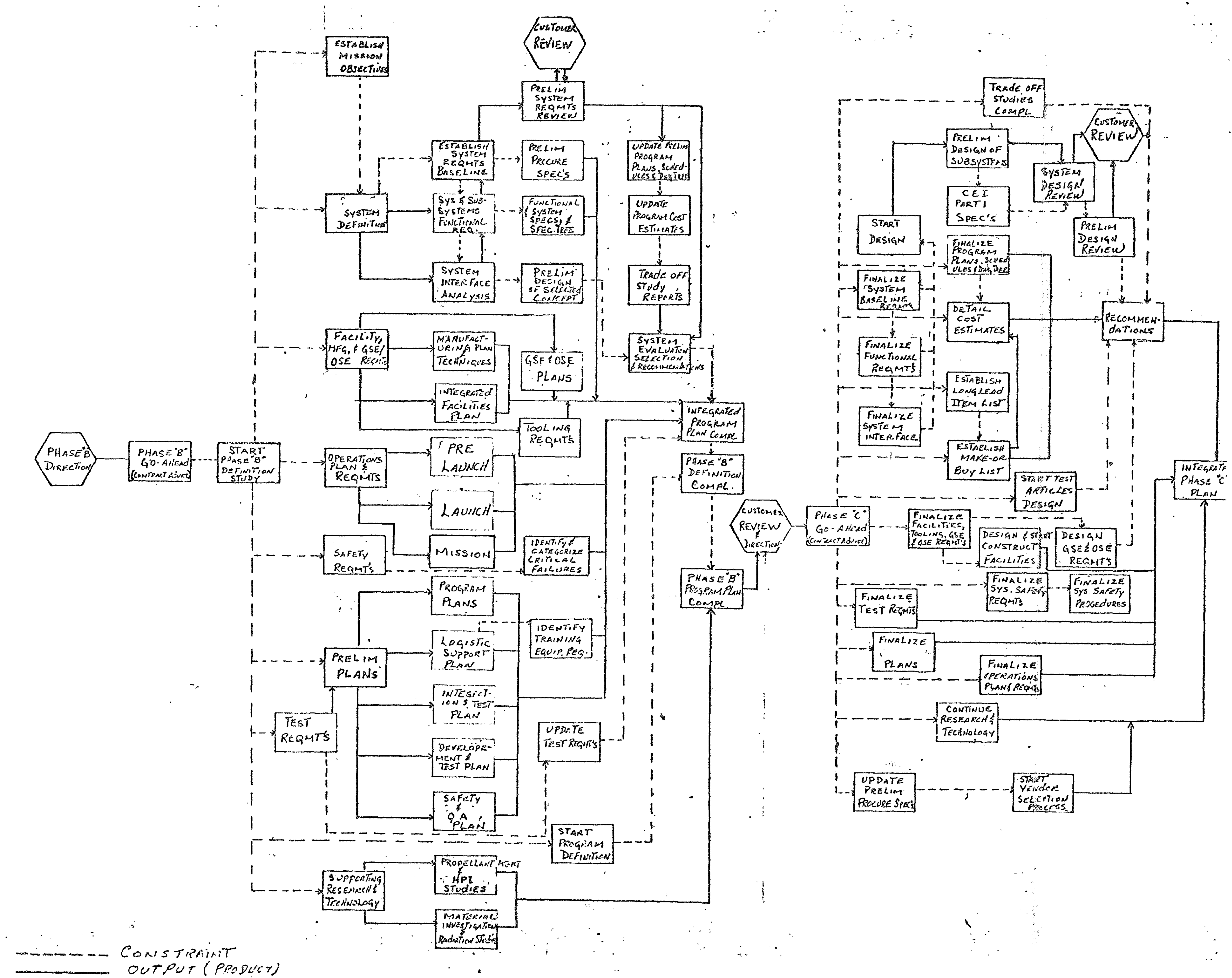


Figure 5-21. RNS Baseline Production/Operations Schedule

6.0 LOGIC NETWORK

An essential element of an effective program management or control is a clear and understandable breakdown of the required tasks, their sequence, and interfaces. Figure 6-1 is a functional block diagram presented in a logic network form which visually portrays the basic tasks to be performed, the sequence in which they are performed, and their interfaces with other functions. The logic network is program phase-oriented and can be used as a baseline for developing schedules and work plan tasks. Administrative steps involved in each related task are not included, since the purpose of this logic network is to show the basic operations which are not influenced by organizational considerations.

