VOYAGER SUPPORT STUDY

IMPLEMENTATION DEFINITION

FINAL REPORT

TRW
SYSTEMS GROUP

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IMPLEMENTATION DEFINITION

FINAL REPORT

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TRW SYSTEMS
ONE SPACE PARK
REDONDO BEACH, CALIFORNIA

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1. INTRODUCTION

A major goal in implementing Voyager is to achieve a program with an inherent capacity for evolving effectively in the coming decade while at the same time retaining for the sake of economy the maximum amount of standard, unchanging elements. This goal has led to the concept of a standard spacecraft and capsule, basically unaltered after their original development, and, for the program under consideration covering six launches, three generations of landed experimental and exploratory gear. The Implementation Definition Task of the TRW Voyager Support Study reported here is a sequel to the previous completed Advanced Mission Definition Study (TRW report 04480-6001-R000, November 1966), which presented such an approach. The project concept developed in this earlier work has been extended in terms of implementation definition covering developmental and operational activities, schedules, and project costs.

Although studied in terms of such a reference program, the basic objective has been to achieve an understanding of the means by which the Voyager project can most effectively and economically be pursued. Although the actual Voyager project may differ from the derived approach, many of the implementation considerations discussed should nevertheless be applicable. The approach for the study has been to identify and evaluate alternatives so as to arrive at a reference implementation definition. Such a reference is not intended to represent a definitive recommendation, however, but rather to facilitate the investigation and evaluation of the various alternatives within a consistent framework.

The underlying motivation for the study, as well as for the preceding advanced mission definition work, has been to generate independent input regarding Voyager program definition. In addition, there will be differences between the study material and current Voyager planning since the study groundrules were established in April 1966. Many of the assertions about the Voyager program are made in the context of the reference approach and so may not apply to current official plans. Although an effort has been made to stay within basic NASA project implementation policy in laying out this overall framework, many Voyager-peculiar considerations have been formulated on an independent basis.

Although based on the advanced mission definition work, the present document recaps this previous technical plan and descriptions of the system elements in order to be essentially self-sufficient. A general framework covering project organization and management, implementation phasing, and various project-level considerations is described in Sections 4 through 10. Implementation definition is then presented individually for the major system elements in Sections 11 through 19. The project cost data is provided in a separate report supplement. There is also an accompanying summary volume.

In examining the development of the capsule system, substantial use has been made of the work completed in this area by Grumman Aircraft Engineering Corporation. Similarly we have made extensive use of the recent work by the AC Defense Laboratories of the General Motors Corporation on the Voyager mobile unit.

2. PROJECT SCOPE AND GOALS

Voyager is a NASA program for carrying out unmanned planetary exploration, with an initial mission in 1973. It utilizes a new generation of automated spacecraft, more advanced than any previously flown, which are to be launched by the Saturn V booster. The program is to significantly extend the scientific exploration of the solar system begun by Mariner, Ranger, and Pioneer. This exploration can be described in overall terms by the following three primary objectives:

- To gain knowledge about the origin of the solar system and planetary evolution
- To gain knowledge about the origin, evolution, and nature of life
- To apply this knowledge to a better understanding of terrestrial life

While not specifically an objective of the program, the technologies developed and the scientific and engineering data obtained will prove invaluable in support of later manned exploration of Mars.

Although ultimately concerned with exploration of much of the solar system, current Voyager plans are concerned mainly with Mars. Therefore, Voyager project planning has emphasized the exploration of Mars, and this planet has been selected as the initial target for detailed exploration. This selection is based on the assessment that Mars offers the best possibility for yielding information regarding extraterrestrial life. Mars exploration also offers substantial benefits in planetary science and related technology on an early time scale, and this will be useful for subsequent exploration of Venus and for other more difficult planetary missions.

The current study is limited to the program of Mars missions covering launch opportunities for 1973 - 1984. In keeping with overall Voyager goals, the Mars program is to obtain information relative to the existence and nature of extraterrestrial life, the atmospheric, surface, and body characteristics of the planet, and the planetary environment.

The biological exploration of Mars is to receive the highest priority. However, specific biological questions are to be considered as part of an ordered sequence of exploration whose purpose is to understand the overall evolution of the planet's crust and atmosphere.

The most significant feature of the Mars program under consideration is the comprehensive nature of the projected exploration. This exploration is expected to lead to a significant level of understanding regarding the planet; and will include an evolving program of unmanned surveys and experiments on a wide front of scientific inquiry, by making use of both orbital and surface operations. Such a program will require large landed payloads on the Martian surface having a substantial and sophisticated automated laboratory capability. At the same time, the need is recognized to acquire early data on the Martian environment as required for design of later advanced missions and subsequent manned exploration. An efficient exploration program is required that takes engineering requirements into account but also puts priority on the activity and data that have maximum relevance for achieving the desired degree of ultimate understanding.

3. TECHNICAL PLAN

The technical plan upon which the present implementation definition study is based corresponds to the results of the Advanced Mission Definition Task as documented in Reference 1. Some general features of this plan are as follows:

- Comprehensive Mars exploration on an expeditious basis
- Initial orbiting and landing missions at the 1973 launch opportunity
- Precursor life detection mission as a prerequisite for definition of the ultimate surface laboratory
- A two- or three-step surface laboratory development
- A standard flight spacecraft with payload changes as appropriate, with propellant loading varied from mission to mission
- A standard flight capsule (less science) sized for the advanced mission payload and offloaded for earlier missions as appropriate

3.1 PROJECT STRATEGY AND EVOLUTION

The basic concept to be applied in considering project strategy is to recognize the evolutionary aspects of the Voyager program. This concept arises because the development lead time for any particular launch opportunity is usually too long to allow substantial application of results from one launch opportunity to the next. A significant advance in system development that requires previous mission experience can occur only after skipping one launch opportunity. Thus any major stage of development is applicable to a set of at least two missions, and such a set is designated as encompassing one mission generation. For the program under consideration covering six launch opportunities, three such generations are possible. Because the basic flight spacecraft and flight capsule are "standardized," project evolution relates primarily to the science payloads, which is dominated by landed science considerations.

The reference project approach calls for either two or three generation programs, as illustrated in Figure 1, depending on what is discovered on Mars. A simplified precursor landed science payload is utilized in the first generation 1973 and 1975 missions. There are then two main alternatives, depending on the results of the initial missions. If life is detected and cultured, then definition and development of the final surface laboratory can proceed. If life is not detected or cultured on the first generation, we proceed to a mission generation which lands a comprehensive precursor payload. This incorporates a long-life automated laboratory whose details will be based on data derived during the first generation but which will provide life detection experiments rather than the capability for advanced biological investigations, since if life is not detected there will be insufficient evidence for defining the requisite advanced laboratory characteristics. On the basis of the more thorough findings from this second generation, then, the third generation will incorporate an advanced surface laboratory to permit sophisticated biological investigations utilizing microbiological experimentation or biochemical analysis as appropriate.

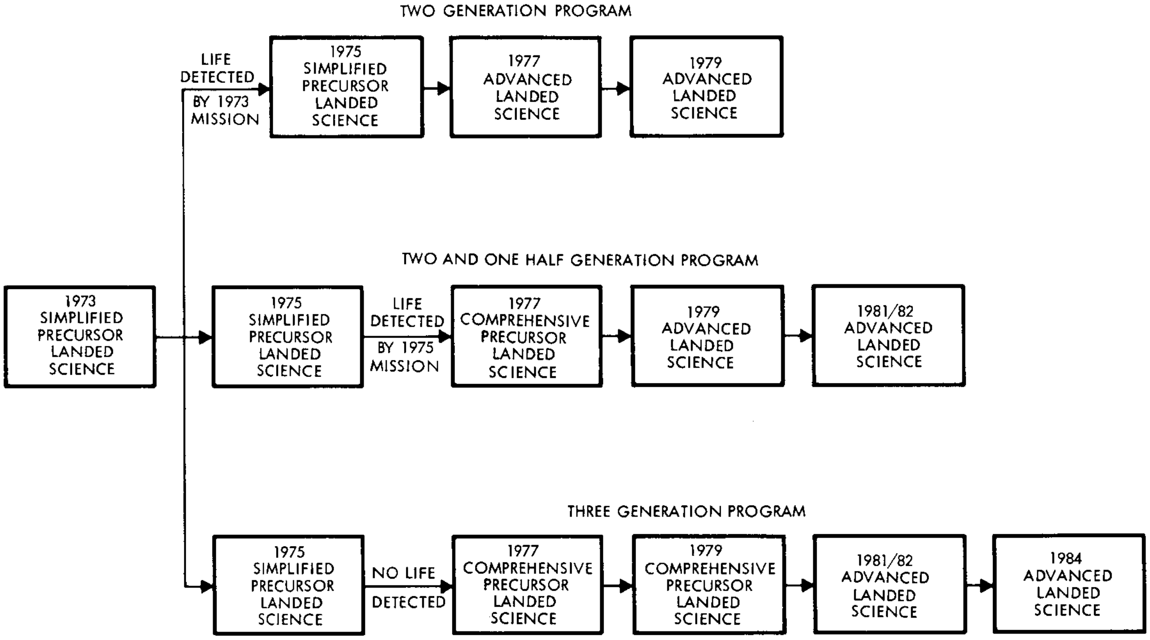


Figure 1 Voyager Program Progression

The strategy thus calls for a standardized basic capsule, flight spacecraft, landed science support, and an approach to the landed science payloads permitting a three-generation evolution utilizing the three landed science building blocks described below.

1) Simplified Precursor Landed Science

A simplified landed science payload is appropriate to reduce the developmental complexity associated with the first generation missions. This corresponds to a simplified precursor laboratory which must be consistent with the limited development span available for the initial (1973) Mars surface mission. Nevertheless, it is to provide considerable life-detection capability with biological culturing experiments and visual imaging, as well as extensive environmental instrumentation. It also incorporates a test version mobile unit to provide remote sampling and a development base for the advanced mobile unit to be utilized in later generation missions. The simplified precursor landed science is characterized as follows:

- Weight: 440 pounds
- Simplified instrument complement
- Simplified biological detection culture experimentation
- Simplified computer and data automation
- Test version mobile unit

2) Comprehensive Precursor Landed Science

An additional precursor mission may be required beyond the first generation to determine whether macroscopic life exists on Mars and whether Martian microorganisms exist and can be cultured. Answers to these critical questions are required before arriving at the final surface laboratory concept and design. In keeping with such a requirement, a comprehensive precursor landed science payload has been defined as a long-stay payload having an extensive exploratory life detection capability. Thus it includes comprehensive biological culturing experimentation with various nutrient media under controlled conditions and in situ, rather than the capability for sophisticated microbiological investigations and biochemical analysis. It includes a visual imaging capability at various resolutions to scan the landing site environs for macroscopic life, and in other respects such as environmental instrumentation, sampling, computer control, and data handling, it represents a "core" advanced surface laboratory. That is, it provides the advanced capability for such functions, at least in prototype version. The comprehensive precursor payload can be characterized as follows:

- Weight: 760 pounds
- Comprehensive instrument complement
- Substantial exploratory biological detection culture experimentation
- Advanced sampling system, including mobile unit with TV monitoring
- Advanced computer and data automation

3) Advanced Landed Science

The advanced mission is characterized by an extensive experimental capability, associated with a sophisticated surface laboratory. Its weight has been estimated at about 1200 pounds and it has the following features:

- Integrated laboratory with central functions
- Comprehensive biological and planetological investigations
- Balance between microbiology and biochemistry based on precursor missions
- Automated by computer control
- Mobile sampler with TV monitor

In keeping with the above landed science payloads, we define the following flight capsule building blocks:

1) First generation flight capsule (6985 pounds)

- Simplified precursor laboratory

- Standard science support
- Standard canister and descent systems, offloaded

2) Intermediate flight capsule (7330 pounds)
   - Comprehensive precursor laboratory
   - Standard science support
   - Standard canister and descent systems, offloaded

3) Advanced flight capsule (8000 pounds)
   - Advanced surface laboratory
   - Standard science support
   - Standard canister and descent systems

3.2 MISSION OBJECTIVES

Objectives for the reference sequence of missions are defined as follows:

1) 1973 Mission (First Generation Flight Capsule)

   a) Demonstrate operation of the standard spacecraft for use throughout the subsequent series of Mars missions; this includes the out-of-orbit capsule delivery mode and continued orbital operations for a period of six months, with a design goal of two years or more.

   b) Perform an orbital science mission emphasizing extensive surface mapping to provide an initial map base and to indicate areas of special interest for subsequent investigation. In particular, such surveys will attempt to correlate local surface investigations by the lander with global phenomena and to develop a basis for the selection of subsequent landing sites.

   c) Demonstrate operation of the standard capsule for use throughout the subsequent series of Mars missions; this includes descent and soft landing and continued surface operations for a period of two months, with a design goal of two years or more.

d) Perform a surface science mission in keeping with the simplified precursor landed science. In particular, basic life detection experiments are to be conducted including imaging and culturing. A test version mobile unit is incorporated to provide remote sampling and to achieve a developmental base for the advanced mobile unit.

e) Develop and demonstrate multisystem mission operations, including high data rate transmission capability from the orbiter and the use of relay link as well as direct transmission from the capsule landed payload.

2) <u>1975 Mission (First Generation Flight Capsule)</u>

Repeat the 1973 mission with minor changes in system design and scientific operations as indicated by the 1973 mission results, and as compatible with schedule constraints. Landing sites will be selected on the basis of the 1973 results.

3) <u>1977 Mission (Intermediate Flight Capsule)</u>

a) Incorporate and demonstrate any major system improvements indicated by results from the 1973 and 1975 missions.

b) Perform an orbiting mission with upgraded imaging capability (resolution of 1 or 2 meters) for detailed investigations of particular areas of interest determined previously. Extend global mapping at the appropriate medium resolution to cover new areas and to extend results for various colors and polarization filters.

c) Perform a surface mission in keeping with the comprehensive precursor landed science. This involves more comprehensive life detection experiments than for the first generation, such as use of a wider variety of nutrients and controlled conditions along with in situ culturing. It also involves demonstration of prototype versions of surface laboratory core equipment such as the mobile unit, proximity sampler, sample handling and processing mechanisms, and sophisticated computer control and data automation.

4) 1979 Mission (Intermediate Flight Capsule)

Repeat the 1977 mission with minor changes in system design and scientific operations as indicated by the 1977 mission results and as compatible with schedule constraints.

5) 1981-82 Mission (Advanced Flight Capsule)

a) Incorporate and demonstrate any system changes associated with accommodating and supporting the advanced surface laboratory. Orbiter missions will correspond to orbits for enhanced relay communication support, although mapping activities will be continued.

b) Perform a surface mission in keeping with the advanced surface laboratory as defined on the basis of the precursor missions for 1973, 1975, 1977, and corroborated by the 1979 mission. This will include comprehensive biological and planetological investigations utilizing an appropriate balance between biological and biochemical techniques.

6) 1984 Mission (Advanced Flight Capsule)

Repeat the 1981-82 mission with minor changes in system design and scientific operations as indicated by the previous mission results, to further validate the results of the previous mission.

3.3 PROJECT ELEMENTS

3.3.1 Systems

The first-level major work breakdown segments for a NASA project are designated as systems. In keeping with this work breakdown definition, such systems correspond to the project organizational structure just below the project level. This structure then corresponds to administrative or contractual alignments having direct responsibility for the related work. At the same time each system is related to some principal functional entity for the project. For the reference Voyager project of the current study there are six such systems:

- Launch Vehicle System
- Spacecraft System
- Capsule System

- Launch Operations System
- Mission Operations System
- Tracking and Data Acquisition System

The first three of these six systems relate to major flight hardware items, while the second three relate to major operational facilities and associated functions. Additional definition of these systems is given below in terms of the related functional elements of hardware, software, facilities, and personnel.

3.3.1.1 Launch Vehicle System

The launch vehicle system corresponds to the project work breakdown for the following:

- Launch vehicle flight hardware, which includes the Saturn V booster, the Voyager shroud and associated spares
- Launch vehicle operational support equipment and associated spares
- Launch vehicle development and manufacturing facilities and support equipment peculiar to the Voyager project
- Launch vehicle contractor personnel assigned to support the launch operations at KSC

3.3.1.2 Spacecraft System

The spacecraft system corresponds to the project work breakdown for the following:

- Spacecraft flight hardware, which corresponds to the spacecraft bus, spacecraft propulsion, the planetary vehicle adapter, launch vehicle mounted spacecraft support equipment if required, and associated spares
- Spacecraft operational support equipment and associated spares
- Mission-dependent equipment for handling spacecraft telemetry data and commands at DSN stations, with associated spares
- Facilities at KSC to assemble and prepare the flight spacecraft and planetary vehicle for launch

- Facilities and support equipment for development and delivery of spacecraft system hardware and for planetary vehicle testing
- Spacecraft developmental hardware
- Software associated with the above
- Spacecraft contractor personnel assigned to develop and deliver spacecraft system hardware and software
- Spacecraft contractor personnel assigned to prepare the spacecraft and planetary vehicle for launch and to support prelaunch, launch, and flight operations

3.3.1.3 Capsule System

The capsule system corresponds to the project work breakdown for the following:

- Capsule flight hardware, which includes the flight capsule, related support equipment mounted on the spacecraft or launch vehicle, and associated spares
- Capsule operational support equipment and associated spares
- Mission-dependent equipment for handling capsule direct link telemetry and commands at DSN stations, with associated spares
- Facilities at KSC to assemble and prepare the capsule flight hardware for launch
- Facilities and support equipment for development and delivery of capsule system hardware
- Capsule developmental hardware
- Software associated with the above
- Capsule system contractor personnel assigned to develop and deliver capsule system hardware and software
- Capsule system contractor personnel assigned to prepare capsule equipment for launch and to support prelaunch, launch, and flight operations

3.3.1.4 Launch Operations System

The launch operations system corresponds to the project work breakdown for the following:

- KSC Complex 39 facilities assigned to Voyager
- All operational support equipment used in prelaunch and launch operations that is not part of any other system
- Software associated with the above
- NASA and/or operational contractor personnel required for develop and test the above
- Operational personnel required for preflight operations not assigned to any other system
- Support from the Air Force Eastern Test Range

3.3.1.5 Mission Operations System

The mission operations system corresponds to the project work breakdown for the following:

- Parts of the SFOF assigned to support Voyager
- Mission-dependent equipment not part of any other system, with associated developmental hardware and spares
- Facilities and support equipment for development and delivery of the above
- Software assigned to develop and deliver hardware and software for Voyager mission operations
- Operational personnel carrying out mission operations and not assigned to any other system

3.3.1.6 Tracking and Data Acquisition System

The tracking and data acquisition system corresponds to a project work breakdown for elements of the following systems that are assigned to support the Voyager project for tracking and data acquisition and handling of mission data and commands.

- Deep Space Net (DSN), made up of the Deep Space Instrumentation Facility (DSIF), the Space Flight Operations Facility (SFOF), and the Ground Communications System (GCS)
- Goddard Space Flight Center network facilities, including the Manned Space Flight Net (MSFN) stations or others, such as the AFETR network, if required

3.3.2 Flight Hardware Elements

The major elements of mission flight hardware are defined below.

1) Launch Vehicle. The launch vehicle consists of the Saturn S-IC stage, S-IC/S-II interstage, S-II stage, S-II/S-IVB interstage, S-IVB stage, instrument unit, and shroud. The shroud is peculiar to Voyager and allows for individual encapsulation and handling of the planetary vehices.

2) Planetary Vehicle. A planetary vehicle consists of one flight capsule and one flight spacecraft mated for launch.

3) Flight Capsule. A flight capsule consists of a lander and a canister/adapter as in Figure 2. The lander is the element that separates and descends to the Martian surface; it is made up of a capsule bus and the capsule science. The capsule science consists of an entry payload that functions only during descent and the landed science that operates on the surface. The canister/adapter serves to attach the flight capsule to the flight spacecraft and to support the lander while maintaining its sterile condition. It consists of the capsule adapter, aft canister, and the canister lid.

4) Flight Spacecraft. A flight spacecraft consists of a spacecraft bus, spacecraft propulsion, and a spacecraft science subsystem.

5) Planetary Vehicle Adapter. A planetary vehicle adapter consists of all structure, cabling, and hardware located between a planetary vehicle in-flight separation joint and the associated points of attachment to the shroud. It includes all spacecraft system flight hardware that remains attached to the launch vehicle after separation of a planetary vehicle.

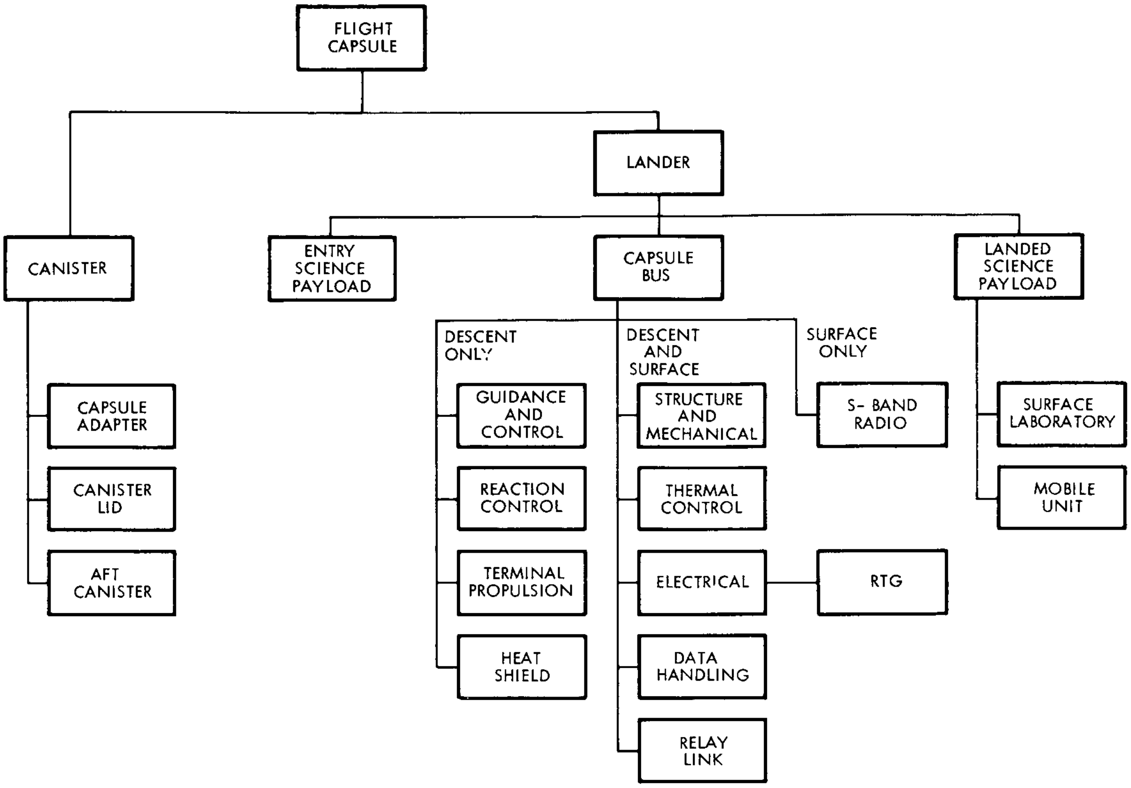


Figure 2. Flight Capsule Breakdown

3.3.3 Mission-Dependent Equipment

Mission-dependent equipment is the operational data handling equipment required at ground stations, solely for the support of Voyager. It is required primarily for the handling of mission data and commands. It operates in conjunction with the general purpose communication and data handling equipment at existing ground stations. The development, modification, and maintenance of this equipment is the responsibility of the Voyager system which provides the particular equipment element.

3.3.4 Operational Support Equipment

Operational support equipment includes the launch vehicle ground support equipment; assembly, handling, and shipping equipment; special test equipment; the spacecraft and capsule system test complexes, the spacecraft and capsule launch complex equipment; and spacecraft simulation equipment required at tracking and data acquisition sites.

3.4 PROJECT CONSTRAINTS AND REQUIREMENTS

3.4.1 Specified Constraints

Current Voyager plans call for the first Voyager mission during the 1973 Mars opportunity and the second mission during the 1975 Mars opportunity. The 1973 and 1975 mission plans are to launch two planetary vehicles on a single Saturn V launch vehicle from Complex 39 at Kennedy Space Center during each opportunity. Each planetary vehicle is to consist of a flight spacecraft and a flight capsule. A shroud diameter compatible with the S-IVB stage diameter is to be assumed.

The Deep Space Net is to provide tracking and data acquisition support after interplanetary trajectory injection. The 210-foot antennas at the Goldstone, Madrid, and Tidbinbilla sites are to be available. Mission operations from injection into an earth parking orbit to end of mission will be centrally controlled and conducted from the SFOF.

The probability that the quarantine of Mars is violated prior to calendar year 2021 as a result of launching two planetary vehicles during a single Mars opportunity is not to exceed 2 x 10^{-4}. The "Planetary Quarantine Plan Voyager Project," Jet Propulsion Laboratory, dated 15 March 1966, as revised 1 January 1967, will be followed in meeting this requirement.

The following order of precedence has been established for science information to be obtained from first generation missions:

1) Environmental data primarily of use in development, design, and operation of equipment for subsequent missions

2) Biologically relevant information primarily supporting the scientific objectives, either directly or by assisting in definition of subsequent biologically relevant experiments

3) Information concerning the nature and history of the planet

4) Interplanetary investigations

3.4.2 Selected Project Guidelines

The Voyager project is expected to lead to a significant level of understanding regarding the planet. The program of exploration is to be generally in accord with recommendations of the Space Science Board of the National Academy of Sciences, and in particular will require large landed payloads on the Martian surface having a sophisticated automated laboratory capability. A precursor biological mission to carry out life detection experiments and to search for macroscopic life is a prerequisite for definition of the ultimate advanced surface laboratory. All missions will utilize soft landings on Mars.

The use of existing hardware, facilities, and procedures is to be emphasized and will be the preferred approach whenever suitable. In addition, the use of standardized hardware for all missions will be emphasized.

Final assembly, checkout, and other prescribed activities will be performed at KSC to ready the space vehicle for launch. Spacecraft and capsule system prelaunch assembly and checkout will be conducted at separate assembly facilities. An explosive safe area (ESA) will be used for propellant and gas loading, final spacecraft alignment, installation of other hazardous components, assembly of the flight capsules and flight spacecraft into planetary vehicles, encapsulation of the planetary vehicles within the shroud sections, and final ETO decontamination. The planetary vehicles will be mounted to the launch vehicle while encapsulated in the shroud sections. After encapsulation the planetary vehicles will be maintained in a sealed condition with access limited to radio telemetry, radio command, and umbilical links.

Type I trajectories are preferred but Type II are acceptable when necessary. The type of trajectory and illustrative trajectory data for each launch opportunity consistent with this technical plan and applicable ground rules and constraints are given in Table 1. The propellant loading for each opportunity will be selected to achieve the most desirable combination of launch period and orbit at Mars, subject to the maximum loading that is compatible with a blowdown mode of propulsion operation for midcourse corrections.

Table 1. Trajectory Information

	Launch Opportunity					
	1973	1975	1977	1979	1981/82	1984
Trajectory Type	I	II	I	I	II	II
Orbit size, km x 10^3	1.1 x 10	1 x 20	1 x 20	1 x 20	1.2 x 5	1 x 20
Launch date						
Initial	July 7	July 19	Oct 28	Nov 13	Nov 3	Dec 13 '83
Final	Aug 15	Aug 7	Nov 16	Dec 2	Dec 2	Jan 1
Arrival date						
Initial	Jan 26	May 28	July 15	July 11	Sep 13	Oct 14
Final	Jan 26	June 29	Aug 20	July 11	Sep 13	Oct 14
Communication distance at encounter, km x 10^6						
Initial	161.2	287	293	235	230	164
Final	161.2	323	323	235	230	164
Transit time, days						
Initial	203	314	260	241	314	276
Final	164	327	277	222	285	257
C_3, twice the injection energy per unit mass, km^2/sec^2						
Initial	18.41	32.8	20.0	11.1	14.4	14.5
Final	18.33	22.9	29.2	16.2	9.8	14.9
Extreme	14.74	-	-	-	9.6	13.3
V_∞, hyperbolic excess velocity at Mars, km/sec						
Initial	3.31	2.43	2.74	3.94	3.13	3.58
Final	3.48	2.38	2.53	3.98	3.11	3.90
Extreme	3.27	2.37	2.46	-	3.06	
DLA, declination of launch asymptote, deg						
Initial	35.2	7	50	34.9	12.5	15.0
Final	14.7	6	32	26.7	33.5	25
ZAL, angle between departure asymptote and sun-earth vector, deg						
Initial	116.9	150	58	70	138	138
Final	61.7	131	33	42	*	*
INC, inclination of heliocentric transfer plane to ecliptic, deg						
Initial	2.6	-2.7	3.6	1.8	1.6	2.6
Final	1.2	-2.5	1.4	1.0	2.5	3.5
SG1, semimajor axis of dispersion ellipse in RT plane, assuming 0.1 m/s error in each of three orthogonal directions a few days after injection, km						
Initial	2900	5500	2000	*	*	*
Final	1425	7300	4900	*	*	*
SG2, semiminor axis of dispersion ellipse, km						
Initial	826	590	1100	*	*	*
Final	736	520	250	*	*	*
θ, angle between $\overline{T}$ axis and SG1 measured clockwise from $\overline{T}$, deg						
Initial	123	139	98	*	*	*
Final	148	43	5	*	*	*
ZAP, angle at Mars between approach asymptote and Mars-sun vector, deg						
Initial	128.5	89	120	146	88	90
Final	142.0	81	85	141	95	95
LVI, latitude of vertical impact point on Mars, deg						
Initial	7.2	-28	30	28	*	*
Final	-3.0	-30	10	21	*	*
ZAE, angle at Mars between approach asymptote and the Mars-earth vector, deg						
Initial	150.8	120	150	*	*	*
Final	164.7	106	110	*	*	*

*Not available

The flight capsule is to be inserted into Mars orbit by the flight spacecraft as part of the planetary vehicle. Subsequently, the lander will separate and descend to the Martian surface.

3.4.3 Mission Requirements

3.4.3.1 Flight Readiness

Each system will demonstrate flight readiness and compatibility with all interfacing systems during the integrated systems tests described later in this report. These tests will be designed to ensure operability of all systems when combined for the mission and will be conducted in Complex 39 at KSC.

The capability is to be provided for launch from one launch pad in a 20-day period with a probability of 0.99. In calculating this probability, it will be assumed that the daily firing window is two hours and that no launch holds are caused by the planetary vehicle.

3.4.3.2 Flight Sequencing and Command

The system design will provide the capability for carrying out the flight mission automatically without ground command on a nominal flight if trajectory corrections, trajectory biasing, instrument calibration, or updating of time-dependent and trajectory-dependent sequences are not required.

For critical mission functions, redundant command capability will be provided for all commands initiated on board. Where feasible, radio commands will be utilized as redundant alternates to on-board initiated commands.

Radio command lockup time prior to mission events (assuming the planetary vehicle or flight spacecraft has been acquired by a tracking and data acquisition station) will not exceed 30 minutes (3σ) plus two-way transmission time, and lockup will extend through completion of the event plus 30 minutes. Nominal operations sequences will not require radio command lockup times substantially less than this.

3.4.3.3 Transfer Trajectory

The launch period for the initial (1973) mission will be at least 30 days and for other missions will be at least 20 days. The minimum daily launch window will not be less than two hours. However, the system is to be designed for a capability to accommodate a launch window as short as one hour.

The parking orbit ascent mode will be utilized. The capability to coast in parking orbit between 2 and 90 minutes will be provided by the launch vehicle.

The advanced Voyager missions will have the capability of launching on azimuths between 35 and 120 degrees east of north. The absolute value of the declination of the launch asymptote (DLA) is not to be less than 5 degrees. The inclination of the heliocentric transfer plane to the ecliptic plane is not to be less than 0.1 degree.

Arrival of the planetary vehicles at Mars will be separated by an appropriate interval. A velocity increment of 200 meters per second is to be provided by each planetary vehicle for this separation and for interplanetary guidance corrections. A velocity increment of 100 meters/sec will be provided by each planetary vehicle for Mars orbit trim prior to capsule separation.

An adaptive guidance policy will be employed during the flight; that is, the exact number and location of interplanetary trajectory corrections will not be specified precisely before flight but will depend upon dispersions, trajectory biasing needed to satisfy the quarantine requirements, maneuver size, operational considerations, and other factors. The decision to perform a midcourse correction will be based primarily upon the difference between the predicted and nominal approach aiming intercepts in the $\overline{R}$, $\overline{T}$ plane as estimated at some time prior to Mars encounter.

3.4.4 Design Criteria

The systems will utilize design, manufacturing, test, operational techniques, and procedures designed to maximize mission success or partial success in the event of a noncatastrophic failure. These efforts are to include the following:

- Comprehensive failure-mode and failure-effect analyses and design for partial mission success in the event of noncatastrophic failure
- Establishment and demonstration of design margin adequacy
- Application of functional and parallel redundancy techniques where constraints can be met and increase in reliability can be demonstrated
- Systematic identification and elimination of unreliable items wherever possible

The useful life of all equipment is to be sufficient to include all operating time from initial turn-on through subsystem checkout and acceptance tests, system checkout and acceptance tests, prelaunch tests, and flight operation to the end of anticipated service either in normal or alternate modes of operation.

Three fully qualified flight spacecraft, four fully qualified flight capsules, and the launch vehicle/shroud with a spare shroud cylindrical section will be provided as flight hardware for each mission. No spare launch vehicle will be provided. The flight spacecraft and flight capsules for the same mission will be interchangeable, as will shroud cylindrical sections and the planetary vehicles. No modification to any flight hardware will be planned after the hardware has been shipped to Cape Kennedy. The intent is to limit repairs at KSC to those failures discovered at KSC, and such repairs will be limited to replacement of equipment at the provisional spares level. To the maximum extent, all such spares are to have had previous test history in fully assembled systems. Failed equipment will be returned to its designated maintenance center for repair and possible use on future missions.

The various Mars opportunities place an absolute constraint on the mission schedule; consequently, all design, development, fabrication, testing, and deliveries must conform to the established mission milestones.

3.5 MISSION PROFILE

The operational phase of a Voyager mission includes all ground and flight activities directly associated with a particular Mars launch opportunity after commitment to the mission. The operational phase starts for each flight element at the completion of a mission acceptance review, or after all acceptance tests and training operations have been completed for operational ground elements. The operational mission is complete when all scientific and engineering data have been returned to earth, processed, and delivered to the cognizant person or organization for evaluation. The basic mission profile is shown in Figure 3.

3.5.1 Prelaunch Operations

Prelaunch operations start with acceptance of the flight hardware and include all activities until the terminal countdown for launch.

Four flight capsules will be processed through mission acceptance for each operational mission and transported to Cape Kennedy. At Cape Kennedy, all flight units will be unloaded and transported to the capsule assembly facility. All flight capsules will be prepared for flight with one stored as a spare and the remaining three assembled into planetary vehicles.

Three flight spacecraft will be processed through mission acceptance for each operational mission, and transported to Cape Kennedy for transfer to the spacecraft assembly facility. At the spacecraft assembly facility the spacecraft will undergo receiving inspection, functional testing, and integrated system testing. After these tests the three spacecraft will be transported to the explosive safe area.

The planetary vehicle shrouds are utilized initially in the VAB for launch vehicle compatibility testing, using planetary vehicle simulators. The shroud assemblies will then be transported to the explosive safe area for assembly and integration with the planetary vehicles.

At the Explosive Safe Area (ESA), each flight capsule will be integrated with a flight spacecraft to form a planetary vehicle. Each planetary vehicle will be fueled, have pyrotechnics installed, and then be mated to a shroud section. After final compatibility and systems tests, the surface of the planetary vehicle will be ETO decontaminated and the vehicle sealed off. The shroud sections with encapsulated planetary vehicles will be moved individually to the launch pad.

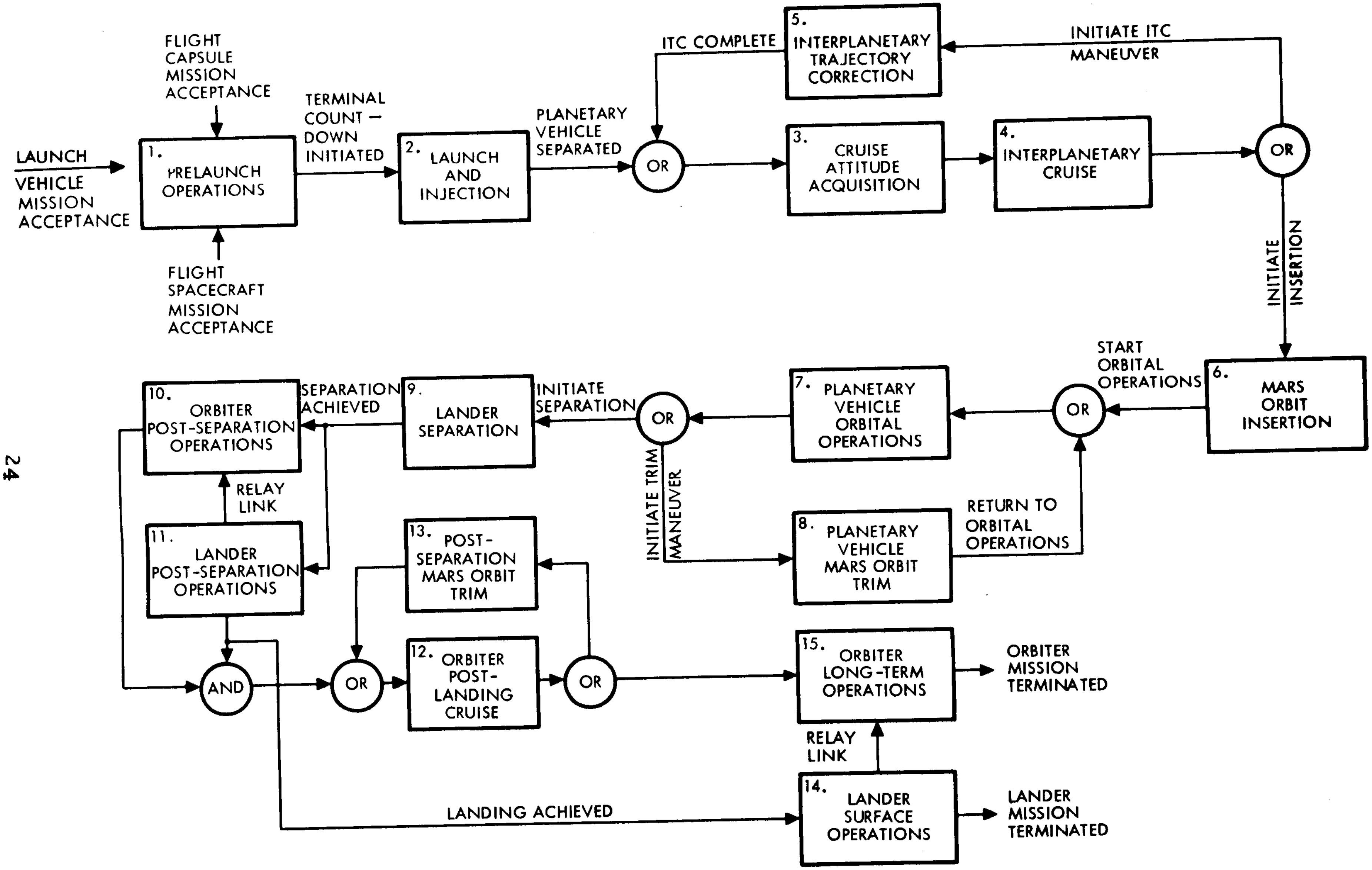


Figure 3. Voyager Operational Mission Phases

At the launch pad, the encapsulated planetary vehicles will be integrated with the launch vehicle and prepared for initiation of launch countdown.

3.5.2 Launch and Injection

The launch countdown begins with the formal time-controlled launch sequence and ends with the Saturn V holddown release. The spacecraft RF links for command and telemetry are tested prior to liftoff and the spacecraft subsystems are commanded into the proper operating modes for powered flight. The DSN Cape Kennedy station acquires telemetry link lock and monitors spacecraft performance during the countdown and early powered flight.

In meeting the requirements for checkout and monitoring on the launch pad, the spacecraft RF signal will not require a mechanical connection between the planetary vehicle and the nose fairing. However, RF windows or equivalent will be required in the shroud to accommodate transmissions to ground stations for both planetary vehicles.

After liftoff the vehicle will rise until the launch tower is cleared and will then roll into the required azimuth. It will fly a preprogrammed pitch trajectory for approximately 150 seconds, at which time the space vehicle will have reached an altitude of approximately 60 km. Propellant depletion will initiate engine shutdown and the dual-plane separation sequence. The S-II stage will propel the vehicle for about 390 seconds to an altitude of 183 kilometers. Propellant depletion will initiate engine shutdown and a single plane separation, including S-IVB ullage rocket firing, S-II/S-IVB interstage separation, retrorocket firing, and S-IVB engine ignition. Insertion into a 185-km (100 nautical miles) earth parking orbit occurs nominally 660 seconds after liftoff by command from the instrumentation unit to the S-IVB stage.

The nose fairing and part of the forward shroud section will be jettisoned during the parking orbit to uncover the forward planetary vehicle.

Powered injection flight initiates with restart of the S-IVB stage and continues until injection into the interplanetary transit trajectory (generation of the separation initiate signal). Upon injection, the instrumentation unit sends signals to the separation initiators of the forward planetary vehicle, and the separation devices impart the necessary velocity increment relative to the launch vehicle. Separation switches are activated to implement spacecraft functions as required. After a time delay to prevent interference with the forward planetary vehicle, the aft shroud section forward part is jettisoned to uncover the aft planetary vehicle. At a time that has allowed the forward planetary vehicle to achieve an appropriate separation distance, the instrumentation unit sends a signal to the aft planetary vehicle separation devices. At a time that has allowed the aft planetary vehicle to achieve a suitable separation distance, the S-IVB stage retrothrusts if required.

During an immediately following separation of the planetary vehicles, continuous tracking coverage by the TDAS is required to establish the orbital elements of the initial interplanetary trajectory.

3.5.3 Cruise Attitude Acquisition

Immediately upon separation, the spacecraft guidance and control subsystem stabilizes the planetary vehicle from the separation transient. Attitude acquisition to a sun-Canopus reference will follow automatically, following programmed maneuvers.

Both the spacecraft and the mission operations system will be operated in appropriate modes to permit maximum recovery of spacecraft engineering telemetry data for real-time analysis during the separation and acquisition sequences.

3.5.4 Interplanetary Cruise

A continuous operational coverage will be provided for the two planetary vehicles until 20 days after the first interplanetary trajectory correction. Coverage during transit will be time shared between the planetary vehicles thereafter. Continuous coverage will be provided to each vehicle from 5 days before encounter through termination of mission operations. The planetary vehicles will be tracked to provide angle, doppler, and ranging data for trajectory determination. During cruise, science data from the flight spacecraft and engineering data from the flight spacecraft and flight capsule will be transmitted by means of the spacecraft communication system. Boresight calibration of directional antennas will be accomplished from ground observation and pointing commands as required. Antennas will be repositioned as necessary, and the Canopus sensor will be updated when needed.

3.5.5 Interplanetary Trajectory Correction

Two or more interplanetary trajectory corrections will be made on an adaptive basis to control conditions at planetary encounter for each of the planetary vehicles. The first correction will occur between 2 and 20 days after launch. The final correction maneuver will probably occur about 1 month before encounter. The correction consists of inertially (gyro) controlled turns which orient the thrust axis in a selected direction, followed by a propulsion burn to achieve the desired velocity increment. The first correction is to counter trajectory dispersion resulting from injection by the launch vehicle as well as to achieve the desired separation in the Mars arrival dates of the two planetary vehicles. Before the maneuver, the magnitudes and direction of the maneuver turns and, the magnitude of the velocity increment will be transmitted to the flight spacecraft. The magnitudes will be computed from information obtained by ground-based tracking and trajectory determination. Upon receipt of the command data, the spacecraft will read out this data for ground verification before the enable command is transmitted. This command turns on gyros for warm up, tests the thrust-vector gimballing system, and switches and points antennas as appropriate. Verification of the proper attitude for thrusting is required before the propulsion firing. The engine is shut down automatically when the proper velocity increment is achieved, with a back-up provided to ensure shutdown. Reacquisition of the proper attitude for cruise is then initiated automatically. Data for monitoring the maneuver is transmitted in real-time as well as recorded on-board for later playback.

3.5.6 Mars Orbit Insertion

Insertion into Mars orbit consists of the same operations as for the interplanetary trajectory corrections. The periapsis point will be controlled to be compatible with the planetary quarantine constraint. Consistent with limiting the probability of contaminating Mars, the system will have the capability for verifying that the desired planetary vehicle orientation has been achieved before orbit-insertion firing. The orbit insertion maneuver is to occur in view of the DSIF station at Goldstone.

3.5.7 Planetary Vehicle Orbital Operations

After the orbit insertion firing, the normal cruise attitude will be reacquired. The planetary vehicle will orbit several days before an orbit trim maneuver. During this time orbital operations will be carried out essentially as for the long-term orbital operations. The orbital parameters will be determined by earth tracking, supplemented by earth occultation data.

3.5.8 Planetary Vehicle Mars Orbit Trim

A Mars orbit trim maneuver will be conducted by the planetary vehicle in essentially the same manner as for an interplanetary trajectory correction. The purpose of this maneuver is to establish the desired orbit for separation of the lander and initiation of its descent to the surface. Following engine shutdown, the cruise attitude is reacquired and the planetary vehicle continues with orbital operations in the same manner as before the trim maneuver.

3.5.9 Lander Separation and Deorbit Maneuver

The lander will be separated 3 to 10 days after orbit insertion. The flight spacecraft will orient the planetary vehicle in a programmed attitude or as updated by ground command. After verifying that capsule preparations have been satisfactory, enabling commands are transmitted from the ground. The planetary vehicle is maintained in its sun-Canopus attitude, and separation is accomplished by separation devices within the flight capsule. The lander is disconnected from the aft canister and reorients for a deorbit thrust maneuver. The canister lid will be deployed just before the lander is separated to minimize cross contamination and to simplify lander thermal control. The time of the maneuver is to be selected so that the orbiter is not eclipsed from the earth at any time between capsule separation and landing and so that lander separation, reorientation, and deorbit retrothrusting occur during a view period of the Goldstone DSIF station.

3.5.10 Orbiter Post-Separation Operations

After lander separation, the orbiter re-establishes its cruise operation and continues with orbital operations that do not conflict with its relay link function. Data received over the capsule-orbiter link is both recorded and transmitted in real-time by the orbiter for the low data rate. During the high data rate mode (for TV) it is possible only to record for later playback. Although the lander may record its entry data on board, it is still necessary to transmit all such data to the orbiter to avoid the possibility of loss in the case of landing failure.

3.5.11 Lander Post-Separation Operations

The lander must be oriented to approximately zero angle of attack (± 10 degrees) during entry. This maneuver requires an inertial reference, an attitude change value stored in the capsule, and a control system. Until the lander approaches the Martian atmosphere, the major requirement in data gathering is for engineering performance on lander subsystem operation. As the lander approaches the atmosphere the on-board logic needs to initiate upper atmosphere measurements and television imaging. The television continues to operate for the remaining descent, nominally for a period of 10 minutes. Data transmittal requirements for the orbital descent are met by a radio link to the spacecraft. When only engineering performance and upper atmospheric measurements are being made, a low data rate of 100 to 250 bits/sec will be adequate. A higher data rate of 50 to 200 kilobits/sec is required for television data. It is probable that communication blackout will occur during Mars entry. As a consequence, there is a requirement to record the blackout period, with subsequent playback. Such a record capability will be required in any case in support of surface operations.

The nozzle of the throttleable retropropulsion system is uncovered at ignition, with the remaining heat shield retained to protect the lander from the retrothrust plume. This shield is jettisoned after the velocity has been suitable reduced and the landing gear assemblies are deployed.

3.5.12 Post-Separation Orbit Trim

Provisions are made for additional orbit trim maneuvers with the orbiter alone in the event these are desired. Perturbations from separation can be corrected or a more suitable orbit for orbital operations can be achieved. The trim maneuver is carried out in a manner similar to the trim of the planetary vehicle orbit.

3.5.13 Lander Surface Operations

Exterior contact by the science equipment in the lander may simply involve removal of a cover to permit free contact with the ambient atmosphere, while extension booms will be required for some instruments. Soil contact instruments will require emplacement. The TV surveillance camera requires a scanning function which allows 360 degrees panorama viewing as well as sky scanning and pointing to the touchdown contact points. Deployment is required for remote samplers, including the mobile unit.

3.5.14 Orbiter Long-Term Operations

For as long as possible, the orbiter will provide the capability to conduct the prescribed experiments and communicate the acquired data to earth. The flight spacecraft will contain the on-board sensors and logic to proceed automatically through the orbital data acquisition sequence of events for this period of time without ground intervention. In addition, ground commands may be utilized to backup on-board sequencing or to alter the sequence of events.

A planetary scanning platform is provided for mounting instruments which require scanning of the planetary surface. The platform will normally operate in an automatic tracking mode to point toward the center of Mars. It will also be capable of command pointing in any required direction.

Each orbital sequence (a data acquisition and playback cycle) will normally last for one orbit but may last for two or more. The functions which must be initiated during the orbital sequence will include the following:

- Turn on planetary science power (if required) at least one-half hour before the instruments take data
- Reposition platform
- Calibrate instruments (if required)
- Start planetary science instruments
- Change data mode for playback of stored data or film readout
- Turn off planetary science power (if required)
- Change data mode
- Change data mode for earth occultation

The science subsystem will present to the spacecraft the science data and the science subsystem engineering data in digital binary form and in a format consistent with the data frame formats of the flight spacecraft telemetry and data storage subsystems. Science subsystem engineering data line to be combined with spacecraft engineering data for transmission.

3.6 MISSION SUMMARY

The characteristics of the Voyager mission can be summarized as follows. Two planetary vehicles in a tandem arrangement are launched each opportunity by a single Saturn V launch vehicle. Each planetary vehicle consists of a flight spacecraft and a flight capsule. The flight spacecraft delivers the flight capsule into an orbit about Mars and then functions as an orbiter. The flight capsule includes a sterile lander within a biological barrier. The lander separates and descends to the surface of Mars while transmitting data to the orbiter for relay to earth.

Additional features of the mission are given below. Illustrative project mission data are given in Table 2.

<u>Prelaunch</u>

- Provisioning: 3 flight spacecraft, 4 flight capsules, 1 Saturn V launch vehicle with segmented shroud, and 1 spare shroud section

Table 2. Illustrative Project Mission Data

Mission Data	First Generation Mission		Intermediate Mission		Advanced Mission	
	1973	1975	1977	1979	1981	1984
Weight Summary (lb)						
Flight Spacecraft	(21, 600)	(14, 415)	(15, 740)	(22, 670)	(22, 860)	(22, 750)
Bus	2, 900	2, 900	2, 900	2, 900	2, 900	2, 900
Science	600	600	600	600	600	600
Propulsion	18, 100	10, 915	12, 240	19, 170	19, 360	19, 250
Flight Capsule	(6, 985)	(6, 985)	(7, 330)	(7, 330)	(8, 000)	(8, 000)
Canister	785	785	785	785	785	785
Capsule Bus	5, 715	5, 715	5, 740	5, 740	6, 000	6, 000
Entry Science	45	45	45	45	45	45
Surface Lab	300	300	560	560	970	970
Mobile Unit	140	140	200	200	200	200
Planetary Vehicle (separated)	28, 585	21, 400	23, 070	30, 000	30, 860	30, 750
Planetary Vehicle Adapter	500	500	500	500	500	500
Planetary Vehicle (installed)	29, 085	21, 900	23, 570	30, 500	31, 360	31, 250
Total Injected Weight	58, 170	43, 800	47, 140	61, 000	62, 720	62, 500
Trajectory Characteristics						
Type	I	II	I	I	II	II
Launch Period (days)	40	20	20	20	30	20
Azimuth Values (degrees)	90-114	90-105	44-66 or 106-114	90-114	90-112	90-105
Transit Time (days)	164-203	314-327	260-277	222-241	285-314	257-276
Communication Distance at Encounter (10^6 km)	161	287-323	293-323	235	230	164
Mars Orbit (10^3 km)	1. 1 x 10	1 x 20	1 x 20	1 x 20	1.2 x 5	1 x 20
Velocity Increments (m/sec)						
Midcourse Maneuvers	200	200	200	200	200	200
Mars Orbit Insertion	1, 846	983	1, 136	1, 921	1, 868	1, 854
Orbit Trim	100	100	100	100	100	100
Mars Operations						
Lifetime at Mars	2 months or longer	2 months or longer	2 years or longer	2 years or longer	2 years or longer	2 years or longer
Mars Seasonal Date Arrival	Mid-March	Early June	Mid-July	Early August	End September	Mid-October
Orbiter Data Rate at Arrival (kilobits/sec)	300	100	100	175	175	300
Lander Data Rate at Arrival (kilobits/sec)	32	11	11	18	18	32

- RTG handling and thermal control for the flight capsule
- Capsule heat sterilization
- Flight-ready planetary vehicles encapsulated in individual shroud sections and surface decontaminated
- Encapsulated planetary vehicle/shroud assemblies transported individually to pad for launch vehicle mate
- Complete encapsulated assembly replaced in event of failure
- No pad propellant loading or unloading

Launch Through Injection

- Standard Saturn V powered flight into 100 naut mi orbit
- Simple active RTG thermal control with planetary vehicle in shroud
- Nose cone taken into orbit and then separated to uncover forward planetary vehicle; over-the-nose shroud jettison
- Planetary vehicle arrival data separation achieved at first trajectory correction maneuver

Mars Orbit

- Orbit insertion compatible with planetary quarantine
- Orbit trim possible before and after capsule separation
- Essentially continuous DSN coverage during Mars orbital operations
- Automatic sequencing of spacecraft with ground command update and override capability

Capsule Separation and Landing

- Separation 3 to 10 days after orbit insertion
- Canister lid jettison just before separation
- Separation and descent in view of Goldstone
- No earth occultation during descent
- Radio link from lander to orbiter with low and high data rates

- TV imaging from lander during descent
- Heat shield jettisoned prior to final descent
- Soft landing (10 to 20 g)

Surface Operations

- Long term duration
- Passive RTG thermal control
- Direct and relay link for lander telemetry
- Automatic sequencing of surface laboratory with ground command update and override capability

4. PROJECT ORGANIZATION AND MANGEMENT

Organization and management for the Voyager project can be described in terms of four levels as shown in Figure 4:

- Program direction
- Project management
- System management
- System implementation

Program direction corresponds to overall executive authority and control, which is vested in the Voyager Program Director, NASA Headquarters. Project management is delegated to the Voyager Project Office, which is either within NASA Headquarters or part of a NASA field center designated to have project management responsibility. The first level of activity below the project level is designated as a system. Management responsibility at this level is delegated to one or more NASA field centers. This responsibility is carried out through system management offices, each having cognizance over one of the Voyager system areas. Implementation of the various system elements is carried out by contractor and governmental organizations under the direction and management of the appropriate system management office.

4.1 PROGRAM DIRECTION

The authorization for a project by NASA general management takes the form of a project approval document. Within the scope defined in this document, the Voyager Program Director has the overall responsibility for achieving the Voyager objectives and ensuring that the Voyager project is compatible with the programmed goals and resources. This involves formulation of project objectives and policy guidelines, programming and allocation of resources, inter-project coordination, external relations, and overall project evaluation and direction. The director is assisted by the Voyager Program Staff and makes use of technical advisory boards as appropriate. He has overall responsibility for definition of the scientific program and selection of the associated principal investigators. Although the basic system

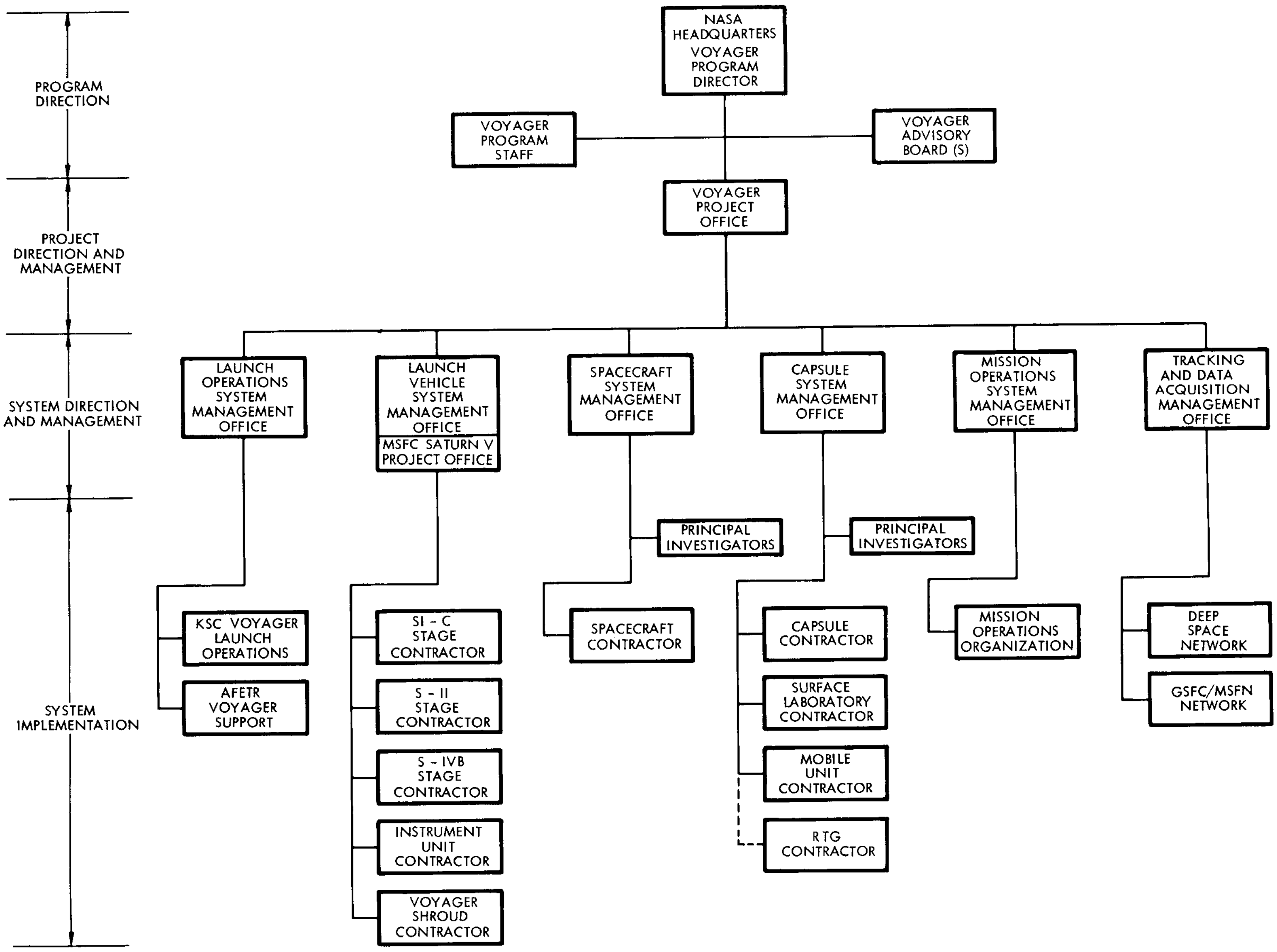


Figure 4. Voyager Project Organization

management assignments are established by the project approval document, the detailed responsibilities are defined by the project development plan as approved by the director.

In addition to general cognizance over the project, the director exercises a specific review and control function at major project decision points to consider immediate technical and program aspects and long-range implications in terms of policy, resources, and interagency relationships.

4.2 PROJECT MANAGEMENT

Project management is delegated to the Voyager Project Office, which consists of a Voyager Project Manager and his supporting organization. The manager is responsible for project-level management as well as project definition and technical direction above the system level. This includes detailed definition of system management office functions and responsibilities through generation of a Voyager Project Development Plan, approved by the Voyager Program Director.

Project definition and technical control are exercised through mission specifications, intersystem interface control specifications, and other project planning and control documents. The project manager approves all system specifications and other major system planning documents issued by the system management offices.

4.2.1 Project Administration and Control

Project administration and control functions are conducted by the project office as follows:

- Development and implementation of project administration and control policies and procedures
- Coordination of project budgets and fiscal plans
- Monitoring and control of project costs and manpower expenditures
- Development and implementation of project functional management systems such as data management, configuration management, and project reporting

4.2.2 Project Standards

Technical functions are defined and identified to develop plans and monitor project-wide activities such as:

- Reliability assurance
- Quality assurance
- Planetary quarantine

4.2.3 Project Science

The project science function provides project definition, monitoring, and direction as follows:

- Develops science objectives and guidelines
- Evaluates and recommends experiments
- Ensures a suitable relationship and proper cross-feed between the spacecraft and capsule science activities
- Monitors science management and direction by the spacecraft and capsule system management offices

4.2.4 Mission Analysis and Engineering

Mission analysis and engineering provides the following functions:

- Generates and maintains the mission specifications to define basic mission characteristics and requirements, system performance requirements, and intersystem interfaces
- Coordinates and monitors on a continuing basis the detailed definition, implementation, and verification of intersystem interface
- Carries out technical project planning, including the sequence of project implementation prerequisites and system implementation requirements
- Defines AFETR support requirements for all missions and identifies interrelationships with other Voyager mission activities (i.e., TDAS, MOS, LOS, etc.)
- Defines and administers mission support requirements

- Provides earth-Mars flight path and Mars orbit design and analysis and monitors the related system mechanizations
- Establishes the overall configuration baseline for each mission and evaluates configuration and project changes at the mission and project level
- Participates in mission operations to evaluate mission performance other than in regard to scientific results
- Carries out project and mission definition studies so as to make recommendations to enhance mission performance and to resolve project-level problem areas

4.3 SYSTEM MANAGEMENT

A System Management Office (SMO) under the direction of a system manager is established for each of the six Voyager systems, as shown in Figure 4. Since a system corresponds to a first major subdivision of work below the project level, it is defined in keeping with administrative or contractual alignments representing direct responsibility for such work. This work breakdown for the Voyager project is indicated in Figure 4 by the association of organizational elements with each system management office at the implementation level. This association corresponds to the system definitions given in Section 3.3. In addition, SMO personnel are provided to support each system manager.

In addition to the definition of primary system cognizance in keeping with project work breakdown, a different alignment of responsibilities along functional lines is needed to carry out launch operations and mission operations, as covered in Sections 11 and 13. Such support elements from one system function under the direction of an organization system as established by appropriate agreements between the affected SMO's and related administrative or contractual arrangements at the implementation level. For example, during planetary vehicle/shroud system operations, support is provided by the capsule contractor and shroud contractor to the spacecraft contractor, who has responsibility for such activities.

4.3.1 Launch Vehicle System Management

The launch vehicle SMO under the direction of the launch vehicle system manager has the overall responsibility for the launch vehicle system to meet the related Voyager project requirements. This includes the system engineering for launch vehicle design, development, manufacture, integration, and testing as required for the Voyager application, and administration and control for the launch vehicle project segment within the guidelines established by the project office.

In carrying out this responsibility, launch vehicle system management is supported by the MSFC Saturn V project office, which supplies the launch vehicle flight hardware, related equipment, software, and support operations through the contractors for the various Saturn V stages and the Voyager shroud system.

4.3.2 Spacecraft System Management

The spacecraft SMO under the direction of the spacecraft system manager has the overall responsibility for the spacecraft system to meet the related Voyager project requirements. In carrying out this responsibility the manager is supported as follows:

1) Spacecraft Contractor

   - Provides spacecraft bus and propulsion flight hardware, the planetary vehicle adapters, and the associated models, spares, software, and OSE
   - Provides designated science-related flight and ground hardware and integrates the spacecraft science
   - Provides prelaunch operations for the spacecraft and planetary vehicle, assembly and integration of the planetary vehicle and the shroud section, and participates in space vehicle launch operations
   - Participates in mission operations in keeping with the spacecraft responsibility

2) Capsule SMO

- Provides, through the capsule contractor, flight capsule hardware for planetary vehicle testing and integration
- Provides prelaunch operations support, through the capsule contractor, to bring the capsule to flight readiness and to support planetary vehicle operations

3) MSFC Saturn V Project Office

- Provides, through the Voyager shroud contractor, shroud hardware for planetary vehicle checkout and encapsulation

4) Launch Operations SMO

- Provides facilities for spacecraft and planetary vehicle checkout and prelaunch operations at Cape Kennedy

5) Principal Investigators

- Determine functional requirements of the science instruments aboard the spacecraft
- Provide support for designated science equipment during assembly and checkout phases
- Analyze science data obtained by the spacecraft to report scientific results

4.3.3 Capsule System Management

The capsule SMO under the direction of the capsule system manager has overall responsibility for the capsule system in meeting the related Voyager project requirements. In carrying out this responsibility the manager is supported as follows:

1) Capsule Contractor

- Provides capsule bus and canister flight hardware and the associated models, spares, software, and OSE
- Provides designated science related flight and ground hardware and integrates the capsule science with the capsule bus

- Provides prelaunch operations for the capsule and participates in the integration of the capsule with the spacecraft, shroud-planetary vehicle integration, and in space vehicle prelaunch operations
- Participates in mission operations in keeping with the capsule bus responsibility

2) Launch Operations SMO

- Provides facilities for capsule checkout and prelaunch operations at Cape Kennedy

3) Surface Laboratory Contractor

- Provides surface laboratory flight hardware and the associated models, spares, software, and OSE
- Provides designated science-related flight and ground hardware and integrates science experiments into the laboratory
- Assists in achieving compatibility of the laboratory with the mobile unit and with the capsule bus
- Participates in prelaunch and mission operations in keeping with the laboratory responsibility

4) RTG Contractor

- Provides RTG hardware and the associated models, spares, software, and OSE
- Assists in achieving compatibility of the RTG system with the capsule bus and surface laboratory
- Participates in prelaunch and mission operations in keeping with the RTG responsibility

5) Mobile Unit Contractor

- Provides mobile unit flight hardware and the associated models, spares, software, and OSE
- Assists in achieving compatibility of the mobile unit with the laboratory and with the capsule bus
- Participates in prelaunch and mission operations in keeping with mobile unit responsibility

6) Principal Investigators

- Determine functional requirements and provide support for entry and landed science experiment packages for both the capsule bus and surface laboratory
- Assist in achieving compatibility of experiment packages with the capsule bus and surface laboratory
- Participate in prelaunch checkout and mission operations in keeping with experiment responsibility
- Analyze scientific data obtained by the capsule bus and surface laboratory to report scientific results

4.3.4 Launch Operations Management

The launch operations SMO under the direction of the launch operations system manager is responsible to the Voyager mission director for space vehicle prelaunch and countdown and for launch vehicle flight through injection into an earth parking orbit. In particular, the launch operations system manager is responsbile for launch readiness of the space vehicle, ground crews, and launch complex facilities and equipment as required to meet the critical Voyager launch window requirement. The manager carries out launch operations development activities as well as operational execution. He also coordinates with KSC to provide facilities and related support for spacecraft, flight capsule, and planetary vehicle prelaunch operations.

The responsibilities relate generally to all launch site activities and specifically to those associated with space vehicle prelaunch, countdown, and flight orbit. The launch operations system manager is therefore responsible for direction and coordination of launch support activities of other systems, as well as the activities of KSC and AFETR operating and support elements under his direct cognizance.

The launch operations system manager is supported as follows:

1) KSC Voyager Launch Operations

- Provides personnel, equipment, and facilities at Cape Kennedy in support of launch operations development and execution

- Conducts space vehicle launch operations, including direction and coordination of related launch vehicle, spacecraft, and capsule contractor activities
- Coordinates with AFETR to obtain launch support as required

2) AFETR Voyager Support

- Provides personnel and equipment in support of launch and flight operations for pad safety, weather observations and forecasting, security, tracking, telemetry, and range safety
- Provides logistic and other required services

3) MSFC Saturn V Project Office

- Provides personnel and equipment, through the launch vehicle contractors, to conduct prelaunch checkout and launch operations for the associated launch vehicle segments

4) Spacecraft SMO

- Provides, through the spacecraft contractor, flight-ready planetary vehicles encapsulated in their shroud sections in support of space vehicle buildup
- Provides personnel and support equipment, through the spacecraft contractor, for spacecraft support of space vehicle launch operations

5) Capsule SMO

- Provides personnel and support equipment, through the capsule contractor, surface laboratory contractor, and the mobile unit contractor, for capsule support of space vehicle launch operations

6) Tracking and Data Acquisition SMO

- Provides, through the DSN Station 71 at Cape Kennedy, support for checkout and final countdown of the space vehicle

4.3.5 Mission Operations Management

The mission operations SMO under the direction of the mission operations system manager is responsible to the Voyager mission director for assurance that mission operations facilities, equipment, and associated personnel are in a ready condition to support the Voyager mission schedule. This responsibility covers all mission-related activities from launch vehicle injection into an earth parking orbit through the end of Mars operations. It also covers planetary vehicle monitoring and evaluation from liftoff.

The mission operations system manager is responsible for the development and implementation of all Voyager mission operations, including activities of supporting organizations. This responsibility includes all activities associated with Voyager mission operations analysis, development, and procurement. He will exercise control of all elements of mission operations and will be responsible for coordination of the associated elements to assure a state of readiness and operation as required.

The mission operations system manager is supported as follows:

1) Mission Operations Organization

- Provides personnel and equipment in support of mission operations development and execution
- Conducts mission operations, including direction and coordination of related activities by other organizations
- Coordinates with the tracking and data acquisition system to obtain support as required

2) Tracking and Data Acquisition SMO

- Provides DSN tracking, telemetry, and command support as required
- Provides GSFC/MSFN tracking, telemetry, and command support as required

3) Spacecraft SMO

- Provides spacecraft mission operations support from the spacecraft contractor

4) Capsule SMO

- Provides capsule mission operations support from the capsule contractor, surface laboratory contractor, the mobile unit contractor, and the RTG contractor

4.3.6 Tracking and Data Acquisition Operations

The tracking and data acquisition SMO under the direction of the tracking and data acquisition system manager is responsible to the Voyager mission director for assurance that the tracking and data acquisition system is in a ready condition to track, acquire telemetry data, and transmit commands as required for the Voyager mission. The manager will exercise control over all elements of the tracking and data acquisition system and will be responsible for proper coordination between his system elements and with the other Voyager systems. He is supported as follows:

1) Deep Space Network

- Provides tracking, telemetry, and command support as required

2) Goddard Space Flight Center

- Provides MSFN tracking, telemetry, and command support as required

4.4 SYSTEM IMPLEMENTATION

Implementation of the various system areas is carried out by contractor or governmental organizations under the direction of the appropriate SMO. As discussed in Section 4.3, these elements function under the cognizance of the SMO requiring the most support from that element, which is indicated in Figure 4. In addition, support is sometimes required from an implementation organization by an SMO other than the one having cognizance over the organization. This support is coordinated with the cognizant SMO and established by appropriate project approved documentation.

Specific organization and management for the various organizations at the implementation level is covered in Sections 11 through 19 along with related implementation definition.

5. IMPLEMENTATION PHASING

5.1 IMPLEMENTATION PHASES

In keeping with NASA policy, the Voyager project will be carried out by a sequence of implementation phases. Each such phase is defined to correspond to a specifically approved activity to be undertaken only after review and analysis of preceding work. Thus each phase represents a focused effort with definable end objectives. Initiation of a phase therefore represents a specific limited agency commitment, both internally and externally.

A fundamental concept pertinent to such phased implementation is participation by top management in the review and decision making activities before proceeding from one phase to the next. As discussed in Section 4.1, this executive review is the responsibility of the Voyager program director, as the representative of NASA general management.

The general definitions for the implementation phases associated with large projects such as Voyager are given below.

1) <u>Phase A Advanced Studies</u>

   Phase A (previously designated as conceptual design, phase zero) corresponds to the analysis of a proposed agency objective or mission in terms of alternative approaches or concepts. It includes the research and technology development required to support such analysis and to assist in determining whether the proposed technical objective or mission is feasible and achievable.

2) <u>Phase B Project Definition</u>

   Phase B (previously designated as preliminary design, Phase IA) includes detailed study, analysis, and preliminary design directed toward the selection of a single project approach from among the alternate approaches resulting from Phase A.

3) <u>Phase C Design</u>

   Phase C (previously designated as system design, Phase IB) includes the detailed definition of the final project concept, including the system design and the breadboarding of critical components and subsystems, as necessary to provide reasonable assurance that the technical milestone schedules and resource estimates for the next phase can be met, and that definitive contracts can be negotiated for Phase D.

4) Phase D Development and Operations

Phase D (previously designated as acquisition, Phase II) includes final hardware design and development, fabrication, assembly and test, and operations.

Throughout each phase, emphasis is placed on identifying those aspects of the proposed project that require the development of technology beyond the current state of the art, and the specific manner in which this technology is to be developed is defined.

5.2 PROJECT SEQUENCE AND BASELINES

In keeping with the phased implementation, formal baselines are established in sequence as illustrated in Figure 5 to allow review and control by various levels of project management. A generic project is discussed below along with the related sequence of project activities.

5.2.1 Program Requirements Baseline

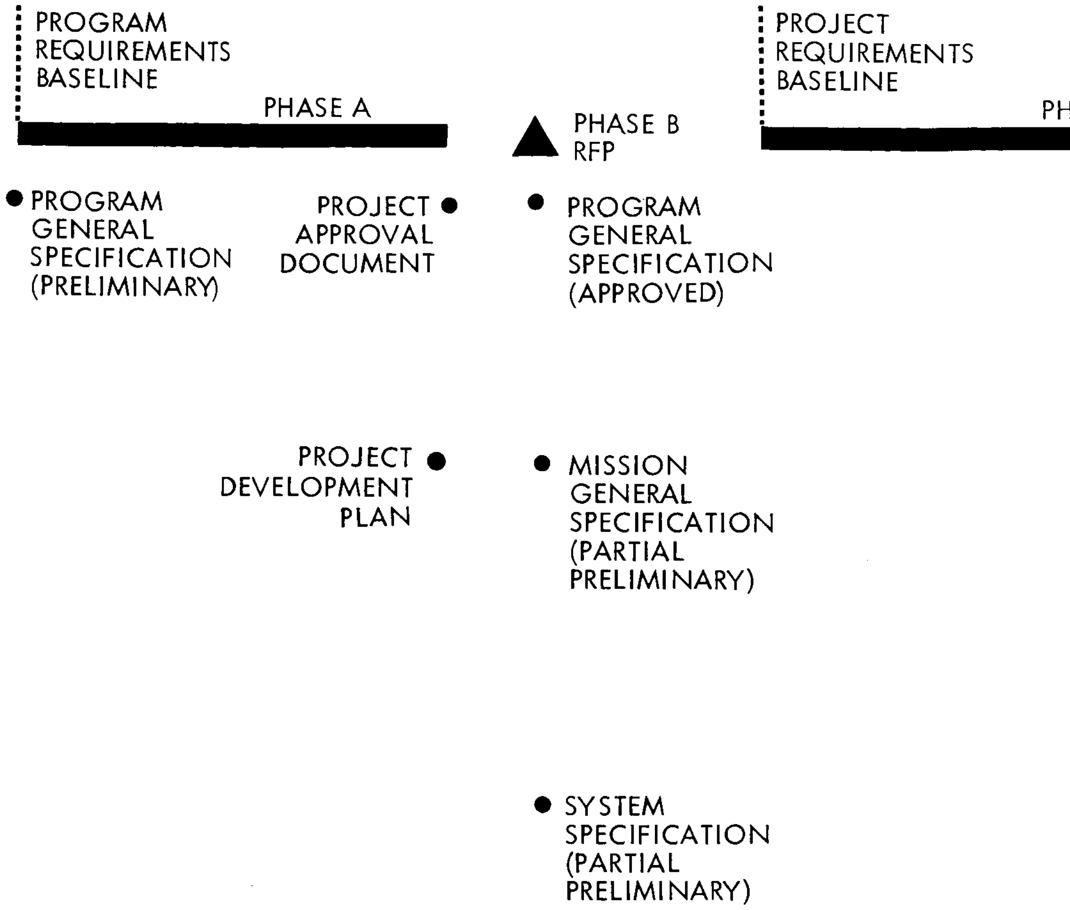
A program level requirements framework is needed as a basis for the Phase A advanced studies. This is provided by the Preliminary Program General Specification. The related project control point is designated as the Program Requirements Baseline. It is established prior to or early in Phase A by the cognizant program office in NASA Headquarters.

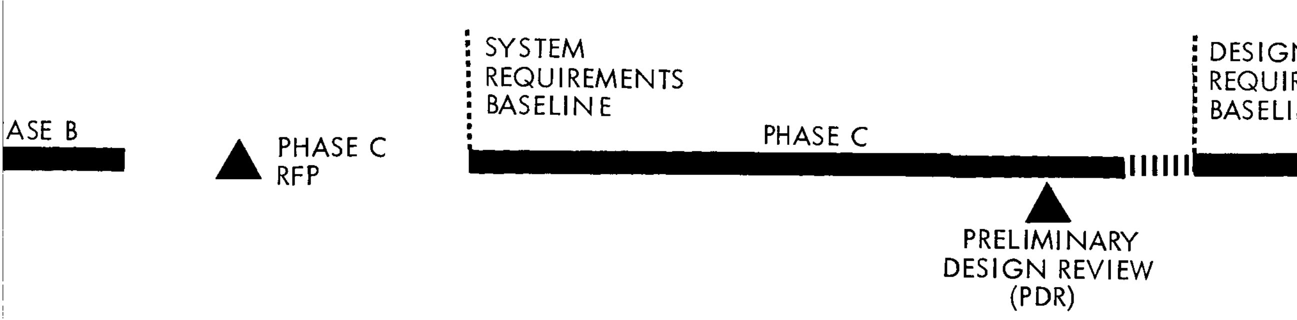
5.2.2 Project Initiation and Planning

On the basis of Phase A, a project proposal is generated by the program office and submitted to NASA general management. The initiation of the project is authorized when a project approval document (PAD) is issued. The PAD establishes the scope of the project and assigns project and system management responsibility. The detailed planning for the project is then done by the project office and documented as a Project Development Plan (PDP). When approved by the program director, the PDP becomes the primary operating document for project implementation.

5.2.3 Project Requirements Baseline

The next major step in project implementation is Phase B project definition. The related technical requirements base to govern the Phase B


PROGRAM REQUIREMENTS BASELINE
PHASE A
PHASE B RFP
PROJECT REQUIREMENTS BASELINE
PH
PROGRAM GENERAL SPECIFICATION (PRELIMINARY)
PROJECT APPROVAL DOCUMENT
PROGRAM GENERAL SPECIFICATION (APPROVED)
PROJECT DEVELOPMENT PLAN
MISSION GENERAL SPECIFICATION (PARTIAL PRELIMINARY)
SYSTEM SPECIFICATION (PARTIAL PRELIMINARY)



- MISSION GENERAL SPECIFICATION (COMPLETE, APPROVED)
- INTERSYSTEM INTERFACE CONTROL DOCUMENTS (PARTIAL, PRELIMINARY)
- SYSTEM SPECIFICATION (PARTIAL, APPROVED)
- GENERAL SPECIFICATIONS (APPROVED)

- INTERSYSTEM INTERFACE CO DOCUMENTS (COMPLETE, APPROVED)
- SYSTEM SPECIFICATIO (COMPLETE, APPROVED)
- CEI PART I SPECIFICATIO (PARTIAL, APPROVED)
- CEI INTERFACE CONTROL DOCUMENTS (PARTIAL, APPROVED)
- CRITICAL COMPONENT LIST (APPROVED)
- LONG LEAD- ITEMS REQUIR (COMPLETE, A

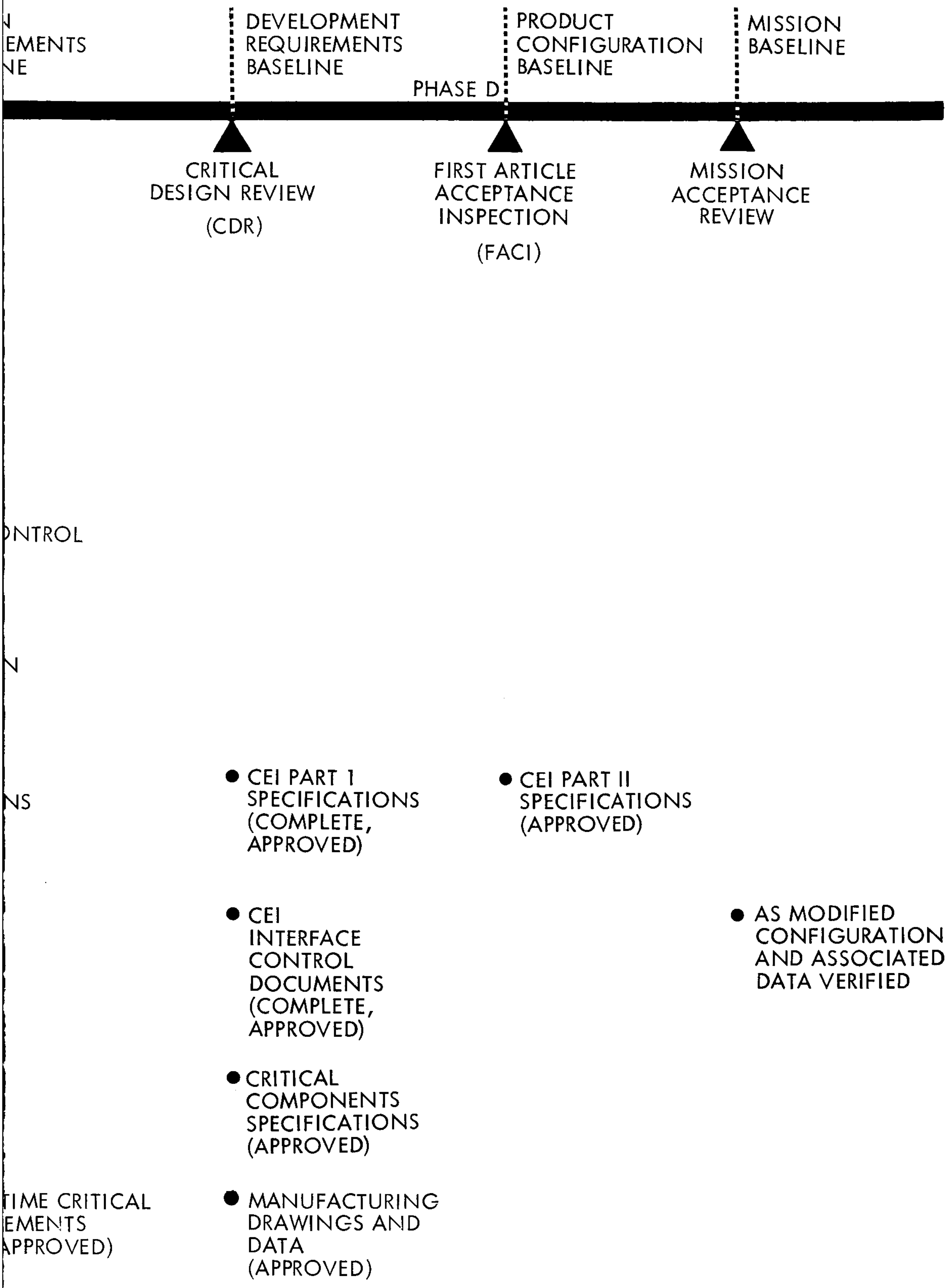


Figure 5. Project Sequence and Baselines

work is provided by the following documents, which correspond to the project requirements baseline:

1) Program General Specification (approved): The preliminary version of this document utilized as the basis for the Phase A studies is updated to incorporate results of the intervening work and is issued under the approval of the program director. It defines the overall performance and design requirements for the project.

2) Mission General Specification (partial, preliminary): This document defines overall performance and design requirements associated with the mission. It includes requirements at the system level and for intersystem interfaces. Requirements peculiar to each launch opportunity are provided either within the main text or by means of individual addenda as convenient.

3) System Specification (partial, preliminary): This document corresponds to the top-level requirements document for a system area. It defines the associated functional system as an entity, establishes system performance requirements, defines directly or by reference the interfaces with other functional systems, identifies the breakdown of the system into functional areas along with related performance requirements, establishes system standards, and delineates system testing requirements.

These three documents are issued as part of the Phase B RFP. The project requirements baseline for a system or major system element is then formally established when these documents are made applicable by a Phase B contract.

5.2.4 System Requirements Baseline

As a result of Phase B, a particular project approach and preliminary design is selected for the associated system to serve as the basis for Phase C. The related configuration data corresponds to the system requirements baseline. This data is embodied in the following documents.

1) Program General Specification (updated, approved)

2) Mission General Specification (complete, approved)

3) Intersystem Interface Control Documents (partial, preliminary): These define and control the various intersystem interfaces when established in the appropriate specifications. They consist of schematic diagrams, functional block diagrams, data sheets, and drawings which define the interfaces in detail.

4) System Specification (partial, approved): The preliminary version used as the basis for Phase B is updated as the result

of the intervening project definition work. Those portions which define technical requirements for Phase C are complete.

5) General Specifications (approved): These define technical requirements generally applicable to all systems. They are issued separately and established by reference in the appropriate specifications to avoid unnecessary repetition of such common requirements.

The above requirements documents for the system requirements baseline are issued as part of the Phase C RFP, and the related work definition is documented as part of the contractor's Phase C proposal. The system requirements baseline is then formally established by the Phase C contract.

As indicated above, the system specification and the intersystem interface control documents are only partially completed when the system requirements baseline is established. However, those portions which define technical requirements for Phase C are complete, and these documents as well as the completed requirements documents come under project configuration control at the beginning of Phase C.

5.2.5 Design Requirements Baseline

To realize the Phase C objectives, a detailed definition of the system must be determined and a definitive Phase D proposal must be generated. The technical data base needed for this corresponds to the design requirements baseline for a particular system. This data is embodied in the following documents, which supplement or update the system requirements baseline data.

1) Intersystem Interface Control Documents (complete, approved)

2) System Specification (complete, approved)

3) Part I CEI Specifications, Performance, and Design Requirements (partial, approved): This part of the CEI specification defines requirements peculiar to the design, development, test, and qualification of the contract end item.

4) CEI Interface Control Documents (partial, approved)

5) Critical Components List (complete, approved): Certain components of a CEI may require individual specification and qualification. These are designated as critical components and are listed in Part I of the associated CEI specification. A combined list of such components is generated for the complete system.

6) Long Lead-Time Critical Items Requirements (complete, approved): Certain components of a CEI (i. e. isotope inventory for the RTG and for supporting facilities, may require early procurement. Hence, approval prior to or at the beginning of Phase D may be required.

The technical basis for the design requirements baseline is defined as the result of a Preliminary Design Review (PDR). A PDR is conducted for each CEI and constitutes a formal technical review of the basic approach for its design. PDR's are completed for each CEI during Phase C when the basic design approach has been identified, and the requisite preliminary design documentation has been prepared.

The required results from the PDR are as follows:

1) The compatibility of the selected design approach with Part I of the detailed specification for the CEI will be established.

2) The compatibility of the CEI with other system equipment/ facilities will be established by review of predesign drawings, schematic diagrams, layout drawings, envelope drawings, in-board profiles, review of performance characteristics for functional compatibility, etc.

3) The integrity of the selected design approach will be established by review of analyses, breadboard models, mockups, circuit logic diagrams, packaging techniques, etc. This is done by the contractor as the basis for selection of the design approach presented.

4) The parts of the design to be subjected to detailed engineering analysis will be identified.

5) The producibility of the selected design will be established by review of the requirements for special tools and facilities to manufacture the CEI in the quantities required.

Phase C must also develop a detailed definition of the Phase D development and operations phase. This is documented as a Phase D proposal. The design requirements baseline is then formally established when this proposed work statement and the related configuration documentation are made applicable by a definitive Phase D contract.

5.2.6 Development Requirements Baseline

On the basis of the design requirements baseline, Phase D proceeds with detailed design and production planning. The next contractual baseline milestone corresponds to the formal identification and approval of specific engineering documentation which defines the design of the CEI. This will be released for manufacturing the end item in the operational configuration and for qualification testing. This stage is designated as the development requirements baseline and is established for each CEI by a Critical Design Review (CDR). The corresponding system baseline is established when development requirements baselines have been attained for all CEI's of the system. The Critical Design Review is a formal technical review of the design of a contract end item. The CDR occurs when the detailed design is essentially complete, to formally establish the design as the basis for technical support data, etc. Prior to the CDR, the exact interface relationship of the CEI to other system (or inventory) equipment/facilities will be established, and will appear in approved interface control documents which fix the interfaces for the CEI.

The required results from the CDR are as follows:

1) The compatibility of the CEI, as designed, with Part I of the detailed specification for the CEI will be established.

2) The system compatibility of the completed design will be established by comparison of the interface control documentation with the engineering drawings for the CEI. The interface documentation will, if appropriate, reflect agreement of contractors that are developing interfacing items of equipment/facilities.

3) The integrity of the design will be established by review of analytical and test data.

As a result of the CDR, all interface control documents are completed and approved. The Part I critical components specifications are also complete. The complete set of manufacturing drawings and associated data are released and put under configuration control, with all subsequent Class I changes referred to the cognizant system management office.

5.2.7 Product Configuration Baseline

After approval of the design and release for manufacture of the operational configuration, Phase D continues with production, type approval (qualification) test, subsystem integration, and system assembly and test. The next contractual baseline milestone corresponds to formal inspection of a first operational unit. This stage is designated as the product configuration baseline and is established for each CEI by a First Article Configuration Inspection (FACI). The corresponding system baseline is established when product configuration baselines have been attained for all CEI's of the system. When a CEI such as a major flight article is composed of many CEI's, it may be appropriate to conduct only one FACI for the integrated article.

The FACI is a formal technical review conducted by the cognizant system management office to audit and approve product configuration and acceptance test requirements constituting Part II of the CEI specification, including the associated manufacturing documentation referenced in the specification. This involves three aspects:

1) Audit of qualification test results to verify that the design embodied by the hardware undergoing qualification testing satisfies the requirements of the Part I CEI specification.

2) Audit of the applicable configuration data and production process to verify that the first operational hardware item is identical to the qualified hardware, and so satisfies the specified requirements by identity.

3) Audit of the acceptance process to verify that it will ensure all subsequent accepted hardware to be identical to the first operational unit.

That is, during the FACI, an audit is accomplished by establishing the exact relationship between the configuration of the CEI identified for follow-on manufacturing (the operational unit under inspection) and the configuration of the CEI qualified. The FACI also establishes the exact relationship of the CEI as described by released engineering documentation to the CEI as manufactured and assembled. Also, the FACI establishes the validity of the acceptance testing of the CEI by direct comparison of the acceptance test methods and test data with the specified performance of the CEI.

Part II of the CEI detailed specification, once audited and accepted at the FACI, serves as the basic documentation for configuration management of the CEI for the remainder of Phase D. All changes to the CEI, after FACI, will be implemented only to reflect approved changes to

Part II of the CEI specification. A major engineering change (new type-model-series) or an indication that the configuration being produced does not accurately reflect released engineering may require repeating the complete FACI.

5.2.8 Mission Baseline

After the FACI, the Part II CEI specification will be complete and approved and the exact relationship between the "as-built" and "as-designed" configuration will have been established; and the acceptance testing will have been validated by direct comparison of specified performance with acceptance test methods and test data. This then establishes the basis for acceptance and delivery of follow-on operational articles. Any approved changes to the configuration after the FACI will be incorporated in the configurational documentation and in the affected hardware and software so as to produce the completely current "as-modified" configuration.

To ensure that all approved changes have been incorporated for a mission, a mission acceptance review is conducted when the item is committed for the mission, to verify that the as-modified configuration corresponds to the final approved configuration for the mission. This then establishes the mission baseline for the item. The mission baseline for the system is achieved when all of its elements have achieved their individual mission baselines.

6. PROJECT FLOW AND SCHEDULE

Overall responsibility for Voyager project control is vested in the Voyager project office, as described in Section 4. Part of project administration and control will be to identify all the major milestones for the Voyager project on a time-phased basis with associated prerequisite conditions. This is essential to assure that all the concurrent system and subsystem implementation activities are accomplished in the proper relationship and early enough to permit timely fabrication, assembly, test, checkout, decontamination, and sterilization operations to be performed.

The major schedule constraints in the Voyager program are, obviously, the launch dates. Additional important factors are long lead items (e.g., RTG system) and recurring development phases for non-standardized systems such as the simplified, comprehensive, and advanced landed science. In the case of the advanced systems (i.e., advanced mobile unit, advanced surface laboratory) the operational hardware cannot be fully implemented until data is obtained and evaluated from the earlier missions. Thus the schedule remains fairly tight for the 1977 mission in regards to the mobile unit and surface laboratory, both of which require major development steps for that mission. Close coordination between all the associate contractors and the various system management offices and the Voyager project office will be required if the critical schedule milestones are to be met. It also appears evident that even though moderate contingencies can be included in the Voyager project plan, any major schedule slippage of a critical system will result in failure to meet the launch window, and cause a two-year program delay to await the next launch opportunity.

6.1 OVERALL SCHEDULE

The gross overall Voyager project flow and schedule is shown in Figure 6. These schedules depict critical milestones and activities that must be implemented for the various major systems. Six major development projects are displayed along with the standard Saturn V booster project segment. Thus a total of 10 associate contractors are involved since the launch vehicle is currently implemented by four different contractors.

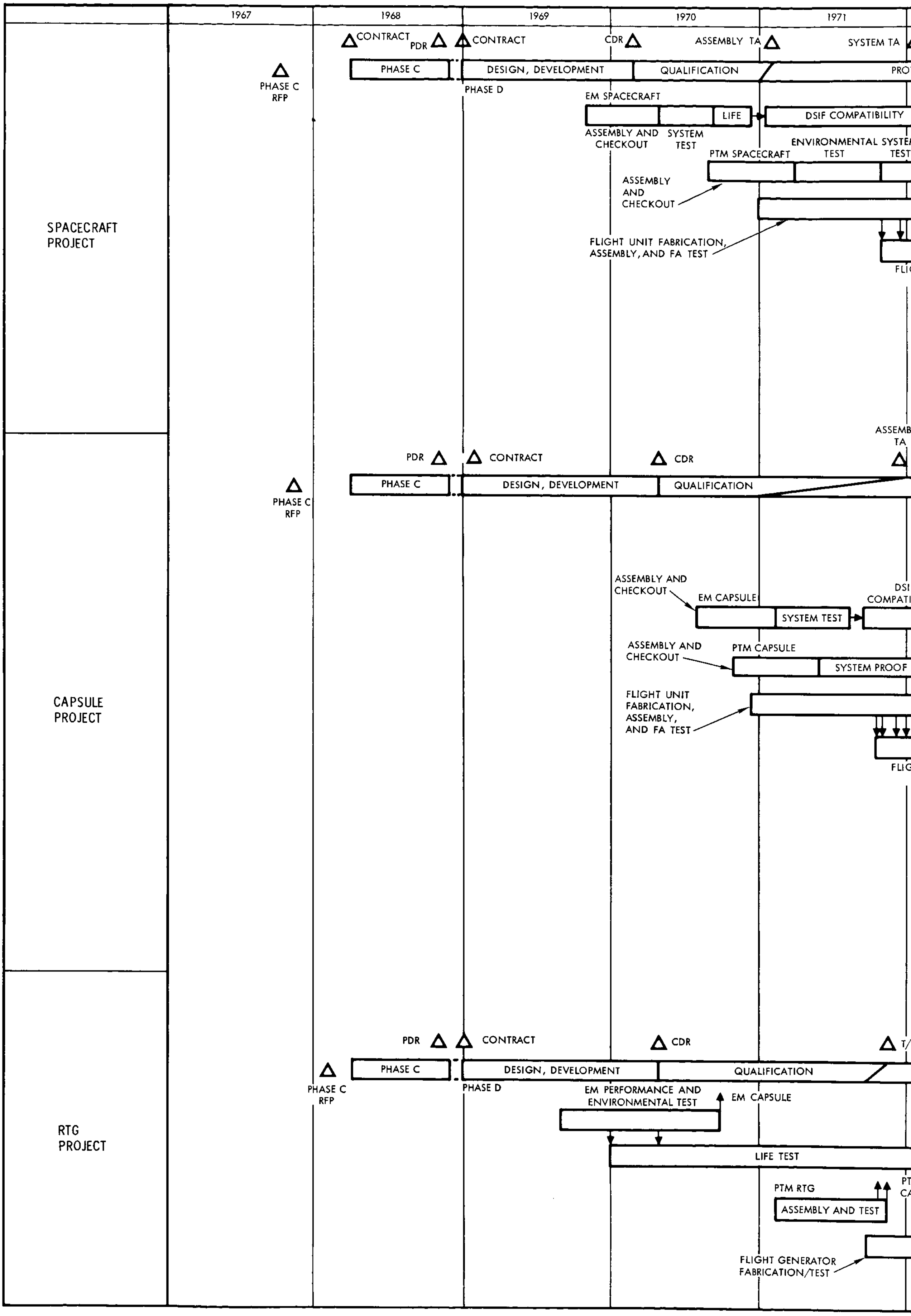
Inspection of Figure 6 brings out how the long span of time for fabrication, test, launch operations, and spaceflight precludes the application of results from one mission to the next. For the spacecraft and capsule, fabrication for the next mission is underway before launch. Indeed, design for the second generation must commence before first generation data from Mars is available. Thus some parallel development will be required initially to provide for a span of possibilities.

6.2 SPACECRAFT SYSTEM SCHEDULE

The spacecraft system implementation for all missions is summarized by Figure 6 and project flow through the initial mission is shown by Figure 7. The project is initiated with the issuance of a Phase C RFP in November 1967. Contract award is assumed to take place early in 1968, with the preliminary design review of Phase C being conducted by November 1968. At that time preliminary designs of the spacecraft system and subsystems will have been completed. In addition, an overall spacecraft system specification will have been completed and approved. In addition, detailed design specifications for all major subsystems will have been prepared. Based upon a make-or-buy plan generated early in Phase C, quotations for cost and delivery will be obtained from all major subcontractors. This activity is important for identifying long-lead-time items whose procurement may have to be handled in an expeditious manner if the spacecraft schedule is to be maintained.

