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PRELIMINARY APOLLO PROGRAM PLAN[redacted]

Contract NAS 9-150

1 March 1962

45.3.1.1

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Approved by

J. W. Paup
Vice President and Apollo Program Manager

NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

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FOREWORD

The Apollo Program Plan is submitted in response to Paragraph 4.5.3.1.1 of Part 4 of the NASA Statement of Work, dated 18 December 1961.

Due to the relatively fluid condition of the program at this time, all data presented in this volume are tentative and restricted in scope.

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INTRODUCTION

Project Apollo will culminate in a manned spacecraft landing on the surface of the moon. The many complex events leading up to and resulting in this achievement are delineated in this volume. The initial phase of the Apollo program is designed to accomplish the successful demonstration of manned earth-orbital operations. This will be accomplished through the design, fabrication, and test of "boilerplate" Apollo vehicles. These boilerplates will initially be gross in detail and in test objectives. Gradually, however, they will become more and more sophisticated through continual design improvement. A result of improved design will be the prototype vehicle. This vehicle will be designed from the beginning with lunar landing compatibility in mind. As in the case of boilerplates, the prototype vehicles will become more and more sophisticated until final earth-orbital operations have been successfully demonstrated.

The second phase of Project Apollo is designed to demonstrate circumlunar and lunar-orbital capability. Design and development approaches will be based on experience gained from the initial phases of the Apollo program.

After successful demonstration of the circumlunar and lunar-orbital phases of the program, more refined techniques will be utilized to demonstrate low lunar-orbit and then lunar-landing capability.

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The Apollo Program Plan describes how the Apollo Division intends to accomplish the effort now under contract and optimize methods to attain the ultimate goals of the overall Apollo project. Program development, design approach, test objectives, supporting effort, and various aspects of management control are discussed in detail. The program plan will serve as a guide for S&ID and its subcontractors and associate contractors in the accomplishment of the program objectives.

The Program Plan is divided into three major sections. The section devoted to Program Summary contains organization data, the Master Phasing Plan, the Master Development Schedule, and pertinent manpower data. Although the Master Phasing Plan and Master Development Schedule are not primarily status documents, provisions have been made to show program status. The accomplishment of scheduled milestones will be indicated by substituting solid for open arrowheads, and a shaded bar technique will be employed to indicate progress on the Master Phasing Plan.

The Program Detail Schedule Section provides an extensive depth of manageable schedule data. There are detail schedules for each General Order, for subcontractor and associate contractor deliveries, and for engineering and manufacturing test and sequencing. Status will be shown as indicated on individual schedules.

The implementation of PERT is being effected rapidly. PERT networks will be included in the schedule section 30 June 1962. Upon the full implementation of PERT, all schedule data shown will be re-evaluated and aligned with PERT data. For additional visual presentation, however, the same schedule format will be retained in all future revisions.

The Program Plan Section contains a summary Technical Development Plan and summary plans for Manufacturing, Logistics, and Facilities. The Technical Development Plan outlines the design and development approaches to be employed for the Apollo Program, emphasizing reliability techniques, and presents a summary of the overall test plan. Potential problem areas and suggested solutions are also included.

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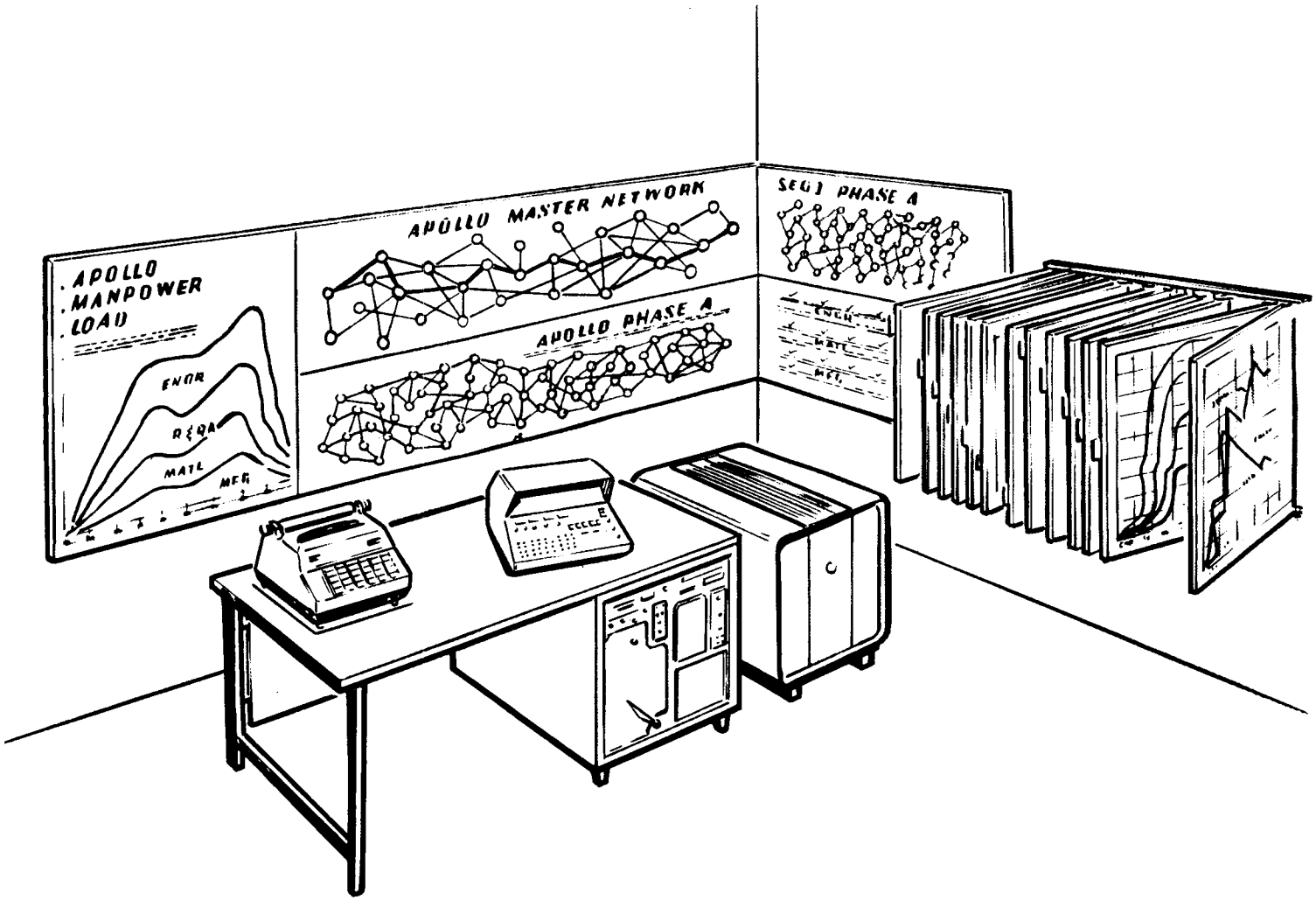

Figure 1. Program Control Center

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S&ID ORGANIZATION

The responsibility of the Space and Information Systems Division in Downey, California, is the development, production, and testing of complete space, missile, and information systems. The term "system" may cover the extremes of cost and complexity of a multi-billion dollar major space system to a very small system program such as the Little Joe Booster project. Because most systems involve critical schedule considerations and many functions that dictate strong control of project activities, a program management office is usually established to complement the functional line structure. The staffing and the placement of that office within the organization are determined by analysis of the program requirements. The Apollo organization is placed organizationally where it has ready access to the Division president as well as to all functional elements. This organization is shown in Figure 2.

APOLLO ORGANIZATION

The Apollo organization, shown in Figure 3, includes provisions for effective project direction issuing from a Program Manager who is a Vice President of the Division. The program manager reports to the Division President and has complete management and technical control of the necessary manpower. Facilities and equipment to ensure a successful program are provided, and the highest possible quality and reliability standards will be maintained at all times. Corporate coordination will be maintained with the NASA technical and management organization, and full cooperation within the NAA corporate organization is assured. The Apollo organization provides flexibility to adapt to changing needs as the program progresses, but will, at the same time, maintain the direction and control necessary for timely and satisfactory completion of the program.

In addition to this combined organizational capability at S&ID, interdivisional arrangements have been made to assure maximum communication among all concerned. The existing transportation and communication links between S&ID and other divisions permit the highest degree of liaison with a minimum expenditure of time and effort.

The Apollo Program manager, Mr. J. Paup, a Vice President of S&ID, is responsible for the overall S&ID Apollo activities and will head a highly project-oriented organization. The program manager, through continuous contact with his staff and key personnel in daily briefings, directs the project and provides specific project decisions. The program manager, his staff, and other key personnel will meet regularly with NASA program management to report progress and discuss plans for the future conduct of the Apollo effort.

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S&ID has established a strong, centralized program control system for the Apollo program which provides complete compatibility with NASA's sequenced milestone system. The goal of the monitoring system is designed to integrate PERT scheduling techniques with a budgetary control monitoring system so as to provide details of the program to each cognizant management level of NASA and S&ID. Cost information will be provided through an IBM 705 financial ledger and control system. Periodic critical path analyses and implementation reports will be prepared through an IBM 7090 program. The S&ID Program Control staff will perform on-line schedule analyses by use of an Autonetics RECOMP II computer to supplement these procedures.

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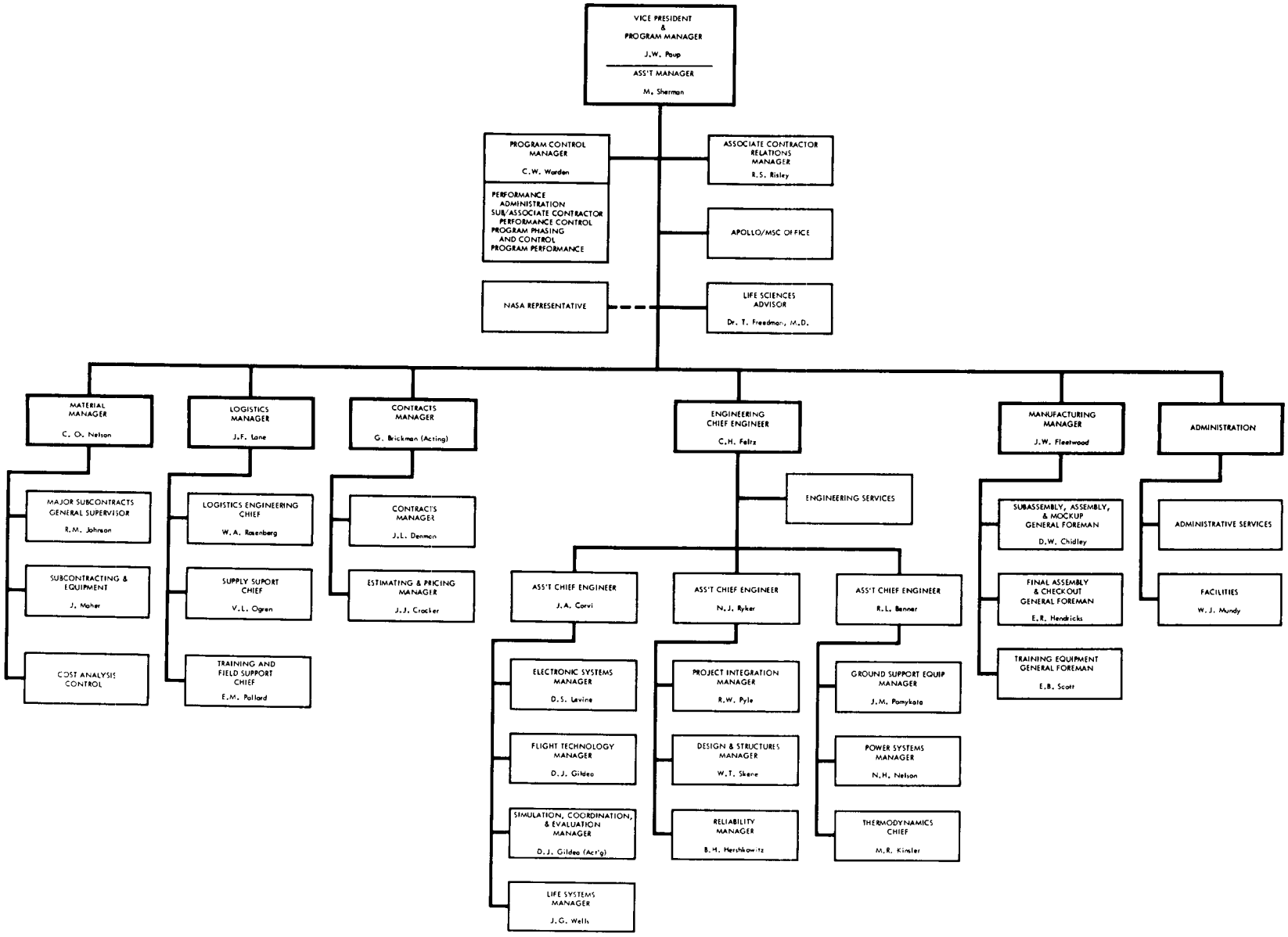

Figure 3. Apollo Program Organization

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APOLLO PROGRAM CONTROL ORGANIZATION

The Apollo Program Control Manager, Mr. C. W. Warden, reports to the Apollo Program Manager and is responsible for establishing overall Apollo Program Schedules, control data, and reporting systems, and is the focal point for compilation and analysis of Apollo Management operating data and information. Program Control is responsible for surveillance of all Apollo program progress and will exercise program control through the use of program planning documents, PERT, periodic reviews, cost and technical reports, and other management data as may be required. By compiling and analyzing such information, the organization can detect and report program difficulties to the Program Manager, recommend corrective action, and implement managerial decisions through its assigned control techniques. The Apollo Program Control organization is shown in Figure 4.

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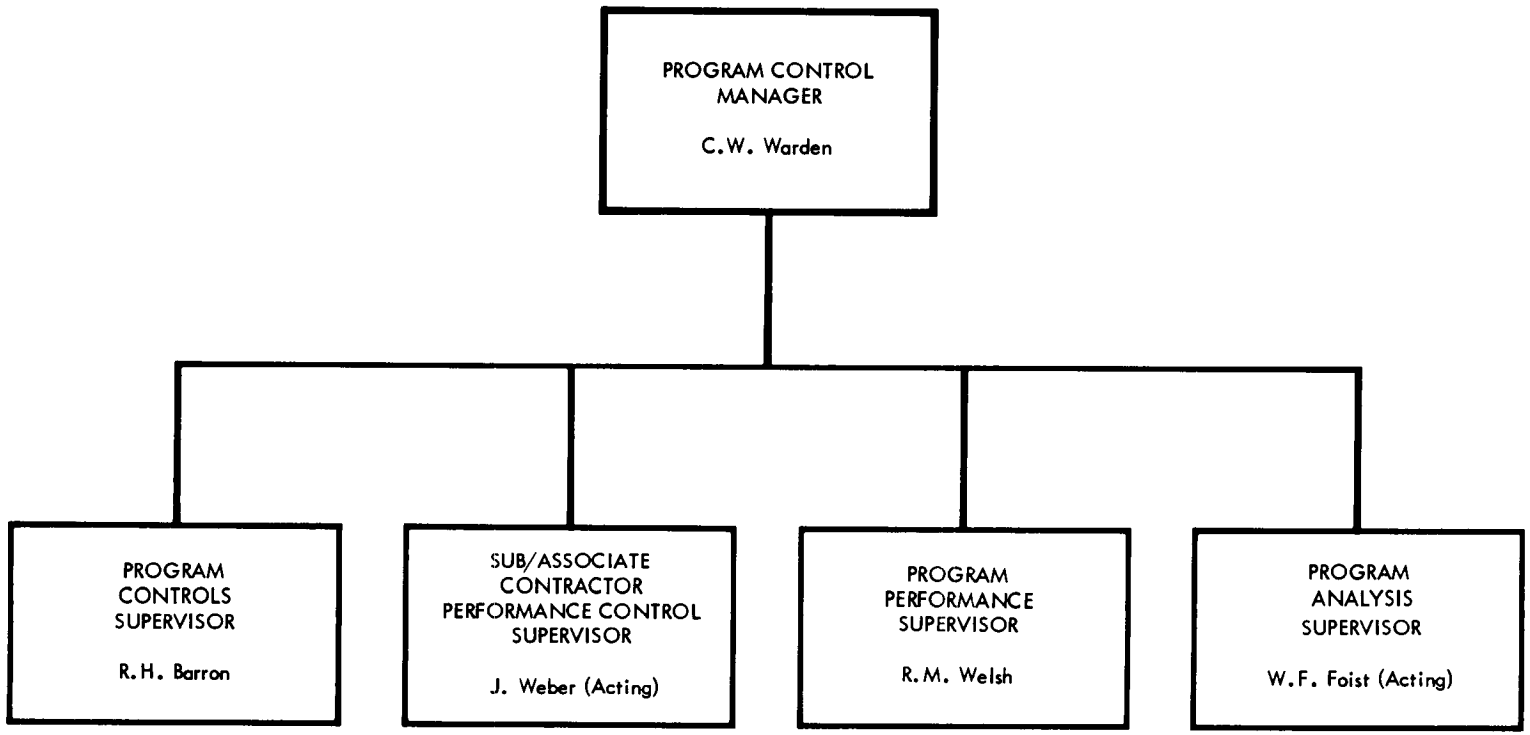

Figure 4. Apollo Program Control Organization

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APOLLO LOGISTICS ORGANIZATION

The Manager of Apollo Logistics, Mr. J. F. Lane, is responsible to the Program Manager for the conduct of the overall Apollo support program. Elements include:

- Maintenance Analysis and Planning
- Programming and Conducting of Technical Training of NAA Field Test and NASA Personnel
- Supply Support Planning and Operations
- Spares Identification, Release, and Control
- Support Manual Development
- Subcontractor Requirements and Technical Liaison for Logistics
- Requirements Interface to Publications Department

The Logistics organization is composed of four sections reporting to the Manager, as shown in the organization chart, Figure 5.

Logistics Engineering includes the Maintenance Engineering and the Service Manual groups. Maintenance Engineering will analyze the spacecraft and supporting equipment to determine the necessary support requirements. The purpose of the analysis is to provide (1) a support plan, which identifies the overall support requirements including materiel, transportation media, equipment overhaul, and requirements for service manuals, and (2) a maintenance plan, which defines the specific maintenance functions required throughout factory testing, storage, assembly, and relaunch testing. Maintenance Engineering will function as single point of contact to ensure the accumulation of assets to perform test site repair or modification. The Service Manual Group will identify and compile the service manuals for supporting test site operations. These will include Operating and Launch Instructions, Maintenance, and Testing and Checkout Manuals.

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Supply Support has the responsibility for compiling data for use by the spares selection team, releasing spares and GSE requirements to production or procurement, and ensuring compliance with their delivery schedules. Initial data will be Hardware Lists and Parts Breakdowns with stock balance and consumption data added as it becomes available. Supply Support will manage a precise accounting system for hardware to provide the accurate control necessary for equipment updating, spares effectivity, and status of repairables in the repair cycle.

The Training Group, in coordination with NASA and subcontractors, will plan and develop the overall Apollo technical training program. A training plan will be prepared with active participation in test and simulation programs for identification of training requirements and evaluation. Training data will be analyzed and training equipment recommendations made. Instructor- and student-oriented training manuals for maintenance, part task, and mission simulator training equipment will be compiled. Training of NAA and NASA ground operations and maintenance personnel will be conducted. Training support will also be provided as required to NASA flight operations and GOSS. Field Engineering will service the maintenance trainers, part task trainers, and simulators furnished to NASA. A staff of engineers and technicians will modify and update the equipment as required and collect failure and usage data to assist in product improvement.

The Planning and Controls unit provides the Logistics Manager and supervision with the necessary detailed planning and controls support to effectively administer the Logistics program.

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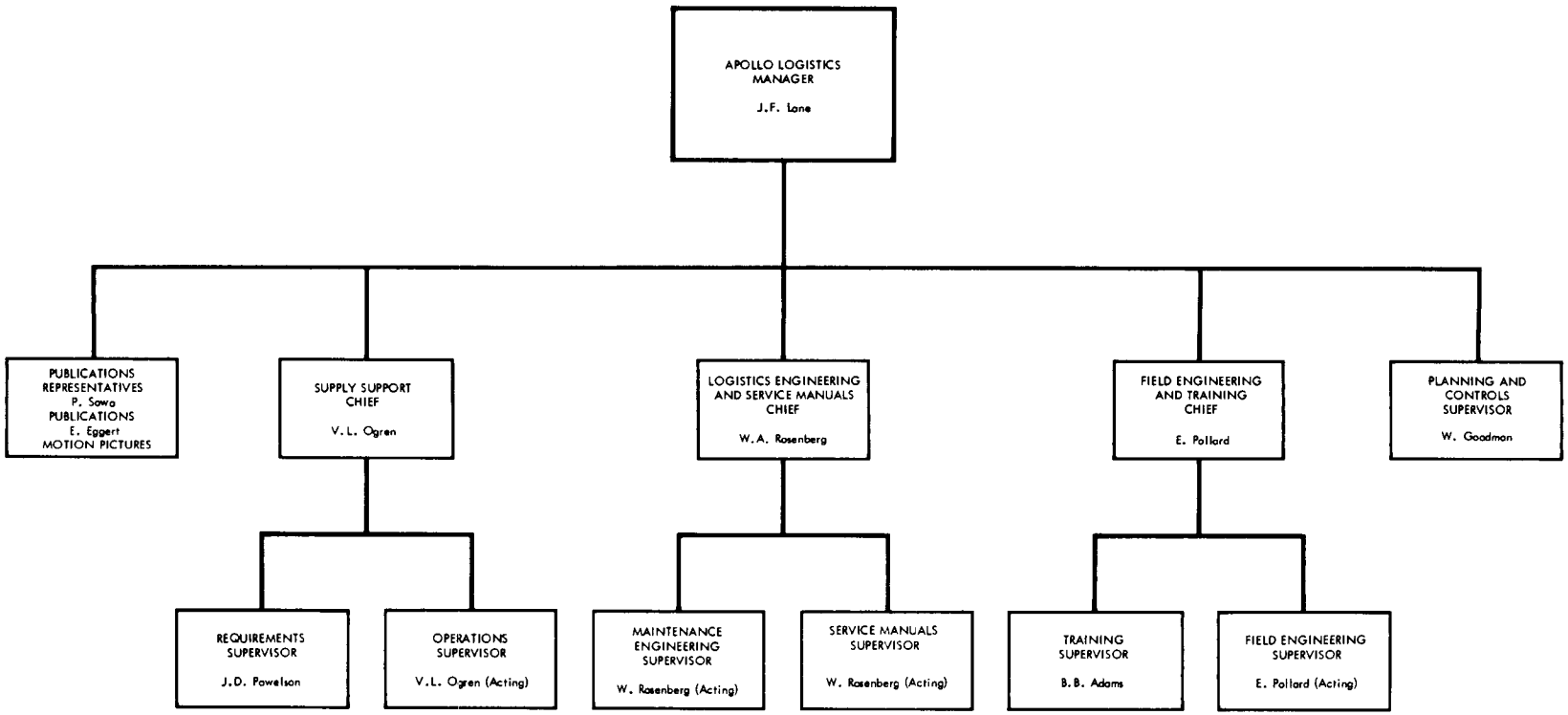

Figure 5. Apollo Logistics Organization

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APOLLO ENGINEERING ORGANIZATION

The Manager of Apollo Engineering, Mr. C. H. Feltz, has the overall responsibility for organizing, staffing, controlling and directing the Apollo Engineering activity as required to attain the objectives and perform the tasks delineated in the project Apollo statement of work. These include the studies required for, and the design of, the spacecraft command module, the service module, the adapter, and their systems, GSE, and "test" spacecraft. Included also is the responsibility for their integration with other systems and components of the Apollo complex and the conduct of all in-house test programs and simulation operations (Figure 6).

Operating authority and responsibility has been delegated and assigned to three assistant Chief Engineers. Mr. R. L. Benner directs the engineering effort of the functional areas of (1) Ground Support Equipment, including establishing overall analysis, criteria, concept, and design of GSE for checkout and training, (2) Power Systems, including the design and selection of components, integration of the components into a system, and testing and developing the systems for propulsion, environmental control, and electric power, (3) Thermodynamics, including aerodynamic heating evaluations, heat transfer calculations, fluid systems analysis associated with power systems, and nuclear shielding requirements.

Mr. J. A. Corvi directs the engineering effort of the functional areas of (1) Electronic Systems, including the determination of adequate radar systems, displays, and controls, in-flight test systems, electromagnetic interference requirements, compatibility of the guidance and navigation system (MIT), and telecommunications (instrumentation, data systems and communication units, and GOSS requirements), (2) Flight Technology, including aerodynamic studies and requirements, and flight dynamics developments, (3) Simulation Coordination, including flight simulation requirements, programs, and facilities, and spacecraft simulation needs and specifications, (4) Life Systems, including the definition of

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crew performance and protection, development of man-machine capabilities, and the design and selection of crew systems and equipment.

Mr. N. J. Ryker directs the engineering effort of the functional areas of (1) Design and Structures, including structural, mechanical, and test vehicle design, structural analysis and structural dynamics, weight control, and materials analysis and selection, (2) Project Integration, including systems requirements, design criteria, specifications and plans, design evaluation studies, surveillance of the spacecraft GSE, and test functions to assure compatibility of all systems and components, the establishment of configuration control records, the coordination of interfaces with other modules and launch vehicles, and the direction of general design and trade off studies, and (3) Reliability, including project direction for the reliability group that apportions, and assesses reliability to the several systems and that develops qualification test plans.

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APOLLO MANUFACTURING ORGANIZATION

The Manufacturing Manager, Mr. J. W. Fleetwood, has complete authority and responsibility for Apollo Manufacturing. Under his direction, four basic line departments will fabricate, assemble, and perform checkout operations on the Apollo spacecraft and trainers. Project groups function within the existing administrative departments to facilitate pre-planning effort and establish the controls peculiar to this program. The product line departments are supported by existing manufacturing support departments, including ground support equipment, which have been expanded and modified to fit the needs of the program. The manufacturing organization is shown in Figure 7.

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APOLLO MATERIAL ORGANIZATION

The Apollo material manager, Mr. C. O. Nelson, has authority and responsibility for acquisition and records of material and equipment for the Apollo program. Under his direction two basic line departments handle major subcontracts, and subcontracts and equipment.

Each department is responsible for providing for materials by evaluating material requirements and recommending a qualified supplier, and each also negotiates and administers the contracts and purchase orders. The organization is shown in Figure 8.

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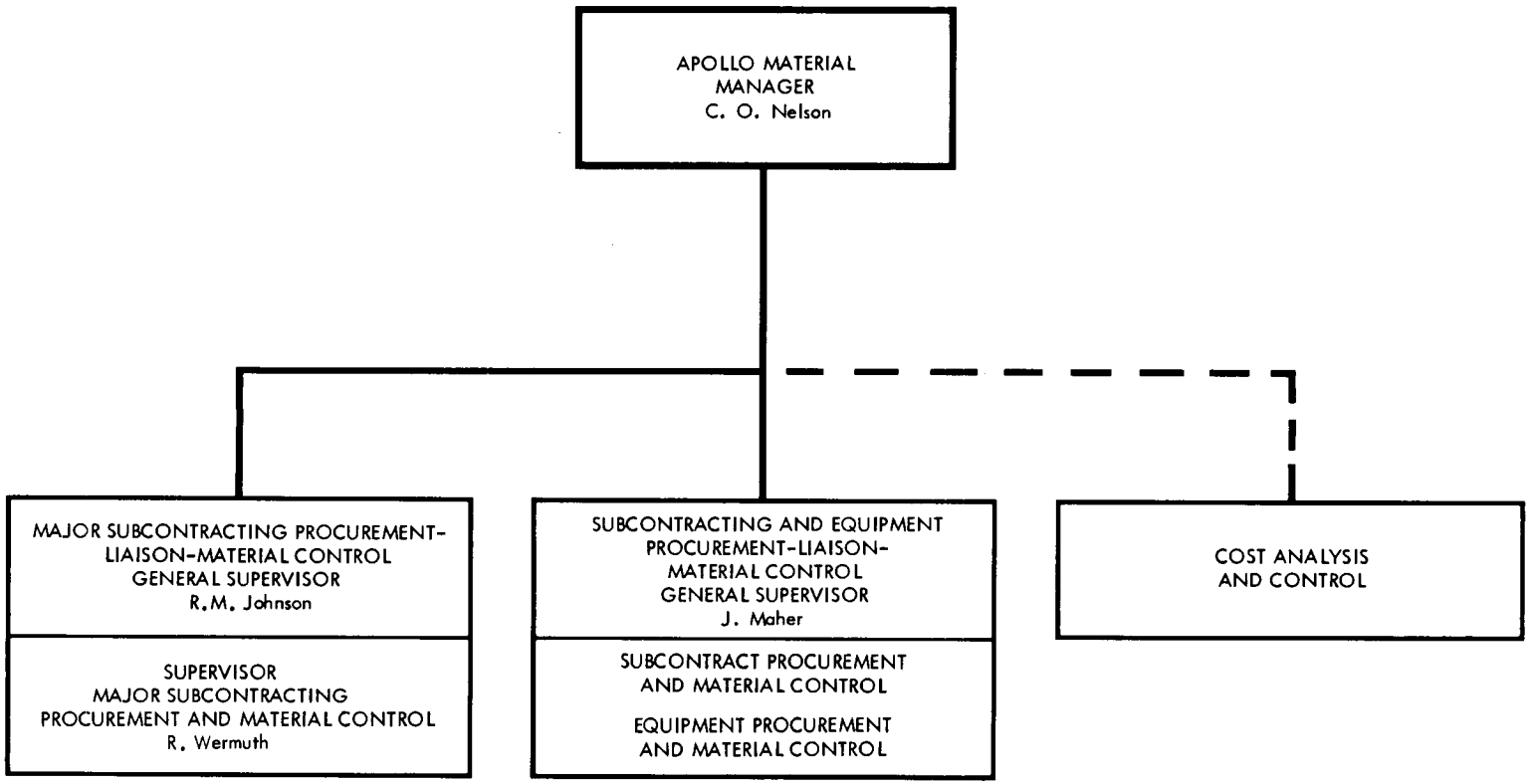

Figure 8. Apollo Material Organization

APOLLO PLANT ENGINEERING

The Manager of Apollo Facilities, Mr. W.J. Mundy, is responsible to the Program Manager for the conduct of the overall Apollo Facilities Program (Figure 9). The following responsibilities are included:

1. To plan, procure, and administer all S&ID Apollo program facilities.

2. To review and approve subcontractors' Apollo program facilities requirements.

3. To review and furnish systems integration facilities criteria to associate contractors.

4. To review and furnish systems integration and test facilities criteria to NASA.

5. To administer company capital and government facilities contract funds for S&ID.

The Apollo Facilities organization is presently composed of two industrial engineering groups, reporting to the Apollo Facilities Manager and Plant Engineer: (1) the Industrial Engineering Group 1, providing all industrial engineering support to the Manufacturing department and providing plant layout and material handling support for the Apollo program requirements and (2) the Industrial Engineering Group 2, providing industrial engineering support for all Apollo Engineering, Applied Science, and supporting departments. This group also provides coordination with S&ID Facilities Planning and Facilities Engineering Design organizations.

Facilities Administration, including Property Control, Job Order and Construction Scheduling, and Accounting liaison will be provided by S&ID Central Plant Engineering. The Apollo Facilities organization is currently proposed to be

expanded to include three supervisory units under each Industrial Engineering Group. Separate Industrial Engineering Groups will be established for (1) Plant Layout, (2) Processing and Material Handling, and (3) Manufacturing and Support departments.

The second Industrial Engineering Group will have three Industrial Engineering Units, including (1) Engineering departments, (2) Engineering Laboratories and Support departments, and (3) off-site facilities.

In addition to the two Industrial Engineering Groups, a Staff and Industrial Planning liaison function will be added, reporting to the Facilities Manager. This group will maintain liaison and coordination with the S&ID Facilities Director and the Central Plant Engineering organizations, who will maintain policy guidance and direction responsibilities for the Apollo Facilities organization.

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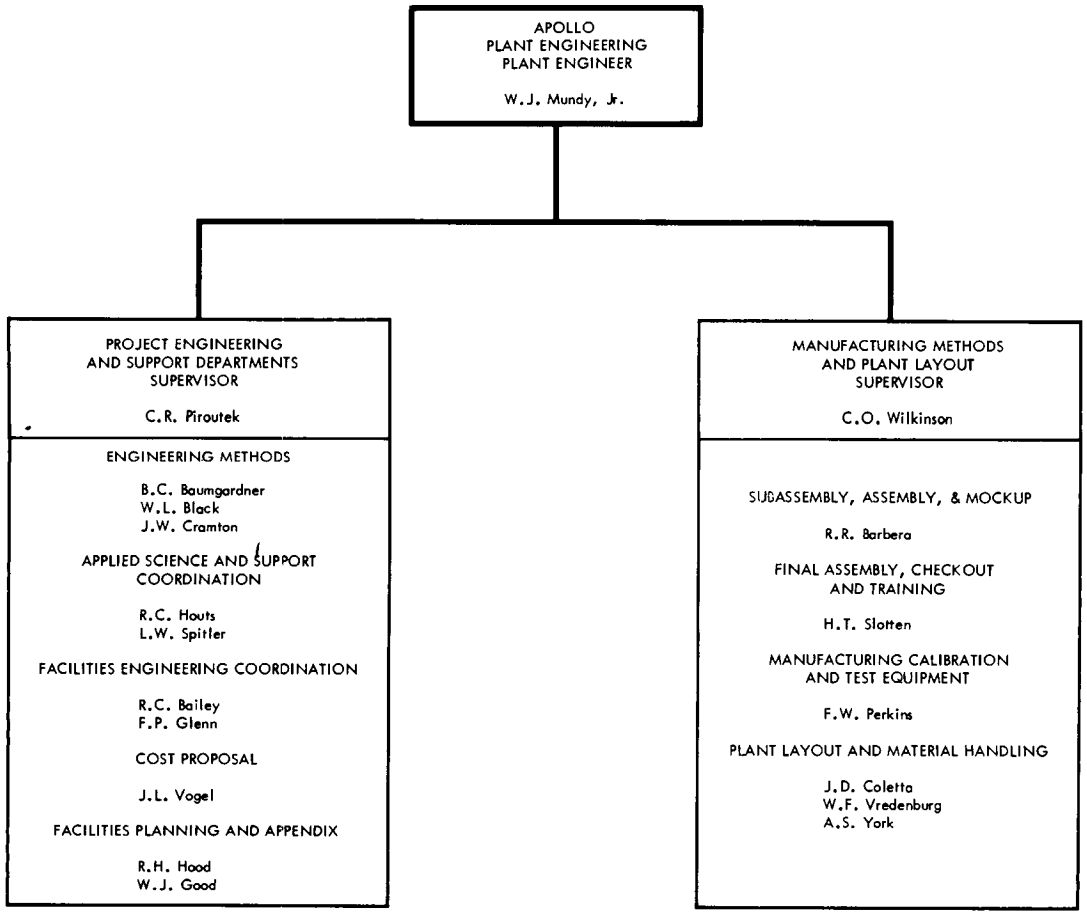

Figure 9. Apollo Plant Engineering Organization

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APOLLO MANPOWER DATA

Current manpower data are not included in this issue of the Program Plan because these data are being compiled for inclusion in the cost proposal to be submitted on 2 April 1962. Future revisions of this plan will include manpower requirements.

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APOLLO MASTER SCHEDULES

The Apollo Program Master Phasing Plan delineates all major hardware requirements and shows these requirements in their proper relationship (Figure 10).

The Apollo Program Master Development Schedule has been prepared to serve as a master summary schedule. Activities of all of the functional departments are summarized to provide total program visibility at a glance (Figure 11).

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PROGRAM DETAIL SCHEDULES

Detail schedules have been prepared for each task, for functional areas that require specific attention, and for subcontractor and associate contractor deliveries. These schedules show effort only through the first manned flight unless information beyond that point is of particular significance (Figures 12 through 36).

S&ID and NASA MSC have agreed upon a method of presenting detail schedule data based on a task structure mutually acceptable to both organizations. This task structure is identified in this volume by the term "General Order."

Functional area detail schedules represent specific kinds of testing or sequencing applicable to a given department. Subcontractor and associate contractor delivery schedules reflect requirements and delivery dates to support system installation requirements for proposed spacecraft.

The next revision of this Program Plan volume will include a "Critical Items" list of scheduled events that could directly impede the successful accomplishment of scheduled launch dates. This list of items will include the Apollo Division's proposed action to resolve the problems associated with each critical item.

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DETAIL SCHEDULES BY GENERAL ORDER

The titles of the detailed schedules contained in this section are listed below:

1. General Order 7121 - Flight Technology
2. Engineering Detail Schedule - Wind Tunnel Model Testing
3. General Order 7122 - Integration and System Analysis
4. General Order 7123 - Reliability
5. General Order 7124 - Instrumentation
6. General Order 7125 - Training and Simulation
7. General Order 7126 - Spacecraft Test Operations - Downey
8. General Order 7127 - Prelaunch and Launch Operations - AMR
9. General Order 7128 - Documentation
10. General Order 7130 - Stabilization and Control
11. General Order 7131 - Crew Provisions
12. General Order 7132 - Launch Escape Subsystem
13. General Order 7133 - Environmental Control Subsystem
14. General Order 7134 - Earth Landing Subsystem
15. General Order 7135 - Communication Subsystem
16. General Order 7136 - Navigation and Guidance Integration
17. General Order 7137 - Command Module Structure and Subsystem Installation
18. General Order 7138 - Service Propulsion Subsystem
19. General Order 7139 - Service Module Structure and Subsystem Installation
20. General Order 7140 - Electrical Power Subsystem
21. General Order 7141 - Reaction Control
22. General Order 7142 - Spacecraft Adapter Design, Fabrication, and Assembly
23. General Order 7143 - Command Module GSE
24. General Order 7144 - Service Module GSE
25. General Order 7145 - Ground Operations Support System (GOSS)

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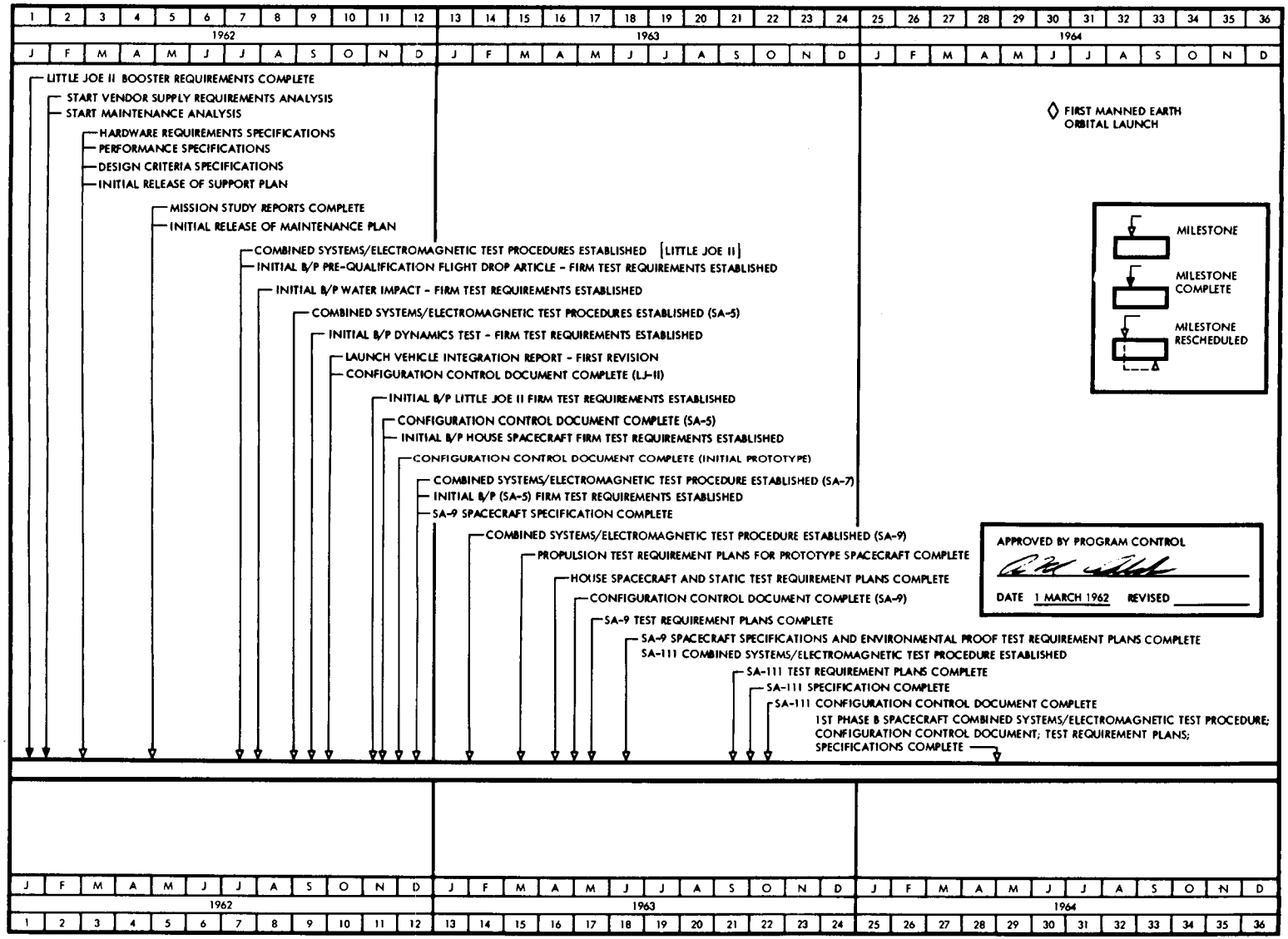

Figure 14. General Order 7122 - Integration and System Analysis

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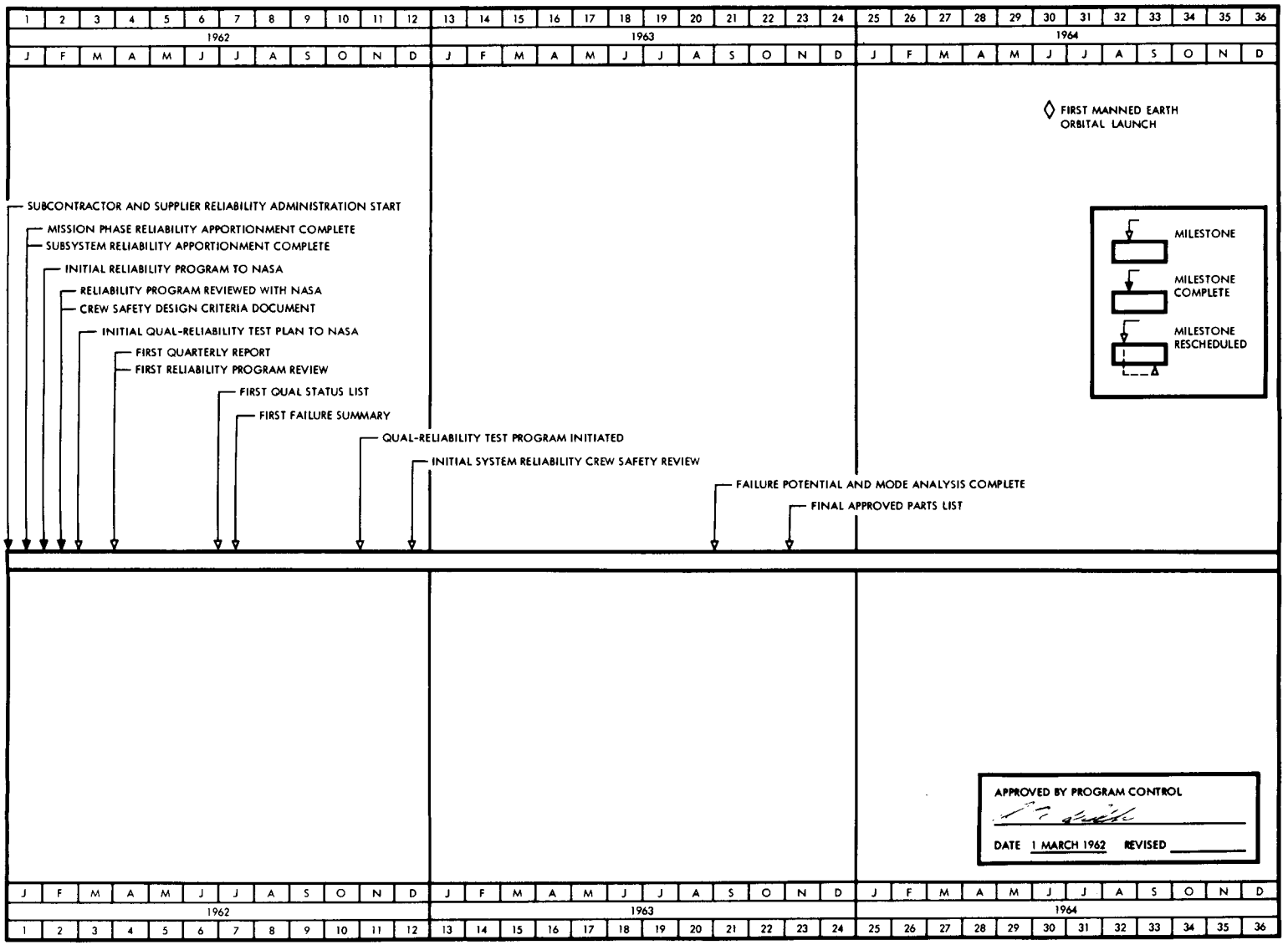

Figure 15. General Order 7123 - Reliability

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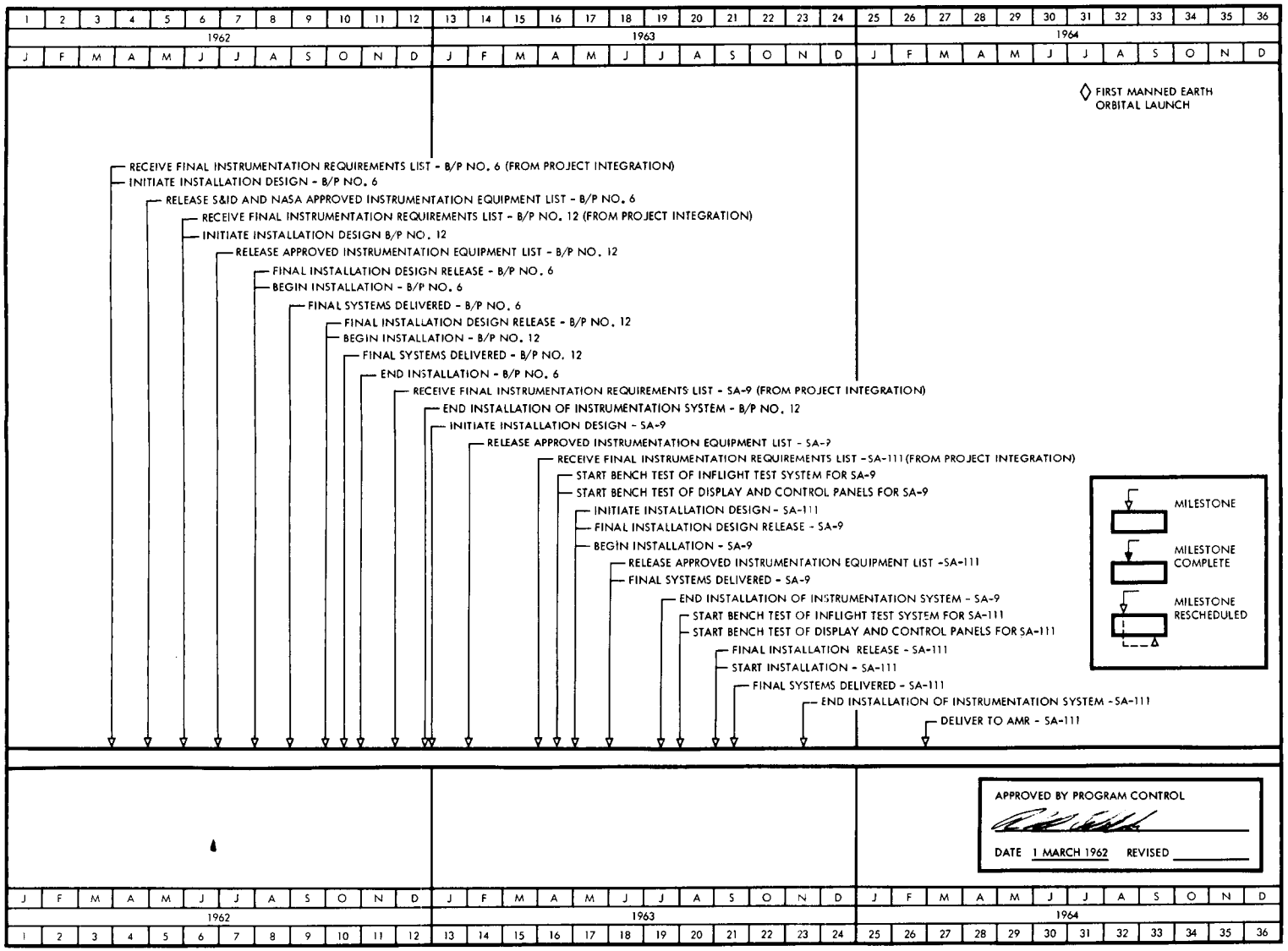

Figure 16. General Order 7124 - Instrumentation

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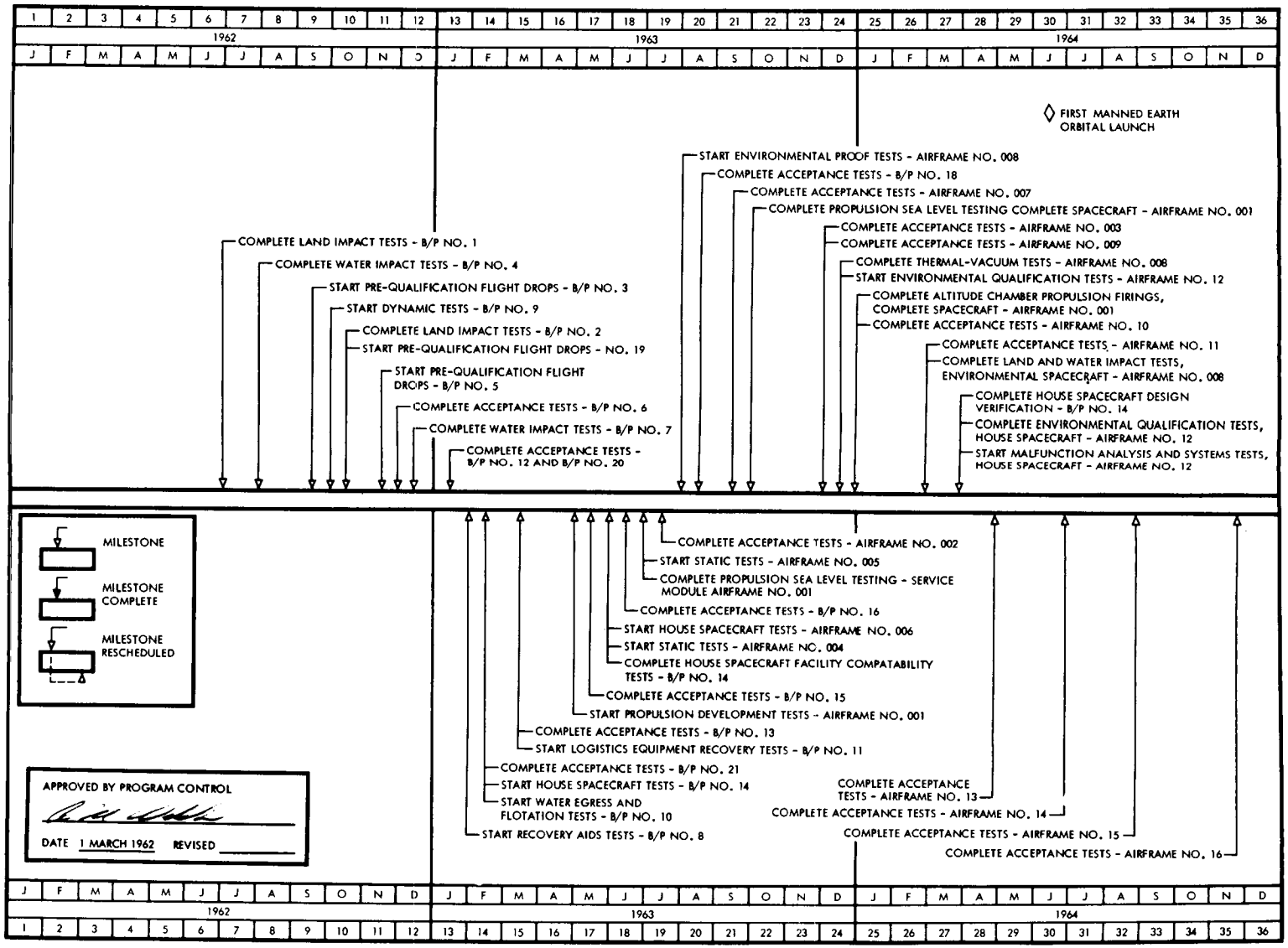