The reusable nuclear shuttle (RNS) program logic network complements the descriptions contained in the technical sections of the study. The required data including the principal tasks and their interfaces are described and discussed as part of the system engineering process. Construction of the logic network is organized in a block diagram form for effective presentation of the planned tasks and functions of Phases B, C and D. References 1, 2, 3 and 4 were used in the preparation of this logic network.


PHASE "B" DIRECTION
PHASE "B" GO-AHEAD (CONTRACT AWARD)
START PHASE "B" DEFINITION STUDY
ESTABLISH MISSION OBJECTIVES
SYSTEM DEFINITION
ESTABLISH SYSTEM REQMTS BASELINE
SYS & SUB-SYSTEMS FUNCTIONAL REQ.
SYSTEM INTERFACE ANALYSIS
PRELIM SYSTEM REQMTS REVIEW
CUSTOMER REVIEW
PRELIM PROCURE SPEC'S
FUNCTIONAL SYSTEM SPECS & SPEC. TREE
PRELIM DESIGN OF SELECTED CONCEPT
UPDATE PRELIM PROGRAM PLANS, SCHEDULES & DOC. TREES
UPDATE PROGRAM COST ESTIMATES
TRADE OFF STUDY REPORTS
SYSTEM EVALUATION SELECTION & RECOMMENDATIONS
FACILITY, MFG, & GSE/OSE REQMTS
MANUFACTURING PLAN & TECHNIQUES
INTEGRATED FACILITIES PLAN
GSE & OSE PLANS
TOOLING REQMTS
OPERATIONS PLAN & REQMTS
PRE LAUNCH
LAUNCH
MISSION
SAFETY REQMTS
IDENTIFY & CATEGORIZE CRITICAL FAILURES
PRELIM PLANS
PROGRAM PLANS
LOGISTIC SUPPORT PLAN
INTEGRATION & TEST PLAN
DEVELOPMENT & TEST PLAN
SAFETY & QA PLAN
IDENTIFY TRAINING EQUIP. REQ.
TEST REQMTS
UPDATE TEST REQMTS
START PROGRAM DEFINITION
SUPPORTING RESEARCH & TECHNOLOGY
PROPELLANT MGMT & HPI STUDIES
MATERIAL INVESTIGATION & RADIATION STUDIES
INTEGRATED PROGRAM PLAN COMPL.
PHASE "B" DEFINITION COMPL.
PHASE "B" PROGRAM PLAN COMPL.
CUSTOMER REVIEW & DIRECTION
PHASE "C" GO-AHEAD (CONTRACT AWARD)
TRADE OFF STUDIES COMPL
START DESIGN
PRELIM DESIGN OF SUBSYSTEMS
CEI PART I SPEC'S
SYSTEM DESIGN REVIEW
CUSTOMER REVIEW
PRELIM DESIGN REVIEW
FINALIZE PROGRAM PLANS, SCHEDULES, DOC. TREE
FINALIZE SYSTEM BASELINE REQMTS
DETAIL COST ESTIMATES
RECOMMENDATIONS
FINALIZE FUNCTIONAL REQMTS
ESTABLISH LONG LEAD ITEM LIST
FINALIZE SYSTEM INTERFACE
ESTABLISH MAKE-OR BUY LIST
START TEST ARTICLES DESIGN
INTEGRATE PHASE "C" PLAN
FINALIZE FACILITIES, TOOLING, GSE & OSE REQMTS
DESIGN & START CONSTRUCT FACILITIES
DESIGN GSE & OSE REQMTS
FINALIZE SYS. SAFETY REQMTS
FINALIZE SYS. SAFETY PROCEDURES
FINALIZE TEST REQMTS
FINALIZE PLANS
FINALIZE OPERATIONS PLANS & REQMTS
CONTINUE RESEARCH & TECHNOLOGY
UPDATE PRELIM PROCURE SPECS
START VENDOR SELECTION PROCESS
CONSTRAINT
OUTPUT (PRODUCT)