The preparation of a complete set of management plans is another important activity that must be implemented during Phase C. Typical of these plans and related data are the following:

- Design Plan
- Test Plan
- Manufacturing Plan
- Make-or-Buy Plan
- Quality Assurance and Reliability Plan
- Contamination Control and Sterilization Plan
- PERT-Cost and Schedule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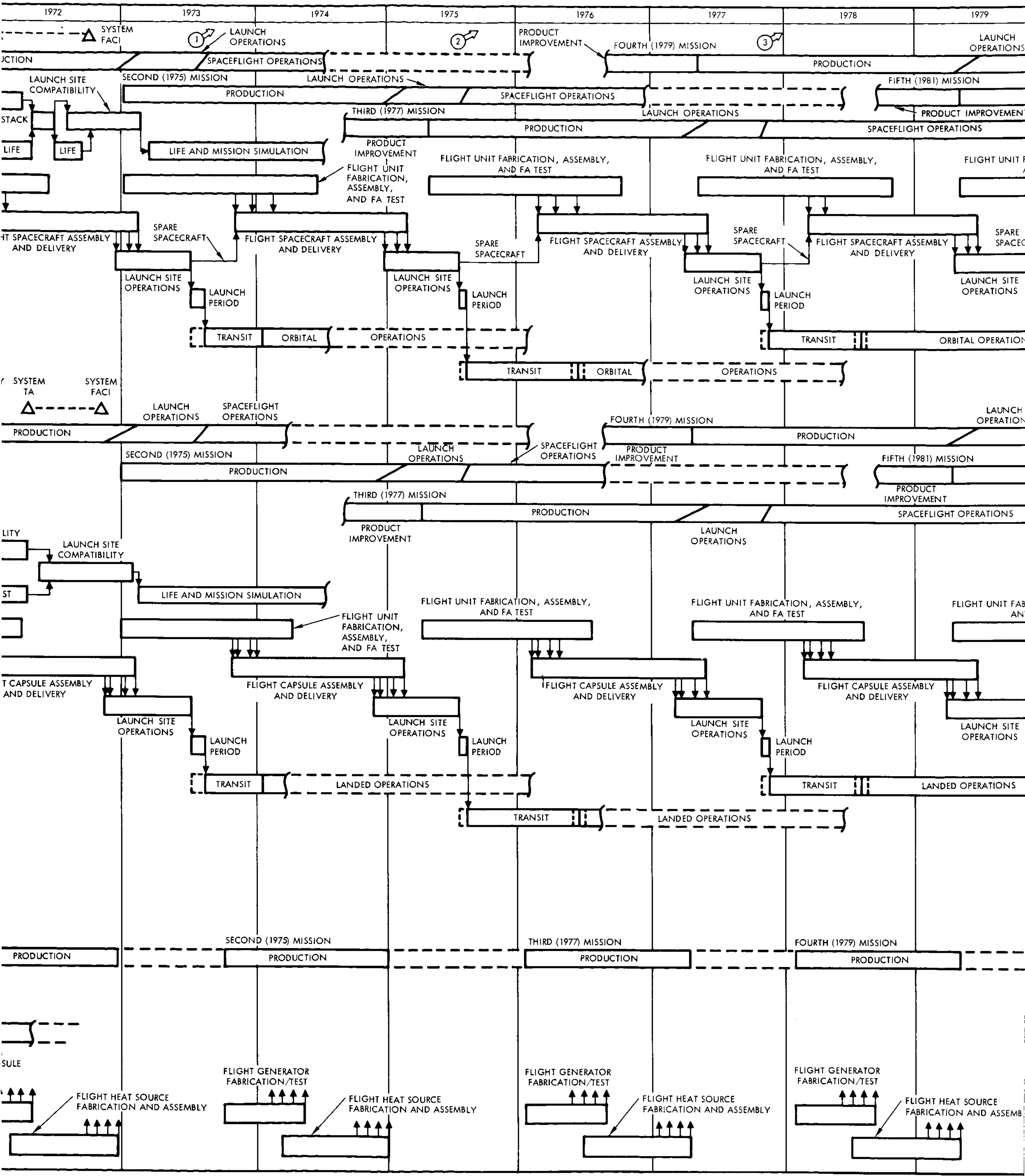
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SECOND (1975) MISSION
LAUNCH OPERATIONS
FIFTH (1981) MISSION
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THIRD (1977) MISSION
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SPARE SPACECRAFT
FLIGHT SPACECRAFT ASSEMBLY AND DELIVERY
LAUNCH SITE OPERATIONS
LAUNCH PERIOD
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LANDED OPERATIONS
FLIGHT CAPSULE ASSEMBLY AND DELIVERY
FLIGHT UNIT FABRICATION, ASSEMBLY, AND FA TEST
FLIGHT GENERATOR FABRICATION/TEST
FLIGHT HEAT SOURCE FABRICATION AND ASSEMBLY
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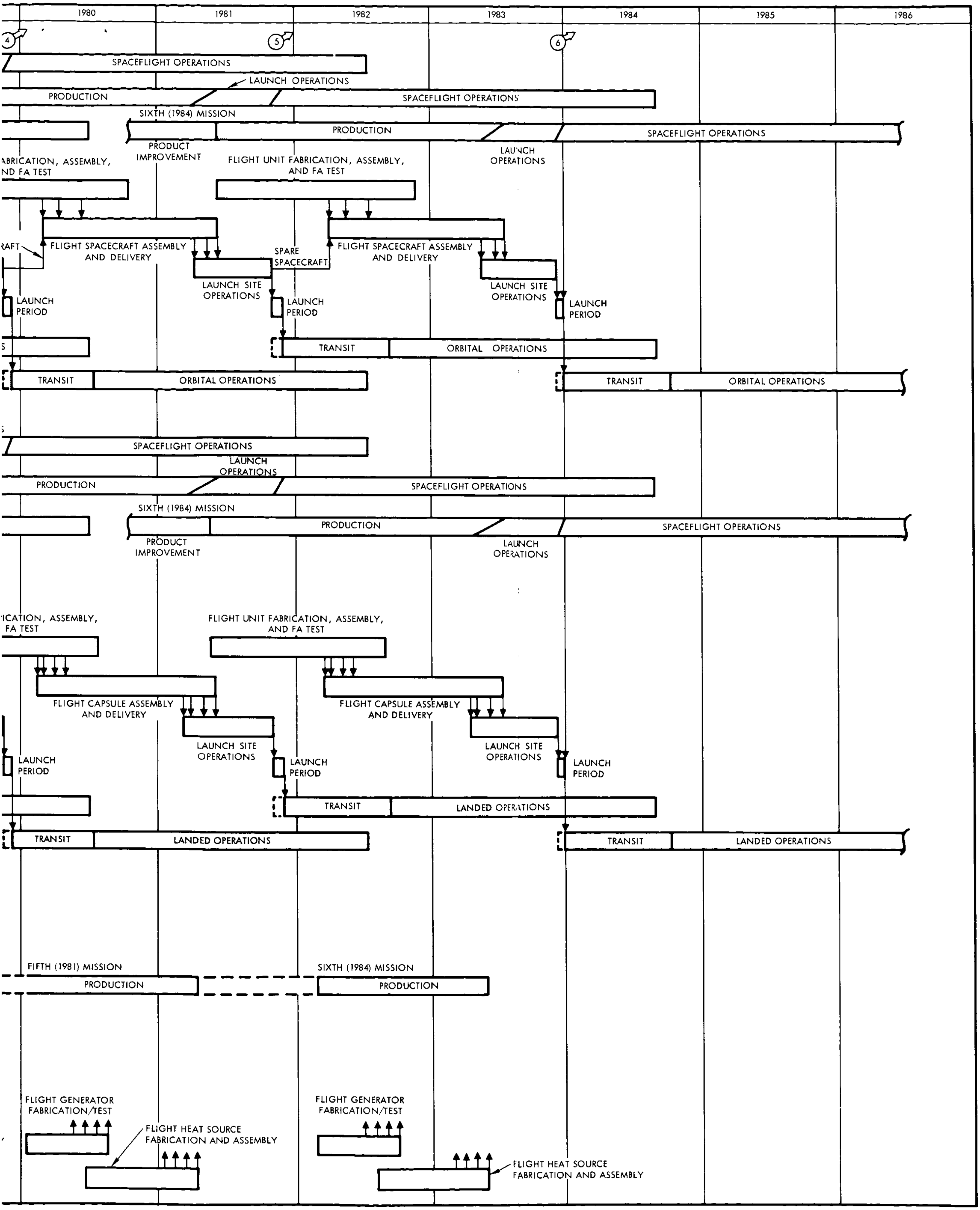
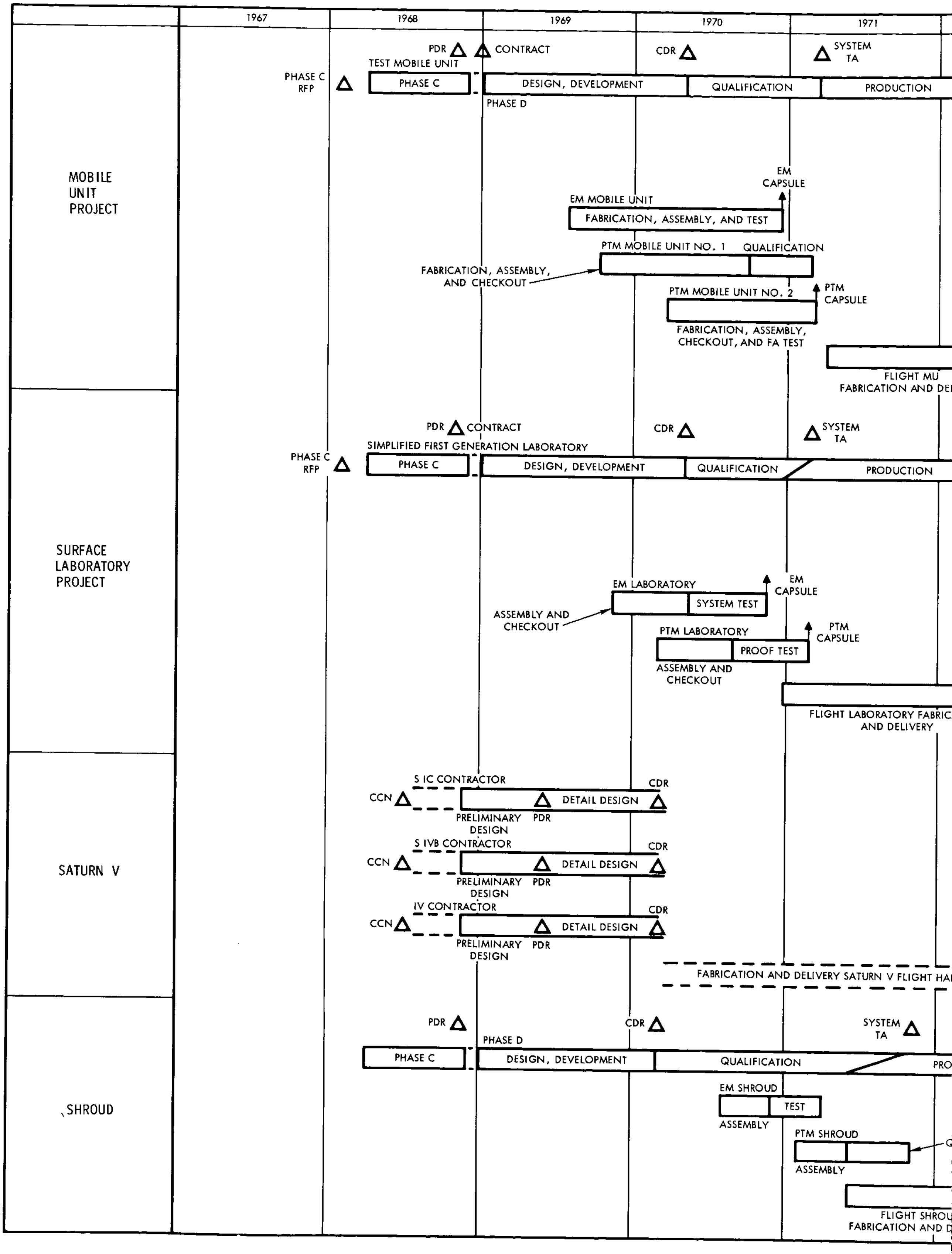


Figure 6. Voyager Project Flow and Schedule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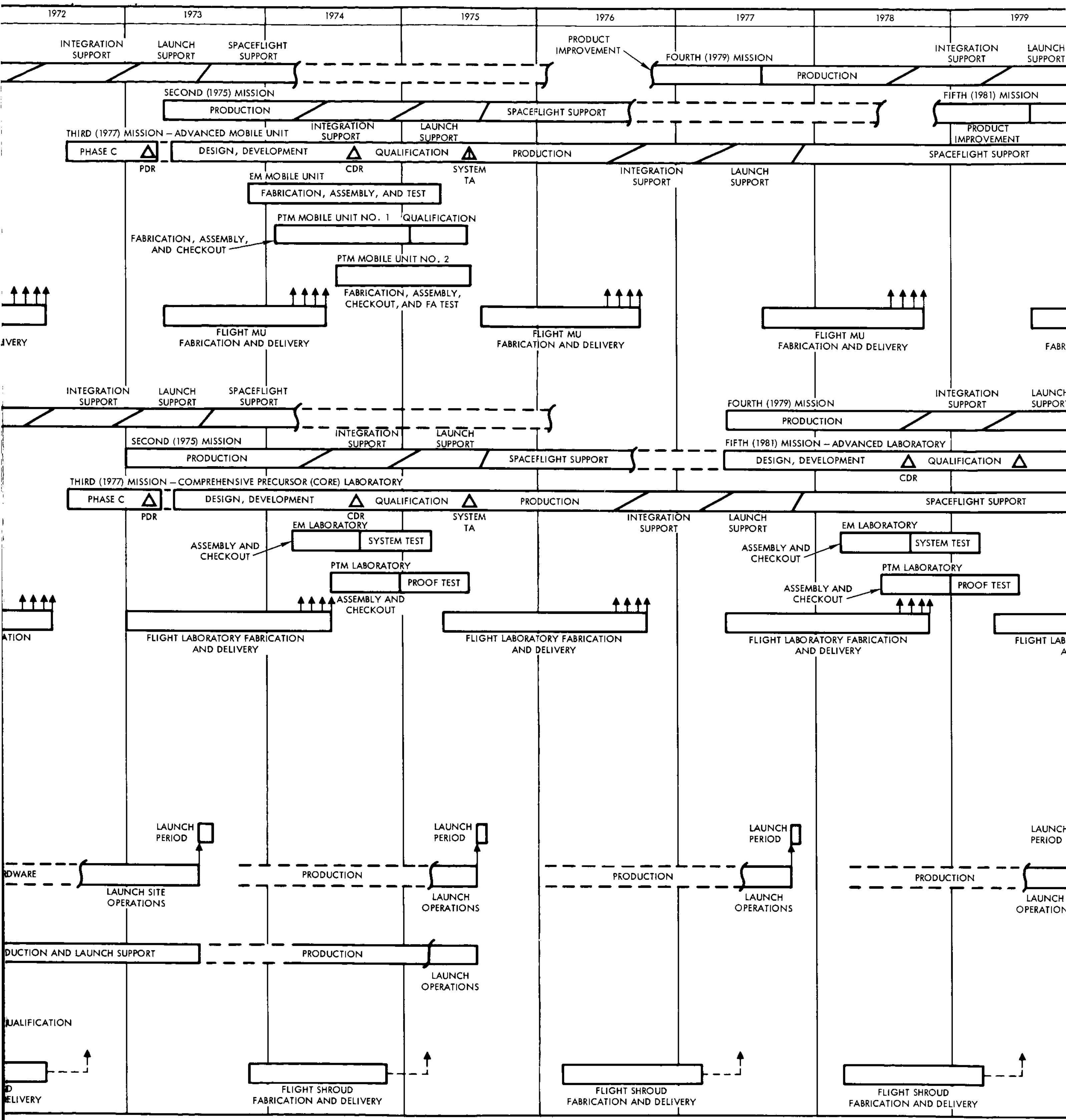
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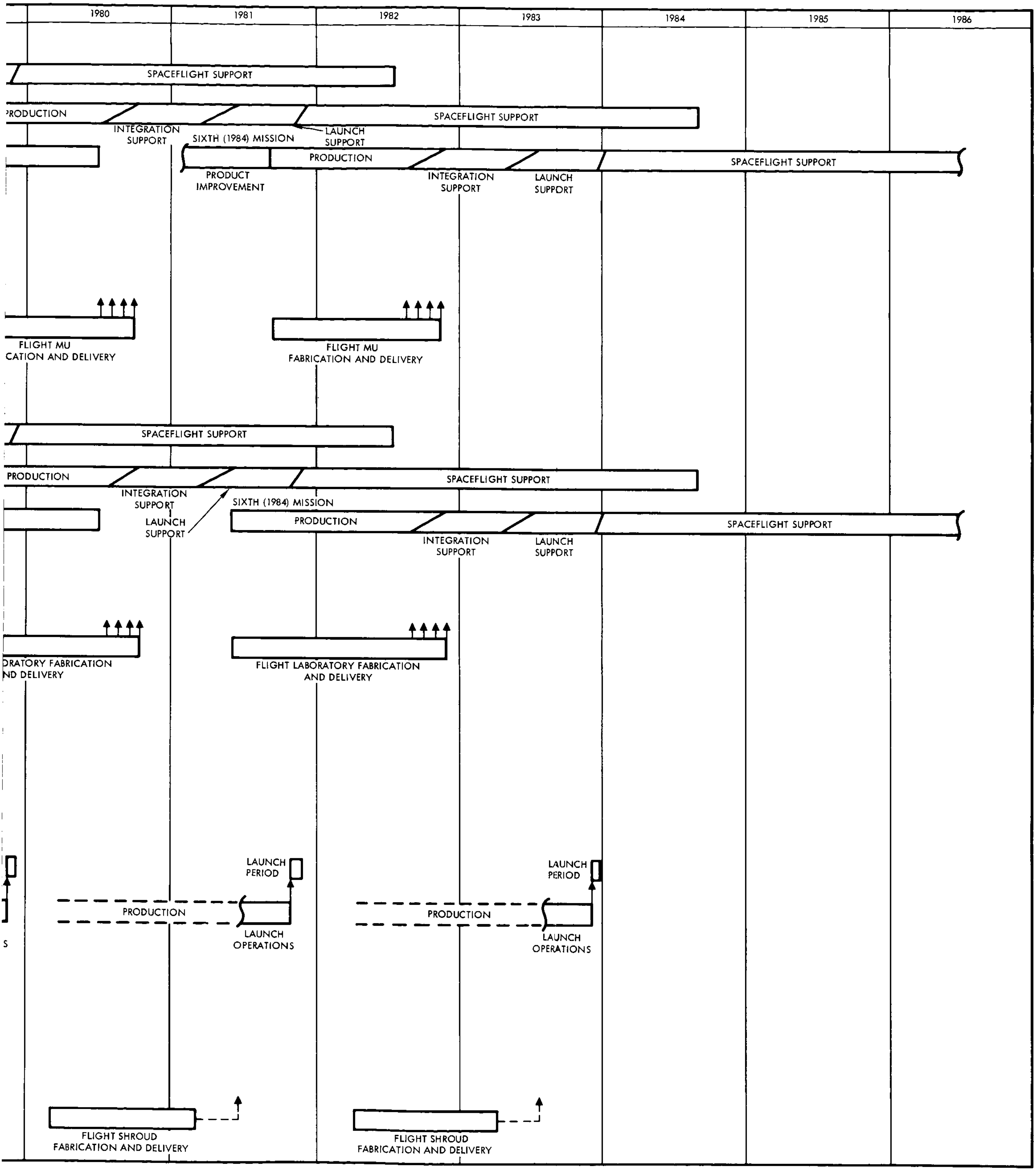
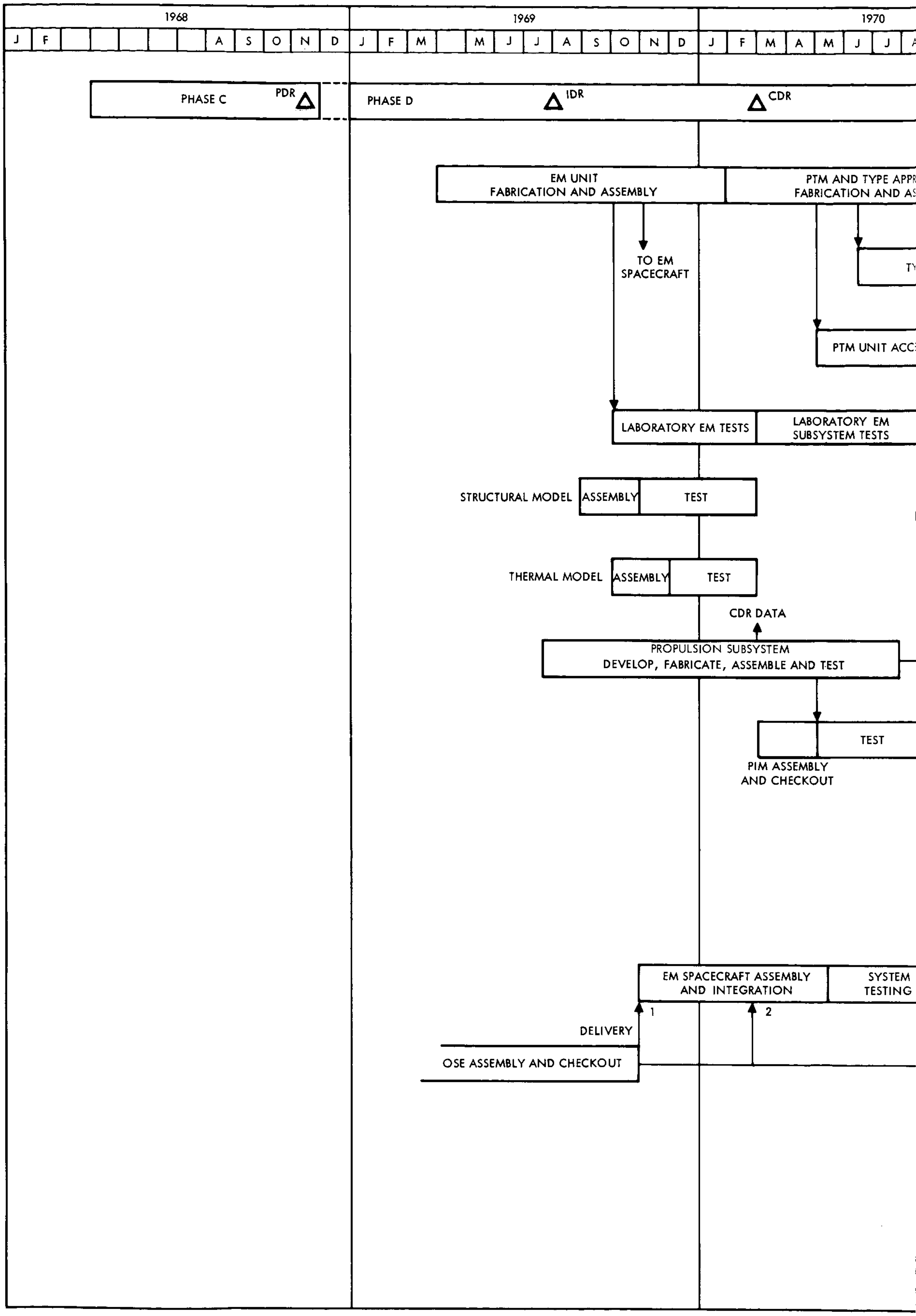


Figure 6. Voyager Project Flow and Schedule (Continued)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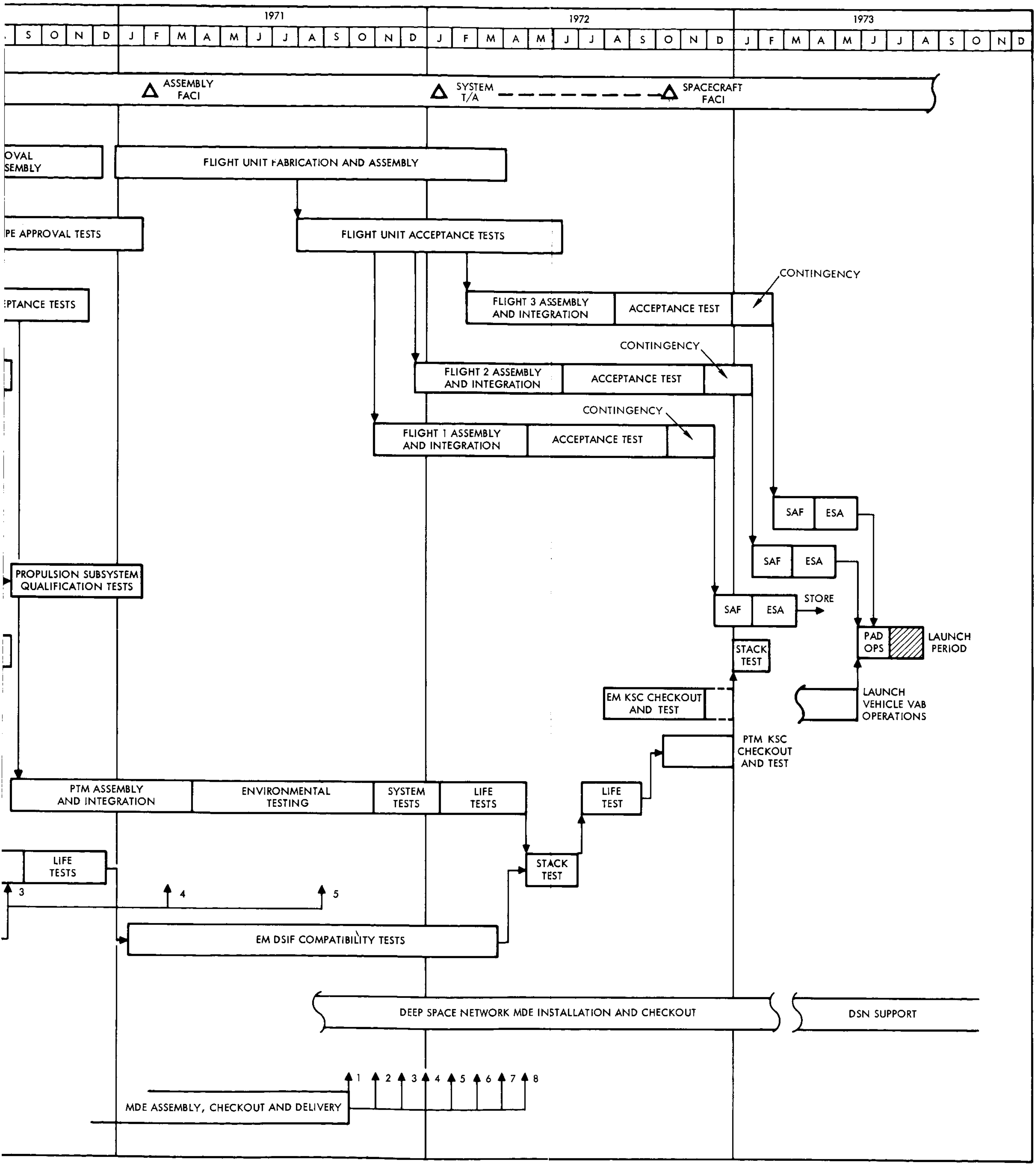


Figure 7. Spacecraft Project Flow for Initial Mission

- Interface Control Plan
- Configuration Management Plan
- Project Management Plan
- Project Control and Data Management Plan
- Flight Evaluation Plan
- Electromagnetic Compatibility Control Plan
- Value Engineering Plan
- Development and Prelaunch Operations Plan
- CEI Identification List
- Critical Components List
- Planetary Quarantine Plan

It has been estimated that Phase D of the spacecraft system will be initiated in January 1969. At that time detailed design of the overall spacecraft system will be started. This will include the design of breadboard systems, engineering models, test facilities, soft tooling, and special manufacturing devices. Design of EOSE and MOSE to support the assembly and checkout of all flight-configured hardware will also be undertaken. Finally, detailed designs of flight-type articles and MDE will be initiated and culminated in a series of subsystem critical design reviews in February-March 1970. This allows over 2.5 years for fabrication, type approval testing, and delivery of the first flight article. Assembly-level qualification is completed by February 1971 and complete spacecraft qualification by February 1972. Flight article unit fabrication starts January 1971. Fabrication of a particular item follows completion of assembly-level qualification as a basic tenet of the spacecraft schedule.

Completion of system FACI, as finalized with acceptance of the first flight article, will occur by November 1972, approximately eight months before the launch period. Three flight-configured spacecraft (two plus one spare) will be fabricated, assembled, checked out, and acceptance tested at the spacecraft contractor's facility prior to shipment to KSC. All three systems will be shipped to KSC during December 1972 to February 1973.

Because the spacecraft system will remain essentially standardized for the additional five missions, only fabrication, assembly, and delivery is shown. The major development activities for these follow-on missions will depend on the nature of the changes imparted to the science packages to be utilized. Modifications to the spacecraft for product improvement and new science or capsule integration requirements will be the pacing activity during these follow-on mission phases.

Further discussion of spacecraft project implementation is provided in Section 15.

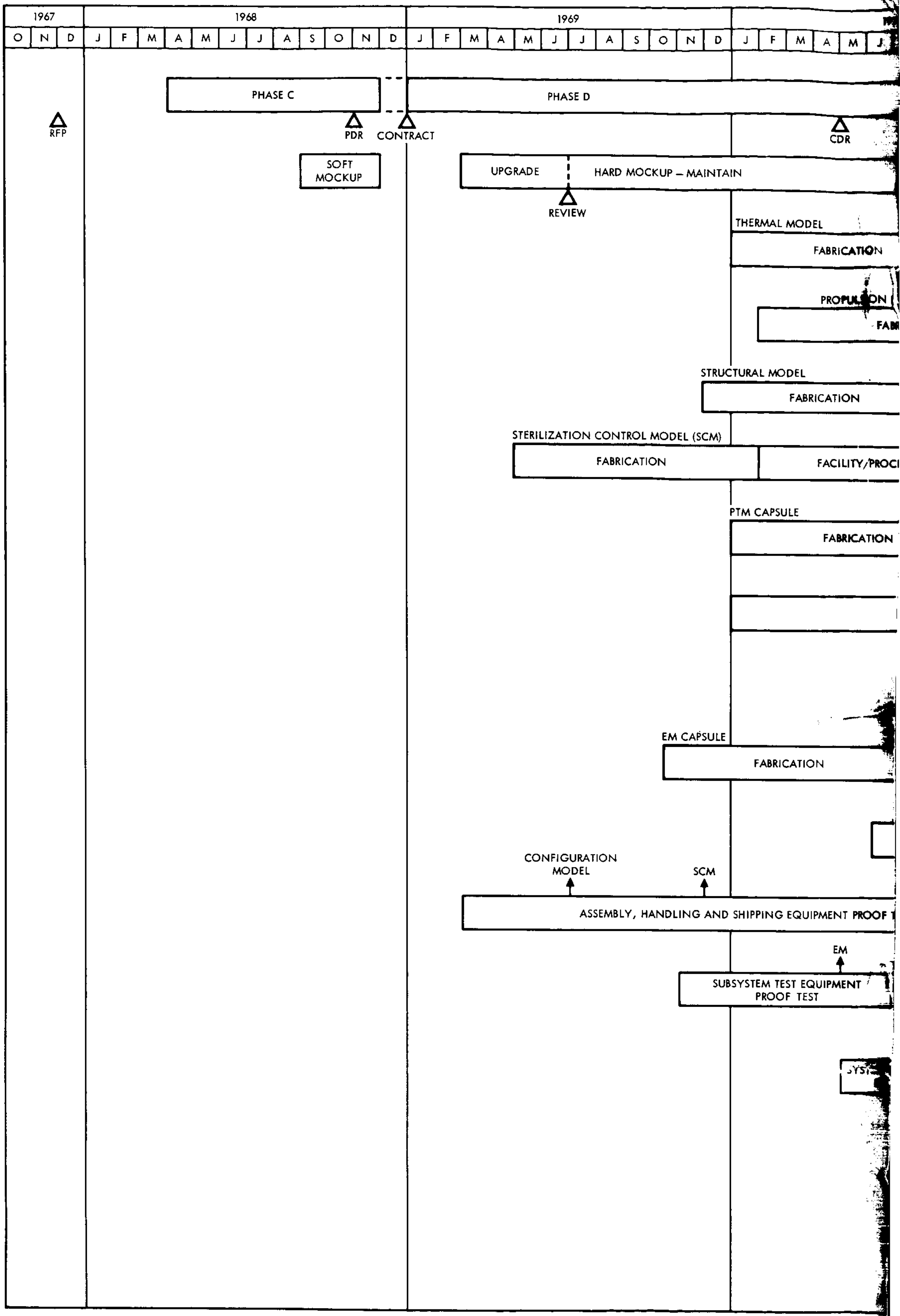
6.3 CAPSULE SYSTEM SCHEDULE

The overall capsule system implementation as depicted in Figure 8 assumes Phase B activities by the capsule contractor during mid-1967. It has been assumed that this effort will be completed by October 1967. During this period all of the mission and system requirements will be identified in the form of general specifications and intersystem interface control documents. These documents will encompass all of the capsule system (i.e., capsule bus, surface laboratory, mobile unit, and RTG) despite the fact that it is assumed that the latter three systems will ultimately be implemented by separate associate contractors.

Phase C implementation for the capsule bus has been assumed to be initiated with the issuance of an RFP by December 1967. Selection of a capsule contractor should be completed by April 1968. The overall schedule and major activities during this phase will be quite similar to those delineated for the spacecraft system in Section 6.2. However, because there will be three intrasystem associate contractors to work with, it is anticipated that the interface control documentation activities for the capsule contractor will be more extensive than for any other major Voyager program associate contractor.

After assembly and integration of the capsule bus with the surface laboratory, mobile unit, and RTG, checkout of the entire capsule system will take place at the capsule contractor's facility.

Upon completion of sterilization operations, acceptance tests, and mission acceptance review, four flight capsules will be shipped to KSC during November 1972 - January 1972. This permits over six months for


1967
1968
1969
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
PHASE C
PHASE D
RFP
PDR
CONTRACT
CDR
SOFT MOCKUP
UPGRADE
HARD MOCKUP – MAINTAIN
REVIEW
THERMAL MODEL
FABRICATION
PROPULSION
STRUCTURAL MODEL
FABRICATION
STERILIZATION CONTROL MODEL (SCM)
FABRICATION
PTM CAPSULE
FABRICATION
EM CAPSULE
FABRICATION
CONFIGURATION MODEL
SCM
ASSEMBLY, HANDLING AND SHIPPING EQUIPMENT PROOF
EM
SUBSYSTEM TEST EQUIPMENT PROOF TEST

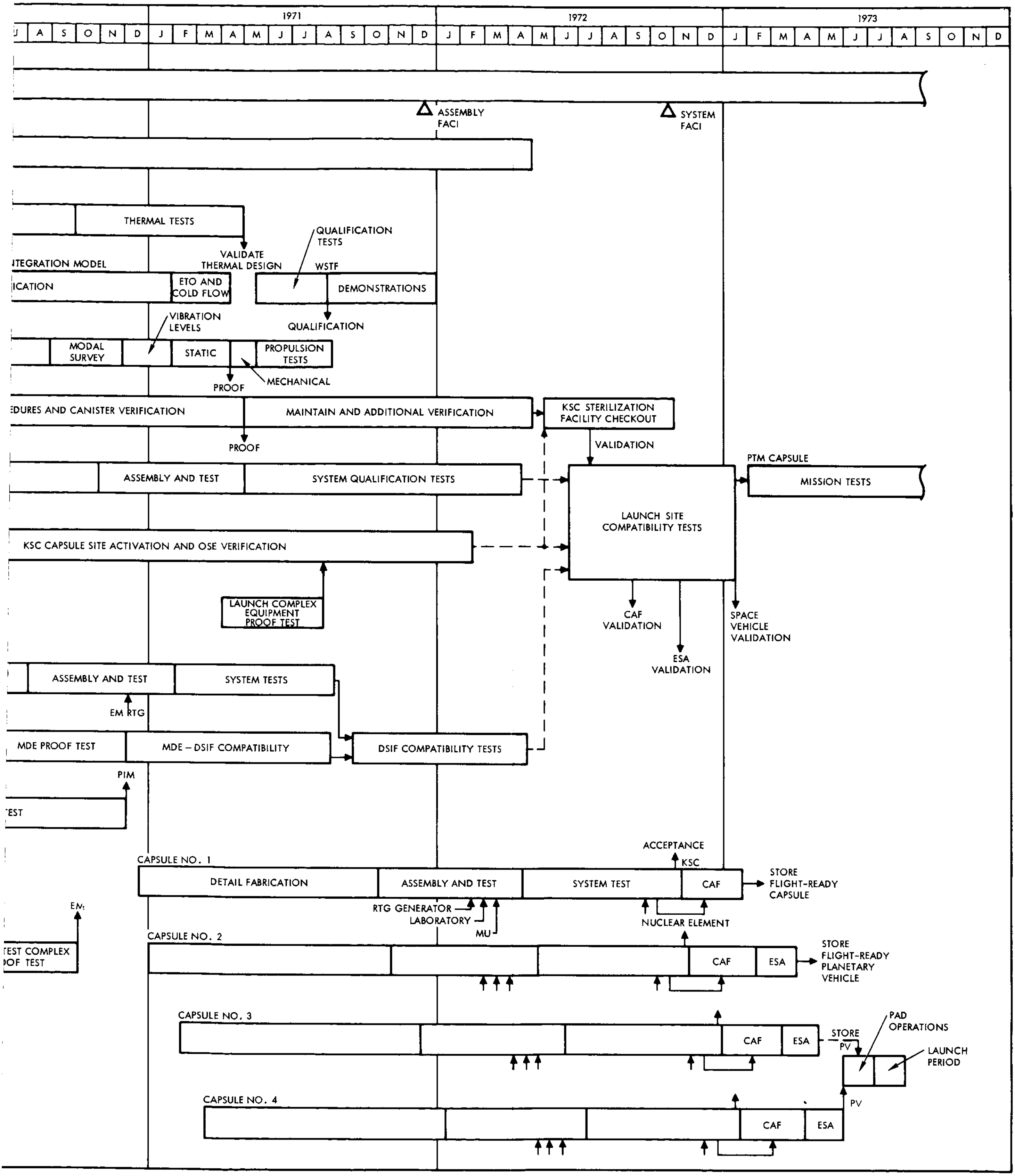
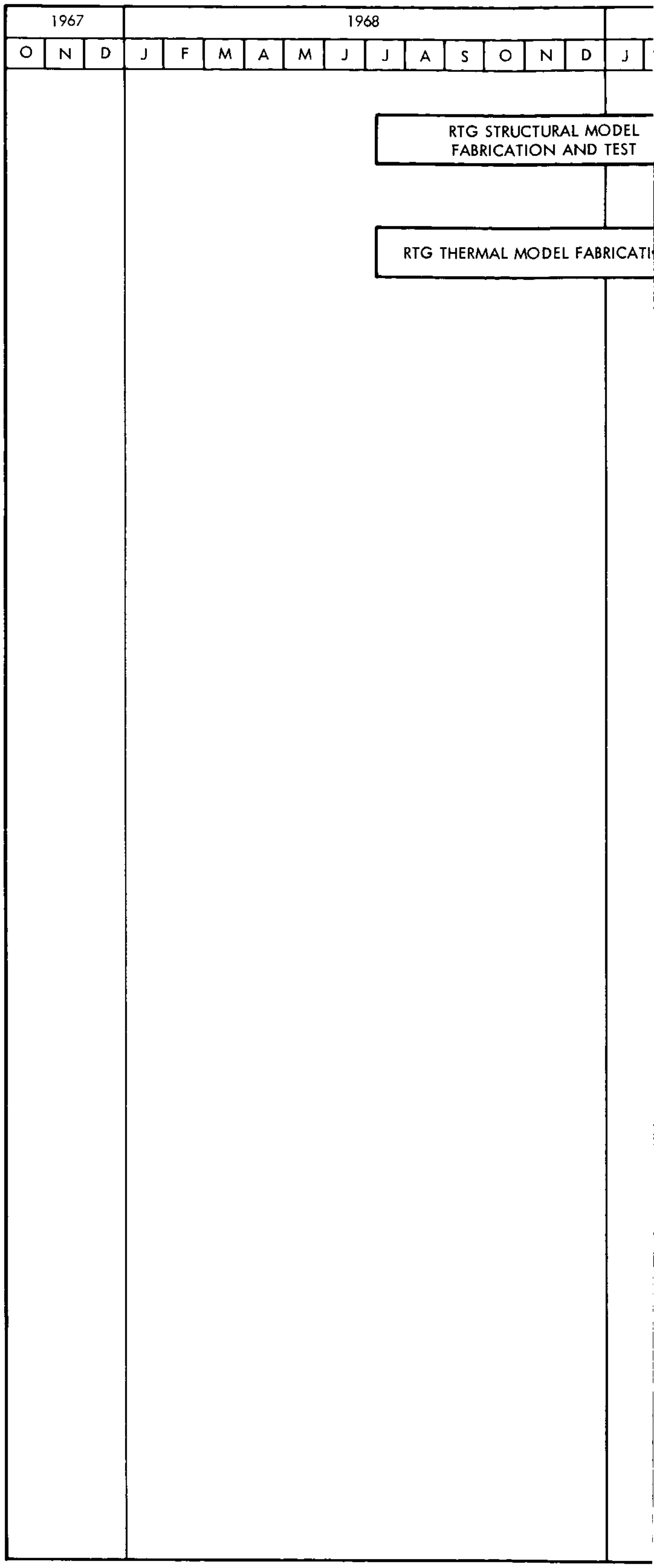


Figure 8. Capsule System Project Flow for Initial Mission (1 of 3)(Capsule Project)


1967
1968
O
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J
F
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A
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S
O
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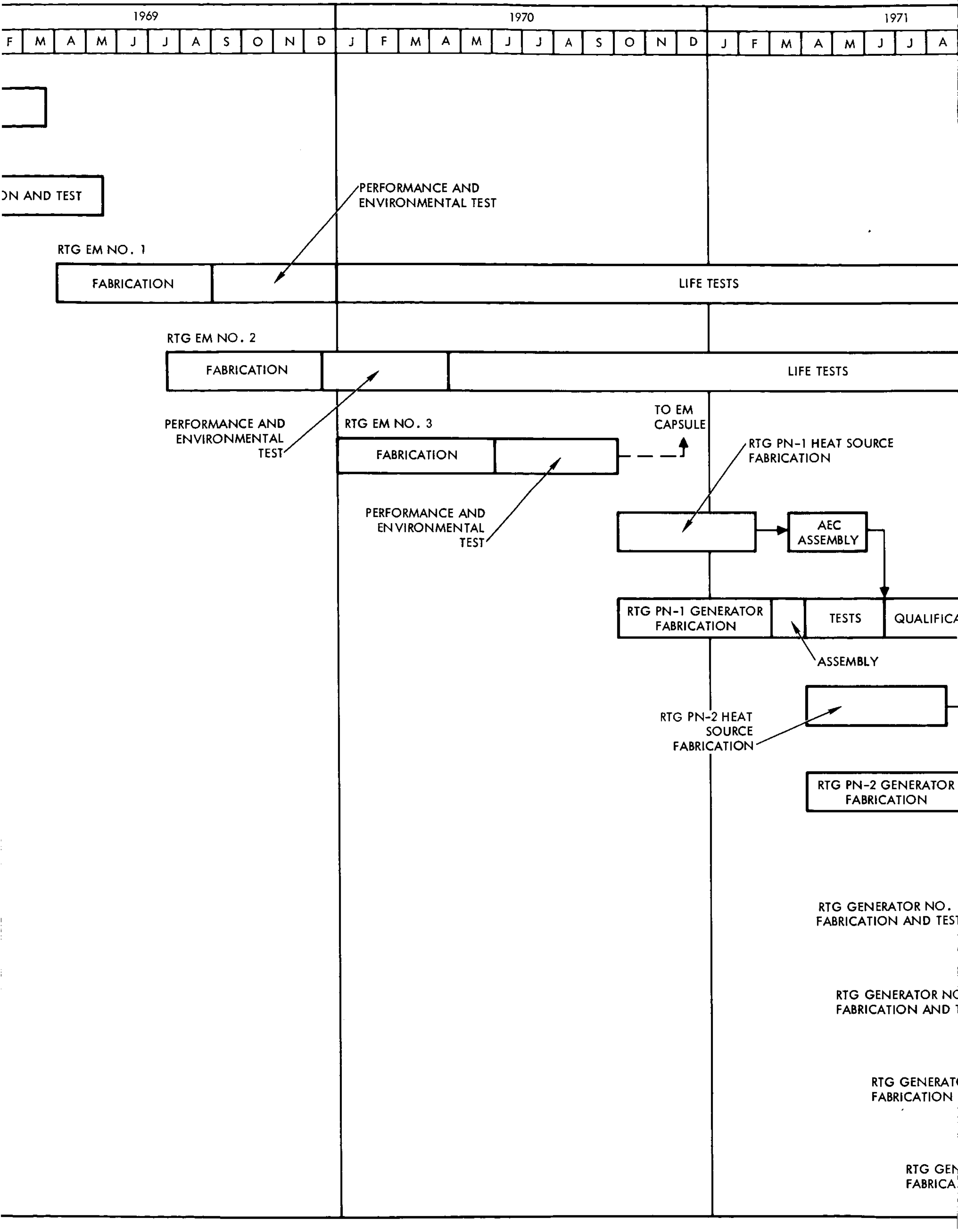
J
RTG STRUCTURAL MODEL FABRICATION AND TEST
RTG THERMAL MODEL FABRICATI


1969
1970
1971
F M A M J J A S O N D
J F M A M J J A S O N D
J F M A M J J A
ON AND TEST
PERFORMANCE AND ENVIRONMENTAL TEST
RTG EM NO. 1
FABRICATION
LIFE TESTS
RTG EM NO. 2
FABRICATION
LIFE TESTS
PERFORMANCE AND ENVIRONMENTAL TEST
RTG EM NO. 3
FABRICATION
TO EM CAPSULE
RTG PN-1 HEAT SOURCE FABRICATION
PERFORMANCE AND ENVIRONMENTAL TEST
AEC ASSEMBLY
RTG PN-1 GENERATOR FABRICATION
TESTS
QUALIFICA
ASSEMBLY
RTG PN-2 HEAT SOURCE FABRICATION
RTG PN-2 GENERATOR FABRICATION
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RTG GENERAT
FABRICATION
RTG GEN
FABRICA

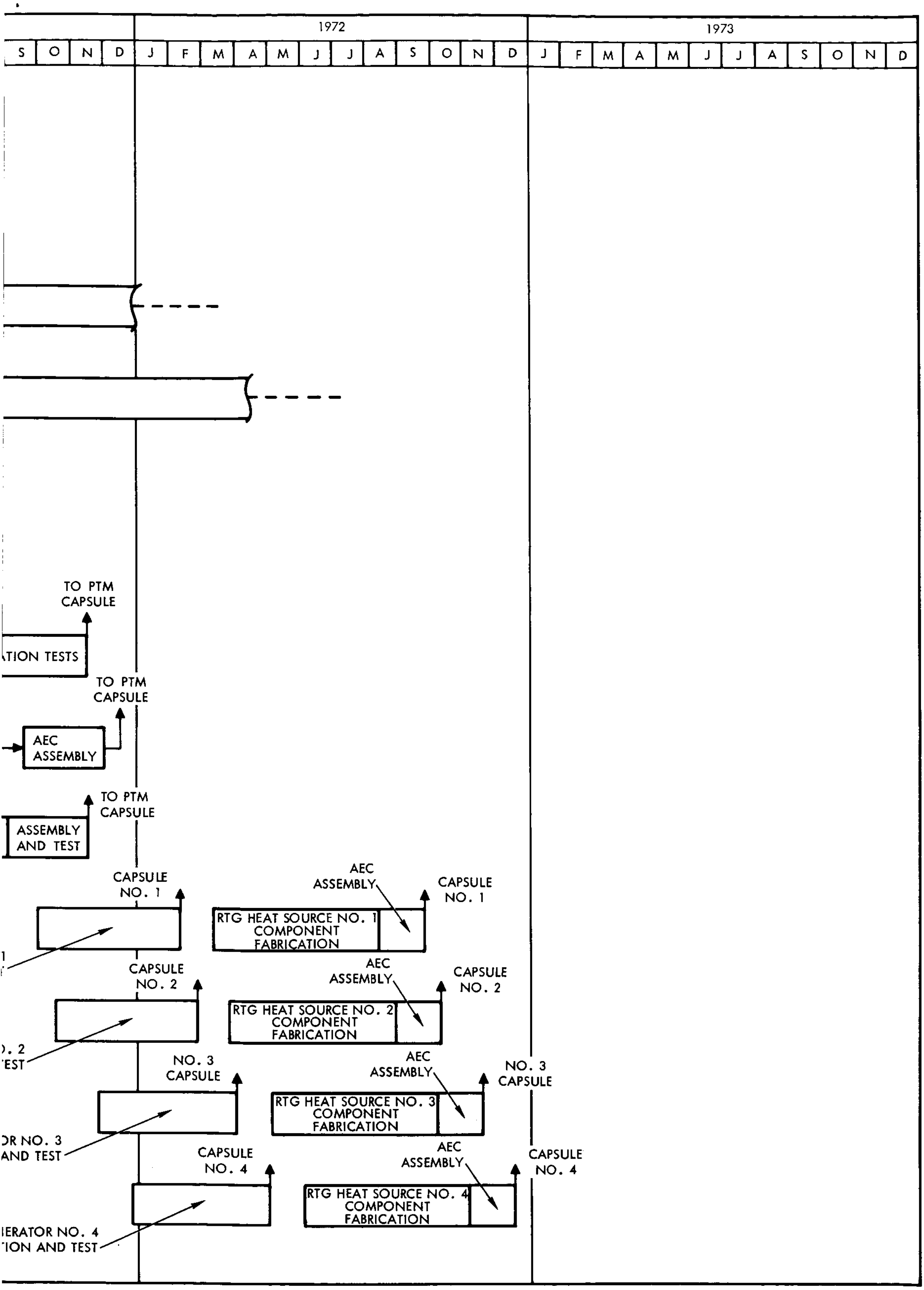
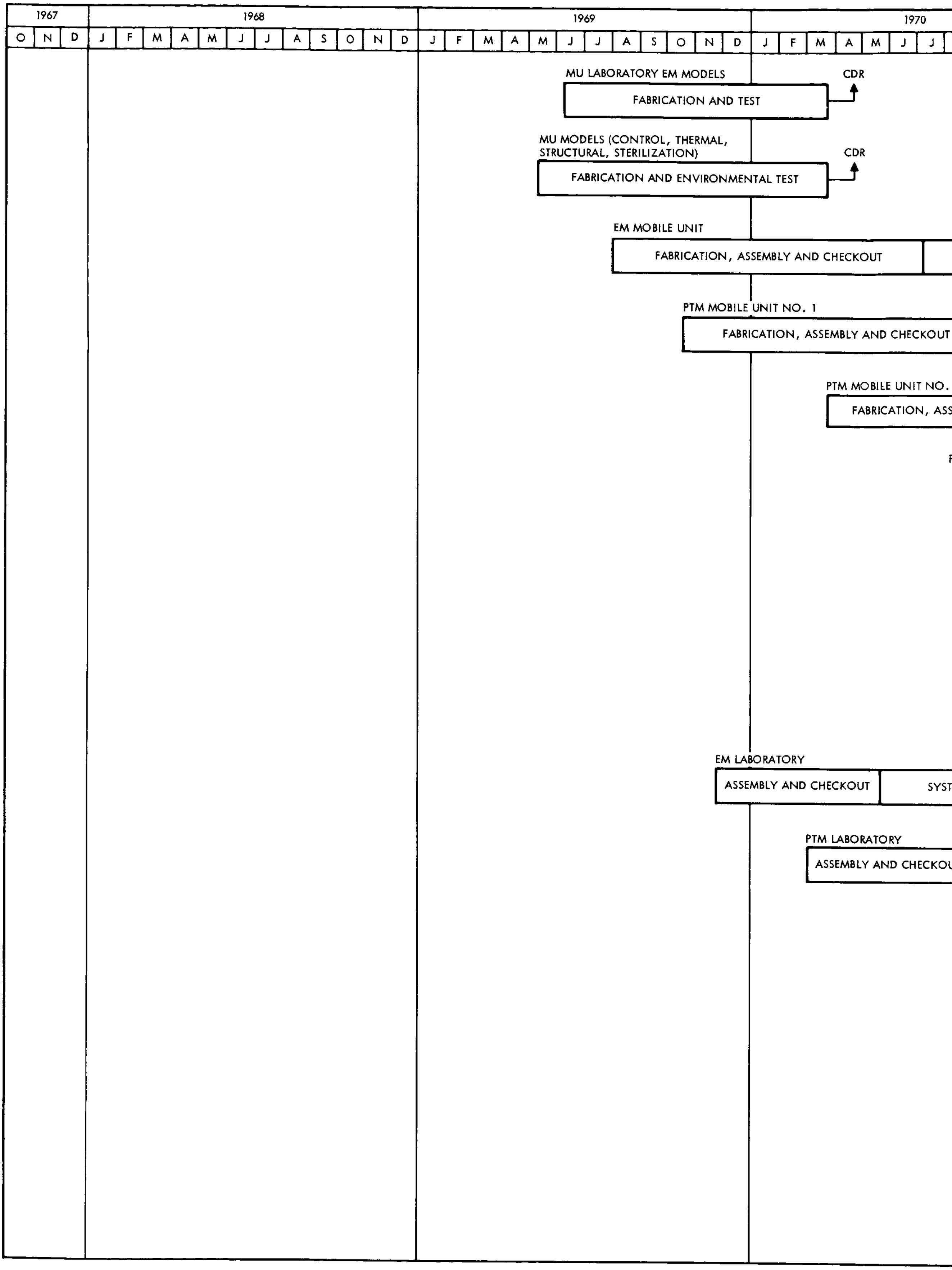


Figure 8. Capsule System Project Flow for Initial Mission (Continued)(2 of 3) (RTG Project)


1967
1968
1969
1970
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J
MU LABORATORY EM MODELS
FABRICATION AND TEST
CDR
MU MODELS (CONTROL, THERMAL, STRUCTURAL, STERILIZATION)
FABRICATION AND ENVIRONMENTAL TEST
CDR
EM MOBILE UNIT
FABRICATION, ASSEMBLY AND CHECKOUT
PTM MOBILE UNIT NO. 1
FABRICATION, ASSEMBLY AND CHECKOUT
PTM MOBILE UNIT NO.
FABRICATION, ASS
EM LABORATORY
ASSEMBLY AND CHECKOUT
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PTM LABORATORY
ASSEMBLY AND CHECKOU

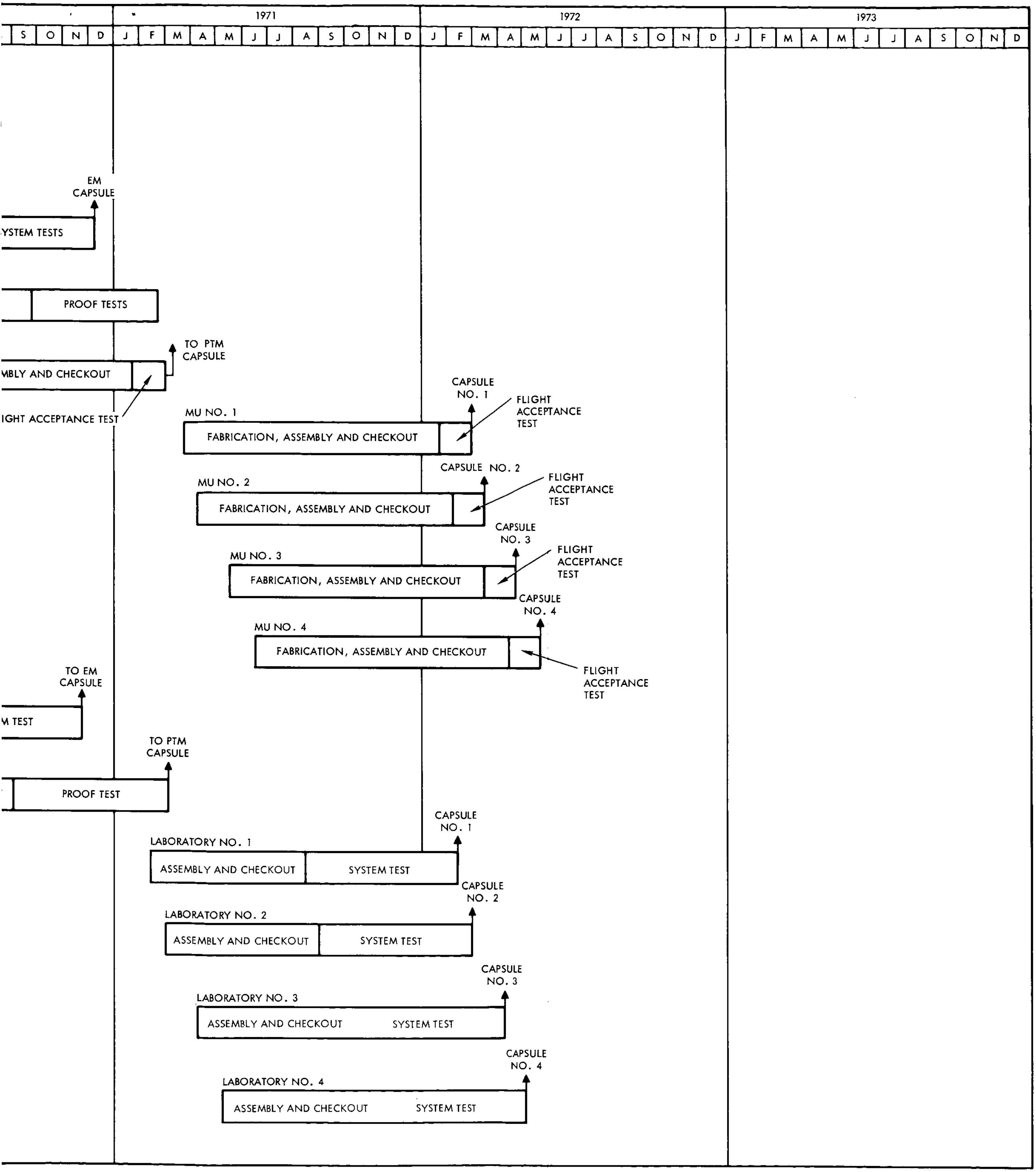


Figure 8. Capsule System Project Flow for Initial Mission (Continued)(3 of 3) (Landed Science)

conducting prelaunch checkout, sterilization operations, planetary vehicle integration support at KSC, and pad operations.

During follow-on missions the capsule bus will remain fairly standardized in its configuration. However, extensive changes to the surface laboratory and mobile unit for the second and third generation missions will impose considerable implementation activities upon the capsule contractor.

Further discussion of capsule project implementation is provided in Section 16.

6.4 RTG SCHEDULE

The RTG will be implemented by an associate contractor under contract to the AEC. The RTG flight hardware will be furnished as GFE to the capsule contractor upon successful completion of proof and acceptance test. Development hardware will also be supplied for capsule integration activities.

The RTG project will be initiated with the issuance of a Phase C RFP in January 1968. It has been assumed in the overall schedule (Figure 6) that the RTG system requirements will have been defined by the capsule contractor during Phase B. These requirements will be provided to the capsule SMO for review, and in turn will be transmitted to the AEC as the cognizant agency for implementation of this system. A contract award from the AEC is estimated to occur in April 1968. The PDR and CDR will be held by November 1968 and April 1970, respectively, to coincide with occurrence of the same events on the other major Voyager program systems. To permit timely integration of the RTG system into the capsule system, delivery of eight RTG systems (with simulated heat sources) has been scheduled for the first half of 1972. The radioisotope heat sources will be shipped to the capsule contractor facility during the last quarter of 1972. The heat source is used only for final capsule acceptance testing to minimize the hazards associated with isotope handling. It is felt that with radiation signature data supplied to the capsule contractor, integration and checkout of the capsule using the RTG system with the simulated heat source will prove adequate for much of the capsule system testing. Eight heat sources are to be supplied for each mission.

This approach will be compatible with supplying two spare flight capsules in a complete flight-ready condition. The RTG systems for the follow-on missions will be implemented on a two-year cycle basis, but with each cycle starting several months after the launch date of the previous mission. Furthermore, to conserve the isotope inventory, it is anticipated that unused spare heat sources will be sent back to the AEC for reprocessing and used again on future missions.

Further discussion of RTG project implementation is provided in Section 17.

6.5 MOBILE UNIT SCHEDULE

In keeping with the technical plan developed in Reference 1, the mobile unit represents a two-generation implementation. The mobile unit project will be implemented by an associate contractor under the cognizance of the capsule SMO. It will have important interfaces with the surface laboratory and the capsule bus. Hence extensive interface control documentation will have to be generated early in the program. Since it has been assumed that Phase B activities for this system will be the responsibility of the capsule contractor, implementation of this system by the mobile unit contractor will commence with Phase C.

Mobile unit implementation will be initiated with the issuance of a Phase C RFP in January 1968. Contract award is assumed to take place by April 1968, and the preliminary design review completed by November 1968. A unique aspect of mobile unit implementation is that the initial test vehicle will be designed to be compatible with the anticipated weights and volumes for the experiment packages to be used on the advanced mobile unit. In this way the reliability of the advanced mobile unit structure and drive mechanism can be enhanced by drawing upon the initial operational experiences of the earlier mobile units. The design compatibility is also essential from a schedule point of view since a minimum of three years is normally required to develop and qualify a mobile unit system.

Phase D for this system will be initiated in January 1969 to assure availability of four qualified units at the capsule contractor's facility by the first half of 1972. About a year and a quarter is scheduled for fabrication and delivery of the flight units. Because of the numerous interfaces and intersystem test requirements, it will be essential that the mobile unit contractor maintain permanent support personnel at the capsule contractor at KSC during launch site operations, and at the SFOF for spaceflight support.

It has been assumed that the mobile unit contractor will have decontaminated his system prior to shipment to the capsule contractor. Hence, from that point on, the mobile units will have to be maintained under Class 100 contamination control. This will have a significant impact on the schedule from that point on since handling procedures become much more complex after this point is reached in the development phase.

Phase C for the second generation mobile unit will be initiated in mid-1972 and terminated with a PDR in early 1973. Phase D will be started immediately thereafter, with the CDR taking place in mid-1974. This configuration will be designed to meet both the second and third generation mission objectives. However, because of the time span involved, the delay of data received from the earlier missions, and the normal technological evolution that will occur over a 10-year period, some updating, improvements, and modifications will undoubtedly be applied to the basic mobile unit, as well as its payload, although these changes will probably not be of a major nature.

As shown in Figure 6, data from the first mission will not be available until early 1974. This is about 15 months prior to qualification and 27 months prior to delivery of the second generation mobile unit for the 1977 mission. The early design and development will thus have to proceed without this data, and the project will then have to react expeditiously as required.

Further discussion of mobile unit project implementation is provided in Section 19.

6.6 SURFACE LABORATORY SCHEDULE

In keeping with the technical plan of Reference 1, the surface laboratory for the reference program is presented as a three-generation implementation approach. The surface laboratory project will be implemented by an associate contractor under the cognizance of the capsule SMO. Because the project definition tradeoffs are assumed to be done during the capsule Phase B, the surface laboratory contractor implementation will commence with Phase C. The RFP for this phase should be issued by January 1968 and a contract award made about April 1968 if the overall schedule of Figure 6 is to be accommodated. It is anticipated that the first generation simplified precursor landed science will neither be complex nor require any advancements in technology, so that about three years for development, fabrication, and delivery should prove adequate. Shipment of four surface laboratory systems to the capsule contractor by mid-1972 has been scheduled.

While Phase C and D activities, in general, will be similar to spacecraft and capsule bus implementation, interface control will become a significant effort because of the numerous interfaces between the surface laboratory, mobile unit, capsule bus, RTG, and the related EOSE and MOSE checkout equipment. In addition, electromagnetic compatibility as well as compatibility with the decontamination and sterilization cycles must also be demonstrated. Second and third generation surface laboratory systems will be considerably more complex than the first generation laboratory. To meet the 1977 launch date, Phase C activities will be initiated by mid-1972 and Phase D nine months later. This will permit approximately 3.25 years for development, fabrication, and delivery of the comprehensive surface laboratory flight hardware. Data from the 1973 mission will become available in early 1974, about 2.5 years prior to delivery of the first flight laboratory for the 1977 mission.

The surface laboratory contractor will provide support to the capsule contractor during the integration and testing activities conducted both at the capsule contractor facility and at KSC. Hence, it has been assumed that the surface laboratory contractor will provide permanent teams of personnel at both the capsule contractor's facility and at KSC, in order to meet the schedules indicated. In addition, extensive support to the mission operations system will be required of the surface laboratory contractor during Mars landed operations.

Further discussion of surface laboratory project implementation is provided in Section 18.

6.7 SATURN V BOOSTER SCHEDULE

The launch vehicle system for the Voyager program, excluding the shroud system, is assumed to be a standard "off-the-shelf" version of the Saturn V booster. As discussed in Section 14, there may be slight modifications required to the Saturn IVB and the instrument unit to make them compatible with the Voyager requirements. Flight dynamics studies will also be required by the S-IC contractor. It has been assumed that by mid-1968, these will have been identified by the Phase C activities of the spacecraft and capsule contractors. At that time contract change notices would be issued to these contractors to permit them to negotiate the costs and schedules for implementating the required work. It has been assumed these negotiations will have been completed by November 1968 and preliminary design work initiated. A preliminary design review will be conducted in May 1969 and a critical design review would be held in the first quarter of 1970, coincident with the CDR's for all the other major Voyager systems.

Following approval of these modifications by the Voyager project office and the launch vehicle SMO, fabrication of the S-IC, S-II, and S-IVB stages and the instrument unit would commence. There should be no difficulty for the launch vehicle project segments in meeting Voyager schedule requirements. The schedule calls for launch site compatibility testing in support of the first mission, followed by prelaunch operations. Subsequent missions will only require preparation for flight.

Further discussion of Saturn V implementation for the Voyager project is provided in Section 14.

6.8 SHROUD SCHEDULE

Implementation of the Voyager shroud will be carried out by an associate contractor under the cognizance of the launch vehicle SMO. Assuming a Phase C RFP is issued in early 1968, it is estimated that a contract award would take place in April 1968. A PDR would be conducted by December 1968 in keeping with the other major Voyager system PDR activities. Phase D would commence at the start of 1969 and a CDR would be held by March 1970, to coincide with similar activities for the other major systems. Since the outside diameter of the cylindrical sections of the shroud system are identical to that of the S-IVB stage, it has been assumed that much of the tooling and fixtures developed for this stage can be used on this system. This factor has been taken into account in scheduling this new addition to the overall launch vehicle system.

The first flight-configured shroud system for the 1973 mission would be manufactured, checked out, acceptance tested, and shipped to KSC by mid-1972, or later as required. At KSC the complete shroud would be integrated with two flight planetary vehicles as part of launch site compatibility testing. An additional activity associated with the shroud system is checkout for compatibility (mate, alignment, electrical, mechanical, etc.) with the Saturn V booster. The shroud contractor will provide support as required during launch site operations. Because the shroud system will become a standardized element of the launch vehicle system, no major schedule problems are anticipated for the implementation of additional systems for the future missions.

Further discussion on shroud implementation for the Voyager project is provided in Section 14.

7. RELIABILITY AND QUALITY ASSURANCE

Beginning with the Project Approval Document (Section 5.2.2), requirements for Voyager reliability and quality assurance programs will be defined, and the Project Development Plan will establish formal project objectives and procedures for both programs. In these programs the Voyager project manager is assisted by the project reliability assurance manager and the project quality assurance manager, and staff managers to assist in implementing the approved policies throughout all Voyager systems.

7.1 PROJECT RELIABILITY

The Voyager project reliability assurance manager will formulate the project reliability program plan to specify the adaptation of NASA NPC 250-1 for Voyager. The plan will define the basic requirements that all individual Voyager system reliability program plans need to meet. These plans will then be prepared by the contractor or agency responsible for each system. The basic requirements imposed on the system plans will include:

- Standardized reliability procedures throughout the project
- The maximum possible use of existing government standards, practices, and procedures
- Departure from NPC 250-1 only after justification and approval, with specific identification of the departure in the system plan
- Definition of responsibilities for reliability for all organizational elements
- Application of MIL-STD-217 for standards applied to reliability prediction
- Compatibility of system reliability analyses with mission analyses
- Justification for selection of parts without a history of successful space application

7.1.1 Program Control

The reliability program will be subdivided into at least eight elements for purposes of monitoring and control:

- Reliability program management
- Design support and analysis
- Design review and control
- Parts control
- Materials and processes control
- Supplier control
- Failure reporting and correction
- Reliability testing

In all of these areas the reliability program plan will specify objectives and milestones and prescribe the documentation and monitoring requirements.

Reliability program reviews will be scheduled within the same framework as the system design reviews and the first article configuration inspection; after FACI, reviews will be held every six months. These reviews will examine the status of each task in the reliability program to search for and to avoid any potential problems.

In addition all project specifications, including qualification test specifications, will be reviewed as part of the control of program reliability. System, subsystem, environmental, and equipment specifications will be checked for the following:

- Reliability requirement, to assess its realism and compatibility with the basic reliability budget
- Operating margins and tolerances to see that the range is adequate in view of anticipated environments and performance
- Reliability demonstration to assure that tests are correctly programmed and designed
- Quality assurance requirements to verify the proper application of reliability techniques and statistical controls

The selection, application, and test of parts to be supplied in the Voyager project will be controlled by establishing an approved parts list and working with formalized procedures and review boards to assure that all parts on the list have proper credentials and that no part is added to the list without adequate evaluation and test.

Similarly the materials and processes to be used on the Voyager project will be kept to a prescribed set, with additions to the list of approved materials and processes incorporated only under controlled conditions.

7.1.2 Reliability Prediction

The reliability program will incorporate proven techniques for reliability estimation based on stress analyses, population analysis, and statistical evaluation. The mathematical tools to be applied will include probability theory, accepted theoretical distributions, and the concepts of theoretical failure rate and corollaries. Reliability estimates will be made for the initial configuration and revised for each design change. Failure rates used will be derived from statistically valid test programs; if applicable programs have not been accomplished. Failure rates will be treated with appropriate conservatism and reviewed regularly to incorporate additional test data.

7.1.3 Failure Analysis

Failure mode, effect, and criticality will be included as integral portions of all design analysis to ascertain the probable locations and mechanisms of failure and then to assess the probable impact on mission success. The initial analysis at the start of each system design will be made at the system level, but as the design progresses the analysis will be expanded to include circuits and parts. The criticality of all possible failures will be analyzed as well from the point of view of the resultant functional variations and the extent to which a failure permits degraded function. Designs will then be adapted insofar as possible to assure that such degraded operation is still within the limits of the system specifications. As a part of the criticality analysis a worst case situation will be defined to determine the cumulative effect on mission success of the worst combination of tolerances, environments, and time-dependent degradations.

7.1.4 Maintainability

The reliability program will cover the necessary project activities to analyze designs for maintainability, institute maintainability into designs, and evaluate the effectiveness of those measures adopted by the project to assure maintainability. Before designs have progressed beyond conceptual approaches, a maintainability design checklist will be furnished to design engineers, manufacturing engineers, and quality assurance personnel. When they are established all fabrication methods will be reviewed for their effects on maintainability.

7.1.5 Failure Reporting

A comprehensive system for prevention of failure recurrence will also be incorporated in the reliability program. The system will rely on a standardized reporting technique to assure that every failure encountered during test and checkout will be analyzed by the appropriate engineers to determine its cause and means to prevent recurrence. The reliability organization will then monitor the subsequent project effort to be certain that the recommended corrective action is reviewed and implemented. In addition as an iterative function in the design process all failure reports will be fed back to responsible design engineers and parts specialists.

7.1.6 Testing

Requirements for reliability evaluation will be established in the project test plan by reliability specialists. These requirements will be revised and reflected in development test procedures based on the failure mode, effect, and criticality analysis and reliability models and assessments. The impact of test results on the reliability models and failure modes will constitute a scheduled portion of the regularly scheduled program reviews.

The objective of the testing with respect to reliability will be early exposure of elements of unreliability and prompt initiation of whatever redesign is indicated to circumvent these elements. Three types of tests will be performed on Voyager components; life tests, wearout tests, and single-function tests as are appropriate in view of the effects of the component on the mission goals.

7.2 QUALITY ASSURANCE

A quality assurance plan for the Voyager project will be established by the project quality assurance manager, based on the provisions of NPC 200-2, to prevent defects in manufactured articles and assure conformance to design and performance criteria. The plan will cover:

- Design and development control
- Supplier control
- Inspection and certification
- Process and fabrication controls
- Sampling
- Workmanship standards
- Nonconforming materials control
- Acceptance test verification
- Handling, shipping, and storing procedures

7.2.1 Design and Development

The quality assurance plan will bear on design and development activities in three ways; participation in qualification and design verification tests, review of drawings and specifications to assure ease of manufacture, inspection, test, installation, and maintenance, and formulating detailed requirements in the following areas:

- Identification
- Storage
- Handling
- Operational hazards to the equipment
- Contamination and cleanliness control
- Test methods
- Conformance limits

7.2.2 Inspection

Inspection requirements and criteria will be issued in the form of written inspection sequences, instructions, and visual aids. The characteristics to be observed will be specified for each point of examination, including tolerances, and conditions under which readings should be taken. Acceptance conditions for visual inspection will also be specified. The inspections will insure conformance with drawings and specifications and cover such details as workmanship, finish, construction, identification, and traceability. Traceability to the fabrication or test operator and to the quality inspector will be provided. A formal discrepancy report system will be an integral part of inspection procedures. In-process and end-item tests and final inspection will be scheduled for all articles.

Items found not to conform to drawings, specifications, or other applicable criteria will be withheld, identified, and analyzed with respect to the nature of the defect and probable cause. Subsequent action will consist of repair, rework, or submittal to material review. Material review will consist of a formally constituted board to judge the final disposition when either repair or rework is not the obvious disposition. The board will follow procedures for the control of nonconforming material specified in the quality assurance program plan.

7.2.3 Supplier Control

All suppliers of equipment for the Voyager project will be first inspected to ascertain their quality capability. The inspection will cover adequacy and status of facilities, quality history, type and extent of in-plant controls and traceability, calibration of test and measuring instruments. In addition all equipment will undergo inspection. Semiconductors and electromechanical components will receive 100 percent inspection for critical parameters. For components requiring parameter drift screening, certified test reports must accompany the components.

8. PLANETARY QUARANTINE

As discussed in the JPL document, "Planetary Quarantine Plan, Voyager Project," revised January 1, 1967, a basic policy in the NASA program for exploring Mars is to quarantine the planet from terrestrial life forms until adequate time has passed for exobiological studies. The quantified constraints that this objective places on the Voyager project are as specified in the quarantine plan.

In general to meet these objectives two types of activities need to be undertaken in the Voyager project; studies and implementation of techniques for prelaunch sterilization and contamination avoidance and studies and implementation of mission operations to avoid the possibility of impact of unsterile particles on Mars.

Although under nominal circumstances during the Voyager mission only the capsule will make physical contact with Mars, the studies that precede the formulation of the precise mechanisms for quarantining the planet need to incorporate the spacecraft as well. Exhaust from the spacecraft engine during midcourse and orbit-injection firing and from attitude-control jets during interplanetary cruise and orbit operations can conceivably reach Mars. Micrometeoroids striking the spacecraft can eject material from the surface which can enter trajectories that impact Mars. In short, no portion of the planetary vehicle or its operations can be overlooked in the studies of the means to achieve quarantine.

Following an initial set of studies and experiments, the Voyager monitoring, control, and capsule sterilization procedures will be detailed in a formal sterilization plan compatible with the planetary quarantine plan. When it is approved, the sterilization plan will be the controlling document for sterilization procedures. The plan will cover:

- Mathematical models for predicting the probability of contamination from all sources
- Sterilization facilities and operating procedures and techniques
- Means for preassembly sterilization, assembly in a quarantine assembly facility, heat sterilization following assembly, and maintenance of the integrity of the sealed capsule canister

8.1 PRELAUNCH ACTIVITIES

8.1.1 Capsule Sterilization

Since the flight capsule to be landed on Mars will be sterilized before launch, the capsule system development will include sterilizable materials and components and the equipment and the procedures that will be required to sterilize the capsule.

Sterilization procedures based on prolonged exposure to dry heat have been selected as the basic approach for Voyager. Before the final assembly of the capsule subassemblies each will be subjected to an ethylene oxide and a dry heat cycle equal to or longer than the corresponding cycles later in the procedure. These will reduce the internal as well as the surface contamination to not more than 10^4 viable heat-resistant organisms.

Later the same subassemblies will be subjected to a second ethylene oxide cycle to further reduce the accumulated surface contamination to nearly zero. Without recontamination of the surfaces, the subassemblies will be introduced into a clean room of downward laminar flow type, conforming to Federal Specification 209, Class 100. All assembly and testing will take place inside the clean room. Bioassays of the quantity of contamination will be conducted during assembly to permit an accurate estimate of the total biological burden at the time of terminal heat sterilization.

The various development contractors will be required to assemble all flight capsule hardware within certified planetary quarantine clean assembly facilities. The environment of these facilities will be monitored regularly by the contractors using approved microbiological procedures. Certification for the various clean assembly facilities, as well as certification to operate an assay laboratory under the NASA planetary quarantine program, will be obtained from the NASA planetary quarantine officer. The contractors will be responsible for meeting NASA standards and specifications, on a continuous basis, to retain the certifications.

Monitoring procedures and assay methods will be continued during assembly to determine capsule contamination and to search for situations that might accidentally increase the microbial load. Air sampling procedures will measure the level of contamination in the air. Similarly, stainless steel strips placed close to hardware being assembled will be used to collect microbial fallout for continuous measurement.

The flight capsule including its science payload will be subjected as subsystems to an ethylene oxide decontamination cycle and a dry heat sterilization cycle as a part of the flight acceptance testing. After acceptance, subsystem assembly, and overall system tests, disassembly and fine inspection will be conducted. If excessive biological load is found, subsystems will be subjected to further ethylene oxide decontamination before they are moved into a Class 100, vertical laminar flow clean room for final assembly. After final assembly and systems check the capsule will be placed in a sterilization canister. It will then be moved to an oven for dry heat sterilization. The canister will be sealed before the capsule is moved from the oven, not to be broken until after launch. During boost the canister will be vented through a biological filter.

8.1.2 Maintenance of Reliability

All actions to comply with planetary quarantine requirements that might degrade the reliability of any portion of the planetary vehicle will be reviewed by the Voyager reliability assurance manager. He in turn will report to the project manager regarding possible consequences and counteractions that may be required.

Problems and failures encountered in activities associated with planetary quarantine will be documented, analyzed, and corrected by means of the failure report system. Problems in contamination control or in sterilization procedure control will be classified as a special category of failure reporting. All functional failures, malfunctions, and unstandard performance will be pursued as hardware problems; appropriate consideration will be given to sterilization procedures and environments as responsible or contributing causes.

8.1.3 Contamination Data Bank

The planetary quarantine contamination data bank will be established as a part of the configuration information system to satisfy a portion of the quarantine requirements. It will be used to:

- Assure that contamination and sterilization documentation is complete and adequate
- Assure that documentation is traceable for all assemblies and components
- Insure applicability of sterilization processes and related specifications
- Implement the planetary quarantine data plan in an efficient manner
- Make certain that identification of the sterilization data establishes the identity of each component or assembly
- Provide current information on short notice to establish or adjust predicted microbial contamination load estimates

The project contamination data bank will be the repository of all contamination and sterilization data for all affected science instruments, data automation equipment, and any other sterilizable equipment down to and including the piece-part level. The data bank will provide computer-processed reports on a predetermined schedule. Demand reporting will be handled on a case-by-case basis. Detailed implementation of the project contamination data bank will be covered in the configuration management plan.

8.2 MISSION OPERATIONS

The environment, events, and sequences of the Voyager mission can affect the quarantine requirements in a number of ways. Gross malfunction of the guidance and control subsystem during the interplanetary cruise, for example, could place the spacecraft on a collision course with Mars. Hence the achievement of quarantine will also need to incorporate mission analyses directed specifically toward maintenance of the quarantine will also need to incorporate mission analyses directed specifically toward maintenance of the quarantine. In general, four mission objectives need to be defined in detail:

1) Prevention of accidental Mars impact by any system element except the sterile lander
2) Prevention of contamination of sterile lander by the unsterile spacecraft during any portion of the mission

3) Prevention of any efflux or debris from the unsterile spacecraft from settline onto Mars

4) Prevention of premature decay of the orbit of the spacecraft about Mars

To these ends substantial analysis must precede the final definition of mission circumstances and sequences, to obtain the following:

- The probability that the launch vehicle guidance system will place the last stage or the spacecraft on an impact trajectory
- The probability that the last stage retromaneuver will be unsuccessful in diverting the spacecraft from an initial impact trajectory
- The probability that the first midcourse maneuver will be unsuccessful in diverting the spacecraft from an initial impact trajectory
- The probability that any midcourse maneuver may put the spacecraft on an uncorrectable impact trajectory
- The probability that sections of the spacecraft will be placed on impact trajectories during such events as final burn to escape, pyrotechnic firings, midcourse firings, orbit insertion, and orbit-trim firings
- The probability that contamination will be jarred off the spacecraft, at the time of either removal of the capsule biological barrier or at capsule separation, and move to the capsule due to electrostatic charges
- The probability that spacecraft emissions, such as attitude control gas, spallation products, outgassing, or particles knocked loose by meteoritic impact, will enter an impact trajectory
- The probability that contamination will be jarred off the spacecraft at the time of capsule separation and placed on an impact trajectory
- The probability that after exhaustion of attitude control gases, solar pressure or any other cause will spin the orbiter and lead to centrifugal forces sufficient to release sections of the unsterile spacecraft on impact trajectories

- The probability that the cumulative force of meteoroids striking the orbiter will lower periapsis sufficient to cause premature entry of the orbiter

In-flight decisions related to the mission sequence of events and guidance policy for the planetary vehicles will be defined to minimize the possibility of violating the quarantine. Recontamination of the sterile lander will be avoided by keeping the canister seal intact until the terminal portion of the mission. The spacecraft will be constructed such that no line-of-sight trajectory will be available from the unsterile spacecraft to the capsule, even after the canister lid is removed.

The injection of the spacecraft will be biased away from the target planet to assure the required probability that the accompanying launch vehicle stage will not enter an impact trajectory. It may also be necessary to provide a retro capability for the last stage of the launch vehicle. The trajectories of unsterile vehicles will be biased away from the target planet as made necessary by the injection and all subsequent midcourse maneuvers.

The apsides of the planetary orbit will be kept high enough to preclude premature orbital decay. Orbit trim capability may be needed to correct the altitude of the apsides. The planetary orbit will be high enough and debris (such as the sterilization canister) discarded in such a way to preclude premature orbital decay of this unsterile debris. The trajectory and guidance policy will be formulated to fulfill the constraints for unsterile efflux reaching the planet. It may also prove necessary to alter the spacecraft construction to fulfill these requirements; filtering or sterilizing the attitude control gas may prove necessary, for example.

9. FUNCTIONAL MANAGEMENT

In the Voyager project three essential management systems will be applied as appropriate to assist in managing all systems. A formal data management system will be used for all project data. Configuration management will be instituted to control all documentation which defines equipment and systems, together with changes as they occur. Formal project control and reporting will be conducted throughout all project elements.

9.1 DATA MANAGEMENT

The Voyager data management program will serve to define and implement all data needed for the project, to see that required data is available when needed and is accurate and adequate, but that no data is handled which is not essential. The program will be based on the NASA data management system established for the Apollo program and described in NPC 500-6.

Primarily responsible for the Voyager data management program will be the data manager on the staff of the project manager for administration and control. The responsibility entails:

- The analysis of project data requirements and the specification of content, form, distribution, and related factors
- The development, implementation, and monitoring of systems and procedures for the identification, definition, generation, preparation, production, and reproduction of project data
- The generation, preparation, production, reproduction, and distribution of selected project data
- The review of data to be released from or approved by project elements to ensure that all review steps have occurred and that the data are consistent with the overall project data program
- The development, implementation, and monitoring of systems and procedures for the acquisition, receipt, recording, routing, indexing, storage, retrieval, and transmittal of data

- The development, implementation, and monitoring of systems and procedures for the accounting and control of specialized data

- The establishment and maintenance of the project data bank, data libraries, files, and distribution centers

- The review of data for security classification and for public information and open literature clearances

- The review of and recommendation for allocations of funds for documentation-related services, excluding those used to generate rough draft or informal engineering data

Certain system offices at subordinate project elements and contractors will be required to establish data management offices. Each of these elements will prepare data management plans. Project office review of such plans will place particular emphasis on the following:

- The compatibility of proposed organization, systems, and procedures with the overall Voyager data management program

- The responsibilities assigned and authorities delegated the system data management office by the system manager

- The organizational interfaces of the system data management office with other system office elements, particularly with the system manager

- The provisions made to ensure an integrated control of all data along with detailed control of individual categories of data

- The means specified for control of data-related activities at levels subordinate to the system data management office

- The plan for utilization of support personnel, equipment, and facilities

As such plans are approved, details of the organizations and functions of system data management offices will be added as supplements to the Voyager Data Management Manual.

9.1.1 Data Management Categories

The general areas of project activity for which data management categories will be established include:

1) Overall Management: Data required to plan, review, and control Voyager activities from an overall management standpoint.

2) Scheduling: Data to define all major milestones, key events, and schedules.

3) Procurement and Contracting: To delineate the practices and procedures for procurement and contracting.

4) Data Management: For identifying, defining, reviewing, and controlling any data generated or used by project elements.

5) Configuration Management: To provide for the establishment and maintenance of a uniform system of configuration identification, accounting, and control.

6) Logistics and Support: For the logistic concepts, programming, planning, and control of such areas as transportation, supply, maintenance, and support facilities.

7) Facilities: For the planning, design estimating, approval, scheduling, construction, inspection, testing, and control of project facilities.

8) Manning and Financial: To plan, review, control, and report manpower and financial resources in support of Voyager.

9) Technical Description and System Engineering: The equipment and mission definitions, specifications, and requirements relative to design goals, performance, reliability, maintainability, transportability, and operational characteristics.

10) Reliability Assurance: Plans, procedures, reports, and related information to ensure that a system, subsystem, component, or part will perform its required functions under defined conditions at a designated time and for a specified operative period.

11) Quality Assurance: Control and review procedures to ensure that component, subsystem, and system design, manufacture, assembly, and testing will produce items that meet the established specifications.

12) Safety: The procedures, controls, methods, studies, and reporting needed to ensure the safety of Voyager operations.

13) Test: Obtain, verify, and provide test information for the evaluation of development objectives.

14) Manufacturing: The planning, designing, tooling, and processes, scheduling, ordering, manufacturing, testing, fabricating, production control, assembly, and reporting necessary to produce a finished product from a set of drawings and specifications.

15) Site Activation for Launch: The activation of sites for flight operations. Documents within this category cover the activities and requirements from facility availability to vehicle launch and identify organizations, locations, and responsibilities, including lines of control for the conduct of site activation, as well as any special test and test support administration and logistics procedures and problems anticipated during site activation.

16) Mission Objectives: The requirements, plans, procedures, and activities required for mission operations from launch through recovery and postflight operations.

17) Mission-Oriented Training: All information on personnel training.

18) Related Project Interfaces: Technical, administrative, and managerial information on related space programs and information regarding their effects on the Voyager project.

19) Advanced Missions: Advanced missions and potential follow-on programs.

20) Planetary Quarantine: Microbiological factors; sterilization, contamination, and decontamination considerations; related assaying, assembly, and testing operations; and all other information of direct relevance to the planning, control, review, and reporting of the Voyager planetary quarantine program.

21) Science: Data used to plan, control, review, and report Voyager activities relative to the selection, preparation, conduct, and interpretation of scientific experiments.

9.1.2 Data Requirements

The determination of specific data requirements within the Voyager data base will be initiated at all project levels by the cognizant data management office. All data will be identified and defined as to need, source, authorization, functional area, and application. A Voyager data requirements description will be prepared for each item of data considered essential. The objectives with respect to the identification and definition of data requirements will be:

- To provide complete data necessary for project implementation
- To ensure the availability of data as needed throughout the development, operation, and maintenance of the project
- To control data acquisition for effectiveness and economy
- To ensure that acquired data are adequate and of high quality
- To expedite the communication of all data needed for review of project progress and for project planning

All proposed data requirements will be validated by joint technical and data management review boards at each system project element and contractor. The boards will be concerned with:

- Determination that each item of data is essential
- Standardization of data requirements by organizational levels and functional categories
- Integration, consolidation, and synthesis of final requirements
- Scheduling
- Distribution requirements

After the reviews, data requirements descriptions will be cataloged on a proposed data requirements list which cites by work statement item or task assignment all data to be provided from individual project elements or contractors and estimates the cost to fulfill the requirements. These will be forwarded to the Voyager data manager for project office review and approval. Such review includes determination of the location and activity for performance of data inspection and acceptance.

9.1.3 Control of Data

Particulars governing the acquisition and dissemination of data from project elements or contractors will depend on the data tasks assigned. The scope of such tasks and the level of detail to be controlled in turn will depend on the sources, processors, and characteristics of individual data items and the frequency and volume of data deliveries. Whenever practicable, package submittals of data will be prescribed, and the loading of individual elements of data support activities will be scheduled on the basis of a mean workflow. Particulars relative to data preparation will be issued in the following documents at the time of task assignment:

1) Instructions for the Preparation of Drawings
2) Instructions for the Preparation of Specifications and Standards
3) Instructions for the Preparation of Technical Manuals and Training Documentation
4) Instructions for the Preparation of Operations Support Documents
5) Instructions for the Preparation of Management and Technical Reports

Particulars relative to data dissemination and control will be issued in the following documents:

1) Voyager Administrative Communications Instructions. These describe media and techniques for communication among project activities. Provisions are also made for coding, serialization, and control of Voyager data, including distribution and master file requirements.
2) Voyager Information Flow Instructions. These define the responsibilities, authorities, and accountabilities to implement information flow functions which will provide for the expedient interchange of pertinent data throughout the project. Instructions are provided for data acquisition, indexing, submittal, media, storage, dissemination, search, and retrieval systems and procedures; and criteria are provided for the handling of security, proprietary, or sensitive documents.
3) Voyager Data Processing Instructions. These describe the automatic data processing techniques to be used and provide formats and programs for ancillary indices.

4) Voyager Data Distribution Lists. These serve as control mechanisms for the dissemination of individual items or packages of project data.

Standards issued will provide criteria and constraints which make possible the standardization and integration of data management. Controls will be specified only to the extent necessary to effect project-wide compatibility of data; enough flexibility will be allowed to permit orientation of data to an individual organization, system, item of hardware, or function.

9.2 CONFIGURATION MANAGEMENT

A formal system of configuration management will be used by the Voyager project, based on NPC 500-1, to assure that equipment is accurately defined at all times and to promote an orderly evaluation of changes in equipment throughout the program. The system will entail administrative control of the technical requirements documents and changes thereto, in coordination with the data management system. Primary responsibility for configuration management will be given to the configuration management office in the staff of the manager for administration and control.

Following the Voyager Configuration Management Manual, five types of activities will be provided in the configuration management program:

1) Uniform specification program

2) Configuration baseline management

3) Configuration identification

4) Configuration control

5) Configuration accounting and reporting

In addition, the program will provide for complete computerized traceability of drawings, parts lists, and all other equipment-related documents and the interface control specifications as they affect the configuration. For all project elements and contractors the program will provide a single-point release of configuration data and approved changes, with change approval authority clearly defined.

The foundation of the configuration management system is the concept of baseline management, achieved by establishing and managing formal baselines or points of departure at major commitment points in the project schedule. Baselines and formal reviews on the Voyager project will serve as configuration management reference points to control the evolution of design documentation and the hardware. Baselines will generally be established for the Voyager project as discussed in Section 5.2.

9.3 PROJECT CONTROL AND REPORTING

The Voyager project scheduling and resources management system will provide schedule information, contractors' resource data, and time-cost data for management control purposes. Project and system level status will be displayed in the Project Control Room. All reporting of resource data will be against the work breakdown structure; PERT networks and fragnets will correspond to specific items in the work breakdown structure; and al reporting will be against categories of the work breakdown structure.

9.3.1 Project Office Reports

A quarterly review of the project will provide a general basis for evaluating the progress of the project. The results of the review will be published in the following form:

a. Introduction
b. Mission Analysis and Engineering
c. Science Status
d. Spacecraft System
e. Capsule System
f. Launch Vehicle System
g. Mission Operations System
h. Tracking and Data System
i. Launch Operations System
j. Reliability and Quality Assurance Planning
k. Project Administration and Control
l. Summary and Action Items

The quarterly reviews are published by the manager for project administration and control following each quarterly review meeting.

The semiannual Program Obligation Plan will summarize manpower, funding, and facilities obligations of the project.

The bimonthly Space Programs Summary will present technical information on flight project activities, research and advanced technology efforts, and DSN activity.

The monthly Voyager Project Progress Report will give details of the current project status, with photographs when available.

The project manager will submit monthly to NASA Headquarters an integrated Project Management Report to the system level of the work breakdown structure. The arrangement of this report will follow in general the OSSA "Program/Project Management Control and Information System for Unmanned Projects" (as defined in Handbook NHB 2340.1).

9.3.2 System Reports

All system managers will report the status of their systems to the project manager at least monthly by the method and format prescribed by the project manager for each system. All aspects of system responsibilities and activities will be covered by system managers in their reports, including contractor reports to systems managers. A similar in-depth reporting system will be applied to and required from the experimenters.

9.3.3 Other Reports

From time to time, meetings will be called by the project manager involving the systems managers, major contractors, and others as applicable to evaluate progress, to disseminate information, to expose key problems, and to provide for their solution. Minutes of these meetings will be distributed to ensure that all appropriate personnel are informed.

9.4 TEST PLANNING AND CONTROL

9.4.1 Integrated Test Planning

The purpose of Voyager test activities is to provide confidence in the total operational system prior to its commitment to carry out the mission. Basically, test is the physical process to acquire confidence not obtainable by analysis. Thus test is closely linked to analysis, and the evaluation process which provides confidence is analysis supported by test.

This implies a close link between the engineering design function and test requirements definition, test planning, test implementation, and test evaluation. The various categories and levels of test must be properly related to supplement each other to achieve the confidence desired in a timely fashion.

Accordingly, an integrated test plan is prepared for each system covering all testing from parts and materials to top-level system and intersystem tests. The applicable system integrated test plan will be prepared by each system implementation organization, subject to approval and control by the cognizant system management office. An intersystems test requirements document is to be prepared by the project office to cover all tests with participation by more than one system. The detailed role of each system in such intersystem tests will be contained in the applicable system integrated test plan.

The plan forms an agreement between the implementing organization and the cognizant SMO relative to overall testing plans and the reporting against those plans. The plan assures technical adequacy of testing, and serves as a means of assessing test value. The test plan is a major part of the SMO technical monitoring effort. Initially, it is a review of the test implementation so that adequate allocation of resources for testing can be assured prior to the onset of design activity. The plan will contain provisions for the formal reporting of test results. The reports of test results will be inputs to the SMO design reviews during the project. The reporting provisions may range from notification of completion and storage of data on minor tests to SMO acceptance of test plans, and test reports, and witnessing or participation on key tests. The plan also forms an input for the resolution of schedule problems during the course of the project.

9.4.2 Test Categories

Three general test categories are defined as follows.

9.4.2.1 Developmental Tests

Developmental tests are those conducted to evolve and verify design approaches. Such tests are applicable to every hardware level: parts and materials, breadboard hardware, component and subsystem engineering models, and engineering models of major elements such as the flight spacecraft and flight capsule.

9.4.2.2 Type Approval Tests

Type approval tests are those conducted to demonstrate the adequacy of the final design and to demonstrate the actual margins inherent in the design. Type approval tests for CEI's or critical components are designated as qualification tests. Qualification tests are designed specifically to demonstrate that hardware, software, or functional entities of a particular design have sufficient performance margin to assure that operational units of the same design, when produced in accordance with approved manufacturing processes and quality control, will meet specified performance requirements. Such tests are utilized as a basis for approving or disapproving a particular hardware, software, or functional entity design. Type approval tests above the CEI level are required. These correspond to compatibility or integration tests such as between a flight article and its OSE, equipment items and a support facility, or between two systems. These tests are also considered as part of the qualification testing of the CEI's involved.

9.4.2.3 Acceptance Tests

Acceptance tests are those to demonstrate that hardware or software produced after the prototype or first article is identical, within specified tolerances, to the prototype or first article as qualified or that the status of a functional entity conforms to the status of the functional entity at the time of qualification. Acceptance tests are utilized as a basis for accepting or rejecting deliverable hardware at any level of assembly, accepting or rejecting duplicate elements of computer software (e.g., paper tapes, punched cards, etc.), and for verifying the status of a functional entity prior to operational commitment.

9.4.3 Intersystem Tests

Intersystem tests are those tests involving more than one major Voyager system. A detailed description of these tests together with the delegated test responsibilities is given in the intersystems test requirements document, which is issued by the Voyager project office after coordination with the affected organizations. Such tests are carried out by the designated implementation organizations. Overall implementation responsibility is generally assigned to that organization having cognizance over the facility where the test is to be conducted.

Currently identified intersystems tests for the Voyager program are as follows:

- Spacecraft System and Deep Space Information Facility Tests
- Spacecraft System and Capsule System Compatibility Tests
- Capsule System and Deep Space Information Facility Tests
- Planetary Vehicle and Launch Vehicle System Compatibility Tests
- Capsule and Spacecraft Radio Link Test
- Planetary Vehicle and Complex 39 Facility Compatibility Test

During the intersystem testing phase of the Voyager program considerable use will be made of engineering models and proof test models. To minimize the number of development models required, it will be important to schedule the use of these models for the various intersystem tests contemplated. Hence, one of the important elements in the intersystem test plan will be to outline the test requirements for these models and to schedule them optimally.

10. MISSION ANALYSIS AND ENGINEERING

Operations in support of the Voyager missions will begin in 1973 and extend beyond 1984 for the three-generation program. This period represents a time cycle approximately equal to a full generation in the evolution of ground operational complexes. Thus the planning for Voyager flight operations must begin immediately and be directed toward an approach which will embody operational methodologies, equipment, and software that are sufficiently advanced to survive the next generation of technological advancement and hopefully to establish the pattern for flight operations during that era.

Much has been done over the past decade in mobilizing and organizing the world-wide tracking networks for simultaneous support of the maximum number of space systems. Giant steps have been taken toward standardization of equipment, facilities, communications, and operational procedures. In recent years much progress has been made in formalizing the "central point of control" concept in spaceflight operations. Tracking networks previously dedicated to research and development activities have matured in their new roles of multiple project support of operational spaceflight programs. In expanding to this new role they have developed the configuration management, standardization of procedures, and interface control practices required for effective implementation of simultaneous multiple mission support.

The Voyager implementation planning should endeavor to further the progress which has been made along these lines and insofar as practicable should be guided by the additional operational guidelines discussed here while extrapolating from the present systems to the more advanced systems which will support Voyager and other spaceflight projects in the next decade.

10.1 DESIGN GOALS

Because of the increasing number of space projects which must be supported by the tracking networks, spacecraft system design should consider the problems associated with multiple project support in implementing the flight systems. To the maximum practical extent the flight and ground systems should be designed for periodic as opposed to continuous coverage by the tracking networks. This concept can be enhanced by:

- Utilizing high communication data rates
- Providing storage capacity in spacecraft systems to preserve data during periods of limited ground coverage
- Transmission of commands in blocks to update space command programmers at periodic intervals and minimize the number of acquisitions for individual command transmissions
- Judicious bandwidth conservation through the the use of error correcting codes so far as is consistent with increased equipment complexity
- Design of communications equipment to minimize the time required for acquisition of the space-to-ground and ground-to-space links

From the standpoint of ground operations, Voyager is the ideal project to maximize the use of automation in the interest of operational efficiency and cost effectiveness. Many of the constraints which apply to manned spaceflight operations will not apply to Voyager so far as mechanizing operational decisions are concerned. Further, because of the long operational life of the Voyager system and its complexity, the maximum yield in cost effectiveness from computer control in elimination of personnel functions can be realized. And finally the possibilities for interrelation of activities between the various Voyager vehicles after arrival at Mars can be exploited through the use of simultaneous monitoring and correlation of data by ground computers.

Voyager system design, both spaceborne and ground system, should adhere to the principles of maximum information yield in the shortest practical time with minimum data flow and storage. The following measures should be considered in support of this concept.

1) Self adaptive telemetry systems and data compression techniques should be utilized wherever possible to minimize transmission of redundant and unnecessary data.

2) The ground data system design should provide for near real-time processing and display of all operational data (both engineering and scientific) which can contribute to optimizing the scientific mission, improving the performance of the planetary vehicles, prevent degradation to some element of the system.

3) The necessary data quality assessment capability should be designed into various elements of the system faults from anomalies in spaceflight hardware.

4) The necessity for collection of large quantities of raw archives data should be avoided by:

   - Use of digital recording at the Deep Space Stations and development of a data processing system capable of fully processing all data for distribution to users on a daily basis as the data is received, thus eliminating handling of analog instrumentation tapes except in cases of temporary malfunction

   - Use of on-line engineering analysis teams and science analysis teams with real-time computer support to sort, sift, collate, and analyze the data and to generate the performance analysis reports. This will help prevent an accumulation of large backlogs of data and will provide the expeditious reporting necessary for feedback into mission planning and system design for the subsequent mission on a two-year launch cycle.

The most demanding requirements for the Mission Operations System (MOS) and the Tracking and Data Acquisition System (TDAS) stem from supporting the long stay surface laboratory. Therefore, the initial design should provide the capability for full support of these ultimate requirements except in those cases where extension capability can be designed into the system to provide for later growth with negligible effect on the system in existence. The basic design goal is to avoid large, costly changes to the operational systems during the life of the project. Even though this approach may lead to excess capability for the more simplified early missions, as long as this excess capability is not activated prematurely the residual costs associated with maintenance of the excess capability early in the program should be small compared to the cost associated with significant changes to the operational systems between Voyager generations. Activation of the full mission operations capability will be phased over the life of the program in accordance with the success achieved in scientific discoveries during each mission.

Because of the complexity of the project, continuity of the personnel is of vital importance. Maintenance of experienced personnel will be enhanced through increased interest from mission to mission due to advancements in scientific objectives. Cross training of operational personnel once they become proficient in early assignments will also help to stimulate interest and reduce the necessity to add more personnel for the more advanced missions. Thus considerable stabilitity in crew size can be achieved with proper organization of the personnel subsystems within the spaceflight organization and with careful planning and phasing of preflight, flight, and postflight activities to balance personnel loading during the two-year cycle between missions.

10.2 ORGANIZATION AND FUNCTIONS

Three of the Voyager Project Systems are operationally oriented and their implementation planning is therefore closly related. The other three flight-hardware-oriented systems are strongly affected by mission considerations. Thus to insure uniformity of approach and to provide the necessary intersystem system engineering support to the project manager, an office of Mission Analysis and Engineering (MA&E) has been defined at the project level with functions as given in Section 4.2.4. This office is headed by the mission analysis and engineering manager, who reports to the Voyager project manager and provides general project level direction and coordination for his area of responsibility. In particular MA&E encompasses the following:

- Identification of LOS, MOS, and TDAS operations constraints

- Planning and design of mission reference trajectories
- Definition of targeting specifications for mission maneuvers
- Development of guidance, targeting and navigation software required to implement mission maneuvers
- Evaluation of mission feasibility
- Determining the sensitivity of the trajectory design to system errors and mission parameters
- Preparation of launch support information required for launch approval and the generation of operational range safety aids
- Generation, maintenance, and dissemination of official mission-related vehicle and system data
- Preparation of operational flight data. The mission design and analysis effort includes specifying interface control documentation, resolving system interface conflicts, and managing intersystem integration engineering activities in relation to flight operations. After each Voyager flight, mission evaluation and critique analyses will be conducted. Figure 9 illustrates the major areas and associated documents resulting from the Voyager mission analysis and engineering effort. In many cases development of the data and preparation of such documents is not carried out by the project office MA&E organization. Nevertheless, MA&E has overall responsibility for such documents.

A primary function of the MA&E organization is to establish the Voyager operational requirements and to insure that the necessary resources are committed to support the Voyager missions. Working through the system management offices, this organization insures that all interfaces are properly effected and that the implementation planning and scheduling of operational personnel, hardware, software, and facilities is as required to fulfill the objectives of the Voyager missions. To carry out such activities a Flight Operations Working

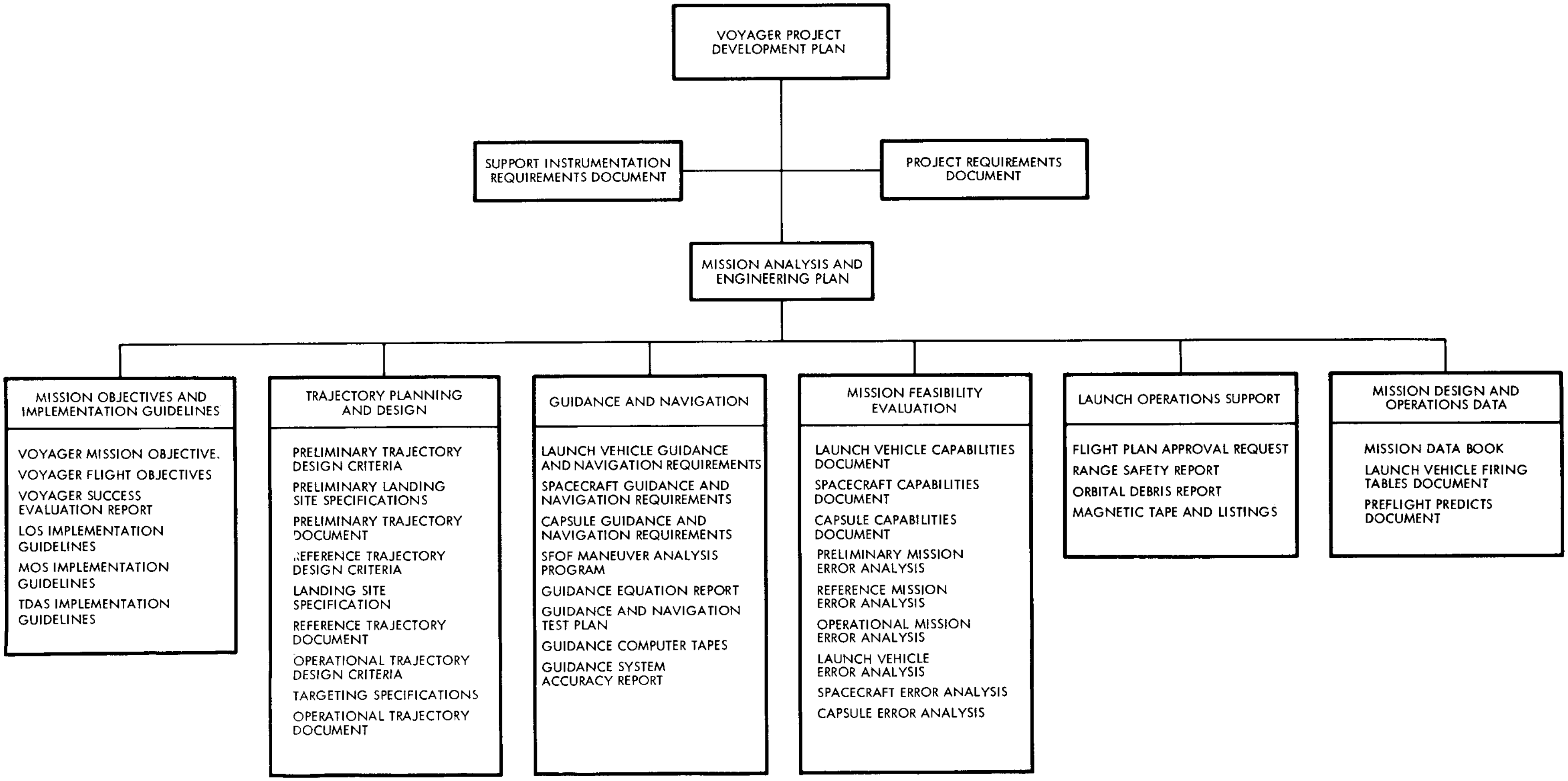


Figure 9. Voyager Mission Analysis and Engineering Functional Areas and Associated Documentation

Group is to be established at the project level under the chairmanship of the MA&E manager. This group will include participants from NASA/Hq, OTDA, or Voyager program office representatives when program level problems arise. The working group should consist of members from each Voyager SMO, each NASA and DOD management or interfacing agency, and members from all major contractors. In particular, science payload considerations should be represented by a science coordinator from the spacecraft, capsule, surface laboratory, and mobile unit contractors to coordinate the matters related to science experiments for their respective systems. Illustrative functions of this working group are given below:

- To establish operational requirements and to insure that operational requirements for all of the systems are properly understood by all affected interfacing organizations
- To identify operational constraints imposed by systems and subsystems
- To insure that the results of mission analysis and mission design efforts are properly promulgated and interpreted to operational personnel in a timely manner for implementation into the operational planning
- To provide inputs to Voyager project office operational planning and documentation
- To make known to the working group members, problem areas in hardware and/or software development which have an effect on the operational planning or implementation of other systems
- To jointly generate and maintain master operations milestone schedules for use in coordinating operations planning
- To present the flight operations portion of the operations readiness review to the Voyager project office and other responsible NASA agencies prior to each Voyager launch.

Two top operational support requirements documents are shown in Figure 9 which are the basis for operational planning. The Support

Instrumentation Requirements Document designates project instrumentation requirements placed on NASA agencies. It includes a project description, flight sequence, vehicle description, trajectory data, telecommunications data, telecommunication system design parameters, trajectory ground traces, tracking requirements definition, telemetry data acquisition requirements, ground command requirements, data rate profiles, on-site data processing and display requirements, central facility data processing and display requirements, a data distribution plan, description of ground communications, and list of communication requirements. The Project Requirements Document is a related document that designates project requirements placed on DOD agencies and includes information similar to that in the support instrumentation document.

10.3 MISSION OBJECTIVES AND IMPLEMENTATION GUIDELINES

The Voyager mission, flight objectives, and implementation guidelines documents are used for mission planning and mission operations support. They are guides for the allocation of manpower and resources throughout the mission. In addition, they are used in scheduling launch operations and evaluating launch readiness. The establishment of launch-hold criteria will be influenced by each flight objective. The flight objectives will also be used to determine the proper course of action for both standard and nonstandard conditions during the flight. Voyager flight success will be measured in terms of how well the flight objectives are achieved.

10.3.1 Mission and Flight Objectives

The mission and flight objectives documents will serve to determine mission success and to evaluate the Voyager project accomplishments at any point in the mission and flight program.

It is necessary to define the Voyager mission and flight objectives so that a uniform set of goals can be established for all phases and project interfaces. Significant performance requirements must be specified. In addition, a guide is established for the design of all operations through mission completion.

The Voyager objectives require an orderly program of continually improving knowledge in science and technology. The aspects of such a program include:

- Scientific and engineering observations and experiments directed towards extending the capability of the Voyager planetary vehicle to operate near Mars and on the Martian surface, and efficiently developing this capability throughout the duration of the Voyager project
- Scientific and engineering observations and experiments directed toward extending the capabilities of the scientific instruments to operate near Mars and on the Martian surface, more specific definition of future experiments concerning exobiology and planetology, and the efficient development of these capabilities throughout the duration of the Voyager project
- Scientific observations and experiments concerning possible biology and biochemistry of Mars
- Scientific observations and experiments concerning the physics and chemistry of the Martian surface and atmosphere directed toward obtaining information essential to the advancement of planetology

To establish design guides, the mission is divided into flight phases. Typical phases include launch, DSIF acquisition, earth parking orbit insertion, interplanetary cruise, and Mars encounter. Each phase has specific objectives or requirements which must be met with varying priorities. The accomplishment of these priority specifications will be the measure for evaluating overall mission success.

The Voyager Mission Objectives document establishes those procedures and goals for the entire Voyager project and does not delineate the immediate purpose of each flight. This document establishes the time dependency of various scientific and engineering experiments which will be sequenced from one flight to the next.

The Voyager Success Evaluation Report correlates postflight mission reconstruction data with the corresponding flight and mission objectives. Success will be judged on the basis of the priorities of those objectives that have been achieved and the priority of unachieved objectives. The evaluation of achieved, or unachieved, flight objectives aids in the preparation for future project flights.

10.3.2 System Implementation Guidelines

The system implementation guidelines will specify LOS, MOS, and TDAS constraints and the mission penalties associated with their violations. These documents will serve as a source of system requirements, capabilities and constraints information necessary for LOS, MOS, and TDAS planning and scheduling.

10.4 TRAJECTORY PLANNING AND DESIGN

The trajectory planning and design documents provide planning and design information for launch, mission, and tracking operations; specify trajectory design requirements and guidelines; official mission and trajectory data in a coordinated format; and design characteristics of the trajectories and powered flight maneuvers.

10.4.1 Trajectory Design Specifications

Three reports will define the relevant ground rules, mission constraints, and guidelines required for the Voyager trajectory design effort. Criteria for the selection of Mars landing sites are presented and justified. Trajectory constraints, shaping criteria and design guidelines are presented for each mission phase from prelaunch to postlanding operations. Design targeting specifications are issued for operational trajectory development, prelaunch operational targeting, and preflight computation efforts.

The Landing Site Specifications describe the criteria and rationale for the selection of prelaunch nominal Voyager landing sites. These landing sites are selected to satisfy the mission science objectives without impairing engineering performance. Specific science objectives are justified by presenting a summary of conclusions drawn from precursor Mars mission results. Specific engineering performance constraints to be considered will include earth communications, lighting, accessibility, relay link communications, and distinguishing terrain features. Ground rules are also presented for the specification of secondary landing sites for assumed nonstandard mission operations.

The Trajectory Design Criteria summarize all trajectory constraints, shaping criteria, guidelines, ground rules, and other mission requirements necessary to define, design, establish, and compute preliminary, reference, and operational mission trajectories. Trajectory simulation assumptions are noted and standards necessary to evaluate the adequacy of the trajectory design effort itself are specified.

The Design Targeting Specifications present targeting aim point and arrival time data for the ascent-to-parking orbit, trans-Mars injection, interplanetary trajectory control, Mars orbit insertion, Mars orbit trim, capsule de-orbit, and capsule landing maneuvers. The aim point determination procedures are presented together with descriptions of how the aim points are determined during real-time SFOF trajectory planning computations. This report will be based upon data published in the Preliminary and Reference Trajectory documents and will control the design of all operational trajectories, computation of firing tables, and the determination of nominal vehicle guidance computer settings. Aim point and arrival time accuracy specifications will be included for each maneuver.

10.4.2 Trajectory Documents

The trajectory documents define the launch-to-mission-completion trajectory characteristics; establish requirements for all vehicle maneuvers implementing the trajectories; present pertinent mission and vehicle information in convenient summary form; demonstrate the extent to which the trajectories are within allowable design limits; and provide planning information for launch operations and tracking station support. These reports will differ from each other only in the completeness and validity of the presented mission data and the accuracy of mission simulation and trajectory computations. Selected trajectories will be designated preliminary, reference, and operational.

Each report will consist of several volumes. The first volume will contain a general description of the mission, a restatement of the primary and alternate mission objectives, and a discussion of the general rationale and pertinent ground rules adopted for the trajectory design effort. Also included will be weight, mass, aerodynamic, performance, and configuration data for each vehicle separately and in the appropriate flight configurations. A general description of vehicle subsystem characteristics will serve to delineate vehicle performance capabilities. The individual launch vehicle, spacecraft, and capsule trajectory designs will be described in detail. For each mission trajectory phase, the design criteria, constraint limits, rationale, and guidelines are presented in conjunction with the reference design parameters to show how well the designed trajectory satisfies all required specifications.

Included in the description of the launch vehicle trajectory design effort will be the launch vehicle target specifications; parking orbit injection requirements; and the flight profile geometry relating the launch site, launch azimuth, and trans-Mars trajectory. The launch vehicle ascent trajectory design will be influenced by aerodynamic loading, aerodynamic heating, staging and separation dynamics, vehicle turning rate limit, range safety, tracking, telemetry, and payload capability considerations. Propellant reserves as a function of launch delay will be presented for nominally performing vehicles. Propellant loading requirements will be identified. The circular parking orbit altitude, orientation, and duration will depend upon payload capability, tracking, communication, and launch probability considerations. The design of the trans-Mars injection maneuver will be based on payload capability, tracking and telemetry coverage, and desired Mars arrival condition considerations.

The description of the spacecraft trajectory design will include a discussion of earth-Mars transfer trajectory requirements; requirements to separate the arrival dates of the planetary vehicles; and Mars orbit design requirements. The effect of quarantine upon the choice of planetary vehicle aim points will be discussed. Maneuver requirements for planetary vehicle separation, interplanetary trajectory control, Mars orbit insertion, and Mars orbit trim maneuvers will be established. The effect on the spacecraft trajectory design of occultation, lighting, communication, visibility, spacecraft propulsion capability, and capsule-spacecraft radio link will be described.

The description of the capsule trajectory design will include a discussion of capsule de-orbit maneuver requirements. In addition, Mars landing sites, capsule performance capability, spacecraft-capsule relay-link and direct-earth communication, lighting, Mars aerodynamic entry, terminal descent and touchdown requirements are described. Sufficient information is provided to demonstrate that the trajectory design satisfies all specifications.

The second volume of each trajectory document includes a description of the most important design characteristics of the launch-to-mission completion trajectories. Mission events, phases, and maneuvers are described together with the sequence of mission events. Since more than one trajectory will be required to portray events representative of operational Voyager missions, the distinguishing characteristics of each will be discussed.

The third volume of each trajectory document will include tabulations of computer-simulated trajectory data. A print key and definitions of the listed physical parameters will also be provided. Tracking station data such as rise and set times, range and range rates, Doppler data and look angles, azimuth and elevation angles will be tabulated for tracking and data acquisition system planning purposes. Launch opportunity information and launch window data will be presented for launch operations and mission operations systems scheduling.

The fourth volume of each trajectory document will describe the sequence of events for each powered flight maneuver required to establish an alternate mission trajectory. Typical contingency plans and a description of likely nonstandard mission operations will be provided.

10.5 GUIDANCE AND NAVIGATION

Navigation computations are performed at the SFOF to estimate the vehicle's current state vector. Guidance and steering computations employ navigation data and desired injection state information to determine for each powered flight maneuver the initial vehicle orientation, engine start time, vehicle turning rate commands, and engine cutoff commands. These guidance and navigation documents will define those requirements necessary to implement Voyager mission maneuvers consistent with vehicle guidance system characteristics.

The SFOF orbit determination programs in combination with the SFOF Maneuver Analysis Program form a ground-based guidance and navigation software system. Significant effort must be devoted to the definition, development, and implementation of this SFOF software. Guidance equations for the launch vehicle, spacecraft, and capsule powered flight maneuvers must be formulated, developed, tested, and certified for operational use. Design review, certification, and validation procedures must be established to assure that guidance computer tapes, navigation computations, and operations procedures are adequate to implement all mission maneuvers in acceptable accuracies. Guidance and navigation system capabilities will be described and measures of accuracy prescribed.

10.5.1 Guidance and Navigation Requirements

The guidance and navigation document defines the requirements for implementing each mission maneuver based upon the respective vehicle guidance system characteristics. Nominal and alternate mission trajectory-related guidance and navigation capability guidelines are formulated. These guidelines will include descriptions of maneuver targeting objectives, maneuver constraints, cutoff and pointing accuracy requirements, maneuver sequence of events, engine options, thrust decay characteristics, and targeting updates. The document specifies the detailed outputs of the guidance and navigation software for each phase of the flight. Guidance discretes and turning command requirements will be specified.

10.5.2 Guidance Equation Report

The guidance equation report will present the basic guidance philosophy and the codable form of the guidance equations. Among other items, the report will include flow diagrams of the launch vehicle, spacecraft, and capsule guidance equations. Guidance constraints and trajectory geometry constraints are described for each relevant mission trajectory phase. An estimate of the cutoff accuracy of the equations will be provided. Targeting specifications, trajectory simulations ground rules, and performance of the guidance equations during non-standard operations are discussed. Guidance equation input requirements are defined and output requirements are specified. This report will demonstrate that the guidance equations meet all imposed requirements.

