NASA CR71505

VOYAGER SPACECRAFT SYSTEM

FINAL TECHNICAL REPORT

VOLUME A

PREFERRED DESIGN FOR FLIGHT SPACECRAFT AND HARDWARE SUBSYSTEMS

PART III

prepared for

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

UNDER
CONTRACT NO. 951111 NAS-7-100
JULY 1965

THE BOEING COMPANY • AERO-SPACE DIVISION • SEATTLE, WASHINGTON

THE BOEING COMPANY

SEATTLE, WASHINGTON 98124

LYSLE A. WOOD
VICE PRESIDENT-GENERAL MANAGER
AERO-SPACE DIVISION

July 29, 1965

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California

Gentlemen:

This technical report culminates nearly three years of Mariner/Voyager studies at Boeing. During this time, we have gained an appreciation of the magnitude of the task, and feel confident that the experience, resources and dedication of The Boeing Voyager Team can adequately meet the challenge.

The Voyager management task is accentuated by three prime requirements: An inflexible schedule of launch opportunities; the need for an information-retrieval system capable of reliable high-traffic transmission over interplanetary distances; and a spacecraft design flexible enough to accommodate a number of different mission requirements. We believe the technical approach presented here satisfies these design requirements, and that management techniques developed by Boeing for space programs will assure delivery of operable systems at each critical launch date.

Mr. E. G. Czarnecki has been assigned program management responsibility. His group will be ably assisted by Electro-Optical Systems in the area of spacecraft power, Philco Western Development Laboratories will be responsible for telecommunications, and the Autonetics Division, North American Aviation will provide the auto-pilot and attitude reference system. This team has already demonstrated an excellent working relationship during the execution of the Phase IA contract, and will have my full confidence and support during subsequent phases.

This program will report directly to George H. Stoner, Vice President and Assistant Division Manager for Launch and Space Systems. Mr. Stoner has the authority to assign the resources necessary to meet the objectives as specified by JPL.

The Voyager Spacecraft System represents to us more than a business opportunity or a new product objective. We view it as a chance to extend scientific knowledge of the universe while simultaneously contributing to national prestige and we naturally look forward to the opportunity of sharing in this adventure.

Lysle A. Wood

Lysle A. Wood

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INTRODUCTION

INTRODUCTION

In fulfillment of the Jet Propulsion Laboratory (JPL) Contract 951111, the Aero-Space Division of The Boeing Company submits the Voyager Spacecraft Final Technical Report. The complete report, responsive to the documentation requirements specified in the Statement of Work, consists of the five following documents:

VOLUME	TITLE	BOEING DOCUMENT NUMBER
A	Preferred Design Flight Spacecraft and Hardware Subsystems	D2-82709-1
	Part I	
	Section 1.0 Voyager 1971 Mission Objectives and Design Criteria	
	Section 2.0 Design Characteristics and Restraints	
	Section 3.0 System Level Functional Descriptions of Flight Spacecraft	
	Part II	
	Section 4.0 Functional Description for Spacecraft Hardware Subsystems	
	Part III	
	Section 5.0 Schedule and Implementation Plan	
	Section 6.0 System Reliability Summary	
	Section 7.0 Integrated Test Plan Development	
B	Alternate Designs Considered--Flight Spacecraft and Hardware Subsystems	D2-82709-2
C	Design for Operational Support Equipment	D2-82709-3
D	Design for 1969 Test Spacecraft	D2-82709-4
E	Design for Operational Support Equipment for 1969 Test Flight Spacecraft	D2-82709-5

For convenience the highlights of the above documentation have been summarized to give an overview of the scope and depth of the technical effort and management implementation plans produced during Phase IA. This summary is contained in Volume 0, Program Highlights and Management Philosophy, D2-82709-0. A number of supporting documents are provided to furnish detailed information developed through the course of the contract and to provide substantiating reference material which would not otherwise be readily available to JPL personnel. Additionally, a full scale mockup of the preferred design spacecraft has been assembled. This mockup, shown in Figure 1, has been delivered to JPL. The mockup has been provided with the view that it would be of value to JPL in subsequent Voyager Spacecraft System planning. Mr. William M. Allen, President of The Boeing Company, Mr. Lysle A. Wood, Vice-President and Aero-Space Division General Manager, Mr. George H. Stoner, Vice-President and Assistant Division Manager responsible for Launch and Space Systems activities, and Mr. Edwin G. Czarnecki, Voyager Program Manager, are shown with the mockup.

During the 3-month period covered by Contract 951111, Boeing has:

1) Performed system analysis and trade studies necessary to achieve an optimum or preferred design of the Flight Spacecraft.
2) Determined the requirements and constraints which are imposed upon the Flight Spacecraft by the 1971 mission and by the other systems and elements of the project, including the science payload.
3) Developed functional descriptions for the Flight Spacecraft and for each of its hardware subsystems, excluding the science payload.

Figure 1: Preferred Design Mockup

Left to Right:

William M. Allen
Edwin G. Czarnecki
Lysle A. Wood
George H. Stoner

4) Determined the requirements for the Flight Spacecraft associated Operational Support Equipment (OSE) necessary to accomplish the Voyager 1971 mission.

5) Developed a preliminary design of the OSE.

6) Developed functional descriptions for the OSE.

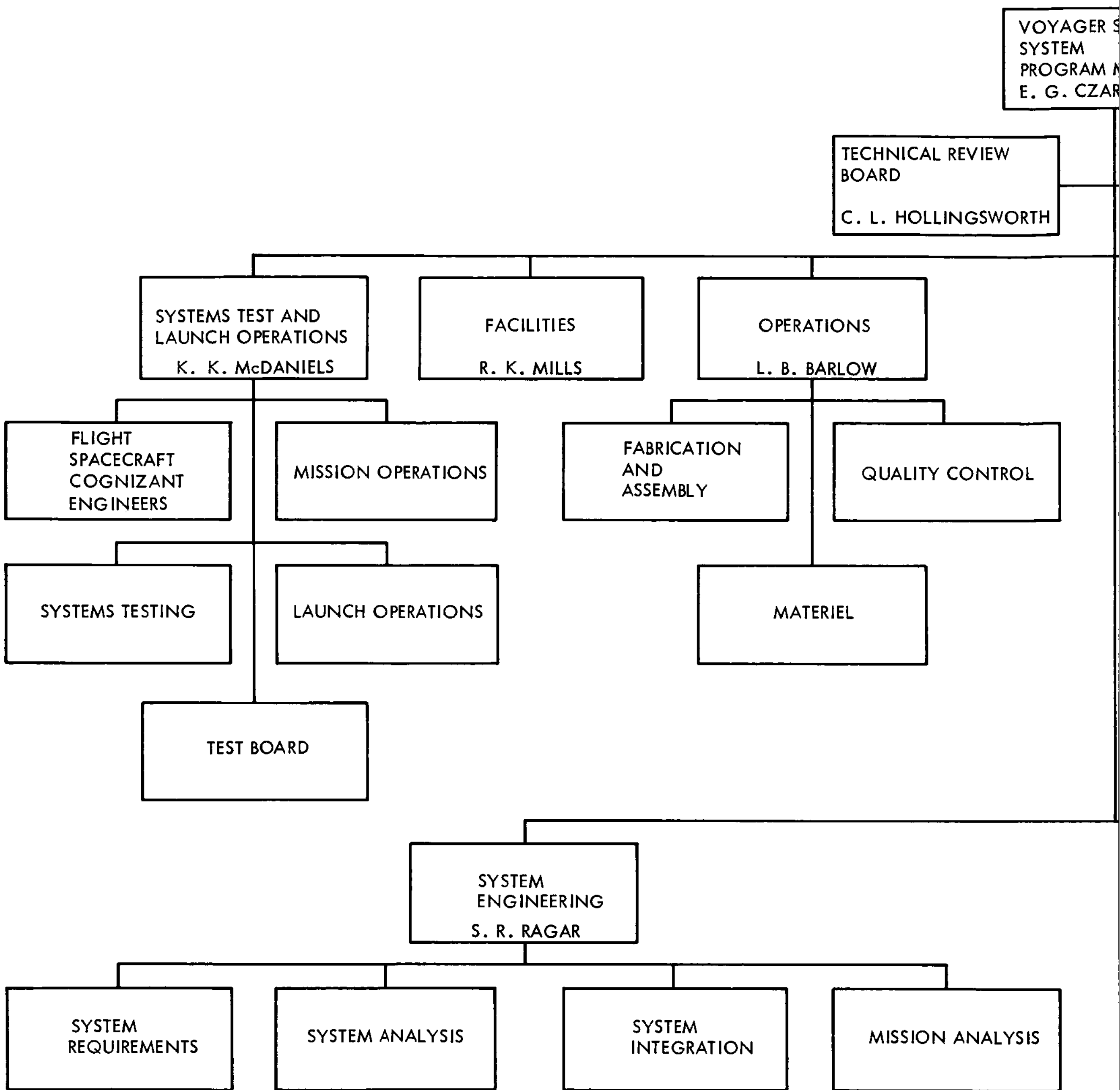
7) Determined the objectives of a 1969 test flight and the design of the 1969 Test Flight Spacecraft using the Atlas/Centaur Launch Vehicle. An alternate test flight program is presented which utilizes the Saturn 1B/Centaur Launch Vehicle.

8) Deveoped functional descriptions for the Flight Spacecraft Bus, and its hardware subsystems, and OSE for the 1969 test spacecraft.

9) Updated and supplemented the Voyager Implementation Plan originally contained in the response to JPL Request for Proposal 3601.

The Voyager program management Team, shown in Figure 2 is under the direction of Mr. Edwin G. Czarnecki. Mr. Czarnecki is the single executive responsible to JPL and Boeing management for the accomplishment of the Voyager Spacecraft Phase IA, and will direct subsequent phases of the program. He reports directly to Mr. George H. Stoner who has the authority to commit those corporate resources necessary to fulfill JPL's Voyager Spacecraft System objectives.

Although Boeing has a technical management capability in all aspects of the Voyager Program, it is planned to extend this capability in depth through association with companies recognized as specialists in certain fields. Use of team members to strengthen Boeing's capability was considered early during pre-proposal activities. The basic concept


VOYAGER S
SYSTEM
PROGRAM
E. G. CZAR
TECHNICAL REVIEW BOARD
C. L. HOLLINGSWORTH
SYSTEMS TEST AND LAUNCH OPERATIONS
K. K. McDANIELS
FACILITIES
R. K. MILLS
OPERATIONS
L. B. BARLOW
FLIGHT SPACECRAFT COGNIZANT ENGINEERS
MISSION OPERATIONS
FABRICATION AND ASSEMBLY
QUALITY CONTROL
SYSTEMS TESTING
LAUNCH OPERATIONS
MATERIEL
TEST BOARD
SYSTEM ENGINEERING
S. R. RAGAR
SYSTEM REQUIREMENTS
SYSTEM ANALYSIS
SYSTEM INTEGRATION
MISSION ANALYSIS

1

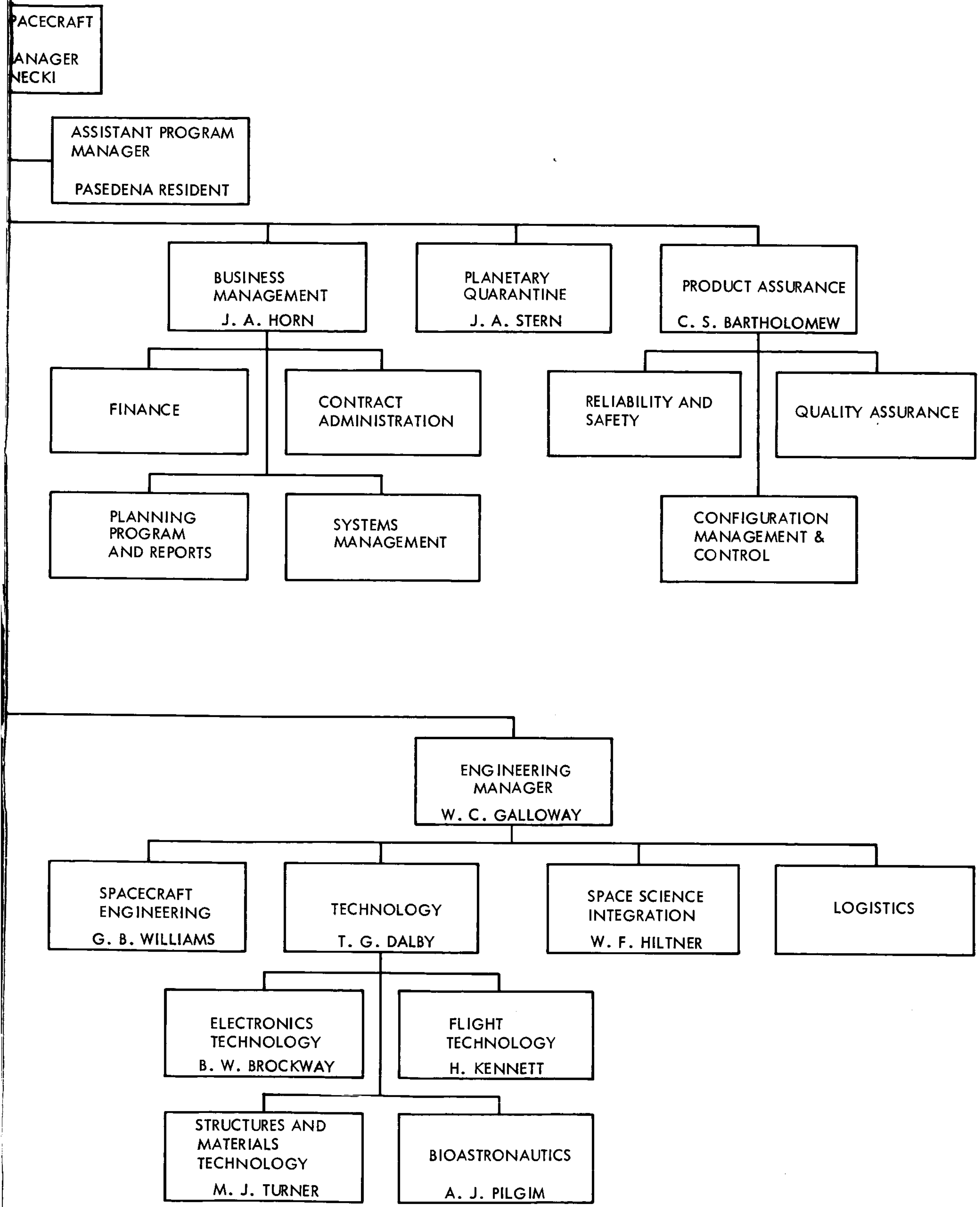


Figure 2 Boeing Voyager
Spacecraft Systems Management Structure

2

was to add team members who would complement Boeing experience and capability, and significantly improve the amount and quality of technical and management activities. Based upon competitive considerations including experience and past performance and giving strongest emphasis to technical qualifications and management willingness to support the Voyager effort, Autonetics, Philco Western Deveopment Laboratories, and Electro-Optics Systems were chosen as team members. This team arrangement, subject to JPL approval, is shown in Figure 3. The flight spacecraft design and integration task to be accomplished by this team is illustrated in Figure 4. Discussions leading to the formation of this team were initiated late in 1964, formal work statement agreements have been arrived at, and there has been a continuous and complete free exchange of information and documentation; permitting the Boeing team to satisfy JPL's requirements in depth and with confidence.

<table>
<tr><td colspan="3">BOEING VOYAGER TEAM

VOYAGER SPACECRAFT AND SPACE SCIENCES PAYLOAD INTEGRATION CONTRACTOR

The Boeing Company
Seattle, Washington

Mr. E. G. Czarnecki - Program Manager</td></tr>
<tr><td>SUBCONTRACTOR

Autonetics, North American Aviation
Anaheim, California

Autopilot and Attitude Reference Subsystem

Mr. R. R. Mueller
Program Manager</td><td>SUBCONTRACTOR

Philco, Western Development Laboratories
Palo Alto, California

Telecommunications Subsystem

Mr. G. C. Moore
Program Manager</td><td>SUBCONTRACTOR

Electro-Optical Systems Incorporated
Pasadena, California

Electrical Power Subsystem

Mr. C. I. Cummings
Program Manager</td></tr>
</table>

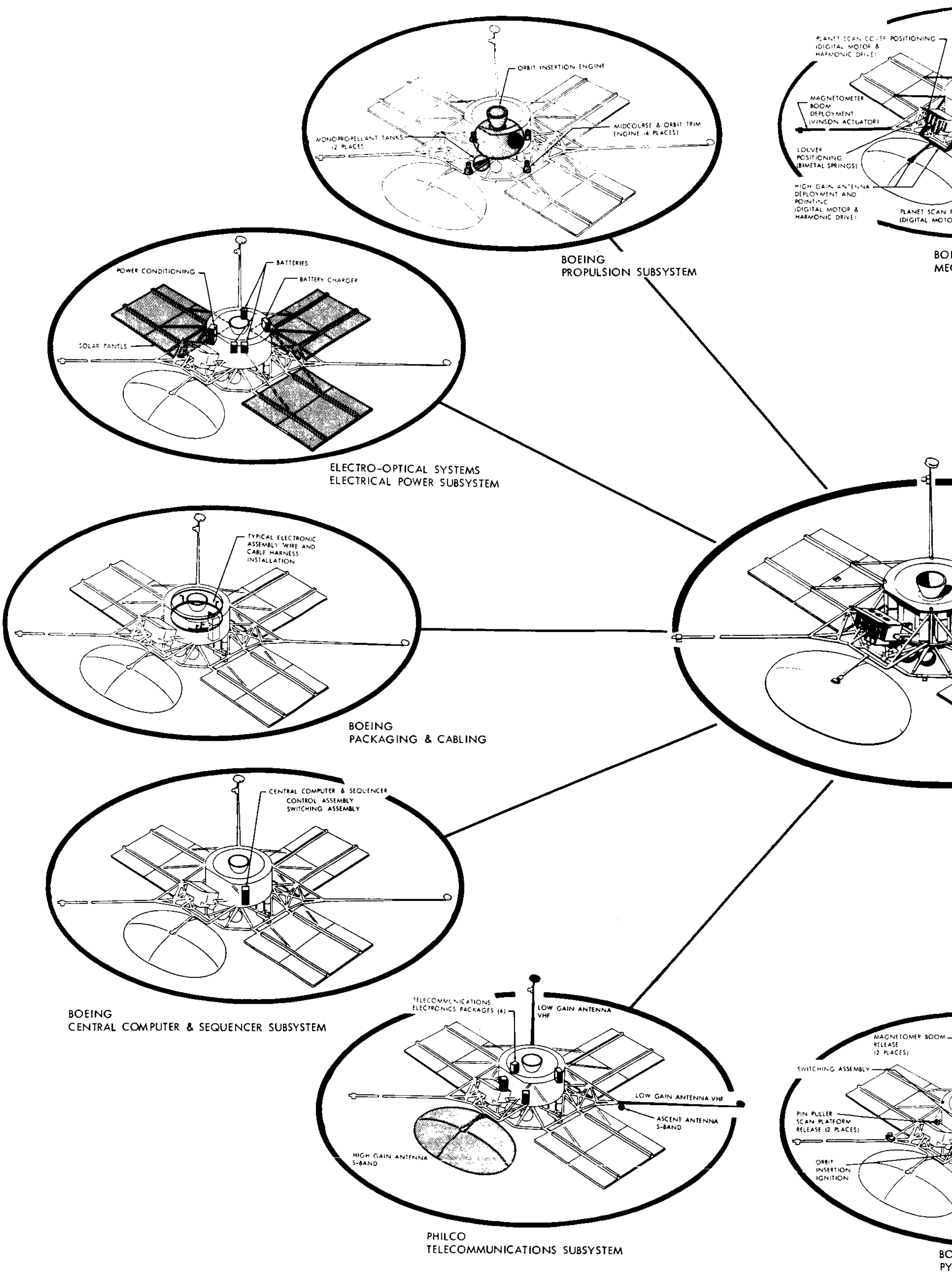
Figure 3

SUMMARY--VOLUME A

The Boeing team's flight spacecraft represents a conservative design based upon selection of space-proven components. The design meets the objectives of the Voyager program for 1969 through 1977 opportunities. The 250-pound science payload, as well as the 2300 or 4500 pound flight capsule can be accommodated and all program and mission objectives achieved.

The Voyager Spacecraft is shown in Figure 4 with equipment deployed in the operational configuration. It is 30 feet wide from solar panel tip to solar panel tip, and the body is 59-inches high. The 31-foot magnetometer boom and 17- and 18-foot antenna booms are shown in position. Estimated weight at this state of the preliminary design is 1565 pounds for the spacecraft, and 3400 pounds for the propulsion module. A contingency of 285 pounds of the specification weight of 5250 pounds is available for selective use during the detail design phase. The 20 equipment modules are fastened to the central magnesium shell with cooling provided by thermal radiation from the external faces of the package. Thermal control is by space-facing louvers.

Outstanding design features of the Boeing team's Voyager Spacecraft are its ability to perform reliably, transmit data to Earth at encounter at the 50,000 bit-per-second rate generated in the science package, and meet all mission energy requirements through 1977 with a single propulsion module design. Use of redundancy in critical components and selection of proven designs requiring a minimum of additional development


ORBIT INSERTION ENGINE
MONOPROPELLANT TANKS (2 PLACES)
MIDCOURSE & ORBIT TRIM ENGINE (4 PLACES)
BOEING
PROPULSION SUBSYSTEM
PLANET SCAN COVER POSITIONING (DIGITAL MOTOR & HARMONIC DRIVE)
MAGNETOMETER BOOM DEPLOYMENT (VINSON ACTUATOR)
LOUVER POSITIONING (BIMETAL SPRINGS)
HIGH GAIN ANTENNA DEPLOYMENT AND POINTING (DIGITAL MOTOR & HARMONIC DRIVE)
POWER CONDITIONING
BATTERIES
BATTERY CHARGER
SOLAR PANELS
ELECTRO-OPTICAL SYSTEMS
ELECTRICAL POWER SUBSYSTEM
TYPICAL ELECTRONIC ASSEMBLY WIRE AND CABLE HARNESS INSTALLATION
BOEING
PACKAGING & CABLING
CENTRAL COMPUTER & SEQUENCER
CONTROL ASSEMBLY
SWITCHING ASSEMBLY
BOEING
CENTRAL COMPUTER & SEQUENCER SUBSYSTEM
TELECOMMUNICATIONS ELECTRONICS PACKAGES (4)
LOW GAIN ANTENNA VHF
LOW GAIN ANTENNA VHF
ASCENT ANTENNA S-BAND
HIGH GAIN ANTENNA S-BAND
PHILCO
TELECOMMUNICATIONS SUBSYSTEM
MAGNETOMER BOOM RELEASE (2 PLACES)
SWITCHING ASSEMBLY
PIN PULLER SCAN PLATFORM RELEASE (2 PLACES)
ORBIT INSERTION IGNITION

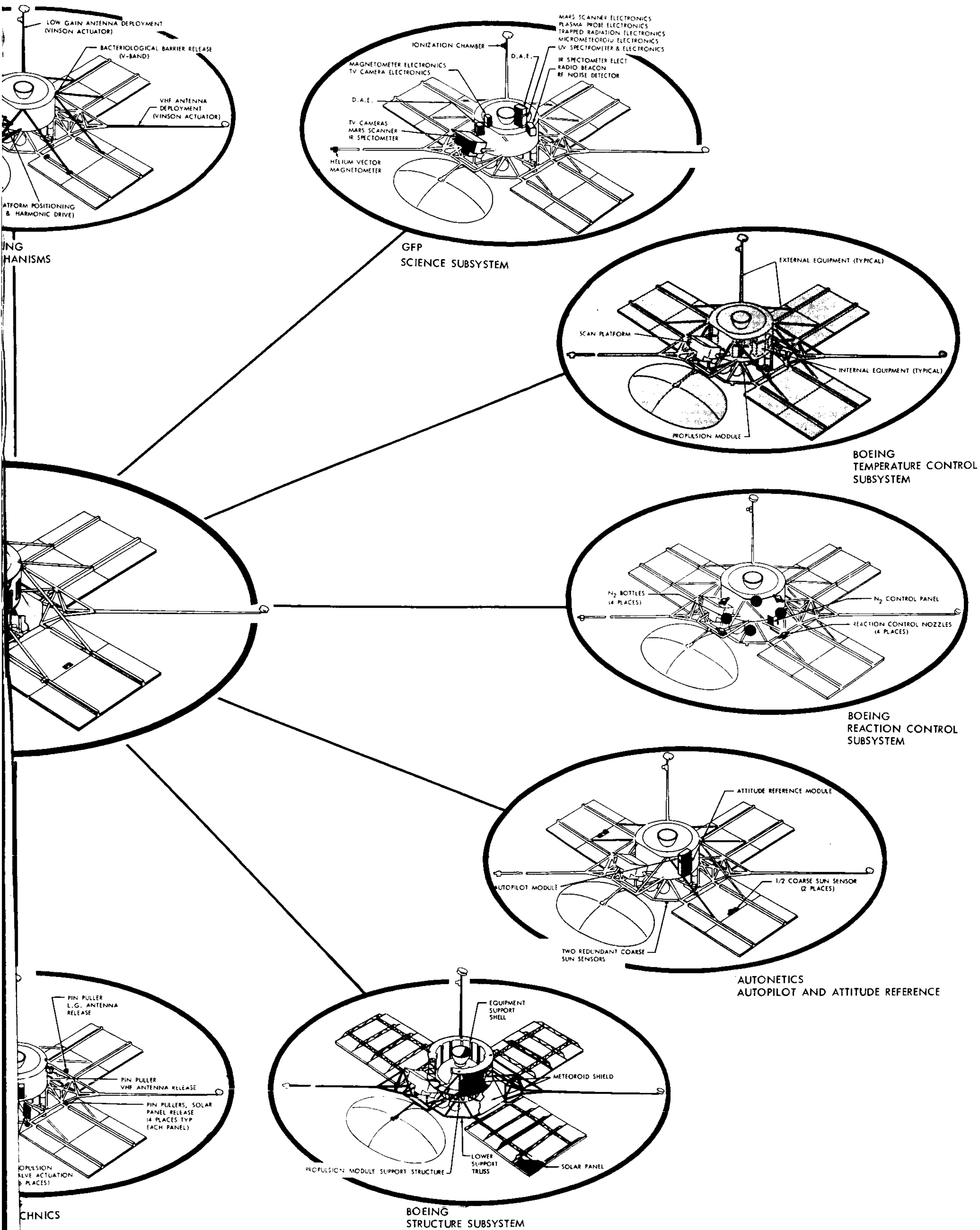


Figure 4. Voyager Flight Spacecraft Subsystem Integration

V

resulted in an overall mission success probability of 47 percent, exceeding the specified 45 percent, including an allocation of 0.674 for the science payload.

The spacecraft can enter biologically safe orbits with periods as low as 18 hours from Mars approach velocities as high as 3.5 km/sec., or with periods less than 9 hours from approach velocities as high as 3.0 km/sec. The 18-hour orbit provides coverage of four different swaths of Mars surface in the first three days after encounter.

In 1971, orbits are available which have no occultation of Canopus or the Sun for the first 60 days in orbit. The periapsis positions are at southern latitudes and at illumination angles which favor the black and white TV experiment. Some adjustment of periapsis position is available with "off-periapsis" orbit insertion techniques. The "off-periapsis" insertion technique allows the utilization of the fixed-total-impulse solid motor for all approach velocities considered.

The telecommunications design includes completely redundant radio subsystems. It features an 8' x 12' paraboloidal high-gain antenna, two 50-watt traveling wave tubes and bi-orthogonal block coding to obtain the high data rate. The 50-watt tube selection is supported by three separate tube designs including test data. Detailed link calculations substantiate a positive communication link margin under worst-case conditions at Mars encounter, with a calculated 48,000 bits per second data rate. (Upon definition of the precise science payload data rate, the telecommunications link can be optimized to that value.) For longer communication ranges, alternate lower data modes and two tape recorders with storage capability for 2×10^8 bits of scientific data are provided. Two 72,000 bit buffers provide temporary storage of spacecraft engineering and capsule data.

The spacecraft propulsion subsystem consists of a solid motor with an oblate spheroidal case for Mars orbit insertion and four 50-pound thrust, jet vane controlled, hydrazine engines operating in pairs for midcourse and orbit trim. The solid propellant motor with a specific impulse of about 300 pounds force seconds per pound mass delivers 10,500 pounds maximum thrust and burns regressively to provide not more than 2.2 g's acceleration. Solid motor TVC is by a Freon secondary injection system. With the available 2306 pounds of solid propellant, an orbit insertion velocity increment of 5700 feet per second is attained. The 50-pound thrust monopropellant engines with a specific impulse of 235 pound force seconds per pound mass have multiple restarting capability. These engines utilize the spontaneous decomposition catalyst. Hydrazine fuel capacity is adequate for 929 total seconds of operation.

Reaction control is produced by expulsion of sterile nitrogen through two redundant sets of eight .25 pound thrusters each, which are body-mounted on the spacecraft. Four titanium tanks contain 60 pounds of cold nitrogen for reaction control and propulsion requirement. The 45 pounds allocated to reaction control is adequate for the 6-month orbital mission with a safety factor of 2. Under nominal conditions, the nitrogen supply is adequate for four years. Both propulsion systems, plus the reaction control subsystem, are assembled in a single sub-module mounted in the spacecraft. This modular arrangement permits complete assembly and checkout, including sterilization, prior to installation on the spacecraft. The propulsion and reaction control systems including all fuel and gas supplies are sterilized to avoid planetary contamination by propulsion ejecta.

The selected attitude reference and autopilot subsystems are comprised of an attitude reference module, autopilot module, and coarse and fine Sun sensors. The attitude reference module includes three redundant Autonetics G-10 gas-bearing gyros, two redundant accelerometers, two redundant Canopus sensors and two fine Sun sensors. The coars Sun sensors are located on two solar panels. The autopilot is an analog type and maintains spacecraft orientation to within $\pm$0.4 degree in cruise, $\pm$0.2 degree in Mars orbit, and the limit cycle period is several hours. All selected components are existing designs with operation and qualification experience.

The electrical power system is similar to Mariner IV, with three solar panels, 8-1/2' x 13', consisting of two sections each. The total area of 236 square feet provides 627 watts of power at the distance of Mars from the Sun. A flat solar cell arrangement is used; three silver cadmium batteries are provided for use during off-Sun periods. The power subsystem regulates and distributes the electrical power to subsystems where additional power conditioning is performed. A 50-percent increase in power is possible by addition of one section to each solar panel.

The Voyager central computer and sequencer (CC&S) provides timing functions and command signals to all other spacecraft subsystems. A magnetic core memory provides storage for 256 21-bit words and a capability to execute 333 different commands. The CC&S minimizes the need for detail ground commands by incorporating preplanned operational sequences. All commands and stored instructions can be monitored and controlled from the ground for complete analysis and control during the entire mission. A modified NASA Lunar Orbiter programmer has been selected as the basic element. This memory-oriented digital computer has been space-qualified and addition of redundant data processing and switching circuits provide a highly reliable unit.

The spacecraft structure includes a simple truss base, 10 feet wide at the bottom and 5 feet wide at the top, fabricated of 6AL4V titanium tubing. This base attaches to the Centaur adapter and supports the antenna and solar panel appendages. The electronic packages are connected to a five-foot diameter, cylindrical, magnesium shell installed above the truss. The flight capsule is supported by an adapter ring with loads carried by four columns through the cylindrical shell.

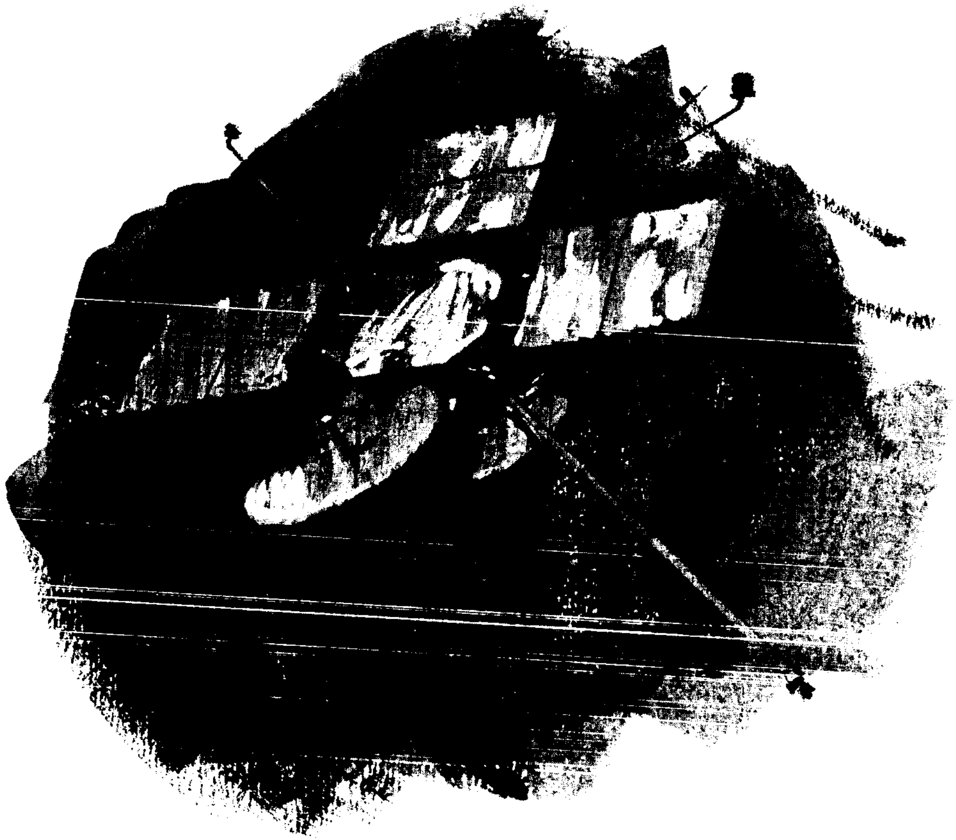
A number of major technical problems were encountered and studied in developing the preliminary design. The most significant of these were as follows:

1) The assessment of the most reliable and highest power transmitter tube meeting the Voyager requirements;

2) The overall spacecraft magnetics problem with particular attention to the magnetic focusing field for the traveling wave tube.
3) Availability and reliability of spacecraft recorders.
4) Selection of a reliable secondary battery with adequate recycle life.
5) Estimation of solar panel degradation from electromagnetic radiation and meteoroids during the mission.
6) The trade-off between proven instruments versus new and inherently simpler instruments.
7) Determination of the degree and type of redundancy, for example, using two identical instruments of two difference designs.
8) The effect of the solid engine exhaust on the structure and solar panel temperature.
9) Accommodating the length of the orbit insertion engine.
10) Selection of installation technique for the equipment packages.
11) Selection of the thrust vector control technique.
12) Effect of heat soak sterilization on equipment.

These problems are the key technical considerations in developing the preferred design.

The subsystems of the Boeing team's spacecraft provide a conservative and highly reliable design. No state-of-the-art advances are required to meet the design criteria for any subsystem.



CONTENTS

PLAN

5.0 SCHEDULES AND IMPLEMENTATION PLANS

5.1 INTRODUCTION

The schedules and plans developed by Boeing for the Voyager Spacecraft System complement and extend the technical approach discussed in the previous sections of this volume.

During Phase IA, Boeing Voyager Spacecraft System personnel have responded to the Statement of Work by developing schedules and plans based on a thorough understanding of the mission objectives, related JPL publications, and other program requirements. Techniques used to tailor the schedules and implementation plan are founded on experience with development type programs that require rapid reaction to change.

The schedules and plans reflect consideration of the preferred design, results of schedule trade studies, various government publications, and customer management practices. Although the schedules and implementation plans were developed to satisfy a specific Statement of Work, they are flexible enough to be readily modified.

The selection of Autonetics as another major subcontractor has increased the technical strength and capabilities of the Boeing Voyager team.

Total company commitment to the Voyager Spacecraft System demonstrated during the Phase IA activity was publicly endorsed by Mr. William M. Allen, President of The Boeing Company, when he said:

"The National Aeronautics and Space Administration's Voyager Program for which the Aero-Space Division is now competing, promises to be the major effort for unmanned exploration of the planets for the next fifteen to twenty years.

We want to be a major contributor to the Voyager Program. It is a key project in an expanding area of business and will place the successful company in a commanding position in the field of unmanned spacecraft."

Based on its understanding of the overall Voyager mission, Boeing is confident that its schedules and implementation plans will lead toward success for a 1969 test flight and primary flights in 1971 and 1973. Boeing is prepared to support JPL in all management and technical areas of the Voyager Project as desired and requested. The combination of JPL's demonstrated leadership in interplanetary exploration and Boeing's experience in design, assembly and test, and systems integration constitutes a team most likely to attain overall mission success--both for Voyager and for future probes of outer space.

5.2 SCOPE

The schedules and implementation plans presented in this section relate specifically to the preferred design of the Spacecraft and Operational Support Equipment (OSE) and take advantage of the versatility inherent in this design. Three master schedules are presented. They are:

1) The accomplishment of a 1971 mission without a prior test flight.

2) The accomplishment of a 1971 mission preceded by a test flight in 1969 using Atlas/Centaur.

3) The accomplishment of a 1971 mission preceded by a test flight in 1969 using Saturn IB/Centaur.

Detailed analysis and schedule trade studies of the alternate spacecraft designs discussed in Volume B indicate that the adoption of any one of these alternates will have no significant effects or implications on the schedules and implementation plans related to the preferred spacecraft design. Moreover, the schedules presented herein are sufficiently flexible to accommodate, without significant impact, any combination of the features of the alternate spacecraft designs.

Summary implementation plans which are a preview of the detailed plans to be submitted in the Phase IB proposed are presented separately in this section. They include a Management Structure that encompasses the Boeing Voyager Spacecraft System management structure and the separate management structures of its three major subcontractors. A comprehensive Project Control Plan, based on an Integrated Management System, is also presented.

Product Assurance is discussed in summary form. The Quality Program Plan summarizes the Quality Assurance System and Quality Control System recommended for the Voyager Spacecraft while the Reliability Program Plan describes how Boeing intends to meet the reliability requirements imposed by JPL. A Configuration Management Plan is presented describing how disciplines used by Boeing on other programs will be applied on the Voyager.

The Manufacturing Plan discussed the in-plant manufacture of structural components, the assembly and installation of electrical/electronic components and systems manufactured by Boeing and suppliers. The Procurement Plan summarizes Boeing procurement policies that will be administered on the Voyager, highlights some of the major procurement tasks and how they will be accomplished. A Safety Plan is also presented which establishes system safety direction and control. The section concludes with a project control system proposed by Boeing for JPL's use in managing the Voyager Project.

With respect to the plans mentioned in this paragraph, Boeing is thoroughly familiar with the contents of NPC 200-2, NPC 250-1, NPC 500-1, AFSCM 375-1, and other customer management practices.

5.3 APPLICABLE DOCUMENTATION

The applicable documentation used in the preparation of Section 5.0 is listed below. Copies of pertinent reference Boeing documents (*) are being submitted with this report.

5.3.1 Boeing Documentation

1) D2-14727-1, Change Processing Manual - Minuteman
2) D2-15000, Configuration Management Manual - Minuteman
3) D2-23814-1, Reliability Technology Resources - Aero-Space Division
4) D2-23850-3, Voyager Spacecraft System Proposal, Volume III, Management, Organization and Scheduling
5) D2-80027, Safety Design Requirements, X-20 Program

6) D2-82707-1, General Requirements - Voyager Spacecraft System

7) *D2-82724-1, Voyager Spacecraft System Reliability Analysis

8) *D2-82724-2, Voyager Spacecraft System Failure Mode and Effects Analysis

9) *D2-82724-3, Voyager Program Reliability - Analysis and Prediction Standards

10) D2-100151, Reliability Program Plan - Lunar Orbiter

11) D2-100174, Configuration Management Plan - Lunar Orbiter

12) D5-11423, Proposed Saturn V Configuration Management Implementation Study for Marshall Space Flight Center

5.3.2 Other Documentation

1) ANA Bulletin 445, Air Force Navy Aeronautical Bulletin-Engineering Changes to Weapons, Systems, Equipment, and Facilities

2) JPL Volume 45, Voyager 1971 Mission Specification

3) JPL Volume 46, Voyager 1971 Mission Guidelines

4) MIL-D-70327 Drawing, Engineering and Associate Lists

5) MIL-Q-9858A, Quality Program Requirements

6) MIL-Q-21549B, Quality Assurance Program Requirements for Fleet Ballistic Missile Weapon System Contractors

7) NPC 200-2, Quality Program Provisions for Space System Contractors

8) NPC 200-3, Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services

9) NPC 250-1, Reliability Program Provisions for Space System Contractors

10) NPC 500-1, Apollo Program Configuration Management Manual

11) AFSCM 375-1, Configuration Management During Definition and Acquisition

12) AFSCM 375-2, System Program Management and Industrial Management Assistance Survey

13) AFSCM 375-3, System Program Office

14) AFSCM 375-4, System Program Management

15) AFSCM 375-5, System Engineering Management

16) AFSCM 375-6, System Management Development Engineering

17) 30265-General Specification, Spacecraft Flight Equipment, Pressure System, Safety Requirements for

5.4 SCHEDULES AND SCHEDULE ANALYSIS

The unalterable launch window for the 1971 mission is the primary constraint on the program master schedule for the Voyager Spacecraft System. The special significance of this constraint must be carefully considered in every technical and programming decision. The master schedule was developed to successfully achieve the 1971 mission objective, based on a Phase 1B go-ahead in January, 1966, a development freeze in July, 1966, and a continuous contractor effort with no break between Phase 1B and Phase II. Detailed schedule analyses confirm that test flights can be made in 1969 that will contribute significantly to the success of the 1971 mission.

Three different program implementation approaches to achieve 1971 mission success were considered.

1) The accomplishment of a 1971 mission without a prior test flight.
2) The accomplishment of a 1971 mission preceded by a test flight in 1969 using the Atlas/Centaur launch vehicle.
3) The accomplishment of a 1971 mission preceded by a test flight in 1969 using the Saturn 1B/Centaur launch vehicle.

All three approaches utilize the preferred 1971 spacecraft configuration for the mission flights with minor modifications for the 1969 test flights on the Atlas/Centaur. The 1969 test flight is considered as an integral part of the total test program to improve the probability of 1971 mission success.

Important ground rules applied to the master schedules are:

1) Phase II will follow Phase 1B with no break between phases.
2) For the selected orbit the earliest 1971 launch window opens on April 30, 1971.
3) Voyager Project and Spacecraft System interface tests will be concluded well enough in advance of flight spacecraft and related operational support equipment (OSE) completion to allow for corrective action as necessary. For 1969 test flights interface tests will use simulated hardware.
4) Three complete flight spacecraft and related OSE will be delivered to the Air Force Eastern Test Range for each launch opportunity.
5) One complete set of subsystems, "burned-in" on the standby vehicle, will be delivered as flight spares.
6) There will be two flights launched during each launch opportunity.

5.4.1 Phase 1B Schedule

The Phase 1B schedule is considered to be the same for all three approaches. In order to accurately schedule all of the program events, it is necessary to develop a clear definition and understanding of the scope of work for Phase 1B and obtain complete agreement on what will be accomplished prior to Phase II initiation. A detail phase 1B schedule was prepared to provide this understanding and is summarized on each master schedule. It reflects the objectives, tasks and outputs as defined in the Phase 1B Specimen Statement of Work, and the Preliminary Voyager Mission Specification and is described below.

Coincident with Phase 1B contract award, JPL will provide an approved formal 1971 Voyager Mission Specification, an approved Organization Plan, and an approved Implementation Plan. These documents, together with the firm Phase 1B work statement, will control and guide the Phase 1B effort. By late February modifications to implementation plans must be approved by JPL to allow early initiation of applicable portions. A Parts, Materials and Processes Control Plan will be prepared and submitted to JPL for approval early in Phase 1B, so that it can be used to discipline hardware design.

The most significant event during Phase 1B is the "development freeze" specified in the preliminary Voyager Mission Specification. Its significance rests on the following definition:

1) By July 1, 1966, all subsystems and component design development, including development tests, necessary for improving on the state-of-the-art will be completed.
2) Development testing in support of component selection and design verification need not be completed by July 1, 1966.
3) The mission specification provided at Phase 1B go-ahead will be verified, with any revision recommendations ready for submittal to JPL. Centerline, inboard profile, and equipment arrangement drawings will be complete.
4) Functional specifications for 1969 and 1971 spacecraft and for the operational support equipment will be complete. Also, preliminary design specifications (Part 1 CEI Specifications) will be complete.

5) Design reviews will have been held for each subsystem or major component. These reviews, in the case of critical long lead time items, will be similar to a Preliminary Design Review (PDR), and will involve Boeing, its team contractors, and JPL.

6) In addition to the specifications and drawings listed above Phase II costs, schedules, and program plans will be included. These plans are Engineering, Manufacturing, Assembly and Checkout, Integrated Test, and Launch Operations.

After development freeze, the final two months of Phase 1B are devoted to continued design effort, completion of the functional specifications, refinement of implementation plans, initiation of procurement surveys, and submittal on August 31 of final report documentation.

5.4.2 Master Schedule - 1971 Mission Only

The master schedule shown in Figure 5.4-1 depicts the significant events and time phasing for the Voyager Spacecraft System to support the Voyager mission flight in 1971, with no test flights in 1969. The 5-1/3 year time period from Phase 1B go-ahead until the 1971 launch opportunity, starting on April 30, 1971, permits an end-to-end schedule approach to achieve mission success. Time is available for an unhurried design phase, followed by extensive ground testing. Only the minimum practical concurrency of timing between design and testing is scheduled.

JET PROPULSION LABORATORY

MAJOR PROGRAM INTERFACES

BOEING

MISSION ENGINEERING

SYSTEM ENGINEERING

PLANETARY QUARANTINE

PRODUCT ASSURANCE (P/A)

SYSTEM CONFIGURATION & DESIGN

SUBSYSTEM DESIGN

- TELECOMMUNICATIONS
- ATTITUDE REFERENCE
- AUTOPILOT
- REACTION CONTROL
- CENTRAL COMPUTER & SEQUENCER
- ELECTRICAL POWER
- STRUCTURES & SPACECRAFT ADAPTER
- MECHANISMS
- TEMPERATURE CONTROL
- PYROTECHNICS
- CABLING
- PROPULSION MIDCOURSE
- PROPULSION ORBITAL INSERTION

SCIENCE PAYLOAD INTEGRATION

MANUFACTURING & TEST PROGRAM

- MOCKUPS

PARTIAL SPACECRAFT

- STATIC TEST MODEL

1965							
	JUN	JUL	AUG	SEP	OCT	NOV	DEC
							SELECT CONTR REL F MISS
				PHASE IB PROPOSAL	PHASE IB PROPOSAL EVALUATION		START PH IB

STER OR D RQMT PRO

ISSUE REQMT' DIRECTI

PRO SPEC RELE

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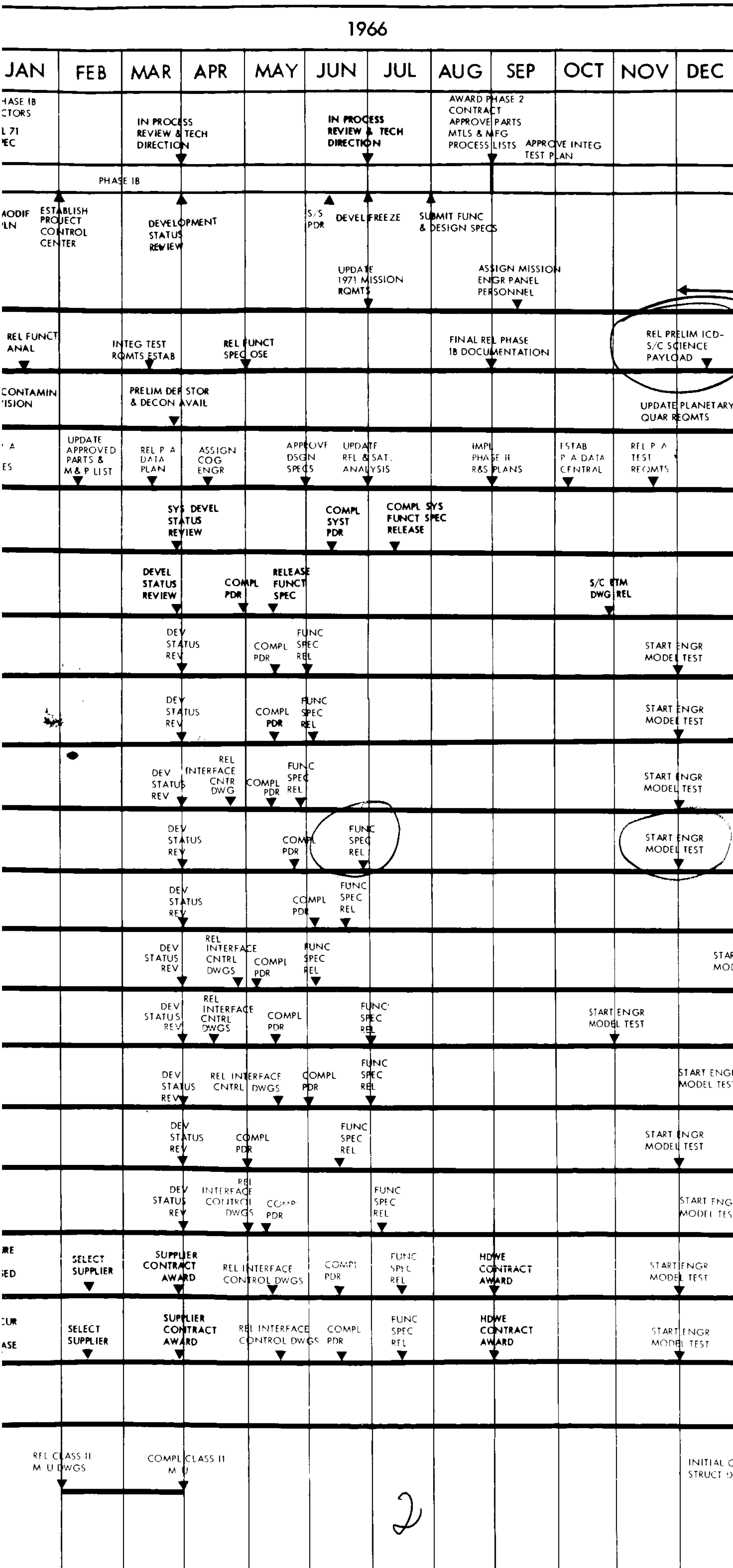
2



1966
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
HASE IB
CTORS
L 71
EC
IN PROCESS REVIEW & TECH DIRECTION
IN PROCESS REVIEW & TECH DIRECTION
AWARD PHASE 2 CONTRACT
APPROVE PARTS MTLS & MFG PROCESS LISTS
APPROVE INTEG TEST PLAN
PHASE IB
MODIF
PLN
ESTABLISH PROJECT CONTROL CENTER
DEVELOPMENT STATUS REVIEW
S/S PDR
DEVEL FREEZE
SUBMIT FUNC & DESIGN SPECS
UPDATE 1971 MISSION RQMTS
ASSIGN MISSION ENGR PANEL PERSONNEL
REL FUNCT ANAL
INTEG TEST RQMTS ESTAB
REL FUNCT SPEC OSE
FINAL REL PHASE IB DOCUMENTATION
REL PRELIM ICD-S/C SCIENCE PAYLOAD
CONTAMIN
VISION
PRELIM DEF STOR & DECON AVAIL
UPDATE PLANETARY QUAR REQMTS
P A
ES
UPDATE APPROVED PARTS & M&P LIST
REL P A DATA PLAN
ASSIGN COG ENGR
APPROVE DSGN SPECS
UPDATE REL & SAT. ANALYSIS
IMPL PHASE II R&S PLANS
ESTAB P A DATA CENTRAL
REL P A TEST REQMTS
SYS DEVEL STATUS REVIEW
COMPL SYST PDR
COMPL SYS FUNCT SPEC RELEASE
DEVEL STATUS REVIEW
COMPL PDR
RELEASE FUNCT SPEC
S/C ETM DWG REL
DEV STATUS REV
COMPL PDR
FUNC SPEC REL
START ENGR MODEL TEST
DEV STATUS REV
COMPL PDR
FUNC SPEC REL
START ENGR MODEL TEST
DEV STATUS REV
REL INTERFACE CNTR DWG
COMPL PDR
FUNC SPEC REL
START ENGR MODEL TEST
DEV STATUS REV
COMPL PDR
FUNC SPEC REL
START ENGR MODEL TEST
DEV STATUS REV
COMPL PDR
FUNC SPEC REL
DEV STATUS REV
REL INTERFACE CNTRL DWGS
COMPL PDR
FUNC SPEC REL
STAR
MOD
DEV STATUS REV
REL INTERFACE CNTRL DWGS
COMPL PDR
FUNC SPEC REL
START ENGR MODEL TEST
DEV STATUS REV
REL INTERFACE CNTRL DWGS
COMPL PDR
FUNC SPEC REL
START ENGI MODEL TES
DEV STATUS REV
COMPL PDR
FUNC SPEC REL
START ENGR MODEL TEST
DEV STATUS REV
REL INTERFACE CONTROL DWGS
COMP PDR
FUNC SPEC REL
START ENG MODEL TES
RE
ED
SELECT SUPPLIER
SUPPLIER CONTRACT AWARD
REL INTERFACE CONTROL DWGS
COMPL PDR
FUNC SPEC REL
HDWE CONTRACT AWARD
START ENGR MODEL TEST
CUR
ASE
SELECT SUPPLIER
SUPPLIER CONTRACT AWARD
REL INTERFACE CONTROL DWGS
COMPL PDR
FUNC SPEC REL
HDWE CONTRACT AWARD
START ENGR MODEL TEST
REL CLASS II M U DWGS
COMPL CLASS II M U
INITIAL C
STRUCT D
2

1967

JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC

APPR AHSE SAFETY

PHASE II

SUPPORT T

PROVIDE UPDATE INTERFACE DATA
UPDATE S/C SYS FUNC ANAL (EVERY 6 MO)
UPDATE OSE FUNC SPECS
PROVIDE FINAL MISSION REQMTS & RESTR S/C-MOS DSN-L/C-CAP

RFL P A MFG REQMTS
MONITOR ENGINEER MODEL TESTING
REL QUAL STATUS DOCUMENT

START SYS ENGR MODEL
COMPL SYS ETM DWG RELEASE

START ENGR MODEL TEST
COMPL ENGR MODEL TEST
COMPL CDR
ETM HDWE AVAIL
S T

COMPL ENGRG MODEL TEST
ETM HDWE AVAIL
COMPL CDR

COMPL ENGR MODEL TEST
ETM HDWE AVAIL
COMPL CDR

S/C ETM DWGS REL
COMPL ENGR MODEL TEST
COMPL CDR
ETM HDWE AVAIL

S/C ETM DWGS REL
COMPL ENGR MODEL TEST
CO CD

START ENGR MODEL TEST
COMPL ENGR MODEL TEST
COMPL CDR
ETM HDWE AVAIL
ETM HDWE AVAIL

ENGR L TEST
S/C ETM DWGS REL
ETM HDWE AVAIL
COMPL ENGR MODEL TEST
COMPL CDR

S/C ETM DWGS REL
ETM HDWE AVAIL
COMPL ENGR MODEL TEST
COMPL CDR

S/C ETM DWGS REL
ETM HDWE AVAIL
COMPL ENG MODEL TES

S/C ETM DWGS REL
COMPL ENGR MODEL TEST
ETM HDW AVAIL

S/C ETM DWGS REL
COMPL MODEL

S/C ETM DWGS REL

S/C ETM DWGS REL

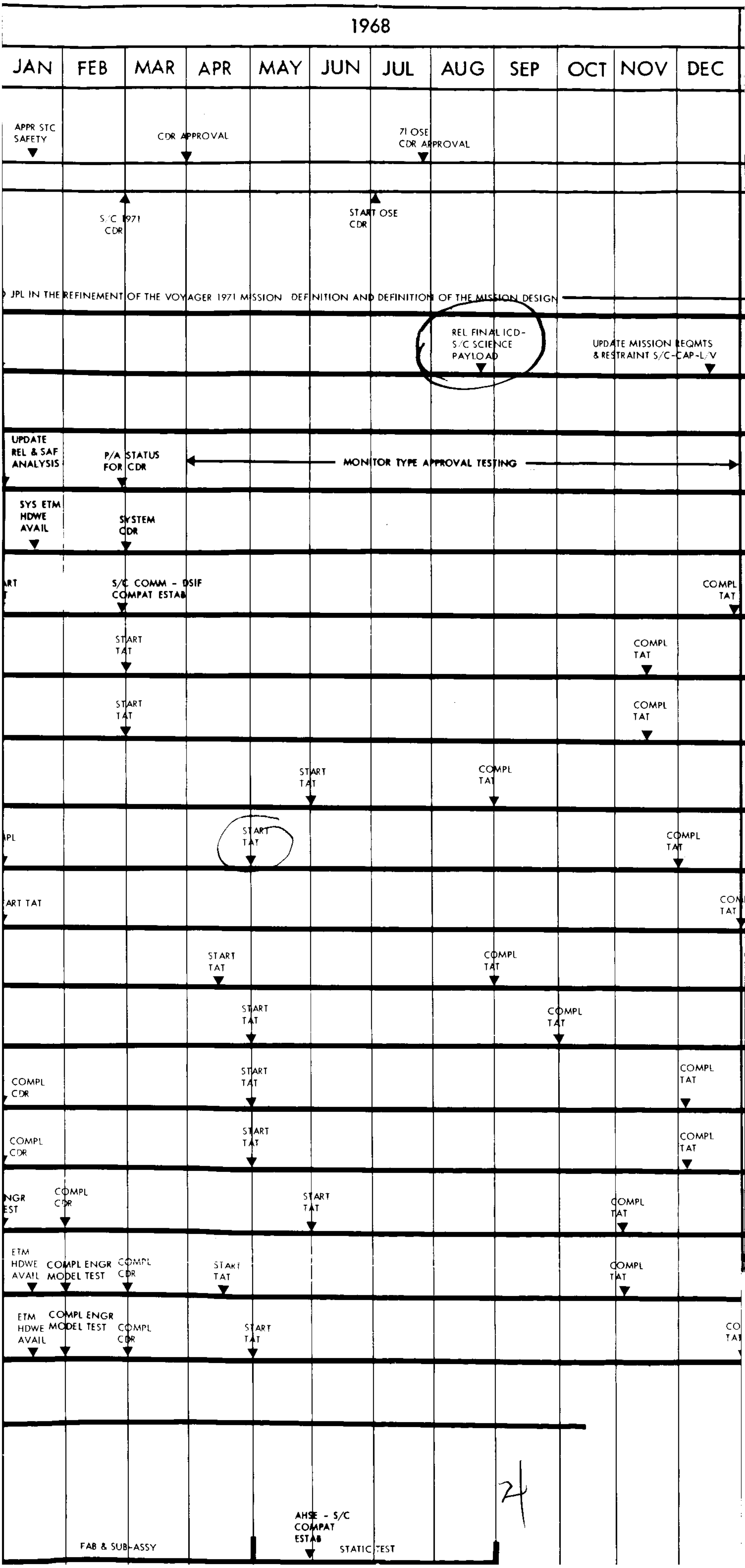
S/C SCIENCE INSTRUMENT INTERFACE SPECS & ASSOC DRAWINGS

ASS III M/U G REL
INITIAL CLASS III M/U SYS & WIRE DWG REL
CLASS III M/U COMPL

3

STATIC TEST MODEL

L



1968
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
APPR STC SAFETY
CDR APPROVAL
71 OSE CDR APPROVAL
S/C 1971 CDR
START OSE CDR
JPL IN THE REFINEMENT OF THE VOYAGER 1971 MISSION DEFINITION AND DEFINITION OF THE MISSION DESIGN
REL FINAL ICD-S/C SCIENCE PAYLOAD
UPDATE MISSION REQMTS & RESTRAINT S/C-CAP-L/V
UPDATE REL & SAF ANALYSIS
P/A STATUS FOR CDR
MONITOR TYPE APPROVAL TESTING
SYS ETM HDWE AVAIL
SYSTEM CDR
S/C COMM - DSIF COMPAT ESTAB
COMPL TAT
START TAT
COMPL TAT
START TAT
COMPL TAT
START TAT
COMPL TAT
START TAT
COMPL TAT
ART TAT
START TAT
COMPL TAT
START TAT
COMPL TAT
COMPL CDR
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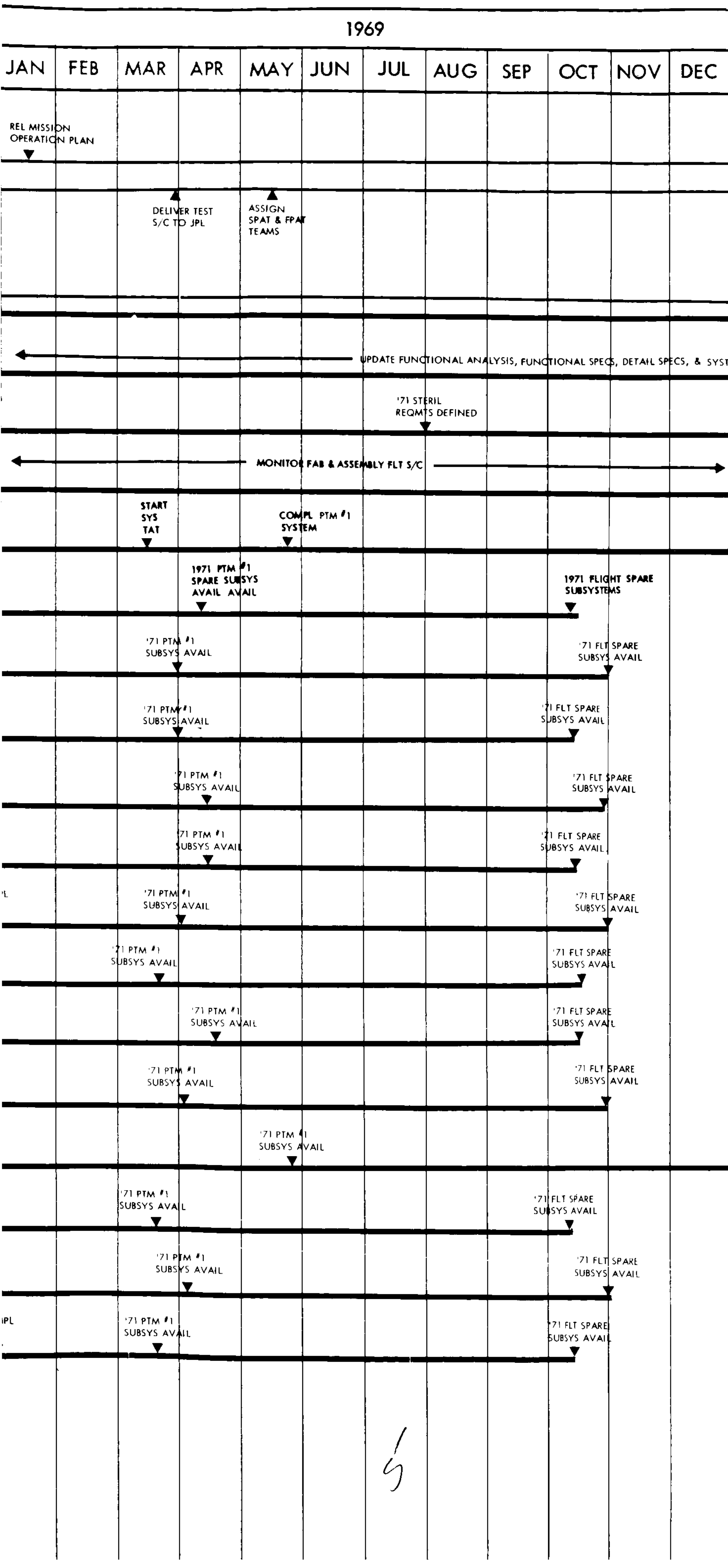
COMPL TAT
COMPL CDR
START TAT
COMPL TAT
NGR EST
COMPL CDR
START TAT
COMPL TAT
ETM HDWE AVAIL
COMPL ENGR MODEL TEST
COMPL CDR
START TAT
COMPL TAT
ETM HDWE AVAIL
COMPL ENGR MODEL TEST
COMPL CDR
START TAT
FAB & SUB-ASSY
AHSE - S/C COMPAT ESTAB
STATIC TEST

4


1969
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
REL MISSION OPERATION PLAN
DELIVER TEST S/C TO JPL
ASSIGN SPAT & FPAT TEAMS
UPDATE FUNCTIONAL ANALYSIS, FUNCTIONAL SPECS, DETAIL SPECS, & SYST
'71 STERIL REQMTS DEFINED
MONITOR FAB & ASSEMBLY FLT S/C
START SYS TAT
COMPL PTM #1 SYSTEM
1971 PTM #1 SPARE SUBSYS AVAIL AVAIL
1971 FLIGHT SPARE SUBSYSTEMS
'71 PTM #1 SUBSYS AVAIL
'71 FLT SPARE SUBSYS AVAIL
'71 PTM #1 SUBSYS AVAIL
'71 FLT SPARE SUBSYS AVAIL
'71 PTM #1 SUBSYS AVAIL
'71 FLT SPARE SUBSYS AVAIL
'71 PTM #1 SUBSYS AVAIL
'71 FLT SPARE SUBSYS AVAIL
'71 PTM #1 SUBSYS AVAIL
'71 FLT SPARE SUBSYS AVAIL
'71 PTM #1 SUBSYS AVAIL
'71 FLT SPARE SUBSYS AVAIL
'71 PTM #1 SUBSYS AVAIL
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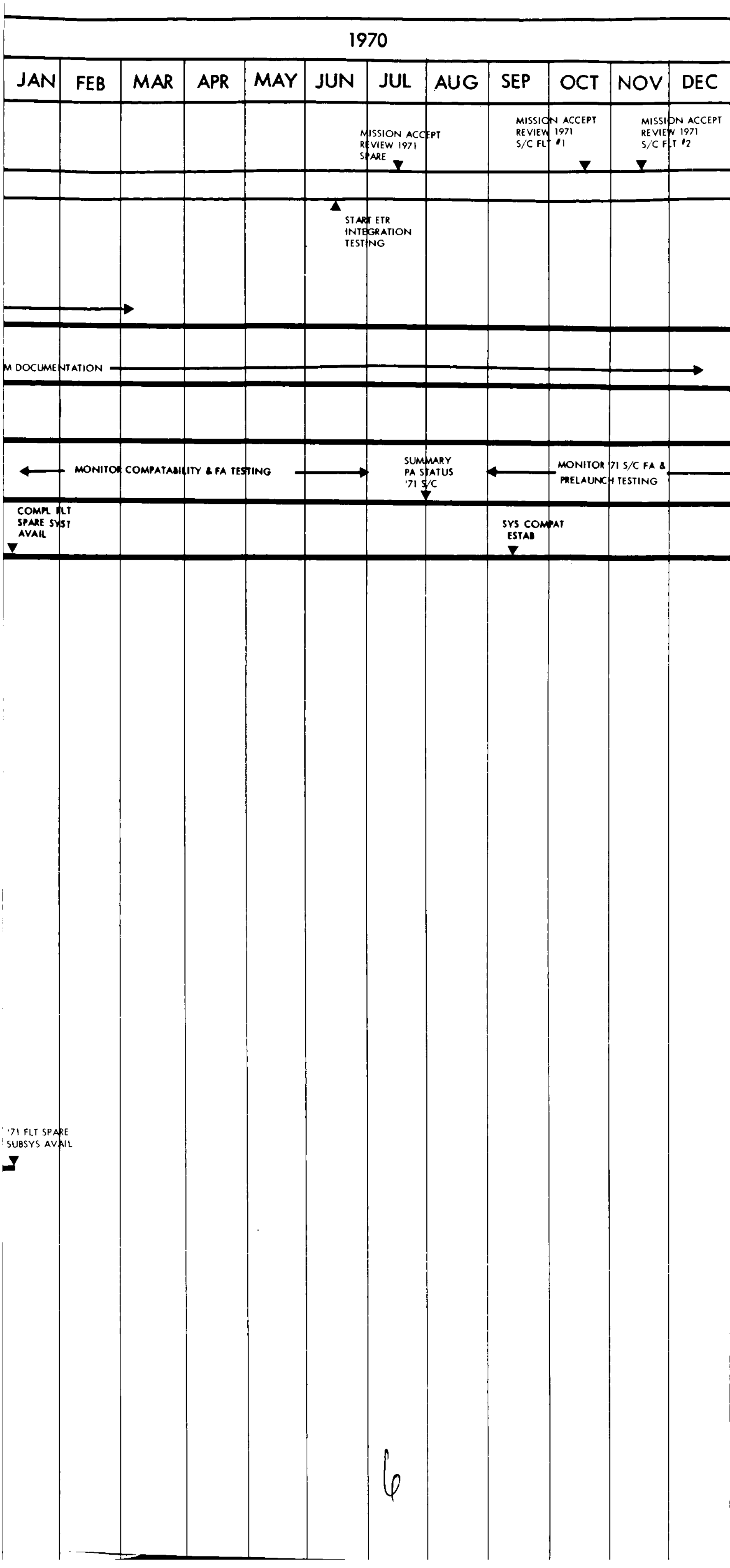
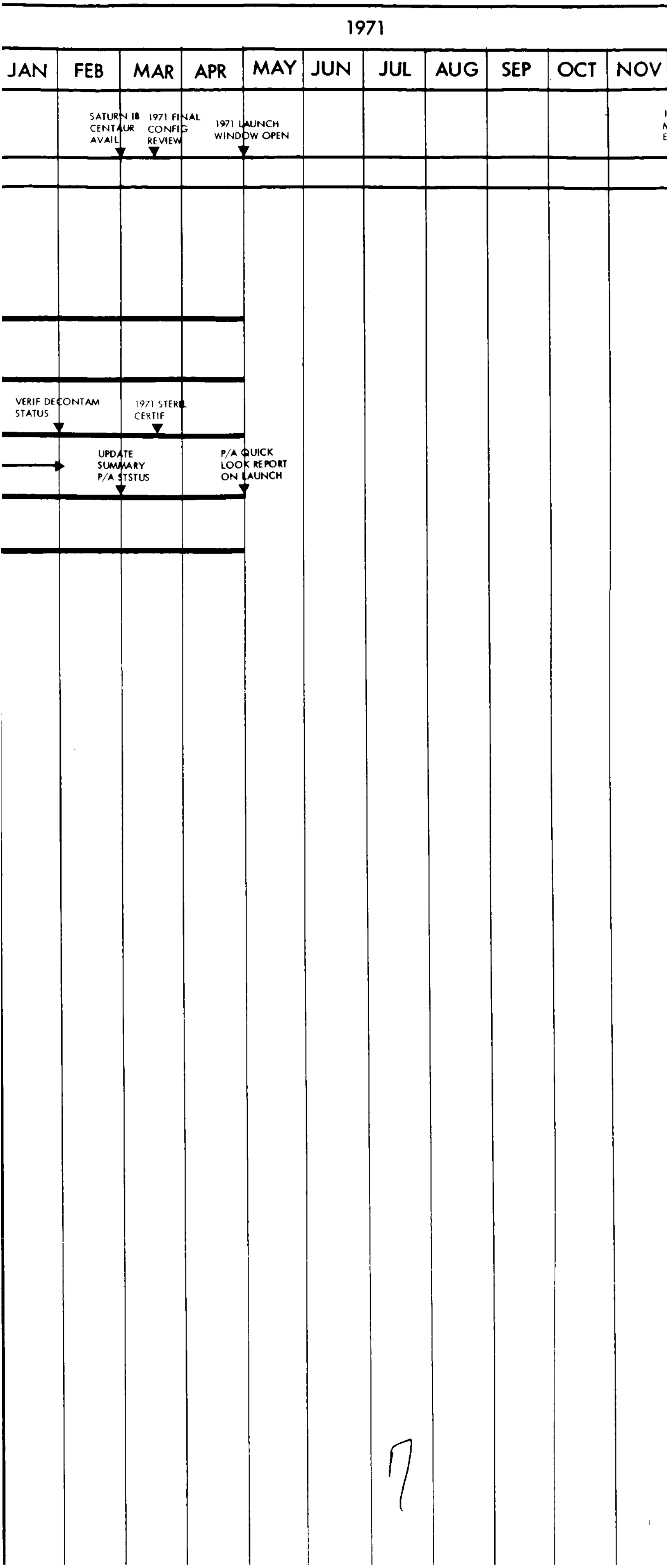
'71 PTM #1 SUBSYS AVAIL
'71 FLT SPARE SUBSYS AVAIL
'71 PTM #1 SUBSYS AVAIL
'71 FLT SPARE SUBSYS AVAIL
'71 PTM #1 SUBSYS AVAIL
'71 FLT SPARE SUBSYS AVAIL
5


1970
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MISSION ACCEPT REVIEW 1971 SPARE
MISSION ACCEPT REVIEW 1971 S/C FLT #1
MISSION ACCEPT REVIEW 1971 S/C FLT #2
START ETR INTEGRATION TESTING
M DOCUMENTATION
MONITOR COMPATABILITY & FA TESTING
SUMMARY PA STATUS '71 S/C
MONITOR '71 S/C FA & PRELAUNCH TESTING
COMPL FLT SPARE SYST AVAIL
SYS COMPAT ESTAB
'71 FLT SPARE SUBSYS AVAIL


1971
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
SATURN IB CENTAUR AVAIL
1971 FINAL CONFIG REVIEW
1971 LAUNCH WINDOW OPEN
VERIF DECONTAM STATUS
1971 STERIL CERTIF
UPDATE SUMMARY P/A STSTUS
P/A QUICK LOOK REPORT ON LAUNCH

	1972											
DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MARS SION COUNTER ▼												
	SUBMIT PRELIM 1971 ENCOUNTER REPORT ▲		▲ SUBMIT FINAL 1971 ENCOUNTER REPORT									

THE BOEING COMPANY

Master Schedule 1971 Mission Only

ABBREVIATIONS

C/O	CHECKOUT
ETM	ENGINEERING TEST MODEL
CDR	CRITICAL DESIGN REVIEW
PDR	PRELIMINARY DESIGN REVIEW
M/U	MOCKUP
FAT	FLIGHT ACCEPTANCE TEST
TAT	TYPE APPROVAL TEST
ASSY	ASSEMBLY
FAB	FABRICATION
SUBASSY	SUBASSEMBLY
REV	REVIEW
REL	RELEASE
MDS	MISSION OPERATION SYSTEM
DEV	DEVELOPMENT
COMPAT	COMPATIBILITY
INSTR	INSTRUMENTATION
HDWE	HARDWARE
FLT	FLIGHT
ANAL	ANALYSIS
IMPL	IMPLEMENT
COG	COGNIZANT
S/C	SPACECRAFT
L/V	LAUNCH VEHICLE
CAP	CAPSULE
ETR	AIR FORCE EASTERN TEST RANGE
BOD	BENEFICIAL OCCUPANCY DATE
DSN	DEEP SPACE NETWORK
DSIF	DEEP SPACE INSTRUMENTATION FACILITY
DWG	DRAWING
OSE	OPERATIONAL SUPPORT EQUIPMENT
SPEC	SPECIFICATION
MTLS	MATERIALS
M&P	MATERIALS & PROCESSES

APPROVALS			
ORGANIZATION	NAME	DATE	APPROVAL
SPACECRAFT SYSTEM PROGRAM MANAGER	E. G. CZARNECKI	7/24	E G Czarnecki
AUTONETICS DIVISION - N.A.A.	R. R. MUELLER	7/23	R R Mueller
ELECTRO OPTICAL SYSTEMS	C. I. CUMMINGS	7/22	[illegible]

THERMAL TEST MODEL

DYNAMIC TEST MODEL

COMPLETE SPACECRAFT
ENGINEERING MODEL-PROTOTYPE

JPL TEST SPACECRAFT

SUBSYSTEM FLIGHT SPARES

1971 PROOF TEST MODEL #1

1971 PROOF TEST MODEL #2

1971 FLIGHT SPARE

1971 FLIGHT 1

1971 FLIGHT 2

OPERATIONAL SUPPORT EQUIPMENT
ASSEMBLY, HANDLING & SHIPPING EQUIPMENT

SYSTEM TEST COMPLEX

LAUNCH COMPLEX EQUIPMENT

MISSION DEPENDENT EQUIPMENT

FACILITIES

CONFIGURATION MANAGEMENT

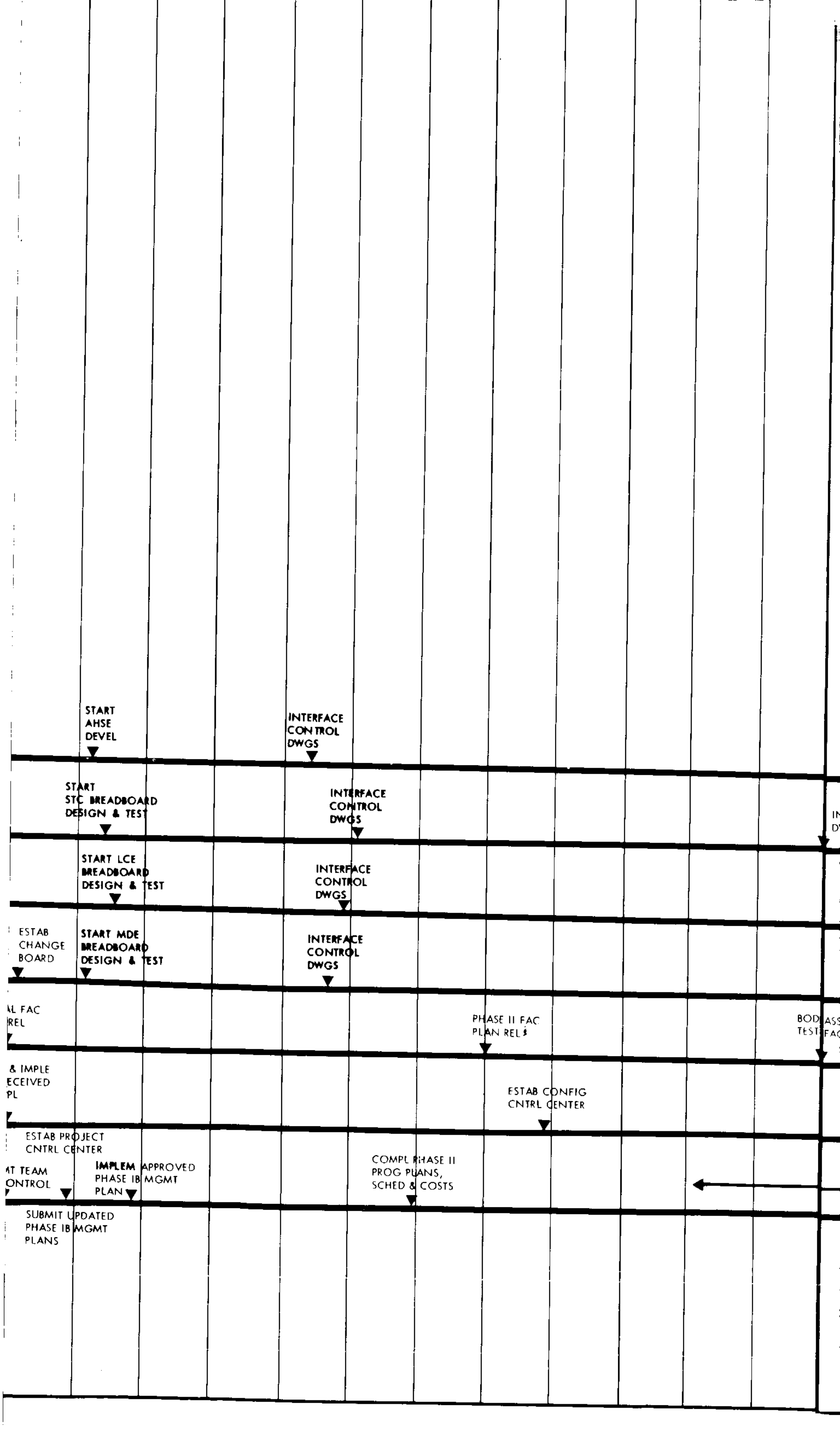
BUSINESS MANAGEMENT

INITI
PLAN

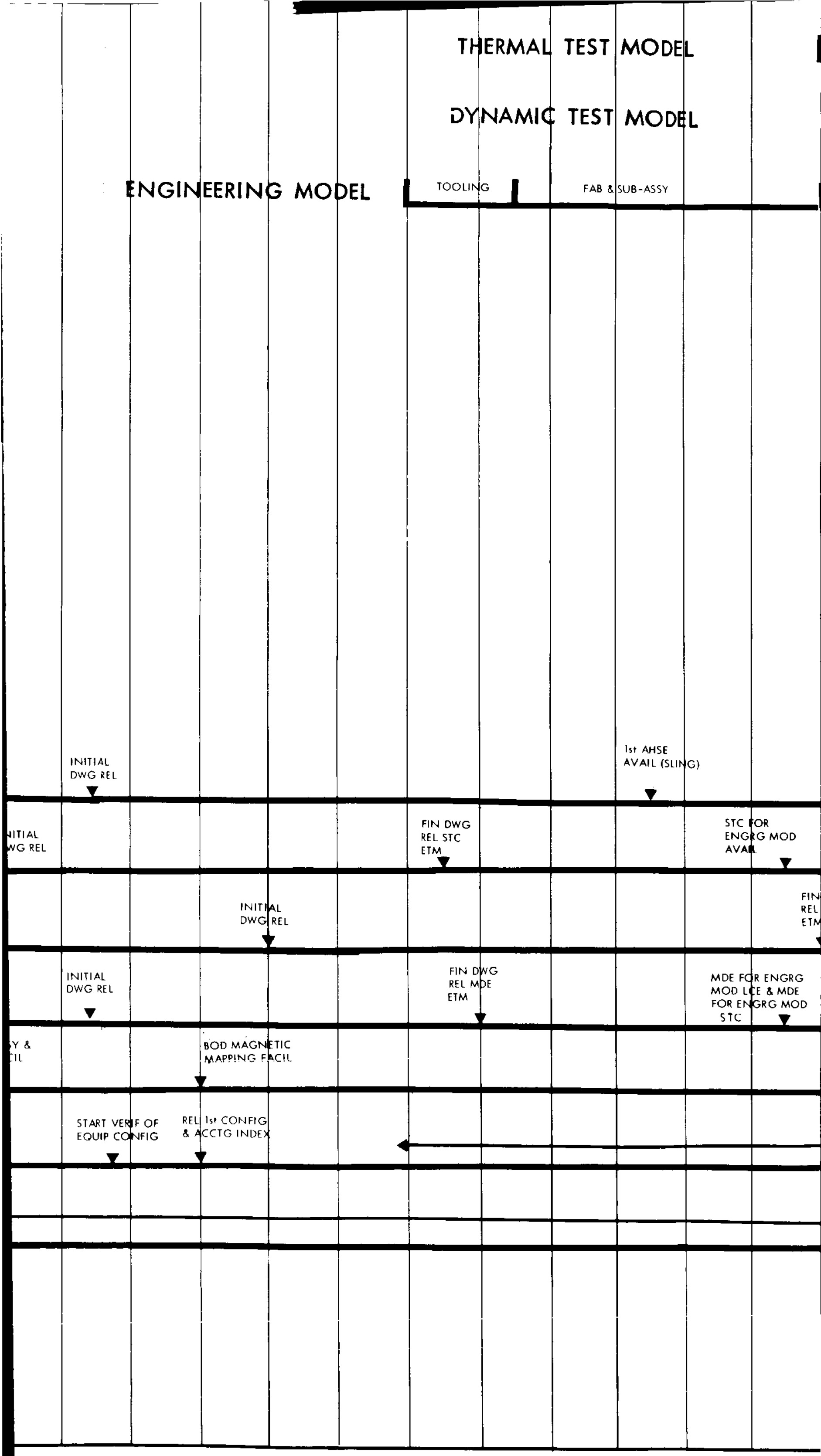
REVIEW
SPECS
FROM

ESTAB MG
& PROG. (

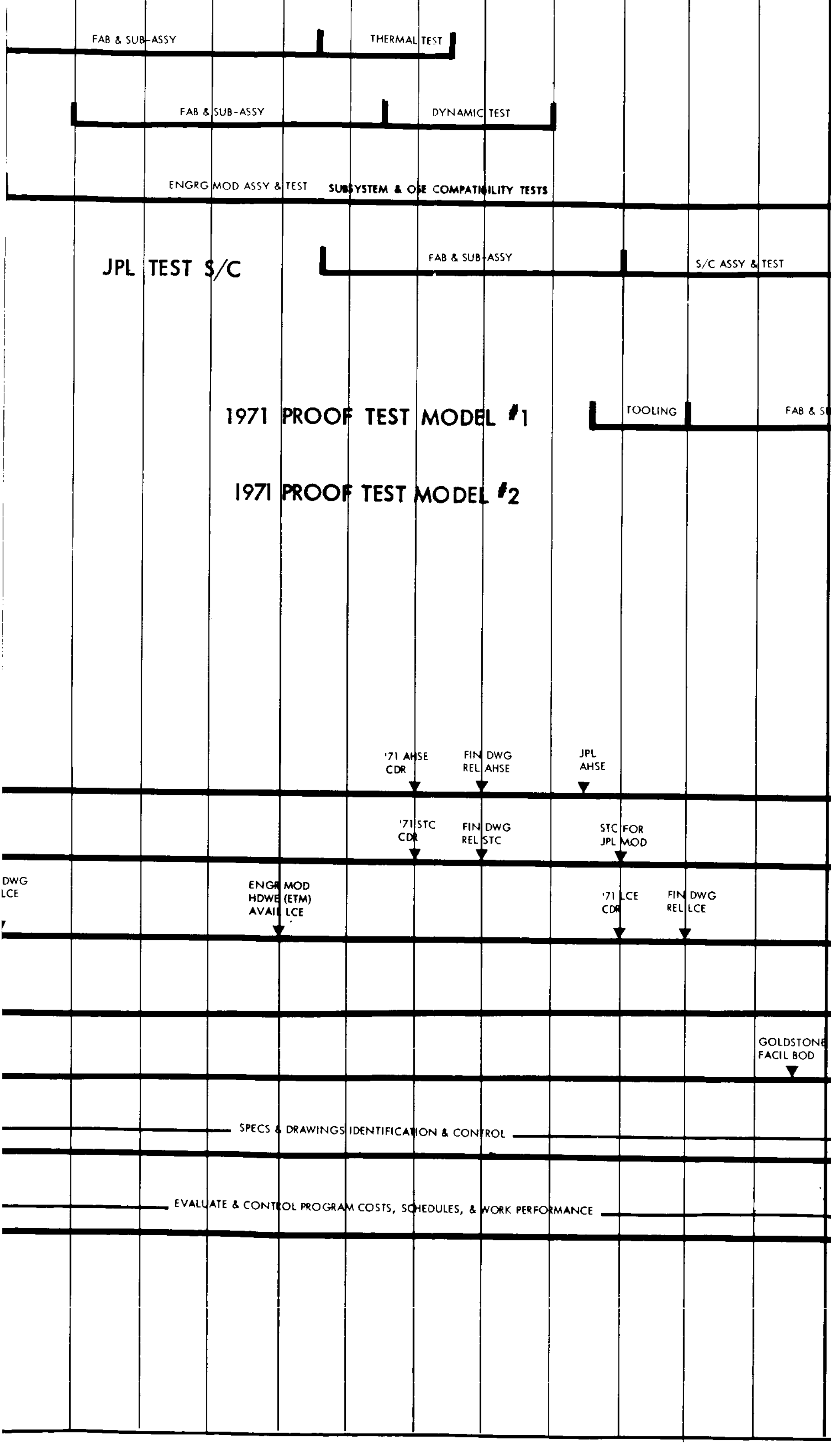
2

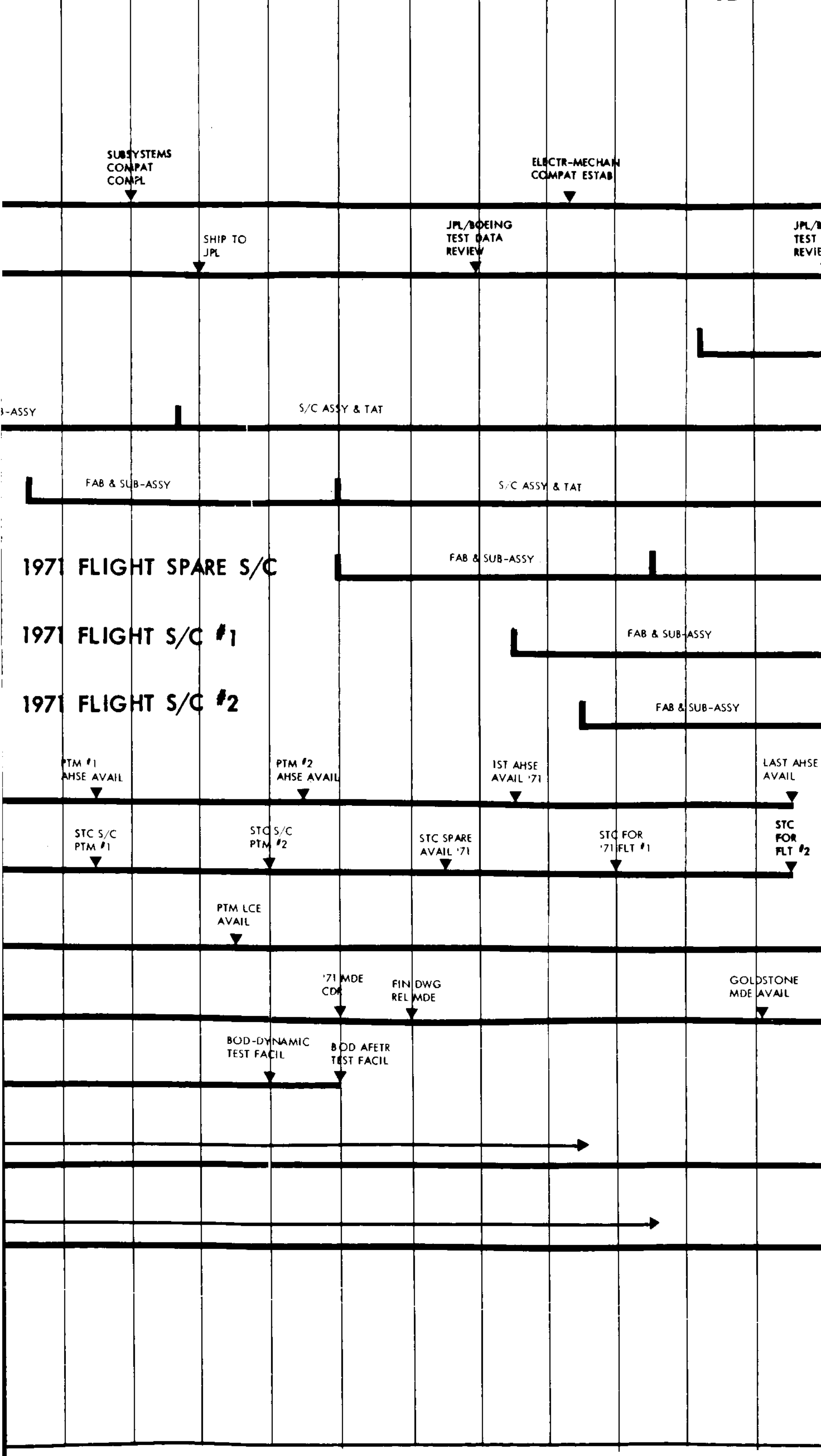

START AHSE DEVEL
INTERFACE CONTROL DWGS
START STC BREADBOARD DESIGN & TEST
INTERFACE CONTROL DWGS
START LCE BREADBOARD DESIGN & TEST
INTERFACE CONTROL DWGS
ESTAB CHANGE BOARD
START MDE BREADBOARD DESIGN & TEST
INTERFACE CONTROL DWGS
PHASE II FAC PLAN REL
ESTAB CONFIG CNTRL CENTER
ESTAB PROJECT CNTRL CENTER
IMPLEM APPROVED PHASE IB MGMT PLAN
COMPL PHASE II PROG PLANS, SCHED & COSTS
SUBMIT UPDATED PHASE IB MGMT PLANS

3

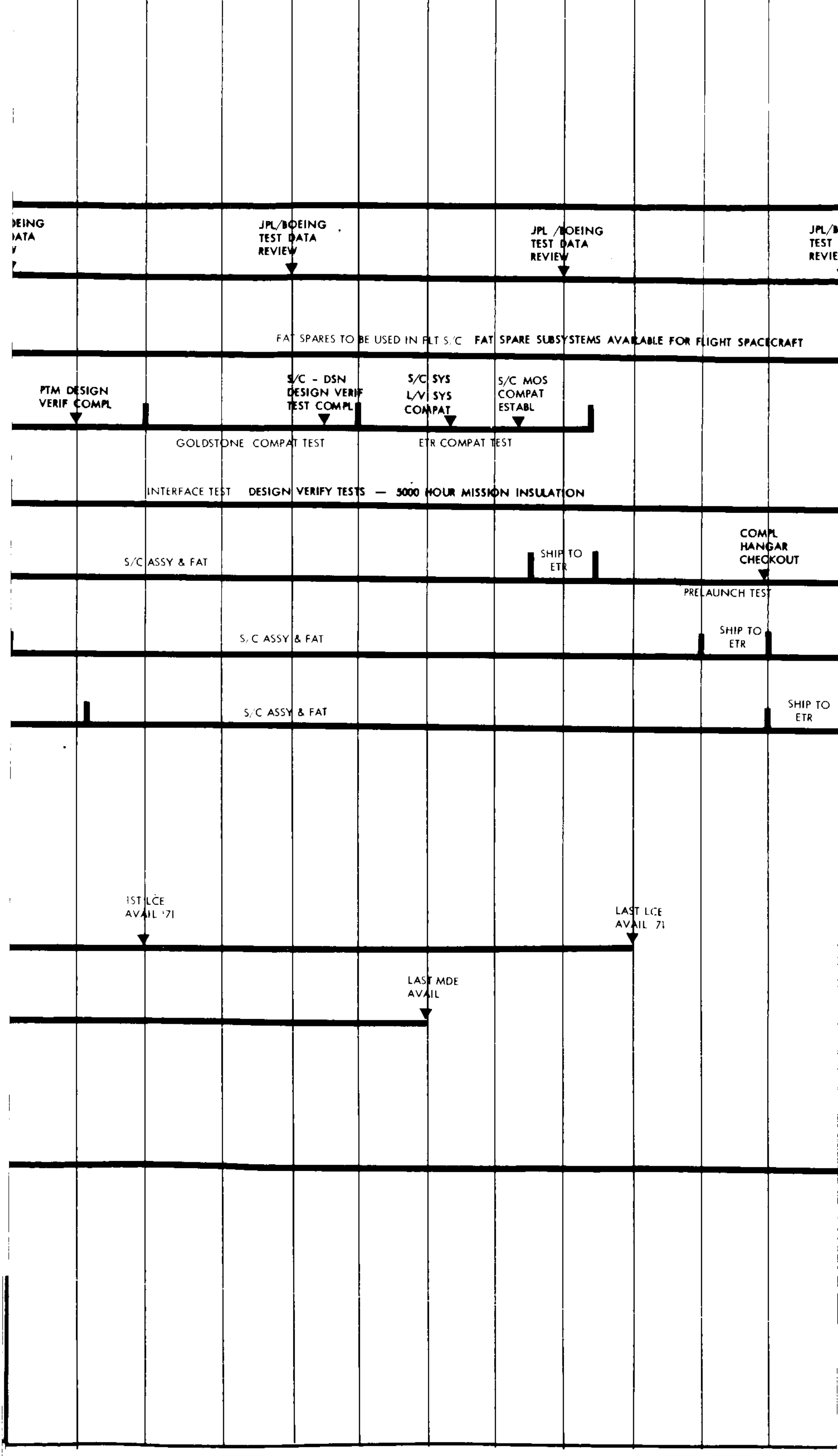

THERMAL TEST MODEL
DYNAMIC TEST MODEL
ENGINEERING MODEL
TOOLING
FAB & SUB-ASSY
INITIAL
DWG REL
1st AHSE
AVAIL (SLING)
NITIAL
WG REL
FIN DWG
REL STC
ETM
STC FOR
ENGRG MOD
AVAIL
INITIAL
DWG REL
FIN
REL
ETM
INITIAL
DWG REL
FIN DWG
REL MDE
ETM
MDE FOR ENGRG
MOD LCE & MDE
FOR ENGRG MOD
STC
Y &
CIL
BOD MAGNETIC
MAPPING FACIL
START VERIF OF
EQUIP CONFIG
REL 1st CONFIG
& ACCTG INDEX

4

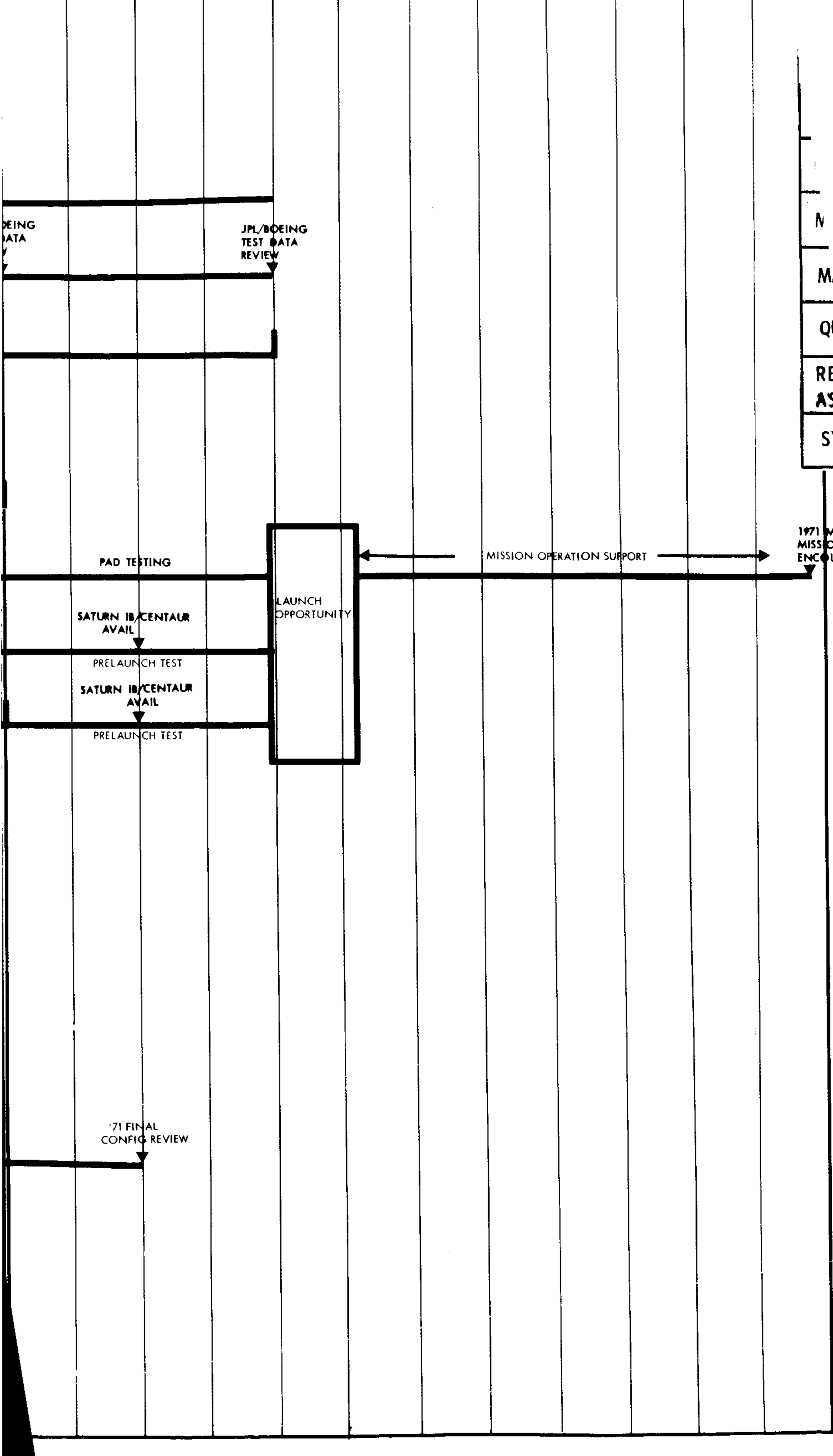

FAB & SUB-ASSY
THERMAL TEST
FAB & SUB-ASSY
DYNAMIC TEST
ENGRG MOD ASSY & TEST
SUBSYSTEM & OSE COMPATIBILITY TESTS
JPL TEST S/C
FAB & SUB-ASSY
S/C ASSY & TEST
1971 PROOF TEST MODEL #1
TOOLING
FAB & S
1971 PROOF TEST MODEL #2
'71 AHSE CDR
FIN DWG REL AHSE
JPL AHSE
'71 STC CDR
FIN DWG REL STC
STC FOR JPL MOD
DWG LCE
ENGR MOD HDWE (ETM) AVAIL LCE
'71 LCE CDR
FIN DWG REL LCE
GOLDSTONE FACIL BOD
SPECS & DRAWINGS IDENTIFICATION & CONTROL
EVALUATE & CONTROL PROGRAM COSTS, SCHEDULES, & WORK PERFORMANCE


SUBSYSTEMS COMPAT COMPL
ELECTR-MECHAN COMPAT ESTAB
SHIP TO JPL
JPL/BOEING TEST DATA REVIEW
JPL/B TEST REVIE
-ASSY
S/C ASSY & TAT
FAB & SUB-ASSY
S/C ASSY & TAT
1971 FLIGHT SPARE S/C
FAB & SUB-ASSY
1971 FLIGHT S/C #1
FAB & SUB-ASSY
1971 FLIGHT S/C #2
FAB & SUB-ASSY
PTM #1 AHSE AVAIL
PTM #2 AHSE AVAIL
1ST AHSE AVAIL '71
LAST AHSE AVAIL
STC S/C PTM #1
STC S/C PTM #2
STC SPARE AVAIL '71
STC FOR '71 FLT #1
STC FOR FLT #2
PTM LCE AVAIL
'71 MDE CDR
FIN DWG REL MDE
GOLDSTONE MDE AVAIL
BOD-DYNAMIC TEST FACIL
BOD AFETR TEST FACIL

6


JPL/BOEING
TEST DATA
REVIEW
JPL /BOEING
TEST DATA
REVIEW
FAT SPARES TO BE USED IN FLT S/C
FAT SPARE SUBSYSTEMS AVAILABLE FOR FLIGHT SPACECRAFT
PTM DESIGN
VERIF COMPL
S/C - DSN
DESIGN VERIF
TEST COMPL
S/C SYS
L/V SYS
COMPAT
S/C MOS
COMPAT
ESTABL
GOLDSTONE COMPAT TEST
ETR COMPAT TEST
INTERFACE TEST
DESIGN VERIFY TESTS — 5000 HOUR MISSION INSULATION
COMPL
HANGAR
CHECKOUT
S/C ASSY & FAT
SHIP TO
ETR
PRELAUNCH TEST
S/C ASSY & FAT
SHIP TO
ETR
S/C ASSY & FAT
SHIP TO
ETR
1ST LCE
AVAIL '71
LAST LCE
AVAIL 71
LAST MDE
AVAIL

7

JPL/BOEING TEST DATA REVIEW
PAD TESTING
SATURN IB/CENTAUR AVAIL
PRELAUNCH TEST
SATURN IB/CENTAUR AVAIL
PRELAUNCH TEST
LAUNCH OPPORTUNITY
MISSION OPERATION SUPPORT
'71 FINAL CONFIG REVIEW

VELOPMENT LABORATORIES	G. O. MOORE	7/22	G. O. Moore
SINESS AND OPERATIONS	L. B. BARLOW	7/24	L. Barlow
GINEERING	W. C. GALLOWAY	7/24	W. C. Galloway
CILITIES	R. K. MILLS	7/23	R. K. Mills
NUFACTURING	R. R. DICKSON	7/23	R. R. Dickson
ATERIEL	J. C. POWERS	7/23	J. C. Powers
UALITY CONTROL	G. J. SIDDONS	7/23	G. J. Siddons
LIABILITY, QUALITY SURANCE, AND SAFETY	C. S. BARTHOLOMEW	7/24	C. S. Bartholomew
YSTEMS TESTING	J. C. TURNER	7/22	J. C. Turner

ARS
N
NTER

9

Figure 5.4-1:

5.4.3 Master Schedule - 1971 Mission and 1969 Atlas/Centaur Flyby Test

This master schedule Figure 5.4-2 depicts the significant events and necessary time phasing for the Voyager Spacecraft System to support the Voyager mission in 1971, preceded by a Mars fly-by test mission in 1969. The test mission omits the Flight Capsule, and is accomplished using an Atlas/Centaur launch vehicle.

The choice of a flyby trajectory affects the launch date for the 1969 test flight, and the use of Atlas/Centaur with its lesser thrust and smaller shroud than Saturn 1B/Centaur requires minor alteration of the 1971 spacecraft configuration used for the 1969 test flight. The most significant of these configuration revisions is shown in Volume D.

5.4.3.1 Schedule Effects

The modifications to the 1971 Flight Spacecraft design required for the 1969 Atlas/Centaur test flight do not affect the master schedule.

An integrated program that includes a flight test in 1969 prior to the 1971 mission is characterized by compression of design and test time as opposed to one that does not include the test flight. To preclude pre-implementation of design development testing during Phase 1B a philosophy of concurrency of design and test was used in the scheduling that includes the 1969 test flight. Judicious selection of key design and test milestones provides design maturity of the 1971 spacecraft for use in 1969 tests and sufficient confidence testing to assure objectives of the 1969 test flight. This approach recognizes that the 1969 test flight is an integral part of the test program insofar as extended life type tests are concerned. Continuation of various model tests, time phased to the 1971 mission, provides an increase in probability of mission success in 1971.

By this philosophy a high-degree of confidence is obtained for the 1969 flight, and engineering data resulting therefrom is incorporated in the 1971 mission tests and designs in a timely manner.

Increased confidence in initial design development testing could be gained by selectively initiating effort in Phase 1B.

5.4.3.2 Conclusion

The implementation of the 1969 test flight is compatible with implementation for the 1971 mission. The schedule for accomplishment of the 1969 test flight is reasonable and valid.