Figure 18. General Order 7126 - Spacecraft Test Operations - Downey

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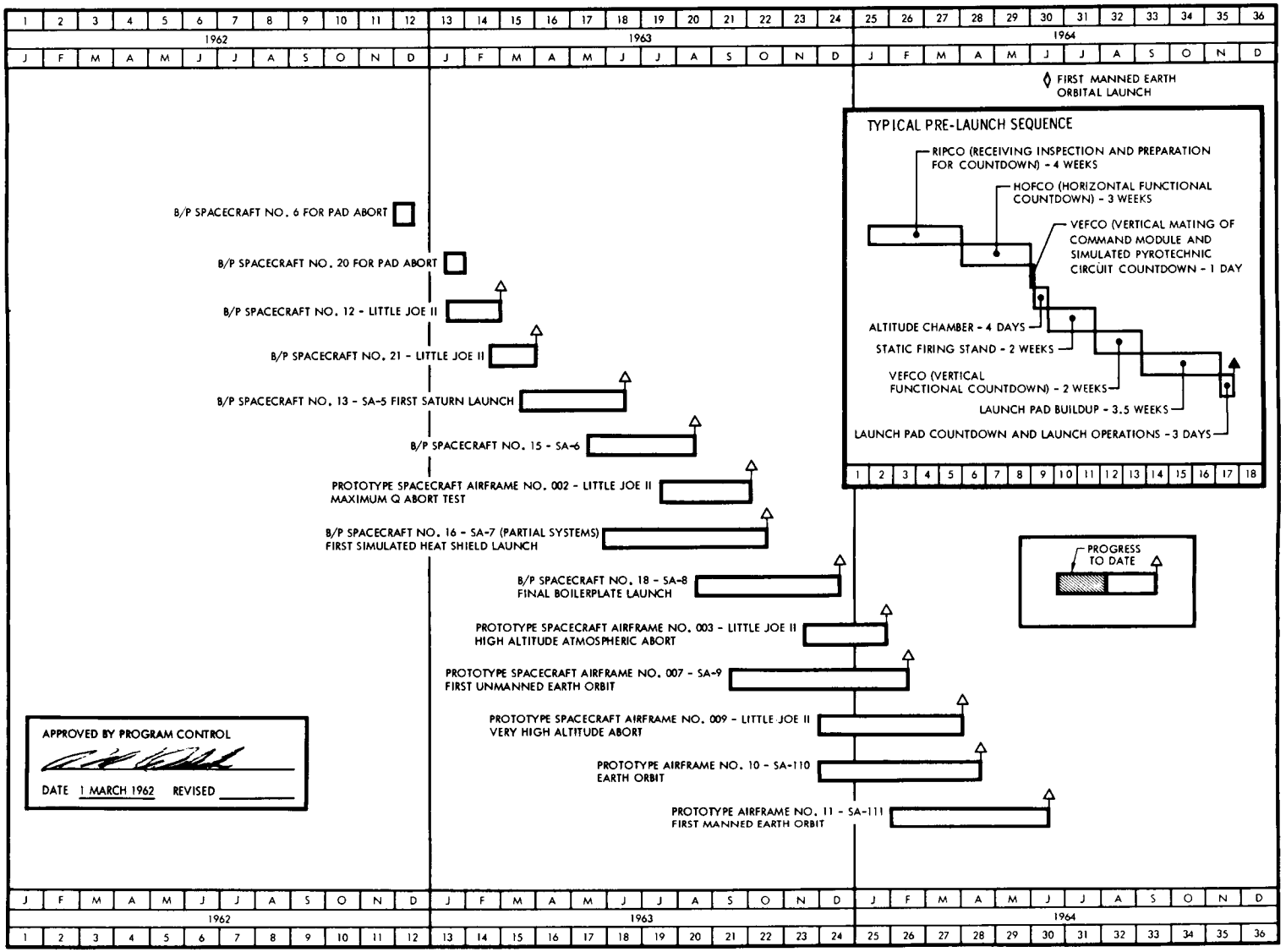

Figure 19. General Order 7127 - Prelaunch and Launch Operations - AMR

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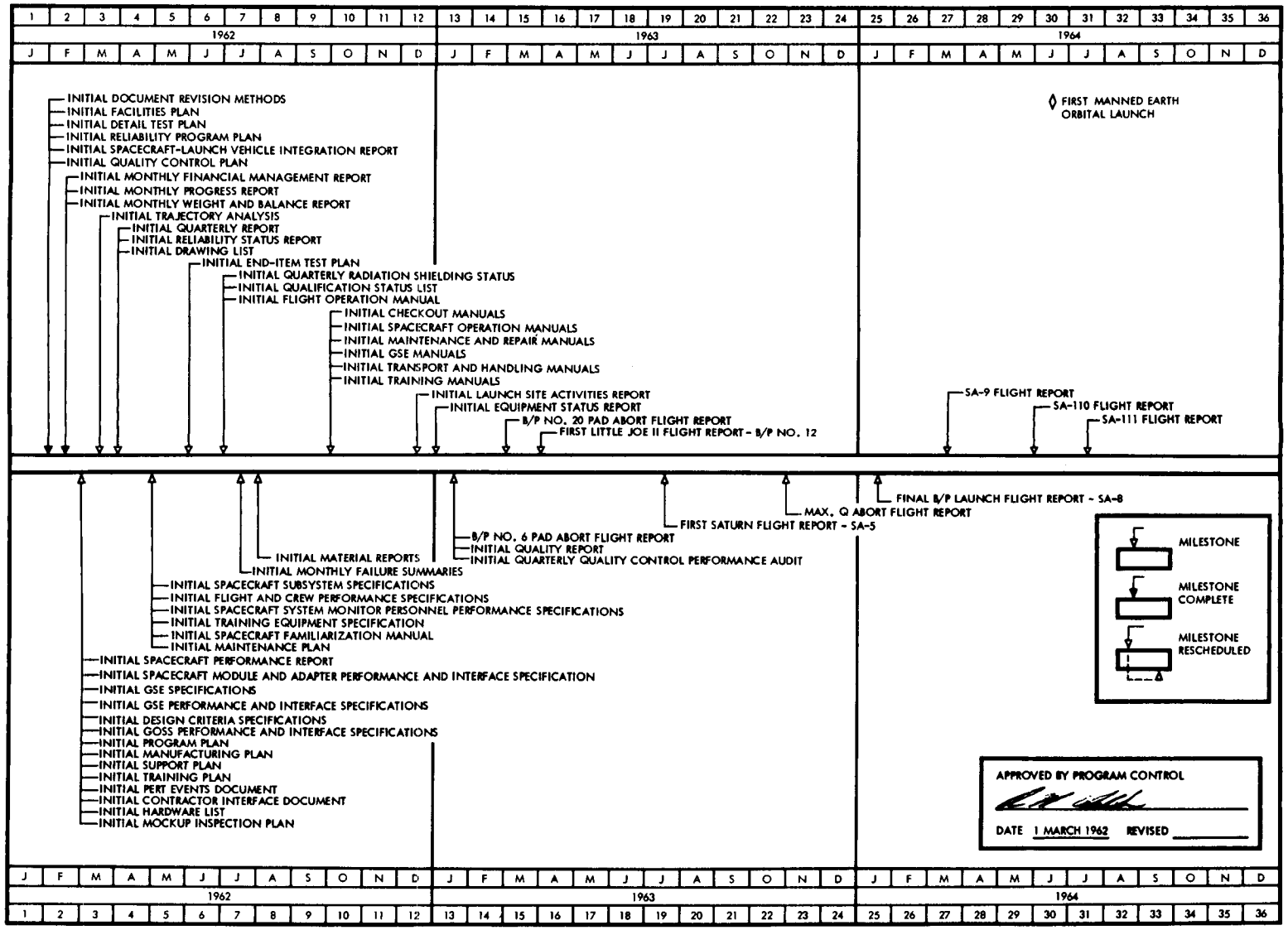

Figure 20. General Order 7128 - Documentation

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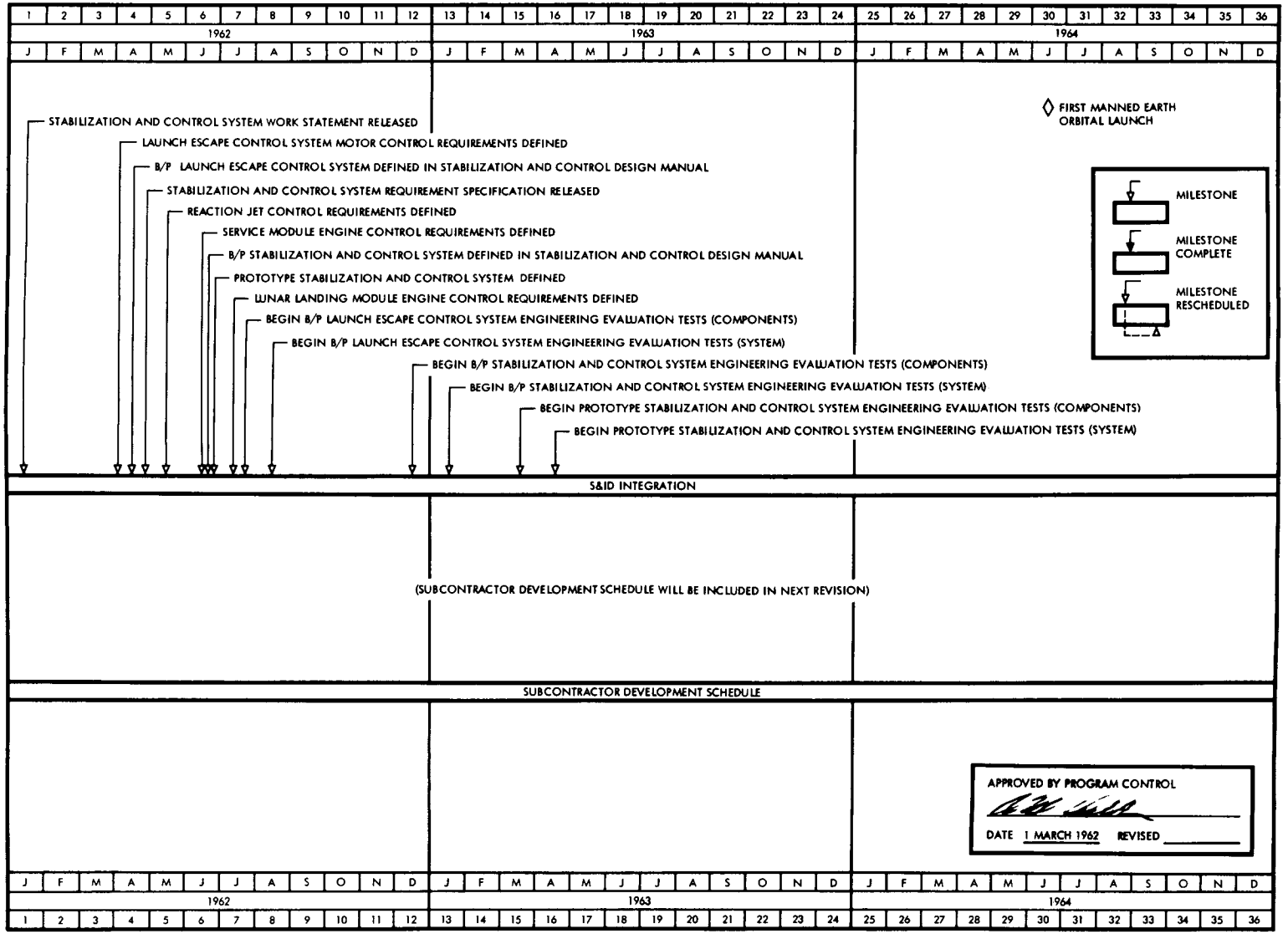

Figure 21. General Order 7130 - Stabilization and Control

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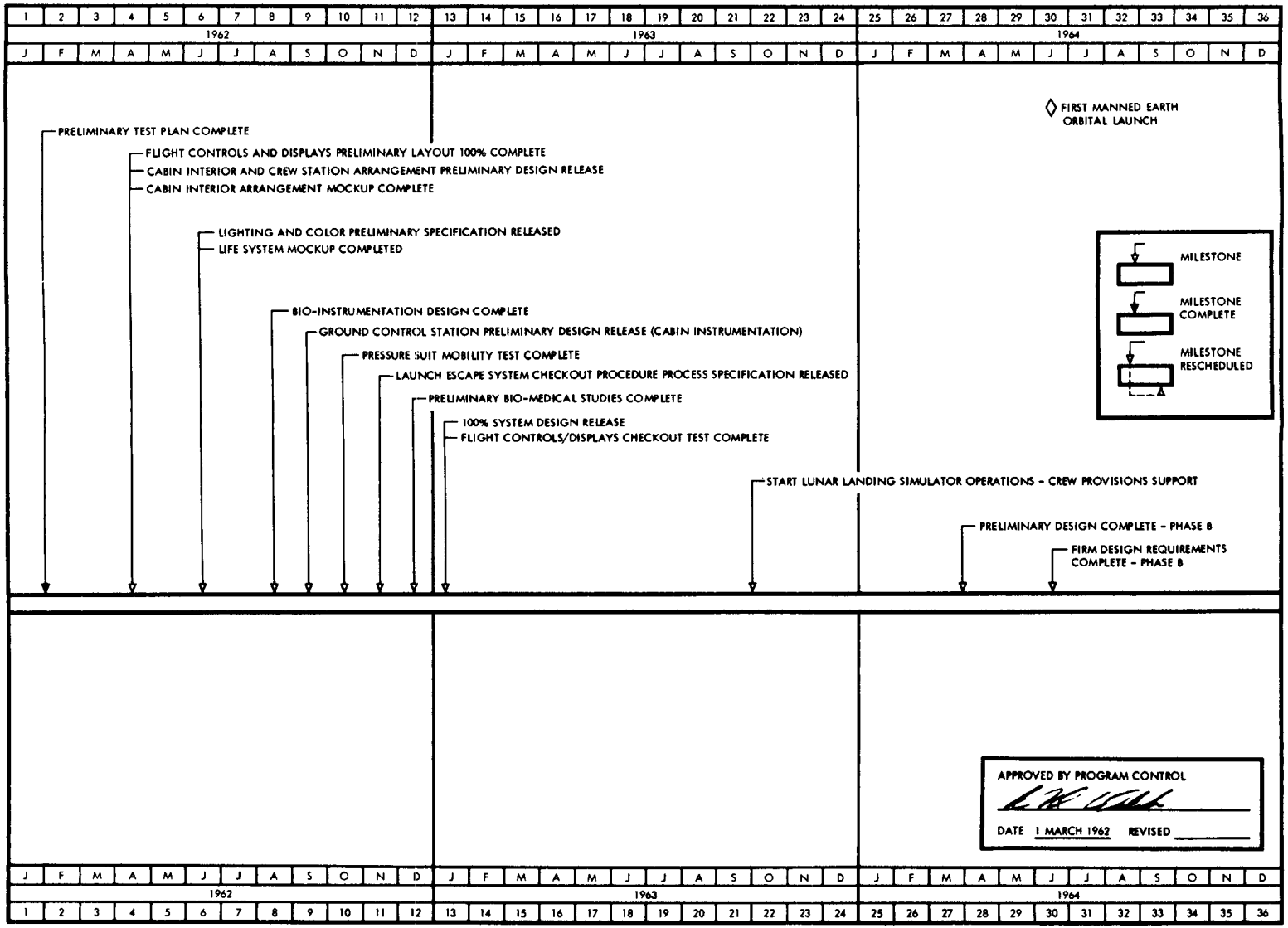

Figure 22. General Order 7131 - Crew Provisions

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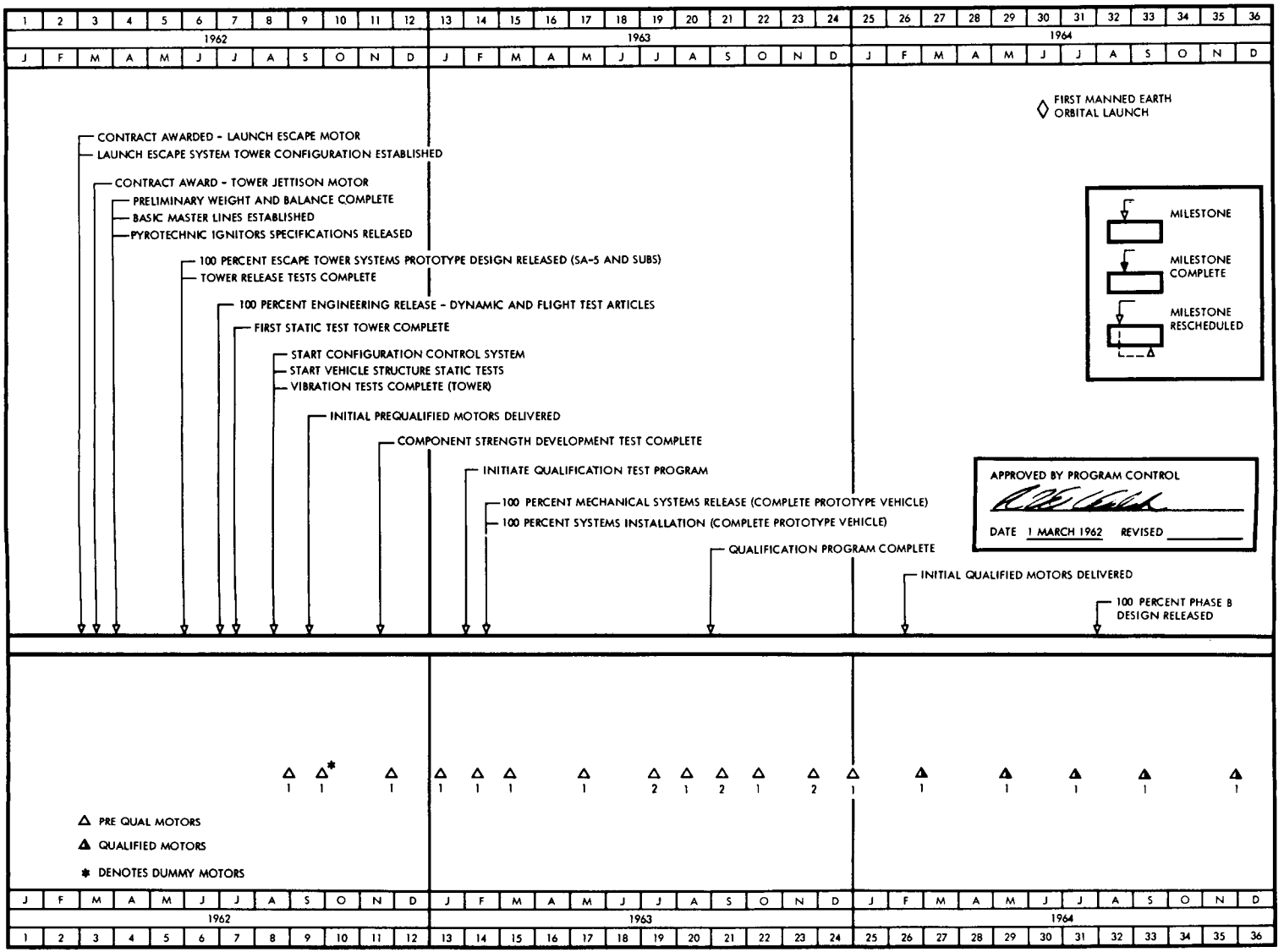

Figure 23. General Order 7132 - Launch Escape Subsystem

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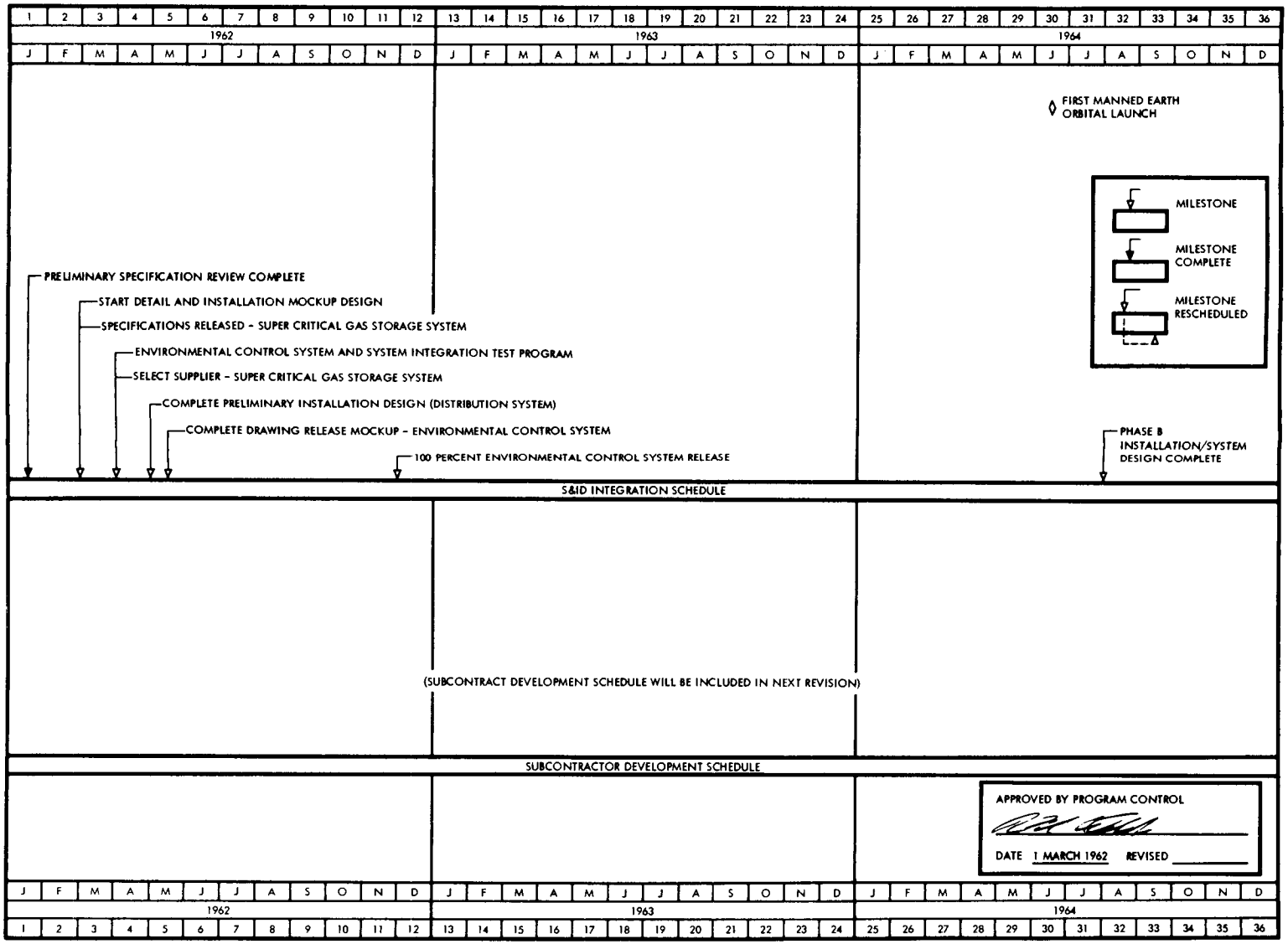

Figure 24. General Order 7133 - Environmental Control Subsystem

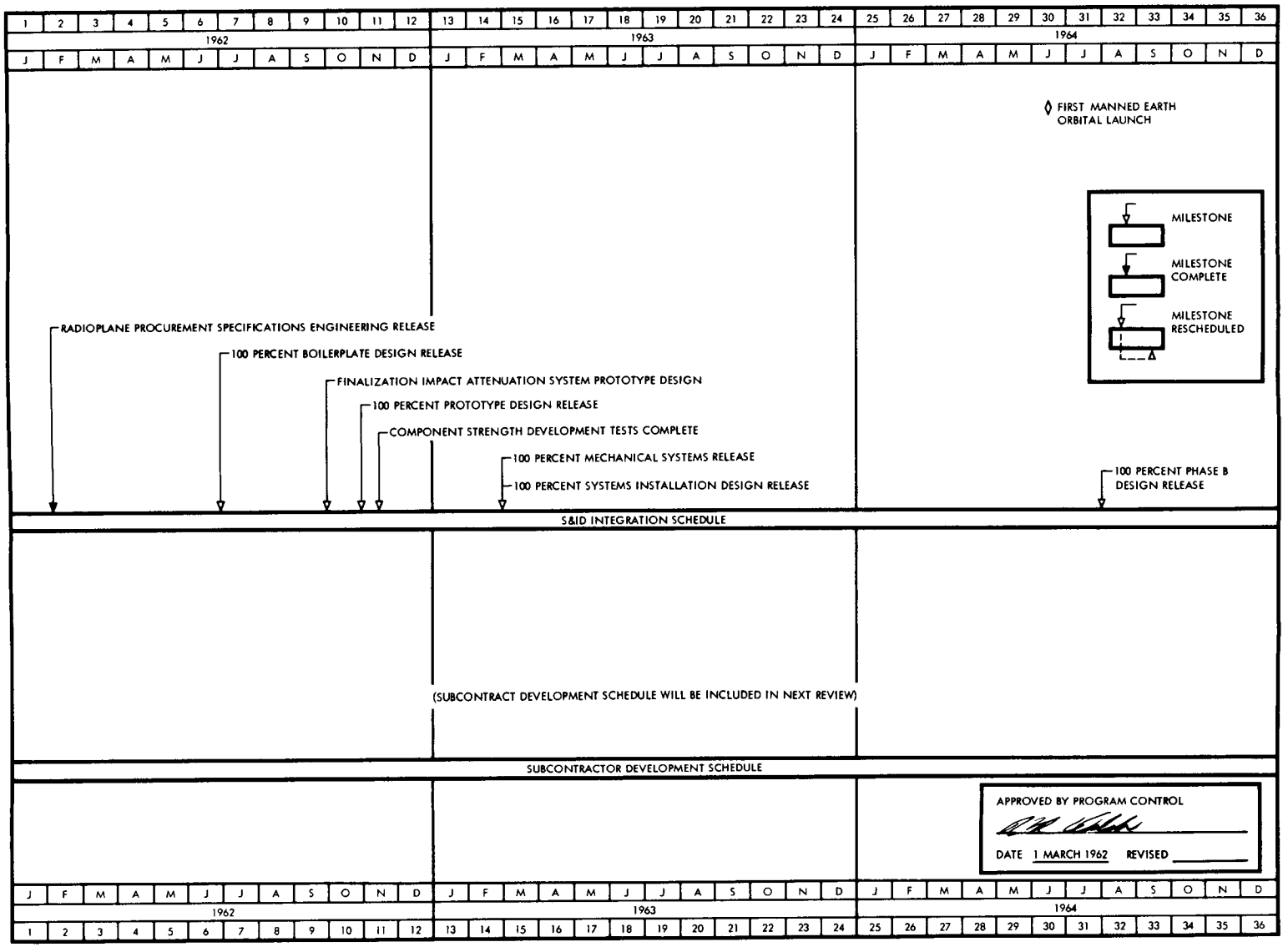

Figure 25. General Order 7134 - Earth Landing Subsystem

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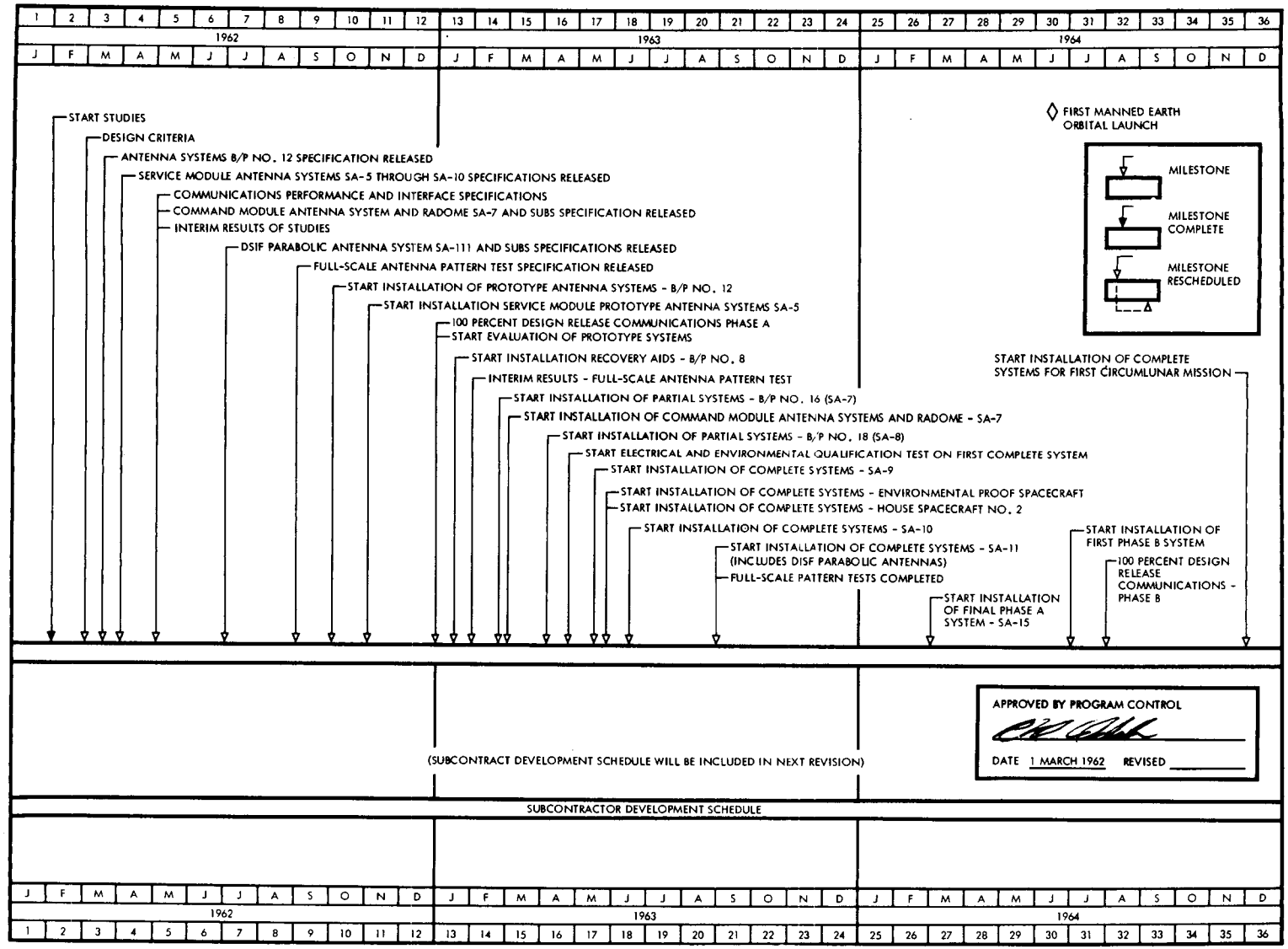

Figure 26. General Order 7135 - Communication Subsystem

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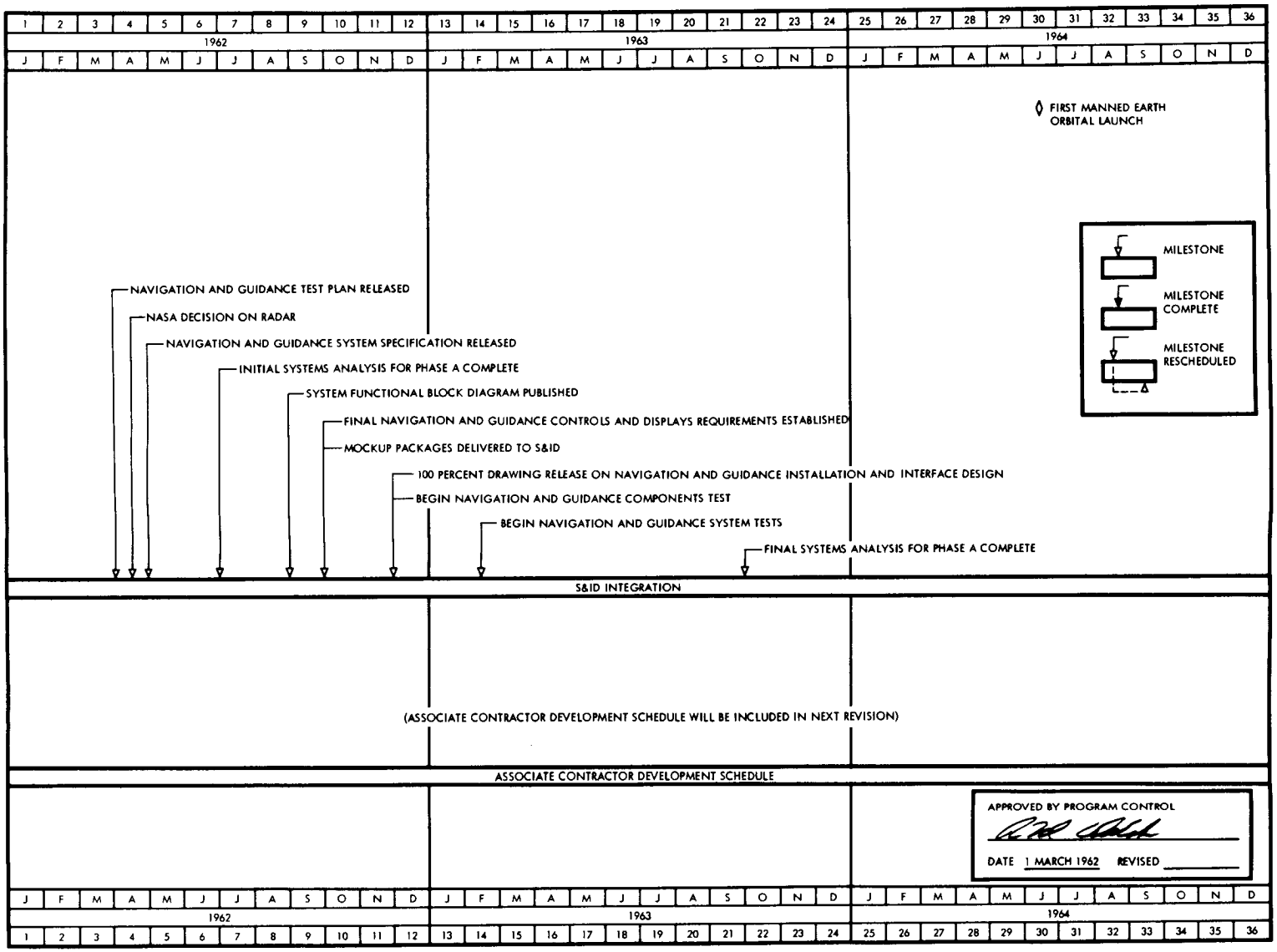

Figure 27. General Order 7136 - Navigation and Guidance Integration

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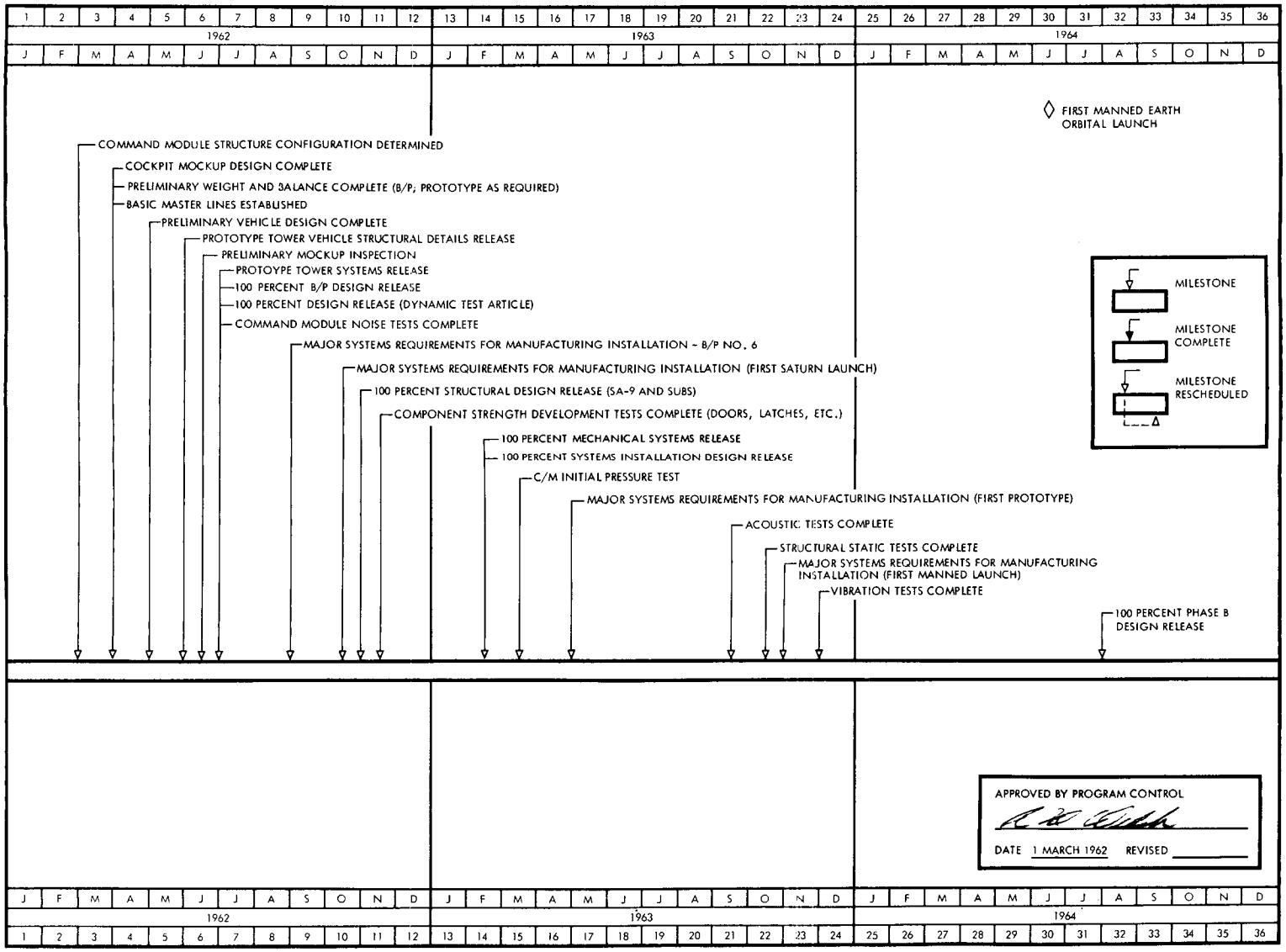

Figure 28. General Order 7137 - Command Module Structure and Subsystem Installation

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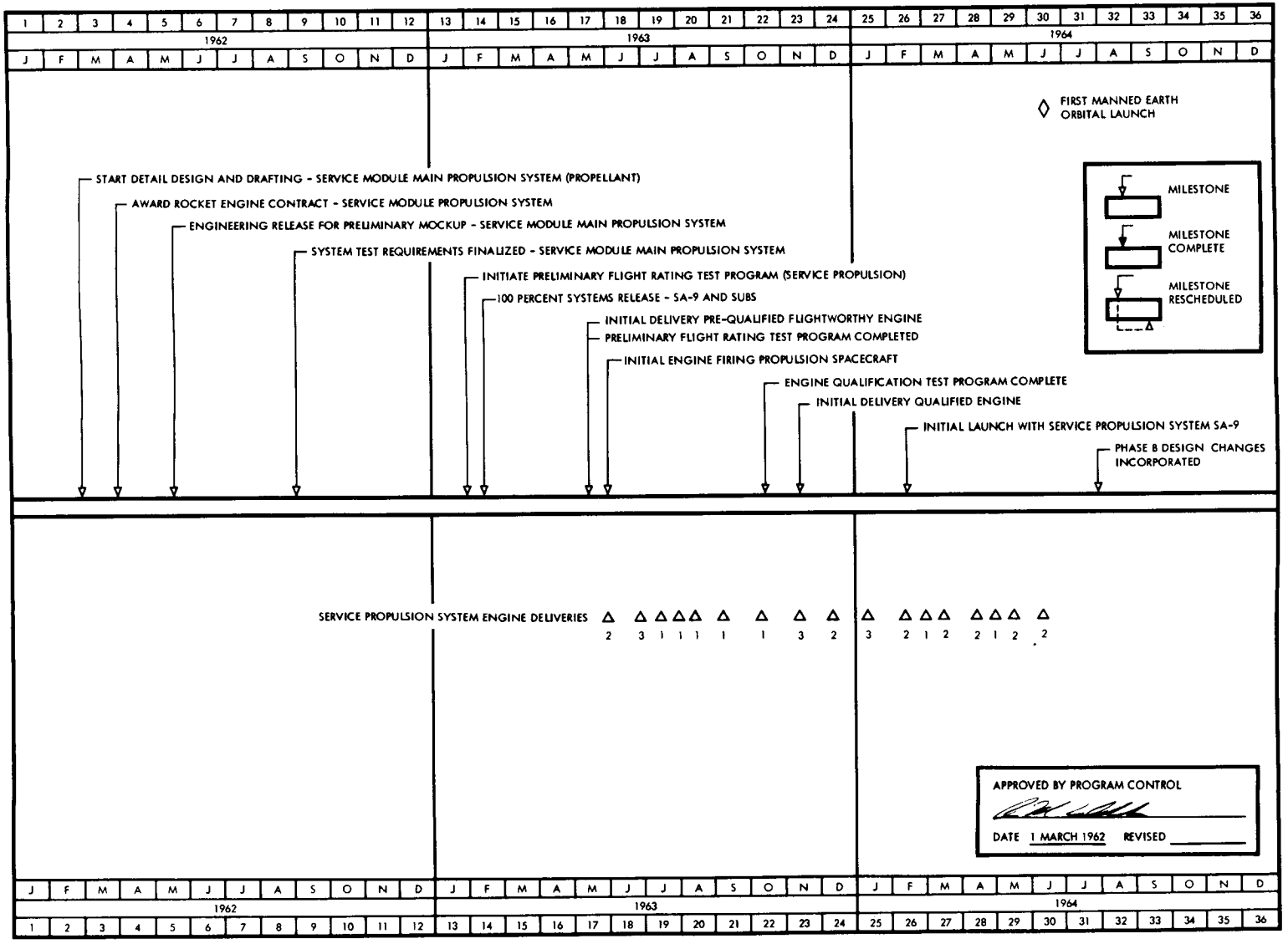

Figure 29. General Order 7138 - Service Propulsion Subsystem

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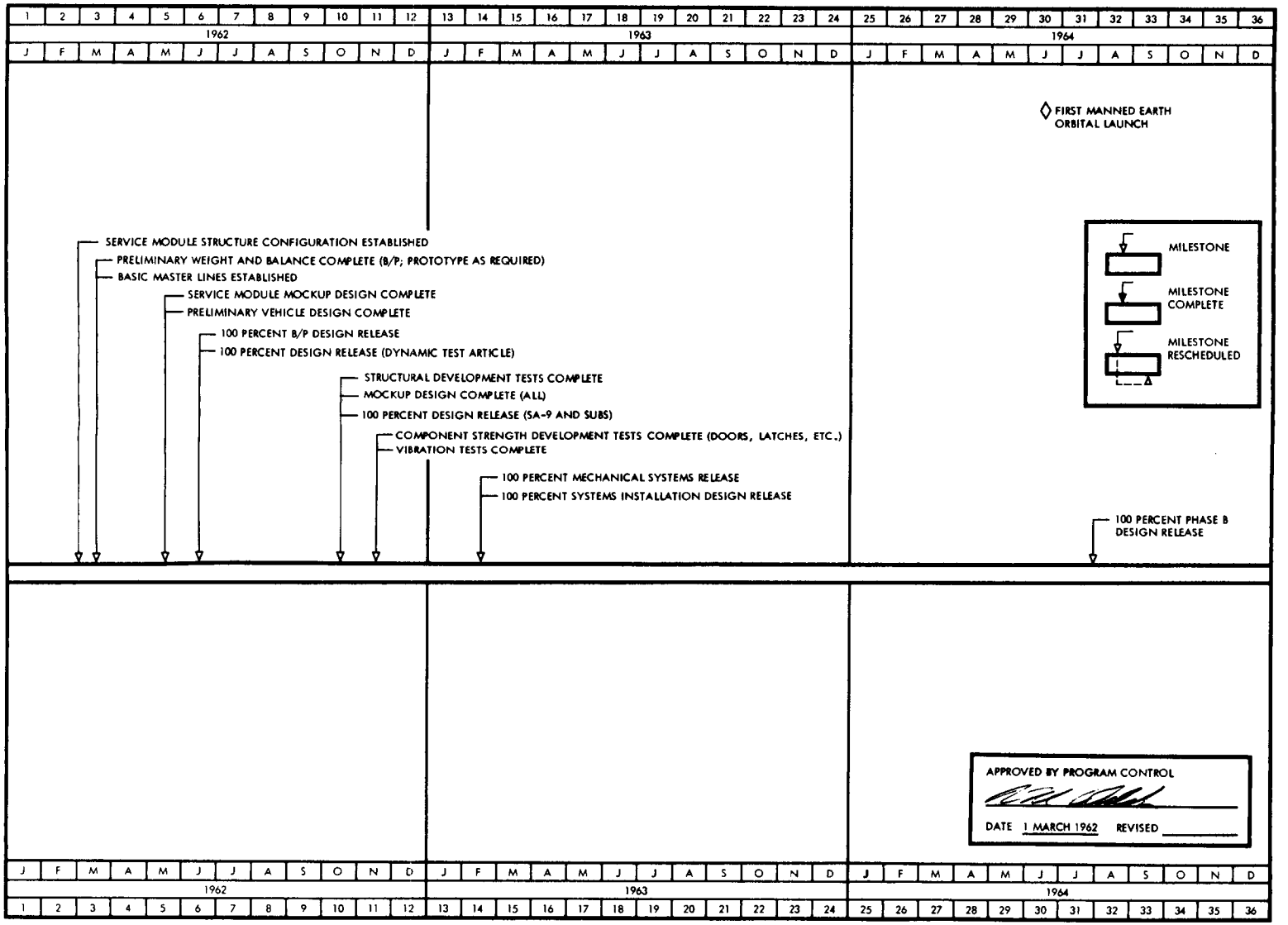

Figure 30. General Order 7139 - Service Module Structure and Subsystem Installation

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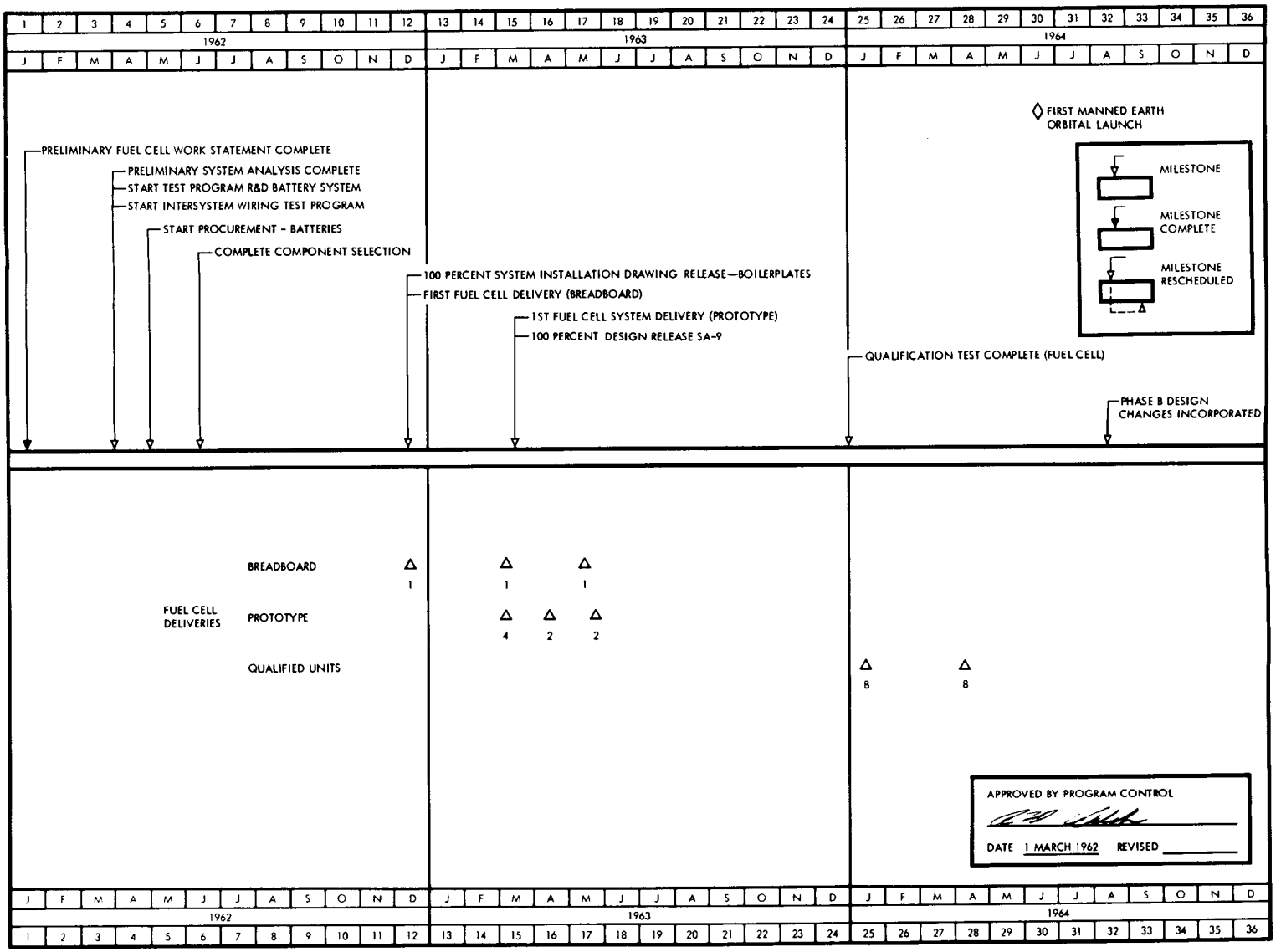