10.5.3 Guidance and Navigation Test Plan

The detailed guidance and navigation equations and test plan document is a vehicle for design review and for dictating computer programming requirements.

Guidance and navigation equations and logic flow are detailed along with the basic theory, design tradeoffs, and reasons for selection logic. In addition, it defines the detailed testing to be performed on the guidance computer programs to evaluate the guidance and navigation equation performance. The distinction between the equations and the computer program is made since it is the latter which will determine the commands that actually guide the vehicle. Programming constraints and guidelines will be specified in this document and scaling, logic nesting, and timing considerations will be described. Performance and acceptance criteria will be established, simulation test ground rules will be specified, and flight computer interpretive simulations will be planned. Additional simulations will serve to evaluate the capability of the guidance and navigation equations to perform in the presence of non-standard vehicle operation.

10.5.4 Guidance Computer Tapes

Tapes must be prepared, certified, and read into the launch vehicle, spacecraft, and capsule guidance computers to provide the guidance equations with all necessary prelaunch constants.

10.5.5 Guidance System Accuracy Report

For each vehicle the best estimate of guidance accuracy will be determined. This report will contain a description of the error analysis technique used, the mission trajectories, the component error values, the RMS magnitude of the required midcourse velocity, injection co-variance matrices, units of variance analysis, and a list of sensitivity coefficients relating the trajectory correction velocity magnitude to guidance component errors.

10.5.6 SFOF Maneuver Analysis and Command Program

The SFOF Maneuver Analysis and Command Program is a real-time oriented computer program capable of determining the guidance constants and comments necessary to plan and implement mission maneuvers. This is the primary inflight analysis tool available to the SFOF mission planners. This program is able to analyze most of the operational situations that may arise during the mission affecting either vehicle and to provide the basis for examining and implementing various maneuver policies and sequences that will best utilize the capabilities of both vehicles.

This program is divided into functional modules which can evaluate standard and some nonstandard modes of operation. Under the control of a program executive monitor, each module can be executed independently or as needed in predetermined computational sequences. The program also allows for the introduction of nonstandard events via manual control, when necessary, while still retaining the automatic feature for standard mission sequences. The following brief description of the functional modes will define the overall program capability.

1) The executive monitor sequences the computational modules depending upon the program input, manually or automatically.

2) The standard midcourse guidance module computes the "optimum" midcourse velocity correction which will cause the spacecraft to enter the desired Mars orbit at the desired location.

3) The thrust orientation command module accepts the midcourse velocity correction vector and, along with the prespecified cruise attitude, computes the required roll and pitch/yaw maneuvers necessary to point the spacecraft thrust axis in the desired direction.

4) The midcourse error analysis module computes the uncertainties in the execution of the midcourse velocity correction and transforms them into uncertainties in the terminal parameters. This subprogram also computes the effect on the terminal parameters caused by an incorrect maneuver execution time.

5) The terminal guidance module accepts the defined post-midcourse injection conditions and computes the necessary phasing data to insert the vehicles into a prespecified Mars parking orbit. The program computes the spacecraft pointing direction and the roll-pitch/yaw-roll maneuvers to achieve this alignment.

6) The deboost guidance module accepts the post-parking orbit injection conditions and computes the necessary deboost phase data to soft land the capsule/lander at a prespecified landing site. The program computes the capsule pointing direction and the attitude adjustment maneuvers necessary to achieve the correct alignment.

7) The alternate landing site module is used to compute accessible alternate landing sites acceptable during nonstandard mission operations.

10.6 MISSION FEASIBILITY EVALUATION

Mission feasibility documents are used to assess the feasibility of the Voyager mission by defining the individual vehicle performance capabilities and projected maneuver dispersions. Each vehicle is analyzed as to its ability to perform those maneuvers specified in the Voyager preliminary, reference, or operational trajectory documents. Each vehicle's performance capabilities are documented separately and include an associated dispersion analysis. One document will be issued to summarize the effects of all system errors upon mission success.

10.6.1 Launch Vehicle Capabilities Document

The purpose of the launch vehicle capabilities document is to provide the results of the launch vehicle performance analysis based on the specified launch vehicle preliminary, reference, or operational trajectories. This document establishes the feasibility of the launch vehicle to satisfy the requirements of the mission. Included will be a comparison of performance capabilities and requirements, dispersed trajectories, nominal ascent profile characteristics, propellant margins, and final weight distribution data. Mission independent constraints and operating procedures will also be identified.

10.6.2 Spacecraft Capabilities Document

The intent of the spacecraft capabilities report is to define spacecraft performance capability, flight performance reserve, and maneuver capability tradeoff coefficients for estimating effects on performance parameters. This document establishes the overall feasibility of the spacecraft to satisfy the maneuver requirements of the Voyager mission. The document will include the spacecraft payload capability as a function of maneuver ΔV requirements, alternate mission capability analysis, maneuver control sensitivities, maneuver sequence of events, and maneuver guidance techniques. Vehicle orientation and thrust vector control procedures will also be discussed.

10.6.3 Capsule Capabilities Document

The capsule capabilities document presents the capabilities of the capsule to perform those maneuvers specified in the preliminary, reference, or operational trajectories. In particular, the attitude control and ΔV requirements for the spacecraft separation, deorbit, and retro landing maneuvers will be discussed. The overall capability of the capsule to satisfy the mission requirements will be assessed. Vehicle and mission tradeoffs will be discussed, and the nominal performance characteristics will be defined.

10.6.4 Mission Error Analysis Documents

Error analysis documents summarize the expected dispersions in the mission trajectories from thrust deviations, aerodynamics, initial conditions, and the guidance and navigation errors. Also included will be a statistical assessment of propellant margins, Mars entry conditions, and preliminary, reference, and operational flight plan events to establish mission feasibility. Typically, this document will include the following: expected initial conditions, expected error sources, trajectory dispersions; guidance and navigation trajectory dispersions, propellant margins, tracking acquisition verification; verification of entry conditions, verification of nominal preliminary, reference, or operational flight plan with nominal dispersions, and alternate flight plan capability.

10.6.5 The Launch Vehicle Error Analysis

Information regarding expected launch vehicle trajectory dispersions will be documented based on the launch vehicle preliminary, reference, or operational trajectories. This document will include: 3σ perturbations, predicted deviations, results of the propellant reserves analysis, predicted trajectory envelopes, predicted probability of mission success considering propellant expenditure and state variable accuracy.

10.6.6 The Spacecraft Error Analysis

The spacecraft error analysis defines the results of an error analysis based on the spacecraft preliminary, reference, or operational trajectory. The analysis will provide information showing the effects that launch vehicle insertion dispersions, spacecraft maneuver execution errors, spacecraft guidance errors, and orbit determination errors will have on the trajectory geometry, spacecraft ΔV requirements, and overall mission plan feasibility. Of primary importance will be the identification of potential error sources.

10.6.7 The Capsule Error Analysis

The capsule error analysis supplies data related to expected capsule trajectory dispersions based on the capsule preliminary, reference, or operational trajectory. This document will present the capsule de-orbit dispersion analysis which propagates the initial conditions and ΔV uncertainties of the capsule to the entry interface and landing point. This analysis indicates the range of de-orbit modes and trajectories as a function of the obtained ΔV for alternate sites and of the available DSN coverage. The analysis uses error and uncertainty data based on previous project data and propagates the expected errors using linear matrices.

10.7 LAUNCH OPERATIONS SUPPORT

For each space program supported by the Eastern Test Range, AFETR management requires range safety reports and data packages which appraise potential hazards to life and property during Voyager prelaunch, launch, and earth-orbital operations; justify requests for Voyager use of a launch azimuth sector and waivers to permit overflight of critical areas; and provide data in an AFETR-prescribed format for the preparation of operational aids to be used by the range safety officer to monitor flight progress and to terminate a flight when safe operating limits are exceeded. Launch and mission operations will be planned in such a way that hazards to life, property and range facilities are minimized.

10.7.1 Flight Plan Approval Request

The flight plan approval request is a letter requesting permission to use a particular launch azimuth sector. Justification and supporting trajectory information are included.

10.7.2 Range Safety Report

The range safety report will contain a general statement of mission objectives; designate flight hardware to be used; describe the overall vehicle dimensions and portray the launch configuration; provide launch information including launch complex, firing azimuth limits, launch dates, and distinguishing countdown procedures; and specify a detailed sequence of flight events for a nominal ascent mission profile.

The vehicle description will be supplemented by a detailed discussion of subsystem functions, distinguishing characteristics, sources of malfunctions, and the consequences resulting from partial or complete subsystem failure. The location and transmission characteristics of RF transmitters used for launch vehicle tracking purposes will be described.

All stage cutoffs will be identified for a normally operating launch vehicle. The latitude, longitude, and downrange distance of all normally re-entering stages will be supplied together with a description of such stages by weight, cross-sectional area, and ballistic coefficient for nominal, dispersed, and backup cutoff ascent trajectories.

The effects due to explosion or destruct action will be documented. The fragments expected to travel a minimum and maximum range will be identified and the effect of an explosion upon remaining fuel and upper stages will be described. The maximum velocity increment imparted to identifiable fragments resulting from destructor charge energy, internal energy of pressurized tanks, and propellant detonation will be supplied. The variation of the fragment velocity with propellant consumption will be supplied for representative and identifiable fragments of all stages.

The combination of factors causing a vehicle to be dispersed from nominal flight conditions will be described and identified. Assumptions concerning the maximum expected head, tail, and lateral winds will be specified. Trajectory dispersion data for vehicles operating in the launch area when maximum winds are expected will also be presented. Velocity vector turn angle data will be used to establish safe operating limits on charts prepared for the Range Safety Officer.

10.7.3 Orbital Debris Report

The orbital debris report describes the probability of casualties resulting from spacecraft orbital debris. It includes analysis of hazards due to orbital decay following possible mission failure in the earth parking orbit. The report excludes consideration of hazards resulting from suborbital flight. The report typically contains trajectory analysis for orbital lifetime predictions; aero-thermal and structural analyses used to determine breakup mechanisms, breakup attitudes, and resulting fragments; survivability analysis of debris; identification of surviving debris by number, size, weight, lethal area, impact dispersions, and descriptions of hazards due to surviving debris; and a discussion of mission procedures that will reduce hazards.

The report provides a sufficiently detailed vehicle description to identify hazard contributions and structural breakup characteristics. Detailed population models and methods for computing casualty probabilities are included.

10.7.4 Magnetic Tape and Listings

The AFMTC theoretical trajectory data package will, in general, always be on magnetic tape in a prescribed format. Tape listings normally are included in the data package. The magnetic tape will contain specified trajectory data common to all categories of launches from AFETR, vehicle parameters for variable launch window space programs, and variable launch window designated trajectory data. Nominal and dispersed trajectory data are presented.

10.8 MISSION DESIGN AND OPERATIONS DATA

10.8.1 Mission Data Book

A mission data book is maintained to summarize the basic information utilized in establishing design trajectories and feasibility evaluations for the Voyager mission. It provides a convenient, single source of information containing all the pertinent trajectory information for the ascent phase of the flight. Contents will include mission constraints; mission profile and sequence of events; launch vehicle, spacecraft, and capsule description and approximate payload capability; trajectory design criteria such as propulsion, weights, aerodynamic characteristics, flight control, atmospheric properties, geodetic data, heating criteria, loading criteria, staging, and jettison criteria; performance exchange ratios; flight performance reserves; and ground based equipment data, standard coordinate conventions, and significant parameter symbols.

10.8.2 Launch Vehicle Firing Tables

Launch vehicle firing tables will contain the launch azimuth hardware settings, the guidance constants, and curves of excess propellants and launch azimuth vs launch time for each launch day. In addition the document will contain listings of the backup trajectories which will verify the targeting and a listing of the injection conditions at uniform intervals throughout each launch window.

10.8.3 Preflight Predicts

The preflight predicts document presents that data necessary for the AFETR, MSFN, and DSN tracking stations to acquire the space vehicle during the launch and earth-orbit phases. This document presents the space vehicle injection conditions for the full range of possible launch times defined by the nominal launch window. Station rise and set times, elevation-angle histories, station view periods, and space vehicle downlink frequency information is provided.

11. MISSION OPERATIONS IMPLEMENTATION

The Voyager mission operations system management office is responsible to the Voyager mission director for assurance that mission operations facilities, equipment, software, and associated personnel are in a ready condition to support the Voyager mission. This responsibility covers in particular all mission-related activities from earth parking orbit injection through the end of Mars operations. It also covers MOS prelaunch activities in support of the LOS and planetary vehicle monitoring and evaluation activities for the ascent flight phase. The MOS manager therefore has an overall responsibility for the developmental and operational activities associated with mission operations, including activities of supporting organizations. This includes all activities associated with Voyager MOS analysis, system design, development, and procurement. He will exercise control of all elements of mission operations and will be responsible for coordination of the associated elements to assure a state of operational readiness.

11.1 SCOPE AND FUNCTIONS

Mission operations elements include parts of the SFOF assigned to support Voyager as the central point of control; parts of the Huntsville Operations Support Center used for operations and monitoring during low activity phases of the mission; mission-dependent equipment including the facilities, equipment, and software required for its development and delivery; computer programs and supporting documentation required for processing mission data and commands; plans, procedures, and data packages necessary for flight preparation, conduct of space flight operations, and postflight evaluation of mission operations activities; and qualified and trained operational personnel conducting space flight operations.

When using the tracking and data acquisition facilities allocated to the project, the MOS operates and controls the space vehicle from insertion into the earth parking orbit until the end of the Voyager mission. During preflight tests and space flight operations the MOS elements and the DSN portion of the TDAS is under direct operational control of the Voyager space flight operations director.

MOS hardware includes equipment built and used exclusively for Voyager mission operations. These items are known as mission-dependent equipment. MOS software includes the necessary computer programs and the documents and procedures used in operating the mission. In addition to systems specifications and planning documents, detailed operating procedures will be prepared for SFOF and DSIF personnel. These procedures take extensive advantage of the capability of rapid computation offered by digital data processing equipment, and incorporate the results of the computer programs prepared to aid in the rapid display and analysis of data and the generation of commands to the space vehicles.

11.2 IMPLEMENTATION PHASING

Readiness to support a Voyager flight will be assured by a sequence of implementation phases as illustrated in Figure 10. Project-level requirements will be imposed upon the MOS manager. Such requirements

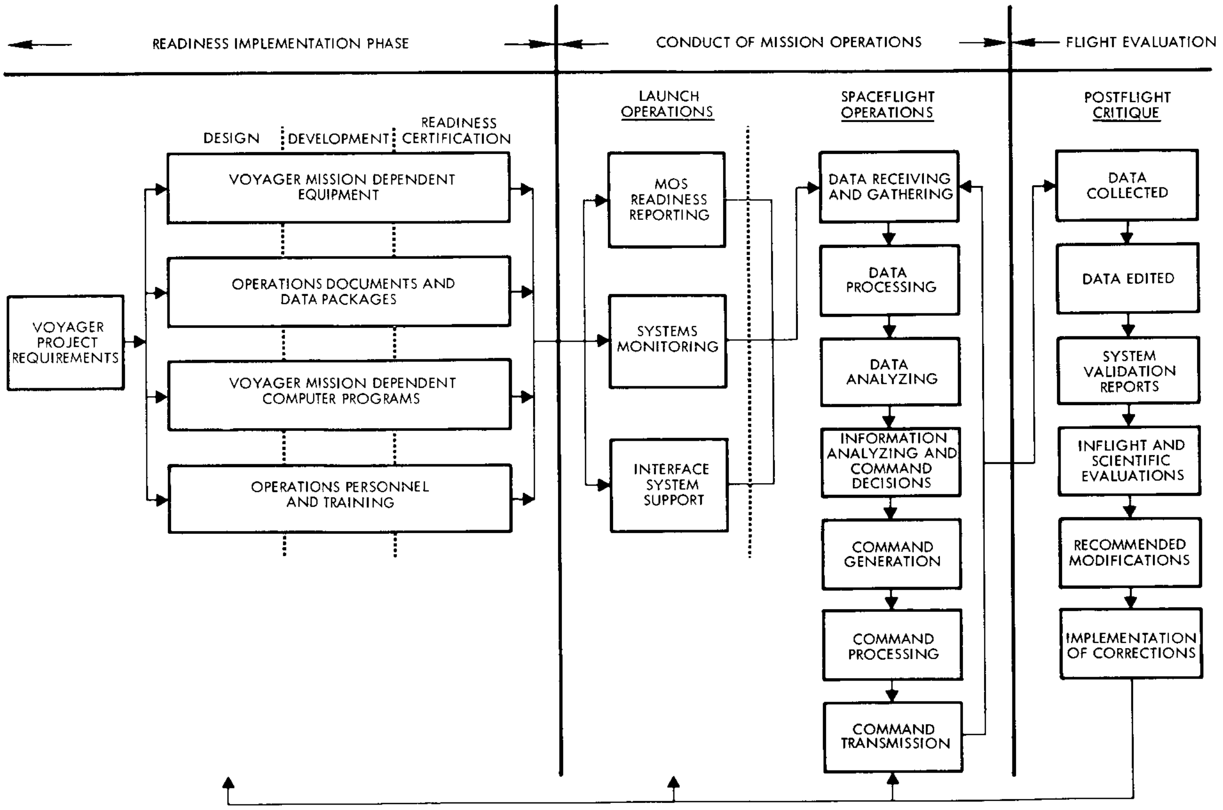


Figure 10. Mission Operations System Organization

typically include schedules, commitment of resources, and system-level interface specifications. The first MOS implementation phase will consist of establishing basic policies of Voyager mission operations by specifying the broad guidelines for MOS preflight planning and design, flight operations support, documentation, scheduling, computer program design, development, and maintenance control activities. Guidelines for the procurement of mission-dependent equipment are developed. Preliminary software configuration control practices are delineated, internal and external MOS interface control procedures are defined, and detailed requirements are imposed upon various MOS elements to assure system operational readiness at the required time.

The second MOS implementation phase consists of development of operations procedures, the preparation of test instructions and data packages, development and integration of computer programs, and the fabrication, delivery, and system integration of mission-dependent equipment.

The third MOS implementation phase corresponds to a comprehensive system test and training program for all personnel and mission-dependent equipment. The achievement of operational readiness status will be consistent with all mission schedules.

The fourth MOS implementation phase includes all Voyager space flight operations from earth parking orbit injection to mission completion. System monitoring and evaluation will be performed by the MOS during the Voyager launch operations phase in preparation for the space flight operation.

The fifth and final MOS implementation phase consists of record keeping, evaluation, and post-mission critique activities. These activities will serve to assure that subsequent Voyager flight preparation and operational support efforts will benefit from previous mission operations experience.

11.3 REQUIREMENTS AND DESIGN CRITERIA

The MOS design must meet the maximum requirements imposed by simultaneous operation of two Mars orbiting spacecrafts and two landed scientific payloads. The MOS design must also reflect requirements imposed by high activity periods of flight support during interplanetary maneuvers, Mars orbit insertion, capsule separation, and Mars entry and landing as well as during critical phases of the Mars mapping operation and surface laboratory peak activity periods. During cruise mode operations, and extended periods of routine scientific exploration, alternate modes of flight support operations are planned to reduce requirements for on-line equipment and operations personnel.

Requirements of the DSN for multi-project support are incorporated in the MOS planning along with the need to reconfigure the Deep Space Station and Space Flight Operations Facility in the fastest possible manner to support multiple projects in quick succession. To this end the equipment, software, and operational procedures must be designed to accommodate rapid switch-over and checkout for Deep Space Instrumentation Facility station pre-pass and post-pass operations.

11.3.1 Operational Procedures

Although each spacecraft and capsule will be programmed to accomplish most of the essential functions automatically, it is nevertheless necessary to provide for real-time flight support capabilities. Operations teams can improve the probability of mission success by altering standard modes of operation to enhance spacecraft and capsule performance. Furthermore, meaningful scientific investigation of Mars and its environment will require that the operations teams be able to vary mission sequences in order to accomplish scientific objectives that may change as scientific information is evaluated during the flight. Thus it is an MOS design goal to increase the effectiveness of SFOF mission operations teams by conducting the following operations: (a) monitor system performance and experiment data; (b) process, correlate, and handle the relevant data required to perform engineering evaluations, conduct scientific experiments, and make operational decisions; (c) formulate alternative courses of action and evaluate the implications of each upon mission success; and (d) select and implement the best course of action from those permissible.

To achieve these design goals, it will be necessary to (a) automate more aspects of the monitoring function; (b) increase the informational content of data through effective use of display devices and data correlation procedures; (c) improve the judgement and decision making capabilities of operations personnel through comprehensive training and participation in numerous rehearsal exercises; and (d) plan extensively for nonstandard operations which can develop. Thus, operations personnel are able to understand the wider implications that their decisions have upon mission success. It will also become increasingly necessary for the functional operations groups to analyze and evaluate system and subsystem performance in near real-time in order to isolate causes of nonstandard operations and to determine required corrective actions.

11.3.2 Computer Programs

The computer programs to be implemented in the SFOF will process and correlate incoming data so as to display information to the science, flight path, and engineering analysis teams in the most useful form possible. The mission-dependent operations computer programs will be integrated into the system with existing mission-independent programs and mission-dependent programs. The Voyager computer system will retain the capability to run certain independent programs off-line to support multiple operational functions simultaneously or for backup of critical functions during maneuvers and periods of intense mission activity.

In addition to the on-line operational computer programs and off-line analysis programs, it will be necessary to develop simulation, diagnostic, and other test computer programs to facilitate the software integration checkout and certification process and to develop the simulation data required for a flexible personnel training and operational test program. It is a design goal to develop computer programs that will generate DSN simulation data for any one of a number of nonstandard operations sequences. These computer programs will furnish training and simulation data for rehearsal exercises to help operations personnel to identify nonstandard operations, diagnose nonstandard operations, and learn to make correct operational decisions.

11.3.3 Mission-Dependent Equipment

The DSN data handling system provides for the presentation of processed science video, command, tracking, and engineering telemetry data to the user areas in the SFOF and for monitoring at the Huntsville Operations Support Center. The data handling is essentially in real-time, thereby aiding the decision-making process and improved response time at the SFOF. Mission-dependent equipment will accommodate patchboard switching at the Deep Space Stations to maximize the capability for off-line checkout and validation with a minimum use of mission-independent equipment. Telemetry and command computer programs for the DSIF station computers will provide for standard interfaces with communications processors, digital instrumentation system, station displays, and timing subsystems.

Equipment in the operational areas of the SFOF will include engineering subsystem displays, science subsystem display, and a dynamics mission display. Because of the number of separate Voyager vehicles to be controlled from the SFOF at any one time, and the high activity flight support requirements during critical mission phases, it is necessary to devise and implement a dynamics mission display depicting the time-varying trajectory geometry relating the various vehicles, the earth, Mars, and the sun.

11.3.4 Training and Testing

A training and testing program for the entire operational configuration of the MOS and of its various components will be conducted. These tests will insure that the equipment, both mission-dependent and mission-independent, can function correctly as a total system; that the MOS software is adequate in concept, execution, and scope; and that the MOS personnel know their individual tasks and can function together as a smoothly coordinated team.

Tests of mission operation equipment and personnel training at levels beneath the full system tests should afford a capability for attaining high levels of confidence without simultaneously excluding DSN facilities from the support of other flight projects. This capability will be implemented by telemetry simulation programs at both the SFOF and the DSIF stations. In addition, communication test and simulation tapes, RF test transponders, and simple simulation devices during subsystem test and checkout of mission-dependent equipment will prevent excessive utilization of general purpose equipment for test and training.

11.4 FACILITIES AND EQUIPMENT

MOS facilities and support equipment fall into two categories: mission-independent and mission-dependent. The former is composed chiefly of the Voyager tracking and data acquisition system equipment, called mission-independent because it is general purpose equipment utilized by more than one NASA project. Selected tracking network facilities will be assigned to perform the functions necessary for Voyager mission operations. Certain Voyager project equipment will be installed at Deep Space Network and possibly at Manned Space Flight Network facilities for specific functions peculiar to the project; such equipment will be designated mission-dependent.

11.4.1 Air Force Eastern Test Range

The AFETR provides the facilities for prelaunch tests and for launching the space vehicles. It also provides tracking of the launch vehicle, telemetry from both the launch vehicle and the planetary vehicle including the capsule and the spacecraft, and provides data handling support. The range instrumentation ships and such range stations as Merritt Island, Cape Kennedy, Patrick AFB, Grand Bahama, Grand Turk, Antigua, Ascension, and Pretoria track the space vehicle from launch. The ground communication system links these land- and ship-based instrumentation systems with the Kennedy Space Center and the Space Flight Operations Facility in Pasadena. Metric data is provided by optical and radar instrumentation and telemetry by separate ground telemetry stations. The program requirements document delineates the project requirements on the AFETR. Included among such requirements is the generation of pointing information and other predict information for the Deep Space Network acquisition stations.

11.4.2 Goddard Space Flight Center/Manned Space Flight Network

The Manned Space Flight Network, either through the use of its own stations or those of other networks managed by the Goddard Space Flight

Center, will provide metric and telemetry coverage to supplement AFETR coverage during the phase from liftoff to planetary vehicle injection. The MSFN facilities include Bermuda, Canary Island, Kano, Carnarvon, and Tananarive.

11.4.3 The Deep Space Network

The Deep Space Network is a precision tracking, communications, and data handling system used to support NASA deep space exploration at earth-referenced distances of more than 10, 000 miles. The DSN includes the Deep Space Instrumentation Facility, the DSN Ground Communications System, and the Space Flight Operations Facility.

During the near-earth phase, support will be furnished by selected stations of the AFETR and GSFC networks to provide metric data, launch vehicle telemetry, and spacecraft S-band telemetry from liftoff to space vehicle injection. After interplanetary orbit injection, the DSN will support two-way communication with the spacecraft until the end of the mission.

The Voyager DSIF stations, Goldstone, Canberra, Madrid, and Ascension Island, furnish precision radio tracking measuring two angles, radial velocity, and range from the station, and provide communications to the space vehicle via command links and from the space vehicle via telemetry links. The Cape Kennedy station supports the final checkout of the space vehicle prior to launch, verifies the compatibility between the DSN and the spacecraft, measures spacecraft frequencies during the countdown, and provides limited telemetry reception from liftoff to local horizon.

The functions of the ground communications system (GCS) are to relay information obtained by the DSIF to the SFOF and relay status information, operational instructions, and spacecraft commands originating in the SFOF to the DSIF. The GCS is, in part, a particular configuration of the NASA Communication System (NASCOM) and includes the services, facilities, and equipment required to provide an integrated network for the DSN when supporting space flight operation and mission tests. It includes voice, teletype, and high-speed data links between the DSIF stations and the SFOF. Included in the GCS, but not an integral part of NASCOM, is the wideband microwave link connecting the Goldstone stations and the SFOF.

The SFOF in Pasadena, California, is the focal point of the DSN. From this facility the entire operation of the DSN will be controlled during the support of a spacecraft, and all spacecraft command, data processing, and data analysis can be accomplished with equipment in this facility. SFOF provides the means for reducing the telemetry, tracking, video, command, and station performance data into engineering and scientific information for analysis and use by the hardware systems personnel and the principal investigators.

Figure 11 illustrates the Voyager mission operations functional data flow and the data handling equipment required for space flight operations including mission-dependent and mission-independent equipment. The equipment assigned to handle video, tracking, telemetry, and command data are briefly described in the following section.

11.4.3.1 Telemetry Data Handling Equipment

The essential mission-dependent and general-purpose equipment for each function in the telemetry flow are shown in Figure 12.

a. Telemetry Receiver

The present S-band system at each Deep Space Station is designed to accommodate two telemetry receiving channels simultaneously; two additional channels are being considered. In that event two orbiting spacecraft and two capsule signals can be received simultaneously when they are present within the antenna bandwidth. The stations incorporate sensitive and stable telemetry receivers that are designed to track the received 2300 MHz carrier and detect both amplitude and phase modulation. The telemetry subcarrier, derived from the appropriate detection channel, is parallel routed to an analog tape recorder and the mission-dependent telemetry demodulator.

b. Telemetry Demodulator

The noise-corrupted modulated telemetry subcarrier provided by the receiver is the input to the telemetry demodulator, in the mission-dependent equipment. The telemetry signal is a composite containing

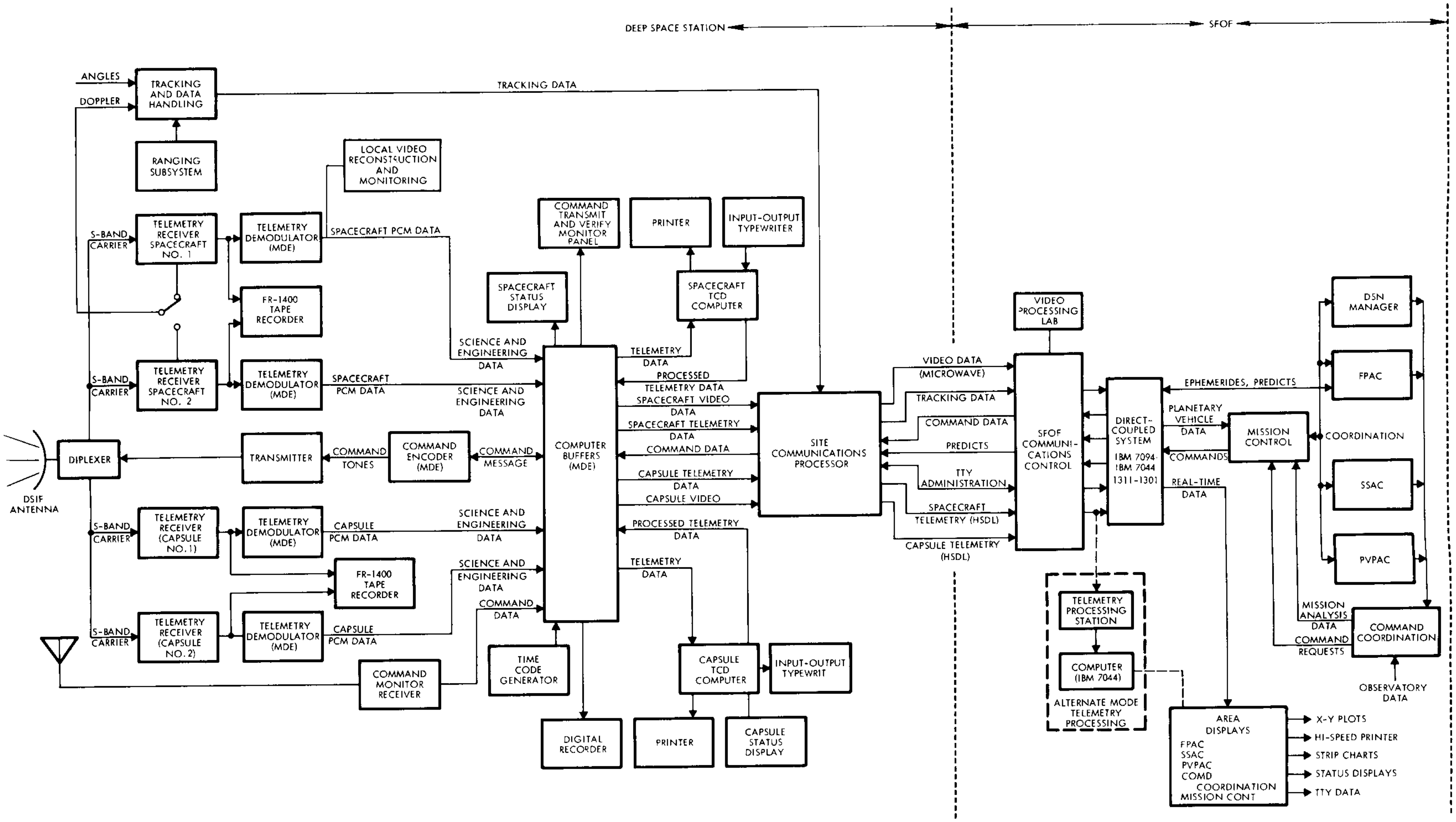


Figure 11. Voyager Mission Operations Data Handling Equipment

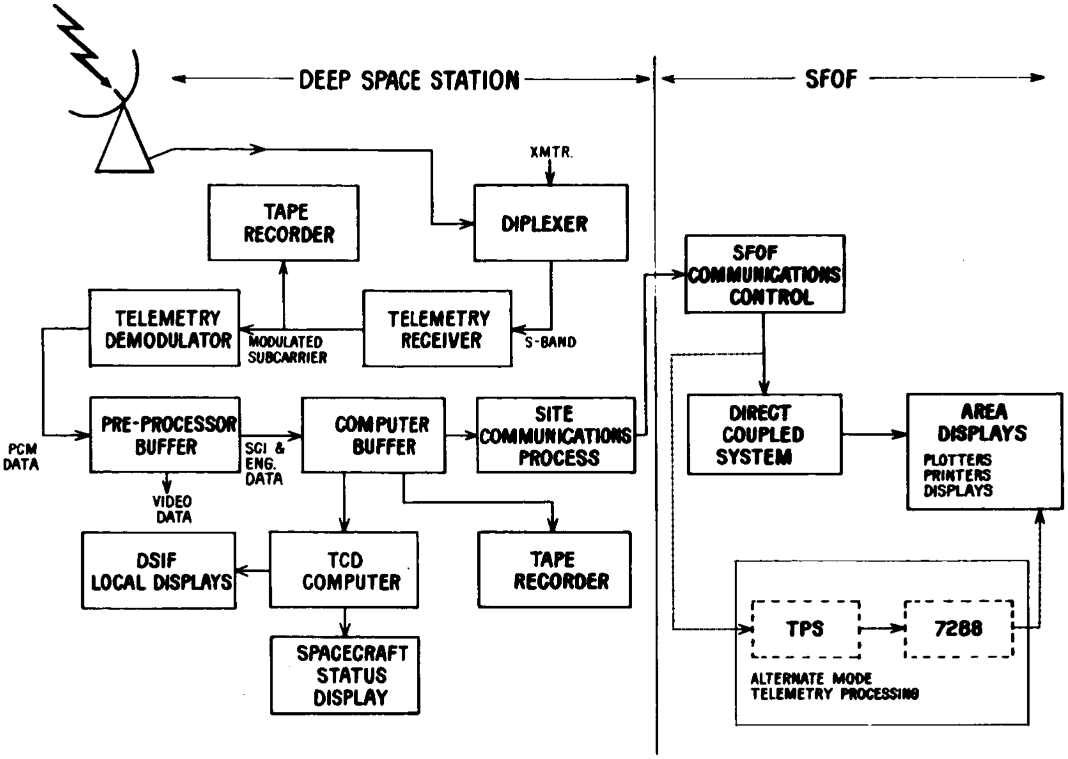


Figure 12. Telemetry Data Flow

both data and synchronization information. The primary outputs of the demodulator are the reconstructed serial PCM bit stream in an NRZ format and a bit rate clock signal.

c. Preprocessor Buffer

The preprocessor buffer has been added to the mission-dependent equipment to provide a simple method of accommodating the higher data rates envisioned by the advanced Voyager mission (300 kbits/sec) while at the same time utilizing the currently planned SDS 920/930 series of computers. If computers with a high-speed processing capability and additional memory are provided, the functions of the preprocessor buffer can be performed by the computer. As indicated in Figure 12 the preprocessor buffers are used only with the spacecraft data channels. Data rates directly from the capsules are low enough to permit direct data input to the telemetry and command computer for capsule data processing.

The basic function of the preprocessor buffer is to accept serial PCM data at rates up to 300 kbits/sec along with synchronization data, perform the frame synchronization function, examine the mode ID word, and separate the data by routing the video data directly to the spacecraft image reconstruction electronics and the science and engineering data to the computer for spacecraft data. By stripping out and buffering the science and engineering data the data rates can be reduced to within the handling capability of the SDS 920 or 930 computers. In the event video data is transmitted on a separate subcarrier the preprocessor buffer will not be required since the demodulated video data would be directly routed to the video reconstruction electronics equipment. If it should be desirable to relay digitized capsule video data via the spacecraft telemetry link the preprocessor buffer could also route this data to capsule video image reconstruction electronics. However, since the telemetry and command computer can process all data other than spacecraft video, the preferred approach is to simplify the preprocessor buffer and program the computer associated with the spacecraft link to route relayed capsule video and capsule science data via the computer buffer to the capsule computer for processing. In this case the capsule computer would then route capsule video to the capsule image reconstruction electronics.

d. Computer Buffer

The computer buffer will serve as a central point of distribution for inputs to the two computers for capsule and spacecraft data and the site communications processor from the preprocessor buffer, capsule telemetry demodulator, command encoder, and command verification receiver. The computer buffer-preprocessor interface consists of serial PCM telemetry data. Under computer control, the buffer transfers this data to the computer in parallel groups of preset size. Similarly, it routes this processed telemetry data from the computer to the site communications processor for transmittal in near-real-time to the SFOF.

e. Telemetry and Command Computer

The telemetry and command data subsystem, two SDS 920 or 930-type computers, provides the on-site telemetry and command data processing. One computer is programmed for processing spacecraft science and engineering data and the other for capsule science and engineering data. Demodulated telemetry from the preprocessor buffer or demodulator is processed by the computer and transferred via the computer buffer to the site communications processor for transmission to the site communication processor for transmission to the SFOF. Typical functions are:

- Selective editing of spacecraft telemetry data
- Decommutation of telemetry data for local displays
- Formatting and time coding of telemetry data for transmission to the SFOF via TTY or high-speed data line
- Determination of data quality

f. DSIF Local Displays

The DSIF requires the telemetering of several spacecraft telecommunications parameters for efficient and reliable operations. Those significant parameters are spacecraft transponder static phase error and received signal level. Other telemetered data, such as spacecraft power output, command verification, and command lock verification, are quite useful. All of these parameters must be provided in engineering units.

g. Site Communications Processor

A communications processor will be provided at each Deep Space Station for circuit routing and for system monitoring functions. It inserts and extracts NASCOM message preambles, recognizes and returns NASCOM circuit assurance messages, keeps a message count, and performs coding and decoding for one duplex error-correcting command channel. It will handle five full-duplex internal and four full-duplex external TTY channels and one simplex high-speed data channel.

The subsystem consists of a general purpose computer with appropriate peripheral data communications equipment to handle the TTY and high-speed data inputs and outputs. Additional peripheral equipment are two buffers to transmit communications channel error counts and self-check (diagnostic) information to the station's digital instrumentation system, a TTY keyboard send-receive unit for communications operator control, and a TTY receive-only page printer for message logging.

h. Direct Coupled System

The direct coupled computer system at the SFOF is a complete, integrated, operating system to meet the requirements of several flight projects for simultaneous flight operation support by the DSN. For the Voyager mission operation this system will be used under the control of a master executive program which will provide sequential calling of appropriate programs and routines.

i. Telemetry Processing Station

At certain times during the mission the telemetry processing station may be used as an alternate to the direct coupled system. The functions performed by the station are to:

- Convert received telemetry data to a 36-bit parallel format compatible with a 7288 high-speed subchannel and to IBM-compatible magnetic tape
- Provide the capability for off-line analog data analysis
- Provide the capability for producing strip chart recordings of analog data outputs
- Provide the capability for recording all composite and high-speed digital data entering the SFOF from the Goldstone microwave link and other DSIF high-speed data sources

The conversion process is either in real-time using signals received from the stations or in non-real-time using data recorded on magnetic tape. The station is designed with the intent of minimizing special purpose equipment as well as obviating the need for a third generation computer over extended periods of time.

During critical portions of the mission the station provides parallel processing, thus assuring a backup in the event of failure of the prime processing path.

Equipment in the operational areas of the SFOF will include display and control consoles, individual subsystem displays, and a mission status board. Because of the number of Voyager space vehicles to be controlled from the SFOF simultaneously and the high activity flight support requirements during critical mission phases, it is necessary to devise and implement display equipment depicting the time-varying relative geometry of the orbiting spacecraft, the landed capsules, and the earth, Mars and the sun.

11.4.3.2 Tracking Data Handling Equipment

For two-way doppler data, a precision frequency is sent to the spacecraft, where it is coherently frequency-shifted by a fixed ratio and retransmitted to the ground station via the telemetry link. The receiving system then compares the received frequency with the transmitted frequency to extract the doppler. A bias frequency is added to discriminate between positive and negative radial velocity. One-way doppler is available by locking the receiver to the downlink signal from the spacecraft auxiliary oscillator.

Precision turnaround ranging capability is available at each station. The range measurement is related to the time difference between two identical, separately generated, pseudorandom noise codes, one generated at the transmitter phase modulated on the uplink carrier, and the other generated at and synchronized by the receiver for correlation detection.

The ground transmitted signal is modulated by a long binary wave train known as the range code. This code is detected by the spacecraft transponder and retransmitted in a turnaround mode to the interrogating station. There the bit train is shifted in time relative to the original signal by the round trip propagation time.

All of the tracking data for TTY transmission is processed by the tracking data handling equipment. This equipment automatically punches out on paper tape and in standard Baudot teleprinter five-hold code characters which represent carriage return, line feed, figures, spaces, and the following:

- Station ID number
- Spacecraft ID number
- Data condition

- Greenwich Mean Time
- Antenna hour or azimuth angle
- Doppler frequency
- Range data, including range conditions code
- Transmitter frequency
- Day-of-year

The computer subsystem provides a capability for the processing of tracking data associated with space tests and operations. The output consists of orbit ephemerides and antenna pointing angles and receiver and transmitter frequency estimates for each station.

11.4.3.3 Video Data Handling Equipment

Either photographic or television data are transmitted at the higher data rates when receiving data via the spacecraft telemetry links, and either type of data is separated from the composite data stream and routed to the appropriate image reconstruction electronics for recording, reconstruction, and data quality monitoring and assessment at the local Deep Space Station.

In lieu of video reconstruction at the sites, an alternate mode of operation provides for stations having access to wideband data transmission facilities to transmit video data via the site communications processor through the ground communications system to the SFOF for reconstruction and visual monitoring and recording in near-real time. Since wideband communication satellite channels are expected to be available for Voyager use, the latter method may be preferred. During either mode of operation the data will be recorded at the local DSS for use in postflight processing.

11.4.3.4 Command Data Handling Equipment

The command encoder (see Figure 13) is responsible for encoding spacecraft commands and is either manually entered by means of switches on the front panel or automatically initiated by Mission Control at the SFOF. The resulting command is a NRZ PCM signal at 1 bit/sec

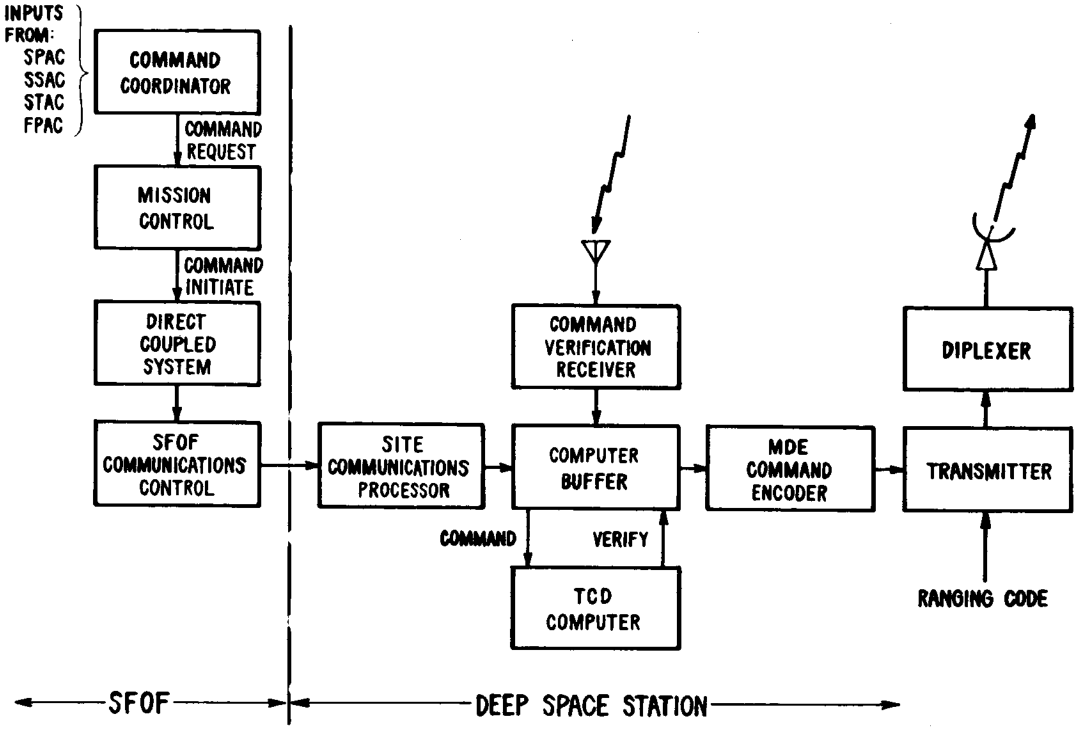


Figure 13. Command Data Flow

containing the maximum of 60 bits. An alternate command data rate in the order of 10 to 100 bits/sec may be employed for automatic commanding operations.

Prior to transmission of a command, it is formatted by the telemetry and command computer from data received from the command generation computer at the SFOF. The command is held in memory by the computer for comparison with the radiated signal during transmission.

The command verification receiver phase demodulates a sample of the transmitted RF signal and sends it to the command detector, which is located in the computer buffer. The detected command bit stream is compared, bit by bit, with the transmitted signal. If an error is detected the command is halted and a "stop" indicator is lit on the encoder front panel. Since the spacecraft executes only complete commands, the partial command will be ignored.

The normal mode of commanding the spacecraft is as follows:

1) Coordination of all command requests from the SFOF technical groups are handled through a command coordinator before they are routed to the space flight operations director.

2) In general, commands will be assembled in blocks and time-tagged according to the desired time of execution. Commands intended for immediate transmission will be tagged accordingly.

3) Following the approval of the space flight operations director, the block of commands is sent to the SFOF computer subsystem for verification and time tag checks prior to transmittal to the station. The commands are also checked against a permissive command list loaded into the computer to insure that the command is compatible with the mission constraints for the current phase of the operation and with the remainder of the command list in the vehicle command programmer.

4) At the DSS telemetry and command computer, commands are formatted in a manner compatible with the command encoder.

5) Command verification data is processed and maintained by the SFOF computer system. Tallies on receipt of commands by the spacecraft and times of execution are maintained as a part of the command list for each vehicle in the computer.

The emergency mode of command initiation and transmission is intended for use in the event of system malfunction in the chain preceding the command encoder. In that case, the space flight operations director may elect to direct the Deep Space Station manager via TTY messages to manually select and transmit the desired commands.

11.5 ORGANIZATION AND SYSTEM INTERFACES

The basic function of the MOS is to control the spacecraft through its mission activities. This, in turn, involves:

a) Coordination and direction of the activities of the DSIF, SFOF, and MOS personnel conducting the mission, evaluation of the spacecraft's progress, and issuance of the requisite commands to the spacecraft.

b) Evaluation of the performance of the spacecraft and scientific instruments as well as of the MOS, during the flight in real time to identify and determine the nature of any nonstandard performance that would require a deviation from the nominal mission plan.

c) Determination in real-time of corrective actions which would maximize the mission capabilities of the systems under nonstandard performance conditions.

d) Coordination and direction of corrective actions in real-time.

e) Recording and dissemination of data for post-mission analysis.

This subsection describes the basic MOS organization and the organizational interfaces with the other Voyager systems during launch and spaceflight operations.

11.5.1 Basic MOS Organization

The MOS manager (Figure 14) is responsible to the Voyager mission director for assurance that mission operations facilities, equipment, program software and qualified personnel are in a ready condition

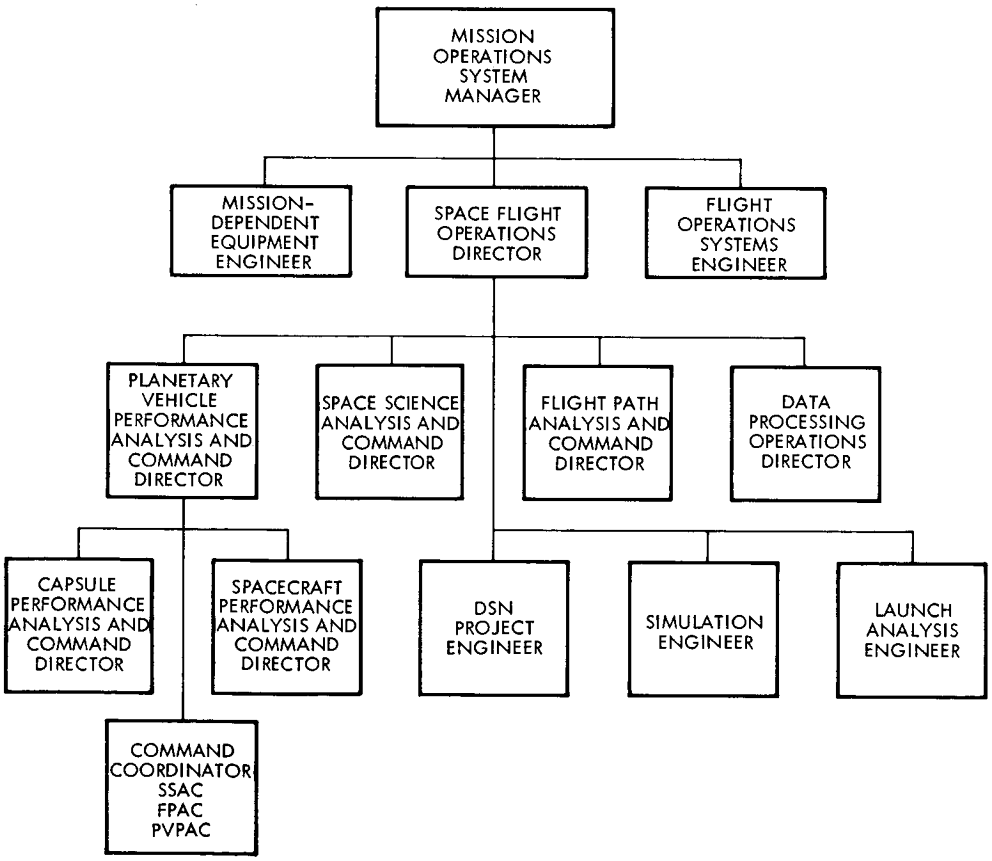


Figure 14. Mission Operations System Organization

to support all Voyager mission-related activities. He is responsible for all planning, coordinating, development, procurement, and implementation activities required to conduct Voyager mission operations. In performing these activities the MOS manager is supported by his own organization which will

- Provide documentation, computer programs, personnel, and equipment to support missions operations
- Conduct mission operations and perform post-flight mission evaluation studies
- Coordinate with the other Voyager system management offices to obtain support as required.

The space flight operations director will be responsible to the MOS manager for ensuring readiness of all flight operations personnel and is responsible for the conduct of space flight operations. The space flight operations director will:

- Prepare all plans, schedules, designs, documentation, and controls relating to the MOS software and preflight training and testing, including the generation of test plans
- Specify, for all mission-dependent equipment and TDAS facilities, the schedules and requirements necessary to support the MOS
- Specify the standard sequence of events, and place requirements consistent with the Voyager Space Flight Operations Plan on the various operating groups
- Establish and document procedures for non-standard operations
- Control and direct the preflight training and testing in accordance with plans approved by the Voyager MOS manager
- Resolve any ambiguities directly associated with the standard sequence of events arising during execution of the mission

- Make appropriate decisions and initiate the required action to ensure success of the mission; the mission director, or duly authorized delegate, is expected to review all critical decisions
- Exercise primary control of space operations, including the procedures to be used and the time of procedure initiation.

The mission dependent equipment engineer will be responsible to the MOS manager for the implementation, integration, and operational readiness of all mission-dependent Voyager equipment.

The flight operations system engineer is responsible to the MOS manager for implementing and ensuring the operational readiness of all flight operations systems.

Each planetary vehicle will be controlled by a mission operations team consisting of an assistant space flight operations director, directors representing the planetary vehicle performance analysis and command group, the space science analysis and command group, the flight path analysis and command group, and the data processing operations group.

Each planetary vehicle group will include subgroups for spacecraft performance analysis and control, and for capsule analysis and control. Similar divisions of responsibility are required within the science and flight path groups. Each group will be functionally responsible for both planetary vehicles.

Many of the personnel who will design and implement the MOS hardware and software will participate directly in the countdown and spacecraft flight operations. Figure 14 depicts the basic MOS organization and representative support groups from the TDAS, spacecraft, and capsule systems and all other interfacing systems.

The DSN project engineer will be responsible for all DSN personnel who operate the equipment and who track, control, and communicate with the vehicles. He will be responsible for the readiness of all SFOF, GCS, and DSIF equipment and personnel who support the MOS.

The simulation engineer will be responsible for conducting the training and test program that ensures operational readiness of software, equipment, and operations personnel.

The launch analysis engineer will be responsible for providing the status of the facilities used for prelaunch tests and during launching of the space vehicle, and insuring that the TDAS provides tracking of the launch vehicle, and telemetry from both the launch vehicle and the planetary vehicle, and relays this information to the MOS. In addition, he will be responsible to the space flight operations director for launch systems monitoring and status through insertion into earth parking orbit.

The project scientist will be responsible to the space flight operations director for the interface between the SFOF and the principal investigators where experiment packages are coordinated in turn by the science coordinator for each hardware system. The science coordinator for each system will work through, and with, the project scientist who is responsible for the implementation of all experiments.

The command coordinator will be responsible for ensuring that all PVPAC, FPAC, and SSAC command activities are coordinated and monitored.

11.5.2 Space Flight Operations

The Voyager project manager (Figure 15) in his capacity as mission director will be in full charge of all mission operations. Aiding him in a staff capacity and acting in his absence or on specific request will be the assistant mission director.

Mission operations are under the immediate primary control of the space flight operations director. During space operations, the space flight operations director maintains overall control of all operations and participates in all major decisions by presenting the alternatives to the mission director. The assistant space flight operations director aids the space flight operations director in the control of the mission and affords him backup.

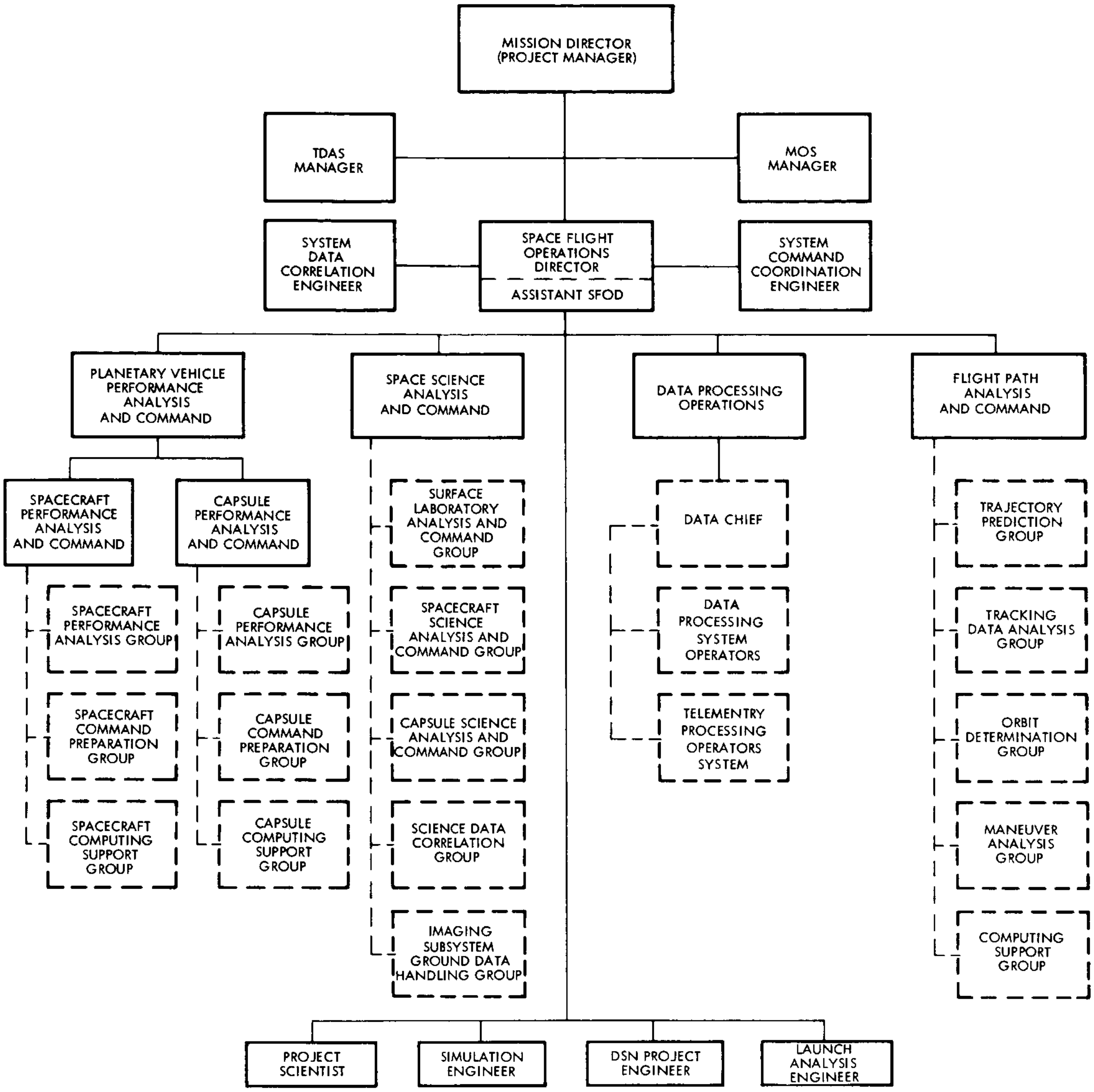


Figure 15. Space Flight Operations Organization

During space flight and Mars operations all orders are from the space flight operations director or his delegated authority. The directors of four groups of specialists provide technical support to the space flight operations director. These technical analysis groups specialize in the flight path, planetary vehicle performance, operations support, and scientific experiment activities.

It will be the responsibility of the technical analysis group directors to organize and direct the respective technical analysis groups. Responsibilities include:

- Scheduling the preflight, flight, and postflight activities of the group
- Disseminating appropriate information within and without the group during the preflight, flight, and postflight phases of the mission
- Placing requirements on members of the group
- Providing single contact and interface with other space flight operations groups and personnel during the preflight planning and preparations phase and during space flight operations
- Preparing all required documents, schedules, and procedures for the group
- Ensuring compliance with all requirements and schedules placed upon the group
- Ensuring technical proficiency of the group

It is the responsibility of each technical analysis group to assist the space flight operations director in the definition and evaluation of the standard mission; to recommend courses of action, during a non-standard mission, that will optimize the value of the mission; to perform the intra-and inter-group technical liaison required to achieve these objectives; and to ensure that the necessary preflight plans, computer programs, and data packages are prepared.

11.5.3 Flight Path Analysis and Command

It will be the responsibility of the flight path group to make the necessary preparations for using the available tracking and pertinent telemetry data, to obtain the best estimate of the actual trajectory of the spacecraft and, supported by the DSIF, to interpret the data supplied by the tracking stations. It will also be the responsibility of this group to prepare and evaluate midcourse maneuvers and to generate spacecraft commands affecting the flight path using, to the degree required, the support of the planetary vehicle performance analysis and command group and the space science analysis and command group. The flight path analysis and command group consists of the following sub-groups:

a) Trajectory Prediction Group

- Determines nominal spacecraft injection data
- Predicts Mars encounter and generates trajectory planning data based on injection conditions reported by AFETR and MSFN and computed from tracking data by the orbit determination group

b) Orbit Determination Group

- Determines vehicle orbits by processing tracking data received from DSN tracking stations by way of the tracking data analysis group
- Generates statistics of parameters to enable maneuver situations to be evaluated
- Generates tracking predictions for DSIF stations
- Recomputes the orbit of each vehicle after maneuvers are performed to evaluate the maneuvers

c) Tracking Data Analysis Group

- Performs quantitative evaluations of tracking data utilizing the data processing system
- Monitors, 24 hours a day, incoming tracking data utilizing the data processing system
- Provides liaison between data users and the DSIF
- Provides predicts to the Deep Space Stations

d) Maneuver Analysis Group

- Analyzes and determines trajectory corrections and terminal maneuvers performed by each vehicle for both standard and nonstandard missions in real-time during actual flight
- Determines proper spacecraft commands to effect maneuvers. Commands are relayed to the command coordination engineer who coordinates the planetary vehicle analysis and command group prior to generation of the commands

- Verifies correctness of calculated commands

e) Computing Support Group

- Acts in a service capacity to other subgroups
- Ensures that all computer programs used in SFOF are fully checked out prior to start of mission operations
- Optimally utilizes the data processing facilities

11.5.4 Planetary Vehicle Performance Analysis and Command

The planetary vehicle group is responsible for the operation of each of the two planetary vehicles, spacecraft and capsules. It will be the responsibility of the group to determine capsule and spacecraft performance and to recommend spacecraft and capsule commands as determined by the performance of each vehicle. This responsibility includes:

- Validation of the engineering performance of the space vehicles at all times throughout the mission
- Recognition of nonstandard conditions on the capsule and spacecraft and to recommend to the space flight operations director alternate procedures or sequences, and to analyze the effects of such alternate procedures or sequences on mission success
- Evaluation and recommendation, from an engineering viewpoint, of all command actions proposed by other technical analysis groups
- Exercise of direct, real-time control of mission command execution activities, when such activities have been approved by the space flight operations director
- Maintenance and dissemination of spacecraft and capsule status throughout the mission
- Preparation of detailed operating procedures for the standard and anticipated nonstandard missions
- Gathering of the prescribed spacecraft and capsule data for post-mission analysis

For each space vehicle there will be three supporting groups of specialists whose functions are described below:

a) Performance Analysis and Command Group

- Monitors incoming engineering data telemetered from each vehicle
- Determines status of each vehicle
- Maintains status displays throughout the mission
- Determines the results of all commands sent to the vehicles
- Analyzes the cause and recommends appropriate nonstandard procedures in the event of a failure aboard a vehicle as indicated by telemetry data

b) Command Preparation Group

- Prepares command sequences to be sent to the vehicles
- Provides inputs to computer programs used in generating command sequences
- Verifies that the vehicle commands have been correctly received at the Deep Space Station
- Verifies that commands have been correctly transmitted to the vehicles
- Verifies that commands have been properly executed by the space vehicle
- Generates the required command sequences for nonstandard operations

c) Engineering Computer Program Operations Group

- Controls operators for the data processing system input-output consoles and related computer equipment in the planetary vehicle performance analysis area
- Handles all computing functions for the rest of the PVPAC groups
- Maintains an up-to-date list of parameters for each program

To take advantage of the knowledge and experience of the personnel who are not a part of the operations teams but who have been engaged in design analysis or testing of the spacecraft and capsules, spacecraft analysis teams and capsule analysis teams have been established. These teams may be located in a building adjacent to the SFOF and will have appropriate data displays to keep them abreast of the current status of the mission. These teams will be available upon request for immediate consultation and detailed analysis in support of the planetary vehicle group.

11.5.5 Space Science Analysis and Command

It will be the responsibility of the space science group to command and control the operation of Voyager scientific instruments. In the event of nonstandard missions, the group will provide the scientific and engineering tradeoff information concerning the payload, which will permit the mission director to optimize the overall return from the mission. Specifically, the group will:

- Plan science operations to optimize the quantity and quality of scientific knowledge that can be obtained
- Recommend command and control functions for the instrument payload operations
- Analyze instrument data on a real-time basis throughout the interplanetary cruise, Mars orbit, capsule descent, and post touchdown phases in order to evaluate and optimize instrument performance in support of subsequent mission operations
- Develop techniques and procedures that will be used for subsequent Voyager flights

a) Surface Laboratory Analysis and Command Group

- Analyzes performance of the surface laboratory including imaging equipment
- Determine the required command sequence for the surface laboratory and its equipment and relays to system command coordinator

b) Spacecraft Science Analysis and Command Group

- Responsible for reconstruction, analysis, and interpretation of photographs or TV images from the Mars mapping mission to ensure that mission objectives are met
- Performs scientific analysis and evaluation of scientific fields and particles or other experiments under the direction of the project scientist
- Determines required command sequences for operation of imaging subsystem and scientific payload

c) Capsule Science Analysis and Command Group

- Performs scientific analysis and evaluation of the capsule entry package experiments
- Determines proper command sequences for capsule science payload

d) Imaging Subsystem Ground Data Handling Group

- Operates as a service organization within the MOS
- Provides direct support to the group director in the form of processed electrical video signals and finished photographic prints
- Provides documentation system checkout and quality control functions

11.5.6 Data Processing Operations Group

The responsibilities of the data processing operations group during preflight preparation are to:

- Generate, maintain, and control the Voyager project computer program development plan
- Participate in the generation and maintenance of computer program documentation, development, and test schedules
- Monitor development of all computer programs required for Voyager and to publish periodic status reports

- Participate in the control and operational certification of all computer programs required for the Voyager mission, and to maintain a program library
- Participate in the planning for, and direction of, all program checkout, integration, demonstration, and test activities, and to coordinate and control the Voyager data processing system during the conduct of these activities
- Coordinate and control the Voyager data processing system during all preflight tests specified in the Voyager Mission Operations System Test Plan

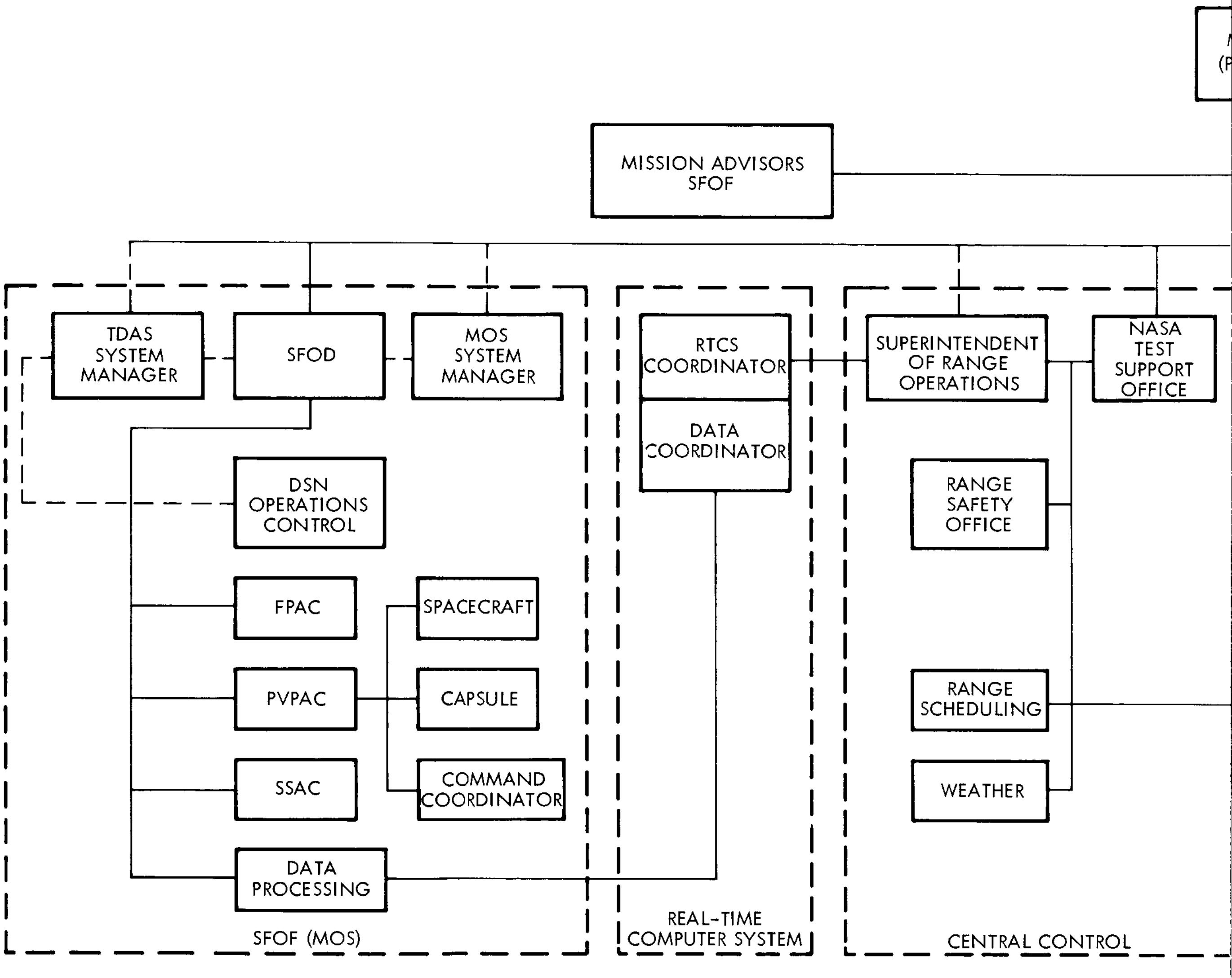
The data chief is in charge of all data processing system personnel and equipment. Included are the input-output console operators throughout the SFOF as well as the equipment operators in the data processing system and telemetry processing system areas.

11.5.7 Launch Operations Interface

Figure 16 shows the relationship among the MOS and the other operation groups during the period preceding the launch and ending at earth orbit injection. Those agencies involved in the management of the Saturn V launch vehicle system and the Kennedy Space Center launch facilities for the Voyager project are the Marshall Space Flight Center and the Kennedy Space Center.

The project manager, who also performs in the function of MOS mission director, resolves interface problems among the systems within the project. He will have the responsibility and authority for mission design and for approving the launch criteria necessary for mission attainment. He will participate in launch operations to ensure mission readiness. No change in operating criteria may be made without his consent.

The Kennedy Space Center will have the responsibility and authority for planning and conducting launch operations. This authority is administered through the launch operations system manager. The launch director will be a member of the Kennedy Space Center and will control the countdown. The launch conductor will supervise the countdown of the space vehicle and will report directly to the launch director.


MISSION ADVISORS SFOF
TDAS SYSTEM MANAGER
SFOD
MOS SYSTEM MANAGER
DSN OPERATIONS CONTROL
FPAC
PVPAC
SSAC
DATA PROCESSING
SPACECRAFT
CAPSULE
COMMAND COORDINATOR
SFOF (MOS)
RTCS COORDINATOR
DATA COORDINATOR
REAL-TIME COMPUTER SYSTEM
SUPERINTENDENT OF RANGE OPERATIONS
NASA TEST SUPPORT OFFICE
RANGE SAFETY OFFICE
RANGE SCHEDULING
WEATHER
CENTRAL CONTROL

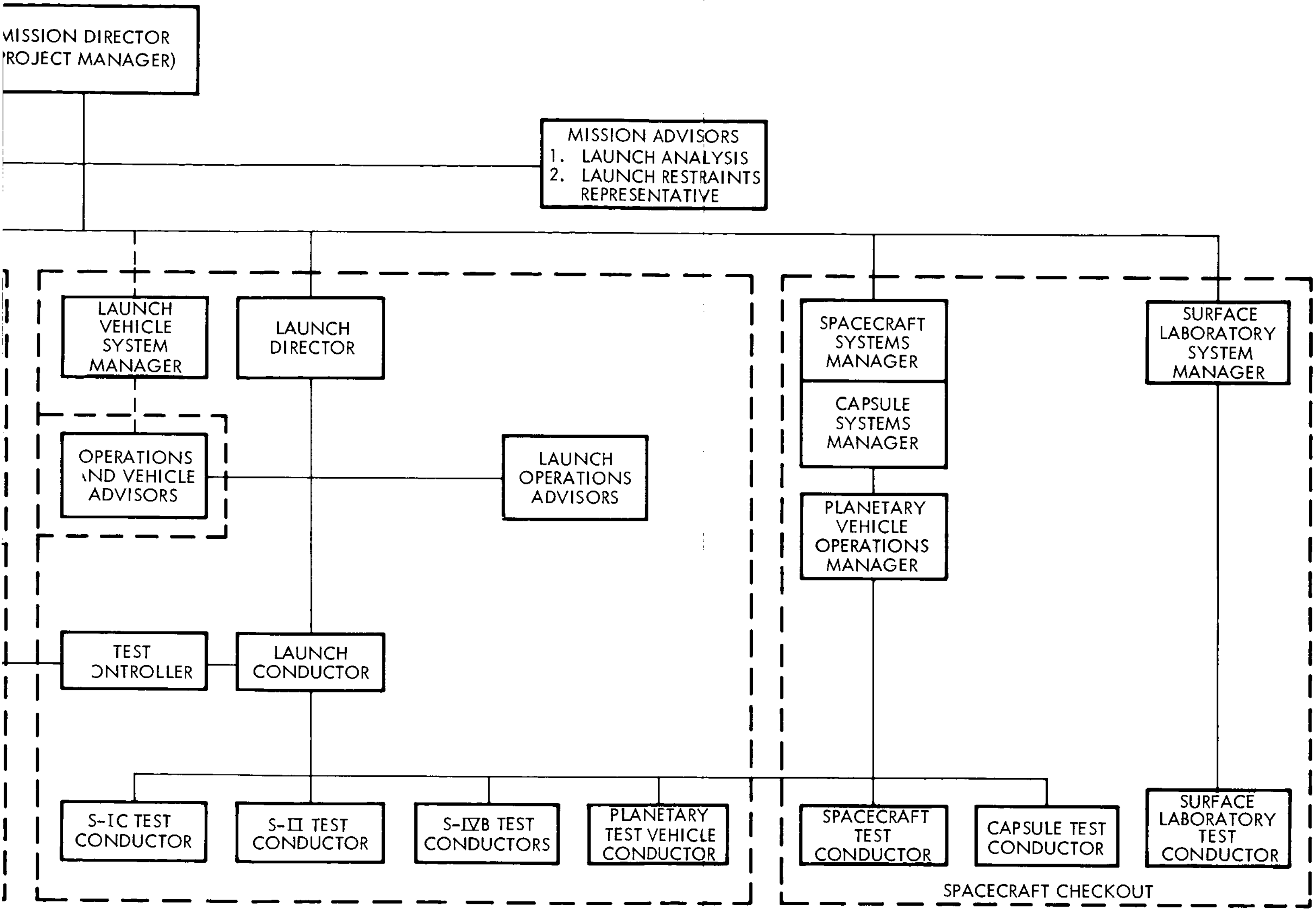


Figure 16. Launch Operations Interface

The planetary vehicle operations manager and his field crew are responsible to the spacecraft system manager for the preparation of the spacecraft for launch, to the capsule system manager for the preparation of the capsule for launch, and to both for participation in the actual countdown. The planetary vehicle test coordinator reports to both the Kennedy Space Center launch conductor and to the planetary vehicle operations manager during launch operations. The MOS manager will also be responsible to the mission director on matters concerning readiness of the MOS and DSN. Range requirements and conditions will be the responsibility of the superintendent of range operations acting through the NASA test support project.

After arrival of the planetary and launch vehicles at AFETR/Kennedy Space Center, each agency will proceed individually with tests to assure that equipment was not damaged in shipment and to assure a minimum of difficulties during compatibility checks on the launch pad.

The Kennedy Space Center has complete responsibility for on-pad operations and facilities, and for installing the required test and checkout equipment. The final determination of the decision to commit the mission to launch will be made by the project manager.

The MOS manager will support the project manager in the preparation and execution of the standard operating procedure for space flight operations. The standard operating procedure is defined as the method by which the space flight operations will be conducted in both the nominal case and anticipated departures from the nominal case.

During the preflight phase, the MOS manager will request information and resolve conflicting requirements within the SFOF and DSN areas.

While the countdown is in progress, telemetry data received by the system test station will be compared with telemetry data monitored by DSS-71 at KSC to ensure that any differences in data processed by the two separate systems are noted. Data received and processed by DSS-71 will be relayed to the SFOF for use by the planetary vehicle team in establishing nominal predicted values for telemetry data received by the acquiring DSN stations.

During near-earth flight operations, it is the responsibility of the MOS manager to interpret the standard operating procedures and place consistent requirements upon the various operating groups. He resolves any ambiguities directly associated with the execution of the standard operating procedures and makes appropriate decisions requiring emergency action.

11.6 COMPUTER PROGRAMS

The MOS computer programs will be integrated into the existing DSN data processing system to enable SFOF mission operations teams to monitor system performance and experiment data; to process and correlate information required for engineering evaluations, scientific experiments, and operational decisions; to formulate alternative courses of action and evaluate the implications of each upon mission success; and to select and implement the best course of action from those possible.

The MOS computer programs are classified according to their use by each technical analysis area and data processing operation group. Figure 17 identifies the computer programs required to support all functional areas in the MOS.

11.6.1 Flight Path Computer Programs

The flight path computer programs aid in formatting, editing, and assembling raw tracking data; determining space vehicle orbits from the tracking data; computing trajectory planning data; calculating the time-varying relative geometry of the space vehicle, the tracking stations, the sun, Mars, and Canopus; and determining the parameters characterizing trajectory correction and terminal maneuvers. The programs are itemized below:

a) The Injection Condition Program determine the Saturn V earth-parking conditions and planetary vehicle trans-Mars injection conditions, as a function of launch time.

b) The Tracking Data Processor develops formats for raw tracking data so it can be handled easily by the orbit data generation program, and tests raw data for validity. Tracking data are entered from various sources and data emerges on punched cards, card images, or on magnetic tape.

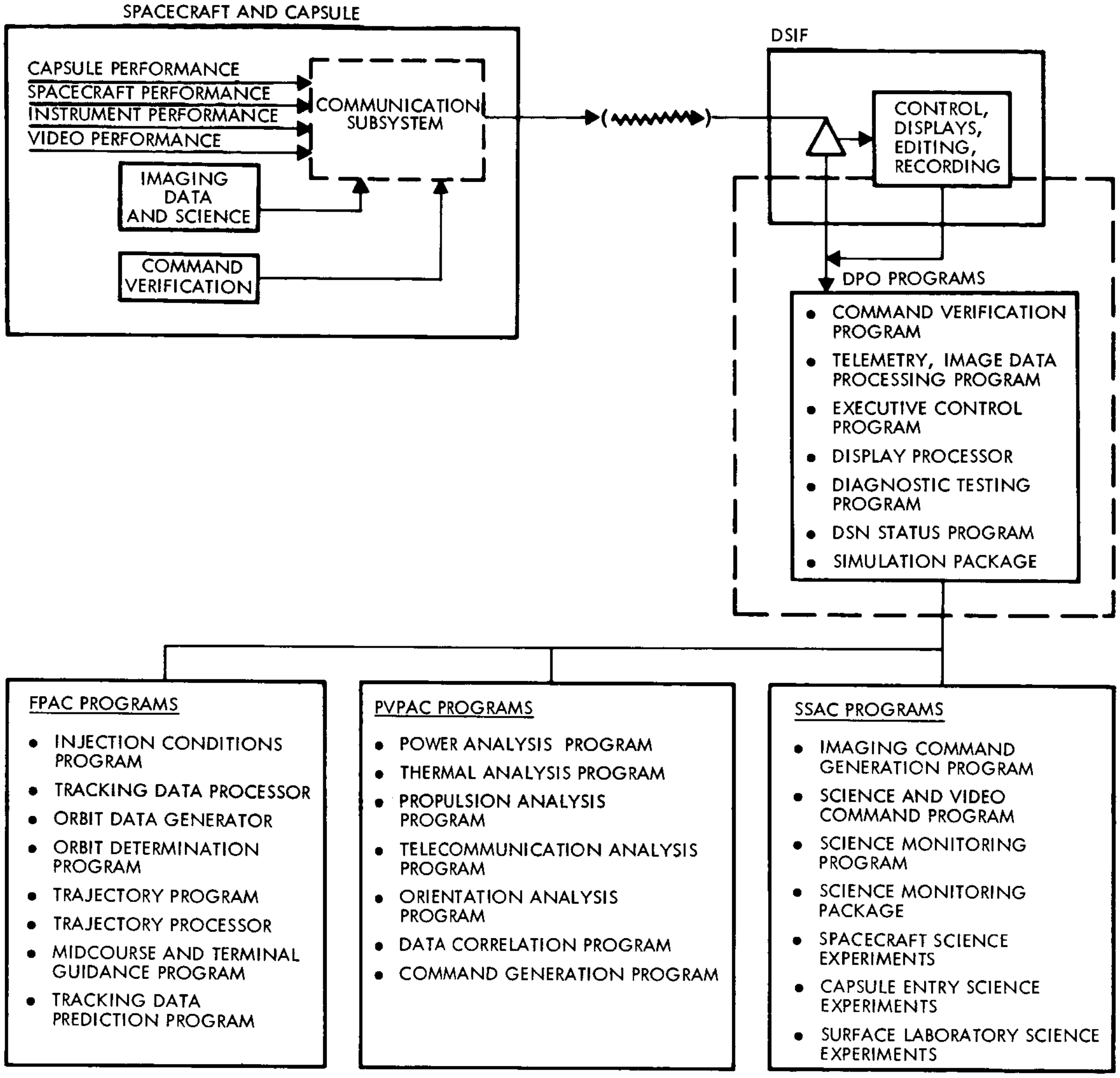


Figure 17. MOS Computer Programs

c) The Orbit Data Generation Program edits tracking data and prepares a data file for the orbit determination program.

d) The Orbit Determination Program computes spacecraft orbit and tracking predictions from edited tracking data or from a given set of spacecraft injection conditions.

e) The Trajectory Program computes the spacecraft trajectory, predicts Mars touchdown sites and other trajectory planning data.

f) The Trajectory Processor computes positions of the DSIF stations, planets, sun, moon, and Canopus with respect to the spacecraft.

g) The Midcourse and Terminal Guidance Program determines the spacecraft midcourse maneuver and computes all required terminal maneuvers.

h) The Tracking Data Prediction Program computes doppler, view periods, occultation times, transmitter VCO frequencies for the tracking stations, predicted events schedules, and other planning information for DSN scheduling.

11.6.2 Planetary Vehicle Computer Programs

The planetary vehicle computer programs support the spacecraft and capsule performance by means of automatic alarm processing procedures; isolating causes of nonstandard performance by modeling and simulating subsystem performance characteristics; predicting subsystem performance parameters for various selected operational sequences; and composing and verifying all command messages sent to the space vehicles. The programs are identified below:

a) The Power Analysis Program integrates all power depletion with time, calculates the parameters characterizing battery and solar array performance, and determines the most effective mode of converting, regulating and distributing power to all other spacecraft and capsule subsystems.

b) The Thermal Analysis Program determines and predicts temperatures of all spacecraft and capsule components, calculates thermal gradients and heat flow parameters, compares the thermal control performance againstestablished design criteria, and computes the required solar panel orientations.

c) The Propulsion Analysis Program budgets fuel expenditure of the propulsion and reaction control systems for the planetary vehicle during interplanetary cruise, spacecraft propulsion system during Mars orbital operations, and the capsule propulsion system during capsule separation, Mars entry, and terminal descent mission phases.

d) The Telecommunication Analysis Program computes nominal DSIF received signal to noise ratios as a function of trajectory, ground system, and space vehicle component parameters, determines anticipated signal strength based upon range, space orientation, antenna pointing, effective radiated power, and other parameters; and generates communication formats for transmission to DSIF stations.

e) The Orientation Analysis Program computes and predicts the time history of planetary vehicle, capsule, and spacecraft orientations. For each of these vehicles the program will compute pointing angles of the earth tracking station, Mars, the sun, and Canopus in vehicle-, earth- and Mars-centered coordinate systems.

f) The Data Correlation Program relates spacecraft or capsule position and attitude with telemetry data and data from external sources such as solar flare observatories. Operational personnel are provided with information relative to the overall condition of the spacecraft and capsule in near-real time.

g) The Command Generation Program generates and time tags blocks of commands for transmission to the spacecraft or capsules; maintains updated command lists of all commands and their ordered sequence of execution as stored in the spacecraft or capsule programs; maintains checks on command verification and execution within the flight vehicles; runs conflict checks and establishes proper sequences as new commands are entered into computer for generation; and formats command messages in NASCOM compatible format for transmission to Deep Space Stations.

11.6.3 Data Processing Computer Programs

The data processing computer programs support all functional operations groups by verifying all commands issued at the SFOF; by identifying, assembling, editing, routing, and processing telemetry and video data; by driving all user area displays, consoles, and status parameters characterizing the DSN; and providing for the generation of simulation data for preflight operational readiness tests. All data processing computer programs will be called, sequenced, and executed by an executive program. The programs are identified below:

a) The Executive Program controls and sequences the computer system, links general purpose and special purpose modules, and updates and maintains look-up tables for data used by more than one module.

b) The Command Verification Program extracts the command message from a system buffer, transforms it into suitable form, checks against a permissive command list, and verifies that the commands are properly stored and executed.

c) The Telemetry and Video Processor receives the data from the mission-independent system; assembles the data stream into complete frames, recognizes changes in the source of the data stream into complete frames, recognizes changes in the source of the data stream, and changes in the edit table mode; decommutates the telemetry frame into time-tagged, identified measurement values; limit-tests designated telemetry measurements and issues alarm messages as required; and makes the identified measurement values available to the mission-independent system for display.

d) The Display Processor causes unprocessed telemetry, science, and command data as transmitted via a high-speed data line to be displayed, causes alarm tables to be displayed, and causes display of the command file currently being transmitted from SFOF to a Deep Space Station to be printed.

e) The Diagnostic Testing Program is used at regular intervals to test elements of the data processing system.

f) The DSN Status Program monitors parameters characterizing status of the DSIF, the DSN/GSC, and the SFOF facilities, equipment, personnel, data flow, and software.

11.6.4 Science Computer Programs

The science computer programs assist in evaluating the performance of imaging subsystem and science instrumentation systems; analyzing and interpreting video data and science data reception quality; correlating the scientific data from the capsules and spacecraft; generating video and science sequence commands for standard and nonstandard operating modes; and modeling and simulating the experiments to aid in formulating alternative scientific objectives during flight. The programs are identified below:

a) The Imaging Command Generation Program interprets the input commands and defines the camera settings for each exposure, arranges the camera parameters in a manner acceptable to the prespecified video data sequences, and generates commands to control the movement of the imaging subsystem during the advent of off-nominal mission procedures.

b) The Science and Video Command Program compares the command sent to the imaging subsystem with those received by the subsystem to insure command integrity, detects any errors in the returned commands, and initiates corrective procedures when an error is experienced; and identifies and time-tags the return video data frames with the matching command and sequence information. This program enables a complete history to be kept of command and identification discrepancies attendant to the imaging subsystems.

c) The Science Monitoring Package allows the scientists to analyze, evaluate, and reconstruct the three major groupings of scientific experiments, i.e., spacecraft experiments, capsule entry experiments, and surface laboratory experiments. The programs perform the following functions:

   1) The Spacecraft Science Experiments Program monitors the readings of interplanetary particle and field measurements; evaluates the low resolution photography of the areas of Mars overflown; analyzes the observations of atmospheric composition and temperature vertical profiles in addition to the measurements of major and minor constituents and water vapor content; assesses the radiometric observations of the Mars surface temperature at low spatial resolution; audits the influx and efflux of gamma, solar, ultraviolet, and cosmic radiation; computes and predicts the physical and dynamic parameters of Mars; and defines the regions of RF occultation.

   2) The Capsule Entry Science Experiments Program analyzes the surface photography performed during descent; calculates and predicts atmospheric density, pressure, and temperature profiles; and monitors and evaluates the predictions of atmospheric composition including the major constituents and water vapor.

   3) The Surface Laboratory Science Experiments Program evaluates local topographic photography; analyzes and predicts near surface (2 to 10 feet altitude) atmospheric pressure, temperature, water vapor, and wind velocity; assesses near surface atmospheric composition including minor inorganic and organic constituents, surface elemental composition, and organic compounds; monitors the readings of subsurface temperature

and gas samplings for the presence of organic compounds; evaluates specific life detection with simple culture experiments; and computes the solar and ultraviolet flux incident upon the martian surface.

11.6.5 Simulation and Training Computer Programs

Training of operating personnel in standard and potential nonstandard procedures is an MOS requirement. The computer program to simulate real-time operation sequences are delineated below:

a) The Telemetry Simulation Program generates simulated real-time space vehicle telemetry signals, stored on analog tapes, containing telemetry data of a simulated Voyager mission. In addition, tapes will be generated which simulate nonstandard Voyager operating modes to familiarize system personnel with nominal and possible off-nominal performance requirements. These tapes will provide telemetry data to simulate response to spacecraft commands in proper time relation. The program will generate telemetry data which simulates engineering and performance data to all display consoles.

b) The Science Experiments Simulation Program generates simulated real-time telemetry signals to drive the science experiments monitoring display consoles. This simulation program will generate all science data required as input to the spacecraft science experiments program, the capsule entry science experiments program, and the surface laboratory science experiments program.

11.7 PLANS, PROCEDURES, AND DATA PACKAGES

Voyager MOS plans, procedures, and data packages are categorized according to Voyager system-level interface descriptions, preflight planning and design documents, flight operations procedures and data packages, and postflight mission evaluation reports.

The development of plans and procedures is conducted in parallel by the various groups within the MOS that have been assigned technical cognizance for specific mission and flight operational functions. These groups will develop their plans and procedures to meet the technical requirements imposed on their areas by the overall MOS plan, and then submit these procedures to the MOS manager or SFOD for approval. When approved, these plans and procedures are published and become the official guidelines and procedures for the mission.

The evolution of operational instructions is illustrated in Figure 18. A brief summary of the content, scope, and purpose of these documents is given below.

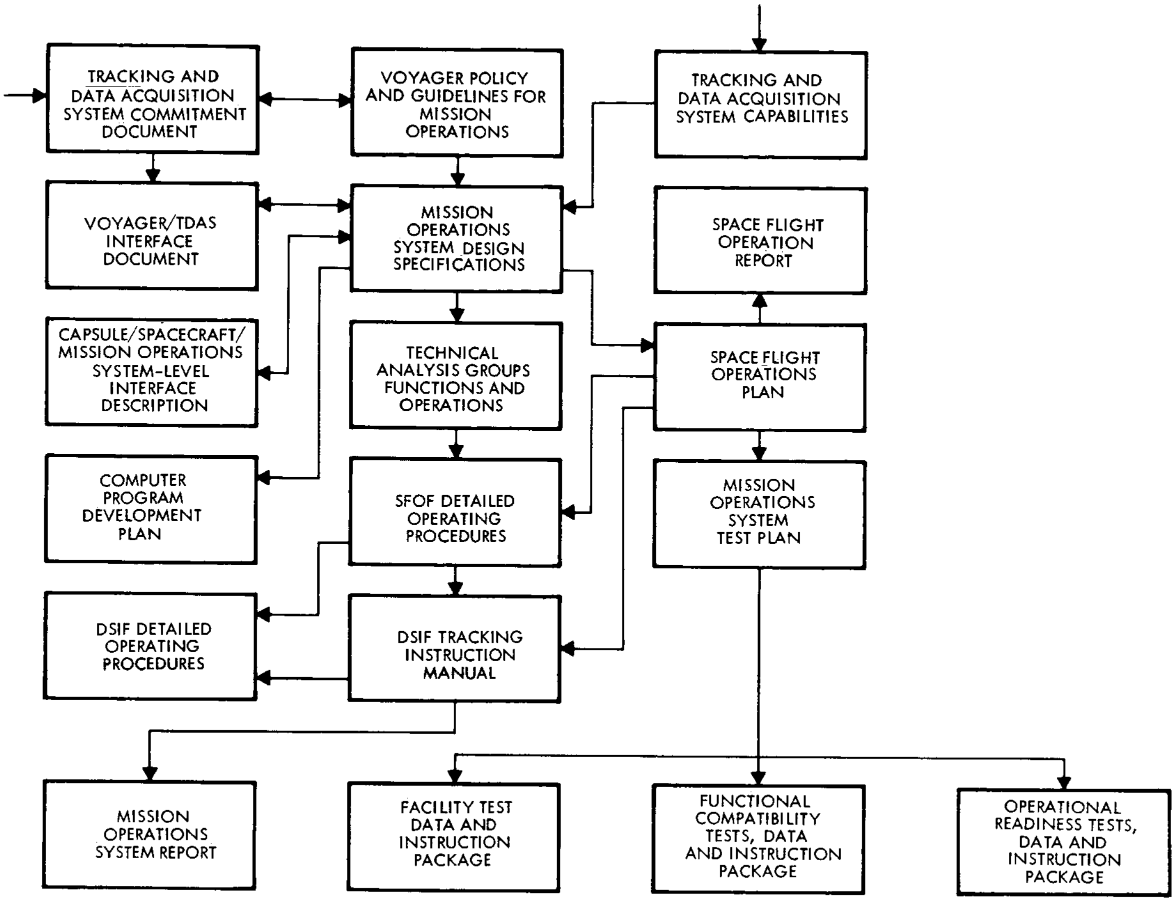


Figure 18. Basic Mission Operations System Documentation

11.7.1 System Interface Descriptions

System interface documents will serve to delineate the capabilities, system-level interface requirements, and commitments for those Voyager systems that support the MOS manager.

11.7.1.1 MOS Policy and Guidelines

The MOS policy and guidelines document establishes basic policies for Voyager mission operations by specifying the broad outlines of MOS preflight planning and design, flight operations, documentation, scheduling, and computer program design, development, and maintenance control. In establishing these policies, requirements will be placed upon supporting organizations. The Voyager project manager and the MOS manager will be responsible for this document, and the Voyager project office will be responsible for its publication, maintenance, and control.

11.7.1.2 Tracking and Data Acquisition

The TDAS capabilities document, provided by the TDAS manager, will describe the tracking and data acquisition capabilities that can be provided to the Voyager project. These capabilities will be used as input for the planning of MOS activities.

11.7.1.3 TDAS Commitment

The TDAS commitment document will state the overall commitment of the TDAS to support the Voyager project. It provides the framework within which the detailed Voyager/TDAS interface is described. The document will be prepared jointly by the Voyager project manager and the TDAS manager.

11.7.1.4 Voyager/TDAS Interface

The Voyager-TDAS interface document will describe in detail the interfaces between the TDAS and the Voyager project, including facility configurations for the various phases of the operations. The preparation of this document will be the joint responsibility of the Voyager project manager and the LOS, MOS, TDAS, capsule system, spacecraft system, and surface laboratory managers. Of particular interest are the interface relationships between the MOS and the TDAS.

11.7.1.5 Capsule, Spacecraft, MOS Interface, Surface Laboratory, Description

A separate interface document defines and controls the interfaces among the capsule system, spacecraft system, surface laboratory, and the MOS. The body of the document will be a series of tables of all major events in the mission profile from the viewpoint of the capsule system, spacecraft system, surface laboratory, and the MOS, respectively. The document will be a joint responsibility of the capsule system, spacecraft system, and MOS managers.

11.7.2 Preflight Planning and Design

Planning and design documents will define the MOS characteristics and criteria, outline the personnel training requirements, establish requirements on the mission-dependent data handling equipment to be implemented, and plan the organized development of the required computer programs.

11.7.2.1 MOS Design Specifications

The MOS design characteristics, criteria, and constraints are defined in the MOS design specifications. A series of specifications sets forth the requirements for the organization and functions of MOS personnel. Another series gives the requirements for the design of mission-dependent data handling equipment required at the DSN. Ground communication requirements and computer programs used for mission operations are described in this document. Voyager command system specifications set forth the basic policy and requirements for the establishment and handling of the spacecraft and capsule commands. This document will be prepared by the MOS manager, with assistance from the other systems manager, and his office will be responsible for its maintenance, revision, and control. It will provide information required for the launch constraint plan and the interface documents.

11.7.2.2 Computer Program Development Plan

The computer program development plan will provide a general description of Voyager computer program development and establish commitments for computer programming support. It will include a statement of program design, development, and maintenance control responsibilities and procedures for the capsule system, spacecraft system, and MOS organizations; it will list all Voyager operational computer programs and give brief descriptions of each; it will prescribe documentation standards for all Voyager operational programs; it will schedule all computer program development efforts; and will establish procedures for certification, maintenance, and control of Voyager operational computer programs. The document will be the responsibility of the Voyager data processing operations director and approved by the space flight operations director.

11.7.2.3 MOS Test Plan

The MOS test plan will describe in detail all tests required to bring the MOS to operational readiness; the criteria for determining the readiness of the MOS to support the mission; and those tests required to ensure that the MOS and all other interfacing systems are compatible and ready to support a mission. The document will be prepared by the space flight operations director and reviewed and approved by the cognizant system managers.

11.7.2.4 Internal Facility Test Data and Instruction

A separate package of documents describes in detail the test plans and provides the data and instructions required to conduct the facility tests. The broad objective of these tests is to ensure that equipment and personnel within a facility have been functionally and operationally integrated so that they are ready to participate in interfacility Voyager mission operations tests.

11.7.2.5 Functional Compatibility Test Data and Instruction

Another package describes in detail test schedules and plans, provides test data and an instruction package required to conduct the functional compatibility tests. The objective of these tests is to ensure that the ground-based facilities are compatible with and capable of processing telemetry and video data from the capsule and spacecraft. Command link compatibility will be verified in all command system configurations and modes of operation that are anticipated for the Voyager mission. The space flight operations director will be responsible for the schedules, detailed plans, and direction of these tests.

11.7.2.6 Operational Readiness Test Data and Instruction

The operational readiness package describes in detail the test schedules, detailed plans, and provides the data, test tapes, and an instruction package required to conduct the operational readiness tests. The primary objective of these tests is to ensure that all MOS elements, including technical and operating personnel, are prepared to operate in accordance with the Space Flight Operations Plan. These tests will

- Use the full complement of personnel required for Voyager flight operations
- Include standard (and will heavily emphasize nonstandard) operational procedures
- Require handling, processing, and interpretation of the full range of mission data under conditions of normal and degraded communication
- Generally establish the operational readiness of the MOS for the Voyager mission

11.7.3 Flight Operations Procedures and Data Package

The following documents will describe the mission, delineate the official procedures to be employed during flight operations, and publish official data required during mission operations support activities.

11.7.3.1 Space Flight Operations Plan

The space flight operations plan describes the space flight operations in standard and selected nonstandard cases. Space flight operations are defined as the operations necessary for obtaining and processing spacecraft information and for determining and executing spacecraft operational commands. This document describes the mission objectives, the launch vehicle, the capsule, the spacecraft, a typical mission profile, and the organization of the operation teams during spaceflight operations. All operational facilities are discussed. Mission-dependent equipment and functions are identified. TDAS coverage plans and the MOS data flow are described in considerable detail. The operational aspects of the facilities available for the ground control of the spacecraft and capsules are defined and all permissible commands are tabulated.

This document will include a standard sequence of events table which specifies a series of detailed activities for normal operations from the start of the Voyager prelaunch countdown to the end of the mission. This sequence of events will be based on a representative Voyager reference trajectory upon which the DSIF station view periods are based. A sequence of events listing will include a complete tabulation of all major command sequences and their constituent minor sequences. Of equal importance will be the discussion of nonstandard Voyager operations. Since it is possible that some deviations from standard procedures may occur during the Voyager mission, MOS personnel will prepare for such an eventuality by defining various failure modes and developing a preplanned approach concerning such problems. Nonstandard procedures will be first developed on the assumptions that only a single fault will occur at any one time and that the telemetry equipment will be operating normally. Fault isolation trees will be developed to meet these situations. The fault isolation trees will be designated nonstandard procedures and will aid the technical analysis teams in diagnosing nonstandard performance and in taking corrective action to assure return to standard operations as rapidly as possible.

This document will commit operational support for Voyager spaceflight operations when approved by the TDAS manager. The document will be the responsibility of the space flight operations director and will be approved by the MOS manager. It will be the governing operational document when signed by the Voyager project manager. All subordinate operational documents must conform to this plan and appropriate change-control procedures will be established by the space flight operations director.

11.7.3.2 Technical Analysis Group

The detailed design, development, and training plans for each MOS technical analysis group will be described within the constraints imposed by the MOS Design Specification Document. Flow diagrams and detailed operations activities will be included. This document will provide information required to prepare the SFOF Detailed Operating Procedures Document. It will be approved by the space flight operations director.

11.7.3.3 SFOF Detailed Operating Procedures

SFOF operating procedures will describe in detail how Voyager personnel will operate within the SFOF during a mission. All interface procedures between mission-dependent and mission-independent personnel will be discussed. The SFOF group of specifications covers general procedures not dealt with in the Space Flight Operations Plan. Detailed task sequences and work specifications are prescribed for each technical analysis and mission control group in accordance with the standard sequence of events table published in the Space Flight Operations Plan. Detailed information on organizational structure, personnel assignment schedules to cover all operations, breakdowns of specific tasks that individuals must accomplish, and information relating to SFOF user area equipment is provided. The document will be the joint responsibility of the space flight operations director and the technical analysis group directors with inputs as required from the systems managers.

11.7.3.4 DSIF Detailed Operating Procedures

The DSIF operating procedures document is a collection of procedures that define in detail the activities of Voyager operational personnel at a DSIF site in support of the mission. These procedures will be utilized by systems personnel operating MDE at the site and will be compatible with general DSIF operational procedures. The document will be the joint responsibility of the planetary vehicle performance analysis and command group director and the DSIF Voyager operations chief with inputs from the systems manager, and require the approval of the space flight operations director and the DSIF operations manager.

11.7.3.5 DSIF Tracking Instruction Manual

The tracking instruction manual will describe the procedures used by the DSIF to support the mission. The document will be the responsibility of the DSIF operations manager and approved by the TDAS manager.

This document is published in three volumes. Volume I describes the mission-independent operational procedures to be employed by the DSIF during a mission, such as tracking, telemetry, and recording. Volume II covers the Voyager mission-dependent aspects of operations at the DSIF stations. In standard situations, operations are controlled from the SFOF according to the standard sequence of events; however, the station can effect limited autonomous operation in the event of communication failure between the SFOF and the DSIF. Under such nonstandard conditions, the station will operate according to the nonstandard procedures contained in this document. Additional information, of importance to DSIF operations during Voyager missions, will be included. Volume III will contain information such as preflight nominal look-angle data and signal-level predictions for the individual DSIF stations.

11.7.3.6 Voyager Data Distribution Plan

The data distribution plan will describe the operational data available from all sources such as teletype tapes, computer listings, magnetic tapes, analog strip chart recordings, X-Y plots, and others. In addition to a description of this data, and its method of presentation and format, a list of all recipients of each type of data will be included. The number of copies, timliness of receipt, and method of transmittal to all recipients will be indicated.

11.7.4 Postflight Mission Evaluation Reports

Mission evaluation reports will serve to record all activities that were required to implement the MOS to assure operational readiness, report all activities performed during flight operations, and evaluate and critique all MOS activities.

11.7.4.1 Mission Operations System Report

The system report will be the final post-mission reporting document describing MOS activities prior to and during the flight. The MOS manager is responsible for this document.

11.7.4.2 Space Flight Operations Report

The operations report will be the final post-mission reporting document of space flight operations and will describe the participation of all elements of the MOS during the flight. The space flight operations director will be responsible for preparing this report.

11.8 COMPUTER SOFTWARE IMPLEMENTATION

The computer software to be implemented includes all Voyager MOS computer programs, program documentation, and procedures. For those mission-independent programs which require no development, "implementation" means integration with the programs which require development.

The implementation process requires a tailored configuration management procedure to insure efficient implementation of software. In this context, configuration management is defined as the formal set of procedural concepts by which a uniform system of configuration identification, control, and accounting is established and maintained. Identification is through the technical documentation that defines an approved requirements or product configuration baseline; control is through the systematic evaluation, coordination, and approval of changes to a baseline configuration; and accounting is the act of reporting and documenting changes to a baseline configuration.

As indicated in a previous section, the Voyager mission requires an increase in the number, size, and complexity of computer programs. As distinguished from the computing support required for previous and current SFOF controlled unmanned space missions, Voyager software configuration management system needs to be implemented to effect the desired software configuration control.

Generally speaking, software configuration management is the implementation of plans and procedures to control distinguishing characteristics of end items by means of three types of review and approval cycles. An "end item" denotes any software segment or documentation designated and recognized as a controlled entity. Typical end items will include subroutines, flow charts, operator's manuals, design specifications, and test cases. Design review and approval cycles will commence after all aoftware requirement specifications have been issued and program development is about to start. From this point on control will be exercised on all items that have bee designated as end items during the planning stages and included in the design specifications.

Development review and approval cycles will be carried out just prior to the completion of milestones also designated in the planning stages. Change review and approval cycles will occur as needed and may even result in design changes.

A large software design, development, and maintenance effort will require specifications for requirements, operational equipment, acceptance test, programming system, and programming maintenance. These documents will completely specify the nature of the environment in which each program must operate. All of these specifications develop from the requirements specification which contains a statement of the problem the program must solve. The functional design or requirements specifications lead to computer program specifications describing the mechanization of the solution by computer, including a code check plan.

Since Voyager programs must be integrated into the existing DSN mission-independent software by the capsule and the spacecraft contractors, clean software interface relationships must be identified and controlled. This is especially true since an executive program operating upon all other Voyager computer programs may be necessary.

Recognizing that the Voyager operations programming task is quite large and that computer program maintenance activities may span more than a decade for the Voyager program, it is apparent that a sophisticated, automated, and flexible software configuration management system needs to be implemented.

Figure 19 shows some of the most important activities, milestones, end items, and documents in the Voyager project computer program design, development, and maintenance effort.

11.8.1 User and Mission Support Program*

A list of all user and mission support programs will be generated and maintained by the data processing operations engineer and approved

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* User programs are those which generally require large core spaces and reside in the IBM 7094 at the SFOF. Mission support programs are those required for direct control of the mission.

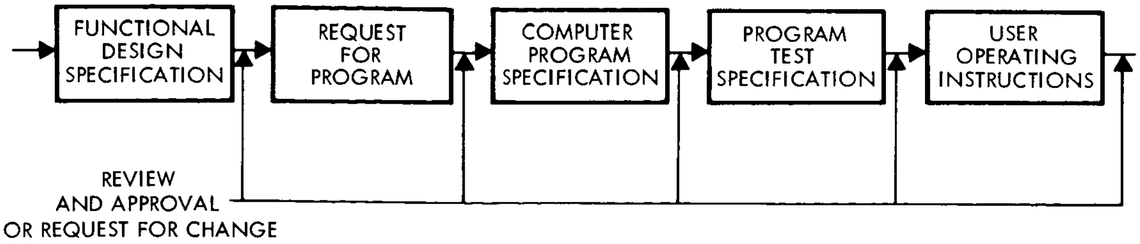


Figure 19. Computer Program Milestones

by the space flight operations director. Programs in the list will be classified as follows:

- Flight Path Analysis and Command Group
- Planetary Vehicle Performance Analysis and Command Group
- Mission Support Programs
- Space Science Analysis and Command Group
- Engineering and Science Simulation Programs

In this list, each program will be identified by name together with a statement of function and effectivity for a specific mission. The space flight operations director and the mission director must approve this list; only programs on this list will be considered candidates for development towards operational status.

11.8.2 Functional Design Specification

It will be the responsibility of the technical analysis area directors and the data processing operations director to indicate to the SFOD that a cognizant engineer has been assigned for each program. This engineer will be responsible for defining program functional requirements and related program design criteria. Based on these requirements and design criteria, he will prepare this document to be approved by the appropriate technical analysis area director and data processing operations director. It will be the principal means by which program functional content will be controlled and will describe the program, delineate all program interfaces, and discuss performance parameters and program limitations.

This document will be submitted to the DPOE if issued by a technical analysis group. He will be responsible for the preparation of a preliminary schedule estimate based on his assessment of program complexity. The SFOD approves this document prior to publication and inclusion into the Mission Operations System Design Specifications. One published, the functional designs are to be considered frozen and no changes will be allowed except through SFOD approval of a written change request issued by the cognizant engineer.

11.8.3 Computer Program Request

The cognizant engineer will prepare a computer program request which will furnish the programmer detailed information required for the design of the computer program. This document will:

- List applicable documents such as technical memoranda, reports, and the Functional Design Specification
- Provide a detailed functional description of the program
- Define the input variables and constants and the formats of each if there is an interface with another program or hardware
- Furnish the equations the program is required to solve, the calculations that are to be performed, and illustrate the logical flow of data
- Define the output variables and constants, the output media (cards, listing, plots, tapes, etc.), and the output format should there be an interface with another program or hardware
- List the people or areas that are to receive the output, the type of output, and the number of copies

This document will be reviewed by a cognizant programmer. For mission support and simulation programs, a programmer will be designated for each program to be responsible for its development. For user programs, the cognizant programmer's assignment will be approved by either the SFOD, the appropriate technical analysis area, or the data processing operations director.