JET PROPULSION LABORATORY

MAJOR PROGRAM INTERFACES

BOEING

MISSION ENGINEERING

SYSTEM ENGINEERING

PLANETARY QUARANTINE

PRODUCT ASSURANCE (P/A)

SYSTEM CONFIGURATION & DESIGN

SYBSYSTEM DESIGN

- TELECOMMUNICATIONS
- ATTITUDE REFERENCE
- AUTOPILOT
- REACTION CONTROL
- CENTRAL COMPUTER & SEQUENCER
- ELECTRICAL POWER
- STRUCTURES & SPACECRAFT ADAPTER
- MECHANISMS
- TEMPERATURE CONTROL
- PYROTECHNICS
- CABLING
- PROPULSION MIDCOURSE
- PROPULSION ORBITAL INSERTION

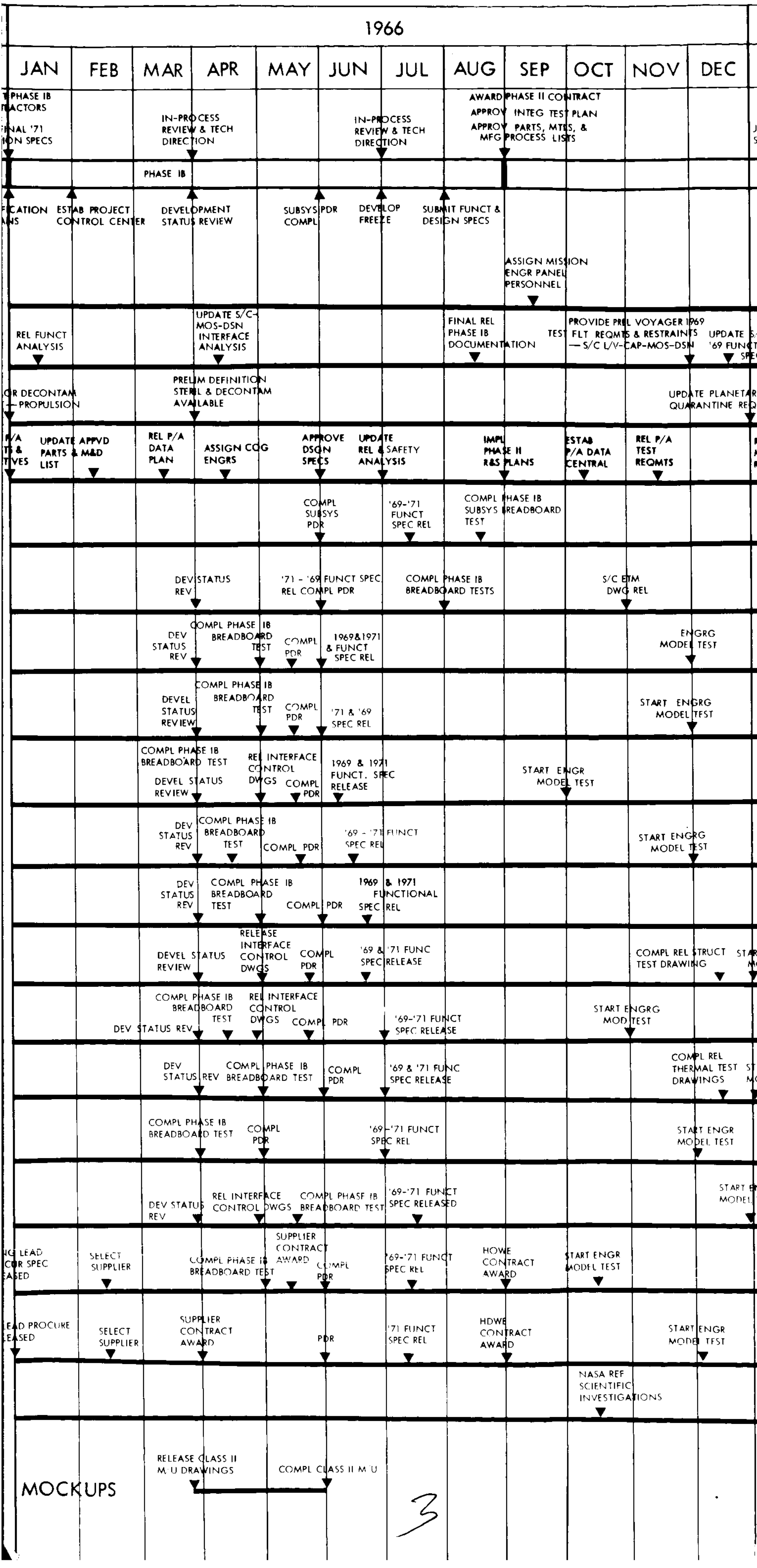
SCIENCE PAYLOAD INTEGRATION

MANUFACTURING & TEST PROGRAM

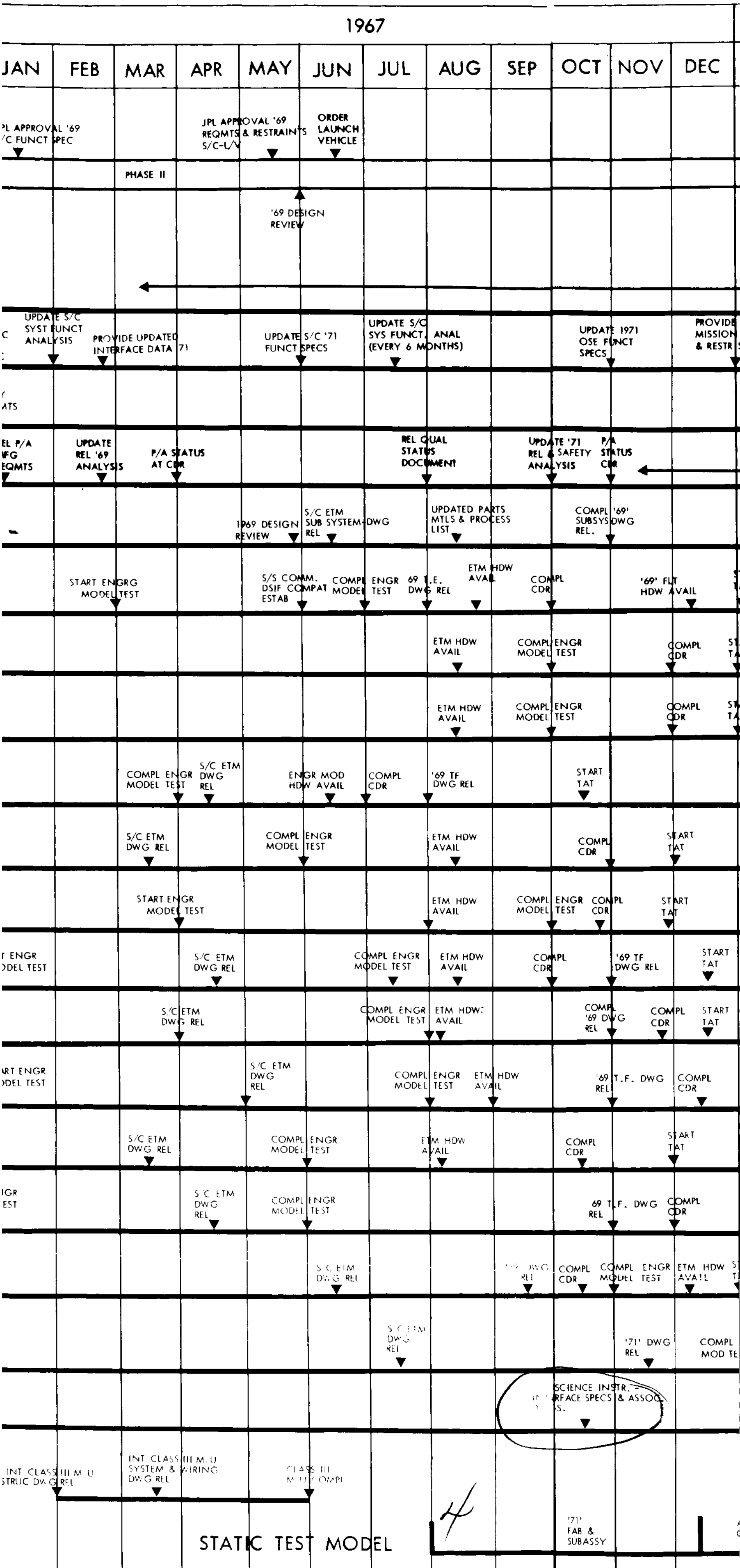
- MOCKUPS
- PARTIAL SPACECRAFT
- STATIC TEST MODEL

1965							
	JUN	JUL	AUG	SEP	OCT	NOV	DEC
							SELEC CON REL F MISS
				PHASE IB PROPOSAL	PHASE IB PROPOSAL EVALUATION		
							START MODI PHASE IB PL STERIL REQMT ISSUE REQM DIREC LON PRO RELE LONG L SPEC REL

2


1966
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
PHASE IB ...ACTORS
...NAL '71 ...ON SPECS
IN-PROCESS REVIEW & TECH DIRECTION
IN-PROCESS REVIEW & TECH DIRECTION
AWARD PHASE II CONTRACT
APPROV INTEG TEST PLAN
APPROV PARTS, MTLS, & MFG PROCESS LISTS
PHASE IB
...FICATION ...NS
ESTAB PROJECT CONTROL CENTER
DEVELOPMENT STATUS REVIEW
SUBSYS PDR COMPL
DEVELOP FREEZE
SUBMIT FUNCT & DESIGN SPECS
ASSIGN MISSION ENGR PANEL PERSONNEL
REL FUNCT ANALYSIS
UPDATE S/C-MOS-DSN INTERFACE ANALYSIS
FINAL REL PHASE IB DOCUMENTATION
TEST
PROVIDE PREL VOYAGER 1969 FLT REQMTS & RESTRAINTS — S/C L/V-CAP-MOS-DSN
UPDATE ... '69 FUNCT ... SPEC
...R DECONTAM ...-PROPULSION
PRELIM DEFINITION STERIL & DECONTAM AVAILABLE
UPDATE PLANETAR... QUARANTINE REQ...
...P/A ...S & ...TIVES
UPDATE APPVD PARTS & M&D LIST
REL P/A DATA PLAN
ASSIGN COG ENGRS
APPROVE DSGN SPECS
UPDATE REL & SAFETY ANALYSIS
IMPL PHASE II R&S PLANS
ESTAB P/A DATA CENTRAL
REL P/A TEST REQMTS
COMPL SUBSYS PDR
'69-'71 FUNCT SPEC REL
COMPL PHASE IB SUBSYS BREADBOARD TEST
DEV STATUS REV
'71 - '69 FUNCT SPEC REL COMPL PDR
COMPL PHASE IB BREADBOARD TESTS
S/C ETM DWG REL
DEV STATUS REV
COMPL PHASE IB BREADBOARD TEST
COMPL PDR
1969&1971 & FUNCT SPEC REL
ENGRG MODEL TEST
DEVEL STATUS REVIEW
COMPL PHASE IB BREADBOARD TEST
COMPL PDR
'71 & '69 SPEC REL
START ENGRG MODEL TEST
COMPL PHASE IB BREADBOARD TEST
DEVEL STATUS REVIEW
REL INTERFACE CONTROL DWGS
COMPL PDR
1969 & 1971 FUNCT. SPEC RELEASE
START ENGR MODEL TEST
DEV STATUS REV
COMPL PHASE IB BREADBOARD TEST
COMPL PDR
'69 - '71 FUNCT SPEC REL
START ENGRG MODEL TEST
DEV STATUS REV
COMPL PHASE IB BREADBOARD TEST
COMPL PDR
1969 & 1971 FUNCTIONAL SPEC REL
DEVEL STATUS REVIEW
RELEASE INTERFACE CONTROL DWGS
COMPL PDR
'69 & '71 FUNC SPEC RELEASE
COMPL REL STRUCT TEST DRAWING
COMPL PHASE IB BREADBOARD TEST
DEV STATUS REV
REL INTERFACE CONTROL DWGS
COMPL PDR
'69-'71 FUNCT SPEC RELEASE
START ENGRG MOD TEST
DEV STATUS REV
COMPL PHASE IB BREADBOARD TEST
COMPL PDR
'69 & '71 FUNC SPEC RELEASE
COMPL REL THERMAL TEST DRAWINGS
COMPL PHASE IB BREADBOARD TEST
COMPL PDR
'69-'71 FUNCT SPEC REL
START ENGR MODEL TEST
DEV STATUS REV
REL INTERFACE CONTROL DWGS
COMPL PHASE IB BREADBOARD TEST
'69-'71 FUNCT SPEC RELEASED
START E... MODEL...
...G LEAD ...OR SPEC ...ASED
SELECT SUPPLIER
COMPL PHASE IB BREADBOARD TEST
SUPPLIER CONTRACT AWARD
COMPL PDR
'69-'71 FUNCT SPEC REL
HDWE CONTRACT AWARD
START ENGR MODEL TEST
...EAD PROCURE ...EASED
SELECT SUPPLIER
SUPPLIER CONTRACT AWARD
PDR
'71 FUNCT SPEC REL
HDWE CONTRACT AWARD
START ENGR MODEL TEST
NASA REF SCIENTIFIC INVESTIGATIONS
RELEASE CLASS II M U DRAWINGS
COMPL CLASS II M U
MOCKUPS

3



1967
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
PL APPROVAL '69 /C FUNCT SPEC
JPL APPROVAL '69 REQMTS & RESTRAINTS S/C-L/V
ORDER LAUNCH VEHICLE
PHASE II
'69 DESIGN REVIEW
UPDATE S/C SYST FUNCT ANALYSIS
PROVIDE UPDATED INTERFACE DATA 71
UPDATE S/C '71 FUNCT SPECS
UPDATE S/C SYS FUNCT. ANAL (EVERY 6 MONTHS)
UPDATE 1971 OSE FUNCT SPECS
PROVIDE MISSION & RESTR
MTS
EL P/A MFG EQMTS
UPDATE REL '69 ANALYSIS
P/A STATUS AT CDR
REL QUAL STATUS DOCUMENT
UPDATE '71 REL & SAFETY ANALYSIS
P/A STATUS CDR
1969 DESIGN REVIEW
S/C ETM SUB SYSTEM DWG REL
UPDATED PARTS MTLS & PROCESS LIST
COMPL '69' SUBSYS DWG REL.
START ENGRG MODEL TEST
S/S COMM. DSIF COMPAT ESTAB
COMPL ENGR MODEL TEST
69 T.E. DWG REL
ETM HDW AVAIL
COMPL CDR
'69' FLT HDW AVAIL
ETM HDW AVAIL
COMPL ENGR MODEL TEST
COMPL CDR
ETM HDW AVAIL
COMPL ENGR MODEL TEST
COMPL CDR
COMPL ENGR MODEL TEST
S/C ETM DWG REL
ENGR MOD HDW AVAIL
COMPL CDR
'69 TF DWG REL
START TAT
S/C ETM DWG REL
COMPL ENGR MODEL TEST
ETM HDW AVAIL
COMPL CDR
START TAT
START ENGR MODEL TEST
ETM HDW AVAIL
COMPL ENGR MODEL TEST
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START TAT
T ENGR ODEL TEST
S/C ETM DWG REL
COMPL ENGR MODEL TEST
ETM HDW AVAIL
COMPL CDR
'69 TF DWG REL
START TAT
S/C ETM DWG REL
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ETM HDW AVAIL
COMPL '69 DWG REL
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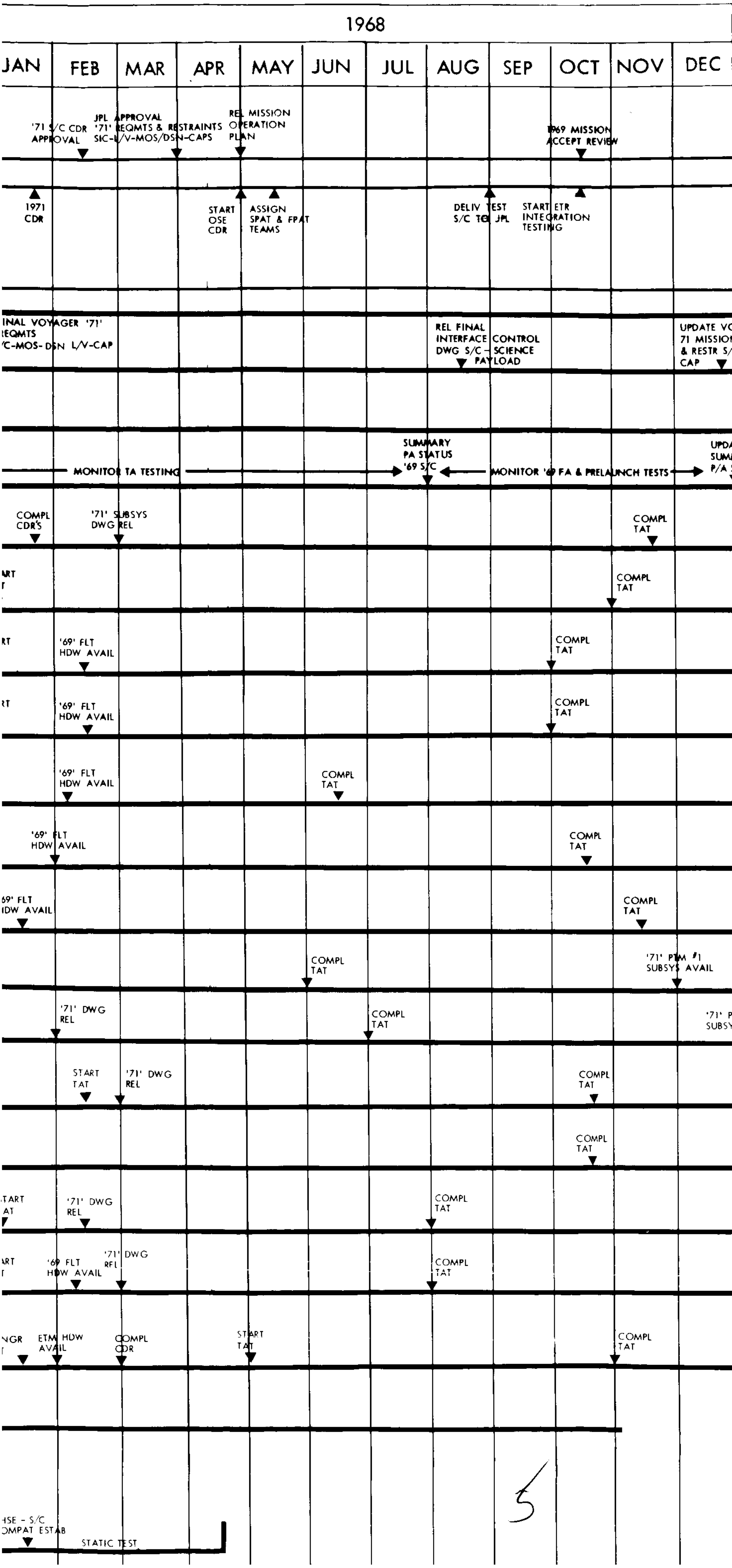
START TAT
RT ENGR ODEL TEST
S/C ETM DWG REL
COMPL ENGR MODEL TEST
ETM HDW AVAIL
'69 T.F. DWG REL
COMPL CDR
S/C ETM DWG REL
COMPL ENGR MODEL TEST
ETM HDW AVAIL
COMPL CDR
START TAT
IGR EST
S C ETM DWG REL
COMPL ENGR MODEL TEST
69 T.F. DWG REL
COMPL CDR
S C ETM DWG REL
COMPL CDR
COMPL ENGR MODEL TEST
ETM HDW AVAIL
S C ETM DWG REL
'71' DWG REL
COMPL MOD TE
SCIENCE INSTR. INTERFACE SPECS & ASSOC
INT CLASS III M U STRUC DWG REL
INT CLASS III M.U SYSTEM & WIRING DWG REL
CLASS III M U COMPL
STATIC TEST MODEL
4
'71' FAB & SUBASSY


1968
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
'71 S/C CDR APPROVAL
JPL APPROVAL '71' REQMTS & RESTRAINTS S/C-L/V-MOS/DSN-CAPS
REL MISSION OPERATION PLAN
1969 MISSION ACCEPT REVIEW
1971 CDR
START OSE CDR
ASSIGN SPAT & FPAT TEAMS
DELIV TEST S/C TO JPL
START ETR INTEGRATION TESTING
FINAL VOYAGER '71' REQMTS S/C-MOS-DSN L/V-CAP
REL FINAL INTERFACE CONTROL DWG S/C - SCIENCE PAYLOAD
UPDATE VO 71 MISSION & RESTR S/ CAP
MONITOR TA TESTING
SUMMARY PA STATUS '69 S/C
MONITOR '69 FA & PRELAUNCH TESTS
UPDA SUMM P/A
COMPL CDR'S
'71' SUBSYS DWG REL
COMPL TAT
ART
COMPL TAT
RT
'69' FLT HDW AVAIL
COMPL TAT
RT
'69' FLT HDW AVAIL
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'69' FLT HDW AVAIL
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'69' FLT HDW AVAIL
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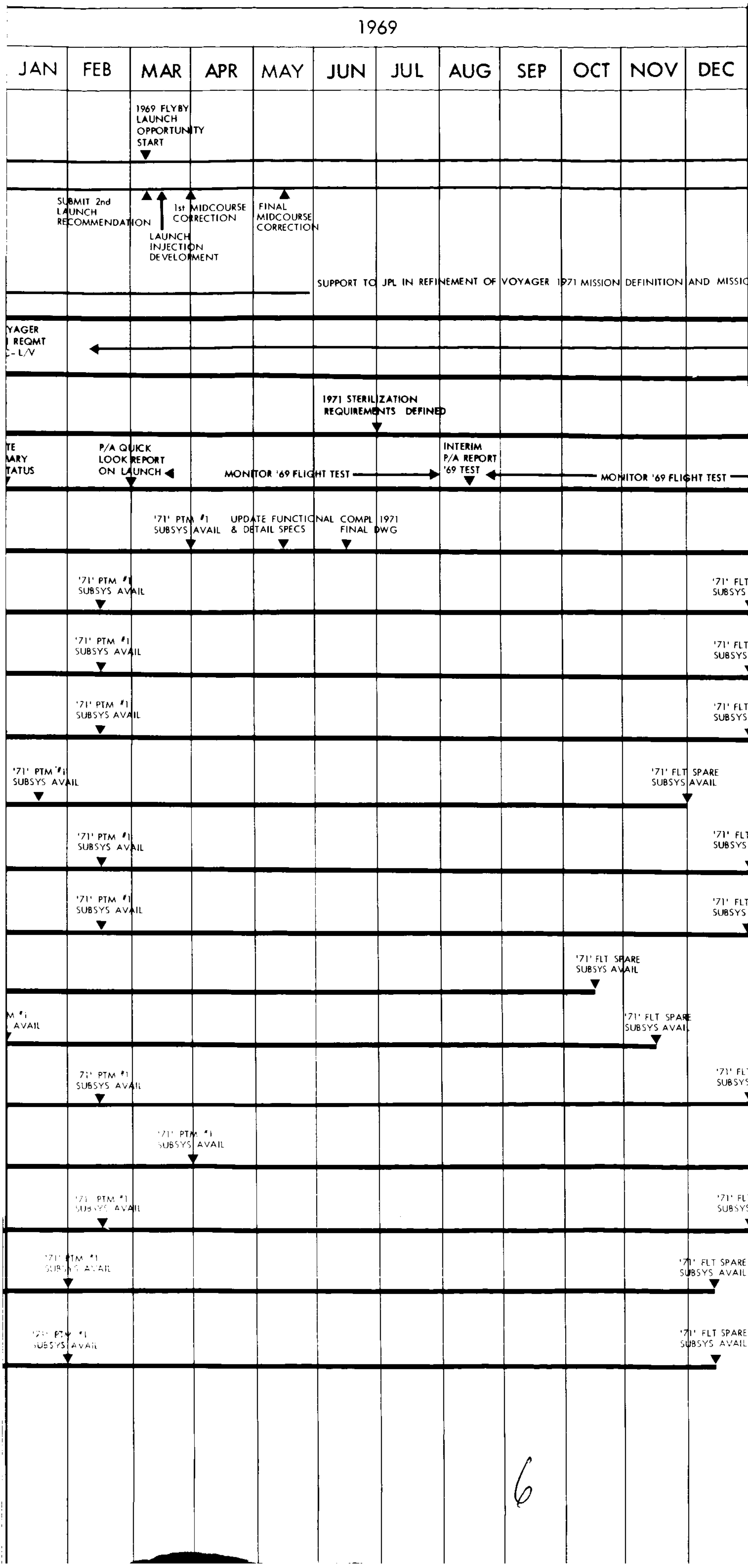
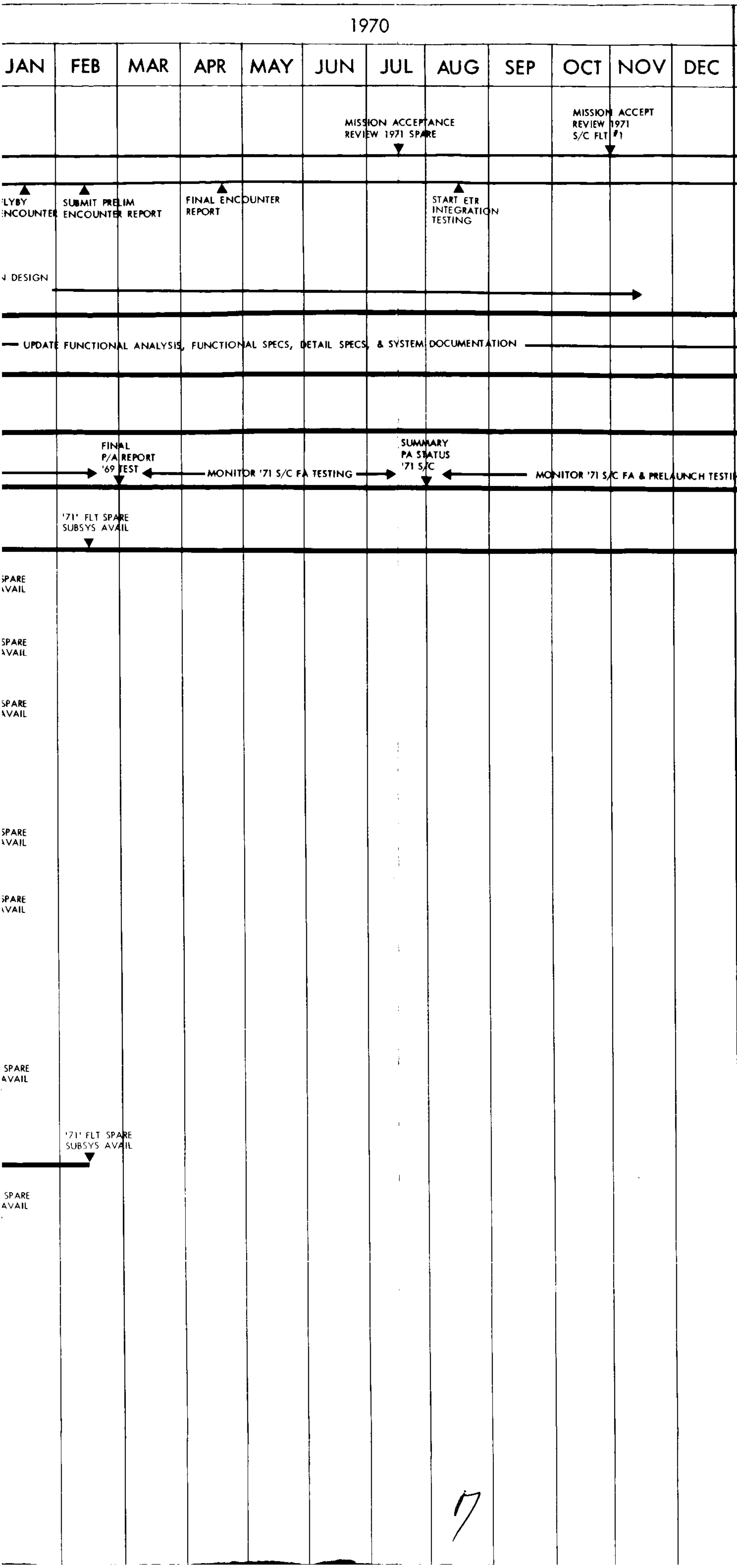
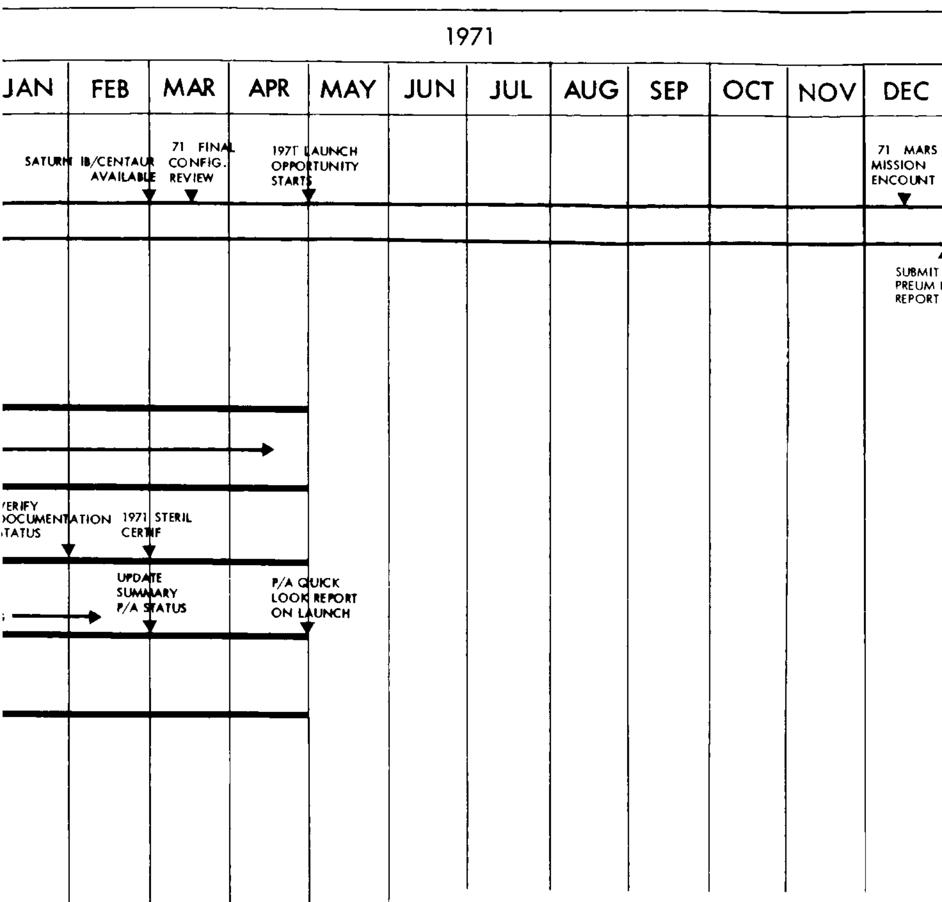
'69' FLT HDW AVAIL
COMPL TAT
COMPL TAT
'71' PTM #1 SUBSYS AVAIL
'71' DWG REL
COMPL TAT
'71' P SUBSY
START TAT
'71' DWG REL
COMPL TAT
COMPL TAT
START TAT
'71' DWG REL
COMPL TAT
ART
'69 FLT HDW AVAIL
'71' DWG REL
COMPL TAT
NGR
ETM HDW AVAIL
COMPL CDR
START TAT
COMPL TAT
HSE - S/C COMPAT ESTAB
STATIC TEST

5


1969
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1969 FLYBY LAUNCH OPPORTUNITY START
SUBMIT 2nd LAUNCH RECOMMENDATION
LAUNCH INJECTION DEVELOPMENT
1st MIDCOURSE CORRECTION
FINAL MIDCOURSE CORRECTION
SUPPORT TO JPL IN REFINEMENT OF VOYAGER 1971 MISSION DEFINITION AND MISSIC
YAGER
REQMT
C- L/V
1971 STERILIZATION REQUIREMENTS DEFINED
TE
ARY
TATUS
P/A QUICK LOOK REPORT ON LAUNCH
MONITOR '69 FLIGHT TEST
INTERIM P/A REPORT '69 TEST
MONITOR '69 FLIGHT TEST
'71' PTM #1 SUBSYS AVAIL
UPDATE FUNCTIONAL & DETAIL SPECS
COMPL 1971 FINAL DWG
'71' PTM #1 SUBSYS AVAIL
'71' FLT SUBSYS
'71' PTM #1 SUBSYS AVAIL
'71' FLT SUBSYS
'71' PTM #1 SUBSYS AVAIL
'71' FLT SUBSYS
'71' PTM #1 SUBSYS AVAIL
'71' FLT SPARE SUBSYS AVAIL
'71' PTM #1 SUBSYS AVAIL
'71' FLT SUBSYS
'71' PTM #1 SUBSYS AVAIL
'71' FLT SUBSYS
'71' FLT SPARE SUBSYS AVAIL
M #1 AVAIL
'71' FLT SPARE SUBSYS AVAIL
'71' PTM #1 SUBSYS AVAIL
'71' FLT SUBSYS
'71' PTM #1 SUBSYS AVAIL
'71' PTM #1 SUBSYS AVAIL
'71' FLT SUBSYS
'71' PTM #1 SUBSYS AVAIL
'71' FLT SPARE SUBSYS AVAIL
'71' PTM #1 SUBSYS AVAIL
'71' FLT SPARE SUBSYS AVAIL
6


1970
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MISSION ACCEPTANCE REVIEW 1971 SPARE
MISSION ACCEPT REVIEW 1971 S/C FLT #1
LYBY ENCOUNTER
SUBMIT PRELIM ENCOUNTER REPORT
FINAL ENCOUNTER REPORT
START ETR INTEGRATION TESTING
N DESIGN
UPDATE FUNCTIONAL ANALYSIS, FUNCTIONAL SPECS, DETAIL SPECS, & SYSTEM DOCUMENTATION
FINAL P/A REPORT '69 TEST
MONITOR '71 S/C FA TESTING
SUMMARY PA STATUS '71 S/C
MONITOR '71 S/C FA & PRELAUNCH TESTI
'71' FLT SPARE SUBSYS AVAIL
SPARE AVAIL
SPARE AVAIL
SPARE AVAIL
SPARE AVAIL
SPARE AVAIL
SPARE AVAIL
'71' FLT SPARE SUBSYS AVAIL
SPARE AVAIL
7



THE BOEING

Master Schedule ~~1971 Mi~~
1969 Atlast/Centaur

ABBREVIATIONS

C/O	CHECKOUT
ETM	ENGINEERI
CDR	CRITICAL D
PDR	PRELIMINAR
M/U	MOCKUP
FAT	FLIGHT AC
TAT	TYPE APPRO
ASSY	ASSEMBLY
FAB	FABRICATIO
SUBASSY	SUBASSEMB
REV	REVIEW
REL	RELEASE
MDS	MISSION C
DEV	DEVELOPM
COMPAT	COMPATIBI
INSTR	INSTRUMEN
HDWE	HARDWARE
FLT	FLIGHT
ANAL	ANALYSIS
IMPL	IMPLEMEN
COG	COGNIZAN
S/C	SPACECRAF
L/V	LAUNCH V
CAP	CAPSULE
ETR	AIR FORCE
BOD	BENEFICIA
DSN	DEEP SPAC
DSIF	DEEP SPAC
DWG	DRAWING
OSE	OPERATION
SPEC	SPECIFICAT
MTLS	MATERIALS
M&P	MATERIALS

8

APPROVALS

1972					
JAN	FEB	MAR	APR	MAY	JUN
'71' NCOUNT		SUBMIT '71' FINAL ENCOUNT REPORT			

COMPANY

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Flyby

a ... ?

IG TEST MODEL
SIGN REVIEW
DESIGN REVIEW

EPTANCE TEST
VAL TEST

N
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PERATION SYSTEM
NT
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TATION

T

HICLE

EASTERN TEST RANGE
OCCUPANCY DATE
NETWORK
INSTRUMENTATION FACILITY

AL SUPPORT EQUIPMENT
ON

& PROCESSES

9

THERMAL TEST MODEL

DYNAMIC TEST MODEL

COMPLETE SPACECRAFT

ENGINEERING MODEL-PROTOTYPE

JPL TEST SPACECRAFT

1969 PROOF TEST MODEL

1969 COMPATIBILITY TEST MODEL

SUBSYSTEM FLIGHT SPARES

1969 FLIGHT 1 S/C

1969 FLIGHT 2 S/C

1971 PROOF TEST MODEL #1

1971 PROOF TEST MODEL #2

1971 FLIGHT SPARE S/C

1971 FLIGHT 1 S/C

1971 FLIGHT 2 S/C

OPERATIONAL SUPPORT EQUIPMENT

ASSEMBLY, HANDLING & SHIPPING EQUIPMENT

SYSTEM TEST COMPLEX

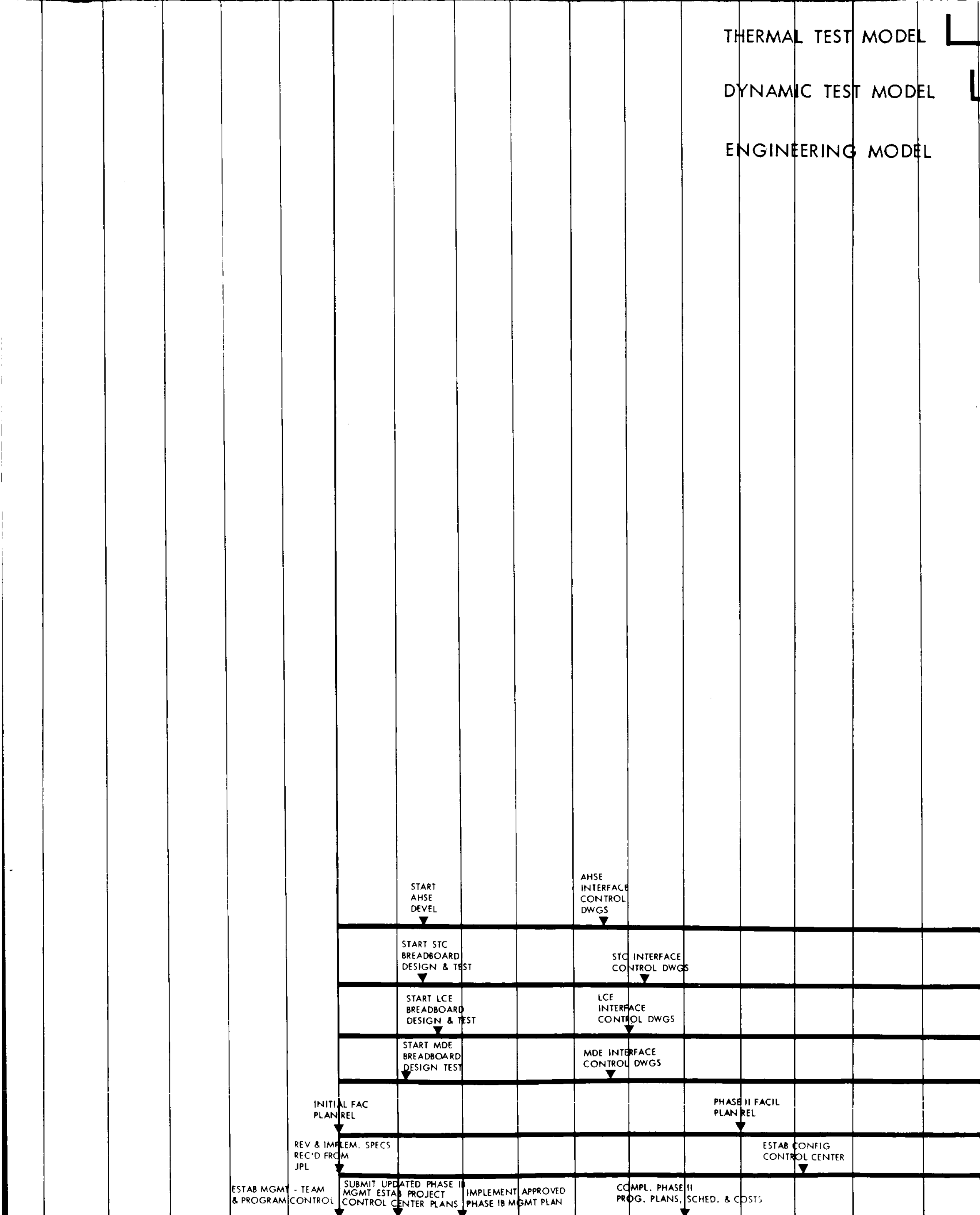
LAUNCH COMPLEX EQUIPMENT

MISSION DEPENDENT EQUIPMENT

FACILITIES

CONFIGURATION MANAGEMENT

BUSINESS MANAGEMENT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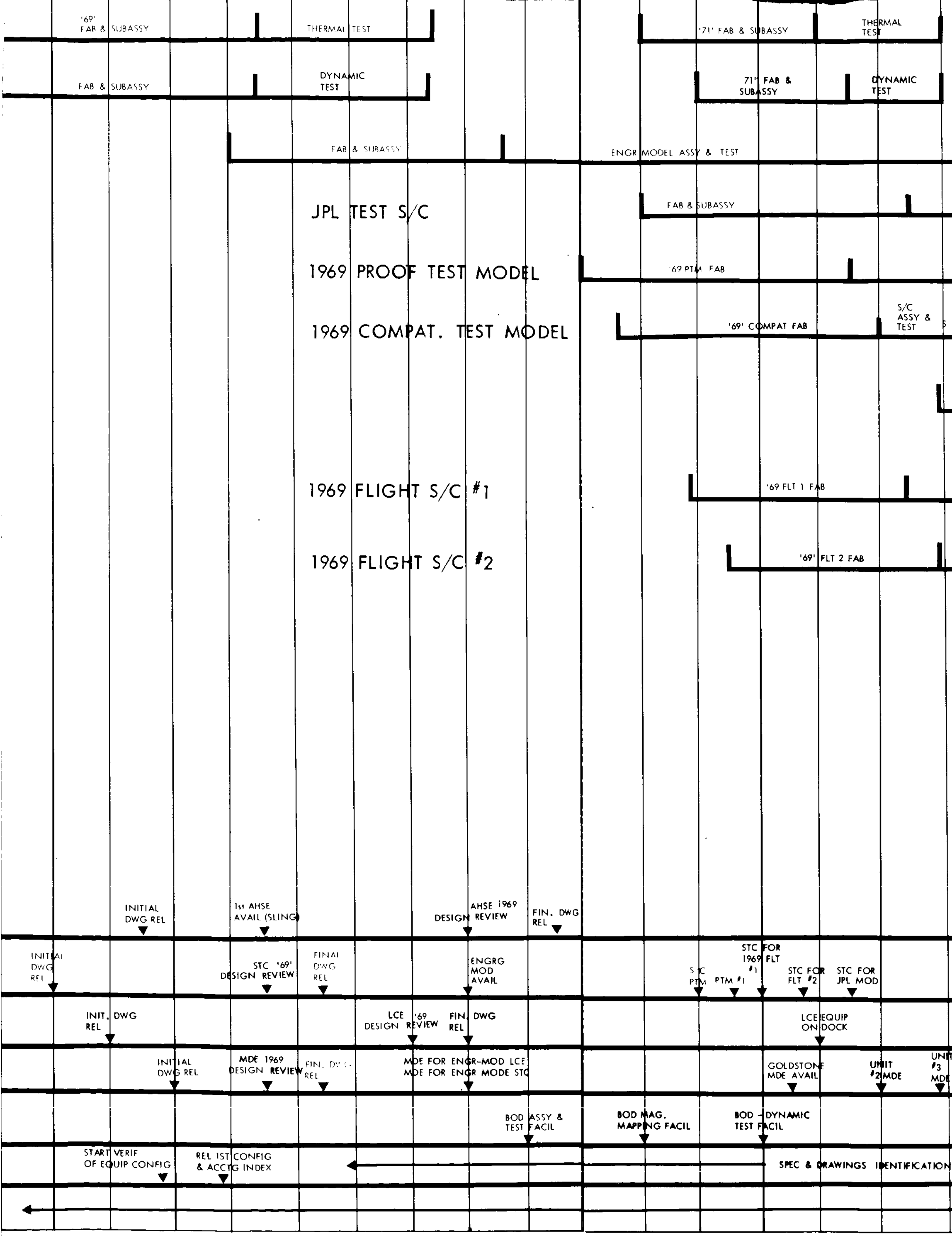
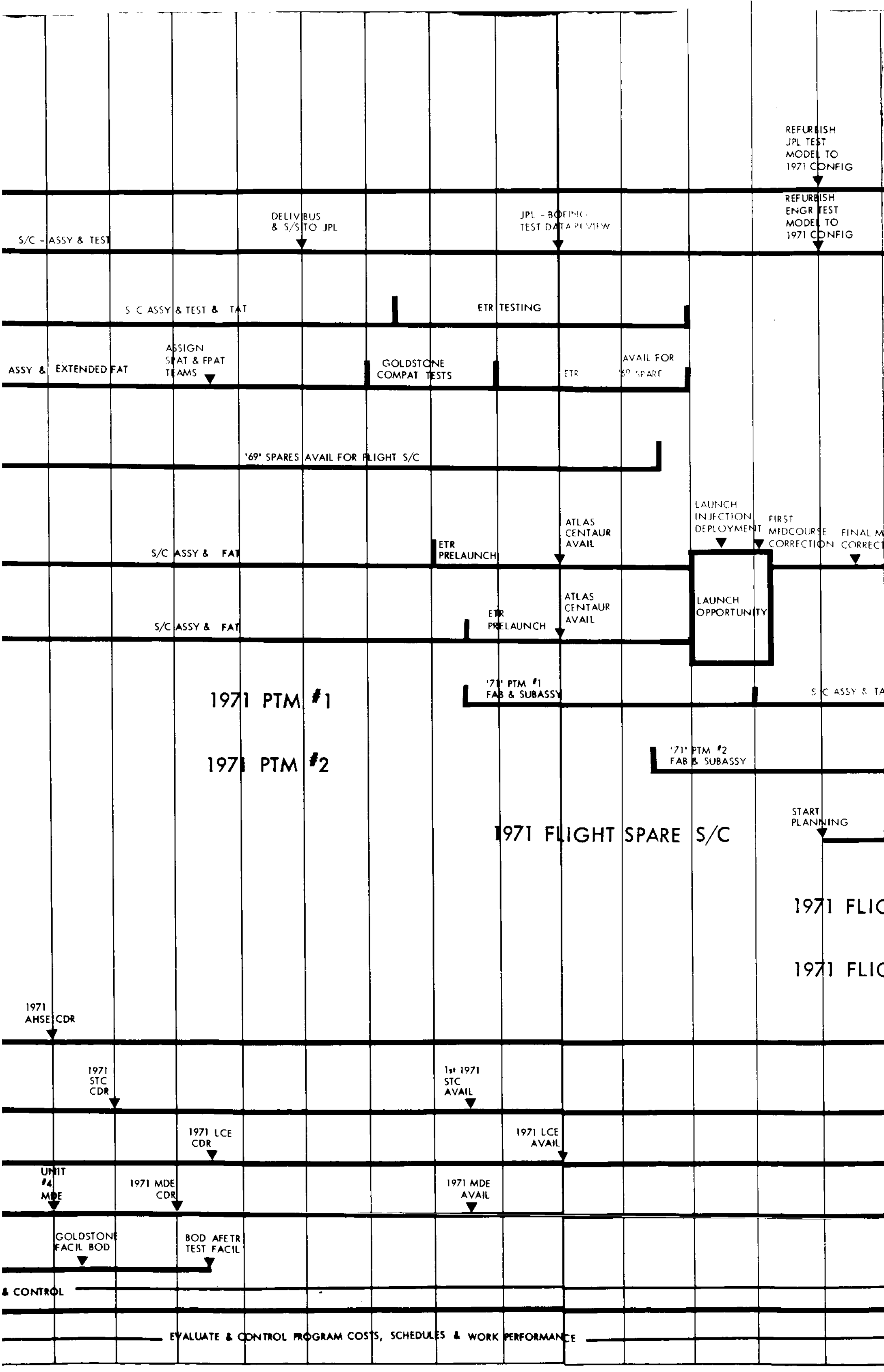
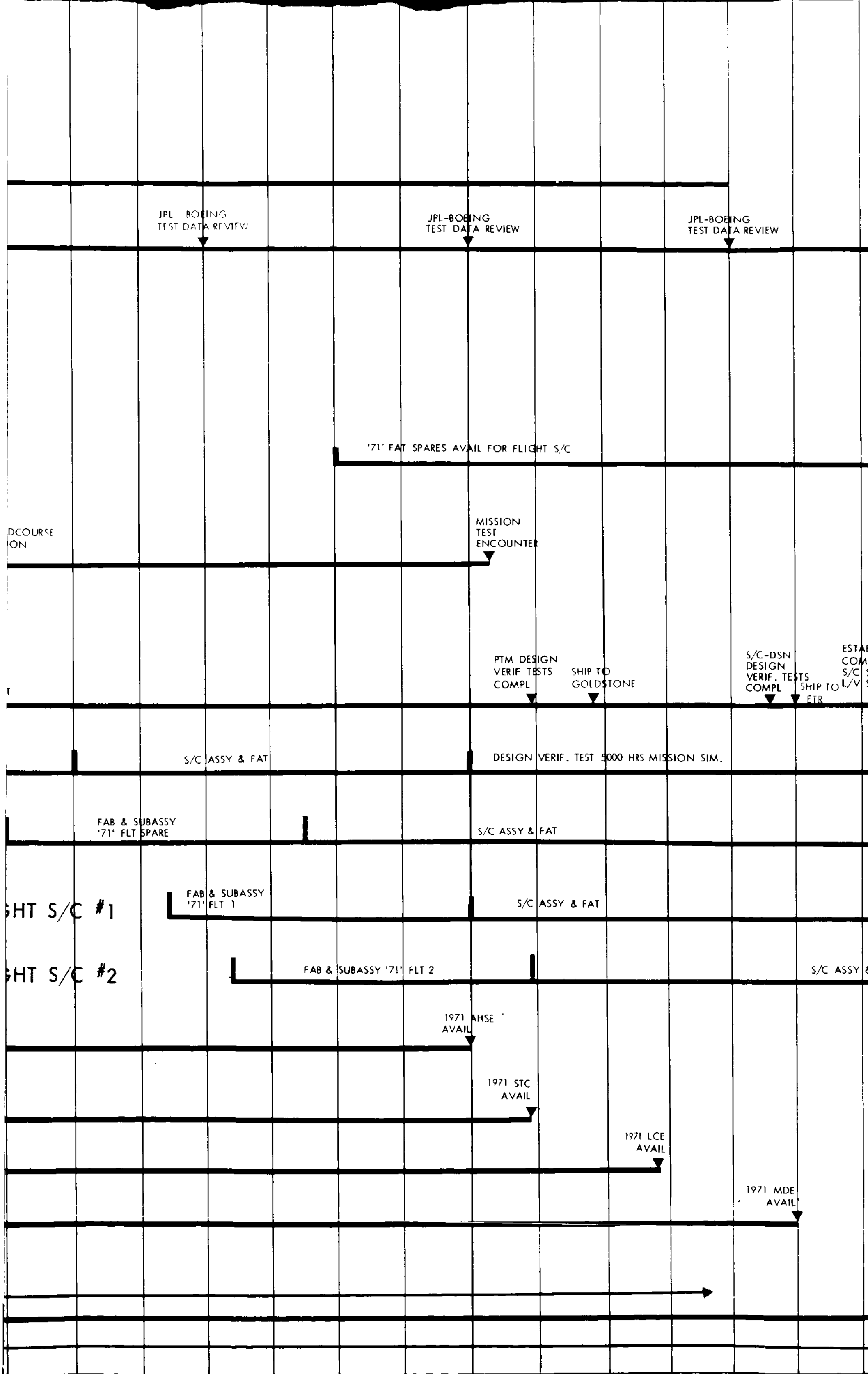
DYNAMIC TEST MODEL
ENGINEERING MODEL
START AHSE DEVEL
AHSE INTERFACE CONTROL DWGS
START STC BREADBOARD DESIGN & TEST
STC INTERFACE CONTROL DWGS
START LCE BREADBOARD DESIGN & TEST
LCE INTERFACE CONTROL DWGS
START MDE BREADBOARD DESIGN TEST
MDE INTERFACE CONTROL DWGS
INITIAL FAC PLAN REL
PHASE II FACIL PLAN REL
REV & IMPLEM. SPECS REC'D FROM JPL
ESTAB CONFIG CONTROL CENTER
ESTAB MGMT - TEAM & PROGRAM CONTROL
SUBMIT UPDATED PHASE IB MGMT ESTAB PROJECT CONTROL CENTER PLANS
IMPLEMENT APPROVED PHASE IB MGMT PLAN
COMPL. PHASE II PROG. PLANS, SCHED. & COSTS

11



'69' FAB & SUBASSY
THERMAL TEST
'71' FAB & SUBASSY
THERMAL TEST
FAB & SUBASSY
DYNAMIC TEST
71" FAB & SUBASSY
DYNAMIC TEST
FAB & SUBASSY
ENGR MODEL ASSY & TEST
JPL TEST S/C
FAB & SUBASSY
1969 PROOF TEST MODEL
'69 PTM FAB
1969 COMPAT. TEST MODEL
'69' COMPAT FAB
S/C ASSY & TEST
1969 FLIGHT S/C #1
'69 FLT 1 FAB
1969 FLIGHT S/C #2
'69' FLT 2 FAB
INITIAL DWG REL
1st AHSE AVAIL (SLING)
AHSE 1969 DESIGN REVIEW
FIN. DWG REL
INITIAL DWG REL
STC '69' DESIGN REVIEW
FINAL DWG REL
ENGRG MOD AVAIL
S/C PTM
PTM #1
STC FOR 1969 FLT #1
STC FOR FLT #2
STC FOR JPL MOD
INIT. DWG REL
LCE '69 DESIGN REVIEW
FIN. DWG REL
LCE EQUIP ON DOCK
INITIAL DWG REL
MDE 1969 DESIGN REVIEW
FIN. DWG REL
MDE FOR ENGR-MOD LCE
MDE FOR ENGR MODE STC
GOLDSTONE MDE AVAIL
UNIT #2 MDE
UNIT #3 MDE
BOD ASSY & TEST FACIL
BOD MAG. MAPPING FACIL
BOD - DYNAMIC TEST FACIL
START VERIF OF EQUIP CONFIG
REL 1ST CONFIG & ACCTG INDEX
SPEC & DRAWINGS IDENTIFICATION


REFURBISH JPL TEST MODEL TO 1971 CONFIG
REFURBISH ENGR TEST MODEL TO 1971 CONFIG
S/C - ASSY & TEST
DELIV BUS & S/S TO JPL
S C ASSY & TEST & TAT
ETR TESTING
ASSY & EXTENDED FAT
ASSIGN SPAT & FPAT TEAMS
GOLDSTONE COMPAT TESTS
ETR
AVAIL FOR
'69' SPARES AVAIL FOR FLIGHT S/C
S/C ASSY & FAT
ETR PRELAUNCH
ATLAS CENTAUR AVAIL
LAUNCH INJECTION DEPLOYMENT
FIRST MIDCOURSE CORRECTION
S/C ASSY & FAT
ETR PRELAUNCH
ATLAS CENTAUR AVAIL
LAUNCH OPPORTUNITY
1971 PTM #1
'71' PTM #1 FAB & SUBASSY
1971 PTM #2
'71' PTM #2 FAB & SUBASSY
1971 FLIGHT SPARE S/C
START PLANNING
1971 AHSE CDR
1971 STC CDR
1st 1971 STC AVAIL
1971 LCE CDR
1971 LCE AVAIL
UNIT #4 MDE
1971 MDE CDR
1971 MDE AVAIL
GOLDSTONE FACIL BOD
BOD AFETR TEST FACIL
& CONTROL
EVALUATE & CONTROL PROGRAM COSTS, SCHEDULES & WORK PERFORMANCE


JPL - BOEING TEST DATA REVIEW
JPL-BOEING TEST DATA REVIEW
JPL-BOEING TEST DATA REVIEW
'71' FAT SPARES AVAIL FOR FLIGHT S/C
DCOURSE
ION
MISSION TEST ENCOUNTER
PTM DESIGN VERIF TESTS COMPL
SHIP TO GOLDSTONE
S/C-DSN DESIGN VERIF. TESTS COMPL
SHIP TO ETR
S/C ASSY & FAT
DESIGN VERIF. TEST 5000 HRS MISSION SIM.
FAB & SUBASSY '71' FLT SPARE
S/C ASSY & FAT
GHT S/C #1
FAB & SUBASSY '71' FLT 1
S/C ASSY & FAT
GHT S/C #2
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S/C ASSY
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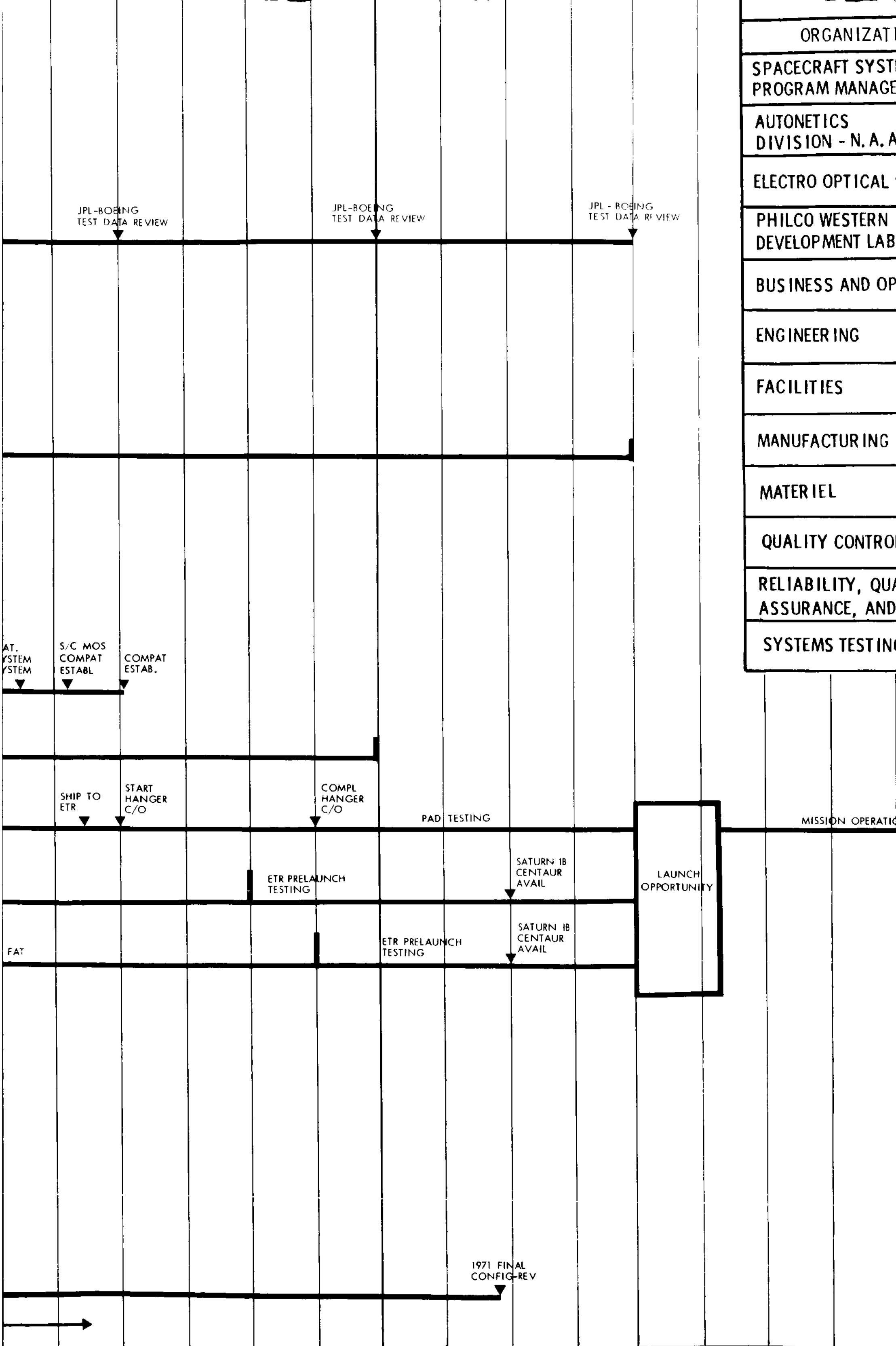
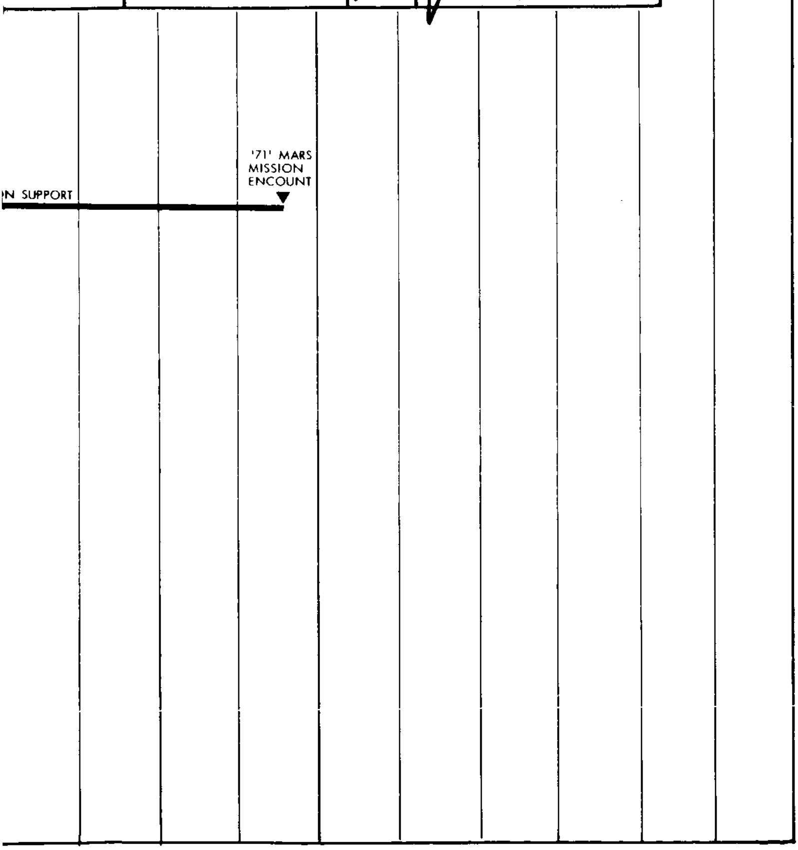
1971 LCE AVAIL
1971 MDE AVAIL


ORGANIZATI
SPACECRAFT SYST
PROGRAM MANAGE
AUTONETICS
DIVISION - N. A. A
ELECTRO OPTICAL
PHILCO WESTERN
DEVELOPMENT LAB
BUSINESS AND OP
ENGINEERING
FACILITIES
MANUFACTURING
MATERIEL
QUALITY CONTRO
RELIABILITY, QUA
ASSURANCE, AND
SYSTEMS TESTIN
JPL-BOEING
TEST DATA REVIEW
JPL-BOEING
TEST DATA REVIEW
JPL - BOEING
TEST DATA REVIEW
AT.
YSTEM
YSTEM
S/C MOS
COMPAT
ESTABL
COMPAT
ESTAB.
SHIP TO
ETR
START
HANGER
C/O
COMPL
HANGER
C/O
PAD TESTING
MISSION OPERATIO
ETR PRELAUNCH
TESTING
SATURN IB
CENTAUR
AVAIL
LAUNCH
OPPORTUNITY
FAT
ETR PRELAUNCH
TESTING
SATURN IB
CENTAUR
AVAIL
1971 FINAL
CONFIG REV

APPROVALS

ON	NAME	DATE	APPROVAL
EM R	E. G. CZARNECKI	7/24	
.	R. R. MUELLER	7/23	
SYSTEMS	C. I. CUMMINGS	7/22	
ORATORIES	G. O. MOORE	7/22	
ERATIONS	L. B. BARLOW	7/24	
	W. C. GALLOWAY	7/24	
	R. K. MILLS	7/23	
	R. R. DICKSON	7/23	
	J. C. POWERS	7/23	
.	G. J. SIDDONS	7/23	
LITY SAFETY	C. S. BARTHOLOMEW	7/24	
	J. C. TURNER	7/22	



16

Figure 5.4-2:

5.4.4.2 Conclusions

The implementation of the 1969 Mars orbit test flight with a Saturn IB/Centaur launch vehicle is compatible with the implementation for the 1971 mission.

Although the total time from Phase IB contract award to test flight is 2 ½ months less for the Mars orbit test flight than it is for the flyby test flight the schedule for accomplishment is reasonable and valid. The major effect is compressed design time, while the system test cycle is the same.

5.4.5 Analysis

Results from analysis and comparison of the three master schedule approaches are:

1) The 1971 mission with no prior test flight provides an optimum time-phase program and involves the least schedule risk. Time is available to provide an extra measure of safety in the performance of all important tasks (design, verification testing, interface testing, and flight acceptance testing) to allow for major rework or retesting.

2) A program encompassing a 1969 test flight compresses the engineering and test flow time to support the 1969 launch opportunity. This causes a slightly greater risk for the 1969 flight than for a 1971 mission only. However, the actual experience from the test flight, plus the substantial increase in system-level ground test experience obtained from the 1969 test flight vehicles will greatly enhance the confidence level for 1971 mission success.

5.4.4 Master Schedule - 1971 Mission and 1969 Saturn IB/Centaur Orbiting Test

This master schedule, Figure 5.4-3, depicts the significant events and necessary time-phasing for the Voyager Spacecraft System program to support the 1971 Voyager mission, preceded by a Mars orbiting test flight in 1969. Both the 1971 mission and the 1969 test flight are accomplished using a Saturn IB/Centaur launch vehicle. An enlarged version of this schedule has been placed in the pocket on the back cover. The choice of a Mars orbit trajectory, made possible by the use of Saturn IB/Centaur, sets an earlier launch date for the 1969 test flight, but the spacecraft will be identical in configuration to that planned for the 1971 mission. An important factor will be the ability to accept additional engineering test data instrumentation on the 1969 vehicle.

5.4.4.1 Schedule Effects

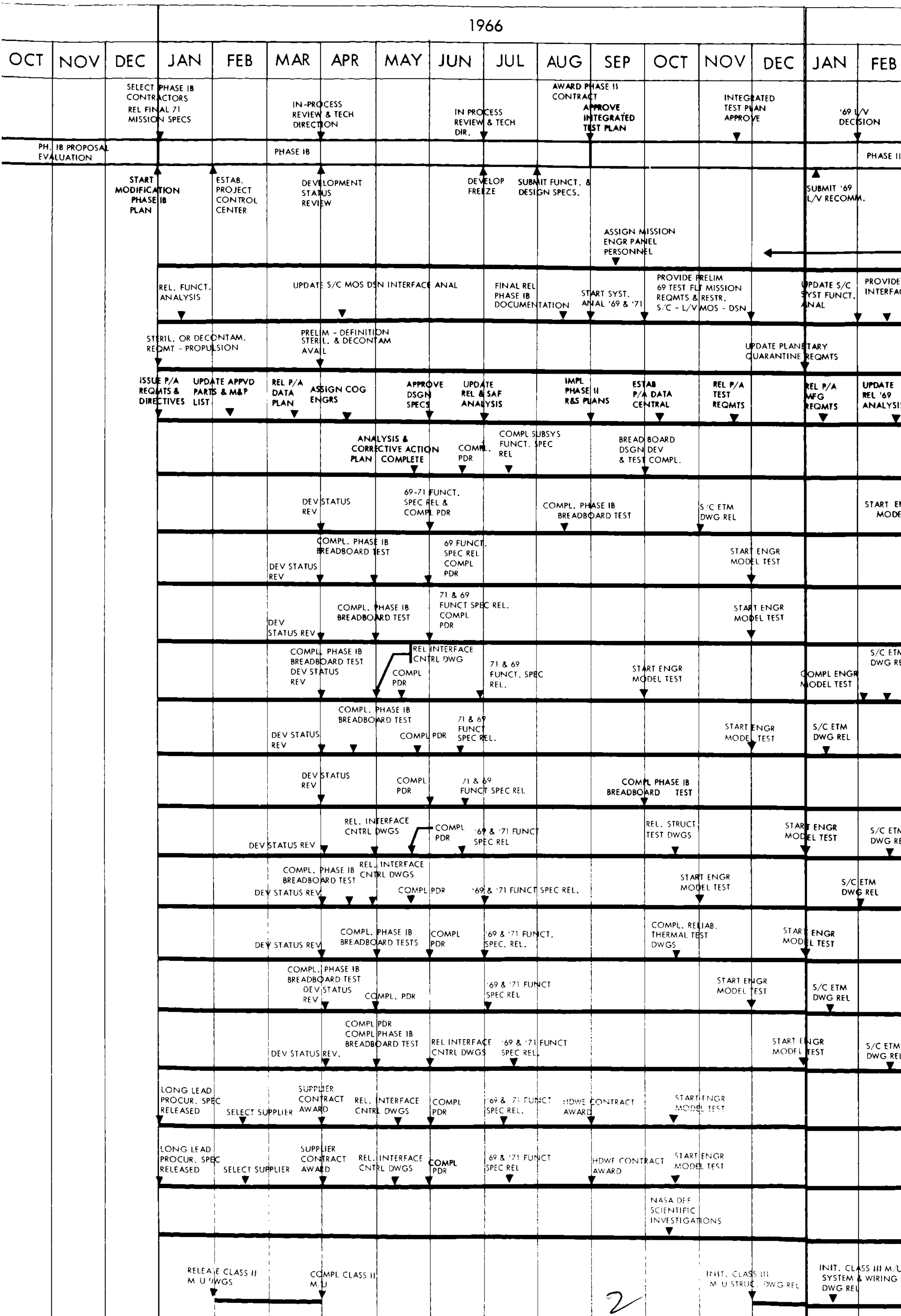
The launch opportunity for a Mars orbit test flight starts on December 30, 1968. This means that flight vehicles and OSE must be available for launch nearly 2 $\frac{1}{2}$ months earlier than for a 1969 flyby test flight. The reduction in total time from Phase IB go-ahead to test flight launch is mostly absorbed in the allocation of time available for subsystem design prior to the construction of test flight hardware.

A 1969 Mars orbit test flight requires consideration of propellant sterilization. Sterilizing of propellant can be accommodated without any pacing effect. Valid estimates for further sterilization effects will require further study to be accomplished early in Phase IB.

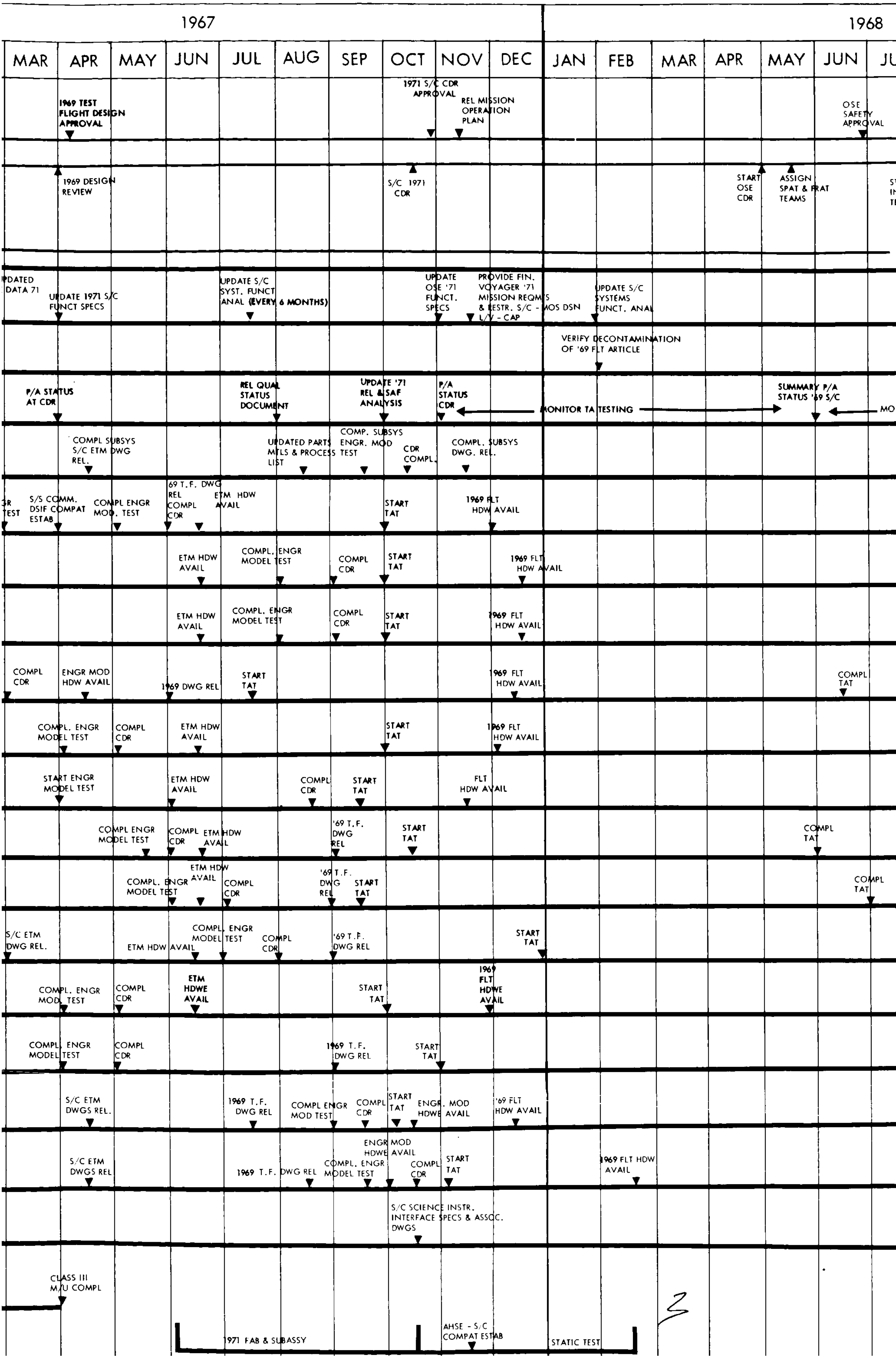
3) Where the Saturn IB/Centaur is used for the 1969 Mars orbit test flight, the schedule is compressed an additional 2 $\frac{1}{2}$ months over the Atlas/Centaur schedule with schedule risk slightly greater than for the Atlas/Centaur. However this option provides a test of all project systems elements, personnel, procedures and mission flight in the true environment prior to the actual 1971 mission. This provides for greater benefits to ultimate mission success when weighed against the schedule risk. The schedule assures timely testing early in the program for a successful 1969 test flight.

4) A high confidence level is inherent in all schedules considered due to the detail level of analysis accomplished to support their preparation, and the use of actual flowtimes from similar system details on programs such as Lunar Orbiter, Mariner and Minuteman to provide further assurance of success.

	1965				
		JUN	JUL	AUG	SEP
JET PROPULSION LABORATORY					
MAJOR PROGRAM INTERFACES					PH. IB PROP.
BOEING					
MISSION ENGINEERING					
SYSTEM ENGINEERING					
PLANETARY QUARANTINE					
PRODUCT ASSURANCE (P/A)					
SYSTEM CONFIGURATION & DESIGN					
SUBSYSTEM DESIGN					
TELECOMMUNICATIONS					
ATTITUDE REFERENCE					
AUTOPILOT					
REACTION CONTROL					
CENTRAL COMPUTER & SEQUENCER					
ELECTRICAL POWER					
STRUCTURES & SPACECRAFT ADAPTER					
MECHANISMS					
TEMPERATURE CONTROL					
PYROTECHNICS					
CABLING					
PROPULSION MIDCOURSE					
PROPULSION ORBITAL INSERTION					
SCIENCE PAYLOAD INTEGRATION					
MANUFACTURING & TEST PROGRAM					
MOCKUPS					
PARTIAL SPACECRAFT STATIC TEST MODEL					



STATIC TEST MODEL



1967
1968
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
1969 TEST FLIGHT DESIGN APPROVAL
1971 S/C CDR APPROVAL
REL MISSION OPERATION PLAN
OSE SAFETY APPROVAL
1969 DESIGN REVIEW
S/C 1971 CDR
START OSE CDR
ASSIGN SPAT & FRAT TEAMS
UPDATED DATA 71
UPDATE 1971 S/C FUNCT SPECS
UPDATE S/C SYST. FUNCT ANAL (EVERY 6 MONTHS)
UPDATE OSE '71 FUNCT. SPECS
PROVIDE FIN. VOYAGER '71 MISSION REQMTS & RESTR. S/C - MOS DSN L/V - CAP
UPDATE S/C SYSTEMS FUNCT. ANAL
VERIFY DECONTAMINATION OF '69 FLT ARTICLE
P/A STATUS AT CDR
REL QUAL STATUS DOCUMENT
UPDATE '71 REL & SAF ANALYSIS
P/A STATUS CDR
MONITOR TA TESTING
SUMMARY P/A STATUS '69 S/C
COMPL SUBSYS S/C ETM DWG REL.
UPDATED PARTS MTLS & PROCESS LIST
COMP. SUBSYS ENGR. MOD TEST
CDR COMPL.
COMPL. SUBSYS DWG. REL.
S/S COMM. DSIF COMPAT ESTAB
COMPL ENGR MOD. TEST
69 T.F. DWG REL
COMPL CDR
ETM HDW AVAIL
START TAT
1969 FLT HDW AVAIL
ETM HDW AVAIL
COMPL. ENGR MODEL TEST
COMPL CDR
START TAT
1969 FLT HDW AVAIL
ETM HDW AVAIL
COMPL. ENGR MODEL TEST
COMPL CDR
START TAT
1969 FLT HDW AVAIL
COMPL CDR
ENGR MOD HDW AVAIL
1969 DWG REL
START TAT
1969 FLT HDW AVAIL
COMPL TAT
COMPL. ENGR MODEL TEST
COMPL CDR
ETM HDW AVAIL
START TAT
1969 FLT HDW AVAIL
START ENGR MODEL TEST
ETM HDW AVAIL
COMPL CDR
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FLT HDW AVAIL
COMPL ENGR MODEL TEST
COMPL CDR
ETM HDW AVAIL
'69 T.F. DWG REL
START TAT
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ETM HDW AVAIL
COMPL. ENGR MODEL TEST
COMPL CDR
'69 T.F. DWG REL
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S/C ETM DWG REL.
COMPL ENGR MODEL TEST
ETM HDW AVAIL
COMPL CDR
'69 T.F. DWG REL
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COMPL. ENGR MOD. TEST
COMPL CDR
ETM HDWE AVAIL
START TAT
1969 FLT HDWE AVAIL
COMPL ENGR MODEL TEST
COMPL CDR
1969 T.F. DWG REL
START TAT
S/C ETM DWGS REL.
1969 T.F. DWG REL
COMPL ENGR MOD TEST
COMPL CDR
START TAT
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S/C ETM DWGS REL
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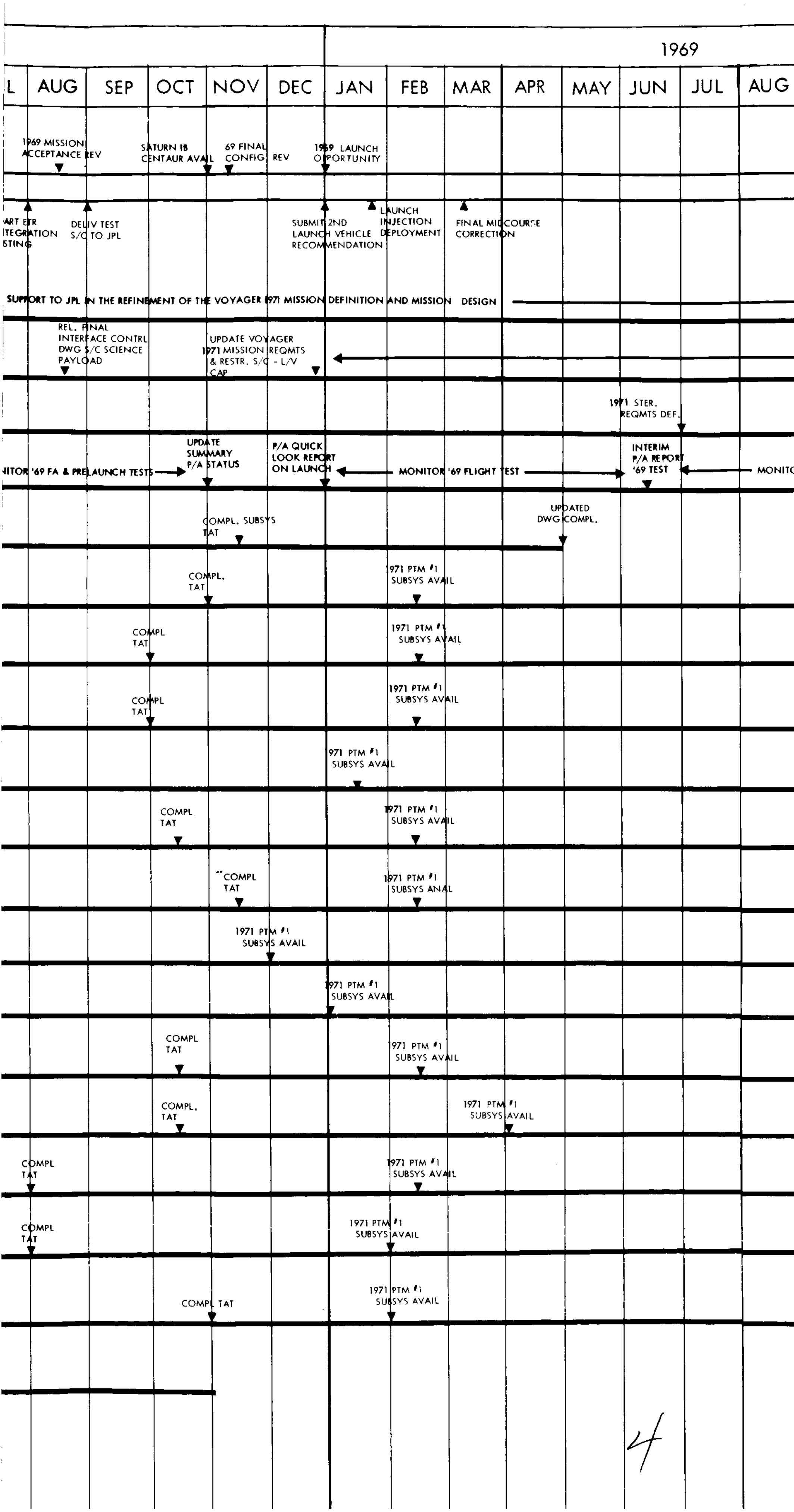
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LAUNCH INJECTION DEPLOYMENT
FINAL MIDCOURSE CORRECTION
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UPDATE VOYAGER 1971 MISSION REQMTS & RESTR. S/C - L/V CAP
1971 STER. REQMTS DEF.
UPDATE SUMMARY P/A STATUS
P/A QUICK LOOK REPORT ON LAUNCH
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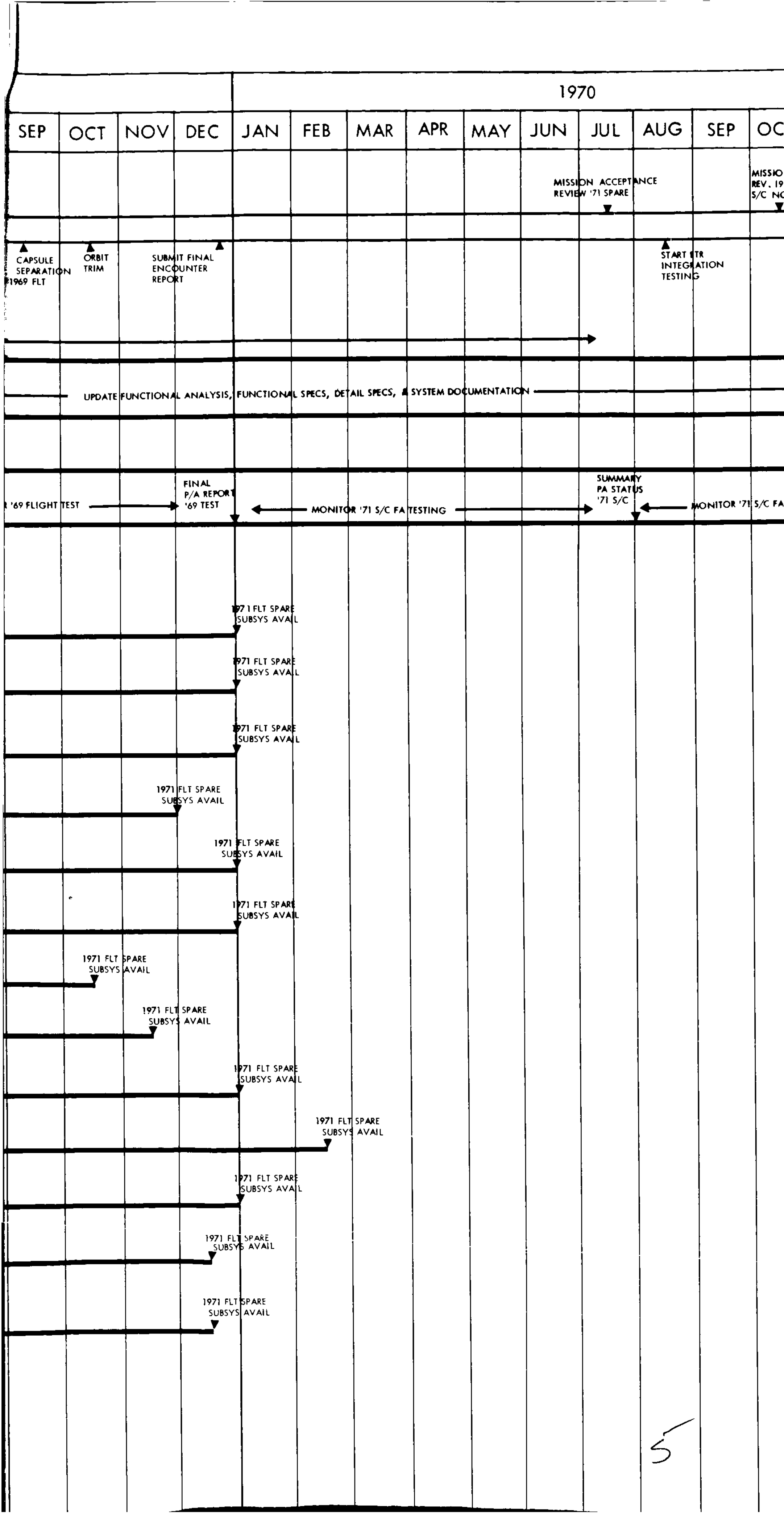

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'69 FLIGHT TEST
FINAL P/A REPORT '69 TEST
MONITOR '71 S/C FA TESTING
SUMMARY PA STATUS '71 S/C
MONITOR '71 S/C FA
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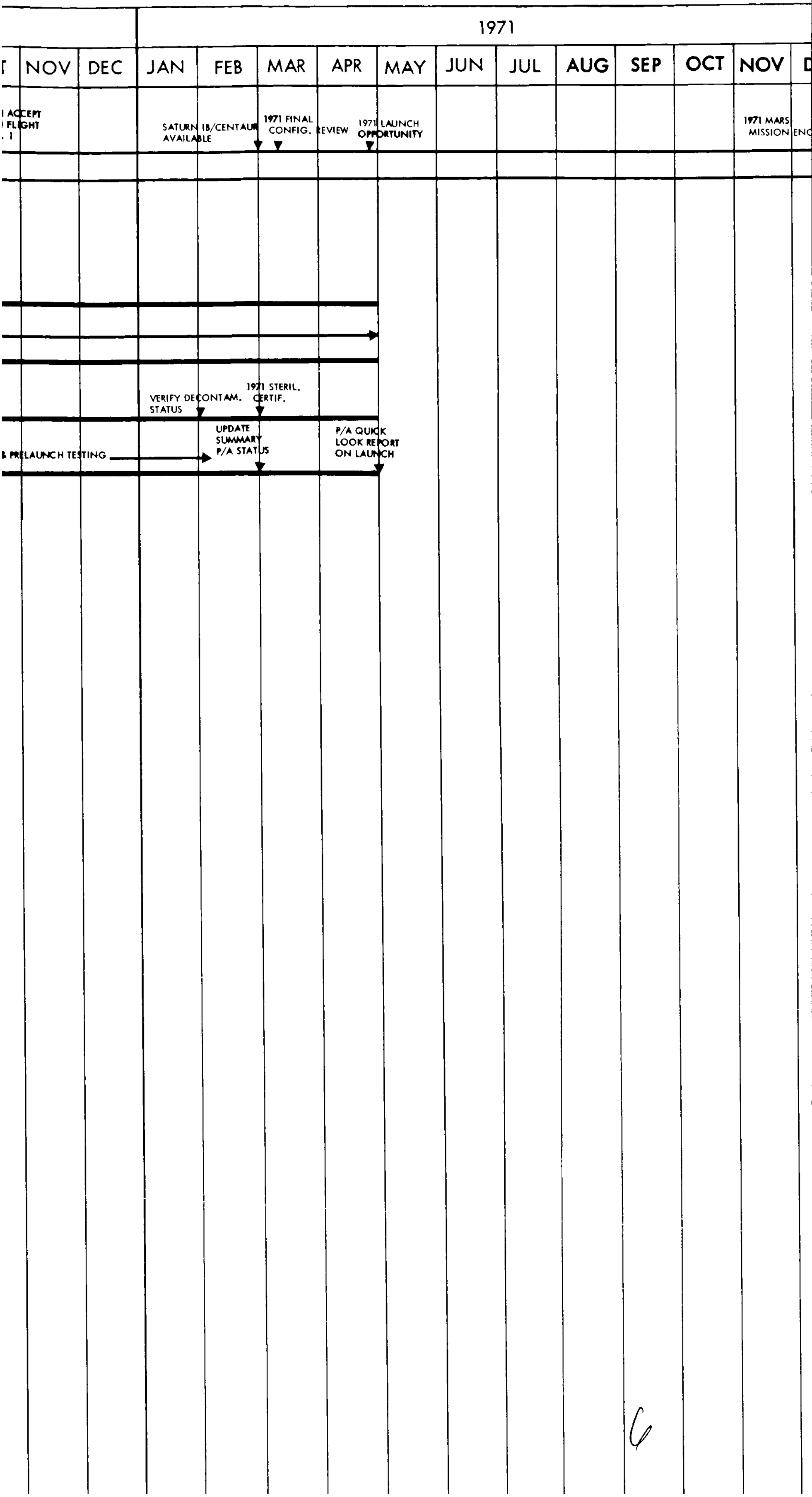
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P/A QUICK LOOK REPORT ON LAUNCH
& PRELAUNCH TESTING

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	SUBMIT '71 PRELIM ENCOUNT REPORT		SUBMIT '71 FINAL ENCOUNT REPORT									

THE BOEING COMPANY

Master Schedule 1971 Mission with 1969 Saturn IB/Centaur Mars Orbit

ABBREVIATIONS

C/O	CHECKOUT
ETM	ENGINEERING TEST MODEL
CDR	CRITICAL DESIGN REVIEW
PDR	PRELIMINARY DESIGN REVIEW
M/U	MOCKUP
FAT	FLIGHT ACCEPTANCE TEST
TAT	TYPE APPROVAL TEST
ASSY	ASSEMBLY
FAB	FABRICATION
SUBASSY	SUBASSEMBLY
REV	REVIEW
REL	RELEASE
MDS	MISSION OPERATION SYSTEM
DEV	DEVELOPMENT
COMPAT	COMPATIBILITY
INSTR	INSTRUMENTATION
HDWE	HARDWARE
FLT	FLIGHT
ANAL	ANALYSIS
IMPL	IMPLEMENT
COG	COGNIZANT
S/C	SPACECRAFT
L/V	LAUNCH VEHICLE
CAP	CAPSULE
ETR	AIR FORCE EASTERN TEST RANGE
BOD	BENEFICIAL OCCUPANCY DATE
DSN	DEEP SPACE NETWORK
DSIF	DEEP SPACE INSTRUMENTATION FACILITY
DWG	DRAWING
OSE	OPERATIONAL SUPPORT EQUIPMENT
SPEC	SPECIFICATION
MTLS	MATERIALS
M&P	MATERIALS & PROCESSES

THERMAL TEST MODEL

DYNAMIC TEST MODEL

COMPLETE SPACECRAFT

ENGINEERING MODEL-PROTOTYPE

JPL TEST SPACECRAFT

1969 PROOF TEST MODEL

1969 COMPATIBILITY TEST MODEL

SUBSYSTEM FLIGHT SPARES

1969 FLIGHT 1

1969 FLIGHT 2

1971 PROOF TEST MODEL #1

1971 PROOF TEST MODEL #2

1971 FLIGHT SPARE

1971 FLIGHT 1

1971 FLIGHT 2

OPERATIONAL SUPPORT EQUIPMENT

ASSEMBLY, HANDLING & SHIPPING EQUIPMENT

SYSTEM TEST COMPLEX

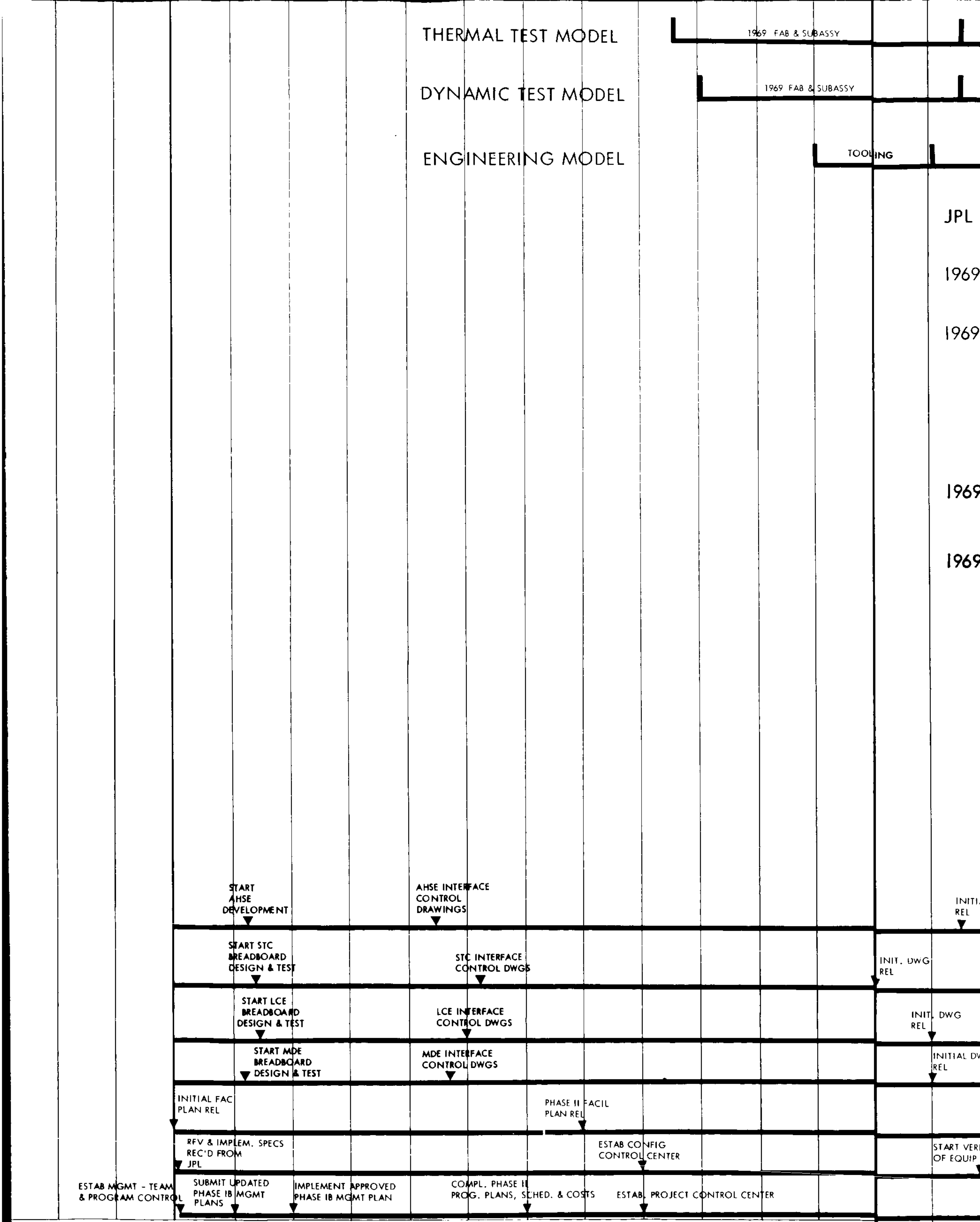
LAUNCH COMPLEX EQUIPMENT

MISSION DEPENDENT EQUIPMENT

FACILITIES

CONFIGURATION MANAGEMENT

BUSINESS MANAGEMENT



THERMAL TEST MODEL
1969 FAB & SUBASSY
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START AHSE DEVELOPMENT
AHSE INTERFACE CONTROL DRAWINGS
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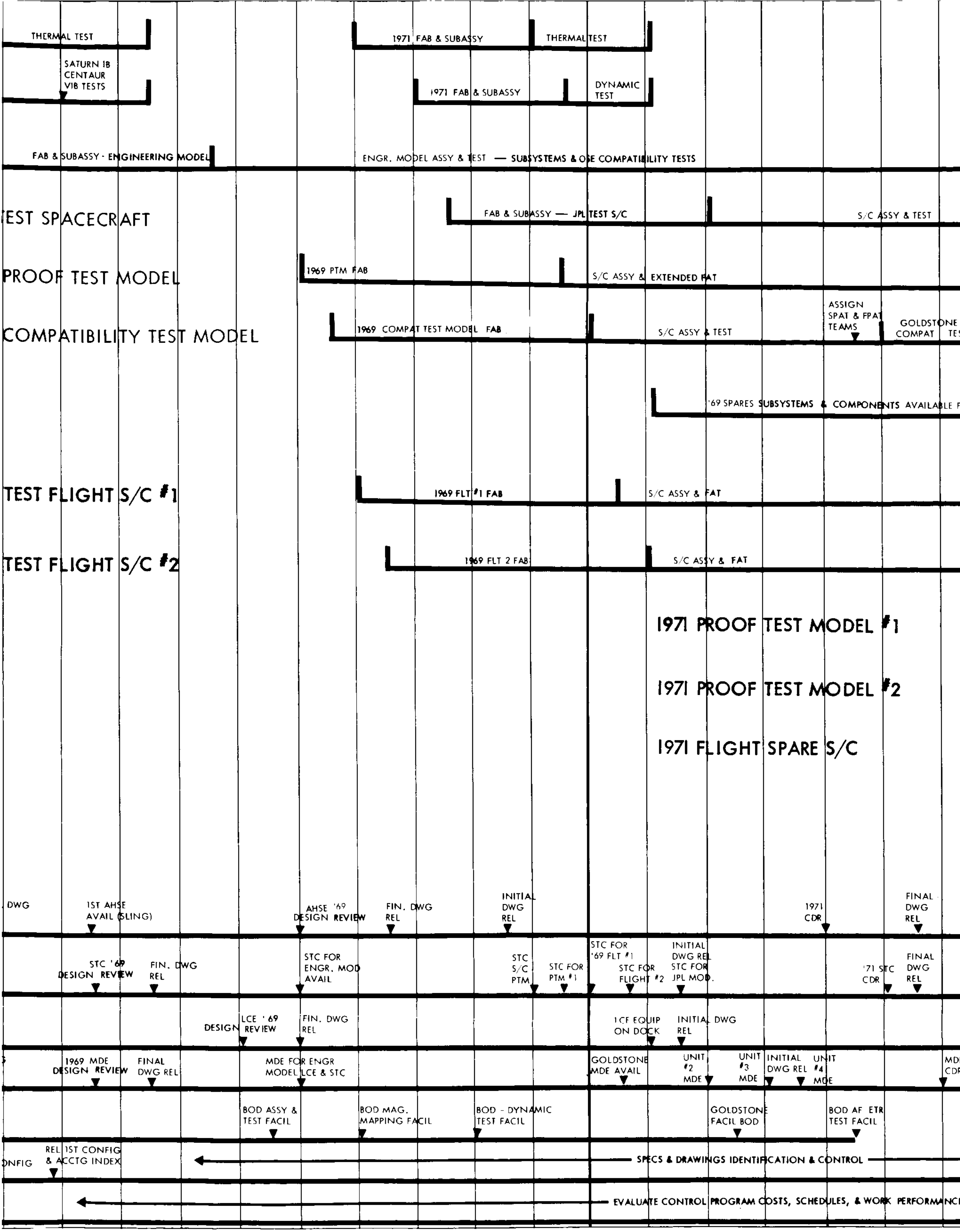
REL
START STC BREADBOARD DESIGN & TEST
STC INTERFACE CONTROL DWGS
INIT. DWG REL
START LCE BREADBOARD DESIGN & TEST
LCE INTERFACE CONTROL DWGS
INIT. DWG REL
START MDE BREADBOARD DESIGN & TEST
MDE INTERFACE CONTROL DWGS
INITIAL DV
REL
INITIAL FAC PLAN REL
PHASE II FACIL PLAN REL
REV & IMPLEM. SPECS REC'D FROM JPL
ESTAB CONFIG CONTROL CENTER
START VERI
OF EQUIP
ESTAB MGMT - TEAM & PROGRAM CONTROL
SUBMIT UPDATED PHASE IB MGMT PLANS
IMPLEMENT APPROVED PHASE IB MGMT PLAN
COMPL. PHASE II PROG. PLANS, SCHED. & COSTS
ESTAB. PROJECT CONTROL CENTER


THERMAL TEST
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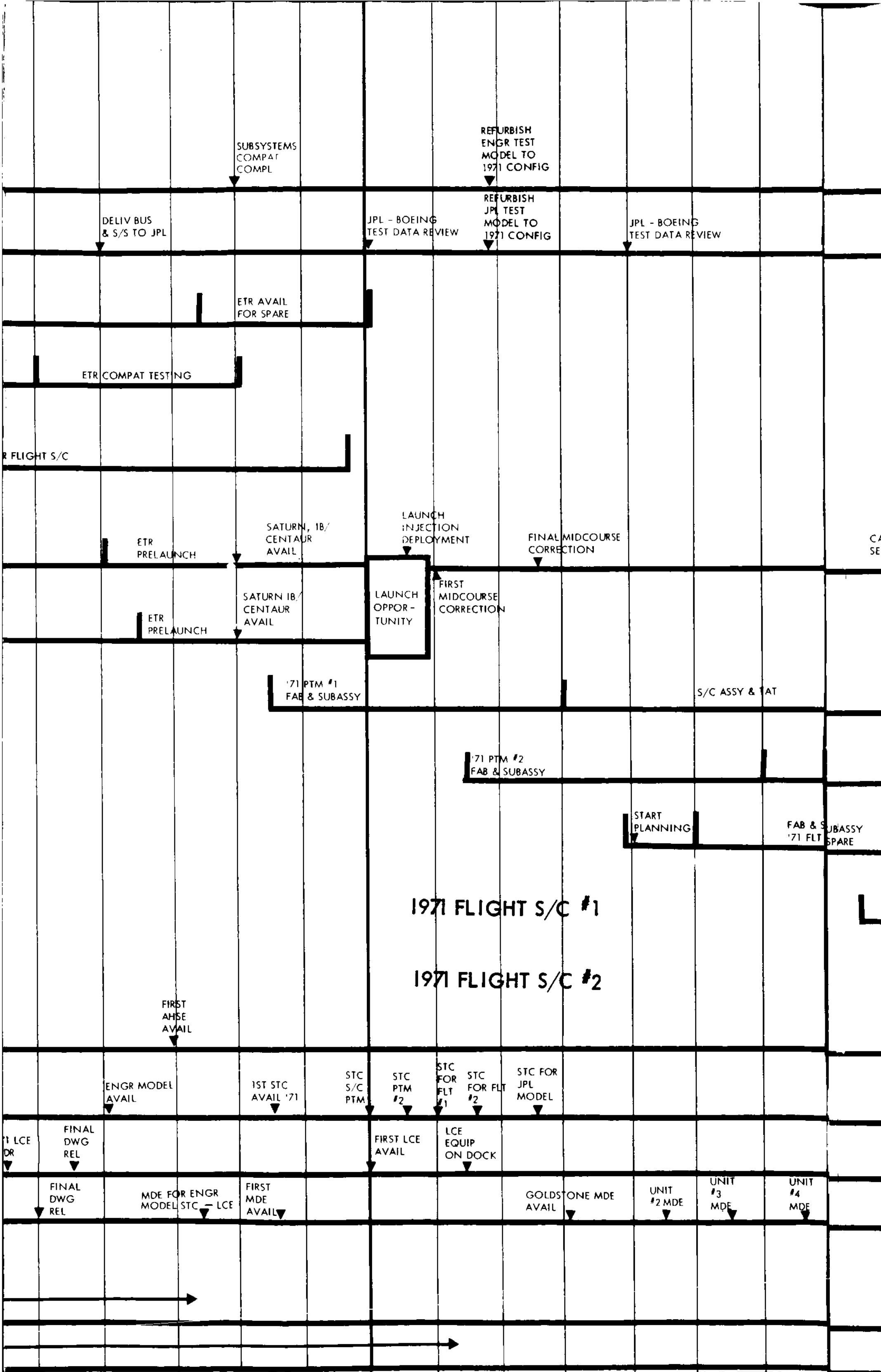
THERMAL TEST
SATURN IB CENTAUR VIB TESTS
1971 FAB & SUBASSY
DYNAMIC TEST
FAB & SUBASSY - ENGINEERING MODEL
ENGR. MODEL ASSY & TEST — SUBSYSTEMS & OSE COMPATIBILITY TESTS
TEST SPACECRAFT
FAB & SUBASSY — JPL TEST S/C
S/C ASSY & TEST
PROOF TEST MODEL
1969 PTM FAB
S/C ASSY & EXTENDED FAT
COMPATIBILITY TEST MODEL
1969 COMPAT TEST MODEL FAB
S/C ASSY & TEST
ASSIGN SPAT & FPAT TEAMS
GOLDSTONE COMPAT TEST
'69 SPARES SUBSYSTEMS & COMPONENTS AVAILABLE FO
TEST FLIGHT S/C #1
1969 FLT #1 FAB
S/C ASSY & FAT
TEST FLIGHT S/C #2
1969 FLT 2 FAB
S/C ASSY & FAT
1971 PROOF TEST MODEL #1
1971 PROOF TEST MODEL #2
1971 FLIGHT SPARE S/C
DWG
1ST AHSE AVAIL (SLING)
AHSE '69 DESIGN REVIEW
FIN. DWG REL
INITIAL DWG REL
1971 CDR
FINAL DWG REL
STC '69 DESIGN REVIEW
FIN. DWG REL
STC FOR ENGR. MOD AVAIL
STC S/C PTM
STC FOR PTM #1
STC FOR '69 FLT #1
STC FOR FLIGHT #2
INITIAL DWG REL STC FOR JPL MOD.
'71 STC CDR
FINAL DWG REL
DESIGN
LCE '69 REVIEW
FIN. DWG REL
LCE EQUIP ON DOCK
INITIAL DWG REL
1969 MDE DESIGN REVIEW
FINAL DWG REL
MDE FOR ENGR MODEL LCE & STC
GOLDSTONE MDE AVAIL
UNIT #2 MDE
UNIT #3 MDE
INITIAL DWG REL
UNIT #4 MDE
MDE CDR
BOD ASSY & TEST FACIL
BOD MAG. MAPPING FACIL
BOD - DYNAMIC TEST FACIL
GOLDSTONE FACIL BOD
BOD AF ETR TEST FACIL
ONFIG
REL 1ST CONFIG & ACCTG INDEX
SPECS & DRAWINGS IDENTIFICATION & CONTROL
EVALUATE CONTROL PROGRAM COSTS, SCHEDULES, & WORK PERFORMANCE


SUBSYSTEMS COMPAT COMPL
REFURBISH ENGR TEST MODEL TO 1971 CONFIG
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JPL - BOEING TEST DATA REVIEW
REFURBISH JPL TEST MODEL TO 1971 CONFIG
JPL - BOEING TEST DATA REVIEW
ETR AVAIL FOR SPARE
ETR COMPAT TESTING
R FLIGHT S/C
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LAUNCH INJECTION DEPLOYMENT
FINAL MIDCOURSE CORRECTION
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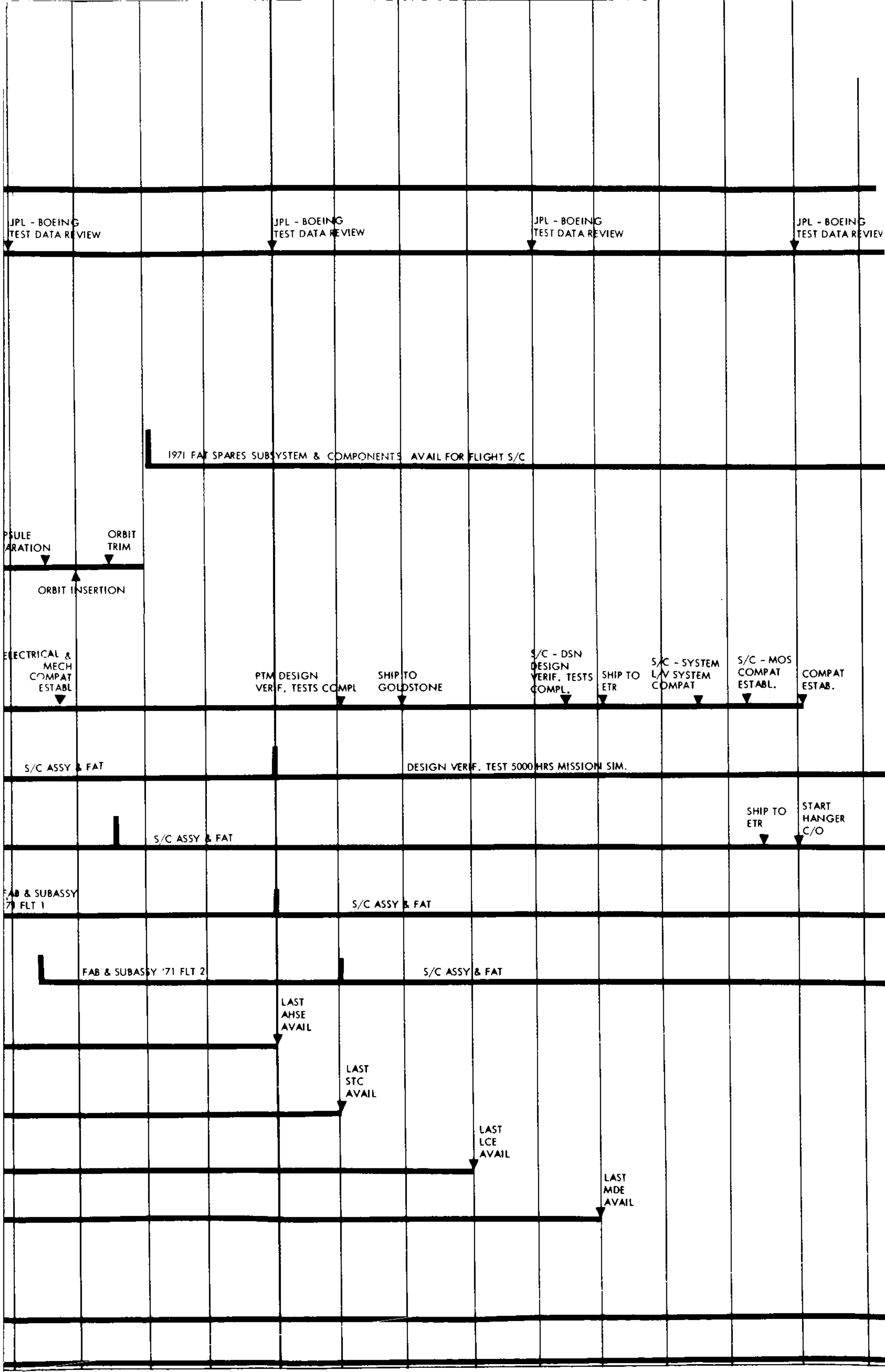
SATURN IB/CENTAUR AVAIL
LAUNCH OPPOR-TUNITY
FIRST MIDCOURSE CORRECTION
'71 PTM #1 FAB & SUBASSY
S/C ASSY & TAT
'71 PTM #2 FAB & SUBASSY
START PLANNING
FAB & SUBASSY '71 FLT SPARE
1971 FLIGHT S/C #1
1971 FLIGHT S/C #2
FIRST AHSE AVAIL
ENGR MODEL AVAIL
1ST STC AVAIL '71
STC S/C PTM
STC PTM #2
STC FOR FLT #1
STC FOR FLT #2
STC FOR JPL MODEL
'1 LCE DR
FINAL DWG REL
FIRST LCE AVAIL
LCE EQUIP ON DOCK
FINAL DWG REL
MDE FOR ENGR MODEL STC — LCE
FIRST MDE AVAIL
GOLDSTONE MDE AVAIL
UNIT #2 MDE
UNIT #3 MDE
UNIT #4 MDE


JPL - BOEING TEST DATA REVIEW
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JPL - BOEING TEST DATA REVIEW
JPL - BOEING TEST DATA REVIEW
1971 FAT SPARES SUBSYSTEM & COMPONENTS AVAIL FOR FLIGHT S/C
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ORBIT TRIM
ORBIT INSERTION
ELECTRICAL & MECH COMPAT ESTABL
PTM DESIGN VERIF. TESTS COMPL
SHIP TO GOLDSTONE
S/C - DSN DESIGN VERIF. TESTS COMPL.
SHIP TO ETR
S/C - SYSTEM L/V SYSTEM COMPAT
S/C - MOS COMPAT ESTABL.
COMPAT ESTAB.
S/C ASSY & FAT
DESIGN VERIF. TEST 5000 HRS MISSION SIM.
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START HANGER C/O
S/C ASSY & FAT
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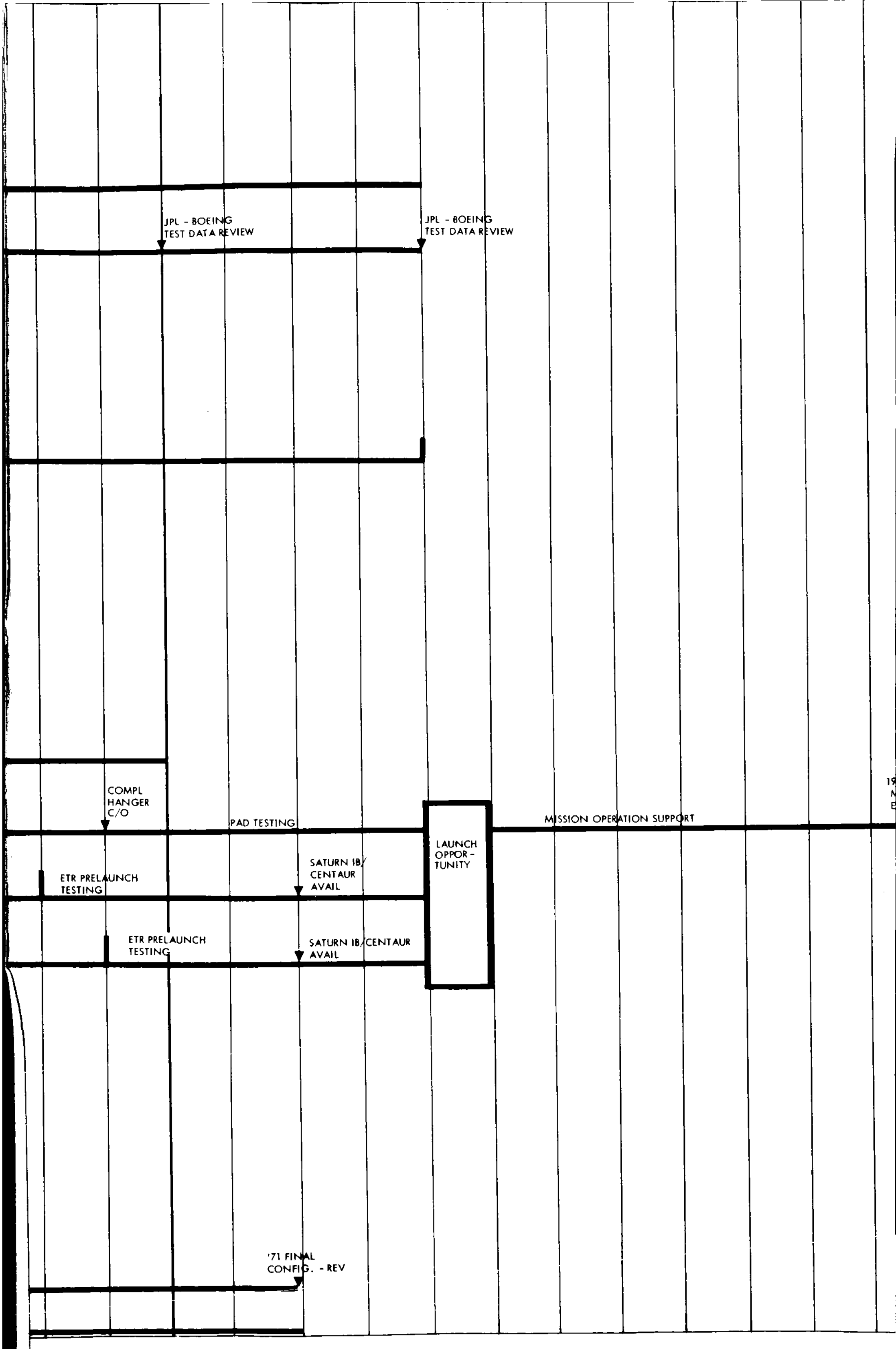
FAB & SUBASSY '71 FLT 2
S/C ASSY & FAT
LAST AHSE AVAIL
LAST STC AVAIL
LAST LCE AVAIL
LAST MDE AVAIL


JPL - BOEING
TEST DATA REVIEW
JPL - BOEING
TEST DATA REVIEW
COMPL
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C/O
PAD TESTING
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ETR PRELAUNCH
TESTING
SATURN IB/
CENTAUR
AVAIL
ETR PRELAUNCH
TESTING
SATURN IB/CENTAUR
AVAIL
'71 FINAL
CONFIG. - REV

APPROVALS

ORGANIZATION	NAME	DATE	APPROVAL
SPACECRAFT SYSTEM PROGRAM MANAGER	E. G. CZARNECKI	7/24	E. G. Czarnecki
AUTONETICS DIVISION - N.A.A.	R. R. MUELLER	7/23	R R Mueller
ELECTRO OPTICAL SYSTEMS	C. I. CUMMINGS	7/22	[illegible]
PHILCO WESTERN DEVELOPMENT LABORATORIES	G. O. MOORE	7/22	G. O. Moore
BUSINESS AND OPERATIONS	L. B. BARLOW	7/24	L Barlow
ENGINEERING	W. C. GALLOWAY	7/24	W. C. Galloway
FACILITIES	R. K. MILLS	7/23	R K Mills
MANUFACTURING	R. R. DICKSON	7/23	R R Dickson
MATERIEL	J. C. POWERS	7/23	J C Powers
QUALITY CONTROL	G. J. SIDDONS	7/23	J. Siddons
RELIABILITY, QUALITY ASSURANCE, AND SAFETY	C. S. BARTHOLOMEW	7/24	C. S. Bartholomew
SYSTEMS TESTING	J. C. TURNER	7/22	J. C. Turner

71 MARS
MISSION
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Figure 5.4-3:

14

5.5 MANAGEMENT STRUCTURE

During the IA definition phase, The Boeing Company and its major subcontractors have selectively implemented changes designed to improve the effectiveness and responsiveness of their management structures. The principal change to the overall management structure described in the IA proposal has been the inclusion of Autonetics as a major subcontractor. Autonetics brings additional strength to the Boeing team by contributing recognized capability and experience and a reputation for high reliability in its area of responsibility - the autopilot subsystem, attitude reference subsystem and related operational support equipment.