Figure 31. General Order 7140 - Electrical Power Subsystem

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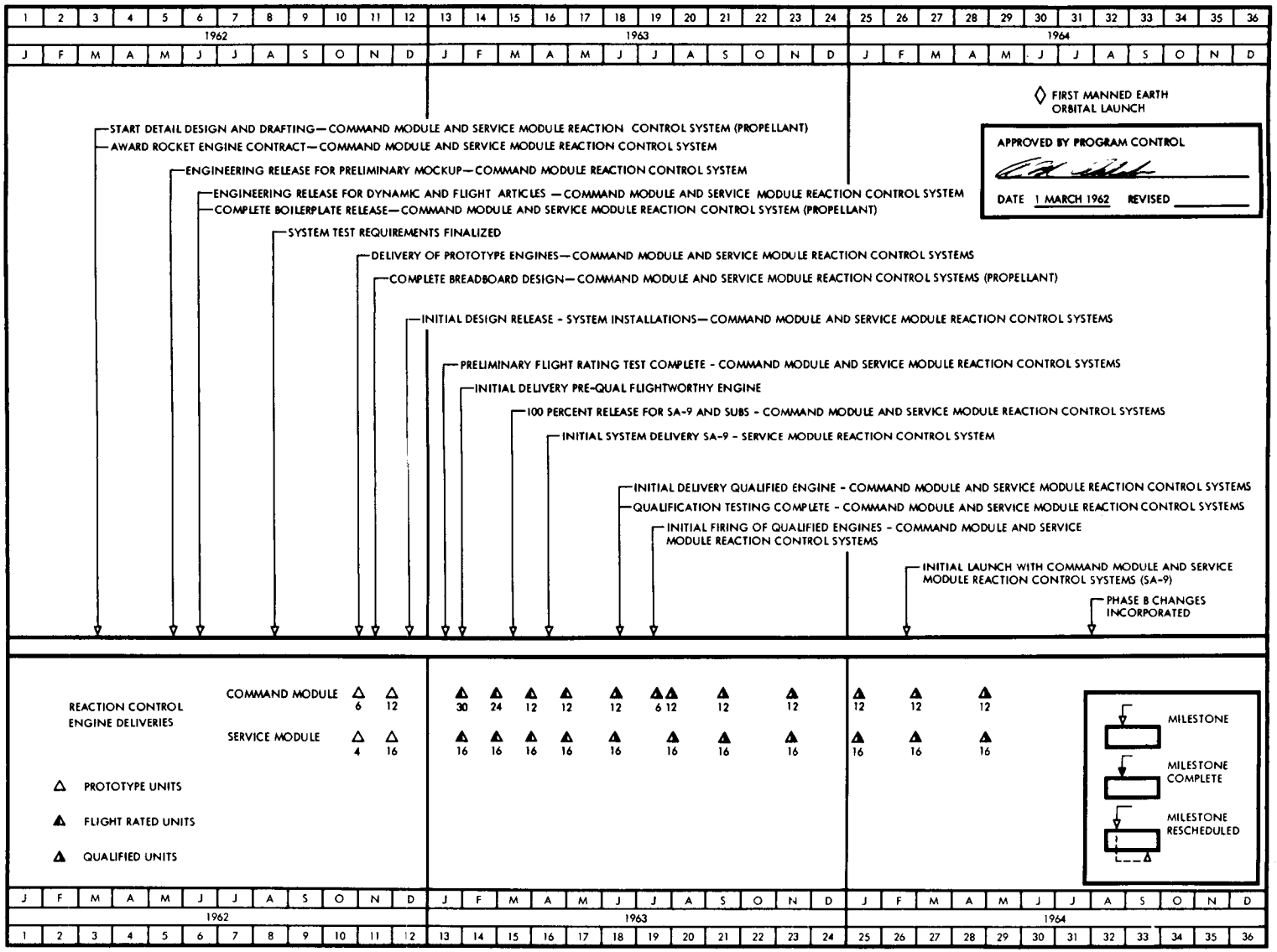

Figure 32. General Order 7141 - Reaction Control

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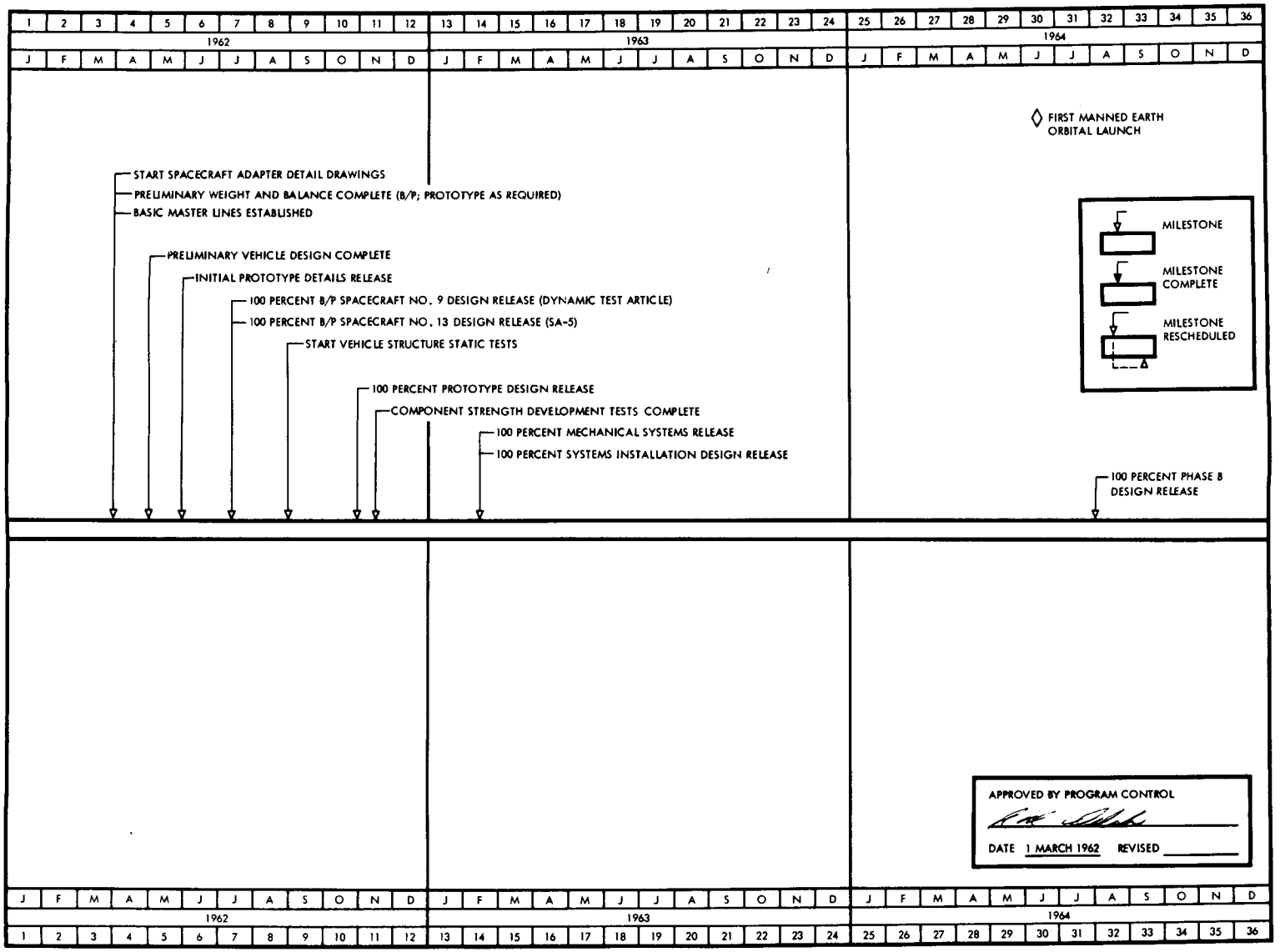

Figure 33. General Order 7142 - Spacecraft Adapter Design, Fabrication, and Assembly

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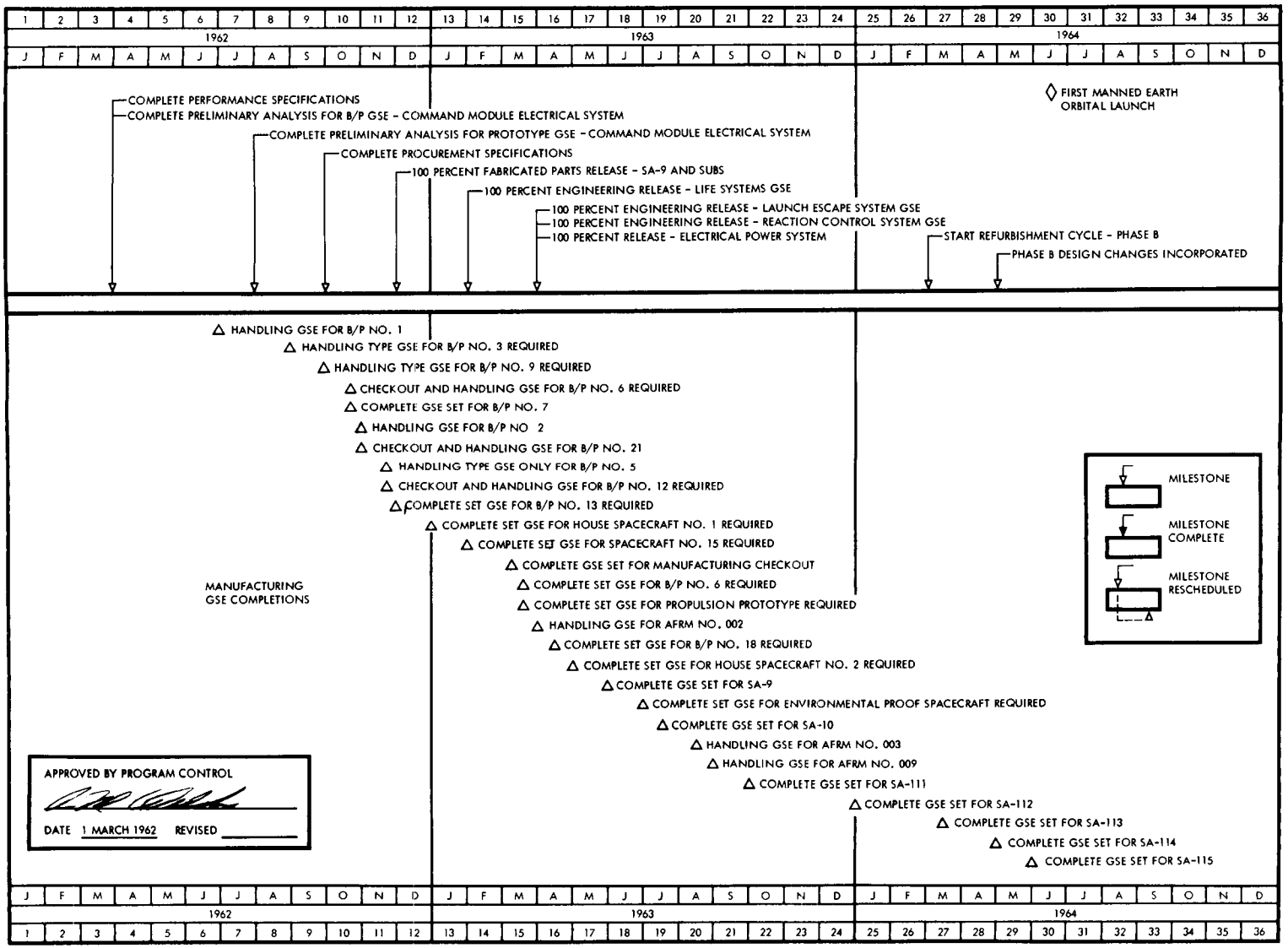

Figure 34. General Order 7143 - Command Module GSE

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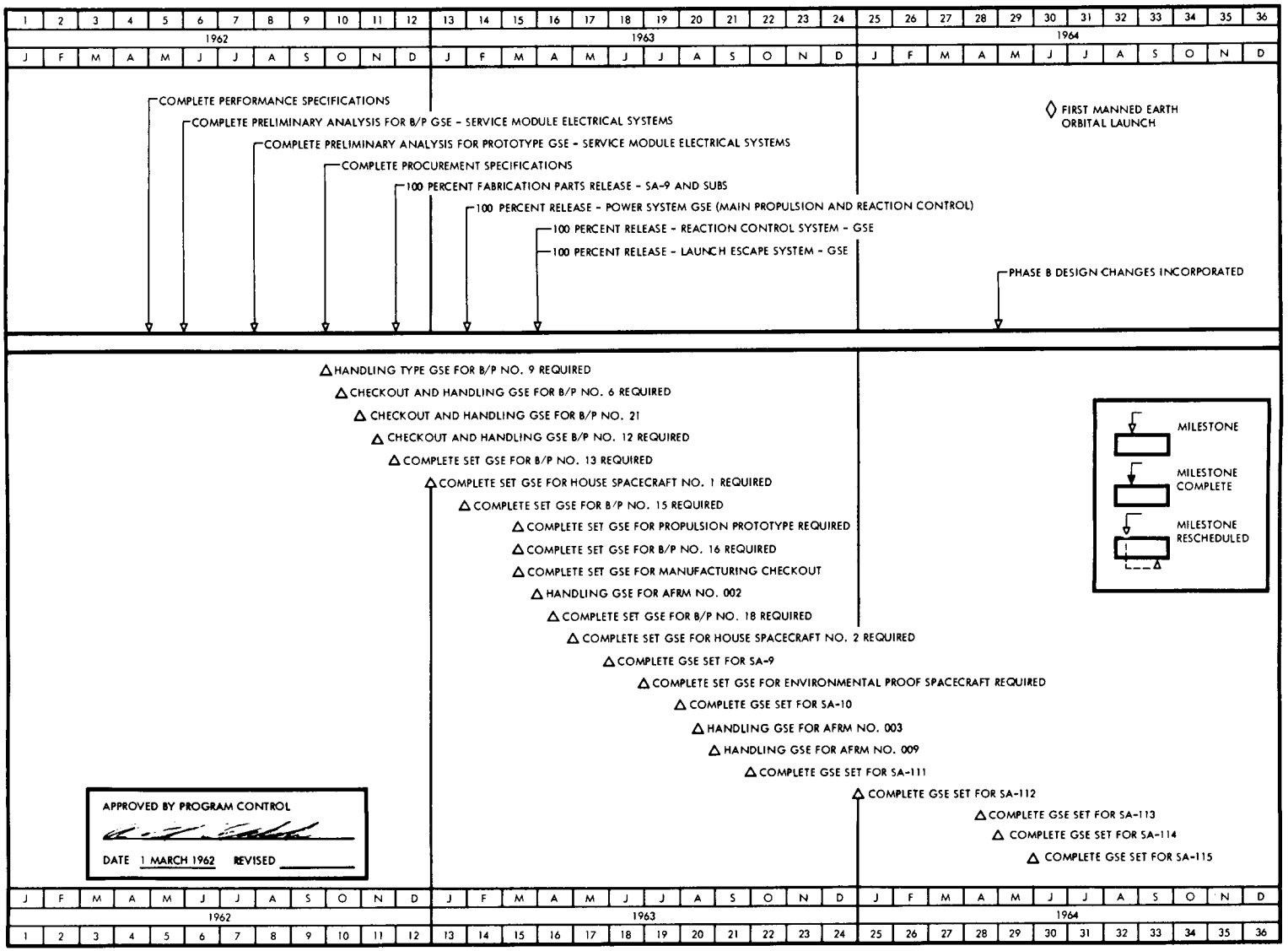

Figure 35. General Order 7144 - Service Module GSE

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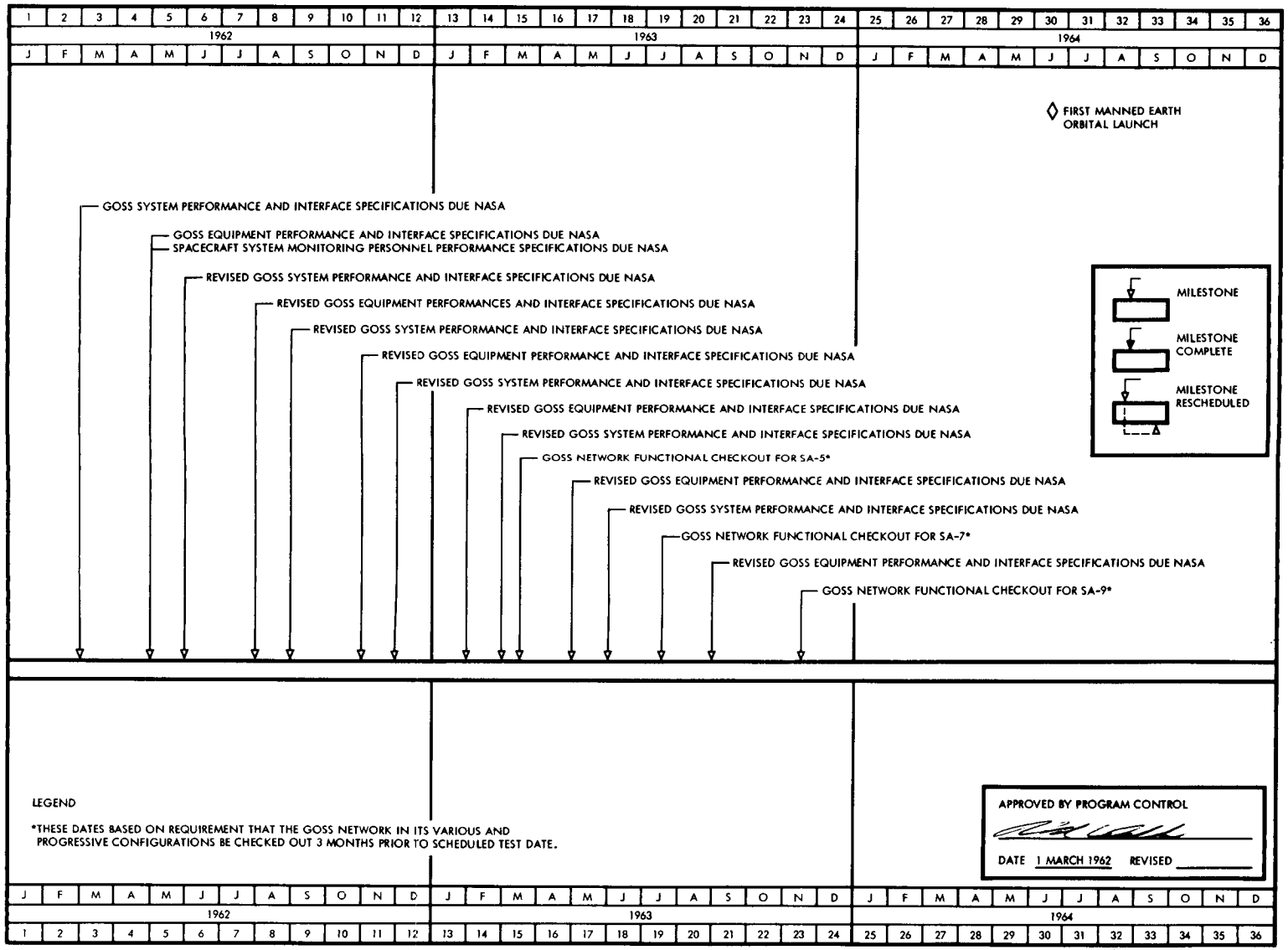

Figure 36. General Order 7145 - Ground Operations Support System (GOSS)

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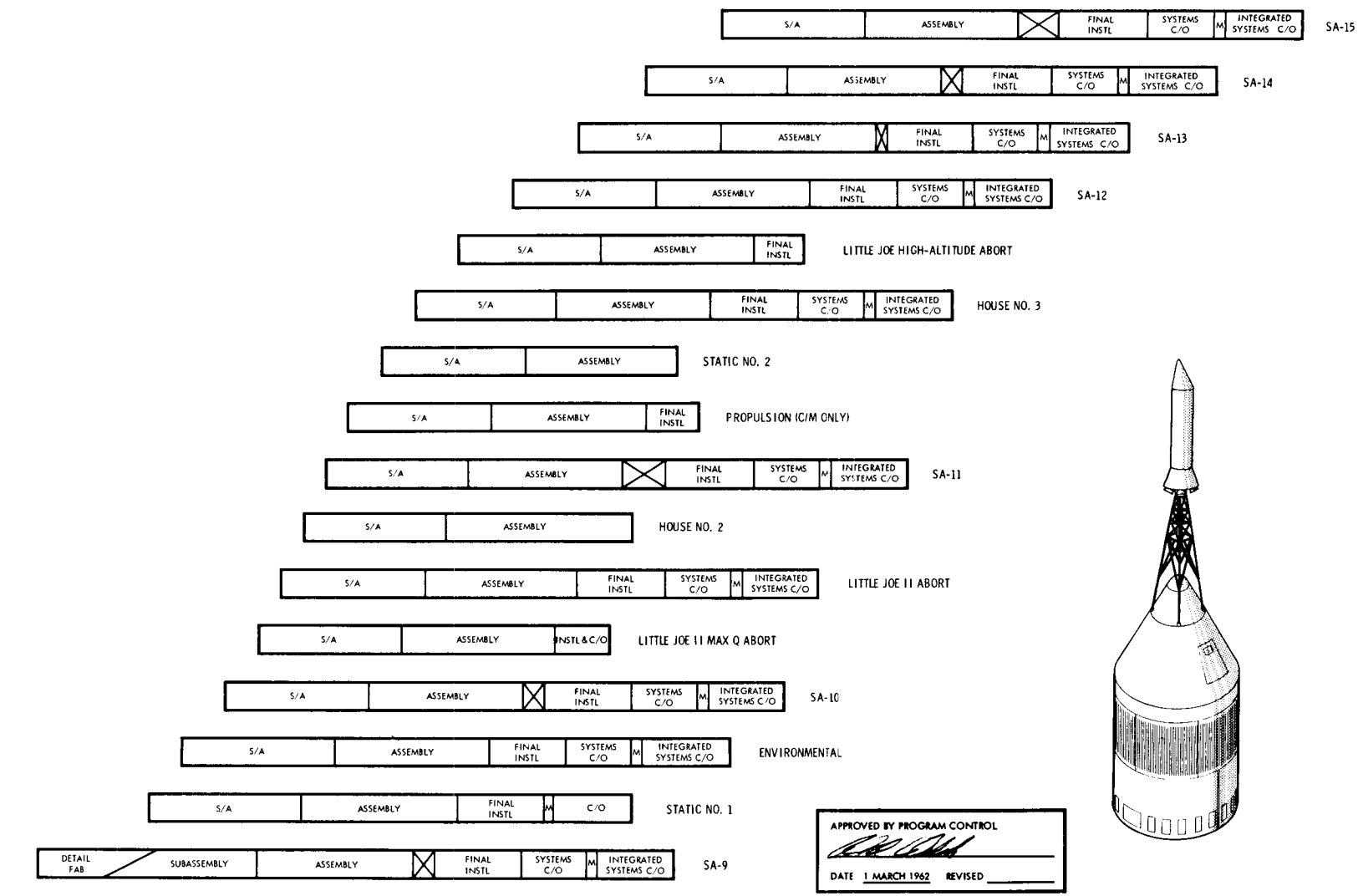

MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1962								1963												1964							
								MONTHLY				3	2	1	1	3		1	1		1		1		1	1	
								CUMULATIVE				3	5	6	7	10		11	12		13		14		15	16	

Figure 43. Apollo Preliminary Prototype Manufacturing Schedule

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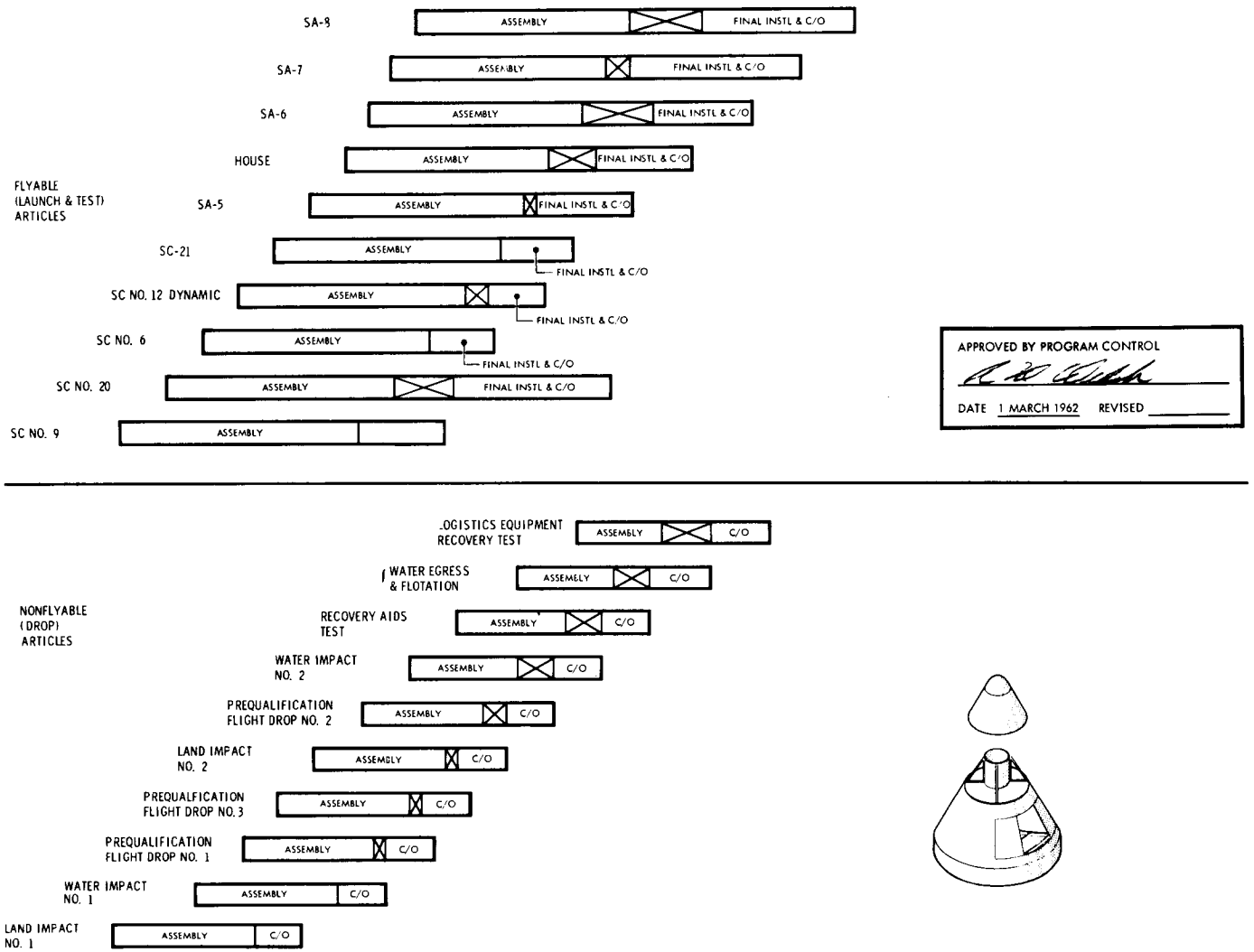

Figure 44. Apollo Preliminary Boilerplate Manufacturing Schedule

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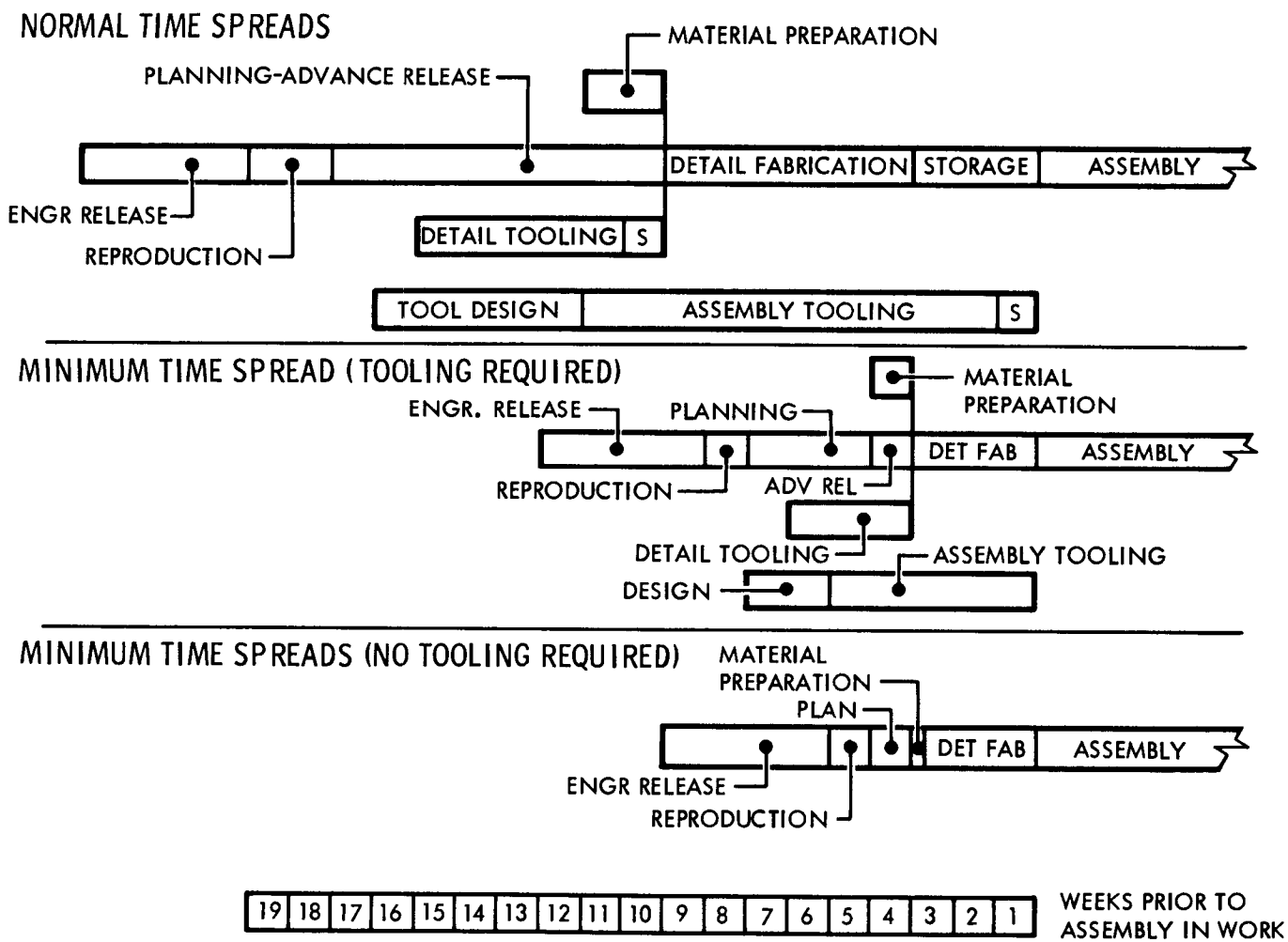

Figure 45. Manufacturing Time Spreads From Release to Assembly

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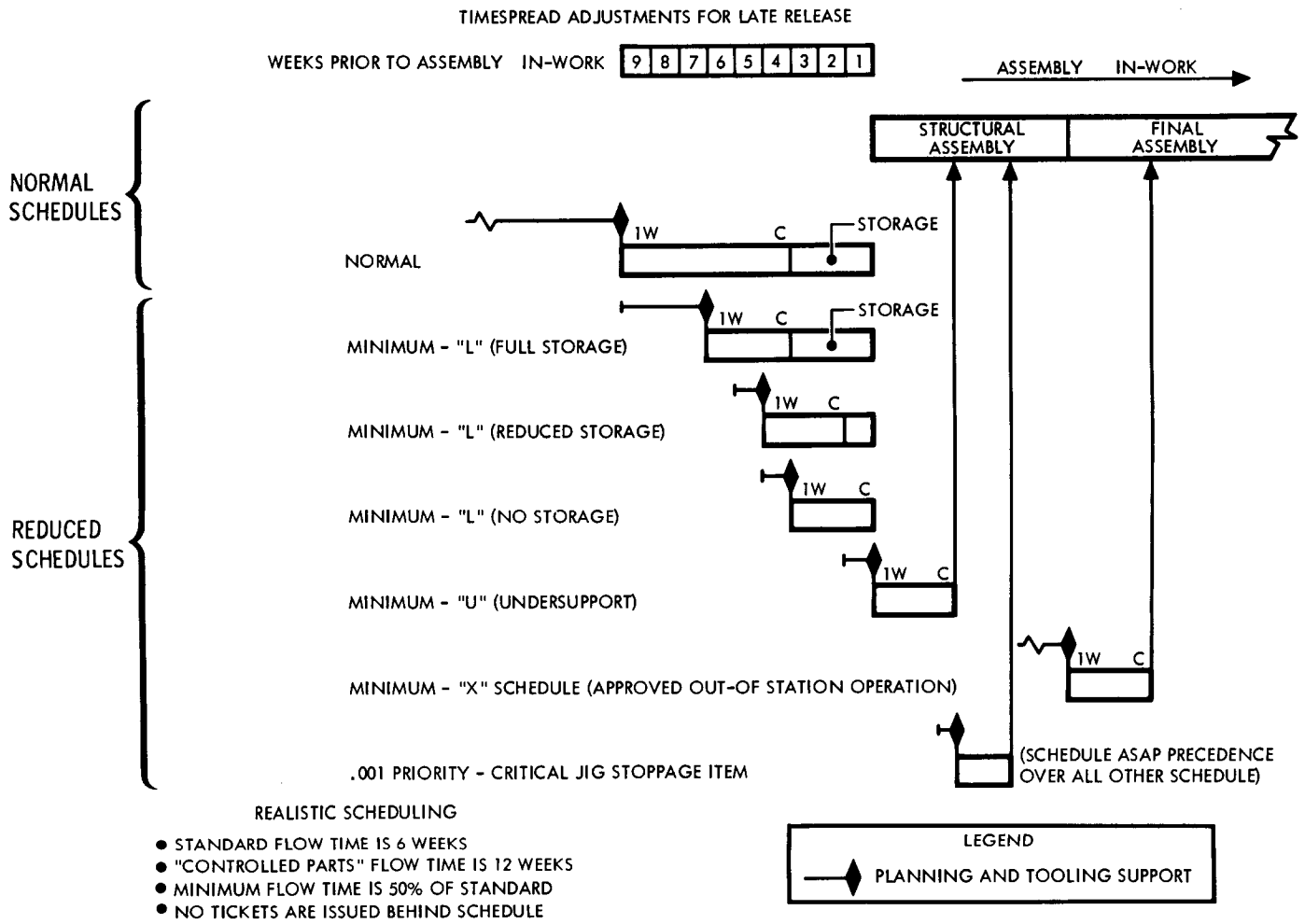

Figure 46. Detail Parts Scheduling Policy

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PRELIMINARY TECHNICAL DEVELOPMENT PLAN

The Technical Development Plan contained in this issue of the Program Plan represents the first month's effort toward evolving the engineering steps required in the development of the Apollo spacecraft. Recognizing the preliminary nature of this initial Technical Development Plan, action has already been initiated to prepare a revised and expanded plan, which will be submitted in the next issue of the Apollo Program Plan and which will reflect the detailed engineering development approach now being defined for each of the major systems and engineering tasks as defined in the Work Statement.

INTRODUCTION

The Apollo is a complex multiphase program with both firm and tentative facets (Figure 47). This technical development plan encompasses a firm plan for Phase A development through manned flight operations with SA-111, and tentative plans for Phase A completion and for Phases B and C. Firm activities also include preparation of requirements for the GOSS, LLPM, Navigation and Guidance, and analyses of the overall mission to determine the optimum techniques for lunar mission operations.

For planning purposes, missions with SA-112 through SA-115, have been included in Phase A, the C-5 booster has been chosen as launch vehicle for lunar missions, and the LLPM has been selected as the means of placing the Apollo spacecraft and astronauts on the moon. With these ground rules, an integrated Apollo/LLPM development plan has been prepared for Phases B and C (Figure 47).

Phase A is compatible with the Phase B and C plans. Present Phase A firm planning includes the effort necessary to prepare an LLPM concept and general configuration to support NASA in the preparation of a preliminary specification for the LLPM. The program integration effort required to coordinate with the LLPM contractor would be included in Phase B.

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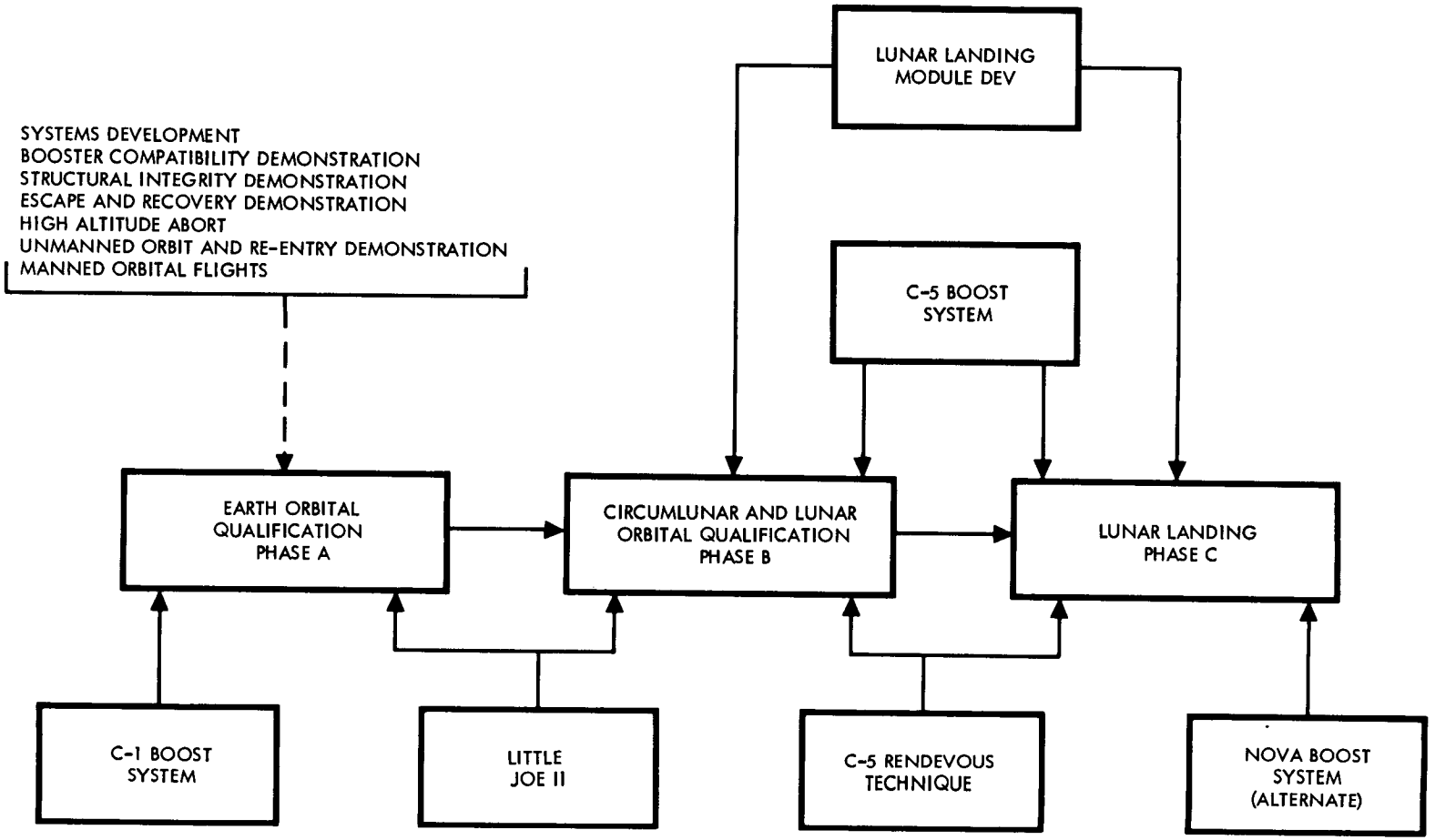

Figure 47. Apollo Development Plan

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Phase A

The Phase A Apollo spacecraft will be designed for the ultimate mission of lunar landing and return. Phase A missions will, however, be limited to manned, low-altitude earth-orbital flights up to two weeks' duration; and, to unmanned re-entry flight from super-orbital velocities. The major effort during the first portion of this phase - approximately the first year - will emphasize (1) study, research, and development testing leading to the definition of comprehensive design and operational criteria, (2) engineering tests, analyses, and mockups verifying the technical approach chosen, and (3) manufacture of "test" spacecraft and long lead-time articles. The specific objectives of Phase A are:

1. Qualification - Qualification of systems to be used in subsequent mission phases within the constraints of the earth-orbital environment or during re-entry from super-orbital velocities.

2. Crew Reaction - Study of physiological and psychological reactions and the capabilities of spacecraft crews under extended periods in the space environment.

3. Operational Experience - Development of flight and ground operational techniques and equipment for space flight of extended periods.

4. Experimental Investigation - Conduct of experimental investigations as needed to acquire information for the lunar missions.

To accomplish these objectives, a series of 20 mockups and 36 boilerplate and prototype test spacecraft will be used. (Tables 3, 4, and 5 identify these articles and their use; Table 2 summarizes the test objectives of the program. These four tables will be found at the end of this Technical Development Plan section.)

The early boilerplate drop tests and abort and launch escape firings on Little Joe II will lead to orbital tests with SA-5 and SA-6, then to super-orbital

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flights from SA-7 and SA-8. Complete, unmanned earth-orbital missions will then be conducted with prototype spacecraft boosted by SA-9 and SA-10. Launch vehicles SA-111 through 115 will then complete Phase A with a series of manned orbital shots. These will provide the much needed data regarding long-term manned space operations, biomedical effects, and crew-spacecraft environmental compatibility and performance. This information will be incorporated into Phase B and Phase C mission formulation and system design and operation.

Phase B

The Phase B plan consists of circumlunar and lunar orbital flights to develop further the spacecraft through operational test, and to allow close-up reconnaissance of the lunar surface for scientific and technological purposes. Phase B will overlap Phase A as Phase C will overlap Phase B (Figure 48). This will provide an uninterrupted flight schedule to accumulate a large amount of data on spaceflight and solution of problems involved in interplanetary flight, return, and re-entry to the earth with manned spacecraft. To accomplish this objective, flights with the C-5 booster will be made for high-speed re-entry to verify the capability of re-entry and recovery with an unmanned spacecraft before man is injected into the program. A lunar landing propulsion module will be developed and tested by an associate contractor to provide propulsion for landing on the lunar surface in Phase C. During Phase B, the LLPM will be fully developed and integrated into the Apollo spacecraft. This will be accomplished by a series of earth orbital rendezvous, circumlunar, lunar orbital, and possibly low lunar approach flights. The first Apollo LLPM flight is planned for August 1965.

Phase C

This phase covers manned lunar landing, limited observation and exploration in the landing area, and safe return to the earth. The launch vehicle will be the C-5 booster or, as an alternate, the NOVA when it is available. Missions as programmed will be accomplished by earth orbit rendezvous of two C-5 Saturn payloads. The first lunar landing is scheduled for September 1966.

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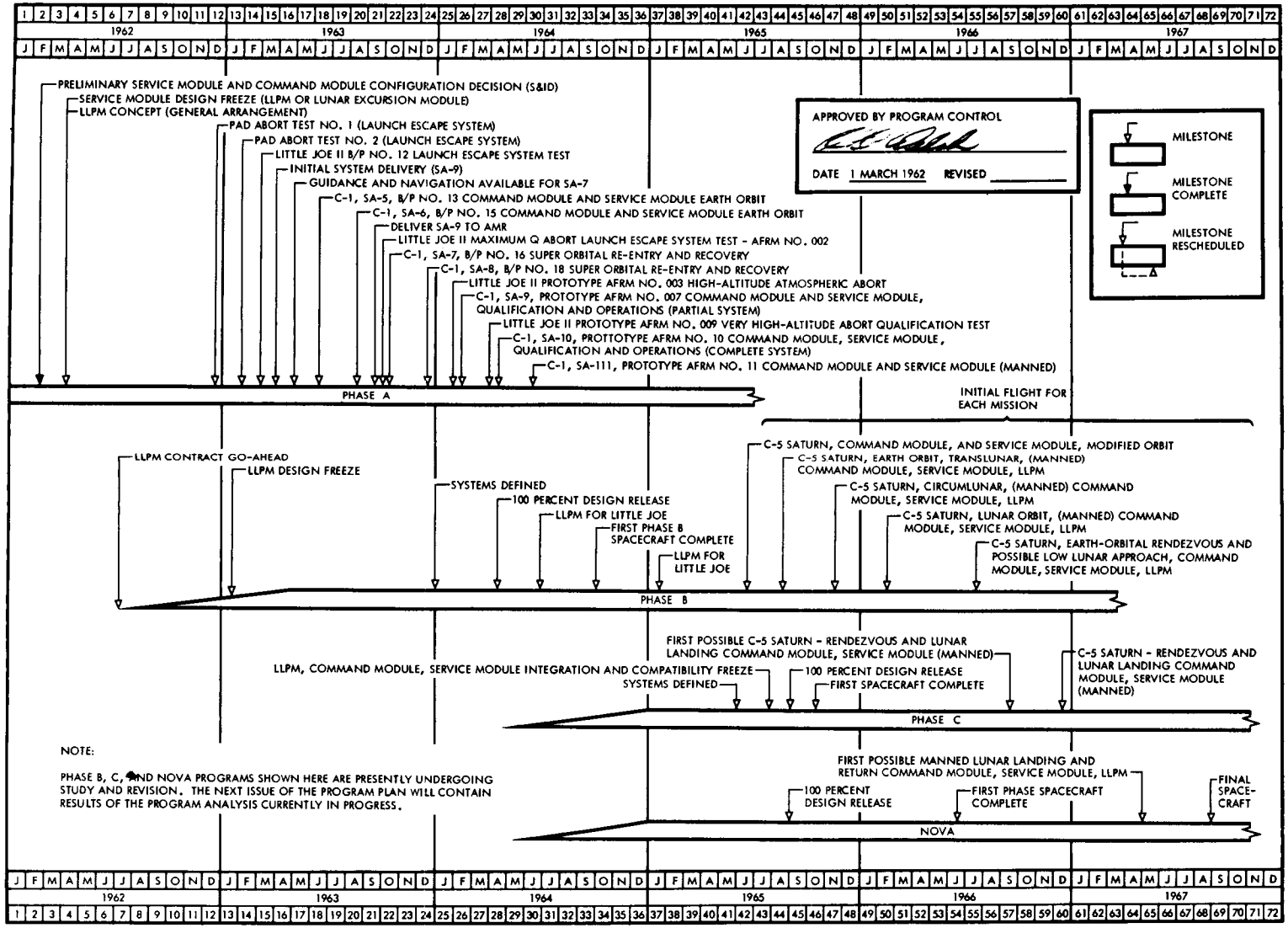

Figure 48. Apollo Development Schedule

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DEVELOPMENT APPROACH AND CRITICAL PROBLEMS

A sound development approach, based on a thorough understanding of the problem, is required in order to translate systems engineering into successful hardware. Only after this development approach has been established can a valid, detailed operating plan be provided. The development must start with the following fundamental principles:

Hardware Orientation

The predominant problem is the successful design and constuction of diverse and complex components and the integration of these components into successful systems. It is within this framework of hardware orientation that the development plan is presented. The problems to be anticipated will not lie in the area of errors in concept; they will occur in the many small details of mechanization and in the day-to-day process of translating design into working systems. It is only with the actual hardware that these detail problems can be discovered. Therefore, hardware must be brought into being as early in the program as possible. From this follows a basic concept: Maximize hardware experience by forcing design releases at the earliest feasible dates. This assumes, of course, the ability to respond to changes and flexibility of the design in tolerating changes.

Integrated Man-Machine Design

Two critical problems of design and provisioning exist with regard to the integrated man-machine design. One of these is radiation protection. The development of techniques for accurately predicting dosage levels and the development of means for protecting the crew against high levels of radiation are vital to the success of the mission. The other critical problem is weightlessness. The long period of low gravity and weightlessness is outside the present range of human experience. The data which will be necessary to accurately predict detail design criteria may not be available from previous manned flights in time to greatly influence the spacecraft configuration.

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Dual Approach

The Apollo schedule is not a safe and comfortable schedule. Technical risks will be assumed, but they will be minimized by providing for dual approaches in critical areas. The development approach will be based upon a technical plan designed to anticipate and identify problems. The program will not succeed unless technical difficulties can be predicted in time to effect alternate courses of action. PERT techniques for schedule planning and control provide a part of the capability, but this alone is not enough. A graphic portrayal of the critical problem areas and planned modes of resolution must be established and maintained. The critical problem summary shown in Table 1 lists some of the development problems that have been identified. Strict adherence to this approach of identifying problem areas before — not after — they have delayed the schedule is planned for the life of the program.

Table 1. Critical Problem Summary

Problem Source	Problem Area	Approach
Radiation.	Prediction and preventation of radiation to crew.	Research program for accurately predicting solar flares. Distribution of equipment in the command module. Provision for radiation protection garments.
Weightlessness.	Prevention of crew illness resulting from weightless environment.	Research in the use of medication and psychological methods of training and conditioning.
	Man body stabilization and restraints.	Provision of special tools, restraint devices, and aids during space operations. Provision of personal reaction devices during space exterior operations.

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Table 1. Critical Problem Summary (Continued)

Problem Source	Problem Area	Approach
Radome for command module antennas.	Selection of adequate radome material for space environment.	Material investigation is currently in progress.
Stabilization and Control System; Guidance and Control System.	Incompatibility between existing hardware deliveries and confidence level requirements as inferred from existing flight test schedule and subcontractor and associate contractor capabilities.	A joint resolution of the problem between NASA and S&ID is requested.
Command module display panels.	Definition of integration methods for requirements from MIT and S&ID.	Establishment of a working committee of representatives from NASA, S&ID, and MIT to meet regularly. Request MIT liaison personnel on display panel to be stationed at S&ID.
In-Flight Test System.	Definition of integration methods for requirements from MIT and S&ID.	Establishment of a working committee of representatives from NASA, S&ID, and MIT to meet regularly.
Desired scope of the reliability-qualification test plan.	Apparent incompatibility of program schedule and proposed test plan.	Problem is presently under investigation.
Implementation in the utilization of Minuteman parts.	Requirement of controls, procedures, facilities, documentation and procurement approaches.	This implementation is presently under investigation.

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Table 1. Critical Problem Summary (Continued)

Problem Source	Problem Area	Approach
Command module heat shield.	Convective and radiative heat transfer during atmosphere re-entry.	Wind-tunnel test program supported by extensive analyses.
	Selection of ablative material.	Selection of heat shield vendors and extensive in-house testing and analyses.
Spacecraft Environmental Control System.	Heat transfer through structure in orbit, on the lunar surface, and after re-entry.	Analysis of structural heat transfer and heat transfer tests on structural composites.
Service module radiator.	Design requirements for radiator.	Extensive IBM analyses and vacuum chamber tests.
Command module nuclear shielding.	Effectiveness of structure, equipment, and special shields in maintaining allowable interior dose rates.	IBM analysis of shielding afforded by structure, equipment, tests and particle accelerators.
Cold plate thermal analysis.	Effects of contact resistance, electrical heat loads, and environmental heat loads.	Analog and IBM computer analysis.

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Table 1. Critical Problem Summary (Continued)

Problem Source	Problem Area	Approach
Noxious Gases	Determination of noxious gas producers and the respective contaminator; e.g., sealants, lubricants, wastes, ozone. Instrumentation for noxious gas determination.	Materials analysis and manufacturing technique review. Testing program for off-conditions.
Space Radiator (Electrical and Environmental Control)	Optimization of weight and reliability.	Investigation of heat pump utilization and movable radiator.
Service module propulsion system.	Operating life requirements are greater than previously demonstrated.	Extending the state-of-the-art for ablative chambers.
Electrical fuel cell.	First major application of a fuel cell system. Extremely short development time is required by the Apollo schedule. Water separation at zero g environment.	Back-up program for a different type of fuel cell.
Power System	Valve operating reliability for manned space flight.	Redundancy in design.

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Table 1. Critical Problem Summary (Continued)

Problem Source	Problem Area	Approach
Guidance and Navigation System	The technical development of the guidance and navigation system as outlined by MIT will not provide sufficient time for proper systems integration by S&ID to assure compatibility between systems.	NASA action is requested.
Lunar Landing System	Characteristics of the lunar surface are not well known, i.e., slope, bearing pressure, coefficient of friction.	Definition dependent upon NASA research (Ranger, Surveyor, etc.).
GSE	Overall concept and extent of automation for combined systems checkout have not been resolved.	S&ID is preparing proposal concepts subject to approval and go-ahead by NASA.
Micrometeorite space environment.	Establishment of confidence levels in the space environment for micrometeorite frequency, density, and size.	Additional astronomical studies and actual satellite meteorite measurement tests.
	Analytical and experimental determination of penetration mechanics.	Development of better hypervelocity guns and analytical techniques.

Table 1. Critical Problem Summary (Continued)

Problem Source	Problem Area	Approach
Radiation	Determination of a more realistic model environment.	Additional basic physical measurement programs by utilization of satellites and balloons.
	Severity of secondary radiation design.	Additional experimentation on secondary radiation.
Re-entry heating	Simulating re-entry environment on large structural components during ground tests.	Further studies on such heat sources as ramjet engines, rocket engines, and radiant heat facilities.
Hatch and access openings through the heat protection system.	Development of effective heat shield enclosures.	Design and testing of a door that will be effective against heat leakage.
Command module leakage.	Maintain below critical leakage rate.	Develop highly reliable sealant techniques, and leakage rate tests.
Recovery system pre-qualification flight drop	Timely availability of test aircraft for Radioplane.	Solution under study.
Command module heat shield		

SYSTEMS DEVELOPMENT

Systems development for the Apollo spacecraft will include three parallel phases of activity, as illustrated by the flow diagram of Figure 49. The rigorous reliability and schedule requirements inherent in the Apollo program require high-integrity systems design and fabrication. To achieve the required overall reliability, the systems design engineering procedure depicted in Figure must be augmented by concurrent detailed mockup investigations, while substantiating each step of the design process by successively more exhaustive development testing, leading up to manned orbital demonstration flights. This parallel approach will utilize twenty mockups to support the systems engineering and pre-development testing leading to a firm configuration. Upon determination of firm system requirements, systems analysis will be run and a firm design selected for verification by use of breadboard test articles. Twenty boilerplate articles will be utilized to test individual components, systems, and configurations to verify that the selected system design provides the maximum reliability, safety, and mission performance within the program development period. In support of these S&ID efforts, subcontractors and associate contractors will also be conducting supplementary pre-development, development, and pre-qualification test to assure that the required systems objectives have been met.