11.8.4 Computer Program Specification

The cognizant programmer will prepare a rough draft of the program specification based upon the information furnished him prior to the start of coding. During the preparation of the rough draft, he will maintain close technical contact with the cognizant engineer to resolve directly any conflicts that may arise. This document will serve as a technical statement from the programmer indicating the manner in which the program request will be translated into an appropriate computer program. The rough draft of this document will:

- State what the program must do and how it must function in relation to an input-output device or to another program
- State specifically the relationship of this program to other programs regarding input-output, tables of data, control information to-from programs and input-output devices
- Estimate timing restrictions such as minimum amount of time that the program must be in without being interrupted by another program
- Show flow charts and describe the logical interaction of various subroutines, input-output devices, and portions of the program which do not necessarily fall into this category. In cases where a subroutine is not appropriate, the functional operation of the program will be indicated.
- State the method by which the program will be checked, describe the program drivers that have to be coded, discuss any limiting factors of the checkout process, estimate the computer time required for checkout, and provide a test plan

When published in final form this document will contain detailed program listings and program descriptions which will

- Identify the program by title, deck, or tape number; author and date; machine, configuration and source language; and SFOF functional area
- State the purpose of the program
- Define all restrictions on its use such as components or programs required, data quantity, data form, and critical timing

- Prescribe the usage including calling sequence, space required, error codes and messages, and format received or generated

- Specify coding information including constants and their locations and erasable input-output locations

- Describe the checkout status and method

- State the required program execution time for representative computations

- Specify all tables by name, function, type, size, indexing, structure, and program usage

All program listings will be accompanied by sufficient commands which establish the relationship between various steps in the detailed flow charts and the program code.

11.8.5 Program Test Specifications

Program test specifications will formally define a series of program acceptance tests whose successful completion is required for program certification and project release. It will be the responsibility of the technical analysis directors to direct its preparation using the Functional Design Specification as a guide. This document will

- Specify all program functions and options that have been designed into the program

- Identify all program data sources that will be used in standard or anticipated nonstandard program operation

- Describe all program output displays, both human and machine readable, which will be generated by the program in standard or anticipated nonstandard operation

- Define test evaluation criteria and program output acceptance standards. Certification will be based on the program's capability to meet such standards.

This document will define a single demonstration test that can be performed in a reasonable length of time. Analysis of computer program output data may be accomplished after the demonstration. This test will be witnessed by the data processing operations director, the technical analysis director, the cognizant programmer, and cognizant engineer. This document also will describe all relevant acceptance test procedures and the test set-up to be implemented. The estimated duration of the test, the required personnel support, computing equipment, and test sequence of events will be provided. Data necessary for the conduct of the test will be specified and will reflect conditions encountered in anticipated standard and nonstandard Voyager space flight operations.

11.8.6 User Operating Instructions

The instructions document will serve as the guideline by which operators who are knowledgeable in DSN computer operations can run the program. Because program operation may require some knowledge of the internal functions of the program, this document will

- Describe loading procedures
- Specify general input-output operations such as data initiation and sense-switch and option-switch control
- Describe procedures for program turn-on and turn-off
- Define feedback or input required of the user to respond to messages printed out
- Discuss abnormal program operation and recovery procedures

11.8.7 Certification

At the completion of the implementation process, it is necessary to perform critical testing and, on the basis of these tests, certify that the software is ready for operational use. The test leading to certification must be preceded by a planned series of preliminary, informal testing to increase the probability of certification and to cover the depth of testing appropriate to software for a "high risk" mission.

11.9 TRAINING AND TEST PROGRAM

The final welding of the major elements of the MOS into a functional unit will be accomplished by a comprehensive training and test program. A master program comprising three basic categories of tests will be implemented to train all mission personnel and to verify that the equipment and operational capabilities of the MOS are adequate for the Voyager mission. To define and verify these capabilities, a space flight operations test plan will be established. This test plan will cover in detail all operational testing activities of the MOS.

Internal facility tests will establish that support facilities function properly within themselves. Functional compatibility tests will be conducted to ensure that the earth-based facilities are functionally compatible with each Voyager vehicle and with each other. Finally, operational readiness tests will be conducted to ensure that all elements of the MOS operate together by demonstrating readiness to support actual space operations. The relationship of these three classes of tests is illustrated in Figure 20.

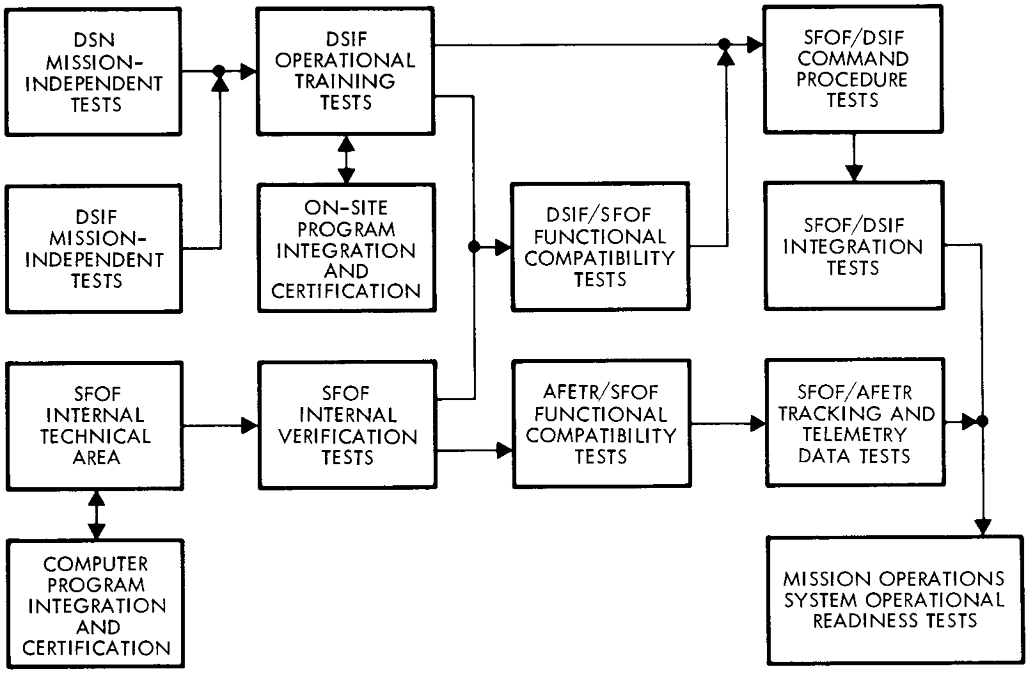


Figure 20. MOS Training and Test Program

11.9.1 Internal Facility Tests

Internal facility tests will be composed of operational training exercises and verification tests. These tests will be designed to ensure that Voyager mission support equipment, computer programs, and personnel within a DSN facility have the required capabilities and are prepared to support subsequent tests. While these tests will generally be conducted within a facility, some extra-facility support may be required to allow a realistic evaluation of the interfaces as seen from inside the facility in which the test is being conducted. Simulated mission data for these tests will be generated in the SFOF.

Operational training tests begin in the SFOF and in each DSIF facility early in the testing program. They provide mission personnel with the opportunity and time to become familiar with their mission operations functions, working areas, equipment, methods of communications, and internal interfaces. Two classes of tests should be successfully completed before DSIF facilities can start training exercises. One class, the DSN mission-independent tests, includes acquisition training with test space vehicles. The other, DSIF equipment tests, determines if the command data handling equipment, system test equipment, S-band receiving and transmitting equipment, video data handling system, and other DSIF instrumentation are functionally compatible.

DSIF operational training tests, conducted within the DSIF stations under the direction of the individual station manager, provide an organized training program for the DSIF crews in preparation for future tests. Interfaces outside the station are simulated with test data packages. These tests also permit, to the extent possible, the evaluation of existing detailed operating procedures and the stating of requirements for procedures not in existence.

The SFOF internal tests verify the capability of the integrated mission operations groups, computer programs, and equipment within the SFOF to control a Voyager mission. The SPAC and SSAC tests will be held in real-time. The FPAC test will be conducted in both real- and nonreal-time. The SFOF integration verification test exercises all SFOF personnel, equipment, computer programs, procedures, and operations techniques throughout an entire simulated mission.

Computer program integration is the process of inserting a user program into the software environment of the SFOF system and making those changes necessary for the program to be compatible with the system. Program certification tests verify the operational status of the user programs for the mission. For each program, a test specification defines a series of cases exercising all options and interfaces with other computer programs. Successful completion of the test leads to program certification, the last step in the development of a Voyager computer program.

The on-site data processing program checkout assembles and checks the various options of the Voyager on-site computer program to find and correct program errors. The on-site data processing program integration process, performed first at Goldstone, then simultaneously at the other DSIF stations, consists of inerting the Voyager on-site computer programs into a checked-out hardware environment and verifying the hardware-software interfaces and the program options. Upon completion of program integration, comprehensive training of DSN operators will begin.

11.9.2 Functional Compatibility Tests

Functional compatibility tests verify that the separate elements of the Voyager MOS can perform together in accordance with the functional requirements specified, and that these requirements are compatible with actual space vehicle data configuration. During these tests, the MOS is exercised under a variety of conditions determined by the combinations of operating modes, bit rates, command sequences, communications capabilities, and equipment configurations, which can occur during standard and certain nonstandard space operations. The tests also verify that all Voyager DSN hardware and software interfaces are compatible by demonstrating acceptable MOS functional performance. It will not be necessary that the tests be performed in real-time, nor is rigid adherence to operational procedures required; however, the use of data from a space vehicle or facsimile is required. Successful accomplishment of these tests verifies that the MOS is functionally capable of supporting the Voyager mission.

11.9.3 Operational Readiness Tests

Following the functional compatibility tests, all facilities participating in the mission are required to establish their operational readiness through a series of operational readiness tests. These tests exercise the personnel, hardware, and software to the maximum extent feasible, within the limitations of a simulated mission. The intent of this series of tests is to progressively increase personnel proficiency and demonstrate their operational readiness. The series begins with single-station tests and culminates with a total-system dress rehearsal. The test philosophy emphasizes both standard and nonstandard operating procedures. The personnel are exercised in the resolution of problems created by the insertion of simulated malfunctions or failures of the space vehicles and of the earth-based equipment, including communication lines.

Each operational readiness test consists of serially arranged truncated mission segment simulations chosen to achieve the stated objectives. The standard flight operations sequence used for these tests is the Standard Sequence of Events published in the Space Flight Operations Plan.

12. TRACKING AND DATA ACQUISITION SYSTEM IMPLEMENTATION

The tracking and data acquisition system management office, under the direction of the tracking and data acquisition system manager, is responsible to the Voyager mission director for assuring that the tracking and data acquisition system (TDAS) is in a ready condition to track, acquire telemetry data, and transmit commands as required for the Voyager mission. The TDAS will provide telemetry data acquisition, tracking, command, and data handling support utilizing existing and planned DSN, other NASA, and Department of Defense facilities as appropriate. The TDAS will provide the following facilities for the Voyager mission:

- General-purpose digital computing facilities at selected DSIF, AFETR, and Manned Space Flight Network stations for real-time handling of tracking, telemetry, and command data
- Data circuits to handle tracking, telemetry, and command data between data acquisitions stations and the SFOF
- Physical accommodations and facilities in the SFOF for mission operations system operations teams
- General-purpose digital computing facilities in the SFOF and at Kennedy Space Center for real-time, near-real-time, and non-real-time processing of mission data
- Standard SFOF communications and instruments, voice nets, display, and computer remote input-output equipment for MOS operations teams

With these facilities the TDAS will perform the following functions in support of the Voyager mission:

- Track the space vehicles and provide metric tracking data
- Receive, record, and relay telemetry data from the space vehicles
- Transmit commands from the operations teams to the space vehicles

- Provide station performance parameters which are required for analysis and evaluation of vehicle performance
- Provide and maintain a library of master data records developed during each flight
- Provide acquisition data required by tracking and data acquisition stations

12.1 SYSTEM REQUIREMENTS

From launch through interplanetary injection, the TDAS is required to provide metric tracking coverage and telemetry data acquisition coverage for the space vehicle. This includes tracking and telemetry data acquisition coverage throughout the earth parking orbit phase. After interplanetary trajectory injection, approximately 2 hours of S-IVB metric tracking coverage are required for S-IVB orbit determination.

For 30 days from interplanetary trajectory injection, the TDAS will provide, within view capabilities, continuous DSN metric tracking coverage, telemetry data acquisition coverage, and command coverage for each planetary vehicle. Approximately 1/2 hour of overlapping metric tracking coverage is required when a planetary vehicle is within view of two DSN sites.

From interplanetary trajectory injection plus 30 days until Mars encounter minus 20 days, the TDAS will provide continuous telemetry data acquisition coverage and command coverage for each planetary vehicle and 12 hours of continuous metric tracking coverage every two days for each planetary vehicle during cruise. During each period, approximately 1/2 hour of overlapping metric tracking coverage will be required when a planetary vehicle is within view of two DSN sites. For planetary vehicle interplanetary trajectory corrections, the system will provide five days of continuous metric tracking coverage prior to the correction and 10 days continuous metric tracking coverage after the correction.

From Mars encounter minus 20 days until spacecraft-capsule separation, the TDAS will provide continuous metric tracking coverage, coverage, telemetry data acquisition coverage, and command coverage for each planetary vehicle. From spacecraft-capsule separation until the termination of Mars orbital operations, the system will provide continuous telemetry data acquisition and command coverage for each flight spacecraft. In addition, the system will provide continuous metric tracking coverage of every other orbit plus continuous metric tracking coverage during occultation experiments for each flight spacecraft.

12.2 FACILITIES AND INSTRUMENTATION

The Voyager project will make use of selected stations and equipment of the AFETR, the NASA networks managed by the Goddard Space Flight Center, and the DSN. Since the range and the NASA networks are undergoing continual development, Voyager will undoubtedly use the new capabilities to meet requirements as stated in the program and support instrumentation requirements documents.

For Voyager the AFETR will track the launch vehicles, receive telemetry from the launch vehicle, each spacecraft and each capsule, and provide data handling support during the near-earth Voyager operations. Instrumented aircraft, ships, and range stations will track the vehicle from launch to provide metric and telemetry data. These aircraft-, land-, and ship-based instrumentation systems will be linked with the KSC and the SFOF during near-earth operations.

The MSFN, either through the use of its own stations or those of other networks managed by the GSFC, will provide metric and telemetry coverage to supplement AFETR coverage normally during the phase from liftoff to planetary vehicle injection. Selected MSFN stations may be used to provide coverage for gaps which exist either in the AFETR or the DSN in meeting project requirements.

12.2.1 Manned Space Flight Network Description

Because of DSN acquisition limitations for planetary vehicles at altitudes less than 10,000 nautical miles, it will be necessary to supplement the combined coverage afforded by the DSN and AFETR stations. Selected MSFN stations will provide this supplementary coverage.

The combined Manned Space Flight Network (MSFN) includes facilities operated by the National Aeronautics and Space Administration, the Department of Defense, and the Australian Department of Supply. It is composed of tracking and data systems around the world and includes a computing, communications, and Manned Space Flight Network Operations Center at the Goddard Space Flight Center.

Each unified S-band station of the Apollo network is composed of a high-gain main antenna, wide-beam acquisition antenna, microwave circuitry, a main reference channel reciever, acquisition reference channel receiver, two main angle channel receivers, two acquisition angle channel receivers, a transmitter, data demodulation circuitry, ranging circuitry, premodulation circuitry, acquisition and programming circuitry, data handling equipment, and peripheral equipment.

The acquisition channels, transmitter, and acquisition antenna are used initially to acquire the space vehicle signal. This operation consists of a search in angle with the acquisition antenna and a search in frequency with the acquisition reference channel receiver for the central pulse modulated carrier component of the space vehicle signal. The local oscillator phase locks to the received carrier, thus activating the angle channels. When the acquisition antenna is sufficiently well aligned, the main antenna acquires the carrier. The main reference channel receiver is then phase-locked and the main angle channels become effective. The drive for the antenna servos is then switched from the acquisition to the main angle channels.

The transmitter subsystem includes a basic rubidium frequency standard, a frequency synthesizer phase-locked to the standard, and a master voltage controlled oscillator. The VCO is phase-locked to a frequency synthesizer and provides the radio frequency driving signal for the transmitter. The synthesizer provides the tuning, or frequency changing, capability for the transmitter. The frequency of the synthesizer is changed manually by the operator in discrete frequency steps.

The ranging circuitry contains digital equipment for generating the various range codes and range measurements, doppler measuring circuitry, and a range code receiver which is fed by the reference channel 10-megacycle intermediate frequency outputs. The ranging circuitry feeds the range code to the transmitter phase modulator, where it is effectively summed with other up-going data from the premodulation circuitry.

The pseudo-random code range measurement is made by synchronizing the receiver code generator phase with the transmitter code generator phase. The receiver clock generator is then locked to the transmitter clock generator and the range tally is set to indicate zero range. The transmitted code is allowed to propagate to the space vehicle and back to the ground. Because of the relative range and velocity of the space vehicle with respect to the ground station, the return code will have a time delay and different clock rate compared to the transmitted code. The received code generator is freed from synchronization with the transmitter code generator. The receiver clock generator is then switched from the transmitter clock generator to acquire and locked to the lock component of the incoming transponded code.

The data demodulator accepts pulse-modulated data from the main reference channel receiver and FM data from the acquisition reference channel. After acquisition, the acquisition reference channel will be available for the reception of other data, since the two reference channel receivers are identical. The data modulation and ranging equipment both interface with the data handling equipment. In addition, the data handling equipment interfaces with the premodulation equipment.

The tracking data processor consists of a computer, data storage units, teletype equipment, doppler counters, tape recorders and a number of gating networks and controls. This system provides time, X and Y angle information, and range and doppler information which is compatible with high and low speed ground communication links. The processor arranges the data in a proper format and provides station identification and other functional information. The inputs to the processor are derived from the ranging subsystem, the antenna shift angle encoding subsystem, the timing subsystem, and the tracking receiver. The tracking data processor also records all data on a magnetic tape recorder. Provisions are also made for the conversion of the slow speed data from binary to decimal form and for printing of these data.

The NASA communications (NASCOM) network provides inter-MSFN site communications capabilities. NASCOM is composed of telepyte, voice, data, facsimile, and television circuits, and are operational on a full- or part-time basis as required between GSFC, network stations, and other supplementary locations. The basic network is supplemented on a scheduled basis by facilities of DOD as necessary to meet the needs of a particular mission.

The GSFC communications center is the hub of the NASCOM network that connects MSFN stations and supplementary stations. Additionally, the NASCOM switching centers at Honolulu, Canberra, and London, and the DOD centers at Wheeler AFB, Hawaii, and Cap Kennedy serve as hubs for MSFN instrumentation facilities in their respective areas. The switching centers are also connected to the GSFC communications center.

12.2.2 Deep Space Network

The DSN is a facility of the NASA Office of Tracking and Data Acquisition under the management and technical direction of the Jet Propulsion Laboratory. The DSN has the capability for two-way communications with and has the tracking and data-handling equipment to support unmanned space vehicle operations at earth-referenced distances greater than 10,000 miles.

The main elements of the DSN are the Deep Space Instrumentation Facility, the Ground Communications System, and the Space Flight Operations Facility.

12.2.2.1 Deep Space Instrumentation Facility

The DSIF will utilize the following S-band stations:

- The planetary vehicle monitor station, Cape Kennedy, will be used for spacecraft-capsule-DSN compatibility verification and for telemetry reception from liftoff until the end of the viewing period

- A network of three 85-foot antenna stations will be used for coverage from near-planetary vehicle injection to near-planetary encounter. The specific stations will be selected from the following complexes:

  Johannesburg, South Africa
  Madrid, Spain
  Camberra or Woomera, Australia
  Goldstone, California

- A network of three 210-foot diameter antenna stations will be used for coverage during the later phases of transit and the orbital and landed Mars operations. These stations are: Goldstone, California; Canberra, Australia; Madrid, Spain

The following additional DSN facilities can be made available for backup or emergency needs on a negotiated basis:

- Venus Site, Goldstone, California
- Spacecraft Command and Guidance Station, Ascension Island (30-foot diameter antenna)

The present ranging system at each station has been designed mainly for midcourse maneuver orbit determination and lunar orbit and landing maneuvers. The range measurement is related to the time difference between two identical, separately generated, pseudo-random signals, one generated at the transmitter and phase-modulated on the carrier, and the other generated at and synchronized by the receiver for correlation detection. The transponder in the space vehicle receives the transmitted signal and retransmits the same modulation in a "turn-around" mode back to the interrogating DSIF station. A turn-around ranging system, capable of being used for precision station-to-station time synchronization to within a few microseconds exists throughout the DSIF at the present time. Planetary ranging equipment with a noncoherent clock will be available at the 210-foot stations. A noncoherent clock allows a ranging fix without first locking the doppler system.

Two-way doppler data is presently the most valuable tracking parameter for orbit determination purposes. The technique involves transmitting a precision carrier to the space vehicle, where it is coherently shifted and sent back. The ground receiver then compares the phase of the received carrier with that of the transmitted carrier to extract the doppler data.

The DSIF stations incorporate sensitive and stable receiver subsystems that are designed to track the phase of the received RF carrier and to detect both amplitude and phase modulation. The receiver consists of a low-noise preamplifier, mixer, carrier, and sideband IF amplifiers, detectors and a voltage-controlled local oscillator. Doppler data are derived from the local oscillator signal, telemetry data from separate detection channels, and range data from a ranging receiver.

The DSIF transmitter subsystem performs the function of transmitting RF carrier frequency, range code modulation, and command information to the space vehicle. Each transmitter subsystem contains a synthesizer-exciter and a final amplifier. The synthesizer accepts a stable reference signal from an atomic frequency standard and synthesizes RF frequencies at a fraction of the transmitter carrier frequency. A voltage-controlled oscillator, phase-locked with the synthesizer, generates an RF signal of high-spectral purity and in the locked mode provides a frequency stability directly related to the atomic frequency standard. This VCO supplies the RF drive signal to the exciter and reference signals for receiver doppler extraction. In the open-loop mode, the VCO can be manually tuned for transmitter tuning to facilitate space vehicle up-link acquisition.

The frequency and timing subsystem provides the basic frequency and time standards in the DSIF station. Typical station timing accuracy related to GMT is presently ± 3 milliseconds, but is expected to be better than 0.5 millisecond by 1970. It is planned that by 1970 the relative time difference between two stations can be corrected to within 10 microseconds.

The digital instrumentation and station monitor and control system computes performance indices for transmission to the SFOF, detects departure from specifications of any part of the station, records a history of events at the station for later analysis, and displays the model configuration of the station and provides an alarm for changes to a given mode. Computer displays are provided for executive monitoring and control of the station.

It is planned that a general purpose tracking data handling system computer will be used to sample and format tracking data for transmission to SFOF. The subsystem will provide programmable sample rates, integration times, and information for the following items: space vehicle ID number; data conditions, Greenwich Mean Time; antenna hour or azimuth angle; antenna declination or elevation angle; doppler frequency; range data including range condition code; transmitter frequency; and the day-of-year. This subsystem will be capable of handling two simultaneous, independent tracking data streams. Software, sample rates, mode-of-operation, ID assignments, and monitoring and validation of tracking data will be provided by the DSN.

12.2.2.2 Ground Communication System

The present GCS is a part of NASCOM and includes the facilities and equipment required to provide an integrated network for the GCS. It is expected that increased GCS capability and improved facilities will be developed for Voyager use, but existing general routing and principal switching centers will not be changed.

NASCOM provides teletype communications between all overseas tracking and data acquisition stations and various computation and control centers. The voice link capabilities include telephone and four-wire, nonsignalling conferencing networks within and between the DSIF stations and SFOF. The NASCOM network includes circuits for information transfer in various rates and forms using standard data-conditioned channels. The high-speed circuits are almost always provided on a fixed point-to-point basis and are not at present switched during normal operation. However, block-by-block message switching of high-speed traffic will be implemented in the near future. A microwave capability between the Goldstone complex and the SFOF provides two wideband channels: a simplex video channel and a duplex data channel.

The GCS utilizes communications-oriented computers called communications processors which automatically read routing information within a given teletype message and, on the basis of this information, switch the message to its proper destination. Processors are located at Greenbelt, Maryland; London, England; and Canberra, Australia. Additionally, a communications processor is being installed at the DSN Communications Center in the SFOF.

In order to facilitate automated switching, the high-speed data stream is broken into uniform "data blocks." Each block contains the following information: sync words, source code, destination code, data ID; data; and an error detection code. In order to provide the blocking of the high-speed data stream, some form of buffer storage will be supplied.

Comsat Corporation is planning two synchronous satellites designated NASCOM/Interim. The two satellites will serve the Atlantic and the Pacific area. By 1973 it is expected that all GCS overseas communications will be satellite relayed.

12.2.2.3 Space Flight Operations Facility

The SFOF houses a central complex providing the means by which the mission, the space vehicle, and the DSN can be controlled and operated. The purpose of the SFOF is to provide for data processing, analysis, display, communications, and support which may be used in conjunction with the DSIF for rehearsing and executing space flight activities.

In its present configuration, the SFOF has four major elements: data processing system, support system, DSN communications system, and a simulated data conversion center.

The data processing system consists of a telemetry processing station, a central computing complex, and an input-output subsystem. The telemetry station formats and time-tags real-time data and magnetically records data arriving in the SFOF from the DSIF stations via the high-speed data lines. The main data processing is accomplished currently by two third-generation computer complexes. They process all data and are capable of generating command messages and antenna pointing angles for the DSIF.

12.2.3 Air Force Eastern Test Range

The AFETR is instrumented to collect, record, analyze, and communicate data for missile and space missions through a variety of electronic and optical instrumentation. The electronic trajectory measuring devices are pulse and continuous wave radars. The optical trajectory measurement devices are theodolites, ballistic cameras, and ribbon frame cameras. Administrative and management activities are largely concentrated at Patrick AFB, while actual vehicle launches and flight tests are conducted at Cape Kennedy Air Force Station and over the downrange areas.

12.2.3.1 Instrumentation Sites, Ships, and Aircraft

Cape Kennedy Air Force Station is the launch site and flight control center for aerospace programs assigned to the AFETR. Data from all the AFETR instrumentation sites are collected, displayed, and analyzed here. These data include radar coverage for technical and range safety purposes, electronic velocity and position information, impact prediction, sequential and documentary data, electronic ship positioning, surface and upper air weather data, optical metric and electronic tracking data for range safety, telemetry receiving and recording data, and that data associated with the command and destruct control functions.

The Grand Bahama Island sites provide electronic velocity and position data, optical metric data, electronic ship positioning data, and midcourse downrange radar coverage for technical and range safety purposes. Similar data are provided by the remaining AFETR instrumentation sites: Eleuthera, San Salvador, Mayaguana, Grand Turk, East Island (Puerto Rico), Antigua, Trinidad, Fernando de Noronha, Ascension, and Pretoria.

The Voyager project may impose AFETR data acquisition requirements in areas outside the coverage limits of presently available land stations. To achieve this additional coverage, one or more of the nine range instrumentation ships may have to be deployed.

Instrumented aircraft are used on the ETR for data acquisition, search and recovery, instrumented checkout, data pickup and transport, and other range operations.

12.2.3.2 Radar Systems

The AFETR employs a large family of radars for precision beacon and skin tracking, real-time determination of position and velocity data, display of range safety tracking data, generation of downrange acquisition predicts, aircraft vectoring, range clearance, midcourse command and control, and NORAD space object identification and cataloging.

The AFETR pulse and continuous wave radars have a wide range of performance capabilities and combine to form different trajectory measuring systems. These radars provide the Voyager metric information required during the launch to earth parking orbit injection.

12.2.3.3 Optical Instrumentation

AFETR photographic equipment and optical instrumentation provide a primary source of information for precise trajectory measurement, attitude information, and documentary coverage. Within its operating range, optical triangulation is more accurate for determining trajectory data than any other form of instrumentation. Optical triangulation with fixed metric cameras is used for maximum precision data and for the calibration of other optical and electronic trajectory measurement systems.

Ballistic cameras are positioned along the trajectory according to the portion of flight for which coverage is desired. The use of shutters for flame chopping with strobe lights, or with flares on the vehicles, permits the recording of data on the film plate at known times. Star traces recorded on the same plate are used to calibrate the camera and to determine camera orientation.

12.2.3.4 Range Support Instrumentation

The Eastern Test Range operates point-to-point, air-to-ground, ship-to-shore, and intrastation communications, including undersea cable; HF radio, both AM and single sideband; troposcatter; VHF ; and UHF links; microwave, standard, and wideband wire distribution; automatic and manual telephones, plus an extensive teletype network. These systems are used for voice or teletype transmission of operational and administrative traffic, transmitting and receiving test data, and for transmitting space vehicle commands.

The countdown sequencing system at Cape Kennedy provides: off-on sequential control of vehicle and instrument functions on a universal time base; hold-fire controls for use by range safety and range user instrumentation control; direct reading display of countdown time; and dissemination of liftoff time. The system includes a countdown generator in central control which may be used before start of vehicle countdown, a sequencer in the blockhouse which automatically controls operations during countdown and firing, a real-time programmer in central control for programming events according to universal time, countdown indicators through Cape Kennedy to show the progress of the count, and a distribution system consisting of three nets for interconnection of these.

The frequency control and anlysis system insures interference-free operations, supplies information on possible interfering transmitting sources, and monitors and reports the operating characteristics of space vehicle and ground support transmitters. Certain frequency bands are monitored to prevent interference to test operations and to check whether or not ETR operational frequency assignments and schedules are maintained within their limits.

The ETR real-time data handling system supplies a variety of data to the range and range users. These data include vehicle performance and position for range safety, target acquisition messages for both local and downrange instrumentation, and critical data quality validation. The system is also used to recover data for postlaunch processing.

The ETR range safety system provides space vehicle position information from launch through burnout or attainment of orbital velocity. This tracking information is visually compared to the nominal space vehicle trajectory submitted by the range user.

12.3 ORGANIZATIONAL RESPONSIBILITIES

The functional responsibilities of the TDAS organization (Figure 21) are outlined in the following sections.

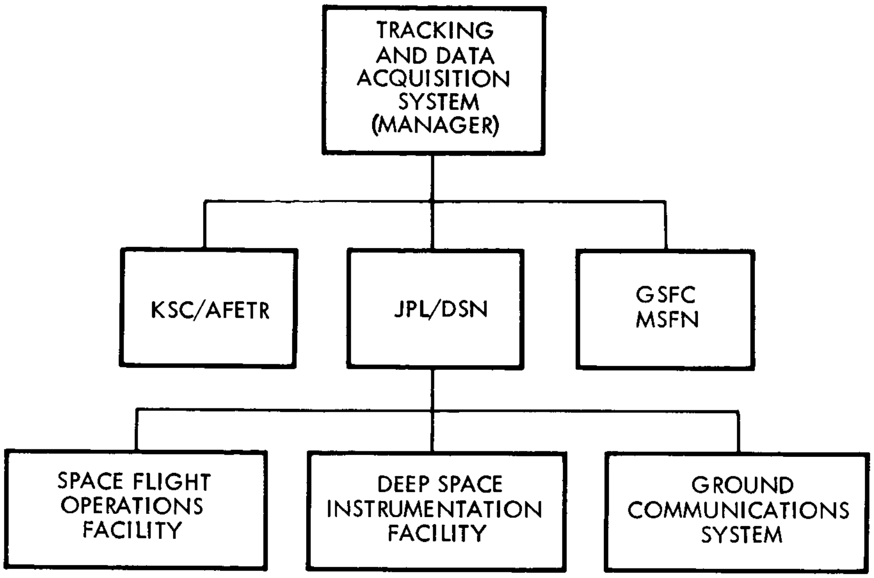


Figure 21. Tracking and Data Acquisition System Organization

12.3.1 Manned Space Flight Network

NASA Headquarters has centralized the responsibility for the planning, implementation, and technical operation of tracking and data acquisition facilities for all NASA manned space flight operations at Goddard Space Flight Center. The relevant organization is shown in Figure 22.

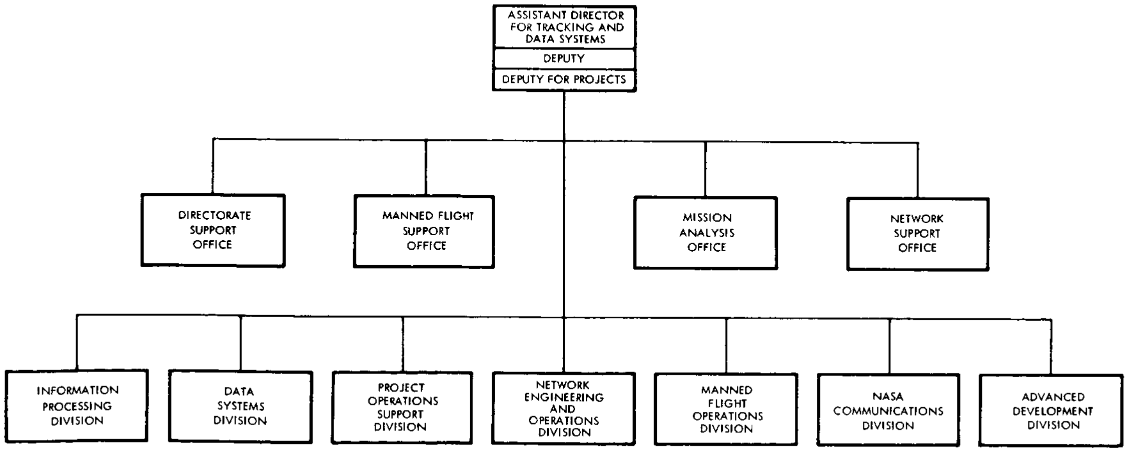


Figure 22. Goddard Space Flight Center Organization

During nonmission period, GSFC is responsible for organizing, engineering, and, as necessary, modifying the MSFN in conjunction with DOD and the Australian Weapons Research Establishment. During both mission and nonmission periods, GSFC is responsible for network simulations, network checkout, calibration and acceptance, and for the maintenance and technical operation of all NASA MSFN facilities, including NASCOM facilities.

The Manned Flight Operations Division (Figure 23 is the responsible GSFC organization for MSFN activities. Its responsibilities include:

- Developing overall network support and technical operations plans based on project data requirements
- Developing, providing, and updating technical operational procedures and checklists peculiar to the operation of stations as a part of the overall network
- Ensuring overall network technical readiness for missions
- Monitoring and analyzing the performance of all network systems and participating stations, ships, and aircraft during mission operations
- Engineering and implementing modifications or additions to equipment at each station and ship
- Administering NASA stations
- Operating the computing system at GSFC
- Administering the funding and reimbursement for DOD stations' operations costs

The NASCOM Division, shown in Figure 24, is responsible for the planning, design, implementation, and operation of the NASCOM network. The NASCOM Division is responsible for all interfaces with the NASCOM network and provides the NASA communications operations procedures.

The MSFN Operations Center, located at GSFC, provides continuity of network direction and coordination during nonmission periods. During specified mission periods, the center is responsible for: ensuring overall network technical readiness, performing testing necessary for checkout and calibration, providing network scheduling consistent with mission

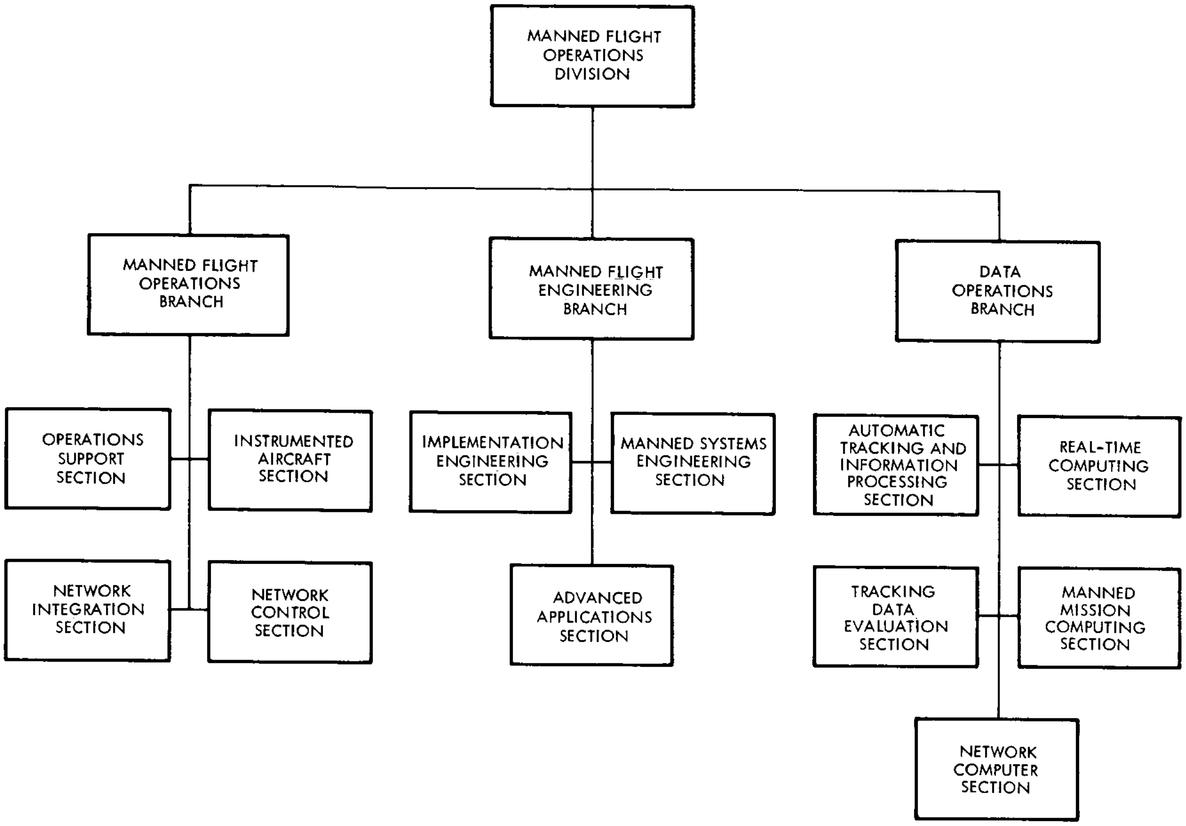


Figure 23. Manned Flight Operations Division Organization

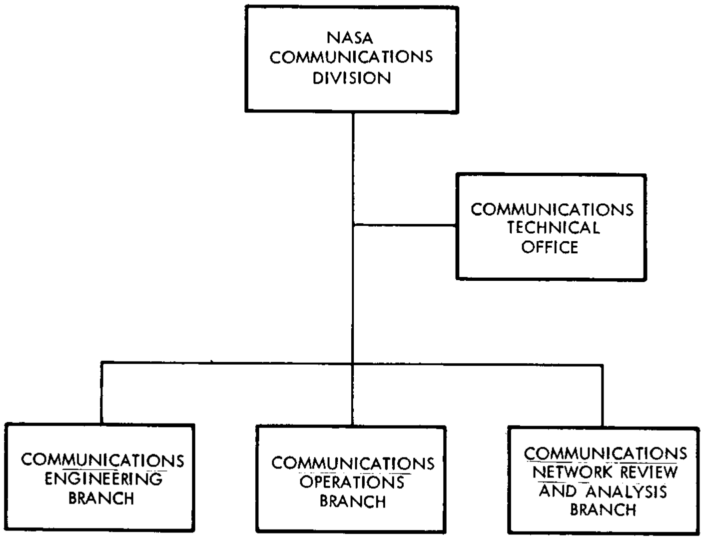


Figure 24. NASA Communications Division

requirements, and providing assistance to MSFN stations in resolving network hardware-software problems.

Under a joint agreement with the United States, the Australian Department of Supply cooperates with NASA in installing, operating, and maintaining that portion of the MSFN located in Australia. Certain communications facilities have been set up to support NASA projects, including a central communications center in Adelaide, South Australia, which controls all NASA communications in and near Australia.

The Australian Department of Supply has assigned to the Weapons Research Establishment, which operates and manages the Woomera Range, the responsibility for management of Australian participation in NASA space flight activities. General management is the function of the Superintendent, American Projects Division, at the WRE Headquarters in Salisbury, South Australia. Operationally, the station directors at Canberra and Carnarvon work directly with either the Manned Flight Operations Division of GSFC or the Mission Director at KSC, depending on the status of operations.

12.3.2 Deep Space Network Organization

The purpose of this section is to provide a background of the organization of the DSN and Voyager interface. The integration of the operations teams and the DSN control teams (Figure 25) is discussed below.

The DSN operations chief is the operational head of the DSN. He is responsible for directing the operational planning and controlling the operational scheduling of the DSN. In addition, he notifies the affected flight projects of any actual or potential conflicts in the use of DSN facilities and requests a resolution from the flight projects, or alternatively, guidelines for resolution.

The space flight operations director heads the design team and interprets the standard operating procedures and places requirements consistent with the space flight operations plan on the various operating groups. Solutions for ambiguities directly associated with standard operating procedures, appropriate decisions, and initiations of required emergency action are required of the director if the project manager or delegate is not available.

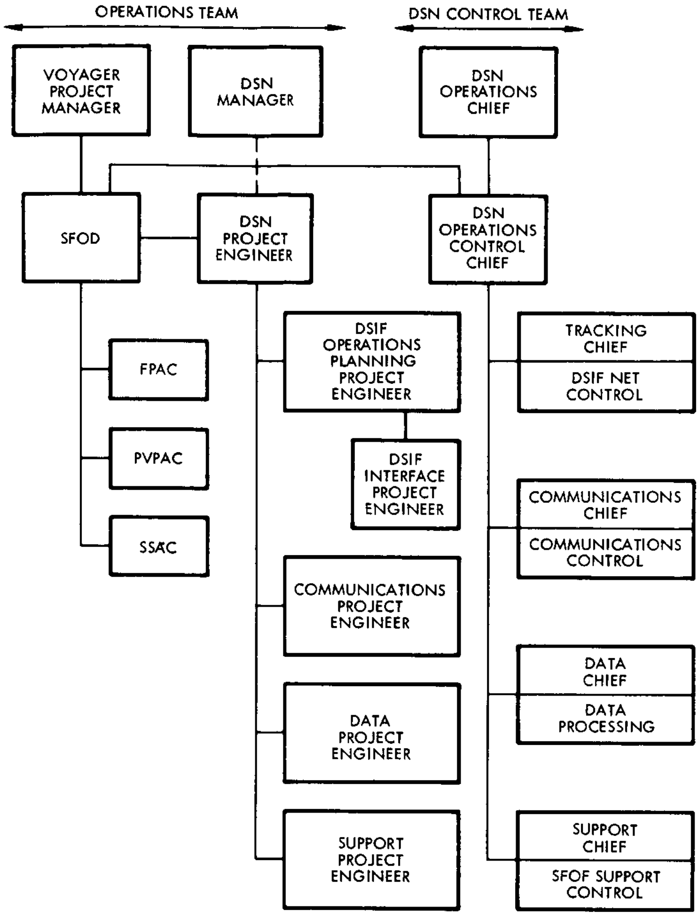


Figure 25. Voyager DSN Organization

The DSN project engineer is responsible for planning and coordinating the interface engineering and for DSN operational planning in support of a specific flight project. His task is to match the requirements of the flight project to the capability of the DSN, and he is responsible to both the DSN and the flight project organizations to ensure this capability. Interface engineering includes the system-to-system integration and testing of the hardware and software subsystems committed to the project. Operational planning includes design and preparation of the operational support to be supplied to the flight project by the DSN.

During the design phase of space flight operations, the DSN project engineer represents the DSN in the MOS organization and directs the necessary system integration for the various elements of the DSN.

The manning of the mission operations team is a joint DSN-flight project responsibility. The functions of the team is to formulate the MOS plans and procedures required for execution of the mission, under the direction of the space flight operations director. Normal composition of the team includes the flight project staff and the DSN system project engineers.

The flight project staff consists of the following:

- Flight path analysis team director
- Planetary vehicle data analysis team director
- Space science analysis and command director

The DSN system project engineers are:

- DSIF operations planning project engineer
- DSIF interface engineering project engineer
- Communications project engineer
- Data processing project engineer
- Support project engineer

12.3.3 Kennedy Space Center Organization

Figure 26 shows the KSC organization. Those organizations within KSC which interface with MSFN organizations are discussed in the following sections.

The Voyager program manager is the central point for the management of all Voyager program activities for which the KSC is responsible. The manager is the official point of interface for Voyager program functions and other space flight centers.

The director of information systems (Figure 27) provides the management and technical direction for KSC's instrumentation activities. These activities relate to radio frequency, telemetry, data acquisition and systems analysis, instrumentation engineering activities, and instrumentation planning and coordination. This office also handles and distributes postflight data collected at KSC and ETR. In addition, it

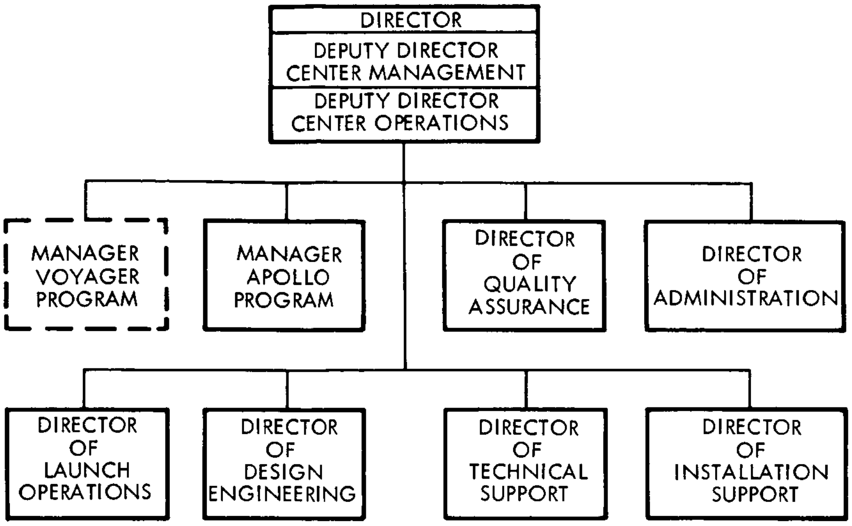


Figure 26. Kennedy Space Center Organization

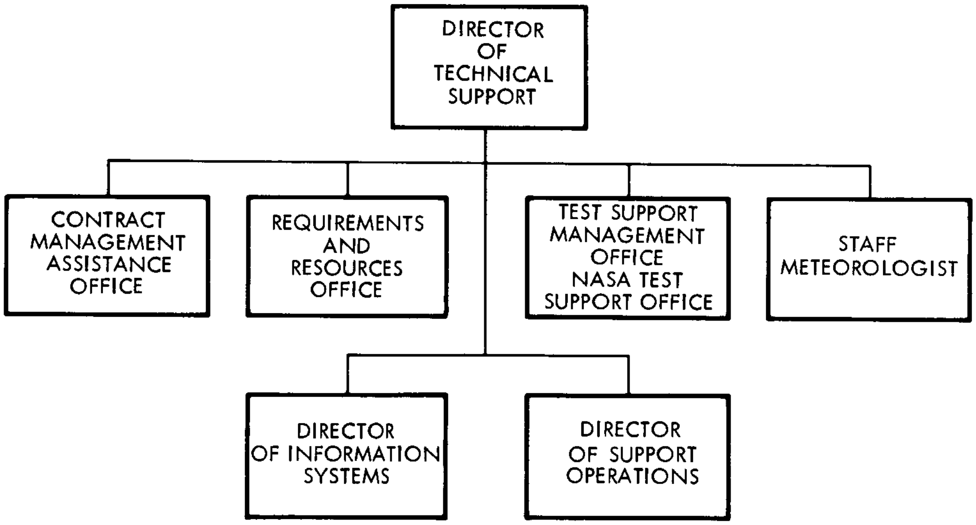


Figure 27. Director of Technical Support Organization

provides for the maintenance and operation of the telemetry portion of the Voyager launch data system under KSC cognizance.

The launch director, acting for KSC, provides the management and technical direction for all operational aspects of preflight integration, test, checkout, and launch.

12.4 SYSTEM OPERATIONS

TDAS operations may be grouped into flight preparation, flight support, and postflight activities. During flight preparation all necessary planning, design, development, procurement, integration, and testing activities are performed to assure system operational readiness. Flight support activities include tracking, data acquisition, data handling, and participation in mission operations. Postflight TDAS activities encompass system performance evaluation, flight navigation data processing, science data dissemination, and recommendations for the enhancement of future TDAS operations in support of the Voyager program.

Figure 28 illustrates the relationships among the TDAS in-flight functions. Figure 29 depicts the relationships between the preflight and flight operation functions and the system elements.

12.4.1 Flight Preparation

12.4.1.1 Planning and Design

Normally, requirements for support by network resources are documented in a project support requirements document. Such basic requirements for resources to support a specific mission usually must be amplified in a procedural document such as mission supplements to the network operations directive. Organizations that are to provide the mission support need both the formal requirements and the associated procedural documents in order to prepare appropriate support directives. It will be the responsibility of organizations that require the support of network resources to provide sufficient information for the preparation of support directives.

12.4.1.2 Integration and Testing

The final welding of the major elements of the TDAS into a functional unit will occur by means of comprehensive training and test program. A master program comprising three basic categories of tests will be implemented to train all mission personnel and to verify that the equipment and operational capabilities of the TDAS are adequate for Voyager. In order to define and verify these capabilities, a TDAS test plan will be established. This test plan will cover in detail all operational testing activities of the TDAS and its elements.

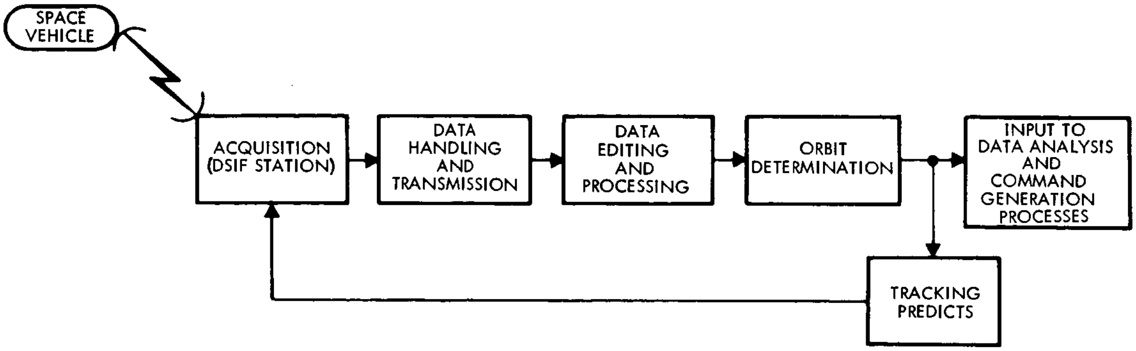


Figure 28. Tracking and Data Acquisition System Functional Flow

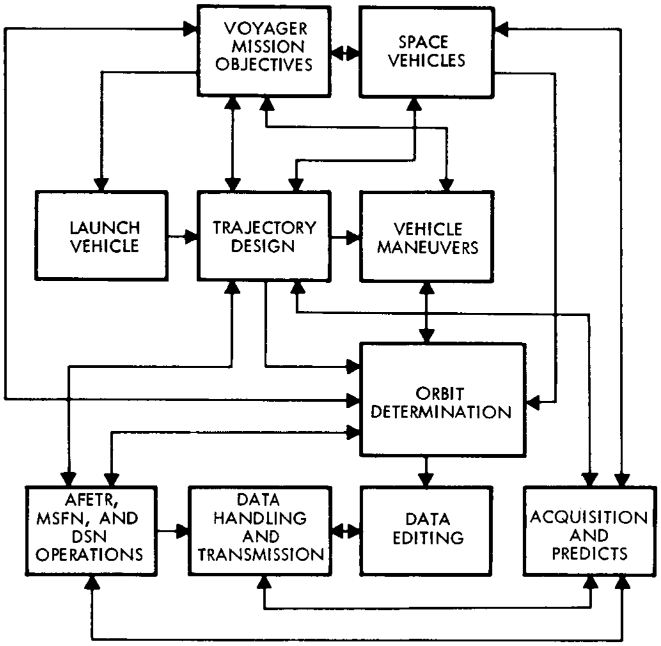


Figure 29. System Elements and TDAS Functions

Internal facility tests will be conducted to establish that support facilities function properly within themselves. Functional compatibility tests will ensure that the earth-based facilities are functionally compatible with each Voyager vehicle and with each other. Finally, operational readiness tests will ensure that all elements of the TDAS operate together by demonstrating readiness to support actual space operations. The relationship of these three classes of tests is illustrated in Figure 30.

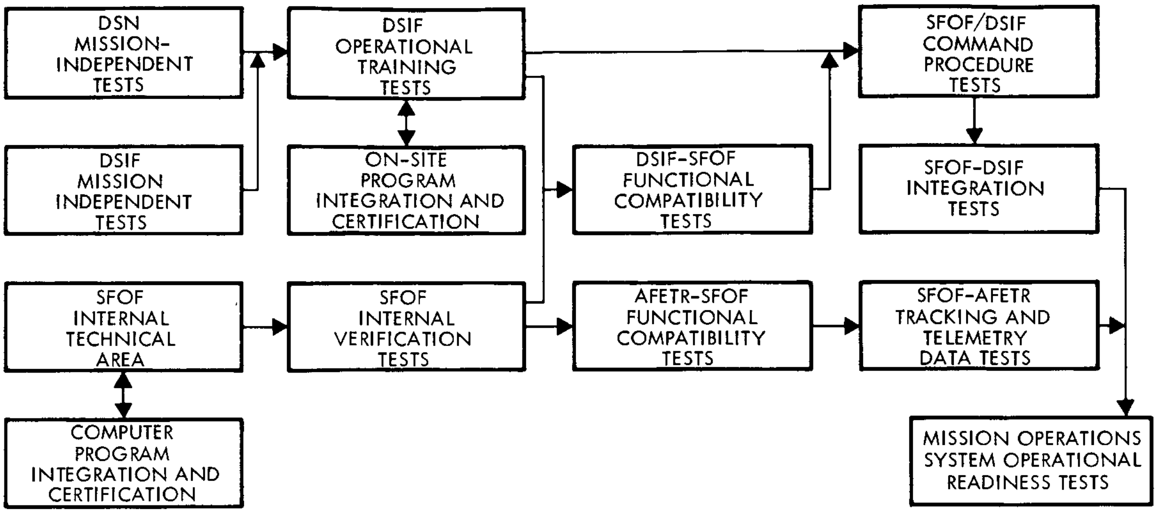


Figure 30. TDAS Test Program

Internal facility tests will be composed of operational training exercises and verification tests. These tests will be designed to ensure that Voyager mission support equipment, computer programs, and personnel within each TDAS facility have the required capabilities and are prepared to support subsequent tests. Simulated mission data for these tests will be generated in the SFOF.

Operational training tests begin in the SFOF and in each DSIF, AFETR, and MSFN facility early in the testing program. They provide mission personnel with the opportunity to become familiar with their mission operations functions, working areas, equipment, methods of communications, and internal interfaces. Two classes of tests should be successfully completed before the facilities can start training exercises. One class, the mission-independent tests, includes acquisition training with test space vehicles. The other, equipment tests, determines whether the command data handling equipment, system test equipment, S-band receiving and transmitting equipment, video data handling system, and other instrumentation are functionally compatible.

DSIF operational training tests, conducted within the stations under the direction of the individual station manager, provide an organized training program for the crews in preparation for future tests. Interfaces outside the station are simulated with test data packages. These tests also permit the evaluation of existing detailed operating procedures.

The SFOF internal tests verify the capability of the integrated mission operations groups, computer programs, and equipment within the SFOF to control a Voyager mission. The SFOF integration verification test exercises all SFOF personnel, equipment, computer programs, procedures, and operations techniques throughout an entire simulated mission.

Computer program integration is the process of inserting a user program into the software environment of the SFOF system and making those changes necessary for the program to be compatible with the system. Program certification tests verify the operational status of the user programs for the mission. For each program a test specification defines a series of cases exercising all options and interfaces with other computer programs. Successful completion of the test leads to program certification, the last step in the development of a Voyager computer program.

The on-site data processing program checkout assembles and checks the various options of the Voyager on-site computer program in order to find and correct program errors. The on-site data processing program integration process consists of inserting the Voyager programs into a checked-out hardware environment and verifying both the hardware-software interfaces and the program options. Functional compatibility tests verify that the separate elements of the Voyager TDAS can perform together in accordance with the functional requirements specified and that these requirements are compatible with the actual space vehicle data configuration. During these tests, the TDAS is exercised under a variety of conditions determined by the combinations of operating modes, bit rates, command sequences, communications capabilities, equipment configurations, etc., which can occur during standard and certain nonstandard space operations. The tests also verify that all Voyager hardware and software interfaces are compatible by demonstrating acceptable TDAS functional performance. It will not be necessary that the tests be performed in real time, but the use of data from a space vehicle or facsimile is required.

Following the functional compatibility tests, all facilities participating in the mission are required to establish their operational readiness through a series of operational readiness tests. These tests exercise the personnel, hardware, and software to the maximum extent feasible, within the limitations of a simulated mission. The intent of this series of tests is to progressively increase personnel proficiency and demonstrate their operational readiness. The series culminates with a total-system dress rehearsal. The standard flight operations sequence used for these tests is the standard sequence of events published in the space flight operations plan.

12.4.1.3 Scheduling

The TDAS manager will insure that all AFETR, DSN and MSFN elements are properly configured to support the Voyager project. The TDAS management must consider a large number of project activities of varying priorities. When necessary, alternative plans are recommended to the project manager. All of the work at all of the stations and at the SFOF is scheduled by the TDAS scheduling office. Figure 31 illustrates a typical TDAS scheduling flow.

The various project inputs must be compatible with each other in order that comparisons can be made and conflicts detected. Requests for support are placed 10 to 14 days in advance of the period covered by the seven-day schedule, which allocates all TDAS resources on an hour-by-hour basis. Prior to the submission of the seven-day schedule requests, the project office will make requests to the 12-week schedule, where potential conflicts are detected on a week-by-week basis. Conflicts detected by the 12-week schedule are considered far enough in advance to allow some rescheduling of activities into the slack time, which is made visible by the same process.

While the 12-week schedule covers project planned activities from one to four months in advance, this time is usually insufficient to install project-peculiar equipment at the selected tracking stations. The planning device used to allocate complete station tracking coverage and SFOF computer loading is the 16-month schedule, which covers the period from the 3rd through the 16th month in the future.

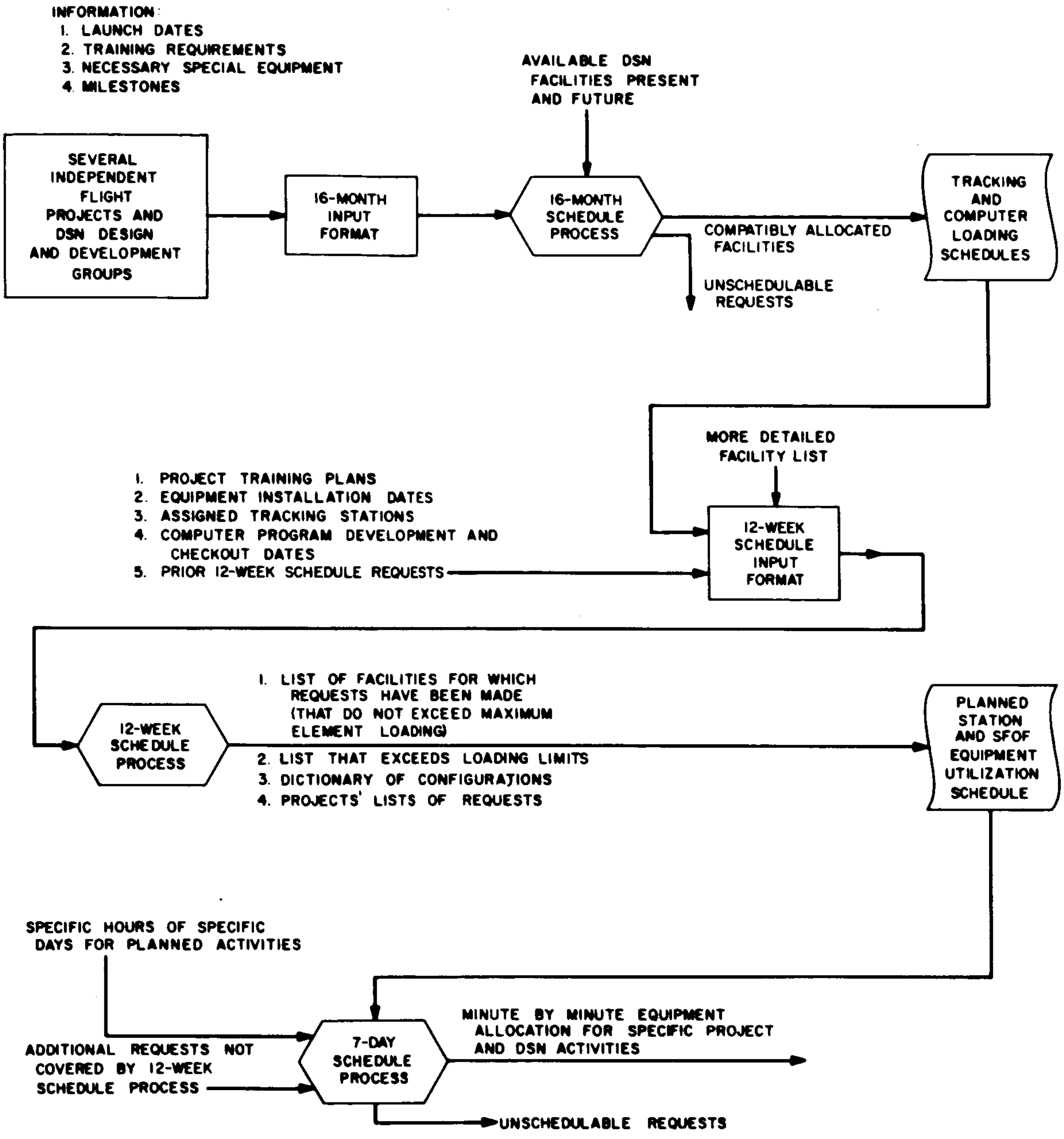


Figure 31. TDAS Scheduling System Flow Chart

12.4.2 Flight Support

During the in-flight phase the TDAS provides in-flight navigational information to the project performing the functions previously described. Figure 28 shows how these functions are related.

After planetary vehicle injection the essential functional relationships appearing in Figure 32 are itemized as follows:

1) The Deep Space Stations take precision measurements along the space vehicle trajectory by transmitting a signal to the space vehicle which is returned by means of a turn-around transponder. The received signal is compared to the transmitted signal to derive the doppler shift. Pointing information and range data may also be derived.

2) Measurements from the Deep Space Stations are transmitted via the GCS to the SFOF.

3) The measurements are fed into the SFOF data processing system, where they are analyzed, edited, and then processed to improve previous trajectory estimates.

4) The monitor area provides alarms and recording equipment to monitor the status of the stations, SFOF, and data stream. This information is used to improve the data editing process.

5) Predicted data values are generated and transmitted to the Deep Space Stations. These values are then used for succeeding acquisitions of the space vehicle transponder.

6) The improved orbit estimates are given to the trajectory group. This group then runs the trajectory program and analyzes the trajectory for the project and public information purposes.

7) During the flight maneuver and orientation, analyses are performed to determine how best to achieve mission objectives.

8) The inputs from maneuvers are sent to the SFOF, where the commands are then formulated. Inputs from the SFOF on space vehicle maneuvers and space vehicle perturbations are also fed into the data analysis and orbit process to account for apparent trajectory anomalies and to predict correlations.

12.4.2.1 Acquisition and Station Transfer

After planetary vehicle injection, prediction data will be furnished to the DSIF at various times during a mission. The identifiers at the beginning of each prediction message determine which set of predictions is to be used at the station. Prediction data include nominal prelaunch predictions for each day of the firing window; prelaunch frequency

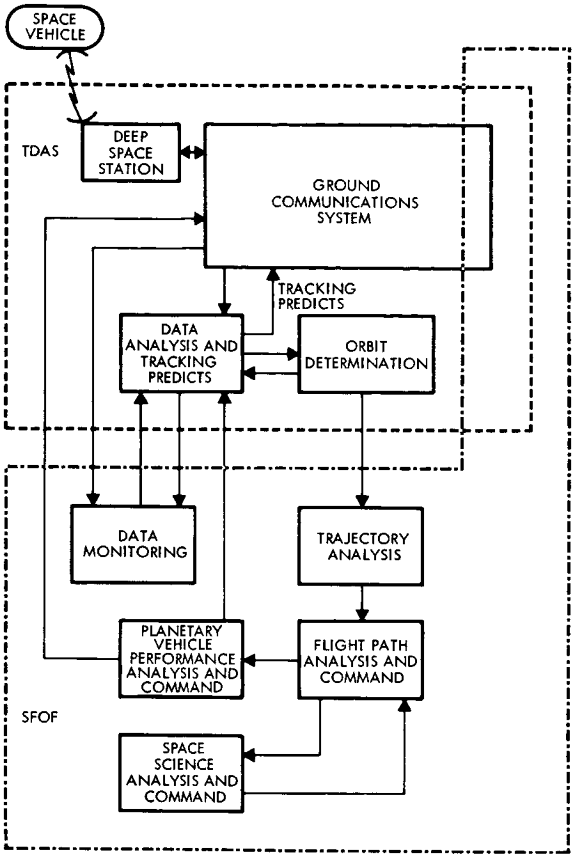


Figure 32. TDAS Interface with SFOF

messages containing adjusted frequency values for the predicted temperature at the time of first view of the first station expecting to acquire; launch time and azimuth of launch information transmitted to all stations as soon as possible after launch; and predictions transmitted to the station expecting to initially acquire the spacecraft at launch plus 5 minutes.

Net control will be kept informed of the acquisition status whenever possible by voice. If the voice line is not available, status information will be forwarded by teletype.

Both the outgoing and the incoming station will be supplied with the best available set of predictions that have been generated for the same orbit and the same frequency to provide zero static phase error at the space vehicle. Ordinarily, it will be the responsibility of net control to notify both stations, by voice and by teletype, of the time the transfer is to be initiated.

12.4.2.2 Data Handling

Figure 25 illustrates the system data flow within the DSN. Figure 33 illustrates the data flow at ETR. DSN tracking data will be recorded at the SFOF and predictions computed at the SFOF control computer facility will be transmitted to the participating stations as indicated in the appropriate sequence of events.

At the moment of first space vehicle visibility at a DSIF station, the immediate objective will be to acquire the signal with the receiver on the S-band acquisition antenna. This will normally be followed by two-way acquisition with the transmitter on the S-band Cassegrain monopulse antenna. If the receiver on the acquisition antenna is not in lock by the time the space vehicle rises to the 10-degree local elevation, RF search-and-angle scan procedures will be followed until acquisition is achieved.

DSIF acquisition of a space vehicle signal may involve six different functions: pointing the antenna; tuning to and locking the ground transmitter to the space vehicle receiver frequency; establishing range lock, where applicable; synchronizing the telemetry system; and in some cases providing for immediate command transmission to the space vehicle.

12.4.2.3 Station Reporting

After planetary vehicle injection each participating DSIF station will report events occurring aboard the vehicle as indicated by telemetry and events occurring within the station itself.

a) Reports Prior to Launch. Daily station status reports will be submitted to net control from each participating station during the 10 days prior to launch. The status report must give the station conditions, station readiness, and system test progress.

b) Pretrack Report. The teletype format for the pretrack report is designed for computer processing. Prior to the start of a tracking period, each DSIF station will submit a pretrack report stating system noise temperature, receiver threshold, serial number of the transponder used, RF losses from the test transmitter to the low-noise amplifier input, test transmitter internal power losses, test transmitter output, ground mode code, AGC calibrations, signal level at which AGC time constant was changed, the receiver reference

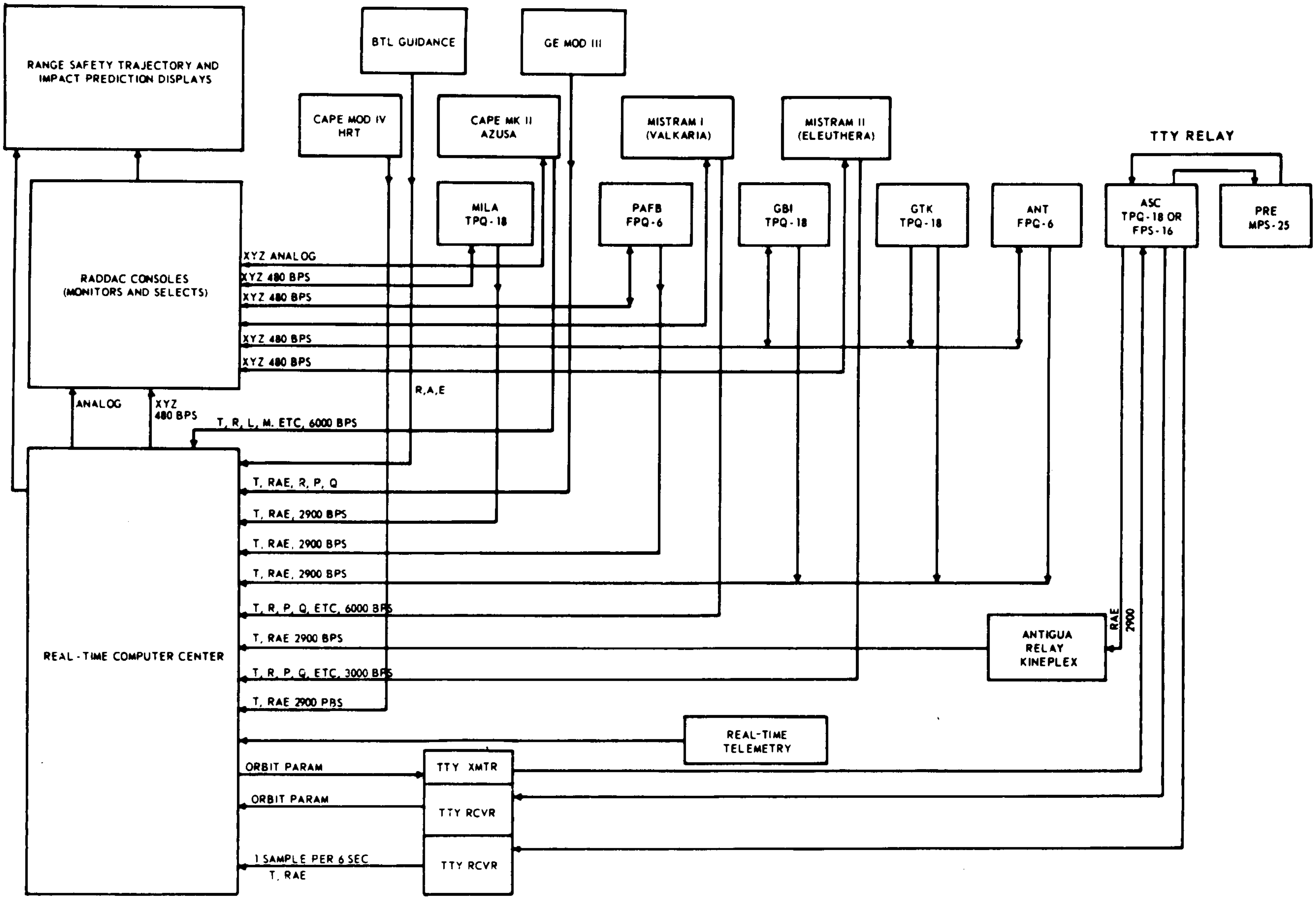


Figure 33. ETR Data Flow

logs bandwidth used in the AGC calibrations, the accuracy of the data sample gate synchronization, the bias oscillator frequency printout, and station digital clock delay.

c) Acquisition Report. Voice reports will be made to net control immediately upon acquisition of the spacecraft. Following the time of acquisition, a teletype report will be submitted to net control stating time (GMT) of first RF lock, time (GMT) of autotrack, signal strength at acquisition, significant events during acquisition, and transmitter VCO frequency at two-way acquisition, after adjustment for static phase error.

d) Tracking Report. The teletype format for the tracking is designed for computer processing.

Each tracking report will contain:

- The last five digits of transmitter initial VCO frequency with corresponding GMT and day of the year and the last five digits of transmitter VCO frequency with corresponding GMT and day of the year, for each subsequent change in value.
- The start and end time of the DSIF tracking mode, the actual DSIF station tracking mode, and the space vehicle telemetry mode.
- The average signal level in dbm and AGC voltage, any variation about this level, and the GMT of the signal level reading.
- The telemetry condition (in- or out-of-lock of each channel, etc.)
- The transmitter power in watts and transmitter on and off times.
- The time (GMT) of significant events followed by exact identification.

e) Acquisition-Assistance Report. The station nearing the end of its tracking period will prepare and transmit an acquisition-assistance report, to assist the incoming station in acquiring the space vehicle signal. Prior to the predicted rise time at the acquiring station, the station actually tracking will submit an acquisition-assistance report to the incoming station and a copy of the report will also be forwarded to net control.

Acquisition-assistance reports will contain the following: station identification (ID) and time of report; received signal level in dbm; ground receiver VCO frequency; space vehicle AGC in dbm; space vehicle static phase error, date number; ground transmitter VCO frequency and deviations from predictions; ground transmitter power in watts; deviation from doppler prediction in cps; and other pertinent information.

f) Post-track Report. The teletype format for the post-track report is designed for computer processing.

Each DSIF station will submit a post-track report giving GMT of acquisition; GMT of autotrack; telemetry of recording conditions; general tracking conditions; events and significant occurrences, with GMTs; GMT at end of track; GMT of changes of doppler data recording condition; GMT for each ground mode; data times of each magnetic tape recording; and post-track measurements including system noise temperature, receiver threshold, serial number of the transponder used, AGC calibrations as prescribed for pretrack measurements, signal level at which the AGC time constant was changed, receiver reference loop bandwidth used in AGC calibrations, and station digital clock delay value and estimated tolerances.

g) Mission Summary Reports. The submission schedule for a long mission such as Voyager will be as follows:

- Interim Summary No. 1 will cover launch through Pass 10
- Interim Summary No. 2 will cover Passes 11 through 30
- Interim Summary No. 3 will cover Passes 31 through 60
- Other interim summaries will be consecutively numbered, each covering a group of 30 passes
- The Mission Summary Report will cover no more than the final 30 passes, but will also synopsize the entire mission

h) Net Control Reports. To assist in the initial acquisition of the space vehicle, DSIF net control will provide the appropriate stations with the necessary data immediately following launch. This data will be in the form of a formal launch report.

Procedures for the generation and issuance of command messages to the stations are necessarily mission-dependent. Instructions will be sent by teletype well in advance of the time of execution. In the teletype message, the type of command and times of execution usually will be repeated three times and followed by other verification. To insure against transmission errors, a voice verification will also be made.

In general, commands of a typical mission will be originated by the SFOD and verified with the DSIF operations chief. The track chief will then ordinarily assume responsibility for subsequent processing and transmission to the DSIF station designated for executing the command transmission.

12.4.3 Postflight Activities

Subsequent to flight operations, in-flight TDAS performance is reevaluated, data is validated, astrocynamic constants determined, and recommendations for improvement of TDAS performance in support of future Voyager missions submitted to the Voyager project manager. Figure 34 illustrates the postflight activity flow.

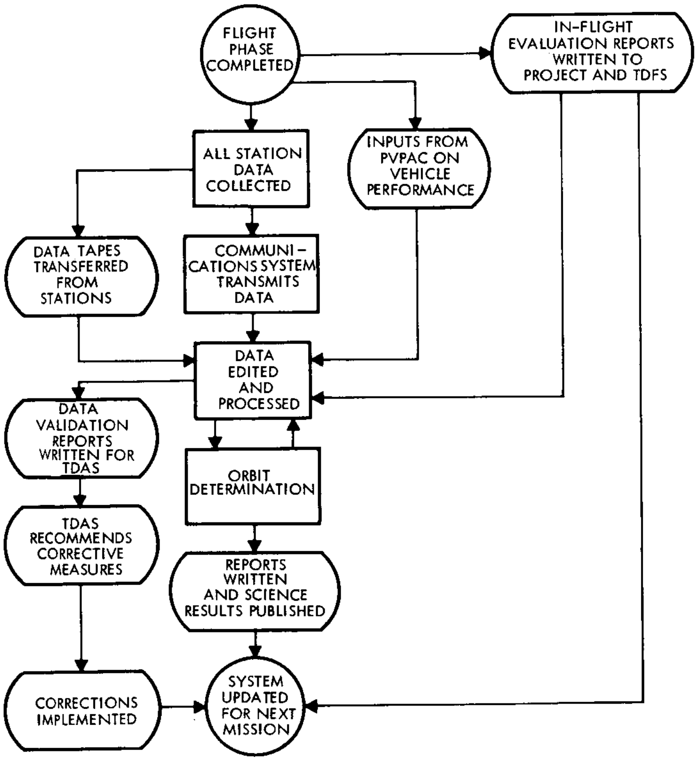


Figure 34. Postflight Phase Activity Flow

12.4.3.1 Orbit Determination

Data is edited by inspecting station records, space performance and command group reports, the interim monitor program, and operations records, in addition to the orbit program plots and residuals. The accuracy of the orbit program often makes it the final arbitrator as to whether data are good or bad. Thus, the data editing and the orbit determination process are tied together in an iterative process. This effort, extending anywhere from 1 month to 1 year after the flight, is to:

- Provide the project with a "best estimate" of the trajectory for comparison with video pictures, etc.
- Provide better estimates of physical constants and station locations
- Provide data analysis for inherent accuracy, etc. These are the primary reasons for the data editing and orbit phases of postflight operations. An additional advantage of this period may be taken as an opportunity for personnel training and program checkout.

The reports include the "Flight Path and Its Determination from Tracking Data" report and project experiment support such as occultation computations. In addition reports such as station location determination will be prepared.

12.4.3.2 Reporting

Although most of tracking data taken is usually analyzed during flight, there are certain special data types that are usually transmitted to SFOF only after the flight is over. Doppler data taken at the rate of one sample per second is an example. Such samples are recorded every second, but they would require an inordinate amount of communication transmission time during the flight. Thus the data may be flown back along with the data records to document control and then to the system data analysis group. These data are taken because they have both project and DSN accuracy applications.

13. LAUNCH SITE OPERATIONS

This section discusses Voyager launch site operations, which include activities associated with prelaunch, launch, and injection into earth orbit. The operational phase commences for a spacecraft, capsule, or launch vehicle segment after completion of the mission acceptance review (mission baseline) at the manufacturing facility. The operational phase commences for an operational support facility, associated personnel, and software when it has completed checkout and acceptance, indoctrination and training, and is in a mission support posture. The launch operations functional flow commences with shipment of flight hardware to the launch site and ends with injection of the space vehicle into earth orbit.

13.1 OPERATIONAL SUMMARY

Voyager operational launch site activities commence with shipment of flight hardware to the launch site and end at the completion of space vehicle earth orbit injection. The operational flow includes shipment to Kennedy Space Center, receiving inspection, assembly and checkout, final prelaunch preparations, space vehicle integration, terminal countdown, launch, powered flight, and earth orbital injection. The flow chart in Figure 35 indicates the operational flow for the Voyager launch site operations. A description of each of the major functional segments follows. Individual tests for each system segment are described in Section 13.5.

13.1.1 Facilities and Operations Demonstration and Acceptance

All facilities, personnel, and software required for each Voyager mission must be in a mission support posture at the start of the operational phase. Each major system support element first demonstrates mission readiness and then participates in a total combined systems operations demonstration. These elements are exercised as a total system through a simulated Voyager mission. All elements are then prepared and ready to support individual activities as shown in Figure 35. This pre-operations demonstration and acceptance process is indicated in Figure 35 by blocks 4 to 8.

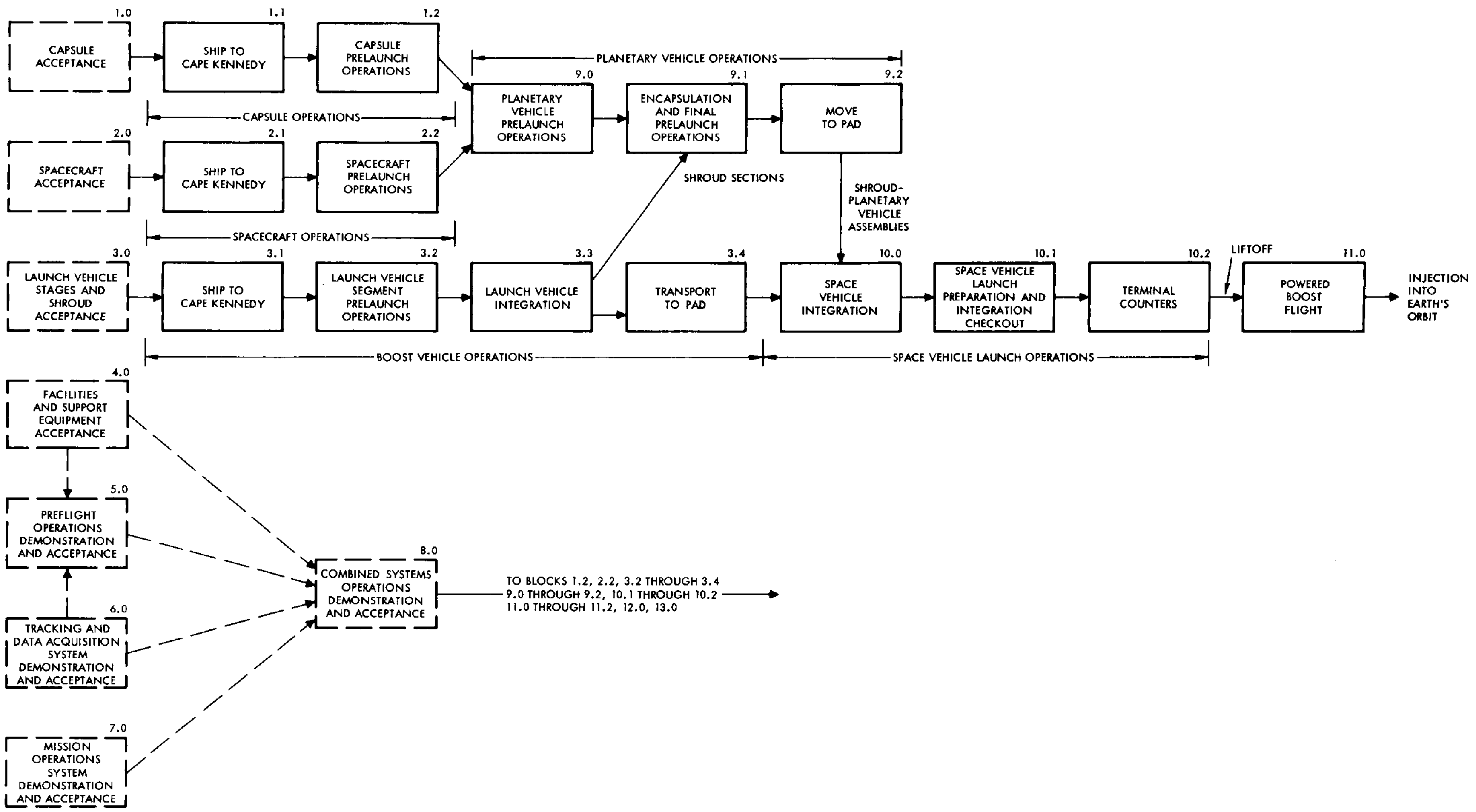


Figure 35. Voyager Launch Site Operations Functional Flow Diagram

13.1.2 Capsule Operations

Capsule operations, shown in Figure 35, commence after capsule mission acceptance tests have been completed at the manufacturing facility. The capsule is prepared for shipment as an integrated entity, less the RTG nuclear element. The capsule hardware is air shipped to KSC, unloaded from the aircraft, and transported to the capsule assembly facility. Prelaunch capsule operations will be conducted to include receiving and inspection, final assembly, and checkout. After assembly and checkout functions are completed and the flight capsule has been heat sterilized, it is prepared and transported to the explosive safe area for planetary vehicle integration.

13.1.3 Spacecraft Operations

Spacecraft operations, shown in Figure 35, commence after spacecraft mission acceptance at the spacecraft manufacturing facility. The spacecraft is prepared for shipment and air shipped to KSC. The spacecraft assembly facility (SAF) and receiving inspection, prelaunch checkout, and assembly operations are performed. After mechanical and electrical interface system checks, the spacecraft is prepared for mate with the capsule. The spacecraft is transported to the explosive safe area for planetary vehicle integration and checkout.

13.1.4 Launch Vehicle Operations

Launch vehicle operations shown in Figure 35 commence after mission acceptance of the launch vehicle stages instrumentation unit and shroud assemblies at the associated contractors' facilities. The launch vehicle stages instrumentation unit and shroud are shipped to KSC by appropriate means. After the stages and shroud arrive at KSC, they are taken to the Complex 39 Vehicle Assembly Building for subsystem mechanical and electrical checkout. After the stage checkouts, the Saturn V launch vehicle segments are mated in the VAB high bay and launch vehicle integration testing performed. During the launch vehicle-shroud integration tests, planetary vehicle simulators are installed in the shroud sections for electrical and mechanical mate and compatibility checks with the launch vehicle. After verifying compatibility with the launch vehicle, the planetary vehicle simulators are removed and the shroud sections transported to the explosive safe area for mating with the planetary vehicles.

After prelaunch checkout operations in the VAB, the Saturn V launch vehicle is prepared for transport to the pad utilizing the mobile crawler-transporter system, mated to the pad systems, and prepared for final integration with the planetary vehicle-shroud assemblies and nose fairing.

13.1.5 Planetary Vehicle Operations

Planetary vehicle operations are shown in Figure 35. The capsule and spacecraft are mated in the ESA to form a planetary vehicle and interfaces are checked. Spacecraft propellant is then loaded and the planetary vehicle is encapsulated in the shroud cylindrical section and decontaminated by ETO surface sterilization. A final all-systems test is performed and the shroud-planetary vehicle assembly is prepared for transport to the pad. Two shroud-planetary vehicle assemblies are transported to the pad and prepared for integration with the Saturn V launch vehicle.

13.1.6 Space Vehicle Launch Operations

Space vehicle operations are shown in Figure 36. After the Saturn V launch vehicle is mated to the pad systems, the two shroud-planetary vehicle assemblies, shroud spacer, and nose fairing are mated to form the space vehicle. A combined all-systems test is conducted to ensure that the space vehicle system is in a launch-ready condition and is compatible with the support systems. During the all-systems test, integration with the tracking and data acquisition system is accomplished to check out the telemetry system. After the final all-systems test, a mission simulation test is conducted from countdown through Mars operations, utilizing the mission control center (SFOF) and the DSN station 71 at Cape Kennedy. After the mission simulation test is satisfactorily completed, terminal countdown is initiated.

13.1.7 Tracking and Data Acquisition System Launch Site Operations

Tracking and data acquisition system launch site operations include support activities for the capsule, spacecraft, launch vehicle, planetary vehicle, and space vehicle as required during prelaunch, terminal countdown, and launch vehicle powered flight operations. Tracking and data acquisition operations include receiving telemetry data during RF operations conducted during the prelaunch and launch countdown checkout. This also includes checkout of tracking and beacon acquisition systems. All prelaunch and flight mission telemetry and tracking data will provide space vehicle performance data, range safety requirements, and trajectory determination data.

13.2 SYSTEM DESCRIPTION

This section describes the facilities, equipment, personnel, and procedures required to implement Voyager activities at Kennedy Space Center.

13.2.1 KSC Complex 39

The major components of the Saturn V Launch Complex 39 include: the Vehicle Assembly Building where the launch vehicle is assembled and prepared; the mobile launcher, upon which the vehicle is erected for checkout, transfer, and launch and which provides internal access to the vehicle; the crawler-transporter, which transfers the vehicle to the launch area; the crawlerway, upon which the crawler-transporter travels to the launch site; the mobile servicing structure, which provides external access to the vehicle at the launch site; and the launch pedestal, from which the space vehicle is launched.

13.2.1.1 Vehicle Assembly Building

The Vehicle Assembly Building, though relatively simple and conventional in basic construction, includes some unique features because of its size. When the launch vehicle and the mobile launcher are carried by the crawler-transporter from the VAB, they leave through an opening 456 feet high. The base of the opening is 149 feet wide and 113 feet high; the remainder is 76 feet wide. There are four such openings in the VAB, one for each of its four bays. To maintain the protective environment of the building, doors have been designed for these huge openings, doors that could withstand winds of 125 miles per hour and could be opened and closed in a 63-mile-per-hour wind.

The two 250-ton cranes serve the four assembly and checkout bays in the high-bay section of the building. Each pair of bays shares a crane. These cranes, whose lifting height is 456 feet, have a travel distance of 431 feet.

Work-platform halves, mounted on opposite walls in the high-bay area, are designed to move in and out like suspended file drawers, mating to form building encircling the space vehicle. Platforms extend or retract in less than 10 minutes. Each platform half is suspended by two wheels, which are driven by electric motors, and two follower wheels. Twenty-ton hydraulic jacks in the follower-wheel housings are used to align platform halves.

13.2.1.2 Mobile Launcher

A primary feature of the mobile launcher is protection of the platform and its equipment from blast and sonic damage. If a hazardous condition occurs at the launch pad, personnel can be evacuated from upper work levels of the umbilical tower by a high-speed elevator, descending at 6000 feet per minute. After leaving the elevator, they can drop through a flexible metal chute into a blast and heat-proof "hardened" room inside the base of the platform. The room is large enough to accommodate all personnel and is stocked and equipped to sustain them for an adequate time.

Intense acoustic energy is generated in the turbulent exhaust of Saturn V. This energy is radiated to the surface of the mobile launcher, where part of it is transformed into vibration of exterior structure and skin panels and part is transmitted into the interior.

The mobile launcher design limits ambient sound level within the platform during Saturn V firing so as not to exceed 92 decibels. Further reduction of sound level is provided by housing the computer, which provides checkout and prelaunch data to the control center, in an "isolated room" constructed of special 4-inch thick panels. In addition, all electronic components in the launcher must be of rugged design and must undergo extensive sonic tests to insure their performance and reliability.

13.2.1.3 Crawler-Transporter

The crawler-transporter, in transit, maintains a level platform within 10 minutes of arc and is capable of locating itself at its launch site and VAB positions within a 2-inch tolerance.

Two identical and independent hydraulic servo systems are provided for leveling. Level sensing and control are initiated by a manometer whose horizontal tube is 130 feet long. It contains two transducers to sense errors in level and transmit error signals to the servo system which operates two variable control servo pumps, one for each diagonal axis. The pumps position support cylinder at each corner of the platform to level the chassis.

Steering of the vehicle is accomplished by a hydraulic system. Two double-acting cylinders at each of the four traction units can turn the crawler-transporter at a maximum rate of 10 degrees per minute. Minimum turning radius is 500 feet.

Other hydraulic systems include an equalization system to distribute the load among the four supporting corners of the vehicle and a jacking system to raise and lower the mobile launcher.

Tractive power is provided by 16 direct-current motors served by two diesel-driven generators. The generators are rated at 1000 kilowatts each and are driven by 2750-horsepower diesel engines. There are four loops of four drive motors. Motors in each loop are wired in series and are located on each traction unit. Each generator drives two loops of motors. Speed of the vehicle is controlled by varying the generator fields. Power for the fields is provided by two 750-kilowatt power units, which also provide power for pumps, lights, instrumentation, and communications.

13.2.1.4 Crawlerway

The crawlerway supports the 17.5-million-pound load of the crawler-transporter, mobile launcher, and space vehicle. Under ideal operating conditions, this load imposes ground pressures of approximately 8500 pounds per square foot. However, pressures could reach 12,000 psf, with momentary pressures as high as 16,000 psf.

The roadbed to support this load, on soil composed of fine sand and shell, extends to a depth of 42 feet.

A dual roadbed, whose prepared surface averages 8 feet in depth, was designed to satisfy these requirements. Its two parallel strips are 40 feet wide on 90-foot centers.

13.2.1.5 Flame Deflector

The wedge-shaped, steel flame deflector used on the launch pad features a replaceable ceramic-coated leading edge. Exhaust from the outer engines strikes the sides of the wedge. The center engine exhaust impinges on the ceramic leading edge. The heat-resistant ceramic surfaces erode slowly in the blast, and as they do the thermal energy generated is carried away in superheated particles. All exhaust and particles are deflected through a flame trench.

The mobile deflector, which weighs 700,000 pounds, is moved to its position beneath the launch pedestal along a rail system. Two deflectors are available for each pad, although only one is required per launch.

13.2.2 Capsule Prelaunch Operations

13.2.2.1 Facilities

After the capsule arrives at KSC it will be taken to the capsule assembly facility (CAF) for preliminary checkout. Capsule facilities may be existing facilities, modified to specific Voyager requirements, or new facilities. The CAF should be located as close to the explosive safe area and the Complex 39 launch pad as possible to reduce road transportation and handling problems after completion of capsule prelaunch operations. It has been assumed that land exists within the NASA Merrit Island complex at KSC for the CAF, if a new facility is required. Grading and site preparation will be required, as well as utility connections and the use of construction contractors and architects.

The CAF will consist of a high bay area approximately 100 x 140 x 50 feet high incorporating a 40 x 70 foot air lock at one end. The total working area in the high bay will be 16,800 square feet. The high bay area will be a FED-STD-209-100, 000 class clean room area. A low bay area with a ceiling height under 15 feet and 140 x 160 inches is required to support subsystem prelaunch operations, and for location of the checkout equipment and associated computers. This support area includes 6000 square feet of FED-STD-209-100, 000 class clean room area. The remaining area in the low bay will be used for spare part storage, support personnel office space, capsule project control center, and other service and support facilities.

The high bay area will incorporate a traveling bridge crane. The air lock portion of the high bay will be used to receive the capsule and remove it from the shipping container. The high bay assembly and test area will be of sufficient area to accommodate four capsules.

A capsule heat sterilization oven will be required as an integral unit of the CAF. Access to the oven will be through the high bay area. The oven dimensions will be 40 x 40 x 30 feet high. A traveling bridge crane will be incorporated into the oven as well as a permanent capsule support structure to support the capsule during the heat sterilizing. The oven temperature will be raised through use of internal heaters and by the circulation of controlled heated nitrogen gas. An automatic temperature control and timing control system will be an integral portion of the sterilization facility. Provisions will be incorporated to connect external cooling systems for capsule systems such as RTG and any other critical temperature sensitive elements.

13.2.2.2 Capsule Equipment

The equipment required to conduct prelaunch and launch operations of each capsule will be identical to that utilized to conduct handling, checkout, and acceptance tests in the factory. All equipment for prelaunch operations will be identical to that required during the manufacturing, assembly, and test sequence. The only major identifiable difference in launch site equipment will be the deletion of fault isolation functions below the black box level since only black box removal and replacement operations will be necessary at the launch site. Electrical simulators for the spacecraft will be required for initial capsule checkout operations prior to delivery to the ESA for planetary vehicle integration operations.

13.2.2.3 Capsule Operating Personnel

Each of the four flight capsules will be prepared for launch by the capsule launch operations team which was responsible for the manufacturing, assembly, and test integration task at the factory. Each of the capsule subsystem engineers will have a crew of technicians performing specific integration and checkout tasks required for each subsystem. An operations crew will be required for each of the capsules. However, multi-assignment of individuals will be possible because of the staggered operational sequence. A total of about 60 technicians will be required to support each capsule prelaunch operation. In addition a staff of secretaries, maintenance personnel for the capsule support equipment, spare part storage personnel, and other administrative supporting staff will be required throughout capsule prelaunch and launch operations.

13.2.2.4 Procedures and Documentation

Prelaunch checkout and launch countdown procedures will be generated to outline all tasks required to assure the flight capsule subsystem and system performance is within the specified values. Documentation will be prepared for all test procedures and operations from receiving inspection through final launch countdown and prelaunch evaluations. Check lists, inspection reports, failure and correction reports, and contamination control reports will be prepared.

13.2.3 Spacecraft Prelaunch Operations

12.2.3.1 Facilities

After the spacecraft arrives at KSC it will be taken to the spacecraft assembly facility (SAF) for preliminary checkout. Spacecraft facilities may be existing facilities, modified to specific Voyager requirements, or new facilities. The SAF should be located as close to the explosive safe area and the Complex 39 launch pad as possible to reduce road transportation and handling problems after completion of spacecraft prelaunch operations. It has been assumed that land exists within the NASA Merritt Island complex at KSC for the SAF, if a new facility is required. Grading and site preparation will be required as well as utility connections and the use of construction contractors and architects.

The SAF will consist of a high bay area approximately 100 x 140 x 50 feet high incorporating a 40 x 70 foot air lock. The total working area in the high bay will be 16,800 square feet. The high bay area will be a FED-STD-209-100,000 class clean room area. A low bay area with a ceiling height about 15 feet and 108 x 120 inches is required to support subsystem prelaunch operations, and for the checkout equipment and associated computers. This support area includes 4000 square feet of FED-STD-209-100,000 class clean room area. The remaining area in the low bay will be used for spare part storage, support personnel office space, capsule project control center, and other service and support facilities.

The high bay area will incorporate a traveling bridge crane. The air lock portion of the high bay will be used to receive the spacecraft and remove it from the shipping container. The high bay assembly and test area will be of sufficient area to accommodate three spacecraft.

13.2.3.2 Spacecraft Equipment

The equipment required to conduct prelaunch and launch operations of each spacecraft will be identical to that equipment utilized to conduct handling, checkout, and acceptance tests in the factory. All equipment required for prelaunch operations will be identical to that required during the manufacturing, assembly, and test sequence. The only major identifiable difference in launch site equipment will be the deletion of fault isolation functions below the black box level since only black box removal and replacement operations will be necessary at the launch site. Electrical simulators for the capsule will be required for initial spacecraft checkout operations prior to delivery to the ESA, for planetary vehicle integration operations.

13.2.3.3 Spacecraft Operating Personnel

Each of the three flight spacecraft will be prepared for launch by the spacecraft launch operations team which was responsible for the manufacturing, assembly, and test integration task at the factory. Each of the spacecraft subsystem engineers will have a crew of technicians performing specific integration and checkout tasks required for each subsystem. An operations crew will be required for each of the spacecraft. However, multi-assignment of individuals will be possible because of the staggered operational sequence. A total of approximately 40 technicians will be required to support each spacecraft prelaunch operation. In addition, a staff of secretaries, maintenance personnel for the support equipment, spare part storage personnel and other administrative supporting staff will be required throughout spacecraft prelaunch and launch operations.

13.2.3.4 Procedures and Documentation

Prelaunch checkout and launch countdown procedures will be generated to outline all tasks required to assure the flight spacecraft subsystem and system performance is within the specified values. Documentation will be prepared for all test procedures and operations from receiving inspection through final launch countdown and prelaunch evaluations. Check lists, inspection reports, failure and correction reports, and contamination control reports will be prepared.

13.2.4 Planetary Vehicle Launch Operations

13.2.4.1 Facilities

After the spacecraft and capsules have completed prelaunch checkout operations in the SAF and CAF, they will be taken to the explosive safe area for assembly and checkout operations. The explosive safe area may be existing facilities modified to specific Voyager requirements, or new facilities. The ESA should be located as close to the Complex 39 launch pad as possible to reduce road transportation and handling problems after completion of planetary vehicle operations. It has been assumed that land exists within the NASA Merritt Island complex at KSC for the ESA, if a new facility is required. Grading and site preparation will be required as well as utility connections and the use of construction contractors and architects.

The ESA will consist of a high bay area approximately 100 x 140 x 90 feet high incorporating a 40 x 70 foot air lock at one end. The total working area in the high bay will be 16,800 square feet.

The high bay area will be a FED-STD-209-100,000 class clean room area. A low bay area with a ceiling height of about 15 feet and 50 x 100 feet is required to support planetary vehicle prelaunch operations and for location of the planetary vehicle checkout equipment and associated computers. The remaining area in the low bay will be used for support personnel office space, project control, and other service and support facilities.

The high bay area also incorporates a special sealed chamber to conduct ETO decontamination of the planetary vehicle-shroud assembly. The chamber is sealed to prevent ETO from escaping, if a minor leak develops in the shroud. Housing is required for the equipment to control the volume, temperature, humidity, and flow, including storage tanks. In addition storage facilities, filtering and sterilization filters and controls will be provided for the dry sterilized nitrogen purge following the ETO decontamination. The chamber will be accessible from the high bay area and will be approximately 50 x 50 x 50 feet high.

The high bay area will incorporate a 25-ton traveling bridge crane. In addition all electrical equipment will be explosion proof and necessary features will be incorporated into the design to permit pressurization of the vehicle pneumatic system, installation of ordnance devices, and loading of vehicle propellants. The air lock portion of the high bay will be used to receive the capsule and spacecraft and remove them from the road transportation covers. The high bay assembly and test area will be of sufficient area to accommodate three planetary vehicles.

13.2.4.2 Planetary Vehicle Checkout Equipment

The equipment required to conduct prelaunch operations for each planetary vehicle will be identical to that utilized to conduct handling, checkout, and acceptance tests in the factory.

Several items of handling equipment will be required at the launch site for planetary vehicle operations which are not required in any manufacturing facility, such as the planetary vehicle handling equipment and the planetary vehicle-transportation equipment. The spacecraft and capsule checkout and associated equipment will be combined into one planetary vehicle checkout test set.

13.2.4.3 Planetary Vehicle Operating Personnel

Each of the three planetary vehicles will be prepared for launch by a combination of spacecraft and capsule launch operations personnel from the teams responsible for the manufacturing, assembly, and test at the factory. An operations crew will be required for each of the planetary vehicles. A total of approximately 65 technicians will be required to support each planetary vehicle prelaunch operation. In addition, a staff of secretaries, maintenance personnel for the capsule support equipment, spare part storage personnel, and other administrative supporting staff will be required throughout planetary vehicle prelaunch and launch operations.

13.2.4.4 Procedures and Documentation

Prelaunch checkout and launch countdown procedures will be generated to outline all tasks required to assure the planetary vehicle system performance is within the specified values. Documentation will be prepared for all test procedures and operations from receiving inspection through final launch countdown and prelaunch evaluations. Check lists, inspection reports, failure and correction reports, and contamination control reports will be prepared.

13.3 REQUIREMENT AND CONSTRAINTS

13.3.1 Maintenance

Maintenance for the Saturn V launch vehicle and support systems will utilize existing maintenance concepts established for the Saturn V Apollo program. No changes in the current maintenance plan are anticipated to meet specific Voyager project requirements, and this plan will apply to the launch vehicle, launch vehicle operational support equipment, and facilities utilized at Complex 39, Kennedy Space Center.

Maintenance for the spacecraft, capsule, experiments, planetary vehicle and shroud assembly, including associated support equipment and facilities, will be accomplished at the assembly replacement level. Maintenance will not be performed on encapsulated planetary vehicles after final surface decontamination. The backup planetary vehicle-shroud assembly will be utilized when a no-go condition exists with a primary unit. Modifications will not be permitted on capsule, spacecraft, or planetary vehicle hardware unless possible under the assembly replacement concept. Replacement modules will be flight qualified to procedures utilized for the primary flight hardware. This policy will also apply to support equipment. Failed modules will be returned to the point of manufacture for repair, where feasible.

A scheduled maintenance procedure will be generated for spacecraft and capsule support equipment. Inspection and preventative maintenance will be performed at scheduled intervals during the Voyager mission series. Scheduled maintenance of subsystem elements will be consistent with established MTBF levels of the associated equipment. Scheduled maintenance of the launch vehicle and associated support systems will be in accordance with the Saturn V maintenance plan applicable to all Saturn V launch vehicles, support equipment, and facilities.

13.3.2 Transportation

The launch vehicle transportation plan for Voyager will be the same as the existing plan now utilized for the current Saturn V-Apollo system. The Voyager spacecraft, capsule, and support equipment will be designed for transportation by road and by air. Road transportation will utilize improved roadways. Speed is not a critical requirement. Proper protection from shock and environmental conditions during transportation will be provided for all elements of the spacecraft system based upon system design requirements and constraints.

13.3.3 Logistics

The logistics plan for the Saturn V-Apollo system will be utilized for Voyager launch vehicle mission support. The logistics plan for spacecraft, capsule, and support equipment will be consistent with the module replacement policy. Determination of spare part requirements will be based upon MTBF levels assigned to specific modules. Spare part requirements will take into account provision of one complete spare planetary vehicle and shroud section, as well as an additional spare capsule and associated science experiment equipment for each flight mission.

13.3.4 Facilities

The launch vehicle will utilize existing facilities at KSC Complex 39, including associated support equipment. Additional facilities are required as follows:

- Spacecraft assembly facility
- Capsule assembly facility, including capsule heat sterilization capability
- Explosive safe area for planetary vehicle preparation, encapsulation, and terminal decontamination

The SAF and ESA will be under the cognizance of the spacecraft SMO for use by the spacecraft contractor. The CAF will be under the cognizance of the capsule SMO for use by the capsule contractor. These facilities will be provided to the cognizant SMO in response to requirements established by appropriate Voyager project office approved requirements documents.

13.3.5 Contamination Control and Sterilization

Contamination control and sterilization for the spacecraft and capsule, including experiments, will be in keeping with the approved Voyager Planetary Quarantine Plan.

13.3.6 Flight Readiness

All Voyager systems will demonstrate flight readiness and compatibility with each interfacing system. All system testing will be designed to assure operability of all systems when combined for the specified Voyager mission. Capability will be provided to enable launch from KSC Launch Complex 39 within a 20-day launch window, constrained to a minimum one hour per day opportunity, with a probability of 0.99. A basic assumption utilized in calculating the required launch vehicle launch probability is that planetary vehicles will cause no holds during the terminal countdown.

13.4 ORGANIZATION AND RESPONSIBILITIES

This section discusses the organization and responsibilities for Voyager launch site operations. The overall organization shown in

Figure 36 functions under the Voyager launch operations director, who in turn reports to the Voyager mission director. The Voyager mission director is responsible to the Voyager project manager for the operational phase of each Voyager mission. His responsibilities include coordination of launch and mission operational schedules and the resolution of major operational problem areas. He will act for the project manager to make operational decisions needed during any phase of operations from prelaunch through mission completion.

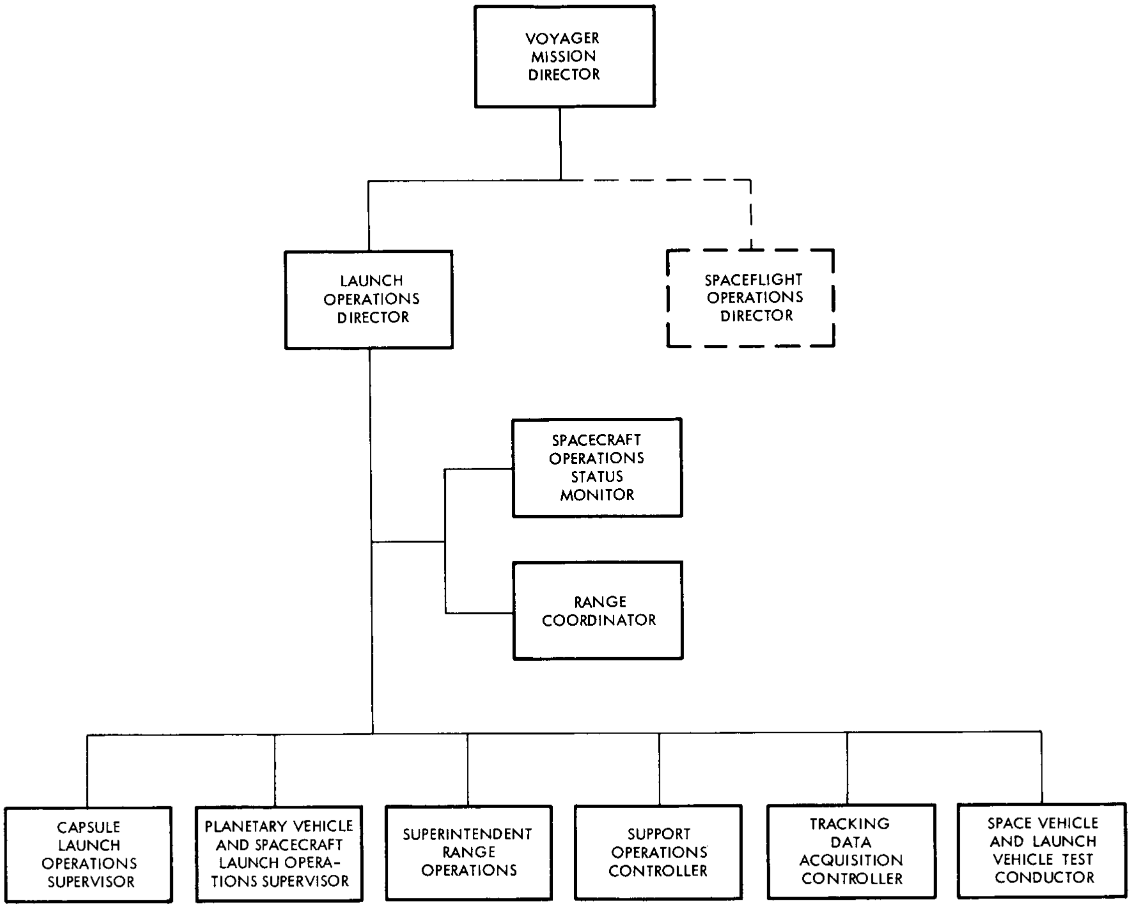


Figure 36. Launch Operations Organization

13.4.1 Launch Operations Director

The launch operations director (who is the launch operations system manager or his designated representative) is responsible for overall management and technical activities of all Voyager launch site operations. The director during prelaunch, launch, powered flight, and earth orbit injection is responsible to the Voyager mission director for the following:

- Provide assurance that the launch site operations organization and launch site support systems are in a launch-ready condition and the specified Voyager launch window will be achieved
- Continue to maintain space vehicle configuration control in accordance with the established Voyager Configuration Management Manual
- Exercise control of all elements of the launch complex and support systems for implementation and coordination to establish and maintain a state of readiness as required to support the Voyager program
- Preside at KSC management meetings concerning Voyager launch operations and inform capsule, planetary vehicle/spacecraft, launch vehicle, and space vehicle launch operation conductors of problem areas which may affect system interfaces, launch, or success of the mission
- Resolve problem areas which may arise between Voyager operating system elements with respect to sequence of operations, support systems, or system interferences and interfaces
- Coordinate functions of the launch site operations organizations with AFETR support organizations
- Compile and publish the Voyager master countdown document based upon schedule and terminal data furnished by cognizant system managers
- Maintain control of all Voyager program hazardous areas during operations through implementation of established KSC safety procedures
- Direct activities of the launch operations conductor for the planetary vehicle and launch vehicle, maintain test schedules, and provide assistance in resolving problem areas which could jeopardize the probability of meeting the launch window
- Issue final clearance for the Voyager launch

The organization under the launch site operations director consists of his staff and designated representatives from capsule launch operations, planetary vehicle and spacecraft launch operations, space vehicle and launch vehicle operations, tracking and data acquisition operations, and launch support operations. The associated functions are discussed below.