To avoid duplicating material submitted in the IA proposal, only significant management structure changes made since then will be described. Biographical material is included for key Autonetics personnel assigned to the program. Resumes for other new personnel are available upon request and will be included in the organization plan submitted as part of the Phase IB proposal.

5.5.1 Management Structures for Phases IB and II

Boeing and each of its major subcontractors have developed and implemented management structures which clearly define lines of authority, delegation of responsibility and accountability for performance.

Each team member has established one basic structure applicable to Phases IB and II. This approach is dictated by the need for starting many program activities during Phase IB in order to accomplish the necessary design, development and testing work in time to meet the program objectives.

5.5.2 Boeing Management Structure

The Boeing management structure has been modified slightly. Figure 5.5-1 indicates changes from the structure submitted in the Phase IA proposal. There are a few personnel changes including a new Engineering Manager, W. C. Galloway, whose resume is included. Changes in functional responsibilities and structuring, principally the realignment of reliability and product assurance activities, are indicated.

5.5.3 Electro-Optical Systems, Inc. and Philco, WDC Management Structures

The changes to these management structures are quite minor. The charts are repeated for convenience on Figures 5.5-2 and 5.5-3 respectively.

5.5.4 Autonetics Management Structure

Autonetics, a major operating unit of North American Aviation, has been actively engaged in Voyager program studies for over two years. Positive evidence of continued commitment is manifested by full participation as a member of the Boeing team. Basic responsibility for Voyager activities within Autonetics has been assigned to the Astrionics Division. Figure 5.5-4 illustrates the Voyager management structure within Autonetics and the significant responsibilities of each position. Resumes of the principal Autonetics personnel assigned to Voyager appear at the end of this section.

TECHNICAL REVIEW BOARD

NAME	TITLE OR POSITION	AFFILIATION
G. L. HOLLINGSWORTH	DIRECTOR	BOEING SCIENTIFIC RESEARCH LAB.
G. H. STONER	VICE-PRESIDENT	AERO-SPACE DIVISION
DR. F. PROSCHAN	VISITING PROFESSOR AT UNIVERSITY OF CALIFORNIA (BERKLEY)	BOEING SCIENTIFIC RESEARCH LAB.
S. SHAPIRO	DIR. OF PRODUCT DEVELOPMENT DESIGN	AERO-SPACE DIVISION
DR. L. DWYER	SYSTEMS ANALYSIS	AERO-SPACE DIVISION
DR. W. HANE	CHIEF SCIENTIST	AERO-SPACE DIVISION
DR. H. L. RICHTER	CORPORATE AREA TECHNICAL SPECIALIST	ELECTRO-OPTICAL SYSTEMS
DR. OTTO SCHWEDE	DIRECTOR TECHNICAL STAFF	PHILCO WDL
E. G. CZARNECKI	PROGRAM MANAGER	AERO-SPACE DIVISION

SYSTEMS TEST AND LAUNCH OPERATIONS MANAGER
K. K. MC DANIEL

- DEVELO PLAN, AND L
- DEVEL MENTA
- IDENT DEPEN

FLIGHT SPACECRAFT COGNIZANT ENGINEERS

- DIRECT SPACECRAFT SYSTEM TESTS
- DIRECT SPACECRAFT FINAL ASSEMBLY TESTS & ACCEPTANCE TESTS
- DIRECT PRELAUNCH OPERATIONS AND CHECKOUT
- DIRECT SPACECRAFT LAUNCH OPS.

SYSTEMS TESTING

- PREPARE ASSEMBLY & CHECK OUT PLAN
- PREPARE INTEGRATED DATA MANAGEMENT PLAN
- ACTIVATE SYSTEM TESTING FACILITIES
- CONDUCT SYSTEM TESTING OF FLIGHT SPACECRAFT

TEST BOARD

- DEVELOP AN INTEGRATED TEST PLAN
- MONITOR INTEGRATED TEST PLAN
- CERTIFY TEST COMPLETION
- VALIDATE TEST DATA

ÞP AND IMPLEMENT INTEGRATED TEST
SPACECRAFT ASSEMBLY & TEST PLAN
AUNCH OPERATIONS PLAN
ÞPMENT REQUIREMENTS AND PLANS FOR IMPLE-
ATION OF THE MOS
FICATION REQUIREMENTS FOR DSN, SFOF MISSION-
DENT EQUIPMENT AND PROGRAMS

FACILITIES

R. K. MILLS

- IDENTIFY INDUSTRIAL AND OPERATIONAL FACILITY REQUIREMENTS
- DEVELOP FACILITY PLANS INCLUDING FUNDING AND SCHEDULES
- COORDINATE FACILITY PLANS WITH JPL
- IMPLEMENT APPROVED PLANS AND CONTROL FUNDS
- CONTROL AND MAINTAIN PROGRAM FACILITY RESOURCES

LAUNCH OPERATIONS

- PREPARE SPACECRAFT LAUNCH OPERATIONS PLAN
- ACTIVATE LAUNCH OPERATIONS FACILITIES
- COORDINATE PRELAUNCH OPERATIONS WITH JPL/AFETR
- CONDUCT SPACECRAFT LAUNCH OPERATIONS

MISSION OPERATIONS

- SUPPORT SPAT AND FPAT AT JPL
- CONDUCT MISSION OPERATIONS TRAINING
- IMPLEMENT MISSION-DEPENDENT OSE
- SUPPORT MOS ACTIVITIES

FABRIC ASSEMBL

- FABRICATE MO AND TEST MOD
- DIRECT PLANN FABRICATION HARDWARE
- DIRECT PLANN FABRICATION AND TEST FUN
- PROVIDE SUPP LAUNCH OPER

OPERATIONS

L. B. BARLOW

- DIRECT FABRICATION AND ASSEMBLY ACTIVITIES
- DIRECT PROCUREMENT ACTIVITIES
- DIRECT QUALITY CONTROL ACTIVITIES
- ENSURE COMPLIANCE WITH ALL APPLICABLE QUALITY CONTROL DOCUMENTS

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ING, ORDERING
AND ASSEMBLY OF

ING, ORDERING, AND
OF TEST EQUIPMENT
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ATIONS

MATERIEL MANAGER

- MAINTAIN ETHICAL AND COMPETITIVE PROCUREMENT SYSTEM
- BE SOLE COMMITMENT AUTHORITY FOR PROCUREMENT
- MAINTAIN INVENTORY MANAGEMENT
- MAINTAIN SOURCE SELECTION SYSTEM
- ESTABLISH INCOMING TRAFFIC ROUTING
- ACCOMPLISH RECEIVAL AND STORAGE OF PARTS
- FURNISH MAKE-OR-BUY SUPPORT

QUALITY CONTROL MANAGER

- ESTABLISH & DIRECT QUALITY CONTROL REQUIREMENTS AND PROCEDURES
- DEVELOP QUALITY CONTROL PLAN TO COMPLY WITH NPC 200-2
- DIRECT PRODUCT INSPECTION & QUALITY ENGINEERING ACTIVITIES
- PROVIDE ACCOUNTABILITY RECORD SYSTEM & DISCREPANCY CONTROL SYSTEM

SYSTEM F

- ESTABLISH SPACE OBJECTIVES
- ESTABLISH SPACE MENTS AND CON
- DEVELOP SPACECR
- ESTABLISH SPACE REQUIREMENTS
- MONITOR DESIG
- MONITOR INTEG

3

SYSTEM ENGINEERING

S. R. RAGAR

- DEVELOP SPACECRAFT REQUIREMENTS AND CONSTRAINTS
- CONDUCT SYSTEM-LEVEL TECHNICAL TRADE STUDIES TO OPTIMIZE THE SPACECRAFT SYSTEM
- DEVELOP SPACECRAFT AND ASSOCIATED OSE FUNCTIONAL DESCRIPTIONS
- DEVELOP TEST REQUIREMENTS FOR THE SPACECRAFT SYSTEM

EQUIREMENTS

RAFT AND OSE DESIGN

RAFT AND OSE REQUIRE-
STRAINTS
AFT TEST REQUIREMENTS
RAFT SYSTEM INTERFACE

N COMPLIANCE
ATED TEST PLAN

SYSTEM ANALYSIS

- CONDUCT SYSTEM-LEVEL OPTIMIZATION AND TRADE STUDIES
- ASSIST IN SELECTION OF PREFERRED SPACE-CRAFT DESIGN
- CONDUCT SYSTEM-LEVEL FAILURE MODE ANALYSIS

SYSTEM INTEGRATION

- ESTABLISH FUNCTIONAL SEQUENCE OF MISSION EVENTS
- DEVELOP SPACECRAFT AND OSE FUNCTIONAL DESCRIPTIONS
- PREPARE SPACECRAFT AND OSE FUNCTIONAL SPECIFICATIONS
- IDENTIFY AND DEFINE SPACECRAFT SYSTEM INTERFACE
  IDENTIFY AND DEFINE VOYAGER PROJECT ELEMENT INTERFACES

4

TECHNICAL REVIEW BOARD

G. L. HOLLINGSWORTH

BUSINESS MANAGEMENT

- DIRECT A
- DEVELOP
- PROVIDE AND CO
- PROVIDE

MISSION ANALYSIS

- ONDUCT MISSION TRADE STUDIES
- UPPORT JPL IN CONDUCTING MISSION NGINEERING STUDIES
- ARTICIPATE ON THE JPL PROJECT MISSION NGINEERING PANEL

FINANCE

T. K. ARMITAGE

- ESTIMATE PROGRAM COSTS
- DEVELOP FUNCTIONAL BUDGETS AND ADMINISTER COST CONTROL SYSTEM
- PROVIDE FINANCIAL INFORMATION AND COST ANALYSIS
- ASSIST IN CONTRACT NEGOTIATIONS

PROGRAM PLANNING AND REPORTS

P. H. SCARLATOS

- PREPARE AND MAINTAIN PROGRAM BR STRUCTURE, MANAGEMENT NETWORK SCHEDULE, AND ACTIVITY/TIME NETW
- PREPARE AND MAINTAIN PROGRAM PL
- ESTABLISH AND DIRECT PROGRAM CO
- PREPARE MAKE-OR-BUY PLAN

5

VOYAGER SPACECRAFT
SYSTEM
PROGRAM MANAGER
E. G. CZARNECKI

ASSISTANT PROGRAM MANAGER
PASADENA RESIDENT

MINISTRATION OF CONTRACTS FUNCTION
ROGRAM PLANS AND DIRECTIVES
NANCIAL AND RESOURCE DIRECTION
TROL
ORRESPONDENCE CONTROL

PLANETARY QUARANTINE

J. A. STERN

- IDENTIFY AND ESTABLISH PLANETARY QUARANTINE REQUIREMENTS AND CONSTRAINTS
- DIRECT PLANETARY QUARANTINE ACTIVITIES
- CERTIFY END-PRODUCT COMPLIANCE WITH PLANETARY QUARANTINE REQUIREMENTS

PRODUCT

C. S. BA

AKDOWN
, MASTER
ORKS
AN
ITROL ROOM

CONTRACT
ADMINISTRATION

H. R. SYVERSON

- DIRECT ADMINISTRATION & NEGOTIATION OF CONTRACTS
- SUBMIT & NEGOTIATE PROPOSALS TO CHANGE CONTRACT STATEMENT OF WORK
- DEVELOP FUNCTIONAL WORK STATEMENTS
- ACCOUNT AND REPORT CONTRACT TASK COMPLETIONS
- CONTROL CONTRACTUAL CORRESPONDENCE

RELIABILITY
&
SAFETY

- PREPARE AND MAINTAIN RELIABILITY AND SAFETY REQUIREMENTS, PROGRAM PLANS, PROCEDURES, AND CONTROLS
- ASSIGN RELIABILITY AND SAFETY TASKS, PERFORM INVESTIGATIONS, AND MONITOR AND REPORT PERFORMANCE
- PREPARE SUBCONTRACTOR RELIABILITY AND SAFETY REQUIREMENTS AND MONITOR PERFORMANCE
- OPERATE A SAFETY OFFICE
- ESTABLISH RELIABILITY TEST REQUIREMENTS AND INCLUDE TEST RESULTS IN PERIODIC RELIABILITY STATUS REPORTING

CONFIGUR
MANAG

- ENSURE PROPER IDE
IS MAINTAINED O
END ITEMS
- ESTABLISH AND MA
RELEASE AND REC
- ENSURE PROPER AC
IS MAINTAINED
- MAINTAIN CONFI
CENTER AND CHA

ASSURANCE

THOLOMEW

- ESTABLISH AND DIRECT IMPLEMENTATION OF POLICIES, PLANS, REQUIREMENTS, BUDGETS, AND PROCEDURES FOR PROGRAM RELIABILITY, SAFETY, QUALITY ASSURANCE, AND CONFIGURATION MANAGEMENT ACTIVITIES
- DIRECT ESTABLISHMENT AND MONITORING OF SUBCONTRACTOR PRODUCT ASSURANCE FUNCTIONS
- ESTABLISH AND DIRECT PRODUCT ASSURANCE DATA CENTRAL FUNCTION

ATION
MENT

NTIFICATION CONTROL
CONTRACT DELIVERABLE

NTAIN AN ENGINEERING
DS CONTROL SYSTEM
COUNTABILITY CONTROL

URATION CONTROL
GE BOARD

QUALITY ASSURANCE

- PREPARE AND MAINTAIN PROGRAM QUALITY ASSURANCE PLAN AND REQUIREMENTS AND AUDIT PERFORMANCE
- ASSIGN TASKS AND MONITOR PERFORMANCE
- DIRECT COGNIZANT ENGINEER ACTIVITIES
- CONDUCT INVESTIGATIONS OF QUALITY PROBLEMS
- ESTABLISH AND MAINTAIN A PRODUCT ASSURANCE DATA SYSTEM

S
EN

G

- CONDUCT PRELI
STUDIES ON SPA
- PREPARE SUBSYST
DOCUMENTS
- SELECT PREFERRE
TYPES, AND PER
DESIGN CONFO
REQUIREMENTS

STRUCTURES AND MATERIALS TECHNOLOGY

M. J. TURNER

CONDUCT ANALYSES, TESTS AND SYNTHESES:
- DESIGN CRITERIA
- STATIC AND DYNAMIC LOADS
- NOISE AND VIBRATION AND TEMPERATURES
- STRESS ANALYSIS
- MATERIALS AND PROCESSES AND PARTS
- WEIGHT PREDICTION AND CONTROL

CONDUCT A
IN THE AREA
- COM
- GUID
- ELEC
- MICR
- RADI
- ANTE

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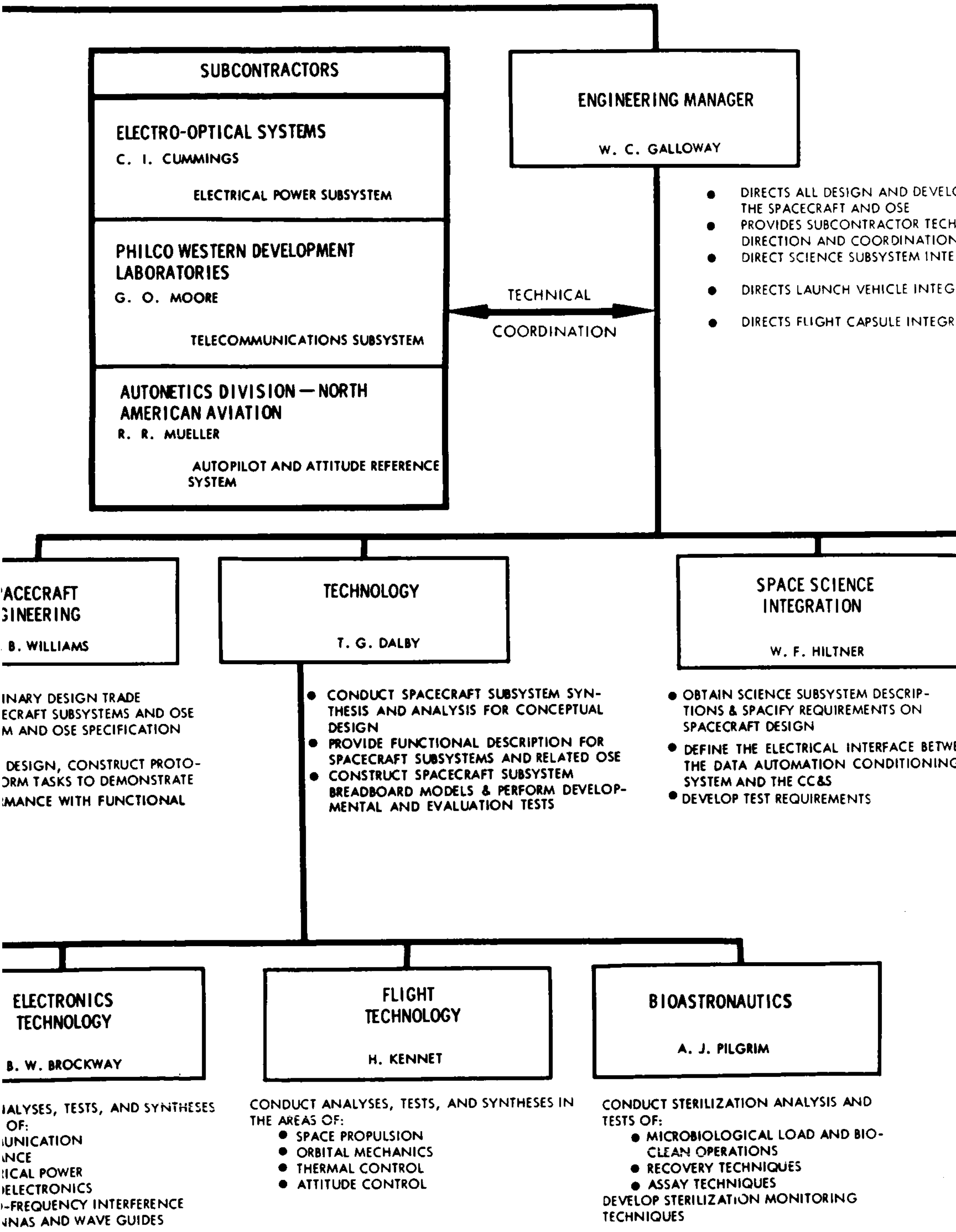

SUBCONTRACTORS
ELECTRO-OPTICAL SYSTEMS
C. I. CUMMINGS
ELECTRICAL POWER SUBSYSTEM
PHILCO WESTERN DEVELOPMENT LABORATORIES
G. O. MOORE
TELECOMMUNICATIONS SUBSYSTEM
AUTONETICS DIVISION — NORTH AMERICAN AVIATION
R. R. MUELLER
AUTOPILOT AND ATTITUDE REFERENCE SYSTEM
TECHNICAL
COORDINATION
ENGINEERING MANAGER
W. C. GALLOWAY
● DIRECTS ALL DESIGN AND DEVEL
THE SPACECRAFT AND OSE
● PROVIDES SUBCONTRACTOR TECH
DIRECTION AND COORDINATION
● DIRECT SCIENCE SUBSYSTEM INTE
● DIRECTS LAUNCH VEHICLE INTEG
● DIRECTS FLIGHT CAPSULE INTEGR
'ACECRAFT
3INEERING
. B. WILLIAMS
INARY DESIGN TRADE
ECRAFT SUBSYSTEMS AND OSE
M AND OSE SPECIFICATION
DESIGN, CONSTRUCT PROTO-
ORM TASKS TO DEMONSTRATE
MANCE WITH FUNCTIONAL
TECHNOLOGY
T. G. DALBY
● CONDUCT SPACECRAFT SUBSYSTEM SYNTHESIS AND ANALYSIS FOR CONCEPTUAL DESIGN
● PROVIDE FUNCTIONAL DESCRIPTION FOR SPACECRAFT SUBSYSTEMS AND RELATED OSE
● CONSTRUCT SPACECRAFT SUBSYSTEM BREADBOARD MODELS & PERFORM DEVELOPMENTAL AND EVALUATION TESTS
SPACE SCIENCE INTEGRATION
W. F. HILTNER
● OBTAIN SCIENCE SUBSYSTEM DESCRIPTIONS & SPACIFY REQUIREMENTS ON SPACECRAFT DESIGN
● DEFINE THE ELECTRICAL INTERFACE BETWE
THE DATA AUTOMATION CONDITIONING
SYSTEM AND THE CC&S
● DEVELOP TEST REQUIREMENTS
ELECTRONICS TECHNOLOGY
B. W. BROCKWAY
IALYSES, TESTS, AND SYNTHESES
OF:
UNICATION
NCE
ICAL POWER
ELECTRONICS
-FREQUENCY INTERFERENCE
NNAS AND WAVE GUIDES
FLIGHT TECHNOLOGY
H. KENNET
CONDUCT ANALYSES, TESTS, AND SYNTHESES IN THE AREAS OF:
● SPACE PROPULSION
● ORBITAL MECHANICS
● THERMAL CONTROL
● ATTITUDE CONTROL
BIOASTRONAUTICS
A. J. PILGRIM
CONDUCT STERILIZATION ANALYSIS AND TESTS OF:
● MICROBIOLOGICAL LOAD AND BIO-CLEAN OPERATIONS
● RECOVERY TECHNIQUES
● ASSAY TECHNIQUES
DEVELOP STERILIZATION MONITORING TECHNIQUES

AVAILABLE SCIENTIFIC CONSULTANTS

NAME	SPECIALTY	AFFILIATION
DR. Z. KOPAL	PLANETARY ASTRONOMY	U. OF MANCHESTER, ENGLAND
DR. G. DEVANCOULEURS	ASTRONOMY AND MARTIAN AUTHORITY	U. OF TEXAS
DR. A. DEPRIT	TRAJECTORIES AND CELESTIAL MECHANICS	BOEING SCIENTIFIC RESEARCH LAB.
DR. C. L. GOUDAS	PLANETARY GRAVITATIONAL PERTURBATIONS	BOEING SCIENTIFIC RESEARCH LAB.
DR. J. F. KENNEY	SCIENTIFIC INVESTIGATIONS, INSTRUMENTATION	BOEING SCIENTIFIC RESEARCH LAB.
DR. D. L. JOHNSON	LINEAR PROGRAMMING	BOEING SCIENTIFIC RESEARCH LAB.
DR. R. I. SCHOEN	UPPER ATMOSPHERE, PLASMA PHYSICS, AND SOLID STATE PHYSICS	BOEING SCIENTIFIC RESEARCH LAB.
J. M. SAARI	MASS SPECTROMETERS AND OTHER INSTRUMENTATION	BOEING SCIENTIFIC RESEARCH LAB.

)PMENT O'
NICAL
GRATION
'ATION
ATION

LOGISTICS

- ESTABLISH LOGISTIC SUPPORT CRITERIA, OBJECTIVES, AND GOALS
- ACCOMPLISH SUPPORT SYSTEM ANALYSIS AND DEVELOP LOGISTICS PLANS
- DETERMINE SUPPORT SYSTEM REQUIREMENTS INCLUDING SPARES, PUBLICATIONS TRAINING EQUIPEMENT, MAINTAINABILITY AND TRANSPORTATION

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Figure 5.5-1: Boeing Voyager Spacecraft System Management Structure

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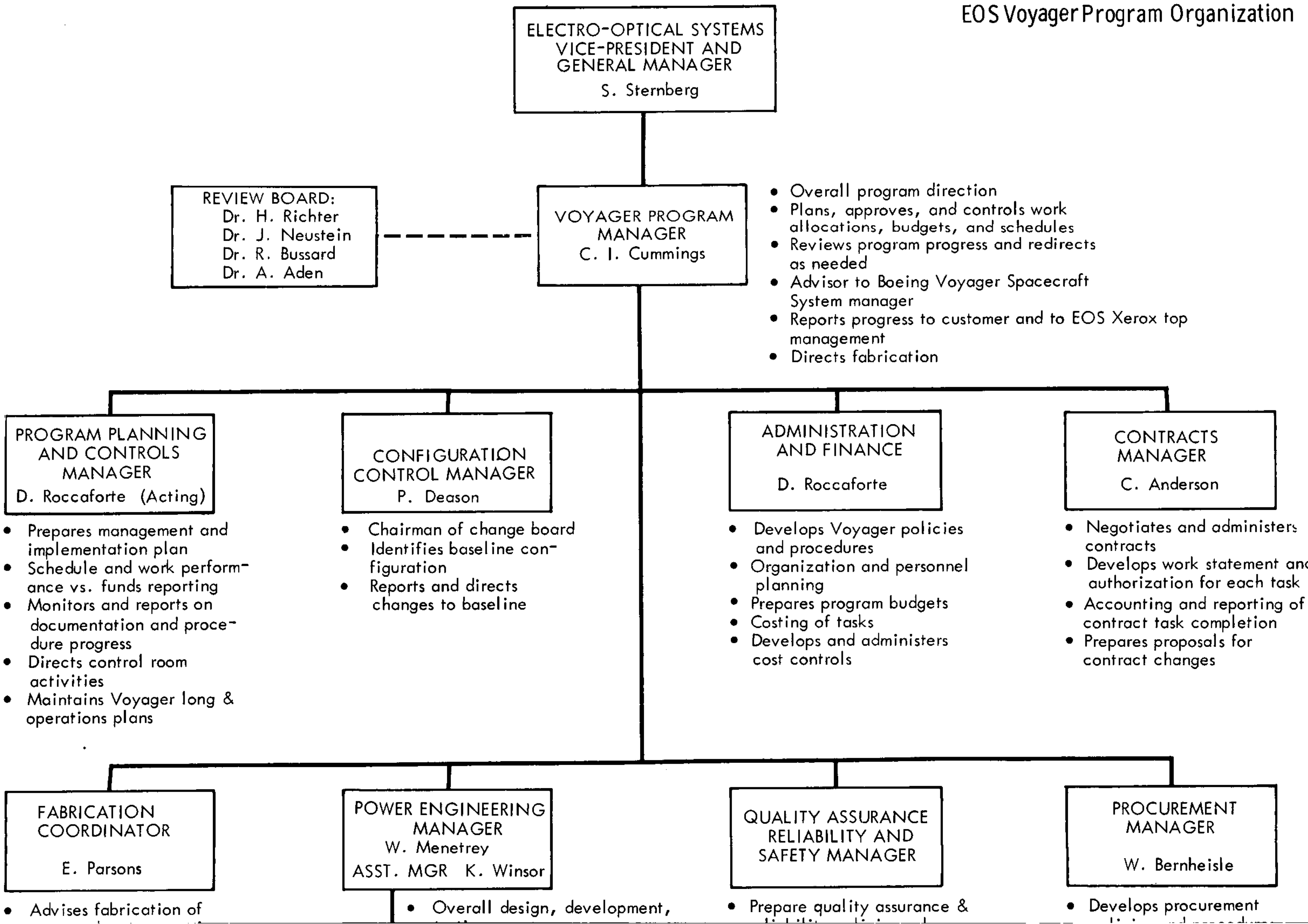
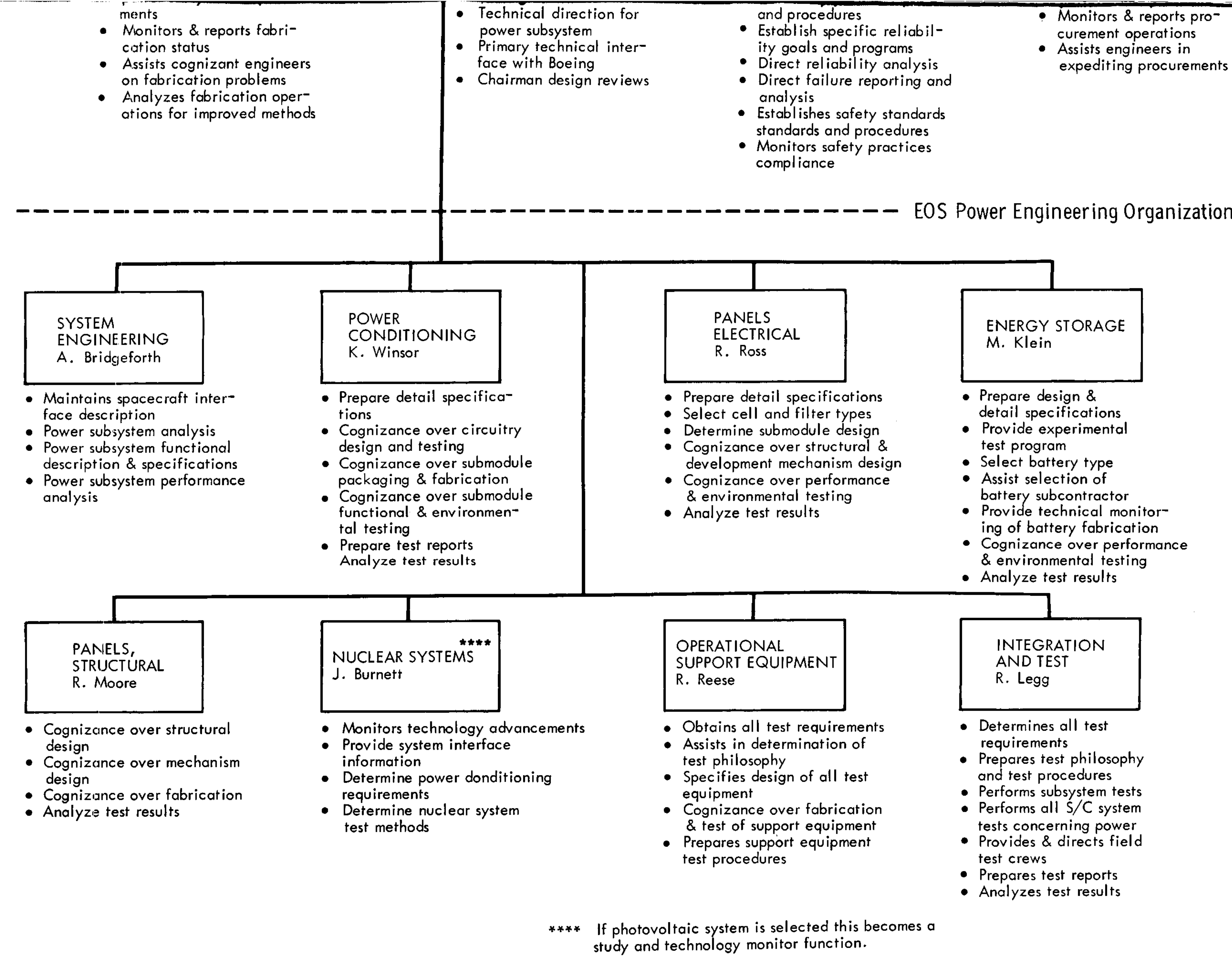
EOS Voyager Program Organization





ure 5.5-2: Electro-Optical Systems, Inc. Voyager Spacecraft System Management Structure

- Provides direction to reliability, quality control & safety plans for Voyager program.
- Prepares Implementation Plans for reliability, quality control, safety programs
- Allocates manpower for specific tasks. Provides function direction in Prod. & Safety Assur. orgn
- Monitors product assurance and safety activities and approves reports

PRODUC
SAFETY
ASSURAN
W. Wahr

DEPUTY FOR PROJECT MANAGEMENT

R. Eris

- Provides staff advise to prog. mgr. in mgmt. techniques
- Evaluates effectiveness of prog. mgmt. & supp prog. mgr. to improve performance
- Provide service to tech. mgr. in cost & sched. control, editing & publish. reports, admin. duties
- Supports Cont. Admin. in cost analysis & proj mgmt. for contract negotiation

SCHEDULE CONTROL

D. Sullivan

- Prepare & coordinate prelim. Master Phasing & Activity/Time relationships of major milestone charts.
- Monitor schedule performance and incorporate changes.
- Advise cognizant personnel & Program Mgr. of anticipated schedule problems.
- Prepare customer sched. reports.

CONFIGURATION MANAGEMENT

R. Blohm

- Prepares & coordinates work breakdown matrix and job orders.
- Organizes and serves as secretary to change board
- Receives, coord & issues engrg changes from change board
- Receives & coord. engrg change proposals to customer

DATA & REPORTS

- Publishes tech. & mgmt. data for status reports
- Supervises preparation of contract film reports.
- Maintains master control room.

COST ANALYSIS
M. Ho

- Negotiates budgets with work r
- Analyzes weekly costs against b
- Advises work recipients and pro
- Prepares cost proposals for chan

TEST ENGINEER

C. Champi

- Test plans
- OSE requireme
- Facility plans
- Test procedures

PROCUREMENT PLANNING

- Plans make or buy action
- Serves as sect'y of make/buy committee
- Prepares sched. of procurement--identifies long-lead items
- Coord. preparation of supply reqn. & other proc. documents
- Provides liaison between Voyager prog. office & Philco centralized procur

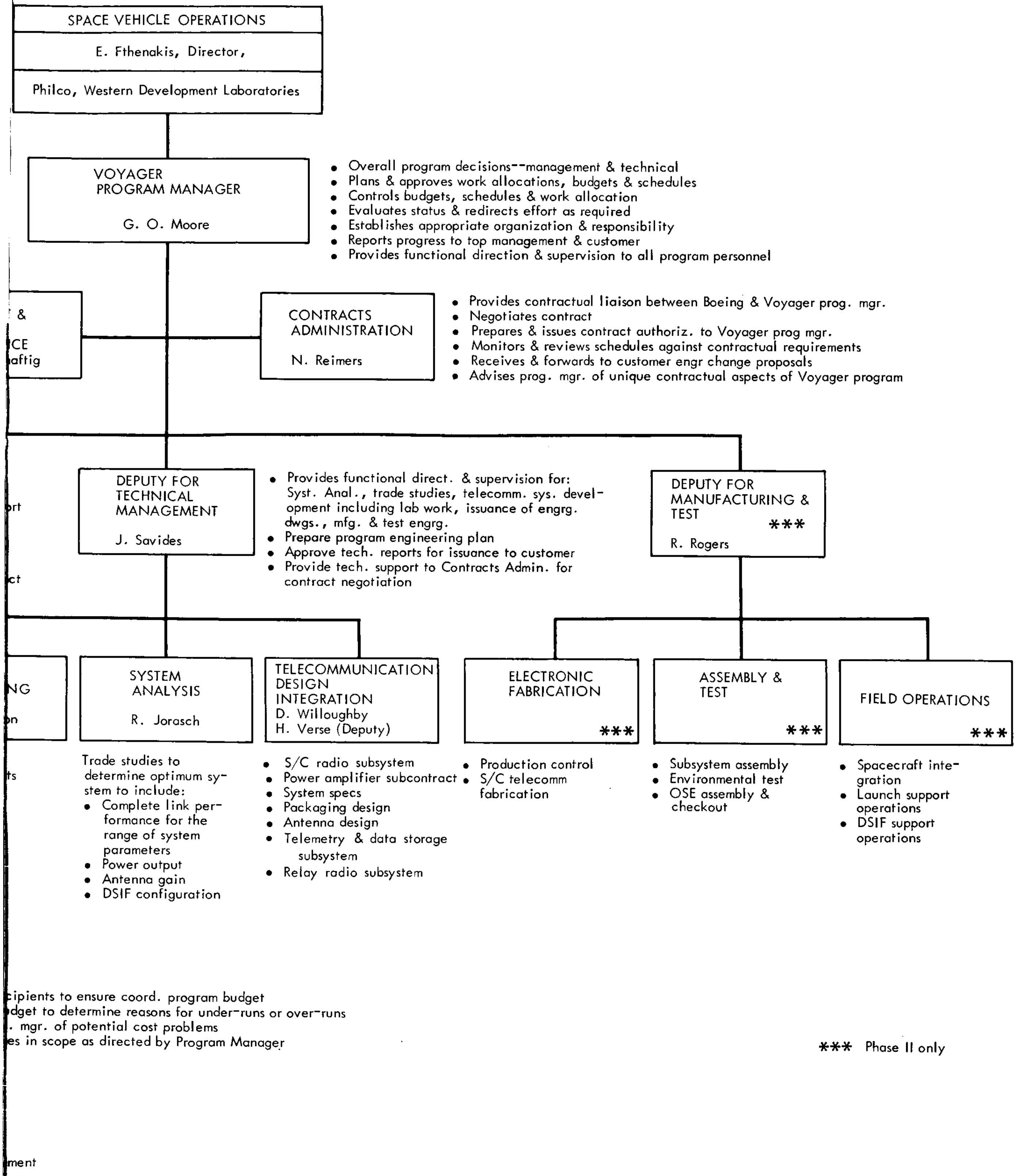


Figure 5.5-3: Philco, Western Development Laboratories Voyager Spacecraft System Management Structure

ELECTROSENSOR SYSTEMS DIVISION

MINUTEMAN SYSTEM DIVISION

STRIKE AVIONICS SYSTEM DIVISION

TECHNICAL REVIEW BOARD

Chief Engineer, Astrionics Div., J. J. Fischer
Chief Scientist, Astrionics Div., Dr. D. P. Chandl
Director, R&E Div., C. F. O'Donnell

- Responsible for Technical Integrity of Program
- Technical Direction of Activity
- Report on Technical Effort to Customer

VOYAGER CHIEF SCIENTIST
T. Mitsutomi

CONTRACTS & PRICING ADMINISTRATOR
R. Lindsay

- Negotiates Contracts
- Evaluates and Negotiates Contractual Changes
- Advises on Contractual Requirements
- Coordinates Budget Allocations with Activity Estimates

MATERIAL SUBCONTRACTING PURCHASING AGENT
R. Moonier

- Coordinates Subcontracting Activity
- Coordinates Make-or-Buy Action
- Prepares Procurement Schedule
- Provides Liaison between Voyager Program Office and Procurement Activities
- Assists in Identifying Long-Lead Items

PROGRAM OPERATIONS MANAGER
W. P. Yetter

- Program Control
- Configuration Management
- Quality Control
- Operations Center
- Production Adminstration
- Product Support

SYSTEM ANALYST
Dr. T. L. Gunckel

- Perform Guidance Analysis
- Perform Flight Control Analysis
- Perform System Studies
- Perform Reliability Analysis

/

AUTONETICS DIVISION
OF
NORTH AMERICAN AVIATION

ASTRIONICS DIVISION
DIRECTOR
M. Boe

DATA
SYSTEMS
DIVISION

er

VOYAGER PROGRAM
MANAGER
R. R. Mueller

- Provides Overall Program Direction
- Establishes Appropriate Organization anc
Responsibilities
- Plans, Approves, and Controls Work All
Budgets, and Schedules
- Evaluates Status and Redirects Effort as
- Reports Program Status to Upper Manage
Customer

CUSTOMER
LIAISON
BOEING

- Assists
with Cu
- In Resic

SENIOR PROJECT
ENGINEER
F. W. Hauf

- Report Status of Engineering Effort to Program Manager and Program Operations Manager
- Preparation of Engineering Work Authorizations and Control of Engineering Expenditures
- Development of Technical Schedules
- Responsible for Documentation of Engineering Effort

DATA SYSTEMS
DIVISION
VOYAGER PROJECT
MANAGER
M Hoffman

- Develop Detailed Specifications
Subsystem and Components
- Develop, Fabricate, and Test A
- Technical Assistance for Autopil
Support
- Subcontract Autopilot Componer
- Maintain Autopilot Production C

SYSTEM INTEGRATION
& TESTS
J. Sterrett

- Prepare Systems Integration Plan
- Prepare Integration Test Procedures
- Determine Operational Support Equipment Requirements
- Prepare Engineering Test and Qualification Procedures

SYSTEM
ENGINEER
Dr. S. White

- Develop System Mechanizat
- Perform Electronics Integrat
- Determine Inertial Instrumer
- Determine Electro-optical C
- Environmental Factors

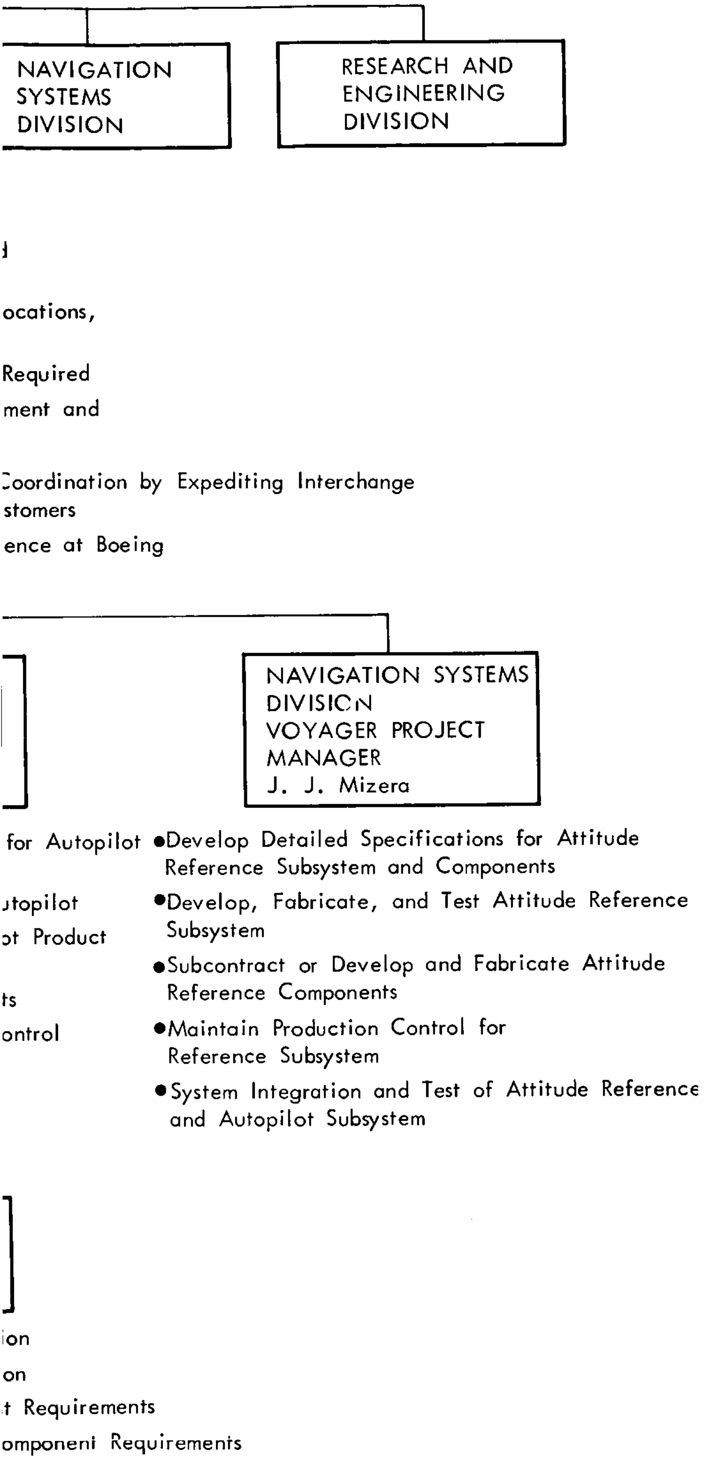


Figure 5.5-4: Autonetics Voyager Spacecraft System Management Structure

5.5.4.1 Program Manager

The Astrionics Division Voyager Program Manager, R. R. Mueller, is directly responsible for the management direction, control and reporting for all Voyager activities within Autonetics. Reporting directly to the Astrionics Division Director, he is charged with the conduct of the program from the inception and proposal stage to completion.

5.5.4.2 Technical Review

A technical review board comprised of the Chief Engineer J. J. Fischer; the Chief Scientist, Dr. D. P. Chandler; and the Director of Research and Engineering, C. F. O'Donnell reviews technical decisions, renders judgments on technical problems and furnishes technical support.

5.5.4.3 Autonetics Key Personnel

Following are resumes of Autonetics key personnel.

WILLIAM C. GALLOWAY (Boeing--Phase IA, IB, II)

Mr. Galloway has been with Boeing for seventeen years. From December 1963 until his recent appointment as Voyager Engineering Manager, he served on the Saturn Program as Manager of Technical Staff. Responsibilities included administrative and technical direction of Huntsville electronic engineering, management of electronic R&D activities supporting Launch Systems Branch new business, and providing technical support to the Saturn S-1C and V Programs. From 1961 through 1963, as Electronic Design Engineering Manager, he directed the design and development of electronic equipment and the development of supporting electronic technologies for the major programs of the Aero-Space Division. In 1960-1961 he served as Assistant Gulf Test Base Manager, responsible for all test and design engineering at the Bomarc test base at Elgin AFB, Florida. Earlier, he progressed through increasingly responsible supervisory appointments in Bomarc Applied Physics, with assignments in flight control and computer development. He became Project Engineer on the Bomarc B Program in 1958, responsible for directing the overall B Program engineering effort. Mr. Galloway has published technical papers dealing with microwave oscillators and pressure recorders. He is a member of IEEE and AIEE.

Education:

B.S., Electrical Engineering, University of Washington, 1944

M.S., Electrical Engineering, Massachusetts Institute of Technology, 1948

JOSEPH A. STERN (Boeing Phase IA, IB & II)

Dr. Stern brings to the position of Voyager Planetary Quarantine Manager experience in the fields of microbiology, chemistry and system engineering. This was gained during his eight years on the faculties of the Massachussets Institute of Technology and the University of Washington, and seven years at Boeing.

He joined The Boeing Company in 1958 as Chief of the Biochemistry Unit and has advanced through positions of Research Program Coordinator of Bioastronautics to Life Sciences Section Chief of the Boeing Lunar Excursion Module Team to Chief of Interplanetary Studies, Advanced Programs.

Beginning in 1963, Dr. Stern has been responsible for a number of space-oriented advanced technological and conceptual studies. These include a study of a satellite system for micrometeoroid measurement, and advanced Lunar Orbiter (LOS) mission studies. He served as Program Manager of the Study of Interplanetary Mission Support Requirements, NASA Contract NAS9-3441, May 1965.

He is author of more than 35 technical papers and encyclopedia articles and is a Fellow of the AAAS.

Education:

B.S., Food Technology, Massachusetts Institute of Technology - 1949

M.S., Food Technology, Massachusetts Institute of Technology - 1950

Ph.D, Food Technology, Massachusetts Institute of Technology - 1953

RUDY R. MUELLER (Autonetics--Phase IA, IB, II)

Mr. Mueller has been with North American eight years. He has been continuously engaged in technical and management responsibilities in the space field throughout virtually this entire period. Prior to his assignment as Voyager Program Manager, he served as project engineer for these Autonetics programs: Voyager Design Studies, the Lunar Logistics System, and the Logistics Spacecraft. Prior to 1957, he taught at the University of Texas and held engineering positions with Convair and Chance-Vought. He has taken a number of post-MS courses in the mathematics and astronautics fields. Mr. Mueller is a member of Tau Beta Pi, Pi Tau Sigma, the Institute of Navigation Astrodynamics, the American Institute of Aeronautics and Astronautics, and has participated in Lunar and Planetary Exploration Colloquia. Mr. Mueller has presented twelve professional papers in the space field including "The Voyager Mission: Guidance and Control Considerations," "An Analysis of Guidance and Control Requirements for a Mars Mission," "An Analysis of Guidance, Navigation, and Control System Equipments for a Mars Mission," and "Investigation of Possible Satellite Position - Sensing Methods." He has also presented a guest lecture at the University of Michigan Space Seminar.

Education:

B.S., Mechanical Engineering, University of Texas, 1955.

M.S., Theoretical and Applied Mechanics, University of Texas, 1959.

BRUCE C. DUNN (Autonetics--Phase IA, IB, II)

Mr. Dunn joined North American Aviation in 1962 as Chief, Quality and Reliability Assurance, Electro Sensor Systems Division, responsible for quality and reliability assurance activities pertaining to airborne radar and electronic test equipment. Mr. Dunn's previous Quality Control experience is extensive, beginning in 1955 in the Quality Control Office, Air Force Air Materiel Command, Dayton, Ohio. Holding successively more responsible positions in different locations, he became Director of Materiel, Chief-Quality Control Planning, and finally Director-Quality Control, Western Contract Management Region, Air Force Systems Command. In the latter position he was responsible for the conduct of all Air Force Quality Control activities in contractor's facilities in thirteen western states and at all Ballistic Missile Sites. His responsibility extended over 1700 quality and reliability engineers and technicians and covered NASA, Air Force, and other DOD Programs. During this same tour of duty, he had an additional responsibility as Assistant to the Commander for Site Activation. Mr. Dunn is a member of the American Society for Quality Control and the American Management Association.

Education:

B.A., Economics, Sioux Falls College, 1941.

M.B.A., Business Administration, Stanford University, 1949.

T. L. GUNCKEL, II (Autonetics--Phase IA, IB, II)

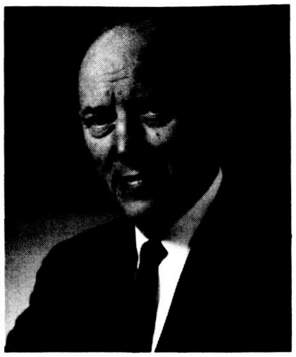
Dr. Gunckel will be responsible for system analytical studies on the Voyager Spacecraft System for all Phases of the Space mission. His first assignment after joining Autonetics in 1961 was contributing to the development of a computer program for the analysis of Minuteman free flight test data. Since December 1961, Dr. Gunckel has been engaged in the analysis of guidance and navigation systems holding progressively more responsible supervisory positions in this field. He has participated in studies of orbit determination techniques, a Lunar Logistics System, the Apollo mission and provided much of the systems analysis effort on the Standardized Space Guidance System Phase IA study contract. Dr. Gunckel's professional papers include "A General Solution for Linear Sampled Data Control," "Orbit Determination Using Kalman's Method," and "The Effect of Physical Constant Uncertainty upon Lunar Orbit Determination." Dr. Gunckel is also author of "Preliminary Guidance and Navigation Study for Apollo Lunar Orbit Rendezvous," an Autonetics Report. He is a member of Tau Betta Pi Honor Society, Pi Tau Sigma, Sigma Xi.

Education:

B.S., Mechanical Engineering, California Institute of Technology, 1958.

M.S., Electrical Engineering, Standford University, 1959.

PhD., Electrical Engineering, Standford University, 1961.



F. W. HAUF (Autonetics--Phase IA, IB, II)

Mr. Hauf's most recent assignment was Project Engineer for Autonetics' next generation guidance system involving advanced concepts of inertial instruments, microminiaturized electronics and system engineering. Mr. Hauf previously served as Space Guidance and Sensor Stabilization Project Engineer coordinating space guidance and sensor stabilization activities within the Navigation Systems Division. Earlier, Mr. Hauf was System and Staff Engineer on the N5B Technical Development program with assignments in systems and project engineering. Previous to this assignment, Mr. Hauf was Project Engineer on the N35S Autonavigation System and was largely responsible for the creation of the most recent Autonetics stellar-inertial space system. His previous experience includes that of Ordnance Engineer, U.S. Government Bureau Ordnance and Research Engineer on Bureau of Ordnance contracts at the General Electric Company, at Shenectady, New York, for 15 years. Mr. Hauf has made patent applications in the field of low - power, low drift gas-bearing gyros for space application. He also has several patents pending.

Education:

B.S., Electrical Engineering, Rennselaer Polytechnic Institute, 1931.

M.S., Electrical Engineering, Rennselaer Polytechnic Institute, 1934.

Graduate Work, University of California at Los Angeles.

MURRAY HOFFMAN (Autonetics--Phase IA, IB, II)

Mr. Hoffman has been with Autonetics for five years. Since 1962, his assignment has been project engineer responsible for the Minuteman Wing VI airborne guidance and control system computer. Previously, he was assistant project engineer for Minuteman I aerospace ground equipment. From 1957-60, he was employed by Nortronics as supervisor of System Integration responsible for advanced design concepts and proposals for automatic test equipment. From 1952-57, he held systems engineering assignments on Navaho instrumentation systems at North American. Mr. Hoffman's sixteen years of professional experience in computers includes pioneering the first production microminiature computer, automatic test equipment, instrumentation, telemetry, radar, and radio command. He was instrumental in establishing the basic design criteria for fully automatic checkout and launch of the Navaho weapon system. He established the design concepts for the Army's Universal Automatic Test Equipment and Polaris Automatic Test Equipment developed by Nortronics. Earlier, he contributed to the development of advanced instrumentation and measurement systems, telemetry, and radio control.

Education:

B.S., American Television Institute of Technology, 1949.

R. E. LINDSAY (Autonetics--Phase IA, IB, II)

Mr. Lindsay joined North American Aviation in 1960. His first assignment involved engineering-manufacturing liaison on Minuteman flight control and accelerometer hardware. He became Manufacturing Project Administrator responsible for various deliverable systems hardware, including the REINS Bomb-Navigation System for the A5C Vigilante. In 1963, Mr. Lindsay was named Project Engineer for the engineering unit responsible for design, development, and fabrication of special test units used to checkout the Apollo Spacecraft subsystems. Shortly thereafter he was assigned as Project Administrator, Contracts, and has been in this position since. Before joining North American Aviation, Mr. Lindsay was Chief Industrial Engineer, and General Supervisor of Production Control at Solar Aircraft Company.

Education:

B.S., Industrial Engineering, Iowa State University, 1951.

T. MITSUTOMI (Autonetics--Phase IA, IB, II)

Mr. Mitsutomi is presently a member of Autonetics Senior Technical Staff-Electronics Research and is responsible for applying advanced technological concepts in generating new devices, products and systems. He has held the position of Group Leader of the Electromechanical Systems Research Group, and Supervisor in the Controls Group of Inertial Navigation Engineering. He has participated in or supervised inertial instrument and platform servo development on all Autonetics autonavigators since 1953. As Manager of the Advanced Techniques Department of Autonetics Navigation Division, he was responsible for research on microelectronics, advanced devices and electro-optics. Mr. Mitsutomi is an instructor at the University of California at Los Angeles and is a member of Sigma Xi, Eta Kappa Nu, Tau Beta Pi, IEEE, AIEE, and AIAA. He has completed two years of course work at USC leading to his PhD. Mr. Mitsutomi has authored six technical papers on inertial platform dynamics, error analysis of inertial instruments, and application of microelectronics to electromechanical control system.

Education:

B.S., Electrical Engineering, Massachusetts Institute of Technology, 1953

M.S., Electrical Engineering, Massachusetts Institute of Technology, 1953

JAMES J. MIZERA (Autonetics--Phase IA, IB, II)

Mr. Mizera, Project Engineer, Advanced Systems, Navigation Systems Division, joined North American Aviation in 1955. Mr. Mizera's responsibilities at Autonetics have included such positions as Supervisor of Systems Cruise Evaluation and Project Engineer for Low-Level Navigation Systems. He has had extensive experience in mechanization and performance analysis of both ballistics and cruise inertial systems. He was responsible for analysis and evaluation of the N7C and N7D inertial and stellar inertial marine guidance systems, respectively. Prior to this, Mr. Mizera performed early system error studies for the GAM-77 and the early launch ballistic missile feasibility studies. He is a member of the AIAA, Institute of Navigation, and served as a member of the AIEE Subcommittee inertial navigation. He was a contributing author to the book, "Inertial Navigation Analysis and Design," edited by C. F. O'Donnell and published by McGraw Hill.

Education:

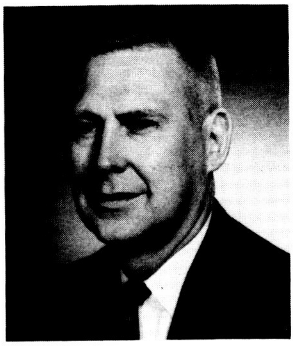
A.B., Physics, Washington University, 1955

R. V. MOONIER (Autonetics--Phase IA, IB, II)

Mr. Moonier joined North American Aviation in 1951 and has served in varied procurement, subcontracting and material positions. He has held responsible supervisory positions including Buyer, General Supervisor and Purchasing Agent. In 1961 he was appointed General Purchasing Agent in the Computers and Data Systems Division, responsible for all procurement, subcontracting and warehousing activities of the Division. During 1963 and 1964, Mr. Moonier was assigned to the Standardized Space Guidance System Division where he was responsible for conducting an industry survey and providing the Divisional interface with all subcontract agencies. In his current assignment, he is Executive Advisor to the Manager of Material and Subcontracting, SAS Division.

Education:

Business Administration, University of California at Los Angeles

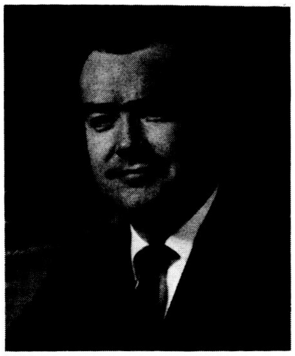


J. P. STERRETT (Autonetics--Phase IA, IB, II)

Mr. Sterrett has been employed at North American for ten years. His most recent assignment prior to Voyager was responsibility for the definition of AGE requirements for a Standardized Space Guidance System. Prior to joining the Astrionics Division in 1963, he supervised Minuteman Aerospace Ground Equipment system engineering for three years. Earlier, he spent two years, 1957-1959, in system development of automatic checkout equipment, AN/GJO-9, and component development for the NAVAHO arming and fuzing system, 1955-1957. Before joining North American in 1955, he was employed by Librascope in fire control development and Sandia Corporation in arming and fuzing development.

Education:

B.S., Electrical Engineering, Illinois Institute of Technology, 1950



DR. STANLEY A. WHITE (Autonetics--Phase IA, IB, II)

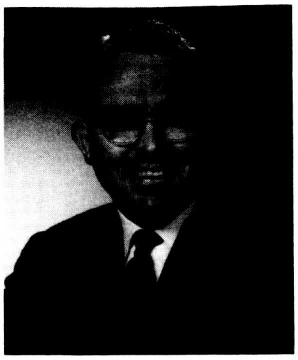
Dr. White has been associated with the Inertial Navigation Division of Autonetics as a Senior Research Engineer for six years. His most recent assignments include the performance of research on the quartz-reed accelerometer, non-linear platform-controller servos, and a simplified digital star-tracking servo; he also recently participated in the design, development, and testing of the MABLE. Previous assignments included an analysis of the Mobile Minuteman platform alignment, as well as gyro-compass and platform error analysis. Earlier, with the Servo Unit of the Component Engineering Section, he was responsible for analysis and design of velocity-meter servos, and performed a Minuteman warhead-arming study. Dr. White's experience in the Aerospace field dates back to 1951 when he was engaged in SHORAN mapping of the Atlantic Missile Range. He was Lecturer in Engineering at the University of California at Los Angeles from 1959 until 1961, and Instructor at Purdue from 1961 until 1963. From 1963 to 1965, he held a NAA Science-Engineering Fellowship. His technical papers include, "Pendulous Velocity-Meter Controller Synthesis," "Linear State Estimation by Network Syntheses," and "Theory and Design of Analog Linear Estimates for Automatic Control Systems." Dr. White has been an invited Seminar speaker at a number of universities.

Education:

B.S., Electrical Engineering, Purdue University, 1957

M.S., Electrical Engineering, Purdue University, 1957

Phd., Electrical Engineering, Purdue University, 1965



W. P. YETTER (Autonetics--Phase IA, IB, II)

Mr. Yetter joined North American Aviation in 1951. For three years preceding his assignment to the Voyager Spacecraft System program, Mr. Yetter has performed project engineer work for Astrionautics in the Systems Division. From late 1959 through 1962 he was the Reliability Project Engineer responsible for the formulation, direction and monitoring of all formal reliability programs within the Armament and Flight Control Division. Earlier Responsibilities included supervision of the Airplane Systems Unit with system responsibilities on F-108, B-70, and A3J flight control systems; supervision of a Systems Engineering Unit responsible for air data computer and automatic landing system development; technical supervision of the Airborne Instruments Group, directing inertial and barometric flight control instrument selection, evaluation, and design; and project staff engineer in the Autonetics NAVAHO Project office with cognizance over autopilots and autonavigators. Mr. Yetter's initial assignment was with the Autopilot Group, where he worked in the field of magnetic amplifier development and stability analysis on autopilot systems. He is a member of the Institute of Electrical and Electronic Engineers, Tau Beta Pi, and Eta Kappa Num.

Education:

B.S., Electrical Engineering, Cornell University, 1950

M.S., Electrical Engineering, Yale University, 1951

5.6 PROJECT CONTROL PLAN

The Voyager Project Control Plan is based on the existing Boeing Integrated Management System. This concept, illustrated in Figure 5.6-1, encompasses a management control and reporting system that ties together the entire spectrum of work package definition, task assignment, schedules, and financial, manpower and subcontract controls. This system, tempered on other important DOD and NASA programs, has been tailored to meet specific Voyager requirements.

5.6.1 Integrated Management System

The Integrated Management System includes the primary program control techniques to be used on the Voyager Spacecraft System as well as the mechanism for developing, reporting and presenting data needed for program evaluation and direction. The following discussion summarizes the most significant features of the Integrated Management System to be used for Phases IB and II.

The Statement of Work provides definitive customer direction concerning the program mission, objectives, schedules, documentation requirements, and report requirements. It establishes the baseline for all subsequent program activities. The Statement of Work should be definitive and its terms and conditions mutually agreed to by all parties.

To facilitate detailed task evaluation, the Statement of Work is translated by Boeing into a Program Breakdown Structure. This delineation of the Statement of Work establishes the relationship between major tasks and work packages and becomes the basis for functional task definitions.

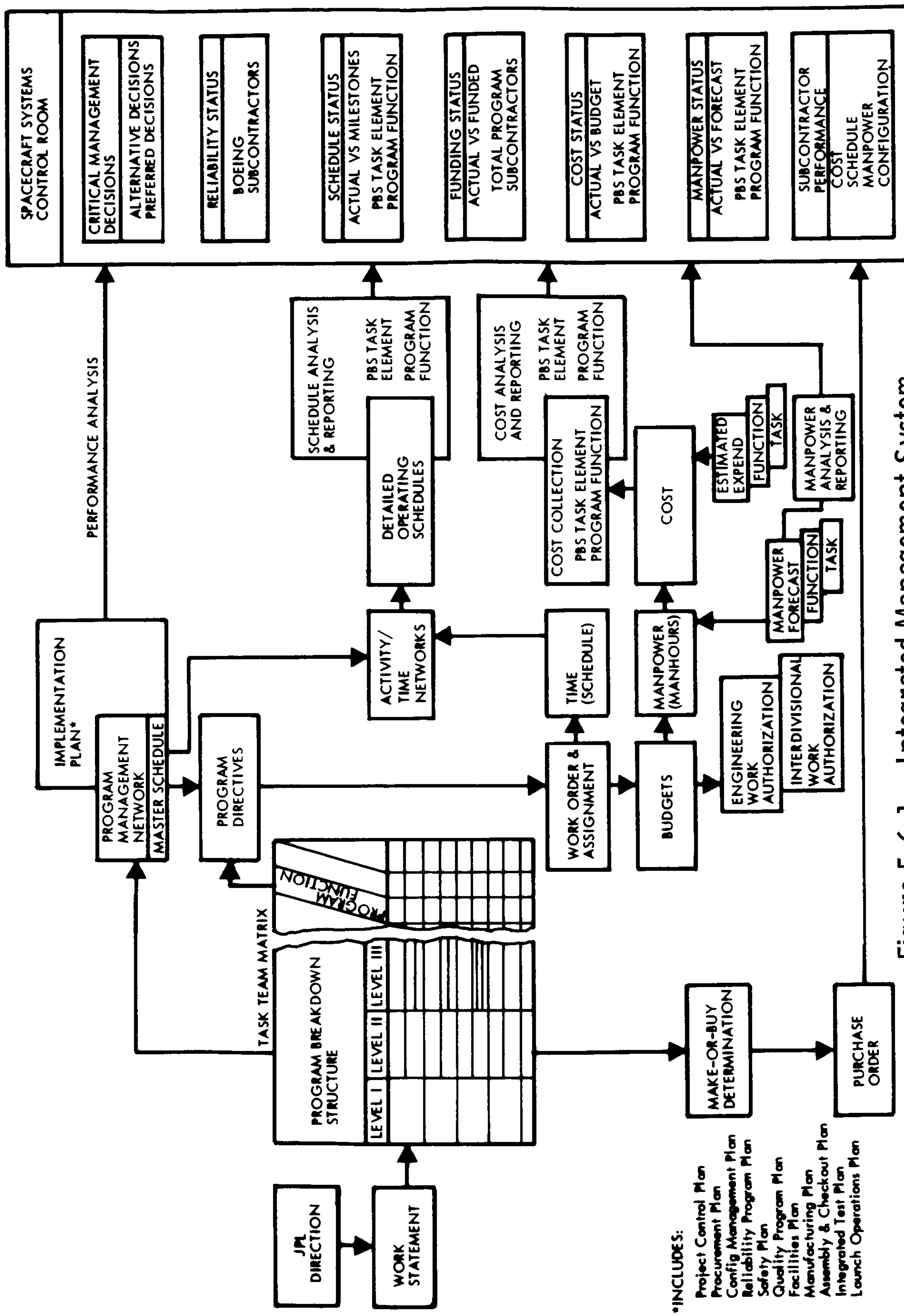


Figure 5.6-1: Integrated Management System

*INCLUDES:
Project Control Plan
Procurement Plan
Config Management Plan
Reliability Program Plan
Safety Plan
Quality Program Plan
Facilities Plan
Manufacturing Plan
Assembly & Checkout Plan
Integrated Test Plan
Launch Operations Plan

A task team matrix is constructed to extend the Program Breakdown Structure to: 1) identify prime and support functional area responsibility for each program task or package; 2) identify the interrelationship of prime and support functions; 3) permit the evaluation of functional performance in detail, either by task or by function; and 4) provide a baseline for planning, scheduling, and budgeting activities in each affected functional area.

Master schedules provide a display of significant milestones and program phasing. The milestones are obtained from specific dates or flow times prescribed by the customer in the contract or RFP Statement of Work and from an evaluation of event/logic relationships to scheduled task completion. These schedules provide the framework for preparing detail schedules which will identify detail tasks, time-phased to support the master schedules. Detail and master schedules will reflect constraining dates set by the Statement of Work or by the Program Manager.

The Program Breakdown Structure extended by the Task Team Matrix plus the program schedules provides the necessary tools for assigning and scheduling work, both on a task and on a functional basis. The systems and controls for authorizing work and for monitoring and controlling output are reflected on Figure 5.6-1. Combined cost and schedule status will be displayed in the program control room. (The program control room is described in Section 5.6.3.2 below.)

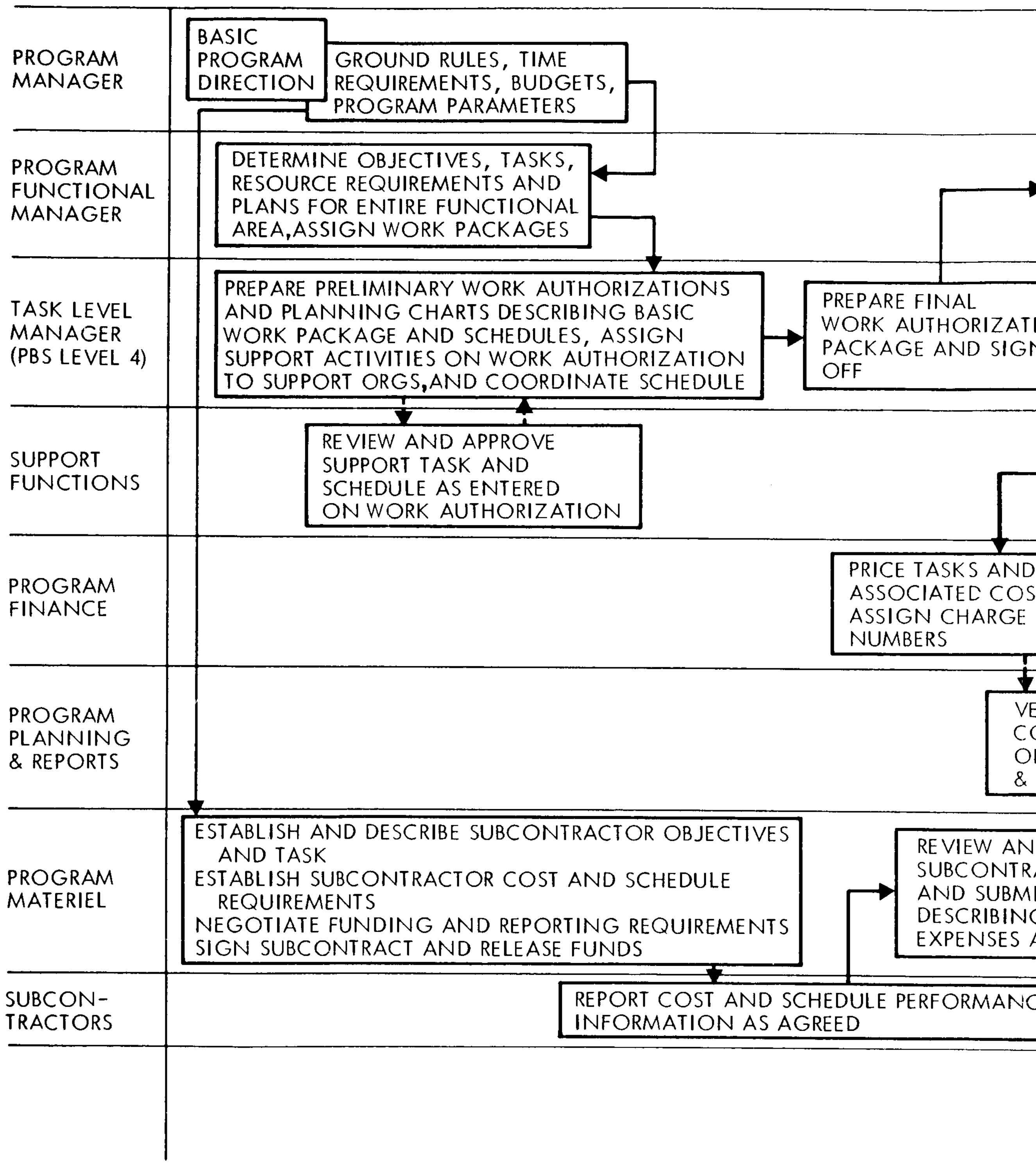
The Implementation Plan is a composite of several corollary plans (see Figure 5.6-1), the Master Schedule, the Program Breakdown Structure, the Task Team Matrix, and the Statement of Work. These documents provide the baseline information and detailed narrative description of what is to be done, how and when it will be accomplished, the functional and support area responsibilities, and how the effort will be controlled.

5.6.2 Financial Control System

The Voyager Spacecraft System will utilize standard Boeing finance practices to manage its financial affairs. The Boeing system employs proven, effective methods for allocating and controlling direct and indirect budgets, collecting and reporting costs and for developing the data needed for timely and effective financial control. Figure 5.6-2 illustrates the system for managing direct costs.

Upon receipt of the contract, the Program Manager will establish operating budgets for each program functional manger. Budgets will be based on labor and non-labor cost estimates previously developed for the work packages included in the task team matrix. Following management review and approval, these cost estimates become the work package budgets and form the basis for the Program Manager's allocation of contract funds.

The Aero-Space Division has an effective dollar budgeting system for the control of overhead costs. Total dollar budgets are established


PROGRAM MANAGER
BASIC PROGRAM DIRECTION
GROUND RULES, TIME REQUIREMENTS, BUDGETS, PROGRAM PARAMETERS
PROGRAM FUNCTIONAL MANAGER
DETERMINE OBJECTIVES, TASKS, RESOURCE REQUIREMENTS AND PLANS FOR ENTIRE FUNCTIONAL AREA,ASSIGN WORK PACKAGES
TASK LEVEL MANAGER (PBS LEVEL 4)
PREPARE PRELIMINARY WORK AUTHORIZATIONS AND PLANNING CHARTS DESCRIBING BASIC WORK PACKAGE AND SCHEDULES, ASSIGN SUPPORT ACTIVITIES ON WORK AUTHORIZATION TO SUPPORT ORGS,AND COORDINATE SCHEDULE
PREPARE FINAL WORK AUTHORIZATI PACKAGE AND SIGN OFF
SUPPORT FUNCTIONS
REVIEW AND APPROVE SUPPORT TASK AND SCHEDULE AS ENTERED ON WORK AUTHORIZATION
PROGRAM FINANCE
PRICE TASKS AND ASSOCIATED COS ASSIGN CHARGE NUMBERS
PROGRAM PLANNING & REPORTS
VE CO OI &
PROGRAM MATERIEL
ESTABLISH AND DESCRIBE SUBCONTRACTOR OBJECTIVES AND TASK
ESTABLISH SUBCONTRACTOR COST AND SCHEDULE REQUIREMENTS
NEGOTIATE FUNDING AND REPORTING REQUIREMENTS
SIGN SUBCONTRACT AND RELEASE FUNDS
REVIEW AN SUBCONTR AND SUBMI DESCRIBING EXPENSES A
SUBCON-TRACTORS
REPORT COST AND SCHEDULE PERFORMANC INFORMATION AS AGREED

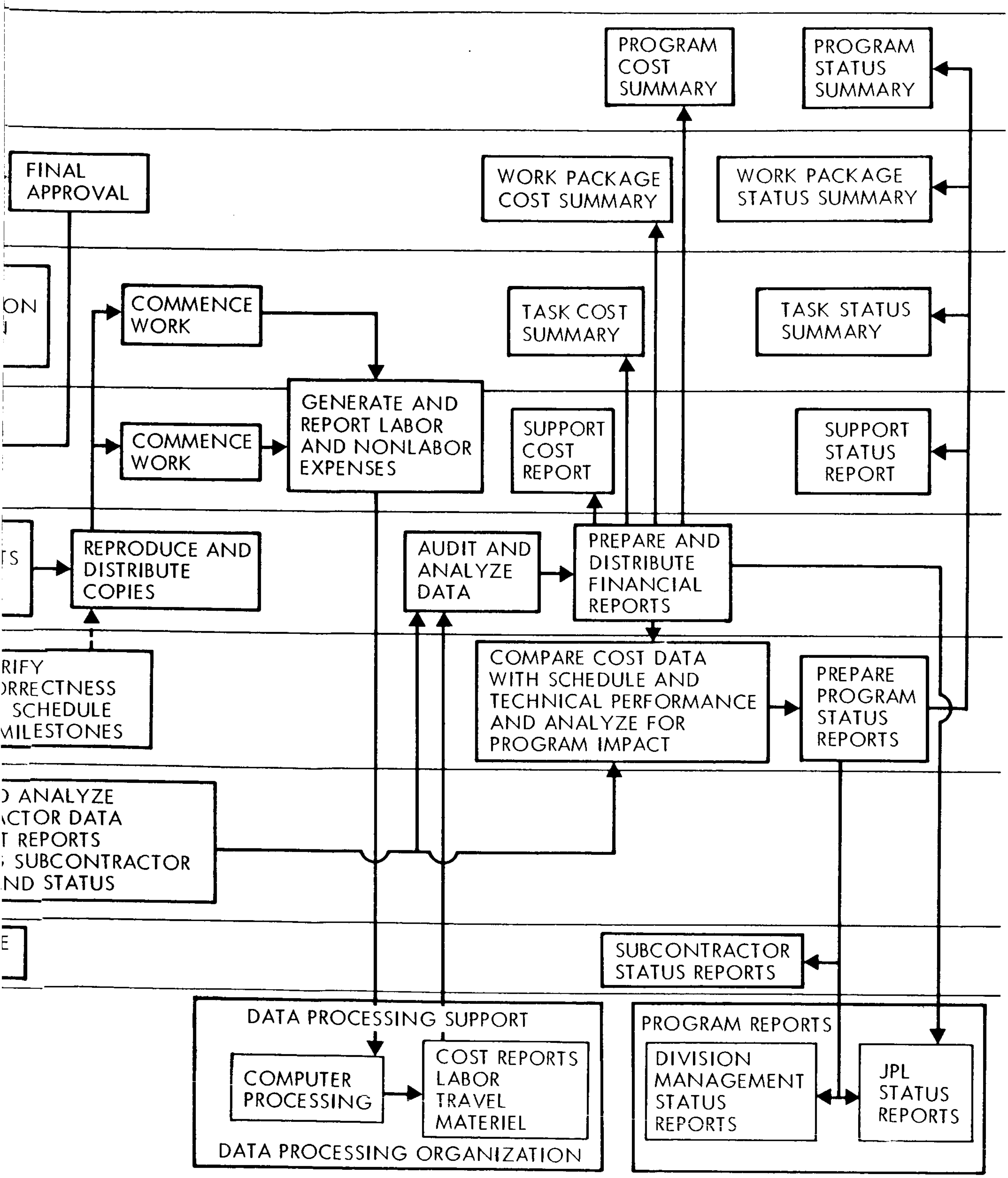


Figure 5.6-2: Direct-Cost Management System

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for functional organizations and programs. The Program Manager has primary responsibility for controlling his assigned overhead budget. Although he apportions his overhead budget dollars among his functional managers, he retains primary responsibility for operating within his total budget.

5.6.3 Program Control Techniques

Two of the most effective control techniques for assuring coordinated, knowledgeable management of complex programs are 1) a comprehensive command media system, flexible enough to encompass basic company direction as well as being responsive to more specialized program needs, and 2) a program control room which centralizes, interrelates and displays in one convenient location all the data necessary for knowledgeable program management. Both of these techniques are discussed below. In addition, the key factors of the program reporting and direction system are described.

5.6.3.1 Command Media

The Boeing command media system is the formal structure for providing written policy and procedural direction to company personnel. It provides for continuity of direction and uniformity of practice at all levels of the organization from the corporate office to the operating divisions. Existing Aero-Space Division command media will be supplemented by internal policies or procedures as necessary to satisfy Voyager Spacecraft System requirements.

5.6.3.2 Program Control Room

The program control room is the focal point for providing the visibility necessary for effective program management. The control room includes carefully selected, graphically displayed in-house and subcontractor cost, schedule and technical performance data. This data, updated weekly, reflects the latest program status and provides a basis for management and customer decision-making and redirection.

The control room presentation stresses "management by exception" by selecting data which highlights trends and identifies deviations from targets. This technique enables the Program Manager, program functional managers, Boeing subcontractors, and JPL to anticipate and avert potential management problems. Here, the Program Manager and his program functional managers convene to review program status, assign action items and determine needed redirection based on complete, current knowledge of program status. Division and corporate executives also participate in program evaluation and decision-making reflecting close attention to Voyager activities by top company executives.

The control room will include a list of critical items, at the subsystem level, in the areas of design, fabrication, and testing which are crucial to program success. This list will be updated regularly and will be monitored by the Program Manager. The list will be available to JPL on request.

The program control room satisfies the Project Control Center requirements outlined in the Phase II specimen Statement of Work. In addition, it is designed so that it can easily be integrated into an overall system of JPL project control such as the one discussed in Section 5.14.

Voyager Spacecraft System direction and redirection is accomplished using a closed loop, completely integrated system. It achieves positive management control by selecting key elements of operating data, collecting these via the cost reporting system or by exception reports, processing and reporting them to the Program Manager and to program functional managers, who close the loop by providing appropriate direction or redirection.

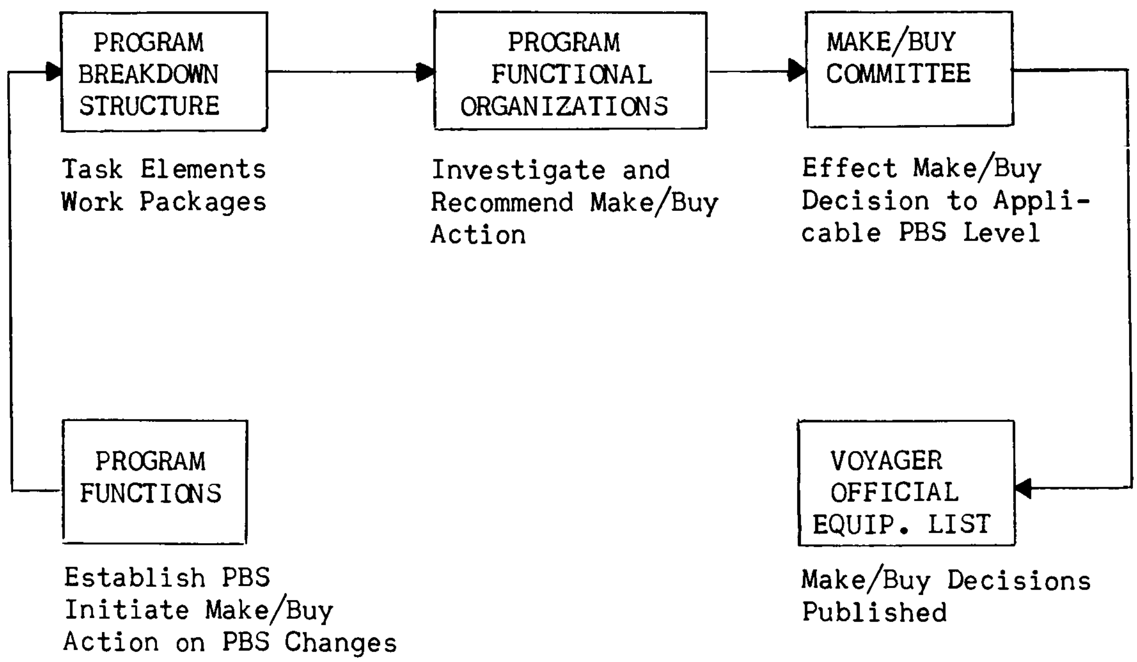
5.6.4 Resources Control System

The Aero-Space Division maintains a central data bank of information relating to the background and experience of all members of management and engineers. This data bank covers 30 different fields with related speciality and functional information for approximately 500 different technical and business areas. It is screened regularly to determine the availability of personnel who have skills and experience applicable to the Voyager Spacecraft System gained from their participation on such successful programs as HiBEX, Lunar Orbiter, Minuteman and Saturn.

Existing systems will be used to authorize, assign, modify and control facility resources. Initial facility requirements have been identified, assigned and time-phased. Mechanized control status systems are used to monitor progress involving new purchases, installation, modification and maintenance.

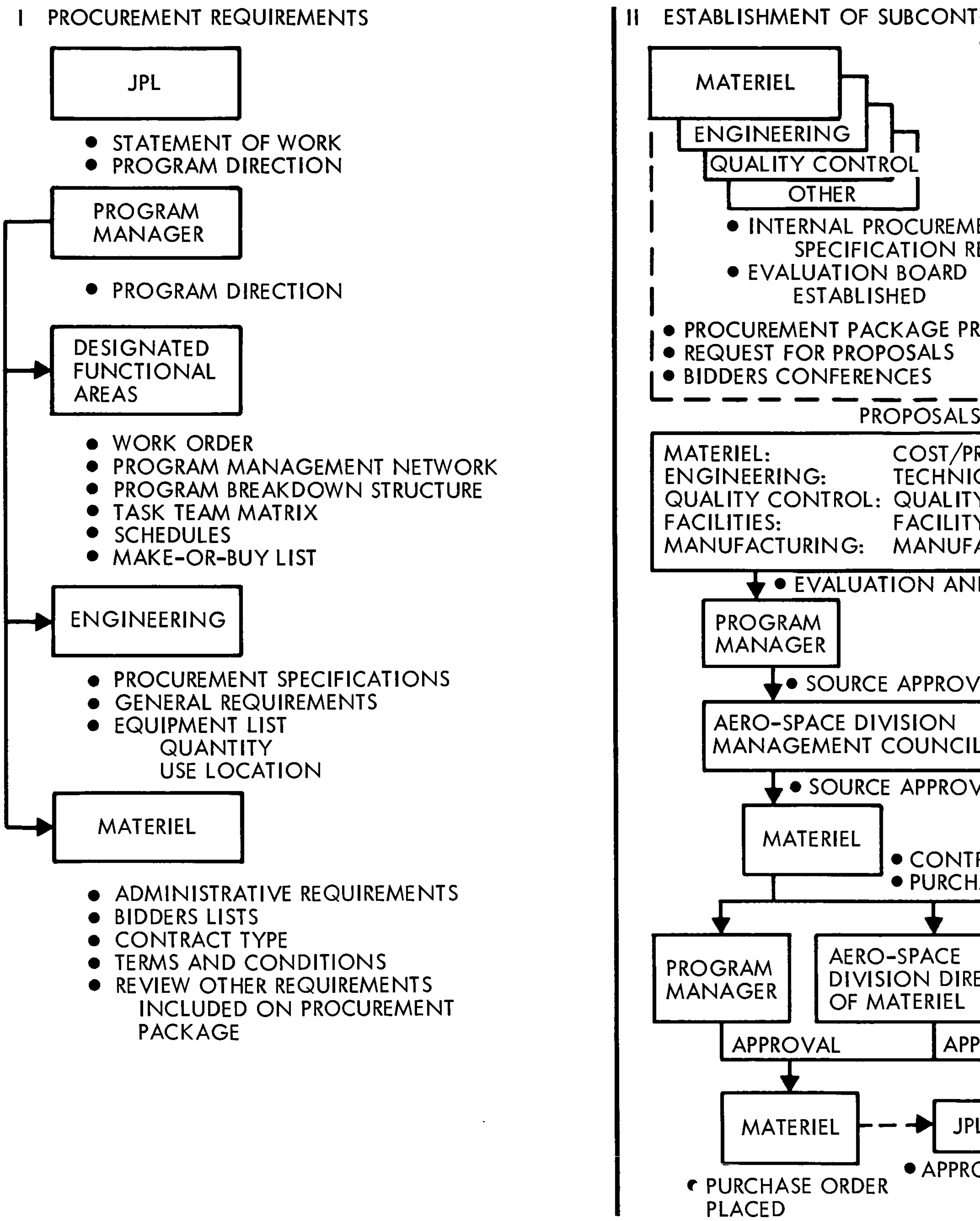
5.6.5 Make-or-Buy System

The Voyager Spacecraft System Make-or-Buy Management Committee is established. The committee is chaired by the Voyager Spacecraft System Program Manager with key management representatives from each concerned program function. The make-or-buy decision cycle is shown below:



5.6.6 Subcontractor Control System

Subcontractor management will be the prime responsibility of the Voyager Spacecraft System Materiel Manager. He will receive direct support from all other program functions with primary assistance from the Engineering, Reliability, and Quality Control Managers. Figure 5.6-3 illustrates the sequence of activity from the establishment of procurement requirements


I PROCUREMENT REQUIREMENTS
JPL
• STATEMENT OF WORK
• PROGRAM DIRECTION
PROGRAM MANAGER
• PROGRAM DIRECTION
DESIGNATED FUNCTIONAL AREAS
• WORK ORDER
• PROGRAM MANAGEMENT NETWORK
• PROGRAM BREAKDOWN STRUCTURE
• TASK TEAM MATRIX
• SCHEDULES
• MAKE-OR-BUY LIST
ENGINEERING
• PROCUREMENT SPECIFICATIONS
• GENERAL REQUIREMENTS
• EQUIPMENT LIST
QUANTITY
USE LOCATION
MATERIEL
• ADMINISTRATIVE REQUIREMENTS
• BIDDERS LISTS
• CONTRACT TYPE
• TERMS AND CONDITIONS
• REVIEW OTHER REQUIREMENTS INCLUDED ON PROCUREMENT PACKAGE
II ESTABLISHMENT OF SUBCONT
MATERIEL
ENGINEERING
QUALITY CONTROL
OTHER
• INTERNAL PROCUREM
SPECIFICATION R
• EVALUATION BOARD
ESTABLISHED
• PROCUREMENT PACKAGE PR
• REQUEST FOR PROPOSALS
• BIDDERS CONFERENCES
PROPOSALS
MATERIEL: COST/PR
ENGINEERING: TECHNI
QUALITY CONTROL: QUALIT
FACILITIES: FACILIT
MANUFACTURING: MANUF
• EVALUATION AN
PROGRAM MANAGER
• SOURCE APPROV
AERO-SPACE DIVISION MANAGEMENT COUNCIL
• SOURCE APPROV
MATERIEL
• CONT
• PURCH
PROGRAM MANAGER
AERO-SPACE DIVISION DIRE OF MATERIEL
APPROVAL
APP
MATERIEL
JPL
• APPRO
• PURCHASE ORDER PLACED

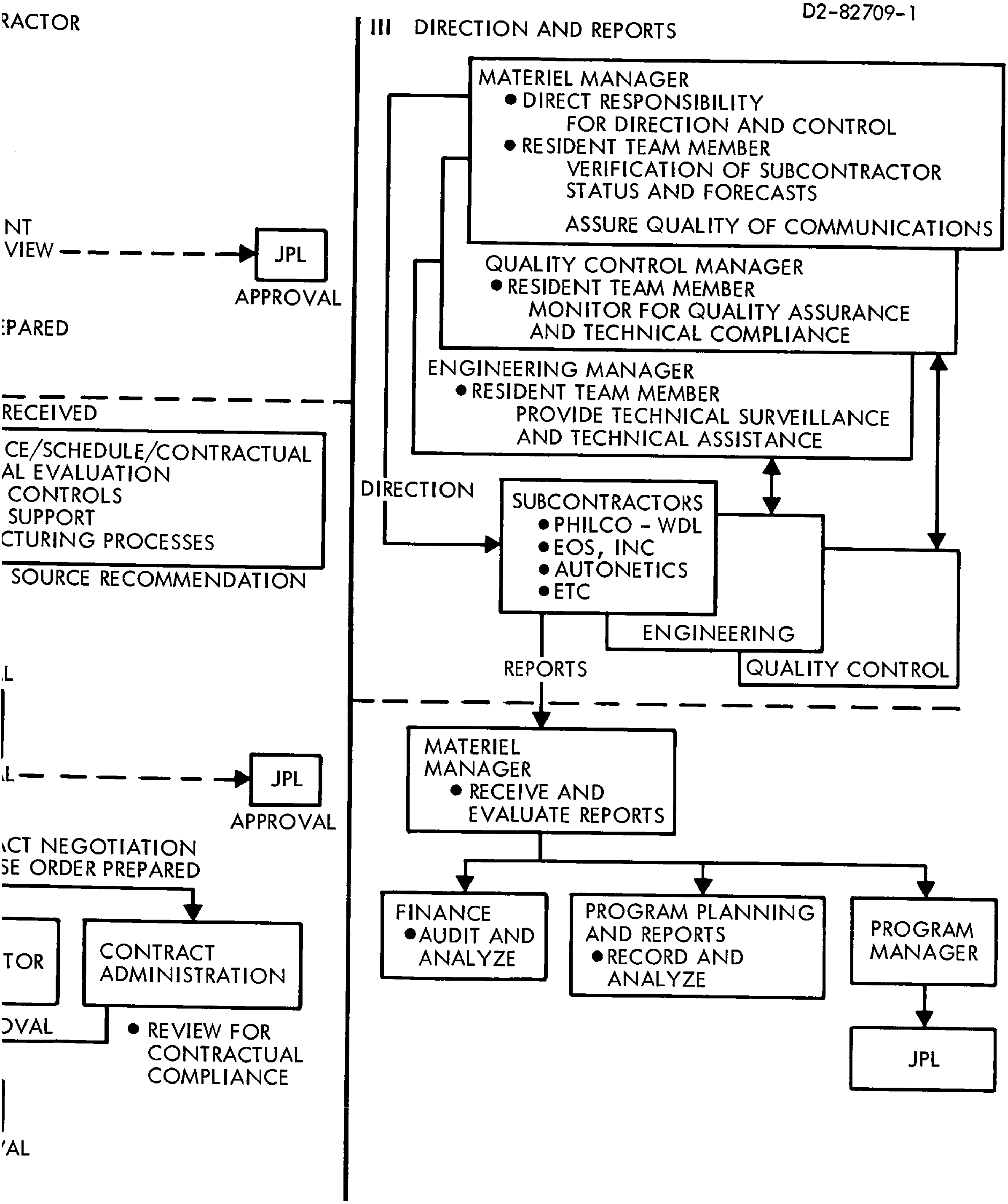


Figure 5.6-3: Subcontractor Implementation-and-Control System

2

through the selection of subcontractors to specific subcontractor administration and control.

5.7 PRODUCT ASSURANCE

Voyager Spacecraft mission success is directly related to the emphasis accorded product assurance disciplines throughout each phase of the program. The Voyager product assurance function has been established to guarantee the required Spacecraft System integrity.

The Product Assurance Manager will report directly to the Spacecraft System Program Manager, and will be responsible for directing and integrating Boeing and subcontractor quality assurance, reliability, safety and configuration management and control functions.

There are several overriding considerations in a complex spacecraft program such as Voyager. These considerations include: (1) the high cost of a single launch, (2) the limited opportunities for launch, (3) the long mission duration with its requirement for high reliability and (4) the complexity of the overall spacecraft system itself with opportunities for reducing the probability of mission success during the long process from design through launch.

To effectively combat the many potential sources of failure, Boeing has established a management function to integrate the required disciplines under the title of Product Assurance. This function will include:

1) Configuration Management, to maintain configuration control without which all the other disciplines become ineffectual;
2) Reliability, to provide design assurance;
3) Quality assurance, to assure the precise translation of designs into hardware, plus those additional measures required to preserve the integrity of the design through launch; and

4) Safety to assure freedom from hazards to personnel and equipment during all phases of the program.

The Product Assurance Manager will integrate and direct these disciplines through:

1) Policy dissemination;
2) Issuance of program plans, procedures, and budget;
3) Dissemination of reliability, safety, configuration control and quality requirements;
4) Dissemination of requirements for data reporting, analysis and documentation;
5) Establishment of a product assurance data central; and
6) Integrated program reviews and status reporting.