Section II of this volume presents the detail schedule of design engineering events and work accomplishment initially planned for the spacecraft program.

Figure 50 represents the required development and qualification test schedule in summary form. A detailed description of the Apollo Test Plan is contained in Space and Information Systems Division report SID 62-109, dated 22 January 1962, entitled "Preliminary Test Plan - Research and Development for Project Apollo Spacecraft."

The systems development approach adopted by S&ID requires that the prototype spacecraft designed in Phase A of the Apollo program be acceptable for qualifying and assuring the reliability required of the spacecraft for manned orbital missions in Phase B. The manned orbital, lunar, and lunar-orbital

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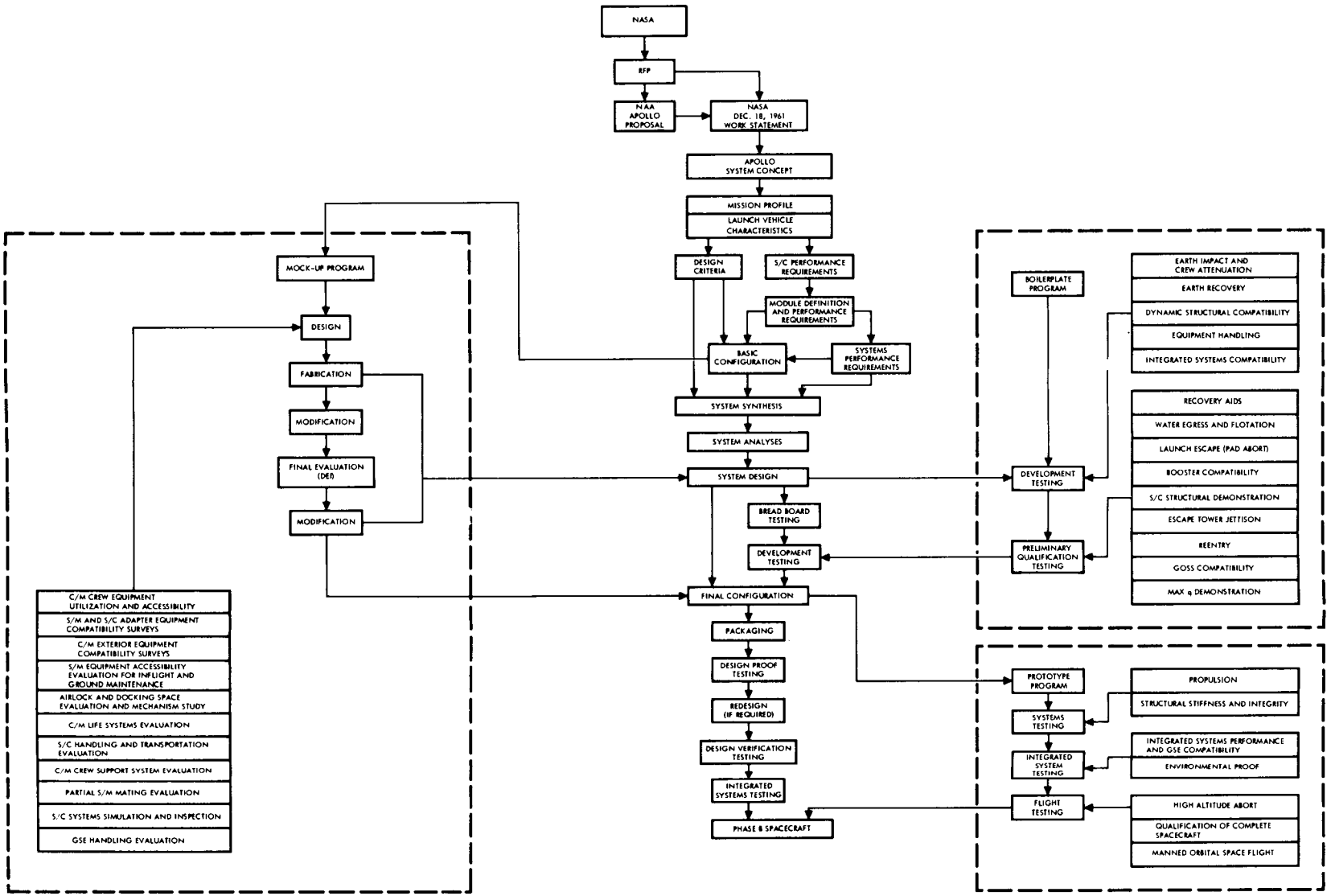

Figure 49. Apollo Development Schematic

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missions of Phase B will in turn qualify the spacecraft and demonstrate its required reliability for manned rendezvous lunar landing and return to be accomplished in Phase C.

System Requirements and Mission Analyses

The development of the Apollo spacecraft is not the development of concepts or theories. It is the development of hardware. Designs will be based upon existing technologies to meet the desired schedule, and dependency upon breakthrough will be avoided. Effort devoted solely to improving performance cannot be tolerated.

The Apollo is a manned system, and a man will be utilized to the utmost for decision and control. Two concepts fundamental to the proposed development stem from this fact. First, the spacecraft design will take full advantage of the capabilities of the crew. Man is the primary mode in the system, and other elements are supplemental. Second, manned flights will be introduced as early as possible in the program. This is probably the most important single aspect of the proposed approach. In the overall knowledge of man-in-space, experience tells us that little may be gained from unmanned flights.

In the development of the Apollo spacecraft, it has been necessary to establish several very important design criteria. Radiation and its effect on the spacecraft as well as its effect on the crew are a major design development problem. General studies have been started to determine the radiation levels and a means of accurately measuring the dosage level. Data obtained through Surveyor and Ranger unmanned spacecraft lunar flights and landing will provide the Apollo project with valuable information. Another major design criterion is the effect of weightlessness on the crew members. Little is known of the effect of weightlessness at the present time, but as manned spacecraft such as Mercury and other manned spacecraft orbit the earth, more knowledge will be gained and applied to the Apollo program. Preliminary aerodynamic test programs have been run to develop the design criteria for the Apollo configuration. There have

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been many studies started to further develop the spacecraft systems and subsystems. These design studies are listed in the following tabulation.

1. Determination of crew complement to be used for various mission segments, including possible redetermination of the basic flight crew.

2. Service module configuration selection, with particular attention paid to confirmation of preliminary choice of single-engine configuration.

3. Selection of command module aerodynamic slope and size.

4. Selection of integrated or modular concept for re-entry.

5. Determination of lunar landing configuration, with particular attention paid to basic decision of whether or not to use the shuttle method.

6. Development of lunar rendezvous methods, with particular reference to shuttle dispatch and rendezvous.

7. Selection of optimum lunar landing methods, trajectories, and control systems.

8. Selection of optimum shuttle configuration if such method is selected.

9. Comparison of earth rendezvous methods and their relationship to booster capabilities and availability.

10. Comparison of earth orbit and direct re-entry methods.

11. Comparison of parachute and parawing recovery methods.

12. Preparation of detailed logic analyses for use in analyzing all man and machine functions and operations and their interrelationships.

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13. Development of integrated abort system to encompass complete missions.

14. Determination of navigation and guidance concept.

15. Selection of radiation "model" for evaluation.

16. Selection of meteoroid distribution model for reference.

17. Determination of feasibility and desirability of creating an artificial g environment.

18. Development of optimum "space lab" capability.

19. Determination of fruitful areas for scientific space measurements.

Preliminary mission analyses have been run to determine crew functions such as inflight maintenance, piloting requirement, and data recording requirements. To support these mission analyses, a series of mockups of the crew compartment will be utilized with an analog computer and simulators to develop the crew equipment, systems, and functions, as well as verify the mission analyses. Information will be obtained from Mercury manned orbital flights to support the mission analyses and the simulator work. Continuing mission analyses are being made of earth recovery systems and abort systems for the pad just after launch and at any point in orbital, lunar, or cislunar flight. Preliminary mission analyses have been run on the type of equipment required to support such missions as a lunar landing and return. These preliminary analyses are the forerunners to the actual development of the Apollo spacecraft and the preparation of a development plan. Continuation of these preliminary mission analyses will provide more data for the design, manufacturing testing, and lunar flight of the Apollo spacecraft.

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FLIGHT TECHNOLOGY DEVELOPMENT

This program is designed to yield the basic aerodynamic data, stability and control information, and trajectory analysis and performance requirements necessary to support the earliest possible release of design. Initial theoretical analyses of aerodynamic and thermodynamic parameters will be verified by subsequent wind-tunnel testing. These studies will include the development of basic aerodynamic force and moment data to support the stability and control analysis and the measurement of pressure and force distribution which make up the air loads required for structural analysis.

Trajectory analysis and performance requirement studies will consist initially of determining methods and establishing automatic computing programs for simulating the basic equations of motion and the environmental and astrodynamic factors affecting the Apollo missions. Studies will be conducted to determine the potential performance and trajectories using various boost systems for the manned missions as well as for the special test vehicles. An evaluation will be made of the trajectory and performance requirements for mission abort from all flight modes. Propulsion system requirements in terms of mass ratio, thrust levels, burning times, and thrust controllability will be determined. Interaction effects of the guidance system, the mission trajectory, and the propulsion and energy management program will be studied. An error analysis for fuel requirements and the effect of error correlation factors will be conducted. Mission placards will be determined. Trajectories resulting from various system malfunctions will be determined.

Flight Dynamics studies will result in the compilation of a stability and control data manual for use in the design and analysis of the earth landing, launch escape, reaction control, and stabilization and control systems. Six-degree-of-freedom studies on digital and analog computers will be made for all flight phases to determine control requirements, thrust levels and response, and to evaluate the stability characteristics of the vehicle. Simulation studies will include man-in-the-loop whereby man's capability is analyzed, and optimum controls and

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displays are determined. A simulation study will be conducted prior to each flight to evaluate the combined dynamic effects of each system, and similar studies will be performed after the flights to correlate test data with theoretical analysis.

Wind Tunnel Tests

Successful development of the Apollo spacecraft demands accurate knowledge of the aerothermodynamic design data which can only be obtained through a well-conceived ground test program supplemented by suitable flight tests and theoretical analyses. The wind tunnel program outlined below uses private and government facilities to obtain design data in the following areas:

1. Static and dynamic stability of the launch escape system and the command module throughout re-entry and recovery including effects of heat shield asymmetric ablation.

2. Escape rocket motor jet effects on stability of the launch escape system.

3. Stability of the escape tower and the command module as a function of separation distance.

4. Static stability of the space vehicle configuration including booster alone and separation simulation.

5. Reaction jet effects on stability of the re-entry configuration.

6. Stability of the re-entry configuration with drogue chute.

7. Steady-state pressures distributions on launch escape and re-entry configuration.

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8. Transient pressures due to aerodynamic noise and buffet of the launch escape system, launch vehicle configuration, and the command module alone, including data recorded during simulated escape motor operation.

9. Heat transfer distributions on the launch escape system and re-entry configuration.

SYSTEMS DEVELOPMENT TESTING

All system development will culminate in a formal qualification-reliability test program which will demonstrate reliability and provide qualification for flight use.

The designated subcontractors will be responsible for their individual component, subsystem,or system developments and development tests. S&ID will not repeat these tests except as required to establish system compatibility and verify performance.

Laboratory tests will be conducted to select and qualify materials and processes. Structural tests will be performed on representative samples from individual parts through major assemblies.

Three mockups and four simulators will be used for the development of systems and operations involving the crew.

Along with the series of design studies listed earlier in this section, a total of 20 mockups defined in Table 3, 21 boilerplate test articles defined in Table 4, 12 prototype test articles defined in Table 5, and 4 additional prototype test articles which remain that have not been technically defined in terms of test philosophy and configuration requirements, will enhance the development of the different Apollo systems.

Spacecraft Structural Tests

The spacecraft structural test program encompasses all the required testing to prove the capability of the spacecraft structure to withstand the design environment without failure or excessive deflection. Particular emphasis will be placed on the development and qualification of the heat protection system, the sequential testing of significant components, and total structures under conditions of simultaneous load and thermal environment.

Subassembly testing of all structural members, including joints, truss sections, welds, attach points, tankage, windows, heat shield, motor supports and many others, will be accomplished at the Contractor's Downey Engineering Laboratories.

Critical flight loads and temperatures will be simulated. Loading will be applied to the assembled modules and separately to the adapter. Application of buffet loads to the external shell will be a separate part of this test and may be performed on a segment of the adapter such as an antenna or a door radiation panel. Limit loads for major critical design conditions will be followed by ultimate design loads. Final objectives will be to increase load until failure occurs in order to obtain ultimate strength capability and mode of failure.

In addition to subassembly and modular testing, a complete boilerplate spacecraft will be delivered to the NASA facility at Huntsville, Alabama, for structural compatibility tests with the launch vehicle, which will verify the overall spacecraft structural integrity.

Crew Integration

Development of an integrated crew support system includes a scientific determination of the scope of the mission in which the airborne crew can satisfactorily perform duties and the extent of the duties they can perform; it includes establishment of the procedures required in these duties, and testing and training in these duties to ensure successful results.

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Crew integration testing is primarily associated with the employment of crew members in a launch mission. Crew participation in non-launch tests will be for training purposes only. The three phases of a launch mission establish the modes of test.

During the boost phase, the operational procedures to be employed during the boost phase of the mission will be established, the response time requirement to determine crew ability to accomplish will be measured, the "no use" time when the crew due to conditions of the flight are unable to perform will be established, and the level of performance to define extent of crew usefulness will be determined. Testing emphasis will be placed on propulsion control and monitoring and stability control monitoring. The mission abort determination devices and the crew response time required to adequately control their own abort procedure will be studied. The establishment of a well-defined line beyond which crew capability to exercise judgment and react to situations cannot be expected, and automatic control devices will be required to ensure mission success or crew safety.

During the earth-orbit phase of the testing, the operation procedures to be employed during this phase of operation, including the monitor of all trajectory information measurement of effectivity of trajectory monitoring devices, will be established as will the operation of controls to maintain correct orbit. Abort monitoring devices to purposely define an abort during this phase and operation of mission propulsion engines to effect an abort from this phase of the operation will be studied. The establishment of well-defined lines beyond which crew capability to exercise judgment and ability to react cannot be expected, and some automatic control devices will be required to insure mission success.

Finally, the recovery phase testing will include establishment and testing of operational procedures to be employed during the recovery phase of the operation. This should include a study of the ability of the crew to effect re-entry into the earth's atmosphere from a circular orbit and the control and monitoring devices required to achieve this re-entry, a study to determine the procedure to be employed during earth landing, and a scientific determination of the ability of the

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crew to cope with malfunctions at this period. Again, the establishment of a well-defined line beyond which crew capability to exercise judgment and ability to react could not be expected.

Environmental Control (AiResearch Division of Garrett Corporation)

The subcontractor will perform the development laboratory testing on the environmental control system to provide data to support the design of components, interfaces, and coupling systems.

Source laboratory evaluation testing to support design analysis and evaluation will be initiated by the subcontractor, who will also provide the required instrumentation, equipment, and facilities to perform the tests to prove that the components will perform within the S&ID specific requirements.

Major areas of interest in design concept are:

1. Temperature distribution.

2. Fluid flow and pressure (gas and liquid).

3. Atmospheric composition (partial pressures).

4. Carbon dioxide removal.

5. Toxic and other contaminant removal.

6. System response to cabin puncture.

7. System operation for 14-day period under normal and emergency conditions.

A breadboard mockup of the entire ECS system will be provided at S&ID to aid in gaining data on the major areas of interest as listed above.

Stabilization and Control (Minneapolis-Honeywell Regulator Co.)

Development and evaluation testing of the stability and control system subsystems and complete systems will be performed at both the subcontractor's and prime contractor's facilities. These tests will include thorough evaluation of component performance characteristics to determine or verify transfer functions, gain characteristics, shaping variations, etc. Subsystems, such as engine gimbaling, servo-loops, and reaction control logic, will be tested in connection with their respective interface systems such as the engine gimbaling actuators and the reaction control system valves to determine and verify compatibility and the effects of both in-design and off-design tolerance excursions. Complete SCS systems will be tested for compatibility with interface systems and GSE, interchangeability, effectiveness of checkout procedures, malfunction mode analysis, and error analysis.

Tests will be conducted first upon systems in the laboratory and later upon systems or subsystems in simulator areas. Simulation tests will include tests on gas bearing tables and tests performed in conjunction with closed-loop analog computer operation.

Communications (Collins Radio Co.)

Normal breadboard development testing will be used to verify analytical design on all components that are not already developed. These breadboard tests, to be accomplished by the equipment subcontractor, will determine optimum circuitry configurations and suitability of selected electronic components with relationship to impedance levels, signal characteristics, and interfaces with connecting systems.

As prototype components and subsystems become available, the equipment subcontractor will verify system performance with regard to design specifications. The prototype systems will then be subjected to the specified environmental

requirements including temperature, vibration shock, acoustical levels, and pressure vacuum where applicable. This will qualify design to the reliability standards required.

The prototype systems will undergo a similar evaluation and qualification program to be conducted by the subcontractor and S&ID.

Instrumentation

Normal breadboard development testing will be used to verify linearity, amplification, power requirements, drift, resolution, stability, etc. This testing will be done by S&ID or subcontractor development laboratory. A mechanical mockup will be utilized to determine that design objectives have been met. These objectives include the following:

1. Ease of maintenance by ground personnel and crew.

2. Standardized modules.

3. Flexibility for future expansion or modification.

4. Human factors requirements.

5. Ease of checkout.

As prototype components and subsystems become available, a verification of the integration of mechanical and electrical design will be made. This phase of testing will verify that systems are ready for the environmental qualification phase. The environmental qualification tests will verify that equipment as designed is able to withstand the anticipated Apollo environment. These tests will be conducted by the subcontractor and/or S&ID. Environmental conditions will be specified by S&ID.

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Electrical Power System

The electrical power system includes the power generating fuel cells and their mechanical accessories, the storage batteries, the electrical regulation and distribution system to control the DC power and to convert and control the AC power, and the electrical lighting system for normal capsule cabin operation, for emergency lighting, and for recovery devices.

Development testing of the fuel cell as the primary source of power will be accomplished at the subcontractor level and will establish normal operating characteristics of the system peak load outputs and nominal outputs available. Subcomponent and total configuration requirements as well as control devices and malfunction detection devices will be developed by the subcontractor. Testing and development as required of the storage batteries as a source of auxiliary power will be conducted at the subcontractor level to establish their ability to meet the mission objectives.

Environmental consideration and interface study of both the fuel cell and the storage batteries will be conducted at the contractor level. This will include studies of heat dissipation necessities of both power devices, installation problems in the service module, and monitoring and control equipment required to maintain surveillance of the system.

Most extensive testing of the totally integrated electrical power system will be accomplished at the S&ID facility to prove the ability of the system to meet all possible mission objectives and to establish safe margins for redundancy. Full electrical loading for all phases of the mission will be simulated, shielding and grounding studies will be conducted, system interaction will be investigated, and operation method and monitor and control procedures will be established.

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Earth Landing System (Radioplane, Division of Northrop Corporation)

The earth landing system includes that mode of the mission from post-entry into the earth atmosphere until the command module has landed. This includes deployment of the parachute recovery system and deployment and operation of electronic and mechanical recovery aids, actuation of the impact attenuation device, and operation of electronic and mechanical recovery aids, and the electrically controlled and mechanical devices to sequence and monitor these various major items.

Major test efforts will be expended to develop the para-recovery system and will be accomplished by the subcontractor. Mechanical and electronic devices associated with the para-recovery system will be simultaneously tested with testing of the para-recovery system. Two or more test vehicles will be employed on these tests. A second major test effort will involve the earth attenuation system and this will include both water and land attenuation. As in the case of the para-recovery tests, recovery aids, both mechanical and electronic, will be tested simultaneously with the earth impact attenuation system. The testing effort for this mode will be conducted by the Contractor. Component testing of items and subsystems which go to make up the major mode system will be tested by the subcontractor and will be required to meet specifications established by the contractor.

Additional testing areas of equal impact as the two major mode tests but not as large in scope are the recovery aids test which will be conducted by the Contractor at both land and water test sites and the egress and flotation tests which will be conducted by the contractor at water sites.

Para-recovery mode testing encompasses the testing by Radioplane which will be performed with Boilerplates No. 3, 5, and 19. It will include 34 air drops

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from a C-130 or equivalent type aircraft to test and qualify the parachute operation, drogue chute operation, sequencing device for actuation of this mode, and recovery devices employed during this mode. The testing phases will simulate 12 entry-from-orbit recoveries, 6 abort recoveries, and 16 entries with one of the drogue or main parachutes inoperative or failed. Contractor monitoring of all tests will be provided.

Earth impact testing will ultimately demonstrate the ability of the system to mitigate the loads imposed on the command module and its crew during touchdown. The testing will consist of landing on both water and various types of terrain. The first phase of these tests will be to develop the impact landing system, and the second phase will be to qualify this system. Boilerplate Test Vehicles No. 1 and 2 will be used for the land tests, and Vehicles No. 4 and 7 for the water impact tests. The results of these early tests will be evaluated to determine whether or not water impact tests should be made using environmental proof spacecraft.

Recovery aids testing and operational qualification of recovery aids employed after earth landing will be accomplished and those used just prior to capsule touchdown will be tested by the Contractor in both land and water tests. The effectiveness of these aids to accomplish and implement the recovery mission will be the prime requirement of these tests; however, reliability of the separate items and their sequence of operation are also to be tested. Boilerplate Vehicle No. 8 will be employed for these tests.

Service Propulsion System

The following test effort will be accomplished on various components and subsystems related to the service propulsion systems. The outlined test effort will be accomplished at the S&ID Downey facility.

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The gimbal actuators for thrust vector control of the service module propulsion engine will be subjected to design evaluation testing at the S&ID Downey facility. The actuators will be tested over a temperature range of 20 F to 140 F to evaluate (1) response rate, (2) position accuracy, (3) redundant system operation, and (4) service life during cyclic operation representative of a mission duty cycle.

The propellant utilization system will be evaluated by a series of propellant flow tests conducted at the S&ID Downey facility. The system will be evaluated to determine (1) ability to detect propellant consumption, (2) ability to compensate accurately for off-design consumption, (3) changes in system accuracy resulting from shifts in propellant bulk temperature, (4) system capability under malfunction conditions, and (5) control valve durability under cyclic operation. An analytical study will also be made on the basis of the test results to determine the effect of propellant utilization control inputs on rocket engine performance.

The system employed for presentation of service module propulsion engine chamber pressure will be evaluated by a series of hot firings conducted with reaction control engines on the breadboard test stand. The system will be evaluated to determine (1) pressure sensor accuracy, (2) sensor susceptibility to combustion gas environment, (3) sensor-indicator service life under cyclic operation, (4) system response to pulse-type operation, and (5) susceptibility to vibration.

The fire detector system installed in the service module will be evaluated at the S&ID Downey facility by a series of temperature-vibration tests. The tests are intended to establish (1) system response to localized high-temperature effects, (2) compliance with actuation temperature limits, (3) operation with partially functioning system, (4) effect of vibration and acoustic environment on overall reliability and accuracy, and (5) durability of detector elements and harnesses.

It is expected that the bulk of development testing will be performed by the individual component suppliers. However, sufficient investigatory and backup

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testing will be performed by S&ID with particular emphasis on critical items such as regulators and relief valves to assure timely action by S&ID to permit alternate courses of action.

This system includes tankage, relief and other safety devices, valves, propellant utilization systems, tank quantity indicating systems and connecting plumbing up to but not including the engine propellant valves. It also includes the required cross ties to the rocket control system. It is expected that the major portion of development testing will be performed by the individual component suppliers. In addition, sufficient backup testing will be performed by S&ID with particular emphasis on critical items such as propellant utilization valves, check valves, and level sensors to assure timely action by S&ID to permit alternate courses of action.

QUALIFICATION AND RELIABILITY TESTS

Qualification and reliability tests will be conducted on all equipment designed for use in the spacecraft command module, service module, adapter assembly, and associated ground support equipment. The statistically designed qualification and reliability test plan provides for the maximum utilization of data (for reliability assessment and confidence development purposes) from all ground and flight tests conducted throughout the Apollo program.

Although tests conducted during development of hardware may be considered preliminary qualification, formal qualification will not be initiated until reasonable assurance exists (from development tests) that the equipment will pass these tests.

The qualification test program will establish the flight-worthiness of the equipments. At the conclusion of the qualification tests, reliability tests intended primarily to provide information to corroborate and update reliability estimates will be performed on prototype and production units.

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Reliability tests will consist of the application of higher environmental and functional stress levels (performance variability tests, performance and environmental design margin verification, and tests to failure) on qualified hardware to assess reliability at high-confidence levels. Confidence in equipment reliability will also be developed from specific tests and data obtained from the environmental proof and house spacecrafts, from equipment acceptance tests, and from tests conducted during the prelaunch and launch operations.

Quantitative and qualitative reliability analysis (logic networks, numerical predictions, and failure mode analyses) will be utilized to assign testing priority to equipments that are essential to crew survival and mission success.

Statistically designed experiments have been devised for application, as determined by such equipment characteristics as complexity, function, application, use history, previous testing, configuration, apportioned reliability, predicted reliability, and frequency and duration of operation.

Results obtained from acceptance, prelaunch, launch, and post-launch operations will be used in developing higher confidence in established reliability levels.

SYSTEMS COMPATIBILITY TESTING

In addition to the analytical integration effort, three complete in-house spacecraft systems are provided as working tools to verify the proper relationship of all systems. All elements of the system must satisfactorily complete a formal test program before the design is accepted for use. One environmental proof test spacecraft, AFRM No. 008 must be subjected to a complete environmental test, commencing in August 1963, before the first manned flight. Structural and dynamic compatibility with the C-1 booster will be demonstrated with a dynamic test article, Boilerplate No. 9, during booster dynamic tests. Prior to delivery to AMR, each spacecraft must pass S&ID in-plant acceptance test.

GENERAL ACCEPTANCE TESTS

The spacecraft acceptance tests are planned for each flight article beginning with early boilerplate models. Boilerplate No. 6 is scheduled for the first pad abort test. The acceptance test program is designed for a logical development of techniques, procedures, and facilities, in parallel with the delivery of spacecraft with increasing equipment levels. The primary objective of the spacecraft acceptance test program is to ensure that spacecraft delivered to the AMR facility have the systems and instrumentation configuration conforming to the flight test objectives and also that individual and combined systems operations (all modules) conform to specification. The flow of hardware to support the test program is shown in Figure 51.

The test program is designed to disclose malfunctions, defects, and off-limit performance in sufficient time to permit corrective action before delivery to the field test site.

HOUSE SPACECRAFT TESTS

House spacecraft will be used on a continual basis as an aid in the development and final design verification of all Apollo major systems. Systems to be tested are all command module systems and major portions of the service module (excluding actual propulsion firing). The GSE will be utilized and evaluated concurrently with these spacecraft development and design verification tests. The operational procedures for field use of the GSE will be developed, and the adequacy of GSE in detection and isolation or critical system failures will be determined.

Data obtained from the continual system operation and tests will be used in determining suitability of design specifications, the reliability and safety factors in design changes (prior to inclusion in flight systems), and mission success probabilities. Simulated mission operations will also be performed to establish specific reliability and crew safety assessments and confidence levels.

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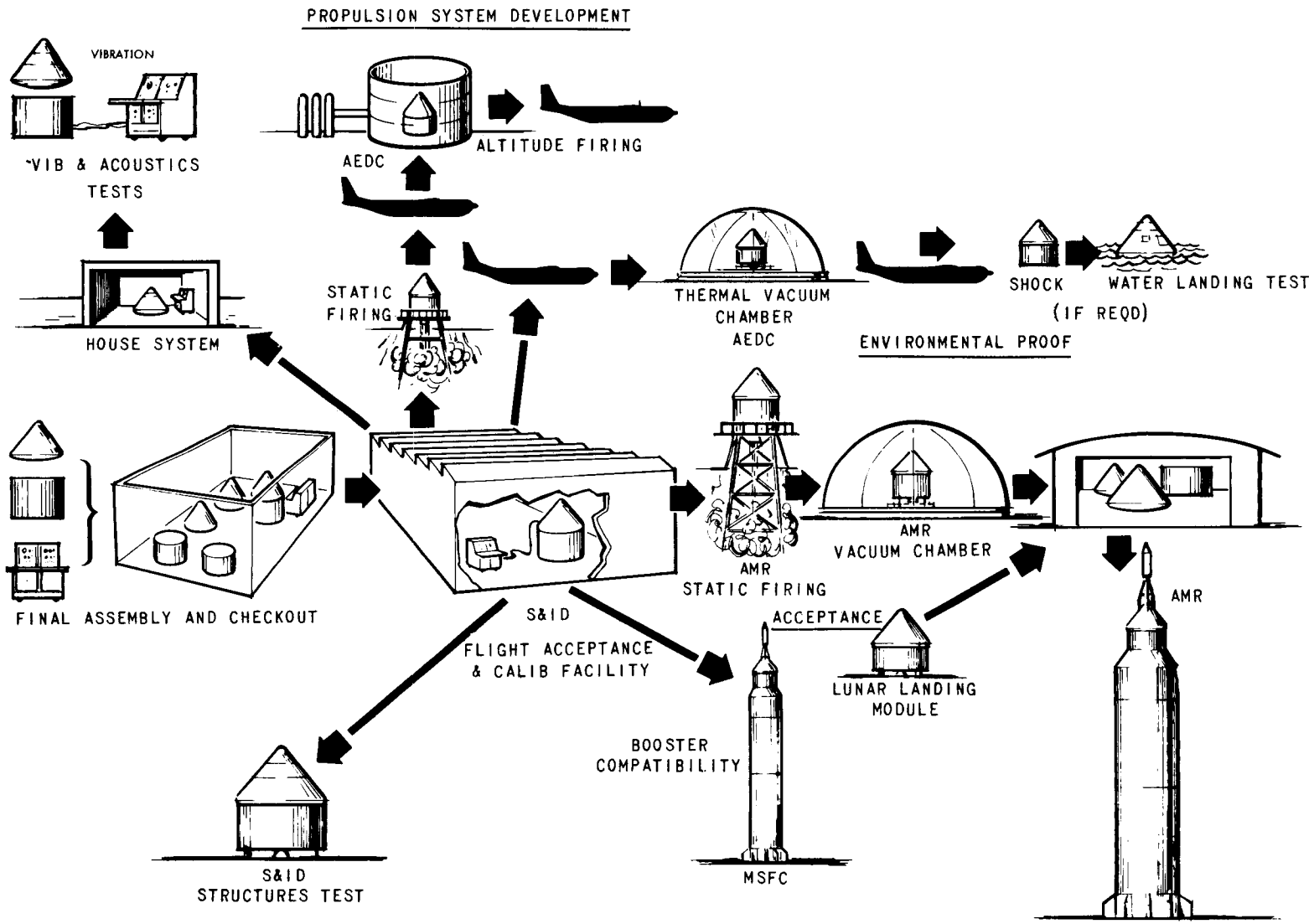

Figure 51. Spacecraft Test Activities

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The house spacecraft program will begin with system development modules installed on a skeleton structure to obtain proper mounting geometry and proper wiring loads. The systems will be tested as individual systems (not integrated systems) until the prototype design is firm.

A second house spacecraft will be utilized with complete prototype structure and systems to develop the integrated systems test program. This program will resolve interface problems, verify systems compatibility, develop and evaluate operational procedures, and perform malfunction analysis as the overall test program proceeds.

A third house spacecraft will be used in support of the environmental test program until the spacecraft systems are qualified for manned flight. This third house spacecraft will replace house spacecraft No. 1 in the integrated system house spacecraft program. House spacecraft No. 1 will be transferred to the simulator program.

During all phases of the house spacecraft test program, the systems will be maintained and updated to the current flyable module configuration. This will make the data usable in determining current flight hardware reliability criteria.

SPACECRAFT ENVIRONMENTAL PROOF TEST

An environmental proof test program will be conducted with assembled prototype spacecraft modules to provide a ground evaluation of the spacecraft system performance under simulated mission environmental conditions. Proof level test, within practicable limits of test facilities and economy, will be conducted to verify that the spacecraft can be expected to reliably meet the critical environments to which it will be exposed. Because no one facility can provide all environmental parameters, it will be necessary to conduct a series of separate tests which, in conjunction with subsystem and system level testing, will provide the desired assurance of the spacecraft suitability for flight operation. Compound stresses will be imposed, whenever possible, to provide the maximum

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attainable reliability confidence. The spacecraft environmental tests will be designed to provide progressive levels of qualification for each flight phase.

The tests scheduled to achieve the desired confidence level prior to the first manned flight will require more than one spacecraft. It is presently planned to utilize the static firing development spacecraft AFRM No. 001 and one of the house spacecraft to support the specifically designated environmental proof spacecraft AFRM No. 008. These spacecraft will contain complete prototype systems installed in structure conforming to production design.

The spacecraft system will be operated in the simulated mission duty cycle while the command module or combined command and service modules are subjected to expected environments. Repeated tests will be performed as necessary to assure reliability. Malfunctions considered critical to mission success will require recycling of the tests, after corrective action, until successful operation is demonstrated. System checkouts at static sea level conditions will be conducted prior to and after each test sequence as an integral process in the evaluation of the environmental stress effects on systems performance and life.

The spacecraft environmental test program will be a sequence of tests initiated with delivery of the environmental test spacecraft on 1 August 1963.

SPACECRAFT STATIC FIRING TESTS

The spacecraft static firing test program will be conducted with a prototype spacecraft to develop the integrated propulsion system, to verify conformance to design specification and to evaluate spacecraft systems interactions under hot propulsion firing operations. Test operation will be performed both at sea level and in a limited vacuum altitude chamber. The primary purpose of the program will be to evaluate the combined propellant, rocket engine, propulsion control system and spacecraft ordnance and pyrotechnic systems.

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In addition, electromagnetic interaction of the spacecraft systems will be investigated during propulsion firing operations to complement the house spacecraft systems integration test effort. Testing will include GSE compatibility, launch pad umbilical compatibility, and spacecraft launch vehicle interface compatibility.

VIBRATION AND ACOUSTIC ENVIRONMENTAL TEST

The vibration-acoustic tests are designed to define the modes and structural amplification factors of the internally mounted components and to evaluate the operational and structural integrity of the combined spacecraft in a high-level noise and vibration environment. Vibration-acoustic tests will be conducted where possible with all systems installed and activated.

Vibration tests of the complete spacecraft will be conducted with systems operating to predetermined test conditions of vibration level, vibration type, and exposure time. Malfunctions or failures will be determined, and general ability to withstand vibration will be ascertained. An experimental program will be conducted to determine vibration transmissibility of the complete spacecraft.

The command module, service module, and spacecraft adapter will be individually subjected to progressive wave acoustic excitation (discrete frequency and broadband random) with excitation levels and exposure times commensurate with mission profiles. Spacecraft systems should be operating where possible. The ability of the modules to withstand acoustic excitation will be determined, and failures or malfunctions will be noted.

If the acoustic excitation tests indicate a need for further tests, the combined structure (command module, service module and spacecraft) will be

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subjected to broadband acoustic excitation. The acoustic field in the vicinity of Edwards Air Force Base test stand 2A (F-1 thrust chamber tests) will be utilized. Sonic-induced vibration will be measured on primary and secondary structures in all modules, and acoustic levels inside the command module and external to all structures will be determined.

ABORT TESTS

Tests will be performed on that portion of the Apollo spacecraft which is required to safely return the capsule and crew from the mission should failure to attain the mission occur at any point. Its components include the launch escape tower and its associated propulsion system which affects lateral and horizontal displacement of the launch escape tower and command module from the launch vehicle; and a stability and control system to maintain both of the major components in a relatively stable flight path until recovery mode is selected.

Pad Abort

Initiation of thrust, with accompanying first movement and the period of transition burning to establish stabilized thrust is the most critical crew safety phase of the total mission and should be tested most extensively. A minimum of two pad aborts will be accomplished; the first of which will be programmed without thrust vector control of the launch escape tower main engine to establish maximum attitude and flight path and to check separation system operation and engine ignition. Boilerplate No. 6 will be used for this test. A second pad abort test will include thrust vector control of the main escape engine and will establish flight path of vehicle, maximum attitude, operational characteristics, stability of the capsule during launch escape phase and after tower separation and separation characteristics. Boilerplate No. 20 will be used for this test. There is no requirement for a launch vehicle on either of these tests; however, a launch vehicle simulator is required, and the separation system which will be used between the command module and the service module on future launch tests should be incorporated so that early reliability demonstrations of this system can commence.

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Maximum Q (Dynamic Pressure) Abort

The maximum expected dynamic pressure during the launch phase of a manned or unmanned Apollo test incorporating the Saturn C-1 launch vehicle has been defined as 745 lb/sq ft at an altitude of 36,700 feet and a speed of 1506 ft/sec. This ability of the launch escape system to separate the command module a safe distance from the launch vehicle while pressures of this magnitude are acting upon it must be demonstrated. To ensure successful study of this test point, two Boilerplates, No. 12 and No. 21, will be used to demonstrate this point and to collect information. Also an additional test of the prototype vehicle with more extensive and more refined systems aboard will be accomplished with prototype AFRM No. 002.

The requirement for a launch vehicle of single design and operation that requires only minimum setup time and operation technique, that is aerodynamically stable when operating in conjuction with the Apollo spacecraft, and that is highly reliable is called for to implement this test program. The study proposal stated in "NASA Project Apollo Working Paper No. 1020," dated 7 June 1961, is an excellent statement of requirements for this launch vehicle.

High-Altitude Abort

The maximum altitude expected to be attained prior to normal separation of the launch escape tower from the capsule is approximately 300,000 feet. The ability of the tower launch escape system to operate and function properly in this peculair pressure-temperature environment will be demonstrated. Capsule stability and control will be employed on this test, and a recovery system on an availability basis will also be tested. Prototype AFRM No. 003 will be used.

Post Tower Escape

After normal jettison of the escape tower, and during or after entry into earth orbit is accomplished, a condition of abort may occur. This test would demonstrate the ability of the mission propulsion engines to return the command module to the earth atmosphere and into the earth recovery mode. The requirement of mission propulsion engines and the service module for this test is dictated. Prototype AFRM No. 009 is scheduled for this mission.

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As is the cases of the maximum Q and high altitude abort test, a special launch vehicle must be available which is capable of placing the Apollo craft in this particular altitude and speed medium to accomplish these tests. Reference is again made to "NASA Working Paper No. 1020" as a guide to requirement for this launch vehicle.

FLIGHT DEMONSTRATION - APOLLO COMPATIBILITY WITH C-1 BOOSTER

The first launch will occur in June 1963 using Spacecraft SA-5 which is Boilerplate No. 13 to demonstrate dynamic compatibility of spacecraft and booster, evaluation of flight loads, vibrations, accelerations and temperatures, and evaluation of escape tower jettison operation.

Flight Demonstration of Apollo Structural Integrity

Spacecraft SA-7 which is Boilerplate No. 16 and Spacecraft SA-8 which is Boilerplate No. 18 will be used to demonstrate the Apollo structural integrity. The first launch with an instrumented structure is scheduled for October 1963 using the C-1 booster with SA-7. This series of three flights will culminate in final demonstration of structural integrity and of the crew escape and recovery system through the full regime of boost and recovery. The last flights in the series will contain interim or prototype systems as required to demonstrate entry. Through this whole series, the compatibility of telecommunication system and range will also be demonstrated.

Manned Orbital Flight

The first spacecraft, SA-111, having qualified prototype systems consisting of the command module, service module, spacecraft adapter, and launch escape tower, and having the capability of manned orbital flight, will be launched in June 1964. Previous demonstration of the integrity of the structure and of the escape and recovery system, backed up by planned ground development programs, lead directly to this first manned orbital flight. A summary of the flight test program is presented in Table 2. This program is based on maximum utilization of the C-1 booster launches as currently scheduled.

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Table 2. Apollo/C-1 Flight Test Summary

Designation	Number	Objective
SA-5	5A	Demonstrate booster and spacecraft compatibility.
	5B	Evaluate flight loads, vibration, acceleration and temperature with regard to structural integrity.
SA-6	6A 6B	Same as SA-5A and 5B.
SA-7	7A	Evaluate prototype heat protection system.
	7B	Demonstrate super-orbital velocity on re-entry and recovery capability and system operation.
	7C	Evaluate telecommunication and range compatibility.
	7D	Demonstrate structural integrity during boost phase.
SA-8	8A, B	Same as SA-7A, 7B, 7C, and 7D.
	8C, D, E	Evaluate navigation and guidance system operation.
SA-9	9A	Demonstrate C-1 and spacecraft compatibility and readiness for manned participation.
	9B	Evaluate worldwide GOSS operation.
	9C	Evaluate readiness of recovery complex.

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Table 2. Apollo/C-1 Flight Test Summary (Continued)

Designation	Number	Objective
	9D	Evaluate P/T systems operation and performance.
	9E	Evaluate flight environment.
SA-10	10A, B, C, D, E	Same as 9A, B, C, D, E.
SA-111	111A	Verify capability of manned spacecraft to complete earth-orbital mission.
	111B	Verify operation of GOSS with manned spacecraft.
	111C	Verify compatibility of the manned spacecraft recovery complex.
	111D	Evaluate flight environment.
	111E	Evaluate P/T systems operation and performance (with emphasis on attitude control).
	111F	Train space flight crews.
SA-112	112A	Orbit re-entry and safe return.
	112B	Demonstrate thrust vector control.
	112C	Evaluate emergency techniques.
	112D	Evaluate guidance system performance.

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Table 2. Apollo/C-1 Flight Test Summary (Continued)

Designation	Number	Objective
	112E	Evaluate reaction control response.
	112F	Demonstrate orbital altitude transfer.
	112G	Train space flight crews.

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Table 3. Mockups

Mockup Number	Description
1	Mockup No. 1 will initially consist of a simulated command module interior. Equipment will later be installed to allow simulation studies, which will be made in conjunction with digital and analog computers.
2, 3	Cabin interior arrangement Mockup No. 2 and No. 3 will consist of a simulated command module to establish the arrangement of crew equipment for maximum accessibility and utilization, and optimum areas utilization (mobility, comfort), to evaluate space required for assemblies and to establish locations for various equipment. Mockup No. 3 will be used by MSC.
4, 6, 17	Service module and interface adapter mockup No. 4, No. 6, and No. 17 will simulate the mating of the service module and the adapter including the mechanical and electrical connections involved to evaluate the characteristics involving mating, to evaluate compatibility characteristics, and to be capable of mounting on the booster.
5	The cabin exterior equipment of mockup No. 5 consists of a simulated command module for aiding the design of the actual hard type command module by establishing location and compatibility of various types of external equipment, accessibility of equipment, accessibility of equipment for maintenance, and to establish location for electrical connections.
7	The service module mockup will simulate the actual service module with outer skin deleted. This mockup will provide evaluation of accessibility of modules for in-flight and ground maintenance, compatibility of various types of equipment, and evaluation of space required for various systems and equipment. In the future, this mockup will be used to conduct various types of anthropometric and maneuverability tests for in-flight and ground maintenance.

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Table 3. Mockups (Continued)

Mockup Number	Description
8	The air lock and docking mockup will duplicate the interior of the air lock and simulate the docking process to the space module. This mockup provides a means to study possible operating mechanisms, compatibility with various types of equipment and systems, to attain maneuverability requirements for system specifications, and to evaluate the space required for the air lock and docking equipment.
10	The life system mockup will duplicate the interior of the command module, all crew equipment, and crew stations for optimum area utilization, maneuverability, and comfort, to establish arrangements for crew equipment; to establish an area for personal hygiene; to attain anthropometric requirements for system specification; and to evaluate primary and secondary duty stations.
9, 11, 15	The spacecraft handling and transportation mockup No. 9, No. 11, and No. 15 will consist of the command module, service module, spacecraft adapters, and launch escape tower to simulate size, weight, distribution of weight, jacking and hoisting points, and to evaluate the characteristics involving the handling and transportation of these modules, the adapter, and tower. Mockup No. 15 is a DEI article.
12, 13, 14	The crew support system mockup No. 12, No. 13, and No. 14 located in the command module will provide design information for support and restraint systems, analyze anthropometric requirements for system specifications, adjustability of couch for crew from 10th to 90th percentile, and establish requirements for crew protection. Mockup No. 14 will be used by MSC.

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Table 3. Mockups (Continued)

Mockup Number	Description
16	The partial service module mockup No. 16 will consist of the lower portion of the service module and the spacecraft adapter to evaluate the characteristics involving mating with adapter, to be used to verify mating parts on a production level and to evaluate compatibility and interchangeability characteristics.
18, 19	The first complete mockup No. 18 and No. 19 of the command module, service module, spacecraft adapter, and launch escape system to incorporate the data compiled from mockups No. 1 through No. 17, to manufacture and assemble the Apollo complete mockups for inspection and to disassemble for individual inspection, and to simulate the actual vehicle with all systems except for some associate contractor supplied equipment. Mockup No. 18 will be used by MSC and mockup No. 19 is a DEI article.
20	Mockup No. 20 will be used as a simulation mockup for determining the command module antenna radiation pattern.

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Table 4. Boilerplate Articles

Article Number	Description
1	Boilerplate No. 1 is a simulated command module for land impact pre-developmental and developmental test to evaluate the earth impact attenuation system, the crew shock absorption system, and the lateral and transverse acceleration loads, and to verify maximum emergency limit g forces.
2	Boilerplate No. 2 is a simulated command module for land impact pre-development and development tests to evaluate the earth impact attenuation system, the crew shock absorption system, and the lateral and transverse acceleration loads, and to verify maximum emergency limit g forces.
3	Boilerplate No. 3 is a simulated command module for Pre-Qualification Flight Drop pre-development and development tests to evaluate the earth recovery system operation in the air.
4	Boilerplate No. 4 is a simulated command module for water impact on the earth impact attenuation system, the crew shock absorption system at water impact, and the lateral and transverse acceleration loads, and to verify maximum limit g forces and verify flotation stability.
5	Boilerplate No. 5 is a simulated command module for Pre-Qualification Flight Drop pre-development and development tests to evaluate the earth recovery system operation in the air and the recovery aids system during and after actual air drop.

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Table 4. Boilerplate Articles (Continued)

Article Number	Description
6	Boilerplate No. 6 is a simulated command module for pad abort with a ground adapter for command module, prototype escape tower, launch escape motor without thrust vector control, launch escape tower release mechanism, and jettison motor for pre-qualification of launch escape propulsion system pre-development and development test to evaluate and qualify the launch escape propulsion system, determine the jet thrust effects on the command module, evaluate the stability margins, cg effects, and maximum altitude determinate.
7	Boilerplate No. 7 is a simulated command module for water impact test pre-development and development tests to evaluate water impact on the earth impact attenuation system, the crew shock absorption system at water impact, and the lateral and transverse acceleration loads, and to verify maximum emergency limit g forces and verification of flotation.
8	Boilerplate No. 8 is a simulated command module for recovery aid pre-development and development tests to evaluate and qualify the recovery aids under the probable landing conditions of actual flight articles.
9	Boilerplate No. 9 is a simulated command module, service module, spacecraft adapter, prototype escape tower, and simulated launch escape motors for dynamic tests. The test objective to be determined by NASA and conducted by NASA.

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Table 4. Boilerplate Articles (Continued)

Article Number	Description
10	Boilerplate No. 10 is a simulated command module for water egress and flotation pre-developmental and developmental tests to evaluate spacecraft ability to recover from any initial attitude and to float upright with normal egress hatches clear of the water, spacecraft seakeeping capability to ensure a seven-day flotation period, crew egress under a variety of sea-state conditions, and need for auxiliary flotation devices.
11	Boilerplate No. 11 is a simulated command module for logistics equipment recovery pre-developmental and developmental test to develop adequate handling aids for use in recovery of the command module on land and in water and handling procedures for land and water recovery.
12	Boilerplate No. 12 is a simulated command module for maximum Q abort with Little Joe II Booster, prototype escape tower, launch escape motor without thrust vector control, launch escape tower release mechanism, and jettison motor for pre-qualification launch escape system pre-developmental and developmental test to evaluate and qualify the launch escape system, to determine the jet thrust effects on the command module, and to evaluate the stability margins and cg effects.
13	This is a simulated command module, service module, prototype spacecraft adapter, and escape tower for the first orbital flight to demonstrate the dynamic compatibility of the spacecraft and booster; structural demonstration for evaluation of flight loads, vibration, accelerations, and temperatures. It will be launched by SA-5.

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Table 4. Boilerplate Articles (Continued)

Article Number	Description
14	The house spacecraft No. 1 is a skeletal command module, skeletal service module, prototype spacecraft adpater, and simulator escape tower for the test platform to develop primary systems to prototype status, to evaluate the interaction of systems, to establish preliminary operational procedures, and to evaluate GSE design and operations.
15	This is a simulated command module, service module, prototype spacecraft adapter, and escape tower for second orbital flight to demonstrate dynamic compatibility of spacecraft and booster; structural demonstration for evaluation of flight loads, vibration, acceleration, and temperatures. It will be launched by SA-6.
16	This is a simulated command module and command module adpater for the first super-orbit velocity recoverable spacecraft for structural demonstration of re-entry and recovery capability, demonstration of compatibility of the telecommunication systems and GOSS, and structural demonstration of boost phase. It will be launched by SA-7.
17	Boilerplate No. 17 has been deleted.
18	This is a simulated command module and command module adapter for the second super-circular orbit recoverable spacecraft for structural demonstration of re-entry and recovery capability, demonstration of compatibility of the telecommunication systems and GOSS, and structural demonstration of boost phase. It will be launched by SA-8.

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Table 4. Boilerplate Articles (Continued)

Article Number	Description
19	Boilerplate No. 19 is a simulated command module for Pre-Qualification Flight Drop and land impact pre-development and development test to evaluate the earth recovery system operation in the air, to evaluate the earth impact attenuation system, the crew shock absorption system, and the lateral and transverse acceleration loads, and to verify maximum emergency limit g forces.
20	Boilerplate No. 20 is a simulated command module for pad abort with a ground adapter for the command module, prototype escape tower, launch escape motor with thrust vector control, launch escape tower release mechanism, and jettison motor for pre-qualification of launch escape propulsion system for pre-development and development test to evaluate and qualify the launch escape propulsion system, determine the jet thrust effects on the command module, to evaluate the stability margins and cg effects and maximum altitude determinate.
21	Boilerplate No. 21 is a simulated command module for maximum Q high altitude atmosphere abort with Little Joe II Booster, prototype escape tower, launch escape motor with thrust vector control, launch escape tower release mechanism, and jettison motor for pre-qualification launch escape system for pre-development and development test to evaluate and qualify the launch escape system, to determine the jet thrust effect on the command module, and to evaluate the stability margins and cg effects.

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Table 5. Prototypes

AFRM Number	Description
001	The propulsion test spacecraft, which consists of prototype command module, service module, escape tower, and modified spacecraft adapter, is for propulsion system operation for normal and emergency flight environments to evaluate propulsion system performance under sea-level and altitude conditions, to obtain environmental data on vibration, acoustics, and base heating, to verify operation of launch escape motors system by tethered tests, and to verify reaction controls system performance and compatibility.
002	The Little Joe II maximum Q abort test spacecraft, which consists of prototype command module, escape tower, and command module adapter, is for qualification of launch escape system at maximum Q to verify abort sequence and recovery complex.
003	The Little Joe II high-altitude atmospheric abort test spacecraft, which consists of prototype command module, escape tower, and modified spacecraft adapter, is for qualification of the launch escape system at high altitude to verify the abort sequence and recovery complex.
004	The static test article No. 1, which is a prototype command module, service module, spacecraft adapter, and launch escape tower, is for static test to verify structural integrity under launch pad static loads, to verify structural integrity under all simulated boost conditions, and to verify structural integrity under simulated lunar landing conditions.