13.4.2 Spaceflight Operations Status Monitor

The spaceflight operations status monitor is responsible to the launch operations director for coordination of activities between launch operations and spaceflight operations. His responsibilities are as follows:

- Maintain current status of all spaceflight operations with particular emphasis on interfaces between these operations and launch operations
- Report to the launch operations director a summary of spaceflight operations status and problem areas which may affect launch operations
- Aid the launch operations director in resolving problem areas related to the above

13.4.3 Range Coordinator

The range coordinator is responsible to the launch operations director for coordination of all AFETR range support activities during Voyager launch operations. His responsibilities are as follows:

- Disseminate pertinent Voyager operational information to AFETR
- Maintain AFETR support status information and make this available to the launch operations director
- Coordinate with the Voyager complex support operations controller and assist in arranging for AFETR ground support
- Coordinate the KSC-AFETR support activities input to the Voyager project support requirements document

13.4.4 Superintendent of Range Operations

The superintendent of range operations (SRO) is responsible to the launch operations director for coordination and control of AFETR resources during Voyager operations. The SRO is the representative of the Department of Defense and will be responsible for the operational readiness of AFETR support systems and personnel in the following areas: range safety, security, range data acquisition and tracking, and weather observations and forecasting.

The operations directive prepared by AFETR in response to the Voyager program requirements document is the instrument which provides guidelines to which the SRO will operate.

13.4.5 Tracking and Data Acquisition Controller

The tracking and data acquisition controller is responsible to the launch operations director for tracking and data acquisition operations during prelaunch through insertion into earth orbit. His responsibilities are as follows:

- Assure that all instrumentation under his control is manned and ready to support Voyager prelaunch and launch operations, specified in the Voyager program support plan
- Provide the launch operations director with equipment status and test progress, and disseminate information to supporting engineers under his jurisdiction
- Inform the launch operations director of instrumentation configuration changes which may affect support capability
- Resolve scheduling and equipment support problems within tracking and data acquisition operations
- Establish interfaces with KSC and AFETR operations to assure required data is received, processed, and transmitted to the required Voyager support areas
- Provide assistance to the spaceflight operations director in postflight analysis for trajectory reconstruction, orbit analysis, guidance and control system performance analysis, etc.

13.4.6 Support Operations Controller

The support operations controller will be responsible to the launch operations director for the readiness of launch complex support systems and associated equipment. His responsibilities are as follows:

- Maintenance of test schedules and assurance that launch complex support is provided as required
- Resolve problems and assign priorities when launch complex support requirements conflict
- Provide information to supporting organizations as required to assure elimination of delays during the launch operations

The support operations organization is shown in Figure 37. The responsibility of the support operations organization is to provide KSC Launch Complex 39 in a ready condition to launch the Voyager space vehicle. Responsibilities of key support operations personnel are described below:

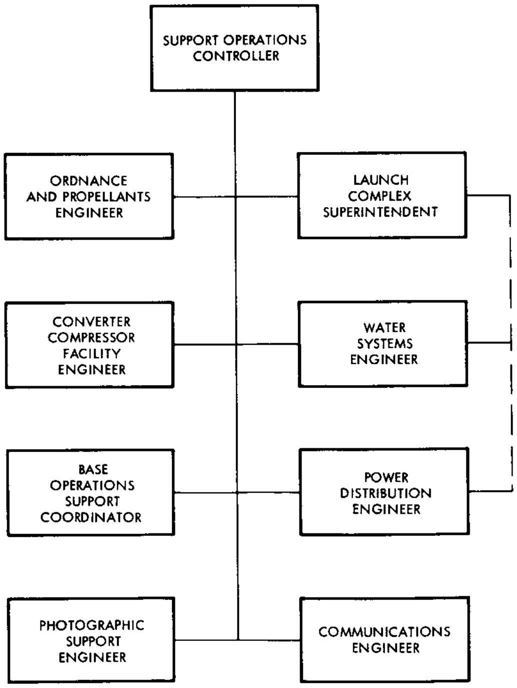


Figure 37. Support Operations Organization

13.4.6.1 Ordnance and Propellant Engineer

The ordnance and propellant engineer is responsible to the support operations controller for delivery of launch and space vehicle ordnance items and propellants to the launch pad as required to meet prelaunch checkout and launch requirements within the launch schedule. The responsibilities are as follows:

- Determine ordnance and propellant requirements for each Voyager launch and procure
- Coordinate and arrange the delivery schedule for each item consistent with the published Voyager launch schedule
- Coordinate delivery procedures to insure KSC and AFETR safety and security standards are met
- Assure required testing and analysis is performed to determine quality control characteristics of each item and prescribed specifications achieved

13.4.6.2 Converter-Compressor Facility Engineer

The converter-compressor facility engineer is responsible to the support operations controller for operational readiness of the converter-compressor facility. The responsibilities are as follows:

- Ascertain requirements for gaseous nitrogen and helium and assure that storage facilities at the Complex 39 launch facility meet program requirements
- Maintain an up-to-date test and checkout schedule and assure that the facility is manned to meet the schedule
- Direct operations and maintenance of this facility

13.4.6.3 Launch Complex Superintendent

The launch complex superintendent is responsible to the support operations controller for the operational readiness of Launch Complex 39 facilities and equipment. The responsibilities are as follows:

- Schedule equipment usage and maintenance downtime to assure the launch complex can support the Voyager prelaunch checkout and launch schedule

- Provide a point of contact for coordination and control of all contractors performing maintenance, modification, or construction tasks at the launch complex

- Coordinate modifications, deletions, or additions to the launch complex or activities of any design or engineering group performing modification activities

- Direct standard operations, maintenance, and services required for the service structures, umbilical tower, and launch pad with the exception of support equipment and instrumentation systems

- Assure that required water and power services are available at predesignated service points and required volume and flow rates are achieved as specified in the Launch Complex 39 operation instructions

13.4.6.4 Communications Engineer

The communications engineer is responsible to the support operations controller for the operational readiness of launch site intercommunication, television, data transmission, public address, oral countdown, point-to-point telephone, wire pairs, and mobile radio systems. The responsibilities are as follows:

- Assure that all communication consoles are calibrated, sealed, and operational prior to initiation of final checkout, terminal countdown, and launch

- Maintain awareness of all communication requirements and schedules and arrange for proper implementation

- Provide direct support to the space vehicle launch operations supervisor as required during prelaunch checkout, terminal countdown, and launch operations

13.4.6.5 Water System Engineer

The water system engineer is responsible to the support operations controller for the operational readiness of all water systems at the launch pad. The responsibilities are as follows:

- Assure that water storage and pumping facilities are in a ready condition to meet launch requirements
- Operate and maintain water from the point of entrance at the launch complex to the point of usage
- Coordinate and assist the complex superintendent in establishing and implementing all water system requirements

13.4.6.6 Power Distribution Engineer

The power distribution engineer is responsible to the support operations controller for the operational readiness of all power distribution equipment. The responsibilities are as follows:

- Assure that power is available at the correct phase and voltage to meet operational requirements
- Assure that proper backup power sources are available and switching devices operational to assure meeting the Voyager launch window
- Operate and maintain power distribution systems from the point of entrance of the power source at the launch complex to the point of usage

13.4.6.7 Base Operations Support Coordinator

The base operations support coordinator is responsible to the support operations controller for fire protection, heavy equipment support, and press site activation during all Voyager prelaunch and launch activities. The responsibilities are as follows:

- Arrange for adequate fire fighting equipment required by the KSC-AFETR safety plan during all operations involving propellants, cryogenics, ordnance, and other hazardous devices
- Arrange for the use of special heavy fire protection equipment as necessary which is not normally assigned to the standard launch complex fire-fighting equipment pool
- Direct setup and activation of press site facilities to insure adequate support

- Provide continuous support to the capsule assembly building, spacecraft assembly building and explosive safe area during all phases of spacecraft, capsule, and planetary vehicle prelaunch operations

13.4.6.8 Photographic Support Engineer

The photographic support engineer is responsible to the support operations controller for photographic support of Voyager prelaunch and launch operations. Still and motion picture photographic coverage will be based upon requirements established in Voyager support requirements documentation. The responsibilities are as follows:

- Ascertain photographic coverage requirements for prelaunch and launch operations and arrange for timely acquisition and deployment of cameras and services to support these requirements
- Assure that copies of all requested photographic coverage are submitted to agencies of the Voyager project requesting this service through Voyager support requirements documentation

13.4.7 Space Vehicle and Launch Vehicle Test Conductor

The space vehicle and launch vehicle test conductor is responsible to the launch operations director for successful completion of launch vehicle prelaunch activity and space vehicle checkout and testing. His responsibilities are as follows:

- Execute launch vehicle prelaunch and launch tasks and procedures outlined in the Saturn V master countdown document
- Resolve problem areas concerning the sequence of launch vehicle operations, support equipment, and launch vehicle interfaces or interfaces between launch vehicle stages and the instrument unit
- Report launch vehicle system status to the launch operations director during prelaunch and launch operations
- Coordinate activities of individual launch vehicle stage operations and space vehicle systems engineering personnel and assist in resolving operational problems as they occur

- Obtain final clearance to launch from the launch operations director and initiate the firing command

- Monitor telemetered data during space vehicle powered flight and participate in making range safety and alternate mission mode recommendations

The space vehicle and launch vehicle test conductor is supported by test conductors and their associated teams for each launch vehicle segment as shown in Figure 38.

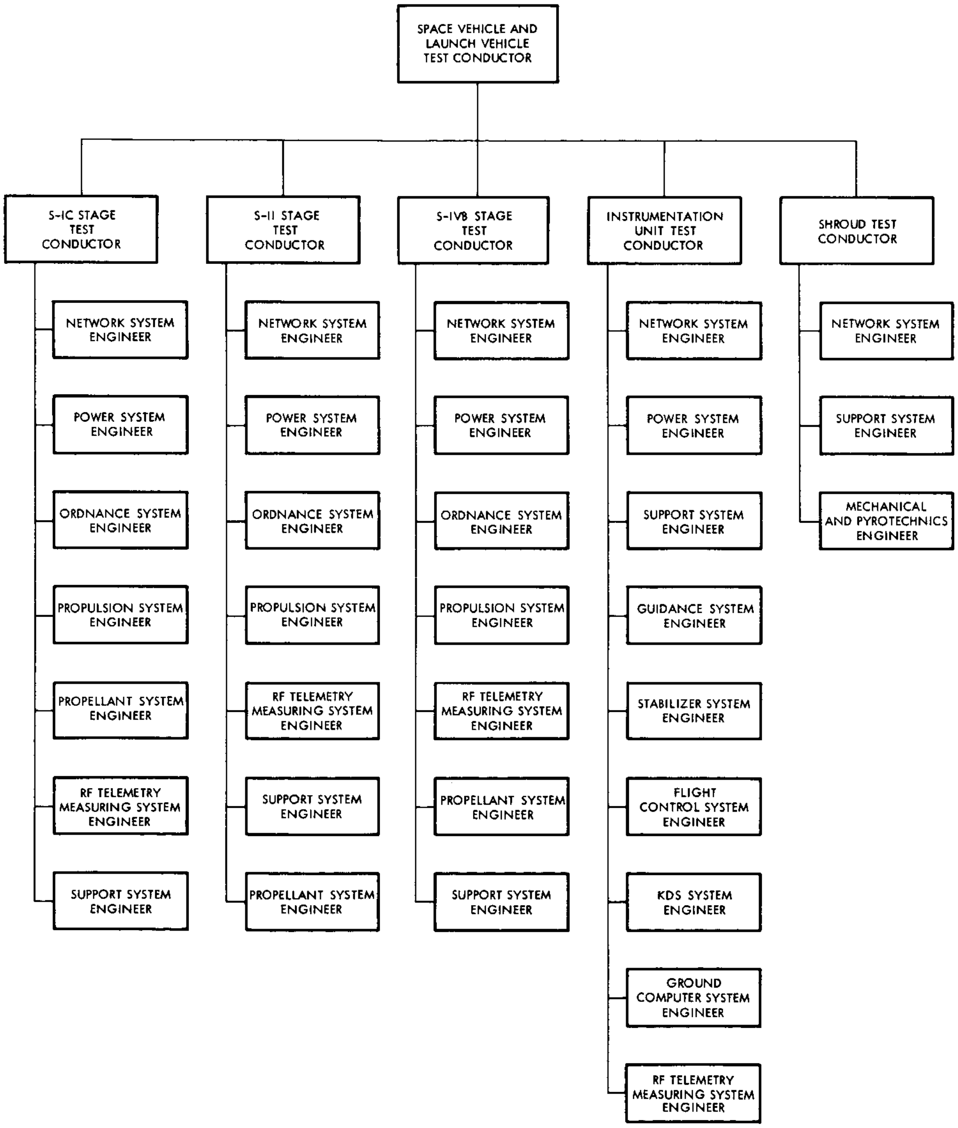


Figure 38. Space Vehicle and Launch Vehicle Operations Organization

13.4.8 Planetary Vehicle and Spacecraft Launch Operations Supervisor

The planetary vehicle and spacecraft launch operations supervisor is responsible to the launch operations director for successful completion of prelaunch and launch activities during spacecraft and planetary vehicle checkout and launch sequences. His responsibilities are as follows:

- Execute spacecraft and planetary vehicle prelaunch checkout and launch operation tasks and procedures as outlined in the master countdown document
- Coordinate spacecraft and planetary vehicle activities with the launch operations director and integrate these activities with the final space vehicle launch operation
- Resolve problems arising during any sequence of spacecraft and planetary vehicle prelaunch operations regarding support systems and flight hardware interfaces and between the planetary vehicle and the launch vehicle segments
- Report spacecraft and planetary vehicle system status to the launch operations director during all phases of prelaunch through launch operations
- Disseminate information to the capsule, spacecraft, and shroud test conductors regarding planetary vehicle launch operations

The spacecraft approach is to utilize the same test conductor and key personnel for launch operations that performed test functions for a particular flight spacecraft during the factory acceptance testing activities. The spacecraft test conductor for a particular spacecraft article becomes the planetary vehicle test conductor after capsule integration with the spacecraft. The associated capsule test conductor then assists him during planetary vehicle operations. Similarly, the shroud test conductor also assists during planetary vehicle operations with the shroud. The shroud test conductor assumes control of the planetary vehicle-shroud assembly when it leaves the ESA for transport to the launch pad.

13.4.9 Capsule Launch Operations

The capsule launch operations supervisor has overall responsibility to the launch operations director for all capsule prelaunch and launch activities. He is also responsible to the spacecraft and planetary vehicle launch operations supervisor for capsule support after integration of a capsule as part of a planetary vehicle.

A capsule test conductor, reporting to the capsule launch operation supervisor, is assigned to each flight capsule starting with factory acceptance operations, along with a surface laboratory test conductor, a mobile unit test conductor, and an RTG test conductor. These associated test conductors support the capsule test conductor in regard to their respective system segments. The capsule test conductor in turn supports the planetary vehicle test conductor during planetary vehicle operations.

13.5 OPERATIONAL FLOW

This section describes the launch site operations required for all segments of the Voyager space vehicle commencing with shipment of hardware to KSC and ending with injection of the space vehicle into earth orbit. Basic tasks for each segment of the launch site operational flow are described, and a detailed time-line diagram is given in Figure 39.

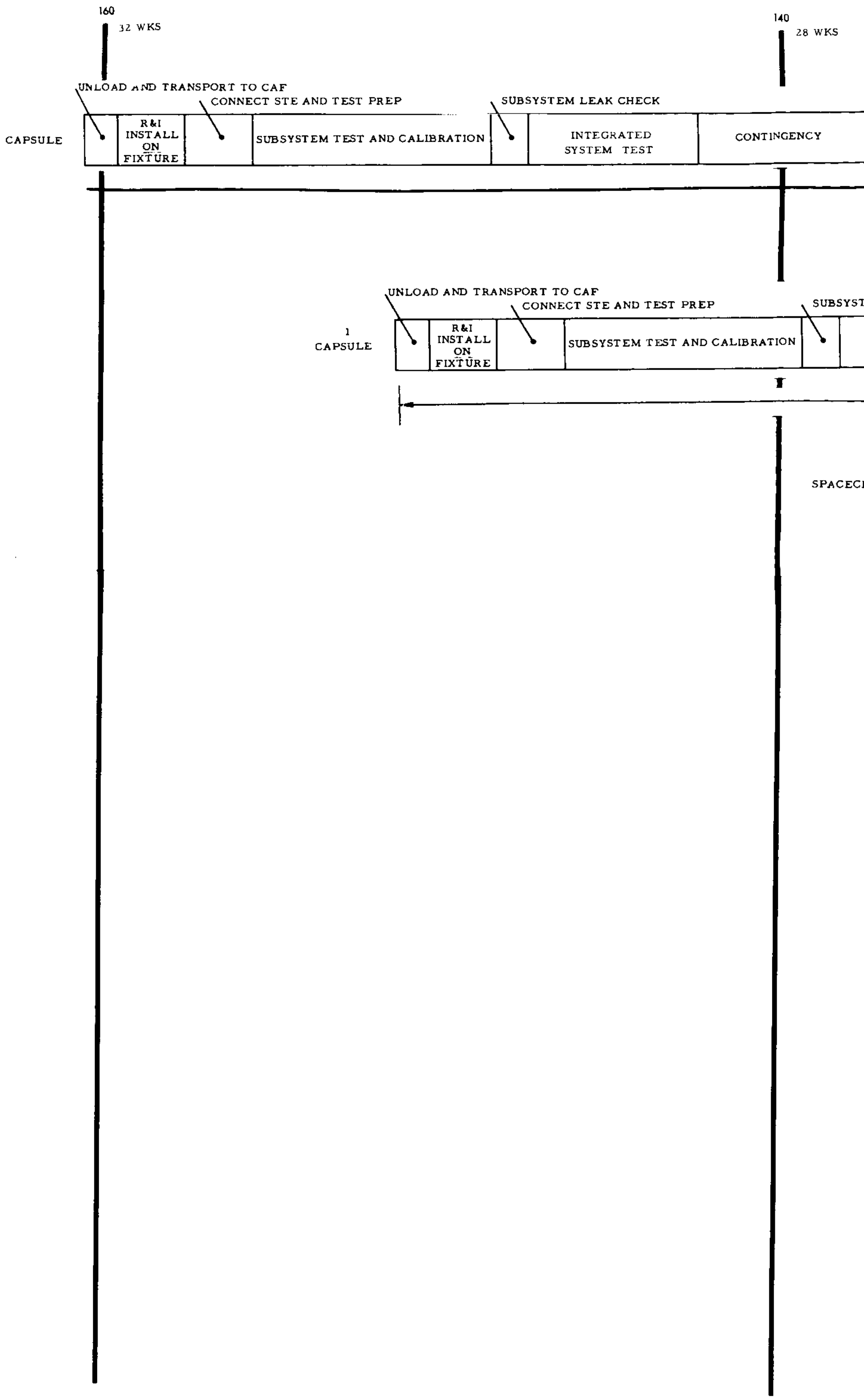
13.5.1 Capsule Operations

After a flight capsule has complete its mission acceptance testing and review at the capsule contractor's facility, it is prepared for air shipment to the launch site. The RTG nuclear element is shipped separately to KSC directly from the preparation facility at the AEC Mound Laboratory. The flight capsule will be shipped in a near flight configuration or if necessary with elements such as the mobile unit shipped separately. The flight capsule is packaged in its shipping container and protective covers and the transportation environmental control system is connected. Recording instrumentation for shock, temperature, humidity, and other required environmental conditions is checked out and also installed into the shipping containers. These operations are under the direction of the responsible capsule test conductor. The packaged flight capsule is transported by road van to the aircraft, loaded on the aircraft, and transported to KSC.

At KSC, the capsule is removed from the aircraft and transported to the capsule assembly facility for unpacking and receiving inspection. It is then mounted on a checkout fixture and prepared for system checkout. All electrical connections to the special test equipment are made and a continuity test conducted. Instrumentation, experiments, and mechanical systems are calibrated and checked as individual subsystems. A subsystem leak check is performed, using inert gas procedures. Upon acceptance of each subsystem, the complete capsule is interconnected and an all-systems test conducted. A period of time has been allowed for contingencies to permit basic modular replacement if it is required.

After the integrated system test with an electrical heat source, the RTG isotope element is installed, all pyrotechnics are installed with proper shorting plugs, and a pyro system electrical continuity test conducted. A final integrated system test is then conducted. A capsule weight and center of mass test is then performed. The canister is then installed over the capsule and sealed in preparation for terminal sterilization operations. After the canister is installed and mating interfaces inspected, the capsule is removed from the checkout stand, the spacecraft simulator removed, and the capsule placed on a transport vehicle and transported to the sterilization oven. At the completion of the sterilization cycle, the capsule is transported back to the capsule test and checkout area and reinstalled on the checkout stand for verification of the sterilization operation. If sterilization is not verified the heat sterilization process will be repeated.

After sterilization the capsule is reconnected to the test equipment and spacecraft simulator and a final integrated system test conducted. At the successful completion of this test, a certification of a readiness condition is submitted to the capsule launch operations supervisor. The spacecraft electrical simulator is removed, the test equipment disconnected, and the capsule is prepared for storage until required for backup or planetary vehicle operations, or is prepared for direct transport to the explosive safe area for planetary vehicle integration. If the capsule is to be stored, it will be installed in a dust protective cover, sealed in a shipping container, and transported to the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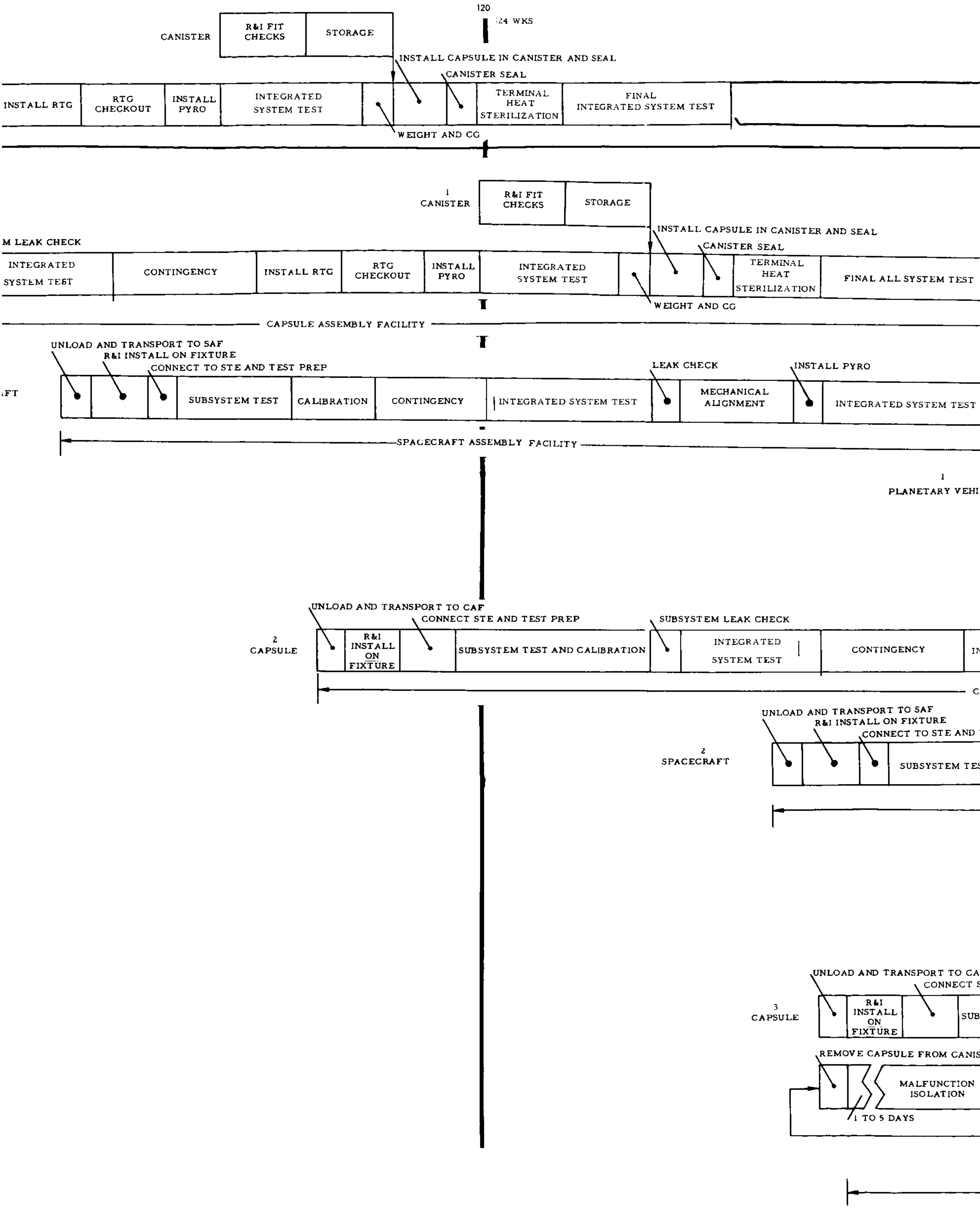
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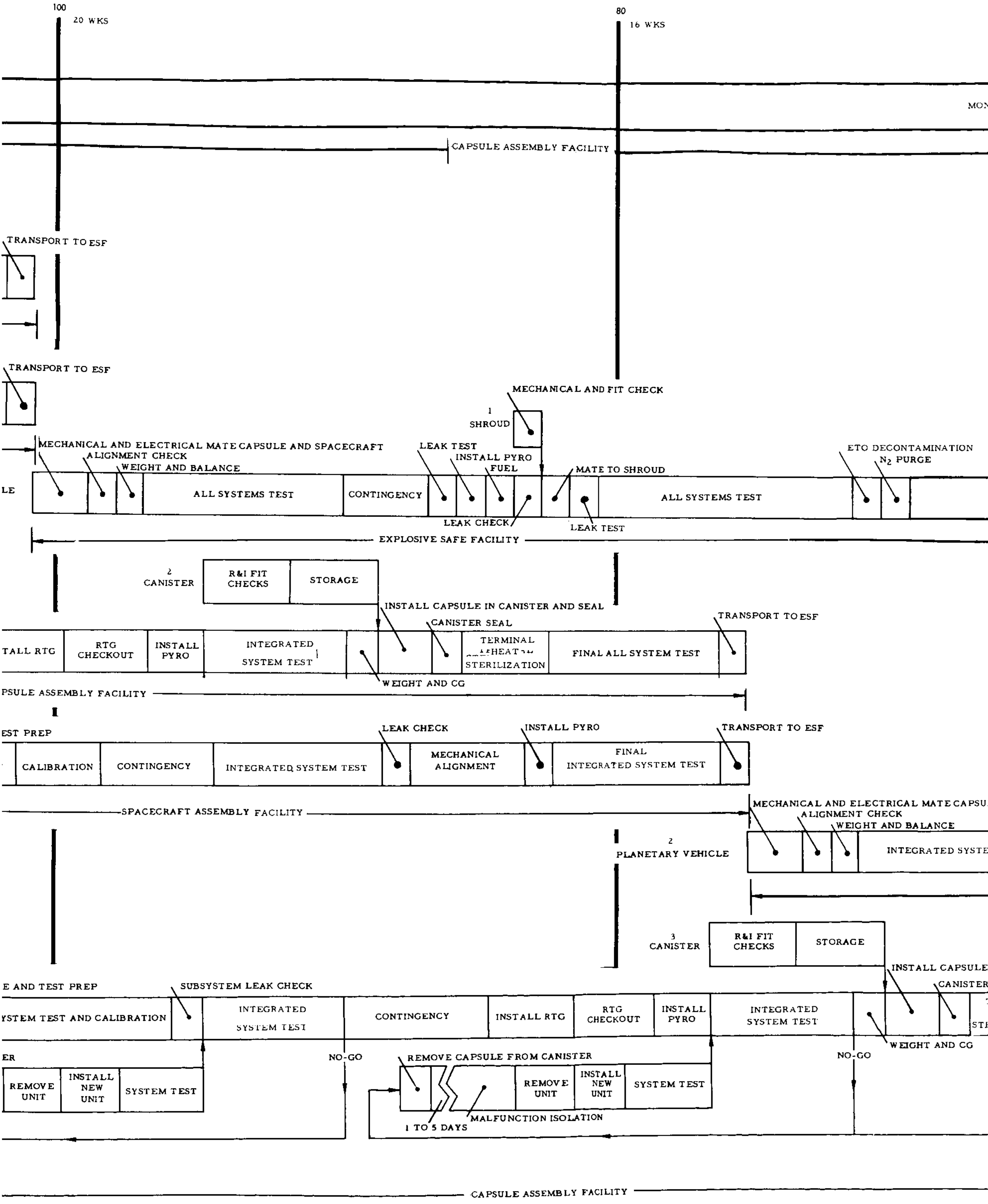
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MALFUNCTION ISOLATION
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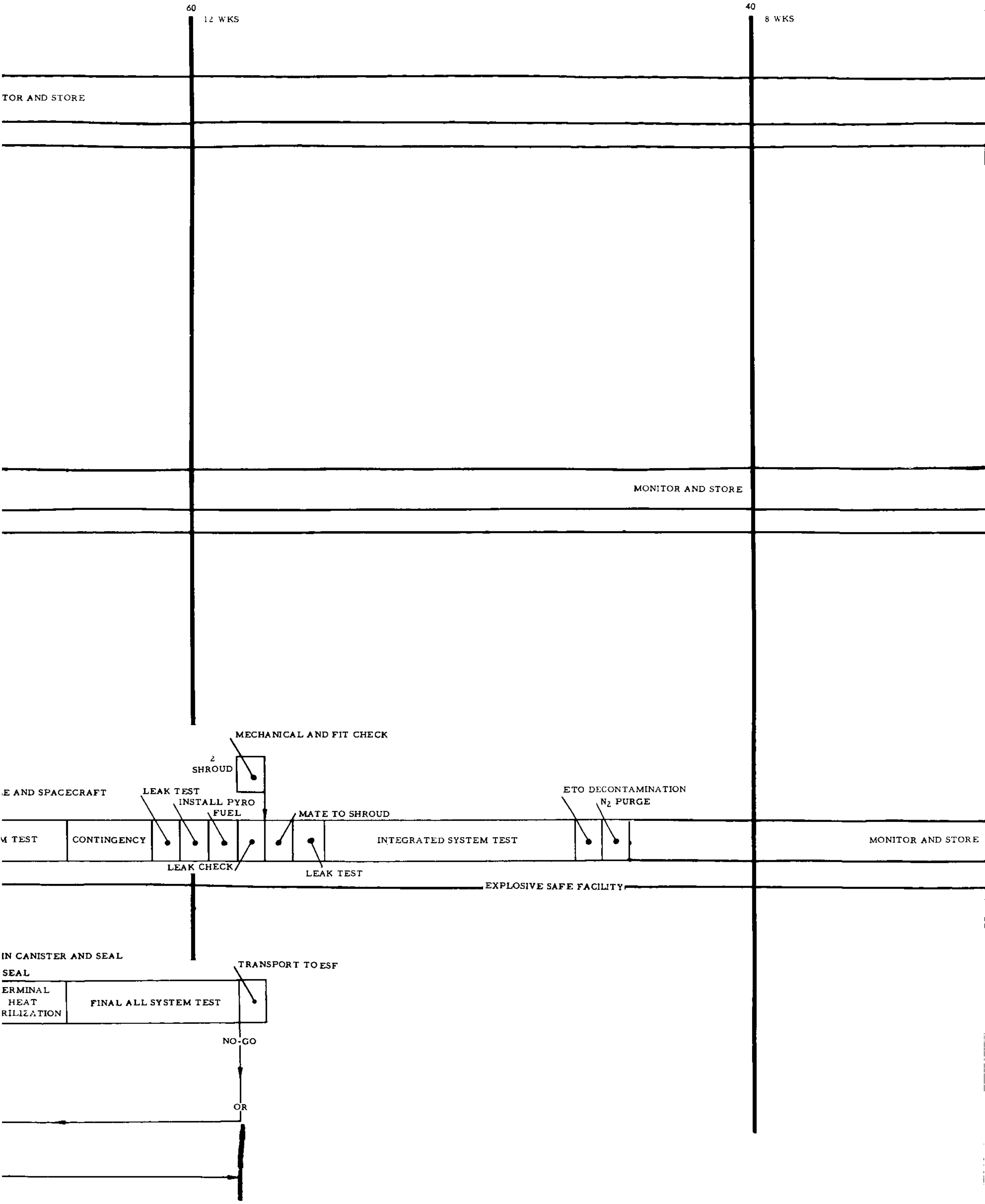
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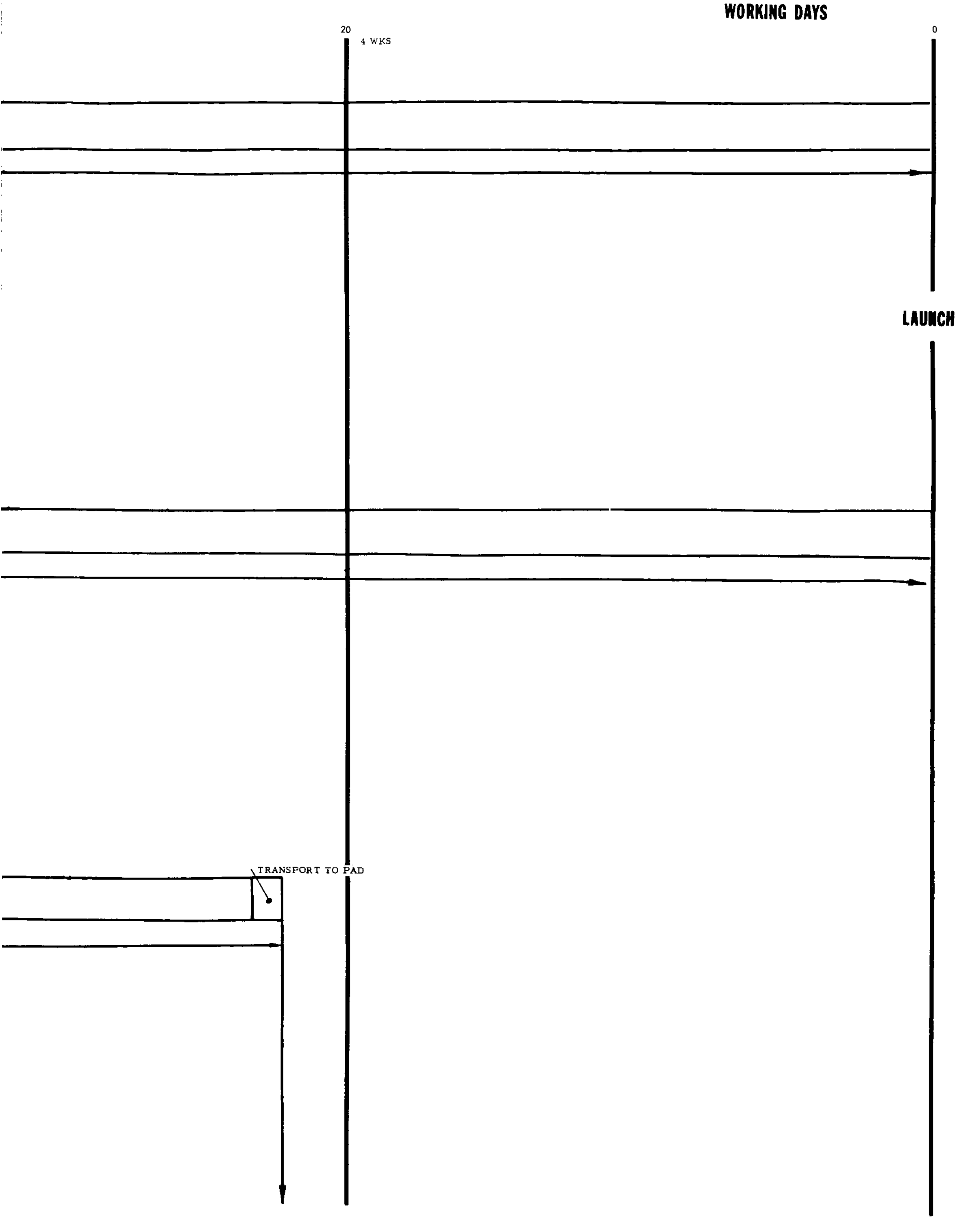
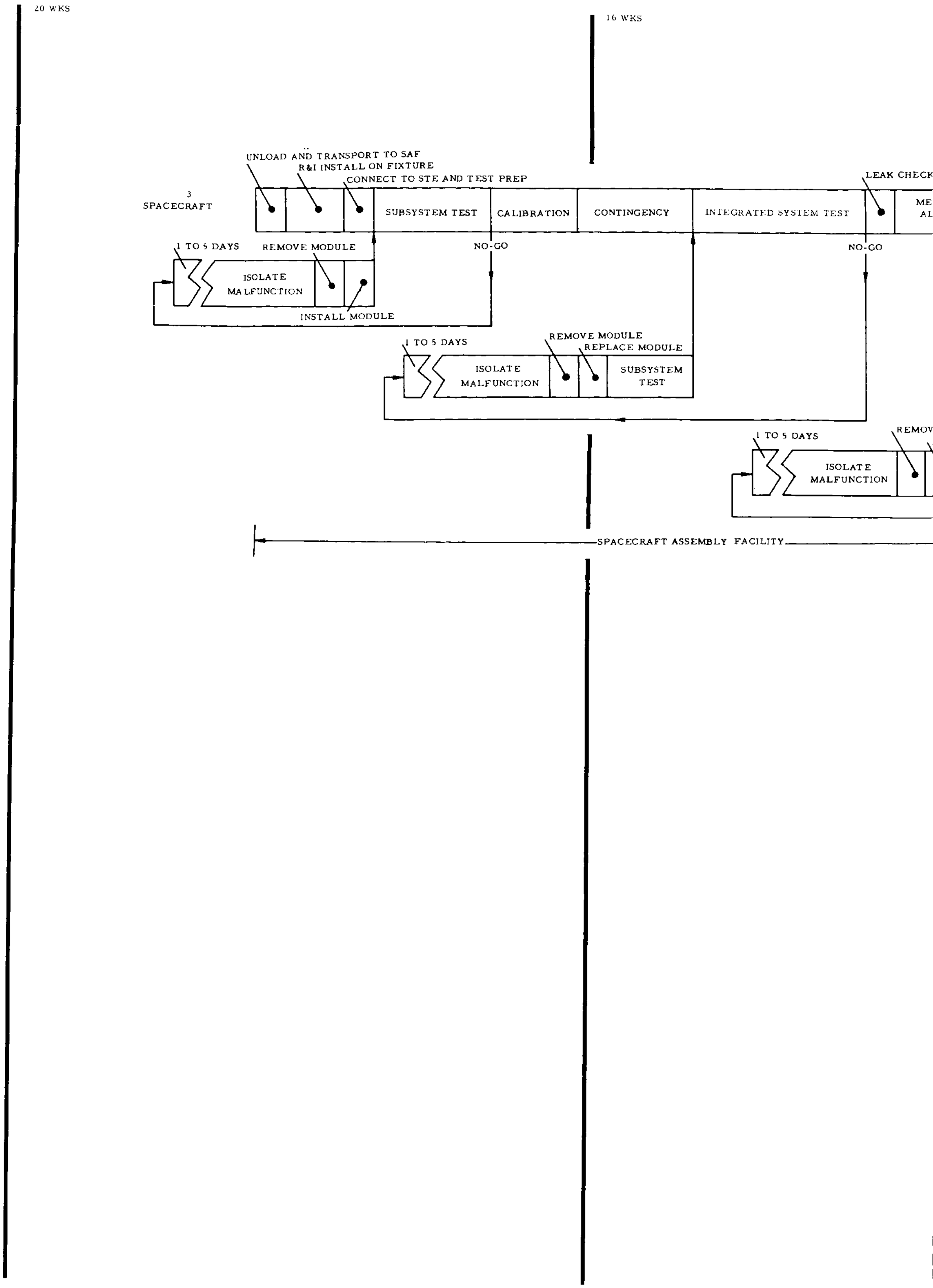
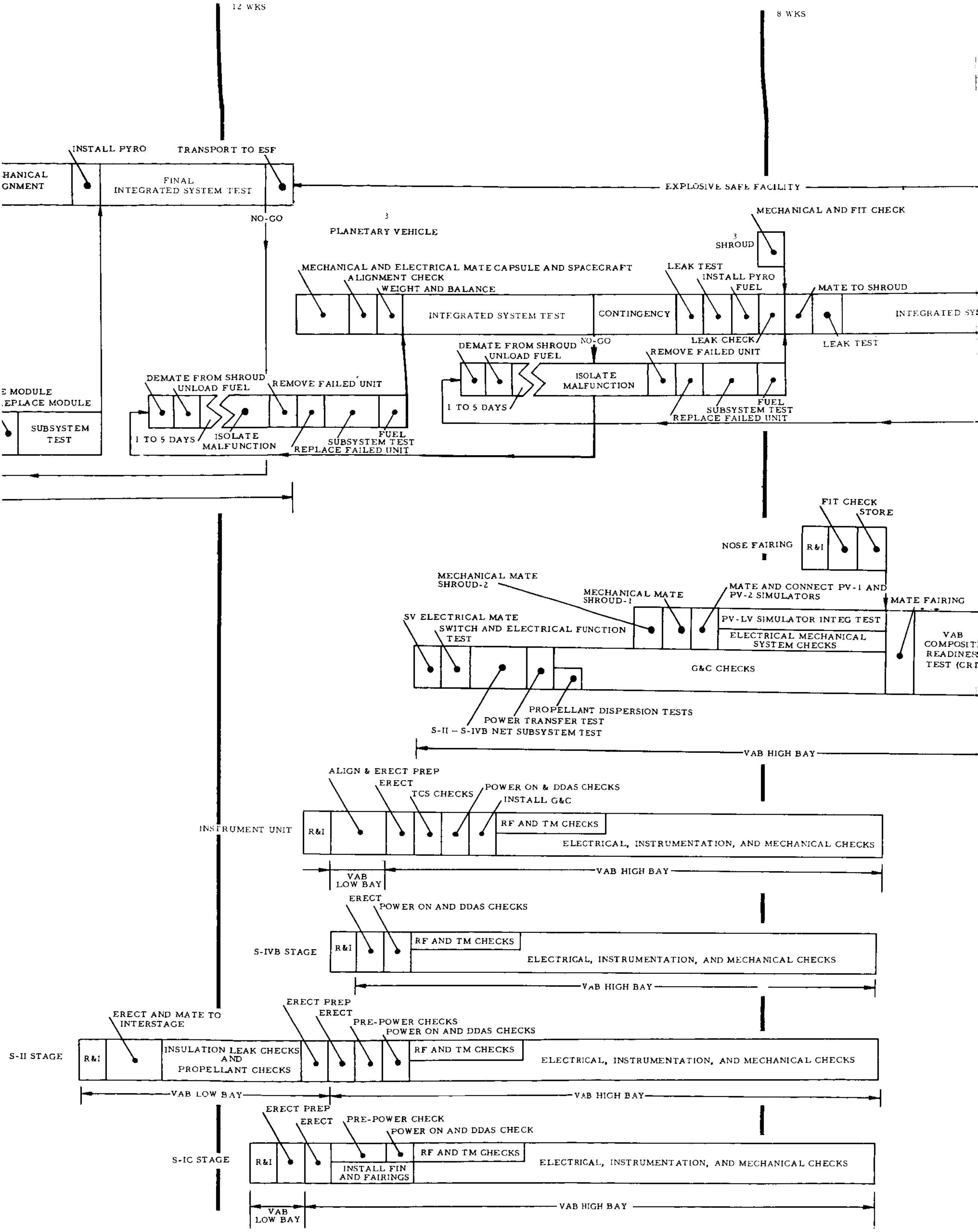


Figure 39. System Flow at Launch Site


20 WKS
16 WKS
UNLOAD AND TRANSPORT TO SAF
R&I INSTALL ON FIXTURE
CONNECT TO STE AND TEST PREP
3
SPACECRAFT
SUBSYSTEM TEST
CALIBRATION
CONTINGENCY
INTEGRATED SYSTEM TEST
LEAK CHECK
ME
AL
1 TO 5 DAYS
REMOVE MODULE
NO-GO
ISOLATE MALFUNCTION
INSTALL MODULE
1 TO 5 DAYS
REMOVE MODULE
REPLACE MODULE
ISOLATE MALFUNCTION
SUBSYSTEM TEST
NO-GO
1 TO 5 DAYS
REMOV
ISOLATE MALFUNCTION
SPACECRAFT ASSEMBLY FACILITY


12 WKS
8 WKS
INSTALL PYRO
TRANSPORT TO ESF
HANICAL
GNMENT
FINAL INTEGRATED SYSTEM TEST
EXPLOSIVE SAFE FACILITY
NO-GO
3
PLANETARY VEHICLE
MECHANICAL AND FIT CHECK
3
SHROUD
MECHANICAL AND ELECTRICAL MATE CAPSULE AND SPACECRAFT
ALIGNMENT CHECK
WEIGHT AND BALANCE
LEAK TEST
INSTALL PYRO
FUEL
MATE TO SHROUD
INTEGRATED SYSTEM TEST
CONTINGENCY
INTEGRATED SY
LEAK CHECK
LEAK TEST
DEMATE FROM SHROUD
UNLOAD FUEL
NO-GO
REMOVE FAILED UNIT
ISOLATE MALFUNCTION
1 TO 5 DAYS
FUEL
SUBSYSTEM TEST
REPLACE FAILED UNIT
DEMATE FROM SHROUD
UNLOAD FUEL
REMOVE FAILED UNIT
E MODULE
EPLACE MODULE
SUBSYSTEM TEST
1 TO 5 DAYS
ISOLATE MALFUNCTION
FUEL
SUBSYSTEM TEST
REPLACE FAILED UNIT
FIT CHECK
STORE
NOSE FAIRING
R&I
MECHANICAL MATE SHROUD-2
MECHANICAL MATE SHROUD-1
MATE AND CONNECT PV-1 AND PV-2 SIMULATORS
MATE FAIRING
SV ELECTRICAL MATE
SWITCH AND ELECTRICAL FUNCTION TEST
PV-LV SIMULATOR INTEG TEST
ELECTRICAL MECHANICAL SYSTEM CHECKS
G&C CHECKS
VAB COMPOSIT READINES TEST (CRI
PROPELLANT DISPERSION TESTS
POWER TRANSFER TEST
S-II – S-IVB NET SUBSYSTEM TEST
VAB HIGH BAY
INSTRUMENT UNIT
ALIGN & ERECT PREP
ERECT
TCS CHECKS
POWER ON & DDAS CHECKS
INSTALL G&C
R&I
RF AND TM CHECKS
ELECTRICAL, INSTRUMENTATION, AND MECHANICAL CHECKS
VAB LOW BAY
VAB HIGH BAY
S-IVB STAGE
ERECT
POWER ON AND DDAS CHECKS
R&I
RF AND TM CHECKS
ELECTRICAL, INSTRUMENTATION, AND MECHANICAL CHECKS
VAB HIGH BAY
S-II STAGE
ERECT AND MATE TO INTERSTAGE
ERECT PREP
ERECT
PRE-POWER CHECKS
POWER ON AND DDAS CHECKS
R&I
INSULATION LEAK CHECKS AND PROPELLANT CHECKS
RF AND TM CHECKS
ELECTRICAL, INSTRUMENTATION, AND MECHANICAL CHECKS
VAB LOW BAY
VAB HIGH BAY
S-IC STAGE
ERECT PREP
ERECT
PRE-POWER CHECK
POWER ON AND DDAS CHECK
R&I
INSTALL FIN AND FAIRINGS
RF AND TM CHECKS
ELECTRICAL, INSTRUMENTATION, AND MECHANICAL CHECKS
VAB LOW BAY
VAB HIGH BAY

2501

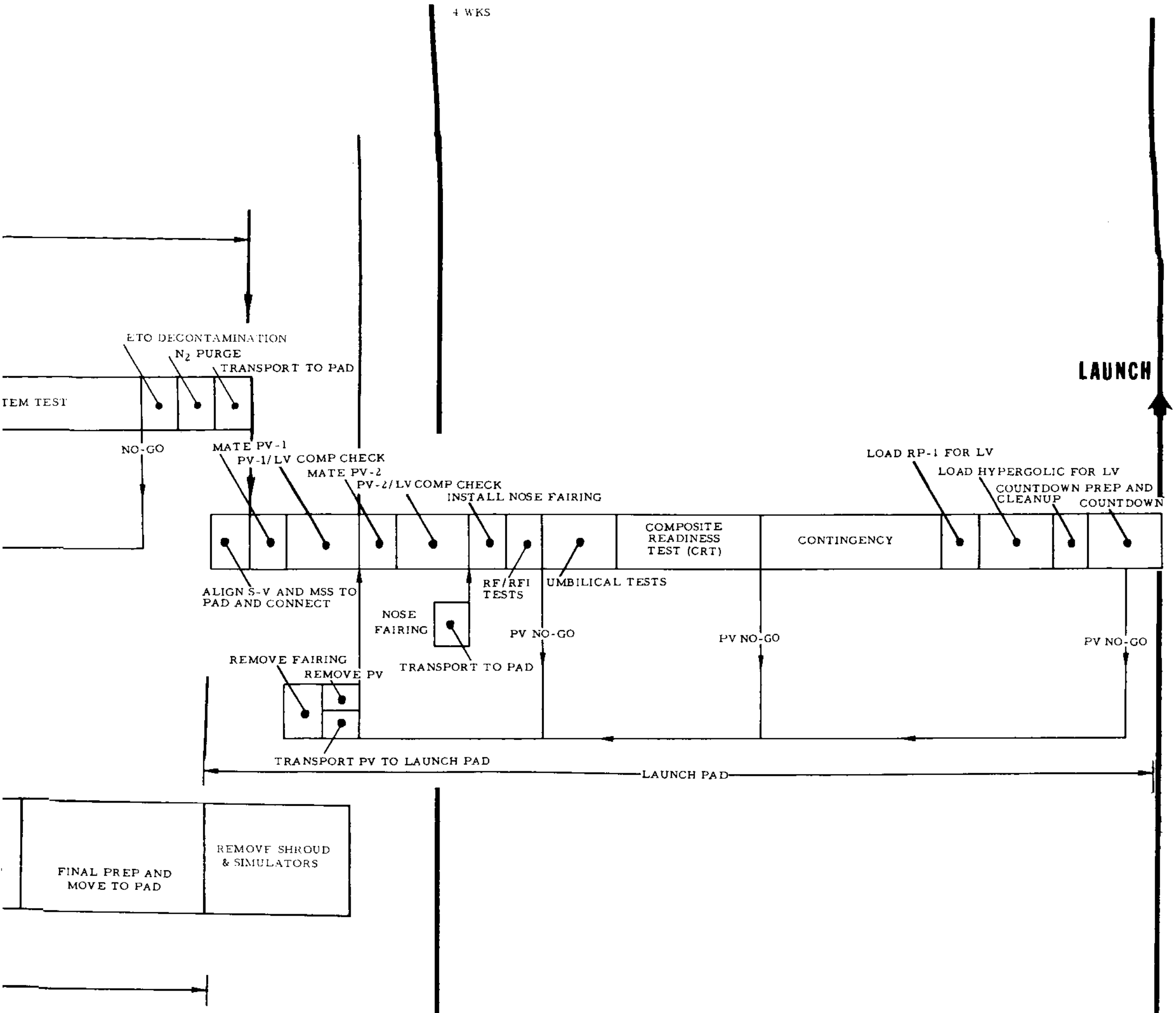


Figure 39. System Flow at Launch Site (Continued)

capsule storage area. If the capsule is to be utilized for immediate planetary vehicle integration operations, it will be installed in the protective cover and in the shipping container and transported by van to the explosive safe area for planetary vehicle operations.

The operations outlined above are repeated for each of the four capsules. It should be noted that capsule sequences are staggered such that no identical capsule testing is done concurrently. This mode of operation requires only one capsule test set.

13.5.2 Spacecraft Operations

After the spacecraft has completed qualification and mission acceptance testing and review at the factory, it is prepared for air shipment to the launch site. The spacecraft is packaged in its shipping container and protective covers in essentially a flight configuration and the transportation environmental control system is connected to the shipping containers. Recording instrumentation for shock, temperature, and humidity, and other required environmental conditions is checked out and connected to the shipping containers.

After the spacecraft arrives at KSC it is unloaded and taken by road van to the spacecraft assembly facility for prelaunch operations. The spacecraft is removed from the shipping containers, the environmental protective covers removed, and the systems installed on work stands for receiving inspection. The transportation instrumentation records are reviewed for indications of excessive transportation environmental conditions. Receiving inspection operations consist of visual inspection of all accessible components for physical damage, checking of attachment bolt torques, proper electrical connections, etc. During receiving inspection, configuration control documentation will be reviewed, updated, and discrepancies in spacecraft hardware noted. Where discrepancies are found during receiving inspection due to transportation damage, component malfunction, or configuration control, the discrepancies will be corrected by the replacement of the failed or damaged unit at the assembly replacement level only. No modifications or rework will be permitted except by module replacement. After these checks, the spacecraft is connected to the spacecraft test equipment. A capsule and launch vehicle electrical simulator is mated electrically to the spacecraft and interface electrical continuity tests are conducted. Discrete signals if required between the spacecraft and capsule and spacecraft and launch vehicle are generated to verify electrical system performance. The capsule and launch vehicle simulators are utilized for spacecraft subsystem and integrated system testing. Complete subsystem functional checks are conducted utilizing the capsule and launch vehicle simulators. All subsystems are functionally tested and calibrated to conform to performance specification limits based upon applicable procedures.

During the integrated system test, subsystem performance data will be recorded on magnetic tape, processed, and stored as part of the permanent spacecraft performance record.

After successful completion of the spacecraft integrated systems test the capsule and launch vehicle electrical simulators will be removed. All spacecraft fluid systems, propellant tanks, and pressurized subsystems will be pressure and leak checked using inert nitrogen gas. After the pressure and leak testing is completed a mechanical alignment test utilizing a mechanical simulator and shroud planetary vehicle attachment simulator will be conducted.

At the completion of alignment checks, pyrotechnics will be installed with proper safe and arming devices, and preparations for a final spacecraft integrated system test will be made. The capsule and launch vehicle electrical simulators will be connected to the spacecraft and the final all-system tests conducted.

If the spacecraft is to be stored, it will be installed in protective covers, placed in a shipping container, and transported to the spacecraft storage area. If the spacecraft is to be transported immediately to the explosive safe area, it will be placed in a protective cover and shipping container and transported to the explosive safe area for planetary vehicle operations.

The above operations will be repeated for each of the three spacecraft required for a Voyager mission. It should be noted that spacecraft sequences are staggered such that no identical spacecraft testing is done concurrently and only one spacecraft test set is required.

13.5.3 Planetary Vehicle Integration Operations

After a capsule and spacecraft have completed assembly and checkout operations and are transported to the explosive safe area, planetary vehicle integration operations commence. The capsule will be removed from the capsule transporter, shipping container, and protective covers. It will be placed on a vertical work stand, all external surfaces cleaned, and a visual inspection performed. Under the direction of the capsule test conductor, the capsule will then be removed from the work stand and transported to the planetary vehicle assembly area where it is prepared for mate with the spacecraft.

Under the direction of the spacecraft test conductor, the spacecraft will be removed from the spacecraft transporter, shipping container, and protective covers. It will then be placed on a vertical work stand, all external surfaces cleaned, and a visual inspection performed. The spacecraft will be transported to the planetary vehicle assembly area where it is prepared for mating with the capsule.

The spacecraft will be placed in a planetary vehicle assembly jig for capsule mating operations. The capsule will be mated to the spacecraft structure and mechanical and electrical attachments made. These operations will be under the direction of the planetary vehicle test conductor. During mating operations detailed capsule operations will be under the direction of the capsule test conductor and spacecraft operations will be under the direction of the spacecraft test conductor.

After mechanical and electrical mating of the capsule and spacecraft is complete, electrical continuity checks will be conducted. Optical alignment of the planetary vehicle and electrical mating continuity checkout will be conducted. The planetary vehicle is connected to the planetary vehicle checkout set which is a combination of the capsule and spacecraft checkout equipment. The launch vehicle electrical simulator is connected and a planetary vehicle functional checkout operation is conducted, including operation over the mission profile.

Upon satisfactory completion of electrical and mechanical alignment the planetary vehicle will be prepared for weight and center of gravity testing. Checkout equipment will be disconnected and loose items of test equipment removed. The weight and center of gravity sling and hydroset will be attached to the crane hook and the sling connected to the planetary vehicle. The planetary vehicle will be weighed utilizing a three-point suspension load cell system. Utilizing the measured weight data the center of gravity of the planetary vehicle will be computed. The planetary vehicle will be rotated 90 degrees and the procedure repeated.

The planetary vehicle will then be installed on the vertical planetary vehicle assembly jig and the sling removed. Protective covers will be replaced and the planetary vehicle prepared for separation and release testing. Special test cables and components suspension lines will be attached to the prescribed attachment points on capsule and spacecraft appendages. The pneumatic console will be connected to the planetary vehicle and all appendage deployment equipment attached. Each planetary vehicle appendage will be released in a simulated zero-g field utilizing live ordnance. After each appendage is individually checked for proper separation and release, all appendages will be reinstalled on the spacecraft and cabling and mechanical mate checks conducted. Ordnance simulators will be reinstalled on the appendages at the completion of the separation and release test.

A spacecraft-capsule compatibility test will be conducted under the direction of the planetary vehicle test conductor. The checkout set and launch vehicle electrical simulator will be connected to the planetary vehicle. All signal line voltages and currents will be verified. Noise and transient levels will be checked to determine that specified performance tolerances are achieved. Where signals indicate that the subsystem performances are out of tolerance, calibrations or adjustments will be made until all performance requirements are achieved. Spacecraft-to-capsule electrical interference checks will be made with all systems. Each subsystem for both the capsule and spacecraft will be individually checked to determine interference problems. The planetary vehicle will then be prepared for an integrated system test.

The planetary vehicle integrated system test is designed to test the planetary vehicle to the fullest extent possible to determine satisfactory system operation. This test will be performed in as close to a flight configuration as possible with only those hard lines connected to the planetary vehicle which are required to aid telemetry and fault isolation to the provisional spares level or to allow testing of redundant elements. The test will include the following operations:

- Perform operational checks on all capsule and spacecraft subsystems
- Perform operational checks of science instruments, spacecraft-capsule interfaces and ordnance circuits
- RF link levels
- Verify test stimuli overall expected flight ranges

The integrated system test will culminate in performance of a mission simulation test. Mission sequence of events will be correlated with expected configurations and at the power levels the planetary vehicle will see during the entire flight mission, commencing with a simulated countdown including umbilical separation. All data from the integrated system test will be recorded on magnetic tape, processed, and stored and become part of the permanent planetary vehicle test record.

After the planetary vehicle integrated system test has been successfully completed, a science quiet test will be conducted. This test is to verify operation of all science instruments and will be accomplished with and without stimulation to the scientific instruments. Interfaces between spacecraft and capsule experiments will be verified and all science instruments will be monitored for interference. The testing will be conducted to minimize interference from facility activities, vehicles, and personnel. At the completion of the science quiet test all discrepancies in the science instruments will be corrected and retested where required.

A final leak test on all fluid subsystems will be conducted and pyrotechnics installed, including proper shorting devices. After leak test and pyrotechnic installation, the planetary vehicle will be prepared for fueling. A final leak check will be conducted and fuel quantity requirements of the planetary vehicle will be verified against the mission requirements.

The planetary vehicle is next prepared for shroud mating under the direction of the planetary vehicle test conductor, assisted by the shroud test conductor. The shroud section will be transported to the planetary vehicles assembly area and installed in the shroud assembly fixture. The planetary vehicle will be removed from the vertical assembly jig and mechanically mated to the shroud section. Electrical mate will then be completed and electrical continuity checks conducted. Mechanical optical aligbment checks between the shroud cylindrical section and the planetary vehicle will be performed. The planetary vehicle will then be leak tested.

The planetary vehicle-shroud assembly will then be prepared for an integrated systems test. The planetary vehicle will then be sealed in the cylindrical shroud segment by installation of the shroud cylindrical section and dome covers and seals and prepared for the ETO decontamination operation. The planetary vehicle shroud cooling system will be connected and checked. The planetary vehicle shroud will be purged with sterilized dry nitrogen under pressure after the ETO decontamination. Pressure in the shroud cylinder will be maintained slightly above ambient. After the dry nitrogen purge and a final integrated systems test, the planetary vehicle-shroud assembly will be transported to the launch pad or stored until required.

13.5.4 Launch Vehicle Operations

13.5.4.1 S-1C Stage Operations

After the S-1C stage has been static fired and accepted for the Voyager mission at the Michoud Test Site, the stage is installed on the road transporter, protective coverings installed, and moved to the transportation barge. The S-1C stage is transported by water to KSC, unloaded from the barge, and taken on the transporter to the vehicle assembly building high-bay area. Protective coverings are then removed and the stage undergoes a receiving inspection while mounted on the transporter. The transportation and receiving inspection operations are under the direction of the S-1C test conductor. After the visual receiving inspection is completed and the transportation instrumentation reviewed and discrepancies noted and corrected, the stage is vertically mated to the launch mount in the VAB high-bay area. Work platforms are employed and S-1C stage subsystem checkout operations commence. Subsystems are functionally tested and calibrated to assure that all subsystems perform within the S-1C stage specification tolerances. The S-1C stage is then prepared for mating with the S-II stage.

13.5.4.2 S-II Stage Operations

After the S-II stage has been static fired and accepted for the Voyager mission at the Michoud Test Site, it is loaded on the road transporter and protective covers installed. The S-II is then moved to the transportation barge for water shipment to KSC. After arrival at KSC the S-II is transported from the barge to the low-bay area of the VAB. Protective covers are removed and receiving inspection conducted. The transportation instrumentation data is reviewed for indication of out-of-tolerance conditions. All discrepancies noted are corrected and subsystem checkout commences. The transportation and receiving inspection operations are the responsibility of the S-II test conductor. Functional testing as well as subsystem calibration is conducted to assure that all subsystems are operating within the S-II specification tolerances. At the completion of subsystem testing and after subsystem discrepancies noted during testing have been corrected, a final stage all-system test is conducted. At the completion of the all-system test, the stage operation engineer informs the launch vehicle operations test conductor that the S-II stage is ready for mate to the S-1C stage.

13.5.4.3 S-IVB Stage Operations

After completion of acceptance testing and static firing at the Douglas/Sacramento Test Facility, the S-IVB stage is prepared for transportation to KSC. The S-IVB stage is installed on the road transporter, protective covers installed, and is transported to the air strip for loading in the transport aircraft. The S-IVB stage is loaded in the transport aircraft and air-shipped to KSC. After arrival the S-IVB stage is unloaded from the transport aircraft, loaded on the road transporter, and transported to the low-bay area of the VAB. The protective covers are removed and visual receiving inspection conducted. The transportation instrumentation data is reviewed to check for indications of out-of-tolerance, transportation conditions. These operations are under the direction of the S-IVB test conductor. After discrepancies are corrected subsystem testing operations commence.

Subsystem testing consists of functional checkout and calibration where required to assure that all subsystems perform within S-IVB specification tolerances. At the completion of subsystem testing with all discrepancies corrected, the integrated system test is conducted and a complete functional checkout completed. After successful completion of these operations, the S-IVB test conductor informs the launch vehicle test conductor that the S-IVB stage is ready for mating to the S-II stage.

13.5.4.4 Instrumentation Unit Operations

After acceptance testing is completed at the factory the instrumentation unit (IU) is prepared for air transport to KSC. The instrumentation unit is placed on the road transporter, protective covers installed, and the IU loaded in the transporter aircraft. The IU is air-shipped to KSC, unloaded from the transport aircraft, and installed on the IU transporter. The IU is transported to the low-bay area of the VAB and protective covers removed. Transportation instrumentation data is reviewed for indications of out-of-tolerance conditions and the IU undergoes receiving inspection. At the completion of receiving inspection and after any discrepancies noted are corrected, the IU is prepared for subsystem testing. Subsystem testing consists of functional testing and calibration required to assure that each subsystem is in a ready condition to support an all-system test. The integrated system test is conducted to assure that IU systems operate in a normal manner. At the completion of the all-system test, the instrumentation unit test conductor informs the launch vehicle test conductor that the instrumentation unis is ready for mating to the S-IVB stage.

13.5.4.5 Launch Vehicle Mating Operations

The S-II stage is taken from the VAB low-bay area to the VAB high-bay area and vertically erected. The S-II stage is mechanically and electrically mated to the S-1C stage. Interface electrical continuity tests are made and mechanical alignment and mating checkout completed. An S-1C /S-II stage interface test is conducted to assure that all systems operate within the Saturn V launch vehicle system specification tolerances. These operations are under the direction of the launch vehicle test conductor assisted by the S-1C and S-II test conductor. At the completion of the S-1C/S-II stage interface test, the S-IVB stage is transported from the VAB low-bay area to the VAB high-bay area, vertically erected, and mated to the S-II stage. Mechanical and electrical mating is conducted and electrical continuity tests completed. At the completion of these tests, an S-IVB/S-II/S-1C interface checkout is conducted, under the direction of the launch vehicle test conductor.

The instrumentation unit is transported from the VAB low-bay area to the VAB high-bay area, vertically erected and mated to the S-IVB stage. Mechanical and electrical connections are made and electrical continuity tests conducted. An integrated systems test of the completed launch vehicle is conducted, under the direction of the launch vehicle test conductor with assistance from the S-1C, S-II, S-IVB, and IU test conductors. At the completion of a successful integrated systems test, two planetary vehicle electrical simulators are connected to the instrumentation unit, electrical continuity checks conducted, and a total mission system test conducted. The integrated mission test is conducted in as close to a flight configuration as possible with only those hard lines connected to the launch vehicle system as are required to aid in telemetry and fault isolation to the provisional spares level or to allow testing of redundant elements. The test will include the following operations:

- Perform operational checks on all launch vehicle subsystems and launch vehicle-planetary vehicle electrical interfaces and discrete signal transmission and receiving

- Operate the space vehicle system in a mission flight profile from prelaunch countdown, umbilical eject, orbital operations, and planetary vehicle separation operations

At planetary vehicle separation, the test will be completed. The launch vehicle test conductor will obtain a critique of system performance from each of the launch vehicle test conductors. Where serious discrepancies exist, the launch vehicle test conductor will determine the necessity for conducting a rerun of the all-system test. After the successful completion of the integrated systems test, the planetary vehicle simulators will be removed. The shroud sections and nose fairing will be mated to the launch vehicle IU section for mechanical and electrical compatibility checks, prior to planetary vehicle encapsulation in the shroud cylindrical section. After mechanical and electrical compatibility is verified, the nose fairing and shroud sections are removed and taken to the storage area or to the ESA. The launch vehicle is then prepared for transportation to the launch pad.

13.5.4.6 Launch Vehicle Launch Pad Operations

The Saturn V launch vehicle is transported to the launch pad utilizing the mobile crawler transportation system under the direction of the launch vehicle test conductor. At the pad, the launch platform will be secured to the launch pad, crawler transporter removed, and the launch vehicle mechanically and electrically mated to the launch pad facilities. Electrical continuity testing will be conducted and launch vehicle subsystem testing conducted to assure that all subsystems are properly mated to the launch pad systems and perform within launch vehicle specification tolerances. Systems elevation will be accomplished, and at the completion of launch vehicle subsystem test operations, preparations will be made for a launch vehicle integrated systems test. The two planetary vehicle electrical simulators will be connected and total system compatibility testing conducted. At the successful completion of this testing the planetary vehicle electrical simulators are removed and the launch vehicle is prepared for planetary vehicle-shroud assembly mating operations.

13.5.4.7 Space Vehicle Operations

Two planetary vehicles-shroud assemblies are transported to the launch pad and mated to the launch vehicle. Mechanical and electrical connections will be made and electrical continuity test conducted. After individual planetary vehicle system checkouts are conducted, the two planetary vehicles are operated together to check for interference. After this is completed the nose fairing is transported from the VAB area to the launch pad and mated to the forward shroud section interface structure. Mechanical alignment checks are made of the total assembly to check alignment of the vertical axis of the nose fairing, two planetary vehicle-shroud assemblies and the Saturn V. At the completion of mechanical alignment checks, a planetary vehicle-shroud assembly to launch vehicle electrical continuity check and a functional compatibility test will be conducted. Discrete signals required between the launch vehicle and planetary vehicle will be exercised and system performance evaluated. After successful completion of the compatibility test a countdown readiness test (CRT) will be conducted.

The countdown readiness test will exercise all space vehicle systems in as close to a mission configuration as possible from launch countdown at T-1 day through the end of the mission. This CRT will include umbilical ejection tests. All systems will be on internal power, where feasible, and instrumentation data will be obtained through RF links insofar as possible. DSN Station 71 at AFETR will transmit commands to the planetary vehicle and receive signals from the planetary vehicles. The SFOF will be exercised during the CRT insofar as possible. This will enable a checkout both of the launch operations and mission operations segment of the system.

Fuses will be substituted for pyrotechnic devices and at the completion of the CRT a check that all fuses are properly blown will be included as a portion of the CRT evaluation. At the conclusion of the CRT, data will be analyzed and critiqued to ascertain that all launch vehicle and planetary vehicle segments performed within specification tolerances.

After successful completion of the countdown readiness test and mission simulation, the space vehicle test conductor obtains a ready condition from the supporting test conductors and notifies the launch operation director that final countdown operations may commence. The launch operations director obtains approval for initiation of final countdown from the Voyager mission director after coordination between launch site operations, and spaceflight operations have indicated that a ready condition exists for both segments. Final countdown will then be initiated.

If contingencies arise during the CRT or countdown, the operations will be halted and recycled to the appropriate operations while discrepancies are corrected. When out-of-tolerance conditions occur in a planetary vehicle during the CRT or final countdown, testing will be halted and the backup planetary vehicle will be mated to the launch vehicle to replace the faulty planetary vehicle-shroud assembly, which will be removed to the ESA for recycling. All launch pad testing will be recycled back to planetary vehicle continuity testing and all tests will be repeated including the CRT.

After the Voyager mission readiness condition is obtained from the Voyager mission director, the space vehicle test conductor initiates the final countdown sequence. The countdown will be divided into two parts and performed on successive days as shown in Figure 40. The first day of the final countdown will consist of the S-1C, S-II, and and S-IVB ordnance systems. S-1C mechanical and electrical checks will be conducted and S-1C fueling operations performed. During checkout of the launch vehicle stages, final planetary vehicle system status checks will be conducted on the two planetary vehicles. All planetary vehice-launch vehicle interface connections will be verified. At the conclusion of planetary vehicle and launch vehicle system checks, a final space vehicle system verification test will be conducted. RF tests will be conducted using DSIF Station 71 for planetary vehicle communications and verification of command receipt and transmission of all signals between the DSIF Station 71 and the planetary vehicles will be completed.

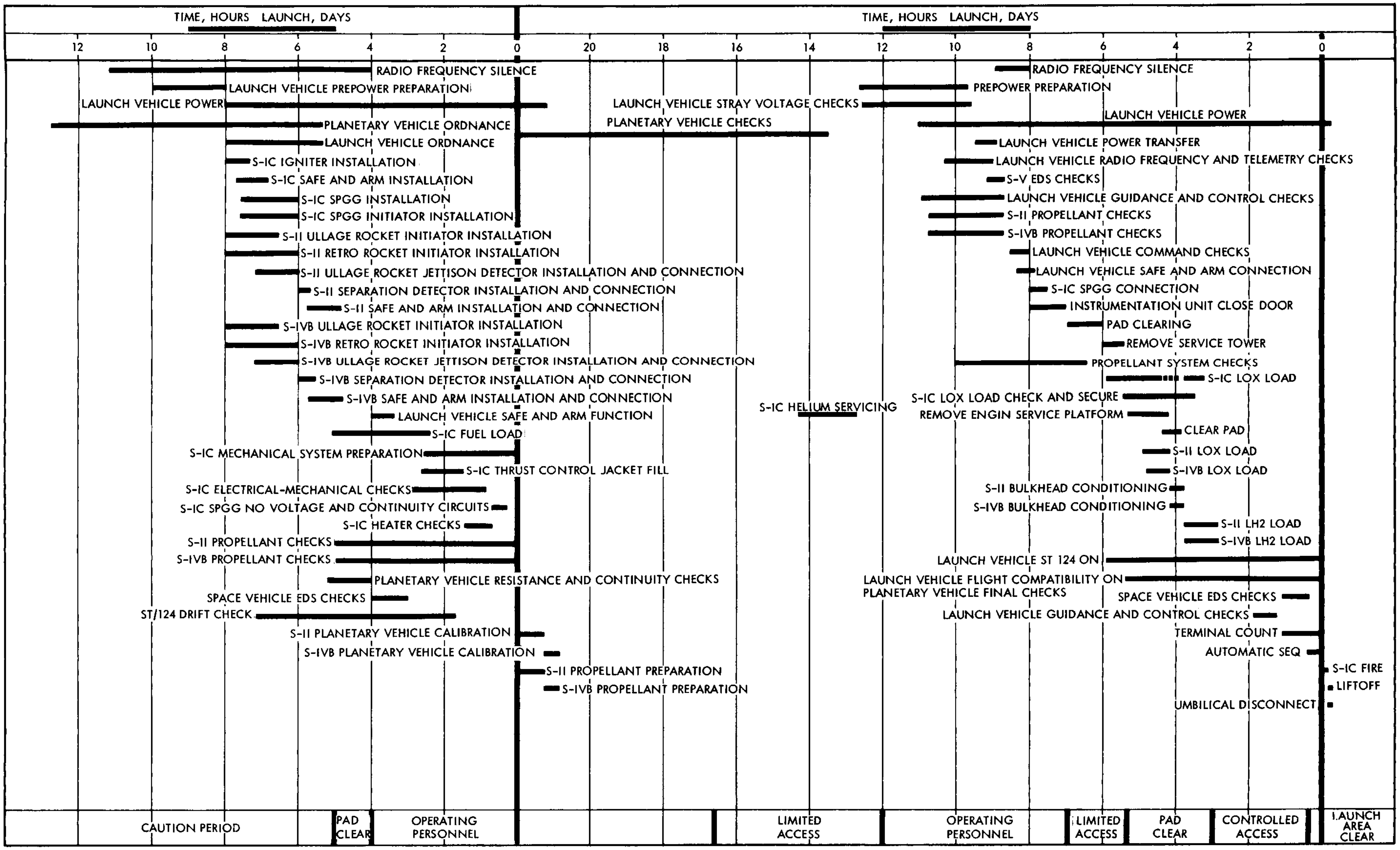


Figure 40. Voyager Space Vehicle Countdown

The final day of the two-day countdown will consist of battery installations in the launch vehicle stages, power transfer testing in which all systems are exercised, final range safety command checks, and remaining ordnance systems installed. Final space vehicle checks, including RF and instrumentation system performance checks, will be conducted and the pad cleared of all personnel in preparation for propellant loading operations for the S-1C, S-II, and S-IVB stages. Liquid oxygen will be loaded in the S-1C stage and liquid hydrogen will then be loaded in the S-II and S-IVB stages. Final planetary vehicle system status checks will be conducted and the service structure will be removed to the launch position. The blockhouse will be sealed and all personnel removed from the pad in preparation for commencement of the terminal phase of the countdown.

The terminal countdown phase will be initiated and all systems will be activated and prepared for launch. Complete subsystem evaluation will be completed and monitoring of launch vehicle and planetary vehicle subsystems will continue. A final summary condition will be received at the control console and after receipt of this signal the final automatic terminal countdown will commence. The terminal countdown will be switched to the automatic countdown sequence and will activate remaining launch vehicle functions automatically through S-1C ignition and liftoff. Emergency procedures, recycle procedures, and securing operations will be available in the event contingencies arise and all launch vehicle functions may be switched to manual operations for backout if necessary. The S-1C ignition signal is given and the S-1C stage engines build up to full thrust after which the hold-down arms release and liftoff occurs. Umbilical disconnects for the launch vehicle occur and the powered flight segment of the mission commences. Skin and beacon tracking of the space vehicle is conducted by the tracking and data acquisition system as well as DSIF Station 71, and all data is received through the appropriate RF links.

13.5.5 Tracking and Data Acquisition Operations

The tracking and data acquisition operations commence during the prelaunch preparations of the launch vehicle in the VAB and the planetary vehicles in the explosive safe area. Tracking stations operate during RF tests to check compatibility between these stations and the planetary vehicle and launch vehicle communication systems. Capability to receive and transmit signals will be demonstrated for all conditions based upon requirements of the Voyager program. Evaluation of data received from the launch vehicle and planetary vehicles will verify the signal strength and signal compatibility. Prelaunch checkout between the stations and launch vehicle and planetary vehicles will determine functional and qualitative operation of two-way doppler, ranging, telemetry, and command. Prelaunch checkout operations are employed to demonstrate that the particular space vehicle to be launched is functionally compatible with the tracking stations at the time of launch.

Operation of the AFETR stations and the DSIF Station 71 will provide complete coverage of tracking and data acquisition requirements for the Voyager program. DSIF Station 71 will provide a stable source of measurement of planetary vehicle receiver power via telemetry and a stable measurement of planetary vehicle transmitter power throughout the period on the launch pad. It will measure planetary vehicle frequencies at launch and transmit data to the first DSIF acquisition station at Ascension Island or Johannesburg. Trajectory information will be provided to the range safety officer during powered flight. Data received during prelaunch and flight operations will be recorded and processed for evaluation of system performance where necessary, and may be utilized at a later date for comparison with data received during the flight mission to determine spacecraft performance.

14. LAUNCH VEHICLE SYSTEM IMPLEMENTATION

14.1 GENERAL

The launch vehicle system (LVS) is implemented jointly by the Voyager shroud contractor and the various contractors for the standard Saturn V booster under the overall management of the launch vehicle system management office. Technical direction and contractual administration of these contractors is delegated to the MSFC Saturn V Project Office in support of the launch vehicle SMO.

This section concerns itself with the LVS implementation carried out by these launch vehicle contractors. The various functional elements are described as well as a work breakdown for the activities needed to achieve the objectives of this segment of the Voyager project. These activities are summarized in a LVS implementation plan and work breakdown matrix.

14.2 SYSTEM DESCRIPTION

14.2.1 General Description

The launch vehicle system is one of six basic functional systems that make up the overall Voyager project. The LVS consists of various elements which can be broadly categorized as flight hardware, support equipment, facilities, and operating procedures and personnel. Specifically the operational LVS consists of the following:

- Saturn V booster
- Voyager shroud
- Launch vehicle OSE at launch site
- LVS software
- Personnel to support mission prelaunch and launch operations

Each of the above elements in turn consists of various subsystems which are described below.

14.2.2 Saturn V Booster

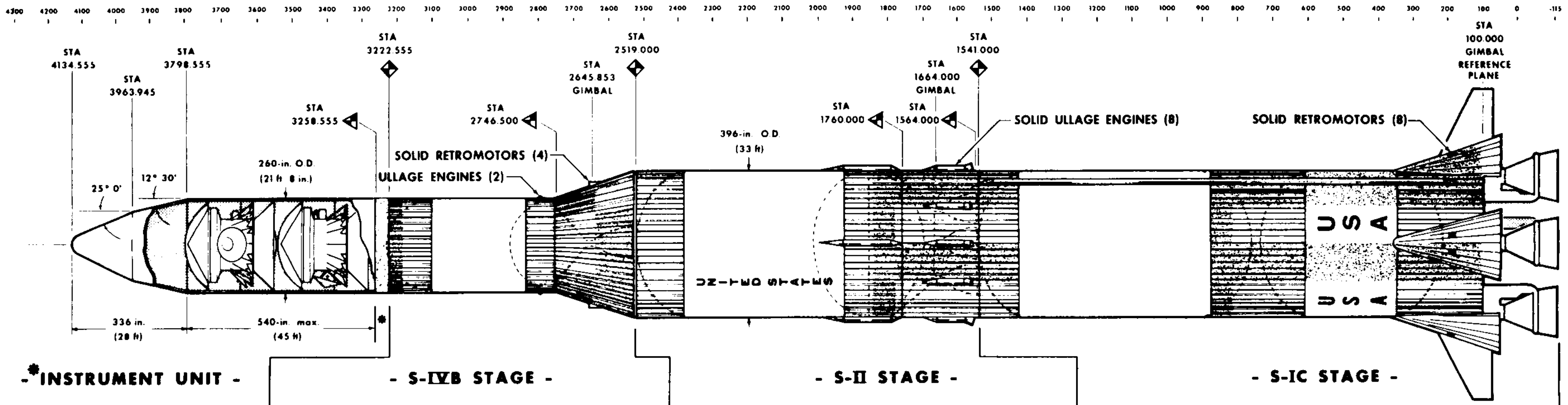
The Voyager project utilizes the standard three-stage Saturn V booster currently under development for the Apollo and Saturn-Apollo Applications Programs. The Voyager space vehicle configuration is shown in Figure 41, which also includes detailed information about the Saturn V booster.

The Saturn V consists of the S-IC stage, S-IC/S-II interstage, S-II stage, S-II/S-IV interstage, S-IVB stage, and instrument unit. In operation, the separation of the S-II/S-IC stages is electrically controlled from the S-IC stage. Separation of the S-II/S-IVB stages is electrically controlled by the S-II stage. The instrument unit, mounted between the S-IVB and the payload adapter, contains the airborne computer, the inertial guidance and control system, and the flight instrumentation systems for all three stages of the Saturn V. The airborne computer initiates all command signals for separation of the S-II/S-IC and S-II/S-IVB stages. The S-II stage, however, controls initiation of the S-II stage ullage rockets and the retrorockets on the S-IVB interstage structure. For guidance and control the instrument unit carries an inertial platform, computers for guidance computations, and signal conditioning equipment for steering commands. Azusa and C-band transponders are carried, together with an S-band command receiver, S-band transmitter, and PCM, FM, and SSB telemetry encoders. The IU also carries a liquid heat exchanger system for thermal control and batteries for electric power supply.

14.2.3 Shroud

The shroud will be a new design to be developed for the Voyager project. The shroud base diameter will be 260 inches, which corresponds to the S-IVB diameter. A 45-foot (540-inch) cylindrical section topped by a standard Saturn V nose fairing represents the reference approach. This configuration is shown in Figure 42.

The cylindrical part of the shroud consists of two identical sections, each of which is capable of encapsulating a single planetary vehicle. Three such shroud sections are provided for each launch opportunity,



-*INSTRUMENT UNIT -

- **PRIME CONTRACTOR** - **IBM**
- **LENGTH** - **3 ft**
- **DIAMETER** - **21 ft 8 in.**
- **WEIGHT (At grd ignition)** - **3850 lb**

◈ - FIELD SPLICE

◀ - SEPARATION

NOTES:

1. All Stations are in inches
2. Vehicle Weights are based on 'Reference' Vehicle SA-516

- S-IVB STAGE -

- **PRIME CONTRACTOR** - **DOUGLAS**
- **LENGTH** - **58 ft 8 in.**
- **DIAMETER**
  (Fwd of interstage) - **21 ft 8 in.**
- **WEIGHT**
  DRY - 25,700 lb (Excl. 7700 lb for S-II/S-IVB interstage and retromotors)
  AT GRD IGNITION - 260,000 lb (Excl. 7700 lb for S-II/S-IVB interstage and retromotors)
- **ENGINE** - 1
  TYPE - ROCKETDYNE J-2 (Restart.)
  NOMINAL THRUST (Vacuum) - 205,000 lb
- **PROPELLANTS** - LOX and LH_2
- **PROPELLANT CAPACITY** - **235,000 lb**
  LOX - 20,650 gal.
  LH_2 - 72,860 gal.
- **MIXTURE RATIO (Wo/Wf)** - 5:1

- S-II STAGE -

- **PRIME CONTRACTOR** - **NORTH AMERICAN**
- **LENGTH** - **81 ft 6 in.**
- **DIAMETER** - **33 ft**
- **WEIGHT**
  DRY - 80,300 lb (Excl. 9600 lb for S-IC/S-II interstage and ullage engines)
  AT GRD IGNITION - 1,062,000 lb (Excl. 9600 lb for S-IC/S-II interstage and ullage engines)
- **ENGINES** - 5
  TYPE - ROCKETDYNE J-2
  NOMINAL THRUST (Vacuum) - 205,000 lb
  TOTAL THRUST - 1,025,000 lb
- **PROPELLANTS** - LOX and LH_2
- **PROPELLANT CAPACITY** - **982,000 lb**
  LOX - 82,700 gal.
  LH_2 - 263,000 gal.
- **MIXTURE RATIO (Wo/Wf)** - 5:1
- **ULLAGE ENGINES** - 8
  PROPELLANT - SOLID
  THRUST - 22,800 lb
  BURN TIME - 4.0 sec

- S-IC STAGE -

- **PRIME CONTRACTOR** - **BOEING**
- **LENGTH** - **138 ft**
- **DIAMETER**
  WITHOUT FINS - 33 ft
  WITH FINS - 63 ft
- **WEIGHT**
  DRY - 286,300 lb
  AT GRD IGNITION - 4,922,000 lb
- **ENGINES** - 5
  TYPE - ROCKETDYNE F-1
  NOMINAL THRUST (Sea level) - 1,522,000 lb
  TOTAL THRUST - 7,610,000 lb
- **PROPELLANTS** - LOX and RP-1
- **PROPELLANT CAPACITY** - **4,636,000 lb**
  LOX - 340,900 gal.
  RP-1 - 205,900 gal.
- **MIXTURE RATIO (Wo/Wf)** - 2.25:1
- **RETROMOTORS** - 8
  PROPELLANT - SOLID
  THRUST - 92,000 lb
  BURN TIME - 0.6 sec

Figure 41. Space Vehicle Configuration

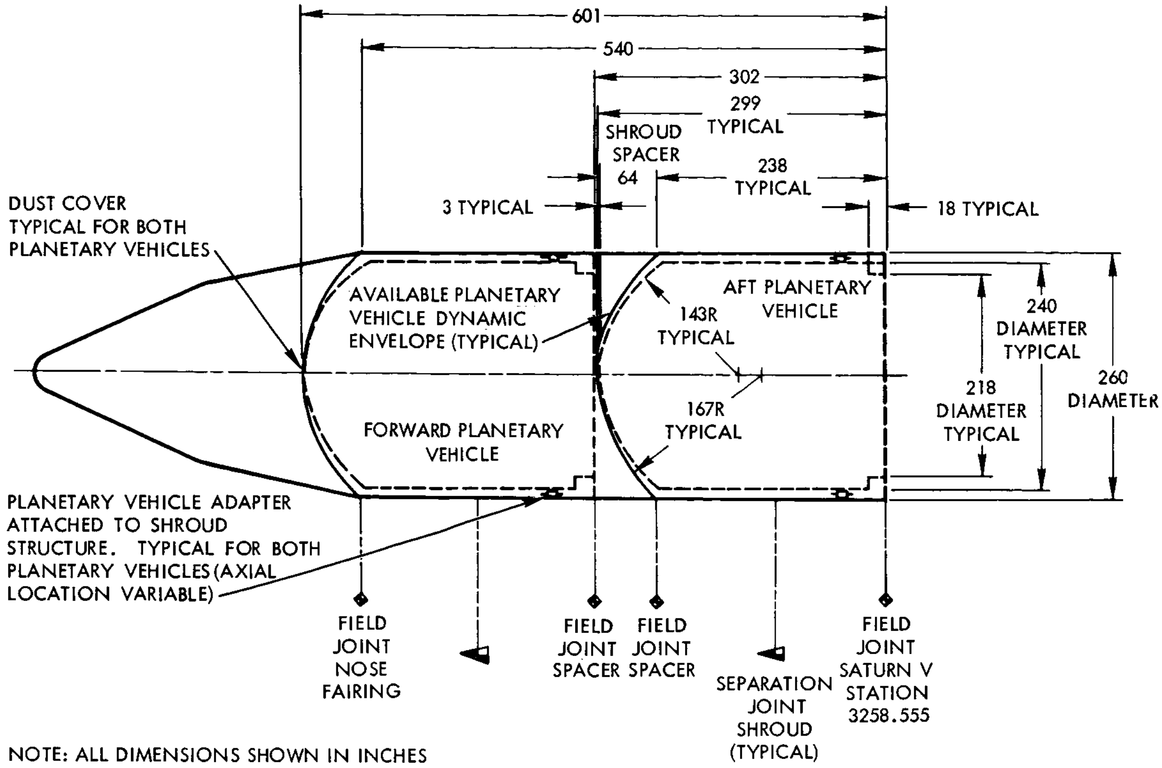


Figure 42. Planetary Vehicle Arrangement and Dynamic Envelopes

with one as a spare. During the launch operations phase, the shroud sections are checked in the vehicle assembly building for compatibility with the launch vehicle using planetary vehicle simulators. The flight planetary vehicles are then installed in the shroud section in the ESA, after which they are sealed to allow ETO decontamination of the surface of the encapsulated planetary vehicle. The planetary vehicles are then maintained in the sealed condition for subsequent launch operations and during atmospheric flight. A pressurized water container on the shroud provides coolant through disconnects to the capsule canister tubes to maintain thermal control of the capsule RTG's during flight while in the encapsulated condition. All other disconnects from each planetary vehicle adapter to the corresponding flight spacecraft are separated remotely before launch.

To separate a planetary vehicle from the shroud (or more accurately from the planetary vehicle adapter), the forward part of the shroud section is separated and jettisoned to expose the planetary vehicle. The nose fairing and part of the forward shroud section are carried into earth parking orbit to avoid the complexity of requiring a shroud separation during powered flight. The firing signals for separating planetary vehicles are supplied via shroud wiring only to the planetary vehicle adapter, and do not require an in-flight electrical disconnect.

14.2.4 Launch Vehicle Operational Support Equipment

The launch vehicle operational support equipment will consist primarily of the ground support and automatic checkout equipment (GSE/ACE) currently being developed for the standard Saturn V launch vehicle. This equipment is utilized to assemble, service, handle, ship, and check the three stages, the instrument unit, and the various systems and subsystems that make up these launch vehicle elements during the prelaunch and launch operations phases. It also includes the existing ground support equipment utilized to checkout the launch vehicle GSE/ACE.

In addition to the OSE described above, additional new OSE will be required for the shroud. This equipment will perform functions similar to that described for the launch vehicle.

14.2.5 Launch Vehicle System Software

To a maximum extent, the standard Saturn V launch vehicle will utilize previously developed software to meet the Voyager mission requirements. These will include magnetic tapes for use in automatic checkout of the launch vehicle. (Because additional requirements exist in regard to guidance for earth-Mars injection, the tapes will have to be modified to be compatible with the changes made to the S-IVB stage and the instrument unit.) In addition, service and overhaul manuals will be supplied to aid in performing these functions during the prelaunch operating phase. Detailed procedures for prelaunch and launch checkout of all launch vehicle systems and subsystems will also be provided. Finally, spare parts lists previously prepared for the standard Saturn V launch vehicle will be needed.

14.3 WORK BREAKDOWN

The implementation of the launch vehicle system for the Voyager mission must proceed in a logical manner to meet the development schedule for the overall program. Most elements of the launch vehicle system will be fully developed and qualified prior to their use on this program. However, it is important to establish a work breakdown for the various implementation tasks so that the new or modified elements can be identified and scheduled to be available for integration with the more readily available off-the-shelf elements.

With the exception of the shroud system, the implementation of the launch vehicle system will consist primarily of initiating the manufacture of stages S-IC, S-II, S-IVB, and the instrument unit. Since the three stages of the Saturn V launch vehicle will remain essentially unchanged, existing specifications, drawings, tooling, special manufacturing devices, and manufacturing checkout and acceptance test facilities, will be utilized. However, because of the configurational differences of the space vehicle from the original Apollo program, a study will have to be conducted by the stage S-IC contractor to evaluate the effect on flight dynamics and attitude control requirements of the launch vehicle system. The need for any structural changes and additional dynamic testing of the launch vehicle and its subsystems will have to be considered at that time. The implementation definition for this report assumes that no changes to the standard Saturn V booster structure will be required.

An additional task will be to identify and specify those changes to the S-IVB stage and the instrument unit that are required to make this launch vehicle system element compatible with the Voyager mission ascent and orbital injection requirements. Design changes to the airborne computer, inertial guidance and control system, and the flight instrumentation systems must be implemented prior to initiation of the manufacture of the instrument unit. The design changes must also include any revisions to the instrument unit GSE/ACE and the software (specifications and procedures) to permit proper checkout and acceptance testing of this element. Variations in S-IVB stage propulsion system first and second burn times must be assessed and any effects on the flight hardware determined.

The final element to be developed to implement the launch vehicle system is in the Voyager-peculiar shroud. This is a new launch vehicle hardware segment and therefore its implementation is dealt with in more detail in the following section.

The overall launch vehicle system implementation flow is shown on Figure 43. This diagram is not time-phased but simply indicates the major activities required to produce a launch vehicle system for the Voyager mission. A matrix depicting the work for implementation of the Saturn V booster is shown in Table 3 .

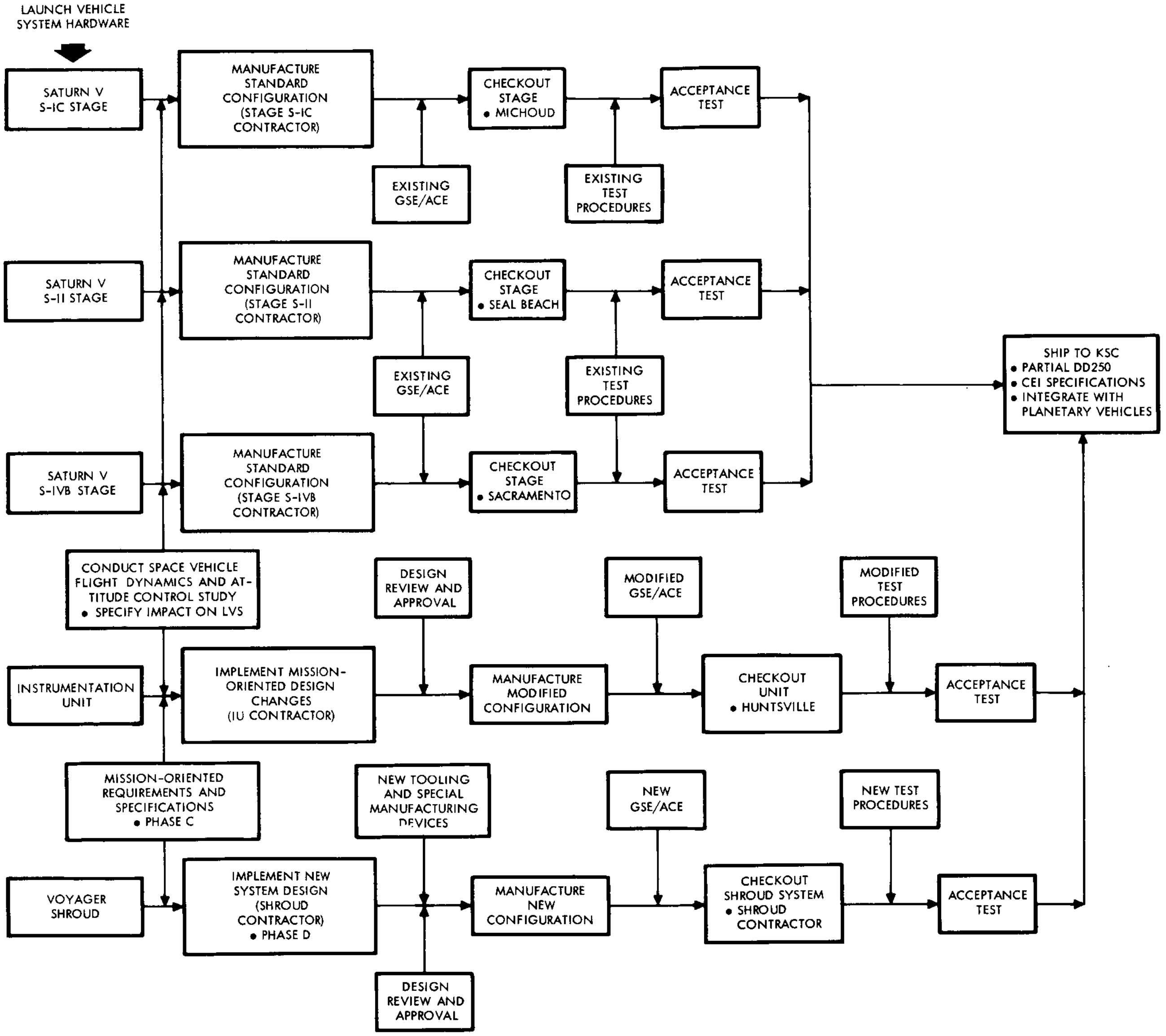


Figure 43. Launch Vehicle System Implementation Plan

Table 3. Saturn V Booster Work Task Breakdown

	LVS System Management Office	Stage S-IC Contractor	Stage S-II Contractor	Stage S-IVB Contractor	Instrument Unit Contractor
Prepare LVS general specification	o				
Establish mission-oriented system requirements	o	□			□
Prepare system design specifications		x	x	x	□
Prepare engineering drawings for flight system		x	x	x	□
Prepare specifications for OSE/MDE hardware		x	x	□	□
Prepare engineering drawings for OSE/MDE		x	x	□	□
Obtain design approval (PDR/CDR)	o	x	x	□	□
Design and develop tooling and special manufacturing devices					□
Prepare checkout specification and tapes		x	x	□	□
Manufacture flight systems		x	x	□	□
Manufacture OSE/MDE		x	x	□	□
Perform development and proof testing					□
Checkout flight systems		x	x	□	□
Prepare acceptance test procedures		x	x	x	x
Conduct acceptance test	o	x	x	x	x
Prepare and obtain approval of CEI Specifications	o	x	x	□	□
Ship flight system or GSE/ACE to KSC	o	x	x	□	□

Legend: x Existing hardware or software

o New hardware or software

□ Modified hardware or software

14.4 SHROUD IMPLEMENTATION

The shroud contractor's responsibility includes the shroud hardware end items and spare end items, software, all required test articles, and operational support equipment. The functions assigned include the management and implementation of all analysis, design, development, reliability assurance, fabrication, procurement, assembly, quality assurance, checkout, integration, and unit, subsystem and system testing and support operations necessary to meet the shroud system requirements.

14.4.1 Project Work Breakdown

The work breakdown for implementation of the shroud for Voyager is shown in Figure 44. The project is organized under a project manager, who has full authority to represent the shroud contractor on all matters within the scope and terms of the contract. The breakdown of the project is into major functional areas of Systems Engineering; Design, Development and Manufacturing; Plan and Control; and Product Assurance. An assistant project manager is directly responsible to the project manager for each of these functional areas. A contracts manager is assigned to support the shroud system project manager as required. Similar support will be assigned from the pricing and material organizations.

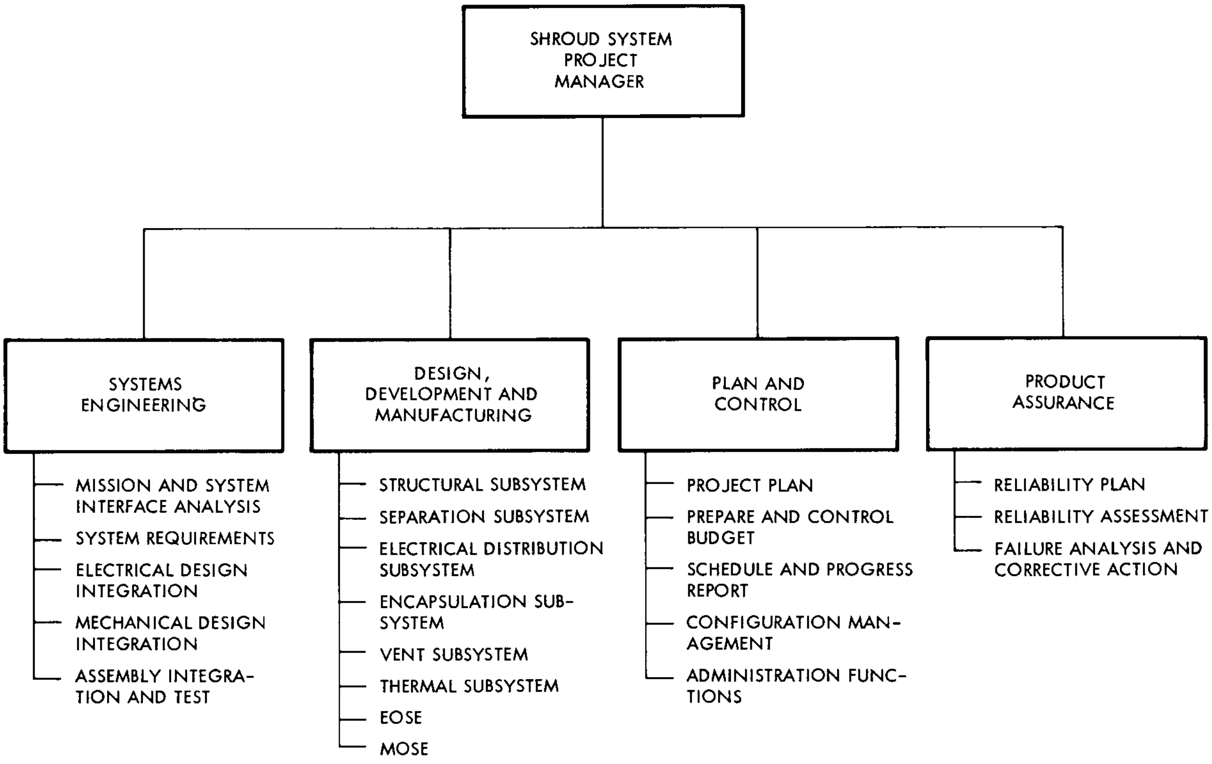
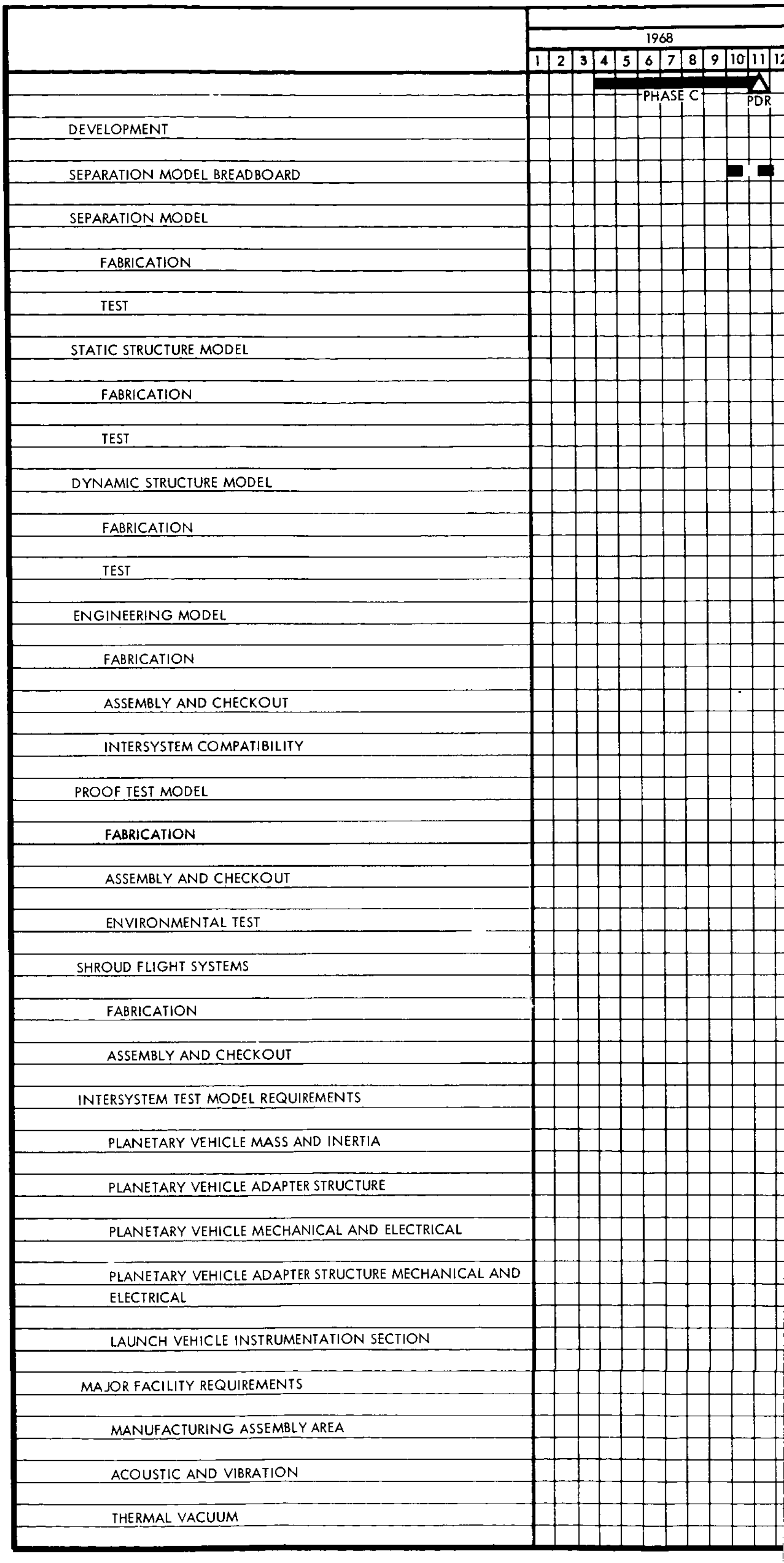


Figure 44. Shroud System Project Work Breakdown

14.4.2 Schedule

The schedule shown in Figure 45 begins with the start of the Phase D development program in February 1969 and ends with the delivery of shroud flight hardware in August 1972. It is assumed that the equivalent


1968
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9
10
11
12
PHASE C
PDR
DEVELOPMENT
SEPARATION MODEL BREADBOARD
SEPARATION MODEL
FABRICATION
TEST
STATIC STRUCTURE MODEL
FABRICATION
TEST
DYNAMIC STRUCTURE MODEL
FABRICATION
TEST
ENGINEERING MODEL
FABRICATION
ASSEMBLY AND CHECKOUT
INTERSYSTEM COMPATIBILITY
PROOF TEST MODEL
FABRICATION
ASSEMBLY AND CHECKOUT
ENVIRONMENTAL TEST
SHROUD FLIGHT SYSTEMS
FABRICATION
ASSEMBLY AND CHECKOUT
INTERSYSTEM TEST MODEL REQUIREMENTS
PLANETARY VEHICLE MASS AND INERTIA
PLANETARY VEHICLE ADAPTER STRUCTURE
PLANETARY VEHICLE MECHANICAL AND ELECTRICAL
PLANETARY VEHICLE ADAPTER STRUCTURE MECHANICAL AND ELECTRICAL
LAUNCH VEHICLE INSTRUMENTATION SECTION
MAJOR FACILITY REQUIREMENTS
MANUFACTURING ASSEMBLY AREA
ACOUSTIC AND VIBRATION
THERMAL VACUUM

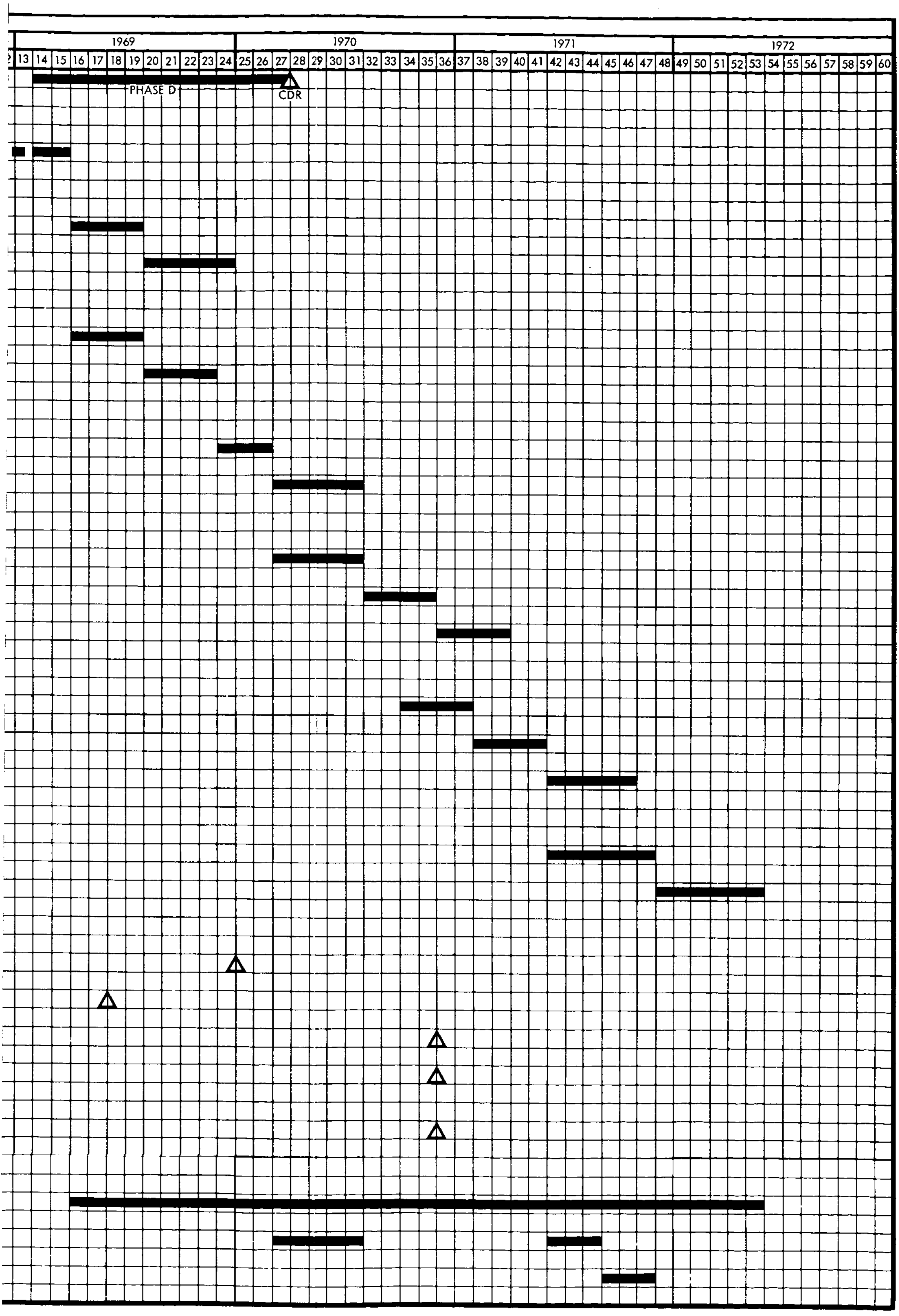


Figure 45. Shroud System Implementation Plan Schedule

of Phase B tradeoff studies will have been completed during 1967 by NASA in-house effort. Contractor selection and Phase C will then be carried out in 1968. For this study, it has been assumed that an over-the-nose separation mode is selected.