Using the integrated record system, the Product Assurance Data Central, and the Cognizant Engineer assigned to the subsystems as sources of information, the Product Assurance Manager maintains current status of product configuration, reliability, quality and safety. He will supplement these sources with periodic unscheduled audits to measure the implementation of product assurance disciplines (i.e., reliability, safety, quality and configuration control), by the responsible line organizations.

Program reviews and status reporting to the customer and Boeing Management will be integrated under product assurance to provide a completely nonredundant picture of product status.

A key feature of the product assurance approach is the assignment of a Cognizant Engineer to each subsystem. He will live with the subsystem through establishment of customer requirements, design, fabrication, test, delivery and launch, and will be the instrument for: (1) monitoring the implementation of the total product assurance, (2) identifying and reporting problems, and (3) assuring adequate follow-up and close-out of problems.

5.8 QUALITY PROGRAM PLAN

The Quality Program Plan contains specific operating procedures for the control of quality from the design concept through delivery and operation of the Voyager Spacecraft and Operational Support Equipment. This plan is composed of a Quality Assurance and Quality Control System and will be submitted in detail form with the Phase IB proposal.

5.8.1 Quality Assurance System

The Quality Assurance (Q.A.) System concerns all actions necessary to provide confidence that the technical customer requirements exist in the finished product. Specific activities within the Q.A. System are:

1) Document the Quality Program Plan;
2) Manage a cognizant engineering function;
3) Develop implementing procedures for the Quality Program Plan;
4) Audit subcontractor and contractor functions;
5) Participate in Preliminary and Critical Design Reviews;
6) Assure that quality aspects are inherent in designs and test.

5.8.1.1 Quality Assurance Tasks

Quality Assurance tasks have been assigned to Engineering, Materiel, Manufacturing, Quality Control, and Systems Test to ensure compliance with quality program requirements. Procedures and directives documenting these tasks will be identified during Phase IB, along with a description of the means for implementing each task during Phase II and specific evidence of compliance. Random unannounced audits by Quality Assurance will be performed to measure the effectiveness of procedures and directives to properly control quality performance. Audits will be conducted in the area or location where the work is actually being performed and will measure compliance both qualitatively and quantitatively.

Analysis of audit results will provide the necessary visibility to program management to assess the adequacy of controls and to report the status of the Quality Program Plan. Periodic Quality Status and Audit Reports will itemize quality problems, tabulate data, and summarize corrective action.

5.8.1.2 Design Quality Assurance

Design planning procedures include: assignment of drawing and part numbers to ensure traceability; selection of materials or components, and establishment of fabrication processes to meet basic reliability and producibility objectives; and assignment of tolerances for quality characteristics.

Engineering requirements will be reviewed by Quality Assurance Cognizant Engineers to identify controls to achieve quality, indicate metrology requirements, define development needed, and verify inspectability and interchangeability. Formal Phase II design reviews will ensure that adequate quality assurance provisions have been incorporated. Change control procedures, imposed in the design flow, provide added assurance of configuration control at the system as well as at the component level.

Design quality assurance actions will reflect consideration of spacecraft and mission constraints in specifications and drawings. Critical characteristics, as dictated by spacecraft function, reliability, and interchangeability, will be reflected in design parameters and quality standards.

When a Voyager manufacturing process is considered reliability sensitive, or when quality cannot be assured by nondestructive tests and only process controls will assure quality, specific instructions are documented for the process.

5.8.1.3 Subcontractor Quality Assurance Provisions

Specific quality assurance requirements will be contractually imposed on each subcontractor through procurement documents reviewed and signed by Quality personnel. Subcontractors will be surveyed for their knowledge, understanding, and ability to design and produce subsystem hardware consistent with Boeing quality assurance requirements. Review and approval of subcontractor drawings, specifications, and inspection and test procedures will confirm that prime contract provisions are satisfied.

Measurement of subcontractor quality performance and planned quality audits conducted at each subcontractor's facilities by Boeing Quality personnel will verify performance of his quality assurance system.

5.8.2 Quality Control System

The Quality Control (Q.C.) System will provide documented evidence that produced articles comply with predetermined design and specification requirements. Specific objectives of this system will be:

1) Demonstrate through measurement and test the quality present in deliverable end items from design and procurement through fabrication and test;
2) Document configuration status, change accountability, and materials traceability;
3) Control special processes through certification and monitoring of facilities and training and certification of personnel;
4) Record actions including human errors affecting the quality of spacecraft hardware and OSE;
5) Collect failure data, perform necessary investigations, and take required corrective action to prevent recurrence;
6) Maintain calibration and certification control of measurement and test equipment;
7) Participate in Preliminary and Critical Design Reviews.

5.8.2.1 Quality Control in Procured and Fabricated Articles

Purchased materials and components inspected at Boeing will undergo preplanned inspection and tests to verify conformance to procurement documents and agreement with supplier designs, test reports, records, and packing sheets.

The quality of workmanship required throughout fabrication, assembly, and test will be designated in material and process specifications as well as in drawings and test documents. This information will be provided to shop personnel in fabrication and inspection planning records, reviewed and signed by Quality personnel. These records are checked against latest drawing releases at time of release for fabrication and at each hardware inspection point. Flow diagrams will illustrate in detail the fabrication and assembly sequence; designate the inspection and test points; and identify the characteristic to be measured, measurement methods, and tolerance requirements.

Release and control of materials used in fabrication and assembly will be in accordance with Voyager-approved material specifications and work instructions. Specific Voyager-oriented equipment and personnel qualification and certification, including requalification and recertification at prescribed intervals will be enforced. Personnel certification will be based on satisfactory completion of approved training courses.

5.8.2.2 Test and Inspection Control of End Items

Test and inspection of deliverable end item hardware will be controlled through use of integrated test sequences. Tests will be implemented at the parts, components, subsystem, and system level to provide the specified degree of quality assurance. Special attention will be given to assure that human errors are recorded and analyzed for corrective action and impact on the integrity of spacecraft hardware. Flight acceptance test results will be compared with design criteria to assure that each end item has been fabricated and assembled in accordance with design specifications and is compatible with OSE.

Complete records and results of end item test and inspection will be maintained to provide objective evidence of compliance with end item specifications, test documents, and detail drawing requirements.

Records used in fabrication, assembly, and test will be summarized on a Configuration Accountability Record. Inspection and test data will be available for review at time of delivery. Demonstration will be made to JPL that spacecraft hardware and OSE configuration is reflected in delivery records.

5.9 RELIABILITY PROGRAM PLAN

A controlled reliability program in conjunction with selective use of redundancy will provide assurance of mission success. Complete freedom in the use of redundancy is not possible within the constraints of spacecraft envelope, weight, and power. Section 6.0 of this volume contains the analyses supporting the design optimization for the Voyager Spacecraft System Phase IA definition study. The reliability program will provide:

1) Thorough system engineering with reliability analyses and trades to optimize design and the use of redundancy.
2) The use of screened high-reliability parts and effective materials and process controls.
3) Highly disciplined design with part application reviews; electrical, thermal and mechanical stress analyses; a.c., d.c. and transient worst-case analyses; and design reviews.
4) Physics-of-failure analysis techniques to predict failure modes and assist the design of effective screens, as well as to analyze failures and identify needed corrective actions.
5) An integrated test program including component, subsystem, and system type approval tests, equipment burn-in, life testing and mission simulation.
6) Effective subcontractor and supplier reliability controls.

5.9.1 Reliability Program Management

The Voyager Reliability Program, initially implemented during Phase IA, will reach full implementation during Phase IB. Major documentation for implementation and control of the reliability program is shown in

Figure 5.9-1. Policies and directives disciplining the Boeing designs and the procurement of components and subsystems will be released at the beginning of Phase IB. Reliability training and motivation programs will be initiated early in Phase IB for engineering personnel and expanded in Phase II to include manufacturing, quality control and test personnel. Key milestones of the program implementation are shown in Section 5.4.

5.9.1.1 Subcontractor and Supplier Control

Success of the Voyager program depends to a large extent on the performance of the major subcontractors and suppliers. Boeing requires all subcontractors and suppliers to adhere to the same reliability disciplines which it imposes upon itself. These disciplines will be monitored and audited by Boeing to assure compliance.

Reliability participates through the Cognizant Engineer in supplier surveys, ratings, and selections and provides technical representation at suppliers' plants to monitor reliability programs for critical equipment.

5.9.1.2 Program Control

The detailed Reliability Program Plan will identify each reliability task, assign responsibility for its execution and specify the evidence of completion.

5.9.1.3 Program Reviews

Scheduled program reviews will be conducted as formal JPL/Boeing monitoring points. Quarterly reviews are planned in Phase II with more frequent reviews during the critical IB phase. These reviews are part of the

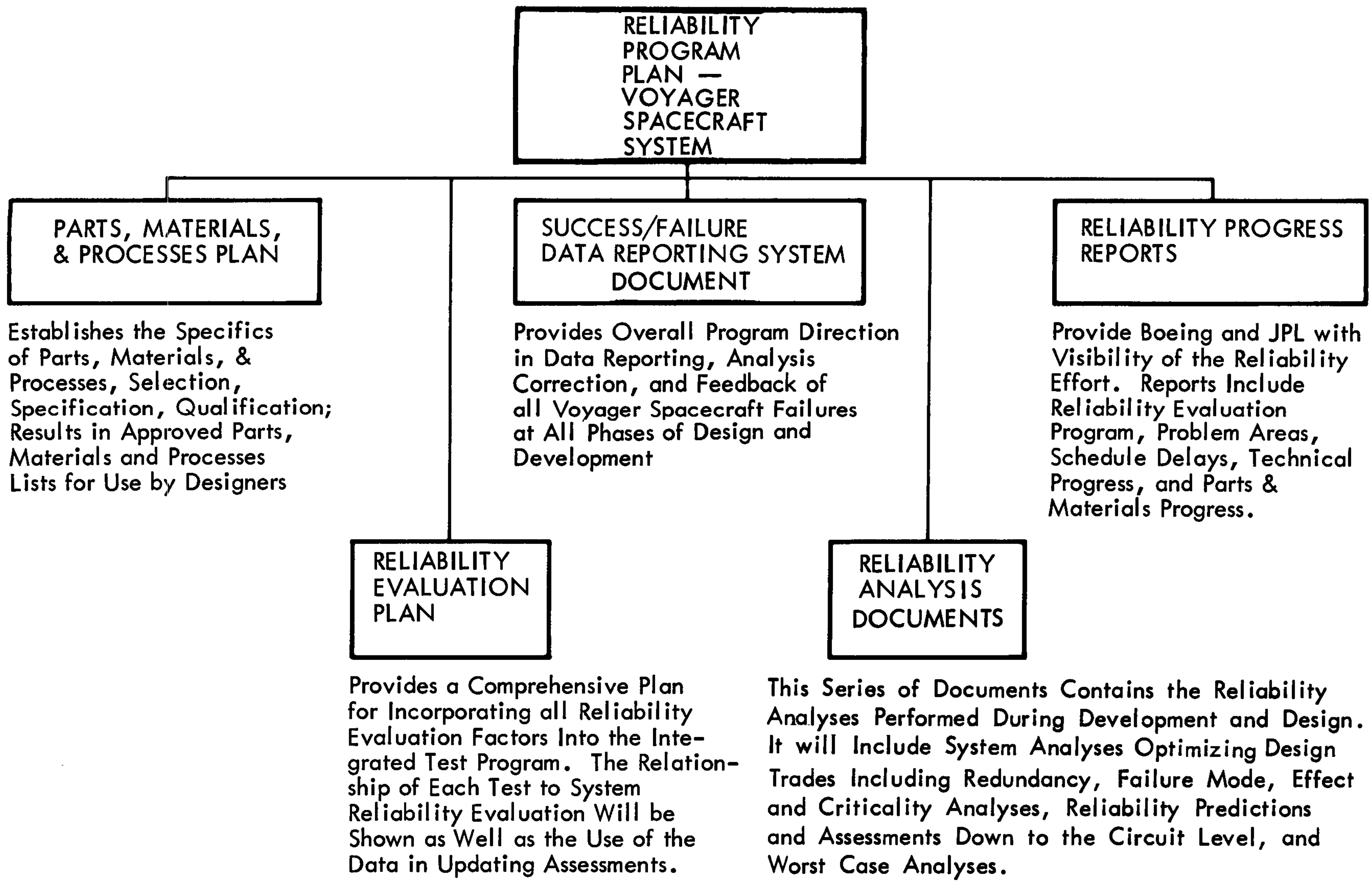


Figure 5.9-1: Reliability Program Documentation

overall product assurance loop described in Section 5.7. They present status of Boeing and subcontractor reliability effort, and provide for effective program adjustment or redirection.

5.9.1.4 Status Reporting

Reliability program status reports include:

1) Weekly Reliability Program Summaries--Brief reports to JPL transmitted by teletype or as prescribed by JPL. They contain highlights of the week's progress such as completions, unscheduled meetings and problem areas.
2) Quarterly Progress Reports--The formal reliability report to JPL containing detailed reliability technical progress during the preceding 3-month period, and detailed information on problem areas and schedule performance.

5.9.1.5 Training

Reliability training is planned for all Voyager personnel whose work directly affects reliability. This training is designed to acquaint each employee with the part reliability plays in a successful Voyager mission and his personal potential contribution to that goal.

5.9.1.6 Parts, Materials and Processes Program

The use of parts and materials will be controlled to maximize quality and standardization. A minimum of part and material types necessary to satisfy design requirements will be maintained as a goal, and emphasized in the training program for designers. The use of parts or materials other than those on the Voyager approved lists must be formally requested, justified, and provisions must be made for their qualification to Voyager requirements.

5.9.1.7 Data Central

A Data Central will be established in Phase IB and maintained as the central agency for all product assurance data and documentation. The activities of Data Central include:

1) Definition and implementation of electronic data programs for processing, presentation, storage and retrieval of data,
2) Failure data collection, collation and presentation,
3) Identification of reliability trends and problem areas and monitoring of analyses and corrective actions,
4) Preparation of status reports for management.

5.9.1.8 Failure Analysis and Recurrence Prevention

All failures of parts, components or subsystems occurring during acceptance testing, assembly, and component, subsystem, and system tests at the factory and the launch site will be formally reported and analyzed. The cause of failure will be identified and appropriate corrective action to prevent recurrence initiated and monitored through to completion. Physics-of-failure analyses will be performed where sophisticated diagnosis of electronics part failure is required to determine the cause. Failure data will be collected and processed by Data Central to present visibility of the effectiveness of the recurrence prevention program.

5.10 CONFIGURATION MANAGEMENT PLAN

Configuration Management is defined as a systematic way of identifying, controlling and accounting for the configuration of a product. It relates to all activities that influence determination of physical and functional characteristics of that product. It includes the control of compliance to (a) the contractual definition, and (b) all specifications, drawings, and documentation used in conjunction with the development, testing and use of that product.

Boeing believes in using proven Configuration Management practices to assure the maintenance of system configuration integrity through an end-to-end control of configuration. This control begins with the establishment of a systems requirements baseline and continues through the development and design stages, procurement, fabrication and test to the end of a system's life.

Configuration Management practices developed and refined by Boeing have been used successfully in the Minuteman and Saturn Programs and are now being used effectively on the Lunar Orbiter Program. These practices recognize the unique requirements of space programs and feature basic configuration requirements for programs requiring rapid reaction to change while maintaining stringent control.

This subsection summarizes the Configuration Management Plan approach recommended for the Voyager Spacecraft System. Boeing is prepared to use variations or modifications to this approach suited to JPL's needs. In this respect Boeing recognizes the existence of JPL's Integrated Information System (IIS) and Central Data Bank.

The Configuration Management Plan will be expanded in the Phase IB Proposal for use during Phases IB and II. During Phase IB, the plan will be modified as directed by JPL and the approved portions applicable to Phase IB implemented according to the Contractual Statement of Work. Boeing will be responsible for requiring its suppliers to comply with the approved Configuration Management Plan. The description and implementation of the plan covers the three major areas that make up configuration management--i.e., identification, control, and accounting.

5.10.1 Configuration Identification

Configuration identification will be required to completely define and identify the Voyager Spacecraft System in terms of its subsystems, hardware, and software; software being all specifications, drawings, documentation and other data required to define a product.

5.10.1.1 Voyager Spacecraft System Specifications

The Voyager 1971 Mission Specification, planned for publication by JPL in the fourth quarter of 1965 will technically define the Spacecraft System.

Each subsystem or piece of equipment designated as a deliverable contract end-item will be technically defined by end-item design and detail specifications.

5.10.1.2 Specifications Maintenance Control

Boeing will establish a specification control center at the start of Phase IB for specification maintenance control. The control center will provide specification number control.

Boeing will use standard identification numbers in accordance with established company procedures to identify spacecraft system configurations during Phase IB and II.

5.10.1.3 Engineering Drawings

Boeing's established drawing procedures, set forth in Corporate Procedures Manual D-4900, will be used for the spacecraft system. These procedures comply with the requirements of Military Specification MIL-D-70327 as amended.

5.10.2 Configuration Control

The major tools of Configuration Control are Baseline Control, Engineering Release Control, Change Control, Interface Control, and Formal Configuration Management Reviews.

5.10.2.1 Baseline Control

Configuration baselines will be established to define formal departure points for future changes in performance and design. It is assumed that JPL will use the following baselines for the definition and acquisition of the spacecraft system; i.e., (1) the Project/System Requirements Baseline; (2) the Design Requirements Baseline; (3) the Drawing Baseline; and (4) the Product Configuration Baseline. Changes to these baselines will be made as directed by JPL.

5.10.2.2 Engineering Release and Records Control System

At the start of Phase IB, Boeing shall establish and implement an Engineering Release and Records Control System in accordance with established Boeing procedures used successfully on other programs.

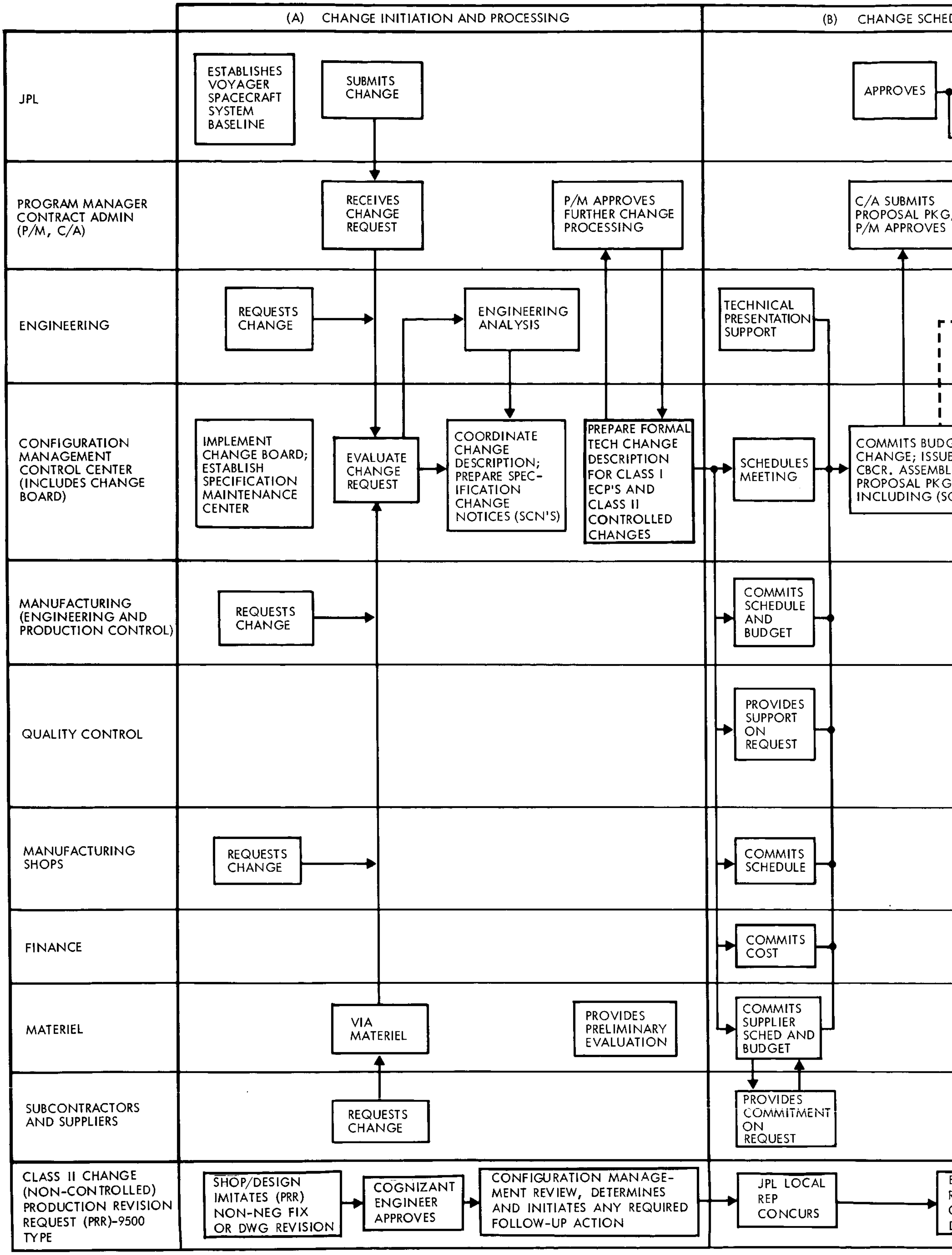
5.10.2.3 Change Control

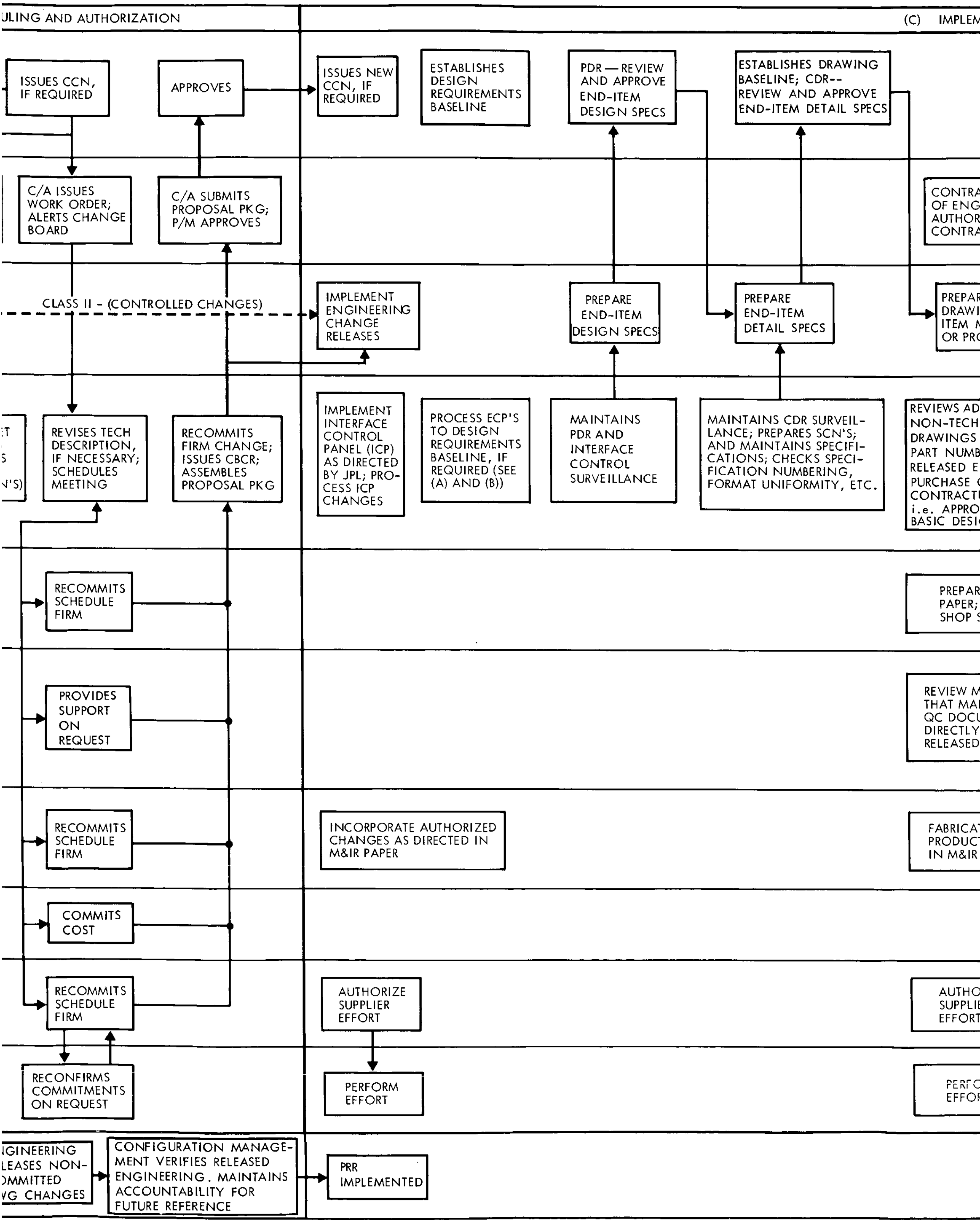
Change Control is the controlled management of engineering design changes to a product and its associated documentation from the time changes are initiated to the time they are incorporated into the product and accounted for in the change record system. Class I changes or deviations from the approved configuration will not be incorporated until they are properly processed through JPL for approval. Class II non-negotiable changes will be processed through the local NASA/JPL representative prior to incorporation.

<u>Change Control and Implementation</u>--A Configuration Control Center will be established at the beginning of Phase II to exercise primary cognizance over the hardware and software configuration of the flight spacecraft, test models, OSE and associated facilities. The activities of the Change Control Board will be coordinated by the Configuration Control Center. Figure 5.10-1 shows the flow for controlling and processing Class I and II changes as well as the disciplines required to insure the kind of configuration management considered necessary for the Voyager Spacecraft System.

5.10.2.4 Interface Control

During Phase IB, an examination of the Voyager 1971 mission specifications, functional flows, schematic diagrams, functional specifications, design specifications, and layout drawings will result in the identification of


(A) CHANGE INITIATION AND PROCESSING
(B) CHANGE SCHED
JPL
PROGRAM MANAGER CONTRACT ADMIN (P/M, C/A)
ENGINEERING
CONFIGURATION MANAGEMENT CONTROL CENTER (INCLUDES CHANGE BOARD)
MANUFACTURING (ENGINEERING AND PRODUCTION CONTROL)
QUALITY CONTROL
MANUFACTURING SHOPS
FINANCE
MATERIEL
SUBCONTRACTORS AND SUPPLIERS
CLASS II CHANGE (NON-CONTROLLED) PRODUCTION REVISION REQUEST (PRR)-9500 TYPE
ESTABLISHES VOYAGER SPACECRAFT SYSTEM BASELINE
SUBMITS CHANGE
APPROVES
RECEIVES CHANGE REQUEST
P/M APPROVES FURTHER CHANGE PROCESSING
C/A SUBMITS PROPOSAL PKG, P/M APPROVES
REQUESTS CHANGE
ENGINEERING ANALYSIS
TECHNICAL PRESENTATION SUPPORT
IMPLEMENT CHANGE BOARD; ESTABLISH SPECIFICATION MAINTENANCE CENTER
EVALUATE CHANGE REQUEST
COORDINATE CHANGE DESCRIPTION; PREPARE SPECIFICATION CHANGE NOTICES (SCN'S)
PREPARE FORMAL TECH CHANGE DESCRIPTION FOR CLASS I ECP'S AND CLASS II CONTROLLED CHANGES
SCHEDULES MEETING
COMMITS BUDG CHANGE; ISSUE CBCR. ASSEMBL PROPOSAL PKG INCLUDING (SC
REQUESTS CHANGE
COMMITS SCHEDULE AND BUDGET
PROVIDES SUPPORT ON REQUEST
REQUESTS CHANGE
COMMITS SCHEDULE
COMMITS COST
VIA MATERIEL
PROVIDES PRELIMINARY EVALUATION
COMMITS SUPPLIER SCHED AND BUDGET
REQUESTS CHANGE
PROVIDES COMMITMENT ON REQUEST
SHOP/DESIGN IMITATES (PRR) NON-NEG FIX OR DWG REVISION
COGNIZANT ENGINEER APPROVES
CONFIGURATION MANAGEMENT REVIEW, DETERMINES AND INITIATES ANY REQUIRED FOLLOW-UP ACTION
JPL LOCAL REP CONCURS



ULING AND AUTHORIZATION
(C) IMPLEM
ISSUES CCN, IF REQUIRED
APPROVES
ISSUES NEW CCN, IF REQUIRED
ESTABLISHES DESIGN REQUIREMENTS BASELINE
PDR — REVIEW AND APPROVE END-ITEM DESIGN SPECS
ESTABLISHES DRAWING BASELINE; CDR-- REVIEW AND APPROVE END-ITEM DETAIL SPECS
C/A ISSUES WORK ORDER; ALERTS CHANGE BOARD
C/A SUBMITS PROPOSAL PKG; P/M APPROVES
CONTRA OF ENG AUTHOR CONTRA
CLASS II - (CONTROLLED CHANGES)
IMPLEMENT ENGINEERING CHANGE RELEASES
PREPARE END-ITEM DESIGN SPECS
PREPARE END-ITEM DETAIL SPECS
PREPAR DRAWI ITEM N OR PRO
REVISES TECH DESCRIPTION, IF NECESSARY; SCHEDULES MEETING
RECOMMITS FIRM CHANGE; ISSUES CBCR; ASSEMBLES PROPOSAL PKG
IMPLEMENT INTERFACE CONTROL PANEL (ICP) AS DIRECTED BY JPL; PROCESS ICP CHANGES
PROCESS ECP'S TO DESIGN REQUIREMENTS BASELINE, IF REQUIRED (SEE (A) AND (B))
MAINTAINS PDR AND INTERFACE CONTROL SURVEILLANCE
MAINTAINS CDR SURVEILLANCE; PREPARES SCN'S; AND MAINTAINS SPECIFICATIONS; CHECKS SPECIFICATION NUMBERING, FORMAT UNIFORMITY, ETC.
REVIEWS AD NON-TECH DRAWINGS PART NUMB RELEASED E PURCHASE C CONTRACTU i.e. APPRO BASIC DESI
RECOMMITS SCHEDULE FIRM
PREPAR PAPER; SHOP S
PROVIDES SUPPORT ON REQUEST
REVIEW M THAT MA QC DOCU DIRECTLY RELEASED
RECOMMITS SCHEDULE FIRM
INCORPORATE AUTHORIZED CHANGES AS DIRECTED IN M&IR PAPER
FABRICA PRODUC IN M&IR
COMMITS COST
RECOMMITS SCHEDULE FIRM
AUTHORIZE SUPPLIER EFFORT
AUTHO SUPPLIE EFFORT
RECONFIRMS COMMITMENTS ON REQUEST
PERFORM EFFORT
PERFO EFFOR
IGINEERING LEASES NON- OMMITTED VG CHANGES
CONFIGURATION MANAGEMENT VERIFIES RELEASED ENGINEERING. MAINTAINS ACCOUNTABILITY FOR FUTURE REFERENCE
PRR IMPLEMENTED

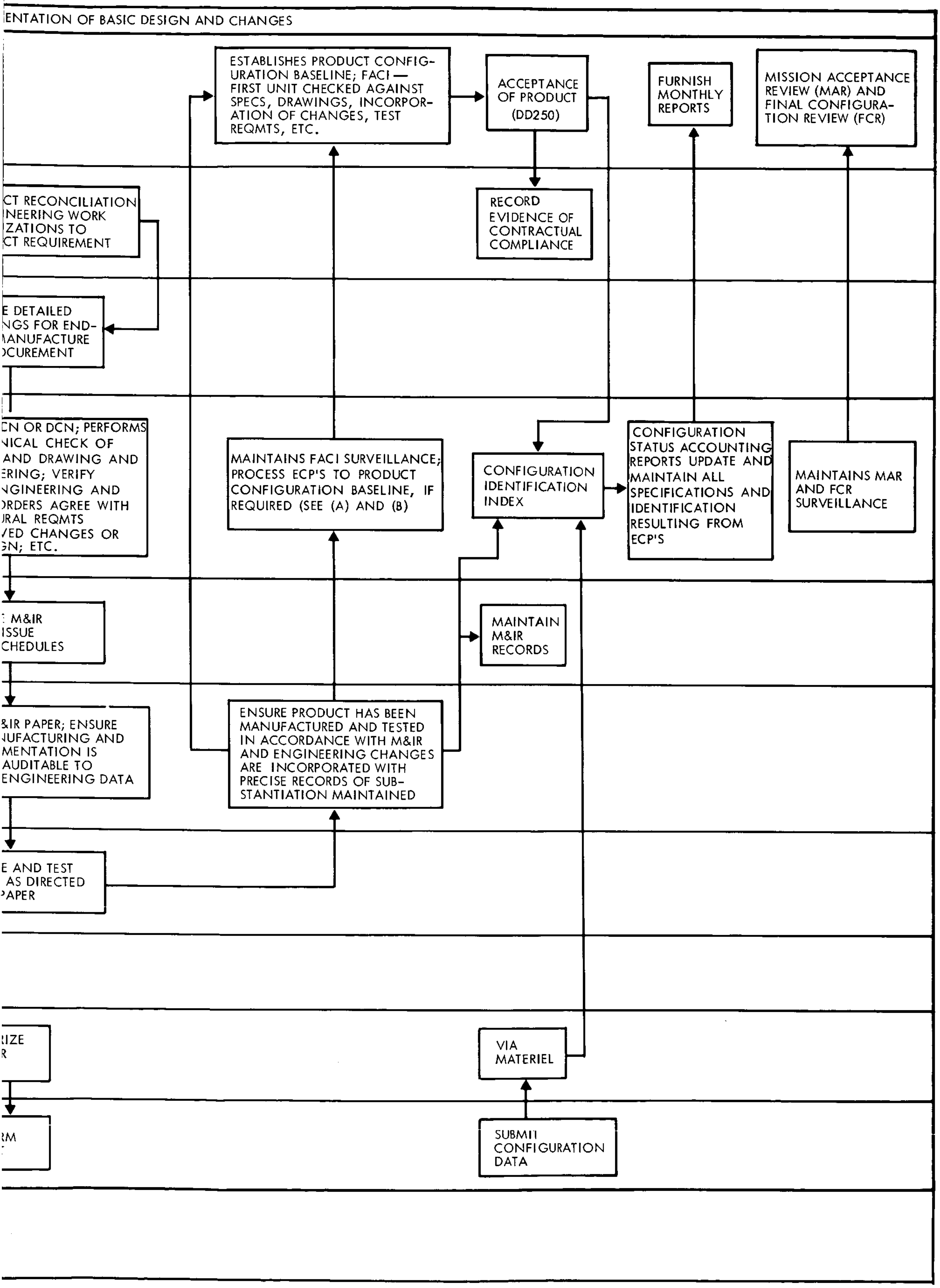


Figure 5.10-1: Voyager Spacecraft System Configuration Management

3

interface control areas. Interface control documents and supporting interface control drawings will be used as required.

Interface Control Relationships with Other Voyager Contractors--Boeing will establish interface control relationships with other Voyager contractors as directed by JPL. In the event that an Interface Control Panel (ICP) is established by JPL at the Project level, Boeing will furnish representation to the panel.

5.10.2.5 Formal Configuration Management Reviews

Formal Configuration Management Reviews are a series of technical reviews conducted by JPL for the purpose of identifying and approving specific configuration data at discrete points in the Spacecraft System.

Preliminary Design Review (PDR)--At the start of Phase II, preliminary design reviews (PDRs) of the "Basic Design Approach" will be held by JPL to review and approve the design specifications for the spacecraft components and subsystems and for the flight spacecraft and OSE.

Critical Design Review (CDR)--Prior to initiating manufacture, critical design reviews (CDRs) of spacecraft components and subsystems and the spacecraft and OSE will be held by JPL to approve detail specifications, drawings and data for fabrication release.

First Article Configuration Inspection (FACI)--A First Article Configuration Inspection (FACI) will be conducted by JPL to ensure that the first completed article is in accordance with the specifications and related engineering drawings and data. In view of the small quantity of articles to be produced, Boeing will establish a configuration inspection plan requiring inspections for each article.

Mission Acceptance Review (MAR)--A mission acceptance review of flight hardware will be conducted at Seattle by JPL prior to shipping to the Eastern Test Range (ETR). This review occurs after all test and training operations, with the exception of pre-launch operations, are completed.

Final Configuration Review (FCR)--Prior to the initiation of a simulated countdown, Boeing shall participate as required in the "Final Configuration Review" (FCR) if conducted by JPL at ETR.

Monitoring Status of Configuration Management Program Milestones--Boeing will schedule each PDR, CDR, FACI, MAR and FCR and will monitor the schedules for these milestones to assure that the configuration definition and status at each milestone is documented for future reference in the program.

5.10.3 Configuration Accounting

Boeing will implement a configuration accounting system that will provide the following:

1) Accounting of configuration identification documentation
2) Equipment configuration reports

Accounting of Configuration Identification Documentation--The functional and end-item design and detail specifications will be the prime document of configuration definition. The development of specifications will be monitored and accounted for from the assignment of the specification number through all approved changes to the specifications.

Equipment Configuration Reports--Configuration Identification Accounting and Status reports comprise a comprehensive system of equipment configuration reports which Boeing will use for the Spacecraft System. These reports can be modified to suit JPL. After Phase II starts, inputs will be made into Boeing's Configuration Accounting Report and submitted to JPL on a monthly basis.

5.11 SAFETY PLAN

Analysis of the Voyager 1971 Mission Specifications and the spacecraft configuration developed in Phase IA indicates that the required assurance of personnel and equipment safety can be achieved with a well planned and implemented safety program. No problems beyond the state-of-the-art in safety control are evident. For this system, even minor hazards capable of disabling equipment are recognized as significant threats to mission success because of the limited quantity of spacecraft and equipment available to support each launch opportunity. Boeing has developed effective safety methods for the potential problems evident in the pyrotechnics, propellants, high voltages, pressure vessels, and radioactive materials present, or likely to be present in the system.

5.11.1 Safety Program Implementation

The Voyager Safety Office will be implemented early in Phase IB during development of the design. Policies and directives will be released imposing safety disciplines on the design and procurement of equipment and subsystems. Analyses and trades will be performed during the IB development to optimize safety design and operational requirements. Conformance to the safety criteria will be confirmed during Phase IB at the subsystem Preliminary Design Reviews and during Phase II at the subsystem Critical Design Reviews. As test and operational data become available in Phase II, safety achievement relative to the goals will be assessed and corrective action initiated as warranted. Key milestones are shown in the schedules of Section 5.4, and the safety organizational relationship is shown in Section 5.5 of this volume.

5.11.1.1 Design Disciplines

Restraints on the Voyager Spacecraft System design for consideration of safety are discussed in Section 2 of this volume. Activities to implement and control these restraints are discussed below:

Directives--Program directives imposing the safety restraints on design will be released at the beginning of Phase IB.

Analyses--Analyses and trade-off studies will be conducted to optimize safety design and operational requirements. Qualitative analyses will be performed early in Phase IB to determine the potential hazards without regard to the probability of their occurrence. Potential hazards will be classified as to criticality and grouped by cause category. Improvement alternatives will be identified and preliminary safety design requirements established. Later in Phase IB, quantitative analyses will be performed to predict the probability of occurrence of undesired events. The "Fault Tree Analysis" technique will be used to identify and evaluate the most critical potential fault paths, determine the effects on the system and operating personnel and optimize the safety and cost trades. The fault tree analyses will use quantative data from the Reliability failure mode analyses. An example of the Fault Tree Analysis technique as applied to the undesired event of contaminating Mars is available in Section 3.7 of reference document D2-82724-1, Voyager Reliability.

Design Review--The Safety Office will provide active participation in all preliminary and critical design reviews to assure conformance to the established safety criteria. Action items will be initiated to correct deficiencies and monitored to completion.

5.11.1.2 Safety Assesement

Safety assessments will be performed from test and operational data collected during Phase II. When comparison of the assessed safety with the goals and requirements establishes the need for corrective action, systems safety shall recommend appropriate revision to the design or operational procedures and monitor corrective action through to completion. Assessment analyses and results of corrective actions will be documented and available to JPL.

5.11.1.3 Recurrence Prevention

The Safety Office personnel actively participate in investigations of all mishaps that have or could have resulted in personnel injury or equipment damage. After identification of the cause and analysis of preventive measures, corrective action will be initiated and monitored to completion. All such investigations and the results will be documented.

5.11.1.4 Personnel Health and Safety

The Boeing Corporate Health and Safety Policy will be effected to safeguard the personnel associated with the program. The use of hazardous materials is controlled. For example, the use of ethylene oxide is controlled by Industrial Hazard Control Bulletin No. 56.

5.12 PROCUREMENT PLAN

This sub-section summarizes major procurement tasks and how they are accomplished for the Boeing Voyager Spacecraft System program.

5.12.1 Buy Items Identified

Program requirements for procurement support are established by the Voyager Make or Buy Committee, which is chaired by the Voyager Spacecraft Program Manager. This committee is comprised of Voyager functional managers and Aerospace Division Planning and Engineering representatives. Each functional manager documents his recommendations to the committee and final decisions are based on the criteria shown on the "Make/Buy Data Record-Summary" which becomes the final Make/Buy documentation. See Figure 5.12-1.

5.12.2 Requirements of Each Procurement

Total requirements are established for each procurement. These requirements are described in specifications, documents, terms and conditions and proposal instructions.

The Voyager General Requirements Document identifies the systems a subcontractor must have to control reliability, quality, configuration, schedules, cost, and audit of these controls to assure they are being used. The design specification identifies specific function, configuration, performance, quality, reliability, maintainability, FAT test, and TAT test requirements. The Administration document describes the Boeing controls and working relationships required during the Administration of the contract. The proposal instructions identify quantities, schedules, methods of shipment, contract type and proposal time.

VOYAGER PROGRAM — MAKE-OR-BUY DATA RECORD —
SUMMARY — COMMITTEE CHAIRMAN

Authority ______________________________

Item Nomenclature ______________________________

Management Committee Decision: Make________ Buy________ GFE ________

Functional Representatives Recommendation: Make ______ Buy ______ GFE______

Est. Unit Cost ______________

Total Program Dollar Potential ____________ Percent Inplant Labor _____

Total Quantity ______

Decision Criteria	MAKE	BUY	GFE
1. Relative cost, contractor vs. potential subcontractor.			
2. Item critical to program mission.			
3. Development/Fabrication complexity.			
4. Critical schedule requirements			
5. Complexity of interfaces with other equipment.			
6. Availability of facilities, contractor vs. subcontractor.			
7. Similar to Boeing product line; and capability for end item delivery exists at Boeing.			
8. Special installation techniques or testing requirements are critical to performance and reliability.			
9. Off-the-shelf equipment or previously developed equipment meets requirements.			
10. Patent or proprietary rights involved.			
11. Potential for small business subcontractors.			
12. Subcontractors are available with a proven history of development and production in this field.			

Figure 5.12-1: Voyager Program — Make-Or-Buy Data Record — Summary — Committee Chairman

5.12.3 Selection of the Best Source to Meet Requirements

A source selection team, comprised of competent personnel with product experience applicable to the item being procured, from Engineering, Materiel, Quality Assurance, Manufacturing, and Finance is established. This team is responsible for evaluating industry capabilities against the requirements to develop bidders lists, select the source, negotiate the subcontract and obtain management approval of each decision as well as customer desired reviews and approvals of decisions. (See Figure 5.12-2)

5.12.4 Subcontract Controls

Control is maintained through contractual requirements for reports comparable to in-house reporting for subsystems such as:

1) Program plan and/or master phasing charts;
2) Subassembly and major assembly status charts;
3) Fabrication order status (actual vs. schedule);
4) Developmental, reliability and qualification test reports;
5) Management and technical progress reports;
6) Program hours and overtime reports;
7) Cost vs. schedule reports;
8) Procurement committments vs. available prime contract funds;
9) Preliminary Design Reviews;
10) Critical Design Reviews;
11) Quality Assurance Audits.

These reports, their evaluation, and action being taken on possible problem areas becomes part of the Voyager Spacecraft System Control Room data. See Figure 5.12-3 and 5.12-4.

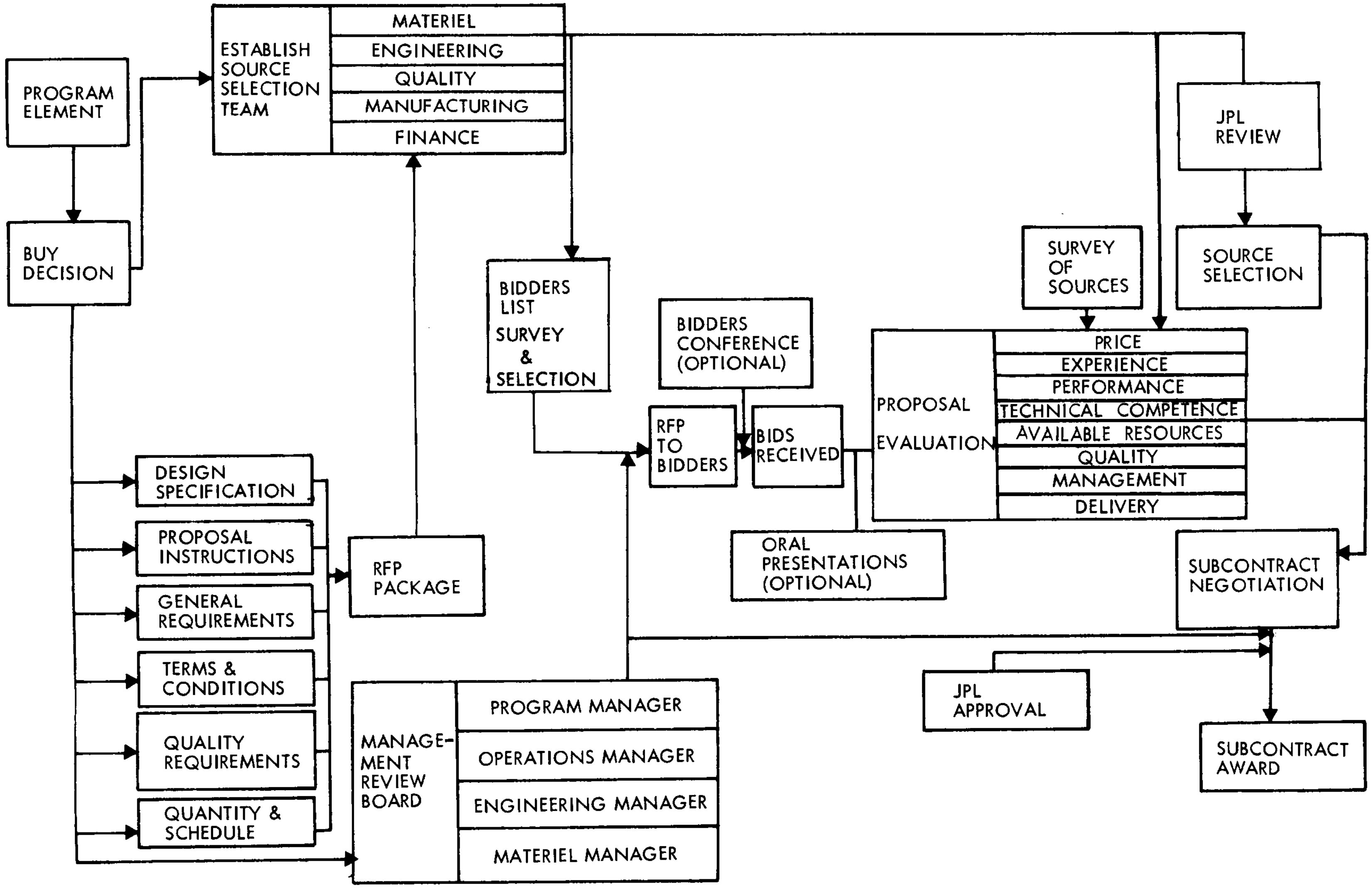


Figure 5.12-2: Source Selection

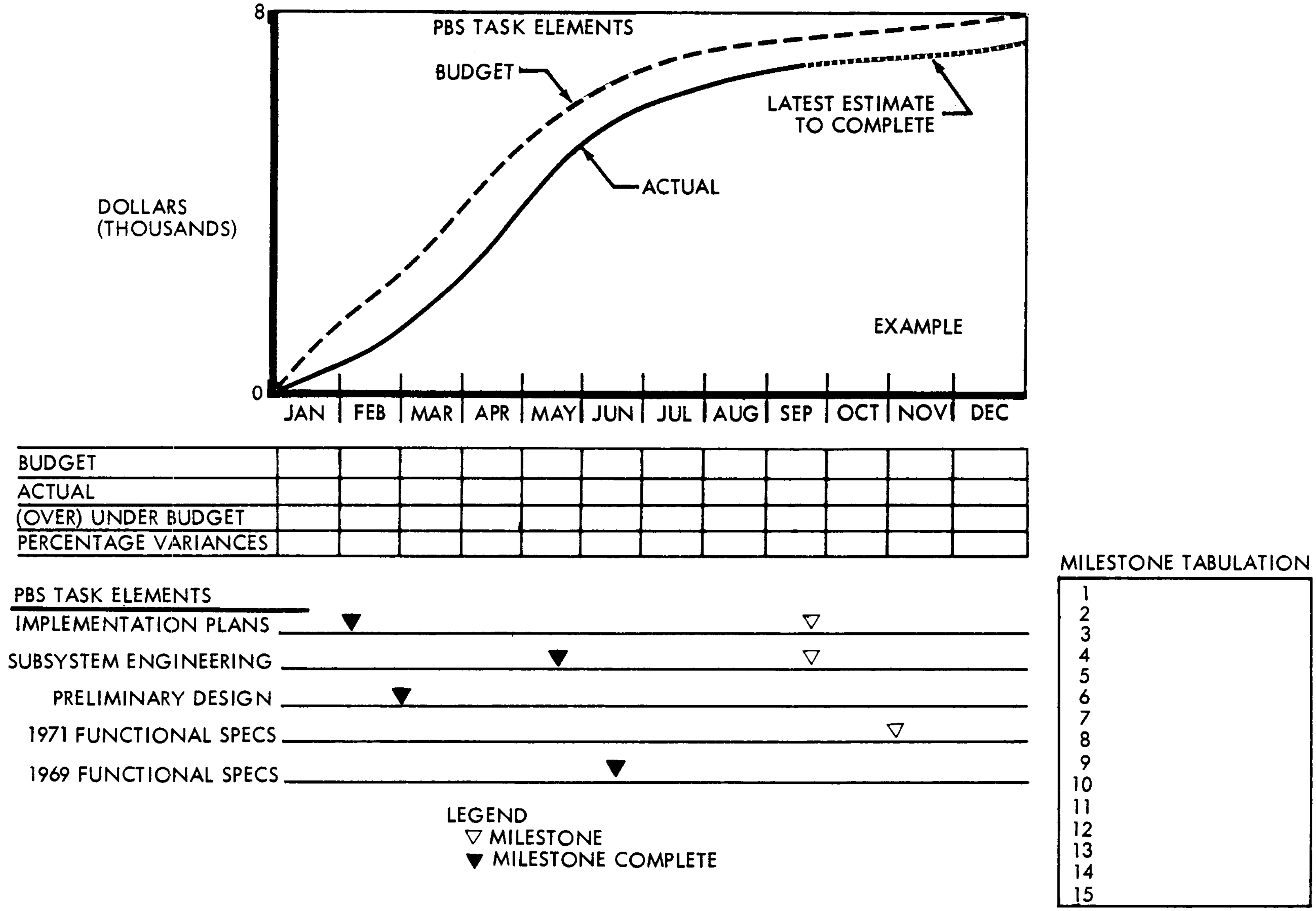
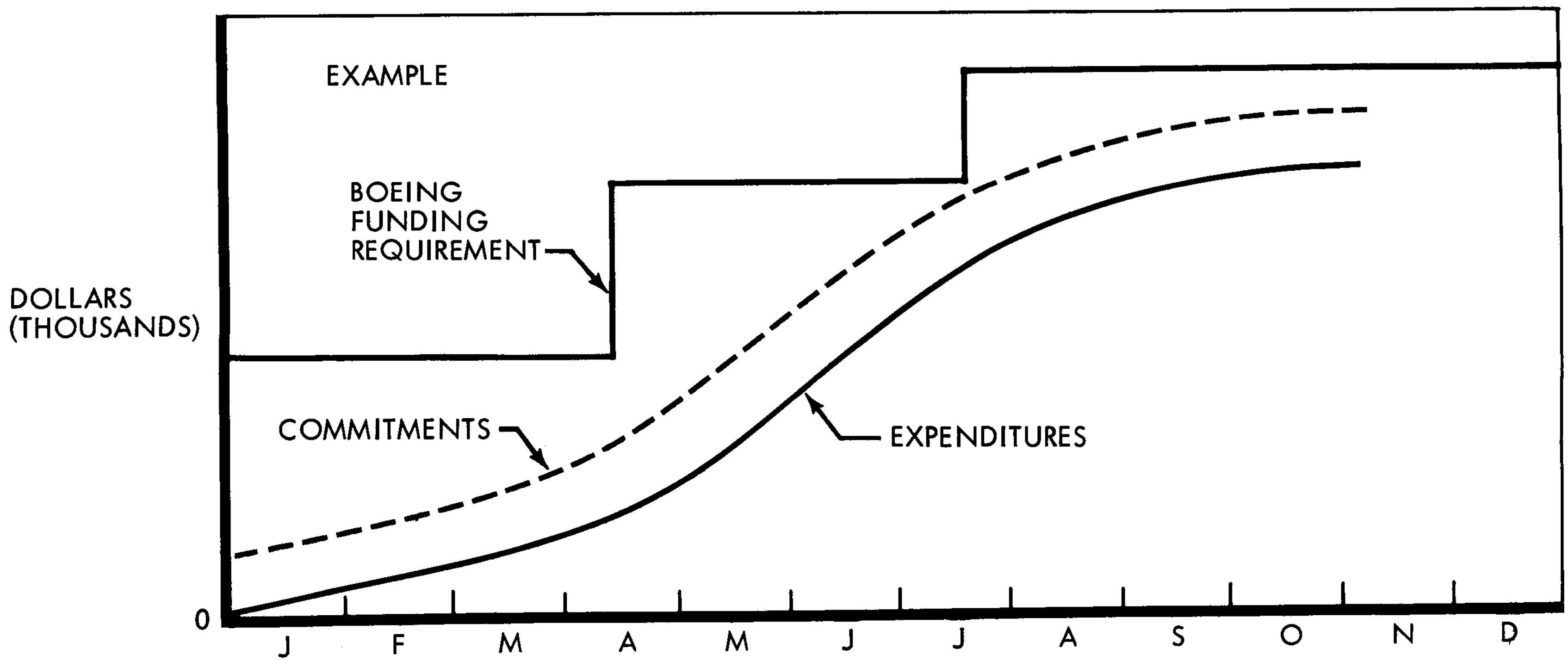


Figure 5.12-3: Voyager Subcontractor Expenditure and Schedule Status — Phases IB and II



CONTRACT TO DATE

	J	F	M	A	M	J	J	A	S	O	N	D
FUNDING												
COMMITMENTS												
(OVER) UNDER FUNDING												

Figure 5.12-4: Voyager Subcontractor Funding and Commitments — Phases IB and II

All subcontract changes involving either hardware or software are controlled by the Voyager Spacecraft System Change Control Board. Firm data is developed prior to change negotiations and subcontractor response times for estimated and firm commitments to cost and schedule changes are contractually established.

5.12.5 Subcontractor Surveillance

Continuous surveillance activities are accomplished by Quality Assurance, Engineering and Materiel personnel in residence at major subcontractors. Beoing Aero-Space Division field personnel accomplish Quality Control surveillance for small subcontracts and suppliers, Figure 5.12-5. These surveillance activities at supplier facilities are an extension of the "in-house" procurement teams and subcontract monitoring activities.

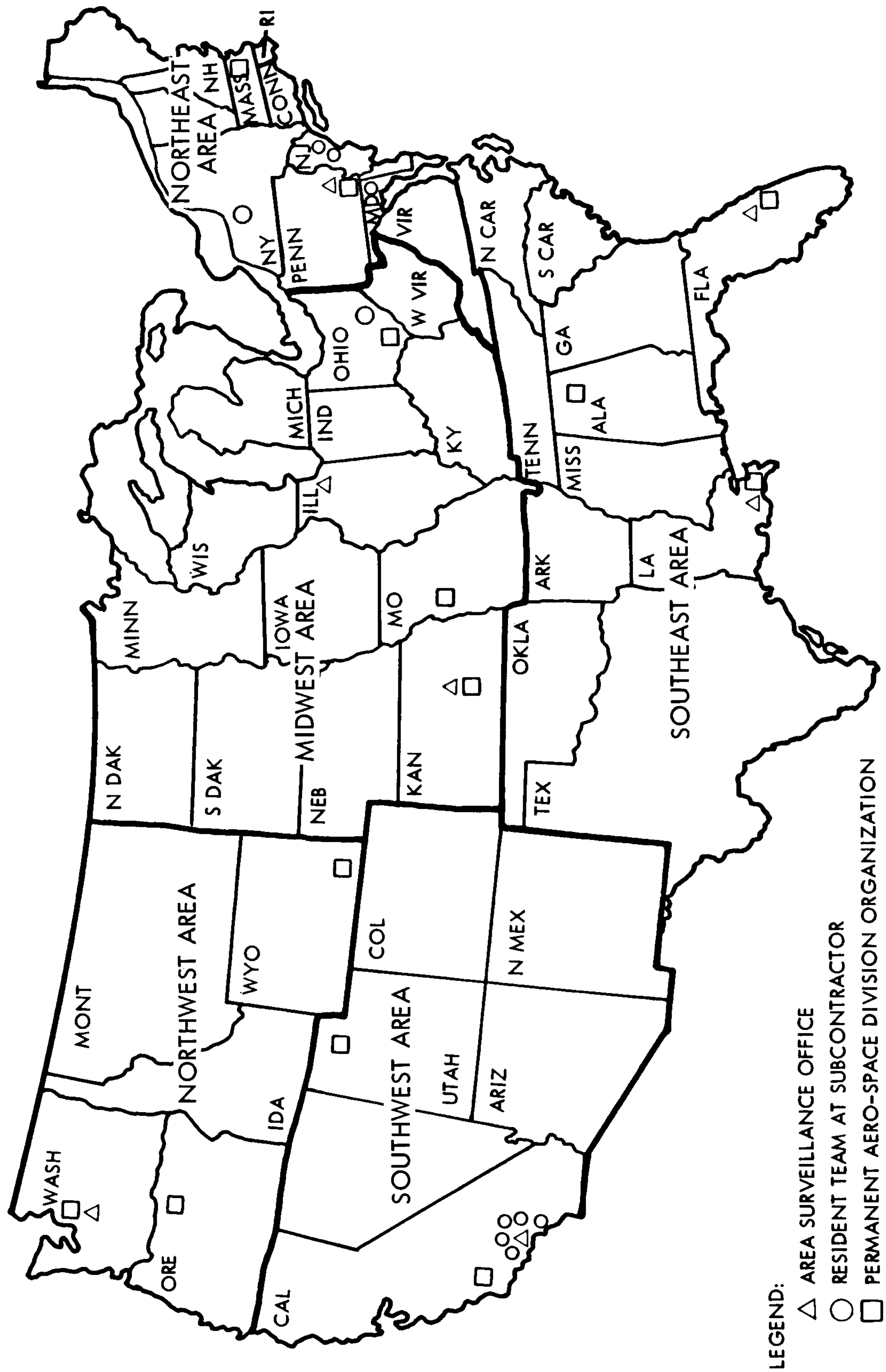


Figure 5.12-5: Location of Aero-Space Division Procurement Surveillance Capability—Materiel, Quality Assurance, and Engineering

5.13 MANUFACTURING PLAN

The plan for manufacture of the Voyager Spacecraft System provides for in-plant manufacture of structural components, for the assembly and installation of electrical/electronic components and systems manufactured both by Boeing and suppliers, and for the provisioning and integration of all Operational Support Equipment. The plan integrates quality control and systems test organizations at all required stages of fabrication, assembly, functional test and checkout. The Boeing facilities within which the various tasks will be accomplished are appropriate to the physical and environmental requirements of spacecraft fabrication and testing. The organizations responsible for the various functions are manned with skilled craftsmen in all areas of fabrication.

The manufacturing tasks for Phase II of the Voyager Spacecraft System are as follows:

1) The implementation of the manufacturing plans developed during Phase IB which provide direction for the fabrication and quality control in compliance with the engineering drawing and specifications.
2) The fabrication, assembly, checkout and quality acceptance of the Spacecraft Operational Support Equipment, and Special Tooling.
3) The documentation and maintenance of the manufacturing control media to accomplish configuration management and quality assurance.

5.13.1 Manufacturing Plans

Manufacturing plans originate during the preliminary design stages where qualified manufacturing engineering personnel, located in the design groups assist in the development of the product design as well as initiate early activities if required in the area of Manufacturing Development and Facilities Procurement.

Subsequent to the release of formal drawings through the engineering release system, detailed manufacturing plans and special tooling requirements are formally established on an Integrated Record System format. This format is used for configuration and quality control as well as historical record of events and is approved by quality assurance personnel prior to release. (Ref. Figure 5.13-1). Actual values within a given tolerance will be entered on the integrated records for all critical measurements.

The release of plans to the manufacturing and tooling shops initiates fabrication activity only after a concurrency audit against the engineering drawings. Revisions to these plans can be accomplished only by Manufacturing Engineering personnel through the use of personally assigned "planners stamps" on each change.

5.13.2 Tool Design and Fabrication

In accordance with the established tooling philosophy and upon receipt of engineering designs special tool design drawings will be prepared for fabrication of all major jigs and fixtures, including provisions for coordination to design master tooling when essential to the requirements for interchangeability. Standards for design of handling equipment other than OSE and special considerations regarding the magnetic influence

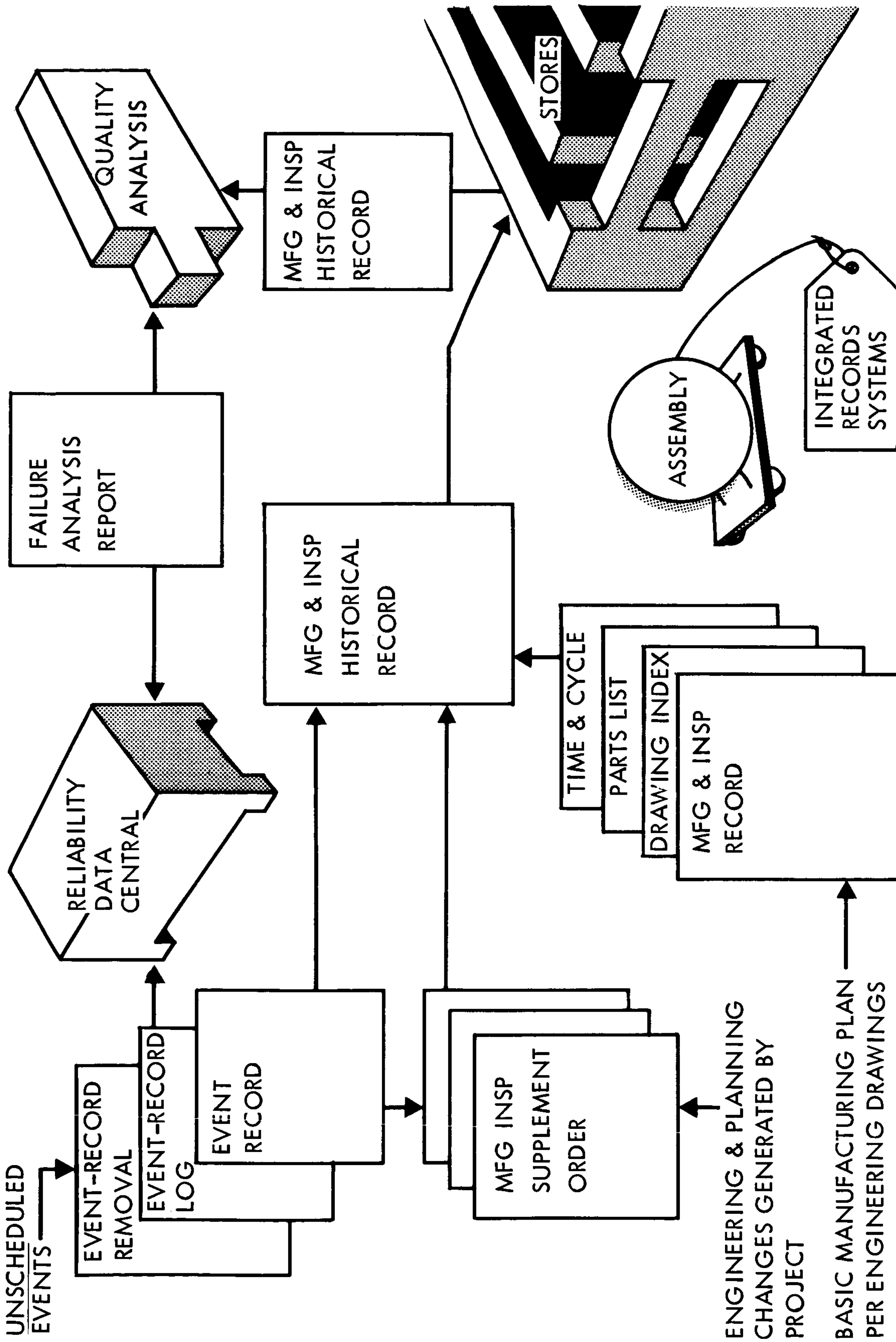


Figure 5.13-1: Integrated Record System

of all tools will be provided. Tools designed for use in clean rooms will have special surface preparation and design features to assist in the maintenance of cleanliness standards.

5.13.3 Fabrication, Assembly and Checkout

The fabrication, assembly and checkout of the spacecraft will be accomplished by skilled technicians in modern aero-space facilities. Only approved materials will be used. Control of details throughout the fabrication sequence will be established through strict part identification.

The requirement for structural interchangeability is accomplished by precision machining, and use of master-tool-coordinated special tooling during assembly of the major subsystems.

Spacecraft and OSE electrical and electronic components and subsystems will be produced in the Boeing integrated electronics manufacturing facility. Recent experience in producing equipment for the Lunar Orbiter spacecraft has resulted in the development of manufacturing processes and controls unique to advanced spacecraft electronics directly applicable to the Voyager Spacecraft System. These processes have been qualified to NASA specifications or NASA-approved Boeing specifications.

Functional testing of electronic assemblies will be performed at successive stages of manufacture by skilled personnel to formal test procedures, approved by quality assurance and test results recorded. All test equipment is calibrated at controlled intervals in Quality Control laboratories utilizing standards traceable to the National Bureau of Standards through the Boeing Metrology Lab.

Electronic packages will be assembled in a clean room where wire harness, connectors, and hardware installation and in-place wiring will be accomplished. After completion, units will receive functional and environmental testing per engineering documents and results recorded by Quality Control. Upon acceptance, assemblies will be protective wrapped and routed to the Voyager assembly area for installation. Systems integration including final assembly, installation, and checkout will be conducted in a special clean room operated solely by Voyager Project personnel. With the exception of the Reaction Control and Propulsion Systems, all assembly work will be accomplished in a down flow clean room complying with Federal Standard 209, Class 100,000. The Reaction Control and Propulsion Systems, due to sensitive valving, require assembly in a Class 100 bench-type environment.

5.13.4 Shipping and Packaging

All packaging and shipping is accomplished by a specialized packaging, preservation, and shipping organization to documented standards which are established in compliance with applicable NASA and military specifications appropriate to the characteristics of the item being packaged and shipped and the anticipated transportation and storage conditions.

All shipments are processed through use of appropriate NASA and government forms providing for approvals by representative personnel of Boeing Quality Control and the customer.

5.14 VOYAGER PROJECT CONTROL SYSTEM

Based on the specimen statement of work for Phase II, one of the tasks that the spacecraft contractor must accomplish is to "establish and maintain a project control center to provide continuing surveillance, evaluation, and measurement of technical, schedule, and cost performance." For this reason, Boeing believes that a project control system operated by JPL management will materially contribute to the success of the total Voyager project. Drawing from its successful experience in implementing project control centers at Marshall Space Flight Center and Ballistic Systems Division, Boeing proposes a complete system of project control for JPL's use in managing the total Voyager project. The proposal is detailed in the following discussion.

Boeing recommends for use by JPL a project control system that features central and supporting control centers with advanced, integrated communications, and computerized information processing. The recommended system will furnish JPL management with complete project visibility, rapid access to predefined levels of project-oriented data and the conferencing capability to quickly convene project personnel throughout the nation so that full and immediate attention can be given to problems.

The need for project control is apparent from the many complex interfaces that must be coordinated to meet the critical launch dates. Despite Voyager's magnitude, a "no surprises" project is possible with the maximum assurance that the overall technical, schedule, and cost objectives can be met. This can be accomplished by a relatively small, fast-reacting JPL staff because Boeing's system places the project manager in "all places at all times." The following sections describe the important aspects of the recommended system.

5.14.1 Voyager Project Characteristics

The important project characteristics that influence the system design are apparent from the project and mission descriptions. Voyager's multiple coordination paths identified by Boeing are shown in Figure 5.14-1 which shows that JPL must direct a nationwide effort. It involves several major system contractors and many cognizant NASA agencies who, in turn, direct the efforts of other important system contractors. During Voyager's 7-year minimum duration, there will be a continuing need to control the large data flows directed to and from JPL and a need for permanent, retrievable storage of all project data for the duration of the project.

5.14-2 Voyager Project Control

Boeing has developed insights into project management from 15 years successful experience in managing increasingly dispersed, complex projects that were paced by difficult schedule objectives. Minuteman and Saturn technical/schedule/cost objectives have been met or bettered because Boeing achieved control over these projects. Boeing recommends that JPL consider the following kinds of information to be reported in the proposed project control system:

1) Technical performance control on the major technical parameters. Science payload status and trends, booster performance and trends, component qualification testing, and other technical parameters can be reported in relation to specifications, to specification profiles, or to mission phases.

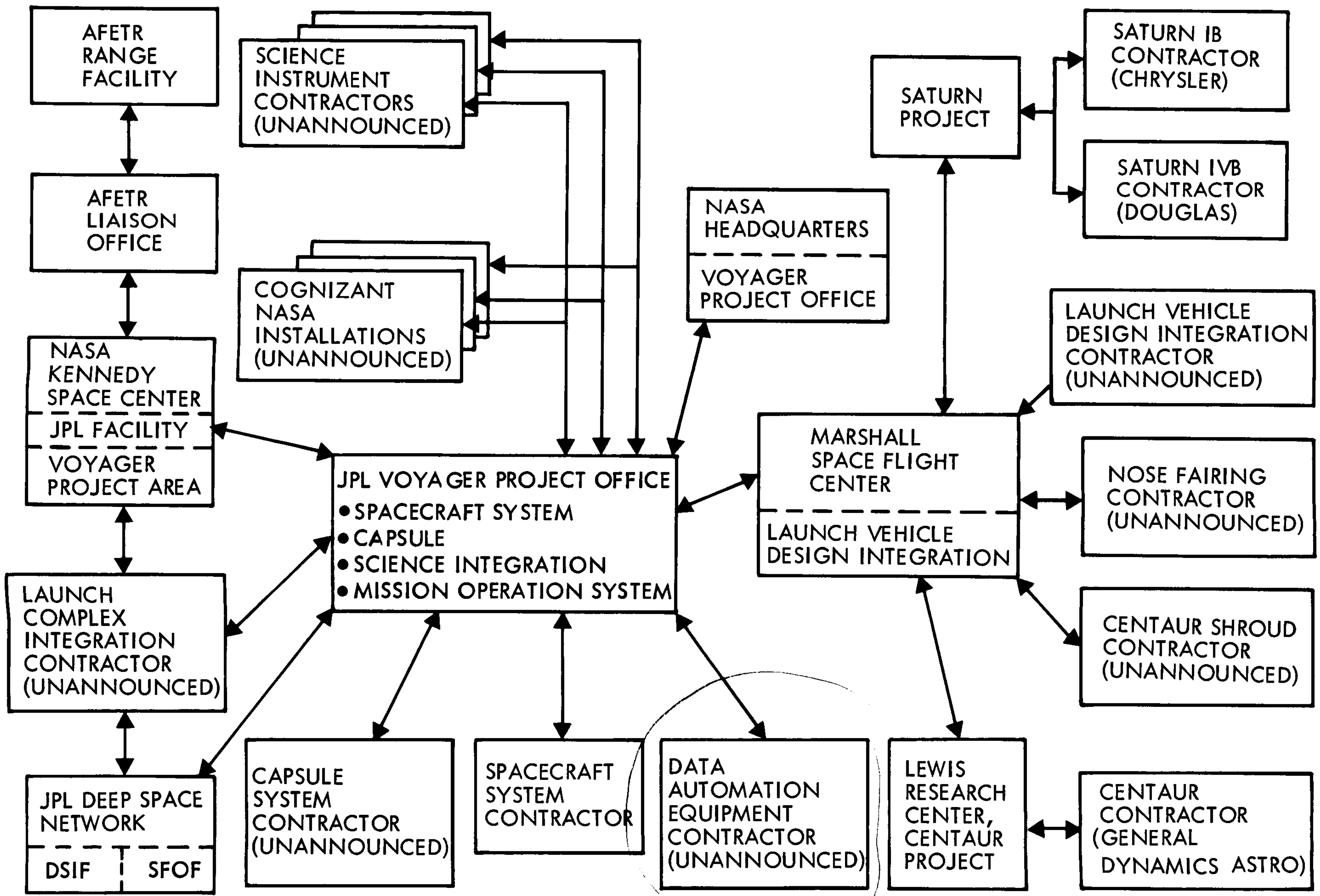


Figure 5.14-1: Voyager Project Coordination Paths

2) Schedule control at the first-tier team-member level (major system contractors and cognizant NASA agencies). All schedule milestones, including important supporting milestones, should be monitored. For every milestone slippage or potential slippage that occurs, the affected follow-on milestones should be identified and analyzed for program impact.

3) Financial control over the first-tier team members. This should include current and cumulative expenditures of labor and non-labor reported in relation to required and allocated funding, cost to complete, and percentage of project complete.

Experience has shown that technical, schedule and financial controls are most useful when the relationships between these three elements can be determined. While not always easy to trace, the existence of a schedule or cost problem may signify an underlying technical problem. Conversely, technical performance may adversely impact program cost and schedule. The recommended system would be designed to accomplish the analysis of data designated by JPL. It is also designed to accommodate additional control methods such as reliability assurance, quality control, testing, and documentation identification.

5.14.3 Boeing Project Control Concepts

Boeing's experience has demonstrated that control of far-flung projects with complex interfaces can be achieved by making it appear to the project manager and all team members that the project is in one place in one time period under one management. The proposed system will achieve this goal by furnishing tools to JPL's project management at Pasadena so that they can be in "all places at all times" to achieve the continuing result of no project "surprises." To accomplish these results, JPL will need:

1) "Face-to-face" conferencing capability between JPL and all first-tier team members.

2) Information at JPL and at all first-tier team members that is in the same time frame, the same format, prepared under the same ground rules, and available to JPL through one mode of inquiry.

Boeing's recommended project control system is based on a closed loop control as reflected on Figure 5.14-2. An important innovation in the control loop is the use of GO/NO-GO authorization "switches" operating at the JPL level. At scheduled expenditure thresholds, designated managers must make explicit decisions to either authorize or postpone resource expenditures on predefined major project sections. Unauthorized portions halt automatically on decision day. Thus, each manager is made an active participant in the dynamic controlling process. The managers must personally certify that they have sufficient knowledge on which to begin each major series of resource-consuming actions. Conditional, partial authorizations can be made and additional authorization "switches" set up. This authorization approach can rather easily be made part of a PERT-type computer system. Naturally, only appropriately high-level decisions would act as "switches."

5.14.4 Control Centers

Project control revolves about a network of interlinked project control centers. Voyager Control Central is at JPL. Every first-tier team member has a supporting control center connected to Control Central with

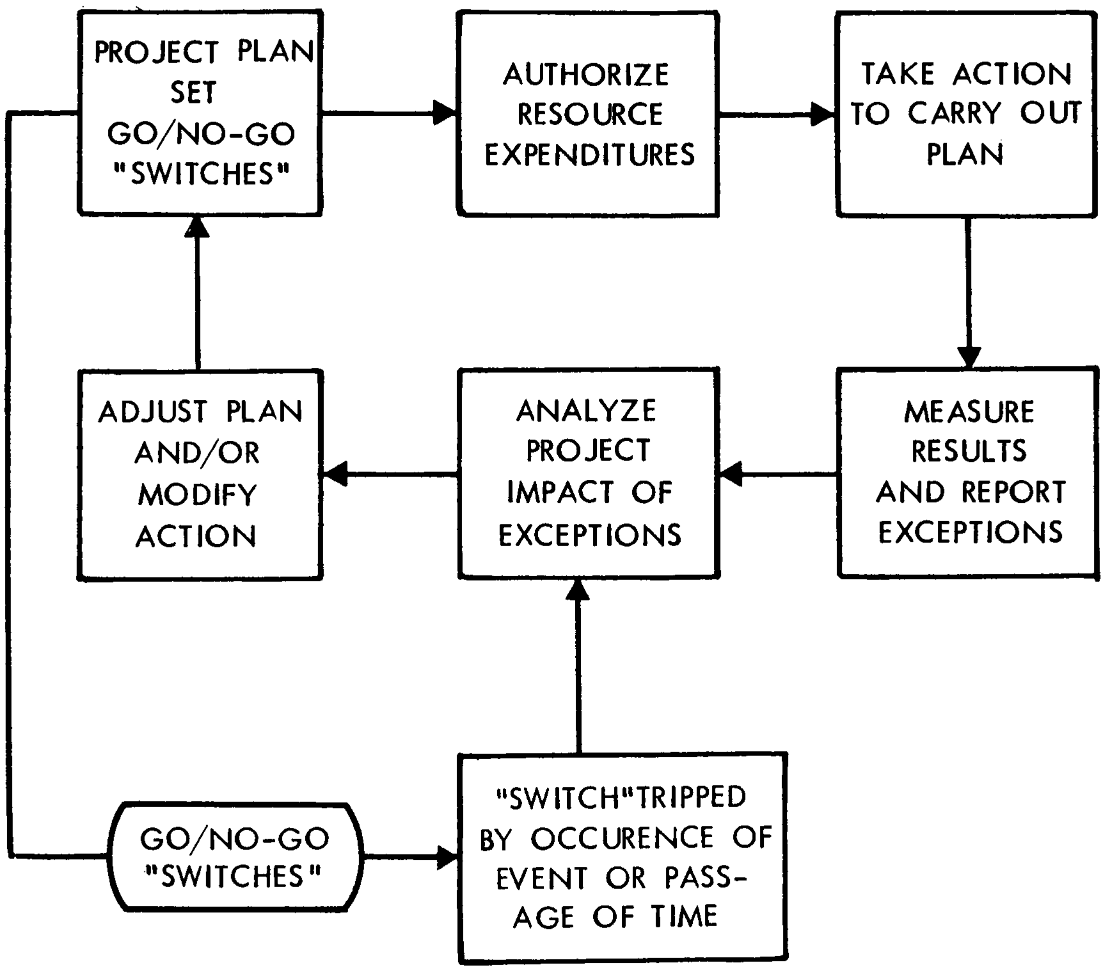


Figure 5.14-2: Closed-Loop Control with Go/No-Go Authorization "Switches"

a wide range of communication media. Control Central will provide JPL top management with a single gathering point where overall perspective can be gained, relative positions compared, and management review meetings held.

Emphasis will be directed toward presenting to the proper level of management actual and potential problems that have been analyzed for total program impact. In this manner, managerial time and talent are focused on the most important problems. JPL Control Central in the proposed project control system will have six elements:

1) Highly selected, clearly presented information in open displays.
2) "Single-thread continuity" of tiered information for vertical and horizontal tracing of project interrelationships.
3) Close correspondence between "reality" and the displays and reporting in Control Central.
4) Data that is processed only once, either in the field or at Control Central, before going on display.
5) Detailed top problem followup.
6) Rapid retrieval of all types of information at any level throughout the project presented at quickly convened meetings with the responsible managers and technical experts. Thus, necessary resources can be simultaneously brought to bear on problems.

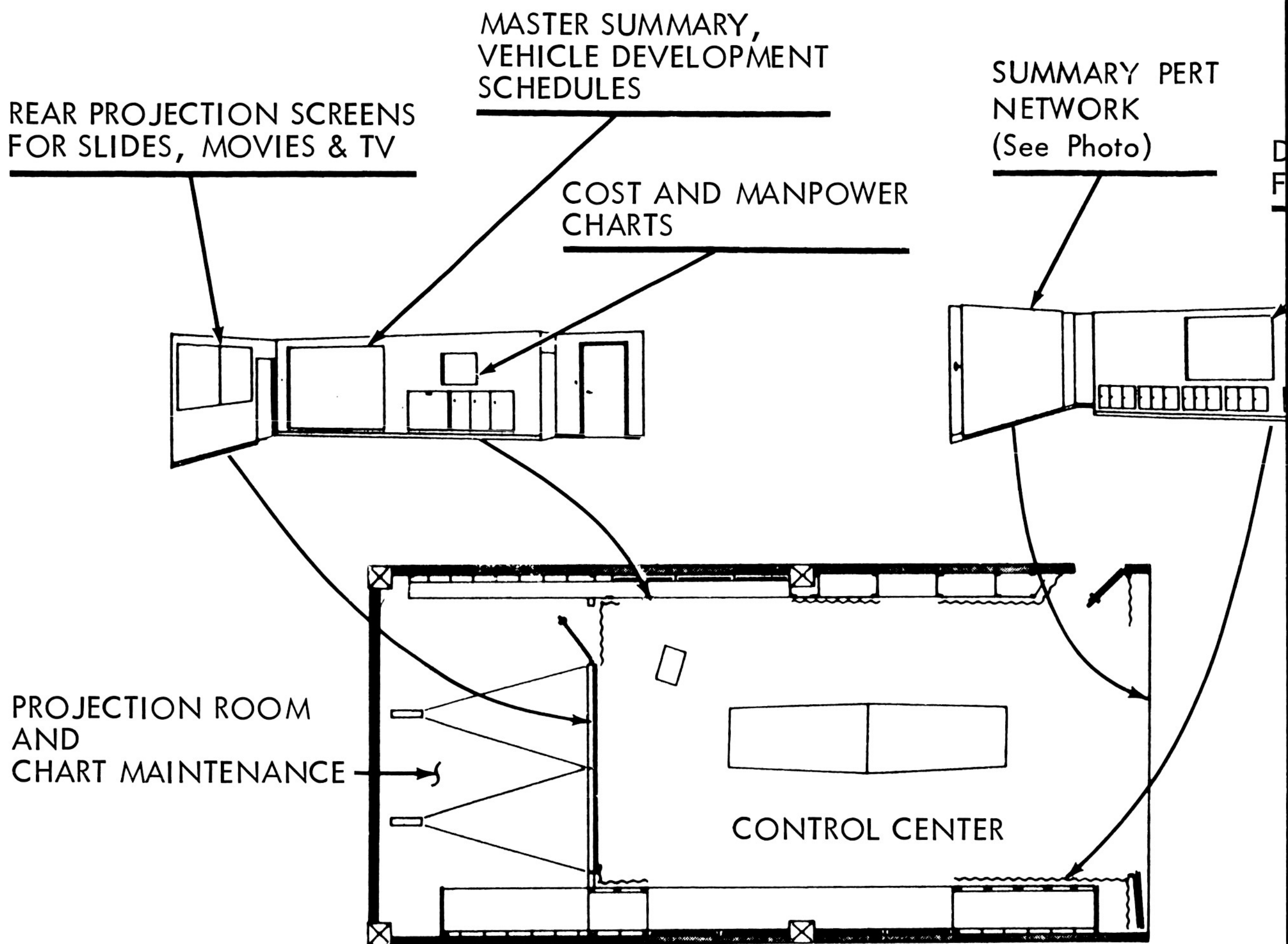
Boeing employs a separate working control center for every major project. These working control centers serve as project management's base of operations. Figure 5.14-3 illustrates and describes the control center that Boeing designed, built, and installed for the NASA Saturn management.

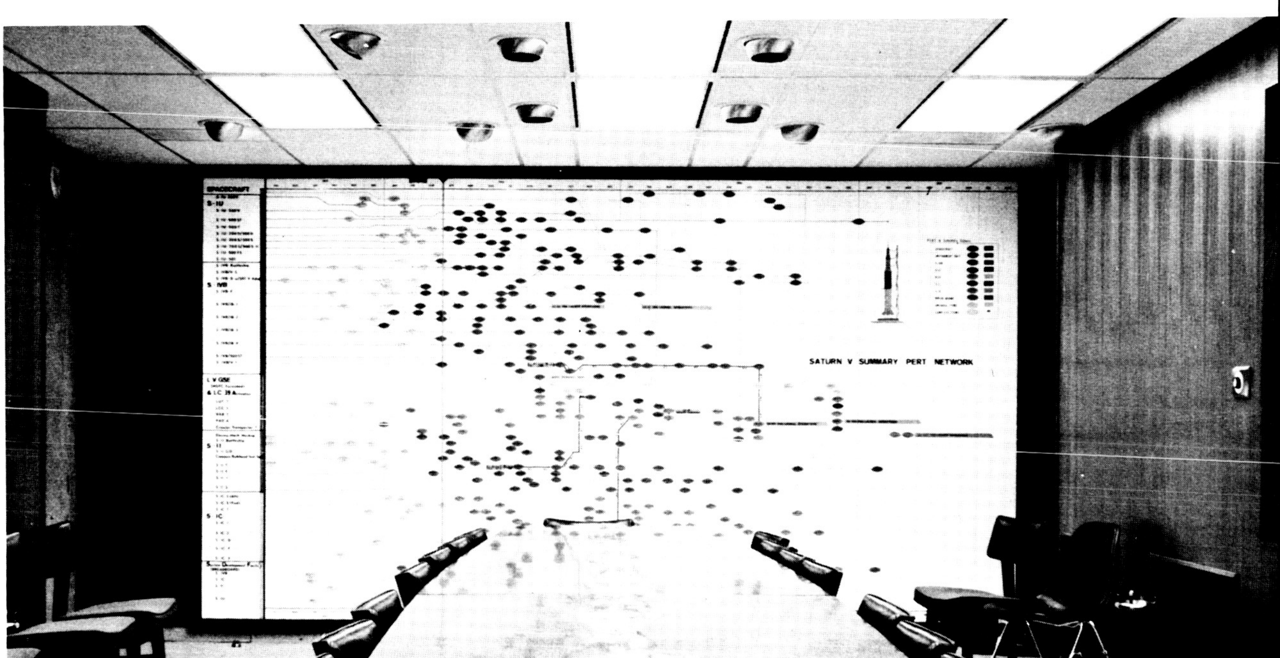
5.14.5 Communication Network

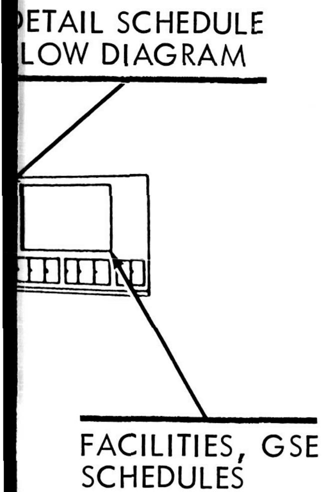
A high capacity, multimedia nationwide dial communications network that links all of the Voyager control centers will be installed exclusively for Voyager. The network will be controlled by JPL's management to guarantee adequate capacity at all times. Voyager's recommended communications network is very similar to the all media common control switching arrangement (CCSA) that AT&T will implement for Boeing in the third quarter of 1966. CCSA is the most important of the many business communication advances first advocated by Boeing. It is a dial network that uses a portion of the nationwide dial switching equipment that is set aside for the subscribers exclusive use. Figure 5.14-4 illustrates and describes the features and capabilities of the Voyager communication network.

5.14.6 Information Processing

The information processing will be integrated with the communication network to provide a flexible, efficient project control system. Information processing/communications will be designed modularly so that they can grow with the project's needs. The several files of information are open-ended to encourage orderly file growth while maintaining continuity of information reporting. The key is a well-defined information master plan and the building of all information files on a complete coding system from the outset. The Mariner C Configuration Identification Index is an indentured coding structure that should be


MASTER SUMMARY,
VEHICLE DEVELOPMENT
SCHEDULES
REAR PROJECTION SCREENS
FOR SLIDES, MOVIES & TV
SUMMARY PERT
NETWORK
(See Photo)
COST AND MANPOWER
CHARTS
PROJECTION ROOM
AND
CHART MAINTENANCE
CONTROL CENTER


SATURN V SUMMARY PERT NETWORK



SATURN V PROGRAM CONTROL CENTER

The diagrams illustrate the Saturn V program control center at Marshall Space Flight Center that Boeing designed and installed under a separate contract. The center was operational by June 1, 1965, and is operated for NASA by Boeing. Complete program data is displayed on approximately 55 charts.

All charts are set up on 3/8-inch translucent plastic back-lighted to highlight information. Program-level summary information is portrayed on 7' by 10' boards. Stage-level schedules, technical performance, and software information is portrayed on 5' by 8' boards. In addition, one end wall of the room is covered by an 8' by 15' summary PERT network of the program. The other end wall includes two rear-projection screens for slide projection, 16-mm films, and television receiver projection. There are three storage bins where classified and sensitive information, in the form of 30" by 40" cards, can be stored. Lighting, sound control, slide projection, films, and television can be controlled either from a console in the lecturn or from a console in the middle of the conference table. The room normally seats up to 20 persons and can accommodate an additional 30 persons when chairs are placed along the side walls.

The NASA Saturn V program manager uses this control center for his staff meetings and for a monthly program-level meeting of all MSFC Saturn V project chiefs. The room is also available for meetings by any of the Saturn V project offices as a place for reviews and familiarization of visitors and for day-to-day program progress review by the Saturn V program manager or any of his project chiefs. Closed-circuit television is planned for installation by October 1965 between the center and the Saturn test towers and the Saturn facilities at Cape Kennedy and Houston.

BOEING CONTROL CENTER BACKGROUND

The Saturn Control Center is the latest of many control centers of similar design that Boeing has installed since 1961 when the Minuteman control center began service. Shortly after that time, Boeing installed under separate contract an almost identical Minuteman control center at BSD Minuteman headquarters, San Bernadino, California. The installation was made in 5 days. BSD frequently uses its conferencing capability for discussions with Boeing in Seattle. The Lunar Orbiter Control Center at Boeing in Seattle is another effective center. It is connected each week with NASA Lunar Orbiter management in Washington, D.C., for project reviews. Boeing also uses conferencing capability to conduct simultaneous quarterly company status reviews with all of its major locations throughout the nation. All centers project identical film-strips of charts and graphs that are distributed just prior to the meeting. The film contents are shown in synchronization to the several audiences while Boeing President William M. Allen and other speakers discuss the status of all divisions or review major program developments.

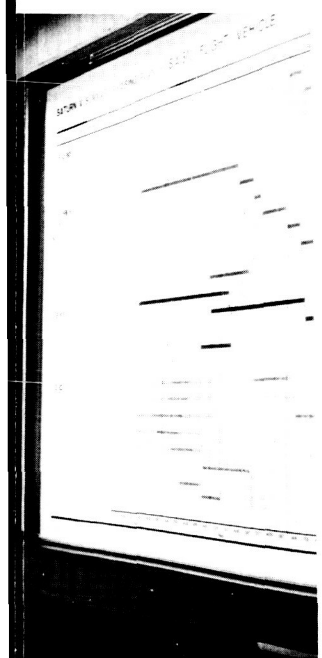


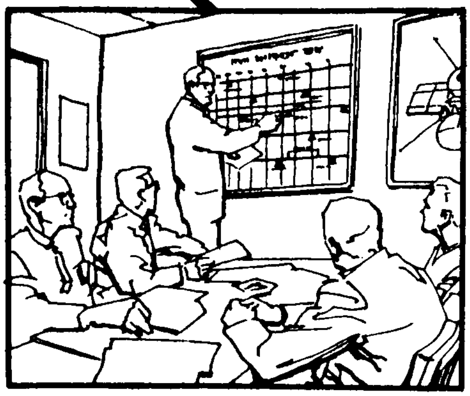
Figure 5.14-3: Saturn V Program Control Center

2

The recommended Voyager network is an
total communications system. Basically,
through telephone company switching of
at wholesale rates. The switching office
specific features are listed below.

FACSIMILE	● 4 or 7
VOICE & TELETYPE	● Natio OFF-N
TELEGRAMS & TELEX	● Routed
DATA TRANSMISSION	● 120 –
ELECTRONIC LONGHAND	● Contr
REMOTE DATA INQUIRY/DISPLAY	● Flicke retriev

SEATTLE



SAN FRANCISCO

VIEWS DEPICT SIMULTANEOUS DAT
DISPLAYS IN SEPARATE CONTROL
CENTERS PERMITTING IMMEDIATE
COORDINATION AND RAPID PROBL
RESOLUTION

LOS ANGELES

JPL

HO

● Major Terminal
■ Switching Center
▲ Control Central

Note: Routing will depend on locations
served and traffic volumes

arrangement that combines a wide range of services into an efficient, economical,
it is a direct, distant-dial network exclusively for Voyager which is interconnected
ices. It bands together large circuit groups and takes advantage of bulk-buying
will automatically route calls by the most economical service available. The

minutes per page over voice circuits and 2 pages per minute over wide-band data circuits.

wide point-to-point dialing (8 digits between ON-NETWORK users - 11 digits to reach
IETWORK users).

via Voyager Network to the Western Union refile point nearest the addressee.

200 Characters Per Second (CPS) over voice circuits and 5000 CPS over wide-band circuits

center to control center instantaneous transmittal and projection of handwritten material.

-Free, 20 x 20 inch, back-lighted, color or black & white data display consoles for
al from random-access computer storage or closed-circuit slo-scan TV projected on large screens.

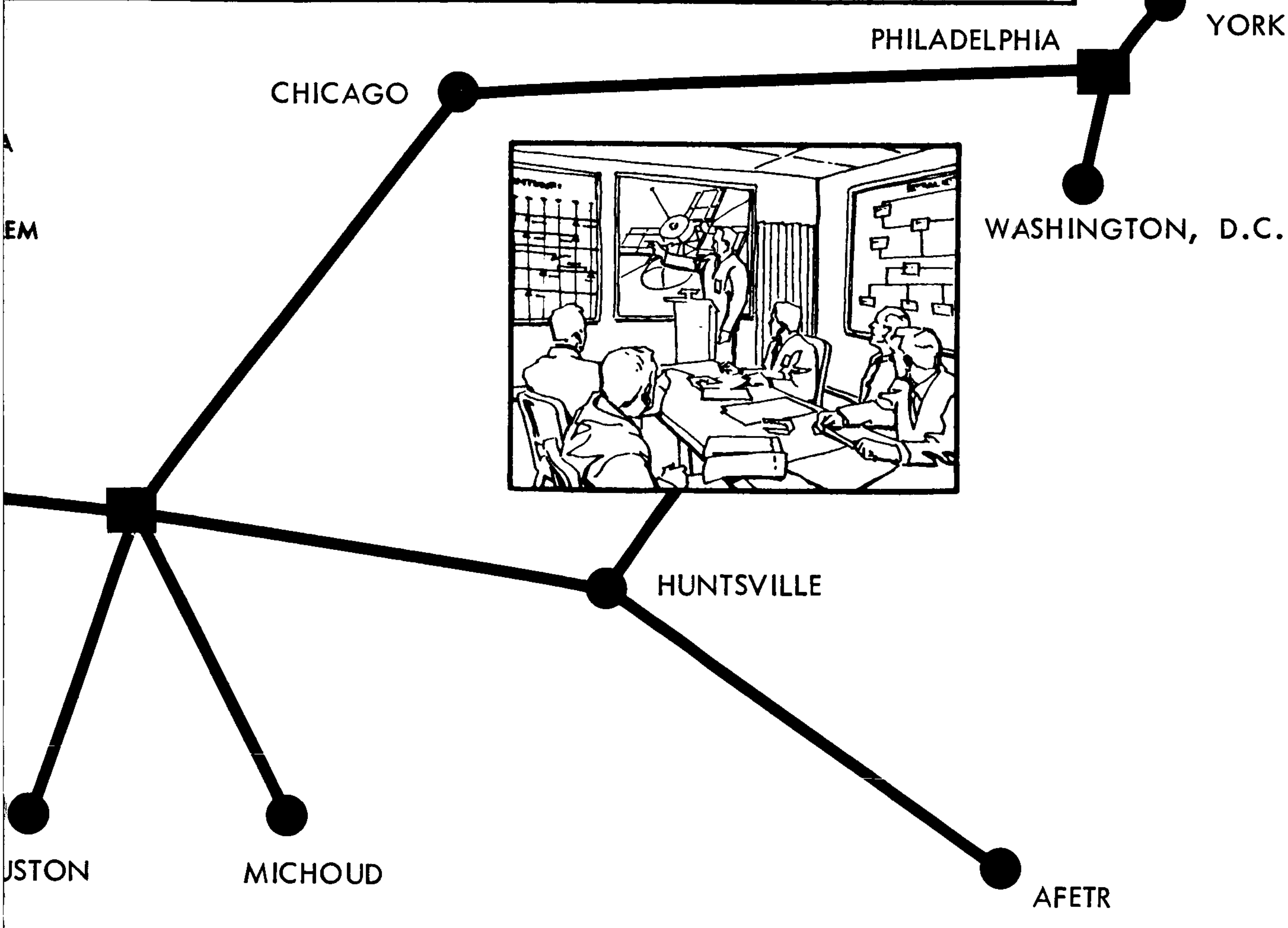


Figure 5.14-4: Voyager Nationwide Communications Network

considered for use. Boeing has recently developed "BALANCE," a universal computerized project coding method, the use of which would also yield an effective coding structure. Modular development will be accomplished on a section-by-section implementation of each file into data banks, as the files are made ready. Development will go through a series of formal phases to precisely define managerial requirements before major programming and equipment decisions are finalized.

Reporting will concentrate on the deviations and exceptions to predetermined project plans, milestones, specifications, funding and other significant criteria. All tiers of project management will receive reporting tailored to their needs. Though highly selective, reporting coverage will be complete to minimize special information requests. All input data will be assigned a specific cutoff time (e.g., daily at 10:00 p.m., Pacific Standard Time). Subsequent file updates throughout the system will put all files in the same time frame. That is, cost data would correlate with schedule data, etc. By the ground rules of the system, JPL would be assured that all data available to it was time coordinated and certified accurate by the input groups. Figure 5.14-5 illustrates the information flow.

JPL's computer files will build up from the contract end item. First-tier team members' computer files will build up from the lowest level of detail. As a result, JPL will have available for inquiry its own project level computer files and first-tier team member project-oriented computer files via the methods described in the next paragraph. This network of computer files is the equivalent of a single, minimum redundancy project data file. JPL will specify for each information element (e.g., schedule data) the data retrieval requirements from team member computer files and control center displays.

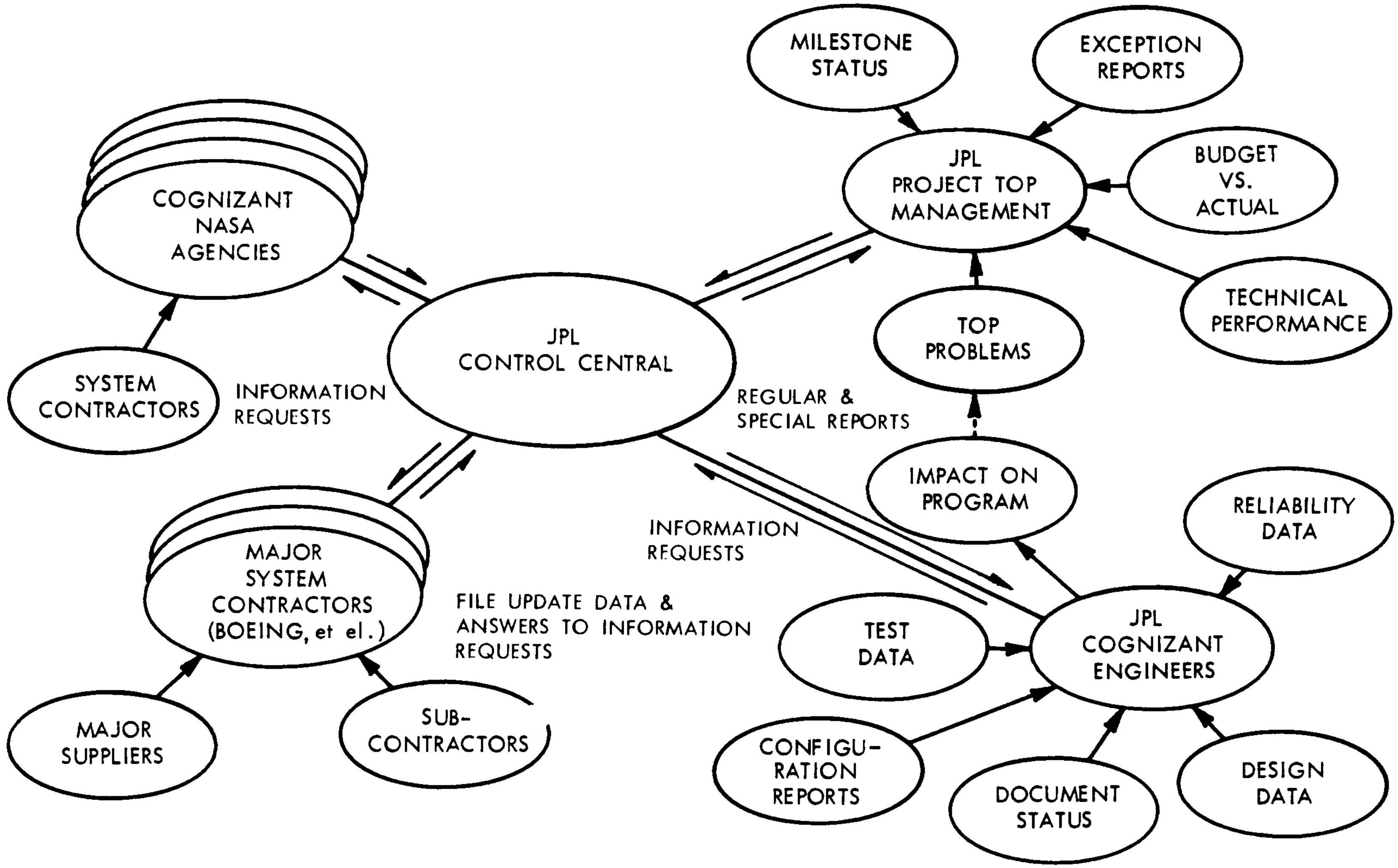


Figure 5.14-5: Voyager Project Control — Information Flow

The three primary data retrieval methods that can be designated are telephone inquiry, direct TV viewing of control room displays and direct inquiry into any program-oriented data portions of first-tier team members on-line computer storage. With immediate computer storage inquiry capability throughout the network, JPL management has access to the latest project data. Computer file inquiry can be made without the knowledge or participation of the team members. To augment control room charts and to track problems in successively greater levels of detail (this is single-thread continuity) computer inquiry is done through remote inquiry devices (like typewriters). Data from computer storage is displayed on an output display device. Copies of the display data can be made on paper for further use, if required. Both devices will be located in the control center. JPL will assure itself of coordinated information processing, reporting, and file interrogation capability through common contractual requirements on first-tier team members and by conducting periodic audits to evaluate compliance.

Boeing has long maintained one of the foremost business computer capabilities in the aerospace industry. Experience has been gained on a wide range of important, complex computer applications that have been developed for divisional management purposes as well as under contracts for project management. These computer systems play a significant role in our management mode. For example, Boeing has two remote data collection systems (Aero-Space Division and Commercial Airplane Division) that are among the largest in the nation. The Aero-Space Division system feeds directly into a computer. Another example is the Minuteman RECON system. Developed, installed, and operated by Boeing at every Minuteman base, it is a successful end-to-end computer system using random-access files. The latest configuration of every missile installed at a base is available through this system. As each base is fully activated, the entire RECON system for that base is turned over to Air Force personnel.

The Aero-Space Division now has under development a long-range complete divisional information master plan that is similar to the information processing recommended for Voyager. The master plan will utilize direct access massive storage and the most advanced generation of computers available to industry. This plan considers as a totality, division information needs in every sphere of division activity.

5.14.7 Systems Benefits

"All places at all times" is the capability which JPL management will derive from the recommended project control system. With all-level information availability project visibility, JPL will have maximum assurance of a "no surprises" project that achieves its objectives. Using a relatively small, flexible project management staff, JPL gains the advantages of centralized management while maintaining its traditional decentralized assignment of component work packages to the cognizant engineers. The cognizant engineer obtains the same management advantages from the recommended system for his work package as JPL obtains at the project level. The cognizant engineers and first-tier team members gain the advantages of minimum time consumed for status reporting. Early warning indicators assist on-schedule recovery without undue expense. Management's attention can be more easily focused on those areas needing additional resources.

Conferencing capability achieves real-time audio-visual rapport between JPL and all participants in the discussion even though many of them are hundreds of miles apart. Misunderstandings, delayed messages, incomplete coordination and consultation, burdensome paper work systems, and hidden variances no longer have to be excused or tolerated. Decisions made during interface conferences, technical performance reviews, schedule, and financial reviews will result in information file update changes and project redirection authorized and made on the spot. Confirming facsimile messages can be sent to all participants before the meeting's close. This arrangement for information retrieval will have the least possible disrupting effect on team member's day-to-day activities.

The proposed system might well be considered for adoption as the principal JPL control system mode for interplanetary missions other than Voyager.

5.14.8 Development, Implementation and Operation

Boeing believes that the probability for total Voyager project success will be significantly increased by an advanced project control system of the type proposed in the foregoing pages. Boeing stands ready to assign its proven, extensive capability to design, develop, and implement the proposed system, or any modification thereof, for JPL.

This could include assisting JPL in the definition of the control method requirements, complete system documentation, all computer programming, engineering, manufacturing, and installing the remote inquiry and display units, procuring all communication computer hardware, including the interfacing computer switch (necessary so that anticipated variety of computers throughout the network talk the same language), designing and installing the control rooms, and implementing the complete system. Boeing could also operate the system for JPL under a separate contract, similar to the contract under which Boeing operates the control center for NASA at Marshall Space Flight Center. Under this arrangement, JPL could devote its major effort to the complex responsibilities implicit in the overall management and technical direction of the Voyager project.