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Table 5. Prototypes (Continued)

AFRM Number	Description
005	The static test article No. 2, which is a prototype command module with a simulated heat shield, is for static test to verify structural integrity under a simulated thermal environment at re-entry, to verify structural integrity under simulated shock conditions during the air phase of recovery, and to verify structural integrity under simulated shock loads at earth impact (land and water simulated).
006	The house spacecraft No. 2, which consists of a prototype command module, service module, spacecraft adapter, and launch escape tower, is for system performance and compatibility to verify performance of major systems, to verify systems integration within major modules, to verify systems integration between major modules, to verify and evaluate GSE compatibility, to evaluate in-flight maintenance capability, to confirm development design changes prior to inclusion in actual flight systems, to develop integrated checkout procedures, to evaluate and develop operational procedures for vehicle and mission, and to verify performance to design specification including reliability.
007	The spacecraft SA-9, which consists of a prototype command module, service module, spacecraft adapter, and launch escape tower, is for the first prototype unmanned earth-orbital recoverable spacecraft to demonstrate C-1 launch vehicle and spacecraft readiness for manned participation in orbital flight and recovery operations, to demonstrate and evaluate world-wide operation of GOSS, to demonstrate and evaluate readiness of the recovery complex, and to evaluate vibration modes of the spacecraft with the completely qualified system employed.

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Table 5. Prototypes (Continued)

AFRM Number	Description
008	The environment proof spacecraft, which consists of prototype command module, service module, spacecraft adapter, and launch escape tower, is for qualifying the design of the assembled spacecraft system to reliably withstand environmental conditions present during the following phases: prelaunch, launch, boost, separation, earth orbit, lunar, and circumlunar environment, re-entry, earth landing, and recovery.
009	The Little Joe II very high-altitude atmospheric abort test spacecraft, which consists of a prototype command module, escape tower, and modified spacecraft adapter, is for qualification of the launch escape system.
010	The Spacecraft for SA-10, which consists of a prototype command module, service module, spacecraft adapter, and launch escape tower, is for the second unmanned earth-orbital recoverable spacecraft to verify the capability of a manned spacecraft to complete an orbital mission, to verify the operation of GOSS with manned spacecraft, to verify the capability of the manned spacecraft recovery complex, and to evaluate vibration modes of the spacecraft, with completely qualified systems employed.
011	The Spacecraft for SA-111, which consists of a prototype command module, service module, spacecraft adapter, and launch escape tower, is for the first manned earth-orbital recoverable spacecraft to verify the capability of a manned spacecraft to complete an orbital mission, to verify the operation of GOSS with manned spacecraft, to verify the capability of the manned spacecraft recovery complex, and to evaluate in-flight crew reaction.

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Table 5. Prototypes (Continued)

AFRM Number	Description
013	The Spacecraft for SA-112, which consists of a prototype command module, service module, spacecraft adapter, and launch escape tower, is for the second manned earth orbital recoverable spacecraft to verify the capability of a manned spacecraft to complete an orbital mission, to verify the operation of GOSS with manned spacecraft, to verify the capability of the manned spacecraft recovery complex, and to evaluate in-flight crew reaction.

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MANUFACTURING PLAN SUMMARY

Immediately after go-ahead was received in December 1961, a manufacturing manager was appointed to form the Apollo Manufacturing organization. Under his direction, three basic line departments were created to fabricate, assemble, and perform checkout operations on the Apollo spacecraft and trainers. Existing manufacturing support departments, including ground support equipment, retained their identity with internal departmental structure expanded and modified to fit the needs of the program. In addition, project groups were formed within existing administrative departments to facilitate pre-planning effort and to establish the controls peculiar to this program. In all areas, key personnel were selected on the basis of their experience, knowledge, and performance history.

ADVANCED PRODUCTION SHOP

Methods to shorten communication and reporting lines between manufacturing, engineering, and support departments are presently available and authorized by established procedures. They have been used on previous projects on an "as required" basis; however, in anticipation of extensive configuration changes and to incorporate new design concepts, the procedures will be expanded to assign personnel to the shop areas. These individuals will operate as an extension of their project groups and will have the authority to approve design changes as they occur. Control will be retained through the modification of present procedures and reporting channels.

TOOLING

The design and fabrication of spacecraft tooling are predicated upon the high reliability factors of this program. Close alliance with engineering has been

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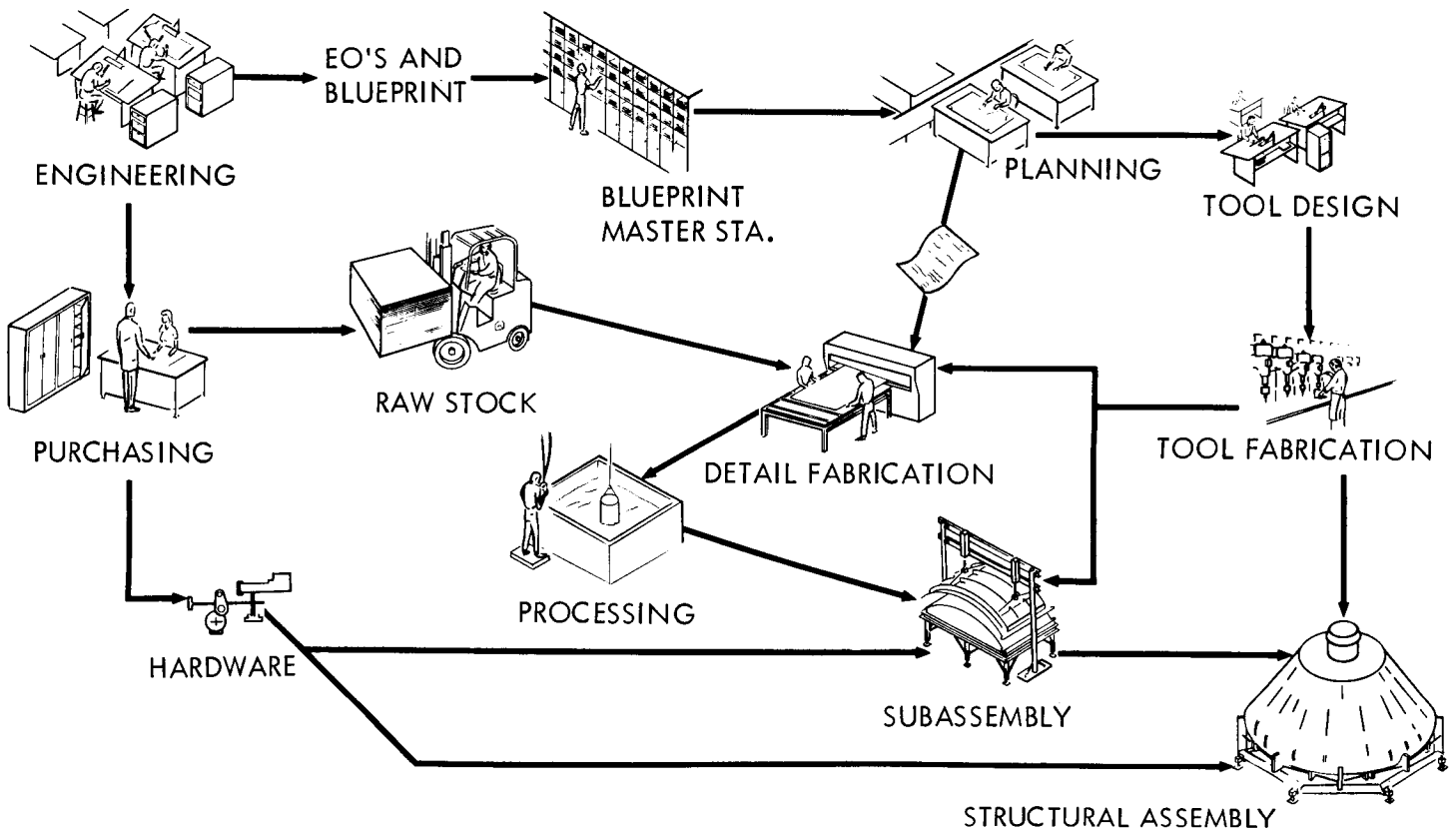

Figure 52. Manufacturing Flow

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established to ensure flexibility in adapting to expected design and technical change. The most complex tooling will be those fixtures used in forming, bonding, and brazing of the outer command module heat shields. Extensive use is made of automatic skate welding and trimming equipment for joining the segments of each assembly.

SPECIAL TOOLING

Six areas comprise the major tool complexities of the command module vehicle. Circumferential welding, cylindrical-section longitudinal welding, adhesive aluminum bonding, high-energy sizing, hydrostatic test fixture, and assembly operations form the six areas where multiple functions are required of each tool. A description of the fabrication and capabilities of these tools is outlined below.

Circumferential Weld Fixtures

Two special circumferential weld fixtures are used. Each is equipped with machining heads for finish machining weld edges within the fixture. The circumferential weld fixture and boom manipulator fixture perform the circumferential weld joining of the floor assembly to the aft wall assembly, to the crew compartment wall assembly, to the bulkhead assembly. A machining head is positioned to the base for precision butt-joint alignment. The weld equipment will be capable of welding AC-DC-TIG for aluminum and stainless steel and MIG for boiler plate articles. (The welding head is on an overhead boom in a stationary position, and the prefit assembly rotates in the trunnion-type fixture.) A similar weld fixture joins the periphery ring to the upper bulkhead, to the cylinder, and the cylinder to the machined ring fitting.

Circle-welding the Marman clamp ring fitting to the honeycomb floor panel assembly is accomplished with a circular weld fixture, with a skate track attached to the outer periphery. The honeycomb floor panel assembly is held secure in the tool by vacuum cups, and the skate track will serve as an attach for machining the

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periphery of floor section to match the ring fitting. The machine skate is removed and a quick connect weld skate is positioned on track for welding. This equipment will weld aluminum, steel, and boiler plate articles.

Longitudinal Weld Fixture

The longitudinal weld fixture performs the vertical weld joining of the inner and outer crew compartment facing-sheet segments and star stringers. Each panel and star stringer is placed edgewise and circumferentially in the longitudinal weld fixture and is held by means of vacuum cups. The gas grooved, backup bars with mounted vacuum cups are located so that the longitudinal weld edges are precisionally aligned and held in proper relationship for weld joining. The welding head is mounted on a dolly which travels on tracks attached to the stationary welding boom. The weld assembly rotates on rollers mounted in the weld fixture to align each weld joint with the weld boom progressively until assembly is weld-joined complete.

Adhesive Aluminum Bonding

All adhesive aluminum honeycomb sandwich bonding is accomplished using a steam inducted bonding fixture fabricated of rolled aluminum. The tool will prefit and bond core and outer skins to welded subassemblies of inner facing sheets and machined ring fittings. The bonding fixture is an aid (supplying heat and pressure) for bond curing the closeout filler strips.

An autoclave will physically support the bonding fixture, provide the vacuum pressure, the positive air pressure, and heat to effect a high-temperature high-pressure cure cycle for the bond curing process. The autoclave is a pressure vessel with a dished bottom and a hemispherical cover joined with a locking ring, containing a sealing arrangement to withstand pressure to 90 lb/sq in. The autoclave is pressurized to 60 psi and has a heating system capable of maintaining a product temperature of 300F to 360F.

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High-Energy Sizing Die

The high-energy form process is used for sizing all skins, facing sheets, and weld-joined face-sheet assemblies supporting the adhesive-bonded aluminum honeycomb assemblies and the brazed steel honeycomb assemblies. The size dies are of cast Kirksite and epoxy-faced construction, held to +0.005 -0.000 bonding tolerance and +0.002 brazing tolerance. Epoxy inserts are used to facilitate sizing of both outer skin and inner facing sheet using one sizing die.

Hydrostatic Test Fixture

The inner face-sheet weld-joined assemblies of the forward bulkhead, crew compartment side wall and aft bulkhead, and the outer surface facing sheets will be hydrostatic pressure-tested after high-energy sizing, using a hydrostatic test fixture.

Final Assembly Fixture

The final assembly of the Apollo Spacecraft, including the command module, service module, spacecraft adapter, and launch escape tower, is performed in a module-mating fixture to adjust fitting and make a fit check of all mating surfaces. The command module is located in the final assembly jig with the service module, and thrust fittings are adjusted to the lower heat-shield surface. The spacecraft adapter is bolted to the service module aft interface and a fit check is made. All assemblies are optically checked and aligned to assure structural compatibility. Combined systems checkout is made within the fixture.

System Measuring Devices

Systems Measuring Device (SMD) is the term applied to test equipment used by Manufacturing for special-purpose factory test and checkout. Some SMD equipment peculiar to the Apollo Spacecraft component and ground support will be required for factory use only. This equipment will be designed or procured by the

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SMD group to requirements established by engineering drawings and process specifications.

Any SMD Unit that has qualified an operation must be initially evaluated for its capability to perform an adequate check in accordance with engineering criteria before it can be certified for operation by Quality Control and the metrology laboratory.

FABRICATION AND ASSEMBLY

Fabrication methods most favorable to quality production have been selected. All system components, including their installation and verification, will be assembled in an environmentally controlled white-room area of the advanced production shop. All procedures used in fabrication and assembly of the Apollo spacecraft and its associated hardware will conform to NASA approved specifications.

Command Module

The command module consists of a crew compartment of adhesive-bonded aluminum sandwich structure, enclosed within a brazed stainless-steel heat shield and shroud assembly.

Crew Compartment

The crew compartment will consist of four major assemblies: the forward bulkhead, wall, aft wall, and aft bulkhead. These assemblies are joined by automatic butt-fusion-weld welding of the inside facing sheets and lap bonding of the outside facing sheets. All assemblies receive hydrostat and x-ray tests to prove the weld joints. The compartment will be of bonded aluminum honeycomb sandwich construction, reinforced by mechanically attached stiffeners and attaching hardware.

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Heat Shield

Tentative plans for the heat shield call for brazed honeycomb sandwich construction consisting of aft, wall, and forward compartment assemblies with ablative material covering the entire heat-shield surface. Machining, trimming, and welding of rings and attach points will be accomplished in the circumferential welder to assure interface compatibility.

Boilerplate Modules

The boilerplate is a simulated module used for development tests leading to the design of a prototype module. Each boilerplate constructed will include different characteristics of the prototype for simulation and will have unique configuration and special test requirements. The boilerplate module is constructed of all-welded aluminum, consisting of an aft bulkhead, simulated heat shield, inner and side walls, forward bulkhead, and the crew compartment structure assembly. Instrumentation and systems installation will be made in a white area if this requirement is included in specifications.

SPACECRAFT SYSTEMS ASSEMBLY

Assembly, installation, and functional checkout of all spacecraft systems will be performed in a Class D dust-free room within the Apollo advanced Production Shop organization. The enclosure, designated the white room, will be equipped with temperature and dust particle controls. Automatic devices will sample and record verification of allowable dust-particle content. All detail fabrication, wire harness fabrication, and standard machine shop operations will provide support to this area.

Component Assembly

Prior to assembly operations in the white room, all purchased items will be checked for damage and engineering specifications compliance by receiving

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inspection. Following inspection approval, the items will be forwarded to the white room subassembly area. Electrical and electronic items, including relays, resistors, transformers, and transistors, are initially assembled into subminiature units such as solid-state logic cards, demodulators, signal amplifiers, converters, phase-sensitive demodulators, bridge adjusts, and power amplifiers.

Before a subminiature assembly can be routed to the checkout area, the planning ticket must be stamped by a member of the Quality Control Group. This stamp verification indicates that the unit has been assembled according to applicable engineering drawings and specifications and that a complete continuity check has been performed on all wiring.

Electronic Systems Assembly

After checkout, the required module, plugs, transformers, relays, interconnecting wire harnesses, and necessary mounting hardware are routed to the subsystem assembly area. Following the assembly operation in this area, all components will be submitted to Quality Control for wiring continuity tests. Certification is made to verify that the unit has been manufactured to applicable engineering prints and process specifications. The subsystem will be weighed and serialized in accordance with Quality Control procedures. When the attached planning ticket is stamped for acceptance approval, the components will be routed to the subassembly checkout area.

Mechanical Components Assembly

Mechanical components, including control valves, pressure regulators, pumps, and pressure vessels, receive their initial acceptance and functional test in the receiving inspection area. Following delivery to the subassembly area, the mechanical components are assembled into subsystems, such as pneumatic control panels, reservoir and actuator units, and related items. After assembly, the units are forwarded to the mechanical testing area where subsystems tests are conducted according to process specifications. All tests will be performed with equipment designed and certified for specific subsystem checkouts.

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Cable Harness Assembly and Checkout

Jig boards for manufacturing of wire harnesses will be utilized. Automatic continuity checks will be conducted. Programming, patch boards, cable adapters, and matrix charts will be certified by Quality Control.

Systems Installation

All spacecraft systems are routed to the module systems installation area for installation in the completed structural assemblies. Following system installation on all Apollo modules, tubing, cables, and structural members will be checked for adequate clearance and for adequate clamping or tie-down points. All installations will be checked to ensure that tubing, feed lines, and ducting are installed in strain-free condition and have proper torque on fasteners.

During systems installation operations, documentary control of all equipment and hardware will be maintained. The documents included in the data package that will be delivered with each Apollo vehicle will contain records of:

1. Equipment serialization
2. Operation time
3. Sign-off
4. Calibration
5. Change verification
6. Part removal
7. Process specification

Following completion of each installation, quality control personnel will verify that the information has been entered and that the system has been installed in accordance with applicable engineering drawings.

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Systems

All interconnecting module spacecraft adapter systems are checked for continuity across the interfaces in preparation for spacecraft test and checkout operations.

GROUND SUPPORT EQUIPMENT

All manufacturing and inspection controls discussed for flight hardware also apply to ground support equipment. Each component, subassembly, and assembly will be visually inspected to verify acceptable levels of workmanship and assurance tested in the same manner as discussed for flight hardware. Fabrication of components for ground support equipment will be accomplished in the same departments as spacecraft subsystems. Drawer modules for control, checkout, and servicing units are enclosed in standard consoles. All electrical, pneumatic, and fluid connections are located in a recessed panel on the back of the console. The consoles can be grouped together to form a complete unit consisting of two, three, or four bays as required.

Functional Testing

Every item of ground support equipment will be functionally tested to verify compatibility with specific system designs. Functional test operations will be accomplished by simulating signals normally received from, or sent to, the Apollo Spacecraft. Signal reactions will then be observed on gages, meters, lights, or electronic indicators on the console.

Calibration

Electronic and pneumatic measuring devices will be calibrated and serviced prior to installation in the consoles. All devices will be individually calibrated, serviced, and verified by Quality Control in a complete laboratory. Laboratory equipment will meet the National Bureau of Standards calibration standards and the functional standards established by quality control and engineering specifications.

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All ground support equipment and factory test equipment (system measuring device) consoles will be completely inspected, serviced, and calibrated at regular intervals. Calibration of measuring devices assures that a GO signal will be within tolerances of engineering specifications.

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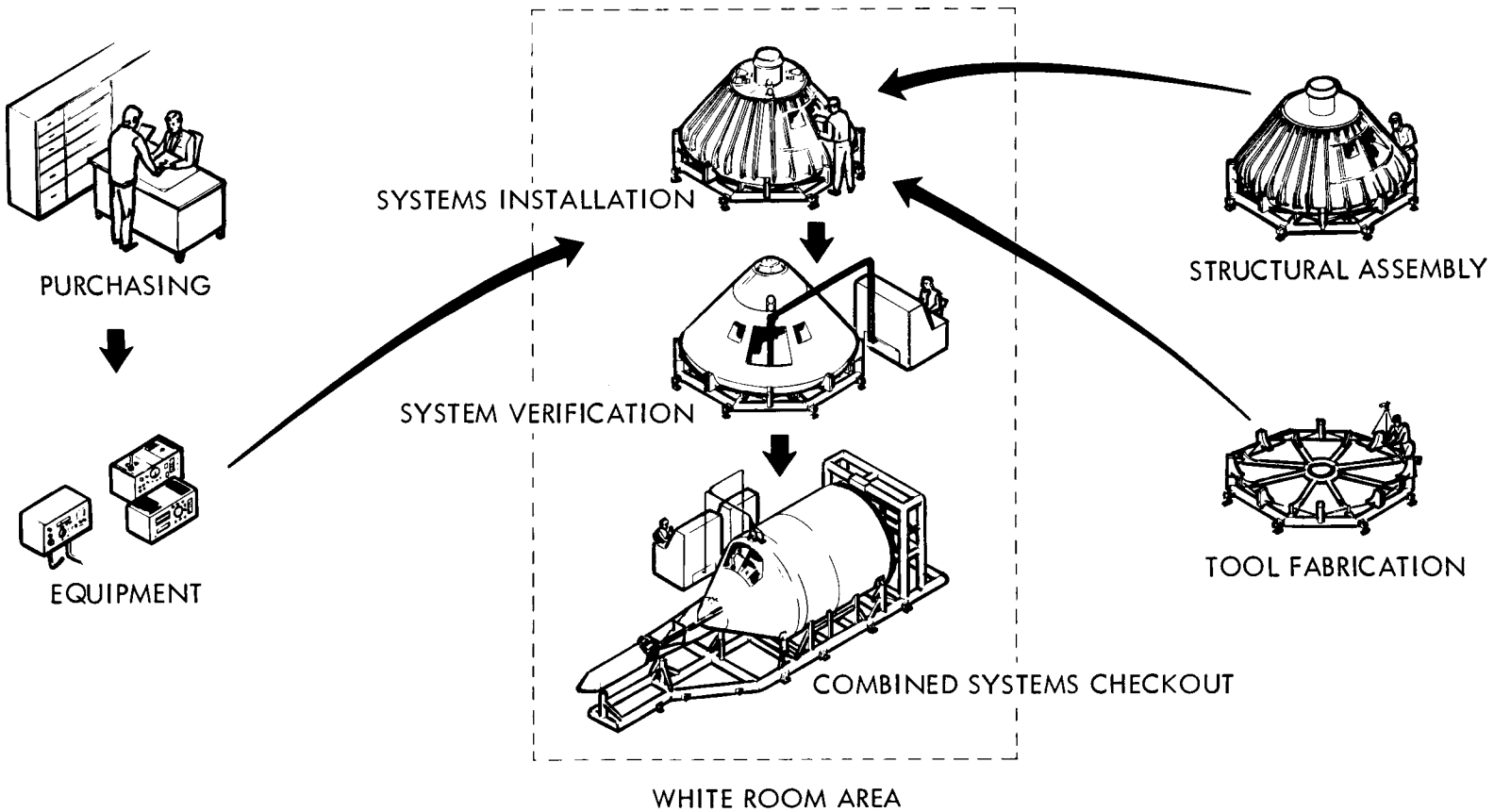

Figure 53. Final Assembly and Checkout

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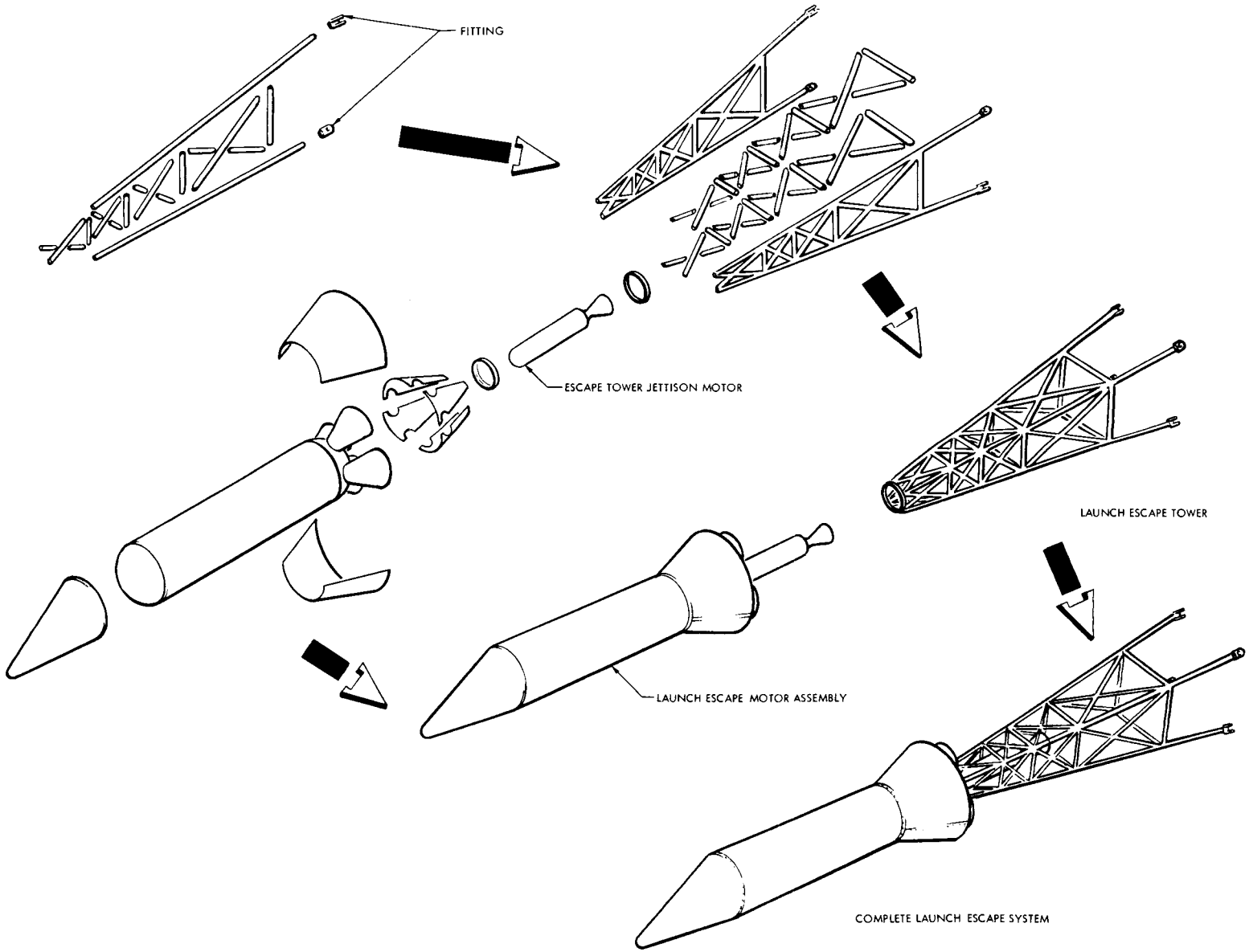

Figure 54. Launch Escape Tower Assembly Sequence

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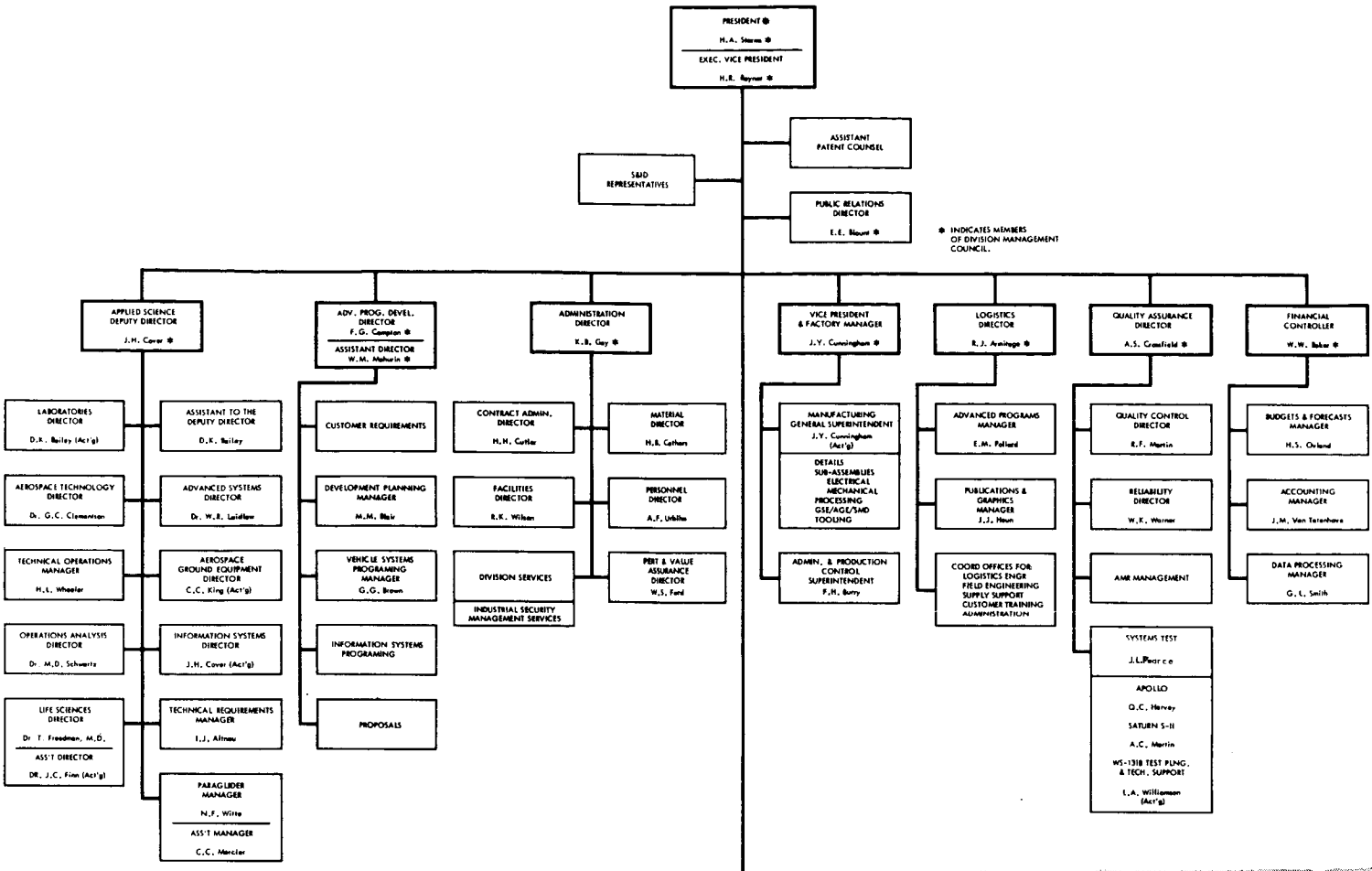
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VICE PRESIDENT & FACTORY MANAGER
J.Y. Cunningham ✱
MANUFACTURING GENERAL SUPERINTENDENT
J.Y. Cunningham (Act'g)
DETAILS
SUB-ASSEMBLIES
ELECTRICAL
MECHANICAL
PROCESSING
GSE/AGE/SMD
TOOLING
ADMIN. & PRODUCTION CONTROL SUPERINTENDENT
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LOGISTICS DIRECTOR
R.J. Armitage ✱
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QUALITY ASSURANCE DIRECTOR
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QUALITY CONTROL DIRECTOR
R.F. Martin
RELIABILITY DIRECTOR
W.K. Warner
AMR MANAGEMENT
SYSTEMS TEST
J.L. Pearce
APOLLO
O.C. Harvey
SATURN S-II
A.C. Martin
WS-1318 TEST PLNG. & TECH. SUPPORT
L.A. Williamson (Act'g)
FINANCIAL CONTROLLER
W.W. Baker ✱
BUDGETS & FORECASTS MANAGER
H.S. Orland
ACCOUNTING MANAGER
J.M. Van Tatenhove
DATA PROCESSING MANAGER
G.L. Smith

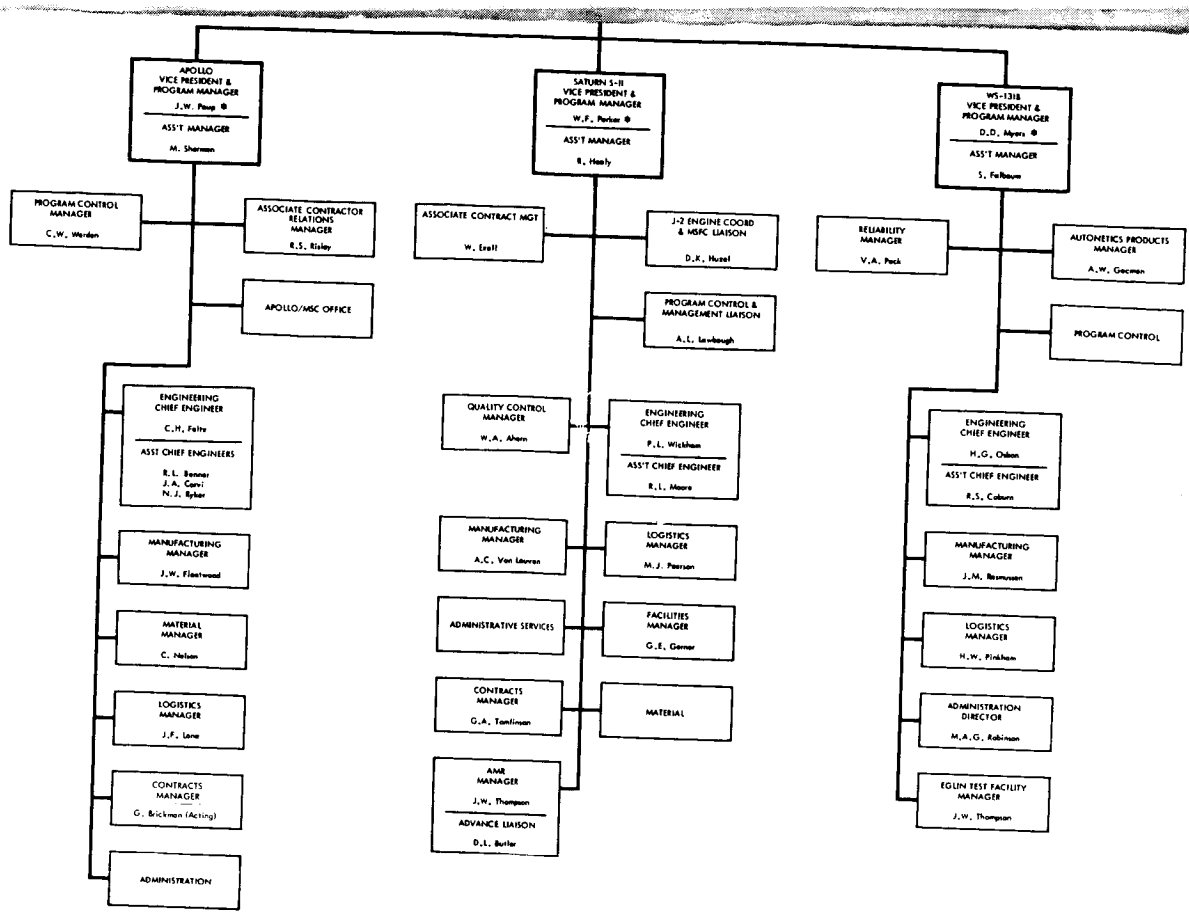

Figure 2. S&ID Organization

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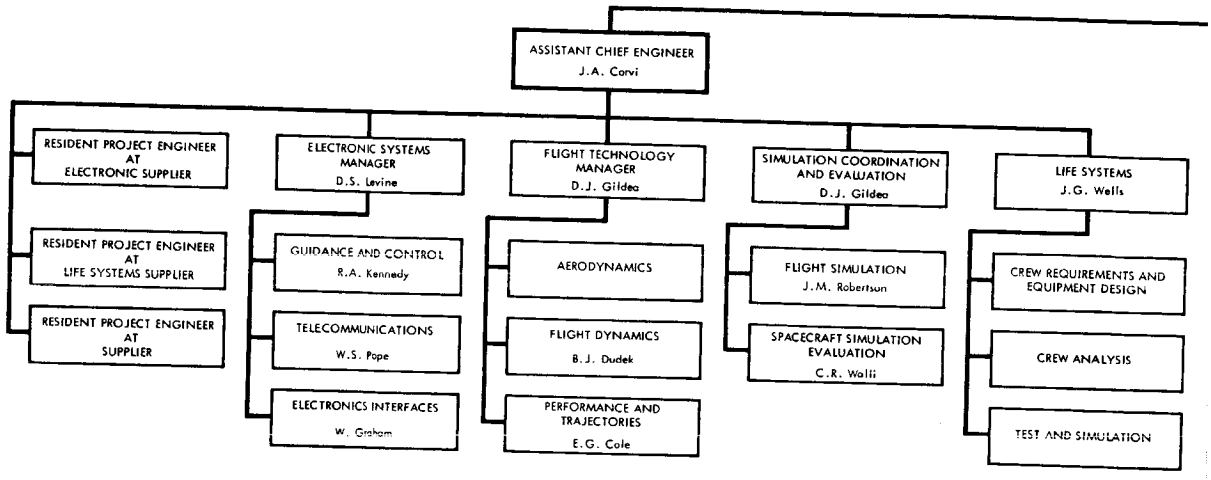

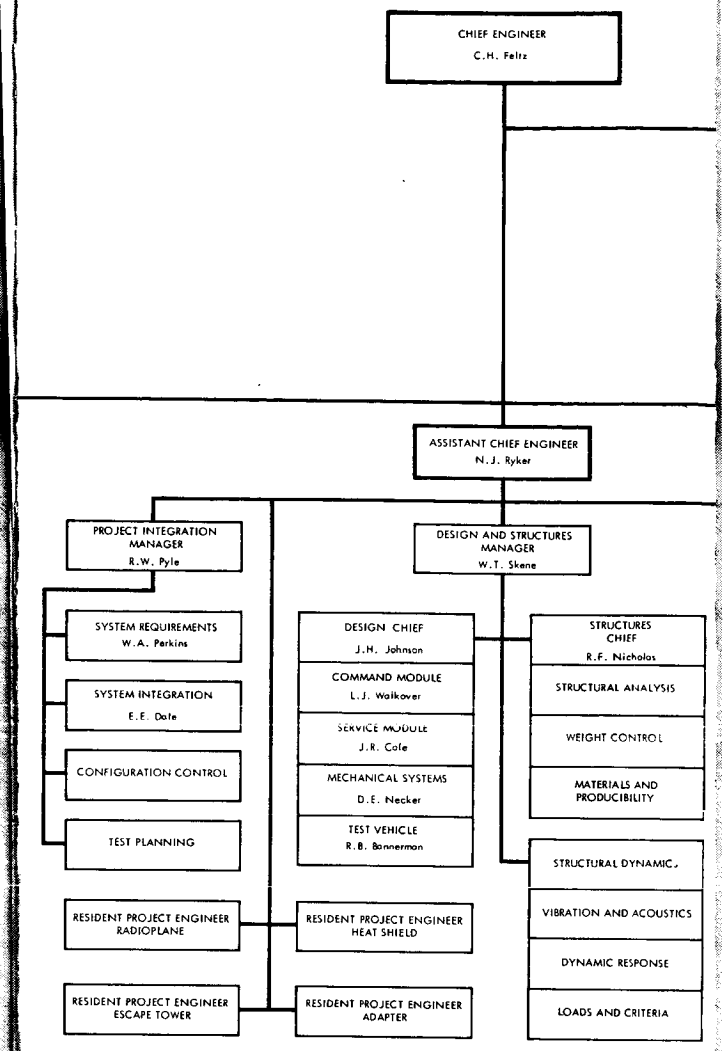
CHIEF ENGINEER
C.H. Feltz
ASSISTANT CHIEF ENGINEER
N.J. Ryker
PROJECT INTEGRATION MANAGER
R.W. Pyle
DESIGN AND STRUCTURES MANAGER
W.T. Skene
SYSTEM REQUIREMENTS
W.A. Perkins
SYSTEM INTEGRATION
E.E. Dale
CONFIGURATION CONTROL
TEST PLANNING
DESIGN CHIEF
J.H. Johnson
COMMAND MODULE
L.J. Walkover
SERVICE MODULE
J.R. Cole
MECHANICAL SYSTEMS
D.E. Necker
TEST VEHICLE
R.B. Bannerman
STRUCTURES CHIEF
R.F. Nicholas
STRUCTURAL ANALYSIS
WEIGHT CONTROL
MATERIALS AND PRODUCIBILITY
STRUCTURAL DYNAMICS
VIBRATION AND ACOUSTICS
DYNAMIC RESPONSE
LOADS AND CRITERIA
RESIDENT PROJECT ENGINEER RADIOPLANE
RESIDENT PROJECT ENGINEER HEAT SHIELD
RESIDENT PROJECT ENGINEER ESCAPE TOWER
RESIDENT PROJECT ENGINEER ADAPTER

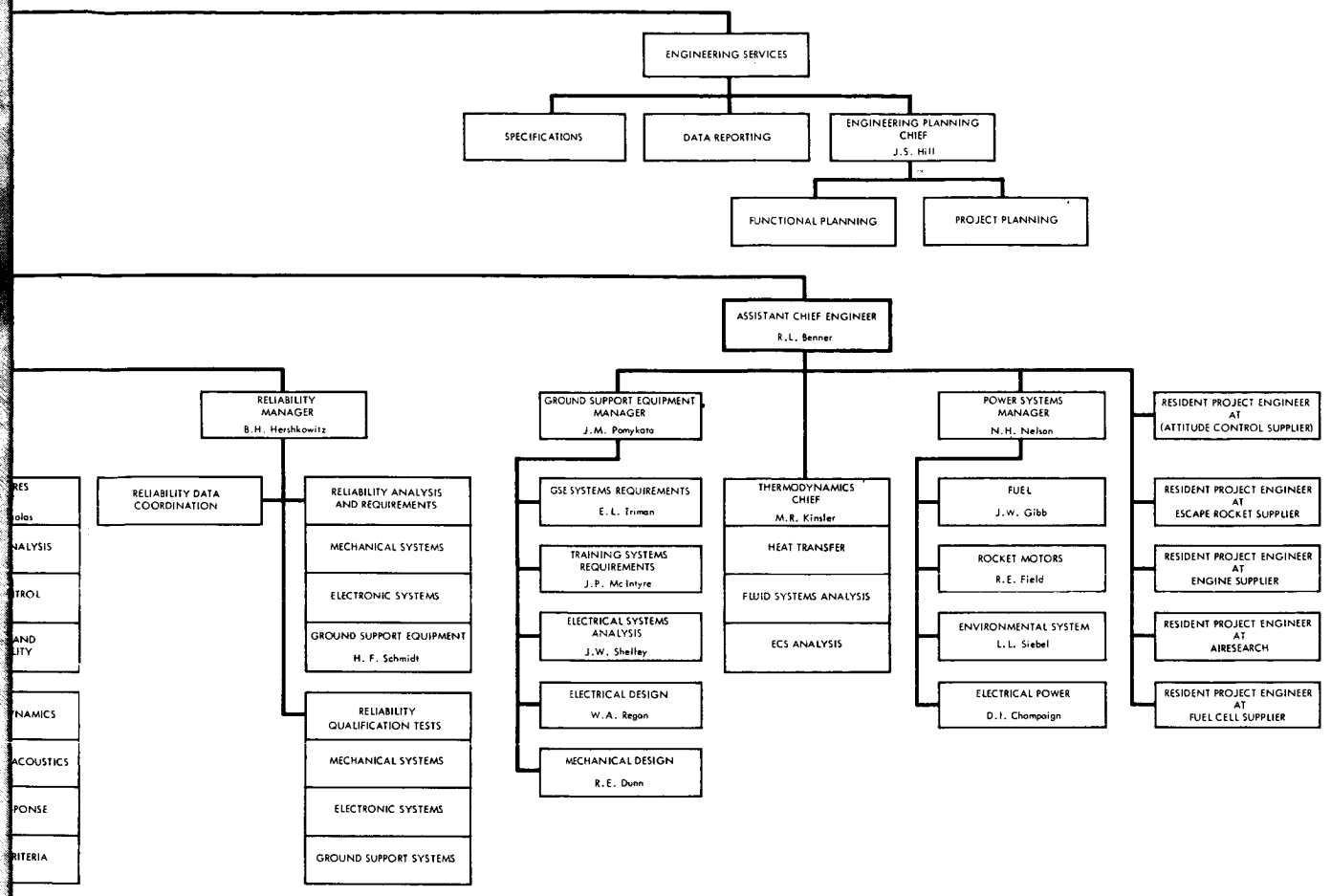

Figure 6. Apollo Engineering Organization

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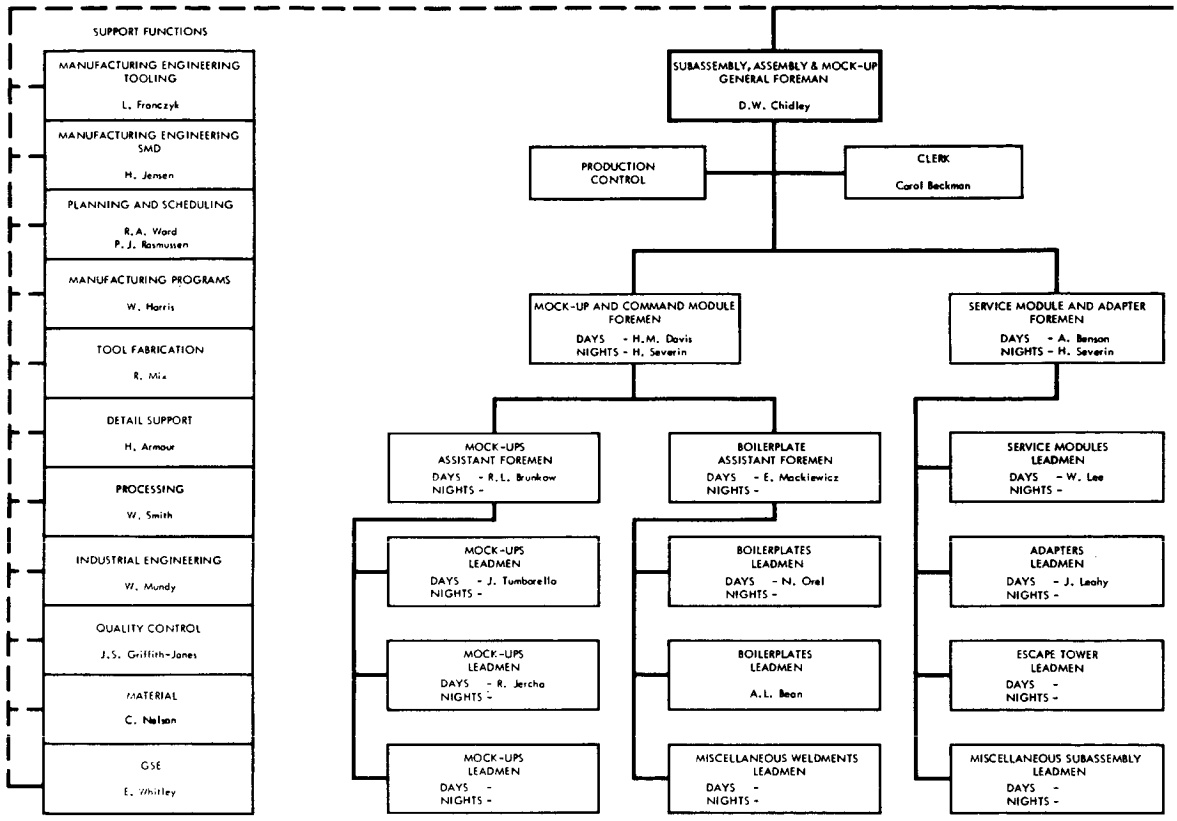
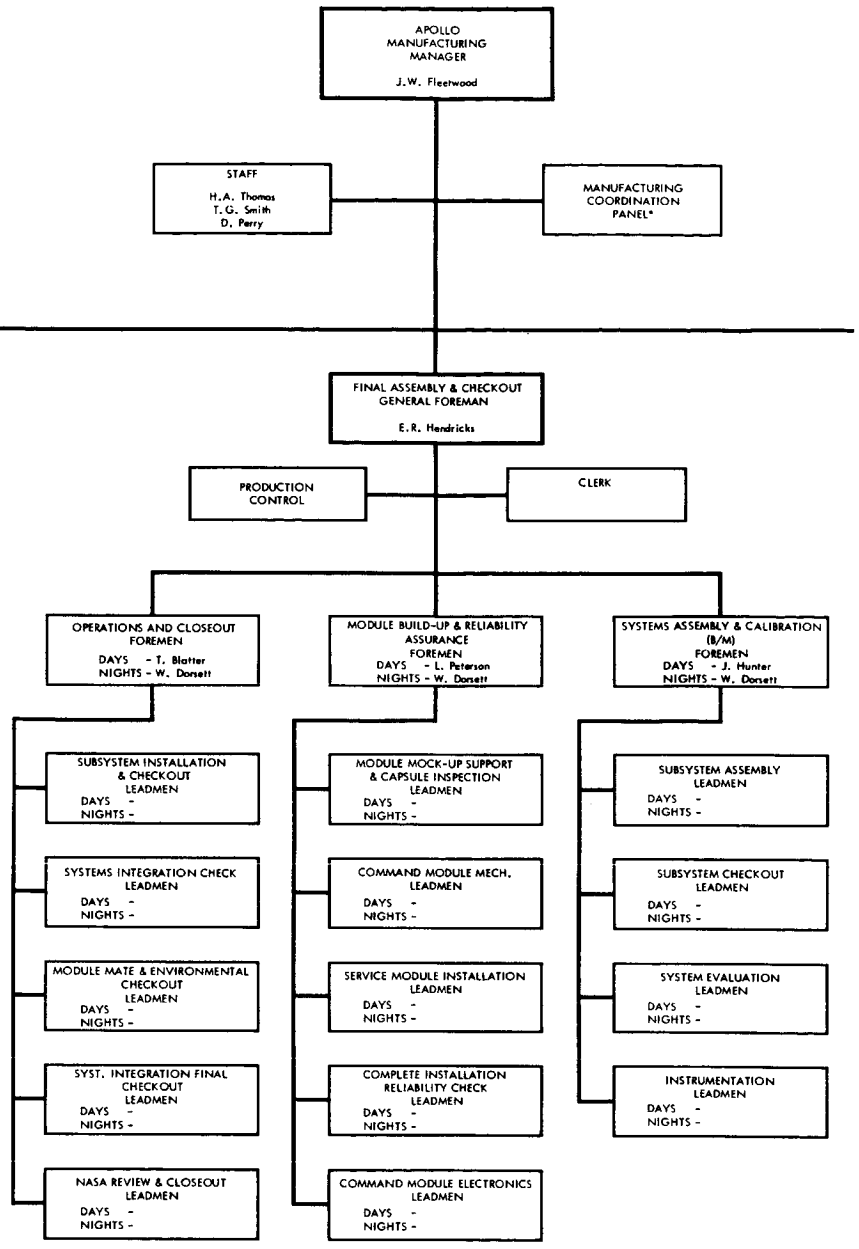



APOLLO MANUFACTURING MANAGER
J.W. Fleetwood
STAFF
H.A. Thomas
T.G. Smith
D. Perry
MANUFACTURING COORDINATION PANEL*
FINAL ASSEMBLY & CHECKOUT GENERAL FOREMAN
E.R. Hendricks
PRODUCTION CONTROL
CLERK
OPERATIONS AND CLOSEOUT FOREMEN
DAYS - T. Blatter
NIGHTS - W. Dorsett
MODULE BUILD-UP & RELIABILITY ASSURANCE FOREMEN
DAYS - L. Peterson
NIGHTS - W. Dorsett
SYSTEMS ASSEMBLY & CALIBRATION (B/M) FOREMEN
DAYS - J. Hunter
NIGHTS - W. Dorsett
SUBSYSTEM INSTALLATION & CHECKOUT LEADMEN
DAYS -
NIGHTS -
SYSTEMS INTEGRATION CHECK LEADMEN
DAYS -
NIGHTS -
MODULE MATE & ENVIRONMENTAL CHECKOUT LEADMEN
DAYS -
NIGHTS -
SYST. INTEGRATION FINAL CHECKOUT LEADMEN
DAYS -
NIGHTS -
NASA REVIEW & CLOSEOUT LEADMEN
DAYS -
NIGHTS -
MODULE MOCK-UP SUPPORT & CAPSULE INSPECTION LEADMEN
DAYS -
NIGHTS -
COMMAND MODULE MECH. LEADMEN
DAYS -
NIGHTS -
SERVICE MODULE INSTALLATION LEADMEN
DAYS -
NIGHTS -
COMPLETE INSTALLATION RELIABILITY CHECK LEADMEN
DAYS -
NIGHTS -
COMMAND MODULE ELECTRONICS LEADMEN
DAYS -
NIGHTS -
SUBSYSTEM ASSEMBLY LEADMEN
DAYS -
NIGHTS -
SUBSYSTEM CHECKOUT LEADMEN
DAYS -
NIGHTS -
SYSTEM EVALUATION LEADMEN
DAYS -
NIGHTS -
INSTRUMENTATION LEADMEN
DAYS -
NIGHTS -