The most critical engineering task to be accomplished will be the definition, design, and development of the separation subsystem. The development will utilize engineering models of the mechanical attachment and electro-explosive devices plus circuitry breadboarding for conceptual design verification. This will be followed by a full-scale separation model for subsystem verification testing.

Structural models will be used for both static and dynamic structural verification testing. An engineering model consisting of functional but not flight configured hardware will be assembled and tested to provide for an early definition of subsystem integration, OSE and procedural problems. It will later be used for intersystem compatibility tests.

The proof test model will be the initial system consisting of flight configured hardware and it will be used for system qualification. After assembly and checkout operations, the total shroud system (with simulated mass-inertia models of the planetary vehicle) will be subjected to vibration and acoustic tests, followed by thermal-vacuum environmental tests. Shroud separation tests will then be conducted to permit verification of separation subsystem operation after exposure to the mission environment and during space environmental conditions.

The schedule (Figure 45) indicates requirements for test models from interfacing Voyager systems. It also indicates requirements for major facilities to support the shroud system development and fabrication.

14.4.3 Requirements and Constraints

The shroud system is to provide protection for the planetary vehicle from prelaunch and launch aerodynamic, dynamics, and thermal environments as well as atmospheric contamination. It is to include two identical, interchangeable sections each of which encapsulates a planetary vehicle and provides for ETO surface decontamination and subsequent purging. A vent system is required to maintain shroud compartment pressure at a suitable pressure relative to ambient.

The shroud system is to provide for structural, mechanical, and electrical attachment of the planetary vehicle to the launch vehicle. No critical adjustments are to be required during prelaunch matchmate of the shroud system assembly to the launch vehicle.

The shroud is to provide for separation into two sections under specified flight conditions so as to avoid physical contact with the planetary vehicle, contamination of the planetary vehicle, and significant stability disturbance to the launch vehicle. Electrical power and initiation signals for the shroud system are to be provided by the instrument unit.

RF windows are to be provided to allow RF operations with the ground station from both planetary vehicles while on the pad and during flight.

14.4.4 Structure

The shroud structure can be divided into two major groupings, the cylindrical group and the conical section. The cylindrical group, which is of constant diameter, extends from the top of the Saturn V instrument unit to the aft end of the conical section. The conical section, a double angle nose fairing which provides the forward closure for the shroud system, attaches to the top of the cylindrical group.

The cylindrical group consists of two identical and interchangeable sections which are identified as shroud-planetary vehicle sections which are separated in the shroud system assembly by a shroud spacer section. The shroud spacer is configured to facilitate shroud section interchangeability, and to provide suitable clearance between the shroud sections.

The shroud section is to provide structural attach points for the nose cone on the forward end and for the Saturn V instrument unit or spacer on the aft end. It is to provide a structural interface for the planetary vehicle adapter and for closure diaphragms at each end of the section, permitting planetary vehicle encapsulation and providing for ETO decontamination and compartment pressurization. Shroud assembly is to be separated in two sections utilizing an over-the-nose sequence. The first shroud separation, exposing the forward planetary vehicle will be during earth parking orbit. The second shroud separation will be during interplanetary flight, after separation of the forward planetary vehicle.

The shroud-planetary vehicle section is not to utilize materials with outgassing properties that would result in planetary vehicle contamination.

Full-scale structural static design verification tests are to be conducted on a structural model assembly which consists of the shroud spacer, one shroud section, and the nose fairing. Tests will be conducted to verify static structural characteristics, primarily structural static load-deflection characteristics. However, due to the mission importance of the shroud structural strength, it may be desirable to conduct shroud ultimate load tests.

Full-scale structural dynamic design verification tests are to be conducted on the same shroud assembly used for the structural static tests, with the addition of the planetary vehicle adapter structure, a planetary vehicle mass-inertia simulator, and other equipment which would affect the mass-inertia or structural stiffness of the shroud assembly. Tests will be conducted to verify dynamic structural characteristics, primarily structural vibratory modes and skin panel resonances which could result in structural fatigue and/or cause equipment failure.

14.4.5 Separation Subsystem

The shroud separation subsystem separates each shroud section at a circumferential plane, as shown in Figure 42. The forward separation plane separates the forward portion of the forward shroud cylindrical section with attached nose fairing as a single unit. The aft separation plane separates as a single unit the forward portion of the aft shroud cylindrical section with the attached shroud spacer and aft portion of the forward shroud section. The aft portion of the aft shroud section remains with the final Saturn V stage.

The shroud separation subsystem consists of all functional elements required to effect the above shroud separations. It encompasses the mechanical attach-release and control devices, electro-explosive devices and associated power and control circuitry. The electrical power and the firing signal required for operation and actuation of the separation devices will be provided by the launch vehicle.

Separation will be effected by a pyrotechnically activated device, completely self-contained, to prevent both planetary vehicle contamination and collision of parts with the planetary vehicle. The separated elements will be required to have a specified separation velocity and be within maximum specified tipoff rates to assure clearance of the planetary vehicle envelope and minimum disturbance to the launch vehicle resulting from shroud separation.

A major effort during the design and development of the separation subsystem pertains to the development of pyrotechnic circuitry and devices. Required reliability will be achieved through the use of proven components and methods, system redundancy, and cross-over circuitry. Proven design techniques will be used to prevent inadvertent RF actuation.

Design and development of the separation subsystem will include unit engineering models of the mechanical attachment and electro-explosive devices plus circuitry breadboarding for conceptual design verification testing. A development model will be used for subsystem verification testing to verify separation velocity and symmetry of separation. The development model will consist of sufficient structure on each side of the separation plane to assure adequate structural rigidity. It will also be necessary to simulate the mass-inertia of the structure to be separated and of the launch vehicle final stage for both the forward and aft shroud separation stage configurations. The development model will be exposed to acoustic and vibration environments and space thermal-vacuum environment for a preliminary determination of subsystem susceptibility to those environments. Operational repeatability tests will also be conducted on the separation model to assist in the determination of subsystem reliability.

14.4.6 Electrical Distribution Subsystem

The electrical distribution subsystem consists of cabling, connectors, and junction boxes which provide for the signal and power flow between electrical elements of the shroud subsystems and the Saturn V instrumentation unit, so as to provide electric power and initiation signals for the shroud system and for the encapsulated planetary vehicles. It also includes those portions of the test harness which are integral with the shroud subsystem.

The electrical distribution subsystem will initially be installed and operationally verified in the engineering model. Testing before the engineering model will consist basically of hi-pot and continuity testing.

14.4.7 Encapsulation Subsystem

The shroud encapsulation subsystem consists of diaphragms located at each end of the shroud section to form a pressure enclosure and provide a means of introducing ETO to this enclosure, and subsequent purging with sterile nitrogen. The encapsulation subsystem is also required to provide a positive pressure subsequent to sterilization and while the shroud planetary vehicle section is exposed to the earth's atmosphere.

During launch ascent it is required that this subsystem maintain the internal pressure at less than a specified level and that it vary in accordance with compartment pressures on either side of the shroud planetary vehicle section to preclude excessive closure diaphragm deflections.

The encapsulation subsystem will be initially tested in the engineering model primarily through mechanical fit and function checks of the umbilical attachment and through operation of the pressure valves and verification of the pressure capability of the encapsulation.

14.4.8 Vent Subsystem

The shroud vent subsystem will provide a means of maintaining a maximum specified nose fairing and shroud spacer compartment pressure from prelaunch to the time of shroud separation. Venting of these two compartments will be by means of openings in the compartment exterior surface and will be required to match the pressure venting characteristics of the Saturn V instrument unit and the shroud planetary vehicle sections to preclude a differential pressure across the closure diaphragms during launch ascent.

This system is comparatively unaffected by intersystem operation; therefore no combined systems type testing will be required. The vent subsystem operation should be amenable to evaluation by engineering analysis.

14.4.9 Thermal Subsystem

It is assumed that no thermal control requirements will be placed on the shroud. It is planned to provide structural provisions for the installation of an RTG heat transfer unit for thermal control of the flight capsule RTG while the planetary vehicle is installed in the shroud. It is also planned to provide fittings in each shroud section for mating with the launch vehicle cooling system to maintain the proper thermal control for equipment within the shroud.

14.4.10 Mechanical Operational Support Equipment

The major portion of the MOSE for the shroud will be that equipment required for assembly, handling, and shipping. There is, however, a requirement for MOSE to provide for planetary vehicle shroud assembly ETO surface decontamination, sterile N_2 purging, and maintenance of the assembly at a positive pressure during the prelaunch operations.

14.4.11 Electrical Operational Support Equipment

The electrical operational support equipment is divided basically into two broad categories:

- System Test Complex
- Launch Complex Equipment

The EOSE will incorporate self-test and fail-safe features. It will provide for testing of each subsystem separately, utilizing the system test complex equipment. The STC will be first assembled and integrated for use with the engineering model. Some system level tests may require special test cables between the EOSE and the separate test connectors. The LCE will be first evaluated as a complete subsystem during the launch site stacking tests to be conducted at KSC.

14.4.12 Engineering Model

The engineering model, which will consist of functional equipment but not flight configured hardware, will be assembled and tested first at the subsystem level using system test complex equipment to allow for early definition of subsystem integration, OSE, and procedural problems prior to final definition, assembly, and checkout of flight configured hardware. Initial electrical and mechanical compatibility will be determined within each shroud section and then between shroud sections when assembled as a system in the launch configuration. The encapsulated sections will be assembled and the decontamination OSE checked out for operation. This operation will constitute the first system test of the electrical distribution subsystem. Simulated launch vehicle electrical power and separation initiation signals will be used to check circuitry integrity and operation. Simulated pyrotechnics will be used. Shroud section mechanical mating and alignment will also be checked.

After the engineering model assembly and checkout but before delivery of the shroud system for launch site stacking tests, mechanical and electrical compatibility tests will be conducted at the shroud contractor's facility with the planetary vehicle adapter structure, planetary vehicle and the launch vehicle instrumentation section. This operation will require one shroud section.

In addition, it is anticipated that a shroud section will be required at the spacecraft contractor facility for compatibility tests.

The engineering model will be utilized for launch site stacking tests at KSC, where it will be integrated with the planetary vehicle and launch vehicle in a manner simulating the planned prelaunch activities utilizing all required OSE and software.

14.4.13 Proof Test Model and Flight Systems

Assembly and checkout operations on the proof test model and shroud flight systems will be conducted after unit and subsystem acceptance tests have been completed in a manner similar to that specified for the engineering model. The complete system will be mechanically and electrically mated and each subsystem tested utilizing system test equipment.

EOSE and MOSE will be evaluated during these tests to determine compatibility with the shroud system. Required test procedures will be evaluated and modified as required.

The PTM with simulated mass-inertia models of the planetary vehicle installed will be subjected to vibration and acoustic tests. Pyrotechnics will be installed during these tests. It will be necessary to divide the shroud system into section groups so that the available hydrodynamic and acoustic test facilities can accommodate the groups. Tests will then be conducted to verify proper operation of the subsystem with simulated electrical signals. The PTM will then be subjected to thermal vacuum tests in a space simulation chamber with the shroud operating as close as practical to a flight configuration. Shroud separation tests are to be conducted to permit verification of the separation system operation after exposure to the mission environment and during space environmental conditions.

Launch operations involving the shroud are discussed in Section 13.

15. SPACECRAFT SYSTEM IMPLEMENTATION

15.1 SPACECRAFT CONTRACTOR'S ROLE

The spacecraft system is implemented by the spacecraft contractor, under the direction and management of the spacecraft system management office, which in turn operates under the general cognizance of the Voyager project manager.

The scope and responsibilities associated with the spacecraft project segment are covered briefly in Section 4. This system responsibility includes the hardware, software, spare end items, development models, and associated operational support equipment, and the management and engineering required for the system activities. The functions assigned include all synthesis, analysis, design, development, reliability assurance, fabrication or procurement, assembly, quality assurance, checkout, integration, and subsystem, system, and mission testing and support operations necessary to meet the spacecraft system requirements.

The spacecraft SMO includes management personnel cognizant of the various technical disciplines required for the spacecraft system. These personnel are charged with responsibility for the quality of system activities within their areas of specialization. To carry out these responsibilities, each supervises the assigned system activity being carried on directly by SMO personnel, and also assists the spacecraft contractor, monitors his activities, and, as necessary, provides him technical direction in carrying out his efforts under the contract.

The spacecraft contractor will be selected competitively on the basis of Phase C proposals in response to an RFP from the spacecraft SMO. The total contractual effort by this contractor starting with Phase C is designated as the spacecraft project. The associated implementation is presented in this section, after a brief description of the system to be implemented.

15.2 SPACECRAFT SYSTEM DESCRIPTION

The spacecraft system includes the flight spacecraft, the planetary vehicle adapter, the spacecraft system test complex, mission-dependent equipment for handling spacecraft telemetry data and commands at ground stations, all special test facilities for spacecraft and planetary vehicle testing; the facilities at KSC utilized to assemble and prepare the flight spacecraft and planetary vehicle for launch; the flight spacecraft launch checkout equipment in the launch complex; and the NASA and contractor personnel working on these elements. The equipment to be developed for the spacecraft project include the flight spacecraft, the planetary vehicle adapter, the operational support equipment, and the mission-dependent equipment. These are described briefly in the following subsections.

15.2.1 Flight Spacecraft

A standardized flight spacecraft with payload changes as appropriate is utilized for all missions, with characteristics as follows:

- Weight breakdown: Bus: 2900 lb
  Science: 600 lb
  Propulsion inert weight: 3340 lb
  Maximum usable propellant: 16,024 lb
- Axial length: 160 inches
- Modified lunar module descent stage, including propulsion and basic structure
- Modular construction
- Insulated equipment compartment with louver-controlled heat flow
- S-band radio: 100-watt transmitter power
  Telemetry rate (high-gain 40 db antenna): 300, 175, 130, 100, 65 kilobits/sec
  (medium-gain 28 db antenna): 9.5, 5.4, 4.1, 3.2, 2.1 kilobits/sec
- Fixed solar array (284 ft^2) augmented by deployed panels (240 ft^2), 1030 watts available at 1.67 AU.
- Sun-Canopus three-axis stabilization with ±0.2 deg limit cycle

- Spacecraft science emphasizing imaging capability; both film and TV camera included

The features of this configuration are listed in Table 4 .

15.2.1.1 Science

The elements of the spacecraft science are listed in Table 5. The major element, the photo-imaging system, incorporates a combination TV and film camera. The science sequencer within the data automation equipment accepts synchronizing and timing signals from the spacecraft computing and sequencing subsystem. It generates detailed timing and sequencing signals to control the experiments and to initiate the transfer of nonreal-time data to the data storage subsystem. The sequencer also accepts revisions to its stored sequences from the science command decoding equipment. The planetary scan platform (PSP) provides suitable mounting interfaces, thermal control, and electrical connections. The PSP accepts angle and angle rate commands and command and timing signals from the science sequencer and is also capable of operating in an automatic tracking mode to keep its boresight axis pointed toward the center of Mars. Various deployment mechanisms position science sensors to achieve adequate antenna patterns, view angles, or isolation from spacecraft effects.

15.2.1.2 Structural Subsystem

The structural subsystem is the framework of the flight spacecraft and provides the platform for support and alignment of all subsystems and the flight capsule. A view of the complete spacecraft structure is shown in Figure 46. The structure is composed of the following major assemblies:

- Flight capsule interstage structure
- Main equipment compartment module
- Outrigger assemblies
- Equipment mounting panels
- Aft equipment module

Table 4. Flight Spacecraft

Item	Weight	Description
Structure and mechanical	790	LM descent stage, modified as follows: a) remove two side panels and replace with 1-in. Al honeycomb panels b) add tubular outriggers for interfact transition between spacecraft and adapter c) add aft equipment module to support solar array and other equipment
Pyrotechnics	51	Release systems for antennas, solar array and science separation, propulsion valve operations, connectors, squibs, and control assembly
Temperature control	130	Insulated equipment compartment with louver-controlled heat flow; insulated solar array
S-band radio	216	Spacecraft-DSN link ● Redundant 100 w TWT's with heat sinks ● Parabolic dish 20 ft, 40. 5 db gain, gimballed, rigid framework construction ● 84 x 36 in. elliptical aperture paraboloid, 28 db gain, single gimbal ● Cup turnstile low-gain antenna ● Redundant receivers, switches, selectors
Capsule radio link	25	UHF antenna, redundant receivers and demodulators
Data storage	72	Tape recorders
Telemetry	8	Redundant PCM encoders
Command	11	Dual decoders and dual command detectors; approximately 170 direct discrete commands plus 21 serial commands

Table 4. Flight Spacecraft (Continued)

Item	Weight	Description
Computing and sequencing	36	Primary and backup sequencers, capable of automatic primary and backup sequencing operations for maneuvers, science sequencing, antenna alignment confirmation, cruise operations timing, and Canopus acquisition calibration, all with ground command override capability
Power	825	Nominal 50-volt system; maximum power required 984 watts • Solar voltaic cells, 6 mil cover glass, aluminum honeycomb substrate; 284 ft^2 fixed to aft equipment module plus 240 ft^2 provided by six deployable panels. Total minimum Mars power available: 1030 watts • Three Ag-Cd batteries, each of nominal capacity 40 amp-hr at 75°F • Redundant 400 Hz and 4.0 kHz inverters, shunt elements, battery regulators, power control unit, and distribution units
Guidance and control	299	Three-axis attitude control of planetary vehicle and spacecraft, antenna orientation, and some science sequence signals; uses engine gimballing plus low thrust N$_2$ reaction jets • Gaseous nitrogen pressure vessels (2), redundant valves, and regulators, plumbing and thrusters • High-gain antenna gimbal mechanisms (32 lb), medium-gain antenna gimbal mechanism (17 lb) • Engine gimbal ±6 deg, electromechanical clutch actuators similar to Apollo SM • Gyro assembly, Canopus sensor (2), sun sensor (3), earth detector, limb and terminator crossing detector, and accelerometer

Table 4. Flight Spacecraft (Continued)

Item	Weight	Description
Cabling	229	Subsystem interconnecting harnesses, junction boxes (4), and umbilical connectors
Balance weight provision	30	Masses mounted on solar panels in two quadrants to offset PSP and high-gain antenna masses
Flight capsule interstage	149	Portion of interstage charged to spacecraft weight; capsule weight remaining with spacecraft after capsule separation is 250 lb
Spacecraft bus weight contingency	157	6 per cent of bus weight
Spacecraft bus total	2879	
Propulsion	3340	LM descent propulsion modified to provide meteoroid protection with new engine nozzle extension and revised propellant valves ● Reaction control supports, meteoroid shielding ● LMDE and associated control valves (586 lb), propellant feed assembly (including tanks) (529 lb), pressurization system (438 lb), tank and engine supports (1621 lb) ● Nonrefillable bellows tanks installed in both fuel and oxidizer lines ● Helium pressurization
Consummable propellant, up to	17, 568	UMDH/N_2H_4 and N_2O_4; orbit trim (100 m/sec), interplanetary correction (200 m/sec), and variable orbit insertion
Spacecraft propulsion total, up to	20, 908	

Table 4. Flight Spacecraft (Continued)

Item	Weight	Description
Spacecraft science	600	● PSP housing, support arm, scan control and drive mechanism ● High and medium resolution imaging system (175 lb) ● Electronic components necessary for science packages operation ● Drive motors and booms for deployed sensors (magnetometer, VLF detector) ● Power switching and command decoding units
Flight Spacecraft Gross Weight, up to	24, 387	
Planetary vehicle adapter	500	Structure, cabling, and interface hardware between planetary vehicle separation joint and nose fairing attachment points
IN-ORBIT WEIGHT	6819 lb	

Table 5. Science Payload

	Weight (lb)	
	On PSP	On Bus
Photo-imaging	150	25
UV spectrometer	18	7
Visible spectrometer	17	7
IR spectrometer	20	2
IR radiometer	10	2
Gamma ray spectrometer	4	2
Polarimeter	2	1
Meteoroid flash detector	10	2
Magnetometer		15
Ion chamber		6
Geiger counters		4
Scintillation counter		13
VLF detector		9
Micrometeoroid detectors		16
Cosmic ray detector		13
Plasma probe		10
Bifrequency occultation		8
	231	142
Mars sensor	12	
PSP structure, shaft, fork	63	
PSP bearing, drives, pickoffs		23
Cabling, wrapups	17	
Attachments and miscellaneous	7	5
Data automation equipment		57
	330	227
Other electronics and contingency	22	21
	352	248

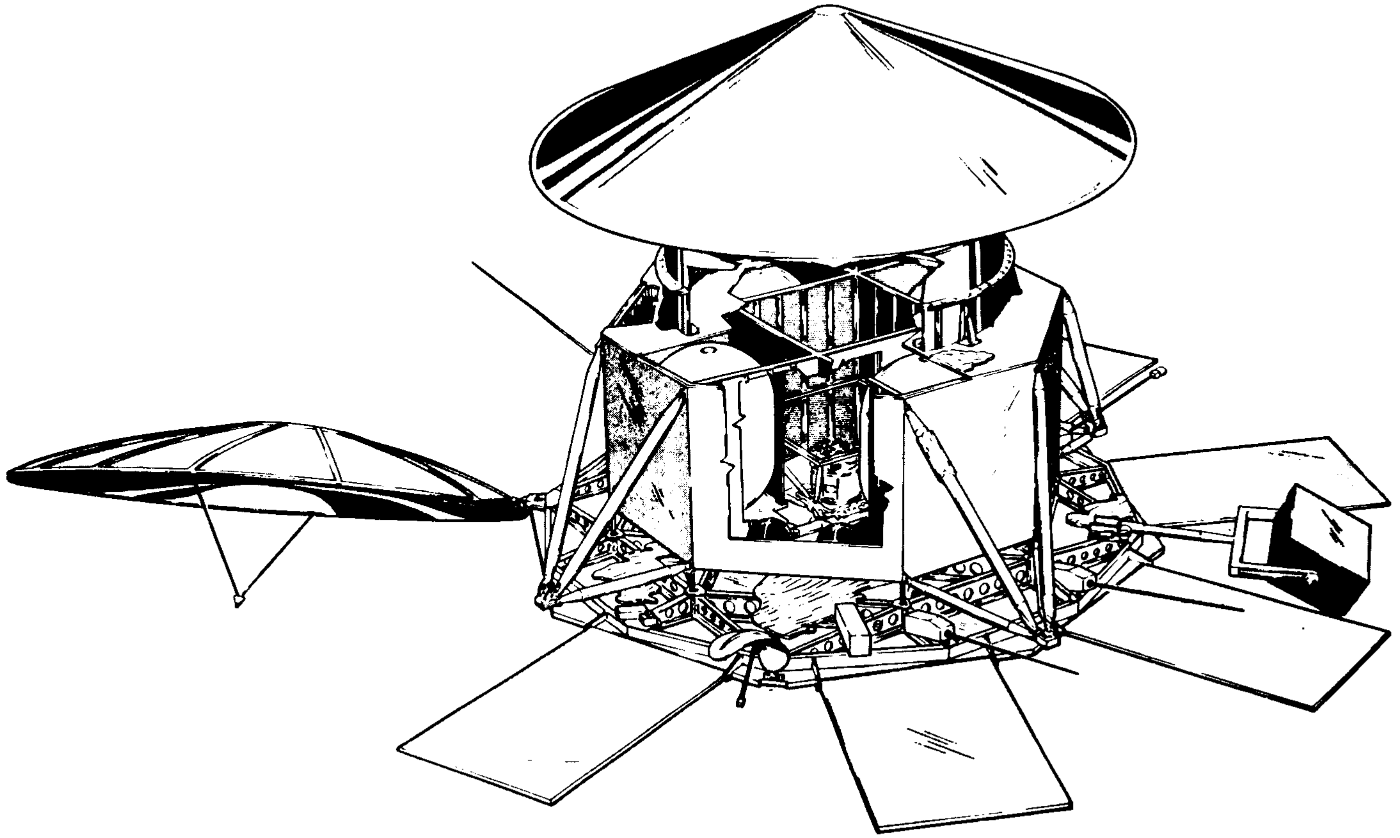


Figure 46. Voyager Flight Spacecraft

The mechanical section of the subsystem consists of the mechanisms required for separation and appendage release and deployment. These functions include: the separation of the planetary vehicle from the PV adapter; the emergency separation of the flight capsule from the flight spacecraft; the retention and release of the high- and medium-gain antennas; the retention, release, and deployment of the low-gain antenna, the planetary scan platform, magnetometer, and other deployed science equipment. All functions are initiated by redundant pyrotechnics. The mechanical elements within this functional subsystem include the following:

- Pyrotechnic separation nuts
- Debris catchers
- Separation springs
- Pyrotechnic pin pullers
- Linear actuators
- Motor-driven boom extenders
- Release bolts and springs

To achieve the quarantine goal of the mission, it is necessary for all structural materials and coatings to be stable in the space environment and compatible with the prelaunch ethylene oxide decontamination treatment.

The propulsion module structure serves as the unifying spacecraft element. All planetary vehicle loads are transmitted through four outriggers which attach to the planetary vehicle adapter. This module supports the majority of electronic and ancillary science equipment. The spacecraft propulsion subsystem, consisting of four propellant tanks, pressurant tanks, the feed system, and the engine, is mounted in this module.

15.2.1.3 Thermal Control Subsystem

The temperature control subsystem includes (a) surface finishes to attain desired radiometric properties, particularly on external equipment, (b) appropriate distribution of electronic components, and

(c) structural design to achieve various degrees of thermal coupling, generally close coupling within the main compartment and poor coupling between the main compartment and solar array and capsule, and between the external equipment and the solar array backup structure. Temperature control hardware includes multilayer aluminized Mylar insulation, bimetal-actuated louver assemblies, and thermostatically-controlled heaters. Approximately 18 square feet of louver-covered radiating area is required on the main compartment. Louver assemblies of the type used on OGO, Pioneer, and Mariner are mounted to the external surface of equipment panels.

15.2.1.4 Propulsion

In addition to the removal of LMDS equipment not required for the Voyager mission, modifications to the propulsion subsystem are incorporated to provide for zero-g start capability, for long-term space storability, for relocation of the engine gimbal plane, and for reducing the radiant heat flux from the nozzle extension to the spacecraft solar array. Additional pressure transducers are incorporated to assist in isolating possible malfunctions, and the two helium tanks are replaced by one larger tank 40.9 inches in diameter. In addition, the metal bellows start tanks and lines, filters, and pressure transducers are added.

The propulsion electrical system encompasses the equipment associated with primary power and signal distribution. It also includes power-dissipating components such as the pressurization regulator solenoids, start and shutdown propellant quad solenoid valves, explosive valves, and the pintle actuator. All of these items are connected by an electrical harness through a propulsion junction box, which contains the electrical control interface connectors, instrumentation interface connectors, and the system checkout connectors.

15.2.1.5 S-Band Radio Subsystem

The S-band radio subsystem includes the following elements:

- S-band receiver
- Receiver selector

- 1-watt transmitter and power monitor
- Modulator-exciter
- Power amplifier, power supply, and RF power monitor
- Transmitter selector
- 4-port hybrid ring and power monitors
- Circulator switch
- Diplexer
- High-gain antenna
- Medium-gain antenna
- Low-gain antenna

The transmitter portion consists of two modulator-exciters cross-strapped via the four-port hybrid ring to drive two redundant 100-watt TWT power amplifiers. These amplifiers can be connected to any of three antennas (low-, medium-, or high-gain) via the circulator switches. A low-power transmitter is provided primarily for launch mode telemetry, but it can also be connected to any antenna for failure mode communications.

The receiver portion consists of three S-band receivers and a receiver-selector. Each receiver is connected to one antenna via a diplexer. The receiver selector provides the logic for selecting the receiver to provide signals to the modulator-exciters, low-power transmitter, and command subsystem.

15.2.1.6 Capsule Radio Link

The equipment in the capsule radio link with the possible exception of the receiving antenna will be supplied GFE to the spacecraft contractor for integration into the spacecraft. The elements of the capsule radio link which mate directly with the spacecraft are:

- UHF receivers (2)
- Demodulators (2)
- Preamplifier
- Tape Recorder

The capsule link antenna is a quad-spiral array which provides a right-hand circularly polarized single lobe radiation pattern, symmetrical about the axis of the array. The array has a gain of 10 db and a half-power beamwidth of 50 degrees. Each element in the array is a cavity-backed, two-arm Archimedian spiral fed by a balm transformer incorporated into the feed transmission line.

15.2.1.7 Telemetry Subsystem

The spacecraft telemetry subsystem consists of two redundant pulse code modulation encoders, each of which has the following major subassemblies:

- Analog multiplexer
- Analog-to-digital converter
- Capsule data buffer
- Pseudonoise generator
- Digital multiplexer
- Modulator-mixer

The multiplexer sequentially samples the analog data inputs, presenting them to the analog-to-digital converter for translation into a 7-bit digital word. Digital outputs of the analog-to-digital converter are applied to the digital multiplexer, as are all digital data, capsule data, the real-time science data, and the outputs of the data storage subsystem. The PN generator provides a 63-bit binary sequence for ground station bit synchronization, which is combined with the serial data stream in the modulator-mixer.

15.2.1.8 Data Storage Subsystem

The spacecraft data storage subsystem contains six separate tape recorders, with separate interfaces and containers. Each recorder has an independent input line, and the subsystem presents six output lines to the telemetry. The recorder playback selection is performed by C and S command with backup via the command subsystem.

The serial input to each recorder is entered into a shift register, then gated to the head drivers. The recording format is biphase saturation. During playback, the data signals are amplified and held in the skew register and then transferred to the output register. The serial output is formed by shifting the contents of the output register with the telemetry bit rate clock.

Recording speed is established by a synchronous record motor driven by 400 cps from the power subsystem. To provide readout that is synchronous with the telemetry bit rate, playback speed is controlled by a servo system comparing the phase of the recorded clock signal with the phase of the telemetry clock.

15.2.1.9 Guidance and Control Subsystem

The guidance and control subsystem provides three-axis attitude control of the planetary vehicle and flight spacecraft at all times after separation from the launch vehicle. It also controls the orientation of the high- and medium-gain antennas, based on pointing commands from the spacecraft sequencer, and provides signals indicating limb and terminator crossings for sequencing science instruments. It also measures vehicle acceleration during propulsion operations. During interplanetary cruise, the spacecraft pitch and yaw axes are stabilized with respect to the sun. Roll stabilization is provided using Canopus as a reference. The subsystem contains the following units:

- Gyro reference assembly
- Accelerometer
- Guidance and control electronics assembly
- Canopus sensor (2)
- Sun sensor
- Limb and terminator detector (2)
- Reaction control assembly
- Antenna drives
- TVC actuators

Thrust vector control during engine firing is provided by gimballing the engine and controlling engine position about the pitch and yaw axes using electrical actuators. Control about the roll axis is provided by the high thrust pneumatics.

15.2.1.10 Computing and Sequencing Subsystem

The computing and sequencing subsystem includes a special purpose sequencer as a primary unit and a backup sequencer as a secondary unit for those functions for which the command subsystem cannot provide an effective backup. The primary sequencer consists of a system of clocks, a central memory, a command input unit, frequency divide logic, a function generator, accelerometer pulse counters, signal input logic, a memory data telemetry register, and a command events telemetry register. The backup system consists of a less extensive system of clocks, a central memory, a command input unit, frequency divide logic, a memory data telemetry register, and simplified signal input logic. The memory is a ferrite core unit with a capacity of 256 20-bit words.

15.2.1.11 Power Subsystem

The power subsystem provides power in suitable forms for distribution to the flight spacecraft and to the flight capsule until its separation. Primary power is by means of silicon photovoltaic cells, mounted on a fixed solar array and deployed panels. Secondary silver-cadmium batteries are used whenever the solar array is incapable of supporting the loads, as during launch, maneuvers, and eclipses. Appropriate controls are provided to maintain proper functioning of the subsystem.

The power subsystem consists of seven major elements: solar array, solar array shunt voltage limiter, power control unit, secondary battery, battery regulator, power conditioning inverters, and power distribution unit. Solar array output is limited to 50 vdc ±1 per cent by shunt regulation of a portion of each series string of solar cell modules.

The three 30-cell, 40 ampere-hour, silver-cadmium batteries, each with a charge-discharge regulator, are operated in parallel under normal conditions. Six deployable solar panels added to the fixed solar array provide a total array area of 524 ft^2. At a sun-spacecraft distance of 1.67 AU, this provides a worst case value of 1030 watts of power at 50 volts, available from the solar array.

15.2.1.12 Electrical Distribution

The spacecraft cabling and electrical distribution subsystem consists of the following elements:

- All spacecraft wiring harnesses except those furnished as integral parts of GFE assemblies
- Junction boxes for the distribution and integration of electrical functions
- Umbilical cabling associated with the spacecraft
- System level test points including hardline test connectors

The functions of the cabling subsystem are to distribute electrical signals and power throughout the spacecraft bus, to integrate all electrical subsystems into the over-all bus, to integrate the science, capsule, and launch vehicle elctrically with the spacecraft, and to provide the system level test points.

15.2.1.13 Pyrotechnic Subsystem

The pyrotechnic subsystem includes the functional elements acuated by electro-explosive devices. The subsystem can be divided into three major areas:

- Pyrotechnic control assembly
- Electro-explosive devices
- Mechanical attach-release devices

The pyrotechnic control assembly includes the safe-arm circuit which controls application of power to the subsystem, the power conversion circuitry which rectifies the AC input to provide the proper DC voltage for the energy storage circuits, and solid state firing circuits which provide initiating current to individual explosive devices on command. The attach-release devices are mechanical assemblies which utilize the explosive pressure impulse as the source of motive power.

15.2.2 Planetary Vehicle Adapter

The planetary vehicle adapter includes all structure, cabling, and hardware between the planetary vehicle inflight separation joint and the associated points of attachment to the nose fairing. It consists of the following elements:

- Main frame
- Intermediate frame No. 1
- Intermediate frame No. 2
- Adapter fittings (4)
- Shroud support fittings (4)

The adapter will attach to the Saturn V shroud and support a single planetary vehicle from preflight through launch vehicle separation. Since two planetary vehicles are positioned in tandem within the nose fairing, two adapters are required.

15.2.3 Operational Support Equipment

The operational support equipment includes bench checkout equipment, nine subsystem electrical OSE test sets, mission operations support test equipment, launch complex equipment, and assembly, handling, and shipping equipment.

15.2.3.1 Electrical OSE

During a systems test, the system test complex (STC) operates nine subsystem test sets in an integrated sequence. The integrating unit is the central data system computer, which controls the activities of and accumulates the data from each of the subsystem test sets.

The five main functions performed by the STC are system test, subsystem test, fault detection and isolation, performance data gathering and record keeping, and trend analysis. Figure 47 pictures the EOSE complement in the STC.

The central data system is composed of the computer main frame, the peripheral equipment and the data entry and monitor racks as shown in Figure 48 . The data entry and monitor racks (DE and MR)

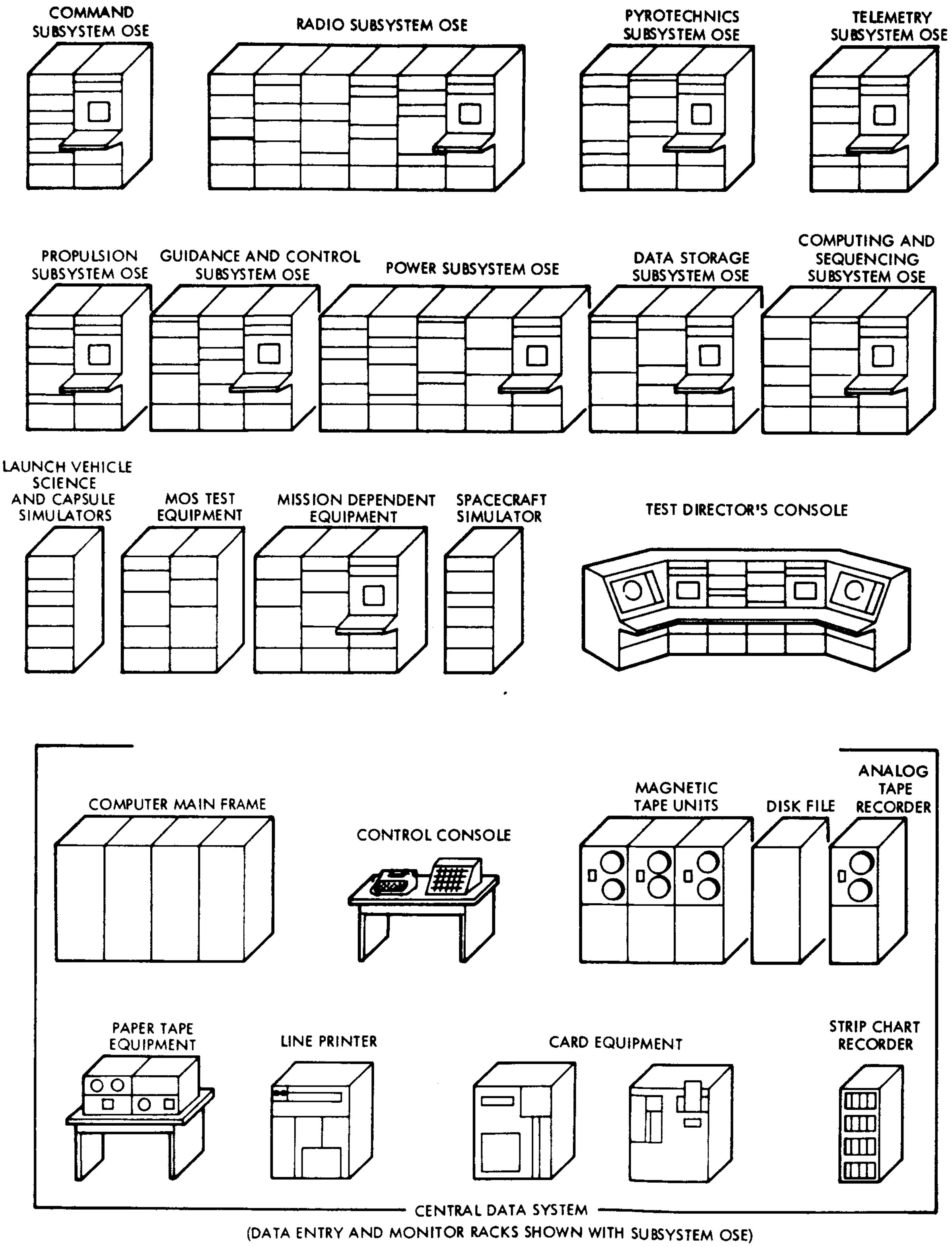


Figure 47. EOSE Complement in the System Test Complex

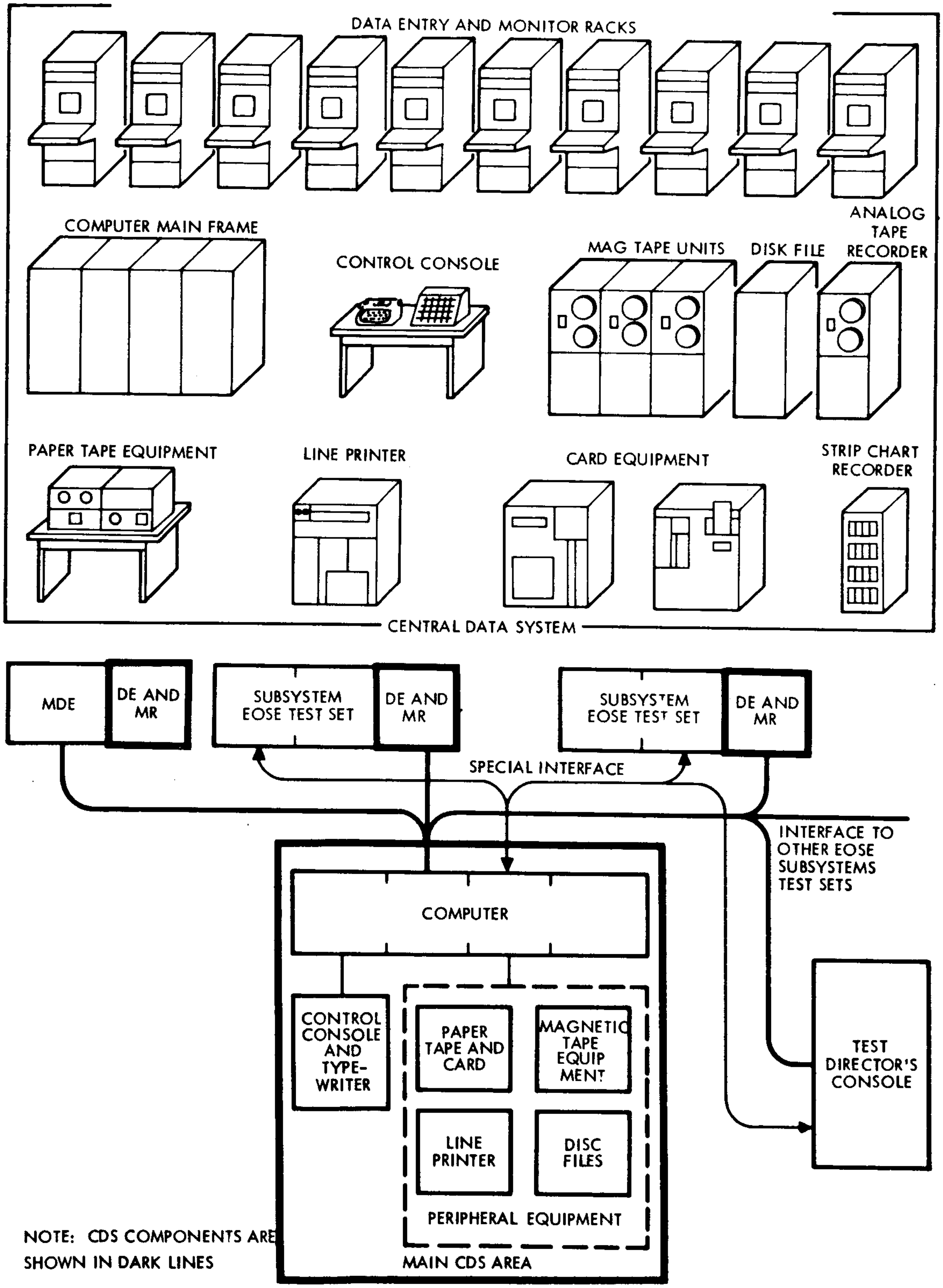


Figure 48. Central Data System EOSE Flow and Rack Layout

are located adjacent to their respective EOSE test sets, while the remainder of the computer units are located in a central computer area.

The power subsystem EOSE provides the spacecraft power subsystem with the following simulation, stimulation, and control functions:

- Simulated solar array voltage and current; variable 400 and 4000 Hz power to provide for power margin tests on the spacecraft
- Simulated battery voltage variable between 29 and 42 vdc
- Inverter and battery loads to simulate the various loads during the different modes of operation
- Shunt element simulation provided from isolated sources
- Simulated C and S subsystem commands
- Battery undervoltage and overvoltage control
- Light source to stimulate the solar panels

The following functions are monitored by the power subsystem EOSE during subsystem and system level testing:

- Battery cell voltage and temperature
- Inverter output current and voltage under various load conditions
- Telemetry sensors voltage
- Power distribution voltage and control capability
- Sync frequency

The computing and sequencing subsystem EOSE contains all test circuitry required to test the spacecraft computing and sequencing subsystem from detailed subsystem testing through integrated system testing to the less detailed launch support operational tests. The C and S EOSE can supply all required input simulation signals and monitor all output data signals.

The guidance and control subsystem EOSE performs functional tests on the spacecraft guidance and control subsystem both before and after spacecraft integration. It operates in either a manual mode or an automatic mode programmed by an external computer.

The radio subsystem EOSE evaluates the performance of the panel-mounted equipment of the Voyager spacecraft radio subsystem. The EOSE includes a stimulus and measurement section, an RF section, and bench test accessories and junction box. The EOSE is configured so that stimulus and monitor equipment selection and signal routing can be controlled either by the CDS or by a manual control panel.

The telemetry subsystem EOSE provides complete subsystem testing capability in both system and subsystem configurations. Testing is performed by simulating the telemetry subsystem input and verifying subsystem operation using the telemetry EOSE. The telemetry EOSE uses the central data system to perform the data processing task and to provide data display on the data entry and monitor rack. The EOSE includes the following major elements:

- Telemetry detector
- Control buffer
- Data format generator
- Telemetry EOSE power supply
- Decommutation and display unit
- Printer

The command subsystem EOSE permits end-to-end testing of the spacecraft command subsystem in subsystem and system test level configurations. The testing is automatic when the command EOSE is used with the CDS, which provides automatic input simulation and output verification. The command EOSE includes a command encoder, output buffer, frequency counter, and a power supply (AC) for the spacecraft command subsystem.

The data storage subsystem EOSE contains all test circuitry required to test the spacecraft data storage subsystem from subsystem testing through integrated system testing to the less detailed prelaunch testing. The data storage EOSE test set is capable of supplying all required input simulation signals and monitoring all output data signals.

The pyrotechnic subsystem EOSE provides discrete commands to spacecraft pyrotechnics via the ordnance initiate circuits, simulated ordnance loads, and monitor lights to indicate ordnance circuit actuation. The subsystem EOSE is operable manually or automatically by the computer via the data entry and monitor rack. The pyrotechnic EOSE consists of an interval generator to generate fire command pulses to trigger the spacecraft ordnance initiate circuits, simulated loads to represent the ordnance load to the initiate circuits, and threshold sensing to evaluate the current pulses delivered to the explosive devices.

The propulsion subsystem EOSE provides for automatic and manual functional electrical testing, at both system, and subsystem levels, for spacecraft propulsion subsystem cold engine operations. It provides the following test functions:

- Measure squib continuity and resistance (100 ma maximum to prevent inadvertent firing)
- Simulate resistance of solenoids
- Determine continuity of normally closed contacts
- Provide analog voltage proportional to transducer output
- Simulate each transducer sensor voltage output over the sensor output range, to provide calibration flexibility
- Drive the pintle actuator to each extreme position and determine the response time
- Include automatic self-test of the EOSE
- Provide fault isolation in the propulsion subsystem to the provisional spare replacement levels

15.2.3.2 Mechanical OSE

Table 6 lists the system mechanical OSE. The major items in the table (noted by *) are then briefly described.

Table 6. System Level MOSE

No.	Item	Source	Quantity
1	Electrical prime	Contractor	4
2	Spacecraft-planetary vehicle sling	Contractor	6
3*	Vertical checkout and assembly stand (movile)	Contractor	6
4	Hydraset, 1 ton	Contractor	4
5	Hydraset, 5 ton	Contractor	4
6	Hydraset, 10 ton	Contractor	4
7	Spacecraft work stands	Contractor	6
8	Mechanics tool kit	Contractor	30
9	Hydraset, 20 ton	Contractor	
10	Capsule (test)	GFE	3
11	Capsule shipping and handling dolly	GFE	3
12	Capsule transporter and hoist sling	GFE	1
13*	Planetary vehicle inverter	Contractor	1
14	Component alignment instruments	Contractor	2
15	Alignment optical instruments	Contractor	2
16*	Equipment kit, mass properties	Contractor	2
17	Miscellaneous shipping container	Contractor	6
18*	Magnetic test fixture	Contractor	1
19	Vibration machine adapter	Contractor	1
20	Special appendage deployment equipment	Contractor	1
21	Thermal-vacuum test adapters	Contractor	1
22	Thermal-vacuum test instrumentation	Contractor	1
23	Free mode test adapter	Contractor	1
24	Shroud-spacecraft clearance measuring instrument	Contractor	1
25*	Sterilization pressure dome	Contractor	2
26	Tag lines	Contractor	9
27*	Flight shroud planetary vehicle transporter	GFE	1
28	Flight shroud section sling	GFE	1
29*	Flight shroud planetary vehicle cover	Contractor	3

Table 6. System Level MOSE (Continued)

No.	Item	Source	Quantity
30*	Flight shroud planetary vehicle hoist beam	Contractor	4
31	Flight shroud assembly fixture	GFE	1
32*	Hoist kit, spacecraft shipping container (DSV-4B-303)	GFE	1
33*	Instrumentation unit (SC) (1B57308)	GFE	1
34	Sterilization unit	Contractor	1
35	Saturn 5-booster simulator	GFE	1
36	Equipment mounting panel handling fixture	Contractor	3
37	Equipment mounting panel hoist sling	Contractor	2
38	Equipment mounting panel installation fixture	Contractor	3
39	Equipment mounting panel shipping container	Contractor	3
40	Test capsule shipping container	GFE	3
41a*	Spacecraft transporter modified S-IVB transporter (DSV-4B-300)	GFE	1
42a*	Instrumentation trailer, S-IVB, modified (NASA 5146-1)	GFE	1
43a*	Handling and support kit spacecraft shipping container modified S-IVB equipment (DSV-4B-462)	GFE	1
44a*	Air conditioning unit	Contractor	1
45a*	Transporter cradles, shipping containers, S-IVB modified (DSV-4B-301)	GFE	1
46a	Purge unit, S-IVB modified (DSV-4B-1865)	GFE	1
47a*	Generator trailer (NASA 5145-9)	GFE	1
48a*	Transporter prime mover, S-IVB	GFE	1
49b*	Roller kit, S-IVB (DSV-4B-1863	GFE	1

---

[a] Required for road and sea transportation of the spacecraft

[b] Required for aircraft (VPG) transportation of the spacecraft

Table 6. System Level MOSE (Continued)

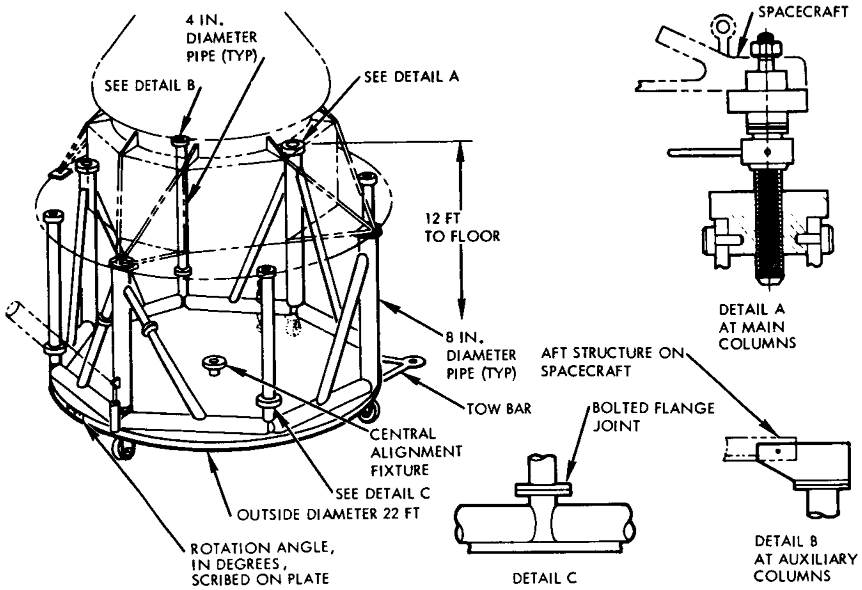
No.	Item	Source	Quantity
50b*	Air carry support kit, S-IVB modified (DSV-4B-1859)	GFE	1
51b*	Tie-down kit, S-IVB modified (DSV-4B-1861	GFE	1
52b*	Access kit, S-IVB modified (DSV-4B-1860)	GFE	1
53b*	Cargo life trailer, S-IVB	GFE	1
54a	AKD barge tie-down kit	GFE	1
55c*	Miscellaneous handling and rigging kit, helicopter	Contractor	1
56c*	Instrumentation kit, helicopter	Contractor	1
57	Magnetic facility adapter	Contractor	1
58a, b, and c*	Spacecraft shipping container	Contractor	4
59	Spacecraft shipping container sling	Contractor	3

[a] Required for road and sea transportation of the spacecraft

[b] Required for aircraft (VPG) transportation of the spacecraft

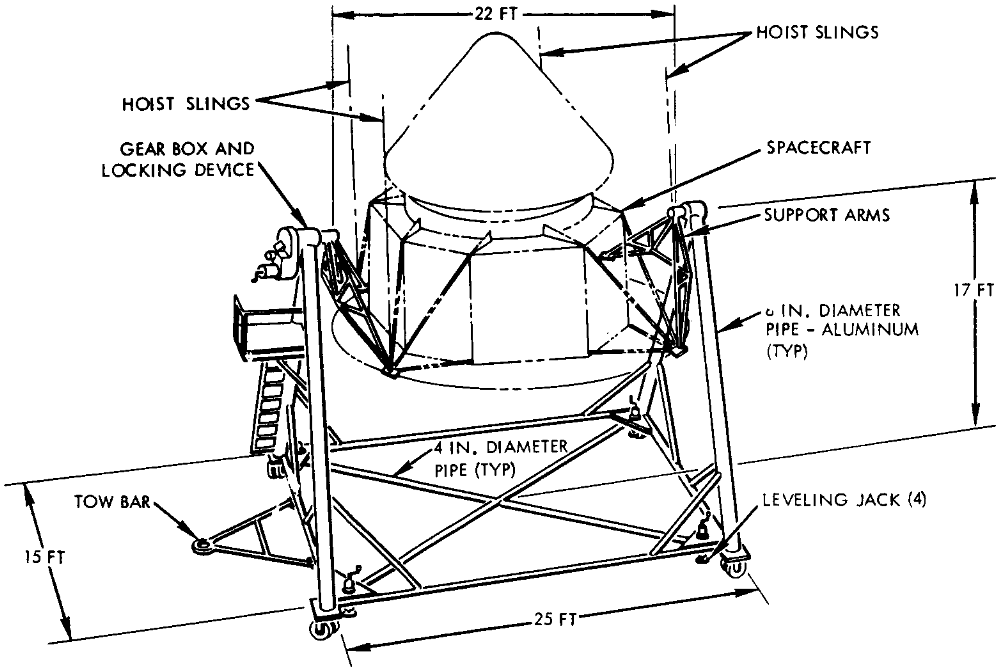
[c] Required for helicopter transportation of the spacecraft

VERTICAL CHECKOUT AND ASSEMBLY STAND, MOBILE, No. 3



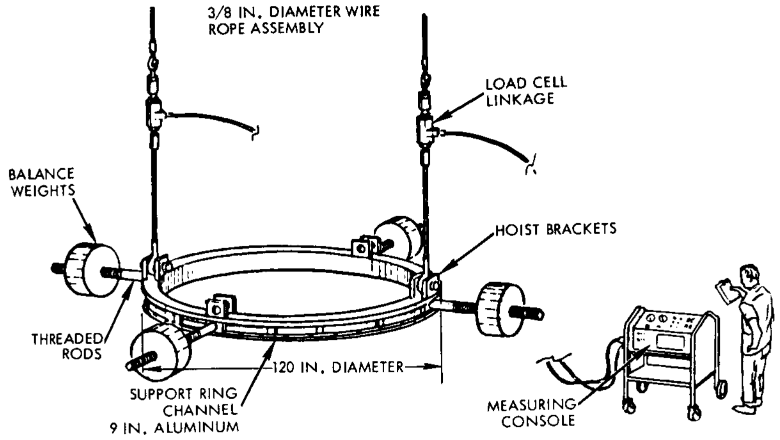
The vertical checkout and assembly stand consists of an octagonal base with vertical columns constructed from pipe. Mobility is provided by three caster assemblies mounted on the underside of the stand. A tow bar is provided. At the stand center is a support bearing which allows complete rotation, the load being supported by three air bearings in the base. Angular readout marks are scribed on the periphery of a circular baseplate and a central alignment fixture is provided. Of the four main columns which support the spacecraft, one is hinged at its base to deploy the antenna. The four auxiliary columns which attach to the spacecraft structure are removable.

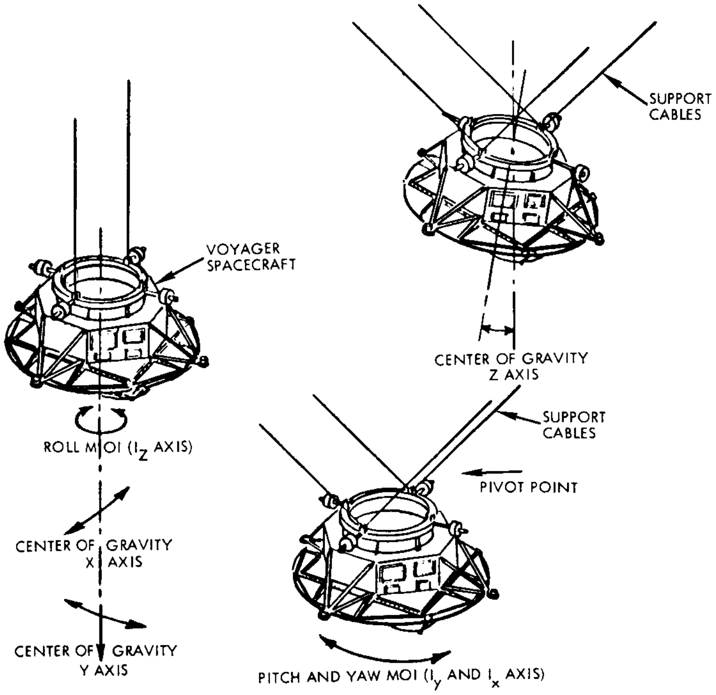
PLANETARY VEHICLE INVERTER, No. 13



The planetary vehicle inverter is composed of basic "A" frames constructed of nonmagnetic 8-inch diameter aluminum pipe and 4-inch diameter support members. The planetary vehicle is supported by two sets of arms so that it will rotate about its center of gravity in the horizontal axis. The support arms are attached to the "A" frames at bearing points and are rotated by a gear box which also serves as a locking and positioning device. A tow bar and set of caster wheels at each member of the "A" frames provide mobility. Four jacks level and secure the inverter.

EQUIPMENT KIT, MASS PROPERTIES, No. 16

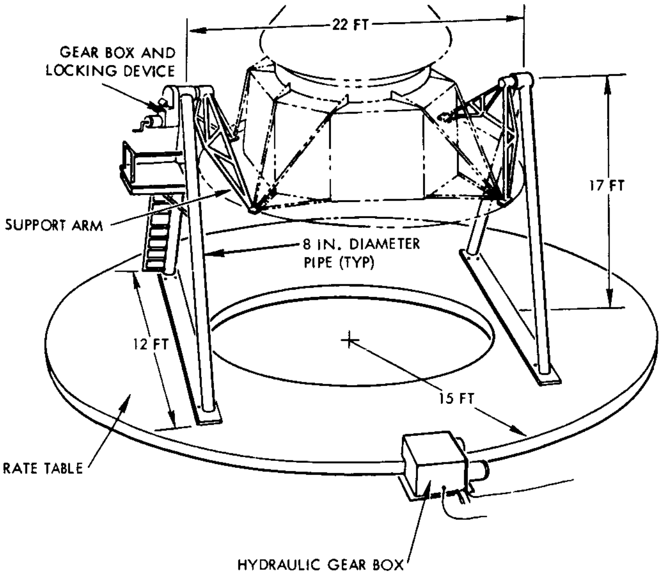




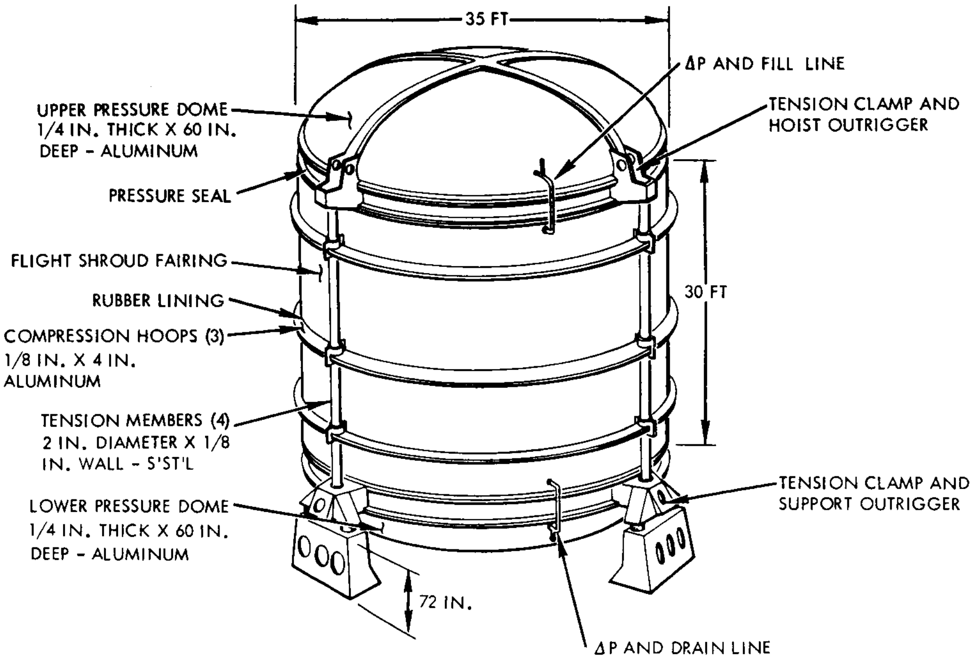
The mass properties equipment kit consists of two major components: a support ring and weighing-suspending equipment. The support ring, a rigid circular aluminum channel structure bolted to the spacecraft-capsule adapter ring, fastens to the capsule mounting holes in the adapter ring.

Four hoist brackets attach to two wire rope cables for MOI measurements or a set of slings and load-cell linkages for weighing. Four threaded rods are fastened to the periphery of the ring at the hoist bracket locations to accept adjustable position weights. The weighing equipment consists of load-cell linkages and a measuring console. Each linkage consists of a Miller-type swivel, 4000-pound load cell, and a wire rope cable assembly.

MAGNETIC TEST FIXTURE, No. 18

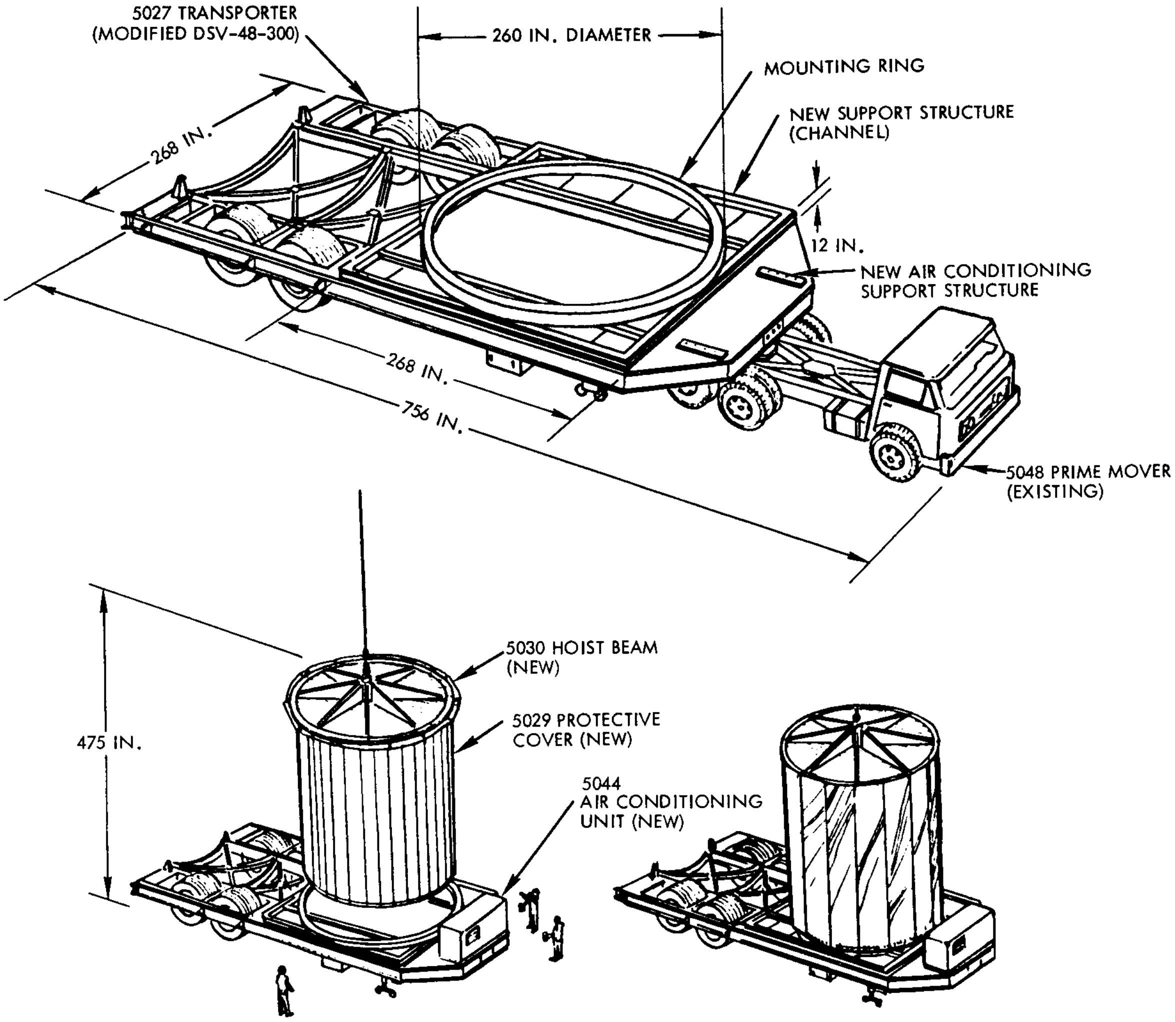


The magnetic test fixture is composed of basic "A" frames of 8-inch diameter aluminum pipe which can pivot the spacecraft about its horizontal axis. The spacecraft is attached by interchangeable support arms so as to maintain the center of gravity of the spacecraft along the axis of rotation. Horizontal rotation is by a hand or power operated gear box which also serves as a locking device. Rotation about the vertical axis is by mounting the "A" frame structure on a hydraulically-driven thrust bearing. The thrust bearing acts as a rate table since the velocity and direction can be controlled as desired.



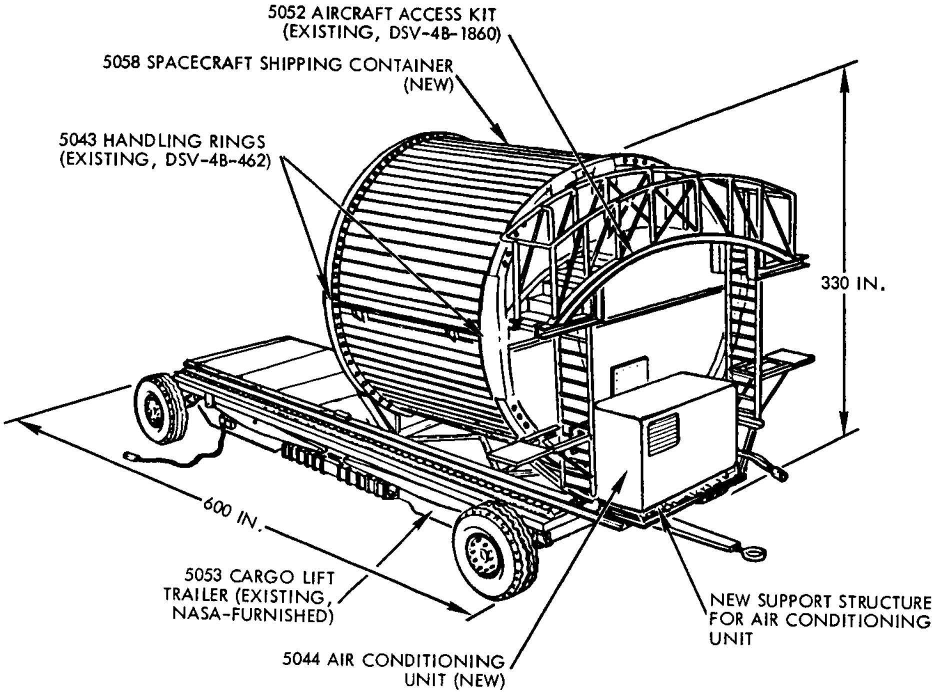
The flight shroud and biological barrier end seals are pressurized through two domes sealing each end. The loads are absorbed through four tension members constructed of 2-inch diameter stainless steel securing the domes to one another. Three compression hoops are equally spaced along the tension members and cushioned from the shroud with rubber to absorb the hoop stresses generated. The entire assembly is mounted vertically on four pedestals.

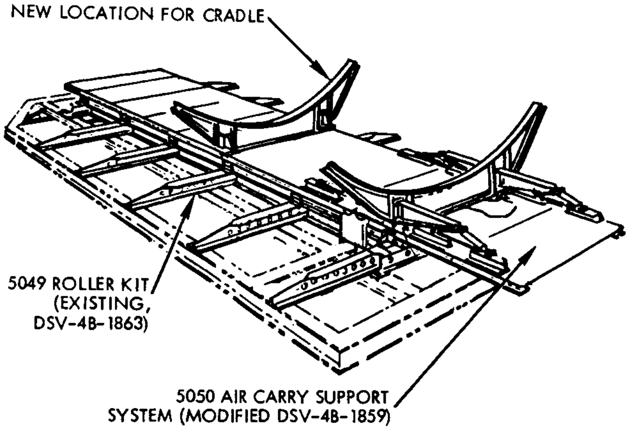
TRANSPORTER GROUP, FLIGHT SHROUD-PLANETARY VEHICLE, Nos. 27, 29, 30, 44, and 48



The flight shroud-planetary vehicle transporter group consists of modified Saturn SIVB transporter, a circular hoist beam, a protective cover, an air-conditioning unit, and a prime mover. Flight shroud-planetary vehicle load size and weight allows use of the Saturn SIVB transporter with minor modifications. Modifications consist of adding a mounting rind and a structural framework to distribute the flight shroud-planetary vehicle loads to the main load-carrying members on the transporter.

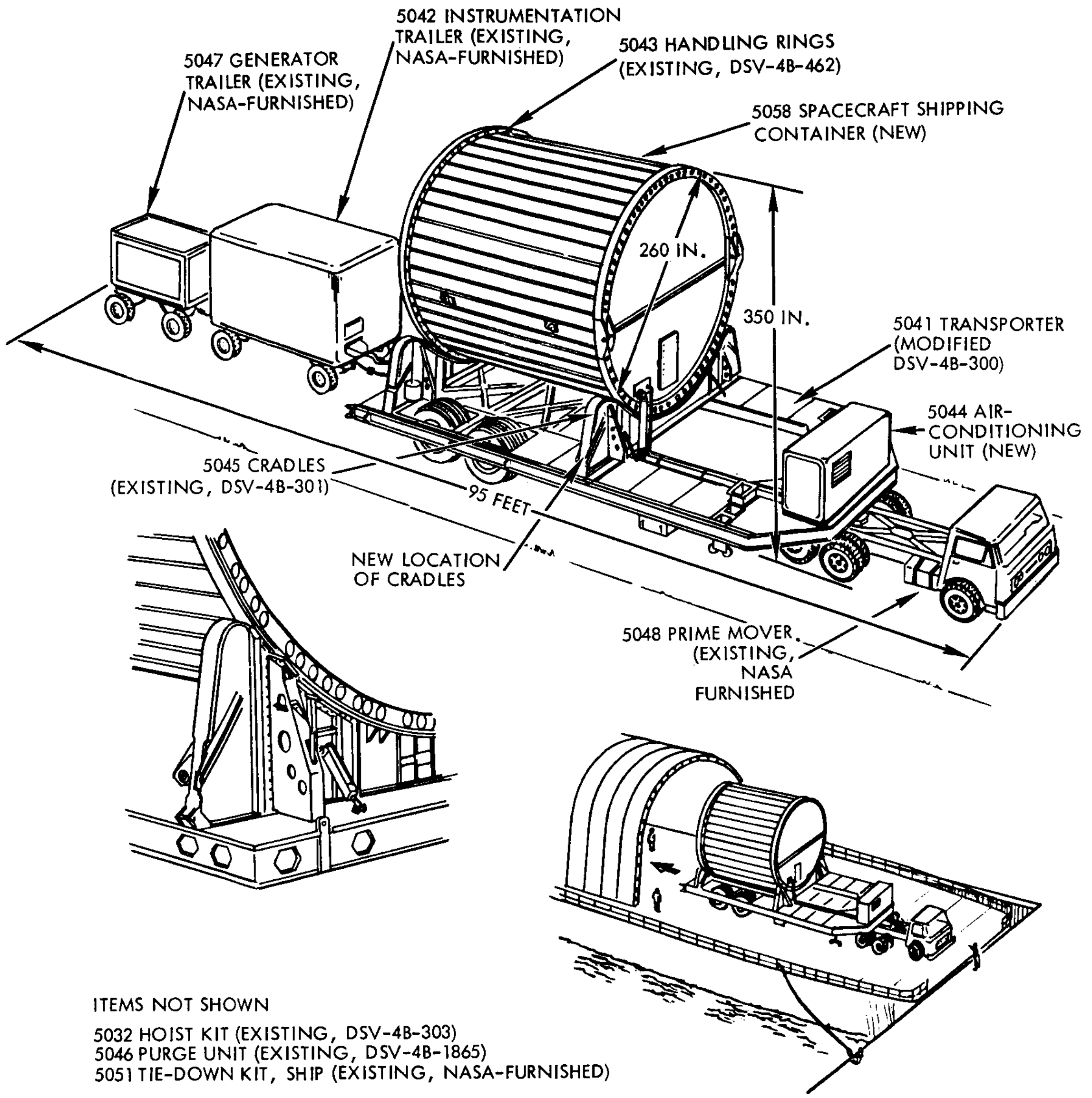
TRANSPORTER GROUP, SUPER GUPPY, Nos. 32, 33, 43, 44, 49, 50, 51, 52, and 53





The Super Guppy transporter group consists of a Super Guppy aircraft; a cargo-lift trailer, a roller kit, an air-carry support system, an aircraft access kit, an aircraft tie-down kit, and handling rings.

TRANSPORTER GROUP, LAND AND SEA, Nos. 41, 42, 43, 44, 45, 47, 48, and 58



ITEMS NOT SHOWN

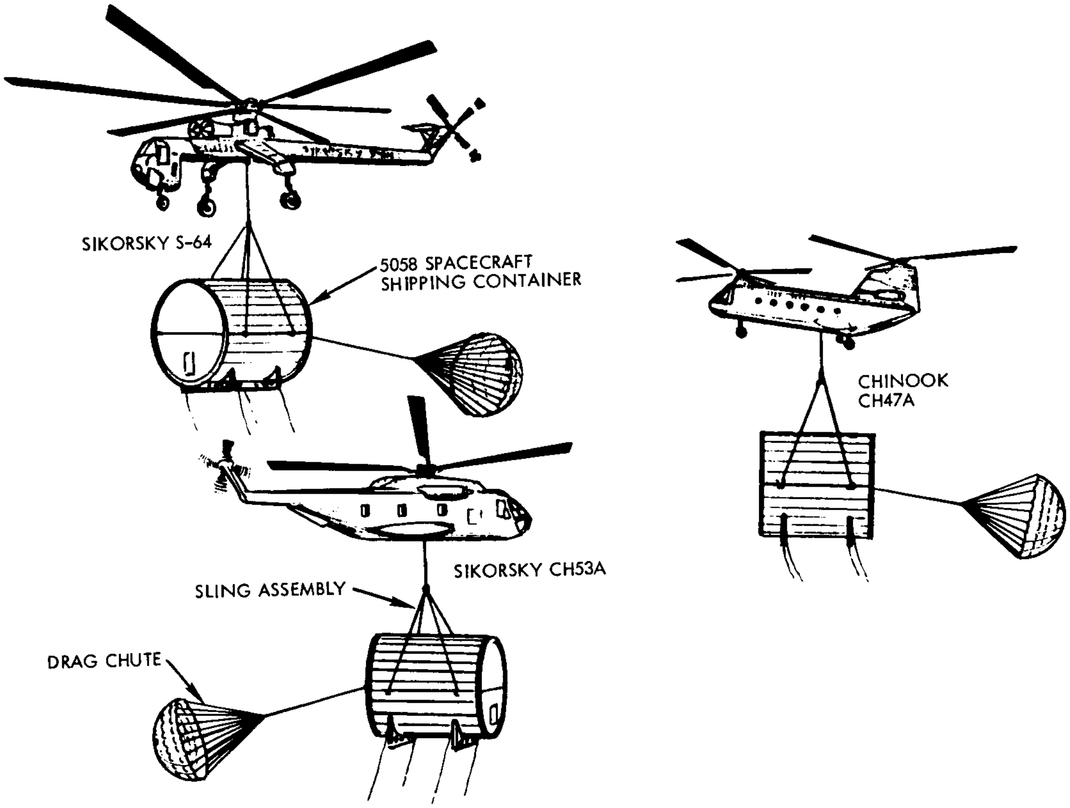
5032 HOIST KIT (EXISTING, DSV-4B-303)
5046 PURGE UNIT (EXISTING, DSV-4B-1865)
5051 TIE-DOWN KIT, SHIP (EXISTING, NASA-FURNISHED)

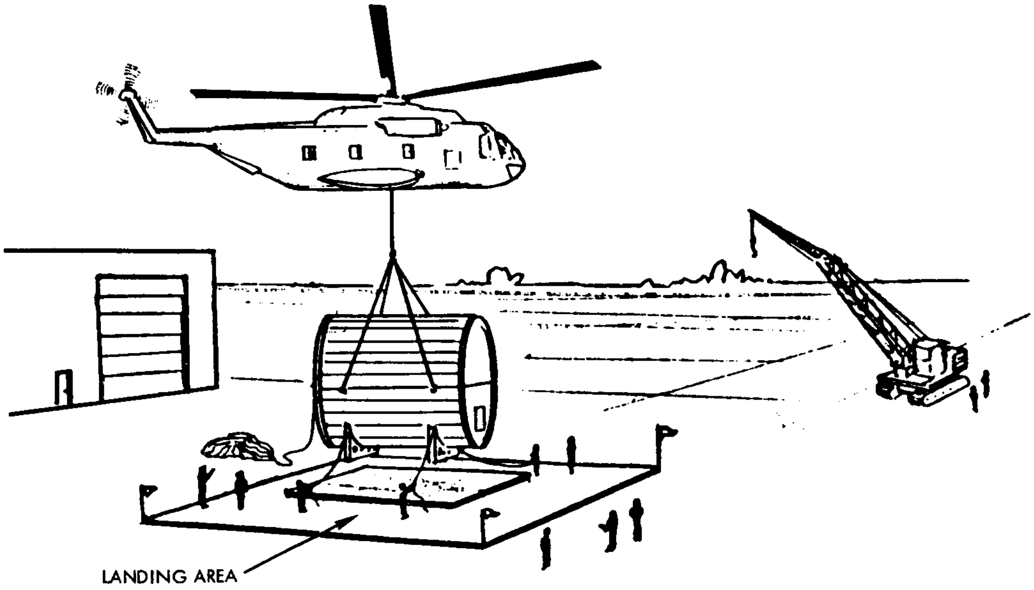
The equipment consists of a transporter, cradles, handling rings, a hoist kit, an instrument trailer, a generator trailer, an air-conditioning unit, a purge unit, an AKD barge tie-down kit, a transporter prime mover, and a spacecraft shipping container. The Voyager spacecraft size and weight allows the use of Saturn SIVB land and sea transporting equipment with minor modifications and additions.

The frame of the Saturn SIVB transporter is modified to support the Voyager spacecraft shipping container by relocating the cradle support installation points. The Saturn SIVB stage cradles can be used without modification except that the location of the cradles on the transporter will be changed. The Saturn SIVB handling rings and hoist kit need no modification.

The air-conditioning unit maintains a temperature of $72 \pm 5^{\circ}F$, a relative humidity of 30 ± 5 percent, and a total dust particle count within the spacecraft shipping container in accordance with Class 100,000 clean area specified in Federal Standard No. 209. The air-conditioning unit is mounted on the bed of the transporter and is a new equipment item.

TRANSPORTER GROUP, HELICOPTER, Nos. 55, 56, and 58





The helicopter transportation group consists of a Sikorsky 64-A, Sikorsky CH-53A, or a Chinook helicopter; a handling and rigging kit, an instrumentation unit, and a spacecraft shipping container. The handling and rigging kit consists of a 25,000-pound nylon bungee rope, a low response hoist sling, a drag chute, tag lines, removable shipping container cradles and brackets, and casters which attach to the cradles.

The following items of mechanical OSE are required for assembly, handling, and shipping subsystems:

Subsystem	Item	Quantity
S-band communication	S-band subsystem electronics shipping container	3
	High-gain antenna container	3
	High-gain antenna sling	3
	Medium-gain antenna container	3
	Medium-gain antenna sling	3
	Low-gain antenna container	3
Capsule relay link	Relay link antenna shipping container	3
Command	Command subsystem shipping container	3
Computing and sequencing	Computer and sequencer system shipping container	3
Telemetry	Telemetry subsystem shipping container	3
Data storage	Data storage subsystem shipping container	3
Guidance and control	Guidance and control subsystem shipping container	3
	Guidance and control subsystem shipping container sling	3
	Reaction control pressure vessel handling fixture	6
	Reaction control pressure vessel handling sling	3
	Pneumatic test set	2
Power	Power subsystem shipping container	3
	Solar array mounting fixture	3

Subsystem	Item	Quantity
Power (cont'd)	Solar array handling dolly	3
	Solar array hoisting sling	3
	Solar array protective covers	4
	Dummy solar arrays	6
	Solar array checkout kit	2
	Solar array shipping container	4
	Solar array handling frame	3
Cabling	Spacecraft harness assembly shipping container	3
Structure and mechanical	Aft equipment module protective cover sling	3
	Aft equipment module lifting sling	3
	Aft equipment module shipping container	3
	Aft equipment module protective cover	6
	Aft equipment module dolly	3
	Flight capsule interstage structure shipping container	3
	Flight capsule interstage structure shipping container sling	2
	Aft equipment module shipping fixture	2
Temperature control	Louvers shipping container	3
	Louvers installation and handling devices	3
	Louvers protective covers	6
	Temperature control subsystem testing kit	3
	Temperature control subsystem module shipping container	3

Subsystem	Item	Quantity
Temperature control (cont'd)	Temperature control subsystem module installation devices	3
	Insulation shipping container	3
	Louvers sling	3
Pyrotechnic	Ordnance checkout kit and handling case	2
	Pyrotechnic subsystem shipping container	3
	Pyrotechnic subsystem shipping container sling	3
Fixed science packages	Fixed science package shipping containers	3
	Fixed science package assembly and handling fixtures	3
	Fixed science package slings	3
	Science subsystem spacecraft fixture	3
LM propellant retropropulsion	Engine test facility adapter	1
	Pyrotechnic initiator test set	3
	Portable clean environment kit	3
	Engine firing control station	3
	Thrust vector control station	3
	Descent stage propellant tank dolly	3
	Helium distribution unit controller	3
	Propellant loading control assembly	3
	Descent stage engine installation dolly	3
	Helium components test stand	3

Subsystem	Item	Quantity
LM propellant retropropulsion (cont'd)	Ascent/descent propellant system checkout unit	3
	Propulsion systems checkout cart	3
	Halogen leak detector	3
	Helium-hydrogen mass spectrometer leak detector	3
	Propulsion systems portable checkout unit	3
	Helium pressure distribution unit	3
	Fuel loading control assembly	3
	Oxidizer loading control assembly	3
	Descent stage propellant tank installation fixture	3
	Pressure maintenance unit	3
	Oxidizer transfer and conditioning unit	3
	Fuel transfer and conditioning unit	3
	Helium transfer and conditioner unit	3
	Helium booster cart	3
	Fuel ready storage unit	3
	Oxidizer ready storage unit	3
	Fuel vapor disposal unit	3
	Oxidizer vapor disposal unit	3
	Helium storage trailer	3
	B-377 PG transportation kit	3
	Descent stage fitting assembly	3
	Descent stage protective cover	6

Subsystem	Item	Quantity
LM propellant retropropulsion (cont'd)	Descent stage handling dolly	3
	Descent stage support stand	3
	Level loading cargo lift trailer	3
	Auxiliary crane control	3
	Console, liquid leveling remote control	3
	Console, test conductor	3
	Sling, D/S propulsion tank assembly	3
	Cover, protective D/S engine	6
	Cover, D/S engine skirt	6
	Fixture, helium tank handling	3
	Sling, spherical tanks	3
	Dolly, D/S engine handling	3
	Plug, D/S engine	3
	Adapter, D/S propellant tank	3
	Drain plug, D/S engine	6
	Support stand D/S	3
	Work stand	3
	Sling, D/S propulsion tank handling fixture	3
	Support stand D/S engine	3
	Dolly, propulsion tank	3

15.2.4 Mission Dependent Equipment

The Voyager mission dependent equipment (MDE) consists of specialized rack-mounted equipment to complement standard DSIF station equipment to enable DSN communication with the Voyager planetary vehicles. Figure 49 is a rack diagram of the MDE/MOS test equipment.

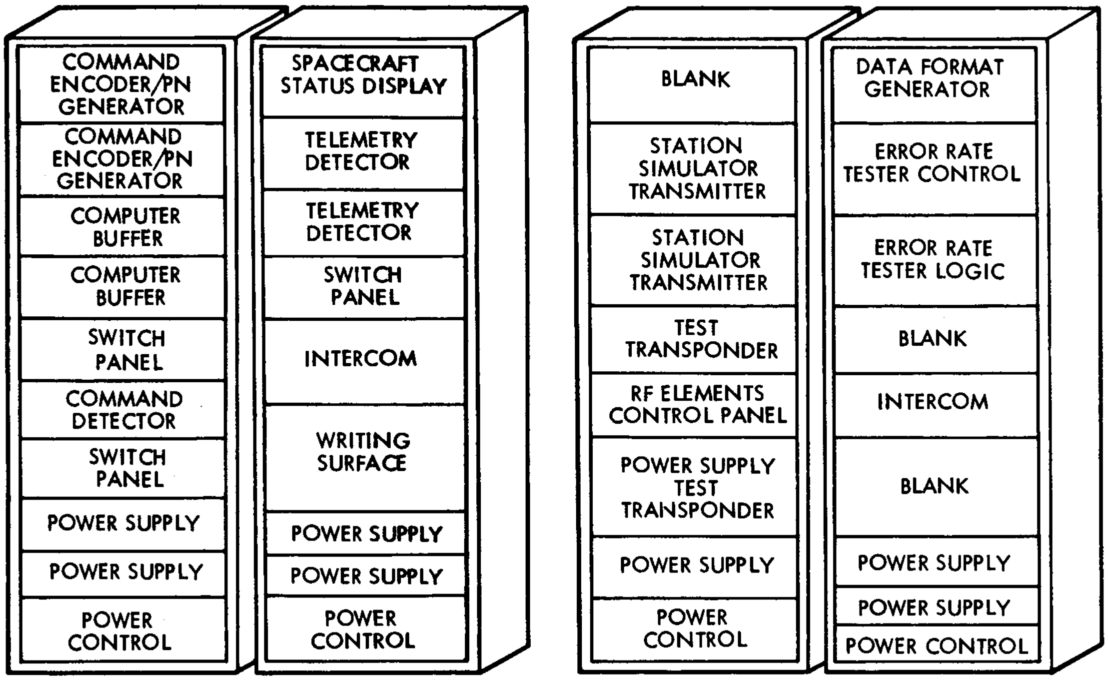


Figure 49. Mission-Dependent Equipment/Mission Operations System Rack Layout

The prime in-line functions of the MDE essential to the DSIF link with the Voyager spacecraft are command generation, telemetry detection, and computer buffering. Secondary in-line functions, not essential to the DSIF spacecraft link but desirable for monitoring, are command verification, spacecraft subsystem status display, and data recording. The Voyager MDE is unique, since the command words and telemetry readout for Voyager differ from those of other programs. Operating with the DSIF, commands are entered into the system manually. Programming permits the station computer to decommutate the Voyager telemetry data, to provide spacecraft status information to the MDE, to make MDE command checks, and to accept station time signals. Telemetry data, command data, and status data can be typed out on the station computer typewriter or line printer. The principal interfaces between the MDE and the DSIF are shown in Figures 50 and 51.

15.3 IMPLEMENTATION SUMMARY

The flow of implementation activities for the spacecraft project is generally as discussed in Section 5. A summary schedule for the total period of interest with launches from 1973-1984 is given in Section 6. A summary schedule and activity flow leading to the first launch is provided by Figures 7 and 52. The associated activities are described below.

15.3.1 Phase C Design

Phase C will include detailed system design of the selected spacecraft system concept, including completion of the System Specification and Part I of Contract End Item Specifications. It includes the fabrication and test of breadboard hardware of selected critical subsystems, as necessary to provide reasonable assurance that the technical milestone schedules and resource estimates for the next phase can be met, and that a definitive spacecraft contract can be negotiated for Phase D.

These Phase C activities will consist of the following:

1) Carry out detailed system design
    - Analysis
    - Definition of system functions and performance
    - Environmental requirements
    - Design requirements
    - Subsystem design and evaluation
2) Define interfaces of spacecraft system with:
    - Spacecraft science
    - Launch vehicle system
    - Capsule system

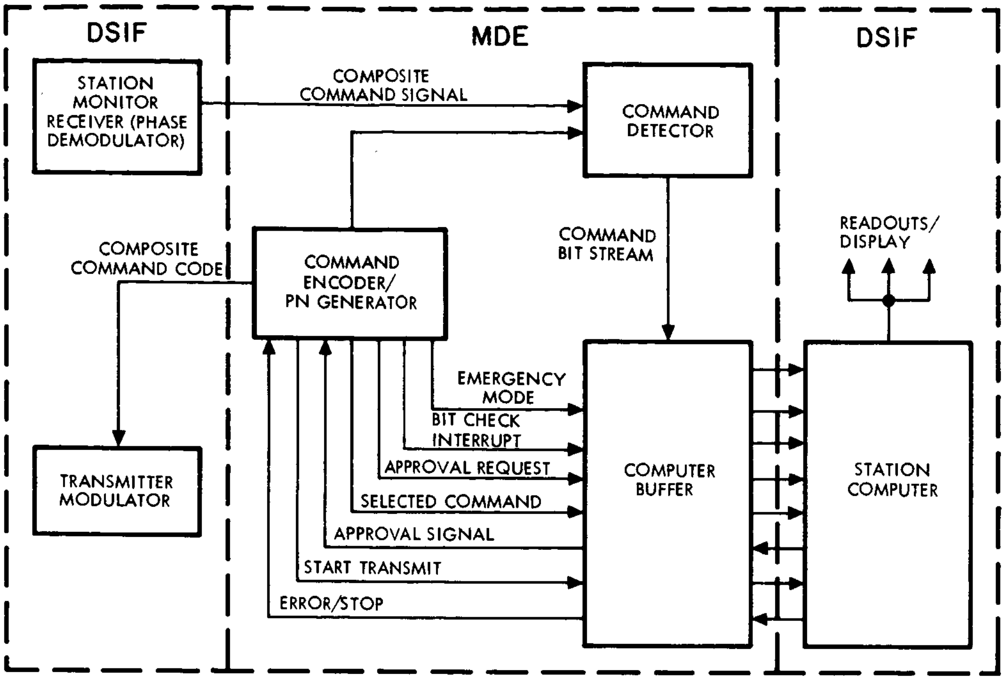


Figure 50. Block Diagram of MDE/DSIF Command Function

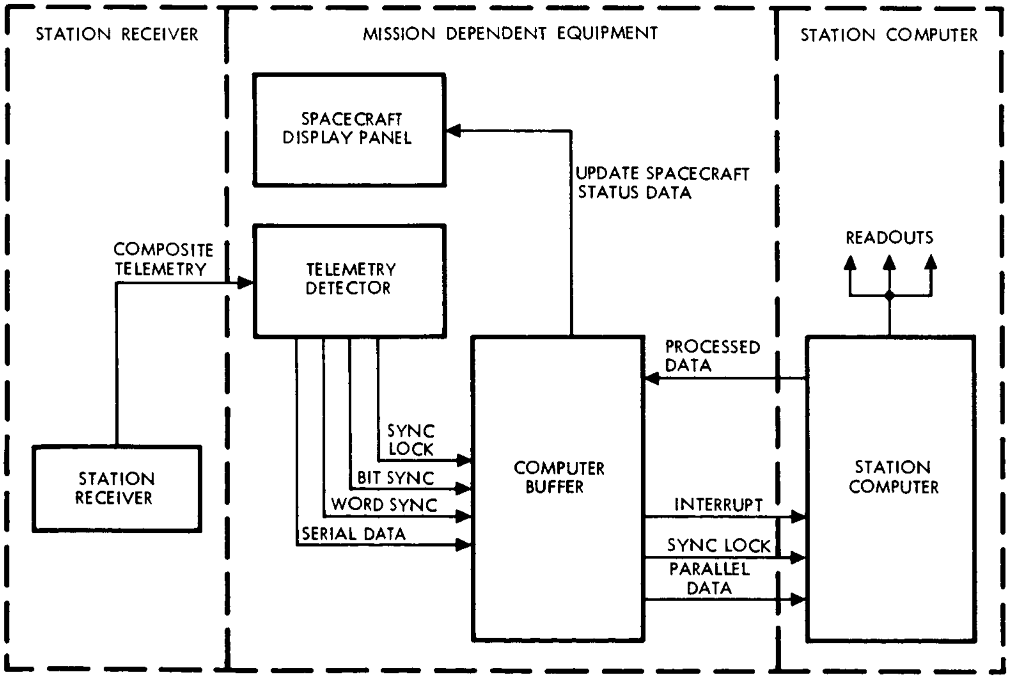


Figure 51. Block Diagram of MDE/DSIF Telemetry

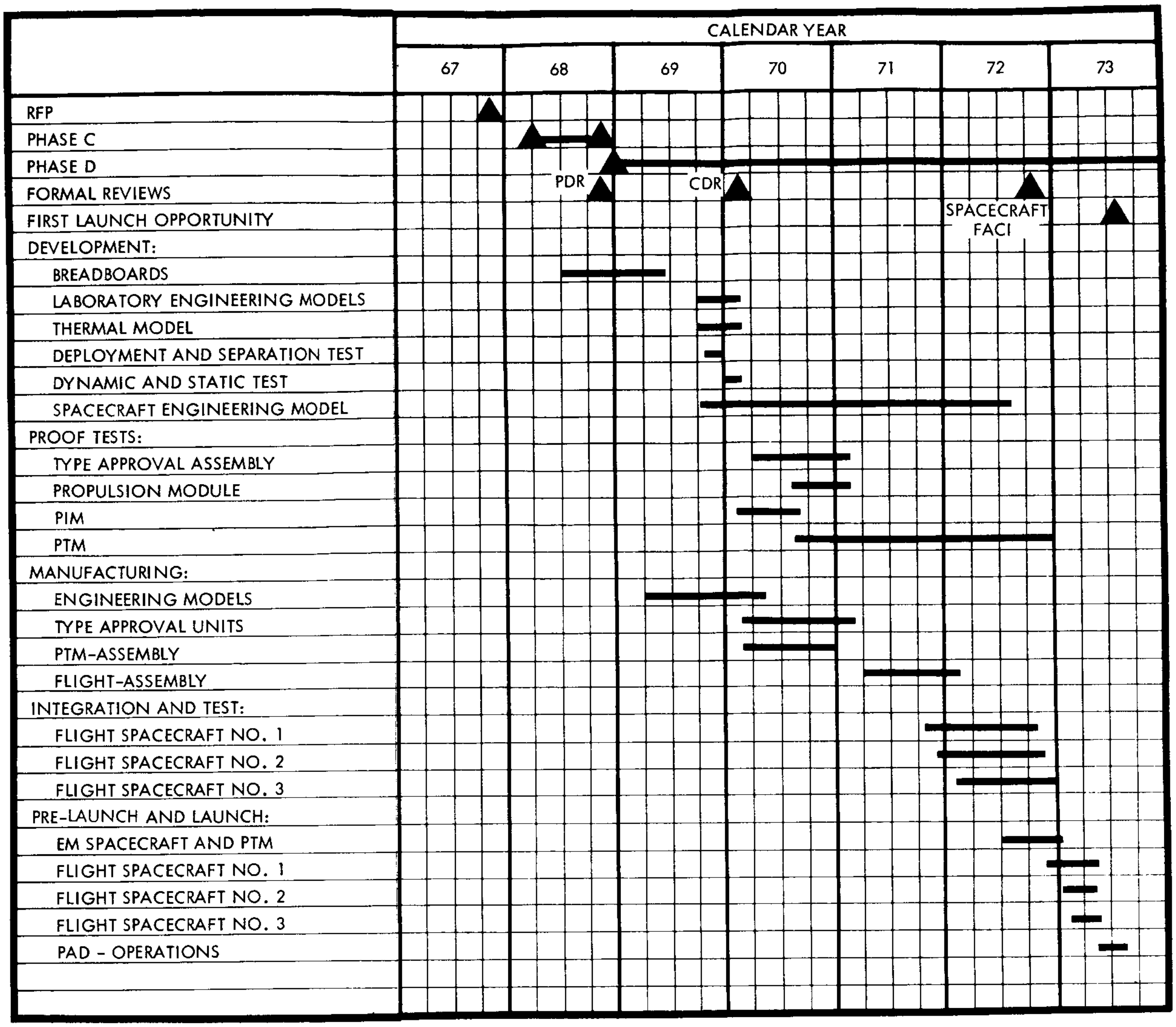


Figure 52. Voyager Spacecraft Summary Schedule

- Launch operations system
- Mission operations system
- Tracking and data system

3) Breadboard fabrication and testing of critical items

4) Preparation of specification tree and Part I CEI specifications, in accordance with the overall project specification guidelines

5) Identification of critical components

6) Update management and technical plans which were submitted with the Phase C proposal

   Organization Plan
   Project Control Plan
   Data Management Plan
   Configuration Management Plan
   Reliability Program Plan
   Safety Plan
   Quality Assurance Plan
   Facility Plan
   Electromagnetic Compatibility Control Plan
   Contamination Control Plan
   Magnetic Properties Control Plan
   Integrated Test Plan
   Procurement Plan
   Manufacturing Plan

7) Prepare input for System Specification and intersystem control documents

8) Conduct Preliminary Design Review and obtain approval of system specification and Part I CEI specifications

9) Prepare technical requirements and contract requirements for subcontractors

10) Prepare and submit a proposal for Phase D

The above activities to be carried out during Phase C include a major system design effort occurring during the first three or four months of the program. Concurrent with this system effort will be subsystem detailed design and analysis and updating and revising the various spacecraft project management and implementation plans in accordance with NASA requirements.

The spacecraft contractor system engineering effort will consist of analysis and design tasks leading to the establishment of spacecraft system, subsystem, and OSE design requirements, and preliminary intersystem interface requirements. This work will be reviewed at the first design audit occurring about the sixth week. These overall design requirements will be given to the various subsystem subprojects along with task statements of work. Under the direction of NASA, the spacecraft contractor will coordinate spacecraft interface requirements with those of other systems in the Voyager project. Final spacecraft intersystem interface requirements documentation will then be prepared and submitted to NASA for approval and issuance subsequent to completion of the Phase C PDR discussed below.

The subsystem engineering effort will consist of an initial updating of subsystem design data and the initiation of design studies and analyses in accordance with the directions of the system engineering design team. The subsystem groups will also define the requirements for critical breadboard testing.

As the design effort continues, the spacecraft system design team, in concert with the subsystem design groups, will evolve input for the spacecraft system specification, subsystem specifications, OSE specifications, and Part I CEI specifications. A second design audit will be held to review and approve the specifications. These updated specifications then will form the basis for continuing design and analysis tasks, for identification of preliminary parts lists and critical long lead-time items, and as input data to the Phase D program plan and initiation of the detailed Phase D costing effort.

The results of these studies and analyses, and those obtained from the breadboard testing, will constitute detail design data as the basis for a third design audit and the preliminary design review (PDR).

15.3.2 Development Activities

Following the preliminary design review and submittal of a proposal for Phase D a definitive contract for that phase will be negotiated. Phase D includes detailed hardware design and development, fabrication, integration, assembly, qualification, checkout, test, and delivery of systems, including science instruments and operational support equipment. Additional technical services will be provided to carry out capsule-spacecraft integration and planetary vehicle/launch vehicle integration conducted by the spacecraft contractor, and as required to support space vehicle launch operations and mission operations.

The sequence of major activities during Phase D is defined by the following milestones, in keeping with the general discussion in Section 5.

- Intermediate Design Review. Prepare updated subsystem specifications and complete Part I CEI specifications for both flight equipment and OSE. Release "E" drawings to manufacturing for engineering models and nonflight test hardware.
- Critical Design Review. Prepare updated subsystem and Part I CEI specifications, and preliminary Part II CEI specifications for flight equipment and OSE. Complete development testing. Release manufacturing drawings for type approval, PTM, and reliability demonstration hardware. Release OSE drawings for all units.
- Completion of PTM Tests. Release updated drawings for flight spacecraft (No. 1, 2, 3, and spares).
- First Article Configuration Inspection. Approve final Part II CEI specifications.
- Ship first flight spacecraft to Cape Kennedy

The schedule embodies these key features:

- Early design data from development test is gained by completing laboratory engineering model unit environmental tests and integrating the engineering model units into the spacecraft engineering model prior to final drawing release
- Early reliability data is available from engineering model and type approval test before initiation of proof test model (PTM) testing. In addition, spacecraft life testing will be conducted on the engineering model spacecraft and subsequently on the proof test model spacecraft
- Type approval environmental testing of units is complete prior to the start of spacecraft proof test model environmental tests
- Verification of final design by PTM tests is achieved six months before flight article spacecraft are committed to environmental tests
- During spacecraft assembly, the buildup and checkout of subsystems will be accomplished "off line", providing high confidence in integration of the subsystem into the spacecraft

- The spacecraft assembly and test spans include realistic operation spans with contingency spans applied in critical areas
- The equipment module and the propulsion module are integrated in parallel to increase physical access to the hardware and allow more operation time
- Time is available after delivery for additional testing prior to flight on the flight spacecraft, to increase confidence in flight performance

Schedule confidence is further reinforced by the modular design concept. The modular design permits "off line" buildup of subassemblies (subsystem elements) and parallel buildup of the equipment module and the propulsion module. The concurrent operations conserve schedule time by reducing end-to-end span links and, in case of unanticipated problems, prevents adjacent interfaces from being changed by retaining decentralized assembly and test operation.

The scheduling of major activities is generated by first defining the time before launch when it is necessary to initiate assembly and checkout of the first flight spacecraft. The time required has been derived from a detailed, elapsed-time analysis of the tasks involved in launch site operations, shipping, flight acceptance testing, and assembly and checkout operations. The next step defines the delivery date for each subsystem in terms of need date during the spacecraft assembly and checkout sequence. In turn, by accounting for the subsystem flight acceptance testing and manufacturing span, the start date for the manufacturing of each flight subsystem is defined. Thus the need dates for flight hardware drawing release are established.

The start of proof test model (PTM) assembly and checkout operations has been determined by scheduling completion of the major portion of the PTM testing (i. e., magnetic, vibration, acoustics, and space simulation testing) prior to completion of assembly and checkout of the first flight spacecraft. This constraint then establishes the delivery dates for the PTM subsystem assemblies.

The drawing release dates for the fabrication of the subsystem type approval and PTM assemblies has been set (for each subsystem) by the following constraints, which are shown in Figure 53.

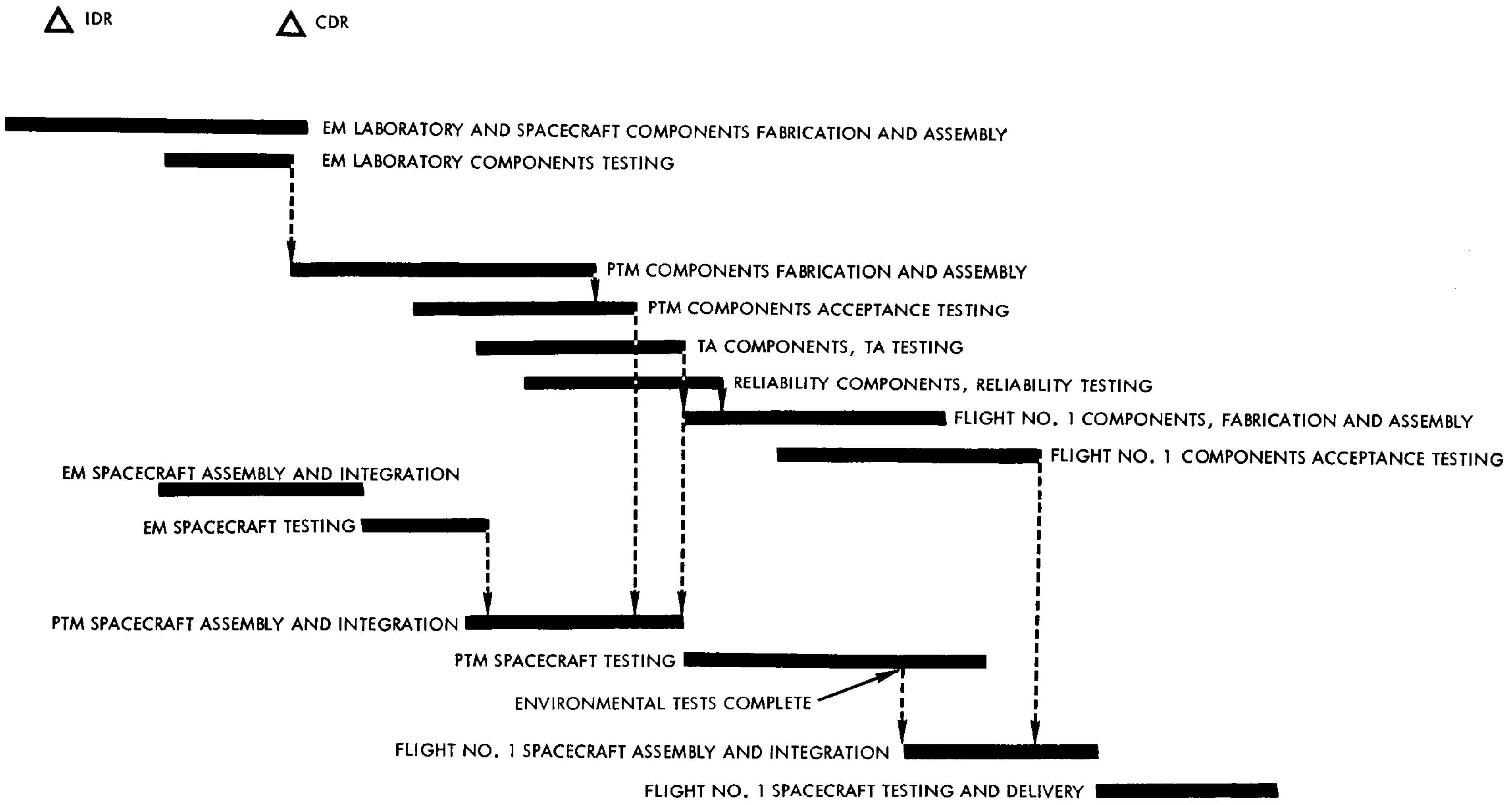


Figure 53. Spacecraft Project Flow

- The fabrication of the subsystem type approval models must precede the fabrication of the PTM assemblies by one month.
- Subsystem type approval testing must be complete prior to start of PTM environmental testing. This establishes the manufacturing drawing baseline dates (hence CDR).