Boeing could provide JPL with increasing control system capabilities on a realistic phasing basis as shown on Figure 5.14-6. Phase IB will have manual project control. During this period, Boeing will make available to JPL any applicable business computer systems that it now has in operation. During this period, a comprehensive interim project control system will be readied for Phase II start. A more sophisticated final project control system could be operational in early 1969.

This schedule, shown on Figure 5.14-6, presupposes an early commitment by JPL to proceed with development so that the critical initial planning and determination of a coding structure can start at the beginning of the fourth quarter in 1965. The long lead times inherent in the advanced equipment necessary for the proposed system make early letter of intent releases to equipment manufacturers vital.

Detailed plans for the recommended system are now being prepared as a

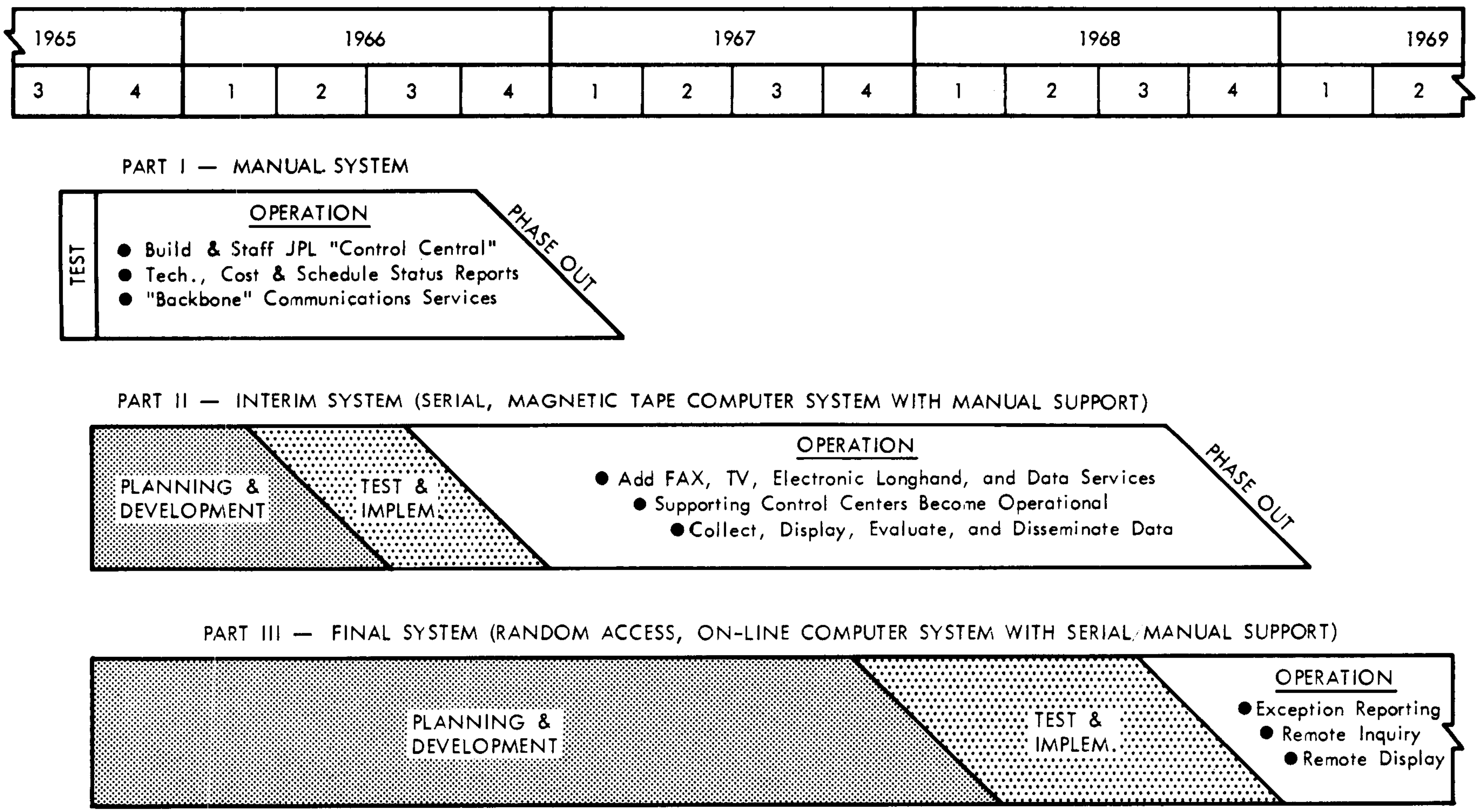


Figure 5.14-6: Voyager Project Control System — Phasing Chart

part of the Phase IB proposal effort. Because the approach taken could be significantly modified by JPL's analysis of the system requirements, Boeing would appreciate an early expression of JPL's interest in this system.

CONTENTS

6.0 SYSTEM RELIABILITY SUMMARY

6.1 INTRODUCTION

6.1.1 Purpose

Successful accomplishment of the Voyager 1971 mission, with its attendant complexity and critical timing, will depend to a large extent on the treatment of reliability as a significant parameter in system and design studies. Documentation of reliability studies, appropriate to various treatments of system elements are dispersed throughout Volumes A through E. The purpose of this section is to introduce the governing approach to system and design reliability and to bring together and summarize the various discussions so as to give overall system clarity.

6.1.2 Approach

The reliability requirements of the Voyager mission, in terms of duration, uncharted environments, and system sophistication, require new highs in system reliability. Analysis shows that these requirements can be met, but will require careful attention to reliability at all levels of design from system to detailed part. To remain within the restraints of weight, volume, and electrical power will also require carefully selected applications of redundancy.

The general approach to meeting this requirement will be to use screened high-reliability parts; highly disciplined design to ensure that the parts develop their potential reliability; redundant components selected on the basis of weight and cost effectiveness; part, component, subsystem, and system burn-in; and a comprehensive test program with effective failure detection, investigation, and follow-up. Within this general framework, system and design reliability evaluation studies were undertaken to provide design direction to optimize mission success probability.

6.1.3 Summary

This section summarizes reliability criteria and requirement studies, evaluations, trade analyses, and allocations. The material is treated systematically according to the actual design sequence: starting with an analysis of mission criteria and requirements; proceeding with feasibility investigations, initial allocations, and analyses of design alternates; and concluding with sections on the 1971 preferred and 1969 test systems. Supplementary documentation in support of these studies is contained in D2-82724-1, "Voyager Reliability;"D2-82724-2, "Voyager Failure Mode and Effects Analyses"; and D2-82724-3, "Voyager Program Reliability Analysis and Prediction Standards."

The above studies were directed primarily at the Spacecraft Bus and its subsystems and components. However, for the purposes of evaluating compliance with overall mission objectives, analyses of the Saturn IB/Centaur launch vehicle, science payload, and operational support equipment (OSE) were included.

In the design area, the principal efforts were directed toward:

1) Establishing ranges of reliability feasibility correlated with defined improvement schemes and compatible with specified requirements;

2) Defining reliability restraints in the form of requirements allocated to the subsystem and component level;

3) Assessing the reliability of candidate configurations as a part of the evolutionary process leading to the preferred system.

To ensure translation of the design reliability features into the Voyager equipment, essential program activities and tasks are defined and documented in a series of implementation plans covering the areas of: (1) general reliability program tasks; (2) parts, materials, and processes; (3) integrated test activities; (4) safety; and (5) reliability data. Summaries of these activities are contained in Volume A, Section 5.9, "Reliability Program Plan" and Section 5.11, "Safety Plan."

6.2 SUCCESS CRITERIA AND REQUIREMENT

6.2.1 Voyager 1971 Mission Criteria and Requirements

Section IIA of V-MA-004-001-14-03, "Preliminary Voyager 1971 Mission Specification", defines the mission functions needed to accomplish the 1971 mission objectives. These objectives constitute the top level of success criteria used as a standard for reliability development. An ordered listing of these criteria, along with the associated cumulative success objectives as applied to the Flight Spacecraft system and its launch vehicle, is given below. (Figure 6-1 graphically displays the cumulative success objectives as a function of mission phase.)

1) Perform a successful launch and injection of the Planetary Vehicle into a prescribed transfer orbit--90-percent probability of success.
2) Perform a successful spacecraft-capsule separation maneuver at a preselected time and location--80-percent probability of success.
3) Place an operating science payload in a selected orbit about Mars and perform the functions necessary to begin orbital operations--65-percent probability of success.
4) Perform necessary orbital operations to obtain data from the orbital science payload and return the data to Earth, for a specified time of 1 month and as long thereafter as possible--45-percent probability of success.

Included in the above listing of objectives are the necessary Flight Spacecraft operations required to support successful Flight Capsule operations. These include the necessary operations associated with

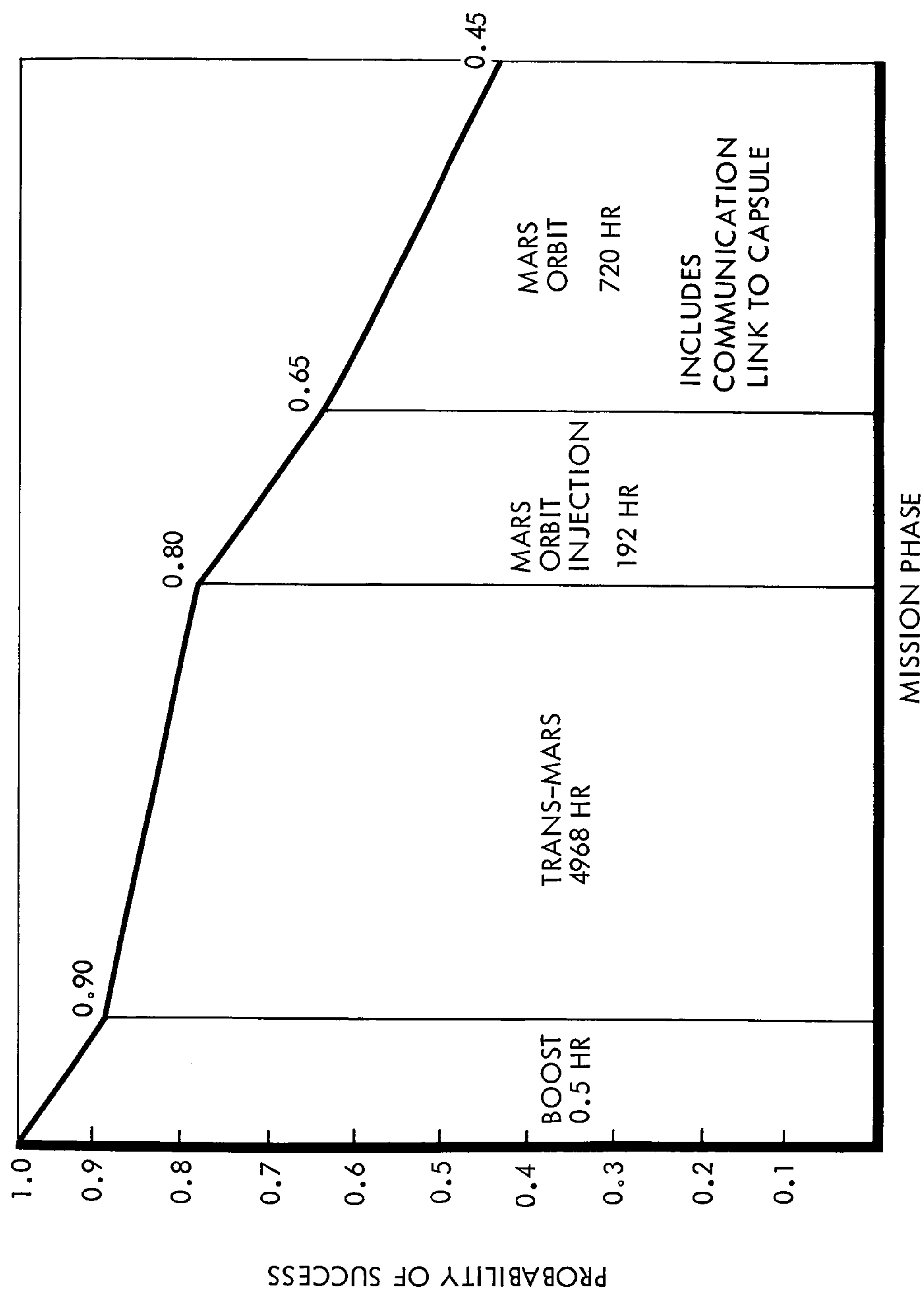


Figure 6-1: Mission Success Requirements – Preliminary Voyager 1971 Mission Specification

Flight Capsule separation (Objective 2) and the provision of a Flight Capsule communication link (Objective 4). The latter provision has been included as a requirement for the telecommunications system (relay subsystem).

Since reliability is defined as the probability of no equipment failure that would terminate or significantly degrade the mission, it is necessary to identify the relationship of other contributing factors along with reliability in the formulation of overall mission success. An adequate description of this relationship is given by the following series model:

$$P_s = P_1 \times P_2 \times .. \times P_n \times P_r$$

where P_s is the probability of mission success, P_1, P_2,..., P_n refer to nonreliability factors, and P_r is reliability.

6.2.2 Flight Spacecraft System Criteria and Requirements

By the definition in Section 6.2.1, reliability must ultimately concern the proper operation or performance of the equipment that contributes to essential mission functions. Each of the four mission phases identified by the Voyager 1971 mission objectives involves spacecraft equipment operating (1) at different duty levels, (2) for various duty periods, and (3) under various environmental stresses. The success of an equipment item is measured by its ability to perform as a function of these factors or criteria.

The above factors are applied to the problem of reliability evaluation by adjusting the generic failure rates applicable to each equipment item and applying the adjusted failure rates over the appropriate duty periods. The adjustments to generic failure rates to account for different duty levels and environments are referred to as K factors. Table 6-1 shows the duty level (K_d) and environmental (K_e) factors as a function of equipment type. Table 6-2 shows an example of duty levels and duty periods as they apply to the electrical power subsystems. A complete listing of success criteria for the spacecraft may be found in Boeing Document D2-82724-1 "Voyager Reliability."

System requirements broken down to the major-component level are set forth in the preferred system reliability allocation of Section 6.6. These requirements are based on meeting or exceeding the mission requirement set forth in Section 6.2.1.

6.2.3 Operational Support Equipment Criteria and Requirements*

The mission success criteria of Section 6.2 assumed a readiness or "launch on time" condition at the time of launch commitment. Major factors contributing to the launch readiness are: (1) flight vehicle prelaunch reliability and maintainability and (2) OSE reliability and maintainability. Paragraph 9 of Section D of V-MA-004-001-14-03 states the success criteria and associated success objective for the launch readiness condition:

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* Operational support equipment requirements as they relate to flight are contained in the requirements of Section 6.2.2.

Table 6-1: Failure Frequency Adjustment Factors — Duty (K_d) and Environmental (K_e) for Various Loadings and Equipment Types

PART/EQUIPMENT CLASSIFICATION

			MECHANICAL	ELECTRICAL POWER (EXCLUDING BATTERIES)	ELECTRO-MECHANICAL	BATTERIES	SOLID-STATE ELECTRONICS	TUBE & CHASSIS ELECTRONICS	ORDNANCE DEVICES
TYPE OF DUTY	OFF-DORMANT	DUTY FACTOR (Kd)	.001	.001	.001	.1	.1	.01	.01
	ON-STANDBY		.2	.2	.2	.05	.1	.1	.01
	ON-NOMINAL		1	1	1	1	1	1	1
TYPE OF ENVIRONMENT	COMPUTER LABORATORY (EARTH)	ENVIRONMENT FACTOR (Ke)	1	1	1	1	1	1	1
	GROUND EQUIPMENT (EARTH)		5	5	5	5	3	5	5
	BOOST FROM EARTH SI-B/CENTAUR		300	500	500	300	150	1200	300
	ORBITS TRANSIT EARTH-TO-MARS		1	1	1	1	1	1	1
	ORBIT INJECTION, & MANEUVERS		6	10	10	6	3	20	6

Table 6-2: Duty Level & Period by Mission Phase

SUBSYSTEM COMPONENT	LAUNCH & INJECTION		INTERPLANETARY CRUISE		MARS ORBIT INSERTION		MARS ORBIT	
	DUTY	△T hr	DUTY	△T hr	DUTY	△T hr	DUTY	△T hr
<u>ELECTRICAL POWER</u> SOLAR ARRAY	DORMANT	0.5	ON	4968.0	ON	192.0	ON	720.0
BATTERIES	ON	0.5	ON STANDBY	4.25 4964.0	ON STANDBY	1.5 190.5	ON STANDBY	6.0 714.0
CHARGER & FAIL SENSE	DORMANT	0.5	ON STANDBY	[illegible].50 [illegible].50	ON STANDBY	9.0 183.0	ON STANDBY	36.0 684.0
BOOSTER/CONVERTER	DORMANT	0.5	ON STANDBY	[illegible].03 4968.0	ON STANDBY	0.083 192.0	STANDBY	720.0
SHARE SENSE CIRCUIT	DORMANT	0.5	ON	4968.0	ON	192.0	ON	720.0
POWER SWITCH & LOGIC	ON	0.5	ON	4968.0	ON	192.0	ON	720.0
DC/DC REGULATOR (1,2)	ON	0.5	ON	4968.0	ON	192.0	ON	720.0
DC/DC REGULATOR (3,4)	ON	0.5	ON	4968.0	ON	192.0	ON	720.0
2.4 KC INVERTER	ON	0.5	ON	4968.0	ON	192.0	ON	720.0
400 CPS INVERTER	ON	0.5	ON	4968.0	ON	192.0	ON	720.0
POWER SYNCHRONIZER	ON	0.5	ON	4968.0	ON	192.0	ON	720.0

"The capability shall be provided for two launches from two launch pads in a 30 day period, with a probability of 0.99, assuming an interval between launches of 5 days and a daily firing window as short as 1 hour. A minimum interval between launches of 2 days shall be required."

Because of the stringent inflight requirements placed on the Flight Spacecraft, the reliability of the preflight operations is not considered a significant addition. Therefore, the above objective is interpreted to apply to the OSE and launch vehicle. Furthermore, the objective is interpreted as a joint reliability/maintainability requirement, inasmuch as delays are a function of both failures and failure repair time.

A model for interpreting the above requirements in terms of specific equipment reliability and maintenance downtimes will be advanced. This model will develop the probability of no launch cancellation as a function of equipment reliability, mean downtime, and launch window duration, and relate this probability to the number of launch opportunities available within a 30-day period considering various interval times between launches. From this model, mean-time-between-failure (MTBF) and mean-time-to-repair (MTTR) requirements will be developed during Phase IB and allocated down to specific equipment items.

6.2.4 Mars Contamination Constraints

The requirement to ensure that the probability of contaminating Mars is less than 1 in 10,000 for a single Mars mission implies another set of reliability criteria. These criteria, in general, restrict the enroute probability of contaminating the sterile capsule and limits the probability of nonsterile equipment or particulate matter landing on Mars. An analysis of these requirements is contained in Section 3.7 of D2-82724-1, "Voyager Reliability."

6.3 SYSTEM FEASIBILITY EVALUATION AND INITIAL ALLOCATION

6.3.1 General

A first step in providing reliability direction to the preliminary design of the Voyager system was to perform a reliability evaluation. This evaluation was performed on a single-thread and redundant configuration to establish a range of feasibility correlated with defined assumptions or improvement factors. A summary comparison of a single-thread and redundant configuration with the requirements of Section 6.2 is given in Figure 6-2. The range of feasibility is indicated by the cross-hatched area between the single-thread and redundant configuration curves.

Both the single-thread and redundant configurations were assessed using the following assumptions:

1) Component and parts at least as reliable as those employed on Minuteman hardware;
2) Design disciplines equivalent to those employed on Minuteman hardware;
3) Failure rates corresponding to Assumptions 1 and 2 and demonstrated by field experience.

In general, the redundant configuration provided redundancy on all critical functions in the form of either single standby elements or "inherent" redundancy. The results of the assessment show that even with close control of components and parts and design and manufacturing disciplines, specified requirements cannot be met without providing

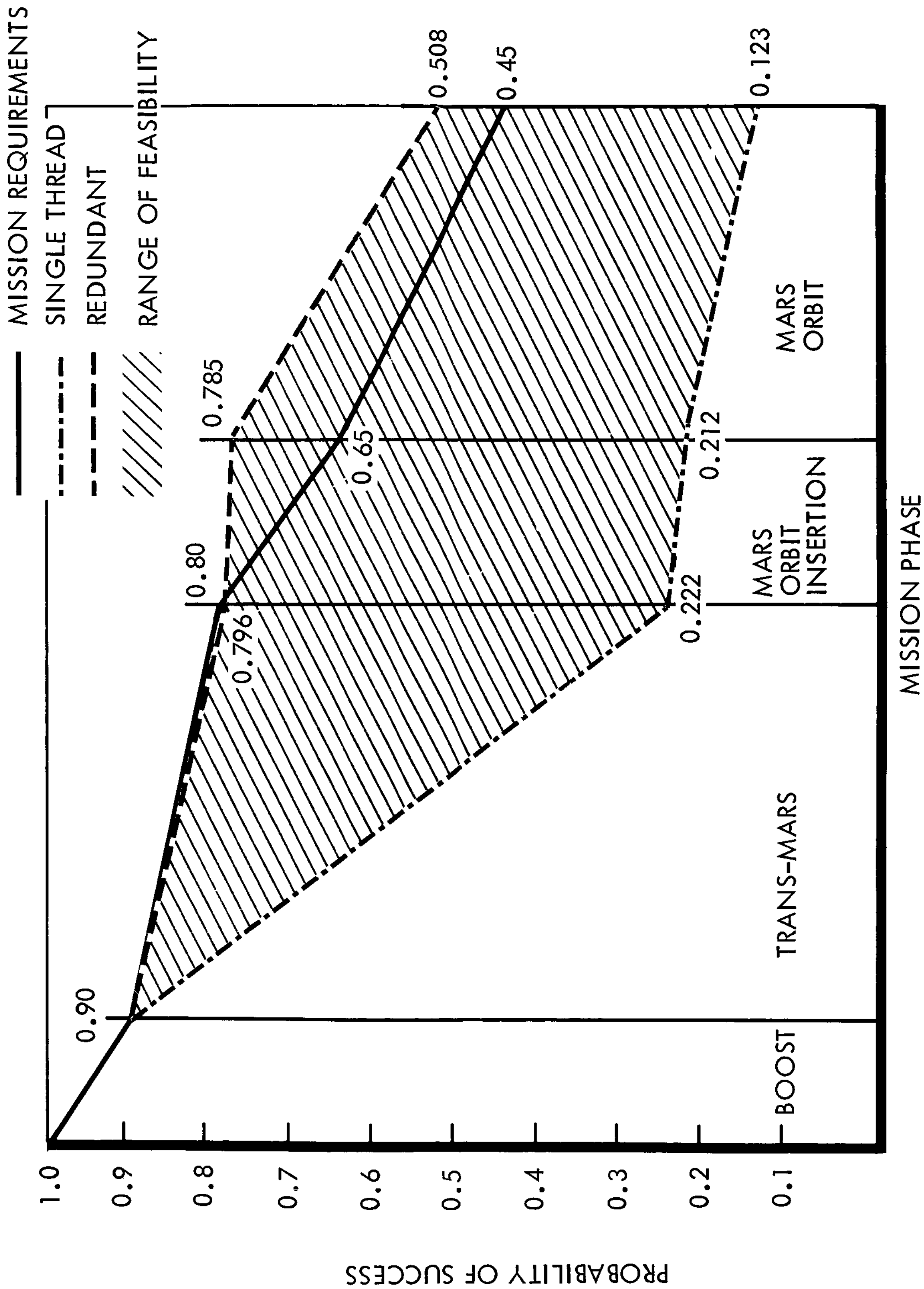


Figure 6-2: Reliability Feasibility

redundant or alternate modes on many critical functions. This fact is reflected in the preliminary design proposed by Boeing and the associated reliability allocation described in Section 6.6

Details of the feasibility assessment, along with initial allocations, are contained in the following paragraphs.

6.3.2 Feasibility Analysis

The range of reliability feasibility was established by performing an evaluation of a single-thread and a redundant Spacecraft Bus configuration and supplementing these studies with the results of a reliability-versus-weight optimization study. The single-thread configuration corresponded approximately to a minimum weight system. It contained no redundancy except that inherent in the design of the components. The redundant configuration used standby units on all critical elements except those protected by inherent redundancy. Failure rates as described in Section 6.3.1 and documented in D2-82724-3 were used in the evaluation of both configurations.

The results, to the subsystem level, of the comparative evaluation of the two configurations are summarized in Table 6-3. As noted in the table, common mission success values for "other" factors are used for both configurations. This was done to enable a comparison between the two Spacecraft Bus configurations insofar as they relate to achievement of overall mission objectives. It should also be noted, that the allocated science subsystem value (0.65) corresponds to the condition of

Table 6-3: Feasibility Evaluation

SUBSYSTEM	RELIABILITY	
	REDUNDANT	SINGLE THREAD
FLIGHT SPACECRAFT		
STRUCTURES & MECHANISMS	0.999	0.991
POWER	0.999	0.975
TEMPERATURE CONTROL	0.997	0.55
ATTITUDE CONTROL	0.995	0.862
COMPUTER & SEQUENCER	0.993	0.876
PROPULSION	0.989	0.946
TELECOMMUNICATION	0.980	0.610
REACTION CONTROL	0.956	*
SCIENCE	0.650	0.650
SUBTOTAL	0.592	0.144
OTHER FACTORS		
OPERATIONAL SUPPORT EQUIPMENT (Mission Dependent Equipment Only)	0.97	
LAUNCH VEHICLE & TRANS-MARS INJECTION	0.90	
HITTING AIM POINT, ± 500 KM, WITH FOUR MIDCOURSE CORRECTIONS	0.997	
ORBIT INJECTION	0.997	
PROBABILITY OF NO METEOROID DAMAGE	0.99	
ORBIT TRIM	0.999	
TOTAL	0.508	0.123

* SINGLE THREAD NOT CONSIDERED

complete success on all data-gathering functions, some of which provide overlapping data. A cursory analysis of this subsystem has indicated that reliability values in the neighborhood of 0.90 can be achieved by using success criteria based on data return requirements rather than operation of all experiments for the full time.

A summary of the reliability versus Spacecraft Bus (excluding science payload) weight trades is shown in Figure 6-3. The curves shown were developed by plotting ordered cumulative reliability gains achieved by the addition of redundant elements as a function of the corresponding weight increases due to the added redundancy. All plots have, as a starting point, a reliability and a weight corresponding to a single-thread Spacecraft Bus system. Ordering was in accordance with the magnitude of the ratio $\Delta R / \Delta W$ (i.e., in order of the largest reliability gain for the least weight).

Plot A is a theoretical optimum curve (based on work done by Dr. Frank Proschan of the Boeing Scientific Research Laboratories and documented in Mathematical Theory of Reliability, Barlam & Proschan, John Wiley and Sons, 1965) based on unrestricted choice of the number of redundant components. Plot B reflects the case where a restriction is placed in the form of no more than one redundant component for each basic component (corresponds generally to what has been described as the "redundant" configuration).

Investigation of the plots shows good agreement in the weight range of interest between the redundant configuration (chosen as a basis for the

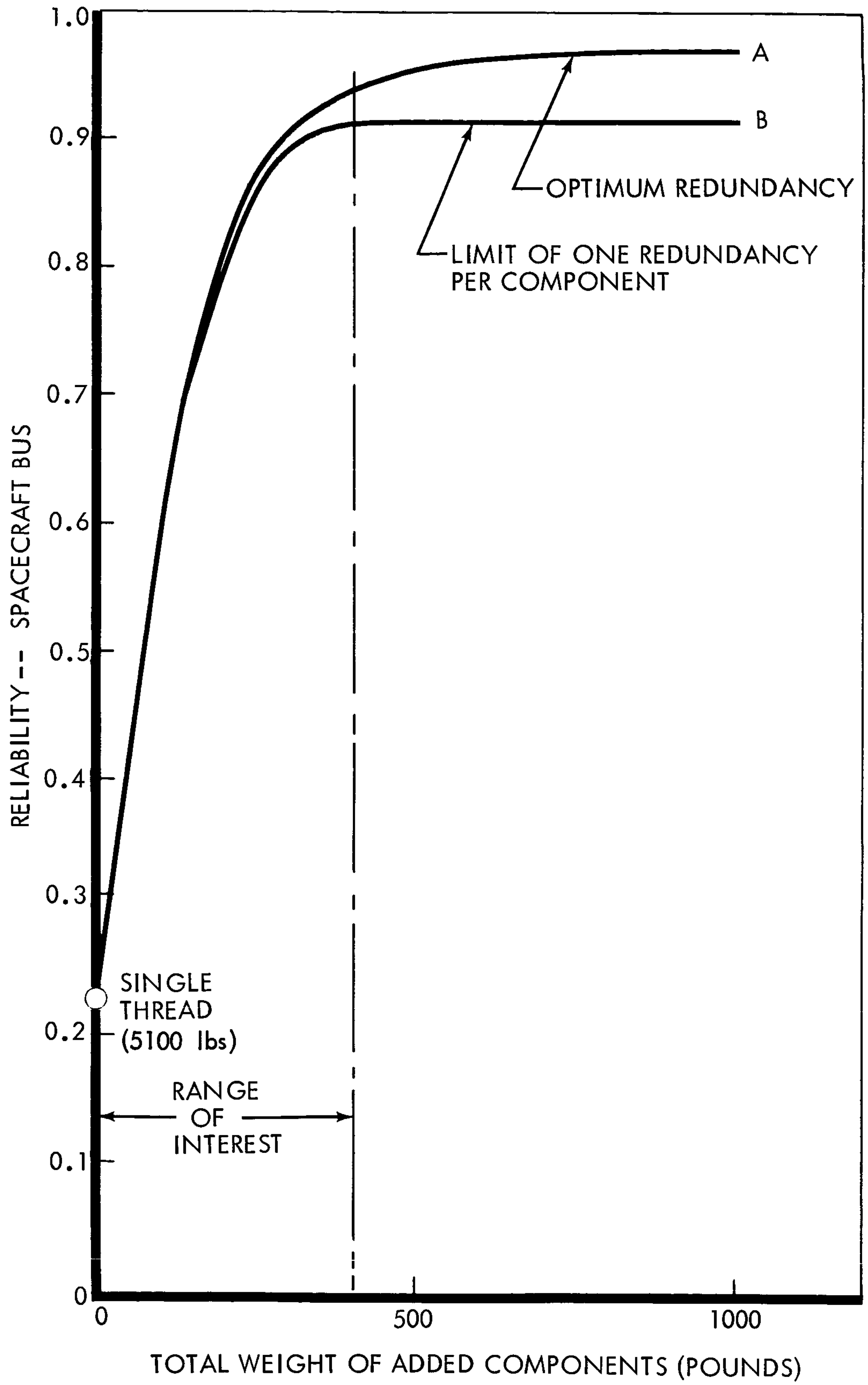


Figure 6-3: Spacecraft Bus — Reliability vs Weight

feasibility upper limit) and the theoretical optimum configuration. Practical design configurations concerning sensing, switching, etc., preclude complete adherence to the theoretical optimum.

6.3.3 Initial Reliability Allocation

6.3.3.1 Rationale

The results of the feasibility evaluation of Section 6.3.2 showed good potential for compliance with, or betterment of, Voyager 1971 mission success objectives without undue weight penalties. As a result, the initial reliability allocation was based directly on the upper limit of feasibility established by this evaluation.

6.3.3.2 Allocation

Table 6-4 shows the initial allocation of mission success for the Voyager system. It includes reliabilities for the Spacecraft Bus, science payload, OSE, and launch vehicle, and probability of success for categories of: no meteoroid damage, midcourse correction, orbit trim, and orbit injection. A contingency category, for the purpose of accounting for undefined equipment and environments, is also included.

Table 6-4: Voyager Spacecraft Mission—Initial Reliability Allocation

SUBSYSTEM COMPONENT	ALLOCATION		
	CONFIGURATION CODE	SUBSYSTEM R	COMPONENT LEVEL R
SPACECRAFT BUS	[1]		
ATTITUDE CONTROL		.995	
INERTIAL REFERENCE UNIT	IR		.9965
REACTION CONTROL ELECTRONICS	R		.9996
CANOPUS TRACKER	R		.9995
SUN SENSOR	R		.9999
PLANET SENSOR	R		.9995
REACTION CONTROL	IR	.956	
HIGH PRESSURE GAS			.9991
NOZZLE ASSY			.9568
CENTRAL COMPUTER AND SEQUENCER	R	.993	
TELECOMMUNICATIONS		.980	
RADIO --S - BAND	R		.9887
RADIO -- VHF	R		.9999
COMMAND	R		.9994
TELEMETRY	R		.9919
ANTENNA	R		.9997
HIGH GAIN S —BAND	R		
LOW GAIN S - BAND AND VHF	S		
ELECTRICAL POWER		.999	
SOLAR ARRAY	IR		.9999
BATTERY	R		.9997
ELECTRICAL POWER CONVERSION & CONTROL	R		.9995
ENVIRONMENTAL CONTROL	IR	.997	
STRUCTURES & MECHANISM		.999	
ACTUATOR ASSY, SOLAR PANEL	S		.9993
PLANET SCAN PLATFORM DRIVE	R		.9999
ANTENNA DRIVE, HIGH GAIN	R		.9999
ACTUATOR ASSY, LOW GAIN ANTENNA	S		.9998
ACTUATOR ASSY, VHF ANTENNA	S		.9998
STRUCTURES, BASIC	S		.9999
SPACECRAFT PROPULSION		.989	
MIDCOURSE CORRECTION			.999
MARS ORBIT			.990
SCIENCE PAYLOAD		.65	
SPACECRAFT SUBTOTAL		.592	
OPERATIONAL SUPPORT EQUIPMENT		.97	
LAUNCH VEHICLE & TRANS-MARS INJECTION		.90	
HITTING AIM POINT ± 500 KM WITH FOUR MIDCOURSE CORRECTIONS		.997	
ORBIT INJECTION		.997	
ORBIT TRIM		.999	
PROBABILITY OF NO METEOROID DAMAGE		.99	
CONTINGENCY [2]		.885	
MISSION TOTAL		.45	

[1] CONFIGURATION CODE: IR INHERENTLY REDUNDANT
R REDUNDANT COMPONENT
S SINGLE THREAD

[2] TO ACCOUNT FOR AS YET UNDEFINED VARIATIONS IN SPACECRAFT EQUIPMENT, SCIENCE PAYLOAD, AND SPACE ENVIRONMENT.

Constraints such as weight, cost, and development time place limits on the choice and degree of implementation of improvement options. While redundancy can provide significant improvements in reliability, it does have disadvantages in terms of both weight and cost. This fact is illustrated in Figure 6-4 where λt reductions are plotted as a function of both additional weight and cost for five selected components. As was the case of the reliability-versus-weight trade curves shown previously, reliability gains (or equivalent λt reductions) are plotted in a cumulative, ordered manner. It will be noted, with the exception of the inversion of Items 2 and 3 on the weight curve, that there is agreement between the order of components, indicating correlation of the two penalty factors. Extrapolation from these curves (and reference to Figure 6-3) indicates the magnitude of the weight and cost problem when requirements dictate redundancy on many of the Spacecraft Bus functions. In general, choice of improvement options will depend on the effectiveness of the option in a particular application. More detailed discussion of these options is contained in Section 6.5.

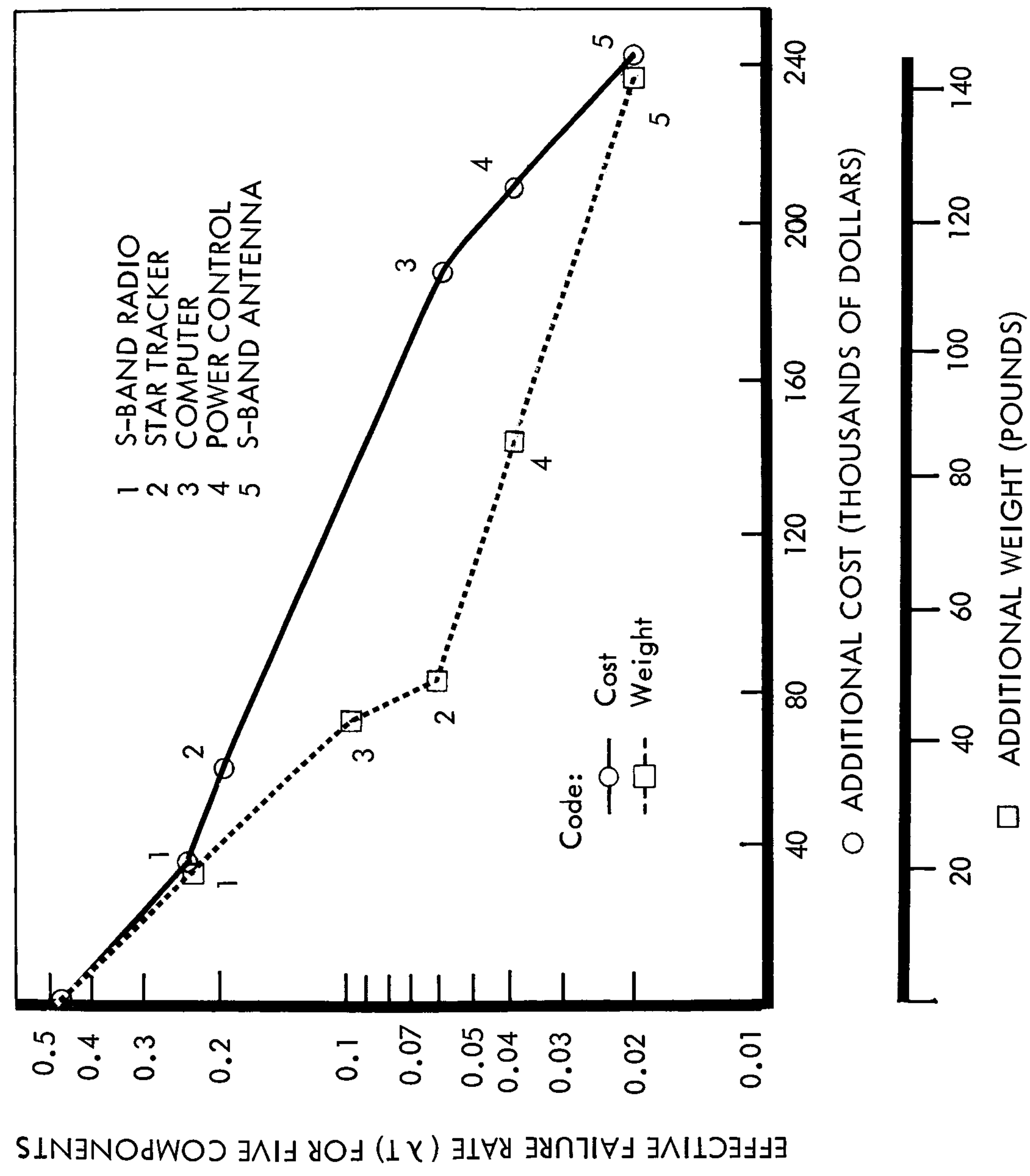


Figure 6-4: Cost & Weight Effectiveness — Standby Redundancy

6.5 ANALYSES OF ALTERNATE AND PREFERRED SUBSYSTEM

6.5.1 General

The following paragraphs summarize and discuss the reliability analyses performed on candidate Spacecraft Bus subsystems. Included also are analyses of the Saturn IB/Centaur launch vehicle, science subsystem, and operational support equipment that were used in determining compliance with overall mission objectives. The material is organized by individual subsystems, with each subsystem section containing material relating to both alternate and preferred designs.

Technical data for each subsystem are presented in summary form. Substantiating data, including mathematical models, data standards, detailed probability analyses, and failure mode and effect analyses are contained in the backup documents referenced in Section 6.1: D2-82724-1, "Voyager Reliability"; D2-82724-2, "Voyager Failure Mode and Effects Analysis"; and D2-82724-3, "Voyager Program Reliability Analysis and Prediction Standards." Examples of the material contained in these documents are illustrated in Tables 6-6, 6-7, and 6-8, respectively.

FACTORS AND INCREMENTS / ITEM	FAILURE RATE PER 10^6 HOURS	LAUNCH & BOOST			
		CUMULATIVE TIME 0.50 H			
		K_D	K_E	ΔT	λ
REACTION CONTROL SUBSYSTEM					
N_2 TANK (2 PAIR, NEED ONE)	0.08 x 2	1	300	0.04	0.000
N_2 TANK (2 PAIR, NEED ONE)	0.08 x 2	1	6	0.46	0.000
TANK λT					0.000
CUM. TANK λT					0.000
R OF TWO PAIR $R = 1 - Q_1^2$ PR.					1.0
SOLENOID VALVE	$P_F = 0.00001$			---	--
REGULATOR	2.4	0.001	300	0.04	--
REGULATOR	2.4	0.001	6	0.46	--
NOZZLE AND CONTROLS	1.1 x 8	0.001	500	0.04	0.000
NOZZLE AND CONTROLS	1.1 x 8	0.001	10	0.46	--
NOZZLE AND CONTROLS	1.1 x 8	---	---	---	--
NOZZLE AND CONTROLS	1.1 x 8	---	---	---	--
SUMMARY FOR SINGLE BRANCH (λt)					0.000
CUMUL. λt FOR SINGLE BRANCH					0.000
CUMUL. R FOR SINGLE BRANCH					0.999
FAILURE DETECTION	1.0	0.1	300	0.03	0.000
		0.1	6	0.46	0.000
FAILURE DETECTION $\Sigma\lambda t$					0.000
FAILURE DETECTION CUMUL. λt					0.000
DETECTION AND SWITCHING (0.99) COMBINED					0.99
STANDBY BRANCH λt					0.000
STANDBY BRANCH CUMUL. λt					0.000
REACTION CONTR. INST. CUM. REL.					0.999

THE FILTER USED IN FILLING THE N_2 TANKS IS ASSUMED TO BE DISCONNECTED AND THE GROUND. WHEN CAPPED AFTER FILLING, THE FILL AND VENT VALVE IS CONSID CONTRIBUTE NEGLIGIBLE UNREALIABILITY. QUAD CHECK VALVES ALSO CONTRIBUTE UNRELIABILITY.

/

	TRANSIT—EARTH ORBIT CAPSULE SEPARATION				SPACECRAFT INSERTION INTO MARS ORBIT				SPACECRAFT IN MARS ORBIT ONE MONTH			
OURS	CUMULATIVE TIME 4968 HOURS				CUMULATIVE TIME 5160 HOURS				CUMULATIVE TIME 5880 HOURS			
T	K_D	K_E	ΔT	λT	K_D	K_E	ΔT	λT	K_D	K_E	ΔT	λT
0019	1	6	0.03	---	1	6	0.083	---	1	1	720	0.000115
00044	1	1	4968	0.000794	1	1	192	0.000031				
00234				0.000794				0.000031				0.000115
00234				0.000796				0.0008273				0.000942
				0.999999+				0.999999+				0.999999+
-			1 CYCLE	0.00001	---	---	---	0.00001			---	0.00001
-	1	6	0.03	0.0000004	1	6	0.083	0.0000012	1	1	720	0.001728
-	1	1	4968	0.011923	1	1	192	0.000461				
003	0.001	10	0.03	---	0.001	10	0.083	---	0.001	1	720	0.0000063
-	0.001	1	4968	0.0000437	0.001	1	192	0.000017				
-	1	10	NEGL.	---	1	10	NEGL.	---	1	1	0.00324	---
-	1	1	0.0[illegible]224	0.0000002	1	1	0.000864	---				
003				0.011977				0.0004739				0.001744
003				0.0119773				0.0124512				0.0141952
7				0.9881				0.9876				0.9859
012	[illegible]	6	0.3	0.00000018	1	6	0.083	0.0000005	1	1	720	0.000720
0027	1	1	4968	0.004968	1	1	192	0.000192				
0147				0.00496818				0.0001925				0.000720
0147				0.00496965				0.00516215				0.00588215
				0.9851				0.9849				0.9842
003				0.0000556				0.0000175				0.000008
003				0.0000559				0.0000734				0.0000814
				0.999758								
9+				0.99970				0.99963				0.99959

LEFT ON
RED TO
NEGLIGIBLE

SUBSYSTEM Temperature Control

COMPONENT	NO.	FUNCTION
Electric heating elements located to supplement heat demands of the electronic, propulsion, and mechanical elements of the spacecraft.	16	Dissipates heat to local area deficient. Turns on upon demand of a temperature sensor. Heaters have not yet been located relative to internal electronic packages. It is planned to locate in places where the electronic gear is dormant for significantly long times and thus not generating any heat.

/

DWG. NO. BY Voyager Re

FAILURE MODE	FAILURE MODE CLASSIFICATION COMP	MISS	RELATIVE CHANCE TO OCCUR	ON COMPONENT
1. Fails open	1.7.6		Possible	Will not heat thus allowing the local area to drop below lower temperature limit.
2. Leads short to ground	[illegible]		Possible	Heater fails to deliver heat.
3. Heater detached from conducting material	1.7.6		Possible	Heater fails to deliver heat to area electronics.
4. Heater activated erroneously	3.7.6		Possible	Heater adds heat to an area not demanding heat.

2

Table 6-7: Subsystem Failure Modes and Effects

liability 2-5956-0

EFFECTS ON SUBSYSTEM	ON MISSION	ALTERNATIVES
Local area electronics operating at lower limits of temperature. Will serve to increase failure probability of "turnon" stresses.	Little or none	The temperature control concept is based on sufficient solar gain to maintain temp limits throughout mission without heaters except for localized conditions. If conduction paths can be devised to level heat dissipation from internal components, louver control will be adequate.
Arcing or contaminants ejected. Ground potential spikes produced. RFI induced. Dissipates battery.	Unknown until positioning of heaters known in more detail. Some will cause mission loss (e.g. inertial reference unit)	It is assumed that some sort of short protection such as fuzing will be employed.
Localized cooling of dormant electronics. May increase failure probability of electronic parts.	None	Louver control plus good design to level heat gradients will minimize
Temperature starts up and louver control activates for greater dissipation.	None	Louver design will consider individual louver or small groups controlled and activated separately.

THE BOEING COMPANY | Table 6-8: | NUMBER D2-82724-3 REV LTR B

5.0 PARTS STANDARD FAILURE RATES (CONT'D)			
NOMENCLATURE	PART CLASS	SOURCE	FAILURE RATE (FAILURES PER HR X 10^6)
TRANSDUCERS (CONT)			
TEMPERATURE (THERMOCOUPLE)	ELECTR	J BOEING	31 A
(SEE ALSO SPECIFIC PART OR ASSEMBLY TYPE)			
TRANSFORMERS			
AUDIO	ELECTR	A	0.011/WINDING
MAGNETIC LOGIC, TORROIDAL	ELECTR	[illegible]	0.02/WINDING
MEMORY CORE (SEE CORE--FERRITE MEMORY)	EL[illegible]		
POWER, LOW VOLTAGE	[illegible]	A	0.018/WINDING
POWER, HIGH VOLTAGE	ELECTR	M PHILCO	0.1/WINDING
PULSE	ELECTR	C	0.01/WINDING
RADIO FREQUENCY	ELECTR	M PHILCO	0.003/WINDING
SATURABLE, CONVERTER	ELECTR	A	0.006/WINDING
TRANSISTORS			
GERMANIUM, HIGH POWER	ELECTR	D	0.041
GERMANIUM, SWITCH	ELECTR	D	0.017
SILICON, FIELD EFFECT	ELECTR	C	0.05
SILICON, POWER	ELECTR	A	0.051
SILICON, SMALL SIGNAL	ELECTR	D	0.034

6.5.2 Telecommunications Subsystem

6.5.2.1 Summary Data

Table 6-9 presents summary data for the telecommunications subsystem.

Table 6-9: TELECOMMUNICATIONS RELIABILITY SUMMARY

	MISSION RELIABILITY
Feasibility Range	0.6100 to 0.9800
Initial Allocation	0.9800
Trade Range	0.6191 to 0.9743
Preferred Subsystem Assessment*	0.8416
Revised Allocation	0.841

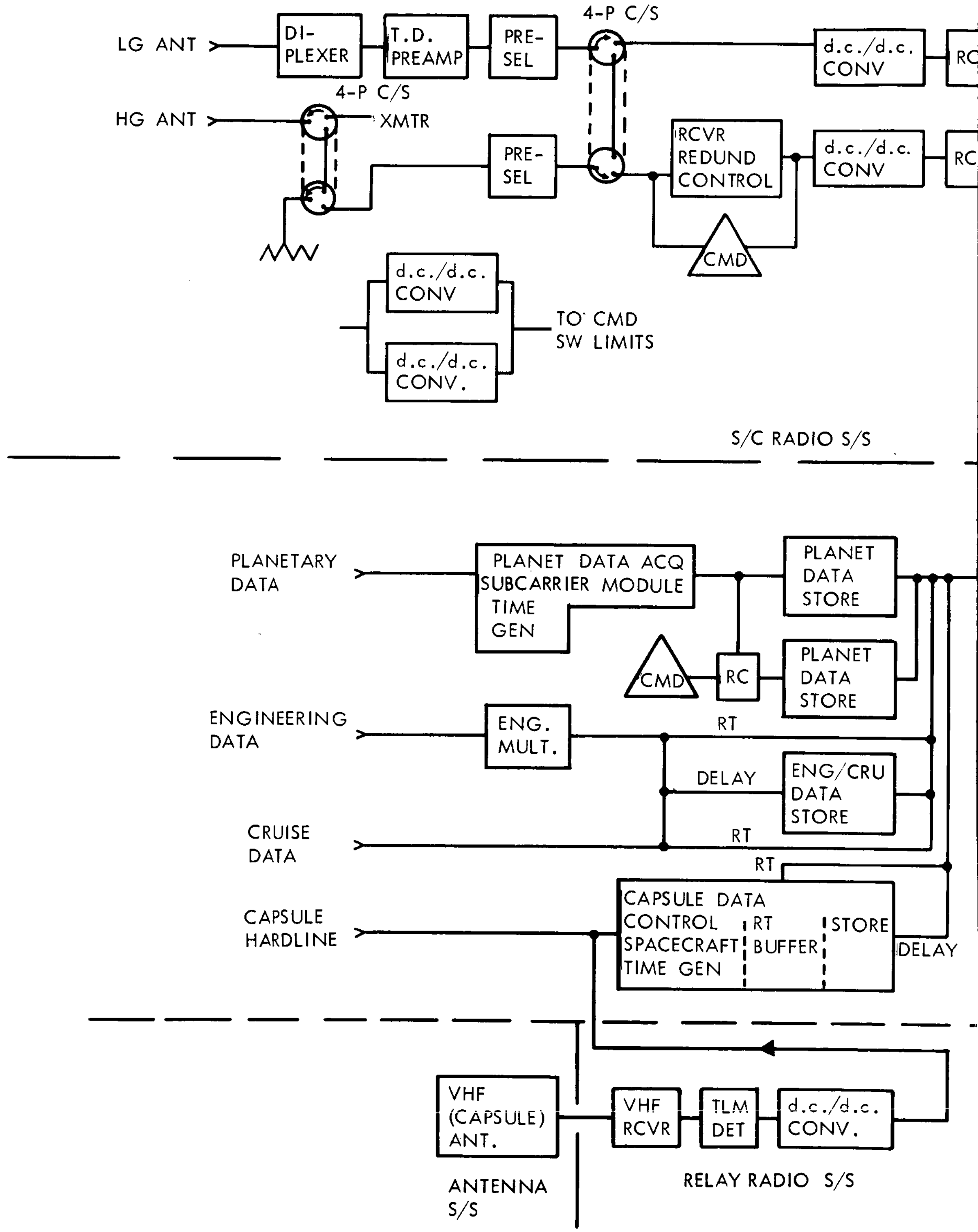
6.5.2.2 Discussion

Table 6-9 is a capsule summary of the pertinent reliability values derived for the telecommunications subsystem. The preferred subsystem reliability assessment of 0.8416 is based on the reliability block diagram in Figure 6-5.

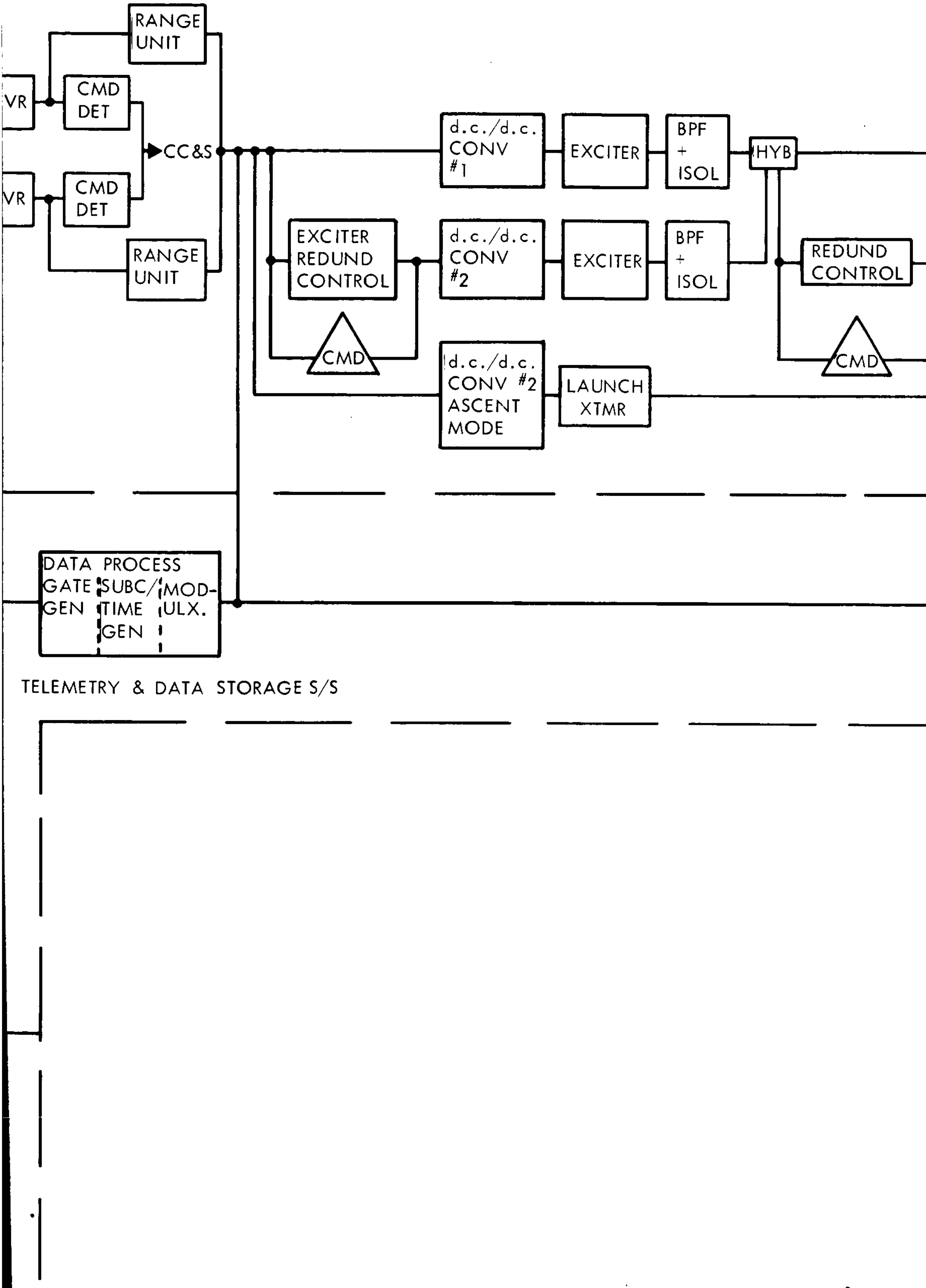
Figure 6-6 summarizes the mission reliability evaluations for the preferred telecommunications subsystem and its major components. It also shows the cumulative mission reliability by mission phase.

The major contribution (approximately 71 percent) to the unreliability of the preferred telecommunication system is made by the telemetry and data storage component, and is primarily due to two subcomponents,

*See footnote to Table 6-17.



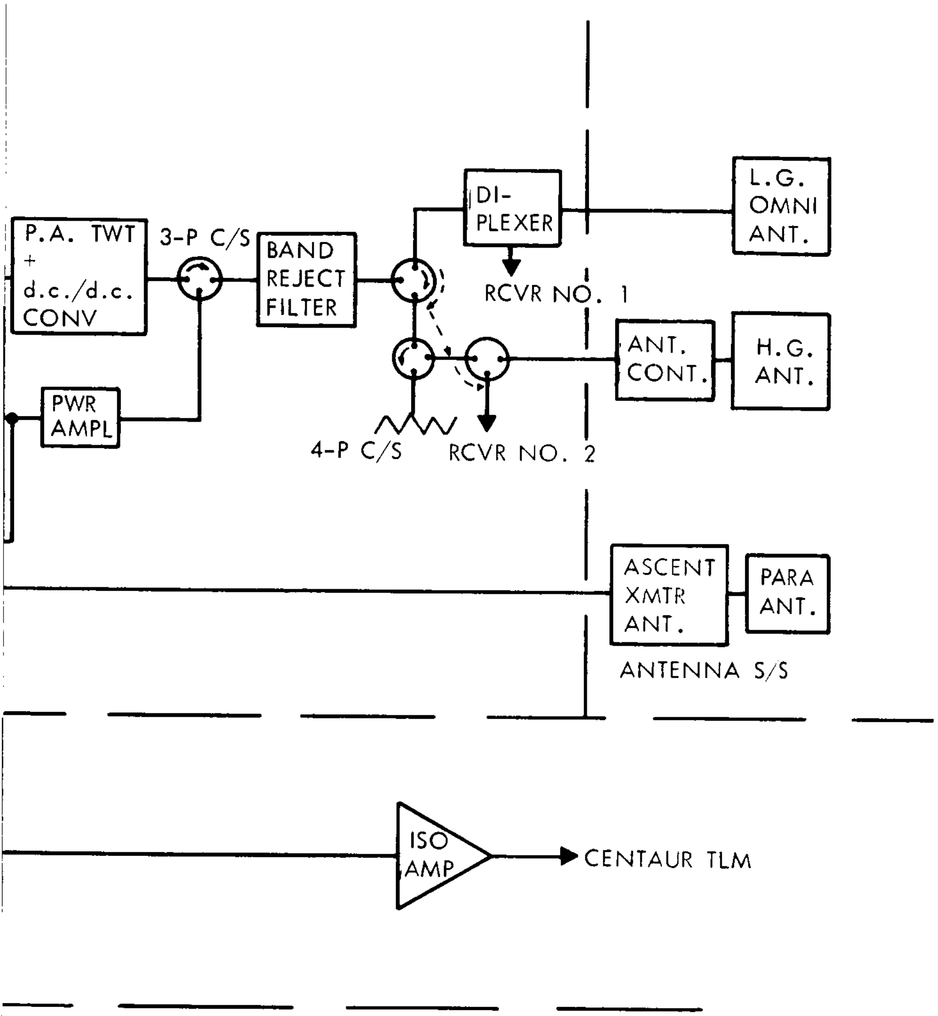
LG ANT
DI-PLEXER
T.D. PREAMP
PRE-SEL
4-P C/S
d.c./d.c. CONV
RC
HG ANT
4-P C/S
XMTR
PRE-SEL
RCVR REDUND CONTROL
d.c./d.c. CONV
RC
CMD
d.c./d.c. CONV
d.c./d.c. CONV.
TO CMD SW LIMITS
S/C RADIO S/S
PLANETARY DATA
PLANET DATA ACQ SUBCARRIER MODULE
TIME GEN
PLANET DATA STORE
CMD
RC
PLANET DATA STORE
ENGINEERING DATA
ENG. MULT.
RT
DELAY
ENG/CRU DATA STORE
CRUISE DATA
RT
RT
CAPSULE HARDLINE
CAPSULE DATA CONTROL SPACECRAFT TIME GEN
RT BUFFER
STORE
DELAY
VHF (CAPSULE) ANT.
ANTENNA S/S
VHF RCVR
TLM DET
d.c./d.c. CONV.
RELAY RADIO S/S



RANGE UNIT
VR
CMD DET
CC&S
VR
CMD DET
RANGE UNIT
d.c./d.c. CONV #1
EXCITER
BPF + ISOL
HYB
EXCITER REDUND CONTROL
d.c./d.c. CONV #2
EXCITER
BPF + ISOL
REDUND CONTROL
CMD
CMD
d.c./d.c. CONV #2 ASCENT MODE
LAUNCH XTMR
DATA PROCESS
GATE GEN
SUBC/ TIME GEN
MOD- ULX.
TELEMETRY & DATA STORAGE S/S

Figure

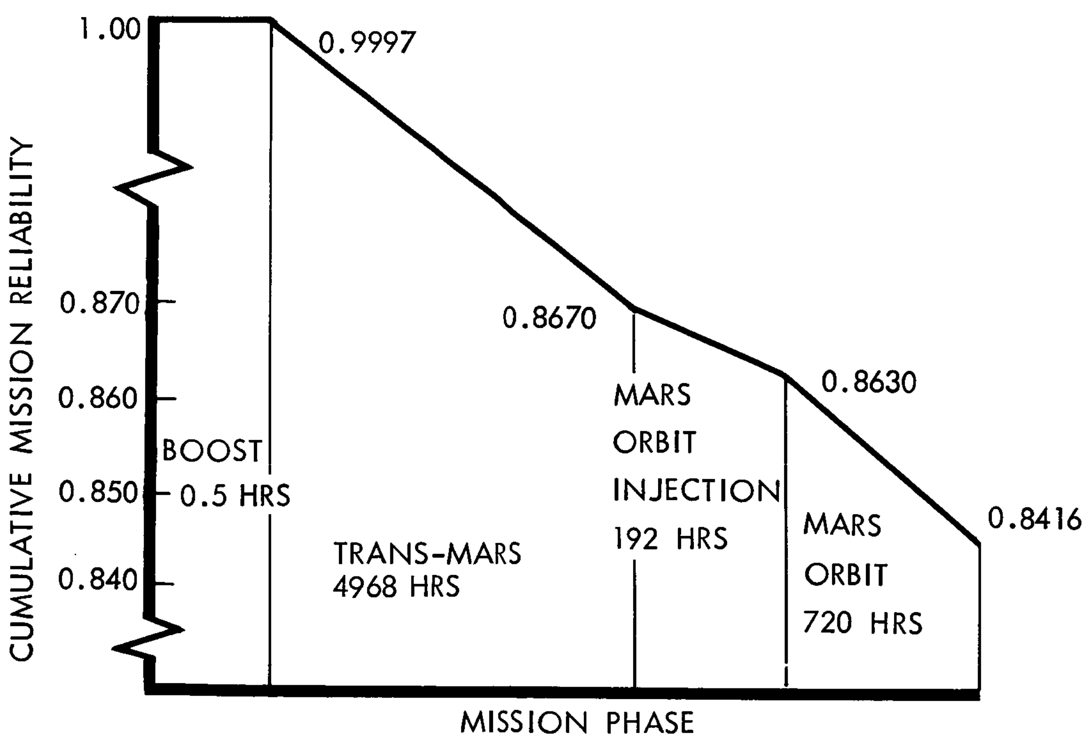
2



6-5: Reliability Block Diagram for Telecommunications

COMPONENT	MISSION RELIABILITY
ANTENNA	0.9838
RELAY RADIO	0.9945
TELEMETRY & DATA STORAGE	0.8833
RADIO	0.9738

RELIABILITY OF SUBSYSTEM COMPONENTS



SUBSYSTEM HAZARD CHART

Figure 6-6: Preferred Subsystem Reliability Summary—— Telecommunications Subsystem namely, the data processing unit, which is used to process all data, and the cruise/engineering data acquisition and storage unit, which is used primarily to obtain engineering data. The former unit accounts for 28 percent of the telemetry data and storage component unreliability and the latter accounts for 60 percent. The radio component, with an assessed reliability of 0.9738, provides the second largest contribution (16 percent) to the preferred telecommunications subsystem unreliability. Although the main r.f. power amplifier section including exciter is redundant, it accounts for 53 percent of radio component unreliability. The unreliability of the antenna control assembly (69 percent of the antenna component) is primarily responsible for the antenna component accounting for 10 percent of telecommunications subsystem unreliability.

Significant improvement in the reliability of any of the above three systems would result in a worthwhile improvement in telecommunications subsystem reliability. Trade studies indicate that the greatest improvement in the telecommunications subsystem's reliability can be achieved by more extensive use of redundancy in the sync/subcarrier generator, format generator and engineering multiplexer/encoder modules. By this means, the unreliability of the telemetry and data-storage component can be reduced by about a factor of 5. This would result in an increase in subsystem reliability from 0.84 to about 0.91.

6.5.2.3 Failure Mode and Effect Analyses Summary

A detailed failure mode and effect analyses summary, by critical component, is shown below.

CRITICAL COMPONENT	FAILURE MODE	EFFECT ON MISSION
High-Gain Antenna	No signal to receiver	Loss of command and tracking (T = 60 days and on)*
	No signal to Earth	Loss of mission through loss of data and tracking (T = 60 days and on)
VHF Antenna	No signal to relay radio	Loss of capsule; Mars entry and surface data
Relay Radio Subsystem	No output	Loss of capsule; Mars entry and surface data
Data Processing	No output	Loss of mission; no capsule, planet orbit or cruise/engineering data
High Gain Antenna Receiver Selector Switch	Fail - off	Loss of command and tracking (T = 60 days and on)
Hy-Brid	Improper output	Loss of mission through loss of data and tracking on both high-gain and low-gain circuits
Notch Filter	No output	Loss of mission through loss of high-gain and low-gain transmission of data and tracking
	Filter failure causing damage to receivers	Loss of command and tracking
Transmitting Antenna Selector Switch	Fail open	Loss of mission through loss of high-gain and low-gain transmission of data and tracking.

*T=O is the time of launch

CRITICAL COMPONENT	FAILURE MODE	EFFECT ON MISSION
Transmitting Antenna Selector Switch (continued)	Fail to switch to high gain	Loss of mission through loss of high-gain data and tracking (T = 60 days and on)
High-Gain Antenna Preselect	Open circuit - No output	Loss of high-gain command and tracking (T = 60 days and on)

6.5.3 Attitude References Subsystem

6.5.3.1 Summary Data

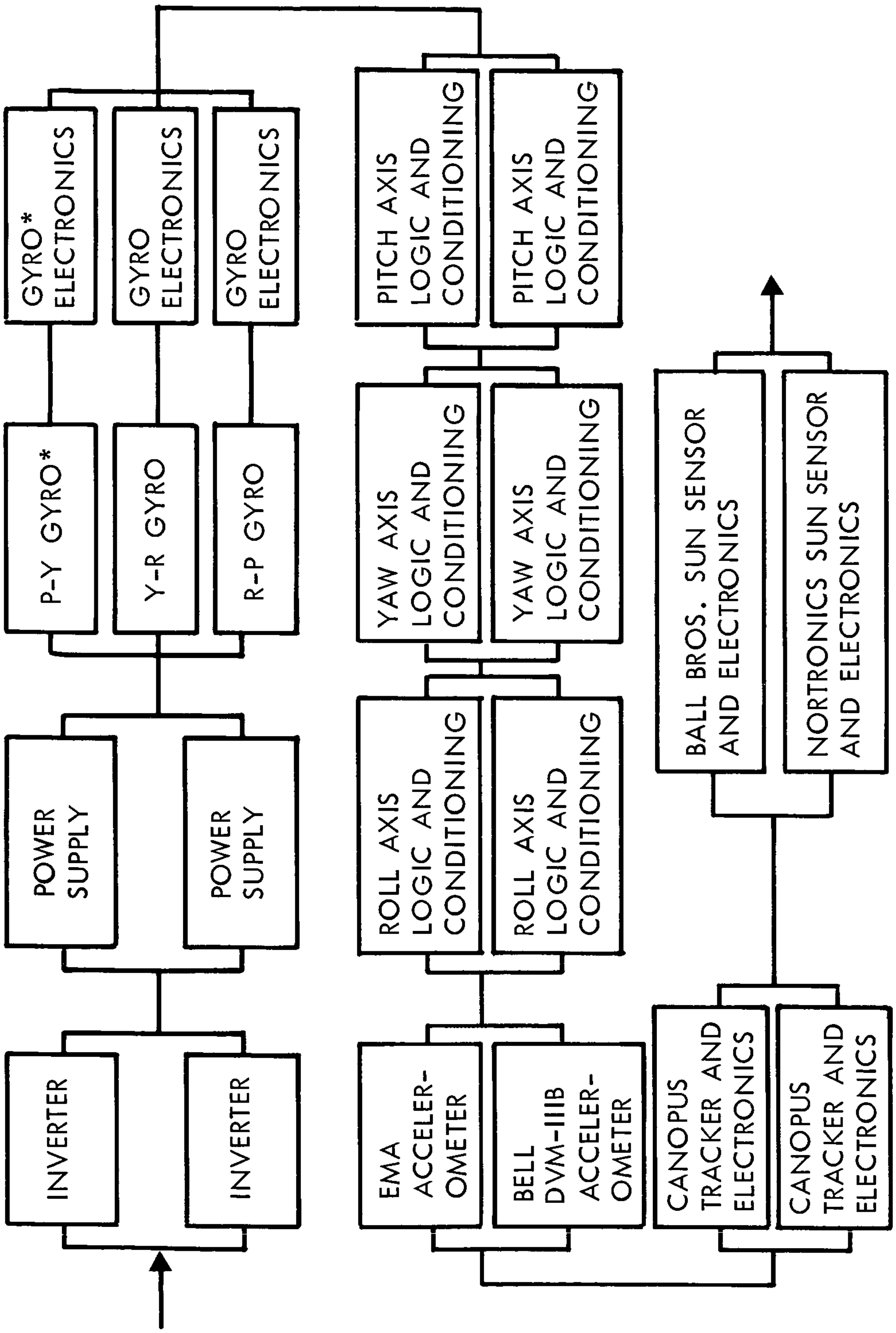
Table 6-10 presents summary data for the attitude references subsystem.

Table 6-10: ATTITUDE REFERENCES RELIABILITY SUMMARY

	MISSION RELIABILITY
Feasibility Range	0.87 to 0.997
Initial Allocation	0.9954
Trade Range	0.995 to 0.997
Preferred Subsystem Assessment	0.9969
Revised Allocation	0.996

6.5.3.2 Discussion

The reliability allocation, feasibility range, trade range, and preferred system assessment for the attitude references subsystem are shown in Table 6-10. The preferred system configuration includes complete redundancy as shown in the reliability block diagram of Figure 6-7.



*Two of Three Gyro-Electronics Groups Required

Figure 6-7: Reliability Block Diagram — Attitude Reference Subsystem

Figure 6-8 summarizes the reliability assessment of the preferred attitude references subsystem. Also shown is the subsystem cumulative reliability by mission phase. Several lower-level trade-offs were considered, with results shown in Table 6-11. To reduce the possibility of systematic failures occurring simultaneously in both of two redundant channels, when feasible the preferred subsystem mechanization consists of alternate hardware produced by different manufacturers. The mechanization should be as different as is consistent with the requirement that they present the same interface to other subsystems.

A reliability summary of the redundancy trades considered is tabulated in Table 6-12. Several lower-level trades considered are also shown in Table 6-11.

Table 6-12: RELIABILITY TRADE SUMMARY

SUBSYSTEM	SINGLE THREAD	REDUNDANT
Gyro	0.9574	0.99937
Accelerometer	0.99938	0.99996
Sun Sensor	0.9411	0.9992
Canopus Tracker	0.9606	0.9984
Total Attitude Reference	0.8650	0.9969

6.5.3.3 Failure-Mode and Effects Summary

The predominant failure modes within the gyro unit are:

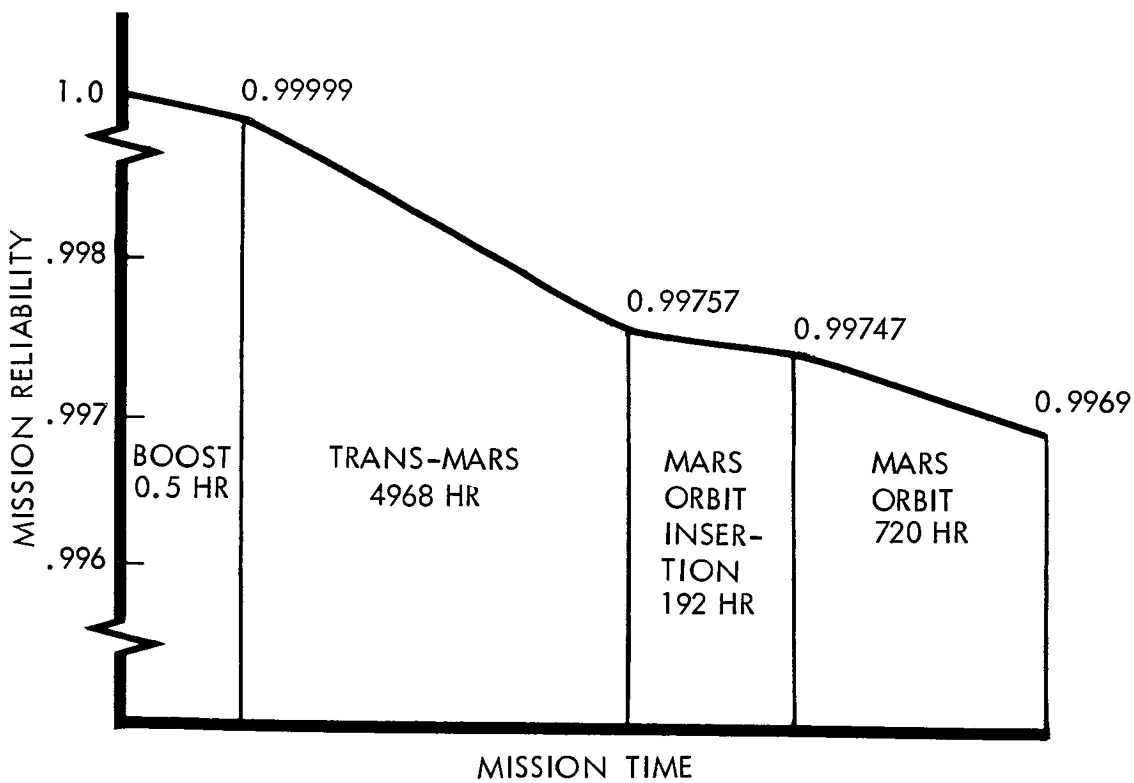
1) Loss of one axis data output;

2) Loss of one gyro data output;

3) Loss of one power supply input.

COMPONENT	MISSION RELIABILITY
Gyro Unit	0.99937
Accelerometer	0.99996
Sun Sensor	0.9992
Canopus Tracker	0.9984

RELIABILITY OF SUBSYSTEM COMPONENTS



SUBSYSTEM HAZARD CHART

Figure 6-8: Preferred Subsystem Reliability Summary — Attitude References

Table 6-11: Reliability Trades

SUBSYSTEM	PRIMARY ELEMENTS	BACKUP ELEMENTS	MISSION RELIABILITY
Gyro Unit	2 Dual-Axis Gyros 3 Single-Axis Gyros	1 Dual-Axis Gyro 3 Single-Axis Gyros	0.99937 * 0.95809
Accelerometer	EMA [1] EMA Bell	EMA [1] Bell Bell	0.99999 0.99996 * 0.9967
Canopus Tracker	Barnes Barnes ITT	Barnes ITT ITT	0.9984 * 0.9984 0.9983
Sun Sensor	Nortronics Ball Bros. Ball Bros .	Nortronics Nortronics Ball Bros.	0.9965 0.9992 * 0.9998

* Preferred Subsystem

[1] Letter designation and names refer to manufacturer or model

Complete three-axis redundancy is provided within the gyro unit. Loss of data on one channel of one axis is unlikely. However, if it does occur, internal circuitry will switch to the other channel for data thereafter. The effect of this failure will be loss of redundancy on one axis. A more predominant failure mode is loss of one gyro. Internal circuitry will then switch to the two good gyros for three-axis data. The effect of this failure mode will be loss of redundancy on the two axes assigned to the failed gyro.

A failure of one of the two IRU power supplies will have no effect on the system operation, other than to lose redundancy in the power supply. Isolation and protective devices will prevent any failure in one supply from influencing the operation of the other supply.

The predominant failure modes in the accelerometer subsystem are low or intermittent outputs and no output. If either failure mode should occur in the primary system, the backup or redundant accelerometer system will provide a thrust-termination signal. Thrust termination by a CC&S signal is a third backup mode.

Known failure modes in the Canopus-tracker subsystem are performance degradation, erroneous outputs, and a complete loss of output data. General failure modes in the Sun-sensor subsystem are the same as for the Canopus-tracker. Complete redundancy is provided on each sensing axis. Failure can be recognized by comparing the four independent sources of data (two gyros and two trackers) for each axis, and switching accomplished either by onboard logic or through ground command.

6.5.4 Autopilot Subsystem

6.5.4.1 Summary Data

Table 6-13 presents summary data for the autopilot subsystem.

Table 6-13: AUTOPILOT RELIABILITY SUMMARY

	MISSION RELIABILITY
Feasibility Range	0.9763 to 0.999812
Initial Allocation	0.9996
Trade Range	0.9982 to 0.999812
Preferred Subsystem Assessment	0.999812
Revised Allocation	0.999

6.5.4.2 Discussion

Table 6-13 summarizes pertinent reliability values for the autopilot subsystem. Three basically different redundancy concepts were considered: single thread, dual redundant, and triple redundant.

The preferred system employs both operating and standby redundancy as well as forms of triple redundancy. The redundancy concept of the system interfaced with and the signal form determine the type of redundancy employed in a given circuit.

Figure 6-9 is a reliability block diagram of the selected d.c. analog autopilot. The power supply and signal-summing amplifiers are connected in a TRISAFE arrangement that provides proper output in every case when two out of three are operating correctly, and when only one is operating

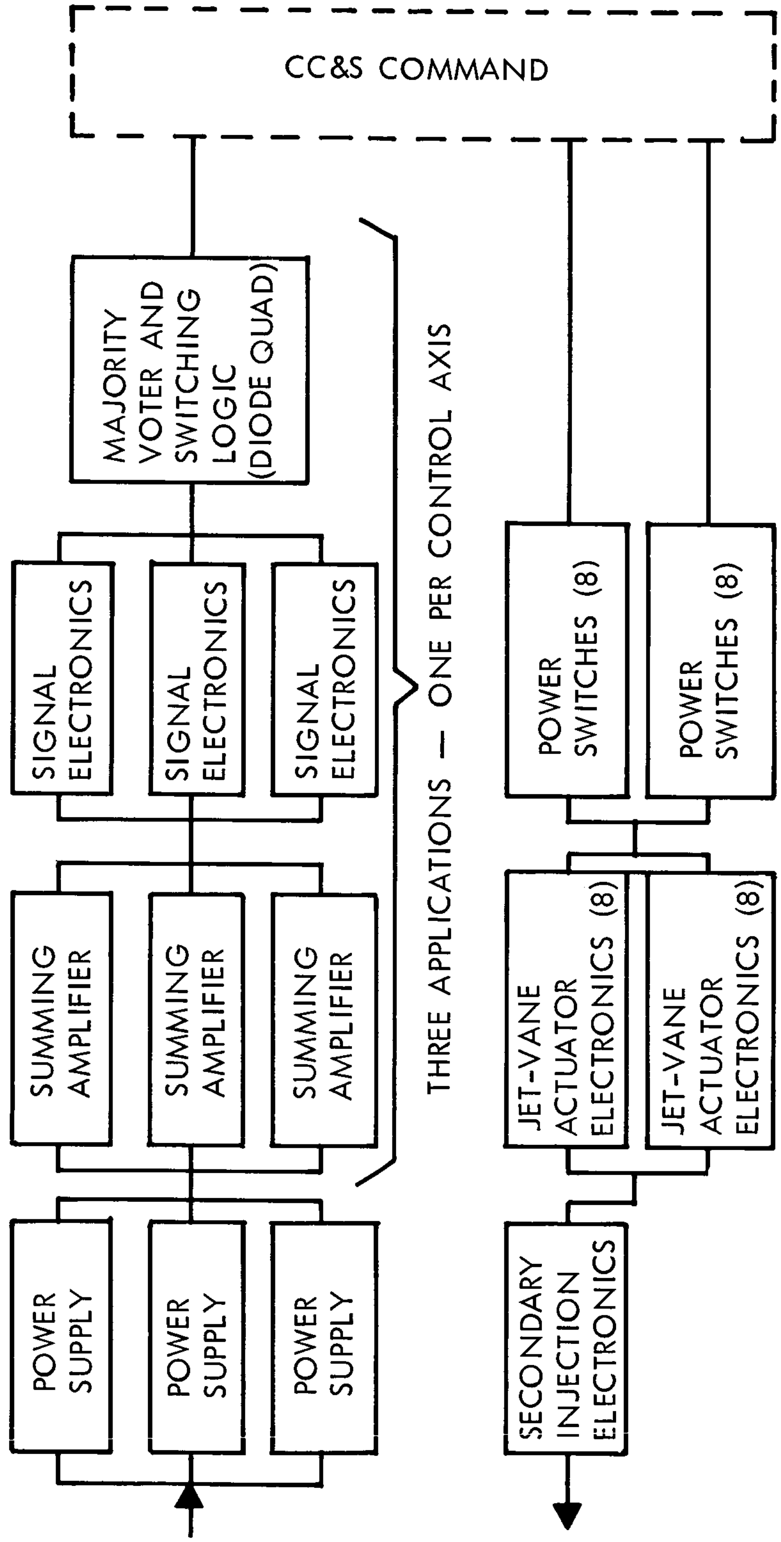


Figure 6-9: Reliability Block Diagram — Autopilot Subsystem

correctly for a significant number of failure modes. The signal electronics majority voter is a diode quad arrangement that provides internal redundancy for both open- and short-circuit failure modes. The reaction-control power switches and jet-vane actuator electronics are connected in series to both the primary and backup items, which they respectively drive. This yields overall redundancy and provides for higher reliability switching (at the signal rather than power level). The secondary injection electronics is not redundant since there is no redundancy in the thrust-vector injection system on the main engine. The single-thread electronics is more reliable than the injection system, and further reliability gains through redundant electronics are insignificant at the system level.

Mission reliability for each block of hardware at the level determined to be optimum for redundancy is shown in Figure 6-10. The subsystem hazard curve for the total autopilot is also shown in Figure 6-10.

Table 6-14 is a reliability summary of the trades considered.

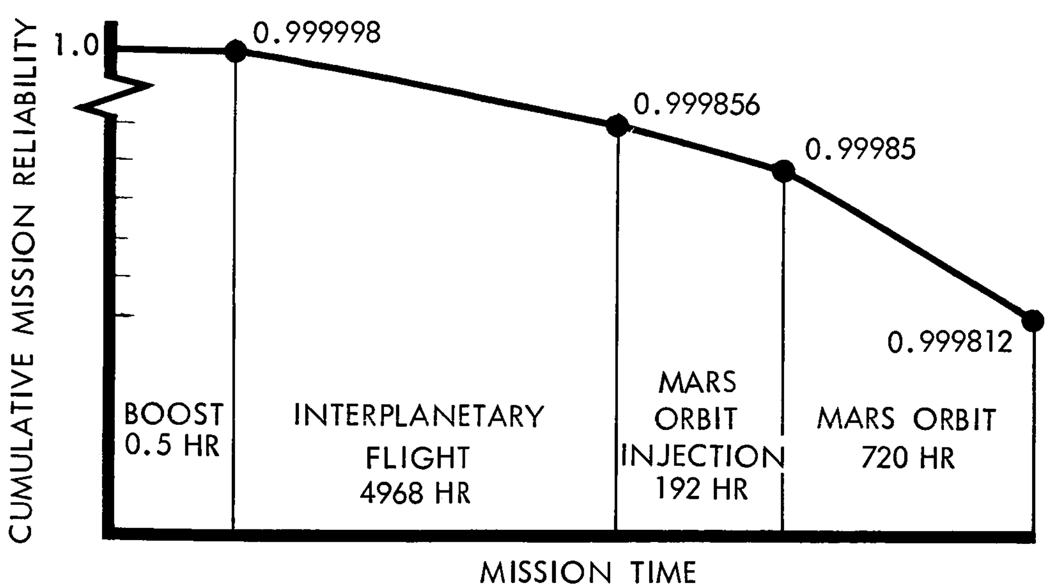
Table 6-14: RELIABILITY TRADE SUMMARY--AUTOPILOT SUBSYSTEM

REDUNDANCY / CONCEPT	SINGLE-THREAD SYSTEM	REDUNDANT SYSTEM
D.C. Analog*	0.99708	0.999812
A.C. Analog	0.99664	0.99972
Digital	0.9763 to 0.9964	0.9982 to 0.99978

*Preferred Subsystem

COMPONENT	MISSION RELIABILITY
Power Supply	0.999919
Pitch Axis Electronics	0.999997
Yaw Axis Electronics	0.999997
Roll Axis Electronics	0.999997
Reaction Jet Power Switches	0.999999
Jet-Vane Actuator Electronics	0.999997
Secondary Injection Electronics	0.999905

RELIABILITY OF SUBSYSTEM COMPONENTS



SUBSYSTEM HAZARD CHART

Figure 6-10: Preferred Subsystem Reliability Summary — Autopilot

6.5.4.3 Failure-Mode and Effects Analysis

Each of the three channels provided in each control axis has two predominant failure modes: the open-circuit type that results in no output from that channel; and one that results in an erroneous channel output. In either case, the majority voter will recognize a difference in data from the failed channel, and will discard this data as long as the fault persists.

The majority voter in each axis also has two predominant failure modes: an open-circuit type that results in no output from the voter; and one that prevents the voter from rejecting data from a failed channel in the control-axis electronics. The probability of both modes is minimized for highest mission reliability by quad arrangement of the diodes in the voter.

The two predominant failure modes in the power supply are loss of regulation and loss of power output. The TRISAFE feature ensures success if any one of the three power supplies fails in either mode, and if specific combinations of two failures occur.

The reliability analysis for each control axis is similar. If any one channel should fail, the majority voter will discard data from that channel. Mission success requires that any two of the three channels be operational in each control axis for the majority voter to have comparison data by which to identify the failed channel.

6.5.5 Reaction-Control Subsystem

6.5.5.1 Summary

Table 6-15 presents summary data for the reaction control subsystems.

Table 6-15: REACTION-CONTROL SUBSYSTEM RELIABILITY SUMMARY

	MISSION RELIABILITY
Feasibility Range	0.956 to (*)
Initial Allocation	0.956
Trade Range	0.99907 to 0.99974
Preferred Subsystem Assessment	0.99959
Revised Allocation	0.999

(*) The feasibility range is represented by a single figure because a single-thread system was not considered

6.5.5.2 Discussion

Table 6-15 summarizes the preferred system reliability assessment, the subsystem allocation, and the trade studies performed on competing configurations.

The reaction-control subsystem owes its rather high reliability to the use of highly reliable parts and components united into a completely redundant gas system. Considerable experience with similar systems on the Mariner, Ranger, OGO, OSE, OAO, and Syncom vehicles has furnished both design direction for this system and an indication of its reliability. Since nitrogen is necessary to the reaction-control subsystem before, during, and after it is needed for propulsion, the N_2 tankage is assessed as part of the reaction-control subsystem. Figure 6-11 is a reliability block diagram of the reaction-control subsystem.

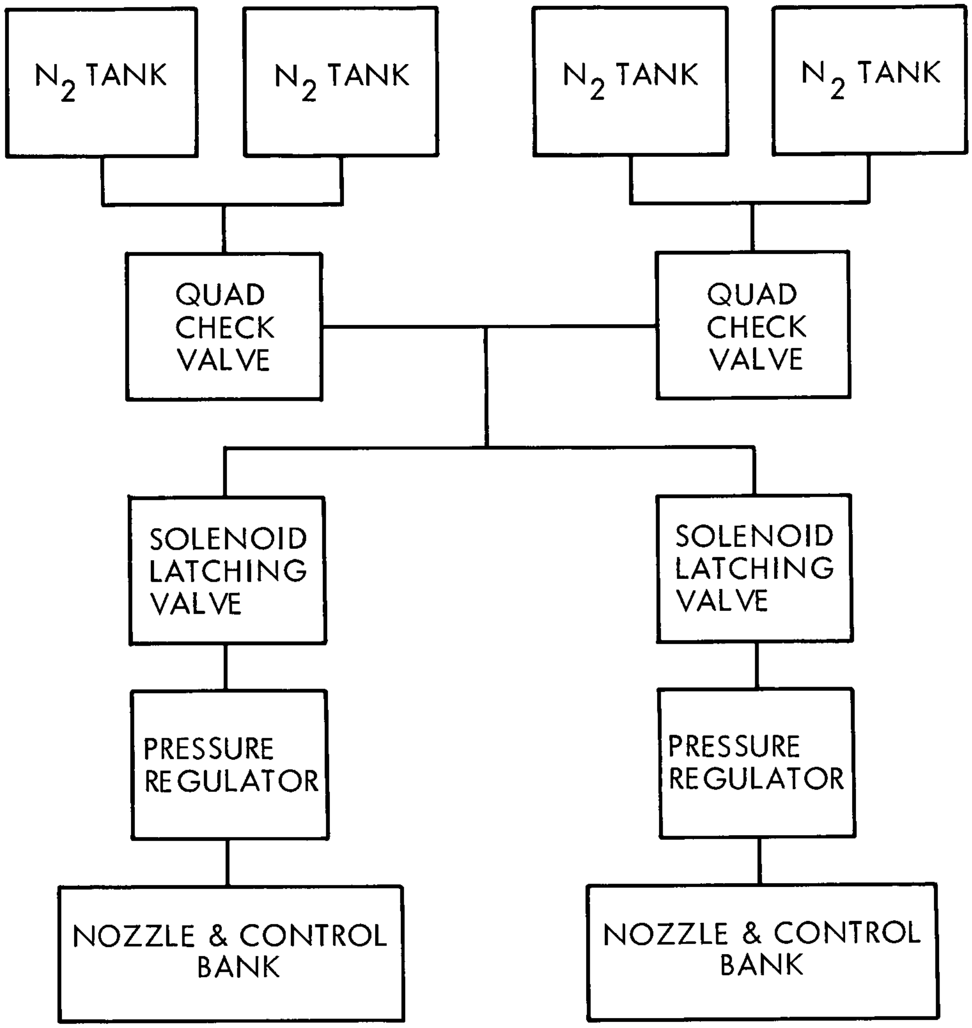


Figure 6-11: Reliability Block Diagram — Reaction Control Subsystem

Figure 6-12 indicates how each piece of equipment compares with others in the subsystem and shows how the subsystem reliability varies as a function of mission phase.

6.5.5.3 Failure-Mode and Effects Summary

This is a completely redundant system comprising two complete and separate legs from the N_2 tanks through the thrusters. Single failures can be remedied if detected and the standby leg switched in (except in two places). External leakage of the quad check valve or the solenoid latching valve (in either leg) allows depletion of the N_2 from all tanks.

6.5.6 Central Computer and Sequencer

6.5.6.1 Summary Data

Table 6-16 presents summary data for the central computer and sequencer.

Table 6-16: CC&S RELIABILITY SUMMARY

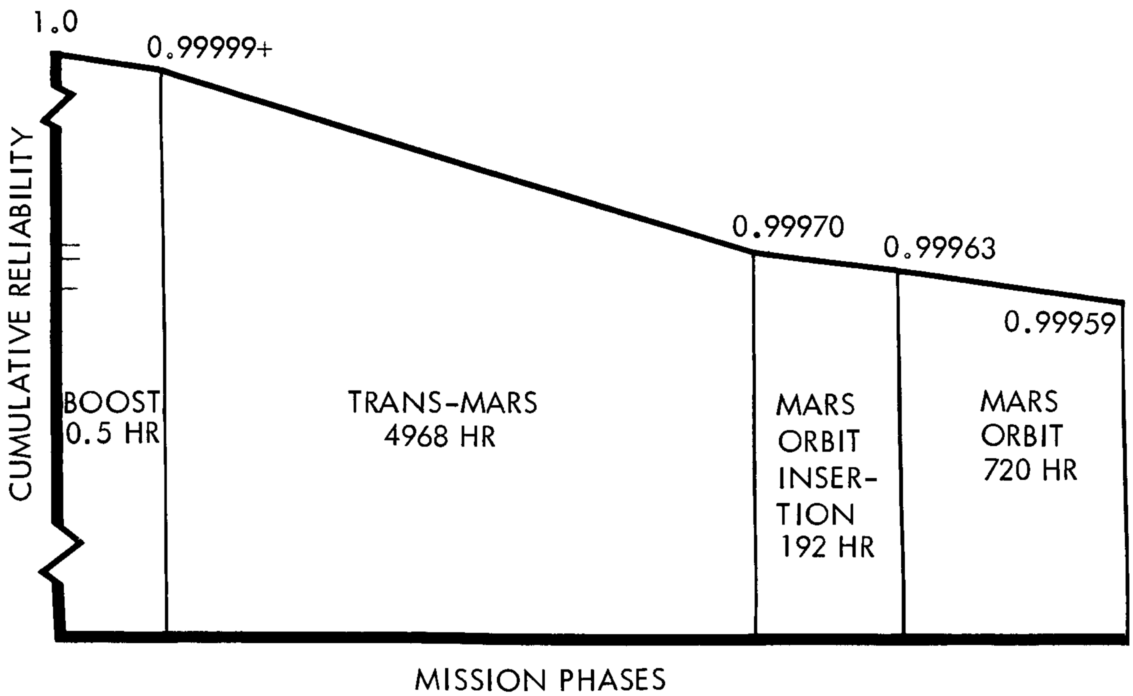
	MISSION RELIABILITY
Feasibility Range	0.876 to 0.9930
Initial Allocation	0.9930
Trade Range	0.9927 to 0.9945
Preferred Subsystem Assessment	0.9941
Revised Allocation	0.994

6.5.6.2 Discussion

Table 6-16 summarizes the results of the reliability assessment and goal of the central computer and sequencer (CC&S) subsystem. The feasibility range is based on an initial analysis of the CC&S considerinag single-thread and completely redundant arrangements. The initial allocation

COMPONENT	MISSION RELIABILITY
N_2 TANKS	0.999999+
SOLENOID LATCHING VALVE	0.99999
PRESSURE REGULATOR	0.9859
NOZZLES & CONTROLS	0.999948

RELIABILITY OF SUBSYSTEM COMPONENTS



SUBSYSTEM HAZARD CHART

Figure 6-12: Preferred Subsystem Reliability Summary — Reaction Control was also based on the results of this analysis. The preferred CC&S is a modified Lunar Orbiter, memory-oriented computer. Two alternate subsystem configurations were also considered:

1) Timer-oriented, fixed-wire (Mariner C);
2) Timer-oriented, fixed-wire (integrated circuit logic approach).

The subsystem reliability assessment of the fixed-wire configuration using integrated circuit logic is 0.9927. A cursory analysis of the Mariner C configuration, which uses core transistor logic (CTL) and relays, revealed that approximately the same number of logic elements would be used for this configuration. However, because of the higher failure rate (5 to 1) of the CTL logic element and the greater weight of this subsystem configuration, it does not appear to be a good candidate. In addition to its higher reliability, the memory-oriented subsystem also provides an advantage in mission flexibility.

Figure 6-13 is the reliability block diagram for the preferred design of the CC&S subsystem. This diagram shows the series and redundant arrangements of the major elements considered for the reliability assessment. The subsystem consists of two major assemblies: control assembly and switching assembly. The major parts of the control assembly are the redundant-processor logic elements, and the major parts of the switching assembly are the squib drivers for the propulsion and solar-panel subsystems.

Figure 6-14 summarizes the results of the detailed reliability assessment of the CC&S and identifies the cumulative mission reliability by mission

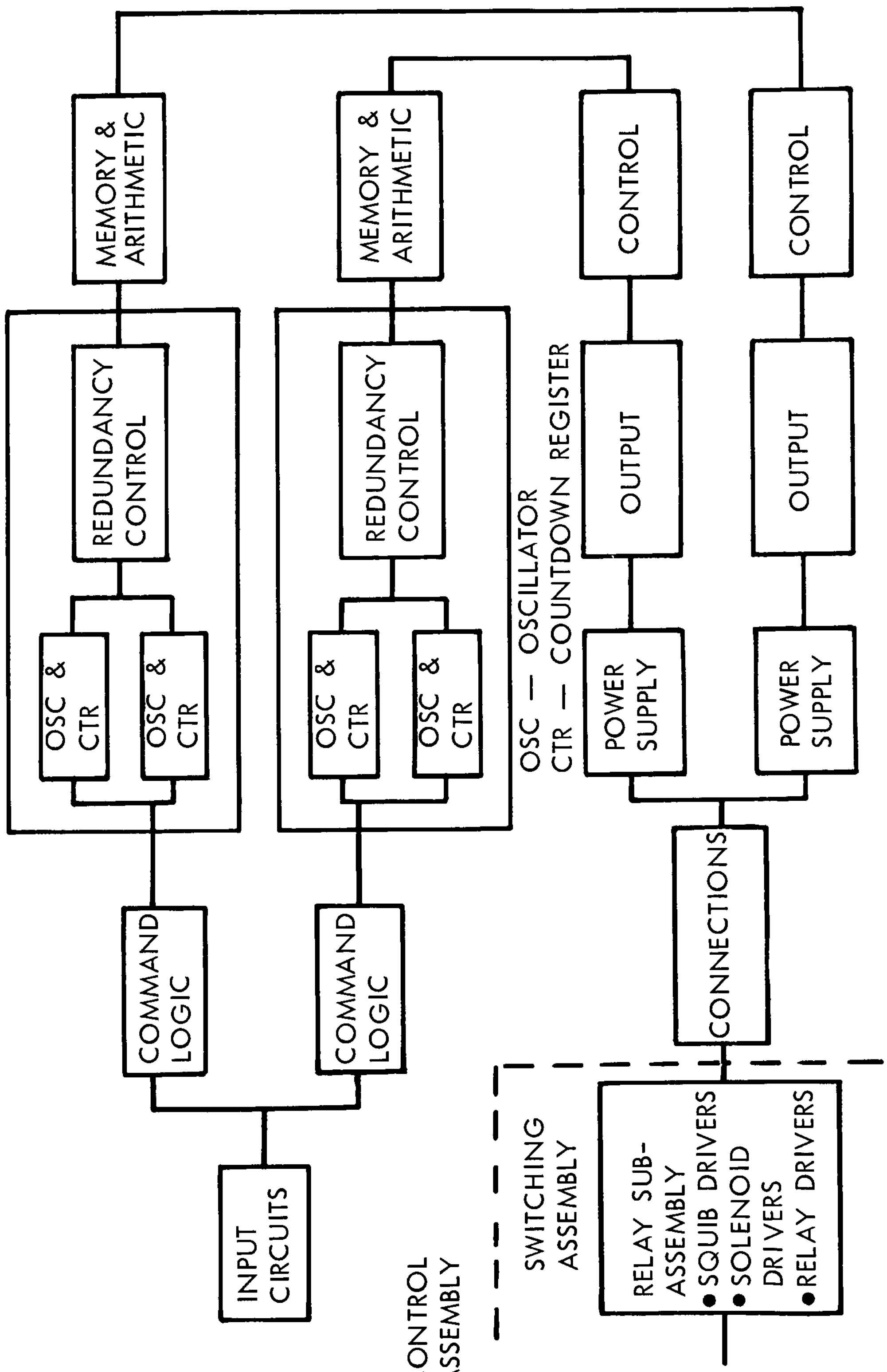
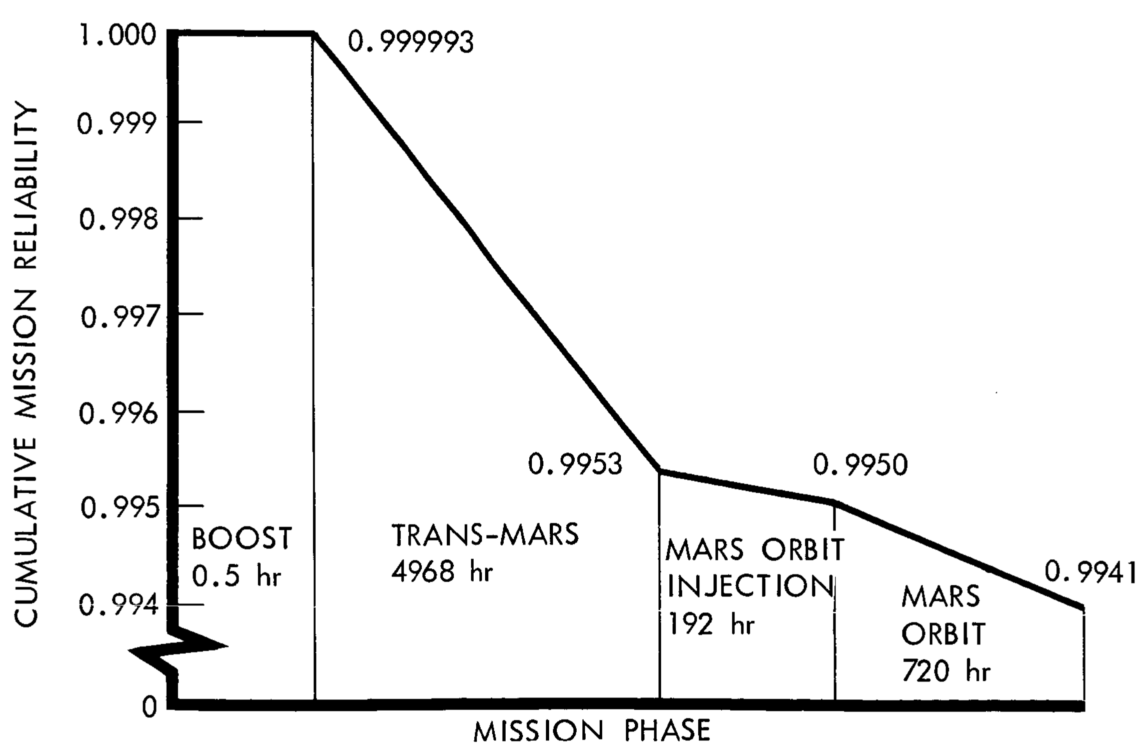


Figure 6-13: Reliability Block Diagram — CC&S Subsystem

COMPONENT	MISSION RELIABILITY
Control Assembly	
Input Circuits	0.9988
Command Logic	0.9915
Oscillator & Countdown Register	0.9999+
Redundancy Control	0.9965
Memory & Arithmetic	0.9867
Control	0.9910
Output Matrix Decoder	0.9913
Power Supply	0.9915
Connections	0.9999+
Switching Assembly	
Relay Subassembly	0.9999+
Squib Drivers	0.9999+
Solenoid Drivers	0.9981
Relay Drivers	0.9997
Connections	0.9999+

RELIABILITY OF SUBSYSTEM COMPONENTS



SUBSYSTEM HAZARD CHART

Figure 6-14: Preferred Subsystem Reliability Summary — CC&S

phase. As shown in Figure 6-14, the low reliability items in the subsystem are:

1) Memory and arithmetic unit;

2) Control logic;

3) Output matrix decoder;

4) Command logic;

5) Power supply.

The CC&S subsystem is basically a redundant configuration. The control-assembly elements are arranged in redundant strings, and the drivers in the switching assembly are also redundant. The input circuits to the control assembly and the driver circuits for the solenoids and relays are essentially the only in-line elements within the subsystem. These elements account for approximately 55 percent of the subsystem unreliability.

6.5.6.3 Failure-Mode and Effects Summary

The primary purpose of the CC&S is to provide signals to the other spacecraft subsystems. Because the CC&S is essentially redundant, few failures would result directly in mission loss or in loss of a function. Failure modes, effects, and workaround schemes have been established for the Lunar Orbiter subsystem (see Boeing Specification D2-100254, Volume 1) that are also applicable to a more detailed analysis of the Voyager CC&S. A potentially serious failure mode is a shorted output in either redundant computer. The effect is that the shorted output would appear as a commanded function resulting in an erroneous signal. Another failure mode that could affect mission success is a combination of a squib breakwire shorting and the squib driver failure to shut itself off. The effect of this failure mode is a power drain. The loss of a command function could also result in mission loss for such functions as solar-cell deployment and midcourse maneuvers or orbit insertion. However, the redundant arrangements of squib drivers and squib breakwires reduce the probability of failure of command for these functions to less than 2.0×10^{-6}.

6.5.7 Electrical Power Subsystem

6.5.7.1 Summary Data

Table 6-17 presents summary data for the electrical power subsystems.

Table 6-17: ELECTRICAL POWER SUBSYSTEM SUMMARY

	MISSION RELIABILITY
Feasibility Range	0.975 to 0.999
Initial Allocation	0.999
Trade Range	0.992±
Preferred Subsystem Assessment*	0.992
Revised Allocation	0.992

6.5.7.2 Discussion

The assessed reliability of the preferred electrical power subsystem is 0.992. As indicated in Table 6-17, this is slightly below the initial allocation and the feasible maximum. The feasibility range reflects

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*Power conditioning equipment providing power to a particular subsystem is subject to integration with that subsystem. Subsequent to the assessment of the preferred system shown here, the 400-cps single-phase inverter (or its equivalent function) was integrated into the telecommunications system.

values for the simplest system of series components compared to a system in which redundancy is provided for each major component. Trades were performed on subsystem components, revealing some variation in parts count in the d.c./d.c. regulator, 2400-cps inverter, and a.c. fail-sense circuit. However, because these components are part of the redundant design, the effect of failure-rate variations is negligible in the reliability calculations. Also, variations were considered in the battery/battery charger configuration, which, due to redundancy, does not significantly affect reliability calculations. In general, choices between alternates were based on performance and weight.

Reliability improvement has been achieved by a two-out-of-three battery/battery charger configuration, standby regulators, and standby 2400-cps inverter. Also, the solar array is inherently redundant because of the extra margin of cells. In addition, command system switching is available for all standby components.

The reliability block diagram of the preferred subsystem is shown in Figure 6-15. The subsystem breakdown in Figure 6-16 shows the power synchronizer, share sense circuit, and 400-cps inverter to be the least reliable. Failure of the synchronizer results in reduced performance of the inverters but does not affect primary mission success. Therefore, the potential problem areas appear to be the 400-cps inverter and share sense circuit.