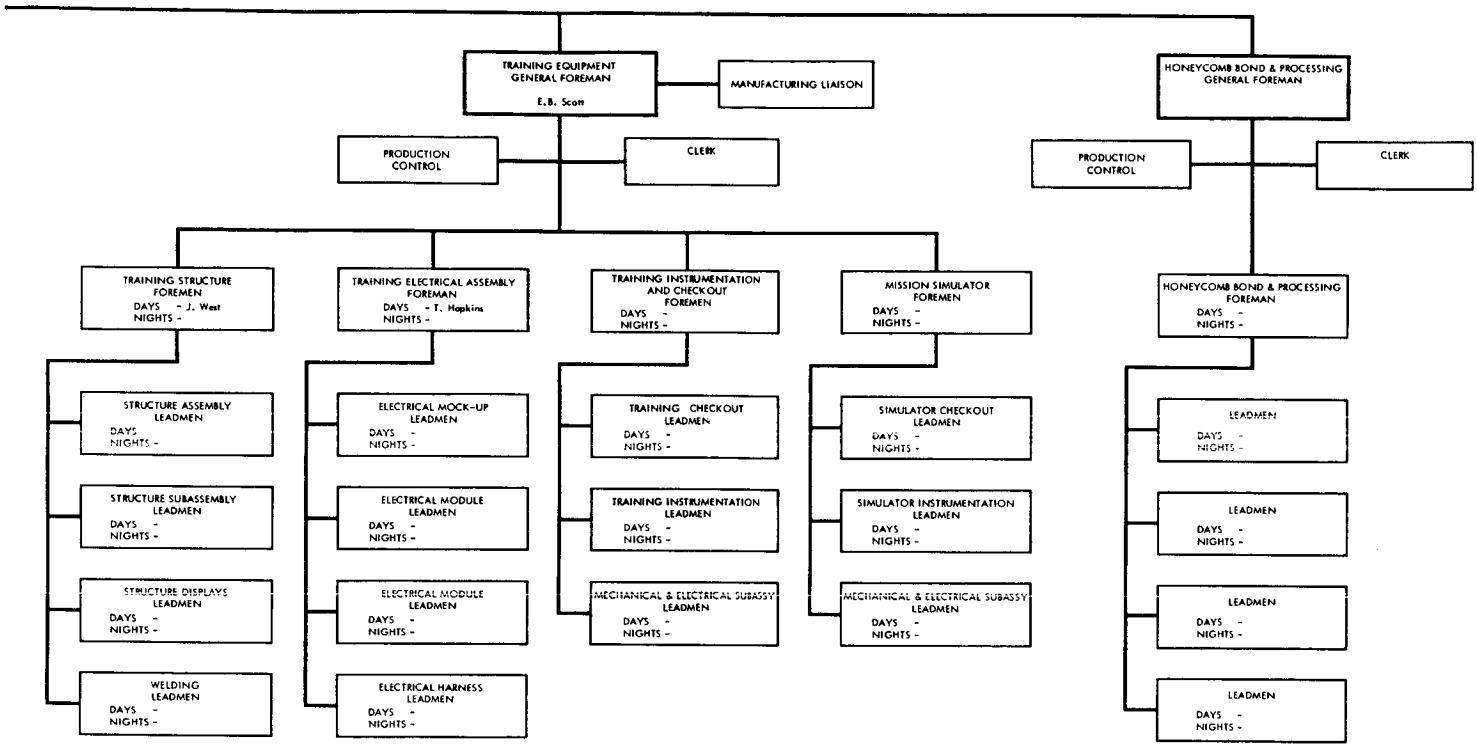
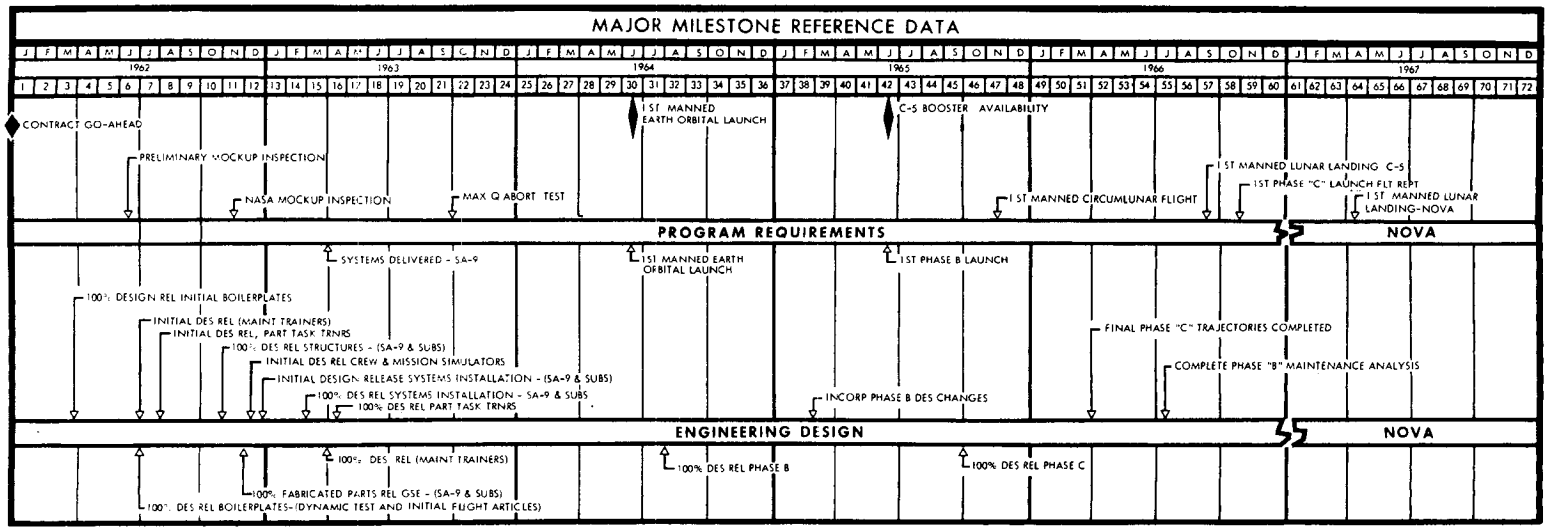
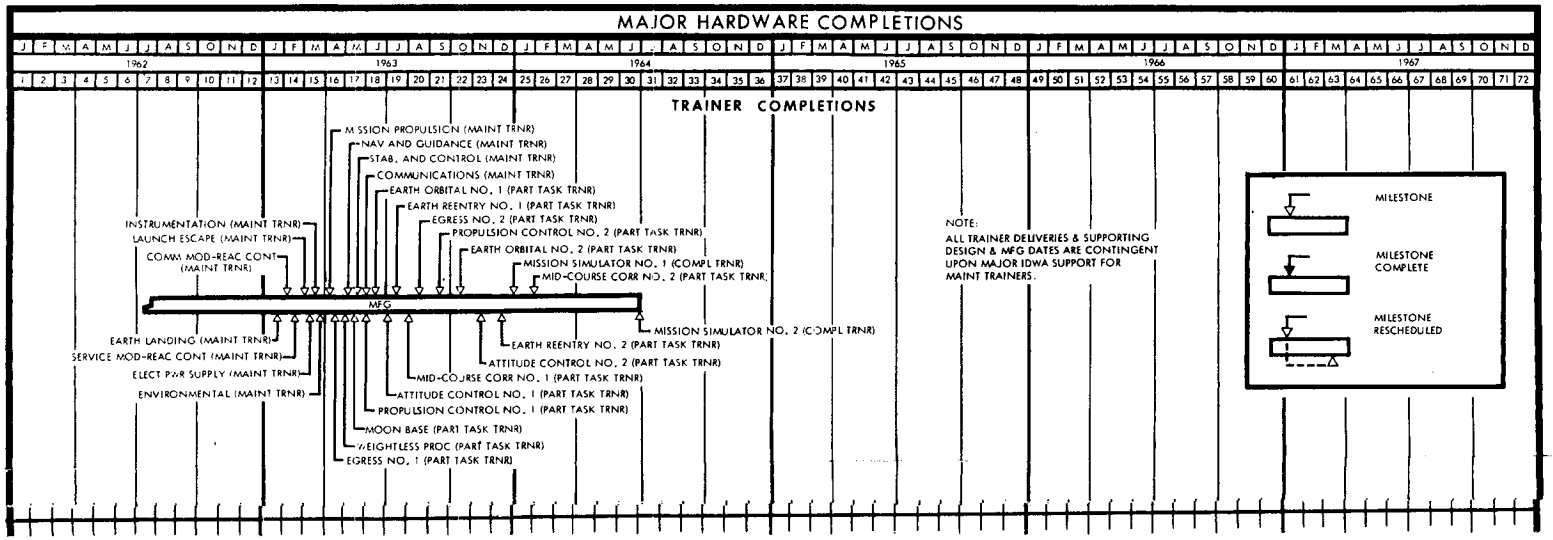


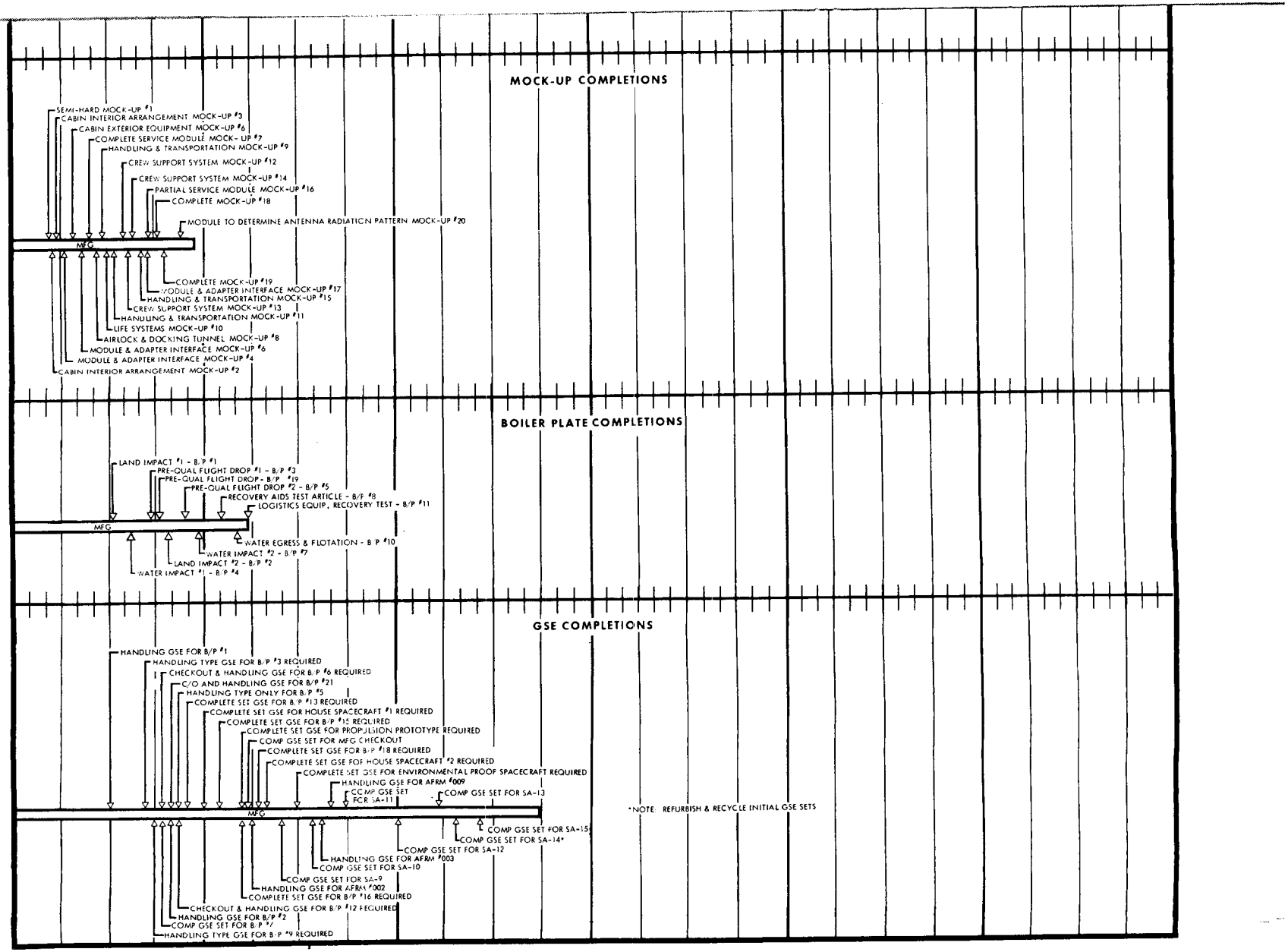
Figure 7. Apollo Manufacturing Organization

NORTH AMERICAN AVIATION, INC. SPACE and INFORMATION SYSTEMS DIVISION

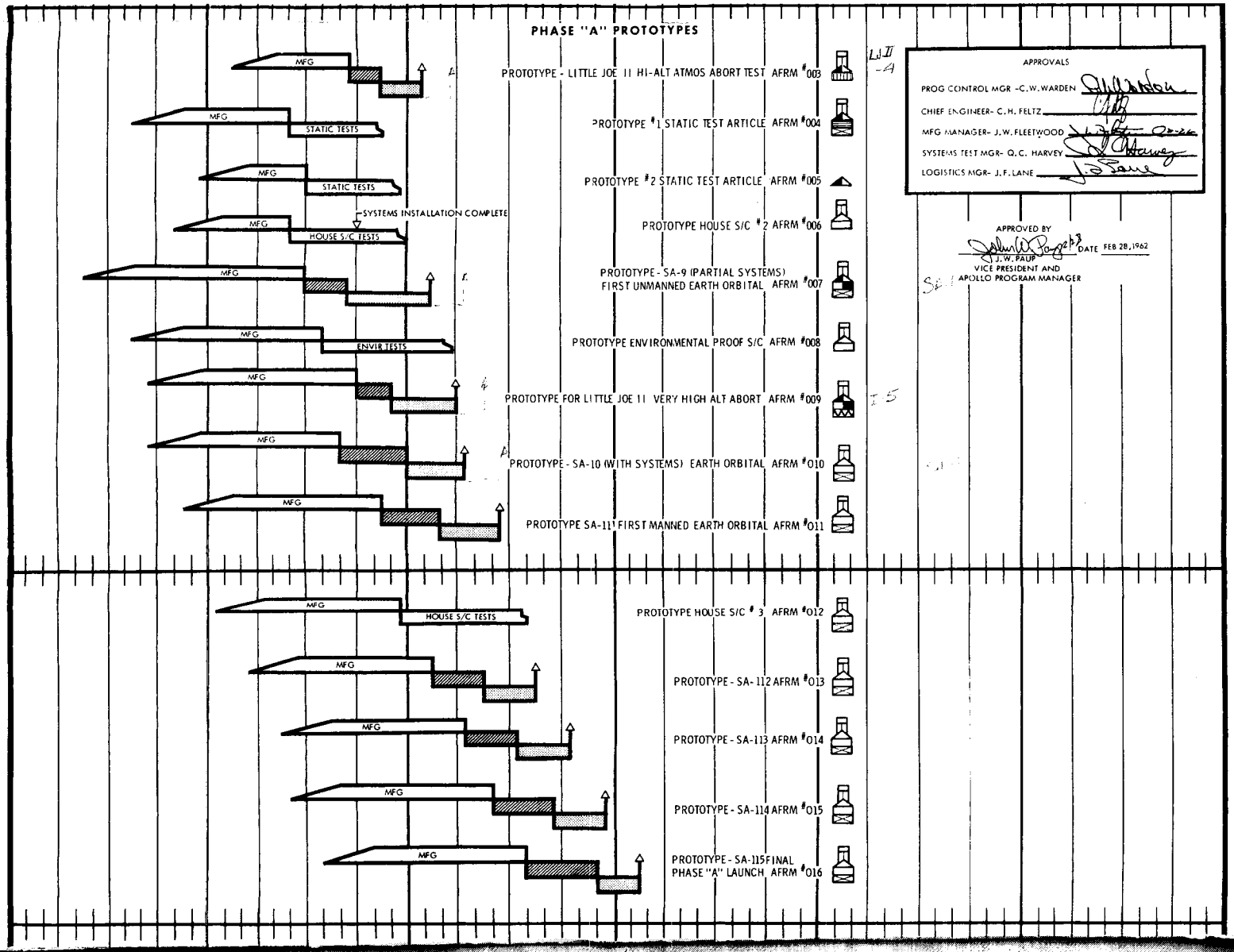
~~CONFIDENTIAL~~






MOCK-UP COMPLETIONS
SEMI-HARD MOCK-UP #1
CABIN INTERIOR ARRANGEMENT MOCK-UP #3
CABIN EXTERIOR EQUIPMENT MOCK-UP #6
COMPLETE SERVICE MODULE MOCK-UP #7
HANDLING & TRANSPORTATION MOCK-UP #9
CREW SUPPORT SYSTEM MOCK-UP #12
CREW SUPPORT SYSTEM MOCK-UP #14
PARTIAL SERVICE MODULE MOCK-UP #16
COMPLETE MOCK-UP #18
MODULE TO DETERMINE ANTENNA RADIATION PATTERN MOCK-UP #20
MFG
COMPLETE MOCK-UP #19
MODULE & ADAPTER INTERFACE MOCK-UP #17
HANDLING & TRANSPORTATION MOCK-UP #15
CREW SUPPORT SYSTEM MOCK-UP #13
HANDLING & TRANSPORTATION MOCK-UP #11
LIFE SYSTEMS MOCK-UP #10
AIRLOCK & DOCKING TUNNEL MOCK-UP #8
MODULE & ADAPTER INTERFACE MOCK-UP #6
MODULE & ADAPTER INTERFACE MOCK-UP #4
CABIN INTERIOR ARRANGEMENT MOCK-UP #2
BOILER PLATE COMPLETIONS
LAND IMPACT #1 - B/P #1
PRE-QUAL FLIGHT DROP #1 - B/P #3
PRE-QUAL FLIGHT DROP - B/P #19
PRE-QUAL FLIGHT DROP #2 - B/P #5
RECOVERY AIDS TEST ARTICLE - B/P #8
LOGISTICS EQUIP. RECOVERY TEST - B/P #11
MFG
WATER EGRESS & FLOTATION - B/P #10
WATER IMPACT #2 - B/P #7
LAND IMPACT #2 - B/P #2
WATER IMPACT #1 - B/P #4
GSE COMPLETIONS
HANDLING GSE FOR B/P #1
HANDLING TYPE GSE FOR B/P #3 REQUIRED
CHECKOUT & HANDLING GSE FOR B/P #6 REQUIRED
C/O AND HANDLING GSE FOR B/P #21
HANDLING TYPE ONLY FOR B/P #5
COMPLETE SET GSE FOR B/P #13 REQUIRED
COMPLETE SET GSE FOR HOUSE SPACECRAFT #1 REQUIRED
COMPLETE SET GSE FOR B/P #15 REQUIRED
COMPLETE SET GSE FOR PROPULSION PROTOTYPE REQUIRED
COMP GSE SET FOR MFG CHECKOUT
COMPLETE SET GSE FOR B/P #18 REQUIRED
COMPLETE SET GSE FOR HOUSE SPACECRAFT #2 REQUIRED
COMPLETE SET GSE FOR ENVIRONMENTAL PROOF SPACECRAFT REQUIRED
HANDLING GSE FOR AFRM #009
COMP GSE SET FOR SA-11
COMP GSE SET FOR SA-13
MFG
*NOTE: REFURBISH & RECYCLE INITIAL GSE SETS
COMP GSE SET FOR SA-15
COMP GSE SET FOR SA-14*
COMP GSE SET FOR SA-12
HANDLING GSE FOR AFRM #003
COMP GSE SET FOR SA-10
COMP GSE SET FOR SA-9
HANDLING GSE FOR AFRM #002
COMPLETE SET GSE FOR B/P #16 REQUIRED
CHECKOUT & HANDLING GSE FOR B/P #12 REQUIRED
HANDLING GSE FOR B/P #2
COMP GSE SET FOR B/P #7
HANDLING TYPE GSE FOR B/P #9 REQUIRED

PHASING PLAN
1962
1963
1964
1965
1966
1967
PHASE "A" BOILERPLATES
MFG
DYNAMIC TESTS
SYSTEM AVAILABILITY
HOUSE S/C TESTS
S/M ONLY
C/M DEL
PROPULSION TESTS
LAUNCH ESCAPE TOWERS (2)
BOILERPLATE S/C # 6 FOR PAD ABORT
B/P S/C #20- PAD ABORT
BOILERPLATE S/C # 9 DYNAMIC TEST ARTICLE
BOILERPLATE S/C #12 FOR LITTLE JOE II
B/P S/C #21 LITTLE JOE II
BOILERPLATE #13-SA-5 FIRST SATURN LAUNCH
BOILERPLATE # 14 HOUSE S/C # 1
BOILERPLATE # 15 - SA-6
PROTOTYPE - LITTLE JOE II MAX Q ABORT TEST AFRM #002
BOILERPLATE # 16 - SA-7 (SYSTEMS AS REQ) FIRST HEAT SHIELD LAUNCH
PROTOTYPE - PROPULSION SPACECRAFT AFRM #001
BOILERPLATE #18 - SA-8 (SYSTEMS AS REQ) FINAL BOILERPLATE LAUNCH
SA-7
SA-8
PROGRESS TO DATE
ENGR ACCEPTANCE TEST
LAUNCH
AMR LAUNCH OPERATION
TOWER
C/M STRUCTURES & PARTIAL SYSTEMS
C/M COMPLETE
S/M PARTIAL SYSTEMS
S/M STRUCTURES ONLY
S/M COMPLETE
PAD ABORT ADAPTER
B/P ADAPTER
C/M - LITTLE JOE II ADAPTER
S/M-C-1, C-5 ADAPTER
C/M TO C-1 ADAPTER
S/M - LITTLE JOE II ADAPTER
LUNAR LANDING PROPULSION MODULE
S M TO DOLLY PROPULSION ADAPTER


PHASE "A" PROTOTYPES
MFG
STATIC TESTS
SYSTEMS INSTALLATION COMPLETE
HOUSE S/C TESTS
ENVIR TESTS
PROTOTYPE - LITTLE JOE II HI-ALT ATMOS ABORT TEST AFRM #003
PROTOTYPE #1 STATIC TEST ARTICLE AFRM #004
PROTOTYPE #2 STATIC TEST ARTICLE AFRM #005
PROTOTYPE HOUSE S/C #2 AFRM #006
PROTOTYPE - SA-9 (PARTIAL SYSTEMS) FIRST UNMANNED EARTH ORBITAL AFRM #007
PROTOTYPE ENVIRONMENTAL PROOF S/C AFRM #008
PROTOTYPE FOR LITTLE JOE II VERY HIGH ALT ABORT AFRM #009
PROTOTYPE - SA-10 (WITH SYSTEMS) EARTH ORBITAL AFRM #010
PROTOTYPE SA-11 FIRST MANNED EARTH ORBITAL AFRM #011
PROTOTYPE HOUSE S/C #3 AFRM #012
PROTOTYPE - SA-112 AFRM #013
PROTOTYPE - SA-113 AFRM #014
PROTOTYPE - SA-114 AFRM #015
PROTOTYPE - SA-115 FINAL PHASE "A" LAUNCH AFRM #016
APPROVALS
PROG CONTROL MGR -C.W. WARDEN
CHIEF ENGINEER- C.H. FELTZ
MFG MANAGER- J.W. FLEETWOOD
SYSTEMS TEST MGR- Q.C. HARVEY
LOGISTICS MGR- J.F. LANE
APPROVED BY
J.W. PAUP
VICE PRESIDENT AND
APOLLO PROGRAM MANAGER
DATE FEB 28, 1962

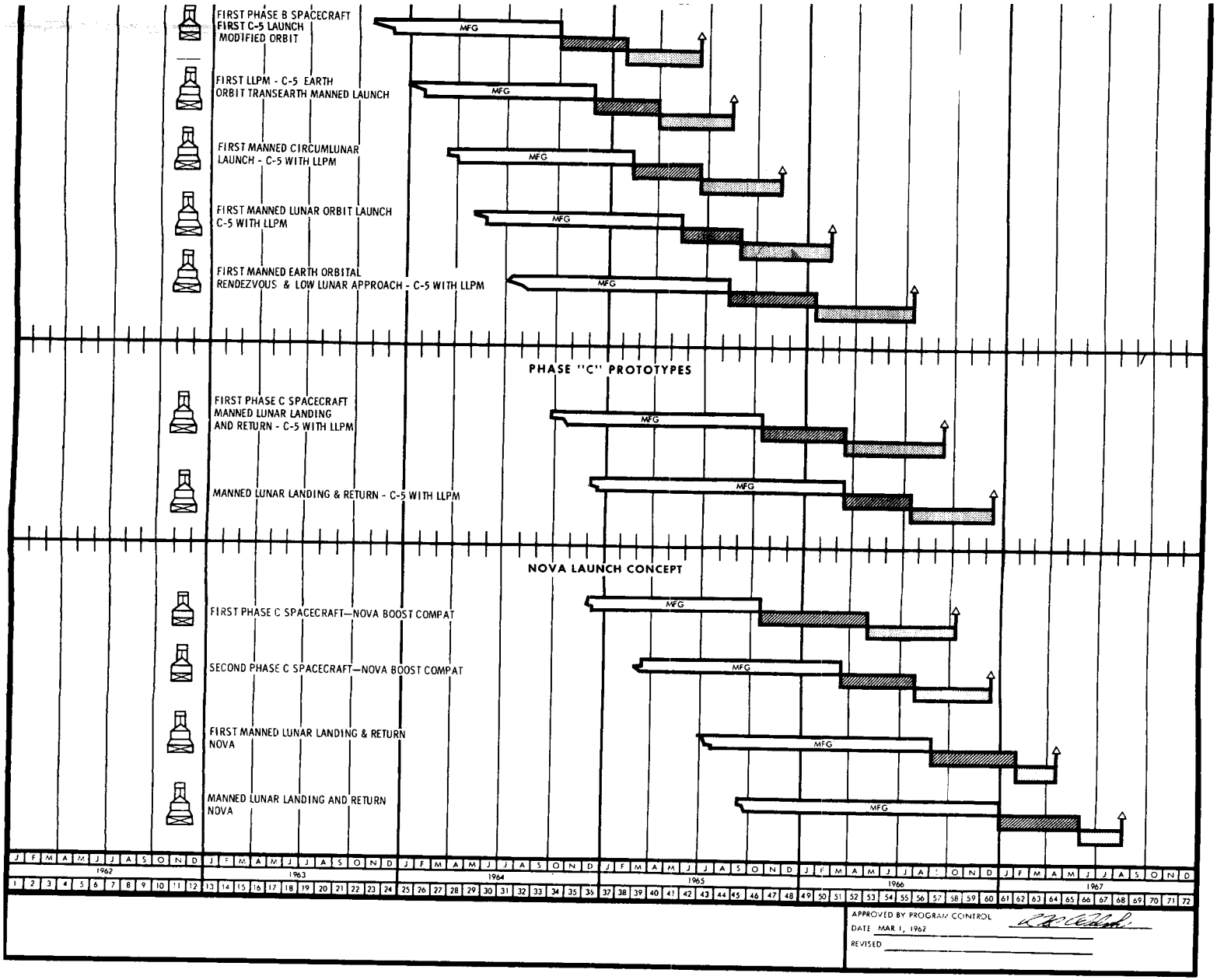


Figure 10. Apollo Program Master Phasing Plan

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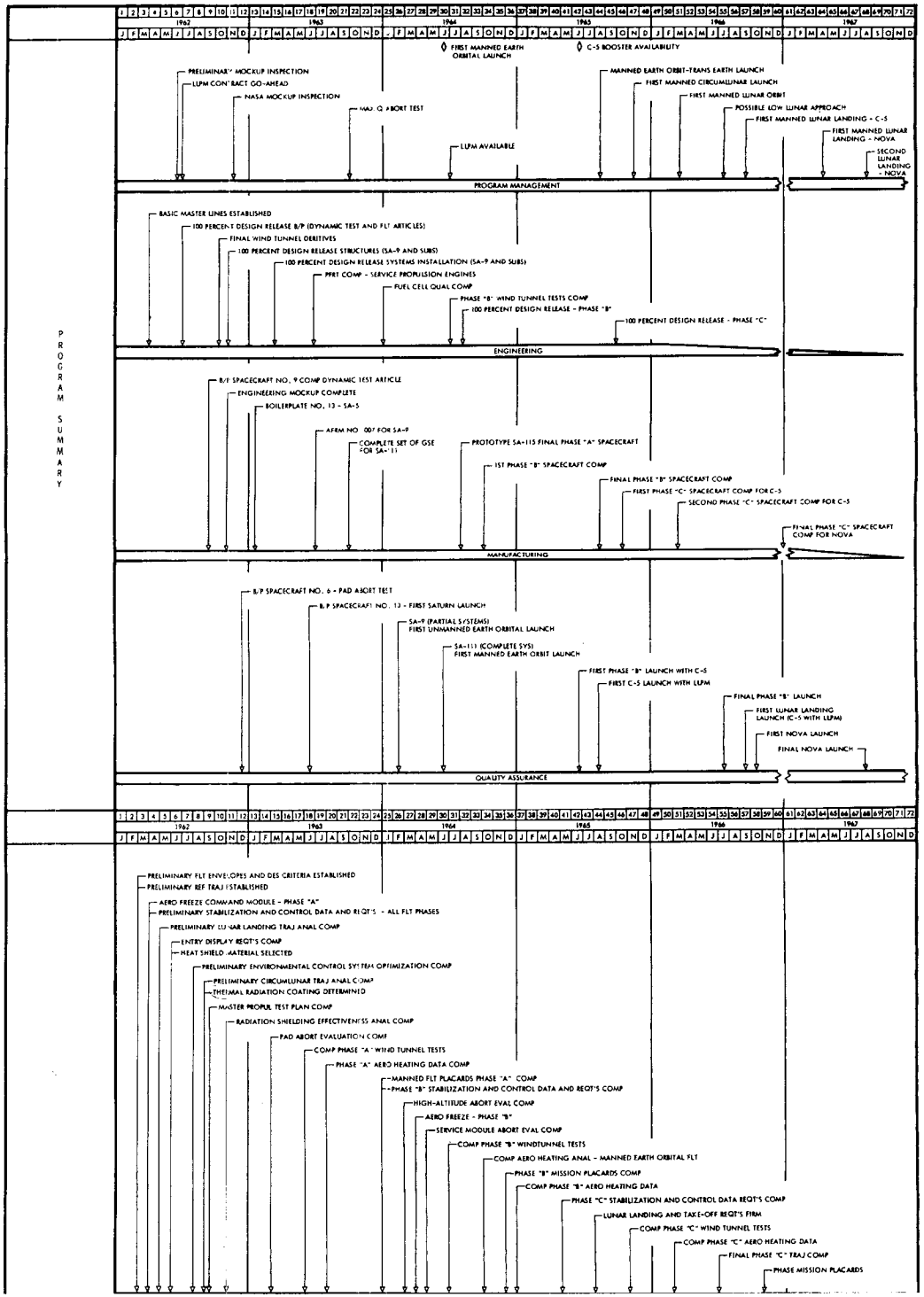
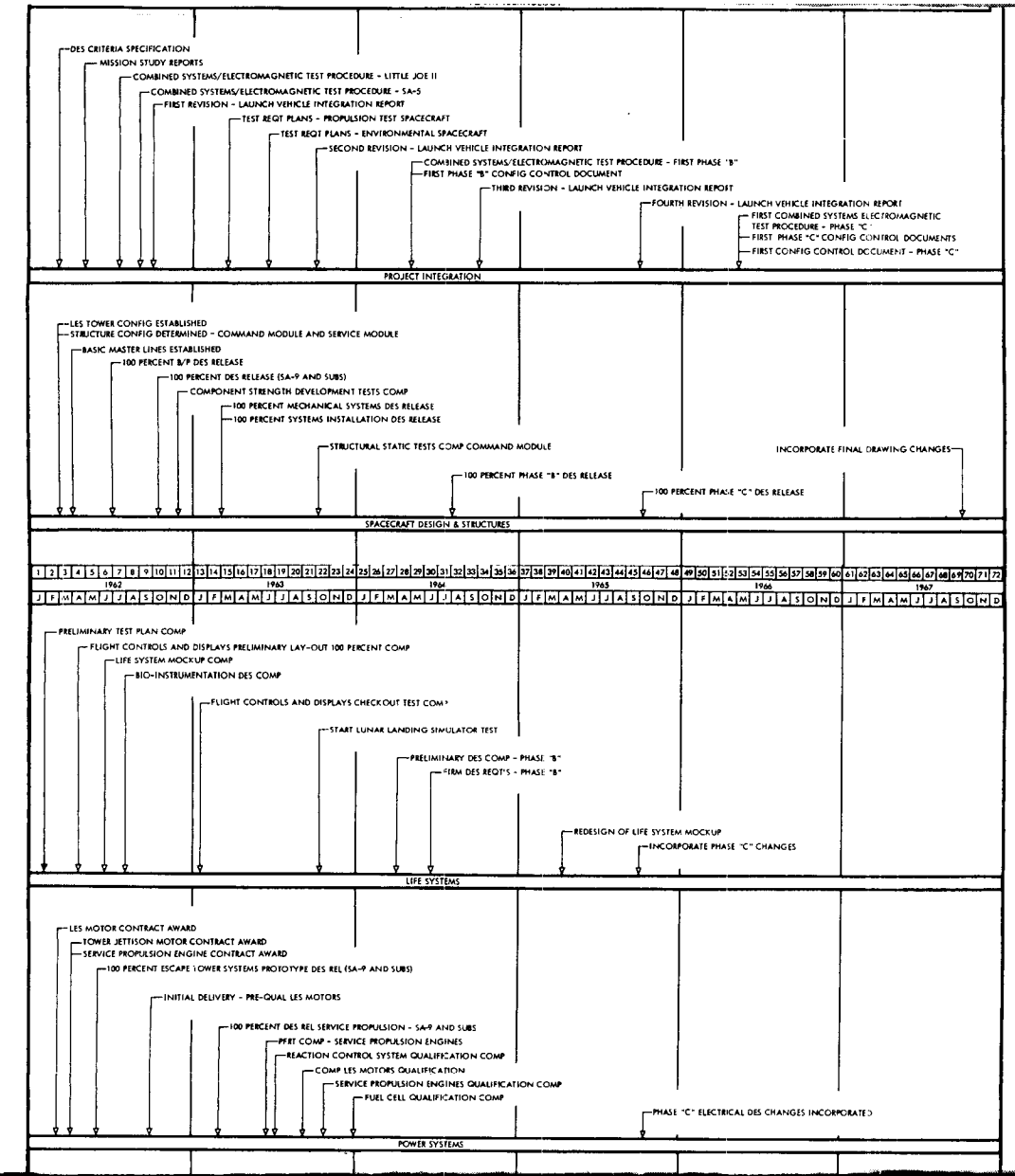
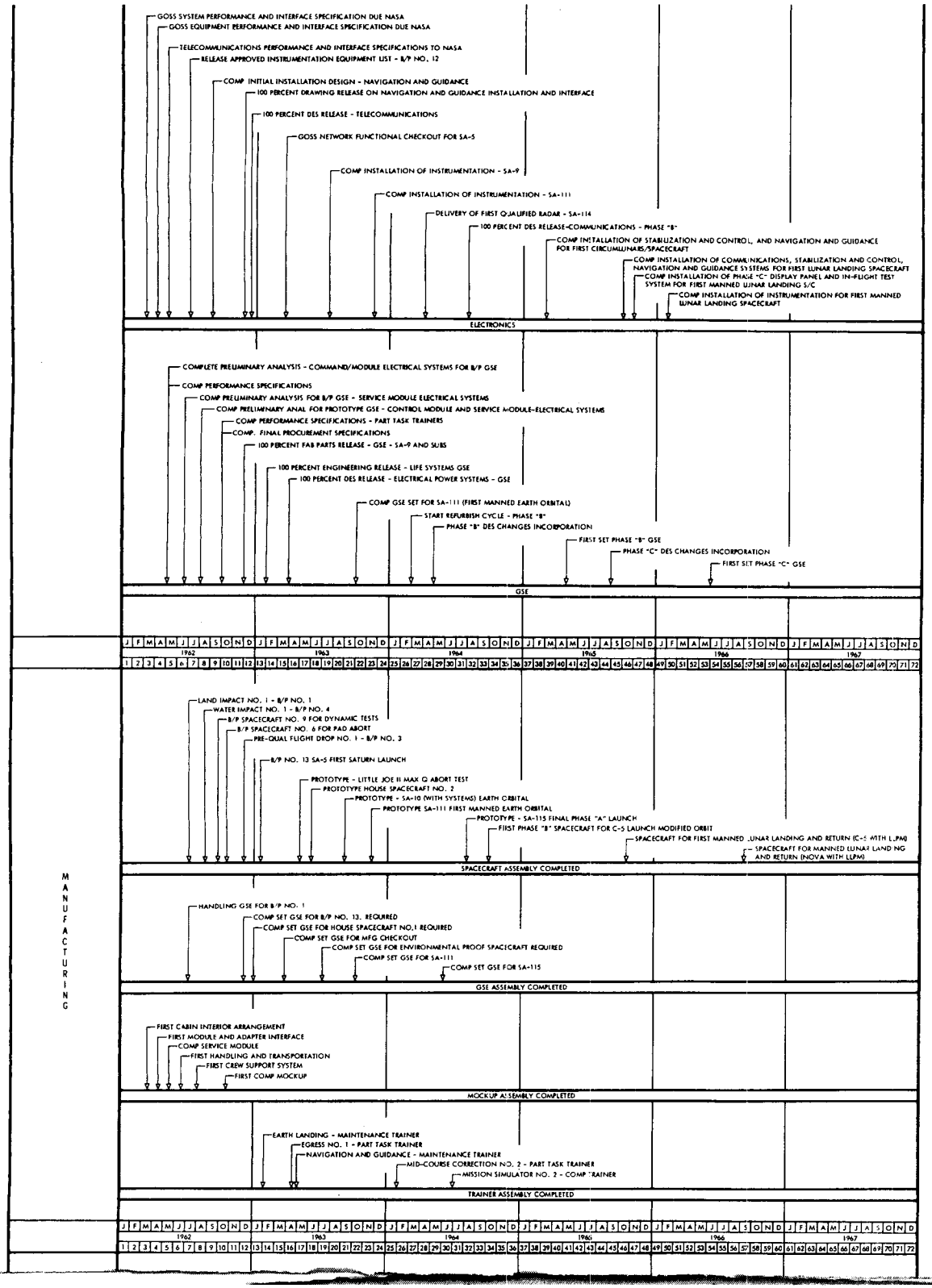
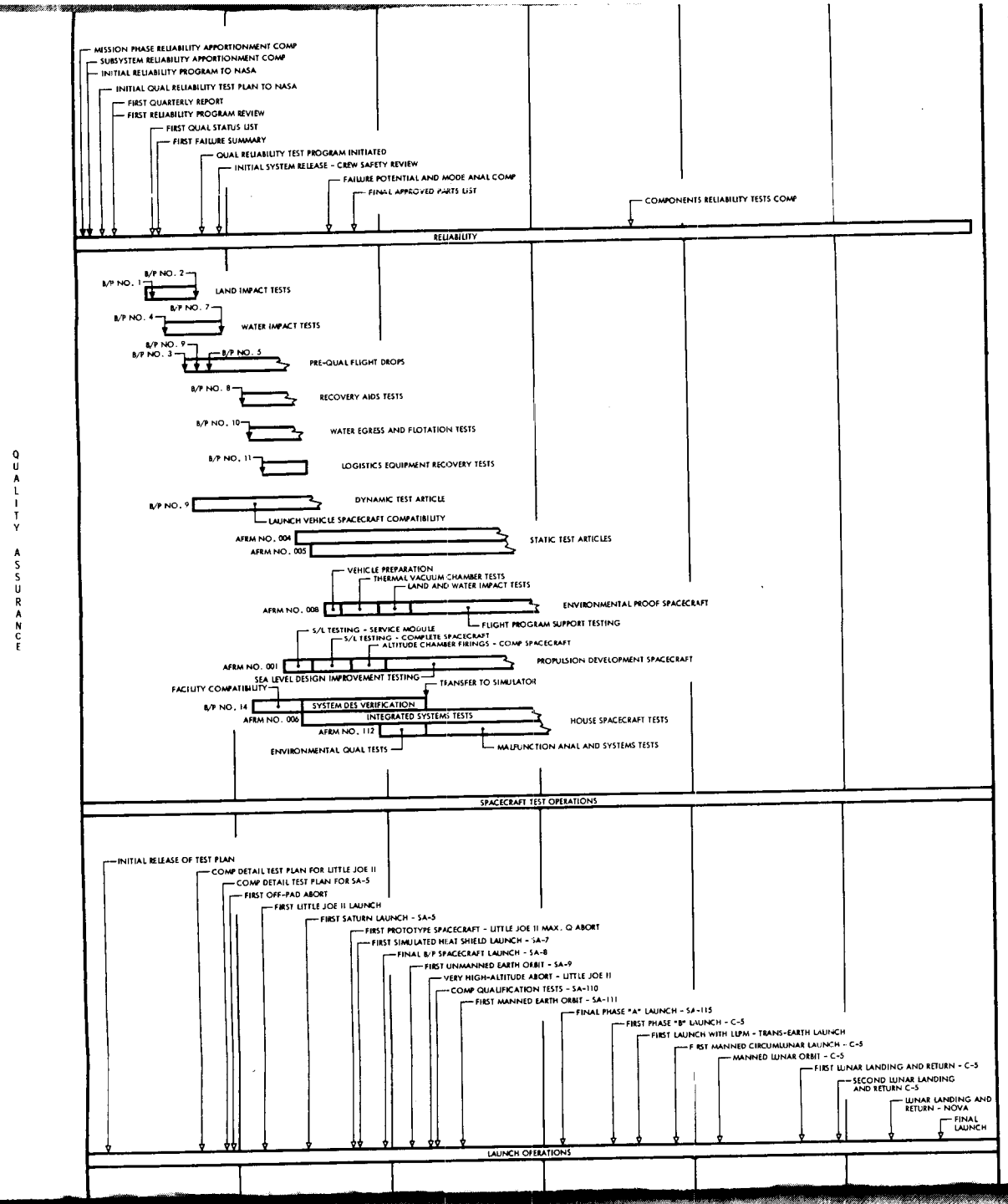

PROGRAM SUMMARY
1962
1963
1964
1965
1966
1967
FIRST MANNED EARTH ORBITAL LAUNCH
C-5 BOOSTER AVAILABILITY
PRELIMINARY MOCKUP INSPECTION
LPM CONTRACT GO-AHEAD
NASA MOCKUP INSPECTION
MAJ. Q ABORT TEST
LPM AVAILABLE
MANNED EARTH ORBIT-TRANS EARTH LAUNCH
FIRST MANNED CIRCUMLUNAR LAUNCH
FIRST MANNED LUNAR ORBIT
POSSIBLE LOW LUNAR APPROACH
FIRST MANNED LUNAR LANDING - C-5
FIRST MANNED LUNAR LANDING - NOVA
SECOND LUNAR LANDING - NOVA
PROGRAM MANAGEMENT
BASIC MASTER LINES ESTABLISHED
100 PERCENT DESIGN RELEASE B/P (DYNAMIC TEST AND FLT ARTICLES)
FINAL WIND TUNNEL OBJITIVES
100 PERCENT DESIGN RELEASE STRUCTURES (SA-9 AND SUBS)
100 PERCENT DESIGN RELEASE SYSTEMS INSTALLATION (SA-9 AND SUBS)
PRRT COMP - SERVICE PROPULSION ENGINES
FUEL CELL QUAL COMP
PHASE "B" WIND TUNNEL TESTS COMP
100 PERCENT DESIGN RELEASE - PHASE "B"
100 PERCENT DESIGN RELEASE - PHASE "C"
ENGINEERING
B/P SPACECRAFT NO. 9 COMP DYNAMIC TEST ARTICLE
ENGINEERING MOCKUP COMPLETE
BOILERPLATE NO. 13 - SA-5
AFEM NO 007 FOR SA-9
COMPLETE SET OF GSE FOR SA-11
PROTOTYPE SA-115 FINAL PHASE "A" SPACECRAFT
1ST PHASE "B" SPACECRAFT COMP
FINAL PHASE "B" SPACECRAFT COMP
FIRST PHASE "C" SPACECRAFT COMP FOR C-5
SECOND PHASE "C" SPACECRAFT COMP FOR C-5
FINAL PHASE "C" SPACECRAFT COMP FOR NOVA
MANUFACTURING
B/P SPACECRAFT NO. 6 - PAD ABORT TEST
B/P SPACECRAFT NO. 13 - FIRST SATURN LAUNCH
SA-9 (PARTIAL SYSTEMS) FIRST UNMANNED EARTH ORBITAL LAUNCH
SA-111 (COMPLETE SYS) FIRST MANNED EARTH ORBIT LAUNCH
FIRST PHASE "B" LAUNCH WITH C-5
FIRST C-5 LAUNCH WITH LPM
FINAL PHASE "B" LAUNCH
FIRST LUNAR LANDING LAUNCH (C-5 WITH LPM)
FIRST NOVA LAUNCH
FINAL NOVA LAUNCH
QUALITY ASSURANCE
PRELIMINARY FLT ENVELOPES AND DES CRITERIA ESTABLISHED
PRELIMINARY REF TRAJ ESTABLISHED
AERO FREEZE COMMAND MODULE - PHASE "A"
PRELIMINARY STABILIZATION AND CONTROL DATA AND REQT'S - ALL FLT PHASES
PRELIMINARY LUNAR LANDING TRAJ ANAL COMP
ENTRY DISPLAY REQT'S COMP
HEAT SHIELD MATERIAL SELECTED
PRELIMINARY ENVIRONMENTAL CONTROL SYSTEM OPTIMIZATION COMP
PRELIMINARY CIRCUMLUNAR TRAJ ANAL COMP
THERMAL RADIATION COATING DETERMINED
MASTER PROPUL TEST PLAN COMP
RADIATION SHIELDING EFFECTIVENESS ANAL COMP
PAD ABORT EVALUATION COMP
COMP PHASE "A" WIND TUNNEL TESTS
PHASE "A" AERO HEATING DATA COMP
MANNED FLT PLACARDS PHASE "A" COMP
PHASE "B" STABILIZATION AND CONTROL DATA AND REQT'S COMP
HIGH-ALTITUDE ABORT EVAL COMP
AERO FREEZE - PHASE "B"
SERVICE MODULE ABORT EVAL COMP
COMP PHASE "B" WINDTUNNEL TESTS
COMP AERO HEATING ANAL - MANNED EARTH ORBITAL FLT
PHASE "B" MISSION PLACARDS COMP
COMP PHASE "B" AERO HEATING DATA
PHASE "C" STABILIZATION AND CONTROL DATA REQT'S COMP
LUNAR LANDING AND TAKE-OFF REQT'S FIRM
COMP PHASE "C" WIND TUNNEL TESTS
COMP PHASE "C" AERO HEATING DATA
FINAL PHASE "C" TRAJ COMP
PHASE MISSION PLACARDS


DES CRITERIA SPECIFICATION
MISSION STUDY REPORTS
COMBINED SYSTEMS/ELECTROMAGNETIC TEST PROCEDURE - LITTLE JOE II
COMBINED SYSTEMS/ELECTROMAGNETIC TEST PROCEDURE - SA-5
FIRST REVISION - LAUNCH VEHICLE INTEGRATION REPORT
TEST REQT PLANS - PROPULSION TEST SPACECRAFT
TEST REQT PLANS - ENVIRONMENTAL SPACECRAFT
SECOND REVISION - LAUNCH VEHICLE INTEGRATION REPORT
COMBINED SYSTEMS/ELECTROMAGNETIC TEST PROCEDURE - FIRST PHASE "B"
FIRST PHASE "B" CONFIG CONTROL DOCUMENT
THIRD REVISION - LAUNCH VEHICLE INTEGRATION REPORT
FOURTH REVISION - LAUNCH VEHICLE INTEGRATION REPORT
FIRST COMBINED SYSTEMS ELECTROMAGNETIC TEST PROCEDURE - PHASE "C"
FIRST PHASE "C" CONFIG CONTROL DOCUMENTS
FIRST CONFIG CONTROL DOCUMENT - PHASE "C"
PROJECT INTEGRATION
LES TOWER CONFIG ESTABLISHED
STRUCTURE CONFIG DETERMINED - COMMAND MODULE AND SERVICE MODULE
BASIC MASTER LINES ESTABLISHED
100 PERCENT B/P DES RELEASE
100 PERCENT DES RELEASE (SA-9 AND SUBS)
COMPONENT STRENGTH DEVELOPMENT TESTS COMP
100 PERCENT MECHANICAL SYSTEMS DES RELEASE
100 PERCENT SYSTEMS INSTALLATION DES RELEASE
STRUCTURAL STATIC TESTS COMP COMMAND MODULE
INCORPORATE FINAL DRAWING CHANGES
100 PERCENT PHASE "B" DES RELEASE
100 PERCENT PHASE "C" DES RELEASE
SPACECRAFT DESIGN & STRUCTURES
1962
1963
1964
1965
1966
1967
ENGINEERING
PRELIMINARY TEST PLAN COMP
FLIGHT CONTROLS AND DISPLAYS PRELIMINARY LAY-OUT 100 PERCENT COMP
LIFE SYSTEM MOCKUP COMP
BIO-INSTRUMENTATION DES COMP
FLIGHT CONTROLS AND DISPLAYS CHECKOUT TEST COMP
START LUNAR LANDING SIMULATOR TEST
PRELIMINARY DES COMP - PHASE "B"
FIRM DES REQT'S - PHASE "B"
REDESIGN OF LIFE SYSTEM MOCKUP
INCORPORATE PHASE "C" CHANGES
LIFE SYSTEMS
LES MOTOR CONTRACT AWARD
TOWER JETTISON MOTOR CONTRACT AWARD
SERVICE PROPULSION ENGINE CONTRACT AWARD
100 PERCENT ESCAPE TOWER SYSTEMS PROTOTYPE DES REL (SA-9 AND SUBS)
INITIAL DELIVERY - PRE-QUAL LES MOTORS
100 PERCENT DES REL SERVICE PROPULSION - SA-9 AND SUBS
PFRT COMP - SERVICE PROPULSION ENGINES
REACTION CONTROL SYSTEM QUALIFICATION COMP
COMP LES MOTORS QUALIFICATION
SERVICE PROPULSION ENGINES QUALIFICATION COMP
FUEL CELL QUALIFICATION COMP
PHASE "C" ELECTRICAL DES CHANGES INCORPORATED
POWER SYSTEMS