This process establishes the required CDR dates for each subsystem. The CDR dates for each subsystem then form the basis for each subproject engineer to establish Phase D implementation plans and schedules.

15.3.3 Spacecraft Assembly and Checkout Sequence

After each assembly has completed environmental and flight acceptance tests, it will be delivered to the subsystem assembly area, where a system test complex has been assembled. Each electrical subsystem will be mechanically assembled to a spacecraft subpanel. The subpanel flight harness is then mechanically installed to the subpanel, electrically tested, and the connectors mated to the boxes. Upon completion of this electrical and mechanical assembly operation, each subsystem will be tested, as a subsystem, using the system test complex equipment.

These tests performed in the system test configuration will allow the necessary subsystem trend data to be compiled into a subsystem history log.

15.3.4 Test Sequence for Spacecraft Models

Following spacecraft assembly and checkout, the integrated articles undergo a sequence of system testing. This test sequence applies to the engineering model (EM) electrical systems, proof test model (PTM), the guidance and control and propulsion subsystems of the propulsion interaction model (PIM), and the flight articles. Because of the schedule constraints imposed by the simulated stack test, in which two spacecraft are tested together, the test sequence will not necessarily be identical for all spacecraft. The second constraint on the sequence is facility usage. All tests and operations will be scheduled such that only one test area of each major type is required.

The general sequence starts with an integrated system test to be performed following the assembly and checkout to verify functional integrity. All spacecraft subsystems and science instruments will be tested, as well as the spacecraft-capsule functions. This test is performed with a test capsule in place. The spacecraft will carry dummy solar arrays at this time.

Following the first integrated system test, the PTM will undergo an ethylene oxide exposure, followed by a system test to determine whether or not the system has been degraded. Following the system test, a series of special tests will be conducted. The first of these will be the power profile test to determine the power drain of the spacecraft in its various operating modes. This data is used for power allocation during flight. The next test, performed on the EM and PTM, is the failure mode and logic test, a detailed check of the on-board logic. A logic matrix will be generated to verify that all combinations and permutations of the spacecraft logic are exercised. A system parameter variation test is then performed on all spacecraft followed by an electromagnetic interference test to determine system interference susceptibility and spacecraft system contribution to the command receiver noise level.

The spacecraft are taken to the Magnetic Test Facility, where the spacecraft magnetic fields are mapped and magnetic stability is determined. Both dynamic and static fields will be measured. The magnetic fields of the flight capsule and the solar array will be mapped separately. The data will then be integrated to form a composite magnetic map. Each spacecraft will be returned and remapped following the vibration and thermal vacuum tests to determine whether or not the fields have changed due to testing and handling operations. Science interference and compatibility will be checked at this site since the electromagnetic noise level will be lower than at any other test facility.

Upon return from the magnetic facility, the solar array will be installed, propellant and pneumatics tanks loaded with inert propellants, and gas and mass property measurements made. Moments of inertia will be measured on the PTM only. Weight and center of gravity will be measured on all spacecraft. The spacecraft alignments will then be performed. All pneumatics and propellant systems will be leak checked and operational checks will be made of the appendage release system. (These last three tests will be repeated, following the vibration-acoustic environment test for flight spacecraft and following the shock test environment for the PTM, to determine any system degradation.)

Upon completion of these tests, the spacecraft will be prepared for the vibration-acoustic test. The spacecraft will be in flight configuration except for the thermal insulation, which may not be completely installed. Flight ordnance will be installed and armed for flight and a test capsule installed. All pneumatics systems will be pressurized to flight pressures. The propulsion subsystem tanks will be filled with inert propellants to simulate the most critical flight propellant loading condition. The spacecraft will be moved to the vibration-acoustic facility and an integrated system test performed to establish a pre-environmental baseline. A combined vibration-acoustic test will be performed with a hydraulic shaker performing the low frequency vibration and a reverbent acoustic chamber generating the high frequency environment.

The PTM will undergo shock testing to verify that the firing of explosive devices and shroud jettison do not have an adverse effect on the spacecraft. A free mode test will then be performed with no electrical interfaces between the spacecraft and the OSE. Mechanical interfaces with test stimulus will exist. The solar array will be illuminated and will power the spacecraft. This test has the dual purpose of serving as a post-dynamic environment system test and as the solar array integration and compatibility test.

The spacecraft is then prepared for space simulation. The flight batteries will be installed and thermal insulation completed. Auxiliary heaters and special thermal vacuum test instrumentation will be installed. The test capsule will be installed and the spacecraft turned upside down for installation in the space chamber.

After installation of the spacecraft and test capsule in the chamber, an integrated system test will be performed to validate all OSE and chamber cabling as well as to establish a system baseline. The thermal-vacuum exposure will be performed in two parts, the first part with the test capsule installed and the second part without the test capsule. Tests on the thermal model spacecraft and the PTM spacecraft may show that the effect of the capsule is negligible, in which case the first part of the test will be deleted for the flight models. Off-axis exposure to the solar simulator will be performed on the PTM spacecraft by rotating the spacecraft in its holding fixture. A system test will be performed before spacecraft removal from the chamber to determine any effect of the environmental exposure on system performance.

Prior to shipment, three system tests will be run which require operating two spacecraft from one control point. The first is a simulated stack test, in which the spacecraft are placed as close to each other as possible, to determine whether or not interference problems exist in this configuration. The second test is a compatibility check with the launch complex equipment, which includes a practice countdown. The final test is a mission operations test The mission-dependent equipment and the Space Flight Operational Facility, along with the STC, will perform a full system test for verification of readiness to ship the spacecraft to Cape Kennedy. The STC will be tied to the Space Flight Operational Facility via data links and communication nets.

The sequence through the electromagnetic interference tests, magnetic properties tests and previbration system tests for the EM is identical to the PTM and flight spacecraft sequence. The EM will not be exposed to environmental testing but it will be taken to each environmental test area for facility validation prior to testing of the PTM spacecraft.

The EM and the PTM are scheduled for shipment to Goldstone at various times for deep space instrumentation facility compatibility checks. When a spacecraft is not available, test data magnetic tapes will be used for mission dependent equipment-deep space instrumentation facility compatibility checks.

The propulsion interaction model (PIM) spacecraft incorporates a flight configuration structure, a ground test propulsion subsystem and that portion of guidance and control subsystem that could adversely respond to propulsion vibration sources. All other equipment is mass simulated. The spacecraft will be assembled and checked out to the point where the spacecraft is ready for propulsion subsystem integration. At that time the partially assembled spacecraft will be shipped to the propulsion interaction test facility at White Sands. The qualification model propulsion subsystem, which will have been at White Sands for subsystem qualification testing, will then be integrated to form the PIM spacecraft. The propulsion interaction test will be performed to verify proper operation of the guidance and control subsystem during operation of the propulsion subsystem and to confirm the absence at adverse dynamic response of the spacecraft structure to that environment.

15.4 TEST PROGRAM

In describing the different test activities it is necessary to refer to a great number of different model designations for the test hardware. These are listed below for convenience along with a brief description of their intended purpose.

1) Engineering Models of Electronic Assemblies. Engineering models represent equipment almost identical with flight hardware, but which can be produced early by use of preliminary tooling. There will generally be two engineering models of each assembly. The first EM article is used for the spacecraft engineering model. The second is used for subsystem tests only and may be made in engineering laboratories and does not require potting.

2) Spacecraft Engineering Model. This model will be produced by manufacturing. It will be used primarily for checking system compatibility and facility validation. Also for debugging of procedures and operations, and for training of personnel. The EM will be used at Goldstone to perfect the mission operation sequence and to verify initial Deep Space Network-spacecraft compatibility. It will be used in verifying OSE, for weight and CG determination, for separation and release tests, for installation of ordnance simulators, and for integration with a test capsule and

mating to a shroud section. The spacecraft EM will also be used to validate launch site procedures, equipment and facilities.

3) Spacecraft Temperature Control Model. This model will be used for subsystem development testing. It includes a full scale structure, propulsion module, inert rocket engine, and thermal mock-ups of equipment. (Not used for type approval tests for the temperature subsystem. The PTM will be used for this purpose.)

4) Structural Model. The structural model consists of the main propulsion module (including tanks, thrust support structure, plumbing), aft equipment module (including solar array modules and appendages), planetary vehicle adaptor fittings, and capsule adaptor. The structural model will be used for both vibration and static load testing. It is also considered to be the type approval test model. Subsequent to these tests, the structural model will be used for deployment tests, mating tests, nose fairing separation tests, AHSE tests, etc.

5) Launch Vehicle Separation Model. This model will consist of a mass-inertia model of the final stage of the launch vehicle (with simulated shroud), a mass-inertia model of the planetary vehicle, and flight configuration planetary vehicle adaptor fittings and pyrotechnic devices. Tests on this model are used to verify correct operation of the planetary vehicle separation system and to determine separation velocities and tip-off rates. Failure modes are simulated to verify design margins.

6) Shroud Separation Model. The shroud separation model will consist of GFE flight type shroud segments, a flight configuration planetary vehicle adaptor, and the structural model spacecraft with test capsule. Explosive separations of the shroud will be performed to determine the shock loads transmitted to the spacecraft, and to verify proper dynamic clearances.

7) Configuration Model. This model represents a hard mock-up of the spacecraft with installed equipment. It will be used for layout of configuration arrangements and display purposes, and will be updated as required.

8) Antenna Model. This model will consist of hard mock-ups for structure, propulsion module, science equipment, and solar array. This full-scale model will be used to perform full scale impedance measurements and full-scale axial ratio measurements.

9) Spacecraft Propulsion Interaction Model. The PIM spacecraft is a flight configuration structure incorporating the guidance and control subsystem and the propulsion subsystem. All other equipment is mass simulated. Assemblies to be built specifically for this model will be fabricated from engineering model drawings by manufacturing and the assemblies will be tested to the equivalent levels and requirements for acceptance of flight units. A propulsion interaction test will be performed to verify proper operation during hot firings.

10) Spacecraft Proof Test Model. The proof test model spacecraft is used for design verification at environmental levels that exceed the mission requirements. It may also be used for reliability life test or to complete DSN-spacecraft compatibility verification. This model is considered to be also the type approval test model for the thermal subsystem.

11) Propulsion Type Approval Module. Integrated propulsion module type approval testing will be conducted at White Sands. These tests will demonstrate the compatibility of the engine and the feed system.

12) Type Approval Units. These units are used to perform type approval tests with environmental levels exceeding the mission requirements (this type of testing is sometimes also called "qualification test.") Type approval tests will be performed on the assembly level and, if practical, on the subsystem level.

13) Flight Acceptance Units. These units will undergo acceptance tests to confirm that workmanship and quality standards have been satisfied. They may also be used to perform subsystem acceptance tests for those subsystems requiring such an acceptance test.

15.4.1 General Testing Below the System Level

The general test program includes testing pertinent to most subsystems. This testing is discussed below.

15.4.1.1 Parts and Materials Tests

The parts and materials test will be in direct support of the approval and listing requirements set for selection of parts, materials, and processes. Specific categories of nonrecurring parts and materials tests include:

- Analysis of basic material properties
- Qualification tests
- Accelerated life tests
- Test-to-failure evaluations
- One-shot success testing

Specific categories of recurring parts and materials tests include:

- Parameter drift screening
- Periodic lot requalification
- Lot acceptance testing

The tests will also include the evaluation of magnetic properties and resistance to conditioning for contamination-control.

15.4.1.2 Magnetic Tests

Magnetic testing is planned at the parts or component level, the assembly level, and the spacecraft level. No magnetic testing is planned at the intermediate assembly level or at the subsystem level.

The tests that are to be performed as part of magnetic testing are:

- Measure the magnetic fields of components
- Measure magnetic fields both operating and non-operating at the assembly level
- Map the field of selected assemblies in the operating and nonoperating modes
- Measure the coercive force at the assembly level

- Measure and map the magnetic fields nonoperating and operating at the spacecraft level
- Measure the coercive force at the spacecraft level

15.4.1.3 Electromagnetic Compatibility Tests

Brief descriptions of the types of EMC tests are given below. Tests on breadboard hardware are applicable to the assembly level only.

- Determine noise and transient susceptibility threshold characteristics for both assemblies and subsystems
- Investigate all signal characteristics as to effect on inverter and transformer-rectifier operation for both assemblies and subsystems
- Investigate electrical bonding, grounding, and shielding effectivity at the subsystem and spacecraft level
- Perform radiated interference measurements at the assembly, subsystem, and spacecraft levels
- Perform antenna conducted interference measurements at the assembly, subsystem, and spacecraft levels

All of the above tests will be done on engineering models and repeated for the type approval units at the subsystem level after the engineering model testing phase has been completed.

The EMC testing for the PTM and flight models is identical to that of the engineering models and type approval models and will take place at the subsystem and spacecraft levels.

15.4.1.4 Manufacturing Tests

Manufacturing tests are conducted before and after conformal coating, encapsulation, or enclosure for each electronic subassembly, assembly, and component. Such tests are performed at nominal input and load conditions to check detailed output requirements. Procedures for these tests include: equipment requirements, test conditions, step-by-step instructions, and criteria for acceptability. Upon acceptance, following such tests, test data is included in and stored with the manufacturing data package.

15.4.1.5 Reliability Demonstration Tests

The planning of reliability demonstration tests for individual subsystem components will utilize their MTBF objectives as appropriate design hypotheses. The spacecraft level reliability test requirements are set at 1750 hours (at 40°C) in the space chamber. Individual subsystem component tests are classified as: life test, wearout tests, and one-shot tests.

Component life tests are continued for either 6, 12, or 18 months depending upon their expected reliability levels. Component quantities and test environments are selected to obtain an equitable reliability assurance for all components. Wearout reliability tests are provided for selected components to assure the ability to perform beyond the maximum mission period. One-shot reliability tests are provided for selected components to provide an engineering confidence in the reliability of critical functional events.

15.4.2 Electronic Subsystem Testing

A general test program for electronic subsystems is presented here. These tests are divided into three categories: development, type approval, and flight acceptance.

15.4.2.1 Development

A typical subsystem development test cycle begins with breadboard testing to develop the design details and, in addition, produces:

- Lists and specifications for materials, parts, and processes
- Specifications for subcontract items
- System design data covering reliability, size, weight, volume, thermal dissipation, and power consumption
- Test procedures for engineering model tests

The test sequence represents a progression from assembly through subsystem level. Some of the tests are omitted if the test and schedule requirements are satisfied by engineering model tests.

The next major subsystem test phase consists of testing engineering models. The completion of this series of test produces:

- Release drawings and specifications
- Full design margin test results
- Demonstration of size, weight, volume, thermal characteristics, power consumption, magnetic properties, intrasubsystem compatibility, and functional performance
- Test procedures for type approval testing
- Engineering models for the engineering model spacecraft

The successful completion of the EM test phase provides firm design data for the spacecraft subsystems design and supports the final release of drawings to enable manufacturing and subcontractors to proceed with a high confidence of producing reliable end items. This information is reviewed at the critical design review.

There will generally be two engineering models of each electronic assembly. The first is used for subsystem tests only. The second is used in the engineering model spacecraft.

The first engineering model may be made in engineering laboratories and does not require potting. The initial tests on this model are the same as the breadboard tests described above and so the breadboard tests may be replaced by engineering model tests when the schedule permits. Engineering model tests also include EMC and magnetics, and after assembly-level tests, the engineering model assemblies are integrated into a subsystem for subsystem-level testing.

The second engineering model of an assembly is used for the engineering model spacecraft This model is made in the manufacturing area and is equivalent to flight hardware with respect to conformal coating and potting. The test program for this model is coordinated with the program for the first model so that a complete spectrum of environments is covered by the two models.

15.4.2.2 Type Approval

Type approval tests are performed to verify that design requirements have been met in environments which are in excess of that expected during the mission. The tests are designed to be nondestructive. They include functional and environmental tests at the assembly and subsystem level.

The standard type approval test concludes with a form of life test interspersed with environmental margin tests. This is not a pure form of life test, since failures are more likely to be caused by the repeated environmental extremes than by the extended operations. Additional life tests specifically designed to investigate expected life, along with the wearout tests and one-shot tests in the reliability demonstration program, are considered as extensions to the basic type approval test program generally required for qualification.

15.4.2.3 Flight Acceptance

The purpose of flight acceptance testing is to confirm that workmanship and quality standards have been satisfied. Flight acceptance (F/A) tests include tests at the subsystem level as well as for assemblies. Steps in the process include pre-environmental functional, vibration, magnetic, thermal vacuum, and post-environmental tests for assemblies, and functional tests for subsystems.

Spares are given the same F/A tests as the flight units. In addition, spares are functionally checked as a subsystem. All flight units and spares are delivered to integration stores after completion of F/A tests. While in stores, they are removed for functional tests at two-month intervals to assure that no deleterious change has occurred.

15.4.3 Mechanical Subsystem Testing

At the same time that the electrical subsystems progress from breadboard through engineering and prototype model testing, each of the mechanical subsystems is also being tested. The structural-mechanical (including planetary vehicle adapter), temperature control, and propulsion subsystems lend themselves to independent testing. Each test shares the general objectives of demonstrating functional performance of the design under the full range of operating conditions in combination with critical anticipated environments. The test articles used during this phase, as in the case of electrical testing, progressively approach the production configuration.

15.4.3.1 Structural and Mechanical Subsystem

Major structural-mechanical tests are needed to support analysis and design. The associated test models include:

- The structural model (a full-scale, flight configuration structure including propulsion module with tanks, planetary vehicle adapter, and capsule interstage)
- The shroud separation model will consist of GFE flight type shroud segments, a flight configuration planetary vehicle adaptor, and the structural model spacecraft with test capsule.

The structural model, which will be used for both vibration and static testing, is considered the type approval test for demonstrating structural integrity. The separation model, which is used to demonstrate the correct operation of the separation devices, is considered the type approval tests for the separation systems.

15.4.3.2 Temperature Control Subsystem

The major temperature control subsystem development tests are described here. Development tests will be run on thermal insulation and engineering model louvers. The major thermal development tests are on the thermal model (a full scale structure, including the propulsion module, an inert rocket engine and nozzle, and thermal mockups of electronic components) and external equipment thermal models. Type approval tests include component tests on louvers, heaters, and thermostats, culminating with the complete subsystem test on the PTM. Flight acceptance tests include louver assemblies, heaters, and thermostats, whereas thermal insulation assemblies will be tested at the system level flight acceptance test.

15.4.3.3 Propulsion Subsystem

The propulsion subsystem tests are divided into development, type approval tests, and flight acceptance as described below.

a) Development Tests

The use of developed propulsion hardware results in a very modest development test effort. The hardware requiring development tests and the associated activities are indicated below.

- Propellant control valves: evaluate physical and functional characteristics and extend previous flight qualifications to the complete range of Voyager conditions.
- Start tank: determine expulsion flow capability and verify mechanical integration with tank.
- Propellant feed: determine flow characteristics and valve cycling effects
- Ablative engine skirt: verify design; minimal program adequate because of applicable technology from Apollo program.

Integration firing tests will be performed on the entire propulsion system. These tests, which demonstrate the compatibility of the engine and the feed system, can be done at the NASA White Sands facility. During this phase of the program, Voyager duty cycles will be simulated on the complete propulsion system under all critical environments in preparation for formal type approval (qualification) testing.

b) Type Approval Tests

Type approval tests are conducted to demonstrate the ability of the hardware to satisfy the mission requirements and to demonstrate operational margins. Functional and environmental tests will be conducted first at the component level and then at the subsystem level. Test firings will be conducted after exposure to the qualification environmental conditions.

c) Flight Acceptance Tests

The purpose of conducting flight acceptance tests of the propulsion subsystem is to confirm that workmanship and quality standards have been satisfied. Testing will be completed at the component and subsystem levels. Each rocket engine will be completely assembled in accordance with the drawings, then visually and dimensionally inspected before commencing the rocket engine tests. The rocket engine and components, as assembled for the inspection, will be subjected to the weight, magnetic, electromagnetic interference, static leakage, calibration, and additional tests specified in the acceptance test plan.

The injector will be mounted in a special combustion chamber designed to test the injector for chamber streaking. This special chamber will be run for sufficient time to demonstrate that no unacceptable streaking occurs during operation. Streaking requirements will be those determined during the LEMDE development program. The rocket engine will then be operated for sufficient duration at minimum and maximum thrust levels to demonstrate compliance with specified performance ratings. Acceptance of the rocket engine and its components will be predicated on maintenance of all parameters within the limits specified throughout all tests.

Flight acceptance tests on the propulsion feed system include leak tests, mass properties determination, propellant loading and tanking tests (inert fluids), cold flow calibration tests, vibration, and space simulation testing. The vibration and space simulation tests will be performed as part of the spacecraft system test cycle.

15.4.4 Flight Spacecraft Tests

The concepts underlying the system test plan are discussed here in terms of the major test articles and associated activities. Additional information regarding the sequence and content of the system testing is given in Section 12.3.4.

15.4.4.1 Test Approach

During system testing, the electrical interfaces between the spacecraft and the OSE will be minimized. Test cables constitute a nonflight configuration and can cause abnormal system operation as well as injecting unwanted noise. The goal will be to operate the spacecraft in a configuration as close as possible to a flight configuration. Sufficient spacecraft telemetry will be provided to isolate faults to the provisional spares level and to enable verification of command status. Certain commands are required for testing and will aid in keeping hardline use to a minimum. These commands will primarily be used to check redundant system operation.

Wherever possible, system test stimulation (external stimuli used to excite flight equipment, usually having only a mechanical interface with the spacecraft) will be used, rather than simulation (signal injection), to perform an end-to-end system test. The same stimuli used during system tests will be used at the subsystem level.

However, the subsystem test may incorporate additional stimulation or simulation.

It is assumed that a prototype capsule will be supplied at the completion of PTM spacecraft assembly to be used by all spacecraft as a test capsule. This test capsule will be required to survive type approval level environmental testing. A capsule simulator will be built to serve as an additional test capsule. The capsule simulator will not be exposed to environmental testing.

15.4.4.2 Engineering Model Testing

System testing of the engineering model spacecraft is performed primarily as a system compatibility and facility validation task. It will be used to verify OSE design, debug procedures and operations, and train personnel. The EM will be used at Goldstone to perfect the mission operation sequence and to verify initial DSN-spacecraft compatibility. The EM spacecraft and the PTM spacecraft will be used to validate launch site procedures, equipment, and facilities.

15.4.4.3 Proof Test Model Testing

The system testing of the proof test model is aimed at system design verification and environmental type approval of flight type hardware. It will also serve to further debug procedures, operations, and OSE and to train personnel. Any design changes made as a result of the EM system tests will be specifically checked. The PTM will also be used to perform reliability life tests, to complete the DSN-spacecraft compatibility verification, and KSC during launch preparations.

15.4.4.4 Flight Acceptance Testing

The acceptance testing of the flight spacecraft is performed primarily as a workmanship verification. The major design problems will have been resolved by the EM, PIM, and PTM spacecraft.

15.5 SPACECRAFT SCIENCE IMPLEMENTATION

15.5.1 General Responsibilities

The general responsibilities associated with spacecraft science are described briefly in Section 4. The Voyager program director has overall responsibility for definition of the scientific program and selection of the associated principal investigators. In addition to various advisory groups, the Voyager program director is supported in this selection by the Voyager Project Office, which provides a project-level science function. This function is concerned with project science definition rather than with its implementation. In particular, the project office

- Develops science objectives and guidelines
- Evaluates and recommends experiments
- Ensures a suitable relationship and proper crossfeed between the spacecraft and capsule science activities
- Monitors science management and direction by the spacecraft and capsule system management offices

The management responsibility for spacecraft science is delegated to the spacecraft system management office. The principal investigators, once selected by the program director, are under the cognizance of the spacecraft SMO, and have contracts with that office for carrying out their particular areas of responsibility. The liaison, coordination, design, development, test, and support activities associated with integration of the experiments into the spacecraft system are carried out by the spacecraft contractor under the technical direction of the spacecraft SMO. Spacecraft SMO science personnel participate in these activities in a monitoring, coordinating, and directing role.

15.5.2 Science Payload Definition

On the basis of plans being formulated for the Voyager Mars Project, an announcement of flight opportunity (AFO) for the initial 1973 Mars mission will be issued by the Voyager Program Office sometime about mid-1967. Proposals for experiments to be incorporated into the mission are expected from interested parties in the scientific community. These will be evaluated and reviewed to allow final selection of mission experiments and the associated principal investigators in time to feed into the spacecraft Phase C design activity during 1968.

Possible experiments for the spacecraft were defined in the previous Advanced Mission Definition Task and documented in Reference 1. These are taken to represent a reference science payload for the current study and are summarized in Section 12.2.

15.5.3 Science Equipment Responsibilities

The implementation of spacecraft science involves both intersystem and subsystem consideration. The relation between the spacecraft contractor and the principal investigators is analogous to an intersystem interface in that the principal investigators have independent contracts with NASA. At the same time, the experiment equipment as well as other spacecraft science payload elements have a complex and intimate relationship to the spacecraft hardware akin to that of a spacecraft hardware subsystem. This latter is the key feature and requires a comprehensive role on the part of the spacecraft contractor for integration of such equipment. As a corollary, such major elements as the planetary scan platform, the fixed science packages, and the science data automation equipment should be developed by the spacecraft contractor as part of the spacecraft bus rather than to be supplied as GFE.

For most experiments in the reference payload there is a particular central science instrument. It is expected that the associated principal investigator will supply such equipment to NASA, and this will in turn be delivered to the spacecraft contractor as GFE. In the case of the imaging system, however, the equipment represents a complex engineering and development task, and for the reference project approach will be supplied by the spacecraft contractor. The experiments which utilize the imaging system will then be defined by selected principal investigators, who will participate in defining the requirements for the imaging system and its design characteristics. They will of course be concerned with how the system is used during the mission. This includes selection of filter, resolution, and areas to be photographed, etc., and they will interpret the pictures obtained for scientific context.

15.5.4 Spacecraft Contractor Science Integration Activities

The spacecraft contractor will establish a special organization to serve as the focal point for his science integration activities. For purposes of the present study, this organization will be designated as the Science Integration Department. It will provide the necessary coordination between the rest of the spacecraft project and the principal investigators and will have overall responsibility for spacecraft project science integration.

The approach presented here is based on experience at TRW with science integration for the OGO and Pioneer programs. A brief description is provided below.

15.5.4.1 Coordination and Liaison

The Science Integration Department provides the principal point of contact between the spacecraft project and the principal investigators. The first function in this regard is to provide the principal investigators with background information regarding the spacecraft. This is done initially through the "Experimenter's Voyager Spacecraft Data Book." This report summarizes the design, operation, and provision for experiments of the Voyager spacecraft. It describes the flexibilities available in the spacecraft. The process of design coordination with regard to view angles, thermal control, and alignment is discussed, and methods are described which will be used to achieve a mutual understanding such as special meetings, contractor documentation, etc. Program planning information of interest to experimenters is given such as compatibility testing, the facilities available for the experimenters' use during science equipment testing, and the integration and test operation involved in testing the Voyager spacecraft.

The major technique for coordination and liaison is through individual experiment responsible engineers. Such a responsible engineer will be designated for each science experiment to provide an individual point of contact for the associated principal investigator(s). The next coordination step to provide information within the spacecraft project on the science experiments is carried out through these experiment responsible engineers. A detailed questionnaire is prepared and distributed to the principal investigators. A personal visit to discuss the experiment and obtain answers to the questionnaire is accomplished by the responsible engineer. This activity leads to a science payload equipment data report. Writeups are prepared on each experiment by the responsible engineer to cover all pertinent information: purpose, requirements, operating principles, test methods, and all information that may be of interest. This report will be as inclusive as possible in order to minimize the chances of omitting significant data.

In all the science integration activities described below, the experiment responsible engineer plays a focal role in coordinating requirements, procedures, testing, and operation support with the principal investigator for the designated experiment.

15.5.4.2 Interface Definition and Design Integration

The Science Integration Department has the responsibility for definition and documentation of the electrical, mechanical, functional, and operations interface between science equipment and the rest of the spacecraft system. This includes the following tasks:

- Prepare specifications, procedures, drawings, and other data necessary to define and control the spacecraft science interface
- Define science support requirements and the interface between science experiment equipment and related OSE
- Arrange for any design studies necessary to evaluate alternative interface design solutions or to solve problems which arise during compatibility testing
- Review spacecraft magnetic properties specification and test results and ensure adherence to magnetic control requirements imposed by science payload

15.5.4.3 Assembly and Checkout

Integration of science equipment into the spacecraft will be conducted by the central spacecraft assembly and checkout function, with the Science Integration Department serving in the same capacity for the science equipment as a spacecraft subsystem project office serves in relation to its subsystem equipment.

To support science equipment assembly and checkout it is proposed to provide a spacecraft electrical simulator to be used for testing electrical compatibility of the spacecraft and science payload subassemblies.

This simulator will be designed and developed as spacecraft OSE. It will be located at the spacecraft contractor's assembly facility to permit convenient tests of science packages at times of removal from the complete spacecraft assembly, particularly for purposes of troubleshooting. The Science Integration Department will be responsible for defining the simulator design requirements and test procedures and for supervising its installation and use.

Particular science integration activities in support of spacecraft assembly and test are listed below.

- Prepare test procedures and criteria in coordination with experimenters and the SMO for testing science equipment
- In coordination with experimenters and the SMO, prepare all written information and procedures required for installation and integration of the science equipment on the spacecraft
- Establish the requirements, with the SMO, for the spacecraft simulator
- Assemble and checkout the spacecraft simulator, in cooperation with Assembly and Test Operations personnel
- Arrange for design and construction of an experiment simulator to support spacecraft tests in the absence of science equipment
- Conduct, or participate in, tests for science equipment, including type approval, acceptance, bench testing, assembly checkout, etc.
    1) Operate spacecraft simulator during science equipment testing
    2) Perform assembly level bench tests with experimenter
    3) Assist experimenters in calibration, troubleshooting, and repair of assemblies on the bench
    4) Maintain the science equipment log containing data on each item (serial number) of science equipment. Make this log available to Quality Assurance as requested

5) Reduce and analyze test data and prepare test reports

6) Keep experimenter and the SMO advised of test progress and results

7) Write any failure reports for experiments

- Support the spacecraft test conductor, test crew, and experimenters during integration, calibration, troubleshooting, and test of science equipment on the spacecraft (or on spacecraft assemblies)

15.5.4.4 Laboratory Support

A science integration laboratory capability will be provided at the spacecraft contractor's facility and at the launch site. This capability will support science interface development by the Science Integration Department as well as provide on-site laboratory services to the principal investigators. Such laboratory support will be provided as follows:

- Receive, handle, store, and ship science equipment
- Developmental testing of science equipment with spacecraft support equipment such as data automation equipment (DAE), planetary scan platform (PSP), fixed science packages (FSP), cabling, etc.
- Developmental testing of science equipment with related OSE
- Acceptance test science equipment
- Integrated testing of science equipment with spacecraft simulator prior to spacecraft integration
- Diagnostic testing in case of malfunction or other difficulty
- Repair and calibration of science test equipment
- Administrative support for laboratory activities, including secretarial, record keeping, etc.

15.5.4.5 Operations Support

The Science Integration Department will provide support to the spacecraft SMO during all phases of science payload operation, as directed, and to the mission operations system during the operational life of the Voyager spacecraft. These responsibilities include:

- Train personnel for participation in preflight and flight operations involving the spacecraft science payload and the interfacing spacecraft subsystems, such as DAE, PSP, command and sequencing and communications
- Assist the spacecraft SMO and MOS personnel in performing in-flight data analysis, troubleshooting, etc., with emphasis on subsystem functions which interface with science equipment
- Assist spacecraft SMO and MOS personnel in detecting emergency conditions and malfunctions, and in selecting backup modes for in-flight science payload operations

15.6 SPACECRAFT PROJECT ORGANIZATION AND WORK BREAKDOWN

The spacecraft project is organized under a project manager having full authority to represent the spacecraft contractor on all matters within the scope and terms of the contract. The breakdown of the project into major functional areas or work breakdown for the performance of the spacecraft contract corresponds to the organization of the spacecraft project.

15.6.1 Management Operations

Management Operations is responsible for all project level management staff activities. These include planning, work direction, scheduling, fiscal matters, project analysis, facilities, and the maintenance of all project baselines. Management Operations operates the Voyager spacecraft Project Control Center and the Voyager Spacecraft Data Center.

The operation consists of three departments. The Planning and Support Department is concerned with overall project plans and the self-consistency and adequacy of all planning. This department focuses on future activities. It also directs formation of management task forces which may be needed for special problems. The Project Control Department concentrates on activities in the present and on the evaluation of performance relative to plans. The Configuration and Data Control

Department operates the Voyager Data Center and manages the implementation of the Configuration Management Plan and the Data Management Plan. Discussion of each of the departments is presented in subsequent sections.

15.6.1.1 Plans and Support

The Plans and Support Department prepares the Voyager Spacecraft Project Plan which is the master document bringing together policies, master schedules, organization, and other elements necessary to complete the total project. The department exercises staff supervision over preparation and updating of all subordinate and supporting plans to see that all of the plans are consistent. The supporting plans include quality assurance, reliability, manufacturing, integrated test, assembly and test, facilities, documentation, configuration management, specifications, materiel, logistics, and organization.

The department manager prepares lists of all plans, assigns responsibility, establishes ground rules for content and format, and sets schedules for plan preparation. He will take initiative to see that adequate coordination and information exchange is accomplished in the preparation of all plans.

The department gives project supervision to facility definition and acquisition and prepares requirements, documentation, and progress reports for facility activities.

The department will make operations research analyses of the management methods used within Voyager and will prepare policies and procedures as necessary. When necessary, training and indoctrination in new procedures will be accomplished.

15.6.1.2 Project Control

The Project Control Department's principal function is to monitor total project progress against the project plan so that status of the total effort is readily communicated to management within the spacecraft contractor's organization and to NASA. The department is directly concerned with status (both performance and cost) at the project, the subproject, and the subcontract level.

Project Control supports the other spacecraft project operations in their management of subcontracts and subprojects. For example, both schedule analysts and cost analysts are assigned as teams to each subproject and subcontract. These analysts provide the necessary support to project personnel in other operations to assure that directives are effectively implemented. The size and composition of these analyst teams is varied in accordance with the nature of the planning or reporting task at hand.

15.6.1.3 Configuration and Data Control

The control of formal engineering data for configuration management is similar to the control of all project data. Therefore both control responsibilities have been assigned to a single individual for the most effective direction of those efforts. The manager of the Configuration and Data Control Department in Management Operations will implement both the data management system and the configuration management system. The related functions are as follows:

1) Data Identification and Control
    - Project data analysis and definition
    - Data requirements and descriptions
    - Data requirements lists (DRL)
    - Data system operations (computer processing)
2) Configuration Control
    - Secretariat to Change Evaluation and Control Board (CECB)
    - Change identification, planning, coordination, and administration
    - Configuration information system
3) Reports and Publications
    - Reports scheduling
    - Editorial services
    - Report publishing
    - Reports monitoring

15.6.2 Product Integrity Operations

Product Integrity Operations contains five elements which are discussed below.

15.6.2.1 Quality Assurance

The quality assurance responsibility covers the following tasks:

- Provides quality program planning, management, and technical direction
- Establishes functional criteria and task requirements for the quality assurance organizational elements
- Performs quality audits to uncover problems, both management and technical
- Develops and maintains the Spacecraft Quality Program Plan
- Provides inspection and quality engineering surveillance of reliability, type approval, and acceptance tests for components, subsystems, and the spacecraft
- Provides source appraisal and surveillance for principal and critical subcontracts
- Provides configuration verification data
- Maintains spacecraft project quality data and provides test data review support
- Functions as final materials review quality authority
- Monitors discrepancy reporting and corrective action activities

15.6.2.2 Product Integrity Engineering

The product integrity engineering function covers planning and maintaining programs for contamination control, material handling, safety, logistics, and personnel training for the spacecraft project. In these areas, it performs the following tasks:

- Establishes and maintains the spacecraft Safety Plan
- Establishes safety design and implementation requirements and monitors their accomplishment
- Develops safety procedures for gaseous and liquid decontaminants and thermal sterilization processes
- Develops discrepancy codes for safety, material handling, contamination control, and logistics
- Evaluates discrepancy reports for safety, material handling, contamination control, and logistics discrepancies

- Initiates corrective action for violations of requirements or as required by discrepancy reports
- Develops and maintains the spacecraft Material Handling and Packaging Plan
- Establishes material handling requirements and monitors activities to assure conformance
- Coordinates the design and manufacture of special storage and handling containers to meet contamination control requirements
- Establishes and maintains the spacecraft Contamination Control Plan
- Establishes design and implementation requirements for contamination control and reviews designs and audits adherence to requirements
- Coordinates research for the development of self-sterilizing adhesives, encapsulants, and coatings
- Develops and maintains a logistics program
- Establishes logistics requirements and coordinates implementation with the spacecraft project organizations
- Develops a training program for the spacecraft project and coordinates training activities
- Participates in design reviews to assure adherence to safety, contamination control, materials handling, and logistics requirements

15.6.2.3 Reliability

The reliability function institutes the reliability activities associated with design, development, manufacture, and test for the spacecraft project. Specifically, it

- Develops and maintains the spacecraft Reliability Program Plan and associated documents
- Establishes requirements for, and monitors the implementation of, reliability tasks, design reviews, failure reporting and correction, reliability estimation and prediction, and the parts, materials, and processes program
- Provides reliability reports
- Establishes and monitors subcontractor reliability controls

- Provides reliability approval of spacecraft project test plans, procedures, specifications, designs, failure reports, and analysis and prediction techniques
- Functions as secretary for spacecraft project design reviews
- Establishes and implements the reliability program reviews
- Supports test planning and data review
- Chairs the Failure Review Board
- Chairs the Spacecraft Parts Selection Board and maintains the Spacecraft Approved Parts List
- Chairs the Spacecraft Materials and Processes Board and maintains the Spacecraft Approved Materials and Processes List

15.6.2.4 Materiel

The materiel function establishes and maintains the materiel program for all spacecraft project procurement activities, except for major subcontract administration. It performs the following tasks:

- Establishes and maintains the Voyager Spacecraft Procurement Plan
- Coordinates procurement for long-lead and critical items
- Establishes procurement criteria and monitors adherence to requirements
- Provides input data regarding supplier capabilities for make-or-buy decisions
- Assists in source selection activities
- Coordinates procurement requirements for design, reliability, quality, contamination control, magnetic control, and material handling
- Supports parts and materials evaluation with performance data
- Monitors corrective action requests to suppliers to assure timely and proper responses
- Monitors the coordination of acceptance test procedures with component suppliers
- Administers spacecraft parts and materials stores

15.6.2.5 Manufacturing Integrity

The manufacturing integrity function is responsible for the development and maintenance of the spacecraft project manufacturing program. It performs the following tasks:

- Develops and maintains the Voyager Spacecraft Manufacturing Plan
- Establishes and monitors the implementation of manufacturing requirements for production control, process control, tool control, assembly techniques, and training
- Coordinates manufacturing standards with designers to assure consistency of application
- Participates in design reviews as necessary to assure that proper attention is given to manufacturability
- Monitors the implementation of special manufacturing procedures for contamination control, magnetic control, materials handling, and reliability assurance
- Assists in the investigation of repetitive or process-related discrepancies
- Participates in tooling analyses

15.6.3 System Engineering Operations

System Engineering Operations will be responsible for overall design and technical development of the spacecraft system to assure that the system fulfills the mission objectives. Within the framework of the mission specification and spacecraft system specifications issued by the spacecraft SMO, System Engineering will establish a system design approach, perform required tradeoff studies, monitor the functional relations among the spacecraft subsystems, and between the spacecraft and its operational support system, and participate in definition of the interfaces between the Voyager spacecraft system and other elements of the Voyager project.

15.6.3.1 Activities

To accomplish the above objectives, Spacecraft Engineering Operations will carry out the following activities:

1) Interpret the system and mission requirements, specifications, and constraints issued by the spacecraft SMO and define the technical approach for the spacecraft project.

2) Generate the spacecraft project system level specification package, including inputs to the Voyager Spacecraft System Specification, as necessary.

3) Generate spacecraft project intersystem interface data including inputs to the corresponding project office interface specifications, as necessary.

4) Define design requirements for Voyager spacecraft subsystems; review and monitor subsystem specifications developed by all subprojects, with particular attention to subsystem interfaces.

5) Exercise responsibility for overall spacecraft system design, including definition of the spacecraft configuration, preparation of functional flow diagrams, and definition of detailed operational sequences.

6) In cooperation with subsystem engineering monitor the design evolution and implementation of an integrated flight spacecraft and its operational support equipment.

7) Participate in the definition of a spacecraft project integrated test plan.

8) Resolve design and development problem areas on the system level and perform tradeoffs, as necessary, to optimize system performance and reliability.

9) Formulate system and subsystem reliability models, coordinate and conduct reliability assessments, and assist the Reliability Department of Product Integrity Operations in spacecraft reliability implementation and monitoring.

10) Perform system and mission analyses in support of system and subsystem development, assembly and test, prelaunch and postlaunch operation.

11) Direct design, development, and documentation of all system mechanical interfaces and implementation of the mechanical interface control plan.

12) Direct design, development, and documentation of all system electrical interfaces and implementation of the electrical interface control plan.

13) Prepare the science payload interface design and implement spacecraft science integration as described in Section 12.5.

14) Support the spacecraft SMO as directed by performing mission engineering tasks, liaison, and coordination, with emphasis on intersystem interface areas and evaluation of critical system performance data.

15.6.3.2 Work Breakdown

The system engineering segment of the spacecraft project is divided into five work areas represented by the following departments:

1) System Requirements
2) System Analysis
3) Science Integration
4) Electrical Integration
5) Mechanical Integration

The System Requirements Department is the focal point for technical coordination with the spacecraft SMO and for establishing requirements and preparing specifications and other engineering documentation. The System Analysis Department specializes in mission analysis, supporting both the spacecraft SMO and the system design effort, and in conducting system and subsystem tradeoff studies in terms of performance, reliability, sizing, and interface requirements. The Science Integration Department has central responsibility for all matters pertaining to the integration of the science payload. The Electrical Integration Department provides requirements, drawings, and controls for electrical distribution circuits, electromagnetic compatibility, and grounding criteria. The department also controls telemetry lists, instrumentation requirements, command lists, data formats, and power allocations. The Mechanical Integration Department establishes the overall mechanical configuration and prepares interface control and assembly drawings. It is responsible for thermal analysis and requirements, dynamics, loads, weights, and deployment mechanization.

System Engineering personnel participate in design reviews, design audits, and pertinent technical decision-making boards, committees, and meetings, including the Test Board and the Change Evaluation and Control Board.

15.6.4 Subsystems Operations

Subsystem implementation for the spacecraft project is based upon the subproject concept in which all aspects of design, development, procurement, manufacture, test, and support equipment for a subsystem are the responsibility of a cognizant subproject manager. The subproject manager prepares a detailed plan which includes explicit descriptions of work content, delivery requirements, and costs for the subproject. Upon approval by the spacecraft project manager, he proceeds with implementation. His responsibilities are defined in detail in the subproject plan. In general, he is responsible for:

- Planning all activity under his cognizance
- Cost and schedule planning, control, and reporting
- Subsystem analysis and engineering
- Detailed design (including packaging design) of each CEI under his cognizance
- Procurement, fabrication, reliability, and quality assurance
- Type approval testing
- Test equipment for CEI level testing
- Life tests on type approval hardware and on equipment under his cognizance as designated in the Voyager Spacecraft Reliability Plan
- Generating and furnishing all technical and planning data needed by others as designated in his subproject plan. Examples are test requirements, test procedures, and logistic planning data.
- Providing sustaining engineering support for spacecraft assembly, test, launch, and mission support
- Generating and maintaining technical data to support design reviews and to meet the other requirements of the Voyager Spacecraft Data Management Plan

15.6.5 Assembly and Test Operations

Assembly and Test Operations is responsible for planning and conducting spacecraft assembly, checkout, test, launch, and mission support operations. It develops specifications, provides subproject management, assembles and tests electrical and mechanical operational support equipment, and identifies facility requirements. In addition, it is responsible for integrated test planning for the total spacecraft system and subsystems development.

Assembly and Test Operations consists of four departments. The Test Planning Department is responsible for the detailed technical and sequence planning of all assembly, test, launch, and mission support operations. The Assembly and Test Department is responsible for scheduling and conducting all assembly and test operations and for personnel training and equipment maintenance. The Electrical Support Equipment and Mechanical Support Equipment departments are responsible for converting OSE requirements into their respective specifications and providing systems engineering and subproject direction to the performing organizations.

There are also three staff groups. Project Test Office is responsible for the preparation, coordination, and evaluation of the integrated test plan and the continuing monitoring and analysis of test results. A planning and control group provides a focal point for the monitoring and control of all plans, schedules, records, and hardware. An administrative group provides the normal support in housekeeping, personnel administration, capital planning, and overhead controls.

15.6.5.1 Test Planning Department

The Test Planning Department is responsible for all technical planning required to support subsystem assembly and test, spacecraft assembly and test, launch operations, and mission support operations; it also analyzes these plans for all support equipment and facilities requirements. The following detailed responsibilities are included:

- Coordination and establishment of system test philosophy in conjunction with System Engineering Operations
- Subsystem assembly and test sequence

- Spacecraft assembly and test sequence
- Launch site operations sequence
- Mission support operations sequence
- Preparation of detailed procedures for all operations
- Preparation of computer software requirements
- Preparation of master phasing schedule for all assembly and test operations
- Coordination and preparation of all OSE, MDE, and facility requirements
- Coordination and preparation of all launch operations planning documents
- Coordination and preparation of all mission support documentation, including test and training plans
- Conduct of spacecraft and OSE design liaison
- Preparation of spacecraft system and OSE design constraints

15.6.5.2 Assembly and Test Department

The Assembly and Test Department is responsible for conducting:

- Subsystem assembly and test operations
- Spacecraft assembly and test operations
- System test complex assembly and test operations
- MDE assembly and test operations
- Major development tests
- Launch site operations
- Crew training
- OSE maintenance operations
- Facility checkout operation
- Data center operations
- Data reduction and identification operations

This department will be responsible for the preparation of detailed day-by-day schedules, in accord with the master phasing schedule, for all the operations listed. It will provide data packages on all tests, properly identified and time tagged, to the Project Test Office and the Test Planning Department. The Test Planning Department will issue the quick look and final data reports. The spacecraft data center will receive originals of all data and reports and will assume responsibility for their storage and retrieval.

15.6.5.3 Electrical Support Equipment Department

The Electrical Support Equipment Department is responsible for providing the subsystem OSE, system test equipment, mission dependent equipment, launch complex equipment, simulators, and other special subsystems, and system test equipment. Responsibilities include:

- Coordination of OSE and special test equipment requirements with the Test Planning Department and System Engineering
- Analysis of technical requirements
- Analysis of schedule requirements
- Preparation of Part I CEI specifications for both OSE and MDE
- Definition of quantities required
- Preparation of implementation plans
- Preparation of computer software specifications
- Preparation of maintenance plan
- Preparation of operating manuals
- Preparation of specifications for special test equipment
- Subproject management

15.6.5.4 Mechanical Support Equipment Department

The Mechanical Support Equipment Department is responsible for analysis and design activities for the spacecraft project in these areas:

- Assembly, handling, and shipping equipment
- Special tooling and test equipment: spacecraft and subsystem test fixtures and special tooling (including factory aids)

- Special models: mechanical simulators or models for test

The department will prepare Part I CEI specifications for all of the equipment in these categories and establish their allocations, quantities, and need dates. In making these determinations, the department will:

- Coordinate detailed operational flows for each spacecraft depicting all operations during assembly and checkout, system test, and launch operations
- Analyze each operational flow to determine specific facility requirements and supporting equipment
- Identify the types of specific supporting equipment required
- Prepare a functional analysis for each spacecraft assembly and checkout, system test, and launch operation flow, correlating each operation, its support equipment, and facility requirements
- Review functional requirements of equipment and facilities to identify those elements capable of fulfilling more than one functional requirement with a view toward consolidating equipment functional capability
- Identify the source for each item
- Define conceptual design requirements for each item of AHSE, special test equipment, and special models
- Preparation of Part I and II CEI specifications
- Preparation of detailed layout and drawing
- Preparation of test plans and procedures
- Preparation of maintenance plans and procedures (including spares)

16. CAPSULE IMPLEMENTATION

16.1 CONTRACTOR ROLES

The central role for capsule system implementation is carried out by the capsule contractor. The landed science payload elements are implemented by the surface laboratory contractor and the mobile unit contractor. The RTG system is also implemented by a separate contractor. All of the capsule elements are integrated into the capsule system by the capsule contractor, and all of these contractors carry out their implementation roles under the direction and management of the capsule system management office, which in turn operates under the general cognizance of the Voyager project manager.

The capsule SMO includes a focal point for management responsibility for the capsule, the surface laboratory, the mobile unit, and the RTG contractors. The capsule SMO also includes management personnel cognizant of the various technical disciplines required for the total capsule system. These personnel are charged with responsibility for the quality of system activities within their areas of specialization. To carry out these responsibilities, each supervises the assigned system technical activity being carried on directly by SMO personnel. In addition, these technical managers assist the contractors, monitor their activities, and as necessary provide technical direction in carrying out the work under their contracts. In particular the capsule SMO is responsible for establishing the capsule bus-surface laboratory, capsule bus-mobile unit, capsule bus-RTG, and surface laboratory-mobile unit flight hardware interfaces along with the associated interfaces in the support equipment. In this interface definition the capsule contractor plays a major support role, because of his responsibility for integration of the surface laboratory, mobile unit, and RTG into the capsule system.

The scope and responsibilities associated with the total capsule project segment are covered briefly in Section 4. The project segment under contract to the surface laboratory contractor is designated as the surface laboratory project. The associated project breakdown covers the two- or three-step approach for laboratory development described in Section 3, and includes the following tasks:

- Provide surface laboratory flight hardware, which includes deployable sample acquisition devices, processing and handling equipment, deployment mechanisms, and other support hardware and structure into which the landed science experiment equipment is integrated
- Provide science support flight and ground hardware, and integrate experiments into the surface laboratory
- Provide developmental models, spares, software, and OSE associated with the above
- Assist in achieving compatibility with the mobile unit and with the capsule bus
- Participate in preflight and mission operations in regard to the surface laboratory

The project segment under contract to the mobile unit contractor is designated as the mobile unit project, and includes the following tasks:

- Provide mobile unit flight hardware and the associated models, spares, software, and OSE
- Assist in achieving compatibility of the mobile unit with the capsule bus
- Participate in preflight and mission operations with respect to the mobile unit

The project segment under contract to the capsule contractor is designated as the capsule project, and includes the following tasks:

- Provide capsule bus and canister flight hardware and the associated models, spares, software, and OSE
- Provide science support flight and ground hardware and integrate the surface laboratory, mobile unit, RTG, and entry science payload with the capsule bus
- Provide preflight operations for the capsule and participate in the integration of the capsule with the spacecraft and in space vehicle prelaunch operations
- Participate in mission operations with respect to capsule project hardware

The RTG elements which are part of the capsule system are provided to the Voyager project by the AEC. The project segment under contract from the AEC to the RTG contractor is designated the Voyager RTG project, and includes the following tasks:

- Provide RTG flight hardware and the associated models, spares, software, and OSE
- Assist in achieving compatibility of the RTG with the surface laboratory and the capsule bus
- Participate in preflight and mission operations in regard to the RTG

This section discusses implementation for the capsule project to be carried out by the capsule contractor, providing an overall framework for the total capsule system implementation. Separate discussions for RTG, surface laboratory, and mobile unit implementation are given in Sections 17, 18, and 19.

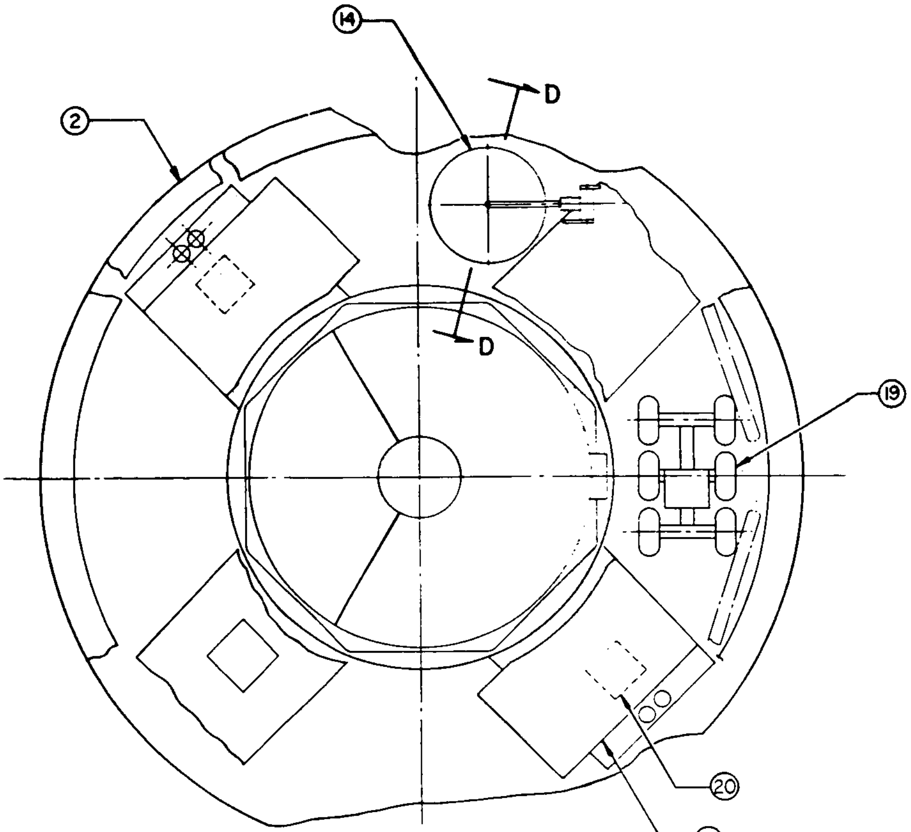
Within the resources of the Voyager Support Study it has not been possible to carry out a preliminary design and develop the related implementation definition for a capsule system. However, a cooperative data exchange between TRW and the Grumman Aircraft Engineering Corporation was arranged to make available data from the extensive work done by GAEC in this area. The present section is founded in large measure on this data.

16.2 CAPSULE DESCRIPTION

16.2.1 General

A standardized flight capsule (less science) is utilized for the complete sequence of missions. It is designed to accommodate the advanced mission landed payload, offloaded as approppropriate for earlier missions. The configuration is shown in Figure 54. The design is for a soft lander using aeroballistic descent and terminal retrothrust. The system provides for an advanced science payload with support for a long-term stay on the Martian surface. The landed payload must be capable of surviving a 20-g shock at touchdown.

The advanced flight capsule has an in-orbit weight of 8000 pounds, made up of a canister of 785 pounds and a lander of 7215 pounds that separates from the planetary vehicle to deorbit and descent to the Martian



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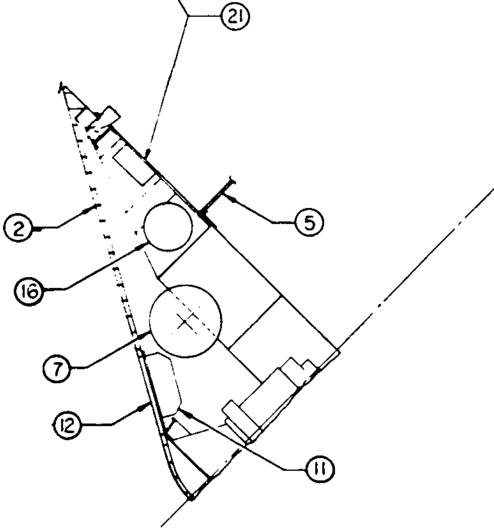

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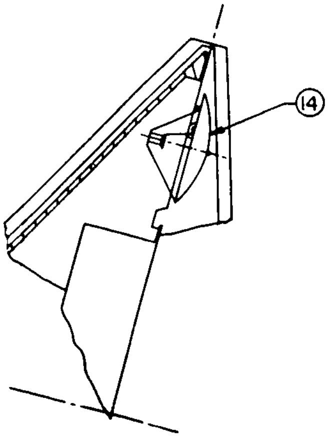

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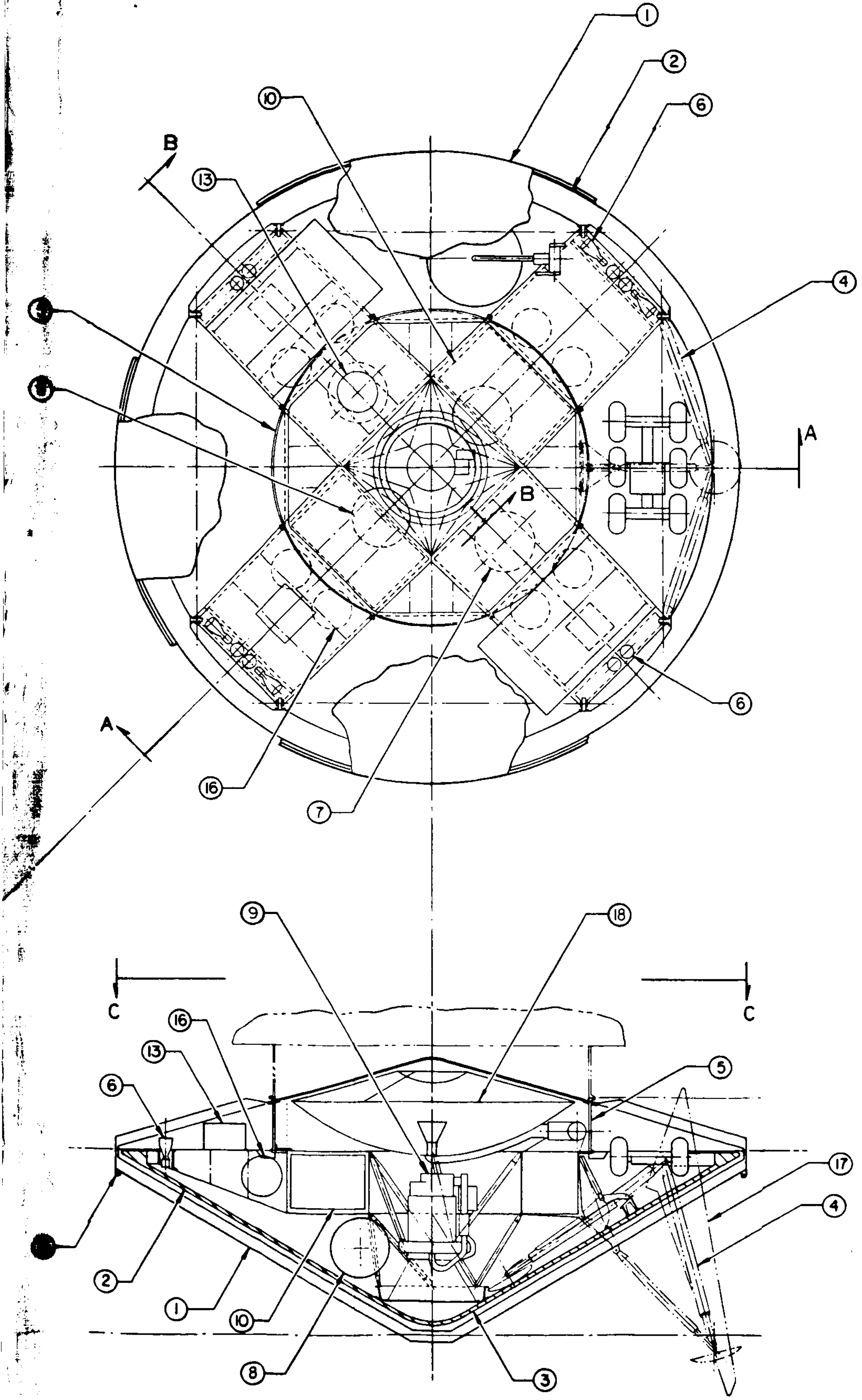


LEGEND

- ① CANISTER
- ② HEAT SHIELD
- ③ HEAT SHIELD BLOW-OUT CONE
- ④ LANDING GEAR ASSEMBLY (4)
- ⑤ FLIGHT CAPSULE/FLIGHT SPACECRAFT ADAPTER
- ⑥ REACTION CONTROL THRUSTERS (12)
- ⑦ PROPULSION FUEL
- ⑧ PROPULSION OXIDIZER
- ⑨ DESCENT ENGINE
- ⑩ SCIENTIFIC PAYLOAD COMPARTMENTS
- ⑪ LANDING RADAR ANTENNA
- ⑫ SEPARABLE RADAR ANTENNA COVER
- ⑬ ANTENNA-RELAY
- ⑭ MEDIUM GAIN ANTENNA-DIRECT
- ⑮ HOIST FITTING (4)
- ⑯ REACTION CONTROL PROPELLANT
- ⑰ HEAT SHIELD SEGMENT DEPLOYED FOR JETISON
- ⑱ HIGH GAIN ANTENNA-DIRECT
- ⑲ MARS MOBILE UNIT
- ⑳ RTG (2)
- ㉑ RTG RADIATOR (2)

Figure 54. Voyager Advanced Flight Vehicle

surface. The lander consists of a capsule bus, an entry science payload, and a landed science payload. The capsule bus includes a heat shield for aerothermal protection during entry and guidance and control reaction control, and terminal propulsion subsystems, which are utilized only for descent. It includes structure, mechanical, thermal control, power, data handling, and relay link subsystems which are used both for descent and post-landing operations. An S-band radio (direct link) subsystem is utilized only after landing. The advanced mission capsule has an entry weight of 6575 pounds resulting from expending 640 pounds for the deorbit maneuver, using reaction control thrusters. The ballistic coefficient M/C_DA is 0.42.

The soft lander sequence provides for canister lid deployment, lander separation, reorientation, deorbit thrusting, and entry and descent. During entry heating the lander is protected by an elastomeric ablating heat shield. Aerodynamic drag after peak heating decelerates the vehicle sufficiently to commence terminal thrusting. Between 30, 000 and 10, 000 feet the heat shield is released and the lander simultaneously rolled to allow the landing radar (4-beam doppler) to acquire the surface. Engine ignition is sequenced with heat shield nose plug jettison at an appropriate altitude. Subsequently, the landing gear is deployed and the remainder of the heat shield is jettisoned. The landing radar provides trajectory data, and the guidance calculations derive commands for a gravity turn to achieve a soft landing.

Weights have been estimated for the advanced, intermediate, and the first generation standard flight capsules to serve as a basis for defining the launch vehicle payload requirements and the corresponding landed payload capability on the surface of Mars. Table 7 presents the related equipment list and weight statement. Characteristics of the standard flight capsule are summarized in Table 8 and are discussed below.

16.2.2 Canister

The canister envelopes the entire lander to preserve sterility from launch through insertion into Mars orbit. A double wall skin provides meteoroid protection to reduce the probability of contamination during cruise.

Table 7. Standard Flight Capsule: Equipment List and Weight Statement

	Weight (lb)		
Item	Advanced Capsule	Intermediate Capsule	First Generation Capsule
Structure and Mechanical	(2715)	(2715)	(2715)
Capsule adapter	130	130	130
Canister lid structure	200	200	200
Aft canister structure	300	300	300
Heat shield	1050	1050	1050
Lander bus structure	700	700	700
Science support structure	55	55	55
Landing gear	275	275	275
Canister lid separation	1	1	1
Lander separation	4	4	4
Guidance and Control	(60)	(60)	(90)
Guidance sensor assembly	30	30	30
Attitude sensor assembly	10	10	10
Electronics package	20	20	20
Guidance computer and sequencer	--	--	30
Reaction Control	(1030)	(970)	(940)
Thrusters (12)	84	84	84
Tankage	86	86	86
Attitude control propellant	220	220	220
Deorbit propellant	640	580	550
Terminal Propulsion	(1495)	(1295)	(1210)
Tankage	57	57	57
Engine	300	300	300
Inert fluid	48	38	33
Usable propellant	1090	900	820
Thermal Control	(355)	(355)	(355)
Canister lid insulation	60	60	60
Aft canister insulation	50	50	50
Aft canister tubing	40	40	40
Lander bus heaters, miscellaneous	20	20	20
RTG radiators (2)	50	50	50
Equipment compartment insulation	40	40	40
Thermal switches (150)	60	60	60
Heat pipes (2)	5	5	5
Science support heaters, miscellaneous	30	30	30
Electrical	(445)	(445)	(445)
RTG units (2)	200	200	200
Shunt regulators (2)	8	8	8
Batteries (2)	96	96	96
Battery charge regulators (2)	10	10	10
400 Hz inverters (2)	8	8	8
4 k Hz inverters (2)	14	14	14
Power distribution unit	4	4	4
Payload cabling, miscellaneous	80	80	80
Lander bus cabling, miscellaneous	25	25	25
S-Band Radio	(158)	(158)	(158)
High-gain antenna with drive	87	87	87
Medium-gain antenna with drive	15	15	15
Drive electronics	5	5	5
Diplexer (2)	3	3	3
Circular switches (2)	4	4	4
S-band receivers (2)	10	10	10
Receiver selector	1	1	1
Power amplifiers, supply, monitors (2)	15	15	15
Transmitter selector	1	1	1
Hybrid ring and power monitor	1	1	1
Modulator exciter (2)	6	6	6
Command detector (2)	5	5	5
Command decoders (2)	5	5	5
Relay Link	(22)	(22)	(22)
Antenna	8	8	8
Diplexer and switch	3	3	3
Receiver/decoder	4	4	4
High power transmitter	4	4	4
Low power transmitter	3	3	3
Data Handling	(55)	(55)	(55)
Telemetry PCM encoders (2)	7	7	7
TV tape recorders (2)	24	24	24
General tape recorders (2)	24	24	24
Contingency	(450)	(450)	(510)
Flight Capsule, less science	(6785)	(6525)	(6500)
Science	(1215)	(805)	(485)
Entry payload	45	45	45
Surface Laboratory	970	560	300
Mobile unit	200	200	140
Total Flight Capsule Weight	8000	7330	6985

Table 8. Standard Flight Capsule Characteristics

Canister:	double walled for meteoroid protection
	superinsulation on inner wall
	biological venting valves
	radiating area for passive RTG heat rejection
	water coolant tubes for prelaunch and boost flight
	5 ft/sec lid jettison velocity
Heat Shield:	60 degree half core
	elastomeric ablation external surface
	aluminum honeycomb sandwich substrate
	four 90-degree segments for jettisoning
	nose cap jettison to uncover descent engine
	jettisoned port for landing radar view
	optical window for entry TV
Lander Structure:	cruciform box beam
	descent support truss in central bay
	two 15 ft^3 thermal controlled equipment compartments
Reaction Control:	provides deorbit thrusting and attitude control moment
	12 Lunar Module bipropellant thrusters
	aerozine 50 fuel and N_2O_4 oxidizer
	100-pound thrust
Guidance and Control:	three strapped down integrating rate gyros
	fine and coarse attitude control and rate control modes
	4-beam landing radar to provide surface velocity and range
	gravity turn during descent retrothrust to achieve soft landing
Terminal Propulsion:	modified Lunar Module Descent Engine
	nominal throttling ratio 10:1
	nominal high thrust 10, 500 pounds

Table 8. Standard Flight Capsule Characteristics (Continued)

	• aerozine 50 fuel and N_2O_4 oxidizer • non-gimbaled • 80-second burn at high thrust
Landing Gear:	• four tripod assemblies • honeycomb crushable pad for impact attenuation
Thermal Control:	• passive thermal control of RTG's • semi-passive equipment compartment thermal control with insulation, heat switches and heat pipes
Electrical Power:	• two 150-watt RTG units • two 100-amp hr AgZn peaking batteries • 19 vdc • 400 Hz and 4 KHz inverters
S-Band Radio:	• 9-foot high-gain, 3-foot medium-gain antennas • 50-watt redundant transmitters • telemetry (high-gain): 32, 18, 13, 11, 7 kilobits/sec • telemetry (medium-gain): 3.5, 2, 1.5, 1.2, 0.8 kilobits/sec • Command: 100 bits/sec
Relay Link:	• 3-watt and 120-watt transmitters • telemetry (120-watt): 150, 75, 30, 10, 2, 0.4 kilobits/sec • telemetry (3-watt): 250 bits/sec • used for descent and surface operation
Data Handling:	• used with direct and relay links • two 10^8 bit TV recorders • two 10^7 bit general recorders • redundant telemetry encoder

The canister consists of forward and aft sections which mate at the shoulder of the 60-degree half cone. The aft section is attached to the adapter and extends through the adapter to complete the biological shield. It contains water coolant tubes to reject RTG heat during encapsulation in the launch vehicle shroud or during ground operations. The mating field joint between the two sections contains an expandable pyrotechnic device for severing the mechanical tie. A series of compressed springs are installed at the separation plane to impart greater than 5 ft/sec relative separation velocity. The inner surface of the canister supports a blanket of superinsulation for thermal control during interplanetary cruise. Biological venting valves are also provided.

16.2.3 Capsule Adapter

The adapter constitutes the mechanical and electrical interface between the flight capsule and flight spacecraft. It provides a field joint for mating the two vehicles.

16.2.4 Heat Shield

The 60-degree half cone heat shield is designed with an aluminum honeycomb sandwich substrate. An elastomeric ablator on the outer surface provides thermal protection during entry. The heat shield is made up of a nose cap and four 90-degree segments which interface with the lander structure. Each segment is supported from two aft landing gear hinge supports and the forward lander apex support ring. Nose cap jettison is initiated with a pyrotechnic mechanical release and completed by engine ignition. The segments are jettisoned by using explosive bolts and landing gear extension to effect deployment and release. One of the segments has a pyrotechnic releasable port for exposing the landing radar prior to terminal thrusting. The heat shield also contains an optical window for the descent TV.

16.2.5 Lander Structure

The lander structure interfaces with the heat shield and the adapter. It contains the landed payload and all the supporting subsystems for descent and landing. The structure is basically a cruciform box beam. The descent engine support truss, in the central bay, can make translational and angular adjustments to minimize thrust-center-of-mass misalignment. The apex support ring, also truss stabilized from the central bay, interfaces with the heat shield and provides a gas seal between the engine bell and adjacent structure. The landing radar is cantilevered from the apex support ring. Two 15-ft^3 compartments are provided for the landed payload on opposite sides of the central bay. These compartments can provide unobstructed sensor deployment either laterally or vertically. The four extremities of the cruciform structure support the reaction control jets, landing gear, and heat shield. The lander structure also supports the high-gain, medium-gain, and the relay link communication antennas, as well as fuel, oxidizer, pressurant, and reactant tankage, reaction jets, and the terminal descent engine.

16.2.6 Reaction Control and Deorbit System

The reaction control and deorbit system combines the separate functions for deorbit propulsion and attitude control torque. The system operates with 12 100-pound thrust LM bipropellant engines. These engines use a 50-50 UDMH-hydrazine fuel mixture with an N_2O_4 oxidizer. Two pairs of opposed thrusters provide roll control. Four thrusters are oriented parallel and rearward for deorbit thrusting as well as for pitch and yaw control. Four additional pitch and yaw thrusters have been added for redundancy.

16.2.7 Guidance and Control

The guidance and control subsystem uses three strapped-down integrating rate gyros to maintain attitude accuracy before and during deorbit thrusting. The flight capsule is oriented for the deorbit maneuver by the flight spacecraft before separation. The gyros are caged until just prior to separation, at which time they are uncaged to provide attitude reference until entry. During atmospheric entry the yaw and pitch gyros are recaged for the rate damping mode of operation, while the roll gyro remains in the attitude control mode. Upon activation of the landing radar, the yaw and pitch gyros are switched back to the attitude mode. The landing provides range and velocity components, for which steering is derived for a guided gravity turn to a soft landing.

16.2.8 Terminal Propulsion

The terminal propulsion system uses a modified LM descent engine; a throttleable bipropellant engine which uses a 50-50 UDMH fuel with an N_2O_4 oxidizer and is rated at 10,500 pounds thrust. The engine is mounted in the lander engine support truss, and the propellant and pressurant tanks are slung beneath the lander structure. The propulsion system will be capable of operating at maximum thrust for approximately 80 seconds and for a longer period at lower thrust levels.

The general interface and envelope for the present LMDE are shown in Figure 53; a schematic representation is shown in Figure 56. A nominal value for specific impulse has been taken as 300 seconds. The burning time is expected to be less than 40 seconds so that a rating of 80 seconds is adequate. Only one start is required during the mission.

The modifications to the LMDE that appear to be necessary to adopt it for the Voyager lander are as follows:

- Remove radiation cooled skirt
- Recontour thrust chamber for reduced nozzle area ratio
- Make compatible with sterilization
- Qualify for 9-month space storage
- Replace ball valves with positive-seal explosive-actuated propellant valves
- Remove ablative material for reduced thrust duration
- Remove gimbal assembly

16.2.9 Landing Gear

The landing gear consists of four tripod assemblies lying within the four quadrants of the cruciform box beam as shown in Figure 54. Two tripod struts are hinged to adjacent ends of the cruciform structure defining a quadrant. These struts remain the same length whether stowed or deployed. The third strut is hinged in-board and unfolds during deployment. Each strut consists of an inner cylinder connected

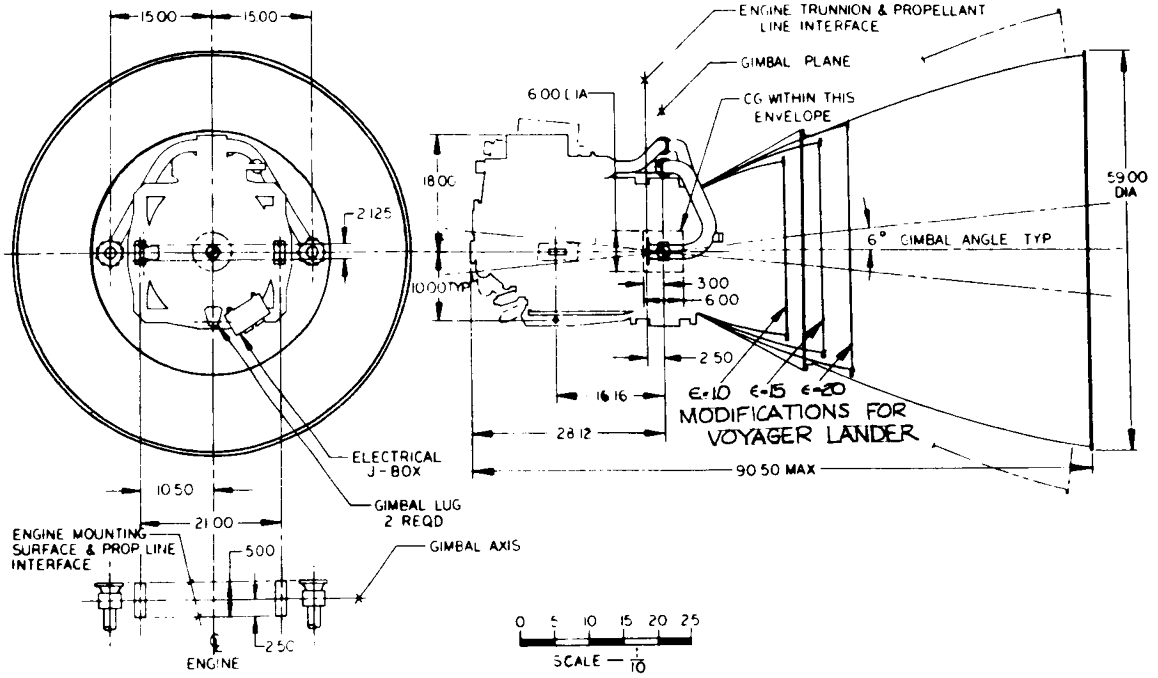


Figure 55. General Interfaces and Envelope of LMDE

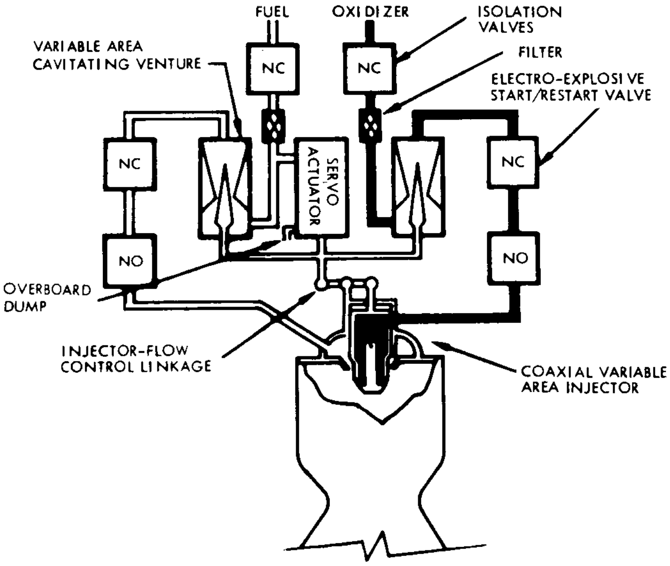


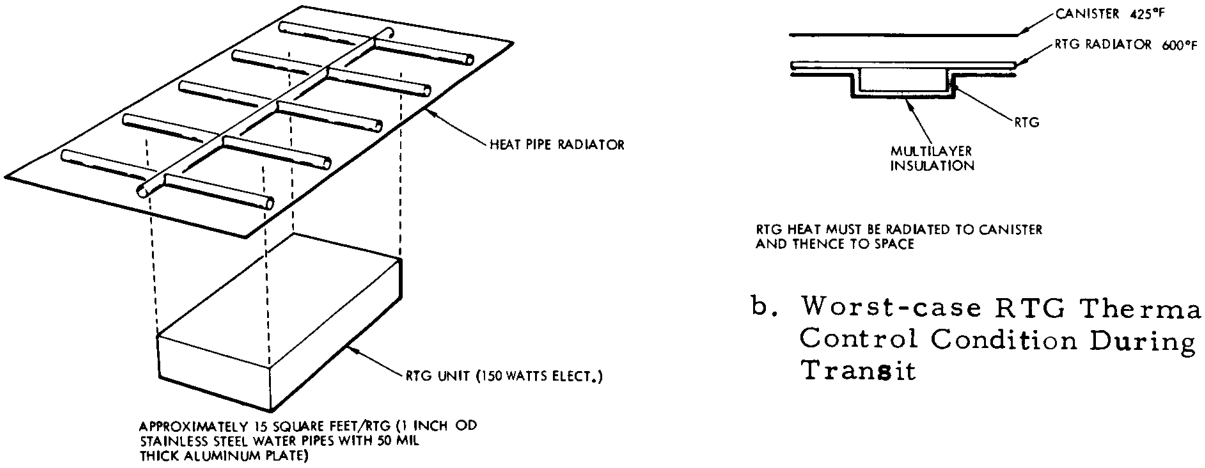
Figure 56. Schematic of LMDE Variable Thrust Engine

to a foot pad at its lower end and an outer cylinder connected to the lander structure. A honeycomb cartridge is provided within each strut to absorb energy at touchdown.

16.2.10 Thermal Control

Thermal control for the capsule centers around thermal control for the RTG units. Each of the two 150-watt RTG's is mounted to a space radiator which in turn is mounted to the top surface of the lander cruciform structure, as shown in Figure 57. Each radiator is 15 square feet in area made up of an 0.05-inch thick aluminum plate. Heat is distributed uniformly throughout the plate by an array of heat pipes made of 1-inch diameter stainless steel piping (see Figure 57a).

Thermal radiation during descent or for the worst Mars surface condition is adequate to maintain the RTG's at an allowable temperature. The worst case condition, however, corresponds to interplanetary transit in which the RTG heat must be radiated to the canister and thence to space. The installation is shown schematically in Figure 57b. The corresponding temperatures are 600°F for the RTG radiator and 425°F for the adjacent canister area.



b. Worst-case RTG Thermal Control Condition During Transit

a. RTG Heat Pipe Radiator Concept

Figure 57. Possible Thermal Control for RTG

When the flight capsule is encapsulated within the launch vehicle shroud, it is necessary to reject heat from the canister by an active cooling arrangement that utilizes cooling tubes incorporated into the aft canister, through which water flows to remove heat. For all prelaunch operations the water coolant is supplied through OSE connections. At liftoff a pressurized water supply attached to the shroud to remove heat by vaporization is utilized for the period through separation, as shown in Figure 58. In-flight disconnects are utilized at separation and all remaining water will evaporate. The cooling passages are topologically external to the canister so they do not break the canister biological barrier. This water coolant system can be utilized as well for all capsule operations prior to encapsulation in the shroud.

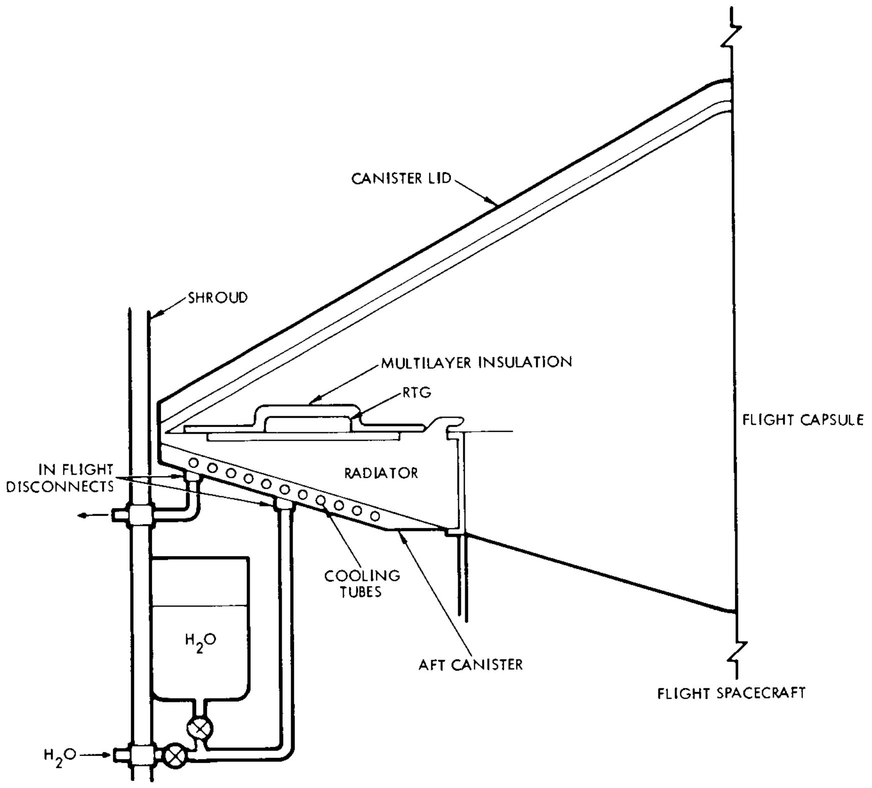


Figure 58. Thermal Control for Shroud Encapsulation

All landed science equipment except units requiring external insulation are mounted within two thermally-controlled equipment compartments.

A total volume of 15 cubic feet is available in the present configuration, with a surface area of 80 square feet. To provide for heat rejection from the compartment, a path is created by means of thermal switches to conduct the excess heat to the upper surface of the lander structure for radiation to space or to the canister wall. Heat is supplied the compartment when needed by a heat pipe using the RTG as a heat source. The heat pipe operates in conjunction with a thermal switch to block this heat when not required. To maintain the equipment between 40 and 115°F, 150 thermal switches and a total radiating area of 16.8 square feet are required. The heat pipe must supply 210 watts to the compartment for night heating.

Equipment mounted outside the compartments is thermally controlled by minimizing thermal coupling between the equipment and its support structure, as well as minimizing the effects of widely varying external radiant environment. Thermal isolation uses low-conductance mounts (stacked washers, phenolic blocks, etc.) and multilayer radiation insulation. Thermostatically controlled heaters prevent excessively low temperatures.

16.2.11 Electrical Power

The electrical power subsystem for the advanced Voyager flight capsule uses a radioisotope thermoelectric generator (RTG) with peaking battery. A system arrangement is shown in Figure 59. Two 150-watt RTG units operate in parallel at a level of 18 vdc. Redundant shunt regulators control this voltage to 1 percent. Two batteries are incorporated, with one activated prior to launch and the other held as a spare. Battery charge control is provided by a charge regulator. Redundant 400 Hz inverters and 4 kHz inverters provide AC power. Power is controlled by a power distribution unit, normally under control of the data automation equipment. Direct ground command can override the DAE.

From launch through interplanetary flight and until a pre-separation activation phase, the flight capsule is essentially passive. Power is supplied by the RTG for thermal control, instrumentation, and battery charge maintenance. From activation through touchdown the RTG furnishes power to the lander bus subsystems and the entry payload. Power is also supplied the landed payload on a maintenance basis.

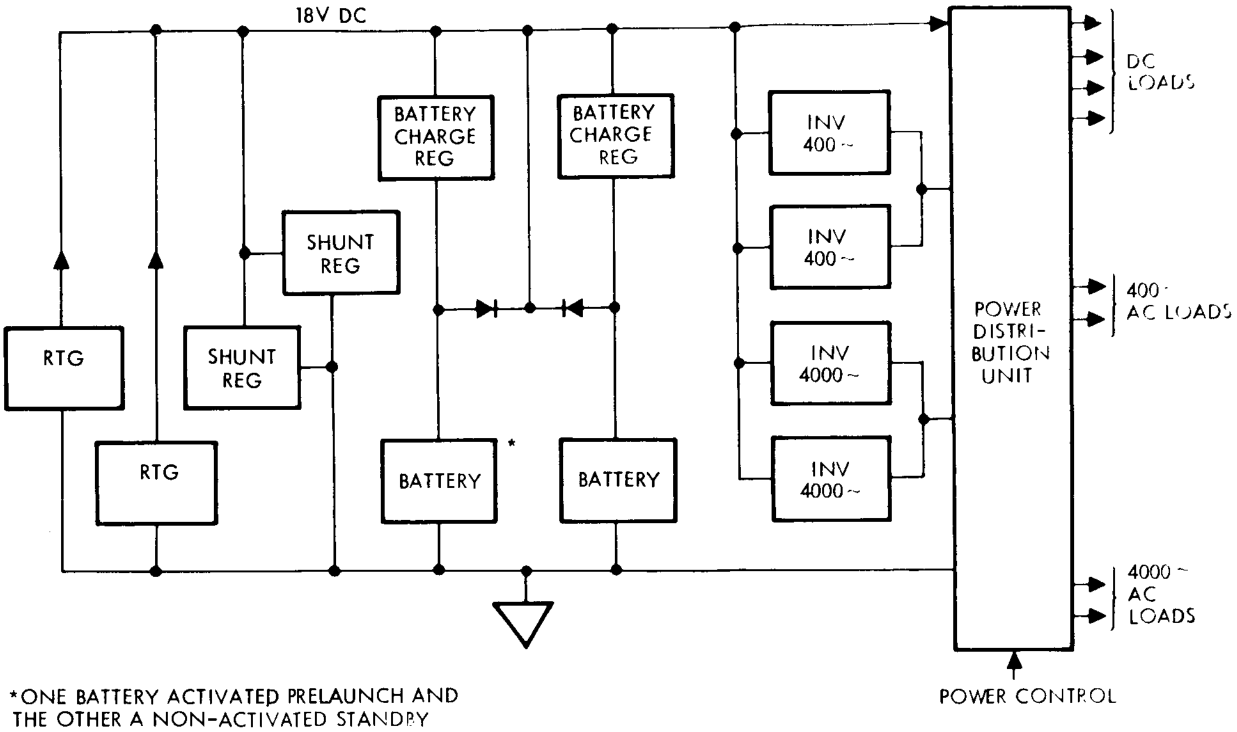


Figure 59. Schematic of Electrical Subsystem

16.2.12 Communications

The S-band radio subsystem for the capsule is illustrated in Figure 60. In the subsystem two 50-watt transmitters are available with the choice controlled by the transmitter selector. Internal logic operates on signals from the power monitor to transfer operation from a unit when its RF output falls below a given threshold level. Override is possible by direct ground command.

A large (9-foot diameter) high-gain antenna is used, with a 3-foot diameter medium-gain antenna utilized as a backup and to allow easier acquisition. Both antennas are of conventional parabolic shapes with a Cassegrain feed for the high-gain and a focal point feed for the other. Each is double gimbaled to allow earth tracking.

The relay link requires equipment on both the orbiter and the lander, as shown in Figure 61. An illustrative antenna design is a cavity-backed planar spiral providing hemispherical coverage. The spiral produces circularly polarized radiation (right or left handed) and operates in conjunction with a polarization diversification receiver on the spacecraft to

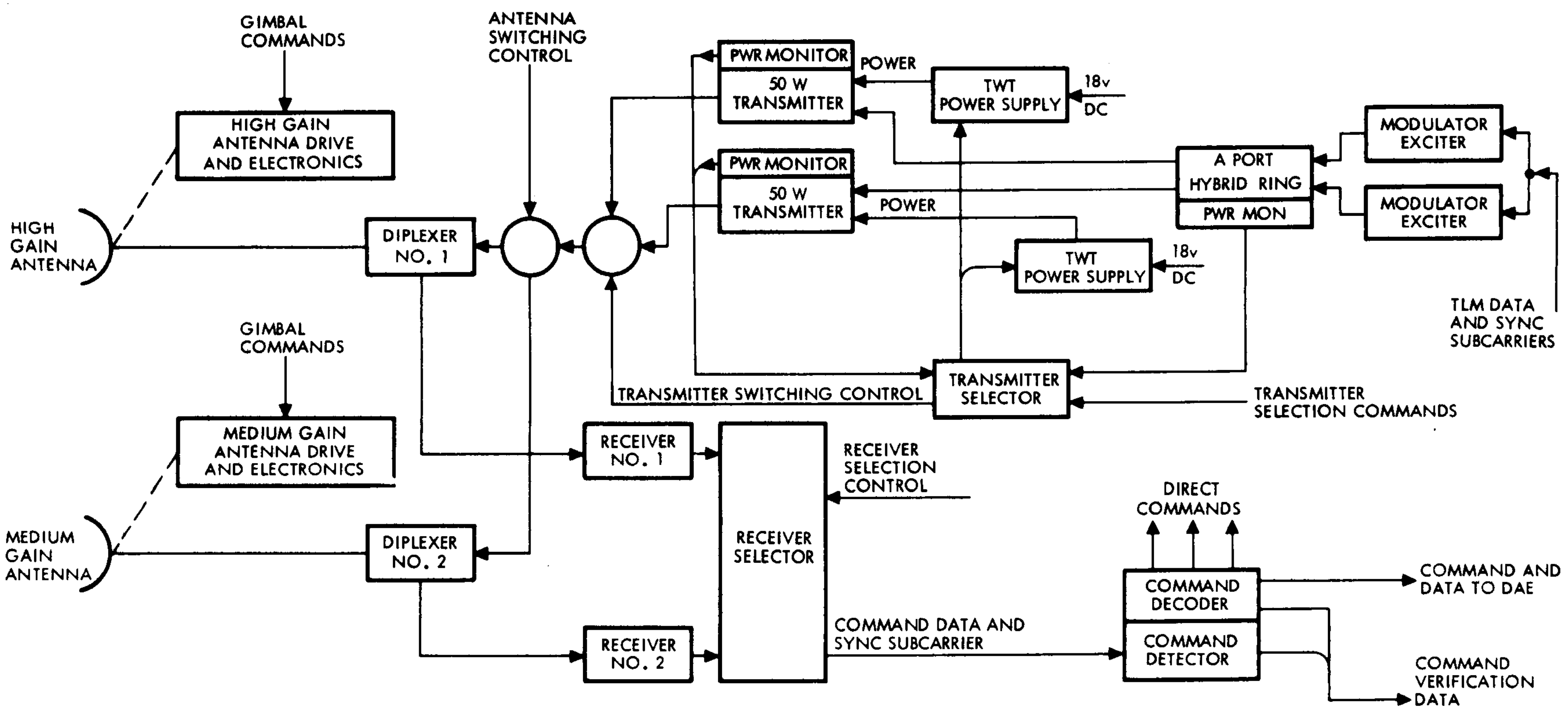


Figure 60. Block Diagram of Capsule S-Band Radio Subsystem

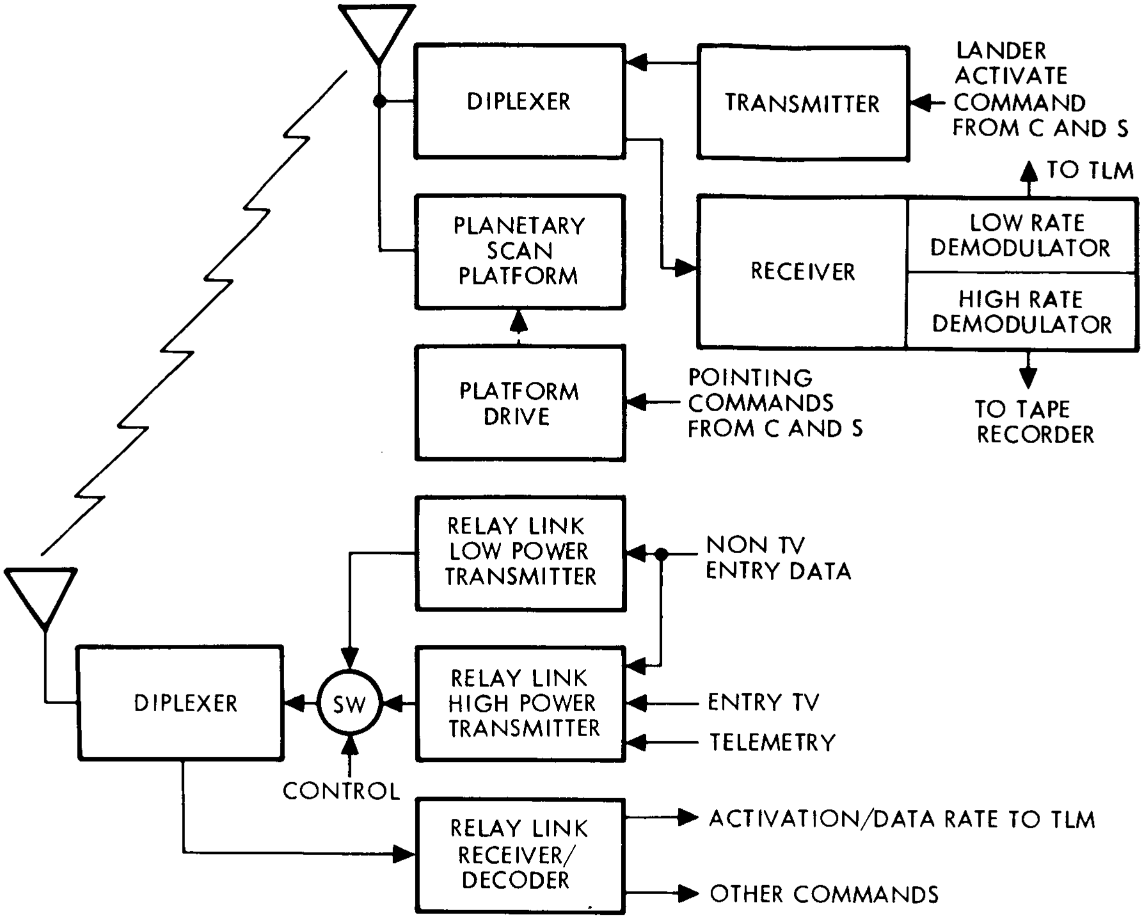


Figure 61. Block Diagram of Lander-Orbiter Relay Link

negate polarization rotation effects caused by the atmosphere or body orientation. An operating frequency of 300 MHz calls for an antenna 16 inches in diameter and 10 inches deep.

A functional schematic of data handling in the capsule is shown in Figure 62. Two identical telemetry encoders are provided for redundancy. To eliminate switching they are always connected in parallel to both the S-band and relay-link transmitters.

For the maximum direct link data rate of 32,000 bits/sec, a total of about 10^9 bits could be transmitted in 10 hours. Hence a large storage capacity is required for television picture data. A storage capacity of 10^8 bits appears to be about the largest capacity available in state-of-the-art recorders. Two such recorders are utilized for the television data,

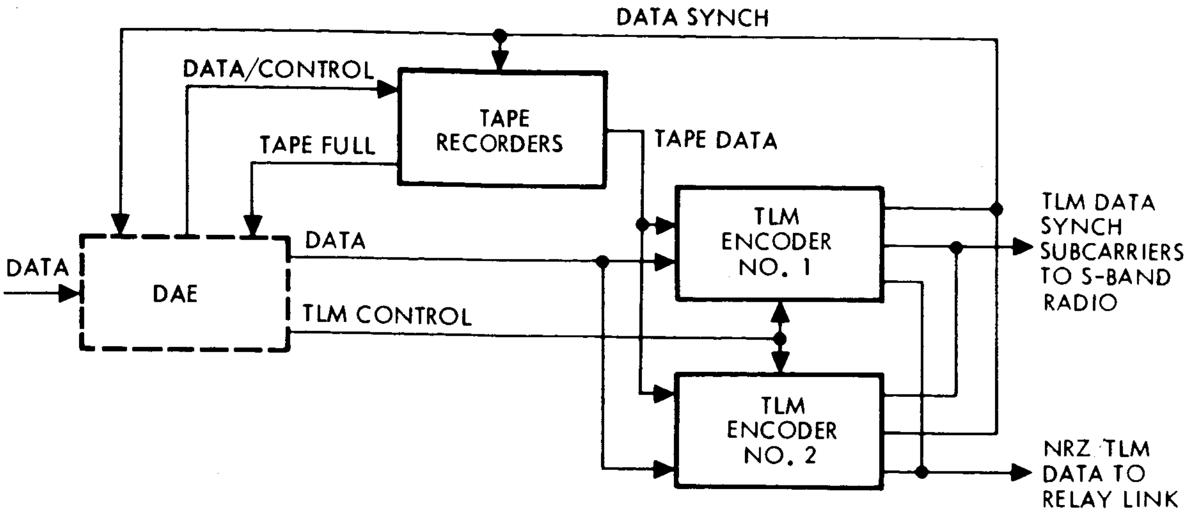


Figure 62. Block Diagram of Data Handling

to provide redundancy as well as to double the storage capacity. Also included are two general purpose 10^7-bit recorders for storing data other than television pictures.

16.2.13 Payload

There are two science payloads carried by the standard flight capsule, the entry science payload and the landed science payload. The landed science payload is described in Sections 18 and 19. The entry payload for the capsule is considered nominally to remain the same for all missions. Information on the entry payload is provided in Tables 9 and 10.

16.3 CAPSULE PROJECT ORGANIZATION

The capsule project will be organized under a project manager having authority to represent his company on all matters within the scope and terms of the contract The breakdown and summary of the related functions and responsibilities is given below:

1) Project Office. Project direction corresponds to the project manager and his immediate staff. This includes support offices for contract administration, subcontract administration, and project administrative functions.

Table 9. Weight Analysis of Entry Payload

Instruments		30
TV system	15	
Temperature sensors	1	
Pressure sensors	1	
Radiometer	3	
Ion mass spectrometer	5	
Accelerometers	2	
Langmuir probe	3	
Data automation equipment		8
Structure and miscellaneous		7
Total		45 lb

Table 10. Entry Experiments

Objective	Instrument	Measurement
Look for macroscopic life	TV camera	Photo interpretation
Ionospheric composition	Ion mass spectrometer,	Ion masses and concentrations
Ionospheric temperatures	Langmuir probe	Ion energy
Ionospheric concentrations	Langmuir probe	Ion density
Temperature versus altitude	Thermometer	Temperature
Pressure versus altitude	Pressure sensor	Pressure
Density versus altitude	Accelerometer	Aerodynamic drag

2) <u>Planning and Control.</u> Planning and Control is the focal point for overall project planning, scheduling, work direction, data management, management systems, and pricing. This operation is responsible for a data center and project control center and prepares all project level analyses and reports. Planning and Control establishes policies and procedures and performs audits of management practices. It formalizes all technical specifications and engineering data received from Systems Engineering and from the other operations and maintains all documentation baselines for the project. It is a staff activity and does not give independent project direction to the hardware-producing organizations.

3) <u>Product Integrity.</u> Project Integrity Operations is a counterpart of Planning and Control for technical support functions. The manager has responsibility for implementing project efforts for reliability, materials and processes, safety, contamination control, product engineering, manufacturing, procurement (except major subcontracts), shipping and handling, logistics, value engineering, and quality assurance. Project quality assurance, established as a subproject, includes detailed supervision of quality engineering and related functions for all the project.

4) <u>Systems Engineering.</u> Systems Engineering is the system engineering activity for the Voyager capsule project. It supports the capsule system SMO and the Voyager project office in mission analysis and prepares all capsule system level specifications and engineering documentation, including configuration drawings, capsule assembly drawings, subsystem specifications, schematics, and interface control drawings. Systems Engineering also performs technical audits of all design activity and participates in all design reviews and major capsule system tests. It is also responsible for capsule science integration.

5) <u>Subsystem Operations.</u> Subsystems Operations is responsible for providing the hardware assemblies which make up the capsule. It covers subsystem subprojects which do subsystem design, development, procurement, manufacture, and test for both flight hardware and related support equipment. The output of Subsystems Operations is acceptance-tested configured items delivered to assembly and test stores and ready for capsule assembly and checkout.

6) <u>Assembly and Test Operations.</u> Assembly and Test Operations receives subsystem hardware provided under cognizance of Subsystems Operations and assembles this hardware into subsystems, capsules, and operational support equipment. It prepares detailed requirements for OSE and supervises the subsystem subprojects in developing and providing this equipment. Overall integration of project testing is the responsibility of a test office within Assembly and Test Operations.

16.4 IMPLEMENTATION SCHEDULE

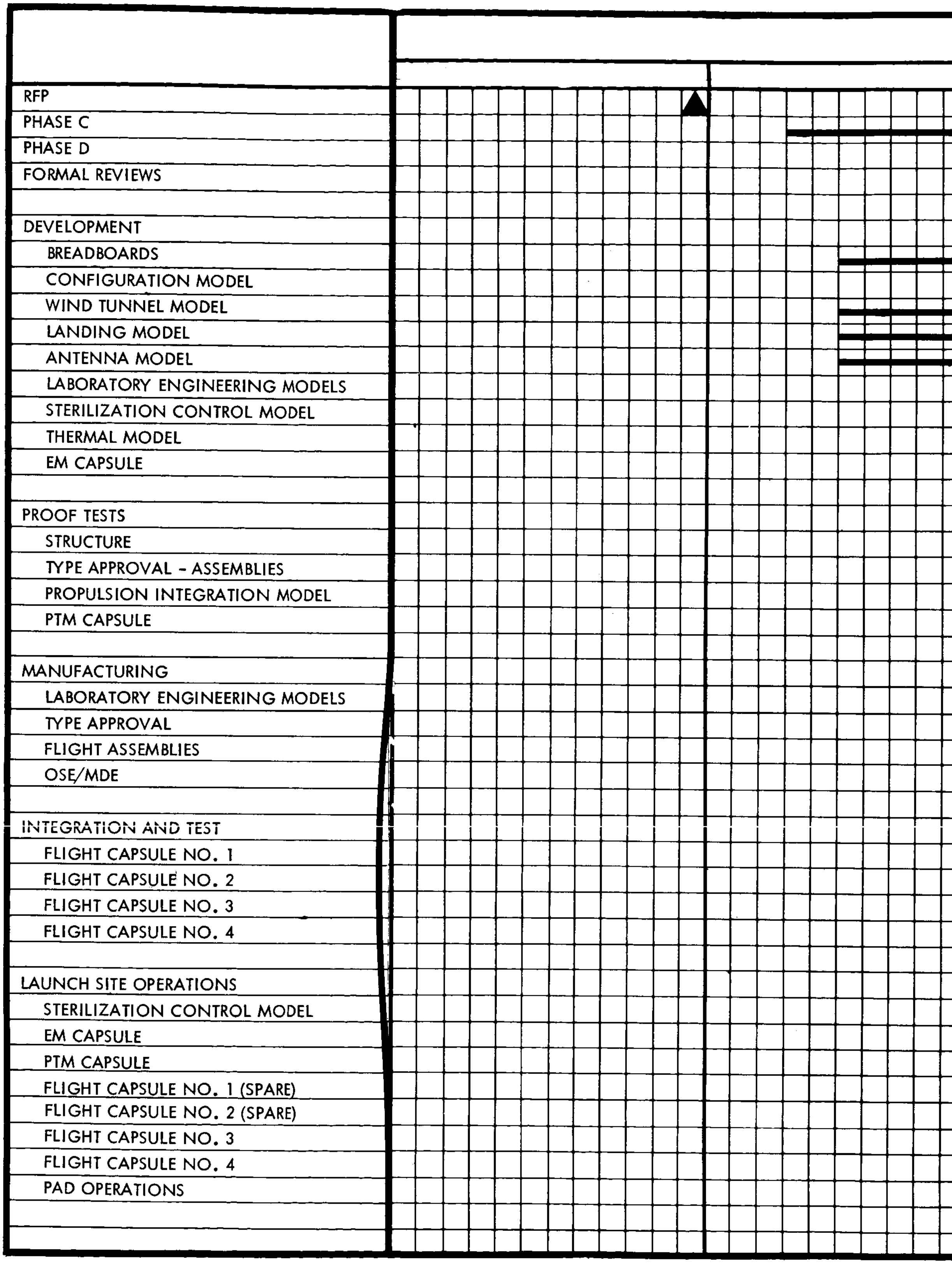
The capsule project implementation schedule pivots about July 7, 1973, the nominal start of the initial launch window, and includes such major milestones as:

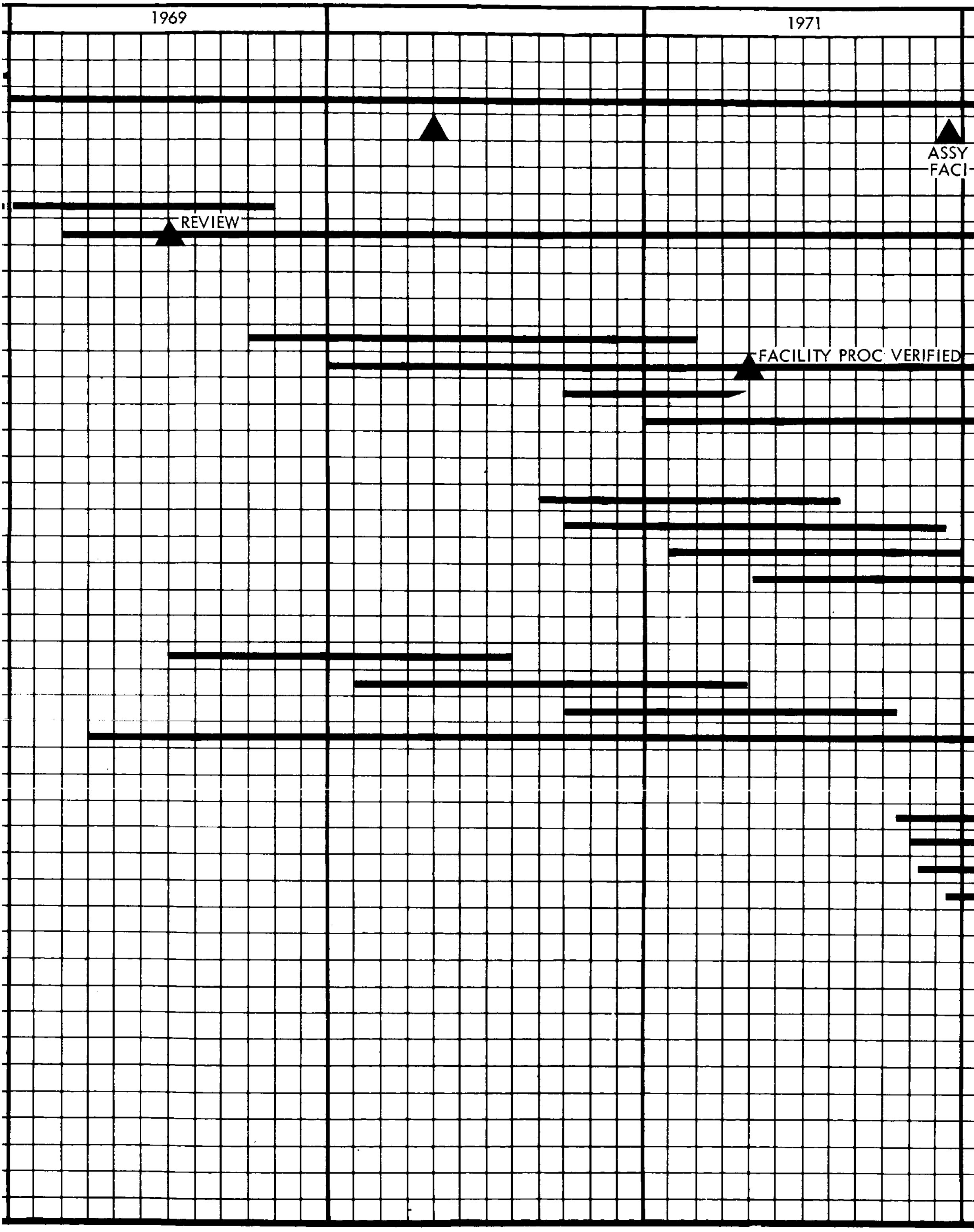
- Freeze of design approach and preliminary design at the preliminary design review in Phase C. This milestone recognizes that the design defined in Phase B may be modified during Phase C. However, to maintain an effective project schedule, an early freeze of the preliminary design is necessary.
- Critical design review just before the start of the assembly of the proof test model. This review will assure acceptability of the design and performance characteristics of the flight hardware which is identically represented by the proof test model.
- Subsystem qualification complete prior to assembly and integration into the flight articles.
- System FACI completed prior to the shipment of the first flight article to the launch complex; this milestone represents the cumulation of sublevels of system qualification covering environmental, system integration, and sterilization. These earlier qualification activities are scheduled to permit modifications to be made on the flight articles while they are still at the contractor's facility where experienced personnel and proper tooling are available to expedite the corrective action.