6.5.7.3 Failure-Mode and Effects Summary

The following are the prominent failure modes in the electrical power subsystem:

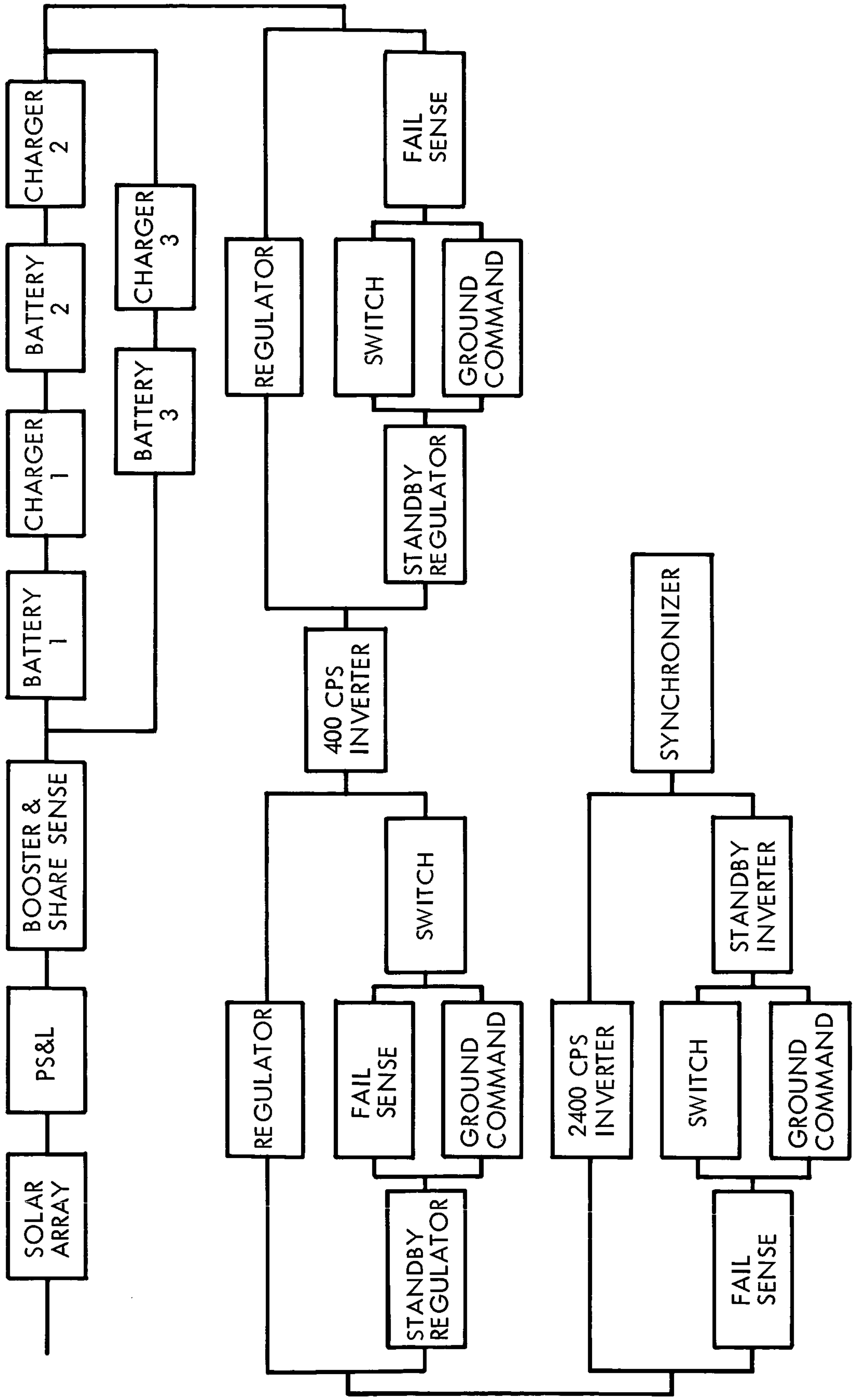
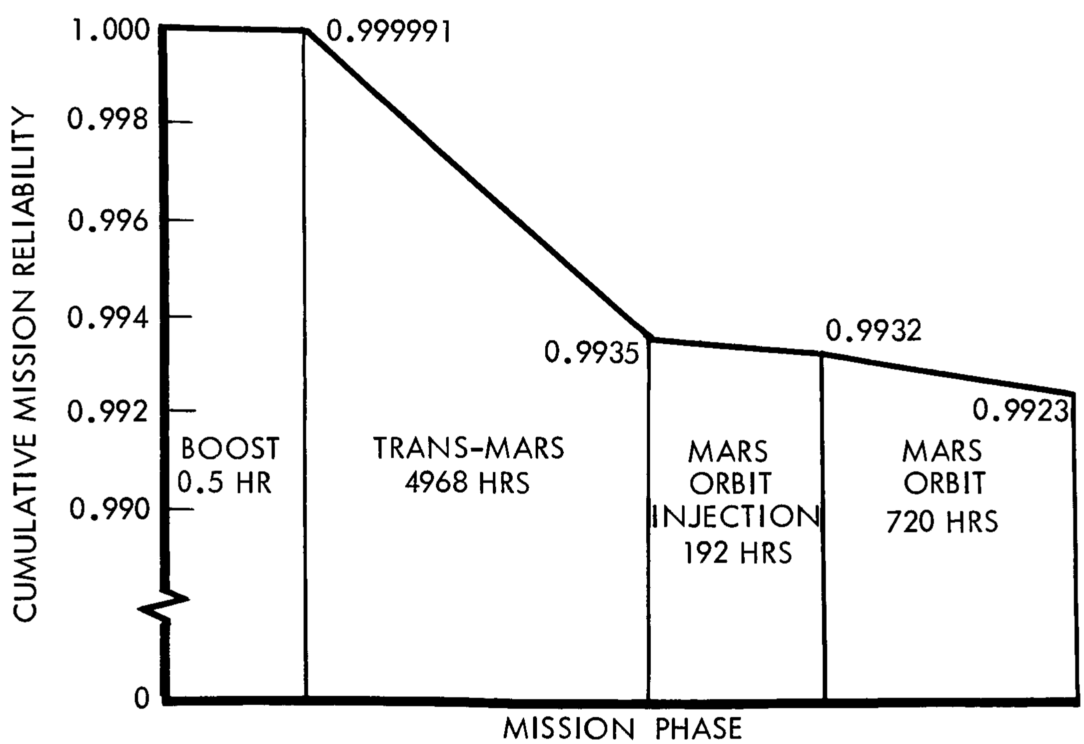


Figure 6-15: Reliability Block Diagram — Electrical Power Subsystem

COMPONENT	MISSION RELIABILITY
SOLAR PANEL ASSEMBLY	0.999319
BATTERY/BATTERY CHARGER-SENSOR	0.999940
BOOSTER CONVERTER	0.999928
SHARE SENSE CIRCUIT	0.996589
POWER SWITCH & LOGIC	0.999992
SERIES SWITCHING REGULATOR	0.999908
SYNCHRONIZER	0.998175
INVERTER 400 CPS SINGLE PHASE*	0.998428
INVERTER 2400 CPS SINGLE PHASE	0.999990
* SEE FOOTNOTE FOR TABLE 6-17	

RELIABILITY OF SUBSYSTEM COMPONENTS



SUBSYSTEM HAZARD CHART

Figure 6-16: Preferred Subsystem Reliability Summary — Electrical Power

1) Failure of the 400-cps inverter would result in loss of power to the telecommunications and cause mission failure.

2) A short in the unregulated d.c. bus would result in mission failure.

3 Failure of the share sense circuit could result in insufficient power to reorient the spacecraft when solar panels are inclined such that their output is lower than the minimum required. This would result in mission failure.

6.5.8 Propulsion Subsystem

6.5.8.1 Summary Data

Table 6-18 represents summary data for the propulsion subsystem.

Table 6-18: PROPULSION SUBSYSTEM RELIABILITY SUMMARY

	MISSION RELIABILITY
Feasibility Range	0.946 to 0.989
Initial Allocation	0.989
Trade Range	0.9458 to 0.99684
Preferred Subsystem Assessment	0.99684
Revised Allocation	0.996

6.5.8.2 Discussion

Table 6-18 summarizes the preferred subsystem reliability assessment, the subsystem reliability allocation, and the trade studies performed on the competing propulsion subsystem configurations. In addition to the preferred subsystem, trade configurations included a large liquid engine for orbit insertion, 100- and 200-pound-thrust engines for midcourse correction, pulsed engine operation, gimbaled engines, larger numbers of small engines, and thrust vectoring of the large engine by pulsing small engines. The preferred system represents the most reliable combination of system elements and functions.

The preferred system reliability is 3.48 times as good as the initial allocation (an assessed mission failure rate of 0.00316 compared to the allocated 0.011). Redundant components, isolation of system parts to reduce them to inactive status while not needed, and choice of highly reliable parts were the main reasons for the higher reliability than expected.

Figure 6-17 is a reliability block diagram of the propulsion subsystem. Figure 6-18 shows the effect of each major grouping of components on mission reliability. Significant redundancy exists in the propellant feed system, and the midcourse correction engines are backed by a standby pair. A solid motor was selected for orbit insertion because of its reliability feature. Historical data on solid motors indicate reliability achievement in excess of 0.99995. Although increased performance requirements may have a degrading effect on reliability, improved design and inspection techniques are expected to provide adequate compensation to maintain the reliability levels demonstrated in the past.

Figure 6-18 also shows how the propulsion subsystem reliability changes as the mission progresses (mission hazard chart). The contribution of major components is shown in the table at the top of Figure 6-18. The

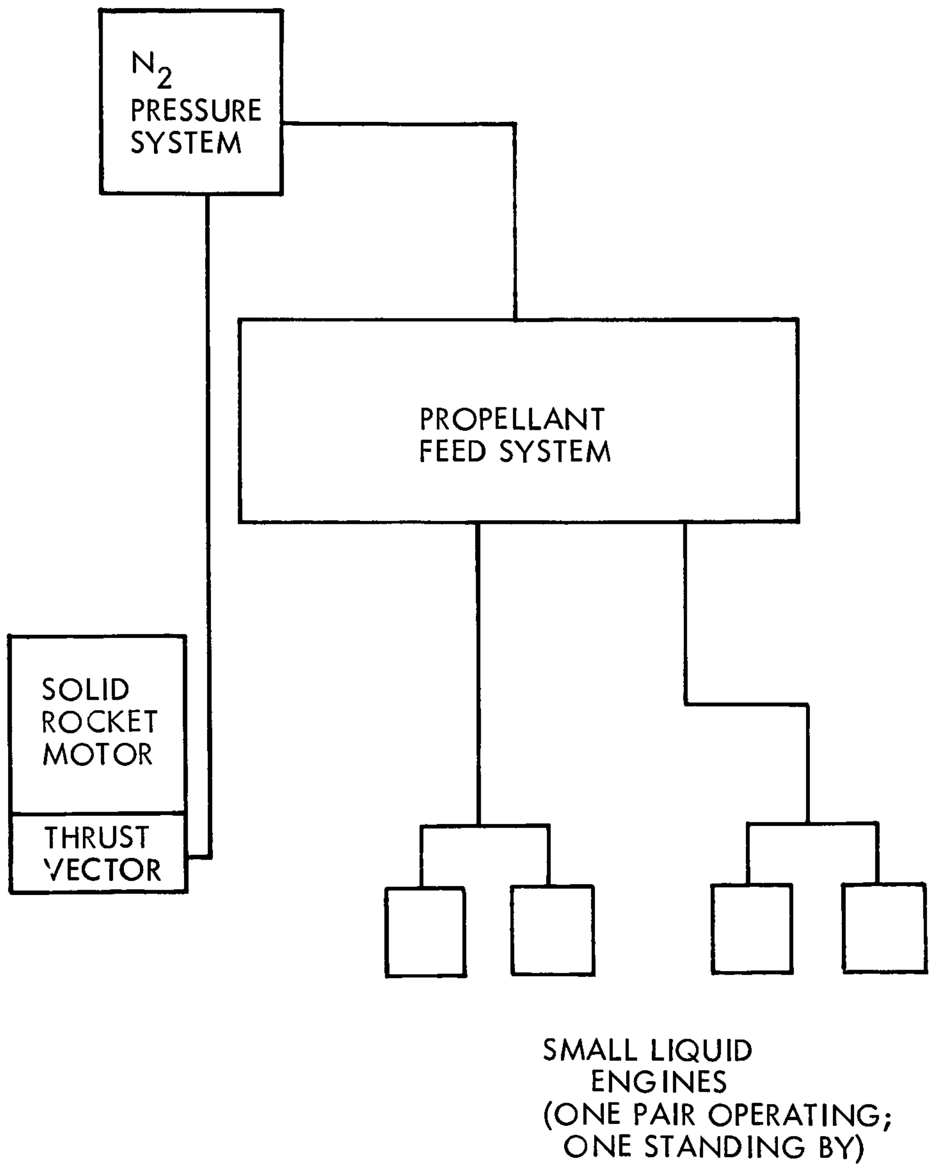
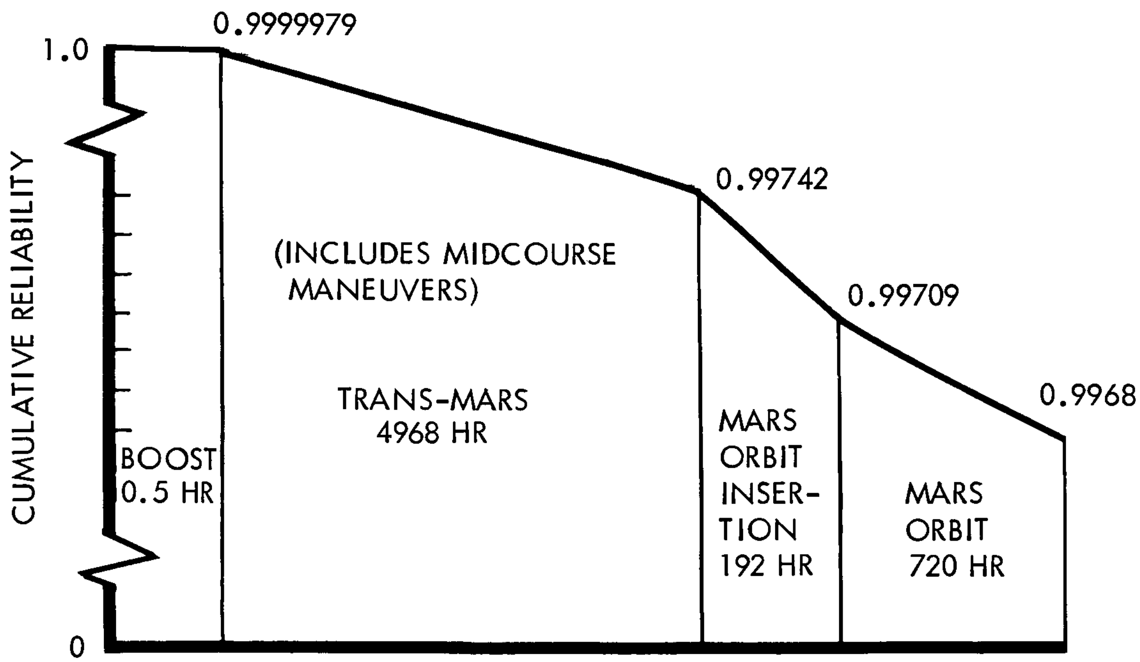


Figure 6-17: Reliability Block Diagram—Propulsion Subsystem

COMPONENT	MISSION RELIABILITY
N_2 PRESSURE SYSTEM	0.99942
PROPELLANT FEED	0.99932
SMALL LIQUID ENGINES	0.99864
LARGE SOLID MOTOR	0.99995
THRUST VECTOR SYSTEM	0.999465

RELIABILITY OF SUBSYSTEM COMPONENTS



MISSION PHASE

SUBSYSTEM HAZARD CHART

Figure 6-18: Preferred Subsystem Reliability Summary — Propulsion Subsystem mission hazard chart of the figure shows the mission phases connected by straight lines for convenience only. The actual change is by a series of gradual changes interrupted by abrupt steps at points of significant failure potential.

6.5.8.3 Failure-Mode and Effects Summary

There are eleven "major leak" or "burst" failure modes that can cause mission loss caused by fuel pressure loss. There are seven internal-leak failure modes that can cause orbit insertion loss. There are four other failure modes that can cause orbit insertion loss. They are associated with squib valves not working and the large engine failing to start.

6.5.9 Structures Subsystem

6.5.9.1 Summary Data

Table 6-19 presents summary data for the structures subsystem.

Table 6-19: STRUCTURES RELIABILITY SUMMARY

	Mission Reliability
Feasibility Range (Combined with Mechanisms)	0.991 to 0.999
Initial Allocation (Combined with Mechanisms)	0.999
Preferred Subsystem Assessment	0.9999
Revised Allocation	0.999

6.5.9.2 Discussion

Structural reliability is assumed to be 0.9999. Because of the lack of statistically significant failure data for comparable structures and environments, this figure is necessarily a judgment.

The approach to structural reliability included the following:

1) Use of materials having proven mechanical properties
2) Use of proven stress analysis techniques
3) Design for simplicity, producibility, and inspectability
4) Conservative safety factors to account for uncertainties of static and dynamic loading
5) Redundant structural arrangements
6) Extensive environmental testing
7) A stringent quality control program

6.5.10 Mechanisms Subsystem

6.5.10.1 Summary Data

Table 6-20 presents summary data for the mechanisms subsystem.

Table 6-20: MECHANISMS RELIABILITY SUMMARY

	Mission Reliability
Feasibility Range (Combined with Structures)	0.991 to 0.999
Initial Allocation (Combined with Structures)	0.999
Trade Range	0.998±
Preferred Subsystem Assessment	0.9988
Revised Allocation	0.999

6.5.10.2 Discussion

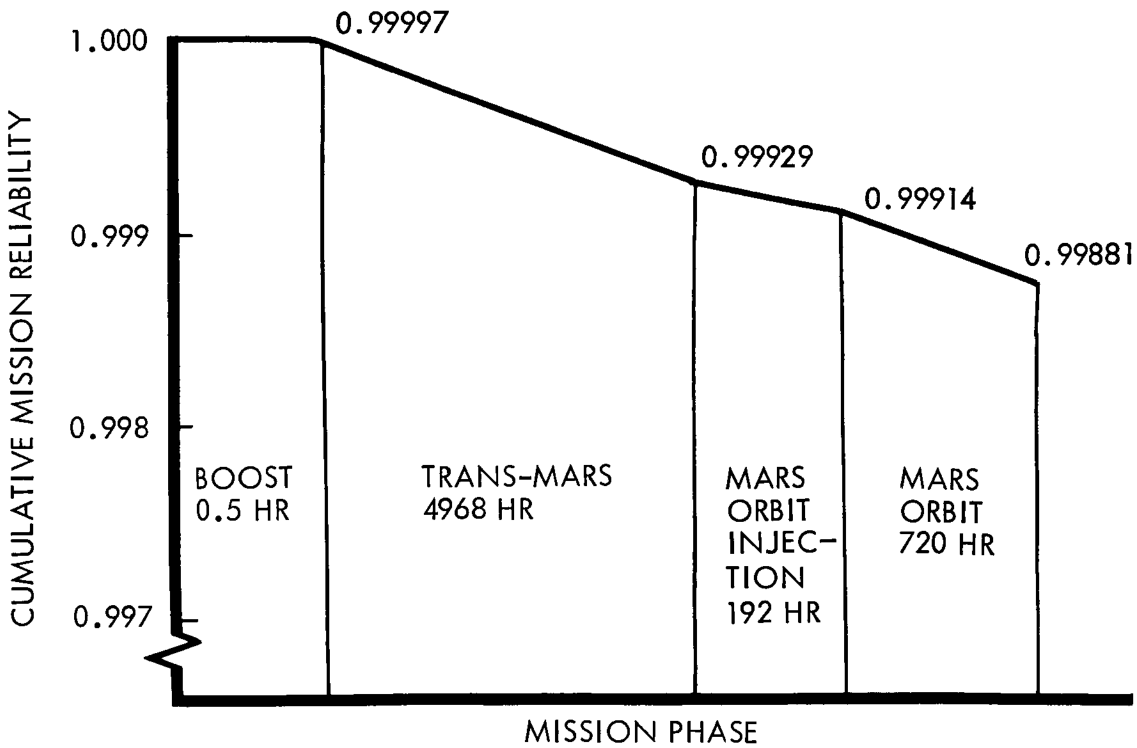
Results of the preferred configuration reliability assessment are shown in Figure 6-19. Figure 6-20 is a reliability block diagram of the mechanism subsystem.

A conservative approach was used for this assessment. All items having time-based failure rates were treated as if they were operating at full load during launch-boost. Because the boom hinges and locking devices may be expected to absorb the brunt of stresses generated by spacecraft maneuvers, an operating cycle is charged against these items each time an engine is fired after boom deployment.

A number of special design features are being incorporated into this subsystem to enhance reliability. All pin-pullers will have redundant

COMPONENT	MISSION RELIABILITY
LOW-GAIN-ANTENNA BOOM ASSEMBLY	0.99973
VHF-ANTENNA BOOM ASSEMBLY	0.99973
PLANETARY-SCAN PLATFORM ASSEMBLY	0.99996
SCIENCE BOOM ASSEMBLY	0.99972
HIGH-GAIN-ANTENNA BOOM ASSEMBLY	0.99968
BACTERIOLOGICAL BARRIER (BASE ONLY) RELEASE MECH.	.99999+

RELIABILITY OF SUBSYSTEM COMPONENTS



SUBSYSTEM HAZARD CHART

Figure 6-19: Preferred Subsystem Reliability Summary — Mechanisms Subsystem

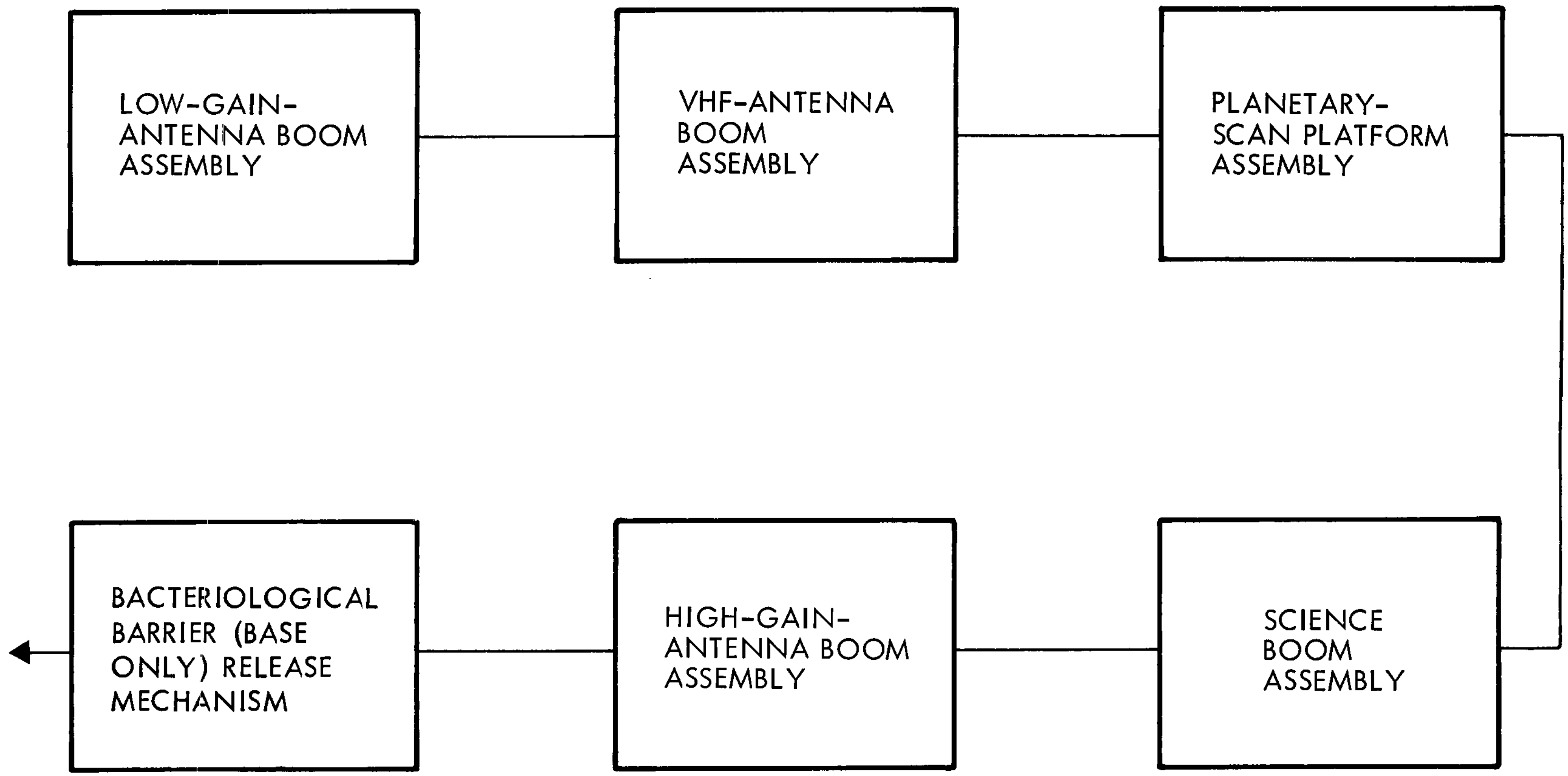


Figure 6-20: Reliability Block Diagram — Mechanisms Subsystem

squibs and firing circuits. All sleeve bearings used will be self-aligning and will incorporate two independent bearing surfaces. Thus, active parallel redundancy is achieved in all bearings. Misalignment of bearing housings caused by thermal deformation will not cause mechanism failure.

6.5.10.3 Failure-Mode and Effects Summary

The subsystem is actually a collection of mechanism units that functionally act as parts of other subsystems such as deployment of antennas for the telecommunications subsystem. Basic failure modes and effects are, therefore, related to these subsystems. Critical, single-effect failure modes and results are:

1) VHF antenna boom does not deploy: loss of capsule, Mars entry, and surface data;
2) Magnetometer (science) boom does not deploy: loss of magnetometer data;
3) Planetary scan platform optics cover sticks closed: loss of Mars pictures;
4) Planetary scan platform does not track or tracks improperly: smeared pictures of Mars surface;
5) Planetary scan platform does not deploy properly: loss of desired Mars surface data;
6) High-gain antenna boom does not deploy: loss of mission through loss of command, tracking, and data (T = 60 days and on);
7) High-gain antenna boom does not respond properly to Earth-tracking signal input: loss of mission through loss of command, tracking and data (T = 60 days and on);

8) Bacteriological barrier release mechanism does not release; loss of orbit and capsule data through damaged firing orbit insertion motor.

6.5.11 Temperature Control Subsystem

6.5.11.1 Summary Data

Table 6-21 presents summary data for the temperature control subsystem.

Table 6-21: TEMPERATURE CONTROL RELIABILITY SUMMARY

	Mission Reliability
Feasibility Range	0.550 to 0.997
Initial Allocation	0.997
Trade Range	0.996±
Preferred Subsystem Assessment	0.996
Revised Allocation	0.996

6.5.11.2 Discussion

The assessed reliability of the preferred temperature control subsystem is 0.996. The wide feasibility range is accounted for by the capability for extensive redundancy in the louver assemblies. Heaters are provided for backup in case louvers fail in the open mode. Each heater is controlled by thermal switches in series which provides redundancy for switches failing in the closed mode. In addition, the capability is present to command control the heaters through the CC&S. Figure 6-21 shows the preferred subsystem reliability block diagram; Figure 6-22 summarizes the reliability assessment.

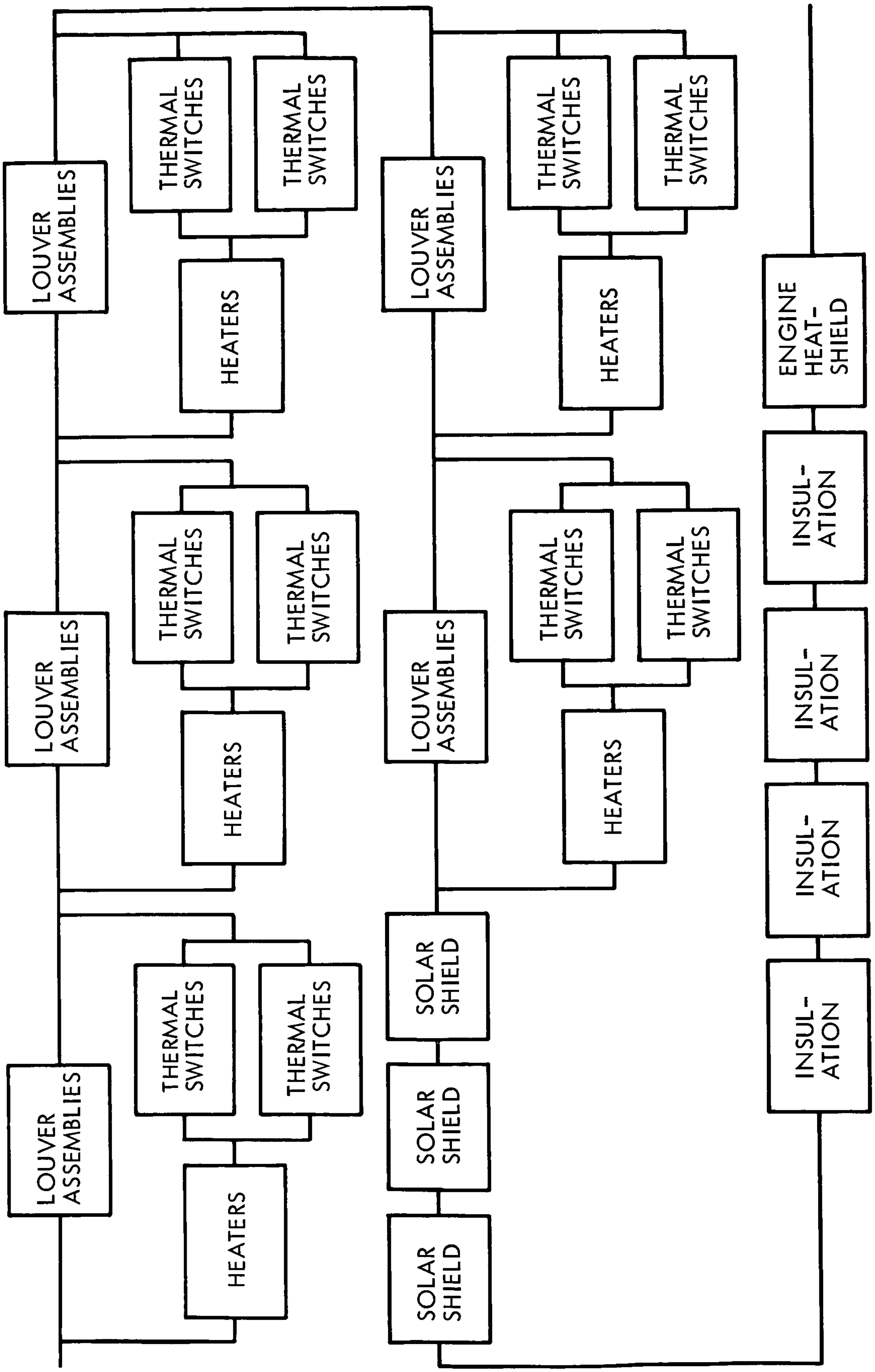
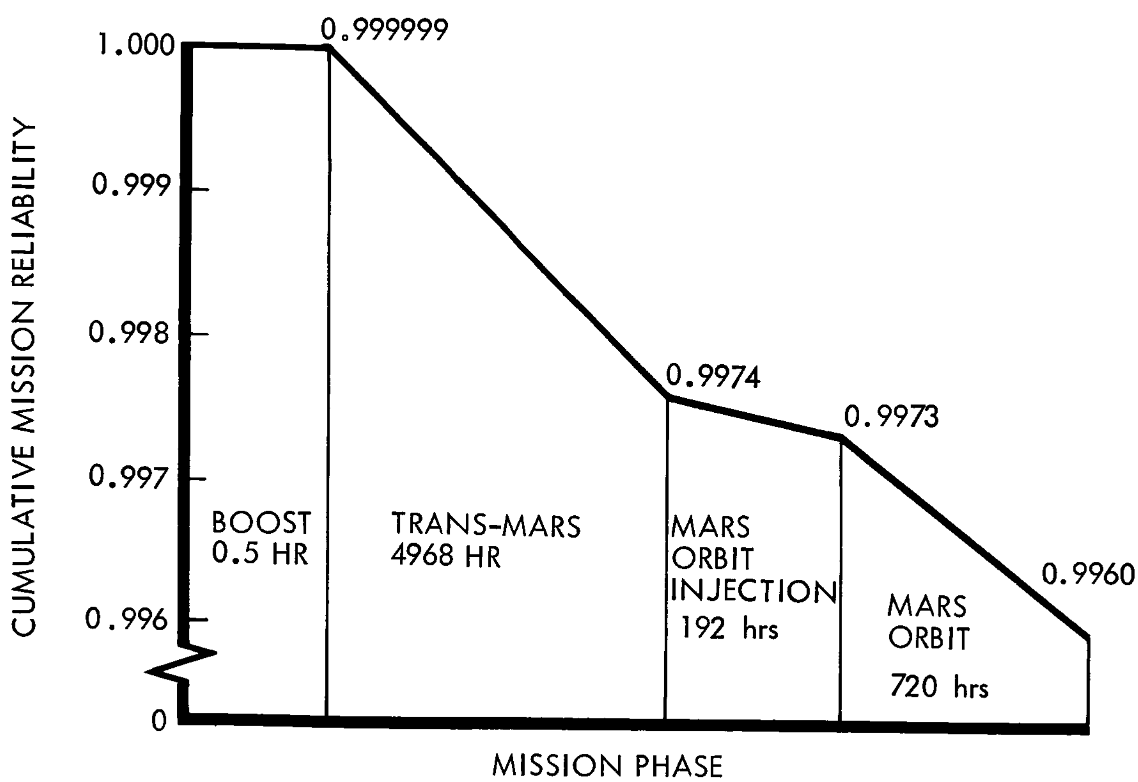


Figure 6-21: Reliability Block Diagram -- Temperature Control Subsystem

COMPONENT	MISSION RELIABILITY
LOUVERS (WITH HEATER BACKUP)	0.996069
INSULATION	0.999976
SOLAR SHIELD	0.999982
ENGINE HEATSHIELD	0.999994

RELIABILITY OF SUBSYSTEM COMPONENTS



SUBSYSTEM HAZARD CHART

Figure 6-22: Preferred-Subsystem Reliability Summary — Temperature-Control

6.5.11.3 Failure Mode and Effect Summary

The temperature control subsystem is composed of passive elements, conventional louvers, and electric heaters. The louvers are individually actuated and controlled by temperature sensing elements which drive the louver from fully closed to fully open. Louver control is based upon a minimum radiation loss from space radiators (with louvers closed) to a maximum (with louvers open). For periods of Mars orbit, when space losses are high, and for close temperature control, the electric heaters back up the louver control. Electric heaters are activated by series wired bimetallic switches that can be overriden by commands from Earth. Maximum temperature excursions expected with either louver control alone or the majority electric heaters alone are well within design temperature ranges of most electronic parts and components. The inertial reference unit is one component identified that will depend upon both electric heaters and louver control.

The only critical failure mode identifiable at this time is the complete failure of such a critical heater as the elements protecting temperature control for the inertial reference unit.

6.5.12 Pyrotechnics Subsystem

The arming switch, separation timer, firing and inhibit switches, and associated wiring have been designated the pyrotechnics subsystem. The squibs, or actual explosive devices, are included with whatever subsystem with which they are associated.

Even the switching mentioned above is included in the analysis and considerations of the CC&S subsystem, leaving only the wiring harnesses unaccounted for. The reliability of these harnesses is conservatively estimated at 0.999 or greater.

The failure mode analysis of the pyrotechnic subsystem revealed but one critical failure mode: a short in the inhibit-switch circuitry could cause mission loss by premature firing of a solid rocket engine during a midcourse correction maneuver.

6.5.13 Science Payload

6.5.13.1 Summary Data

Table 6-22 presents summary data for the science payload.

Table 6-22: SCIENCE PAYLOAD RELIABILITY SUMMARY

	MISSION RELIABILITY
Reliability Range	0.510 TO 0.912
Initial Allocation	0.650
Total Payload Assessment	0.510
Primary Objectives (Planetary Experiments Only)	0.672

6.5.13.2 Discussion

Reliability of the science payload is estimated at 0.672 (see Table 6-22). This is the reliability of those planetary experiments which satisfy primary mission objectives. Certain interplanetary experiments are included as secondary objectives which, added to primary objectives, brings the total payload reliability down to 0.510. Since all experiments are isolated, failure of any instrument or combination of instruments will not result in failure of the mission. Therefore, success of any experiment may be regarded as partial success of the payload. Table 6-23 shows breakdowns of various combinations of instrument reliabilities. It should be noted that reliability of the data automation equipment enters all calculations since no data can be collected without it. The most desired experiments are the television system and the Mars scanner; therefore, the reliability limit to satisfy these primary objectives would be 0.775.

6.5.14 Operational Support Equipment (OSE)

6.5.14.1 Summary

The mission success criteria for the Voyager Project dictate that the reliability of the OSE be established in terms of two operational mission phases; namely: (1) a reliability requirement which would be associated with the probability of reaching and maintaining a state of readiness to launch or a launch-on-time status at the time of launch commitment, and (2) a reliability requirement associated with that equipment (located at DSN) used throughout the actual mission flight.

Table 6-23: Science Payload Reliability Range

		λ T	RELIABILITY
I.	DATA AUTOMATION EQUIPMENT	0.0659	
	MARS SCANNER	0.0266	
	TOTAL	0.0925	0.912
II.	DATA AUTOMATION EQUIPMENT	0.0659	
	TV SYSTEM	0.1616	
	TOTAL	0.2275	0.798
III.	DATA AUTOMATION EQUIPMENT	0.0659	
	TV SYSTEM	0.1616	
	MARS SCANNER	0.0266	
	TOTAL	0.2541	0.775
IV.	ALL PLANETARY EXPERIMENTS		
	DATA AUTOMATION EQUIPMENT	0.0659	
	TV SYSTEM	0.1616	
	MARS SCANNER	0.0266	
	IR SPECTROMETER	0.0415	
	UV SPECTROMETER	0.0415	
	DUAL-FREQUENCY RADIO BEACON	0.0390	
	MARS RF NOISE DETECTOR	0.0209	
	TOTAL	0.3970	0.672
V.	ALL EXPERIMENTS		
	DATA AUTOMATION EQUIPMENT	0.0659	
	TV SYSTEM	0.1616	
	MARS SCANNER	0.0266	
	IR SPECTROMETER	0.0415	
	UV SPECTROMETER	0.0415	
	DUAL-FREQUENCY RADIO BEACON	0.0390	
	MARS RF NOISE DETECTOR	0.0209	
	HELIUM VECTOR MAGNETOMETER	0.0842	
	PLASMA INSTRUMENT	0.0744	
	TRAPPED RADIATION DETECTOR	0.0349	
	MICROMETEORITE DETECTOR	0.0122	
	IONIZATION CHAMBER	0.0699	
	TOTAL	0.6726	0.510

Reliability requirements to be associated with the launch readiness phase of the mission (Category 1) have not been established. Their values will be greatly influenced by factors such as the philosophy advanced for maintenance and repair, the workaround capability, time and equipment availability during the critical prelaunch period, and the definition of the critical prelaunch period, with its attendant OSE operational requirements.

A reliability of 0.97 has been allocated to the DSN-OSE (Category 2) requirement during the actual mission flight. This reliability estimate is believed to be consistent with the reliability experienced with equipment having similar operational environments and functional and electronic parts complexity.

6.5.14.2 Discussion

Generally, the OSE falls into two basic types: Type 1, which includes those equipments required for the assembly, servicing, checkout, handling, shipping, and testing of the space vehicle subsystems; and Type 2, which includes those equipments (software and hardware) required at the DSN to meet the functional mission requirements of the Voyager project not required for any other project. This type is commonly referred to as mission dependent equipment (MDE). Those equipments that are considered critical to a successful checkout, launch, and mission flight will be subjected to appropriate reliability and design disciplines comparable to those imposed on spacecraft equipment.

The methodology used to determine the level of reliability required by the two types of OSE to meet mission objectives will depend on such considerations as the following:

1) Maintainability ground rules for OSE and subsystems in the launch vehicle
2) Protection from overstress or degradation of the spacecraft system during test or as a result of OSE malfunction
3) In terms of time and equipment, the availability of workaround capability during various operational phases of prelaunch and mission flight.

After determining all the pertinent factors, a mathematical model, based on such factors as indicated above will be formulated. This model will provide the means for determination and interpretation of all OSE reliability requirements which will then be allocated to specific equipments in terms of MTBF's and MTTR's.

6.5.15 Launch Vehicle System

The launch vehicle system--consisting of an S-IB first stage, an S-IVB second stage, and a Centaur third stage--must inject the overall flight spacecraft into a prescribed transfer orbit. A probability of success of 0.90 is the assigned objective for this function. Because this configuration is in a developmental state, assessment of the 0.90 objective has been performed by an analysis of each of the stages. Two of these have been based on actual flight data.

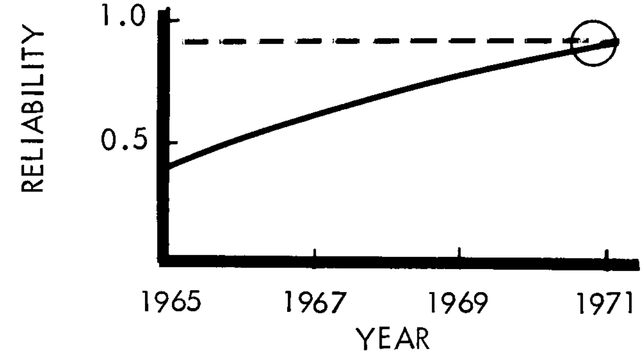
The S-IB stage, composed of the most mature engine derivative in the United States, has completed nine successive, successful flight tests; these conservatively indicate a reliability in excess of 0.92. The Centaur has scored two successes out of four opportunities, with one opportunity lost by first-stage failure. No flight trials have been conducted on the S-IVB, necessitating a design analysis to derive an assessment.

Chart A of Figure 6-23 shows 50-percent confidence limits (labeled "low" and "high") and a midpoint assessment for the S-IB and Centaur stages. The low and high values for the S-IVB were based on the midpoint value derived from the design assessment. Chart B of the figure shows current estimates (based on the latest firing data) for the Atlas-Mercury and composite Mercury-Gemini shots. These data provide typical booster maturity points. Chart C represents a typical booster reliability growth curve showing the cumulative reliability for 33 firings of the Titan II booster. By combining midrange data of Chart A (as a starting point), the typical growth of Chart C, and the maturity range of Chart B, the Voyager 1971 launch vehicle reliability was forecast as shown in Chart D. This analysis indicates that an objective of 0.90 for the Voyager launch vehicle is feasible. This is true in light of the experience of our Saturn I and manned space shots where, by conservative design, by component screening, and rigorous control, significant gains in booster reliability were achieved.

Ⓐ BOOSTER STAGE — CURRENT ASSESSMENT

BOOSTER STAGE	LOW	MP	HIGH
S-IB	0.92	0.96	1.00
S-IV B	0.90	0.93	0.96
CENTAUR	0.24	0.50	0.76
TOTAL	0.20	0.45	0.73

Ⓓ 1971 FORECAST VOYAGER LAUNCH VEHICLE



Ⓑ OTHER LAUNCH VEHICLES (MATURE)

ATLAS (MERCURY SHOTS)	0.90
MERCURY-GEMINI SERIES (REDSTONE, ATLAS, TITAN II)	0.86

Ⓒ TITAN II GROWTH

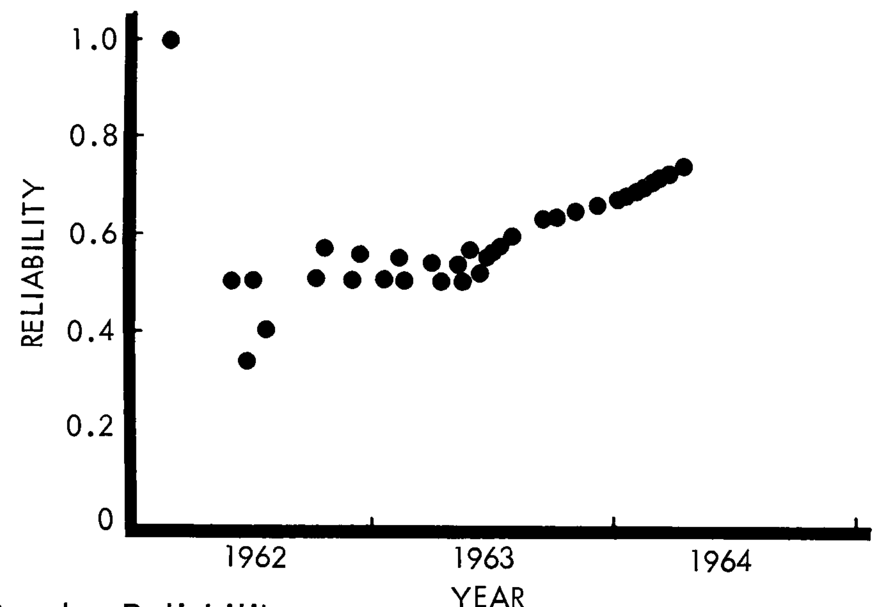


Figure 6-23: Booster Reliability

6.6 PREFERRED SYSTEM EVALUATION AND ALLOCATION

6.6.1 Evaluation

The preferred Spacecraft System, comprised of subsystems "preferred" from the standpoint of most effectively meeting overall design criteria, has an assessed reliability level of 0.552 for the full Voyager mission. It reflects those trades occasioned by constraints on weight, cost, and development time. Table 6-24 summarizes the reliability evaluation of the preferred system.

Table 6-24: PREFERRED SYSTEM EVALUATION SUMMARY

SYSTEM ELEMENT	INITIAL ALLOCATION	EVALUATION
Spacecraft Bus	0.911	0.820
Science Payload	0.650	0.673
Spacecraft (Subtotal)	0.592	0.552
Launch Vehicle	0.900	0.900
Operational Support Equipment (MDE)	0.970	0.970
Other Factors	0.954	0.983
Contingency	0.885	
Spacecraft & Launch Vehicle (Total)	0.450	0.474

Figure 6-24 shows by mission phase a comparison of cumulative mission success plots of the fully redundant, single-threat, and preferred systems with the Voyager mission objectives. A breakdown of major subsystem contributions to the cumulative mission success is shown in Table 6-25. As indicated in the Table, assessment of the science sub-

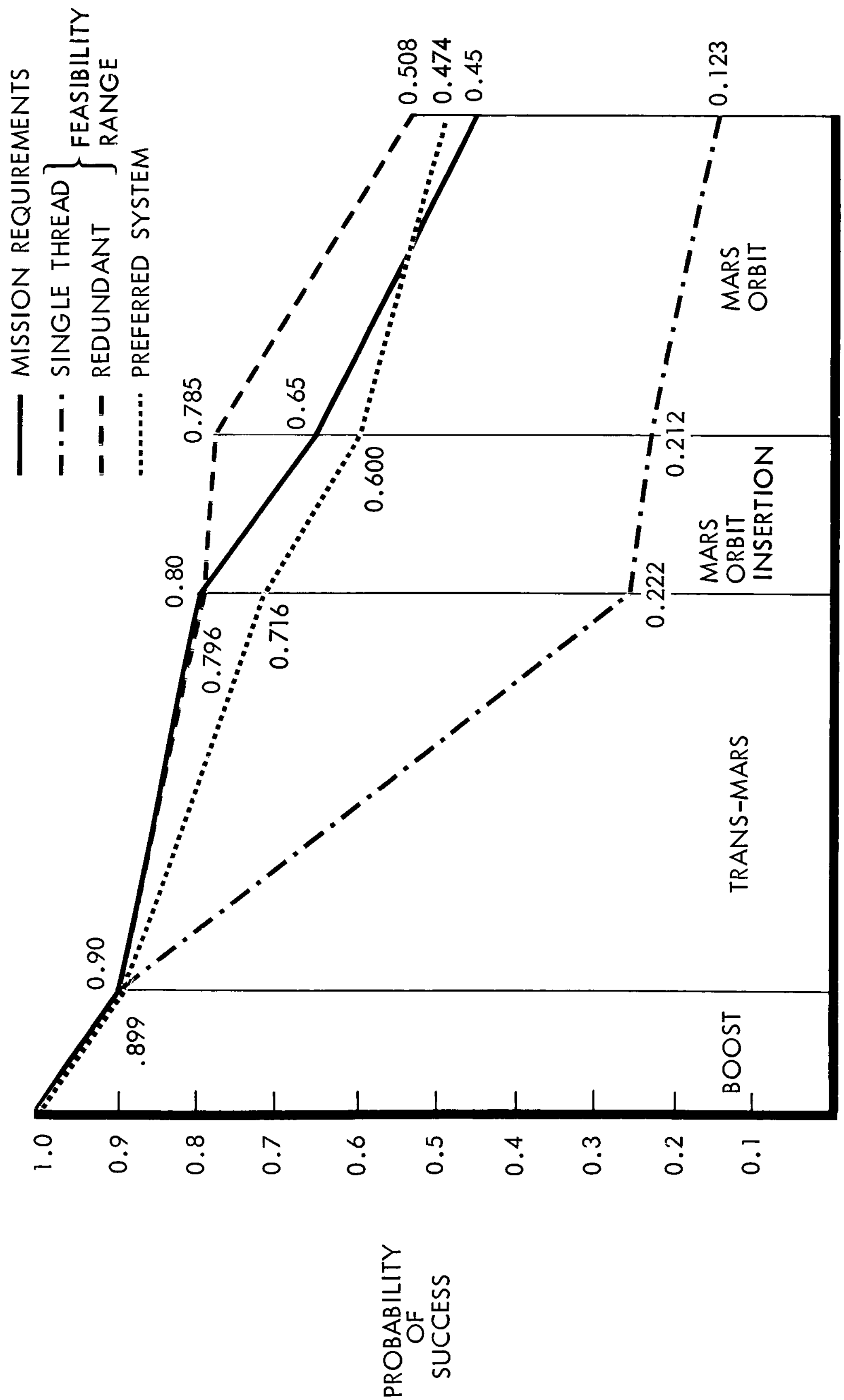


Figure 6-24: Mission Reliability Comparison

Table 6-25: Preferred System Reliability Evaluation Summary Chart

SYSTEM ELEMENT	ASSESSED RELIABILITY	
Spacecraft		
Spacecraft Bus		
Telecommunications	0.8416	
Attitude Reference	0.9969	
Autopilot	0.9998	
Reaction Control	0.9996	
CC&S	0.9941	
Electrical Power	0.9923	
Propulsion	0.9968	
Structure	0.9999	
Mechanisms	0.9988	
Temperature Control	0.9960	
Pyrotechnics	———	1
Spacecraft Bus (Subtotal)	0.8201	
Science Payload	0.6726	2
Spacecraft (Subtotal)	0.5516	
OSE	0.970	
Launch Vehicle	0.900	
Performance Factors		
Midcourse	0.997	
Orbit Injection	0.997	
Orbit Trim	0.999	
No Meteoroid Damage	0.990	
Contingency	--	
TOTAL	0.4735	

1 Included for reliability purposes in CC&S

2 For all planetary experiments

system was premised on performance of all planetary experiments. Values for other levels of success, ranging from complete success of all data gathering functions to success of a defined minimum number of functions was shown in Table 6-23 of Section 6.5.13.

6.6.2 Preferred System Reliability Allocation

The initial allocation, described in Section 6.3.3 was used as a guide in the first round iteration of the preliminary design. It was based on the feasibility study (Section 6.3.2) which showed that compatibility with specified design objectives could be achieved by the use of high reliability component/parts (equivalent to Minuteman) applied in a design employing redundancy on critical functions.

Subsequent design efforts evolved candidate configurations aimed not only at meeting allocated reliability objectives, but meeting overall design criteria and in the most effective manner. As a part of the latter studies, the reliability of each candidate was assessed to determine compliance with objectives and to establish relative ranking for selection criteria. Details of these trade studies were set forth in Section 6.5. From these studies, the preferred or selected system (evaluation given in Section 6.6.1) was evolved.

The reliability allocation for the preferred system, shown in Table 6-26, is based on the studies described above and assumes the implementation plan as described in Section 5.0.

Table 6-26: Preferred System Reliability Summary Chart

SYSTEM ELEMENT	REVISED ALLOCATION
SPACECRAFT	
SPACECRAFT BUS	
TELECOMMUNICATIONS	0.841
ATTITUDE REFERENCE	0.996
AUTOPILOT	0.999
REACTION CONTROL	0.999
CC&S	0.994
ELECTRICAL POWER	0.992
PROPULSION	0.996
STRUCTURE	0.999
MECHANISMS	0.999
TEMPERATURE CONTROL	0.996
PYROTECHNICS	*
SPACECRAFT BUS (SUB TOTAL)	0.817
SCIENCE PAYLOAD	0.650
SPACECRAFT (SUB TOTAL)	0.531
OSE	0.970
LAUNCH VEHICLE	0.900
PERFORMANCE FACTORS	
MIDCOURSE	0.997
ORBIT INJECTION	0.997
ORBIT TRIM	0.999
NO METEOROID DAMAGE	0.990
CONTINGENCY	0.987
TOTAL	0.450

*INCLUDED FOR RELIABILITY PURPOSES IN CC&S

The preferred system reliability allocation will serve as the main numerical control procedure for the follow-on design phase. Demonstration of compliance to allocated objectives will be required by means of detailed design analyses supported by agreed upon data standards and analyses procedures.

6.7 1969 TEST SPACECRAFT RELIABILITY EVALUATION AND ALLOCATION

6.7.1 Evaluation

Reliabilities of alternate and preferred 1969 test spacecraft were assessed by revising the evaluations of the 1971 preferred system to account for differences in: (1) equipment configuration, and (2) mission profiles and objectives. Although it is expected that the test spacecraft equipment maturity will be less than that for the 1971 system, this factor has not been included in this analysis. In terms of overall mission success, the test system compares favorably to the 1971 system in that its reduced complexity will more than offset equipment maturity degradation. Summary data for each candidate configuration and mission are presented below in Table 6-27.

Table 6-27: 1969 TEST SPACECRAFT RELIABILITY EVALUATION

TEST/MISSION CONFIGURATION	DEVIATION FROM 1971 CONFIGURATION	MISSION DURATION (Days)	RELIABILITY*
Atlas/Centaur Launch	Reduction in Electrical Power, Temperature Control, Mechanism No., Orbit Insertion Engine, No Science Payload		
Mars Flyby		315	0.761
Heliocentric		225	0.825
Earth Orbit		270	0.800
Saturn/Centaur Mars Orbit	Dummy Science Payload	270	0.792

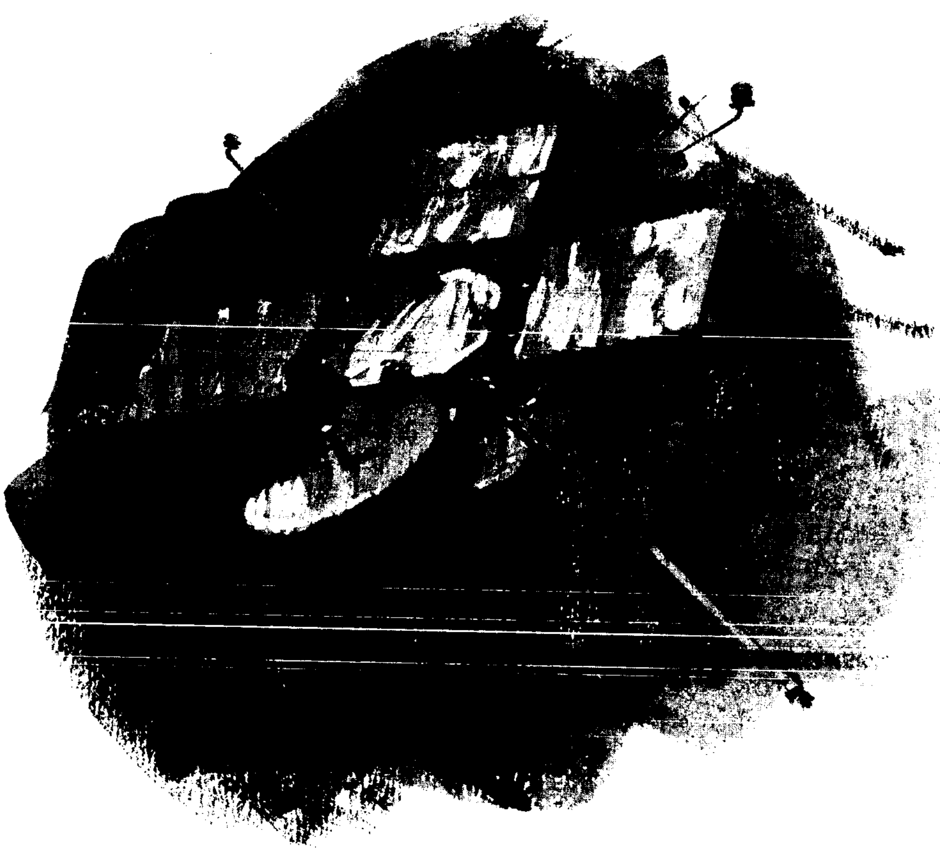
* For test spacecraft only

6.7.2 Allocation

The reliability allocation for the preferred 1969 test spacecraft will be the same as that for the preferred 1971 configuration, with minor adjustments to account for differences in equipment configuration. The approximate 2-year difference in launch dates between the two systems will affect achieved reliability. However, because the reliability allocation serves primarily as a design control and not as demonstration criteria for hardware, no adjustments will be made to account for maturity differences. Table 6-28 lists reliability allocation for the 1969 test spacecraft. Deviations are noted by an asterisk.

Table 6-28: ALLOCATION FOR 1969 TEST SPACECRAFT

SUBSYSTEM/COMPONENT	RELIABILITY ALLOCATION
Telecommunications	0.841
Attitude Reference	0.996
Autopilot	0.999
Reaction Control	0.994
CC&S	0.994
Electrical Power	0.979*
Propulsion	0.998*
Structure	0.999
Mechanisms	0.999
Temperature Control	0.997*
TOTAL	0.805



CONTENTS

7.0 INTEGRATED TEST PLAN DEVELOPMENT

7.1 INTRODUCTION

The importance of testing to Voyager Mission Success and the extensive test interface with flight hardware and the Mission Operating System requires that preliminary planning for Integrated Testing be developed concurrently with the Spacecraft System Design. This preliminary planning includes review and analysis of requirements and constraints and examination of certain alternative approaches. It culminates in a selected approach and scheduling to support program planning. The impact of '69 test flights on the test plan will be highlighted.

A preliminary Integrated Test Plan has been prepared based on the study and planning described in this section. This plan will be developed and completed during Phase IB. Salient features of the plan include:

1) A highly disciplined test operation through automatic programmed test equipment, detailed test procedures, and a test team training program.
2) Documented assurance of performance and reliability status through a Central Data collection and analysis system.
3) Integration of test time from all tests into equivalent mission to provide a numerical index of reliability assurance.
4) Collection, collation and analysis of trend data.
5) Test flows and scheduling that optimize test effectiveness with efficiency.
6) Use of a moving test complex including equipment and test team for STC level testing.

7) Burn-in and screening of parts.

8) Accumulation of sufficient test time on flight articles during flight acceptance and interface testing to detect potential infant mortality failures.

9) Incorporation of life test requirements in Type Approval Test specifications for components, subsystems and systems.

10) Environmental testing of non-flight hardware to explore design margins and degradation rates.

11) Environmental tests of flight hardware in the Planetary Vehicle configuration to assure integrity of all interfaces and interactions.

7.2 OBJECTIVE

The overall objective of the Integrated Test Plan is to demonstrate the ability of the totality of systems to meet the Mission Flight Requirements. This objective is achieved by choosing tests and environments and sequencing them to produce documented assurance at the time of launch that all significant failure modes have been investigated and the risk of their occurrence during the mission is at an acceptable level. The basic concept is to summarize test requirements from all project elements, i.e., system engineering, design, operations, quality assurance, reliability and safety and to integrate these into a composite test program which satisfies the test program objectives.

7.3 REQUIREMENTS AND SCOPE

Table 7-1 depicts the various tests identified by the Preliminary Voyager '71 Mission Specification, categorizes them into either type approval tests or flight approval tests and indicates the hardware involved.

7.3.1 Interface Tests

An important facet of the test program is the impact of the interface tests on the scope of the test program. The Spacecraft Integrated Test Program is a part of a larger test program and must be viewed in the context of the total Voyager Project. Figure 7-1 shows how the program elements come together to constitute a project. Each junction represents an interface whose integrity must be verified by test and formally controlled. Figure 7-2 is a simplified spacecraft integration diagram which includes the Operational Support Equipment. Figure 7-3 illustrates how geographical factors complicate interface test and control.

7.3.2 Environmental Test Requirements

The spacecraft test program will be required to demonstrate the capability of the spacecraft to meet the requirements for normal and back-up modes of operation in all the ground-handling and mission environments. Simulated environmental tests will consider the mission phases of Table 7-2.

Table 7-1: TEST REQUIREMENTS

TEST CATEGORY	HARDWARE	TEST SPEC. ENVIRONMENTAL	SUBSYSTEM COMPATIBILITY	DESIGN VERIFICATION	SPACECRAFT INTERFACE	FLIGHT QUAL.
Type Approval	Proof Test Model	S/C Systems Subsystems Assemblies	Elec. Compat. Mech. Compat.	Mission Sequencing Parameter Variation Magnetic Field Mapping Space Simulation Vibration Simulated Mid-course and Retro Inter-actions Free Mode Failure Mode	S/C-OSE Intersubsystem-STC S/C-LCE S/C-Capsule *S/C-DSN S/C-MOS S/C-L/V *S/C-Launch Complex *OS/C-L/VS *AHSE-S/C	
Flight Approval	Components Assemblies Subassemblies S/C Test Models	Performance Environmental Life Margin				
	All Flight Hardware	Performance Environmental Margin Inspection Calibration				Subsystems Systems F S/C-L/V F S/C-MOS F S/C-Capsule F S/C-DSN
Models	Engine-ering Model Other		Subsystem Compatibil-ity			

*Includes Test Models

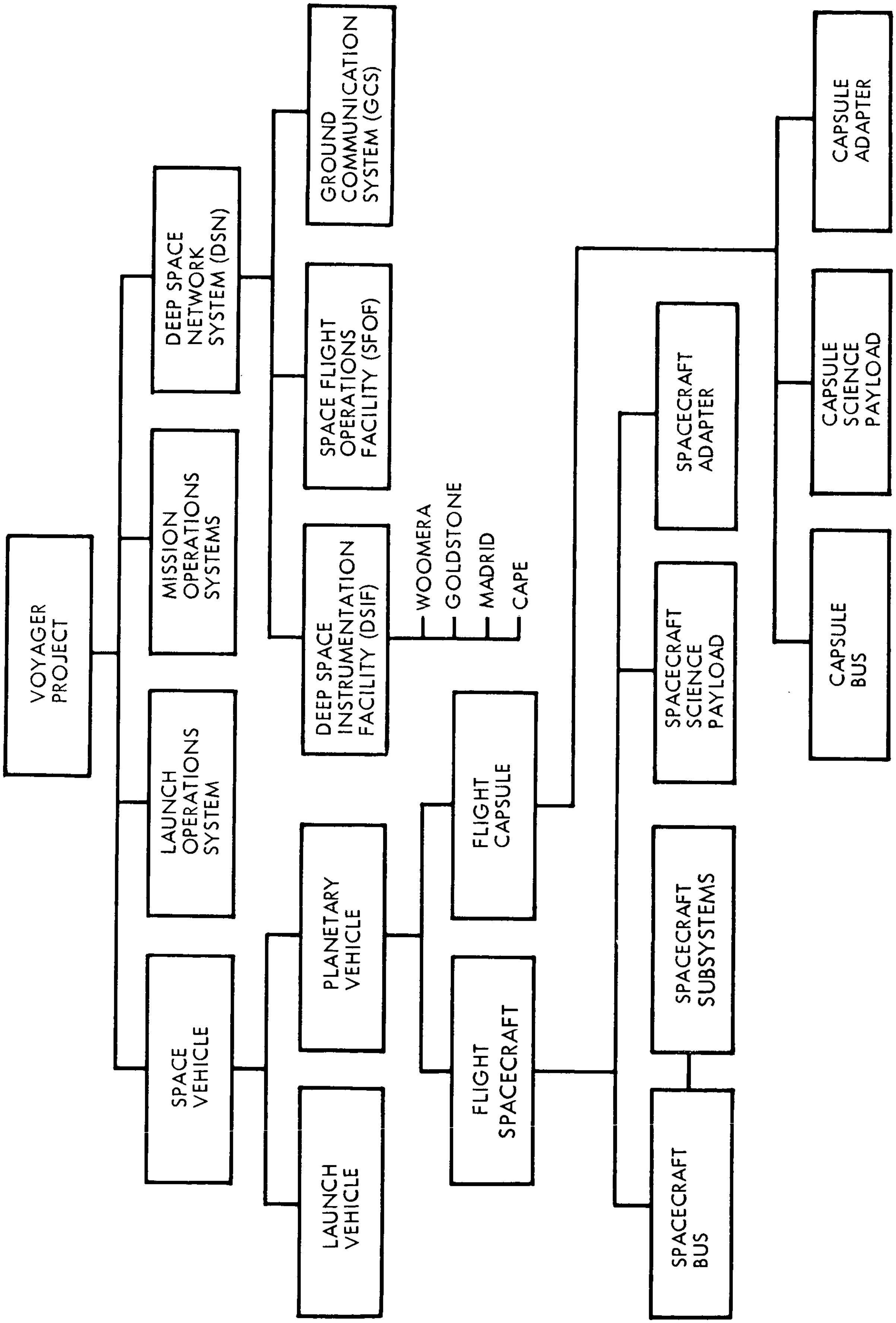


Figure 7-1: Voyager Project Elements

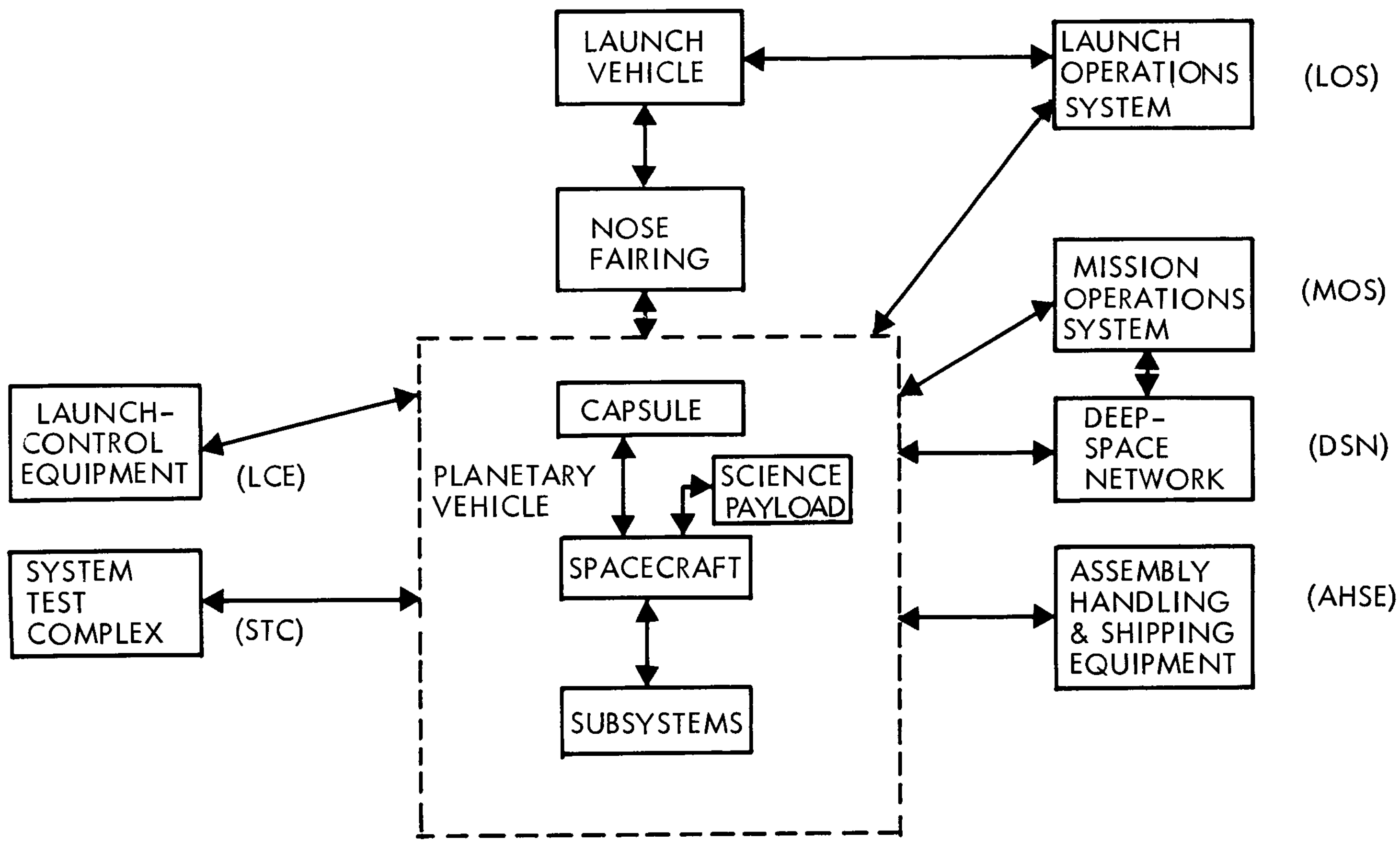


Figure 7-2: Voyager Spacecraft System Interfaces

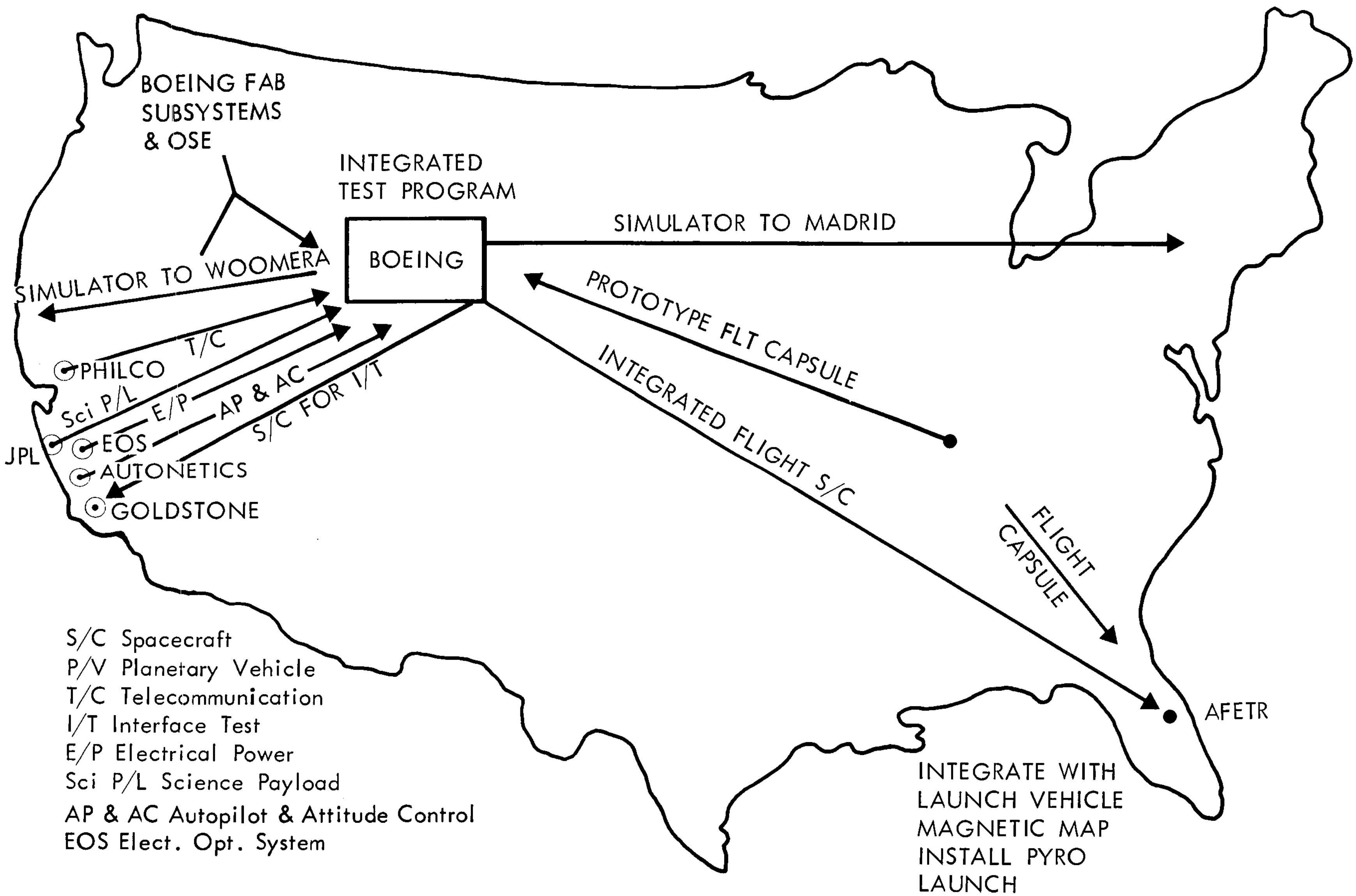


Figure 7-3: Test Program — Geographical Scope & Flow

Table 7-2: MISSION PHASES

Environment \ Mission Phase	Ground Handling	Pre-launch	Launch and Injection	Inter-Planetary Cruise and Orbit Insertion
Temperature		X		X
Humidity	X	X		
Shock	X		X	X
Vibration	X		X	X
Electrical Transients		X	X	
Ethylene Oxide*	X	X		
Electromagnetic Radiation		X	X	
Magnetic Field & Field Stability	X	X		X
Acceleration			X	X
Pressure			X	
Vacuum				X
Solar Radiation				X
Corpuscular Radiation				X
Meteoroid				X
Electrostatic Charge			X	X
Acoustic			X	
EMI		X	X	

* Only if sterilization employed.

7.3.3 Interchangeability Requirements

The probability of being able to launch during a given window is a function of the interchangeability of systems where problems develop or failures occur. Figure 7-4 illustrates the interchangeability pattern required to provide maximum availability of a complete Planetary Vehicle for launch. The test program must provide adequate integration testing to assure the interchangeability of systems and subsystems.

7.4 RELIABILITY ASSURANCE

There are several possible approaches to designing a test program to provide reliability assurance. Three were considered:

1) Statistical demonstration testing; for example, a life test based on setting the requirement equal to a lower confidence limit. Such tests are usually impractical for longlife systems as they require at least 2.3 times the mission length to demonstrate to 90% probability that the MTBF of the system is at least as long as the mission life. The Spacecraft Bus reliability requirement for a 6000 hour mission is 0.88 or equivalently a Bus MTBF of approximately 46,000 hours. To demonstrate this reliability to 90% confidence in a test as described above would require more than 100,000 equipment hours of testing. This method has the advantage of low risk, but is not as cost effective as the approaches described under 2) and 3) below.

2) A different approach to reliability assurance testing is to make the main purpose the exploration and elimination of potential failure sources. This approach involves identification of the probable failure causes and the design of tests to explore for susceptibility

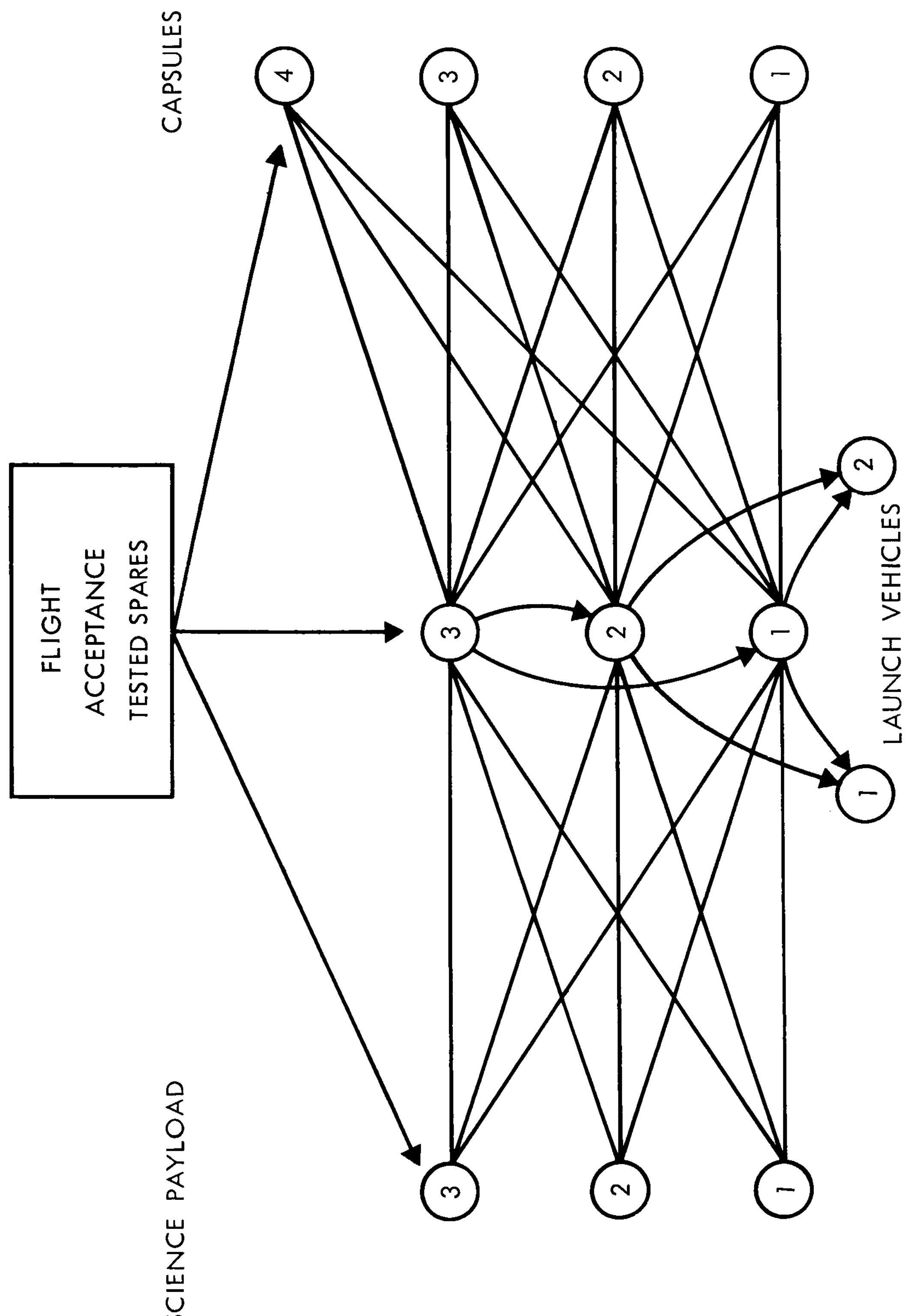


Figure 7-4: System Interchangeability

to these causes. For this purpose, we will classify failure causes into the following general categories:

<u>Random Failures (so called)</u> - These are due to manufacturing defects or handling damage which reduces the "strength" of the part significantly below the expected value. They are not truly random in time but fail at a higher rate during early life (infant mortality) and are susceptible to detection by part and equipment burn-in and screening.

<u>Over Stress Failures</u> - These are caused by misapplication or accidental over stress. Misapplication may be due to inadequate application data or designer error plus inadequate application review. Type approval and design verification tests should confirm the adequacy of the strength margin for all important mission stresses.

<u>Wear Out Failures</u> - These are a special case of the over stress failure wherein time is an important variable in the failure mechanism. They result from misapplication or part defect. Two types of testing are indicated,

a) Life testing to establish wear out characteristics and,

b) Testing to obtain trend data indicating abnormal wear rates.

<u>Degradation Failures</u> - These are another form of time dependent failures and result from inadequate allowance for part parameter drift or degradation. Life tests for a substantial fraction of

the mission operating time should be incorporated in type approval tests to insure adequacy of the design. Trend measurements on flight hardware should be used to monitor this source of failures.

This method has the advantages of being a more direct attack on sources of unreliability, and readily incorporated into an integrated test program, but affords no quantitative measurement of the degree of assurance achieved.

3) A third method adds to 2) a quantitative dimension by converting test time and cycles into equivalent missions. Thus, burn-in time on parts components and subsystems, time from life tests which are a part of type approval testing, and time used in interface testing can be modified with appropriate K factors and accumulated into equivalent missions. This third method has been selected by Boeing as the most appropriate for Voyager and is described in greater detail below.

The objectives of the selected Test Assurance Plan are:

1) Qualification of hardware for mission (Type Approval and Design Verification Tests)
    a) Establish adequacy of environmental stress margins.
    b) Establish adequacy of performance.
    c) Establish adequacy of performance degradation rates.
2) Screening out defective hardware (Flight Acceptance Tests)
    a) Parts burn-in and screen.
    b) Component burn-in.
    c) Subsystem burn-in.
    d) System burn-in.

3) System Integration (Interface Tests)

   a) Checkout and debug component - subsystem - system interfaces interactions, and interaction margins.

   b) Checkout spacecraft - OSE - software integration.

   c) Crew training - failure and corrective action simulation.

   d) Maintainability checkout and training.

4) Detect design, quality or reliability deficiencies, analyze and initiate corrective action (All tests)

   a) Flight readiness demonstration (Flight Acceptance Tests)

   b) Reliability Status (All Tests)

The preferred plan has the following major elements which will be discussed in some detail in subsequent subparagraphs.

1) Identification of test program elements as they relate to failure causes.

2) Incorporation of reliability requirements into test specifications and procedures to obtain adequate levels of test assurance against potential failure modes.

3) Creation of a data collection and analysis system to:

   a) Collect and collate data.

   b) Identify problems.

   c) Identify and monitor trends.

   d) Convert test hours and cycles to equivalent missions.

   e) Provide continuing visibility of the status of system reliability.

7.4.1 Test Program Elements Versus Failure Causes

Table 7-3 shows which test program elements provide assurance against the various general causes of system unreliability. This chart also serves as a guide for preparing reliability requirements for test specifications.

7.4.2 Reliability Requirements for Test Specifications

The following are typical of requirements which will be incorporated into test specifications to provide the necessary assurance against the major causes of failures:

1) Type Approval Tests - Hardware exposed to these tests does not fly, so near design limit stresses will be used to explore design margins.
   a) Parts -- Parts will be qualified to environmental levels which exceed the mission environment, e.g., mission vibration plus 5 db and mission temperature + 40°C and -20°C. Performance application data will be substantiated by test data.
   b) Components -- Components will be qualified to the mission environment plus the specified factors except those in Spacecraft controlled environments. In addition, components will be required to pass an accelerated life test equivalent to one half of the mission operating time with degradation trend monitoring to verify design limits for performance degradation.
2) Design Verification Tests - These tests qualify the subsystems and system to the flight environment and include component and subsystem interfaces not included in the component type approval tests. Reliability requirements for these tests will include:

Table 7-3: Integrated Test Program Elements

TEST	HARDWARE		EQUIPMENT LEVEL					ASSURANCE OF					
	TEST	FLIGHT	PART	COMP	SUB-SYSTEM	S/C	P/V	DESIGN MARGINS	FREEDOM FROM MFG DEFECTS	INTERFACE DESIGN	PARAMETER LIFE STABILITY	OPERATION PROCEDURES	SYSTEM LIFE
DESIGN VERIFICATION													
VIBRATION	DVT					X		X					X
THERMAL	DVT					X		X					X
STATIC	DVT					X		X					X
MISSION SIMULATION	DVT					X		X				X	X
FREE MODE	DVT	FAT					X	X	X	X			X
PARAMETER VARIATION	DVT				X	X		X		X	X		X
MAG MAP	DVT	FAT				X	X	X	X	X			X
FAILURE MODE	DVT				X	X						X	X
QUALIFY TO FLIGHT ENVIRONMENT	TAT		X	X	X	X		XXXX		XX	XX		XXXX
PERFORMANCE BURN-IN AND ENVIRONMENTAL CHECK		FAT	X	X	X	X	X		XXXXX	XXX	XX		XXXXX
INTERFACE													
SCIENCE P/L	TAT					X		X		X		X	
		FAT				X			X				
CAPSULE	TAT					X	X	X		X			
		FAT				X	X		X				
LCE	TAT					X	X	X		X		X	
STC	TAT				X	X		X		X		X	
AHSE	TAT					X	X	X		X		X	

a) Qualification to mission environment plus specified margins.

b) Simulate mission operation and exercise of redundant modes of operation.

c) Subsystem accelerated life tests for at least 30% of mission life requirement.

d) Accelerated system life test of at least one complete mission with trend degradation measurement to confirm design margins for performance degradation.

3) Flight Acceptance Tests - These tests are designed to assure freedom from defects, deficiencies, and abnormalities and be specifically designed to detect potential infant mortality failures prior to launch. They will include 95 percentile vibration environments and burn-in times as indicated below.

a) Parts -- Part acceptance tests will typically include 168 hours of burn-in plus other non-destructive environmental exposure and screening.

b) Components -- Component acceptance tests will include burn-in and screening for early degradation and/or failure. Burn-in time will be tailored to the components but 200 hours will be typical for electronic components. Critical parameters will be measured before and after to obtain trend data.

c) Subsystems -- Subsystem acceptance tests will include 250 hours of operation of electronics and equivalent number of cycles and hours for other types of devices. Subsystem tests will also include trend measurement.

d) System -- At least 300 hours of operation will be accumulated at the system level to assure subsystem interfaces and to detect any abnormal trends.

7.4.3 Data Collection and Analysis System

The documented assurance of flight readiness is supported directly by the data system which is described below. All test data will be collected and programmed to provide a numerical measurement of assurance by converting time to equivalent missions. Tables 7-4 through 7-6 show how time is derived from the various tests and accumulated into equivalent missions.

The Data Collection & Analysis System is shown on Figure 7-5. The Engineering requirements and test specifications are incorporated in the Manufacturing & Inspection Record (M&IR).

All test data, including both success and failure data is recorded. The test record will include all critical design parameter measurements, test conditions, test time and all other pertinent data necessary for performance, trend analysis and/or failure analysis.

Provisions are made on the Planned Events Form to give all instructions necessary to provide configuration accountability, and to account for supplements or revisions to the original planning. Unplanned events, which include all failures caused by personnel, test equipment, or procedures to perform according to plan, are recorded.

Table 7-4: TEST ASSURANCE FROM TAT

TYPE APPROVAL TEST TIME

One Mission Equivalent Operating Time for Each Component

Environmental acceleration

Duty cycle acceleration

Distribution of Time Among Equipment Levels

	Approximate % of Mission Time
Component	50
Subsystem	30
System	20

Range of Test Times

Components

Subsystems

System

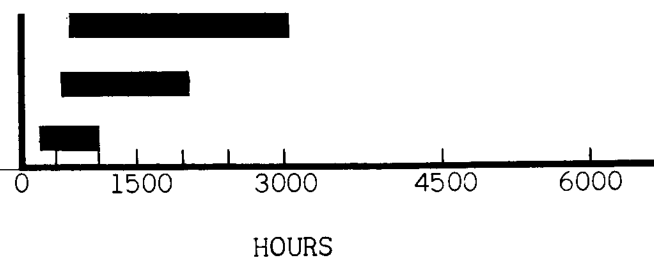


Table 7-5: TEST ASSURANCE ACCUMULATION

SYSTEM INTERFACE TESTS	FLIGHT ACCEPTANCE
Subsystem - 50 Hours	Part - 168 Hours
S/C System - 100 Hours	Component - 200 Hours
S/C - OSE - 50 Hours	Subsystem - 250 Hours
	System - 350 Hours
DESIGN VERIFICATION - (RELIABILITY)	
Life Test & Mission Simulation - 5000 Hours	

Table 7-6: TYPICAL TEST ASSURANCE SUMMARY

TEST	1971 FLIGHTS ONLY TEST HOURS OR EQUIVALENT MISSIONS				FLIGHT UNITS 71	FLIGHT SPARES	TEST UNITS [1]	FACTOR [2]	EQUIV. MISSION
	PART	COMPONENT	SUBSYSTEM	SYSTEM					
SCREENING	168 H.				3	1	2	2	0.34
TYPE APPROVAL		0.5 E.M.	0.3 E.M.	0.2 E.M.	-	-	1	5	5
INTERFACE			50 H	100 H.	3	-	1	5	0.5
FLIGHT ACCEPTANCE (BURN-IN)		200 H.	250 H.	350 H.	3	1	1	2	1.3
DESIGN VERIFICATION (LIFE-TEST)				5000 H.			1	2	1
					TOTAL EQUIVALENT MISSIONS				7.14

H - Hours

E.M. - Equivalent Mission - 6000 hours

[1] Excludes incomplete test modes such as structural

[2] Acceleration factor based on test environment

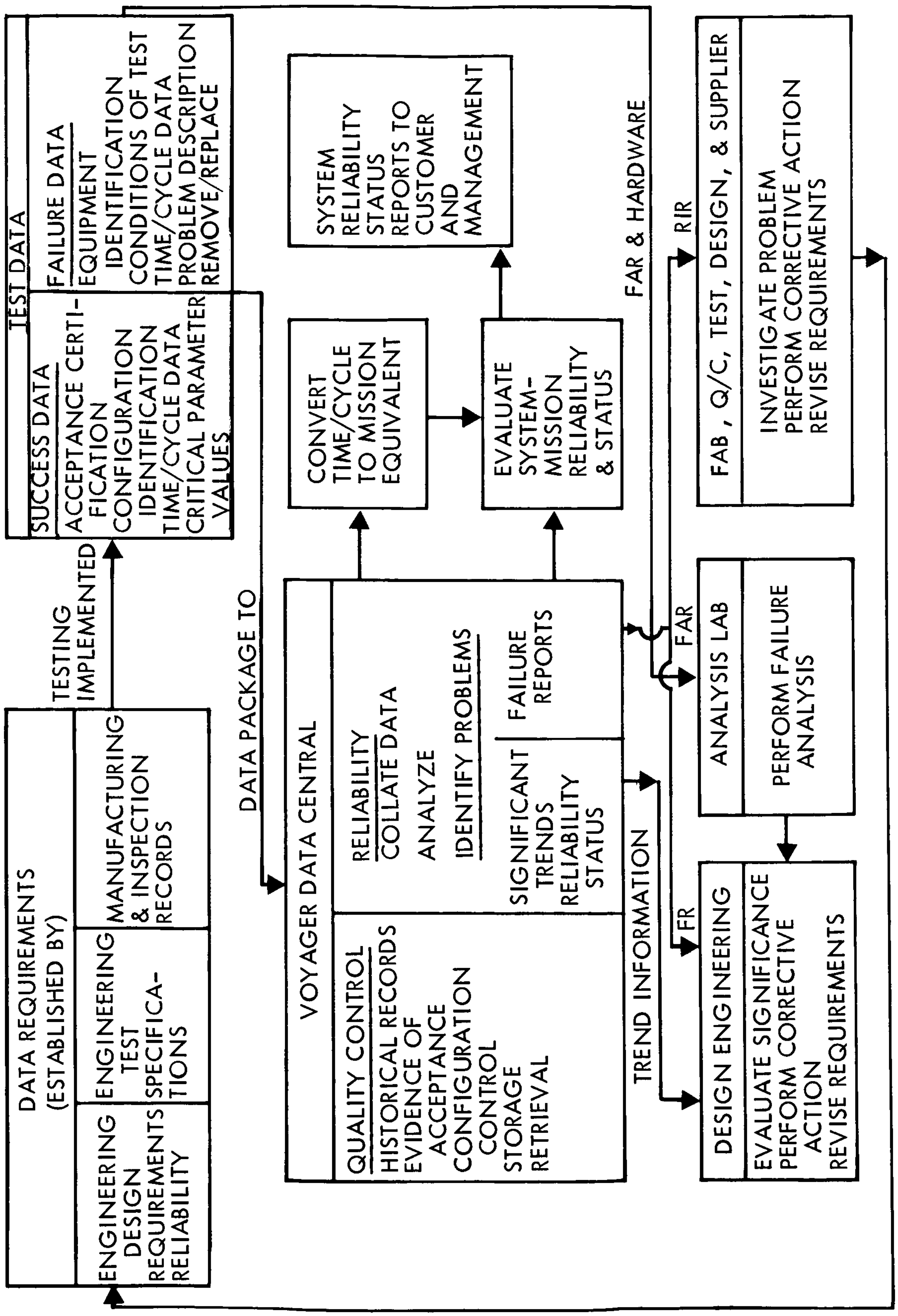


Figure 7-5: Voyager Test-Data Collection & Analysis System

Each failure of flight hardware or OSE which occurs during test is thoroughly evaluated. The test is stopped immediately and an evaluation is made to determine the direct cause of failure before the testing is allowed to resume. All test anomalies are completely investigated by a failure analysis to determine the mode(s) of failure and the appropriate corrective action.

Planned and unplanned event data are sent to the Voyager Data Central for processing, storage, and retrieval. If evaluation of the test data discloses that a hardware problem exists, a Failure Analysis Request (FAR) is prepared and the discrepant hardware is sent to a laboratory for a complete failure analysis. If the problem is a result of test procedure deficiencies, or human induced failures, a Reliability Investigation Request (RIR) is issued to the responsible organization for corrective action.

The "critical parameter" test values are also examined using data plots and statistical techniques. All data are evaluated for drift trends and potential component incompatibilities. These data, with conclusions and recommendations, are sent to the responsible design group for any required corrective action. The Boeing system provides for followup of such assignments to assure adequate closeout of the problem.

Reliability status reports will include the mission equivalent time and the failure data for component, subsystem, and system levels. Charts will be prepared from the data and analyses to highlight reliability status, trends, problem areas, and action requirements.

7.5 SPACECRAFT TEST FLOW AND SEQUENCE

Spacecraft Test Flow and Sequence patterns were studied to optimize a progressive assembly and checkout sequence which could demonstrate the compatibility of system elements and the capability of the spacecraft to meet the requirements of all phases of mission profile as well as all flight and ground handling environments, and to establish confidence that the totality of all systems will meet the mission flight requirements. Four basic alternatives are considered (Table 7-7).

Table 7-7: BASIC ALTERNATIVES

Mate Spacecraft with:	Assembly Location			
	A	B	C	D
Science Payload	AFETR*	Seattle	Seattle	Seattle
Flight Capsule	AFETR	AFETR	Seattle	Seattle
Nose Fairing and Adapter	AFETR	AFETR	AFETR	Seattle

* Air Force Eastern Test Range

The alternatives consider the range of options from integration of the Science Payload and Flight Capsule with the Spacecraft at AFETR to complete integration at Seattle. Integration of flight systems at locations other than Seattle is considered as a special variation of integrating the flight systems at AFETR. There are also variables to be considered within each alternative, such as, test locations for specific tests; test sequencing and scheduling; OSE requirements; use of Proof Test Models instead of actual flight hardware.

In assessing the advantages and disadvantages of the basic options, the impact on the following factors has been considered:

1) Handling Requirements
2) Test-Flow Requirements
3) Test Assurance of Mission Success
4) Test-Redundancy
5) Delivery Schedules
    a) Spacecraft
    b) Science Payload
    c) Flight Capsule
    d) Nose Fairing
6) AFETR Facility Requirements
7) AFETR Operations Schedules
8) Launch Schedule
9) OSE Requirements

Figures 7-6 through 7-9 show the general test flow sequence for each of the four alternatives and the relative advantages for each of the factors listed above are tabulated on Table 7-8.

The selection of the preferred approach is based on incorporating the major advantages derived from assessment of the several basic test flow sequences into a composite Spacecraft test-flow sequence which meets program objectives. Further iteration of the selected sequence will be required to develop the test-flow sequence in depth as program elements are defined in more detail.

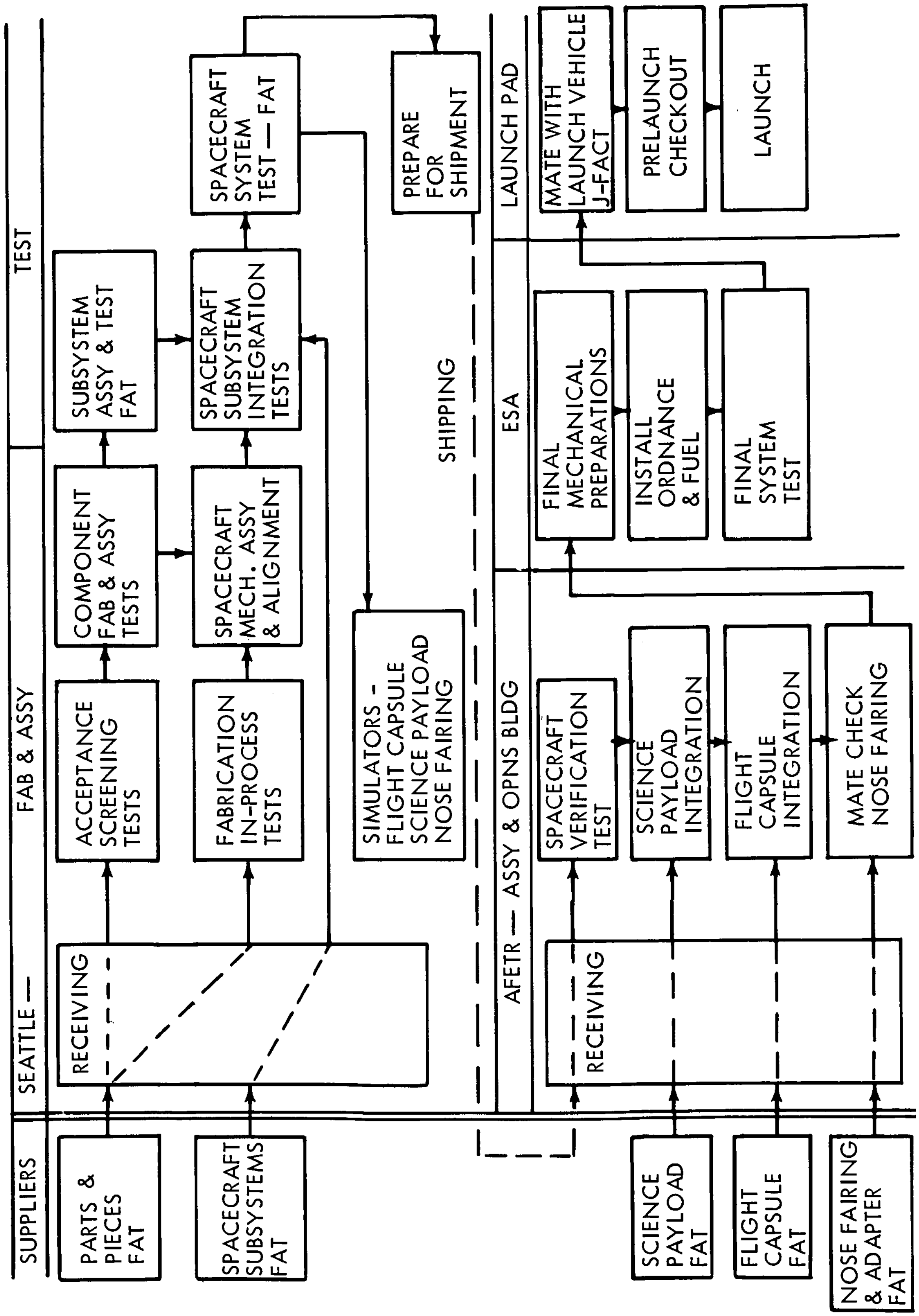


Figure 7-6: Test Flow A

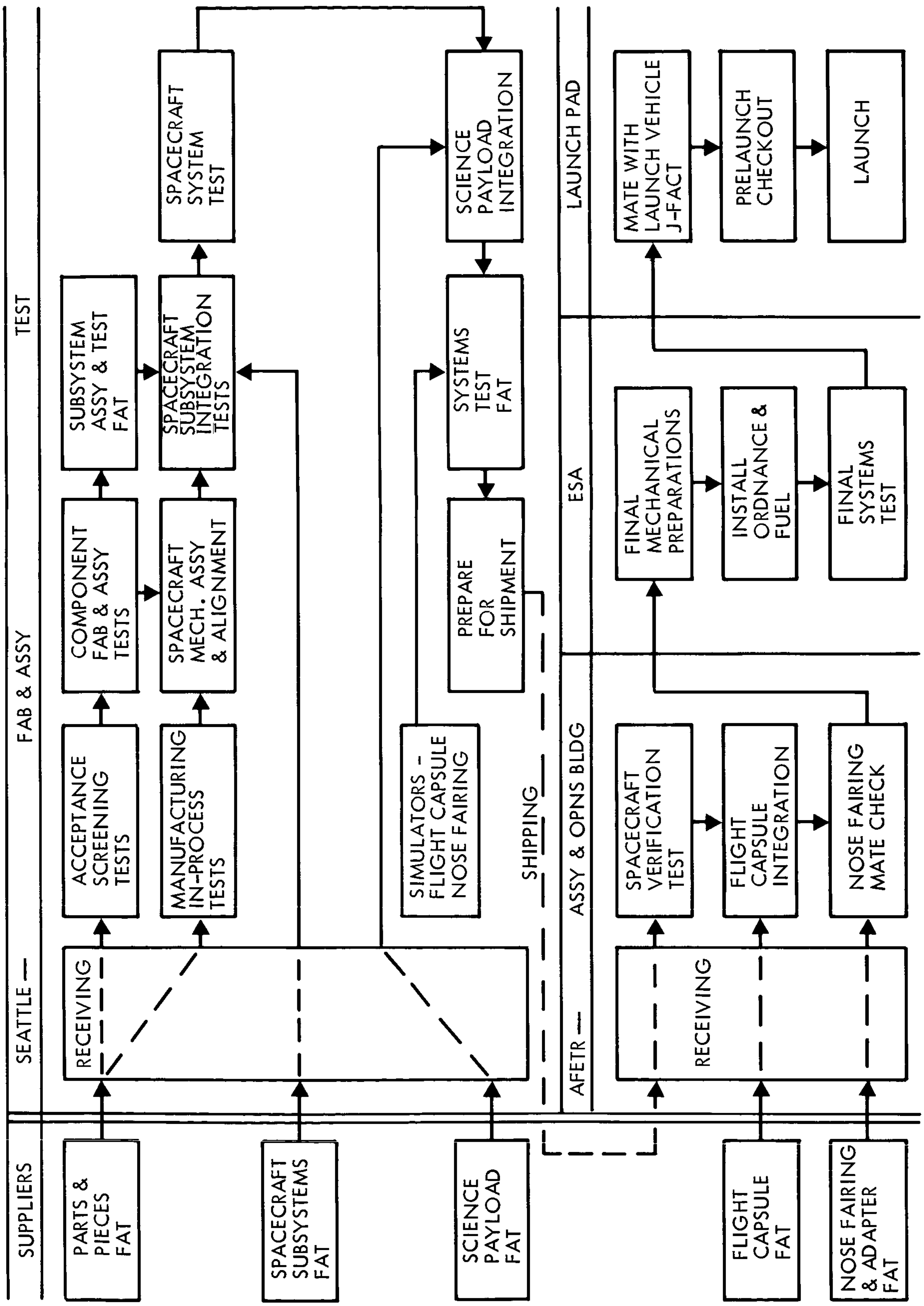


Figure 7-7: Test Flow B

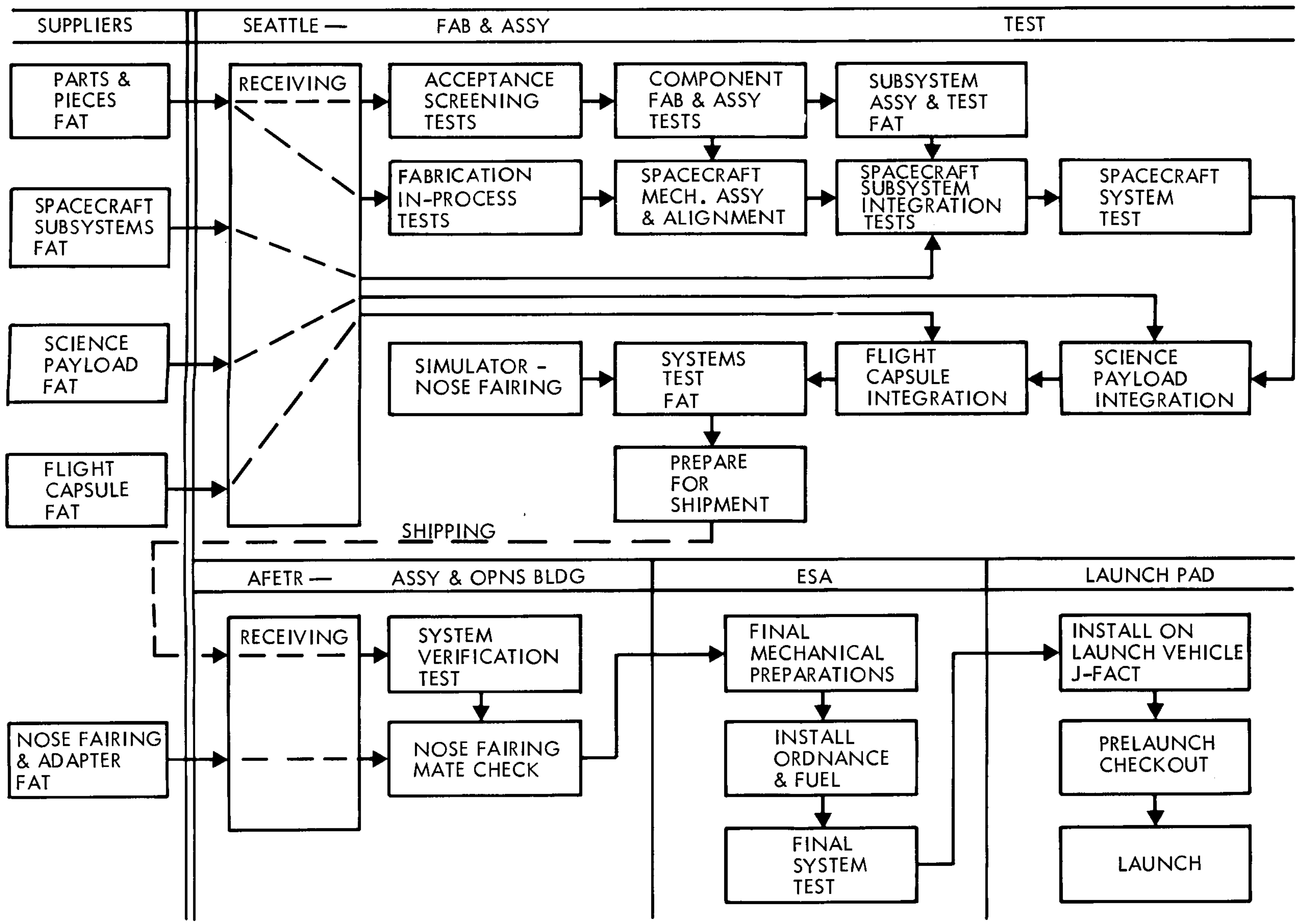


Figure 7-8: Test Flow C

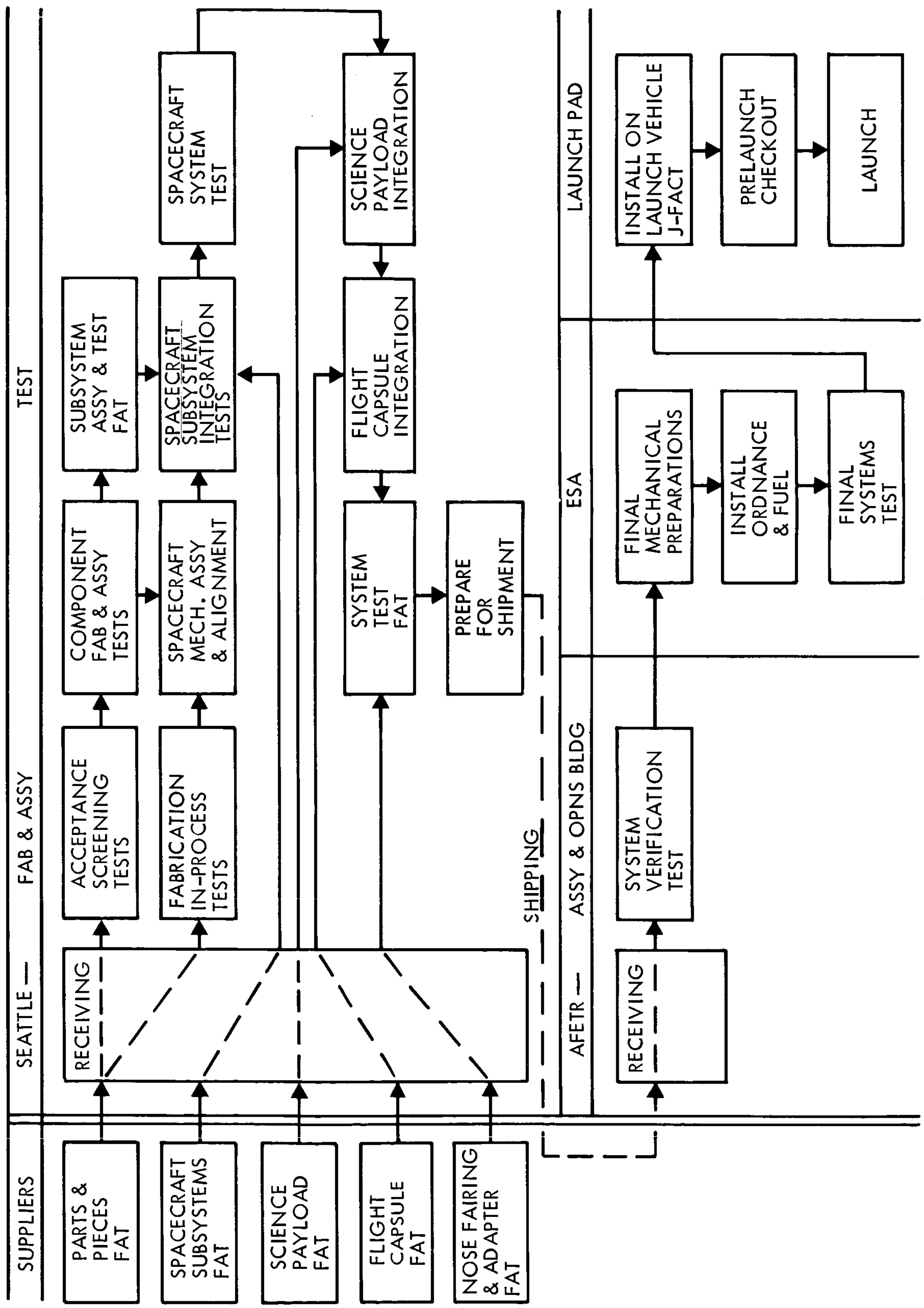


Figure 7-9: Test Flow D

ALTERNATIVE A

Integrate Spacecraft, Science Payload, Flight Capsule, and Nose Fairing at AFETR

a) Requires minimum handling of flight systems because all flight hardware is shipped directly to AFETR for integration.

b) Requires longest test-flow time at AFETR because flight systems are integrated for first time.

c) Provides least confidence of mission success because spacecraft flight acceptance test is accomplished using simulators for Science Payload and Flight Capsule. Integration of the flight systems at AFETR may disclose incompatibilities that will require recycling hardware back to contractor facility.

d) Affords less interface testing of flight hardware because systems are delivered directly to AFETR.

e) Requires earliest delivery schedule for on-dock of flight hardware at AFETR.

f) Modification of flight hardware may be required to integrate planetary vehicle systems at AFETR. Additional AFETR facilities such as cleanroom environments for disassembly, and vibration and space simulation facilities for confidence testing will be required to re-establish confidence level.

g) Scheduling of AFETR operations is more difficult due to contingency for problems that may result from first-time integration of flight systems.

h) Interface problems between flight hardware systems are identified too late for effective corrective action to meet launch commitment.

i) Additional OSE is required at AFETR to support integration of Spacecraft, Science Payload and Flight Capsule.