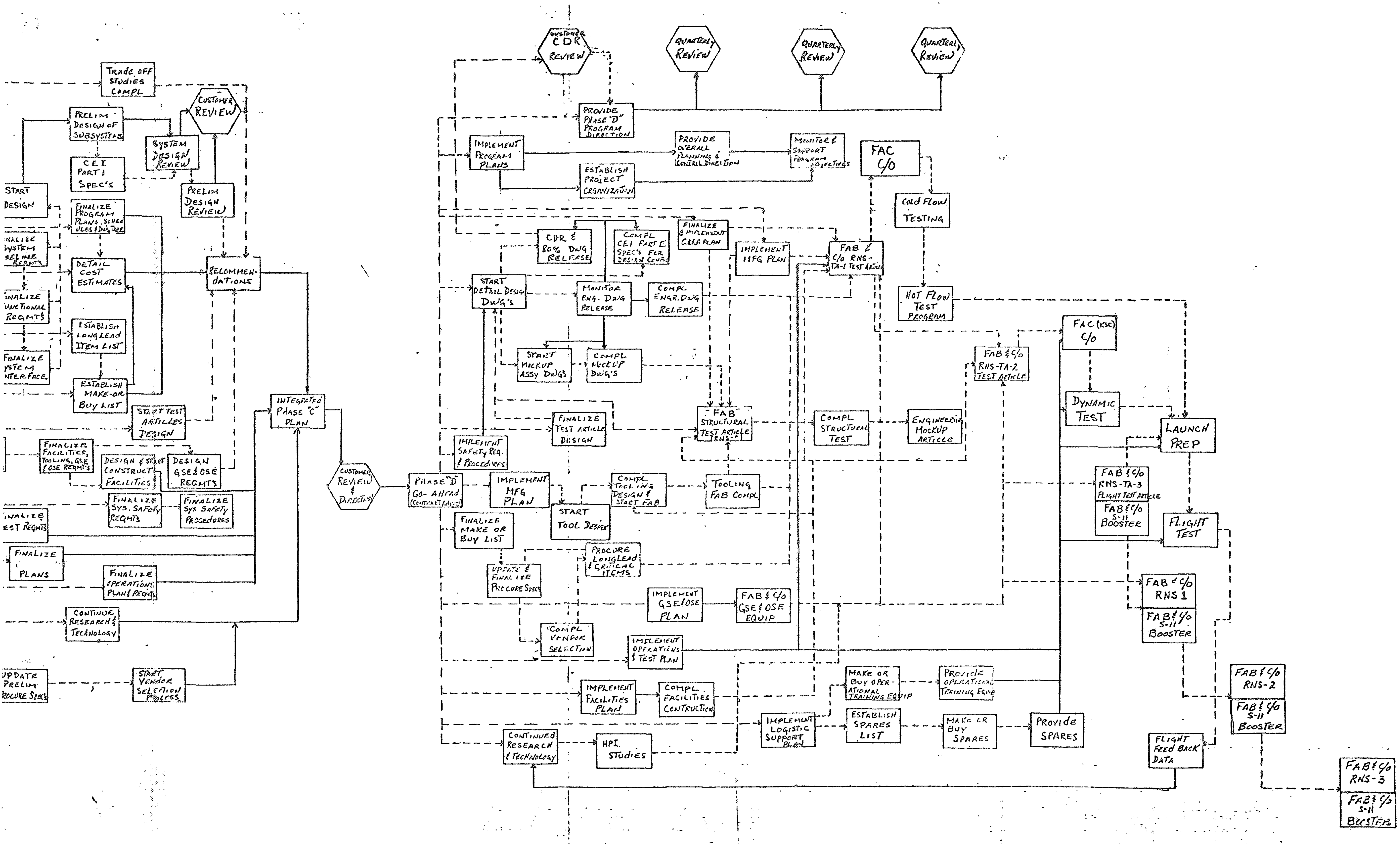


Figure 6-1. Reusable Nuclear Shuttle Program Management Network

6-3, 6-4

2

3

REFERENCES

1. Phase Project Planning, National Aeronautics and Space Administration (NASA) Policy Directive NPD 7121.1 (29 October 1965).

2. Phase Project Planning Guidelines, NASA NHB 7121.2 (August 1968).

3. Program Scheduling and Review Handbook (NASA) NHB 2330.1 (October 1965).

4. NR Space Division's Organization and Procedures.