GOSS SYSTEM PERFORMANCE AND INTERFACE SPECIFICATION DUE NASA
GOSS EQUIPMENT PERFORMANCE AND INTERFACE SPECIFICATION DUE NASA
TELECOMMUNICATIONS PERFORMANCE AND INTERFACE SPECIFICATIONS TO NASA
RELEASE APPROVED INSTRUMENTATION EQUIPMENT LIST - B/P NO. 12
COMP INITIAL INSTALLATION DESIGN - NAVIGATION AND GUIDANCE
100 PERCENT DRAWING RELEASE ON NAVIGATION AND GUIDANCE INSTALLATION AND INTERFACE
100 PERCENT DES RELEASE - TELECOMMUNICATIONS
GOSS NETWORK FUNCTIONAL CHECKOUT FOR SA-5
COMP INSTALLATION OF INSTRUMENTATION - SA-9
COMP INSTALLATION OF INSTRUMENTATION - SA-111
DELIVERY OF FIRST QUALIFIED RADAR - SA-114
100 PERCENT DES RELEASE-COMMUNICATIONS - PHASE "B"
COMP INSTALLATION OF STABILIZATION AND CONTROL, AND NAVIGATION AND GUIDANCE FOR FIRST CIRCUMLUNARS/SPACECRAFT
COMP INSTALLATION OF COMMUNICATIONS, STABILIZATION AND CONTROL, NAVIGATION AND GUIDANCE SYSTEMS FOR FIRST LUNAR LANDING SPACECRAFT
COMP INSTALLATION OF PHASE "C" DISPLAY PANEL AND IN-FLIGHT TEST SYSTEM FOR FIRST MANNED LUNAR LANDING S/C
COMP INSTALLATION OF INSTRUMENTATION FOR FIRST MANNED LUNAR LANDING SPACECRAFT
ELECTRONICS
COMPLETE PRELIMINARY ANALYSIS - COMMAND/MODULE ELECTRICAL SYSTEMS FOR B/P GSE
COMP PERFORMANCE SPECIFICATIONS
COMP PRELIMINARY ANALYSIS FOR B/P GSE - SERVICE MODULE ELECTRICAL SYSTEMS
COMP PRELIMINARY ANAL FOR PROTOTYPE GSE - CONTROL MODULE AND SERVICE MODULE-ELECTRICAL SYSTEMS
COMP PERFORMANCE SPECIFICATIONS - PART TASK TRAINERS
COMP. FINAL PROCUREMENT SPECIFICATIONS
100 PERCENT FAB PARTS RELEASE - GSE - SA-9 AND SUBS
100 PERCENT ENGINEERING RELEASE - LIFE SYSTEMS GSE
100 PERCENT DES RELEASE - ELECTRICAL POWER SYSTEMS - GSE
COMP GSE SET FOR SA-111 (FIRST MANNED EARTH ORBITAL)
START REFURBISH CYCLE - PHASE "B"
PHASE "B" DES CHANGES INCORPORATION
FIRST SET PHASE "B" GSE
PHASE "C" DES CHANGES INCORPORATION
FIRST SET PHASE "C" GSE
GSE
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 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 S O N D J F M A M J J A S O N D
1962 1963 1964 1965 1966 1967
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72
LAND IMPACT NO. 1 - B/P NO. 1
WATER IMPACT NO. 1 - B/P NO. 4
B/P SPACECRAFT NO. 9 FOR DYNAMIC TESTS
B/P SPACECRAFT NO. 6 FOR PAD ABORT
PRE-QUAL FLIGHT DROP NO. 1 - B/P NO. 3
B/P NO. 13 SA-5 FIRST SATURN LAUNCH
PROTOTYPE - LITTLE JOE II MAX Q ABORT TEST
PROTOTYPE HOUSE SPACECRAFT NO. 2
PROTOTYPE - SA-10 (WITH SYSTEMS) EARTH ORBITAL
PROTOTYPE SA-111 FIRST MANNED EARTH ORBITAL
PROTOTYPE - SA-115 FINAL PHASE "A" LAUNCH
FIRST PHASE "B" SPACECRAFT FOR C-5 LAUNCH MODIFIED ORBIT
SPACECRAFT FOR FIRST MANNED LUNAR LANDING AND RETURN (C-5 WITH LPM)
SPACECRAFT FOR MANNED LUNAR LANDING AND RETURN (NOVA WITH LPM)
SPACECRAFT ASSEMBLY COMPLETED
HANDLING GSE FOR B/P NO. 1
COMP SET GSE FOR B/P NO. 13, REQUIRED
COMP SET GSE FOR HOUSE SPACECRAFT NO.1 REQUIRED
COMP SET GSE FOR MFG CHECKOUT
COMP SET GSE FOR ENVIRONMENTAL PROOF SPACECRAFT REQUIRED
COMP SET GSE FOR SA-111
COMP SET GSE FOR SA-115
GSE ASSEMBLY COMPLETED
FIRST CABIN INTERIOR ARRANGEMENT
FIRST MODULE AND ADAPTER INTERFACE
COMP SERVICE MODULE
FIRST HANDLING AND TRANSPORTATION
FIRST CREW SUPPORT SYSTEM
FIRST COMP MOCKUP
MOCKUP ASSEMBLY COMPLETED
EARTH LANDING - MAINTENANCE TRAINER
EGRESS NO. 1 - PART TASK TRAINER
NAVIGATION AND GUIDANCE - MAINTENANCE TRAINER
MID-COURSE CORRECTION NO. 2 - PART TASK TRAINER
MISSION SIMULATOR NO. 2 - COMP TRAINER
TRAINER ASSEMBLY COMPLETED
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 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 S O N D J F M A M J J A S O N D
1962 1963 1964 1965 1966 1967
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72
MANUFACTURING


QUALITY ASSURANCE
MISSION PHASE RELIABILITY APPORTIONMENT COMP
SUBSYSTEM RELIABILITY APPORTIONMENT COMP
INITIAL RELIABILITY PROGRAM TO NASA
INITIAL QUAL RELIABILITY TEST PLAN TO NASA
FIRST QUARTERLY REPORT
FIRST RELIABILITY PROGRAM REVIEW
FIRST QUAL STATUS LIST
FIRST FAILURE SUMMARY
QUAL RELIABILITY TEST PROGRAM INITIATED
INITIAL SYSTEM RELEASE - CREW SAFETY REVIEW
FAILURE POTENTIAL AND MODE ANAL COMP
FINAL APPROVED PARTS LIST
COMPONENTS RELIABILITY TESTS COMP
RELIABILITY
B/P NO. 1
B/P NO. 2
LAND IMPACT TESTS
B/P NO. 4
B/P NO. 7
WATER IMPACT TESTS
B/P NO. 9
B/P NO. 3
B/P NO. 5
PRE-QUAL FLIGHT DROPS
B/P NO. 8
RECOVERY AIDS TESTS
B/P NO. 10
WATER EGRESS AND FLOTATION TESTS
B/P NO. 11
LOGISTICS EQUIPMENT RECOVERY TESTS
B/P NO. 9
DYNAMIC TEST ARTICLE
LAUNCH VEHICLE SPACECRAFT COMPATIBILITY
AFRM NO. 004
AFRM NO. 005
STATIC TEST ARTICLES
VEHICLE PREPARATION
THERMAL VACUUM CHAMBER TESTS
LAND AND WATER IMPACT TESTS
AFRM NO. 008
ENVIRONMENTAL PROOF SPACECRAFT
FLIGHT PROGRAM SUPPORT TESTING
S/L TESTING - SERVICE MODULE
S/L TESTING - COMPLETE SPACECRAFT
ALTITUDE CHAMBER FIRINGS - COMP SPACECRAFT
AFRM NO. 001
PROPULSION DEVELOPMENT SPACECRAFT
SEA LEVEL DESIGN IMPROVEMENT TESTING
TRANSFER TO SIMULATOR
FACILITY COMPATIBILITY
B/P NO. 14
SYSTEM DES VERIFICATION
AFRM NO. 006
INTEGRATED SYSTEMS TESTS
AFRM NO. 112
HOUSE SPACECRAFT TESTS
ENVIRONMENTAL QUAL TESTS
MALFUNCTION ANAL AND SYSTEMS TESTS
SPACECRAFT TEST OPERATIONS
INITIAL RELEASE OF TEST PLAN
COMP DETAIL TEST PLAN FOR LITTLE JOE II
COMP DETAIL TEST PLAN FOR SA-5
FIRST OFF-PAD ABORT
FIRST LITTLE JOE II LAUNCH
FIRST SATURN LAUNCH - SA-5
FIRST PROTOTYPE SPACECRAFT - LITTLE JOE II MAX. Q ABORT
FIRST SIMULATED HEAT SHIELD LAUNCH - SA-7
FINAL B/P SPACECRAFT LAUNCH - SA-8
FIRST UNMANNED EARTH ORBIT - SA-9
VERY HIGH-ALTITUDE ABORT - LITTLE JOE II
COMP QUALIFICATION TESTS - SA-110
FIRST MANNED EARTH ORBIT - SA-111
FINAL PHASE "A" LAUNCH - SA-115
FIRST PHASE "B" LAUNCH - C-5
FIRST LAUNCH WITH LEM - TRANS-EARTH LAUNCH
FIRST MANNED CIRCUMLUNAR LAUNCH - C-5
MANNED LUNAR ORBIT - C-5
FIRST LUNAR LANDING AND RETURN - C-5
SECOND LUNAR LANDING AND RETURN C-5
LUNAR LANDING AND RETURN - NOVA
FINAL LAUNCH
LAUNCH OPERATIONS

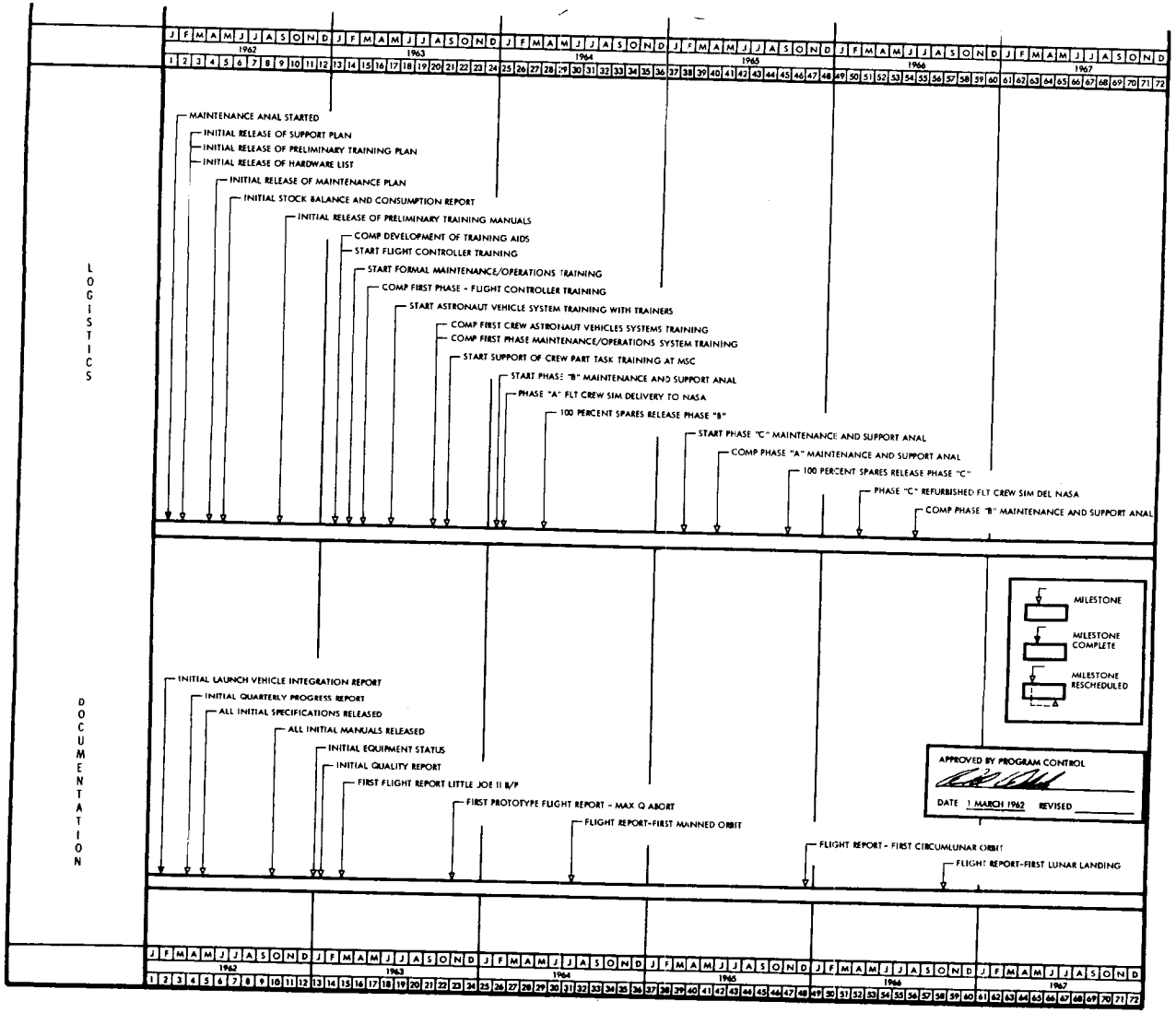
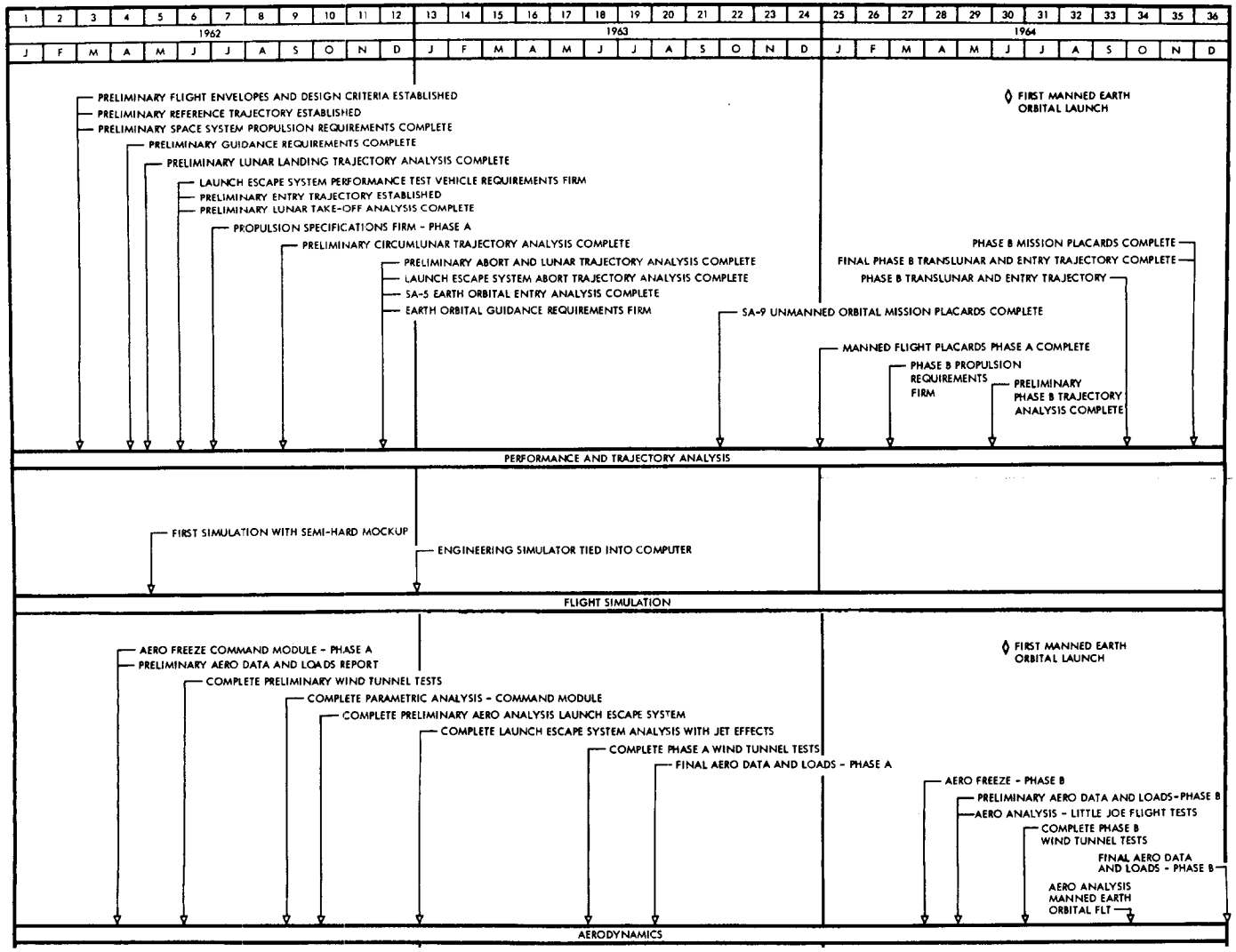


Figure 11. Apollo Program Master Development Schedule

NORTH AMERICAN AVIATION, INC. SPACE and INFORMATION SYSTEMS DIVISION

[redacted]



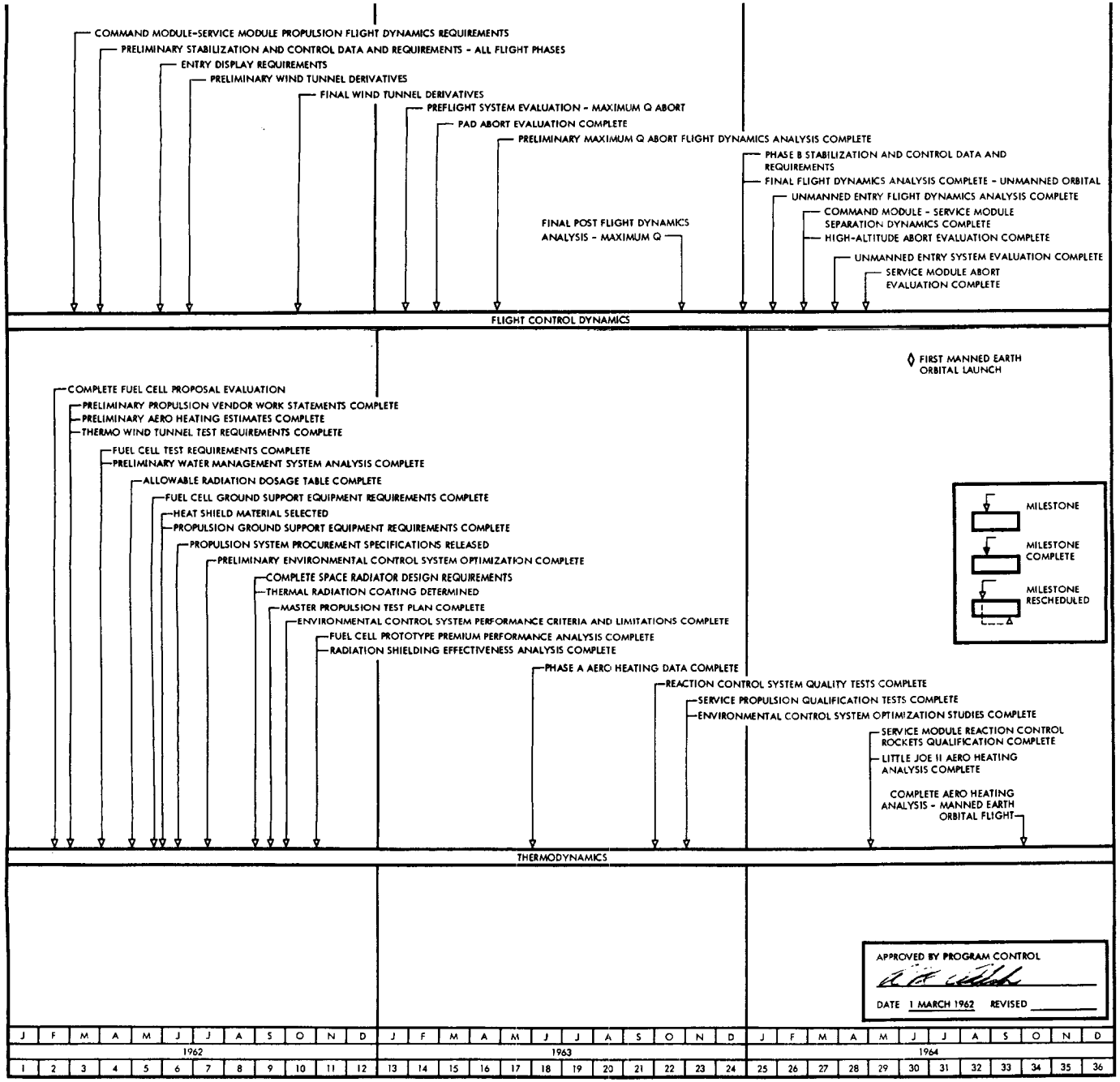


Figure 12. General Order 7121 - Flight Technology

[redacted]

[redacted]

	C/M	C/M + ET	C/M+S/M	LV + ET	LV	C/M DIA (IN.)	WIND TUNNEL FACILITY	MACH NO.	1962	1963	1964	1965
SPACECRAFT DESIGN EVALUATION												
STATIC STABILITY AND CONTROL	X	X				16	NAAL	SUBSONIC	Δ40			
	X	X				3	NAA SAL	0.7, 1.56 - 3.75	Δ			
	X	X				16	NAA TWT	0.2 - 3.5	Δ80 Δ80 Δ80	Δ80		
	X	X				3	JPL 20" SWT	1.3 - 5.0	Δ80			
	X	X				3	JPL 21" HWT	5 - 11	Δ80			
	X	X				16	AMES 11' X 11' UPWT	0.7 - 1.4	Δ40 Δ40	Δ60 Δ60		Δ60
	X	X				16	AMES 9' X 7' UPWT	1.5 - 2.6	Δ40 Δ40	Δ60 Δ60		Δ60
	X	X				16	AMES 8' X 7' UPWT	2.4 - 3.5	Δ40	Δ40 Δ40		Δ40
	X					2	AMES 6" ARC JET	12, 14	Δ80			
	X					0.5	AMES PHFFF	45,000 FPS	Δ160	Δ80	Δ160	
	X	X				7	AEDC TUNNEL A	1.5 - 6	Δ80			
	X	X				7	AEDC TUNNEL B	8	Δ80			
	X		X			7	AEDC TUNNEL C	10, 12	Δ80	Δ80 Δ80		Δ80
	X		X			6, 4	AEDC HOT SHOT 2	16 - 21	Δ80 Δ80			
	X		X			6	CAL 48" SHOCK	5 - 18	Δ80 Δ80			
	X					6	BRL TRANS. RANGE	UP TO 3	Δ80			
DYNAMIC STABILITY	X	X				3	JPL 20" SWT		Δ40			
	X	X				3	JPL 21" SWT		Δ40			
	X	X				8.5	LANG. UPWT		Δ80 Δ80			
	X	X				8.5	LANG. TRANS. PRESS.		Δ80			
	X	X				8.5	LANG. 12' LOW SPEED		Δ80			
	X	X	X			7	AEDC TUNNEL B		Δ80	Δ80	Δ80	
	X		X			7	AEDC TUNNEL C		Δ80	Δ80	Δ80	
PRESSURES; STEADY STATE AND TRANSIENT	X	X				16	NAAL		Δ40			
	X	X				16	NAA TWT		Δ80 Δ160			
	X	X				3	JPL 20" SWT		Δ80			
	X	X				3	JPL 21" HWT		Δ80			
	X	X	X			7	AMES 3.5' HYPERS.		Δ80 Δ40			
	X	X				7	LEWIS UPWT		Δ80	Δ80		
	X	X				7	LEWIS 8' X 6' SWT		Δ80	Δ80		
	X	X	X			7	AEDC TUNNEL B		Δ80 Δ40			
	X		X			6, 4	AEDC HOT SHOT 2		Δ80 Δ80			
	X		X			6	CAL 48" SHOCK		Δ80 Δ80			

THE SYMBOL Δ IN CONJUNCTION WITH THE NUMERALS 40, 60, 80, AND 160 INDICATES THE NUMBER OF WIND TUNNEL HOURS.

APPROVED BY PROGRAM CONTROL

DATE 1 MARCH 1962 REVISED _____

HEAT TRANSFER	X	X	X			3	JPL 21" HWT		Δ80
	X	X	X			7	AMES 3.5' HYPERS.		Δ120
	X		X			2	AMES 6" ARC JET		Δ80
	X					0.5	AMES PHFFF		Δ160
	X	X	X			7	LANG. UPWT		Δ80
	X	X	X			7	AEDC TUNNEL B		Δ80
	X		X			7	AEDC TUNNEL C		Δ80
	X		X			6	AEDC HOT SHOT II		
	X		X			6	CAL 48" SHOCK		Δ80 Δ80
LAUNCH VEHICLE INTERFACE STUDIES									
STATIC STABILITY AND CONTROL				X	X	3	NAAL		Δ40
				X	X	3	NAA TWT		Δ40
				X	X	3	AMES 11' UPWT		Δ40 Δ40
				X	X	3	AMES 9' X 7' UPWT		Δ40 Δ40
				X	X	3	AMES 8' X 7' UPWT		Δ40
				X	X	3	AEDC TUNNEL B		Δ40
				X	X	3	AEDC TUNNEL C		Δ40
PRESSURES, STEADY STATE AND TRANSIENT				X	X	7	NAAL		Δ40
				X	X	7	NAA TWT		Δ40
				X	X	7	LEWIS UPWT		Δ40
				X	X	7	LEWIS 8' X 6' SWT		Δ40
				X	X	7	AEDC TUNNEL B		Δ40
HEAT TRANSFER				X	X	7	AEDC TUNNEL C		Δ40
				X	X	7	LANG UPWT		Δ80
							AEDC TUNNEL B		Δ80
							AEDC TUNNEL C		Δ80
JET REACTION STUDIES									
CONTROL EFFECTIVENESS (REACTION JETS)	X					7	AEDC TUNNEL B		Δ80
	X					7	AEDC TUNNEL C		Δ80
SERVICE MODULE BASE HEATING							AEDC J2		Δ40

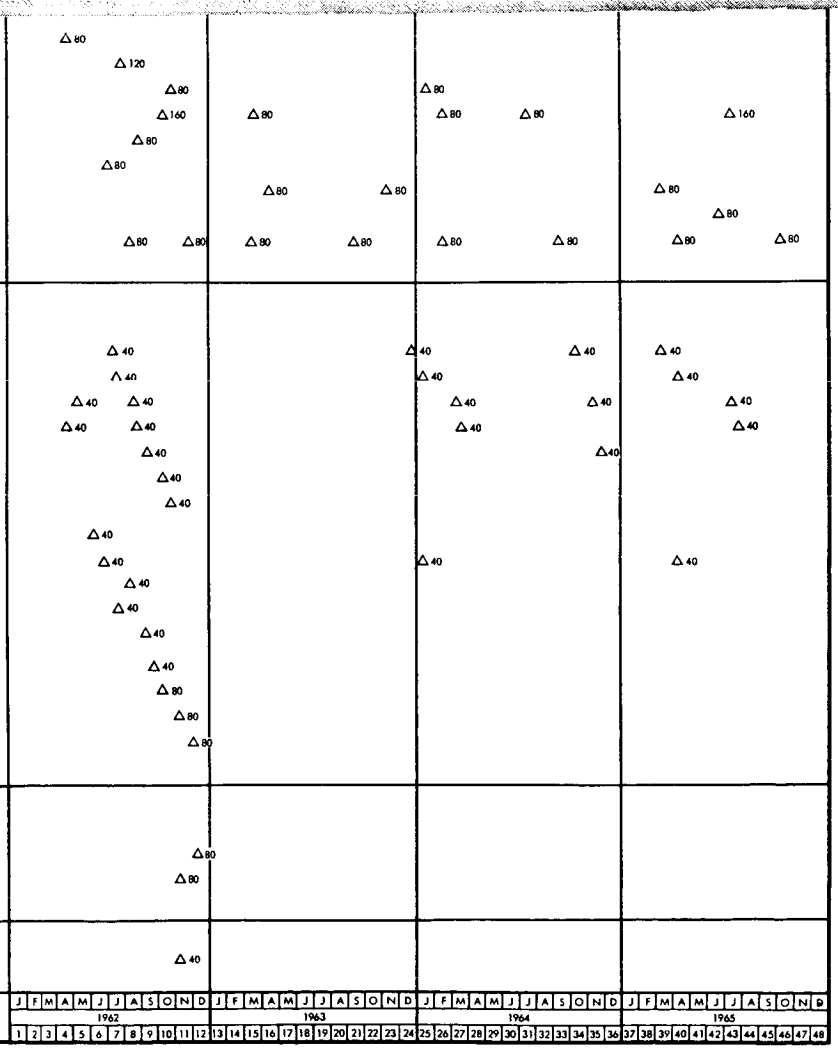


Figure 13. Engineering Detail Schedule - Wind Tunnel Model Testing

[redacted]

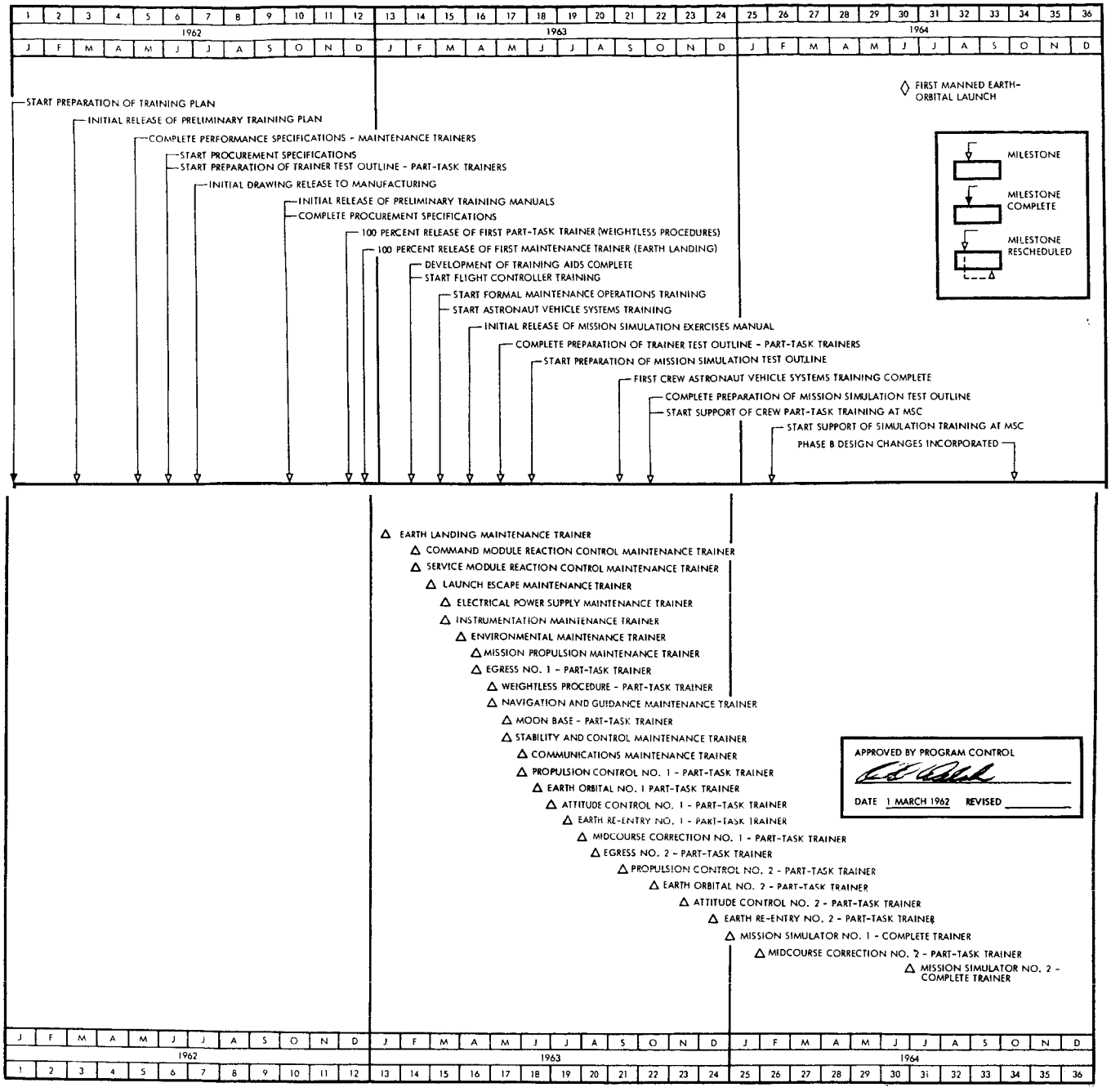
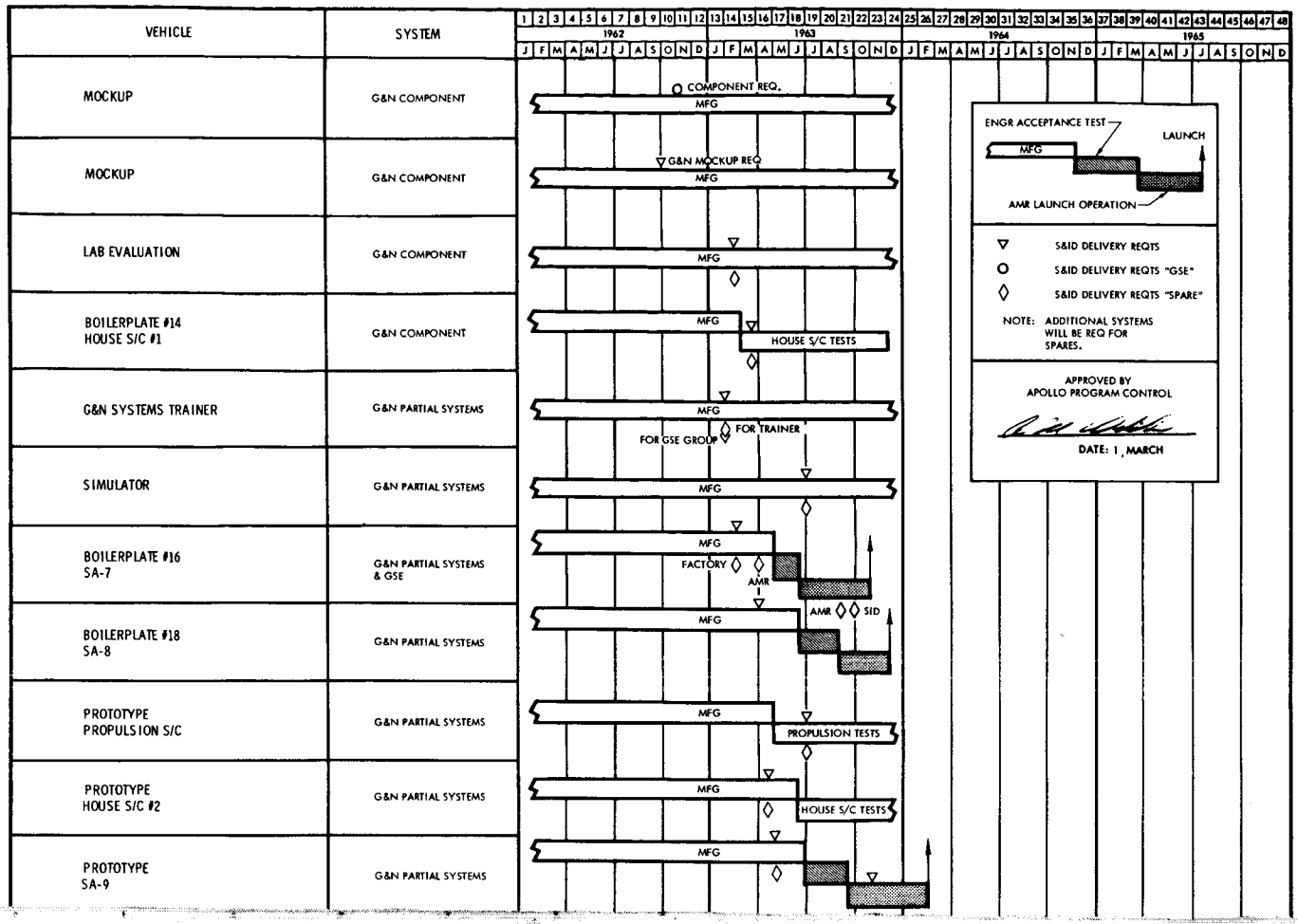


Figure 17. General Order 7125 - Training and Simulation

[redacted]


VEHICLE
SYSTEM
1962
1963
1964
1965
MOCKUP
G&N COMPONENT
COMPONENT REQ.
MFG
MOCKUP
G&N COMPONENT
G&N MOCKUP REQ
MFG
LAB EVALUATION
G&N COMPONENT
MFG
BOILERPLATE #14
HOUSE S/C #1
G&N COMPONENT
MFG
HOUSE S/C TESTS
G&N SYSTEMS TRAINER
G&N PARTIAL SYSTEMS
MFG
FOR GSE GROUP
FOR TRAINER
SIMULATOR
G&N PARTIAL SYSTEMS
MFG
BOILERPLATE #16
SA-7
G&N PARTIAL SYSTEMS & GSE
MFG
FACTORY
AMR
BOILERPLATE #18
SA-8
G&N PARTIAL SYSTEMS
MFG
AMR
SID
PROTOTYPE
PROPULSION S/C
G&N PARTIAL SYSTEMS
MFG
PROPULSION TESTS
PROTOTYPE
HOUSE S/C #2
G&N PARTIAL SYSTEMS
MFG
HOUSE S/C TESTS
PROTOTYPE
SA-9
G&N PARTIAL SYSTEMS
MFG
ENGR ACCEPTANCE TEST
MFG
LAUNCH
AMR LAUNCH OPERATION
S&ID DELIVERY REQTS
S&ID DELIVERY REQTS "GSE"
S&ID DELIVERY REQTS "SPARE"
NOTE: ADDITIONAL SYSTEMS WILL BE REQ FOR SPARES.
APPROVED BY
APOLLO PROGRAM CONTROL
DATE: 1 MARCH

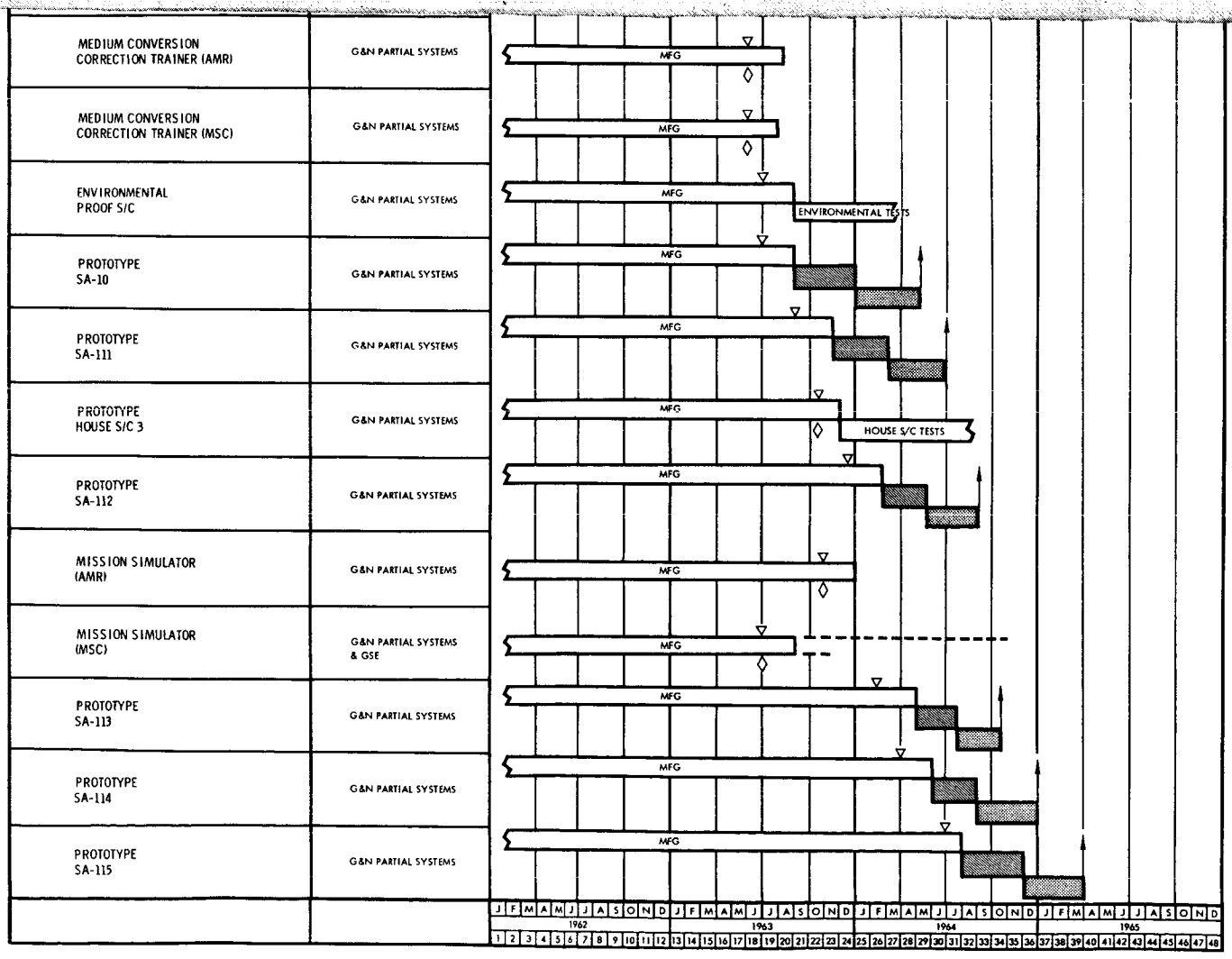
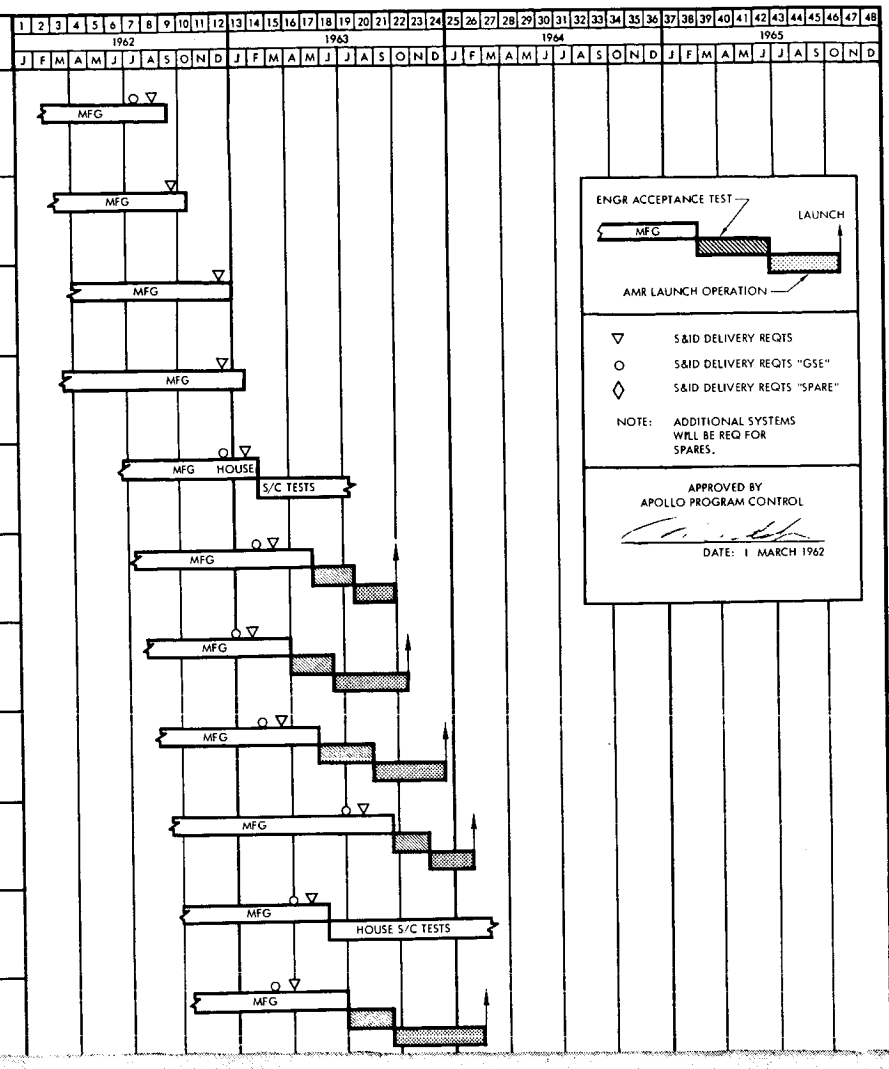


Figure 37. MIT Guidance and Navigation Delivery Schedule

[redacted]

VEHICLE	SYSTEM
BOILERPLATE #3 PRE-QUAL FLIGHT DROP #1	PARACHUTE SUBSYS TAPE RECORDER COMMUNICATIONS (AS REQUIRED)
BOILERPLATE #19 PRE-QUAL FLIGHT DROP #2	PARACHUTE SUBSYS TAPE RECORDER COMMUNICATIONS (AS REQUIRED)
BOILERPLATE #5 PRE-QUAL FLIGHT DROP #3	PARACHUTE SUBSYS RECOVERY AIDS SUBSYS TAPE RECORDER COMMUNICATIONS (AS REQUIRED)
BOILERPLATE #8 RECOVERY AIDS TEST ARTICLE	RECOVERY AIDS SUBSYS
BOILERPLATE #14 HOUSE S/C #1	PARACHUTE SUBSYS RECOVERY AIDS SUBSYS
PROTOTYPE AFRM #002 LITTLE JOE II MAX Q ABORT TEST	PARACHUTE SUBSYS RECOVERY AIDS SUBSYS
BOILERPLATE #16 SA-7 FIRST HEAT SHIELD LAUNCH	PARACHUTE SUBSYS RECOVERY AIDS SUBSYS
BOILERPLATE #18 SA-8 FINAL BOILERPLATE LAUNCH	PARACHUTE SUBSYS RECOVERY AIDS SUBSYS
PROTOTYPE AFRM #003 LITTLE JOE II HI-ALT ATMOS ABORT TEST	PARACHUTE SUBSYS RECOVERY AIDS SUBSYS
PROTOTYPE HOUSE S/C #2 AFRM #006	PARACHUTE SUBSYS RECOVERY AIDS SUBSYS
PROTOTYPE SA-9 AFRM #007 FIRST UNMANNED EARTH ORBITAL	PARACHUTE SUBSYS RECOVERY AIDS SUBSYS



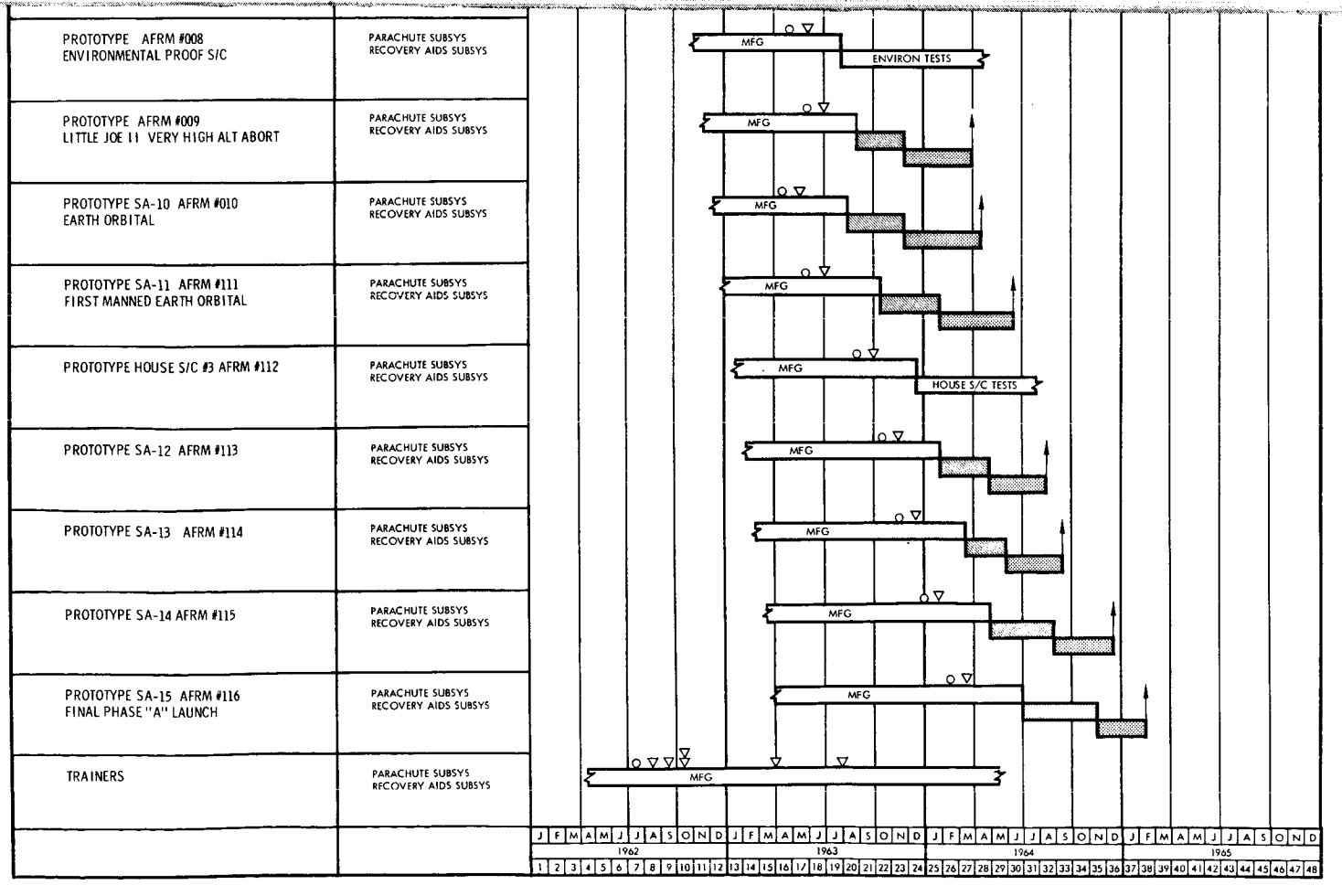


Figure 38. Radioplane Parachute Recovery System Delivery Schedule

[redacted]

VEHICLE	SYSTEM
BOILERPLATE #14 HOUSE S/C #1	COMPLETE
BOILERPLATE #16 SA-7 FIRST HEAT SHIELD LAUNCH	PARTIAL SYSTEM
BOILERPLATE #18 SA-8 (SYS AS REQ'D) FINAL BOILERPLATE LAUNCH	PARTIAL SYSTEM
PROTOTYPE SA-9 AFRM #007 FIRST UNMANNED EARTH ORBITAL	COMPLETE
PROTOTYPE AFRM #006 HOUSE S/C #2	COMPLETE
PROTOTYPE AFRM #008 ENVIRONMENTAL PROOF S/C	COMPLETE
PROTOTYPE AFRM #009 LITTLE JOE II VERY HIGH ALT ABORT	PARTIAL SYSTEM
PROTOTYPE SA-10 AFRM #010 EARTH ORBITAL	COMPLETE
PROTOTYPE SA-111 AFRM #011 FIRST MANNED EARTH ORBITAL	COMPLETE
PROTOTYPE HOUSE S/C #3 AFRM #012	COMPLETE
PROTOTYPE SA-112 AFRM #013	COMPLETE
PROTOTYPE SA-113 AFRM #014	COMPLETE
PROTOTYPE SA-114 AFRM #015	COMPLETE
PROTOTYPE SA-115 AFRM #016 FINAL PHASE "A" LAUNCH	COMPLETE
TRAINERS	COMPLETE