ALTERNATIVE B

Integrate Spacecraft with Science Payload at Seattle and with Flight Capsule and Nose Fairing at AFETR

a) Requires additional handling of Science Payload because flight hardware is delivered to Seattle and tested with Spacecraft before delivery to AFETR. Actual increased handling is small because Science Payload shipped as part of Flight Spacecraft.

b) Reduces test-flow time at AFETR by that required to integrate Science Payload into Spacecraft.

c) Provides more confidence of mission success since Science Payload mechanical, electrical, and thermal interfaces are exercised with Spacecraft during Spacecraft flight acceptance testing.

d) Requires redundant testing of Science Payload because flight acceptance testing of Spacecraft will exercise the Science Payload. Additional testing is considered as an advantage as it represents an additional screen for defective or marginal equipment.

e) Requires earlier delivery of the Science Payload to Seattle for integration with the Spacecraft.

f) Eliminates possible modifications to Spacecraft or Science Payload after delivery to AFETR, which may be necessary to interface the systems. Integration of Flight Capsule at AFETR will require additional assembly and test capability.

g) Provide more confidence in AFETR test scheduling because no unknown contingency for integration of Science Payload and Spacecraft is required.

h) Interaction problems between Spacecraft and Science Payload are identified early enough to enable effective corrective action. Integration of Flight Capsule may disclose other problems too late for effective action to meet launch commitment.

i) OSE requirements at AFETR are reduced to that required to integrate Flight Capsule and mate nose fairing to verify overall performance and to prepare planetary vehicle for launch.

Table 7-8: Compar

ALTERNATIVE C Integrated Spacecraft with Science Payload and Flight Capsule at Seattle and with Nose Fairing at AFETR
a) Requires additional handling of Science Payload and Flight Capsule because systems are delivered to Seattle and tested with Spacecraft before delivery to AFETR. b) Test-flow time at AFETR is further reduced since the planetary vehicle is totally integrated before delivery. c) Provides more confidence of mission success since Spacecraft flight acceptance testing is accomplished with other interfacing systems. d) Provides more testing of Science Payload and Flight Capsule because these systems are exercised during Spacecraft flight acceptance testing. e) Requires earlier delivery of Science Payload and Flight Capsule for integration with Spacecraft at Seattle. f) Eliminates possible modifications to flight hardware at AFETR (which may be required to integrate flight systems) and deletes requirement for special facilities at AFETR to support integration. g) Provides greater confidence in scheduling AFETR operations because contingency for integration problems can be deleted. h) Integration problems between flight systems are identified early to enable effective corrective action to meet launch commitment. i) OSE requirements at AFETR consist only of those necessary to verify overall performance and prepare planetary vehicle for launch.

son of Alternate Spacecraft Test Flow & Sequences

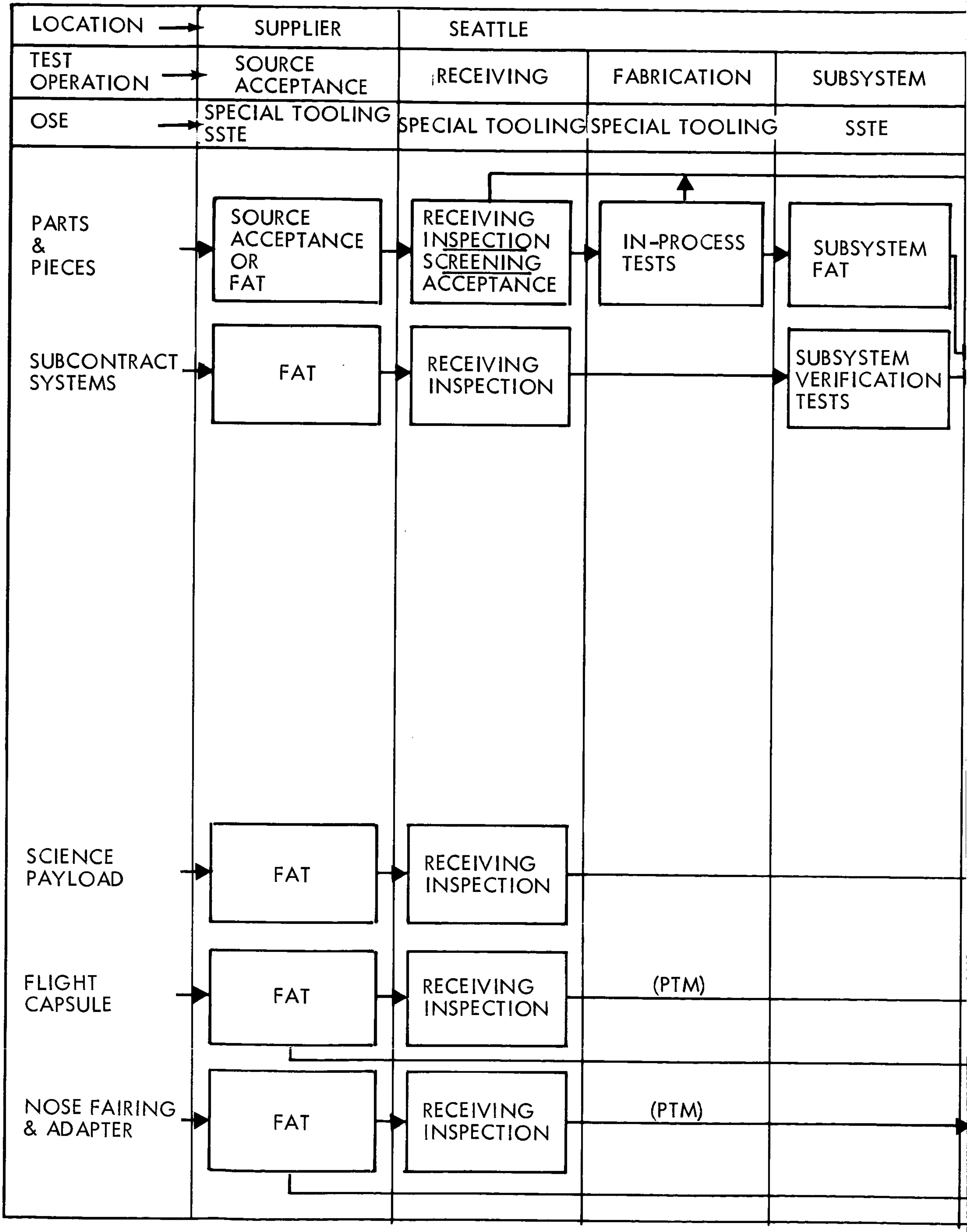
ALTERNATIVE D Integrate Spacecraft Science Payload Flight Capsule, and Nose Fairing at Seattle
a) Requires additional handling of Science Payload, Flight Capsule, and nose fairing since all flight hardware is delivered to Seattle for integration with Spacecraft before delivery to AFETR. b) Requires least test-flow time at AFETR because all systems are integrated before delivery. (This alternate would permit delivery of complete planetary vehicle encapsulated nose fairing, and would require only final preparation at ESA for mating with launch vehicle on launch pad.) c) Same as Alternate C d) Same as Alternate C e) Requires earlier delivery of Science Payload, Flight Capsule, and nose fairing for integration with Spacecraft in Seattle. f) Same as Alternate C g) Same as Alternate C h) Same as Alternate C i) Same as Alternate C

7.5.1 Preferred Spacecraft Test Flow and Sequence

The preferred test flow and sequence is shown in Figure 7-10 and 7-11 and is a composite approach which incorporates the major advantages offered by each of the alternatives. The criteria applied in developing the preferred sequence includes the following:

1) Minimum handling of flight hardware.
2) Latest on-dock dates for flight hardware at AFETR.
3) Most confidence of mission success.
4) Minimum test-flow time consistent with maximum test assurance.
5) Minimum AFETR facilities.
6) Most confidence in scheduling AFETR operations to meet launch commitment.
7) Minimum OSE requirements.

The preferred test flow sequence features the Flight Acceptance Testing of the Spacecraft in a complete Planetary Vehicle Configuration. The actual science payload is delivered to Seattle and integrated with the Spacecraft. The advantages of integrating the actual Flight Capsule and nose fairing with the spacecraft for Flight Acceptance Testing of the Spacecraft at Seattle are achieved by using Proof Test Models which must be identical to the flight systems. This deviation has been made to meet the objectives of minimum handling of flight hardware and for the latest on-dock date of flight hardware at AFETR, while at the same time, providing a high degree of assurance that the Spacecraft and Flight Capsule can be mated and flown together without problems. Since the Science Payload has closer form, fit, and function interfaces with the Spacecraft, and its performance is more sensitive to the


LOCATION
SUPPLIER
SEATTLE
TEST OPERATION
SOURCE ACCEPTANCE
RECEIVING
FABRICATION
SUBSYSTEM
OSE
SPECIAL TOOLING SSTE
SPECIAL TOOLING
SPECIAL TOOLING
SSTE
PARTS & PIECES
SOURCE ACCEPTANCE OR FAT
RECEIVING INSPECTION SCREENING ACCEPTANCE
IN-PROCESS TESTS
SUBSYSTEM FAT
SUBCONTRACT SYSTEMS
FAT
RECEIVING INSPECTION
SUBSYSTEM VERIFICATION TESTS
SCIENCE PAYLOAD
FAT
RECEIVING INSPECTION
FLIGHT CAPSULE
FAT
RECEIVING INSPECTION
(PTM)
NOSE FAIRING & ADAPTER
FAT
RECEIVING INSPECTION
(PTM)

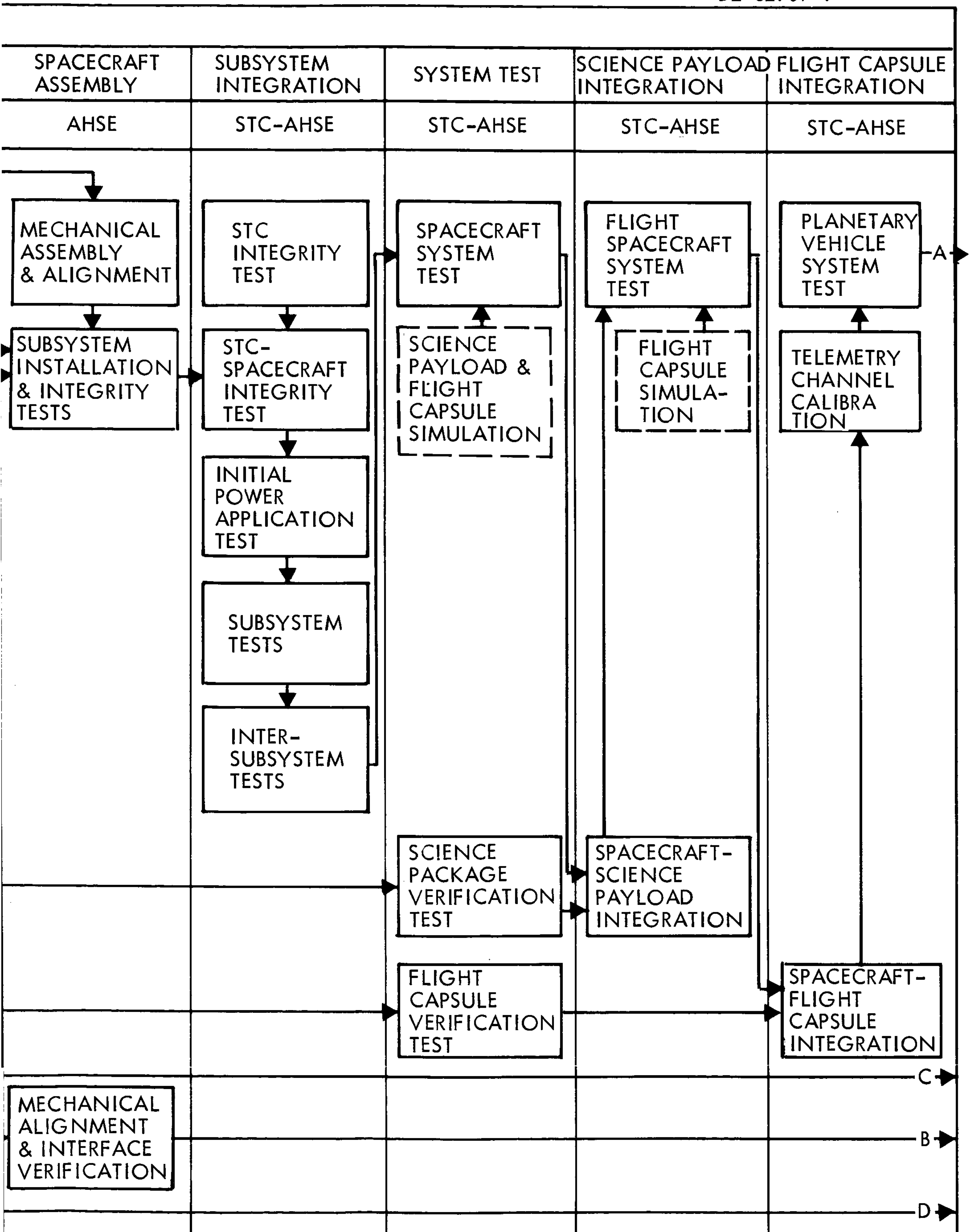
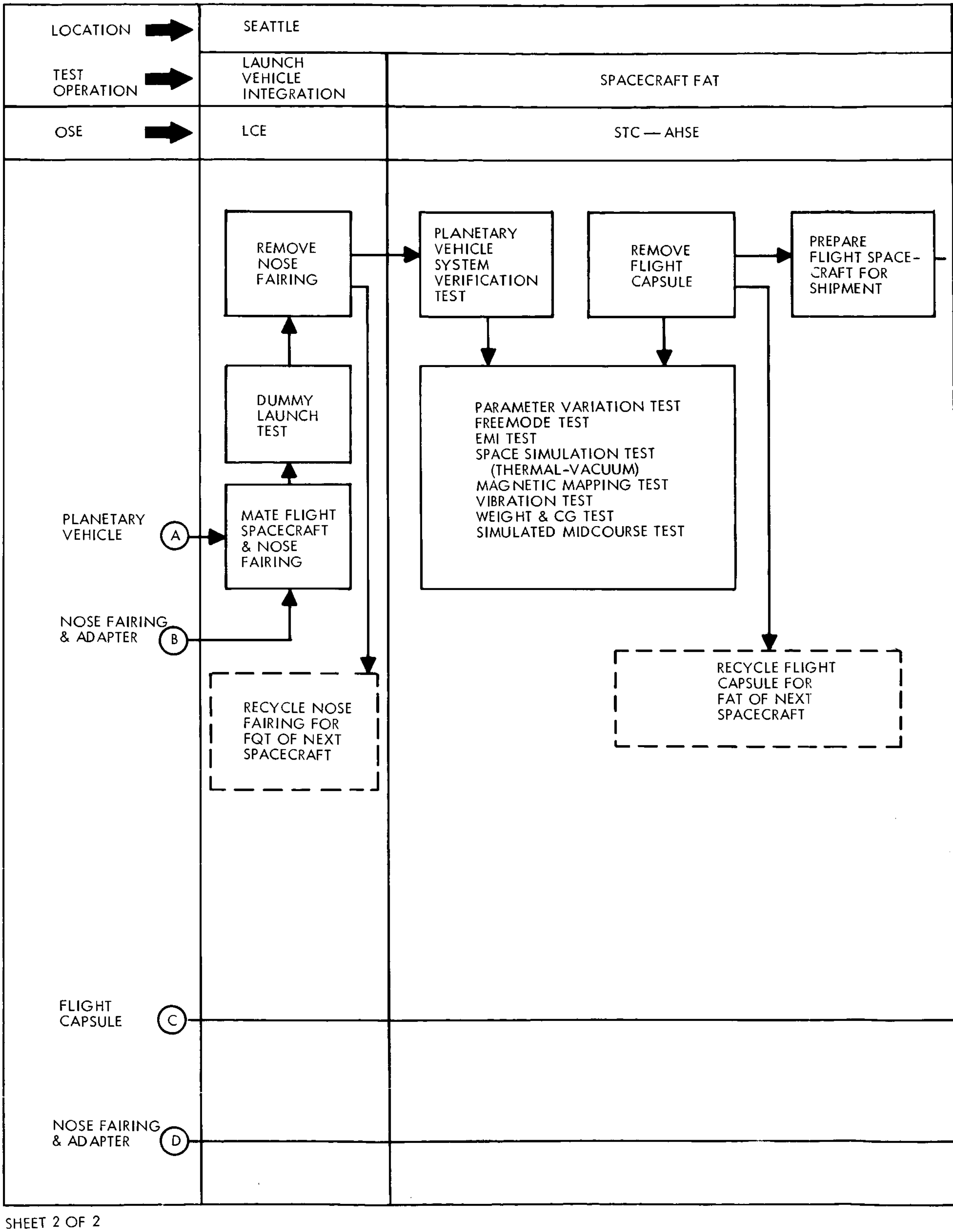


Figure 7-10: Preferred Test Flow
SHEET 1 OF 2

2


LOCATION
TEST OPERATION
OSE
SEATTLE
LAUNCH VEHICLE INTEGRATION
SPACECRAFT FAT
LCE
STC — AHSE
REMOVE NOSE FAIRING
DUMMY LAUNCH TEST
MATE FLIGHT SPACECRAFT & NOSE FAIRING
PLANETARY VEHICLE
A
NOSE FAIRING & ADAPTER
B
RECYCLE NOSE FAIRING FOR FQT OF NEXT SPACECRAFT
PLANETARY VEHICLE SYSTEM VERIFICATION TEST
REMOVE FLIGHT CAPSULE
PREPARE FLIGHT SPACE-CRAFT FOR SHIPMENT
PARAMETER VARIATION TEST
FREEMODE TEST
EMI TEST
SPACE SIMULATION TEST
(THERMAL-VACUUM)
MAGNETIC MAPPING TEST
VIBRATION TEST
WEIGHT & CG TEST
SIMULATED MIDCOURSE TEST
RECYCLE FLIGHT CAPSULE FOR FAT OF NEXT SPACECRAFT
FLIGHT CAPSULE
C
NOSE FAIRING & ADAPTER
D

SHEET 2 OF 2

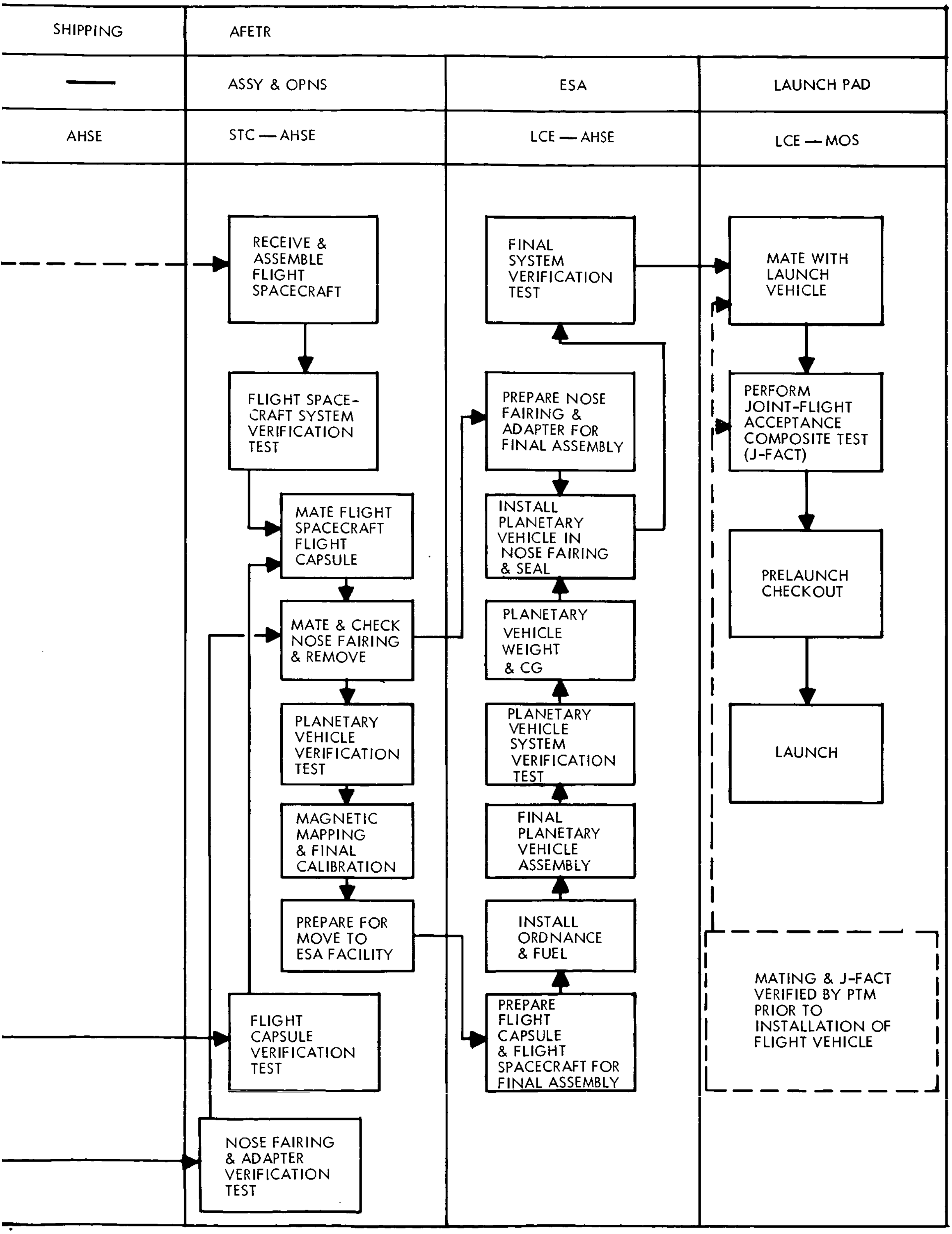


Figure 7-11: Preferred Test Flow — Sheet 2 of 2

2

spacecraft environment, it is considered necessary to integrate the actual Science Payload early in the spacecraft testing sequence and to verify the Science Payload performance during the Spacecraft Flight Acceptance testing. Further analysis of this approach is required to confirm that all test objectives can be accomplished by use of Proof Test Models. Environmental acceptance testing of the spacecraft with science payload and capsule installed provides more realistic simulation of actual flight conditions, thus improving test assurance of mission success.

Salient features of the preferred test flow sequence are discussed below:

1) Procured items will be source tested to approved procedures under Boeing Engineering and Quality Control surveillance. Parts Screening and Burn-In Tests, and Flight Acceptance Testing will be performed by the subcontractor prior to delivery to Boeing.
2) All flight hardware received at Boeing will be inspected and tested to verify status and meet reliability assurance requirements for subsequent assembly into the spacecraft.
3) Flight acceptance tests on all components and subsystems will be completed prior to assembly into the spacecraft.
4) The Spacecraft System will be first tested with functional simulators for the Science Payload and Flight Capsule systems to verify subsystem and system performance limits.
5) The actual Science Payload for the flight mission is integrated with the spacecraft; then a PTM Flight Capsule is integrated with the Flight Spacecraft.

7.6 TEST STATION TEAM CONCEPTS

The alternates considered for selection of the Test Station concept to implement the Test Flow for assembly and testing of the Spacecraft through final checkout of the Spacecraft are listed below:

Alternate A -- Permanently located Test Stations equipped with all necessary test equipment and facilities, and operated by qualified personnel to receive and perform specific tests on each Spacecraft.

Alternate B -- Assign test crew to each Spacecraft and move Spacecraft and crew to fixed Test Stations equipped with the necessary test equipment and facilities to perform specified tests.

Alternate C -- Assign test crew and Systems Test Complex Equipment to each Spacecraft and move the Spacecraft, its test equipment, and crew to each test facility from assembly through launch.

To optimize the Test Station Concept Approach, the following factors are considered for each of the above Alternatives:

1) Quantity of Test Equipment
2) Number of Test Personnel
3) Learning Factors
4) Test Compatibility
5) Test Equipment Reliability
6) Test Responsibility
7) Test Confidence
8) Test Flow Time

The testing of parts, components, assemblies, subassemblies, and subsystems will be accomplished at Fixed Test Stations to assure uniformity of tests and interchangeability of flight hardware. Therefore, the above alternatives only consider the Spacecraft system testing from initial assembly through launch.

Table 7-9 summarizes the number of test sets to support the above alternatives.

Since the total number of Spacecraft to be assembled is small compared to the number of fixed Test Stations required for Flight Acceptance Testing of a Spacecraft, the quantity of STC equipment and the total number of personnel required to implement and operate the fixed Test Stations will be greater and the utilization of equipment and personnel less than for Alternative C where test equipment and personnel move with the Spacecraft to each test facility.

Learning rate for the Test Team concept will be higher than for the fixed Test Station concept since the Test Team personnel conduct all Spacecraft testing instead of being limited to one test phase. Further, the Test Team concept will provide the best test continuity and develop greater depth of knowledge of Spacecraft system performance since the Test Team is intimately associated with each Spacecraft through all system test phases.

Assignment of STC equipment to each spacecraft to move through all test phases assures OSE interface compatibility and provides the best

Table 7-9: TEST SETS

Test Facility	Fixed Test Station STC	Fixed Test Station LCE	Movable Test Station STC	Movable Test Station LCE
Engineering Test Model	1		1	
Proof Test Model	2		2	
Assembly Tests	3		3	
Flight Acceptance Tests				
Vibration	1			
Space Simulation	1			
Magnetic Mapping	1			
EMI	1			
Parameter Variation	1			
Simulated Propulsion	1			
Free Mode		1		1
Dummy Launch		1		1
AFETR Testing				
A&O	3			
Magnetic Mapping	1			
ESA		2		2
Launch	—	2	—	2
TOTAL	16	6	6	6

basis for performance trend analysis. Processing each Spacecraft through the same Test Station will better assure interchangeability. However, in the event of a spares replacement, it will be necessary to retest the Spacecraft to establish functional compatibility in either case.

Moving the STC equipment to each test facility will require recalibration and integrity checkout of the STC after setup at each new location. The fixed Test Station may require less comprehensive integrity checkout, since moving the STC can damage and/or degrade performance of the test equipment. The total number of times that the Spacecraft will be connected and disconnected to the STC is approximately the same for each of the Alternatives.

Assignment of a Test Team to perform all test phases on a Spacecraft will fix responsibility and assure best test confidence. Mating of Spacecraft and test equipment can result in tailoring the Spacecraft performance and obscuring system deficiencies; however, close coordination between Test Teams and correlation of test data will minimize this problem. Moving the Spacecraft and its test equipment to the various test facilities will require more time to install, checkout, and perform the testing than to move only the Spacecraft to a fixed Test Station which has been prepared in advance to receive the Spacecraft.

Table 7-10 summarizes the general evaluations of the several Test Station concepts. An "X" in the Alternative column indicates the best choice for each of the factors noted. Based on this brief

Table 7-10: TEST-STATION EVALUATIONS

Factor	Alternative		
	A	B	C
Quantity of Test Equipment			X
Number of Test Personnel		X	X
Learning Factors			X
Test Compatibility			X
Test Equipment Reliability	X	X	
Test Responsibility		X	X
Test Confidence			X
Test Flow Time	X	X	

discussion, Alternative C, the assignment of a Test Team and STC equipment to move with each Spacecraft through all test phases, is indicated as the best approach to meet the Spacecraft test program objective. Further iteration of the selected Test Station concept is necessary to develop the planning in depth and to minimize the inherent disadvantages.

7.6.1 Preferred Test Station Team Concept

The preferred Test Station Team concept is based on selection of the best approach derived from consideration of the alternate concepts discussed in paragraph 7.6. The concept selected is a hybrid which utilizes:

1) A fixed test complex and personnel for testing of parts, components and subsystems before they are installed in the spacecraft, and
2) A moving System Test Complex (STC) and test team to accompany each spacecraft through all system test phases from assembly to launch.

Figure 7-12 shows the movement of test teams and test equipment through the test phases.

The basic test team will include at least the following assignments:

Test Director

Science System Engineer

Flight Capsule Engineer

Guidance and Control System Engineer

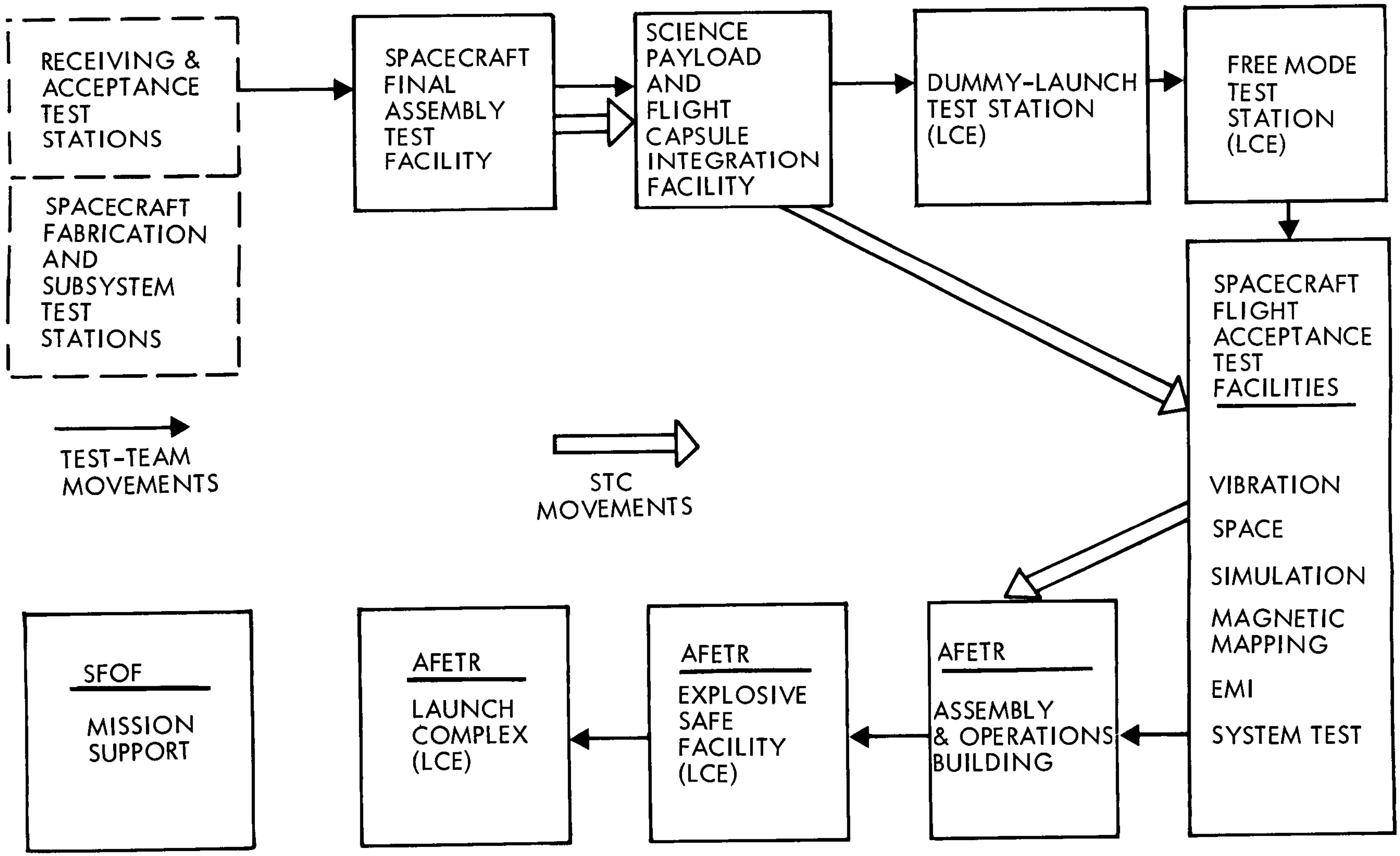


Figure 7-12: Test Station Plan

Telecommunication System Engineer

Mechanics and Propulsion System Engineer

Power System Engineer

Data Specialists

STC System Engineer

Lead Technician

Additional specialists will be available at each Test Facility to support the Test Team as required.

The heavy reliance on testing for reliability assurance and the use of trend data demand a well trained and disciplined test crew supplemented by:

1) Machine programmed stimuli measurement and data recording wherever possible.
2) Control of test variance through a carefully designed calibration/certification program.
3) Documented test procedures.
4) Formalized data recording for all manual operations.
5) Periodic audit of test operations.
6) Periodic retraining.

In developing the final Test Station Plan, it is the objective to meet the following criteria:

1) Require minimum test equipment.
2) Require smallest number of test specialists.

3) Provide maximum learning opportunity.

4) Establish and maintain test compatibility through all test phases.

5) Assure test responsibility and accountability.

6) Provide required test assurance and confidence of spacecraft performance.

7) Provide for continuity of test data.

8) Provide a highly disciplined test operation.

7.7 OSE CONCEPTS

Fulfillment of test program objectives requires the development of test equipment concepts and selection of criteria for a preferred design of OSE which will meet all requirements and remain within the constraints of cost, schedule, reliability and performance.

7.7.1 Requirements

OSE must:

1) Demonstrate the capability of all systems to meet all mission requirements.

2) Demonstrate the capability of the Spacecraft to meet the requirements of the mission profile, and all flight and ground handling environments.

3) Support flight acceptance testing at both Spacecraft subsystem and system levels.

4) Support Spacecraft interface testing with other system elements to establish and verify design compatibility.

5) Demonstrate compatibility of Spacecraft with the Launch Vehicle, MOS, Flight Capsule, and DSN.

7.7.2 Constraints

The major constraint in meeting test program objectives is time. In order to assure maximum data return and standardization of testing, OSE design must provide automatic programming and mechanized stimulation capability. The design must also provide manual override capability to support detail analysis of failures, design deficiencies, or interface incompatibilities.

The requirement for transportable OSE design is influenced by the requirements of schedules, test location, test flow, and the selected test station concept.

7.7.3 Reliability

Since one of the major contributing factors to reliability assurance is performance trend information, it is mandatory that all data be collected, and evaluated expeditiously and in a uniform format. This requires an automated data system having the capability to store, process, and recall data. Performance trend analysis is based upon quantitative performance; it is therefore essential that all data be in numerical form rather than simply establishing that a function is within limits. To obtain trend data it is also necessary to keep test variance an order of magnitude below the trend level. The required degree of repeatability would be difficult with manual testing due to human variance.

7.7.4 Performance

End-to-end testing of the spacecraft and exercising of its systems in a manner simulating flight conditions required to establish that all systems perform properly. Isolation of faults to a flight spares level requires OSE capability for inter- and intra-subsystem monitoring of all dependent and independent functions including supporting functions. Closed-loop testing provides the best capability for performance measurement and fault analysis. In order to verify integrity of OSE interfaces and to isolate subsystems within the spacecraft for performance testing and fault analysis, it is necessary to provide functional simulation of the interfacing subsystems.

7.7.5 Documentation

OSE designs must facilitate test program documentation. Data Summarizing to support reliability and test status must be obtainable with a minimum of processing.

7.7.6 Alternatives

The OSE requirements and constraints, when considered in the light of the unalterable Voyager launch opportunities, allows very little latitude in the choice of OSE. The alternatives of Table 7-11 have been evaluated to determine which best satisfies OSE objectives. In each case, the concept which is superior and would thus become a preferred OSE design criteria item is listed first:

Table 7-11: ALTERNATES EVALUATED

OSE FUNCTION	ALTERNATIVES	
Stimuli	Programmed/Automatic	Manual
Test Control	Programmed/Automatic	Manual
Configuration	Transportable OSE	Fixed OSE
Connection to Test Item	Combination RF & Hardline	Hardline
Data System	Automated	Forms/handwrite
Type of Measurements	Quantitative	Qualitative
Test Characteristics	Dynamic	Static
	Closed Loop	Open Loop
	End-to-End	Individual items

7.7.7 Preferred Concepts

The Voyager Spacecraft System OSE elements are defined and described in detail in Volume C and will not be further discussed here. The preferred concepts will be formalized as OSE design criteria and will govern the development of hardware items. These design criteria are summarized as follows:

1) Automation - The OSE at all test levels will be designed to be automatically sequenced. Manual override and single step control will permit troubleshooting and fault isolation to the part level in the Subsystem Test Equipment and to the Flight Acceptable Spares level in the System Test Complex.

2) Data Measurement - The OSE will be designed to display and record quantitative data at all levels of testing.

3) Transportability - The OSE design will permit transportation with the Spacecraft Systems of all OSE having critical interfaces with the Spacecraft Systems. The design will provide for movement and reassembly of OSE so as to minimize the time required for re-calibration, realignment and recertification.

4) Design Commonality - The OSE design will be such that identical functions are implemented by common designs for all levels of test.

5) Testability - The OSE design will include self check capability which in general will be accomplished by simulation.

6) Maintainability - The design commonality and self-check capability of the OSE will facilitate maintenance and reduce spares requirements.

7) Safety - The principles of equipment and personnel protection will be emphasized in OSE preliminary design. The major safety criterion is that the design must be such that an OSE malfunction or operator error will impose no performance degradation of a test article and no hazard to personnel.

7.8 TEST SCHEDULE DEVELOPMENT

Testing plays a major role in the Voyager Program. The scope of the test program, in terms of time, facilities, geographical factors and cost, creates critical interfaces with almost every program activity. As a result, the test schedule is central to the program schedule and demands attention early in the planning phase to assure first, feasibility of the program, and then availability of the necessary facilities, manpower, equipment and technology. This section will discuss schedule constraints, the application of Proof Test Models, the '71 mission schedule and test flows, and the impact of the '69 test launches on the '71 test schedule.

7.8.1 '71 Mission Schedule Constraints (W/O '69 Test)

The test schedule to support the '71 mission is constrained on the right by a fixed launch window and on the left by equipment availability for testing. The equipment availability constraint is eased by using prototype hardware for debugging and checking out subsystem, system, OSE, and MOS interfaces. A preliminary review of PTM usage indicates the need for two PTMs in order to support all the requirements for interfact tests, design verification, mission simulation and system life tests. The schedule is also sensitive but not critical with respect to STC setup and calibration time for the moving test complex mode of operation.

7.8.2 '71 Proof Test Models

The primary purpose of the two proof test models is to verify the adequacy of the spacecraft design; secondary benefits will include training and verification of procedures and testing which will be used on flight spacecraft.

The proof test flow is planned to be as much like the acceptance cycle as possible. The test approach considers the need for testing a spacecraft identical to the flight article, the priority of the data (design verification comes first), and the ease of obtaining the data. As an example, although space simulation has historically disclosed more defects than vibration testing, space simulation is time consuming and has been planned following vibration. Miscellaneous tests, judged less likely to produce requirements for significant changes have been deferred until the latter part of the flow. A significant portion of the tests of the proof test models will be directed to measuring the environments seen by the subsystems when installed in the spacecraft. A comparison can then be made with the design and subsystem qualification environment to provide confidence in the results. In some cases, it may be necessary to change the design of the subsystem or its installation to achieve the required confidence.

7.8.2.1 1971 PTM #1 Test Flow

Table 7-12 details the test flow for PTM #1. This model will undergo testing intended to verify the capability of the hardware to perform its mission under both nominal and extreme environments. At the completion of this testing, this model will be used to demonstrate compatibility with the DSIF at Goldstone, and later to prove compatibility with the facilities, equipment, and launch vehicles at ETR.

7.8.2.2 1971 PTM #2 Test Flow

Tables 7-13 and 7-14 detail the flow of PTM #2. The second proof test model will be subjected to a total of 5000 hours of testing composed of a FAT identical to the FAT for flight spacecraft, three 30-day space chamber tests, and approximately nine months of accelerated mission simulations and system reference tests. Each space chamber test will

Table 7-12: 1971 PTM #1 TEST FLOW

	Weeks
Subsystem Assy & Power Off Test	6
STC - Spacecraft Ground Integrity Test	2
Power Applications	1
Subsystem Tests	2
Inter-Subsystem Tests	2
Telecommunication Calibration	1
Science Subsystem Calibration	1
Systems Test	3
Parameter Variations Tests	2
System Reference Tests	1
S/C Capsule Compatibility Tests	3
Magnetic Mapping	2
Midcourse Interaction Tests	3
Retro Interaction Tests	3
Pyrotechnic Shock Test	2
Vibration Tests (FAT & TAT)	4
Magnetic Mapping (After Vibration)	1
Space Simulation	12
Free Mode Test	1
S/C - Centaur Compatibility	1
EMI	3
Weight & Balance	1/2
S/C - LCE	2
Simulated Countdown	1
Special Tests	3
System Reference Tests	2
Cleanup, Buy-off, Prepare to Ship	2
TOTAL	66-½ Wks.
Schedule Contingency	4
Arrive Goldstone, Inspect, Set-up STC, System Reference Test	3
S/C - DSN Compatibility Test	4
System Reference Test	1
Pack & Ship (Air Ship)	1/2
Goldstone	12-½ Wks.
Arrive ETR, Inspect, Set-up STC, System	3
Reference Test	3
Pad #1 Compatibility Tests	5
Pad #2 Compatibility Tests	5
ETR	16 Wks.

Table 7-13: 1971 PTM #2 TEST FLOW

	Weeks
Subsystem Assy. & Power Off Test	6
STC - S/C Ground Integrity Test	2
Power Applications	1
Subsystem Tests	2
Inter-Subsystem Tests	2
Science Subsystem Calibration	1
Telecommunication Calibration	1
System Test	3
Parameter Variation Tests	2
System Reference Test	1
S/C Capsule Compatibility Tests	1
Magnetic Mapping (2 modes)	2
Vibration Test (FAT only)	2
Magnetic Map & Deperm. after Vibration	1
Space Simulation	4
Free Mode Test	1
EMI	2
S/C - Centaur Compatibility	1/2
S/C - LCE	1
Simulated Countdown	1
Weight & Balance	1/2
System Reference Test	1
Clean-up, Buy-off, prepare for Mission Sym.	2
TOTAL	40 Weeks

Table 7-14: 1971 PTM #2 DESIGN VERIFICATION & MISSION SIMULATION

Test	
(1) Space Simulation Tests	
30 day space vacuum and solar simulation test (720 hrs.)	
5 day pretest setup and checkout	
7 day system reference test	
TOTAL 6 Weeks	
(2) Earth Ambient Mission Simulation	
Part 1 - Prelaunch through midcourse correction	(1 day)
Part 2 - Midcourse correction, cruise, capsule separation, flight S/C cruise, Mars orbit insertion data acquisition and transmittal	(2 days)
Part 3 - Repeat Part 2 using alternate operational modes	(2 days)
Part 4 - Repeat Part 2 - Free Mode except batteries replenished from external power	(2 days)
Part 5 - Systems Reference Test	(5 days)
TOTAL 12 days	
Approximately 20 cycles of test (2) with test (1) repeated three times will be performed as a life demonstration of the Voyager design.	

require continuous, 24-hour per day, operation throughout the test period. The mission simulation and system reference tests are scheduled for a three-shift, seven day week operation with actual testing normally being confined to the "first shift" period of each day and the other two shifts being used for operating time maintenance and contingencies.

7.8.3 '71 Mission Schedule (W/O '69 Test)

Table 7-15 is a test flow for the '71 flight spacecraft. The schedule for the test and flight vehicles is shown on Figure 7-13, "Integrated Test Program Schedule." This testing is scheduled to include some slack time to assure meeting the launch window in the event of contingencies.

7.8.4 '71 Test Schedule With '69 Test Flight

The integration of '69 test flights into the total '71 mission test program requires some compression of the development testing period. This is offset by the early availability of full scale flight test data.

The '69 test flights provide real mission environment for qualifying '71 mission hardware, OSE, and MOS on a time scale that is competitive with ground testing in terms of supporting the '71 mission. On the other hand, they create additional schedule constraints. Our review of schedule factors shows that the STC setup and calibration time will become a critical factor. This problem will be solved by designing for transportability or mobility so that the integrity of the test system may be quickly re-established after each move.

Table 7-15: Figure 7.4.5.3-4:
'71 FLIGHT SPACECRAFT TEST FLOW

	Weeks
System Assy. & Power off Test	6
STC - S/C Ground Integrity Test	2
Power Applications	1
Subsystem Tests	2
Inter-Subsystem Tests	2
Science Subsystem Calibrations	1
Telecommunication Calibrations	1
System Test	3
Parameter Variation Tests	1
System Reference Test	1
S/C Capsule Compatibility Tests	1
Magnetic Mapping (2 modes)	2
Vibration Tests	2
Magnetic Mapping & Deperm. After Vib.	1
Space Simulations	4
Free Mode Test	1
EMI	2
S/C - Centaur Compatability	1 1/2
S/C - LCE	1
Simulated Countdown	1
Weight & Balance	1/2
System Reference Test	1
Clean-up, Buy-off, prepare for shipping	2
	40
TOTAL = 40 weeks = 9-1/2 mo.	

1971 S

	1966	1967
I. DEVELOPMENT TESTS	DEVELOPMENT FREEZE	
SUBSYSTEMS DESIGN CRITERIA DEVELOPMENT & VERIFICATION	BREADBOARD TESTS; ENGINEERING MODEL TESTS	
STRUCTURAL TEST MODEL GT-1		FAB; TES
THERMAL TEST MODEL GT-2		FAB
DYNAMIC TEST MODEL GT-3		FAB
ENGINEERING MODEL GT-4		FAB; ASSY & TEST
II. TYPE APPROVAL TESTS (TAT		
SUBSYSTEMS		TAT
PROOF TEST MODEL 1971 NO. 1		
PROOF TEST MODEL 1971 NO. 2		
* JPL TEST SPACECRAFT		
III. FLIGHT ACCEPTANCE TESTS (FAT)		
FLIGHT SPACECRAFT (SPARE) (1971)		
FLIGHT SPACECRAFT NO. 1 (1971)		
FLIGHT SPACECRAFT NO. 2 (1971)		

*Per Specimen Statement of Work — Phase

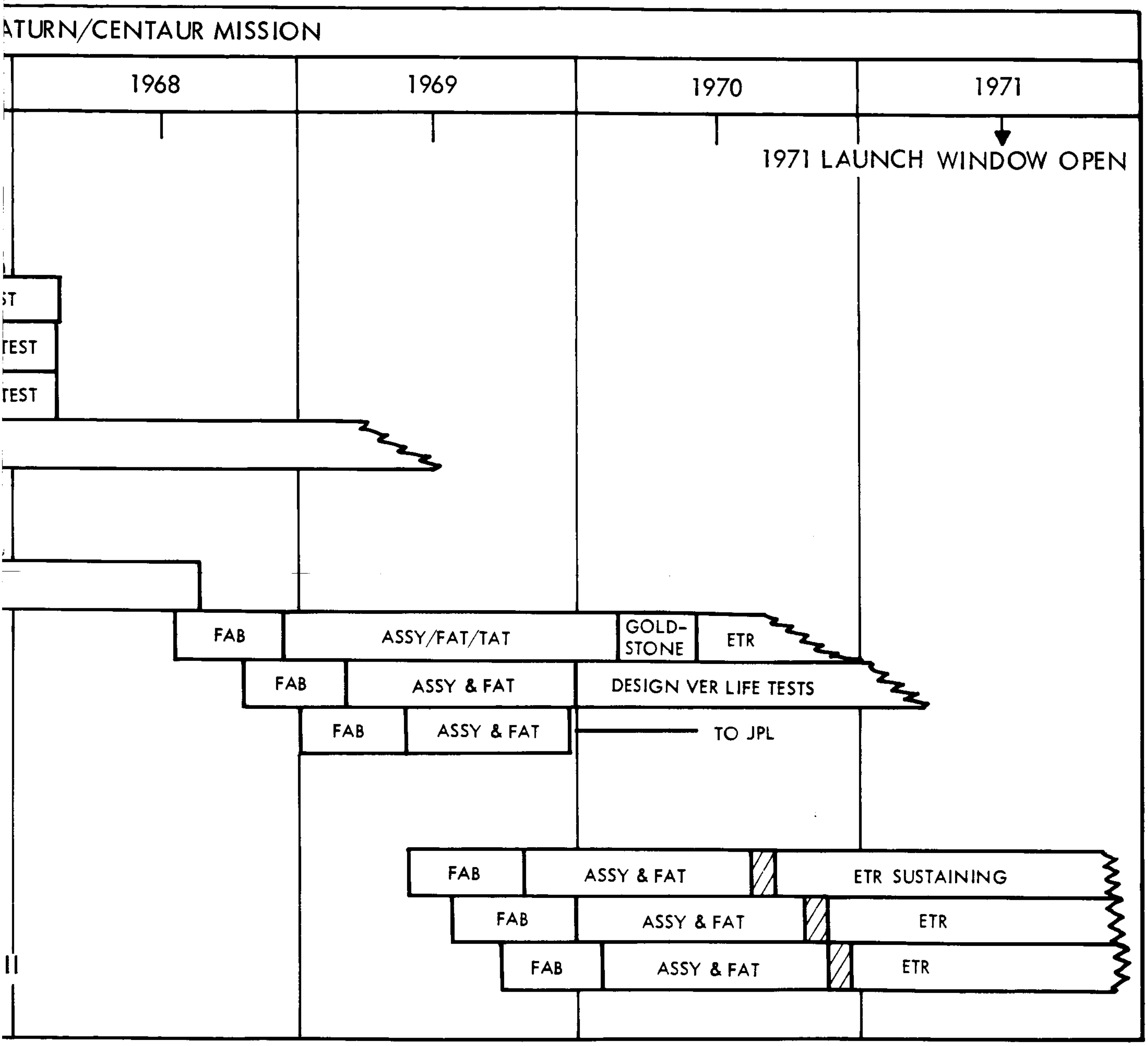


Figure 7-13: Integrated Test Program Schedule

2

It is essential to sustaining the validity of the '69 launches as qualification tests for '71, that the configuration of the '69 S/C be substantially identical to the '71 S/C. This means either bringing the S/C design to a firm configuration earlier than would be required by the '71 launches, shortening the test cycle, or some of both. The integrated '69 test - '71 mission schedule was developed using the latter approach. Inasmuch as the '69 launches are test shots, it is logical to require a lesser degree of test assurance before launch than is required for the mission. It is, however, necessary to complete sufficient testing to assure an adequate probability of success as well as a degree of design maturity that will minimize the probability of significant changes between '69 flight hardware and '71 flight hardware.

This assurance will be obtained through comprehensive testing on the 1969 Proof Test and Compatibility Test Models in addition to flight acceptance testing (FAT) of the flight spacecraft. The Proof Test Model will be the first 1969 flight configuration system to be tested and will undergo a combined FAT/TAT program of sufficient scope to demonstrate adequacy of the system design for its test flight. Levels of testing on the PTM will be limited, however, such that its capability to serve as a spare flight spacecraft will not be compromised. The Compatibility Test Model will undergo ambient system level FAT including EMI, launch countdown simulations and other special tests pertinent to both the Goldstone and ETR compatibility tests. Space simulation, vibration and other tests not critical to the compatibility tests will not be conducted due to schedule restrictions. The Flight Spacecraft will undergo complete FAT, both ambient and environmental, prior to delivery to ETR.

7.8.4.1 '71 Test Schedule with Saturn/Centaur '69 Test Flight

Figure 7-14 shows a representative integrated test schedule for a 1971 mission with a 1969 Saturn/Centaur Test Flight and Tables 7-16, 7-17, and 7-18 outline the specific tests to be accomplished on the 1969 PTM, Compatibility Model and Flight Spacecraft, respectively. Salient features of this integrated test schedule are:

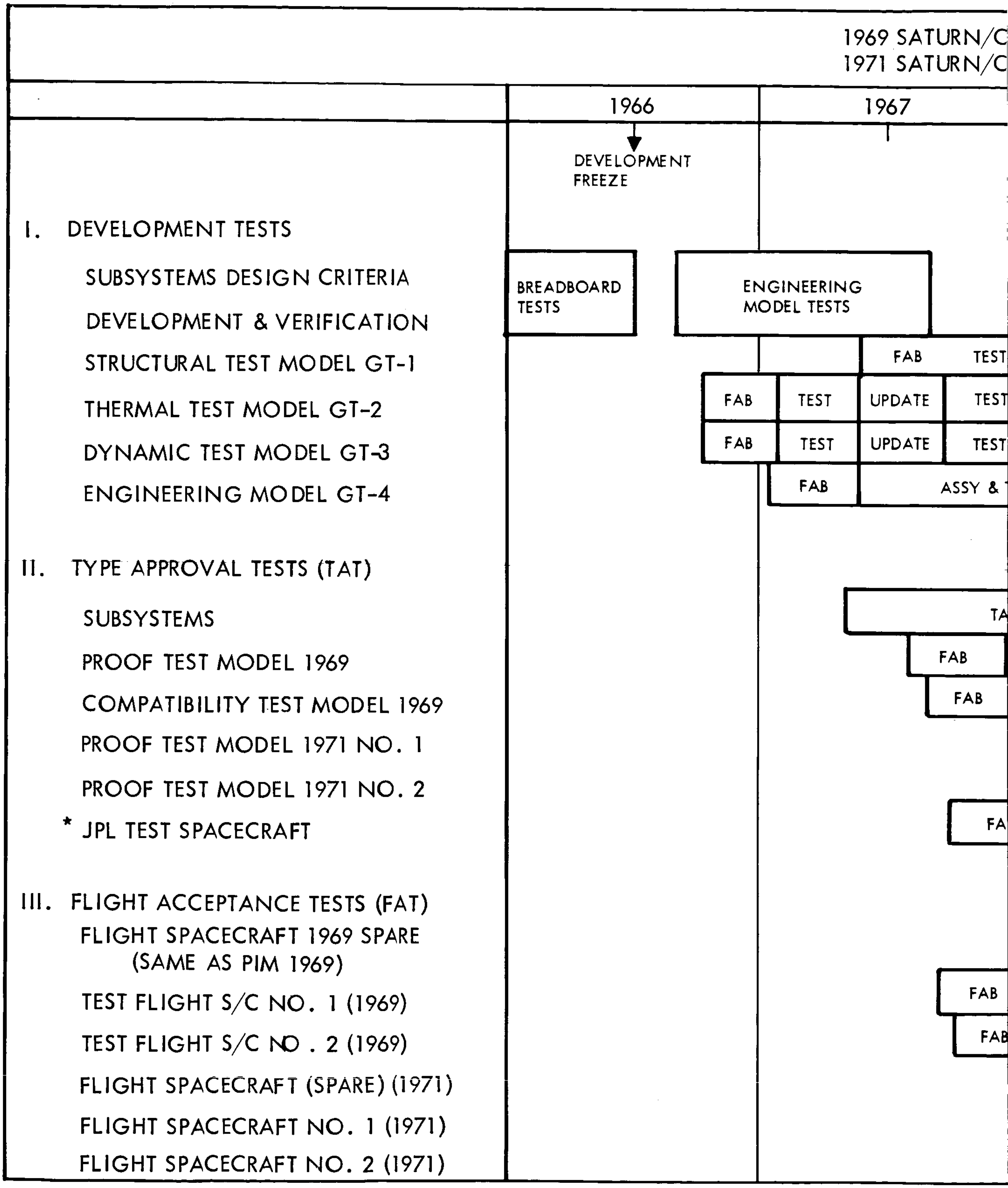
1) Early initiation of subsystem level engineering model testing such that an engineering model spacecraft is available for test seven months prior to start of the '69 PTM testing. This will allow initial design compatibility tests between subsystems to precede the PTM assembly and testing.

2) While type approval tests at the subsystem level will not be completed prior to start of PTM testing, any mandatory changes identified during subsystem TAT can be incorporated during system level testing.

3) Time is available in the 1971 PTM #2 test program to incorporate design changes brought about as a result of the 1969 test flight.

4) A capability exists to upgrade the 1969 compatibility model to the 1971 Proof Test Model #2 assuming no major configuration changes between models.

5) A potential reassignment of 1971 PTM #2 to a 1971 Flight Spacecraft exists if a successful 1969 test flight satisfies the design verification life test requirement.



*Per Specimen Statement of Work Phase II

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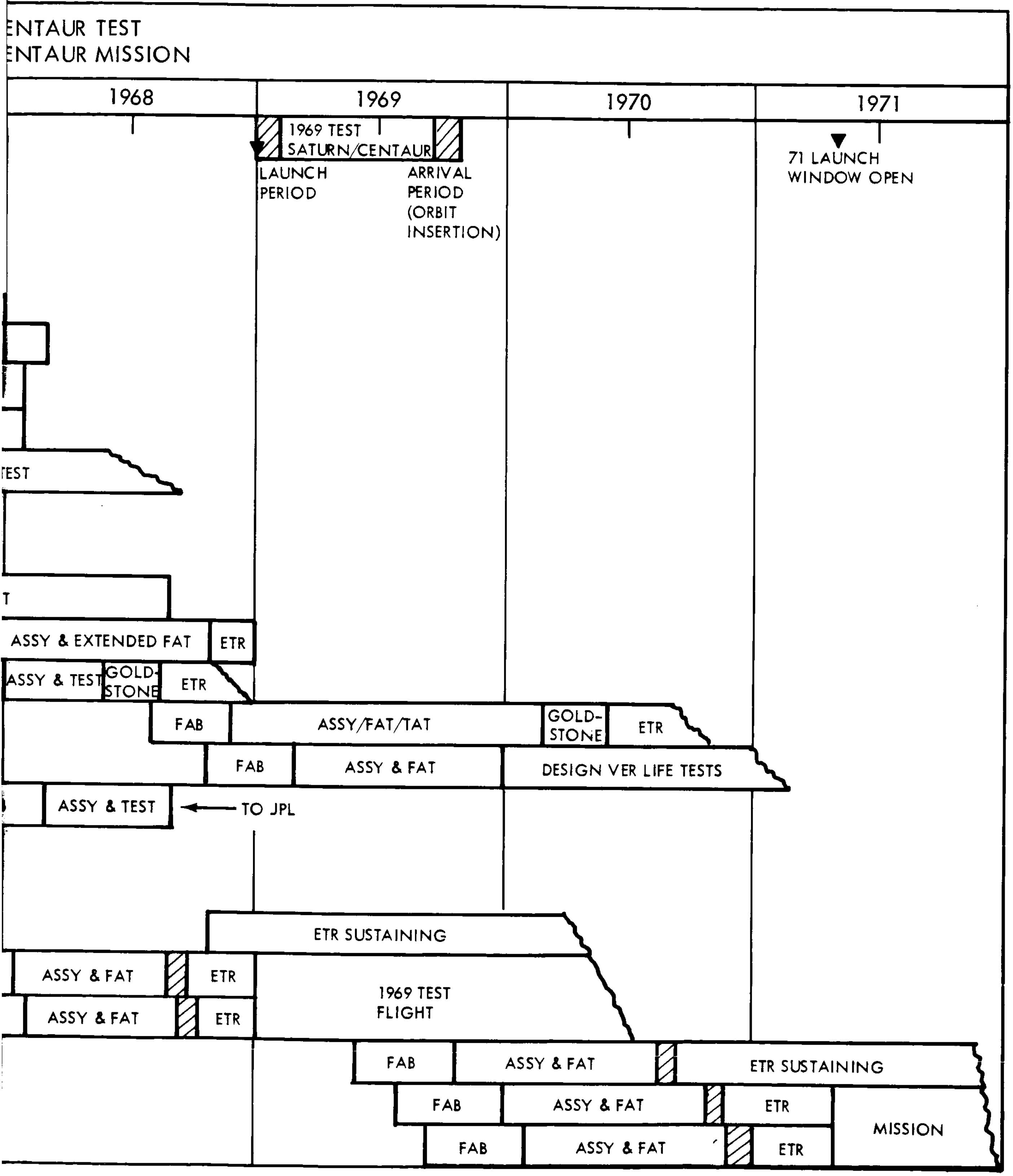


Figure 7-14: Integrated Test Program Schedule

2

Table 7-16: 1969 PTM/SPARE TEST FLOW

		Weeks
Subsystem Assy. & Power Off Test		4
STC - S/C Ground Integrity Test		2
Power Applications		1/2
Subsystems Tests		1-1/2
Inter-Subsystem Tests		1
Telecommunications Calibrations		1
Systems Test		3
Parameter Variations Tests		1
System Reference Test		1
	SUB-TOTAL	15 weeks
Simulated Midcourse Interaction Tests		2
Vibration Tests		3
Space Simulation		7
Free Mode Test		1/2
S/C - Centaur Compatibility		1
EMI		2
Dummy Capsule Interface Test		1
Weight and Balance		1/2
S/C - LCE		1
Simulated Countdown		1/2
Special Tests		2
Spares Burn In		4
System Reference Test		1
Clean-up, Buy-off, prepare to ship		2
	SUB-TOTAL	27-1/2 Weeks
TOTAL = 43-1/2 weeks		

Table 7-17: 1969 COMPATABILITY MODEL

		Weeks
Subsystem Assy. & Power Off Test		4
STC-S/C Ground Integrity Test		2
Power Applications		1/2
Subsystem Tests		1
Inter-subsystem Tests		1
Telecommunications Calibrations		1
Subsystem Test		3
EMI Tests		2
Dummy Capsule Interface Test		1
Simulated Countdown		1/2
System Reference Test		1
Clean-up, Buy-off, Ship (Air ship)		2
	Seattle	9-1/2 Weeks
Arrive Goldstone, Inspect, Set-up STC, System Reference Test		3
S/C - DSN Compatibility Test		4
System Reference Test		1
Pack & Ship (Sir ship)		1/2
	Goldstone	8-1/2 Weeks
Arrive ETR, Inspect, Set-up STC, System Reference Test		3
Pad #1 Compatibility Tests		5
Pad #2 Compatibility Tests		5
	ETR	13 Weeks
TOTAL 41 weeks		

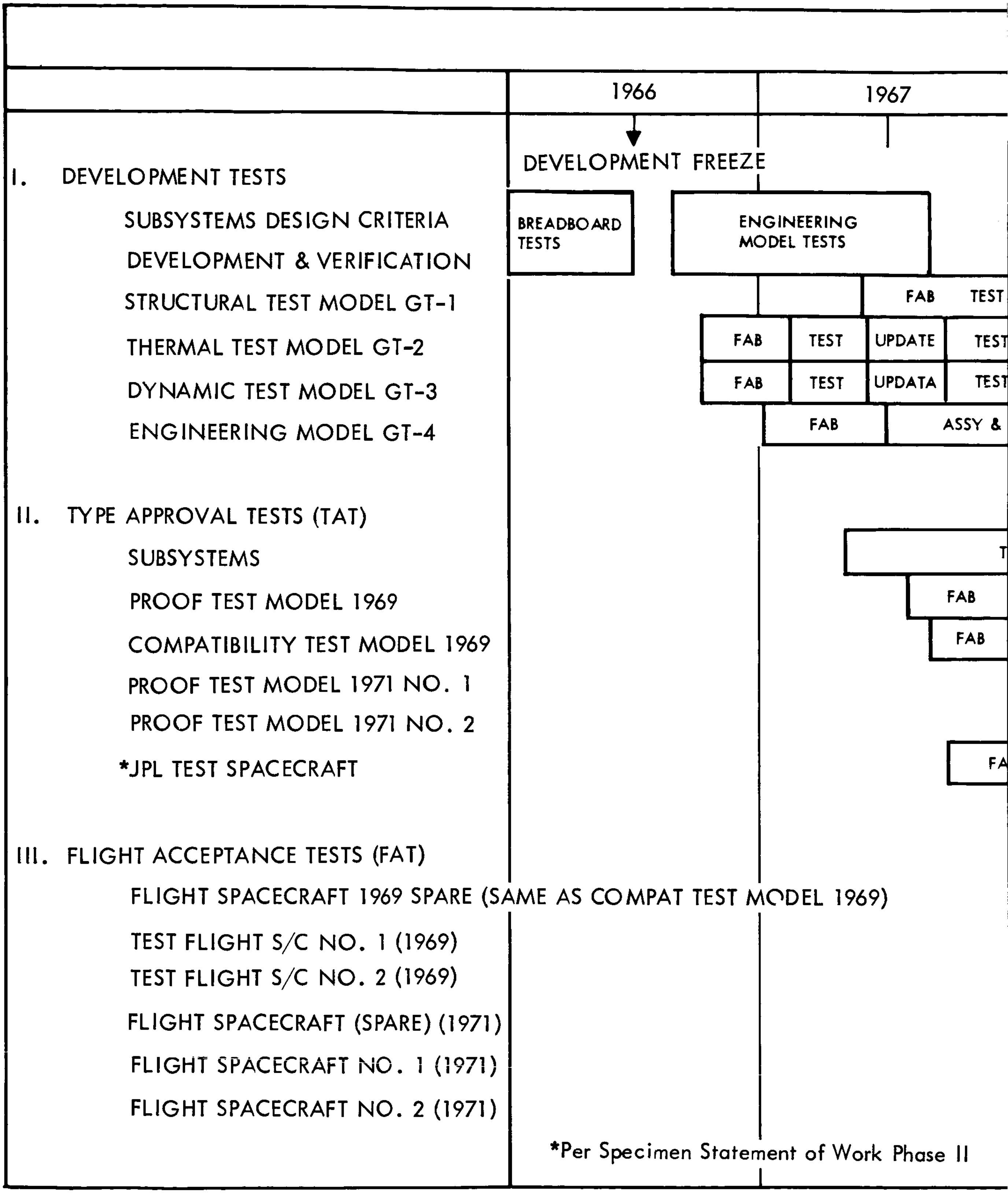
Table 7-18: 1969 FLIGHT SPACECRAFT TEST FLOW

		Weeks
Subsystem Assy. & Power Off Test		4
STC - S/C Ground Integrity Test		2
Power Applications		1/2
Subsystem Tests		1-1/2
Inter-Subsystem Tests		1
Parameter Variations Tests		1
Subsystems Reference Tests		1
	SUB TOTAL	15
Vibration Tests		2
Space Simulation		4
Free Mode Test		1/2
Weight & Balance		1/2
Simulated Countdown		1/2
Special Tests		2
Systems Reference Test		1
Clean-up, Buy-off, Ship (Air ship)		2
	SUB TOTAL	12 1/2
Total Seattle - 27-1/2 weeks		
Arrive ETR, Inspect, Set-up STC, System Reference Test		3
Shroud & Booster Mate		3
Simulated Countdown		1
Weight & Balance		1/2
Fuel and Arm		1
Final Pad Assy & Prelaunch checks		4
	TOTAL ETR	12-1/2 Weeks

7.8.4.2 '71 Test Schedule With Atlas/Centaur '69 Test Flight

Figure 7-15 shows the test schedule if Atlas/Centaur is used for the '69 flight. The later launch window provides approximately 2-1/2 months more test time. The absence of a dummy capsule and associated interface tests provides additional schedule relief. This additional time is sufficient to allow a full FAT on the compatibility test model, thereby making it usable as a flight spare. This in turn will permit the proof test model to be tested to full TAT levels and will provide added assurance for the flight articles.

The test schedule is otherwise essentially the same as the schedule for the '69 test with the Saturn/Centaur.


1966
1967
DEVELOPMENT FREEZE
I. DEVELOPMENT TESTS
SUBSYSTEMS DESIGN CRITERIA
DEVELOPMENT & VERIFICATION
BREADBOARD TESTS
ENGINEERING MODEL TESTS
STRUCTURAL TEST MODEL GT-1
FAB
TEST
THERMAL TEST MODEL GT-2
FAB
TEST
UPDATE
TEST
DYNAMIC TEST MODEL GT-3
FAB
TEST
UPDATA
TEST
ENGINEERING MODEL GT-4
FAB
ASSY &
II. TYPE APPROVAL TESTS (TAT)
SUBSYSTEMS
PROOF TEST MODEL 1969
FAB
COMPATIBILITY TEST MODEL 1969
FAB
PROOF TEST MODEL 1971 NO. 1
PROOF TEST MODEL 1971 NO. 2
*JPL TEST SPACECRAFT
III. FLIGHT ACCEPTANCE TESTS (FAT)
FLIGHT SPACECRAFT 1969 SPARE (SAME AS COMPAT TEST MODEL 1969)
TEST FLIGHT S/C NO. 1 (1969)
TEST FLIGHT S/C NO. 2 (1969)
FLIGHT SPACECRAFT (SPARE) (1971)
FLIGHT SPACECRAFT NO. 1 (1971)
FLIGHT SPACECRAFT NO. 2 (1971)
*Per Specimen Statement of Work Phase II

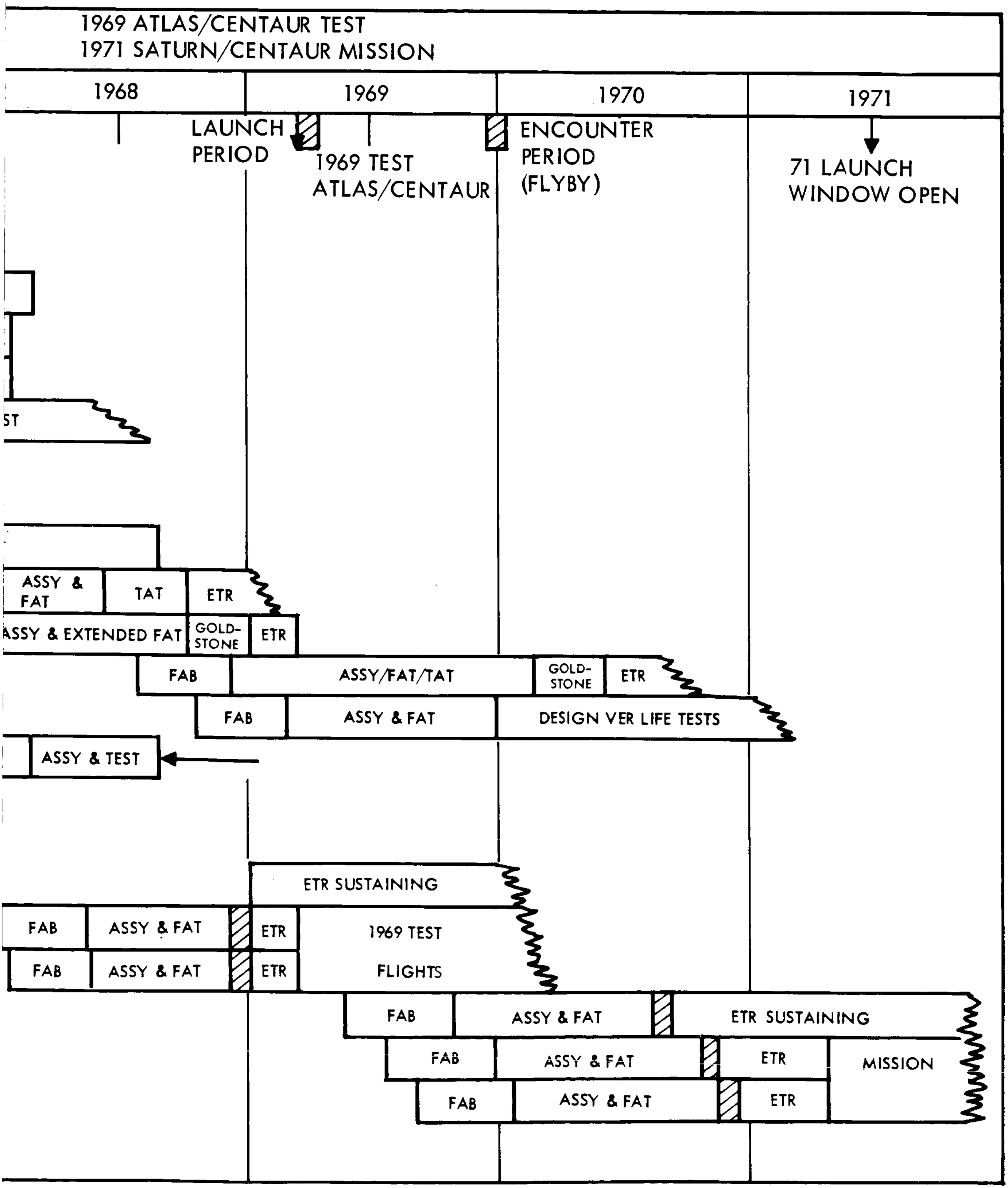


Figure 7-15: Integrated Test Program Schedule

2

ERRATA - VOLUME A

Page No.	Paragraph, Table, or Figure No.	
		Part III
17	Summary	See Part I - same deletion and addition
5-11	Fig. 5.4.1	Revise figure per following data: Facilities line: Change "BOD-Dynamic Test Facitity" from 5/1/69 to 3/15/68 Change "BOD Magnetic Mapping Facility" From 4/1/37 to 3/15/68 Change "Goldstone Facitity BOD" from 12/15/68 to 12/15/69 Change "BOD AFETR Test Facility" from 6/1/69 to 3/15/70
5-15	5.4-2	Revise figure per following data: Facilities line: Change "BOD-Dynamic Test Facility" from 1/1/68 to 4/15/67
5-17	5.4.5	Change page designation from 5-17 to "5-19".
5-19	5.4.4.1	Change page designation from 5-19 to "5-17."
5-21	Fig. 5.4-3	Revise figure per following data: Facilities line: Change "BOD-Dynamic Test Facility" from 11/1/67 to "2/15/67"
5-33	Para. 5.5.4.3	Delete "Autonetics" twice
7-55	Table 7-12	Delete: "Weeks"column Add: Following "Weeks" column (Insert Nos. Verticall "5,2,1,2,2,1,1,2,1,1,2,1,2,1,1,3,1, 10,1,1,1,1/2,1,1,1,1,2,48-1/2 weeks"
7-56	Table 7-13	Delete: "Weeks" column Add: Following "weeks" column (Insert Nos. vertical) 5,2,1,2,1,1,1,2,1,1,1/2,1,2,1,4,1, 1/2,1/2,1,1/2,1,30 weeks. Delete "EMI " delete line "clean-up Buy off....."
7-65	Fig. 7-14	Replace with revision
7-71	Fig. 7-15	Replace with revision.

Table 2-1: GUIDANCE AND CONTROL DESIGN CHARACTERISTICS AND RESTRAINTS

	Attitude Control	Velocity Control
Initial Acquisition	. Damp initial rates of 3 degrees/second . Acquire Sun in 1.5 hours . Acquire Canopus before first midcourse	None
Cruise	. Maintain stable base for antenna (±0.4°) with reference to Sun and Canopus	None
Course correction (midcourse orbit insertion, and orbit trim)	. Point course correction velocity vector to within ±10 MR (1σ) of desired direction. . Attitude for thrusting must allow antenna to point at Earth. . Return to celestial references without a search sequence.	Midcourse: Proportional error < 1% (1σ) Nonproportional error < 0.1 m/sec (3) Minimum ΔV < 1 m/sec Orbit Insertion: (Assumed same as midcourse except nonproportional error < 5 m/sec) Orbit Trim: (Assumed same as midcourse)
Capsule Separation	. Assume capsule separation attitude within ±1°. . Attitude for separation must allow antenna to point at Earth. . Damp disturbance caused by separation. . Return to celestial references.	None
Mars Orbit	. Maintain stable base for antenna (±0.2°) . Maintain stable base for science experiments (rates < 0.01 o/s)	None
Occultation	. Maintain attitude during Sun and Canopus occultations such that reacquisition does not require search sequence.	None

1969 SATURN
1971 SATURN

	1966	1967

DEVELOPMENT FREEZE

I. DEVELOPMENT TESTS

SUBSYSTEMS DESIGN CRITERIA DEVELOPMENT & VERIFICATION — BREADBOARD TESTS — ENGINEERING MODEL TESTS

STRUCTURAL TEST MODEL GT-1 — FAS

THERMAL TEST MODEL GT-2 — 1969 FAB TEST — 1971

DYNAMIC TEST MODEL GT-3 — FAB TEST

ENGINEERING MODEL GT-4 — FAB

II. TYPE APPROVAL TESTS (TAT)

SUBSYSTEMS

PROOF TEST MODEL 1969

COMPATIBILITY TEST MODEL 1969

PROOF TEST MODEL 1971 NO. 1

PROOF TEST MODEL 1971 NO. 2

* JPL TEST SPACECRAFT

III. FLIGHT ACCEPTANCE TESTS (FAT)

FLIGHT SPACECRAFT 1969 SPARE (SAME AS PTM 1969)

TEST FLIGHT S/C NO. 1 (1969)

TEST FLIGHT S/C NO. 2 (1969)

FLIGHT SPACECRAFT (SPARE) (1971)

FLIGHT SPACECRAFT NO. 1 (1971)

FLIGHT SPACECRAFT NO. 2 (1971)

*Per Specimen Statement of Work Phase II

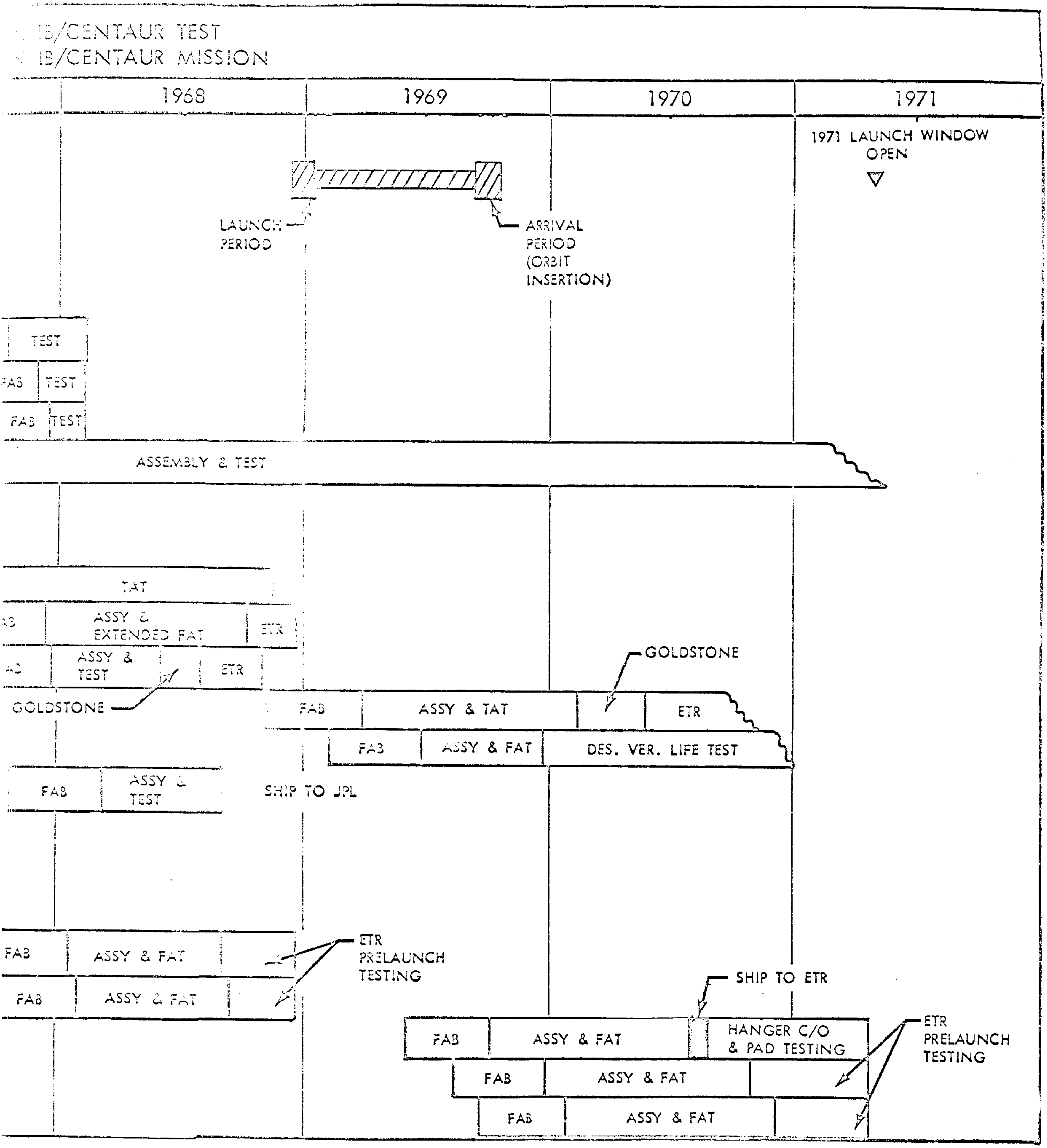


Figure 7-14: Integrated Test Program Schedule

	1966	1967
I. DEVELOPMENT TESTS	∇ DEVELOPMENT FREEZE	
SUBSYSTEMS DESIGN CRITERIA DEVELOPMENT & VERIFICATION	BREAD-BOARD TESTS	ENGINEERING MODEL TESTS
STRUCTURAL TEST MODEL GT-1		FAB
THERMAL TEST MODEL GT-2	1969	FAB TEST
DYNAMIC TEST MODEL GT-3		FAB TEST
ENGINEERING MODEL GT-4		FAB
II. TYPE APPROVAL TESTS (TAT)		
SUBSYSTEMS		
PROOF TEST MODEL 1969		
COMPATIBILITY TEST MODEL 1969		
PROOF TEST MODEL 1971 NO. 1		
PROOF TEST MODEL 1971 NO. 2		
*JPL TEST SPACECRAFT		
III. FLIGHT ACCEPTANCE TESTS (FAT)		
FLIGHT SPACECRAFT 1969 SPARE (SAME AS COMPAT TEST MODEL 1969)		
TEST FLIGHT S/C NO. 1 (1969)		
TEST FLIGHT S/C NO. 2 (1969)		
FLIGHT SPACECRAFT (SPARE) (1971)		
FLIGHT SPACECRAFT NO. 1 (1971)		
FLIGHT SPACECRAFT NO. 2 (1971)		

* Per Specimen Statement of

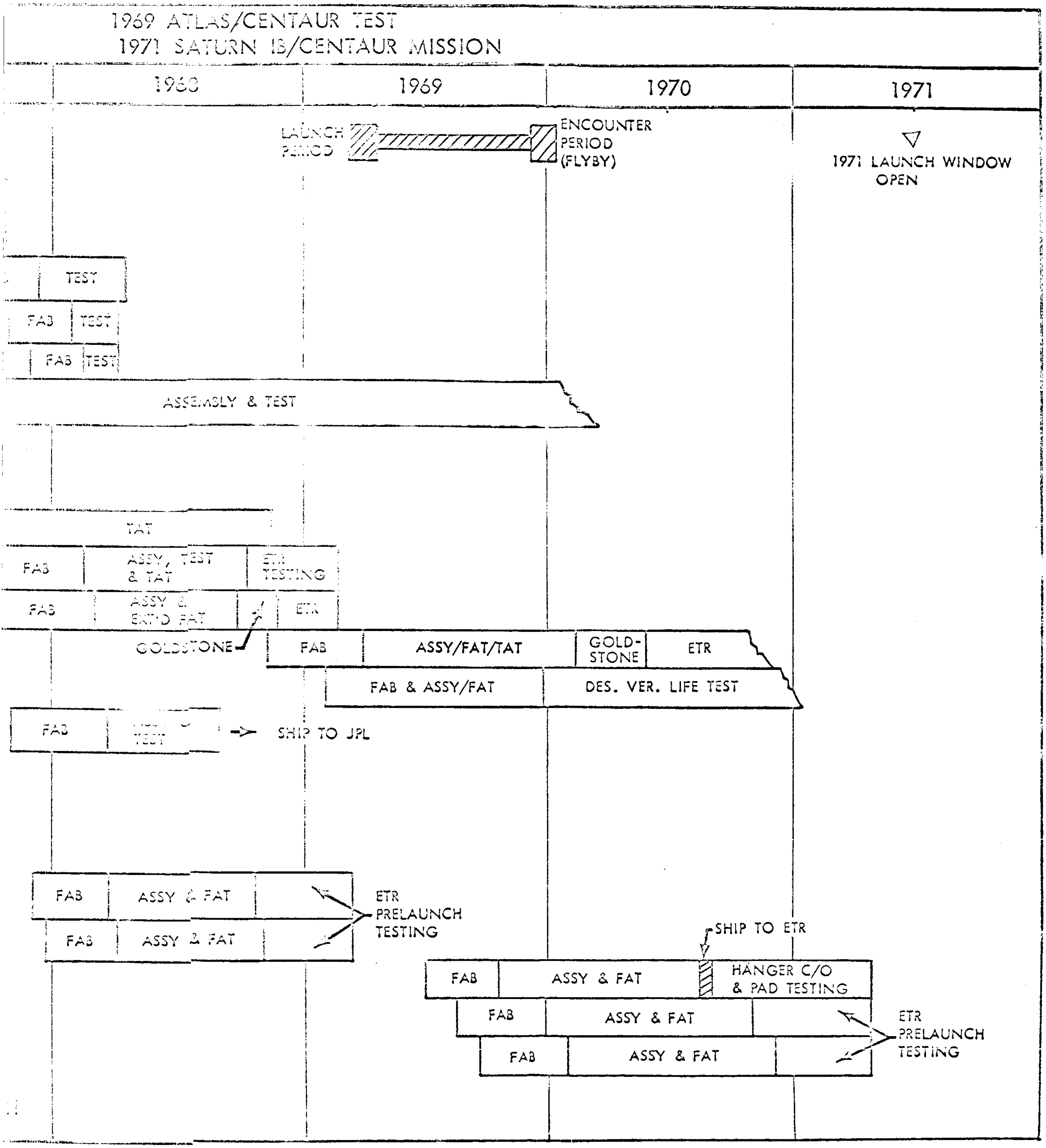


Figure 7-15: Integrated Test Program Schedule

JET PROPULSION LABORATORY

MAJOR PROGRAM INTERFACES

BOEING

MISSION ENGINEERING

SYSTEM ENGINEERING

PLANETARY QUARANTINE

PRODUCT ASSURANCE (P/A)

SYSTEM CONFIGURATION & DESIGN

SUBSYSTEM DESIGN

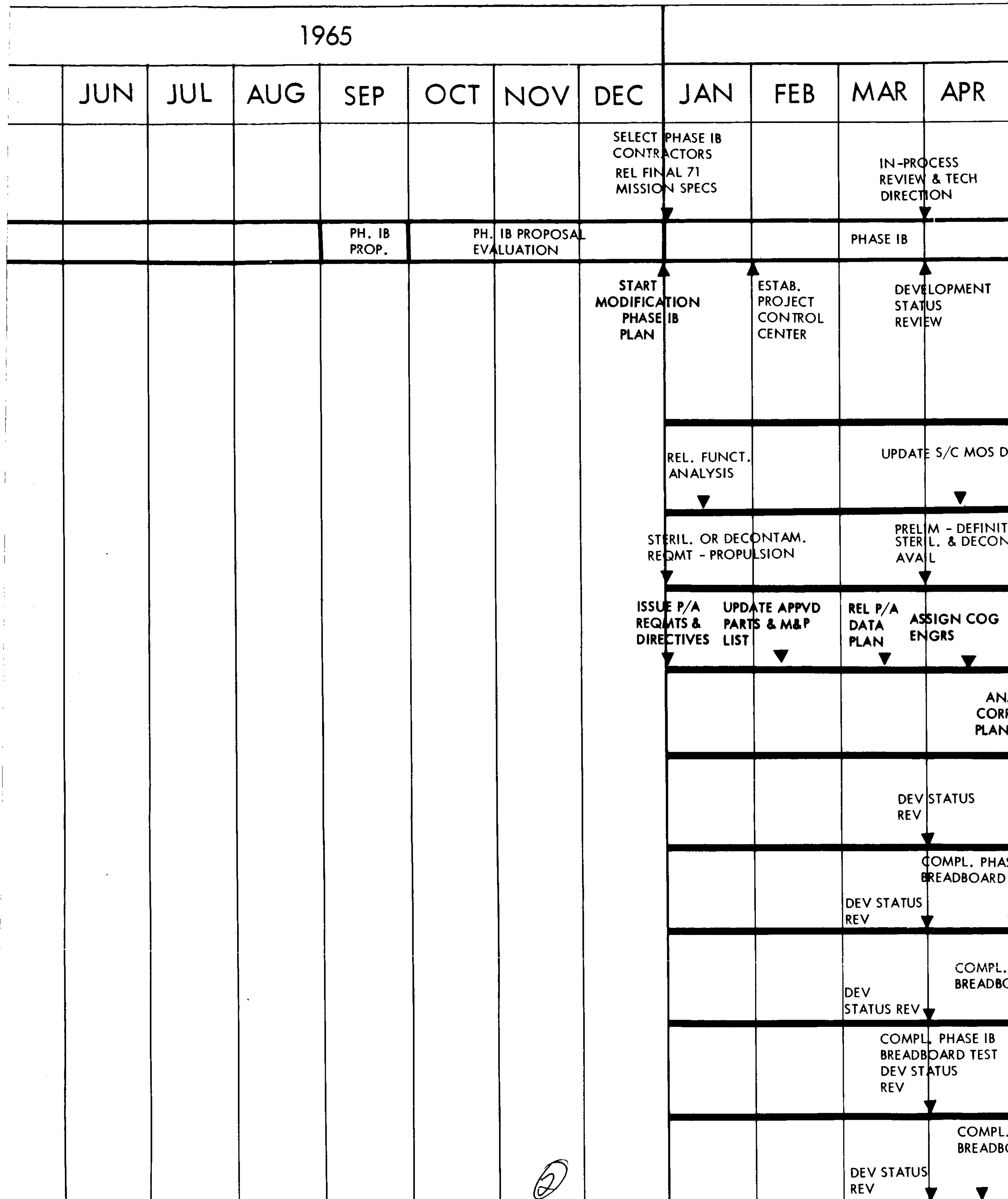
TELECOMMUNICATIONS

ATTITUDE REFERENCE

AUTOPILOT

REACTION CONTROL

CENTRAL COMPUTER & SEQUENCER (1)


1965
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
SELECT PHASE IB CONTRACTORS
REL FINAL 71 MISSION SPECS
IN-PROCESS REVIEW & TECH DIRECTION
PH. IB PROP.
PH. IB PROPOSAL EVALUATION
PHASE IB
START MODIFICATION PHASE IB PLAN
ESTAB. PROJECT CONTROL CENTER
DEVELOPMENT STATUS REVIEW
REL. FUNCT. ANALYSIS
UPDATE S/C MOS D
STERIL. OR DECONTAM. REQMT - PROPULSION
PRELIM - DEFINIT
STERIL. & DECON
AVAIL
ISSUE P/A REQMTS & DIRECTIVES
UPDATE APPVD PARTS & M&P LIST
REL P/A DATA PLAN
ASSIGN COG ENGRS
AN
CORR
PLAN
DEV STATUS REV
COMPL. PHAS
BREADBOARD
DEV STATUS REV
COMPL.
BREADBO
DEV STATUS REV
COMPL. PHASE IB BREADBOARD TEST DEV STATUS REV
COMPL.
BREADBO
DEV STATUS REV

1966

MAY	JUN	JUL	AUG	SEP	OCT

IN PROCESS REVIEW & TECH DIR.

AWARD PHASE II CONTRACT

APPROVE INTEGRATED TEST PLAN

DEVELOP FREEZE

SUBMIT FUNCT. & DESIGN SPECS.

ASSIGN MISSION ENGR PANEL PERSONNEL

N INTERFACE ANAL

FINAL REL PHASE IB DOCUMENTATION

START SYST. ANAL '69 & '71

PROVIDE F
69 TEST FL
REQMTS &
S/C - L/V

ON
AM

APPROVE DSGN SPECS

UPDATE REL & SAF ANALYSIS

IMPL PHASE II R&S PLANS

ESTAB P/A DATA CENTRAL

LYSIS &
CTIVE ACTION
COMPLETE

COMPL. PDR

COMPL SUBSYS FUNCT. SPEC REL

BREAD BOARD DSGN DEV & TEST COMPL.

69-71 FUNCT. SPEC REL & COMPL PDR

COMPL. PHASE IB BREADBOARD TEST

IB
EST

69 FUNCT. SPEC REL COMPL PDR

PHASE IB
RD TEST

71 & 69 FUNCT SPEC REL. COMPL PDR

REL INTERFACE CNTRL DWG

COMPL PDR

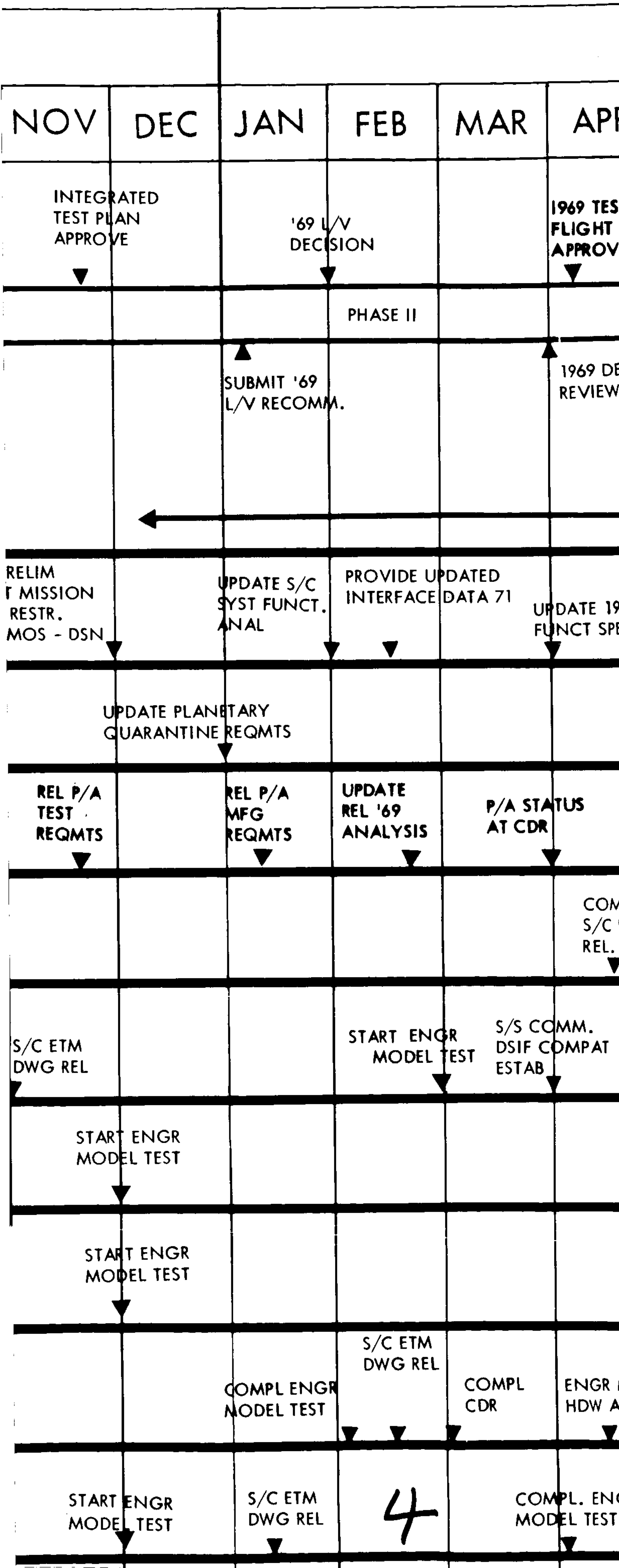
71 & 69 FUNCT. SPEC REL.

START ENGR MODEL TEST

PHASE IB
RD TEST

COMPL PDR

71 & 69 FUNCT SPEC REL.