The overall schedule is shown in Figure 8 and the schedule through the 1973 launch in Figure 63. Since the capsule contractor is responsible for integrating the surface laboratory, mobile unit, and RTG with the bus, schedules for these other elements of the capsule must be compatible to the requirements of the capsule bus schedule.

16.5 DESIGN AND DEVELOPMENT

Phase C will include detailed system design of the selected capsule system concept, including completion of the system specification and Part I of contract end item specifications. It includes the fabrication and


RFP
PHASE C
PHASE D
FORMAL REVIEWS
DEVELOPMENT
BREADBOARDS
CONFIGURATION MODEL
WIND TUNNEL MODEL
LANDING MODEL
ANTENNA MODEL
LABORATORY ENGINEERING MODELS
STERILIZATION CONTROL MODEL
THERMAL MODEL
EM CAPSULE
PROOF TESTS
STRUCTURE
TYPE APPROVAL - ASSEMBLIES
PROPULSION INTEGRATION MODEL
PTM CAPSULE
MANUFACTURING
LABORATORY ENGINEERING MODELS
TYPE APPROVAL
FLIGHT ASSEMBLIES
OSE/MDE
INTEGRATION AND TEST
FLIGHT CAPSULE NO. 1
FLIGHT CAPSULE NO. 2
FLIGHT CAPSULE NO. 3
FLIGHT CAPSULE NO. 4
LAUNCH SITE OPERATIONS
STERILIZATION CONTROL MODEL
EM CAPSULE
PTM CAPSULE
FLIGHT CAPSULE NO. 1 (SPARE)
FLIGHT CAPSULE NO. 2 (SPARE)
FLIGHT CAPSULE NO. 3
FLIGHT CAPSULE NO. 4
PAD OPERATIONS


1969
1971
REVIEW
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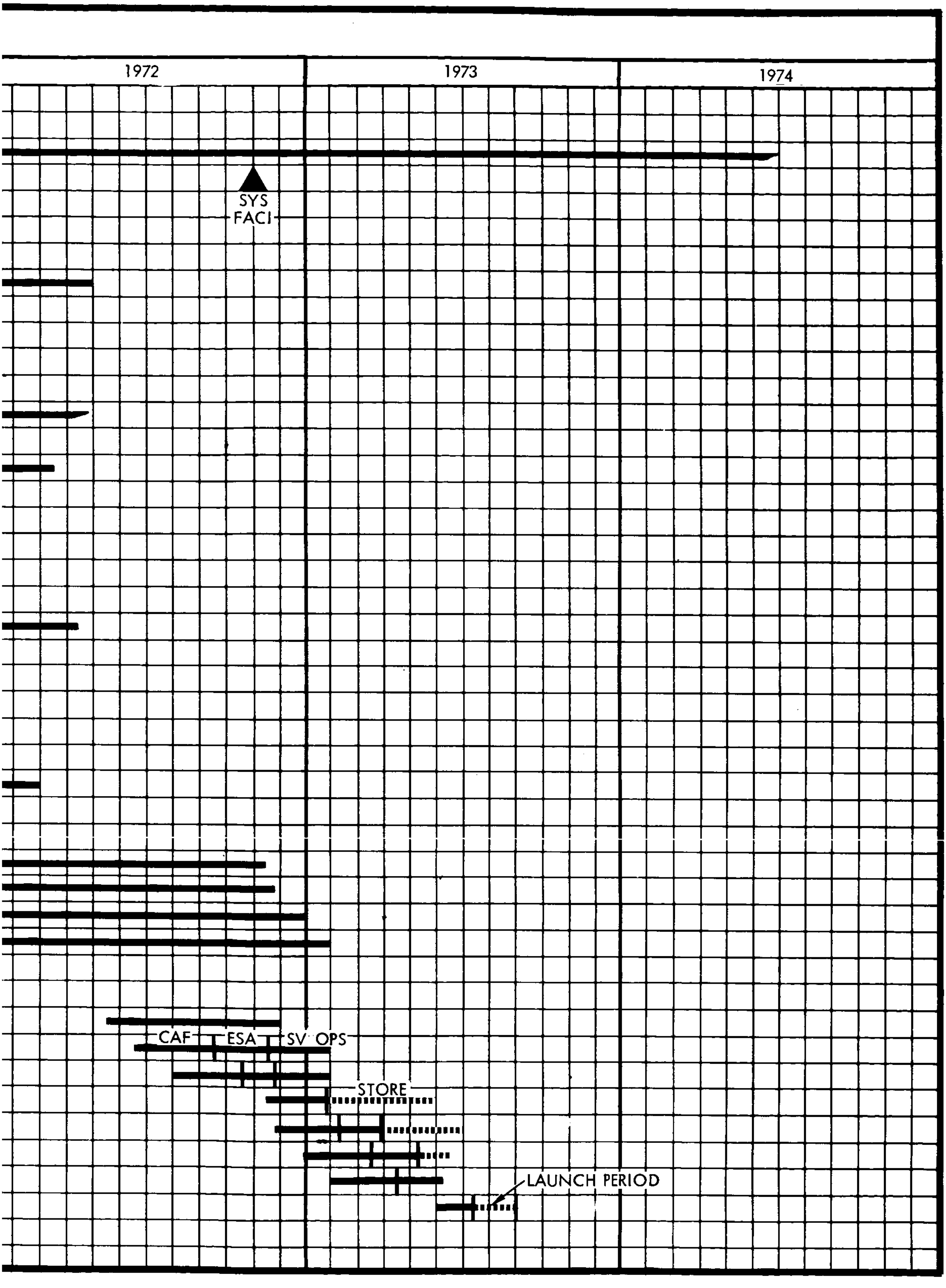


Figure 63. Capsule System Summary Schedule

test of breadboard hardware of selected critical subsystems, as necessary to provide reasonable assurance that the technical milestone schedules and resource estimates for the next phase can be met. These Phase C activities will consist of the following:

1) Carry out detailed system design
    - Analysis
    - Definition of system functions and performance
    - Environmental requirements
    - Subsystem design and evaluation
2) Define all interfaces of capsule system
3) Breadboard fabrication and testing of critical items
4) Preparation of specification tree and Part I CEI specifications, in accordance with the overall project specification guidelines
5) Identification of critical components
6) Completion of management and technical plans
7) Preparation of input for system specification and intersystem control documents
8) Preliminary design review and approval of system specification and Part I CEI specifications
9) Preparation of technical requirements and contract requirements for major subcontracts

The above activities constitute a major system design effort during the Phase C and will require a concerted effort covering both system engineering and subsystem design.

Design feasibility tests are performed on breadboard models of an item to evaluate the feasibility of the design concept. Some of these tests are initiated during Phase C, and include wind tunnel testing of aerodynamic and aerothermodynamic entry and retro landing configurations; materials compatibility screening tests; antenna testing, and critical subsystems breadboard testing. Phase C terminates with the final definition of each subsystem enabling the procurement of "buy" items and the development of "make" items to commence at the start of Phase D. Design feasibility testing will continue into Phase D.

Design verification tests are performed in Phase D on engineering models to evaluate the suitability of the proposed final design and to assure successful completion of the formal qualification tests. These tests include: breadboard testing of the pyrotechnic, guidance and control, radio/command, data storage/telemetry, electrical power, and experiment subsystems; cold flow and hot firing testing of the attitude control and propulsion subsystems; sterilization compatibility testing of critical subsystems and components, and mechanical testing of deployment and separation mechanisms.

Type approval or qualification tests are conducted on flight-type hardware to formally demonstrate compliance with design specifications. These tests include functional performance and sequential operations under critical environment conditions. They also encompass sterilization compatibility tests, design margin tests, and life tests. To provide confidence in mission success, qualification test levels are made more severe than those anticipated for the actual mission. As a consequence of being overstressed, test articles used for qualification testing are disqualified for use as flight hardware.

The major development test models required to support capsule development leading to formal qualification testing of capsule hardware are as follows:

- Configuration model
- Sterilization control model (SCM)
- Structural model (SM)
- Thermal model (TM)
- Engineering model (EM)
- Propulsion integration model (PIM)
- Proof test model (PTM)

These models are used primarily for design verification testing. The SM and PIM, however, are also used for initial subsystem qualification testing and the PTM is used to complete subsystem qualification, perform systems level qualification, and verify capsule flight acceptance test procedures.

16.5.1 Configuration Model

The configuration model is initially constructed as a soft article and is later upgraded to a hard configuration. This mockup is used as an engineering tool early in the program. The hard mockup will be maintained correspondent with design until the completion of the first deliverable capsule. The principal functions are as follows:

- Develop internal and external flight configuration
- Develop routing of plumbing and harnessing
- Represent spacecraft-capsule interfaces and interfaces with the surface laboratory and mobile unit and the RTG
- Develop OSE interfaces

16.5.2 Sterilization Control Model

The SCM simulates a full-size capsule configuration and is capable of enduring repetitive exposures to the ETO/heat-sterilization cycle. It consists of a representative metallic structure with dummy subsystems. At the contractor's facility this model is used primarily in support of the capsule clean-room and sterilization-facility operations. The principal functions of the SCM are as follows:

- Train and orient personnel involved in operations within the Class 100 facility
- Develop factory operation procedures in contamination-controlled areas
- Verify clean-room facility procedures. Completion of this activity relieves the constraint upon the start of the PTM structure final assembly by demonstrating the validity of capsule factory buildup.
- Conduct contamination control investigation and verification tests. Completion of this phase relieves the constraint upon the start of PTM testing by demonstrating validity of contamination control techniques.

This model would also be made available to KSC for terminal sterilization facility verification tests and capsule contamination control procedures verification.

16.5.3 Structural Model

The SM is used to demonstrate the structural integrity of the capsule design. It consists of flight-weight capsule bus structure, prototype mechanisms, dummy subsystems having flight equivalent inertial masses, including the surface laboratory and the mobile unit. The model will be used for modal surveys; dynamic and static testing of the primary flight configurations from launch through terminal descent; related mechanical demonstrations, and drop tests. These tests will demonstrate the integrity of interface cabling, umbilicals, plumbing, and interfacing systems. Completion of static testing relieves the constraint to start capsule final structural assembly.

16.5.4 Thermal Model

The TM will be the same size and configuration as the capsule. It consists of prototype structure, prototype mechanisms, dummy subsystems and a dummy SLS, and has flight-equivalent thermal masses, and a prototype thermal control subsystem. This model will be used for the following functions:

- Verify thermal balance during planetary vehicle operations (launch and trans-Mars cruise)
- Verify thermal balance during capsule descent and landed operations

Verification of capsule thermal balance relieves the manufacturing constraint against the installation of insulation and thermal shielding in the PTM.

16.5.5 Engineering Model Capsule

The EM provides a tool for integrating all electronic and electrical subsystems in the capsule and for verifying their operation in a near-flight-type configuration. The EM contains all electronics and electrical components within each subsystem. This model will be utilized at the capsule contractor's facility to support qualification and acceptance testing of the PTM and deliverable capsules. It will then be utilized off site for DSIF and KSC compatibility testing. The principal functions of the EM are as follows:

- Conduct subsystems buildup and integrated testing
- Verify EMC
- Operations personnel training
- Verify DSIF-MDE compatibility
- Verify KSC facility and operations procedures
- Verify KSC/OSE compatibility

16.5.6 Propulsion Integration Model

The PIM contains flight weight structure, and fully operable flight configuration attitude control and propulsion subsystems with flight configuration engines. The pyrotechnic subsystem is operable to the extent required by the attitude control and propulsion subsystems. The other subsystems are simulated by dummy masses having the proper inertial characteristics. During model buildup the attitude control and propulsion subsystems will be exposed to the required levels of ETO and heat. This model will qualify the attitude control and propulsion subsystems by demonstrating operation under high-altitude conditions after sterilization. It will perform the following functions at the White Sands Test Facility:

- Verify subsystem vibration levels during nominal mission duty-cycle hot-firing. Completion of this test will permit subsystem plumbing to be installed in the first deliverable capsule.
- Verify factory cold-flow calibrations with live propellants
- Demonstrate off-nominal and malfunction mission duty cycles

16.5.7 Proof Test Model

The PTM is used to complete subsystem certification, perform systems level qualification for the capsule bus, perform intersystem qualification with the other elements of the capsule system, and verify capsule flight acceptance test procedures. Since the PTM is the first systems-level article manufactured with flight-type hardware, it will also demonstrate the validity of flight article capsule factory buildup and biocontamination control procedures. To this end, the PTM precedes the flight article in the sequence of disassembly, ETO decontamination of subsystems, and reassembly in the Class 100 facility.

The PTM will demonstrate that the capsule can survive terminal sterilization and is capable of meeting the mission design requirements. Systems-level testing of the PTM, therefore, is initiated at the completion of factory buildup and proceeds through systems-level ETO/heat-sterilization qualification cycles, and subsequent critical mission environmental tests. Completion of the PTM test program permits the start of flight acceptance testing.

16.6 MANUFACTURING

The manufacturing critical path lies in the progressive build-up of the capsule bus structure and its associated equipment. Its structural subsystems (aeroshell, sterilization canister, and spacecraft adapter) become feeder assemblies and do not influence the total lead time. The influence of the decontamination and sterilization requirements is reflected in the following major manufacturing tasks:

- Fabrication of details (performed in a normal machine shop environment) will be cleaned, decontaminated, and suitably packaged for storage in a controlled environment prior to assembly

- Assembly of the capsule bus structure and installation of fluid and electrical lines will be performed in the structural assembly facility (Class 100, 000 clean room environment). The feeder assemblies (harnesses, plumbing sections, and minor structural subassemblies) will be fabricated in adjacent controlled areas. Each completed structure, with fluid and electrical lines installed, will be subjected to an ETO and heat cycle.

- Fabrication of both the canister and adapter will be performed in the subassembly area of the structural assembly facility. These assemblies will be decontaminated and subjected to a dry-heat cycle prior to storage in the subassembly and final assembly facility.
- Subsequent assembly operations comprising the installation of subsystem equipment and payload packages will be performed in the subassembly and final assembly facility. Each subsystem and payload package will have been subjected to decontamination and heat sterilization cycles prior to final assembly. After assembly and test, the capsule will be disassembled to the subsystem level in this area and each component carefully identified to ensure a "matched system" final assembly.
- Final assembly of the capsule will be performed in an adjacent bioclean room maintained at a Class 100 level. Each subsystem component will be inspected, cleaned, and decontaminated prior to final assembly.

16.7 ACCEPTANCE TESTS

Acceptance tests for flight hardware will be performed at two levels: component-assembly, and systems. Both will be subjected to critical mission-level environments to verify performance characteristics and ferret out "infant mortality" failures associated with undetected substandard parts or poor workmanship. These tests also serve to burn-in the system for stabilizing performance characteristics. Component-assembly level acceptance tests will be performed at the point of manufacture to demonstrate specification compliance and product quality, ensure the integrity of the manufacturing process, and control the microbial load within acceptable limits. These tests will encompass physical inspection, functional tests, ETO/heat-sterilization cycle, and mission environmental tests. Capsule hardware such as batteries and pyrotechnic squibs which are degraded or destroyed upon activation may be accepted on a lot basis by random sampling.

Structural assemblies and pressurizable assemblies will go through all of the foregoing tests, except the mission environments, which will be performed at the systems level of acceptance. The attitude control and propulsion subsystems, less thrusters and engines, will undergo cold-flow checkout, proof test, and calibration prior to the ETO-heat-sterilization cycle.

Figure 64 describes the sequence for assembly checkout and acceptance of the flight capsule system. To reduce the duration of facility time required for nuclear operations, the RTG will not be fueled with the radioisotope until required for the final acceptance test operation. A means to provide the equivalent thermal energy for operation of the RTG will be included where the RTG power is specifically required for test purposes. Auxiliary power sources will be used wherever practical.

All subsystems will have completed environmental and flight acceptance tests prior to assembly in the capsule. In addition, one complete subsystem will have completed type approval (qualification) tests. Flight units will be delivered to a bonded storage area after acceptance tests, from which area they will be withdrawn as required for capsule system buildup.

During the assembly sequence, each mechanical or electrical installation will be tested as appropriate to assure integrity of the operation. These will include high potential and continuity tests of the electrical harness installation; RF power, modulation index frequency and modulation gain of the S-band radio assembly; and end-to-end calibrations when electronics subassemblies are connected.

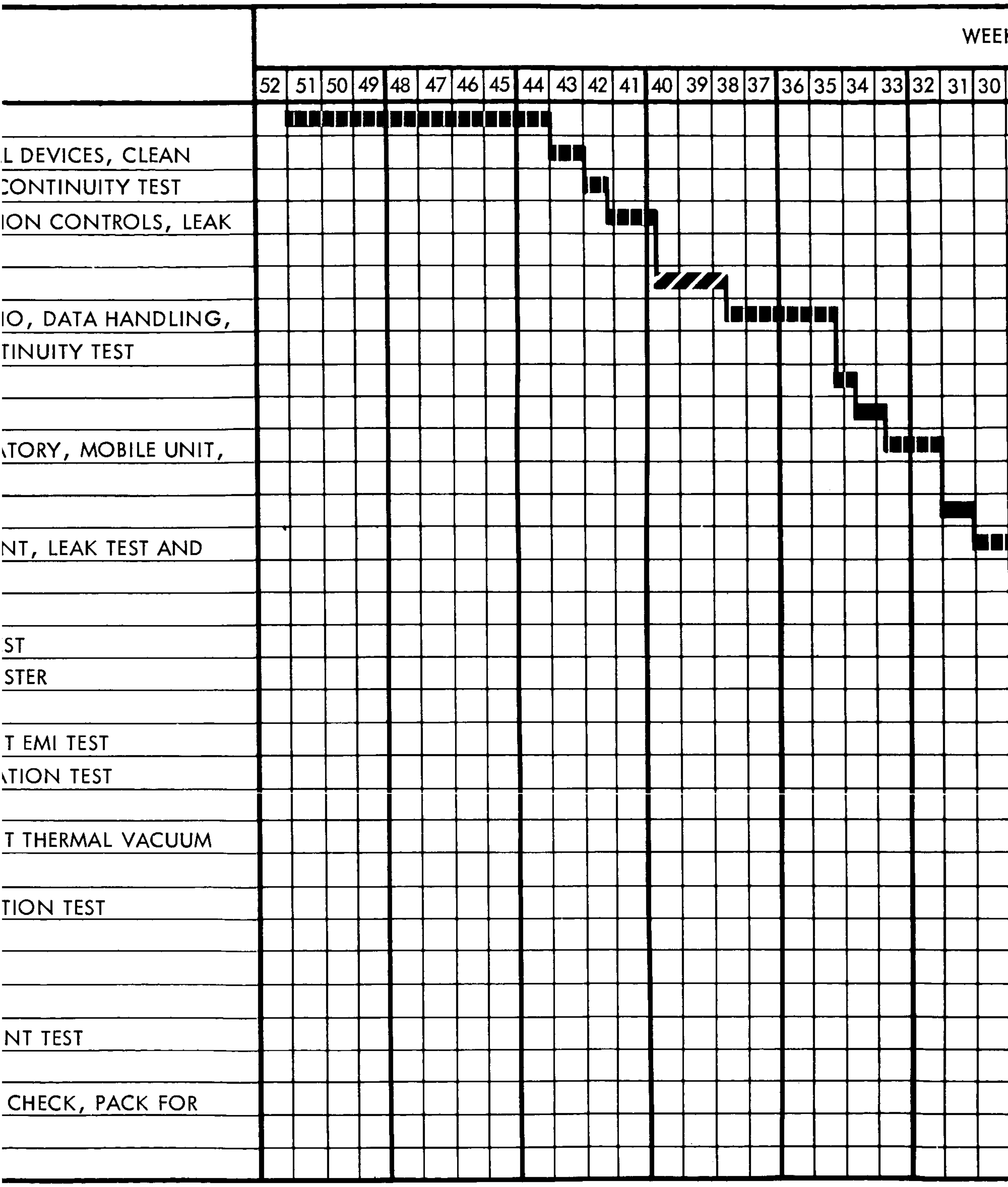
An integrated systems test will be conducted and is defined as a test of all capsule equipment except for the science experiments' simulators which will be used in place of experiments and ordnance. This test will be designed to follow a flight sequence of events.

16.8 CONTAMINATION CONTROL

Throughout the manufacture, assembly, test, and handling of capsules and capsule hardware, effective contamination control, both particulate and biological, must be maintained. In the main, particulate contamination control is relatively routine due to extensive experience gained in several space programs. The significant task remaining is that involved in instituting a biological contamination control program.

The development of an effective biological contamination control program for the Voyager capsule must commence with a contamination allocation for all events in the manufacture and testing of deliverable

1.	ASSEMBLE STRUCTURE
2.	INSTALL PNEUMATICS, VALVES MECHANIC
3.	INSTALL HARNESS, CONDUCT ELECTRICAL
4.	INSTALL GUIDANCE AND CONTROL, REAC
	TEST AND CLEAN
5.	ETO AND HEAT STERILIZE
6.	INSTALL THERMAL CONTROLS, S-BAND RA
	RELAY LINKS, ANTENNAS, CONDUCT CO
7.	INSTALL RTG LESS RADIOISOTOPE
8.	CONDUCT INTEGRATED SYSTEMS TESTS
9.	INSTALL ENTRY SCIENCES, SURFACE LABOR
	CONDUCT CONTINUITY TEST
10.	CONDUCT MOBILE UNIT DEPLOYMENT TES
11.	INSTALL TERMINAL PROPULSION, ALIGNM
	CLEAN
12.	INSTALL LANDING GEAR, HEAT SHIELD
13.	CONDUCT LANDING GEAR DEPLOYMENT
14.	WEIGHT AND CG WITH AND WITHOUT CA
15.	CONDUCT INTEGRATED SYSTEMS TEST
16.	INSTALL CANISTER AND ADAPTER, CONDU
17.	CONDUCT LAUNCH CONFIGURATION VIB
18.	CONDUCT INTEGRATED SYSTEMS TEST
19.	REMOVE CANISTER AND ADAPTER, CONDU
	TEST
20.	CONDUCT LANDER CONFIGURATION VIBR
21.	INSTALL NUCLEAR HEAT SOURCE
22.	CONDUCT INTEGRATED SYSTEMS TEST
23.	REMOVE NUCLEAR HEAT SOURCE
24.	CONDUCT PNEUMATIC LEAK AND ALIGN
25.	ETO AND HEAT STERILIZE
26.	INSTALL CANISTER AND ADAPTER, PRESSU
	SHIPMENT


WEEK
52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30
L DEVICES, CLEAN
CONTINUITY TEST
ION CONTROLS, LEAK
IO, DATA HANDLING,
TINUITY TEST
TORY, MOBILE UNIT,
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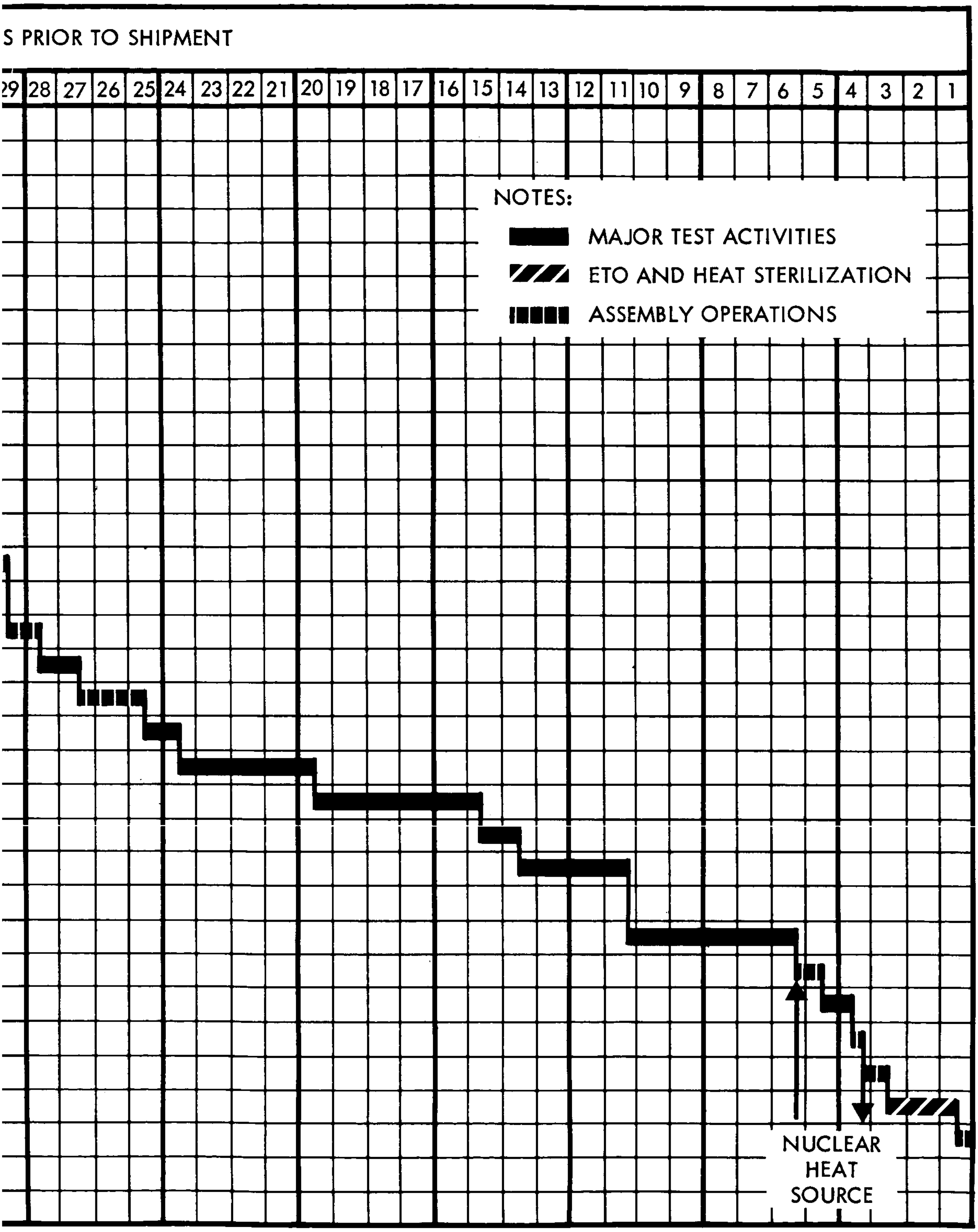

Figure 64. Flight Capsule System Assembly, Checkout, and Test Schedule

capsules. This allocation, identified in terms of an allowable microbial load on each item of capsule hardware, is the basis for formulating the program and measuring its effectiveness.

The assignment of an initial microbial contamination allocation for each item, whether piece part or subsystem, must consider the contamination contributed by the nature of the item; the sequence, nature, complexity, and phasing of all operations and processes required in its fabrication, inspection, assembly, handling, test, alignment, etc.; its mode of operation, and its material and configuration, among others. The microbial contamination at any given time in the build-up sequence is a function of the foregoing items plus the frequency and effectiveness of decontaminants and the contribution of the environment to the die-off rate of the various contaminating organisms. This approach will most likely yield an initial total capsule microbial loading which will exceed the required level of 10^8 organisms of which no more than 10^5 are viable spores. The preferred allocation approach will highlight those items which are most susceptible to microbial contamination. At this point, it will be possible to specify a biological contamination control program designed to meet quantitative objectives and assure the attainment of the required level of cleanliness. Iterative re-allocations will be made in the course of the program as experience is gained, always remaining within the required limits. The input data for this task will require the judgment of qualified manufacturing, producibility and methods, and sterilization control groups, the generation of mathematical models, and the use of controlled experiments.

During the manufacturing, assembly, and testing of capsules, sample quantities of incoming materials and piece parts will be tested for conformance to particulate and biological contamination specifications, compatibility with ETO and dry-heat sterilization, and performance evaluation. When testing is satisfactorily completed the remaining lot will be released for use.

Capsule subsystem and system assembly follows in a Class 100 clean room utilizing the accepted parts and piece parts. Upon entry into the Class 100 laminar downflow bioclean facility, each component or subsystem is exposed to one ETO cycle. Biological contamination control commences with the installation of assay coupons and packaging. The contamination allocation is the basis for maintaining effective control. From this point forward, decontamination will be employed when biomonitoring indicates that the allocation level has been exceeded. Contamination analyses of control item fabrication followed by corrective action will assure acceptable cleanliness levels. Biomonitoring will be continuous. Capsule hardware will be packaged and protected when idle or when transported within or between facilities.

The capsule is tested and prepared for shipment. Stringent contamination control will be continued during the launch operations at KSC through terminal sterilization and encapsulation.

16.9 OSE AND MAJOR FACILITIES

The successful implementation of the flight hardware program is dependent upon the availability of support equipment and facilities. The schedule of activities in Figure 65 allows adequate time for contingencies which experience has shown will occur. Initially, interfaces will be described by control documents and then functionally exercised with test models. Individual categories of OSE-MDE will be mated and verified with development test models. This is demonstrated in Figure 65 by the "first use" of the various categories of OSE. The prime purpose of first-use events is to support the test model; however, it also serves as a preliminary verification of OSE interfaces. Final OSE qualification will be conducted with flight-type hardware. The accomplishment of typical early verifications as indicated on the schedule are:

- KSC facility verification, completed 15 months prior to launch
- KSC OSE/MDE verification, completed 17 months prior to launch
- DSN verification, completed 11 months prior to launch

The capsule mission operations and launch operations are discussed in Sections 11 and 13.

		1968											
		J	F	M	A	M	J	J	A	S	O	N	D
OSE/MDE DESIGN AND PLANS	PREPARE PLANNING AND REQUIREMENT DOCUMENTATION					■	■	■	■	■	■	■	
	LEVEL 1 SUPPORT DIAGRAMS COMPLETE											▲	
	SUPPORT PLAN						■	■	■	■	■	■	
	OSE/MDE DESIGN				■	■	■	■	■	■	■	■	
	SUBSYSTEM TEST EQUIPMENT				■	■	■	■	■	■	■	■	
	SYSTEM TEST COMPLEX				■	■	■	■	■	■	■	■	
	LAUNCH COMPLEX EQUIPMENT DEFINITION										■	■	
	LAUNCH COMPLEX EQUIPMENT DESIGN												
	ASSEMBLY HANDLING AND SHIPPING EQUIPMENT DESIGN						■	■	■	■	■	■	
	MISSION DEPENDENT EQUIPMENT DESIGN				■	■	■	■	■	■	■	■	
	IDENTIFICATION OF LONG LEAD ITEMS							▲					
	OSE DESIGN REVIEW (PRELIMINARY)											▲	
	OSE DESIGN FREEZE												
	PREPARE AND RELEASE PERFORMANCE SPECIFICATIONS						■	■	■	■	■	■	
	PREPARE AND RELEASE ICD'S AND IDD'S								■	■	■	■	
	PREPARE AND RELEASE VERIFICATION TEST PROCEDURES										■	■	
	IDENTIFY OSE/MDE FLIGHT HARDWARE SPARES							■	■	■	■	■	
	PROVISION SPARES												
MFG	OSE/MDE MANUFACTURING												
OSE/MDE VALIDATION AND INTEGRATED VEHICLE CHECKOUT	PROOF TEST, CALIBRATION AND VERIFICATION												
	ASSEMBLY, HANDLING AND SHIPPING EQUIPMENT												
	SUBSYSTEM TEST EQUIPMENT												
	SYSTEM TEST COMPLEX												
	LAUNCH COMPLEX EQUIPMENT												
	MISSION DEPENDENT EQUIPMENT												
	GOLDSTONE/MDE COMPATIBILITY TESTS												
	MDE INTEGRATION AT DSN												
	DSN/MDE COMPATIBILITY TESTS												
TEST AND LAUNCH SITE ACTIVATION	DEFINE AND MODIFY CONTRACTOR SUPPORT FACILITIES									■	■	■	
	OSE INSTALLATION AT CONTRACTOR												
	DEFINE AND MODIFY WSTF SUPPORT FACILITIES												
	OSE INSTALLATION AT WSTF												
	DEFINE AND MODIFY KSC SUPPORT FACILITIES												
	OSE INSTALLATION AT KSC												
	LAUNCH COMPLEX EQUIPMENT INSTALLATION AT KSC												
	KSC DSN/MDE VERIFICATION												
	KSC FACILITIES VERIFICATION												
	ACTIVATE GOLDSTONE FACILITY FOR GDS												
CONTRACTOR'S MAJOR FACILITIES	SPACE CHAMBER FACILITIES												
	FACILITIES DESIGN COMPLETE				▲								
	CONSTRUCT FACILITIES					■	■	■	■	■	■	■	■
	VERIFY FACILITIES												
	MANUFACTURING SUBASSEMBLY AND FINAL ASSEMBLY BUILDING												
	FACILITIES DESIGN COMPLETE			▲									
	CONSTRUCT FACILITIES				■	■	■	■	■	■	■	■	■
	VERIFY FACILITIES												

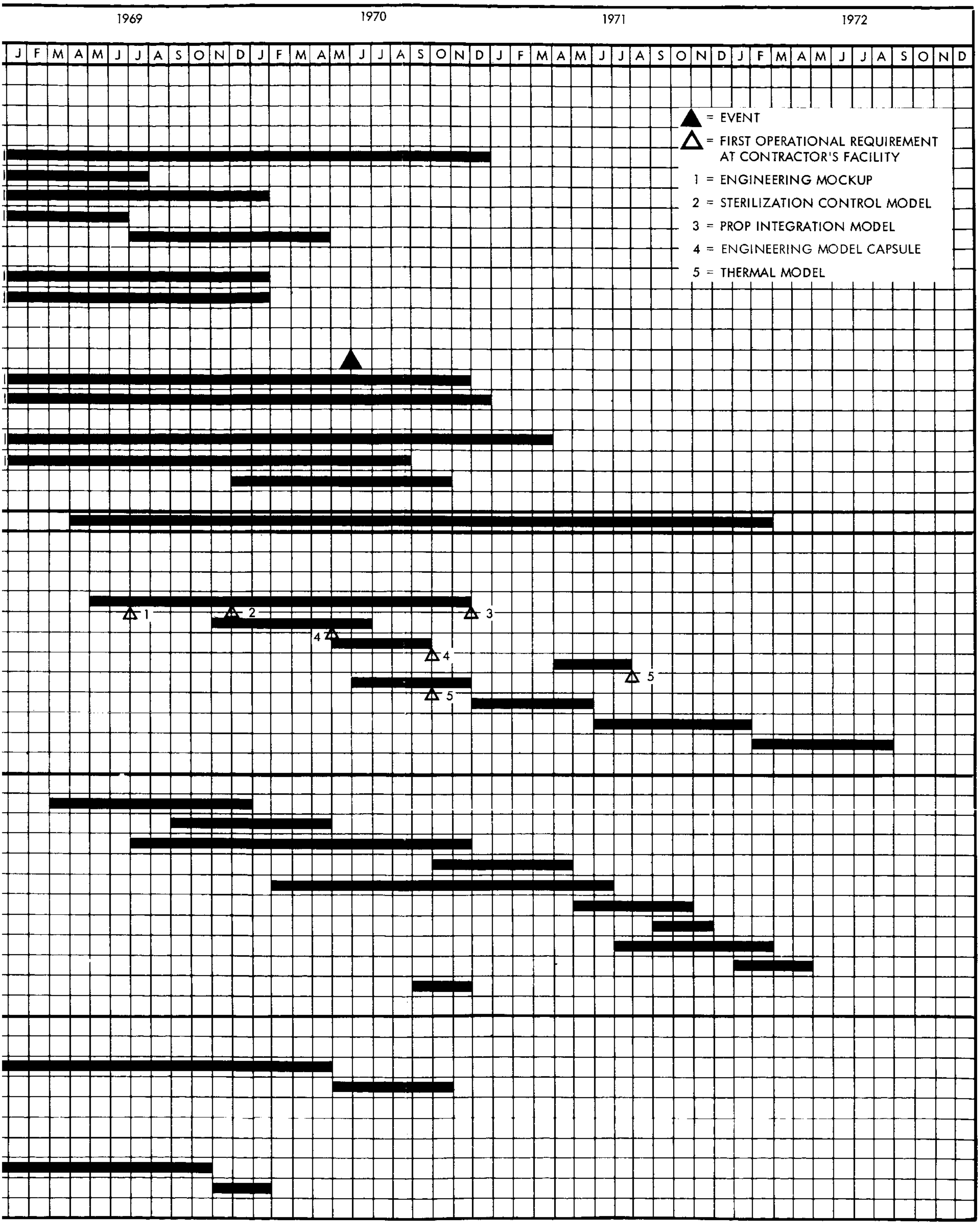

Figure 65. OSE/MDE and Major Facilities Schedule

17. RTG IMPLEMENTATION

This section discusses RTG implementation, which is part of the capsule system implementation discussed in Section 16. The AEC RTG contractor functions as an associate contractor with the capsule contractor as described in Section 16.1.

17.1 RESPONSIBILITIES

After the RTG objectives are defined jointly by the AEC and NASA, the AEC will assume RTG development responsibility and NASA will assume RTG-vehicle integration responsibility. The RTG will be a government-furnished item to be integrated into the capsule by the capsule contractor under the technical direction of the capsule SMO. Close liaison between the two contractors and the NASA and AEC project offices concerned will be essential, since RTG and vehicle interactions give rise to a complex engineering job.

The RTG contractor will design, develop, test, qualify, and deliver the complete RTG including flight units, spares, prototypes, engineering models, and ground equipment for handling, shipping, monitoring, maintenance, and checkout during all factory-to-flight operations. If subcontractors are used for the thermoelectric converter or heat source, the RTG contractor will direct their programs, integrate the total RTG system, and conduct final qualification tests on prototype RTG units.

Although vehicle integration of the RTG will be carried out by the capsule contractor, the RTG contractor will provide extensive support. A particularly critical interface arises in rejecting RTG heat through the capsule canister and launch vehicle shroud. Other important interfaces involve countermeasures for the effects of RTG radiations and magnetic fields, and system checkout and handling procedures after nuclear heat source installation. The formation of an RTG-Voyager capsule interface working group with AEC, NASA, and contractor participants for resolving such interfaces is advisable.

The stockpiling, processing, shipment, and encapsulation of Pu 238 fuel in the form and quantities required will be an AEC responsibility. Fuel capsule design, development, qualification, and component fabrication will be an RTG contractor task. Components other than fuel will be shipped by the RTG contractor to an appropriate AEC facility, such as Mound Laboratory, for fuel capsule loading and closure and heat source assembly. Shipping containers which dissipate the heat source power and reduce its radiation will also be provided by the RTG contractor.

Safety documentation necessary to obtain approvals for operations involving nuclear heat sources will be generated by the RTG contractor, with Voyager vehicle, trajectory, environmental, and mission inputs furnished as required. These documents will include safety analyses for normal and all conceivable abort circumstances, presented in accordance with AEC-established format. They will also include substantiating experimental evidence and test results from the heat source development program. Preliminary, interim, and final safety reports will be processed through AEC, NASA, and DOD (range operation) channels. The earlier reports will form the basis for approving nuclear ground test operations in RTG contractor and Voyager capsule contractor facilities.

17.2 RTG DESCRIPTION

The RTG consists of a radioisotope heat source, thermoelectric converter, and radiator completely packaged and insulated as required for vehicle installation. A power control unit (PCU) has been defined as an RTG component and its development included in the RTG program. Power processing and distribution functions will be assigned to the capsule contractor electrical power subsystem and rejection of RTG heat to the Voyager capsule contractor thermal control subsystem.

The reference RTG design approach is responsive to the aerospace safety criterion that the radioisotope fuel be completely contained in the event of transportation or launch accidents and ascent or orbital aborts. The requirement for containment during earth atmospheric re-entry has a large effect on RTG design. A completely passive re-entry protection system is desired, without dependence on commands, separation, initial attitude, tumbling modes, spin rates, or pyrotechnic sequences.

Inherent re-entry survival capability in the heat source itself is most desirable. High re-entry temperatures virtually preclude this approach with superalloy fuel capsule systems, on which RTG development programs to date have been based. The use of isotope capsules with refractory metal alloy substrates for structural strength and noble metal alloy claddings for oxidation and corrosion resistance is recommended, with the fuel capsule sheathed in a suitable composite of graphitic materials for re-entry protection.

The high-temperature capability sought for re-entry purposes also permits long-duration operating temperatures to be increased over those allowable with superalloy systems. As a result, Si-Ge thermoelectric converters can be used in conjunction with these heat sources. In relation to PbTe converters, this reduces radiator area, reduces RTG magnetic fields, eliminates thermoelement compressive springs, eliminates hermetically sealed pressurized converter canisters, and decreases converter output degradation rates.

The estimated capsule electrical power requirement is supplied by two 150-watt, 18 vdc RTG units operating in parallel and in conjunction with a storage battery to meet peak demands. Since four flight capsules are prepared for each launch opportunity, two for flight and two for back-up, eight flight-configured RTG units are required. In addition, two fueled prototype RTG units are required for qualification testing. The total quantity (37.5 kwt) of Pu 238 fuel which must be committed for the 1973 launch is five-sixths of the minimum projected inventory at that time, although 60 percent of that quantity will not be launched and is recoverable.

The heat source consists of six isotope capsules, each containing approximately 600 thermal watts of Pu 238, supported in a planar array which is radiatively coupled to the converter. Superinsulation is used to minimize heat leaks in other directions. The multi-walled isotope capsule includes a fuel liner, structural member or pressure vessel, cladding, and material to provide re-entry protection.

The refractory alloy capsule liner provides a chemically protective barrier between the capsule structural member and the fuel. The liner material must therefore be compatible with the fuel form and its decay products and with the capsule structural material. The structural member, also a refractory metal alloy, is used to resist creep at high temperature due to the pressure of helium generated as the isotope decays. It must also survive impact (aided by heat source cushioning) at terminal velocities to insure that the isotope fuel will be completely contained.

The cladding, a noble metal alloy, provides long-term corrosion and oxidation protection to the refractory capsule pressure vessel in the event of a mission abort. Helium is used in the small gap between capsule and cladding to minimize the temperature difference between them. Each fuel capsule is enclosed in a graphitic material to provide re-entry protection. The thickness of the graphitic material is selected to insure that capsule temperatures remain well below component melting points during re-entry.

The thermoelectric converter is a flat rectangular structure containing uniformly spaced Si-Ge thermoelectric elements with a fibrous insulation material between the couples. The thermoelectric elements are connected in two strings with parallel connections between the elements of each string such that an open circuit in one couple results in a small power loss rather than a major failure. The thermoelectric elements are cantilevered from a radiator plate which is mounted to the top surface of the lander cruciform.

Approximately one thermal kilowatt must be dissipated for every 40 watts of electrical power output. A capsule with two 150-electrical-watt RTG's installed must dispose of 7.5 thermal kilowatts. In the launch configuration, the RTG's are inside a sealed capsule canister emplaced within an outer shroud. A series of thermal linkages, preferably passive for reliability and safety, is thus required. A combination of radiative coupling and heat pipe linkages for this purpose is indicated.

The integrated thermal control subsystem will function both to dump excess heat and to divert it as necessary in maintaining system temperatures. The RTG is used in this way as a source of thermal energy to compensate for variations in solar flux throughout the mission, including in-flight variations from changing vehicle attitude and solar distance and seasonal and diurnal variations on the Martian surface.

To minimize radiation exposure of peronnel during capsule assembly and checkout, it is desirable that the RTG be constructed so that the flight unit, without nuclear heat source, can be installed in the capsule and operated with an electric, simulated heat source. Heat pipes, where used, and other thermal control components as well as the thermoelectric converter and electrical power components can then be operated in a radiation-free environment. When the capsule system is functioning properly in this configuration, the electrical heater is replaced by the flight nuclear heat source. System checkout sequences are then repeated before the canister is sealed, and again after it is sterilized, to verify flight-readiness. RTG accessibility and heat rejection are primary considerations in both RTG and capsule design.

17.3 IMPLEMENTATION FLOW

In this section, the term "generator" is used for an RTG which does not include the heat source but which is otherwise complete. It consists of the converter, radiator, PCU, insulation, structure, mounting plate, and ancillary hardware. Designators are used to distinguish between generators to be equipped with nuclear heat sources (N) from those to be equipped only with simulated heat sources (S). Thus, engineering models are designated, EMS; prototype units, PN; flight units, FN; and flight spares without heat sources, FS.

The RTG development program should be preceded by heat source and converter advanced technology programs. One such program, aimed at developing a high-temperature (2000^{o}F) radioisotope capsule, has been initiated by the AEC in mid-1967 and will yield timely data on the creep, oxidation resistance, and on the fabricability of refractory metal capsules with noble metal claddings. Techniques to protect radioisotope capsules from re-entry and impact environments should also receive the earliest possible emphasis as part of nuclear safety.

Before initiating an RTG development program specifically for Voyager, other RTG applications should be reviewed for common requirements. Consideration can then be given to defining the Voyager capsule to permit these requirements to be met by developing a single RTG module, without compromising mission objectives. This would eliminate conflicts for the limited supply of radioisotope fuel. For example, it may be desirable to revise duty cycles, data rates, direct transmission links, redundancy provisions, and other Voyager capsule features when RTG size and fuel quantities associated with them are fully evaluated in terms of integration complexity and the requirements of other programs.

After extensive testing of heat source materials and components and of RTG engineering models operated with simulated heat sources, two prototype RTG's complete with nuclear heat sources are programmed as shown in the RTG implementation flow chart (see Figure 66). The first prototype RTG (PN-1) to be fabricated is used for qualification tests conducted by the RTG contractor. It is then shipped to the capsule contractor's facility. A second prototype RTG (PN-2) is also shipped to the capsule contractor, but in this case only the generator is processed through the RTG contractor's facility while the assembled heat source is shipped directly from Mound Laboratory. PN-1 and PN-2 are then installed in the capsule proof test model for qualification testing of the entire capsule system in its nearly exact flight configuration. Thereafter, the prototypes are available for KSC facility checkout.

Four flight-ready Voyager capsules are programmed for each launch opportunity, and flight RTG's with nuclear heat sources (FN) are provided for each of these. FN-1A and FN-1B are installed in the first capsule, which is processed through the KSC capsule assembly facility through canister sealing and sterilization and then held in a flight-ready condition as a standby capsule. FN-2A and FN-2B are installed in the second capsule, which is completely processed (including sealing and sterilization), mated with the spacecraft bus,

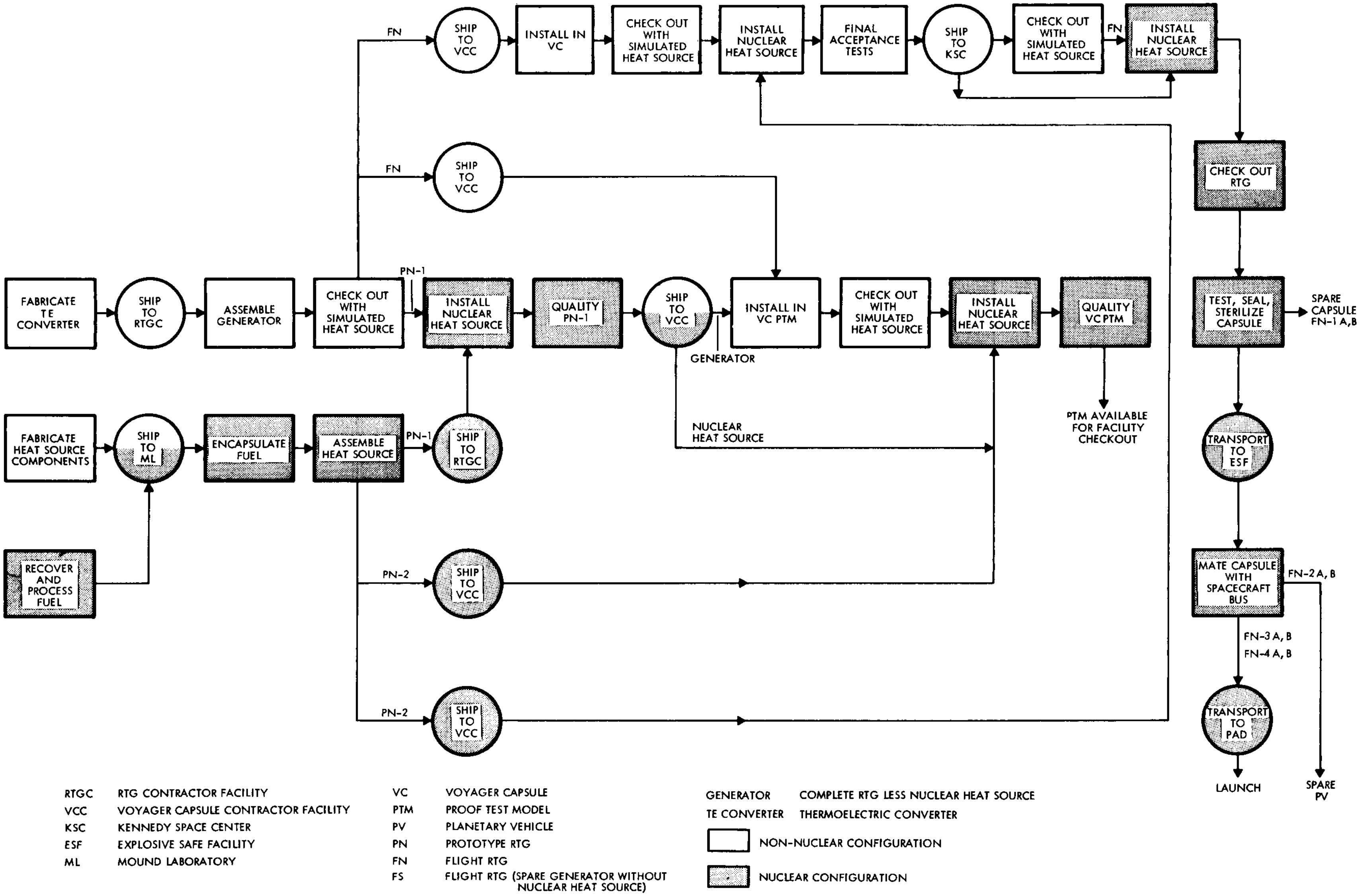

Figure 66. RTG Development Flow

and held as the standby planetary vehicle. FN-3A, -3B and FN-4A, -4B are installed in the third and fourth capsules which are processed through the capsule assembly facility and planetary vehicle operations for space vehicle integration.

The standby planetary vehicle is available for immediate substitution if a "no-go" condition arises in either of the flight planetary vehicles. The malfunction is then corrected and the initial vehicle recycled as necessary to restore it to flight-ready condition. If the trouble is within the capsule, the flight-ready standby capsule is integrated with the spacecraft to create a flight-ready planetary vehicle-shroud assembly spare. The failed capsule is recycled if time is available.

All generators are checked before and after vehicle installation using electrical heat source simulators. Flight generators are fabricated in advance of their nuclear heat sources, acceptance-tested by the RTG contractor, and shipped to the capsule contractor facility. There, they are installed in the capsule and heated electrically during capsule checkout and the majority of acceptance tests. They remain in the capsule when shipped to the launch site and during all subsequent movements and testing. Nuclear heat sources are assembled at Mound Laboratories and shipped to the capsule contractor's facility for installation prior to the final capsule integrated system test. They are then removed and shipped separately to KSC. At KSC they are installed in the generators at the latest possible time, which is just prior to canister sealing and sterilization.

Earlier operations with the non-nuclear RTG engineering models are shown in the schedules but not in the flow charts. Three EMS units are fabricated and subjected to performance and environmental tests by the RTG contractor. Two of these units are retained for life testing while the third is shipped to the capsule contractor for use, if required, with various test configurations including the capsule thermal model, engineering model, and propulsion integration model.

17.4 WORK BREAKDOWN

Major RTG tasks are identified as follows:

- Heat Source: development of a high-temperature heat source capable of operating at 2000°F for at least two years following a shelf life of one year, withstanding higher temperatures for short periods of time in abort situations such as launch pad fires and re-entry, and surviving all other environments which may be encountered without release of fuel.
- Converter/Radiator: development of a Si-Ge thermoelectric converter with integral radiator to operate for at least two years at hot-junction temperatures in the neighborhood of 1700°F.
- Power Control Unit: development of a power control unit to boost and regulate RTG voltage, provide ac power, and protect the RTG from load fluctuations.
- Operational Support Equipment: development of ground equipment for transporting, storing, handling, installing, and checking the RTG and for RTG-related launch operations.
- Aerospace Nuclear Safety: conduct analyses and tests to establish safety of all nuclear operations on the ground and of normal and aborted launches, and preparation of safety documentation required for approval.
- System Design and Integration: overall design, planning, and programming in developing and qualifying the RTG and in integrating it into the vehicle system.
- Fuel Processing and Encapsulation: stockpiling, processing, and preparation of Pu 238 in suitable form and encapsulating it in heat source capsules.

17.5 SCHEDULES

The RTG development program is assumed to be initiated before the end of the first quarter of CY 1968 and is further assumed to draw upon the high-temperature radioisotope capsule technology program initiated in mid-1967, augmented by additional re-entry and impact studies. Preliminary design is to be completed in the fourth quarter of CY 1968 and sufficient heat source and converter test data are to be available to start fabricating RTG engineering models by April 1969.

Three engineering models have been programmed as shown in Figure 67 to permit design changes in the third unit based on performance and environmental test results obtained with the first, and CDR is also scheduled to make use of these results. The first two units are life tested, while the third is used with Voyager capsule models. Performance and environmental tests on all three units will have been completed before prototype fabrication begins in October 1970.

Qualification of one prototype RTG is completed in December 1971 and qualification of the Voyager capsule proof test model with that prototype and a second one installed in it is completed by mid-1972.

Flight generator hardware is delivered in time for installation and integrated checkout at the Voyager capsule contractor's facility, while flight heat sources are delivered to the capsule contractor's facility later for final acceptance testing. Heat sources for FN-1A and FN-1B are available by October 1972, and the others follow before March 1972.

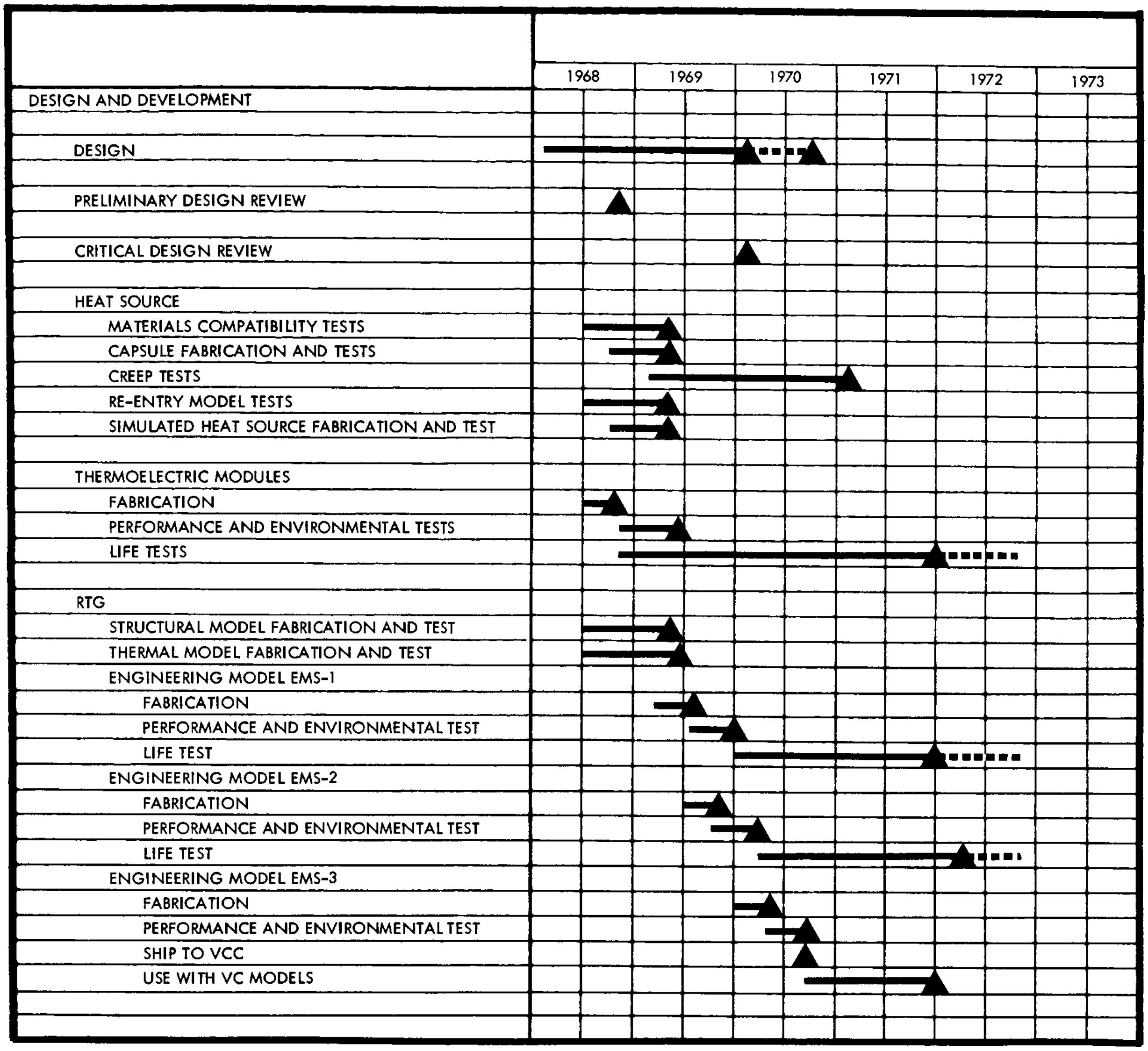

Figure 67. RTG Implementation Schedule (Design and Development)(1 of 4)

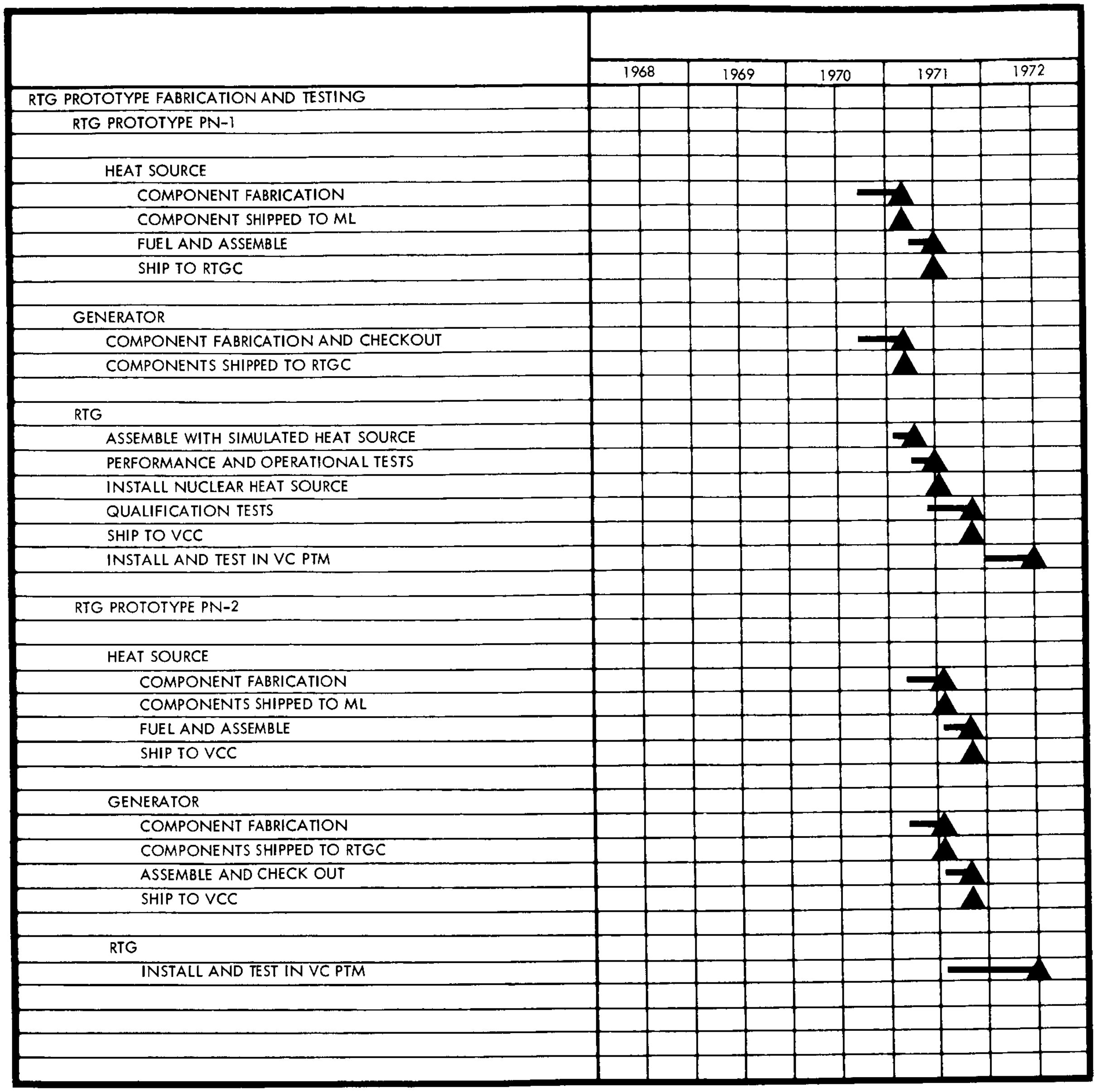

Figure 67. RTG Implementation Schedule (Prototype Fabrication and Testing (2 of 4) (Continued)

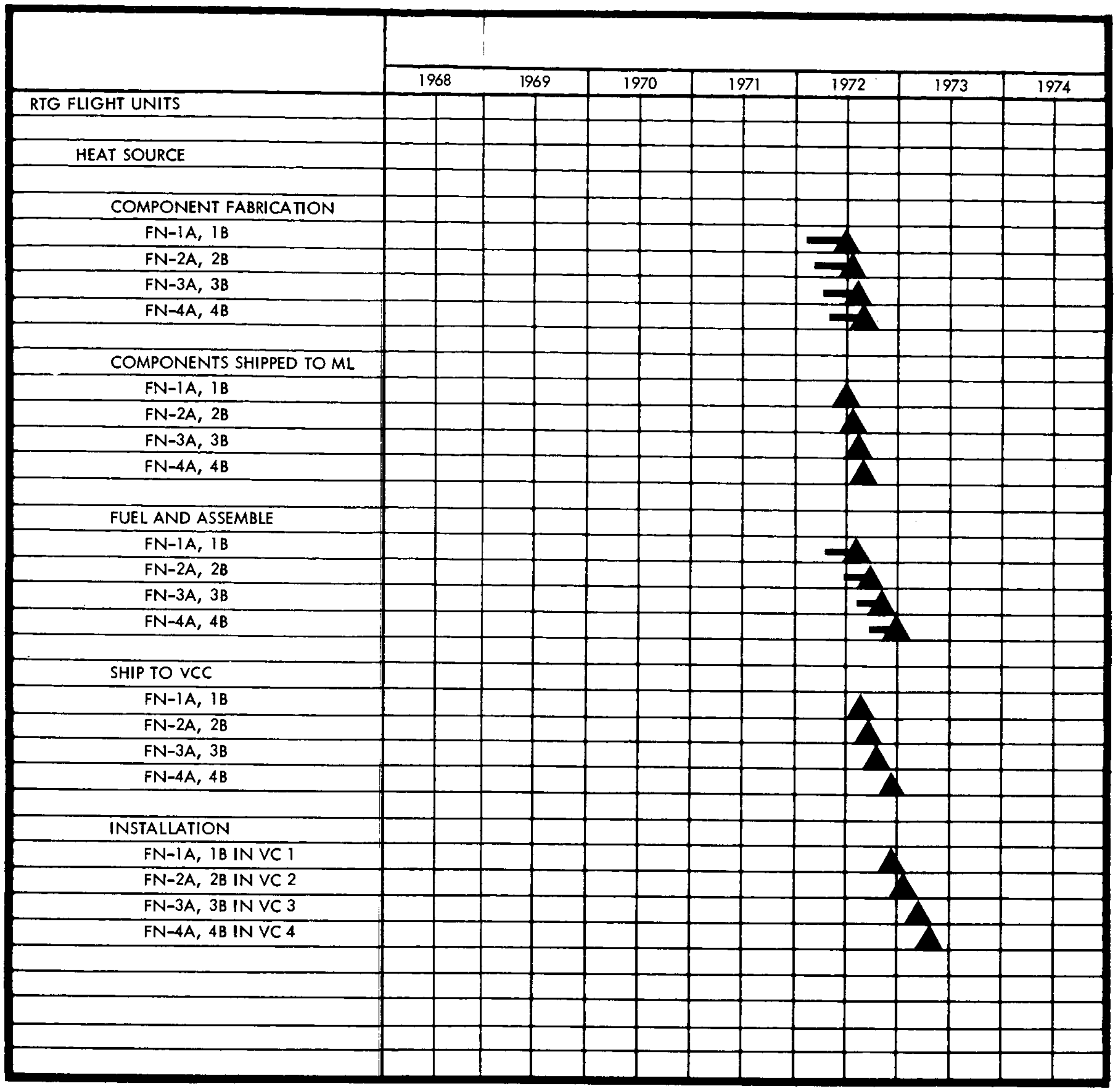

Figure 67. RTG Implementation Schedule (Flight Units)
(3 of 3) (Continued)

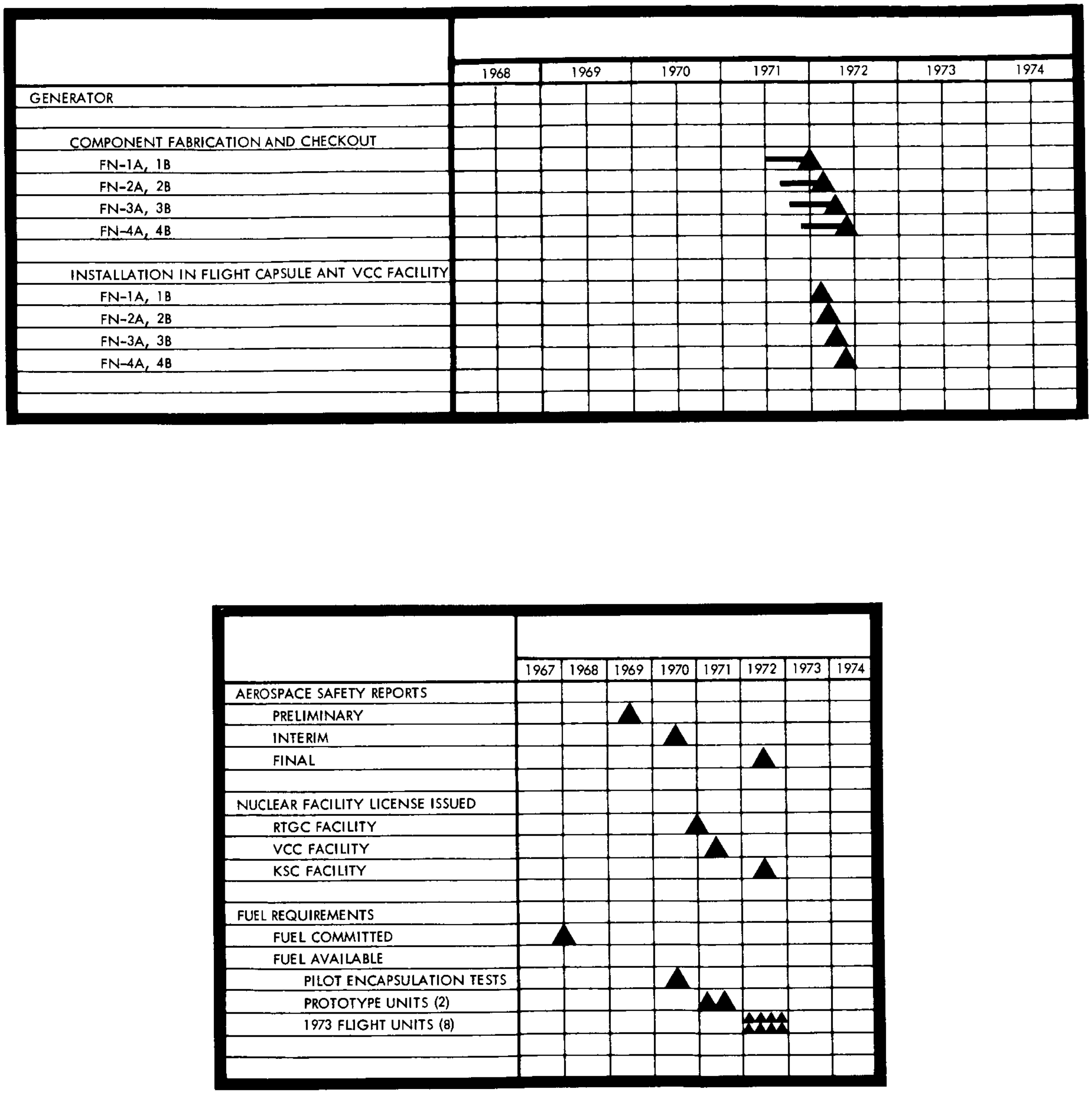

Figure 67. RTG Implementation Schedule (Generator and Aerospace Safety Reports) 4 of 4) (Continued)

18. SURFACE LABORATORY IMPLEMENTATION

18.1 GENERAL FEATURES

The relative difficulty of developing the type of experiments desired for automated operation on Mars and the need for exploratory results to establish the characteristics of the ultimate system lead to the three-generation approach to the surface laboratory, as discussed in Section 3.1. The increasing level of complexity in these three-generations is suggested by Table 11 beginning with the "simplified precursor laboratory," moving to the "comprehensive precursor laboratory," and finally the "automated biological laboratory."

The surface laboratory contractor has two principal functions, that of integrating experiment packages into a total laboratory and providing the structure, mechanisms, and electronic equipment which are required to support the experiments. He must accomplish these functions for successively more complex laboratories, and implementation must be such that the overlapping of the requirements to begin development of the comprehensive precursor laboratory does not interfere with operations for the simplified precursor laboratory. The overall schedule is given in Figure 6 and for the first launch in Figure 8.

18.2 DEVELOPMENT

18.2.1 Science Definition

The science definition program will be managed by the NASA Voyager project office, with direct management of the principal investigators by the capsule system management office.

During preliminary design the system approach for the science program is developed in detail. Operating procedures are established in detail to ensure maintaining the scientific integrity of the experiment program, to direct participation and control by the principal investigators, to define acceptable interface arrangements for all participants, and to provide for adequate decision-making machinery during system development and Mars surface operations. These operating procedures and the definition of the nominal surface laboratory define the instrument complement, sampling, and processing capability,

Table 11. Weight Analysis of Surface Laboratories

Instruments	Simplified	Comprehensive	Advanced
TV survey camera (2)	50	50	50
Sun sensors	1	1	1
Infrared radiometer	3	3	3
Infrared spectrometer	10	10	10
UV and visible spectrometer	20	20	35
Bolometer	5	5	5
Photometer	5	5	5
Ion chamber	3	3	3
Geiger tube assembly	2	2	2
Atmosphere parameter sensor	1	1	1
Microphonic detector	1	1	1
Seismometer		30	30
Gas chromatograph	10	12	40
Mass spectrometer	8	8	8
Soil probe (2)		5	5
Core hole sonde		3	3
TV microscope			25
pH meter			2
	125	165	235
Sample Acquisition and Preparation			
Dust collector		1	1
Core drill		15	15
Pulverizer and grader		10	10
Collector and weight scale		4	4
Proximity sampler	25	25	25
	25	55	55

Table 11. Weight Analysis of Surface Laboratories (Continued)

	Simplified	Comprehensive	Advanced
Processing and Culturing			
Pyrolyzer		2	2
Vacuum pump		6	6
Internal transport		12	12
Chemical processing and culture chamber	100	120	70
Dialysis chambers (3)			3
Waste storage			5
Refrigerator heat exchanger			2
Reagent supply storage			70
Processor attachments			120
Chemical supply			190
	100	140	480
Data Automation Equipment	50	200	200
	300	560	970

data processing and analysis capability, and generic description of science and experiment types contemplated. Potential principal investigators would respond to RFP's for the proposed experiments planned to utilize the specified laboratory capability.

An initial selection of principal investigators would be made to participate in the final science definition. During this period the group of selected experiments would be further defined to maximize the combined information content and to optimize the surface laboratory configuration. It is possible that specific experimental procedures and techniques would be modified where the experiment integrity would not be compromised, that experiment intent would be expanded to cover open areas or provide redundant related information, and that other such changes would be made in arriving at the final science program.

Concurrently, the principal investigators would develop the specific experimental techniques so that the step-by-step experimental procedures are available. This information establishes the requirements for the corresponding parts of the laboratory and defines the operating requirements for the related subsystems.

The principal investigators continue on the program, coordinating continuously with the surface laboratory contractor as the hardware is developed and tested. They participate in development of operating procedures for Mars operations. During the operating life on Mars, they analyze the appropriate scientific data and participate in control of experiment operation.

18.2.2 Science Equipment Responsibilities

Under the foregoing guidelines, the principal investigators will have responsibility for the development of the experimental methods for the particular experiments and the design, development, and fabrication of instrumentation required to perform the experiments as appropriate. The surface laboratory contractor will have the responsibility for all mechanisms required for sample acquisition and deployment as well as those mechanisms to support experiment packages.

The implementation of the experiments involves both intersystem and subsystem consideration. The relation between the laboratory contractor and the principal investigators is analogous to an intersystem interface in that the principal investigators have independent contracts with NASA. At the same time, the experiment equipment as well as other science elements have a complex and intimate relationship to the other hardware akin to that of a laboratory hardware subsystem, a fact which requires a comprehensive role on the part of the laboratory contractor for integration of such equipment. As a corollary, such major support elements as the equipment for sample acquisition and preparation and the data automation equipment should be developed by the laboratory contractor.

18.2.3 Long Lead Time Instruments

Development of the surface laboratories will be initiated on the basis of the nominal system defined in the preliminary design phase. In addition, continuous tradeoff and evaluation studies will be conducted in support of the science definition program which is proceeding concurrently. Specific effects on the various subsystems will be fed into the development programs as they occur.

Certain of the instruments and sensors considered (see Table 11) present the most critical development and lead time problems. Although the concepts for the instrumentation are based on well-established principles used routinely in normal laboratory operation, development for the automated flight configuration with usable sizes, weights, power requirements, performance, and reliability presents challenging problems. In particular, three major instruments are in this category. The UV and visible spectrometer, the gas chromatograph, and the mass spectrometer.

The spectral analyzer is a special instrument that combines the functions of a fluorimeter, UV spectrometer, and polarimeter. Significant volume and weight advantages can be realized by multiple use of the structural, optical, and control systems that are common to the three instruments. In addition, the simplification of the sample handling system offers further advantages of reliability. The primary sensor is a photomultiplier; currently available types are suitable for relatively high g-level shocks, and are compatible with sterilization requirements. Primary development problems are associated with the lens-mounting system to maintain the required close optical alignment during and after shock and vibration, and during temperature changes that would be experienced in operation. In addition, the complex lens assemblies which conventionally use special cements appear to be incompatible with heat sterilization. Special methods of compounding lenses must be developed.

The combined gas chromatograph and mass spectrometer has not previously been combined into a single unit in space flight configurations. The advantages realized by combing the instruments to permit continuous operation without intervening handling of the gas sample are major, and justify extensive development effort. The basic controls of the gas chromatograph are relatively conventional; primary problems are expected in miniaturization of the columns and development of packing techniques to obtain uniform and predictable performance. Compatibility with sterilization of the packing materials may present problems.

The mass spectrometer problems are associated with miniaturization of the instrument while maintaining the range and suitable operation at power levels available on the surface laboratory. Units are currently available in the weight ranges required but without the sensitivity required. Other units with reasonable sensitivity do not cover the necessary range. The development problems here in the time required may involve real risk.

Since the instruments are the longest lead-time components, it is important that their development start as soon as feasible. It is planned that the initial development would be of a breadboard nature, during which the fundamental techniques would be established and sterilization compatibility determined. During this time, functional changes affecting range, resolution, sensitivity, etc., can be accepted with minor impact, as long as basic operating principles are not modified. The prototype designs would be based on specific performance requirements, and would be fabricated of components that are (short term) qualified for sterilization, shock, and other environments.

18.2.4 Sterilization

In broad terms, the sterilization program will be required to provide:

- Documentary support for the certification of sterility of the flight hardware through audits of the critical steps and through reports of the critical tests performed in the program to build sterility into the laboratory

- Technical support of the design effort through early identification of technical need and solutions arising out of the sterilization requirement

- Technical support of the manufacturing departments through suitable training of personnel operating on or testing the hardware, and through provision of appropriate facilities and techniques for both the manufacture of the laboratory and the certification of its final sterility

18.2.4.1 Hardware Definition and Selection

Sterilization testing is applied at the levels of assembly at which there are reasonable questions of sterilization compatibility, including where necessary original selection of materials. The functions of the various subsystems will be divided into simple and complex parts so that lists of alternative materials and designs can be developed for sterilization compatibility screening as needs arise. Design revision will occur as the proof test data are developed.

Before the design begins to become firm the sterilization program will provide guidelines information defining the acceptable materials, the appropriate packaging, and the appropriate portions of the post-sterilization functional proof testing. When appropriate, the sterilization program will provide audit of vendor facilities and capabilities as they pertain to the attainment of sterility.

18.2.4.2 Hardware Development and Qualification

The laboratories will contain many commonly used parts, components, and materials, but will also use materials and parts not a part of other programs; growth media and reagents used in chemical processing may not otherwise be considered for sterilization compatibility. It is assumed that standard parts and components will generally be sterilization qualified in supporting technology programs. For those identified parts where this is not true, qualification must be planned as part of the surface laboratory program.

Sterilization qualification of essential materials and parts must be started very early. Breadboard subsystems and prototype subsystems would incorporate components and materials that have been short-term sterilization qualified. By the time of assembly of the engineering prototype, all components and materials should be qualified.

Toward the final stages of development of each subsystem, thermal soak evaluation and any necessary design revision will be performed. The analytical aspects of thermal soak will be performed concurrently with design. The laboratory proof tests will be applied only to reasonably complex assemblies in which the mathematical models used in the analysis might be expected to deviate significantly from the actual results. The effectiveness of the overall sterilization program depends critically on the thoroughness of the thermal soak model analysis and complete laboratory confirmation.

18.2.4.3 Procedures Development

From the standpoint of the sterilization program, procedures development is intended to fulfill three broad objectives. The first objective is the definition of the steps to be performed in preparing, fabricating, assembling, and packaging of assemblies and parts to integrate the details of manufacturing operations, cost control, reliability attainment, and built-in sterility. These procedures will be prepared before the engineering prototype assembly phase, and as the prototype program progresses will go through several iterations to attain smooth integration. Definition of manufacturing and quality control record requirements is the second objective. The third objective will be the definition of procedures for:

- Selection, training, and auditing the performance of personnel in a position to affect sterility
- Verification of materials, parts, and facilities suitability
- Detecting deviations from procedures, instituting corrective action, and follow-up
- Monitoring and verification of contamination control

18.2.5 Development Program

Phase C will include detailed system design of the selected system concept, including completion of the system specification and Part I of contract end item specifications. It includes the fabrication and test of breadboard hardware of selected critical subsystems, as necessary to provide reasonable assurance that the technical milestone schedules and resource estimates for the next phase can be met. These Phase C activities will consist of the following:

1) Detailed system design
   - Analysis
   - Definition of system functions and performance
   - Environmental requirements
   - Design requirements
   - Subsystem design and evaluation
2) Interface definitions within the laboratory and between the laboratory, the capsule, and the mobile unit
3) Breadboard fabrication and testing of critical items
4) Preparation of specification tree and Part I CEI specifications
5) Identification of critical components
6) Revising management and technical plans
7) Preliminary design review and approval of system specification and Part I CEI specifications

These efforts lead to a major system design effort during the first three or four months of the program, followed by subsystem and component preliminary design.

Phase D includes detailed hardware design and development, fabrication, integration, assembly, qualification, checkout, test, and delivery of systems, including science instruments and operational support equipment. Additional technical services will be provided to carry out capsule-laboratory integration and as required to support space vehicle launch operations and mission operations.

The sequence of major activities during Phase D is defined by the following milestones, in keeping with the general discussion in Section 5.

- Intermediate Design Review. Prepare updated subsystem specifications and complete Part I CEI specifications for both flight equipment and OSE. Release drawings to manufacturing for engineering models.
- Critical Design Review. Prepare updated subsystem and Part I CEI specifications, and preliminary Part II CEI specifications for flight equipment and OSE. Complete basic type approval testing. Release drawings for type approval, PTM, and reliability demonstration hardware. Release OSE drawings for all units.
- Completion of subsystem type approval tests. Release updated drawings for flight units.
- First Article Configuration Inspection. Approve final Part II CEI specifications. Ship first flight laboratory to capsule contractor.

The scheduling of major activities is generated by first defining the time before delivery when it is necessary to initiate assembly and checkout of the first flight laboratory. The time required is based on capsule need later derived from a detailed, elapsed-time analysis of the tasks involved in capsule integration, launch site operations, shipping, flight acceptance testing, and assembly and checkout operations. The next step defines the delivery date for laboratory hardware in terms of need date during the assembly and checkout sequence. In turn, by accounting for the corresponding system flight acceptance testing and manufacturing span, the start date for the manufacturing of each flight subsystem is defined. Thus the need dates for flight hardware drawing release are established.

The start of proof test model assembly and checkout operations has been determined by scheduling completion of the major portion of the PTM type approval testing one month prior to completion of assembly and checkout of the first flight laboratory. This constraint then establishes the delivery dates for the PTM subsystem assemblies, and in turn the drawing release dates for the fabrication of the subsystem type approval and PTM assemblies. This process establishes the required CDR dates for each subsystem. The CDR dates for each subsystem then form the basis for establishing Phase D implementation plans and schedules.

18.3 ASSEMBLY AND CHECKOUT

18.3.1 Subsystem Assembly

After each assembly has completed environmental and flight acceptance tests, it will be delivered to the subsystem assembly area, where a system test complex has been assembled. Each electrical subsystem will be mechanically assembled; the harness is then mechanically installed, electrically tested, and the connectors mated. Each subsystem will then be tested, as a subsystem, using the system test complex equipment. The following subsystem tests will be included:

- Perform all functions with ±15 percent variations in external supply voltages over the flight acceptance temperature range.
- Perform all functions with nominal voltage and temperature 15 percent in excess of flight acceptance limits.
- Exhibit noncatastrophic performance in the presence of noise injection, power frequency variation, power overshoot, and power transients, all at 15 percent in excess of those specified in the appropriate detailed specification, and demonstrate that components have not been degraded by the test.

These tests performed in the system test configuration will allow the necessary subsystem trend data to be compiled into a subsystem history log.

18.3.2 Experiment Integration

To support science equipment assembly and checkout an electrical simulator for the laboratory is needed for testing electrical compatibility of the laboratory and the science subassemblies. This simulator will be designed and developed as spacecraft OSE. It will be located at the surface laboratory assembly facility to permit convenient tests of science packages, particularly for purposes of troubleshooting.

Particular science integration activities in support of assembly and test of the surface laboratory are listed below.

- Prepare test procedures and criteria in coordination with experimenters for testing science equipment
- In coordination with experimenters, prepare all written information and procedures required for installation and integration of the science equipment
- Establish the requirements for the laboratory simulator
- Assemble and check out the laboratory simulator
- Arrange for design and construction of an experiment simulator to support tests in the absence of science equipment
- Conduct, or participate in, tests for science equipment, including type approval, acceptance, bench testing, assembly checkout

A science integration laboratory capability will be provided at the surface laboratory contractor's facility and at the launch site. This capability will support science interface development as well as provide on-site laboratory services to the principal investigators.

Such laboratory support will be provided as follows:

- Receive, handle, store, and ship science equipment
- Developmental testing of science equipment with laboratory support equipment such as data automation equipment, cabling, etc.
- Developmental testing of science equipment with related OSE
- Acceptance test science equipment
- Integrated testing of science equipment with laboratory simulator prior to integration
- Diagnostic testing in case of malfunction or other difficulty
- Repair and calibration of science test equipment

18.3.3 Test Sequence

Following assembly and checkout, the integrated laboratories undergo a sequence of system testing. The general sequence starts with an integrated system test to be performed following the assembly and checkout to verify functional integrity. All subsystems and science instruments will be tested, as well as the laboratory-capsule functions. This test is performed with a capsule bus and mobile unit simulator.

Following the first integrated system test, the PTM will undergo an ethylene oxide exposure, followed by a system test to determine whether or not the system has been degraded. Following the system test, a series of special tests will be conducted. The first of these will be the power profile test to determine the power drain of the laboratory in its various operating modes. The next test, performed on the EM and PTM, is the failure mode and logic test, a detailed check of the on-board logic. A system parameter variation test is then performed followed by an electro-magnetic interference test.

Upon completion of these tests, the laboratory will be prepared for the vibration-acoustic test, in flight configuration insofar as possible, using a dummy capsule. A combined vibration-acoustic test will be performed with a hydraulic shaker performing the low frequency vibration and a reverbent acoustic chamber generating the high frequency environment.

The laboratory is then prepared for space simulation with complete thermal insulation. Auxiliary heaters and special thermal vacuum test instrumentation will be installed. After installation in the chamber, an integrated system test will validate all OSE and chamber cabling and establish a laboratory baseline. A system test will be performed before removal of the equipment from the chamber to determine any effect of the exposure on system performance.

The sequence through the electromagnetic interference tests, magnetic properties tests, and previbration system tests for the EM is identical to the PTM and flight laboratory sequence. The EM will not be exposed to environmental testing but it will be taken to each environmental test area for facility validation prior to testing of the PTM. The PTM will be used for extensive mission simulation tests. This will consist of operation of the surface laboratory model in a chamber approximately duplicating the 10 mb, CO_2 atmosphere (with the atmosphere model revised as more recent data is available) and the thermal cycling anticipated at the projected landing site.

19. MOBILE UNIT IMPLEMENTATION

Implementation of a Voyager mobile unit is discussed in this section in keeping with ground rules of the current study. Within the resources of the study it has not been possible to carry out a preliminary design and develop a related implementation definition for such a unit. However, a cooperative data exchange between TRW and the AC Defense Laboratories of the General Motors Corporation was arranged to make available data from the extensive work of General Motors in this area. This information has served as the basis for the material presented below.

The mobile unit, as a major element of the capsule system, is implemented by the mobile unit contractor under the direction and management of the capsule system management office. This contractor functions as an associate contractor with the capsule contractor and the surface laboratory contractor as described in Section 16.1.

19.1 MOBILE UNIT

The mobile unit will be configured as a test unit for the first generation missions, and as an advanced mobile unit for later flights. The primary function of the test mobile unit is to check out the feasibility of the concept and techniques. It will also have the capability to retrieve soil samples at distances up to about 200 feet from the lander. The advanced mobile unit will have the capability to make repeated traverses of several hundred feet radius from the lander to retrieve soil samples, take closeup pictures, and make scientific measurements in situ.

The test unit is configured so that it has inherent growth potential for the advanced mission. Both versions use the same basic mobility design, lander adapter and deployment, sample acquisition and transport equipment, and command system.

The advanced mobile unit, shown in Figure 69, is a six-wheel, flexible frame, articulated device, with electric drive at all wheels. It has a gross weight of 200 pounds and an overall length of 8 feet. In addition to sample acquisition equipment, it carries a scientific payload weighing about 35 to 40 pounds, including stereo imaging. A weight summary is given in Table 12, and size and performance data are presented in Table 13.

Table 12. Advanced Mobile Unit: Weight Summary

Basic mobility subsystem	80
Power subsystem	12
Imaging subsystem	14
Sample acquisition and transport	15
Telecommunication	20
Thermal control	5
Sensors (navigation and control)	4
Science and data automation	30
Lander adapter and deployment	20
Total gross weight	200 lb

Table 13. Advanced Mobile Unit: Dimensions and Performance

Dimensions (in.)	
Overall length	96
Overall width	40
Wheel diameter	24
Wheel base (overall)	72
Performance	
Obstacles	
Step height (in.)	34
Crevice width (in.)	28
Stability (static) on slopes	
Lateral (deg)	45
Longitudinal (deg)	60
Maneuverability	
Minimum turning radius (in.)	92
Steering encroachment (in.)	9
Nominal speed (level ground) (ft/sec)	0.3

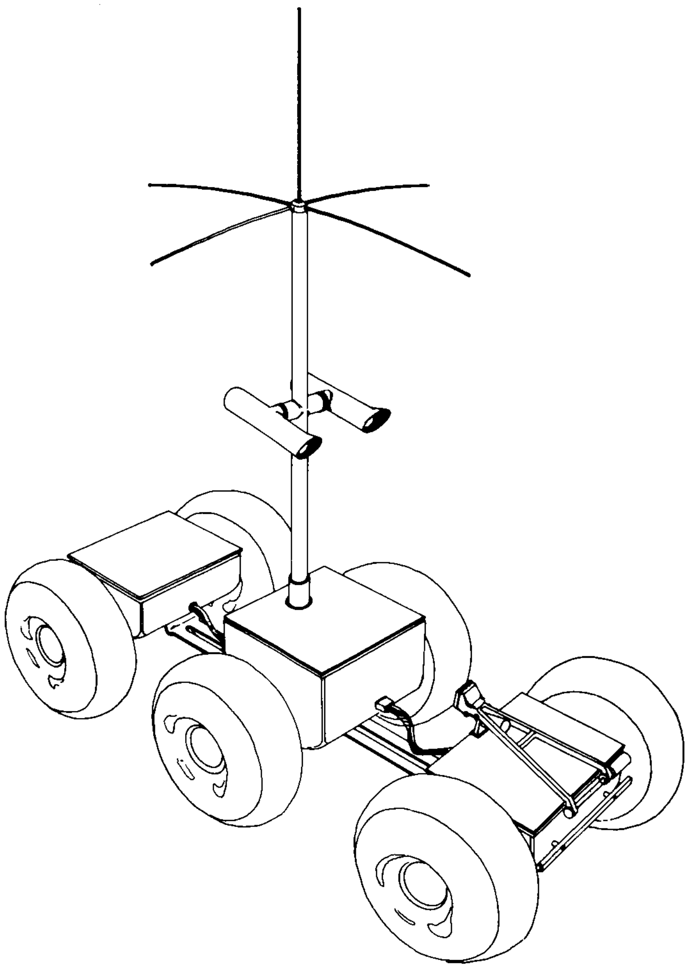

Figure 69. Advanced Mobile Unit

The mobile unit uses line-of-sight radio communication with the lander. Close-up stereo pictures and panoramic views can be taken and transmitted to earth via a radio relay link through the lander. Control from earth relies on analysis of the pictures received in conjunction with past views and pictures from the lander. Command sequences are transmitted via the lander to enable the vehicle to proceed to destinations within its own line-of-sight. Control errors and unforeseen hazards are compensated for by control sensors and safety devices (tilt, roll, bumper switches, etc.), which switch off drive power whenever the vehicle encounters a hazard and automatically transmit the stop conditions to earth. A single round-trip traverse of 300 feet radial distance will require about two Martian days during early stages of the mission, but this time should decrease with detailed knowledge of the local terrain.

The test mobile unit uses the same basic mobility system as the advanced unit but omits the science and data automation equipment and image sensor subsystem. This, in turn, eliminates the need for the radio transmitter and reduces the energy requirements per traverse. This unit is controlled in the same manner as the advanced unit except that pictures are obtained only by means of the lander camera subsystem. Limiting of the traverse distance to about 200 feet permits weight reduction in the batteries. A weight breakdown of the test mobile unit is shown in Table 14.

Table 14. Test Mobile Unit: Weight Summary

Basic mobility subsystem	80
Power subsystem (including power management)	8
Sample acquisition and transport	15
Telecommunication	8
Thermal control	5
Sensors (navigation and control)	4
Lander adapter and deployment	20
Total gross weight	140 lb

19.2 MOUNTING AND DEPLOYMENT

The lander adapter has the dual function of providing support for the vehicle loads incurred during launch, transit, and landing and deploying the vehicle from the lander under unpredictable attitudes and surface conditions. The adapter consists of three structural elements: a basic load-carrying platform atop the spacecraft, a ramp assembly, and the vehicle superstructure support frames.

To deploy the vehicle, the following sequence is used. The hinged superstructure frame is initially released. The superstructure elements are spring-actuated to swing clear of the mobile unit for deployment. The ramp and platform tiedown points are then released, the spring-loaded ramp swings into position, and the vehicle is free to drive off the lander.

19.3 MISSION-DEPENDENT EQUIPMENT

The mobility of the unit allows control with relatively simple equipment. Surface reconnaissance data from the orbiter and pictures by the lander may further simplify control constraints and provide a navigation aid. The mission-dependent equipment complements the vehicle design characteristics. The equipment has been grouped into the four functional areas described below.

19.3.1 Mission Control

For overall direction of the mobile mission and for navigation, mission control equipment is needed. Included will be the establishing of locations to which the unit is to be maneuvered; defining the requirements for pictures to be used for mapping, navigation, surveillance, and experimentation; performing the navigation function; monitoring mission status; and making command decisions. This function exists only at the SFOF.

19.3.2 Vehicle Evaluation

The task of monitoring subsystem performance in the mobile unit is accomplished by vehicle evaluation equipment, making use of standard general purpose hardware. This activity relies on digital computers for real-time evaluation of individual parameters and of related functions and for performance prediction based on trends and experience. The equipment is duplicated at each DSIF site.

19.3.3 Vehicle Control

The vehicle controller's function is to view the immediate terrain and select vehicle commands based on visual, telemetry, and navigational data. Stereo viewers, film processors, and perceptive aid generators are used at each DSIF site.

19.3.4 Data Processing and Computation

Data processing and computation equipment, duplicated at each DSIF site, is used for the reception, processing, and distribution of data, the computation and distribution of navigational data, and the processing, generation, and transmission of command data. The command

and data requirements for overseas DSIF operations allow standard general-purpose equipment for the most part; little specialized hardware will be required at these sites. Special equipment required at DSIF sites and at SFOF includes the following.

- TV Monitors and Perceptive Aids: the electronics and displays necessary to present to the vehicle controller the information required for selection of vehicle motion and steering commands. The display consists primarily of the image and projected vehicle tire tracks. The steering aids (simulated tire tracks) are automatically selected based on the camera angle and the intended steering angle. Side lighting of the display is included to alert the driver automatically to an abnormal condition, e.g., low receiver signal strength or improper execution of a command.
- Command Selector: groups of switches to select a vehicle command or series of commands.
- Film Processor: to record image and ID data and make this information rapidly available for use in the stereo viewer.
- Wide Baseline Stereo Viewer (Vehicle Control Area): similar to the one above except that it utilizes film clips from the SFOF film processor. This unit is used to evaluate terrain features for determining or modifying the objective points, and for updating navigational plots if previously established landmarks are visible.

19.4 OPERATIONAL SUPPORT EQUIPMENT

19.4.1 Launch Complex Equipment

The launch complex equipment is used to verify proper operation of the major electrical subsystems while the mobile unit is stowed during integrated systems tests and launch pad activities. During checkout, commands resulting in nonmechanical operations are sent to the vehicle and verified, the imaging subsystem operation is checked, and the instrumentation parameter values are reviewed. These checks, coupled with laboratory functional test data, enable test personnel to establish a "launch ready" status. During the countdown, the OSE will be used to monitor key telemetry channels for positive retention of ready status. The OSE will also be used to provide ground power to the vehicle and to control power switching.

19.4.2 System Test Equipment

System test equipment will allow complete testing and evaluation of an assembled mobile unit. It is essentially identical to in-plant test equipment used to perform final functional acceptance tests, and is capable of providing sufficient data to certify flight worthiness. These tests are performed in a laboratory environment (i.e. no dynamic or thermal stresses). This equipment will interface with the mobile unit via radio link. Measuring equipment is provided to decode telemetry signals and to make an engineering evaluation of the vehicle status. Equipment is provided to evaluate the status of the imaging subsystem. Three basic electronic test sets are envisioned, a command and monitor, transmitter-receiver, and video test consoles.

19.4.3 Assembly Handling and Shipping Equipment

Handling and holding fixtures are provided to facilitate transportation of the mobile unit, and to suspend the unit in various attitudes for wheel drive, clinometer, and steering actuator tests.

19.5 DEVELOPMENT

This section describes the implementation for the Voyager mobile unit. A schedule for this plan through first launch is shown in Figure 70.

19.5.1 Phase C: Design

The objectives of the Phase C design effort are as follows:

- To define the design and specification of the Voyager mobile unit
- To define the design and specifications of supporting systems
- To perform the appropriate systems engineering tasks, to identify mobile unit and support systems interface requirements for other Voyager equipment, and provide data for integration of the mobile unit with the capsule system
- To define design, development, and acquisition plans for the unit and its supporting systems and define the resources (time, funding, manpower, and facilities) required for completion of the program

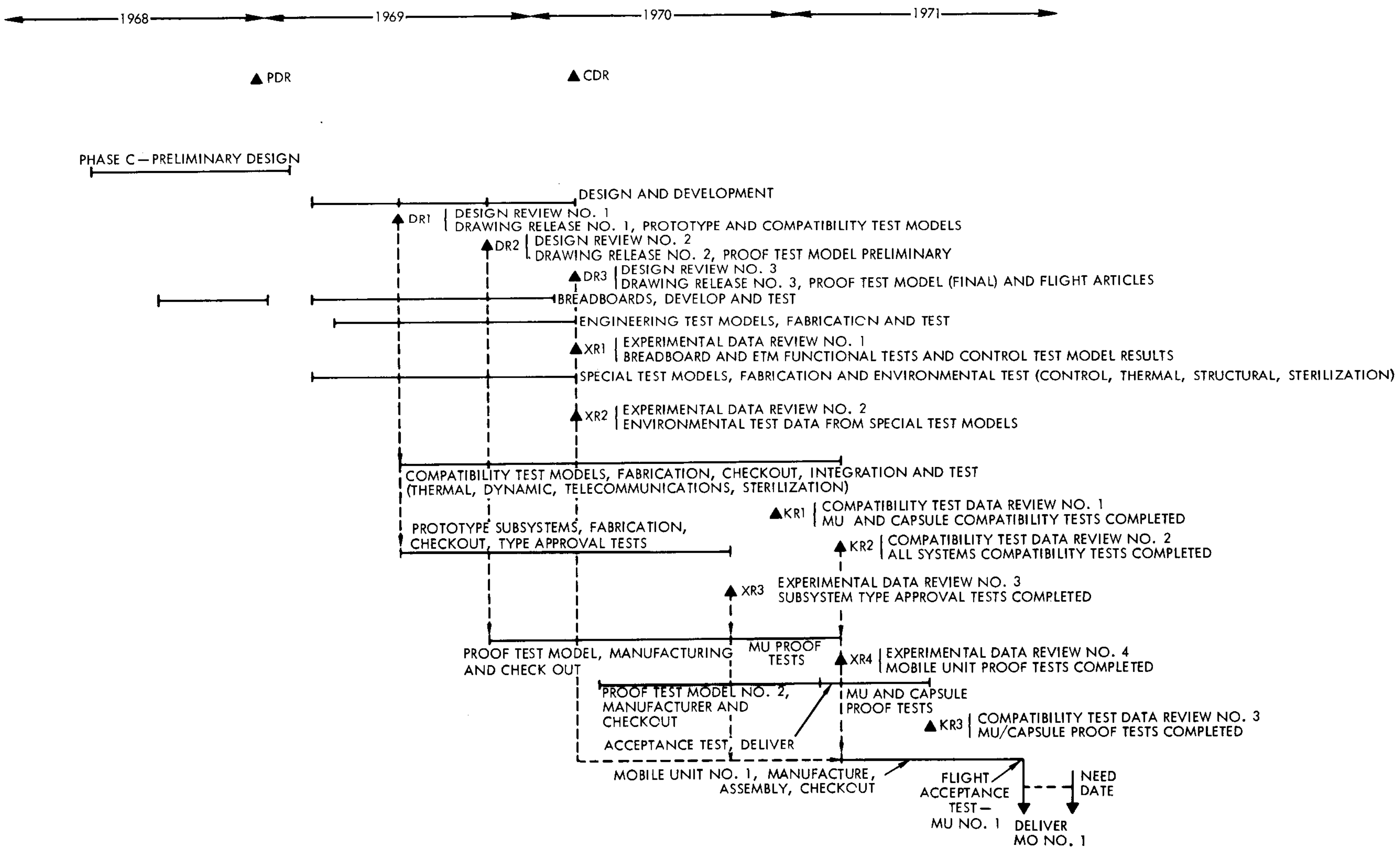

Figure 70. Mobile Unit Development Plan

In addition, Phase C may include the fabrication and test of breadboards of critical subsystems, as well as tests of materials and components.

To accomplish the above objectives, the following activities will be conducted:

- Conduct systems analyses
- Prepare CEI specifications and configuration drawings
- Prepare CEI specifications and configuration drawings for the mobile unit and support systems
- Perform mobile unit and subsystem growth studies
- Provide interface data for the capsule bus, surface laboratory, and other Voyager equipment
- Fabricate a full-size mobile unit mockup
- Prepare functional activity implementation plans
- Prepare design, development, and acquisition plans

19.5.2 Phase D: Development Activities

The program for development and test of the mobile unit is best explained in terms of the groups of models and equipment which comprise the cycles of evolution of the flight system design, and in terms of the major milestones of design reviews, drawing releases, experimental data reviews, and system performance evaluations. The development plan is shown in Figure 70. The purpose of the design review and drawing release milestones is to permit the initiation or continuance of activities (development, manufacturing, and test) which in turn properly lead to other milestones, primarily experimental data reviews, which in turn permit other releases, until the major objectives are achieved. The activities of the development plan are those of design, breadboarding (development and test), general engineering test model work, special engineering test model work, systems compatibility test model work, prototype subsystems, proof test model, and flight article manufacture, integration, and test.

Milestones are considered in three categories: "DR," which stands for both design review and drawing release, the project manager's main control for plateau determination or the halting of design activities and the initiation of development, procurement, or fabrication activities; "XR," which stands for experimental data review, the project manager's main control as to whether tests are completed satisfactorily and designs validated; and "KR," which stands for systems compatibility test data review, referring to tests of the mobile unit in combination with other systems, for which the mobile unit contractor has only a supporting role. The first drawing release is for certain engineering test models, including the compatibility test models, and for subsystem prototypes. It is considered desirable to initiate the design of special test models before the normal start of Phase D. The second drawing release permits the start of proof test model manufacture. The third, or final, drawing release is for flight hardware manufacture. The timing of the second and third releases is such that if the further design or the impact of experimental data is such that the drawings of the third release are significantly different from those of the second release, it is not too late to modify or retrofit the proof test model design. This is accomplished by timing the releases such that the proof test model manufacture has progressed only up to that stage where potting and sealing will follow on electronic assemblies, and sealing and surface treatment on mechanical assemblies.

The breadboard and general engineering test model activities fulfill the normal purposes of such hardware in a development program. As is the usual practice the distinction between breadboards and engineering test models is made on a form factor basis; the latter models follow the form factor of the current design insofar as is practicable for their purposes. The primary output from these activities is functional test data, taken under moderate environments with continuous feedback to the design process. Review of this data, with positive results, constitutes the achievement of milestone "XR1."

The special test models include thermal, structural, mobility and control, and sterilization test models. The purpose of the special test models is to facilitate the earliest possible experimental evaluation of critical design areas and to determine empirically the environmental constraints on mobile unit subsystems and assemblies. To this end, the special test models each are representative of one or more aspects of the mobile unit design and merely simulate it in other aspects. For example, the thermal test model will include only those real elements of the mobile unit design that critically affect thermal conduction and radiation, and merely simulate other elements in regard to their heat source, heat transfer, and heat storage characteristics. The thermal test model is environmentally tested with internal and external instrumentation to evaluate the preliminary design and provide checkpoints for redesign as may be required. From these tests, the functional and environmental specifications on mobile unit subsystems which were prepared under Phase C may be refined.

In a like manner, the structural test model will be equipped with real and simulated mechanical assemblies, and instrumented internally and externally for shock, vibration, and strain measurements.

The mobility and control model will be used to evaluate the mobility characteristics of the mobile unit including step obstacle, crevice, and ditch-crossing performance as well as soft soil mobility. It will also provide data on vehicle control techniques, design data on vehicle obstacle avoidance sensors, and design data for operational support equipment. This model may also be used later as a training model. Operator training may be conducted simultaneously with control tests.

The sterilization model will be used to assure the capability to sterilize to the level required for delivery and integration at the next higher level.

The compatibility test models include models for systems compatibility testing in their thermal, dynamic, sterilization, and telecommunications aspects. These are intended for combined system testing with the surface laboratory, capsule, the launch vehicle, support equipment, and elements of the Deep Space Network. Such tests will be conducted with the vehicle in the stowed condition. It is the responsibility of the mobile unit contractor to deliver the models and to assist in the integration and combined testing program. Thermal, dynamic, and sterilization, compatibility test models, functionally similar to the special test models described above, will be furnished with real electronics and mechanisms included only where an adequate simulation is not otherwise possible. However, these compatibility test models are based on a later design and should more accurately represent the final configuration.

The RFI/EMI compatibility test model will include real electronics, power, and mechanisms. In order to reduce program costs, an engineering test model mobility unit may be used for this purpose. The employment of this model in joint tests with the breadboard ground support equipment will help evaluate that equipment and insure mutual compatibility.

A sterilization test model will be provided for sterilization tests conducted on the entire flight capsule system. Each of the mobile unit subsystems will be designed for and tested in the sterilization environment but the mobile unit system sterilization test will be conducted in the flight capsule test program.

The prototype subsystems manufacturing is based upon Drawing Release 1. A typical schedule for manufacturing the type approval test article is shown in Figure 70.

The proof test program is the next set of activities outlined in Figure 70. The purpose of this test program is proof of design under environmental stress. These tests include both ambient and thermal-vacuum tests under simulated operational conditions. The actual Martian surface operations conducted with the test mobile unit in the 1973 and 1975 missions will also serve as additional proof tests on those elements of the mobile unit included with test version.

Drawing Release 2 is employed for proof test manufacture. This will permit the early procurement and fabrication of components and assemblies as early as possible. In order to provide for maximum commonality between the proof test model and subsequent flight hardware, manufacturing is carried to the point where such processes as potting, sealing, and coating would be applied. It is intended that milestone DR3, final drawing release, will occur at this time and any late changes in design can be reflected in proof test model configuration with a minimum of rework.

Upon completion of proof test model manufacture and checkout, an additional constraint is invoked: satisfactory completion of all subsystem type approval tests before formal proof testing. Other potential constraints between proof test model and flight article integration and test programs are indicated in Figure 70. After mobile unit proof testing, combined environmental testing with the capsule will be conducted. During this period, technical support equipment and personnel will be provided.

REFERENCES

1. Voyager Support Study, Advanced Mission Definition, Final Report. TRW No. 04480-6001-R000, Volume I, Preferred Approach, November 1966. Also, Volume II, Parts I and II, Alternative Approaches and Supporting Analyses, November 1966.

GLOSSARY

AFETR	Air Force Eastern Test Range
CAF	Capsule Assembly Facility
CEI	Contract End Item
CRT	Countdown Readiness Test
DE and MR	Data Entry and Monitor Rack
DPO	Data Processing Operations Group
DSIF	Deep Space Instrumentation Facility
DSN	Deep Space Network
DSS	Deep Space Station
EOSE	Electrical Operational Support Equipment
ESA	Explosive Safe Area
ESF	Explosive Safe Facility
ETO	Ethylene Oxide
FACI	First Article Configuration Inspection
FPAC	Flight Path Analysis and Command Group
GCS	Ground Communications System
KSC	Kennedy Space Center
LOS	Launch Operations System
MA and E	Mission Analysis and Engineering
MOS	Mission Operations System
MOSE	Mechanical Operational Support Equipment
MSFN	Manned Space Flight Network
NASCOM	NASA Communications Network
OTDA	Office of Tracking and Data Acquisition
PAD	Project Approval Document

GLOSSARY (Continued)

PDP	Project Development Plan
PDR	Preliminary Design Review
PVPAC	Planetary Vehicle Performance Analysis and Command Group
RTG	Radioisotope Thermal Generator
SAF	Spacecraft Assembly Facility
SFOF	Space Flight Operations Facility
SMO	System Management Office
SSAC	Space Science Analysis and Command Group
TDAS	Tracking and Data Acquisition System
VAB	Vertical Assembly Building