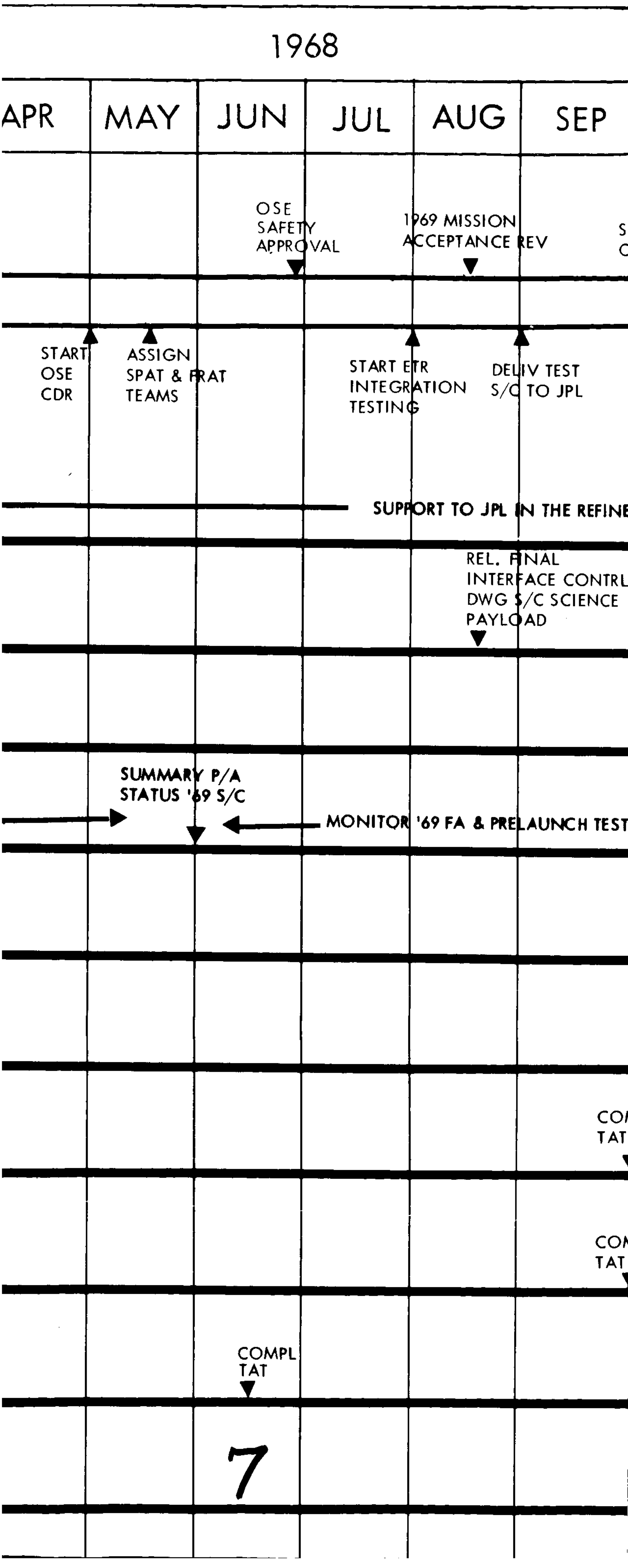


NOV
DEC
JAN
FEB
MAR
APR
INTEGRATED TEST PLAN APPROVE
'69 L/V DECISION
1969 TES FLIGHT APPROV
PHASE II
SUBMIT '69 L/V RECOMM.
1969 DE REVIEW
RELIM T MISSION RESTR. MOS - DSN
UPDATE S/C SYST FUNCT. ANAL
PROVIDE UPDATED INTERFACE DATA 71
UPDATE 19 FUNCT SPE
UPDATE PLANETARY QUARANTINE REQMTS
REL P/A TEST REQMTS
REL P/A MFG REQMTS
UPDATE REL '69 ANALYSIS
P/A STATUS AT CDR
COM S/C REL.
S/C ETM DWG REL
START ENGR MODEL TEST
S/S COMM. DSIF COMPAT ESTAB
START ENGR MODEL TEST
START ENGR MODEL TEST
S/C ETM DWG REL
COMPL ENGR MODEL TEST
COMPL CDR
ENGR HDW A
START ENGR MODEL TEST
S/C ETM DWG REL
COMPL. ENG MODEL TEST

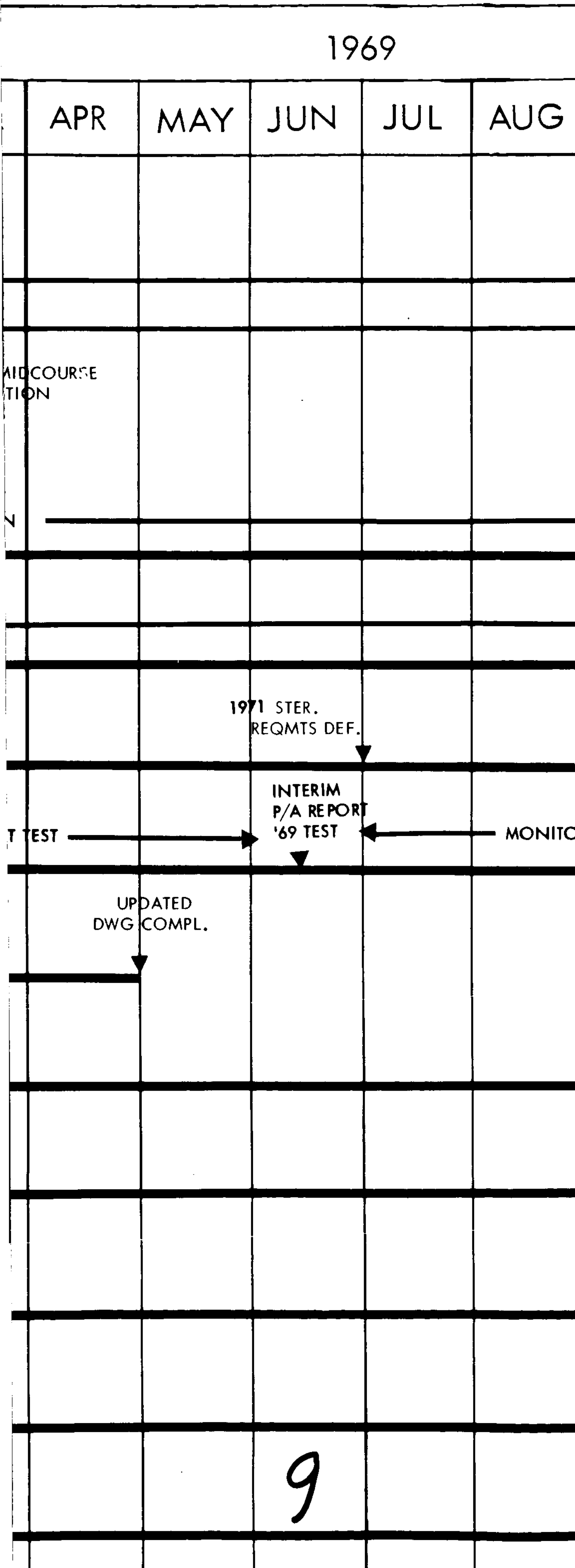
1967

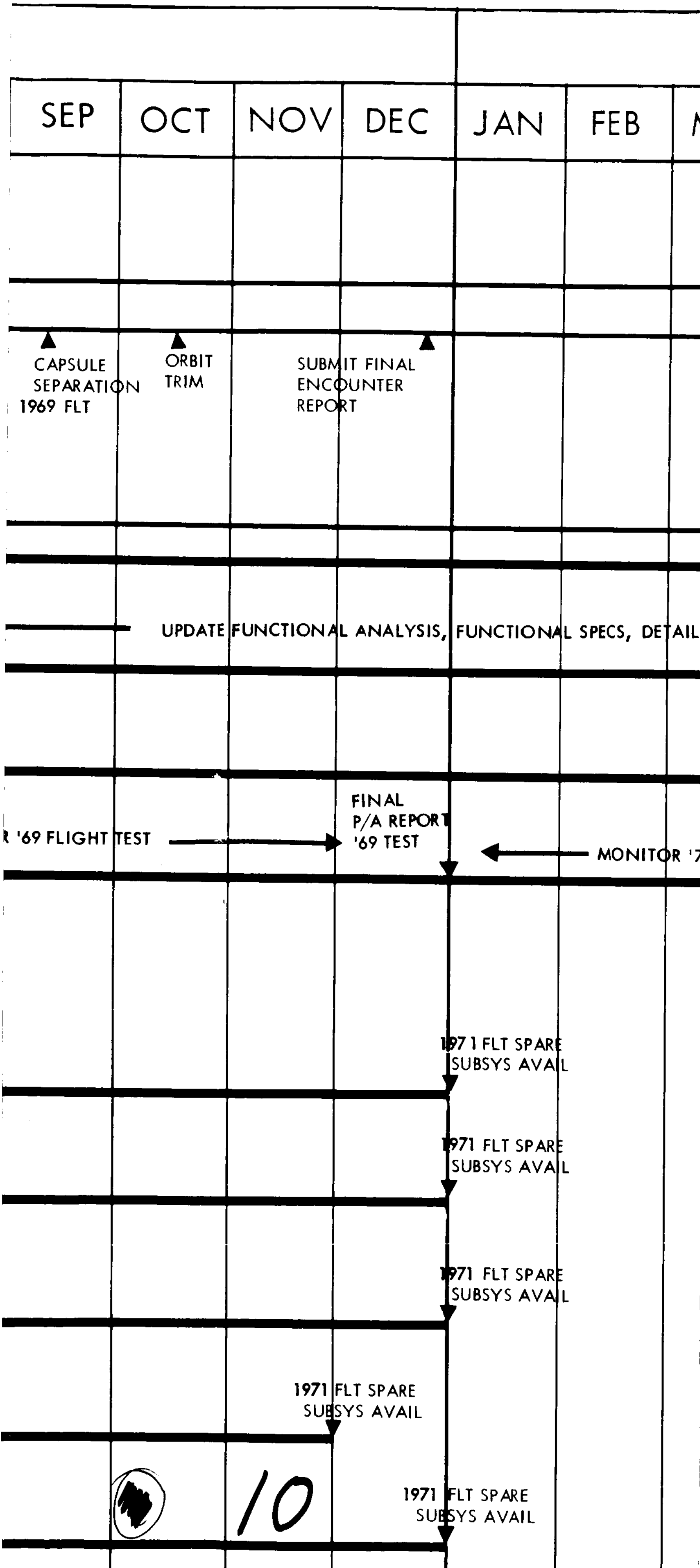
R	MAY	JUN	JUL	AUG	SEP
T DESIGN AL					
SIGN					
71 S/C CS			UPDATE S/C SYST. FUNCT ANAL (EVERY 6 MONTHS)		
			REL QUAL STATUS DOCUMENT		UPDA REL & ANAL
PL SUBSYS ETM DWG			UPDATED PARTS MTLS & PROCESS LIST		COMP. SU ENGR. MO TEST
COMPL ENGR MOD. TEST		69 T.F. DWG REL COMPL CDR	ETM HDW AVAIL		
		ETM HDW AVAIL	COMPL. ENGR MODEL TEST		COMPL CDR
		ETM HDW AVAIL	COMPL. ENGR MODEL TEST		COMPL CDR
MOD VAIL		1969 DWG REL	START TAT		
GR	COMPL CDR	ETM HDW AVAIL		5	

OCT	NOV	DEC	JAN	FEB	MAR
1971 S/C CDR APPROVAL	REL MISSION OPERATION PLAN				
S/C 1971 CDR					
UPDATE OSE '71 FUNCT. SPECS	PROVIDE FIN. VOYAGER '71 MISSION REQMTS & RESTR. S/C - MOS DSN L/V - CAP			UPDATE S/C SYSTEMS FUNCT. ANAL	
			VERIFY DECONTAMINATION OF '69 FLT ARTICLE		
TE '71 SAF YSIS	P/A STATUS CDR ←		MONITOR TA TESTING		
BSYS D CDR COMPL.	COMPL. SUBSYS DWG. REL.				
START TAT	1969 FLT HDW AVAIL				
START TAT		1969 FLT HDW AVAIL			
START TAT		1969 FLT HDW AVAIL			
		1969 FLT HDW AVAIL			
START TAT		1969 FLT HDW AVAIL		6	

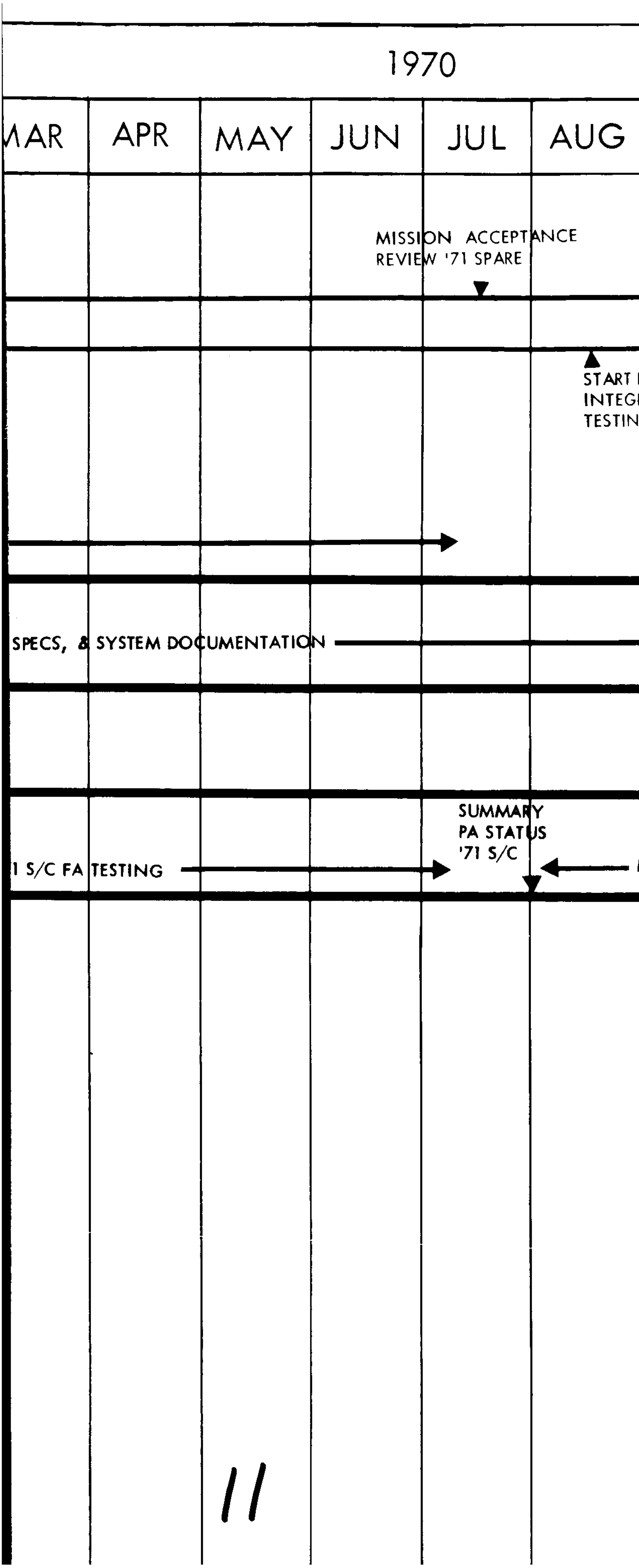

1968
APR
MAY
JUN
JUL
AUG
SEP
OSE SAFETY APPROVAL
1969 MISSION ACCEPTANCE REV
START OSE CDR
ASSIGN SPAT & FRAT TEAMS
START ETR INTEGRATION TESTING
DELIV TEST S/C TO JPL
SUPPORT TO JPL IN THE REFINE
REL. FINAL INTERFACE CONTRL DWG S/C SCIENCE PAYLOAD
SUMMARY P/A STATUS '69 S/C
MONITOR '69 FA & PRELAUNCH TEST
COMPL TAT
7

OCT	NOV	DEC	JAN	FEB	MAR
ATURN IB ENTAUR AVAIL	69 FINAL CONFIG. REV		1969 LAUNCH OPPORTUNITY		
		SUBMIT 2ND LAUNCH VEHICLE RECOMMENDATION		LAUNCH INJECTION DEPLOYMENT	FINAL CORREC
MENT OF THE VOYAGER 1971 MISSION DEFINITION AND MISSION DESIG					
	UPDATE VOYAGER 1971 MISSION REQMTS & RESTR. S/C - L/V CAP				
UPDATE SUMMARY P/A STATUS		P/A QUICK LOOK REPORT ON LAUNCH		MONITOR '69 FLIGH	
	COMPL. SUBSYS TAT				
COMPL. TAT				1971 PTM #1 SUBSYS AVAIL	
MPL				1971 PTM #1 SUBSYS AVAIL	
MPL				1971 PTM #1 SUBSYS AVAIL	
			971 PTM #1 SUBSYS AVAIL		
COMPL. TAT			8	1971 PTM #1 SUBSYS AVAIL	


1969
APR
MAY
JUN
JUL
AUG
MIDCOURSE
TION
1971 STER.
REQMTS DEF.
INTERIM
P/A REPORT
'69 TEST
T TEST
MONITO
UPDATED
DWG COMPL.
9

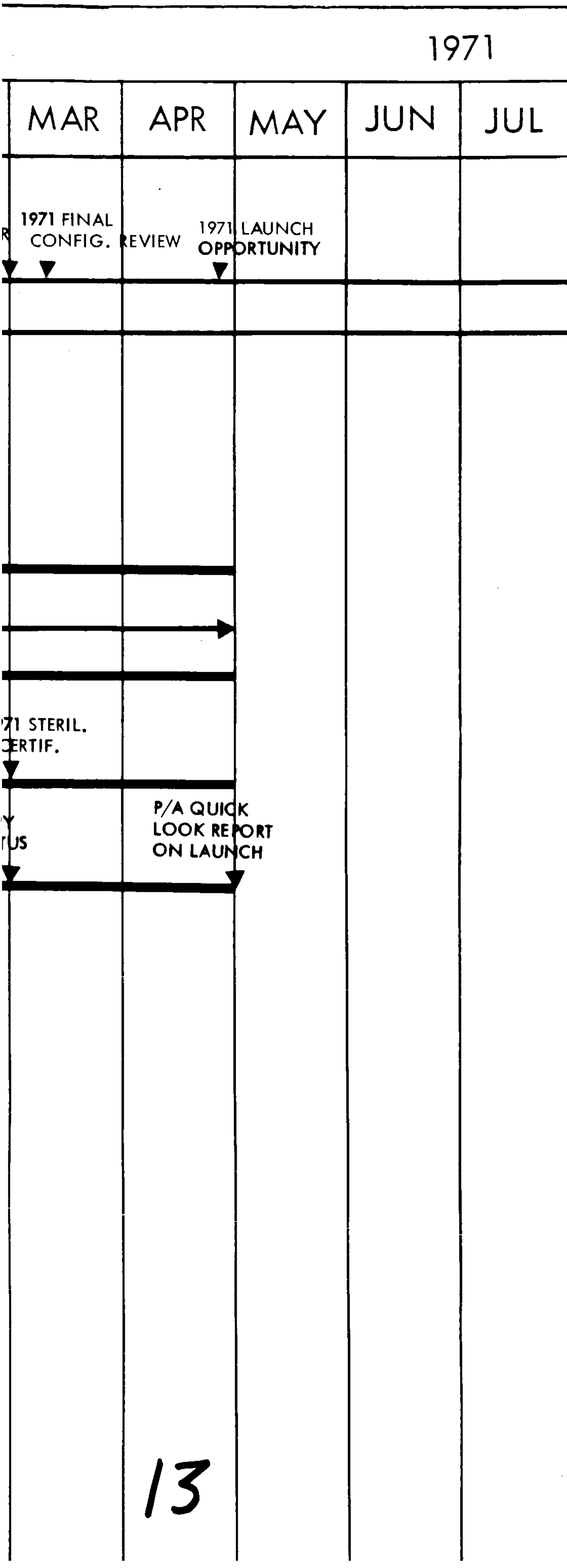


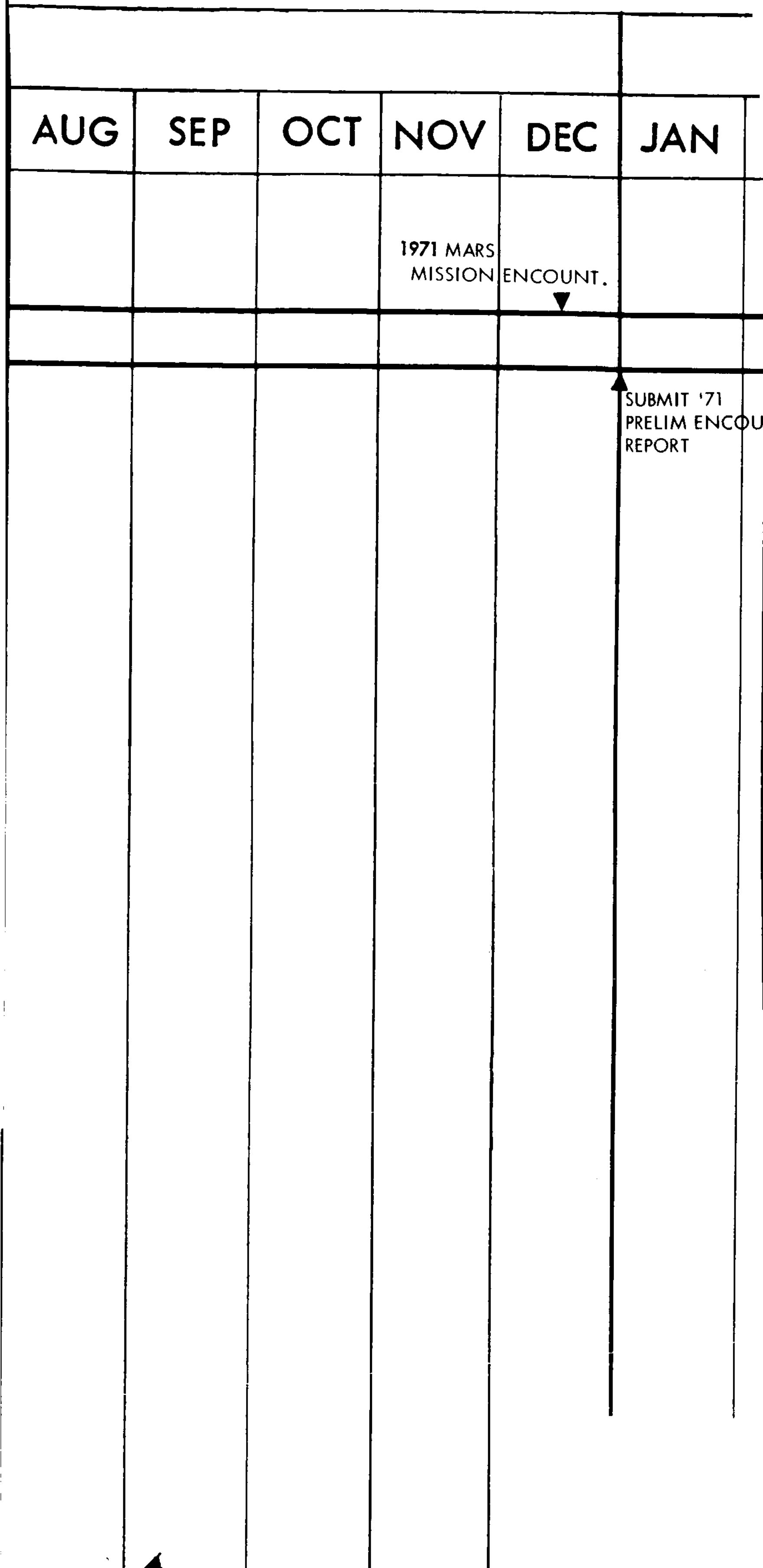
SEP
OCT
NOV
DEC
JAN
FEB
CAPSULE SEPARATION 1969 FLT
ORBIT TRIM
SUBMIT FINAL ENCOUNTER REPORT
UPDATE FUNCTIONAL ANALYSIS, FUNCTIONAL SPECS, DETAIL
'69 FLIGHT TEST
FINAL P/A REPORT '69 TEST
MONITOR
1971 FLT SPARE SUBSYS AVAIL
1971 FLT SPARE SUBSYS AVAIL
1971 FLT SPARE SUBSYS AVAIL
1971 FLT SPARE SUBSYS AVAIL
1971 FLT SPARE SUBSYS AVAIL
10


1970
MAR
APR
MAY
JUN
JUL
AUG
MISSION ACCEPTANCE
REVIEW '71 SPARE
START
INTEG
TESTIN
SPECS, & SYSTEM DOCUMENTATION
SUMMARY
PA STATUS
'71 S/C
1 S/C FA TESTING
11

SEP	OCT	NOV	DEC	JAN	FEB
	MISSION ACCEPT REV. 1971 FLIGHT S/C NO. 1			SATURN IB/CENTAU AVAILABLE	
TR ATION G					
				VERIFY DECONTAM. STATUS	19
MONITOR '71 S/C FA & PRELAUNCH TESTING →					UPDATE SUMMA P/A STA

3


1971
MAR
APR
MAY
JUN
JUL
1971 FINAL CONFIG. REVIEW
1971 LAUNCH OPPORTUNITY
71 STERIL. CERTIF.
TUS
P/A QUICK LOOK REPORT ON LAUNCH


AUG
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JAN
1971 MARS MISSION ENCOUNT.
SUBMIT '71 PRELIM ENCOU
REPORT

1972										
FEB	MAR	APR	MAY	JUN	JUL					
NT	SUBMIT '71 FINAL ENCOUNT REPORT									

THE BOEING COMPANY

15

ELECTRICAL POWER

STRUCTURES & SPACECRAFT ADAPTER

MECHANISMS

TEMPERATURE CONTROL

PYROTECHNICS

CABLING

PROPULSION MIDCOURSE

PROPULSION ORBITAL INSERTION

SCIENCE PAYLOAD INTEGRATION

MANUFACTURING & TEST PROGRAM

MOCKUPS

PARTIAL SPACECRAFT

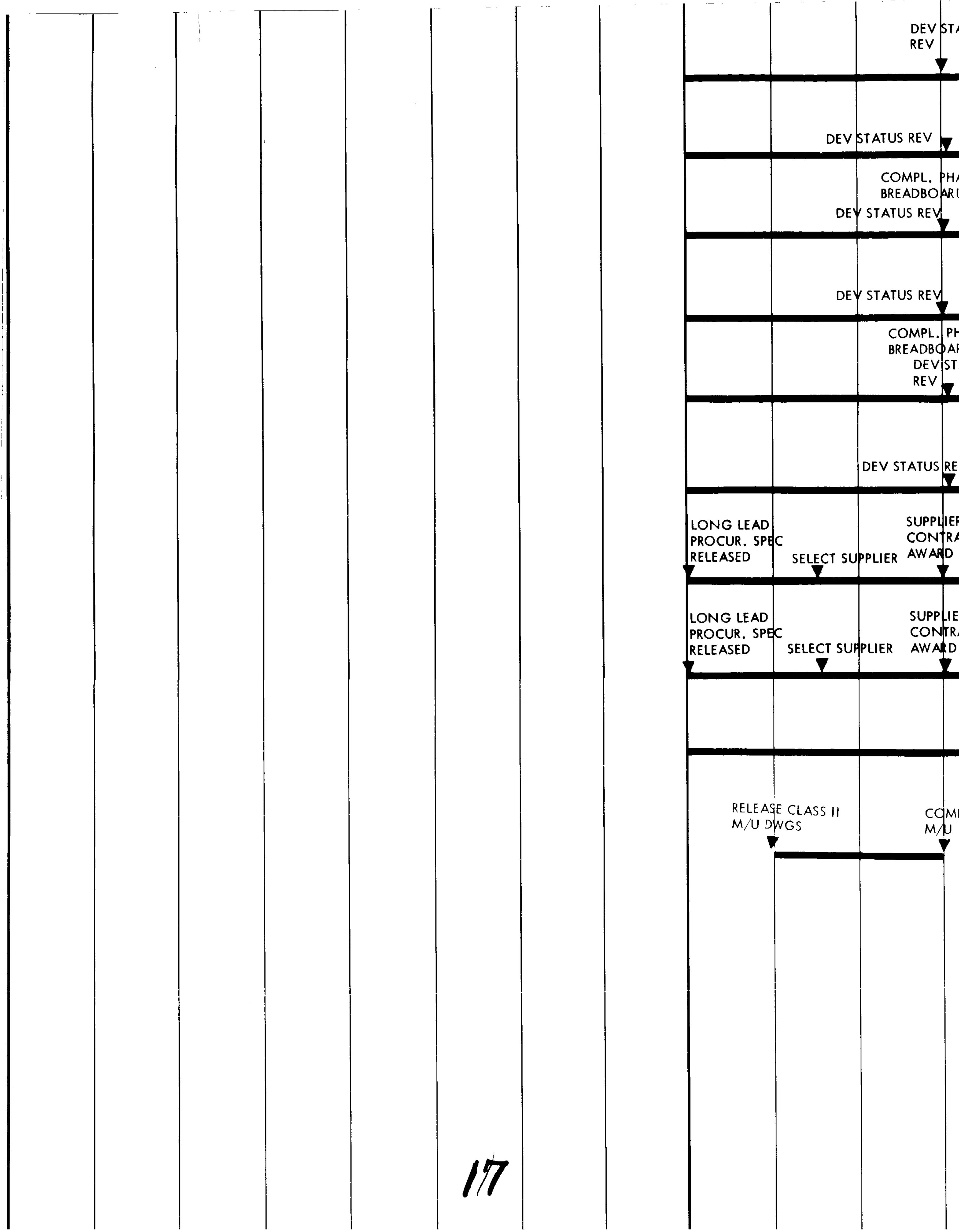
STATIC TEST MODEL

THERMAL TEST MODEL

DYNAMIC TEST MODEL

COMPLETE SPACECRAFT

ENGINEERING MODEL-PROTOTYPE


DEV STA
REV
DEV STATUS REV
COMPL. PH
BREADBOARD
DEV STATUS REV
DEV STATUS REV
COMPL. PH
BREADBOAR
DEV ST
REV
DEV STATUS RE
LONG LEAD
PROCUR. SPEC
RELEASED
SELECT SUPPLIER
SUPPLIER
CONTRA
AWARD
LONG LEAD
PROCUR. SPEC
RELEASED
SELECT SUPPLIER
SUPPLIE
CONTR
AWARD
RELEASE CLASS II
M/U DWGS
COM
M/U

17

ATUS
COMPL PDR
71 & 69 FUNCT SPEC REL
COM BREADBC

REL. INTERFACE CNTRL DWGS
COMPL PDR
'69 & '71 FUNCT SPEC REL

ASE IB
D TEST
REL. INTERFACE CNTRL DWGS
COMPL PDR
'69 & '71 FUNCT SPEC REL.

COMPL. PHASE IB BREADBOARD TESTS
COMPL PDR
'69 & '71 FUNCT. SPEC. REL.

IASE IB
RD TEST
ATUS
COMPL. PDR
'69 & '71 FUNCT SPEC REL

COMPL PDR
COMPL PHASE IB BREADBOARD TEST
V.
REL INTERFACE CNTRL DWGS
'69 & '71 FUNCT SPEC REL.

R
ACT
REL. INTERFACE CNTRL DWGS
COMPL PDR
'69 & '71 FUNCT SPEC REL.
HDWE CONTRACT AWARD

R
ACT
REL. INTERFACE CNTRL DWGS
COMPL PDR
'69 & '71 FUNCT SPEC REL
HDWE CONT AWARD

'L CLASS II

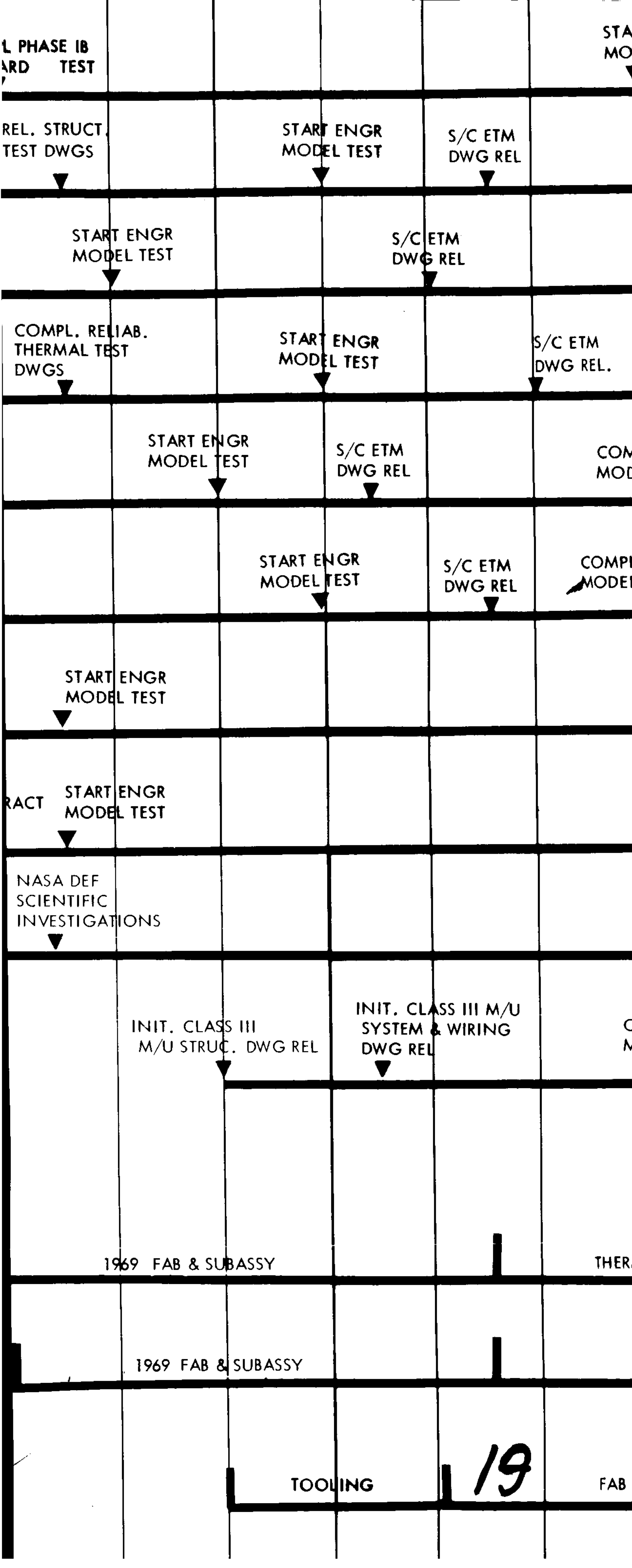
STATIC TEST MODEL

THERMAL TEST MODEL

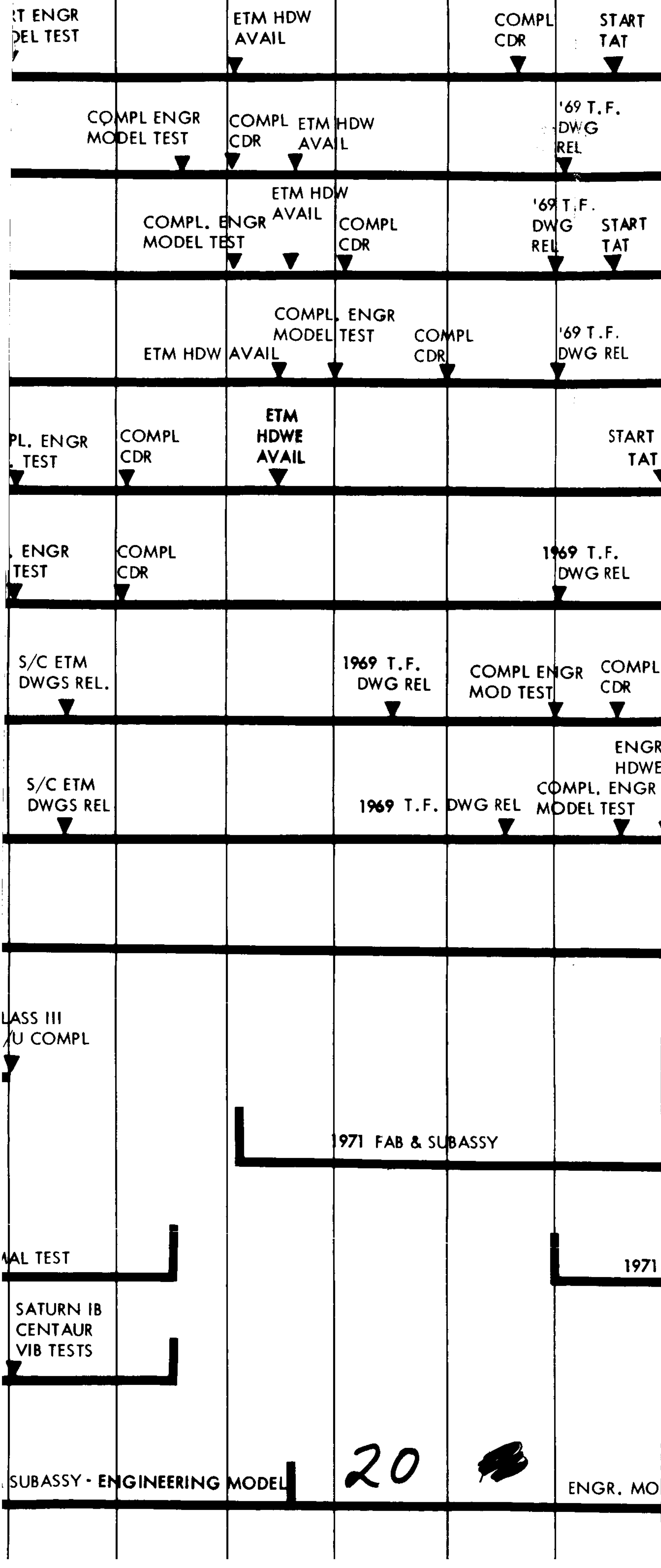
DYNAMIC TEST MODEL

ENGINEERING MODEL

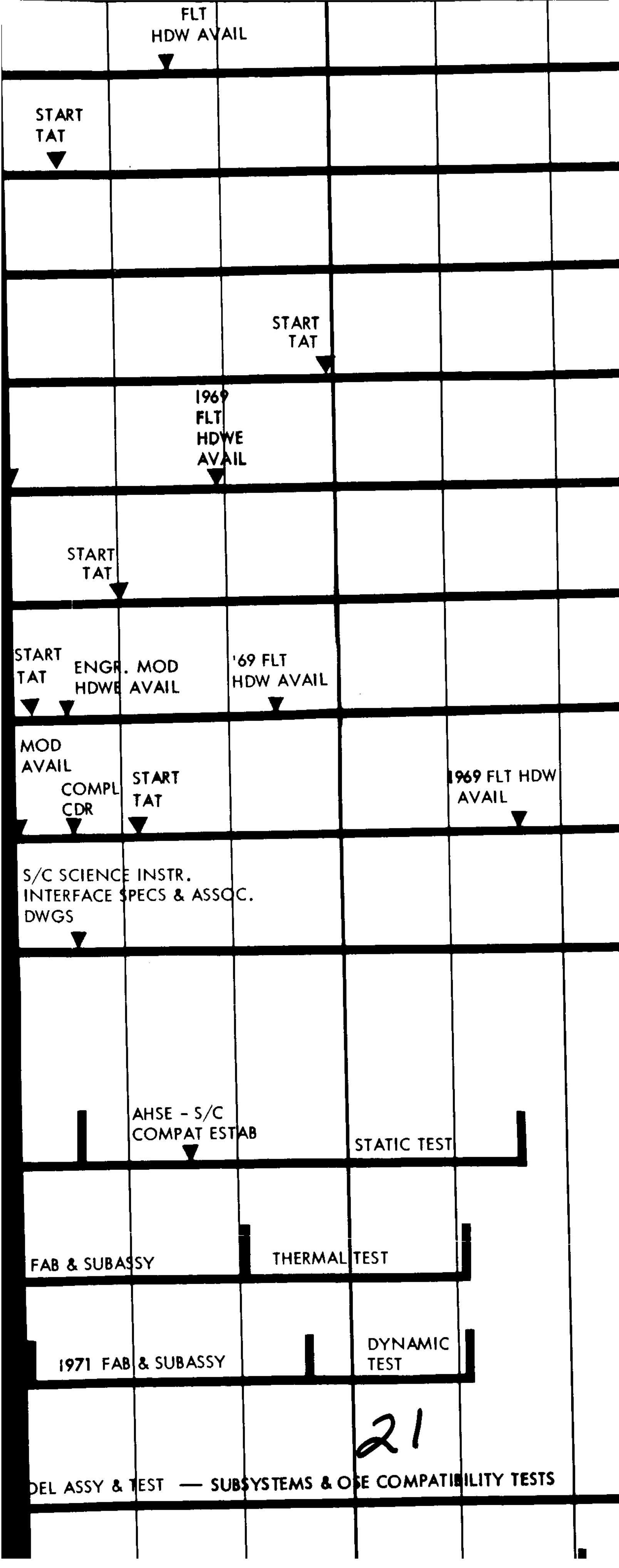
18



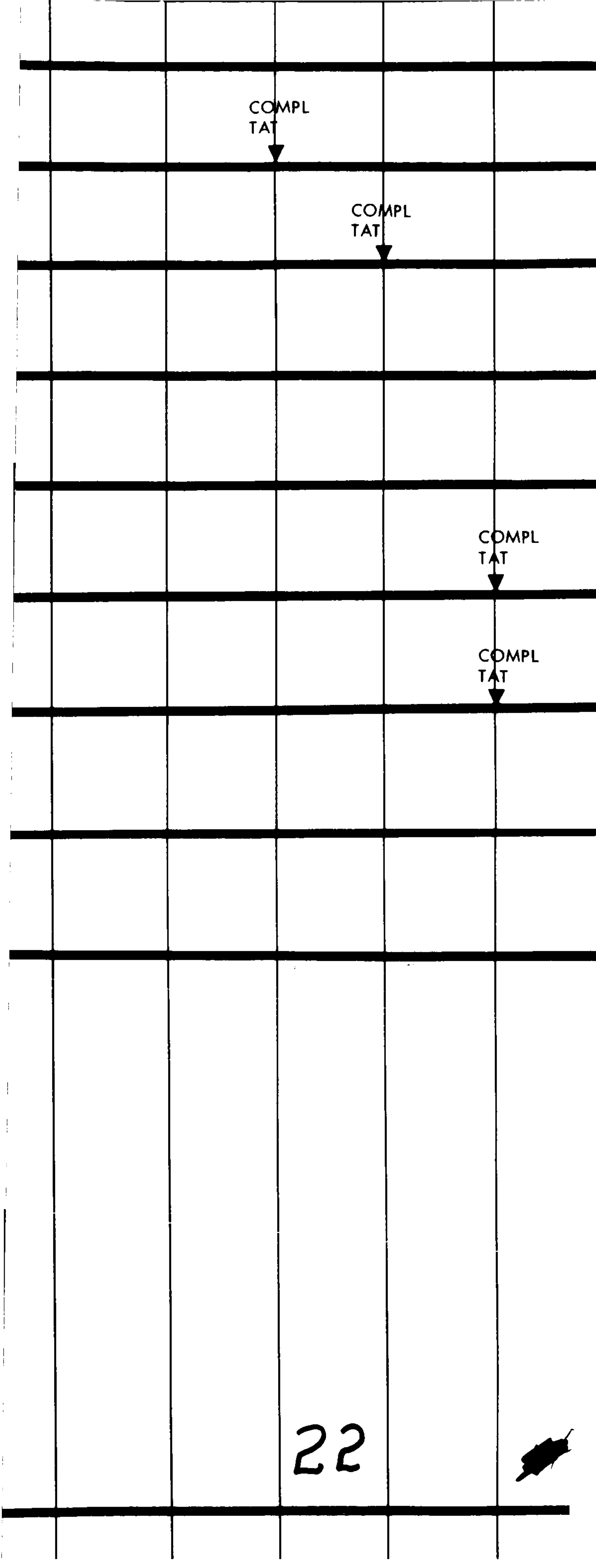
L PHASE IB
ARD TEST
STA
MO
REL. STRUCT.
TEST DWGS
START ENGR
MODEL TEST
S/C ETM
DWG REL
START ENGR
MODEL TEST
S/C ETM
DWG REL
COMPL. RELIAB.
THERMAL TEST
DWGS
START ENGR
MODEL TEST
S/C ETM
DWG REL.
START ENGR
MODEL TEST
S/C ETM
DWG REL
COM
MOD
START ENGR
MODEL TEST
S/C ETM
DWG REL
COMPL
MODEL
START ENGR
MODEL TEST
RACT
START ENGR
MODEL TEST
NASA DEF
SCIENTIFIC
INVESTIGATIONS
INIT. CLASS III
M/U STRUC. DWG REL
INIT. CLASS III M/U
SYSTEM & WIRING
DWG REL
1969 FAB & SUBASSY
THER
1969 FAB & SUBASSY
TOOLING
19
FAB



ETM HDW AVAIL
COMPL CDR
START TAT
COMPL ENGR MODEL TEST
COMPL CDR
ETM HDW AVAIL
'69 T.F. DWG REL
ETM HDW AVAIL
COMPL. ENGR MODEL TEST
COMPL CDR
'69 T.F. DWG REL
START TAT
COMPL. ENGR MODEL TEST
ETM HDW AVAIL
COMPL CDR
'69 T.F. DWG REL
COMPL CDR
ETM HDWE AVAIL
START TAT
COMPL CDR
1969 T.F. DWG REL
S/C ETM DWGS REL.
1969 T.F. DWG REL
COMPL ENGR MOD TEST
COMPL CDR
S/C ETM DWGS REL
1969 T.F. DWG REL
COMPL. ENGR MODEL TEST
1971 FAB & SUBASSY
1971
SATURN IB CENTAUR VIB TESTS
SUBASSY - ENGINEERING MODEL
20
ENGR. MO


FLT HDW AVAIL
START TAT
START TAT
1969 FLT HDWE AVAIL
START TAT
START TAT
ENGR. MOD HDWE AVAIL
'69 FLT HDW AVAIL
MOD AVAIL
COMPL CDR
START TAT
1969 FLT HDW AVAIL
S/C SCIENCE INSTR. INTERFACE SPECS & ASSOC. DWGS
AHSE - S/C COMPAT ESTAB
STATIC TEST
FAB & SUBASSY
THERMAL TEST
1971 FAB & SUBASSY
DYNAMIC TEST
DEL ASSY & TEST — SUBSYSTEMS & OSE COMPATIBILITY TESTS

21


COMPL TAT
COMPL TAT
COMPL TAT
COMPL TAT
22

COMPL
TAT

1971 PTM #1
SUBSYS ANAL

1971 PTM #1
SUBSYS AVAIL

1971 PTM #1
SUBSYS AVAIL

COMPL
TAT

1971 PTM #1
SUBSYS AVAIL

COMPL.
TAT

1971 PTM #1
SUBSYS AVAIL

1971 PTM #1
SUBSYS AVAIL

COMPL TAT

1971 PTM #1
SUBSYS AVAIL

SUBSYSTEMS
COMPAT
COMPL

23

REFUR
ENGR
MODE
1971 C

REFUR
JPL T

DELIV BUS

JPL - BOEING

1971 PTM #1
SUBSYS AVAIL

BISH
TEST
L TO
CONFIG

24

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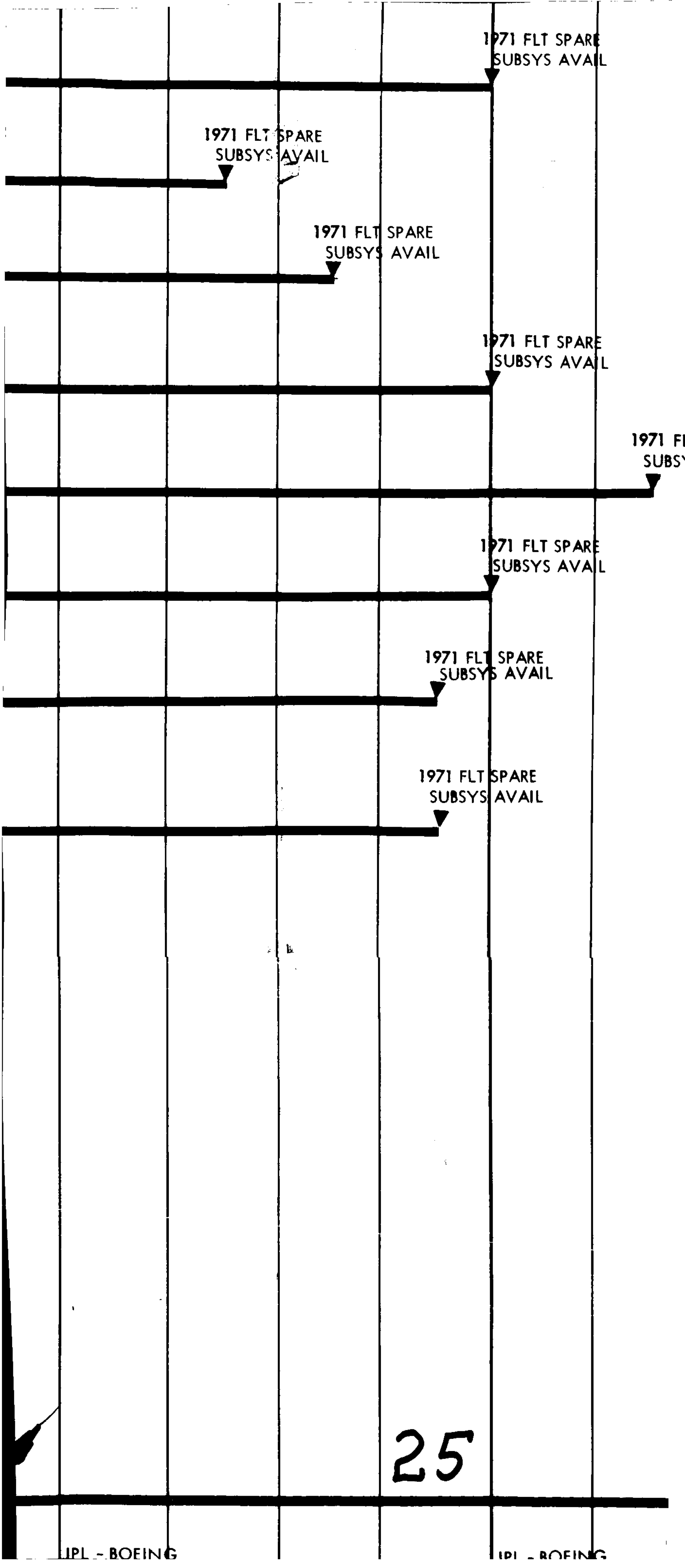
JPL BOEING


1971 FLT SPARE SUBSYS AVAIL
1971 FLT SPARE SUBSYS AVAIL
1971 FLT SPARE SUBSYS AVAIL
1971 FLT SPARE SUBSYS AVAIL
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SUBSY
1971 FLT SPARE SUBSYS AVAIL
1971 FLT SPARE SUBSYS AVAIL
1971 FLT SPARE SUBSYS AVAIL
JPL - BOEING
JPL - BOEING

T SPARE
'S AVAIL

26

M

ORG

SPACECRA
PROGRAM

AUTONETI
DIVISION

ELECTRO C

aster Schedule 1971 Mission With 1969 Saturn IB/Centaur Mars Orbit

ABBREVIATIONS

C/O	CHECKOUT
ETM	ENGINEERING TEST MODEL
CDR	CRITICAL DESIGN REVIEW
PDR	PRELIMINARY DESIGN REVIEW
M/U	MOCKUP
FAT	FLIGHT ACCEPTANCE TEST
TAT	TYPE APPROVAL TEST
ASSY	ASSEMBLY
FAB	FABRICATION
SUBASSY	SUBASSEMBLY
REV	REVIEW
REL	RELEASE
MDS	MISSION OPERATION SYSTEM
DEV	DEVELOPMENT
COMPAT	COMPATIBILITY
INSTR	INSTRUMENTATION
HDWE	HARDWARE
FLT	FLIGHT
ANAL	ANALYSIS
IMPL	IMPLEMENT
COG	COGNIZANT
S/C	SPACECRAFT
L/V	LAUNCH VEHICLE
CAP	CAPSULE
ETR	AIR FORCE EASTERN TEST RANGE
BOD	BENEFICIAL OCCUPANCY DATE
DSN	DEEP SPACE NETWORK
DSIF	DEEP SPACE INSTRUMENTATION FACILITY
DWG	DRAWING
OSE	OPERATIONAL SUPPORT EQUIPMENT
SPEC	SPECIFICATION
MTLS	MATERIALS
M&P	MATERIALS & PROCESSES

APPROVALS

ANIZATION	NAME	DATE	APPROVAL
FT SYSTEM MANAGER	E. G. CZARNECKI	7/24	E. G. Czarnecki
CS - N. A. A.	R. R. MUELLER	7/23	R R Mueller
PTICAL SYSTEMS	C. I. CUMMINGS	7/22	

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JPL TEST SPACECRAFT

1969 PROOF TEST MODEL

1969 COMPATIBILITY TEST MODEL

SUBSYSTEM FLIGHT SPARES

1969 FLIGHT 1

1969 FLIGHT 2

1971 PROOF TEST MODEL #1

1971 PROOF TEST MODEL #2

30

JPL TEST SPA

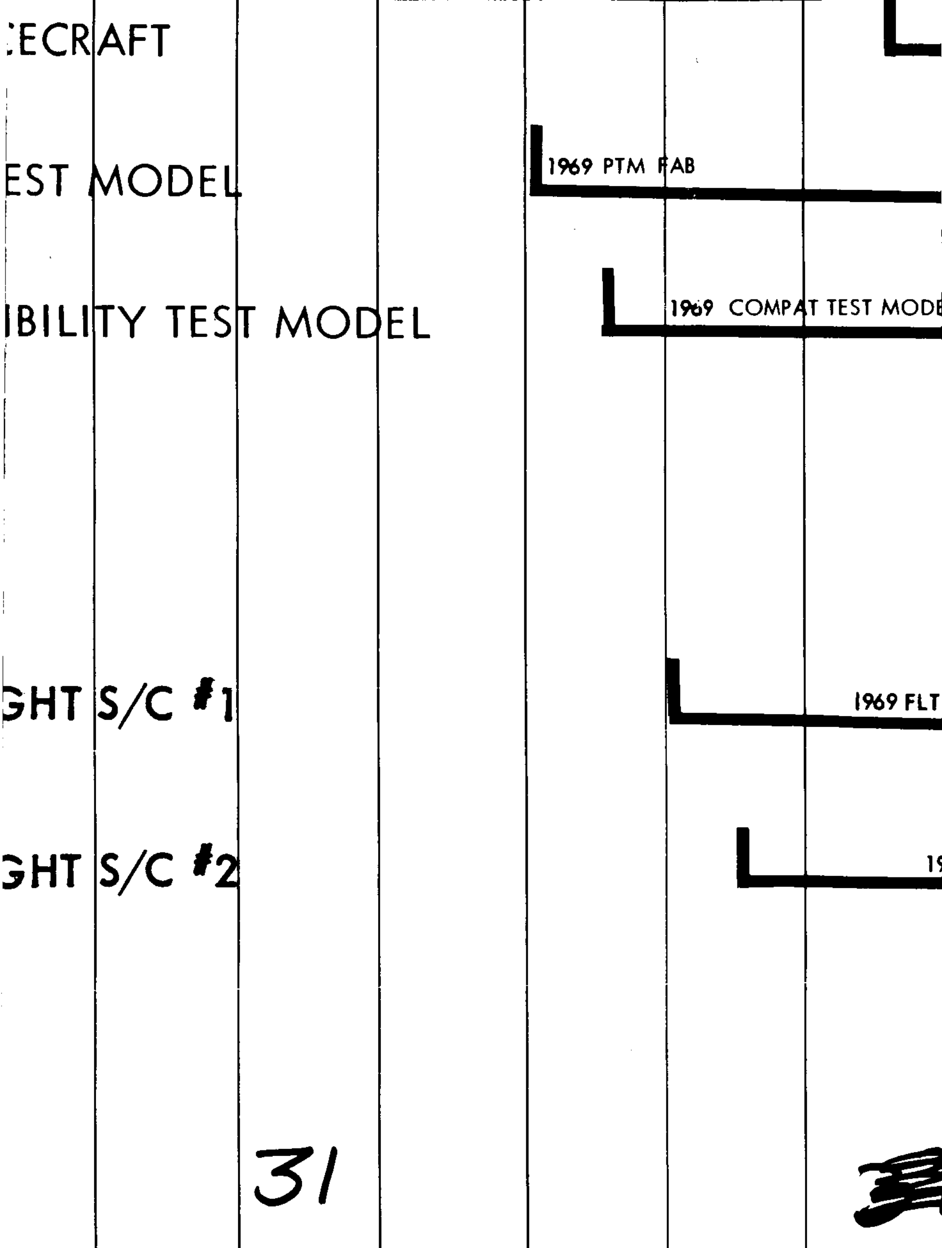
1969 PROOF

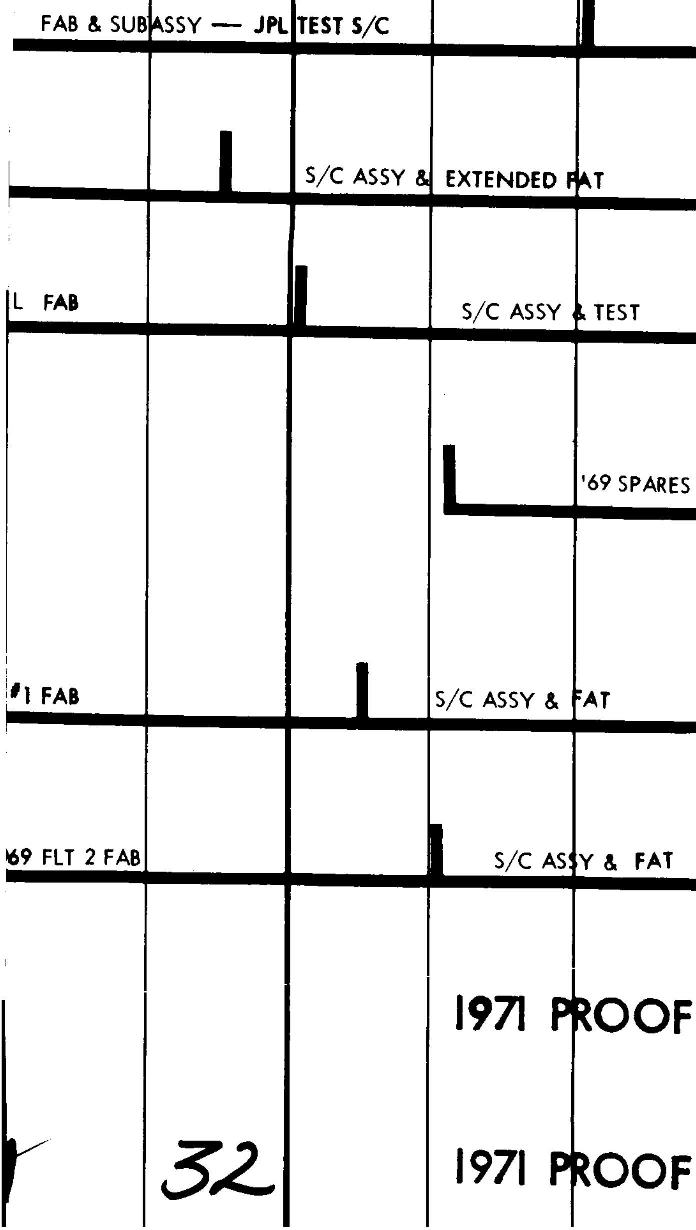
1969 COMPAT

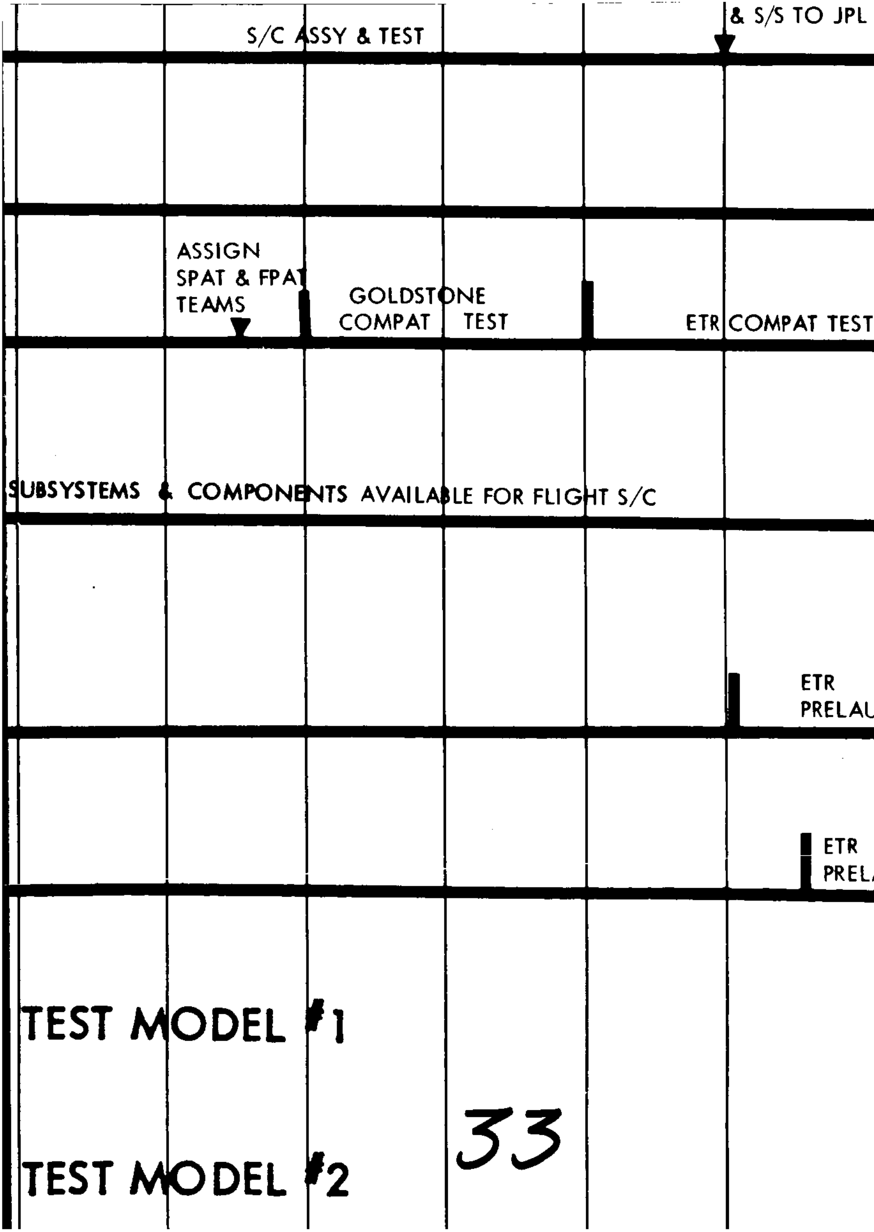
1969 TEST FLI

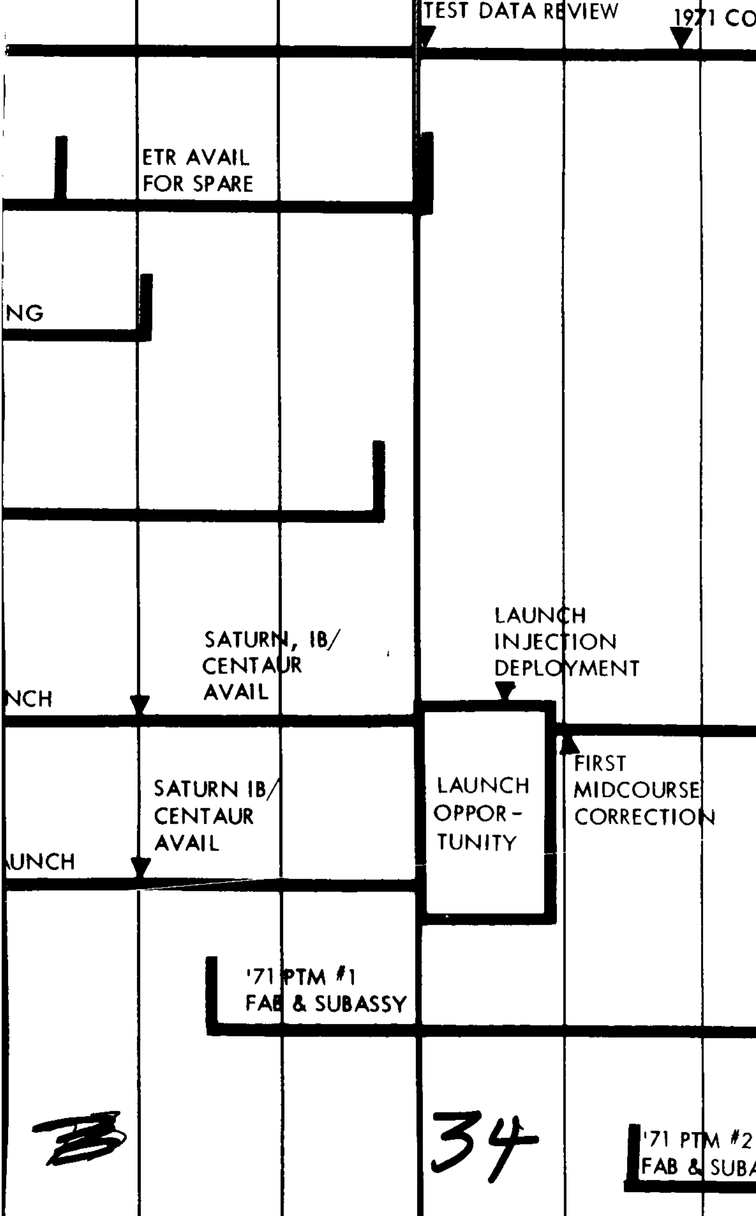
1969 TEST FLI

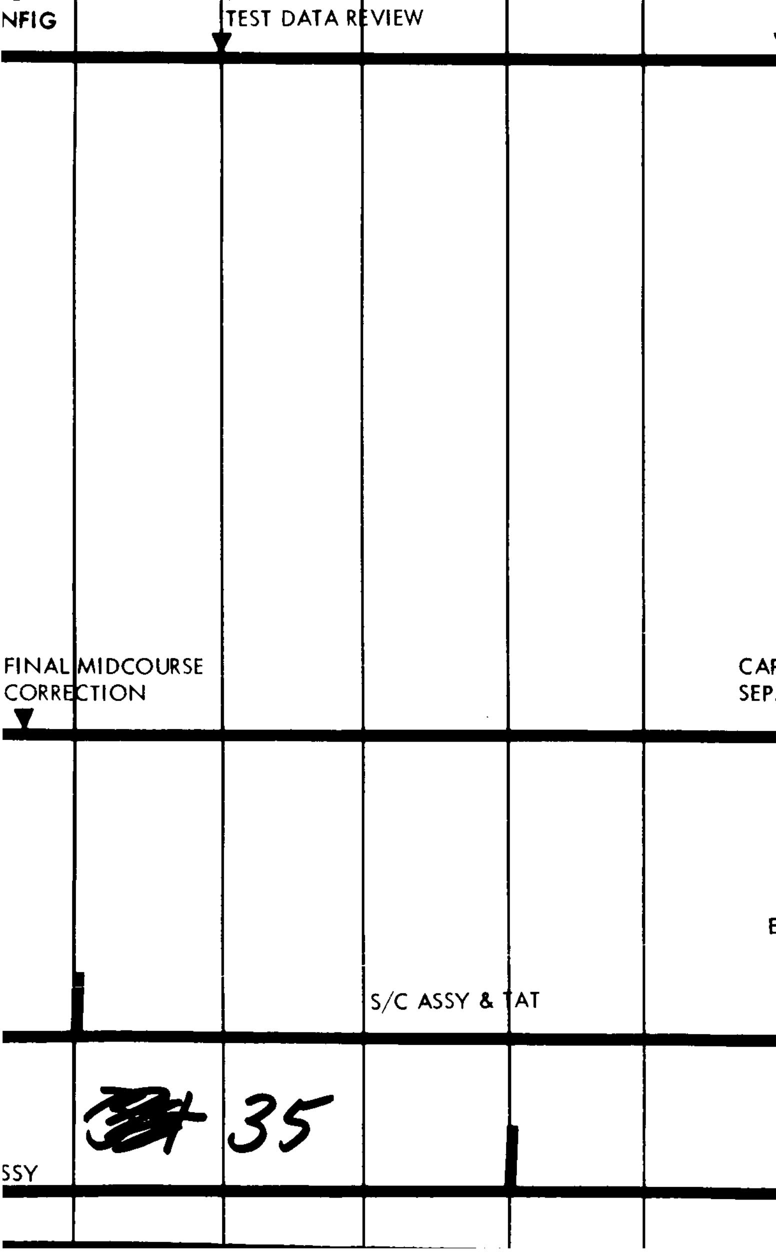
30


ECRAFT
EST MODEL
1969 PTM FAB
IBILITY TEST MODEL
1969 COMPAT TEST MODE
GHT S/C #1
1969 FLT
GHT S/C #2
31

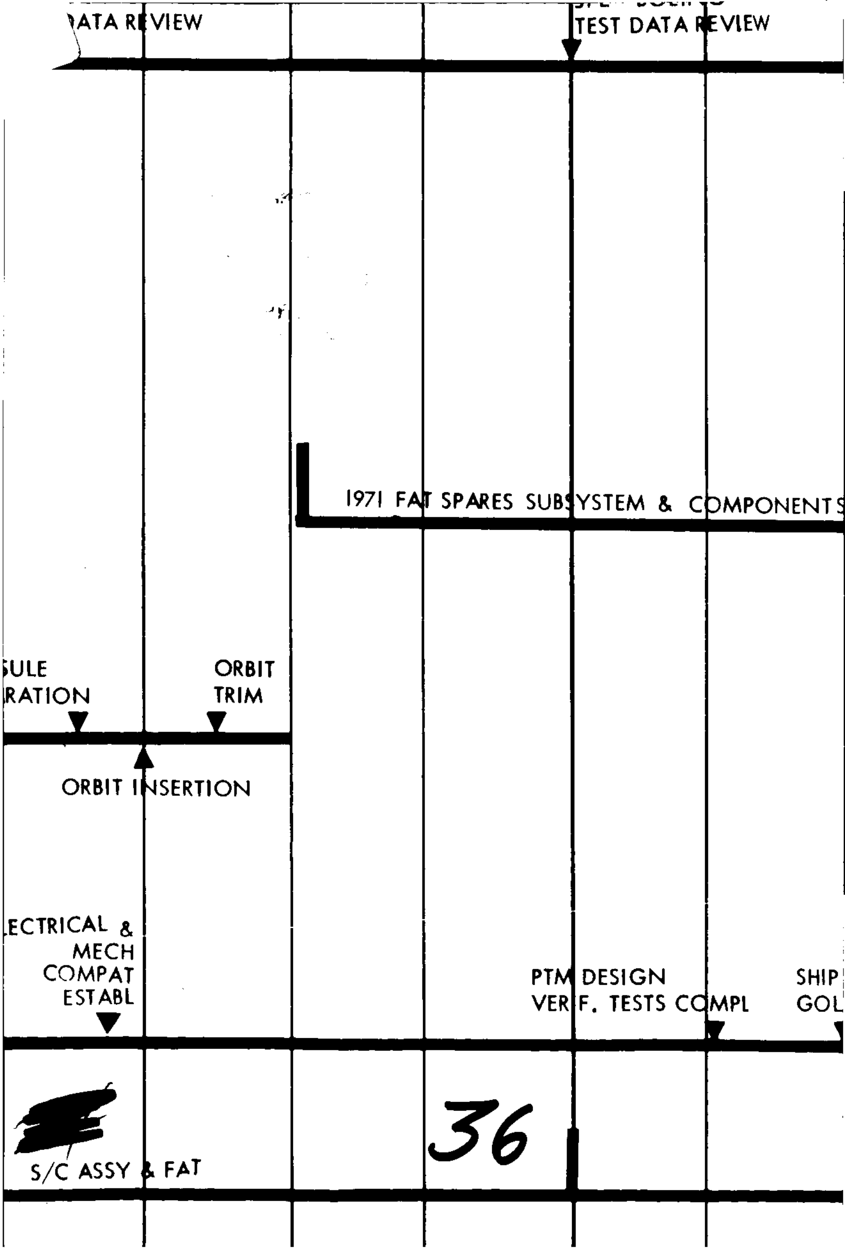

FAB & SUBASSY — JPL TEST S/C
S/C ASSY & EXTENDED FAT
L FAB
S/C ASSY & TEST
'69 SPARES
#1 FAB
S/C ASSY & FAT
'69 FLT 2 FAB
S/C ASSY & FAT
1971 PROOF
1971 PROOF


& S/S TO JPL
S/C ASSY & TEST
ASSIGN SPAT & FPAT TEAMS
GOLDSTONE COMPAT TEST
ETR COMPAT TEST
SUBSYSTEMS & COMPONENTS AVAILABLE FOR FLIGHT S/C
ETR PRELAU
ETR PRELA
TEST MODEL #1
TEST MODEL #2


TEST DATA REVIEW
1971 CO
ETR AVAIL
FOR SPARE
NG
SATURN, IB/
CENTAUR
AVAIL
NCH
LAUNCH
INJECTION
DEPLOYMENT
SATURN IB/
CENTAUR
AVAIL
UNCH
LAUNCH
OPPOR-
TUNITY
FIRST
MIDCOURSE
CORRECTION
'71 PTM #1
FAB & SUBASSY
34
'71 PTM #2
FAB & SUB


NFIG
TEST DATA REVIEW
FINAL MIDCOURSE
CORRECTION
CAF
SEP.
E
S/C ASSY & TAT
SSY

35


DATA REVIEW
TEST DATA REVIEW
1971 FAT SPARES SUBSYSTEM & COMPONENTS
ULE
RATION
ORBIT
TRIM
ORBIT INSERTION
ECTRICAL &
MECH
COMPAT
ESTABL
PTM DESIGN
VERIF. TESTS COMPL
SHIP
GOL
S/C ASSY & FAT

JPL - BOEING
TEST DATA REVIEW

AVAIL FOR FLIGHT S/C

TO
DSTONE

S/C - DSN
DESIGN
VERIF. TESTS
COMPL.

SHIP TO
ETR

S/C - SYSTEM
L/V SYSTEM
COMPAT

S/C - MOS
COMPAT
ESTABL.

37

DESIGN VERIF. TEST 5000 HRS MISSION SIM.

JPL - BOEING
TEST DATA REVIEW

JPL - BOEING
TEST DATA REVIEW

COMPAT
ESTAB.

~~#~~

38

START

COMPL

JPL - BOEING
TEST DATA REVIEW

PHILCO WE
DEVELOPME

BUSINESS

ENGINEERI

FACILITIES

MANUFACTU

MATERIEL

QUALITY C

RELIABILIT
ASSURANC

SYSTEMS T

40

1971 MARS

STERN NT LABORATORIES	G. O. MOORE	7/22	G.O. Moore
AND OPERATIONS	L. B. BARLOW	7/24	[illegible]
NG	W. C. GALLOWAY	7/24	W.C. Galloway
	R. K. MILLS	7/23	[illegible] Mills
IRING	R. R. DICKSON	7/23	R.R. Dickson
	J. C. POWERS	7/23	[illegible]
ONTROL	G. J. SIDDONS	7/23	[illegible]
, QUALITY , AND SAFETY	C. S. BARTHOLOMEW	7/24	C.S. Bartholomew
ESTING	J. C. TURNER	7/22	J.C. Turner

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1971 FLIGHT SPARE

1971 FLIGHT 1

1971 FLIGHT 2

OPERATIONAL SUPPORT EQUIPMENT

ASSEMBLY, HANDLING & SHIPPING EQUIPMENT

SYSTEM TEST COMPLEX

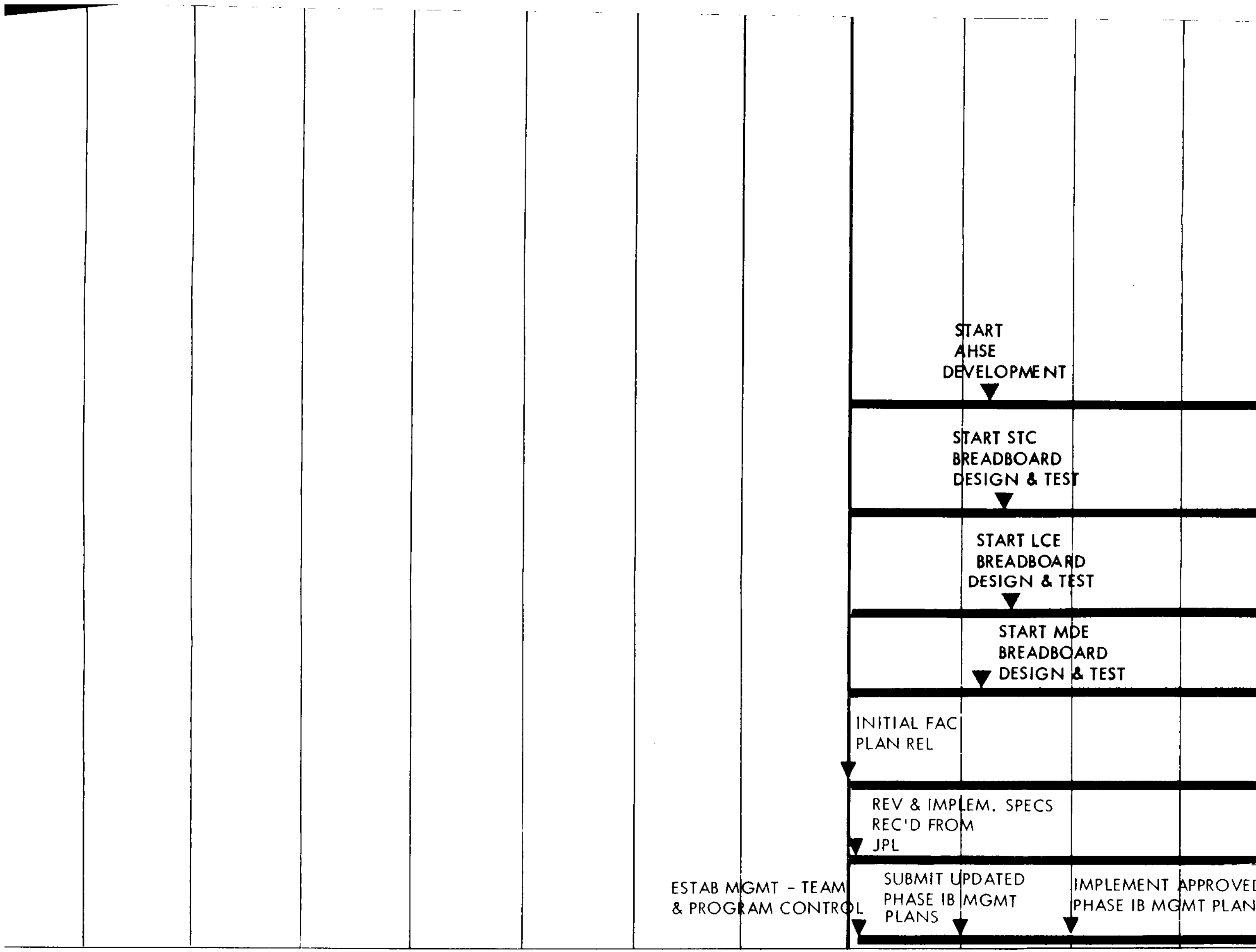
LAUNCH COMPLEX EQUIPMENT

MISSION DEPENDENT EQUIPMENT

FACILITIES

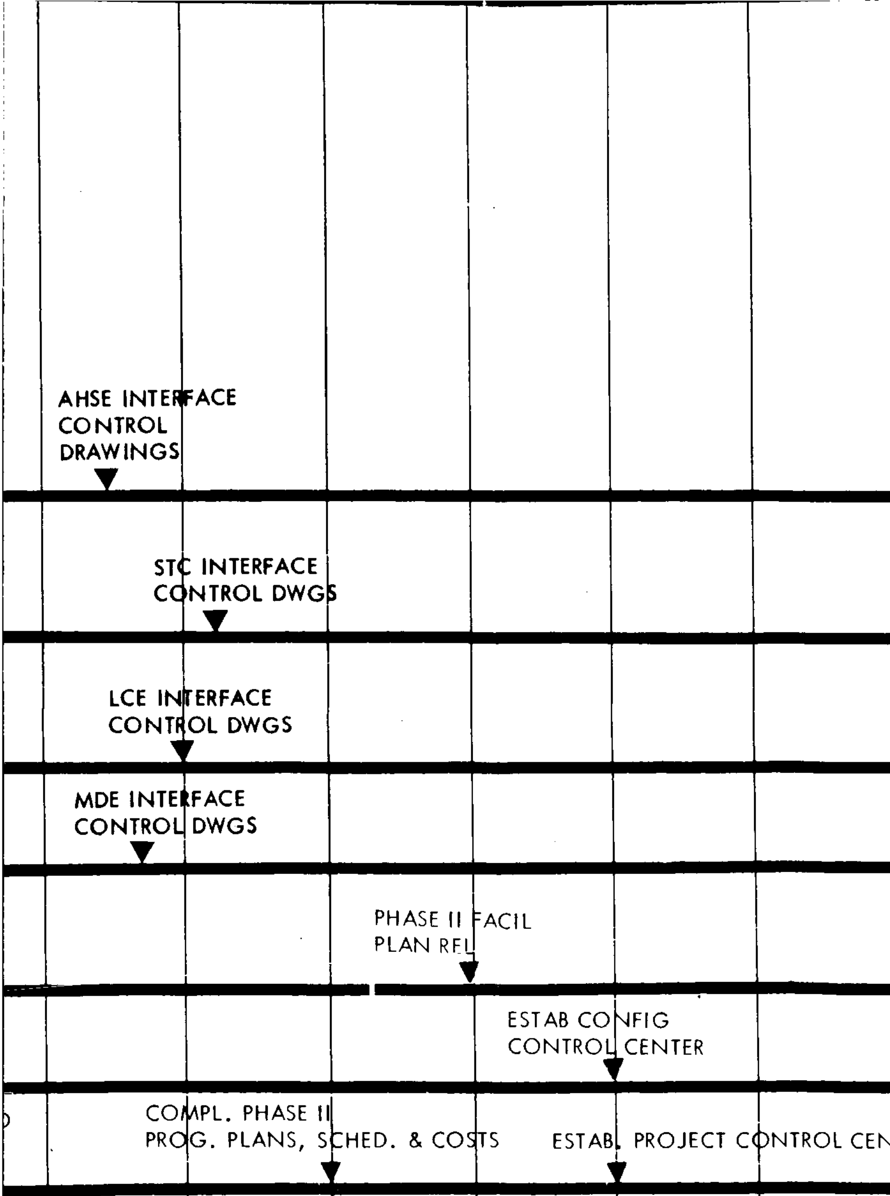
CONFIGURATION MANAGEMENT

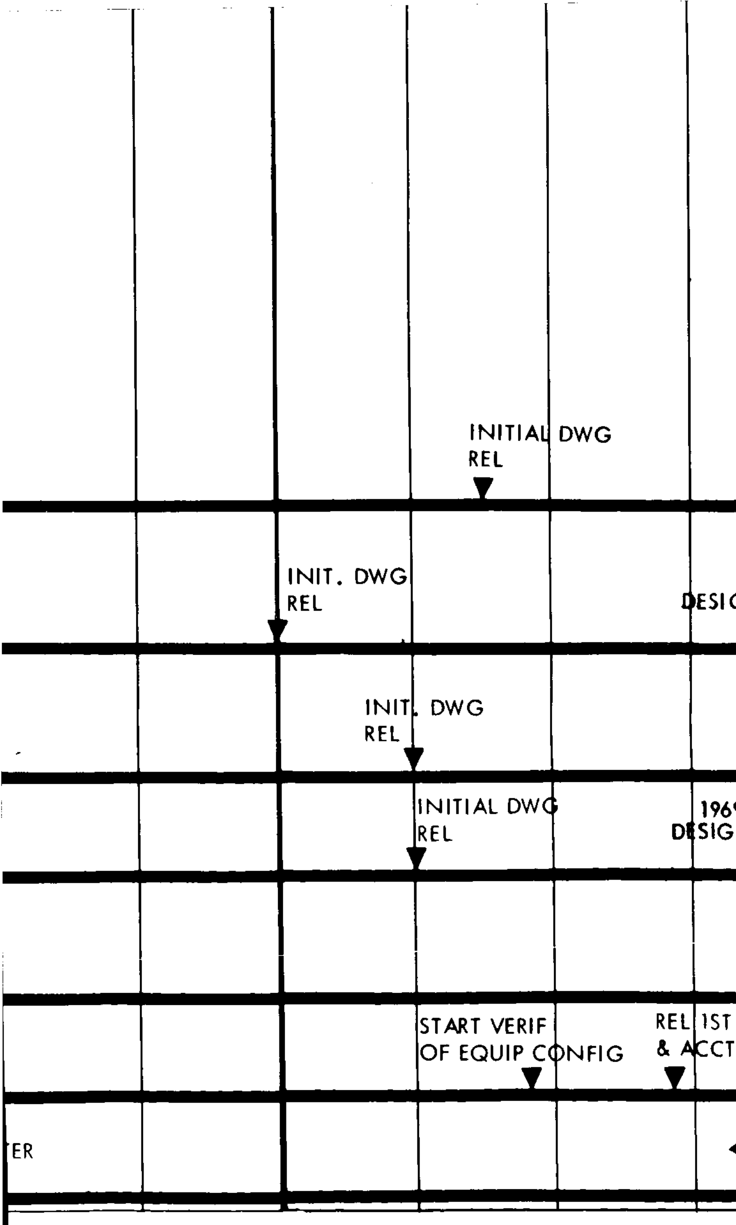
BUSINESS MANAGEMENT

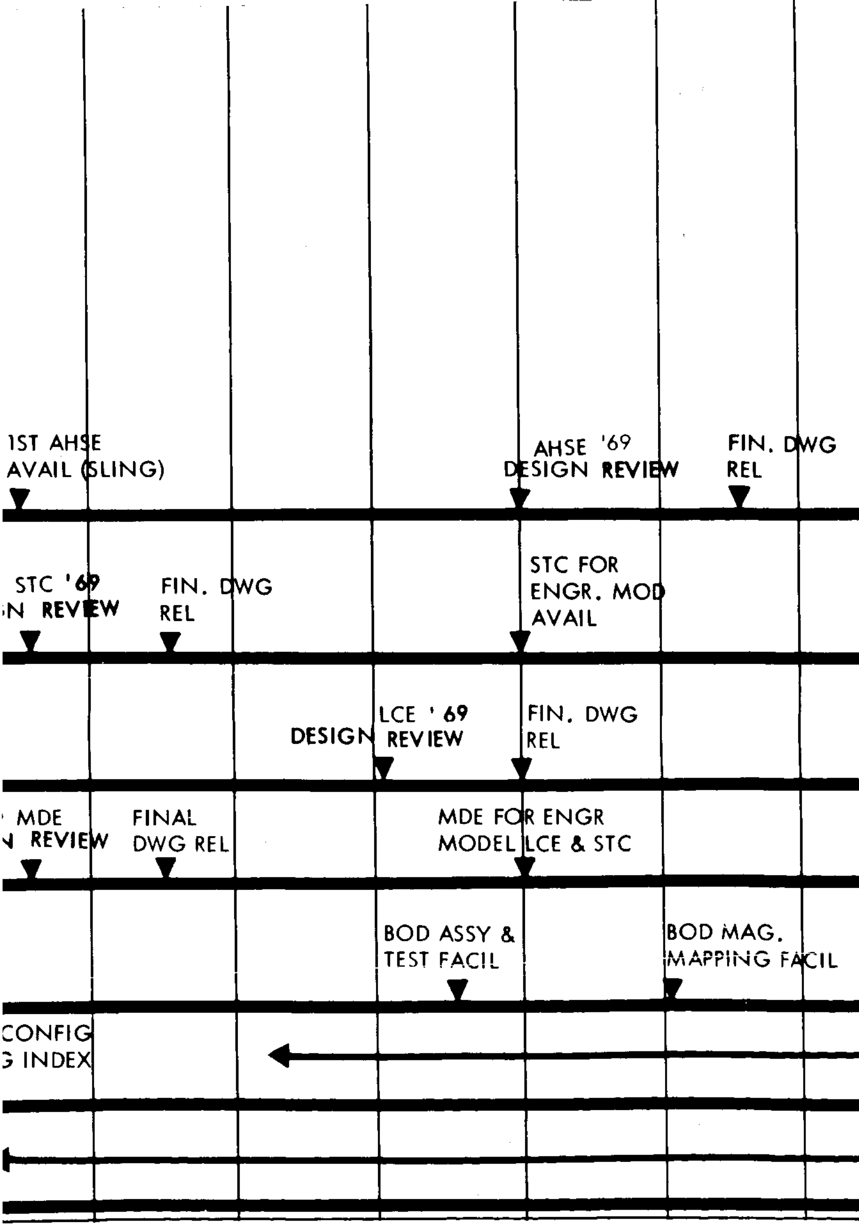


START AHSE DEVELOPMENT
START STC BREADBOARD DESIGN & TEST
START LCE BREADBOARD DESIGN & TEST
START MDE BREADBOARD DESIGN & TEST
INITIAL FAC PLAN REL
REV & IMPLEM. SPECS REC'D FROM JPL
ESTAB MGMT - TEAM & PROGRAM CONTROL
SUBMIT UPDATED PHASE IB MGMT PLANS
IMPLEMENT APPROVED PHASE IB MGMT PLAN

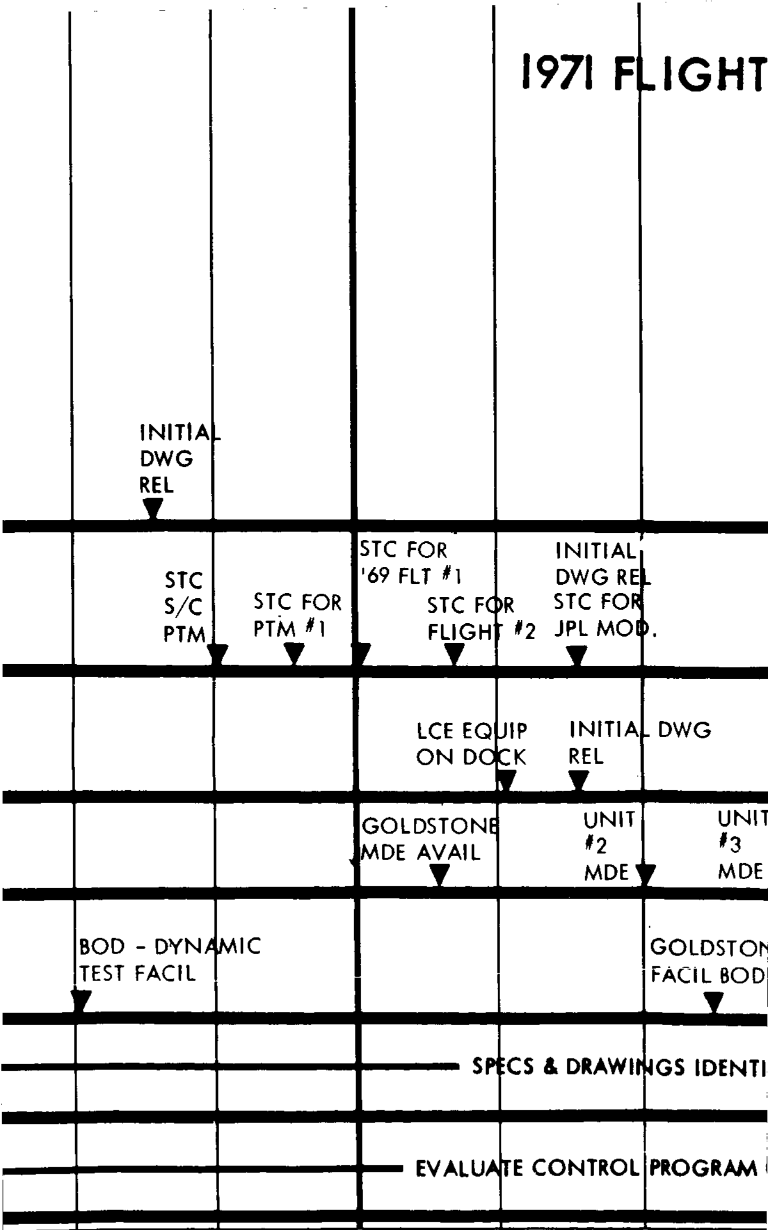
43

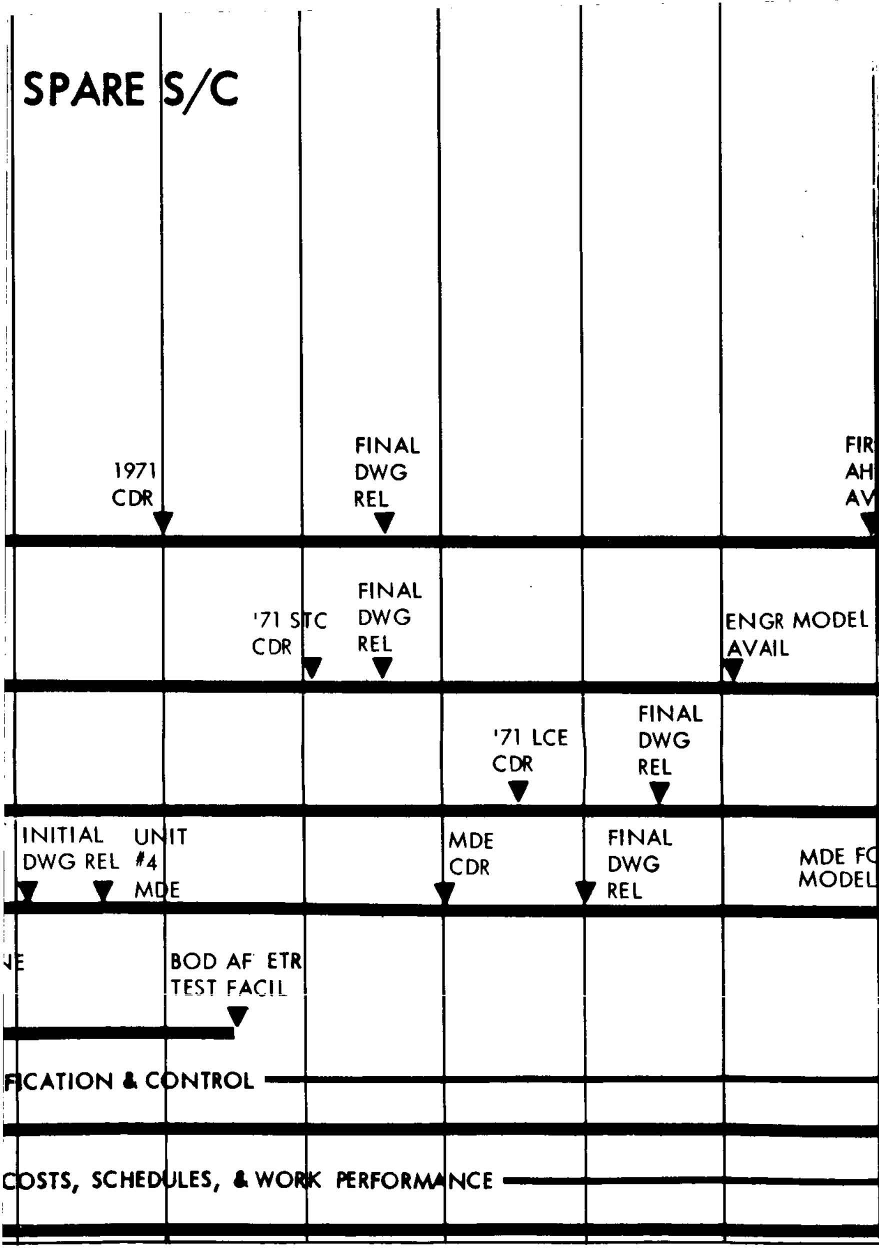

AHSE INTERFACE
CONTROL
DRAWINGS
STC INTERFACE
CONTROL DWGS
LCE INTERFACE
CONTROL DWGS
MDE INTERFACE
CONTROL DWGS
PHASE II FACIL
PLAN REL
ESTAB CONFIG
CONTROL CENTER
COMPL. PHASE II
PROG. PLANS, SCHED. & COSTS
ESTAB. PROJECT CONTROL CEN


INITIAL DWG REL
INIT. DWG REL
DESIG
INIT. DWG REL
INITIAL DWG REL
196
DESIG
START VERIF OF EQUIP CONFIG
REL 1ST & ACCT
ER



1ST AHSE AVAIL (SLING)
AHSE '69 DESIGN REVIEW
FIN. DWG REL
STC '69
N REVIEW
FIN. DWG REL
STC FOR ENGR. MOD AVAIL
LCE '69 DESIGN REVIEW
FIN. DWG REL
MDE
N REVIEW
FINAL DWG REL
MDE FOR ENGR MODEL LCE & STC
BOD ASSY & TEST FACIL
BOD MAG. MAPPING FACIL
CONFIG
G INDEX


1971 FLIGHT
INITIAL DWG REL
STC S/C PTM
STC FOR PTM #1
STC FOR '69 FLT #1
STC FOR FLIGHT #2
INITIAL DWG REL STC FOR JPL MOD.
LCE EQUIP ON DOCK
INITIAL DWG REL
GOLDSTONE MDE AVAIL
UNIT #2 MDE
UNIT #3 MDE
BOD - DYNAMIC TEST FACIL
GOLDSTON FACIL BOD
SPECS & DRAWINGS IDENTI
EVALUATE CONTROL PROGRAM


SPARE S/C
1971 CDR
FINAL DWG REL
FIR AH AV
'71 STC CDR
FINAL DWG REL
ENGR MODEL AVAIL
'71 LCE CDR
FINAL DWG REL
INITIAL DWG REL
UNIT #4 MDE
MDE CDR
FINAL DWG REL
MDE FC MODEL
NE
BOD AF ETR TEST FACIL
FICATION & CONTROL
COSTS, SCHEDULES, & WORK PERFORMANCE

1971 FLIGHT

1971 FLIGHT

ST
SE
AIL

1ST STC
AVAIL '71

STC
S/C
PTM

STC
PTM
#2

STC
FOR
FLT
#1

STC
FOR FLT
#2

ST
JP
MO

FIRST LCE
AVAIL

LCE
EQUIP
ON DOCK

R ENGR
STC – LCE

FIRST
MDE
AVAIL

49

START
PLANNING

FAB & SUBASSY
'71 FLT SPARE

S/C #1

FA
'7

S/C #2

C FOR

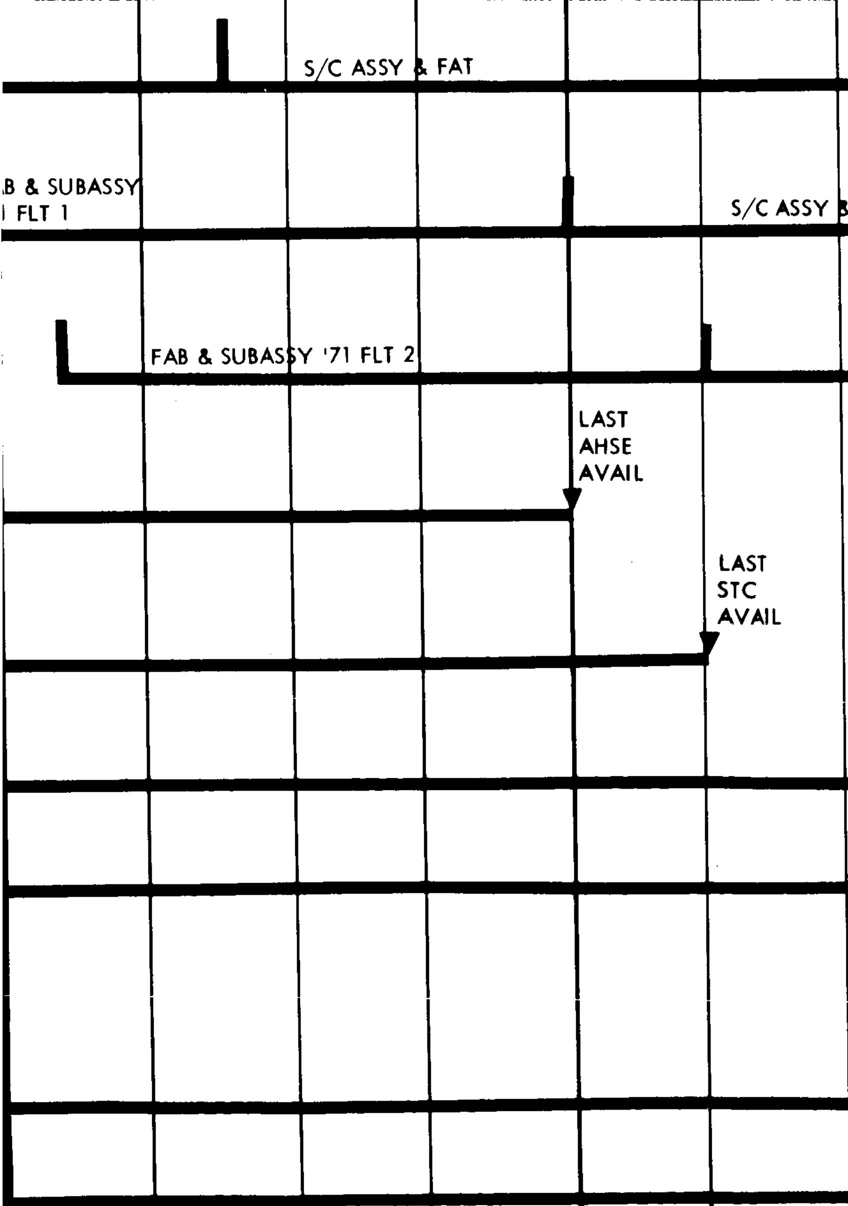
DDEL

GOLDSTONE MDE
VAIL

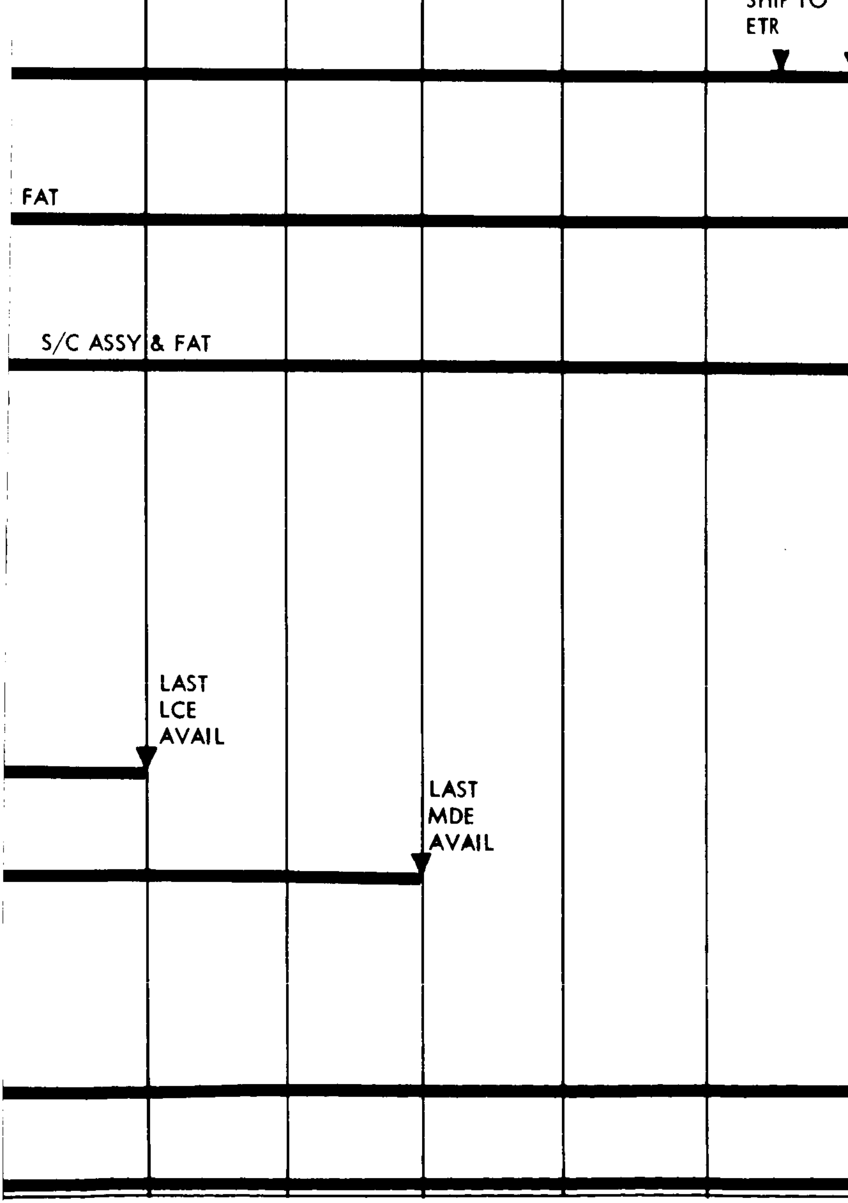
UNIT
#2 MDE

UNIT
#3
MDE

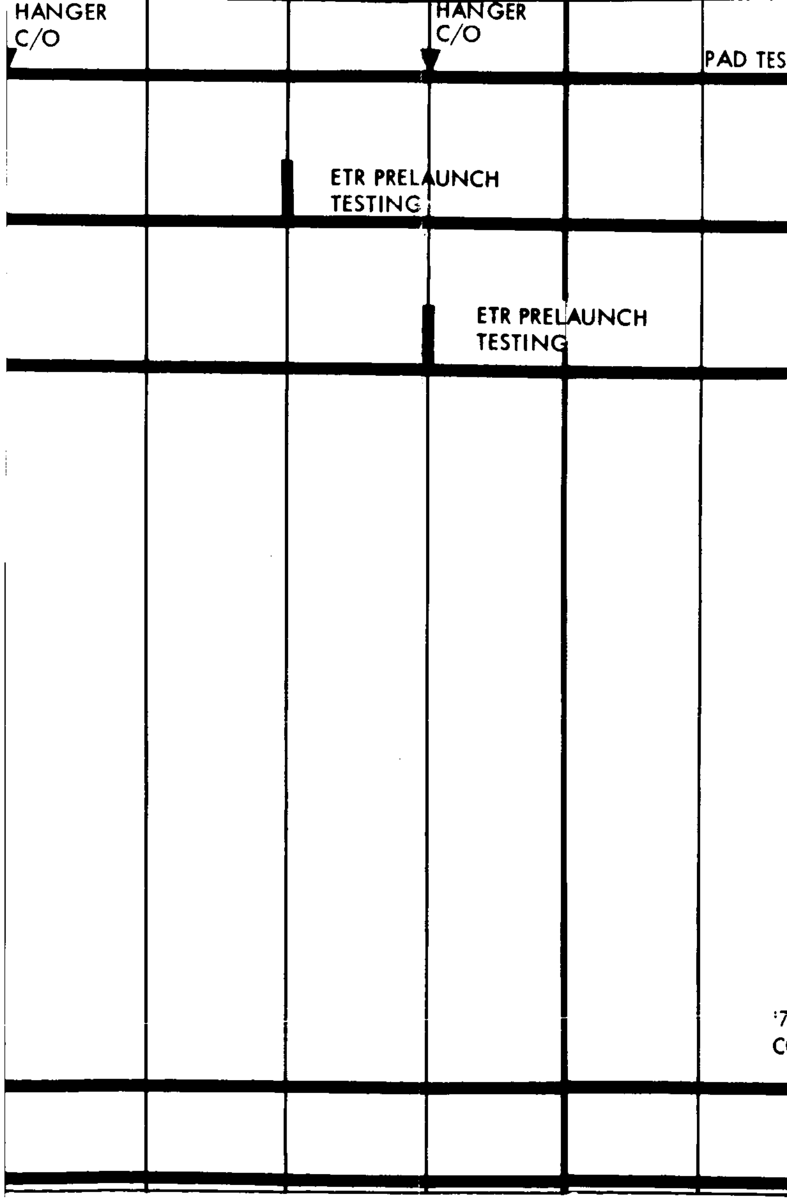
UNIT
#4
MDE

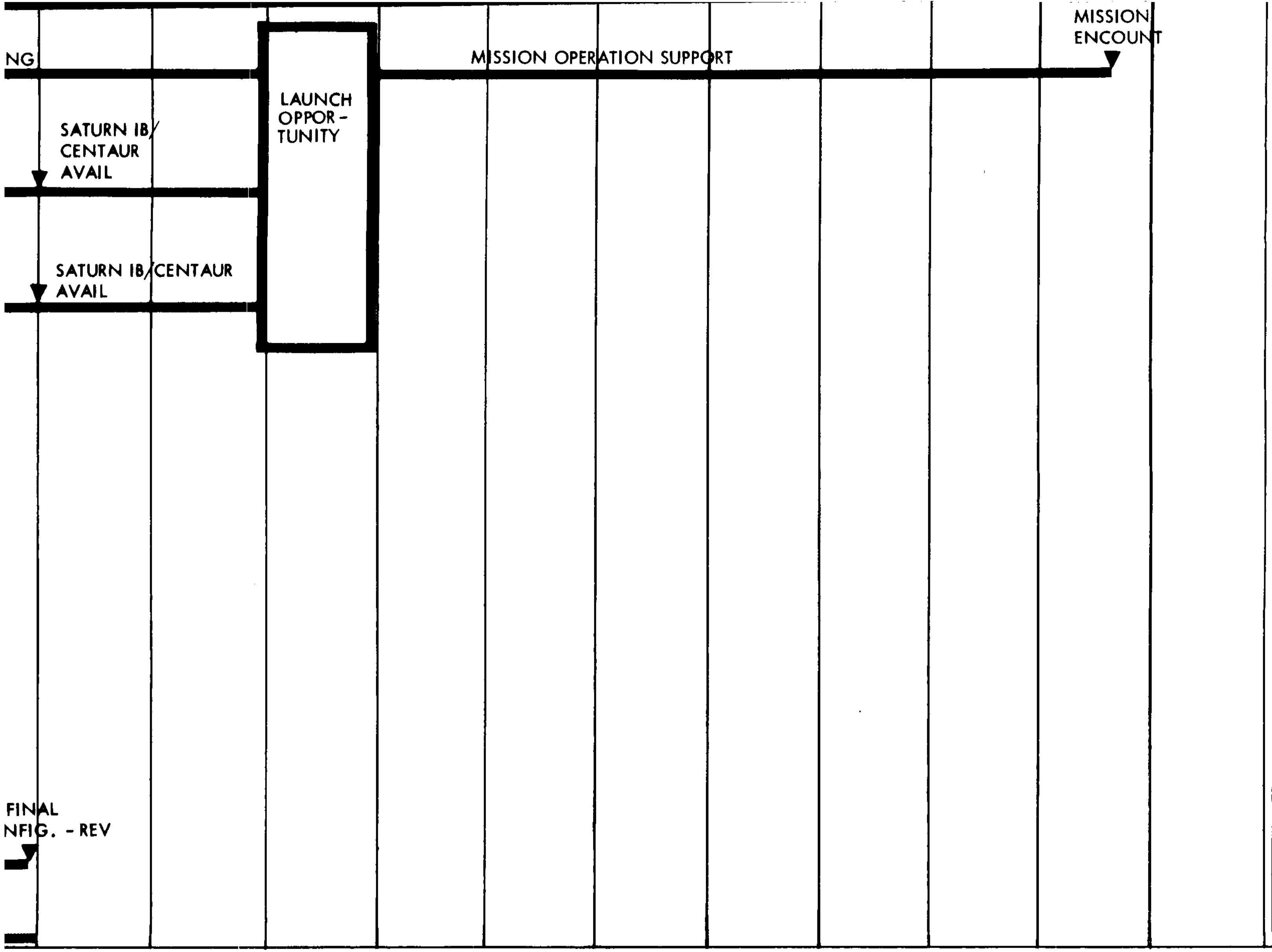


S/C ASSY & FAT
B & SUBASSY
FLT 1
S/C ASSY
FAB & SUBASSY '71 FLT 2
LAST
AHSE
AVAIL
LAST
STC
AVAIL



ETR
FAT
S/C ASSY & FAT
LAST
LCE
AVAIL
LAST
MDE
AVAIL


HANGER C/O
HANGER C/O
PAD TES
ETR PRELAUNCH TESTING
ETR PRELAUNCH TESTING


NG
SATURN IB/
CENTAUR
AVAIL
SATURN IB/CENTAUR
AVAIL
LAUNCH
OPPOR-
TUNITY
MISSION OPERATION SUPPORT
MISSION
ENCOUNT
FINAL
NFIG. - REV