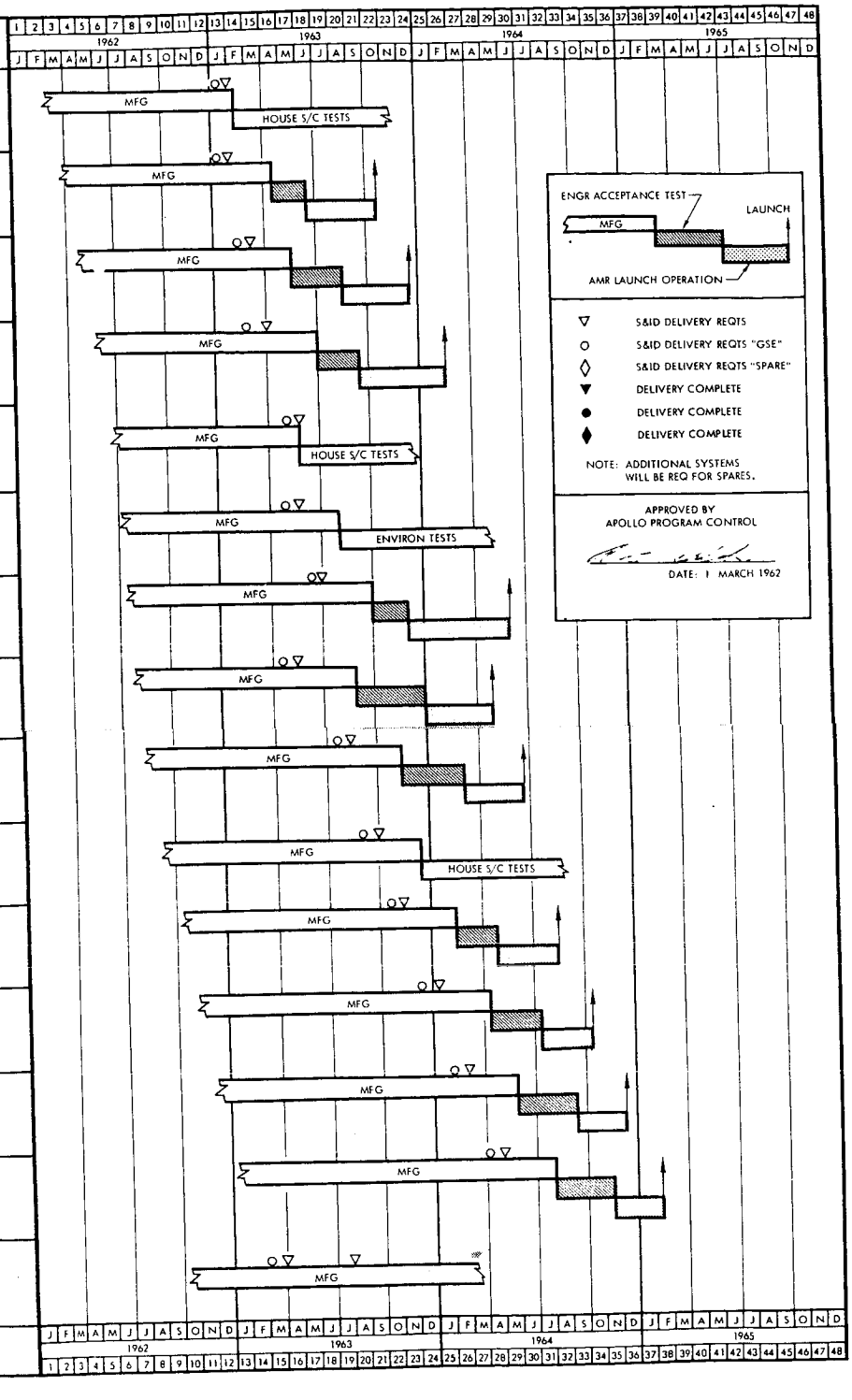
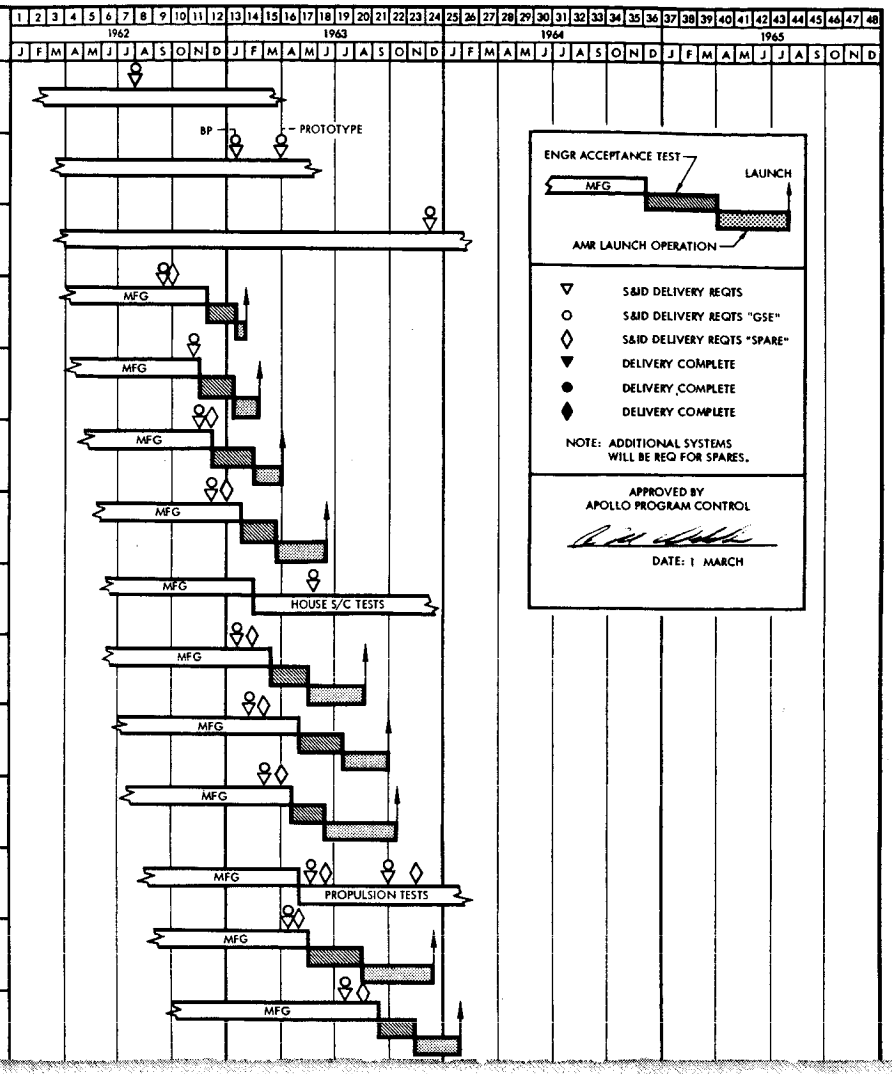


Figure 39. AiResearch Environmental Control Systems Delivery Schedule

[redacted]

[redacted]

VEHICLE	SYSTEM
ENGINEERING EVALUATION	LAUNCH ESCAPE CONTROL SYSTEM & GSE
ENGINEERING EVALUATION	STABILIZATION & CONTROL SYSTEM COMPLETE & GSE
SIMULATION	STABILIZATION & CONTROL SYSTEM & GSE
BOILERPLATE S/C #20 FOR PAD ABORT	LAUNCH ESCAPE CONTROL SYSTEM & GSE
BOILERPLATE S/C #12 FOR LITTLE JOE II	LAUNCH ESCAPE SYSTEM COMPLETE & GSE
BOILERPLATE S/C #21 FOR LITTLE JOE II	STABILIZATION & CONTROL SYSTEM & GSE
BOILERPLATE #13 SA-5 FIRST SATURN LAUNCH	STABILIZATION & CONTROL & GSE
BOILERPLATE #14 HOUSE S/C #1	STABILIZATION & CONTROL & GSE
BOILERPLATE #15 SA-6	STABILIZATION & CONTROL & GSE
PROTOTYPE - AFRM #002 LITTLE JOE II MAX Q ABORT	LAUNCH ESCAPE CONTROL SYSTEMS & GSE
BOILERPLATE #16 SA-7 FIRST HEAT SHIELD LAUNCH	STABILIZATION & CONTROL & GSE
PROTOTYPE AFRM #001 PROPULSION SPACECRAFT	STABILIZATION & CONTROL & GSE
BOILERPLATE #18 SA-8 FINAL BOILERPLATE LAUNCH	STABILIZATION & CONTROL & GSE (PROGRAMMER & R-C COUPLER)
PROTOTYPE - LITTLE JOE II AFRM #003 HI-ALT ATMOS ABORT TEST	LAUNCH ESCAPE CONTROL SYSTEMS & GSE



PROTOTYPE HOUSE S/C #2 AFRM #006	STABILIZATION & CONTROL & GSE
PROTOTYPE SA-9 AFRM #007 FIRST UNMANNED EARTH ORBITAL	STABILIZATION & CONTROL & GSE
PROTOTYPE AFRM #008 ENVIRONMENTAL PROOF SPACECRAFT	STABILIZATION & CONTROL & GSE
PROTOTYPE - LITTLE JOE II AFRM #009 VERY HIGH ALT ABORT	STABILIZATION & CONTROL & GSE
PROTOTYPE SA-10 AFRM #010 EARTH ORBITAL	STABILIZATION & CONTROL & GSE
PROTOTYPE SA-111 AFRM #011 FIRST MANNED EARTH ORBITAL	STABILIZATION & CONTROL & GSE
PROTOTYPE HOUSE S/C #3 AFRM #012	STABILIZATION & CONTROL & GSE
PROTOTYPE SA-112 AFRM #013	STABILIZATION & CONTROL & GSE
PROTOTYPE SA-113 AFRM #014	STABILIZATION & CONTROL & GSE
PROTOTYPE SA-114 AFRM #015	STABILIZATION & CONTROL & GSE
PROTOTYPE SA-115 AFRM #016 FINAL PHASE "A" LAUNCH	STABILIZATION & CONTROL & GSE
TRAINERS	STABILIZATION & CONTROL & GSE

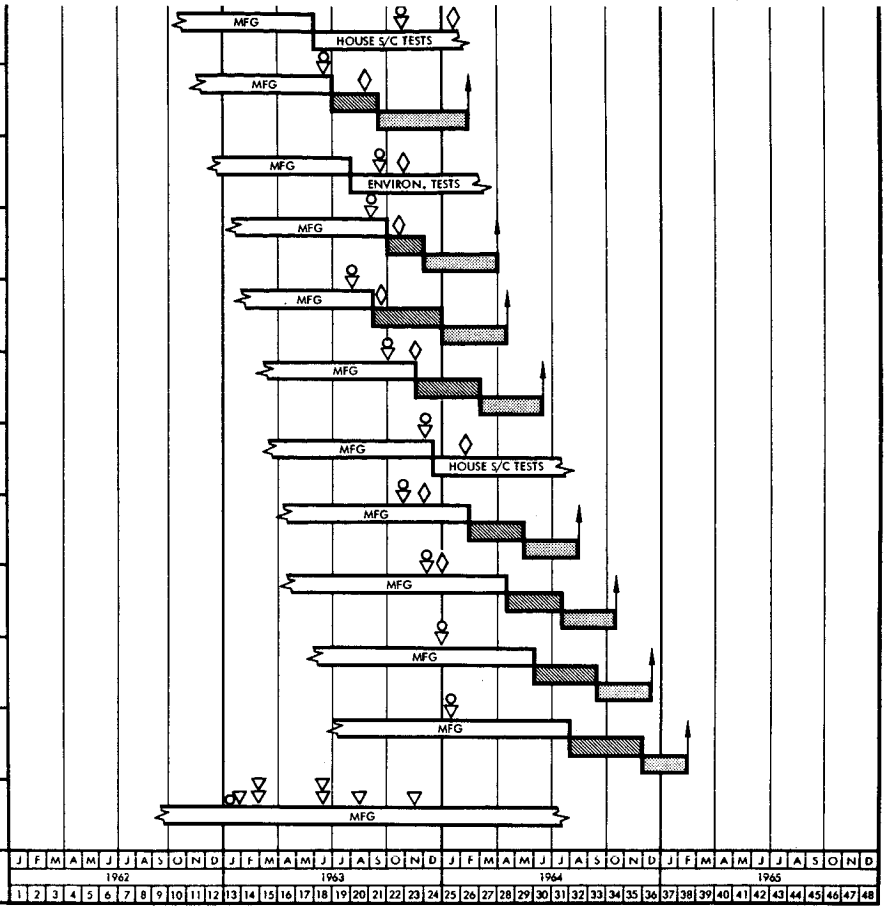


Figure 40. Minneapolis-Honeywell Stabilization and Control System Delivery Schedule

[redacted]

[redacted]

VEHICLE	SYSTEM ITEMS SEE KEY FOR IDENTIFICATION
BOILERPLATE #6 PAD ABORT	12
BOILERPLATE #8 RECOVERY AIDS TEST ARTICLE	7 8 10
BOILERPLATE #10 WATER EGRESS & FLOTATION	5
BOILERPLATE #20 PAD ABORT	12 13
BOILERPLATE #12 FOR LITTLE JOE II	9 12 13 14
BOILERPLATE #21 FOR LITTLE JOE II	9 14
BOILERPLATE #13 SA-5 FIRST SATURN LAUNCH	4
BOILERPLATE #14 HOUSE S/C #1	3 5 6* 7* 8 9 10 12 13 14 15*
BOILERPLATE #15 SA-6	4 12 13 14
PROTOTYPE AFRM #002 LITTLE JOE II MAX Q ABORT	9 12 13 14
BOILERPLATE #16 SA-7 FIRST HEAT SHIELD LAUNCH	4 5 10 12 13 14
BOILERPLATE #18 SA-8 FINAL BOILERPLATE LAUNCH	4 5 7 8 9 10 12 13 14 15*
PROTOTYPE AFRM #003 LITTLE JOE II HI ALT ATMOS ABORT	9 12 13 14
PROTOTYPE HOUSE S/C #2 AFRM #006	
PROTOTYPE SA-9 AFRM #007 FIRST UNMANNED EARTH ORBITAL	1 2 3 4 5 6* 7* 8 9 10 12 13 14 15*
PROTOTYPE AFRM #008 ENVIRONMENTAL PROOF S/C	1 2 3 5 6* 7* 8 9 10 12 13 14 15*
PROTOTYPE AFRM #009 LITTLE JOE II VERY HI ALT ABORT	9 14
PROTOTYPE SA-10 AFRM #010 EARTH ORBITAL	1 2 3 4 5 6 7* 8 9 10 14 15*
PROTOTYPE SA-111 AFRM #011 FIRST MANNED EARTH ORBITAL	1 2 3 4 5 6 7* 8 9 10 11 12 13 14 15*
PROTOTYPE HOUSE S/C #3 AFRM #012	TO BE INCLUDED IN NEXT REVISION
PROTOTYPE SA-112 AFRM #013	TO BE INCLUDED IN NEXT REVISION
PROTOTYPE SA-113 AFRM #014	TO BE INCLUDED IN NEXT REVISION
PROTOTYPE SA-114 AFRM #015	TO BE INCLUDED IN NEXT REVISION
PROTOTYPE SA-115 AFRM #016 FINAL PHASE "A" LAUNCH	TO BE INCLUDED IN NEXT REVISION
TRAINERS	TO BE INCLUDED IN NEXT REVISION

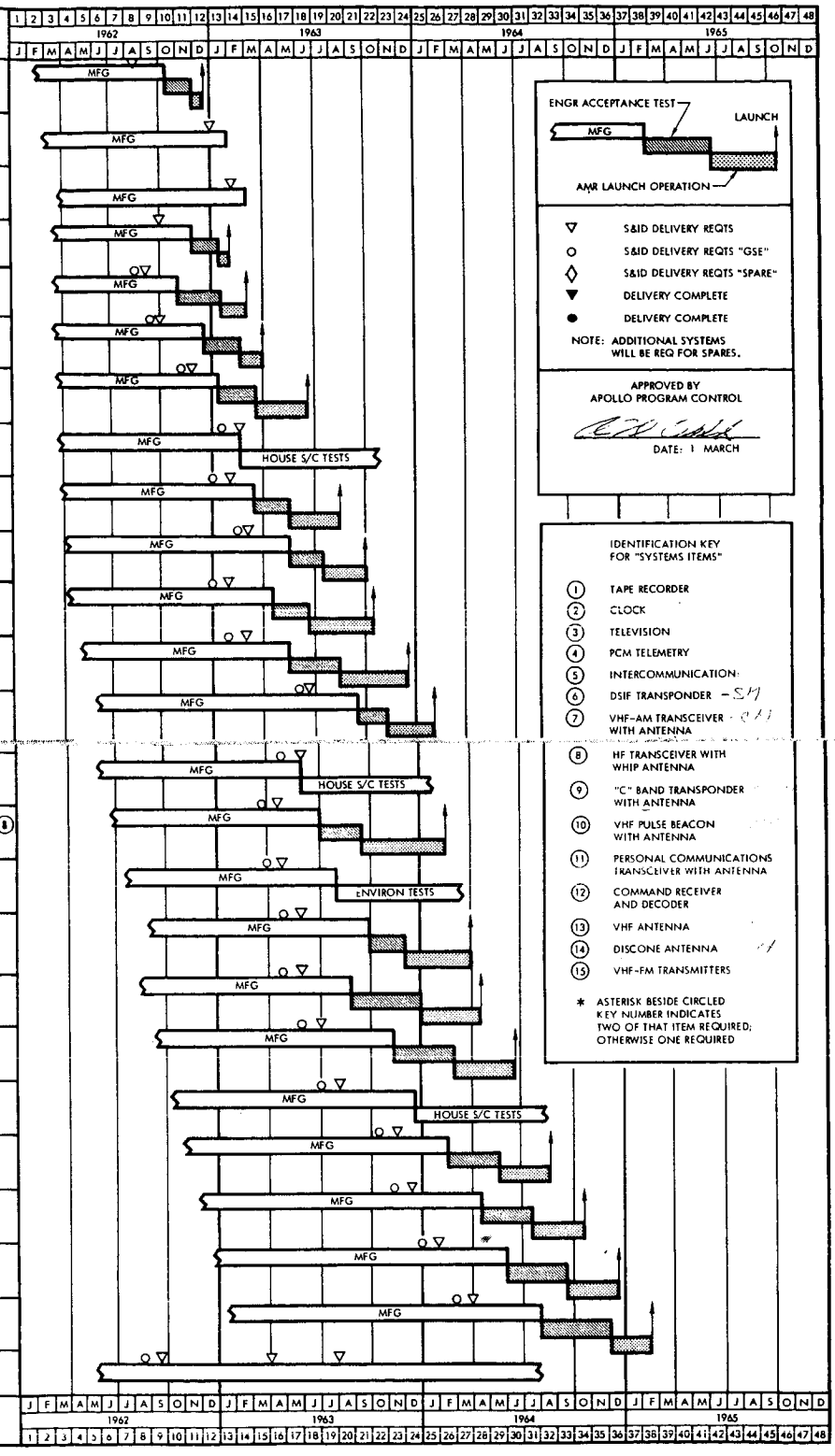


Figure 41. Collins Radio Co. Communications and Instrumentation Systems Delivery Schedule

[redacted]

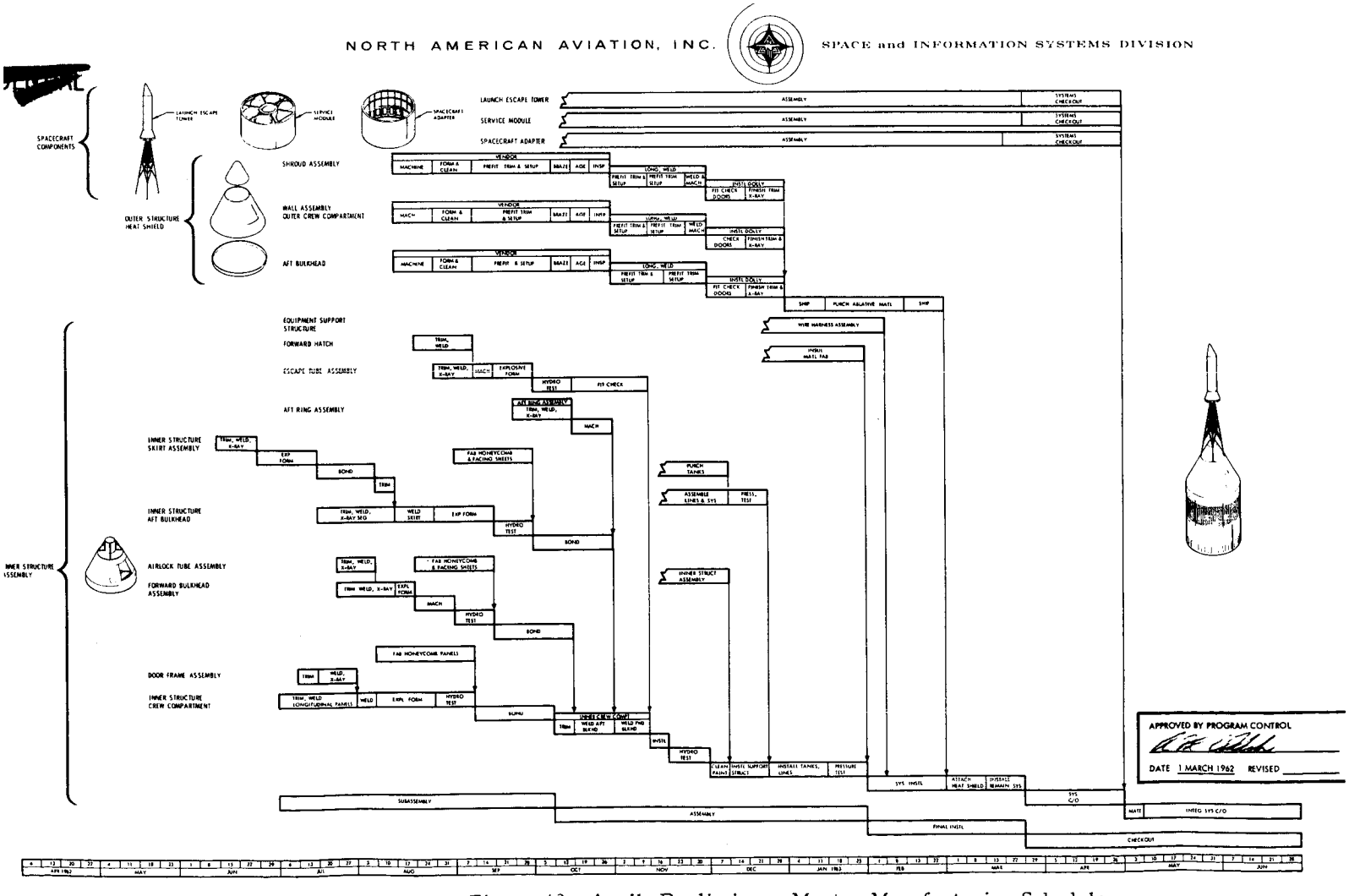
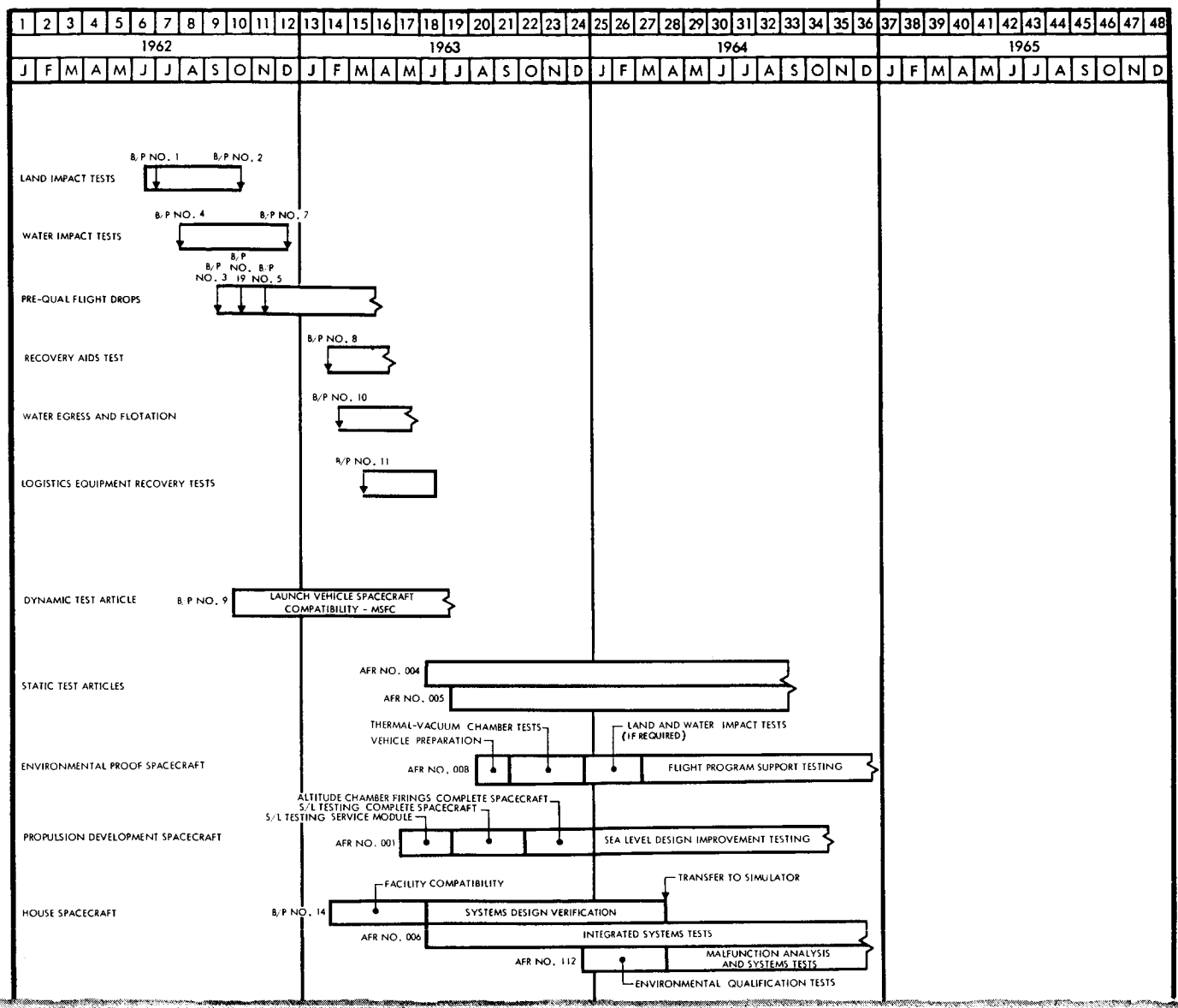


Figure 42. Apollo Preliminary Master Manufacturing Schedule

[redacted]


1962
1963
1964
1965
LAND IMPACT TESTS
B/P NO. 1
B/P NO. 2
WATER IMPACT TESTS
B/P NO. 4
B/P NO. 7
PRE-QUAL FLIGHT DROPS
B/P NO. 3
B/P NO. 19
B/P NO. 5
RECOVERY AIDS TEST
B/P NO. 8
WATER EGRESS AND FLOTATION
B/P NO. 10
LOGISTICS EQUIPMENT RECOVERY TESTS
B/P NO. 11
DYNAMIC TEST ARTICLE
B/P NO. 9
LAUNCH VEHICLE SPACECRAFT COMPATIBILITY - MSFC
STATIC TEST ARTICLES
AFR NO. 004
AFR NO. 005
ENVIRONMENTAL PROOF SPACECRAFT
THERMAL-VACUUM CHAMBER TESTS
VEHICLE PREPARATION
LAND AND WATER IMPACT TESTS (IF REQUIRED)
AFR NO. 008
FLIGHT PROGRAM SUPPORT TESTING
PROPULSION DEVELOPMENT SPACECRAFT
ALTITUDE CHAMBER FIRINGS COMPLETE SPACECRAFT
S/L TESTING COMPLETE SPACECRAFT
S/L TESTING SERVICE MODULE
AFR NO. 001
SEA LEVEL DESIGN IMPROVEMENT TESTING
HOUSE SPACECRAFT
FACILITY COMPATIBILITY
TRANSFER TO SIMULATOR
B/P NO. 14
SYSTEMS DESIGN VERIFICATION
AFR NO. 006
INTEGRATED SYSTEMS TESTS
AFR NO. 112
MALFUNCTION ANALYSIS AND SYSTEMS TESTS
ENVIRONMENTAL QUALIFICATION TESTS

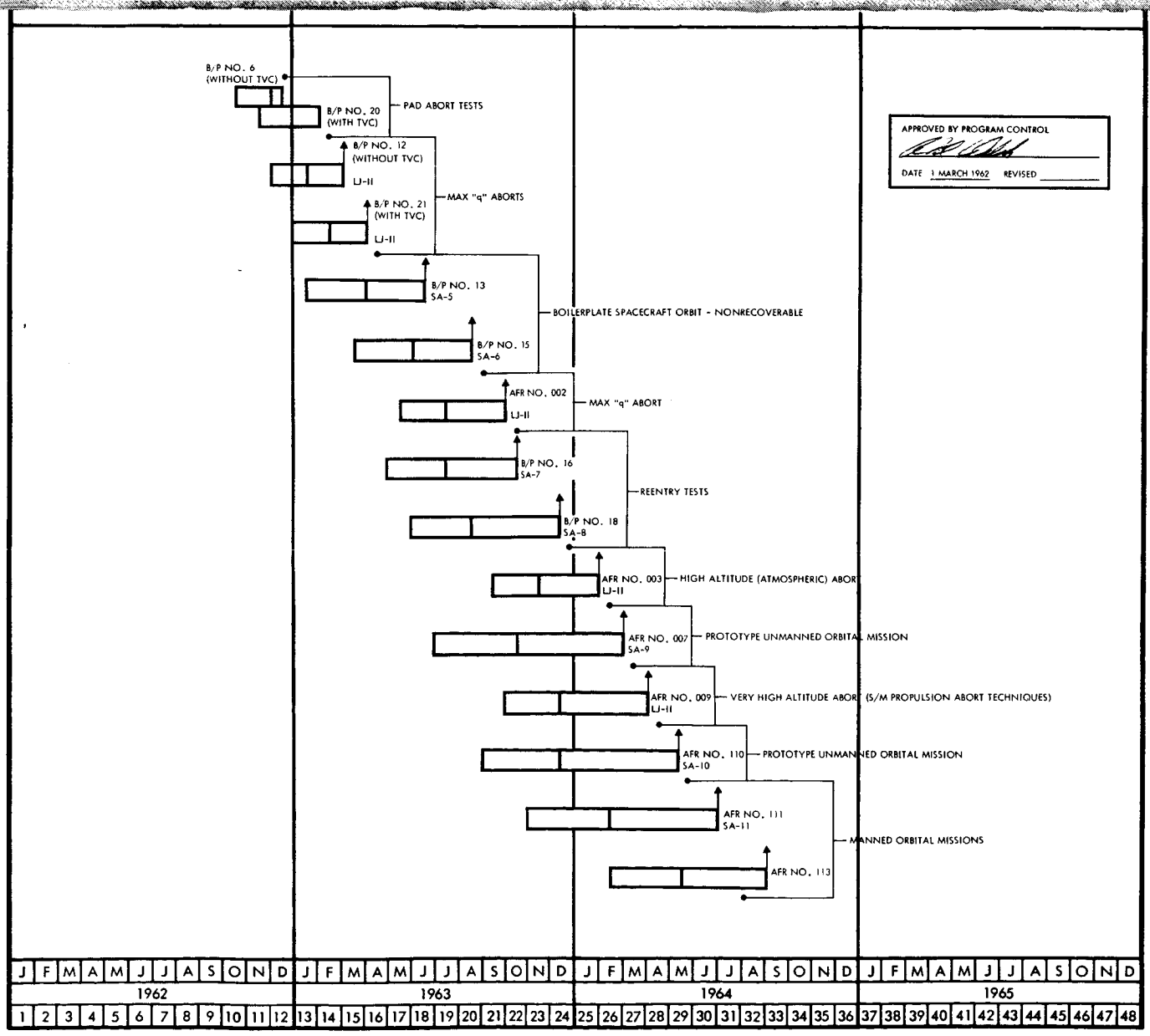
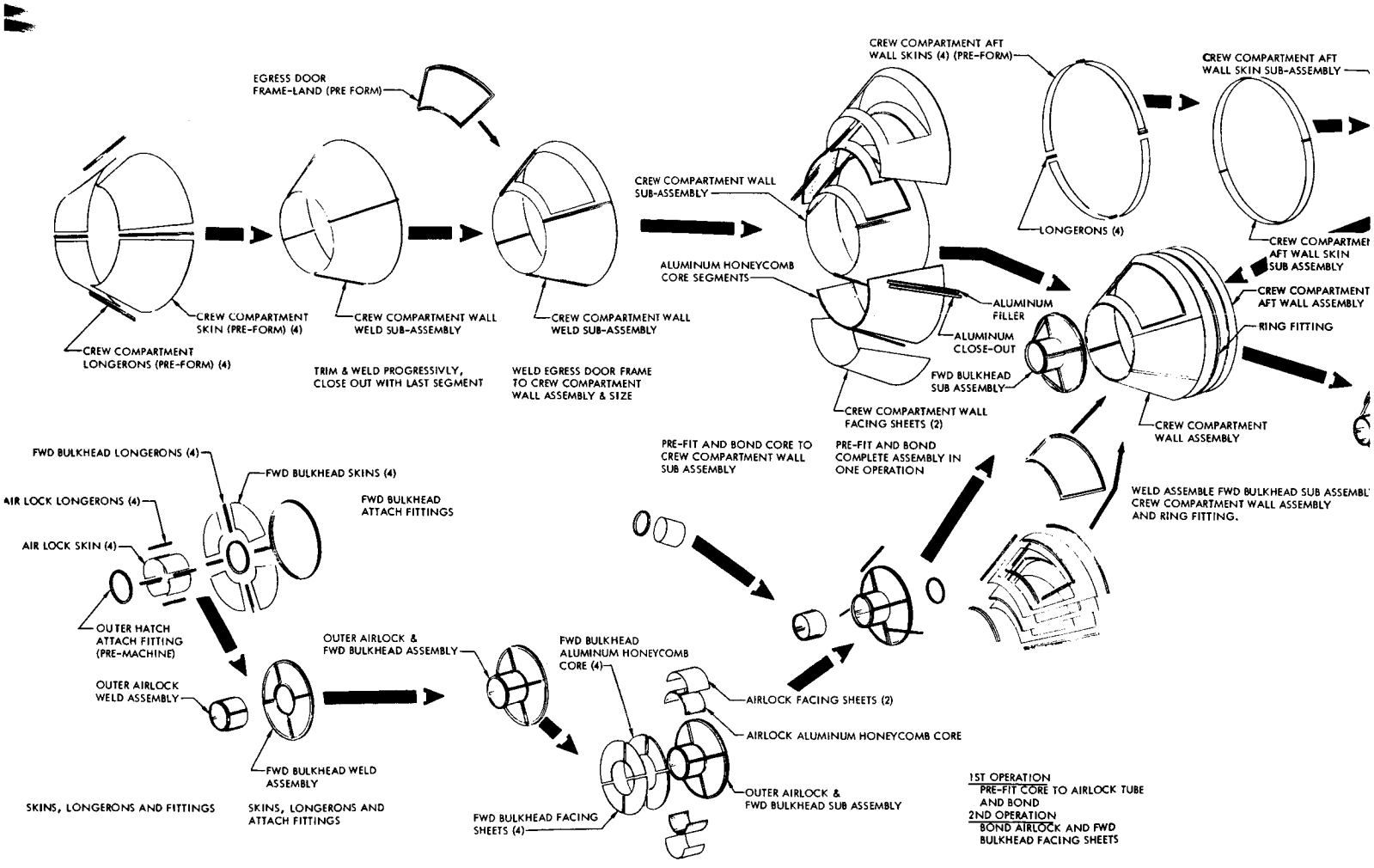


Figure 50. Apollo Summary Test Schedule


EGRESS DOOR FRAME-LAND (PRE FORM)
CREW COMPARTMENT SKIN (PRE-FORM) (4)
CREW COMPARTMENT LONGERONS (PRE-FORM) (4)
CREW COMPARTMENT WALL WELD SUB-ASSEMBLY
CREW COMPARTMENT WALL WELD SUB-ASSEMBLY
TRIM & WELD PROGRESSIVLY, CLOSE OUT WITH LAST SEGMENT
WELD EGRESS DOOR FRAME TO CREW COMPARTMENT WALL ASSEMBLY & SIZE
CREW COMPARTMENT WALL SUB-ASSEMBLY
ALUMINUM HONEYCOMB CORE SEGMENTS
CREW COMPARTMENT AFT WALL SKINS (4) (PRE-FORM)
LONGERONS (4)
CREW COMPARTMENT AFT WALL SKIN SUB-ASSEMBLY
ALUMINUM FILLER
ALUMINUM CLOSE-OUT
FWD BULKHEAD SUB ASSEMBLY
CREW COMPARTMENT WALL FACING SHEETS (2)
CREW COMPARTMENT AFT WALL SKIN SUB ASSEMBLY
CREW COMPARTMENT AFT WALL ASSEMBLY
RING FITTING
CREW COMPARTMENT WALL ASSEMBLY
PRE-FIT AND BOND CORE TO CREW COMPARTMENT WALL SUB ASSEMBLY
PRE-FIT AND BOND COMPLETE ASSEMBLY IN ONE OPERATION
WELD ASSEMBLE FWD BULKHEAD SUB ASSEMBLY CREW COMPARTMENT WALL ASSEMBLY AND RING FITTING.
FWD BULKHEAD LONGERONS (4)
FWD BULKHEAD SKINS (4)
AIR LOCK LONGERONS (4)
FWD BULKHEAD ATTACH FITTINGS
AIR LOCK SKIN (4)
OUTER HATCH ATTACH FITTING (PRE-MACHINE)
OUTER AIRLOCK WELD ASSEMBLY
FWD BULKHEAD WELD ASSEMBLY
SKINS, LONGERONS AND FITTINGS
SKINS, LONGERONS AND ATTACH FITTINGS
OUTER AIRLOCK & FWD BULKHEAD ASSEMBLY
FWD BULKHEAD ALUMINUM HONEYCOMB CORE (4)
FWD BULKHEAD FACING SHEETS (4)
AIRLOCK FACING SHEETS (2)
AIRLOCK ALUMINUM HONEYCOMB CORE
OUTER AIRLOCK & FWD BULKHEAD SUB ASSEMBLY
1ST OPERATION
PRE-FIT CORE TO AIRLOCK TUBE AND BOND
2ND OPERATION
BOND AIRLOCK AND FWD BULKHEAD FACING SHEETS

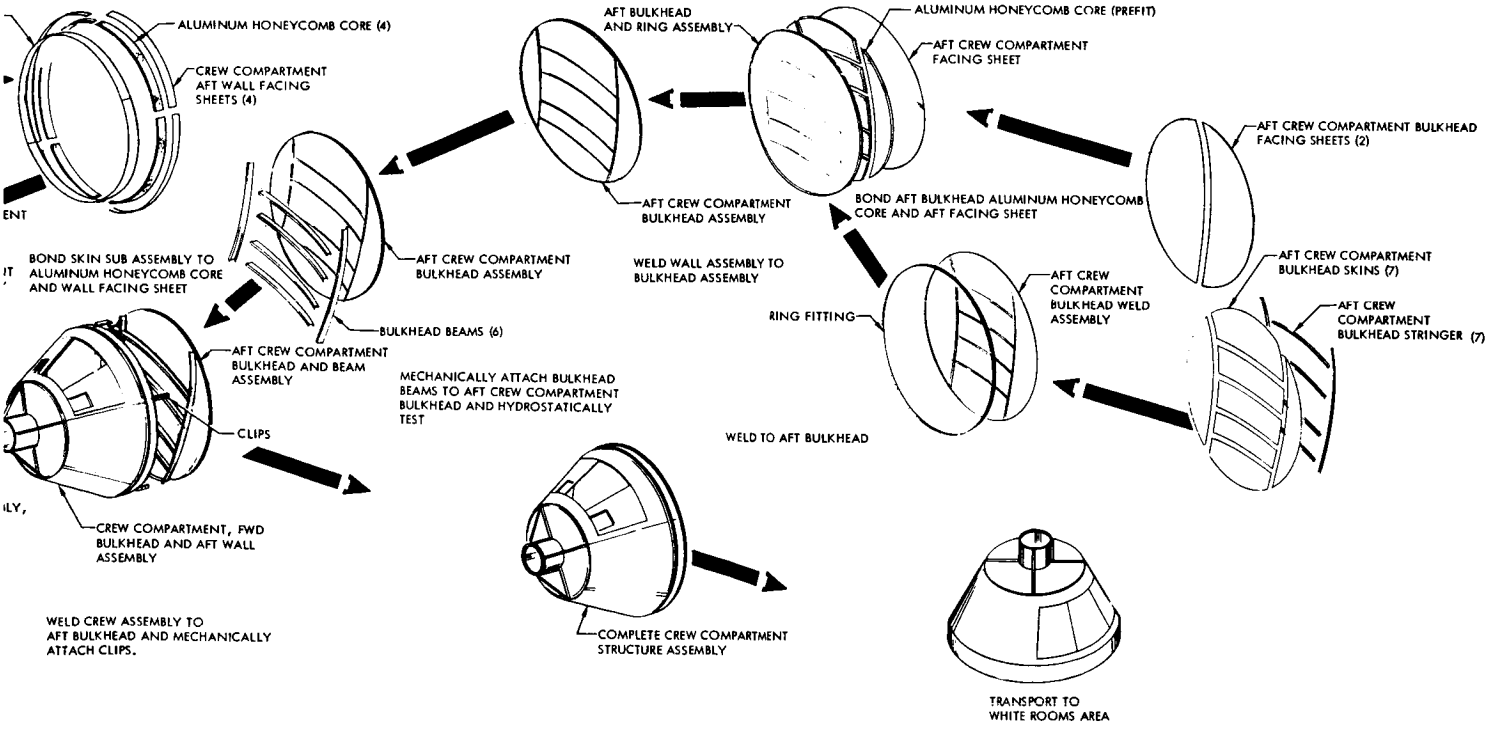
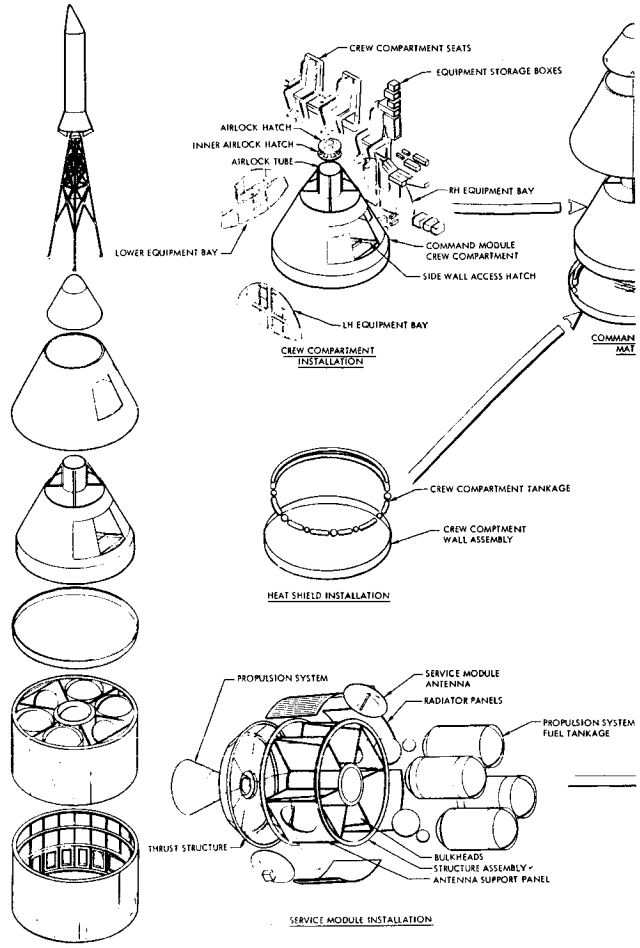


Figure 55. Crew Compartment Assembly Sequence


CREW COMPARTMENT SEATS
EQUIPMENT STORAGE BOXES
AIRLOCK HATCH
INNER AIRLOCK HATCH
AIRLOCK TUBE
RH EQUIPMENT BAY
LOWER EQUIPMENT BAY
COMMAND MODULE CREW COMPARTMENT
SIDE WALL ACCESS HATCH
LH EQUIPMENT BAY
CREW COMPARTMENT INSTALLATION
CREW COMPARTMENT TANKAGE
CREW COMPTMENT WALL ASSEMBLY
HEAT SHIELD INSTALLATION
PROPULSION SYSTEM
SERVICE MODULE ANTENNA
RADIATOR PANELS
PROPULSION SYSTEM FUEL TANKAGE
THRUST STRUCTURE
BULKHEADS
STRUCTURE ASSEMBLY
ANTENNA SUPPORT PANEL
SERVICE MODULE INSTALLATION

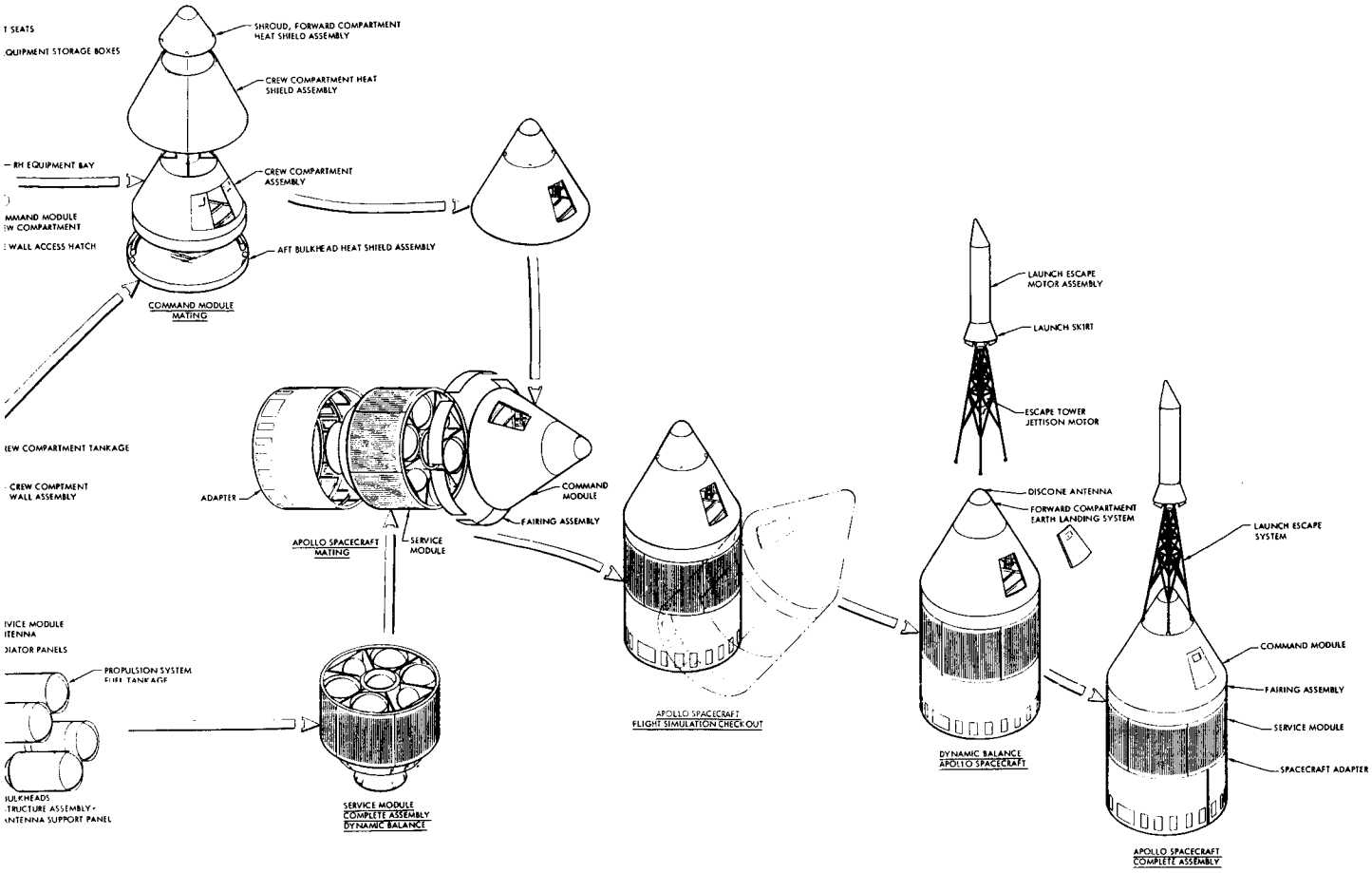


Figure 56. White Room Assembly Sequence

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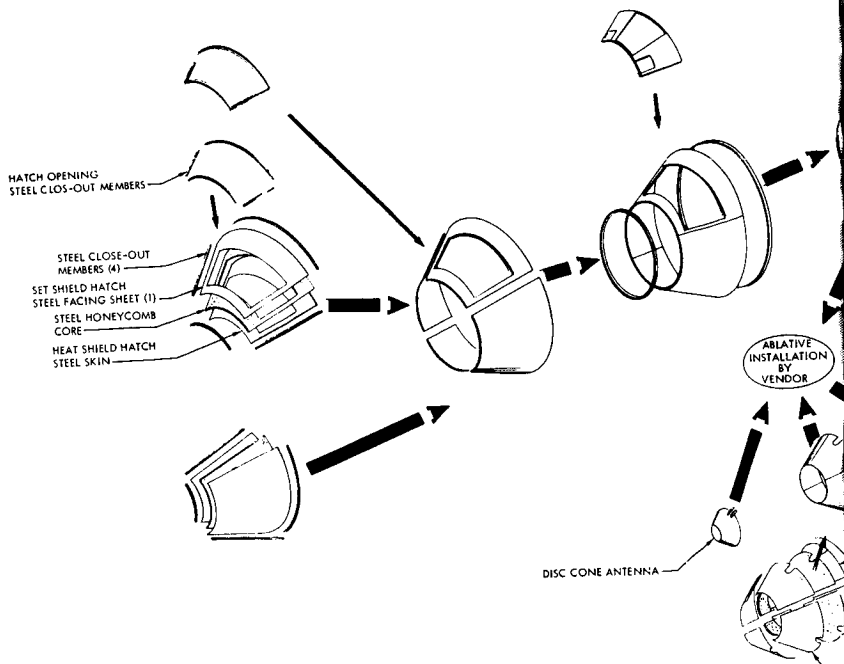
HATCH OPENING
STEEL CLOS-OUT MEMBERS
STEEL CLOSE-OUT MEMBERS (4)
SET SHIELD HATCH
STEEL FACING SHEET (1)
STEEL HONEYCOMB CORE
HEAT SHIELD HATCH
STEEL SKIN
ABLATIVE INSTALLATION BY VENDOR
DISC CONE ANTENNA

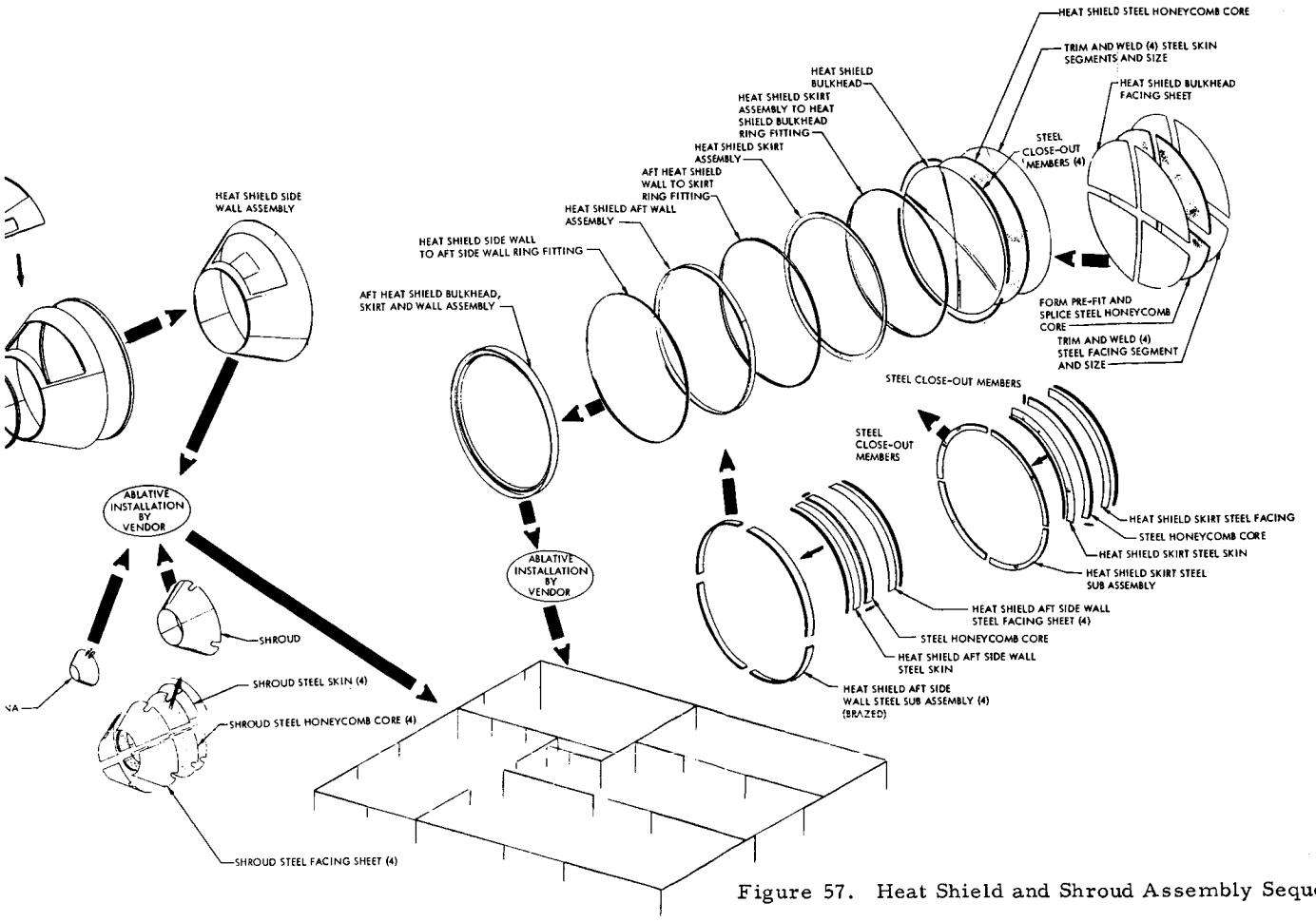

Figure 57. Heat Shield and Shroud Assembly Sequence

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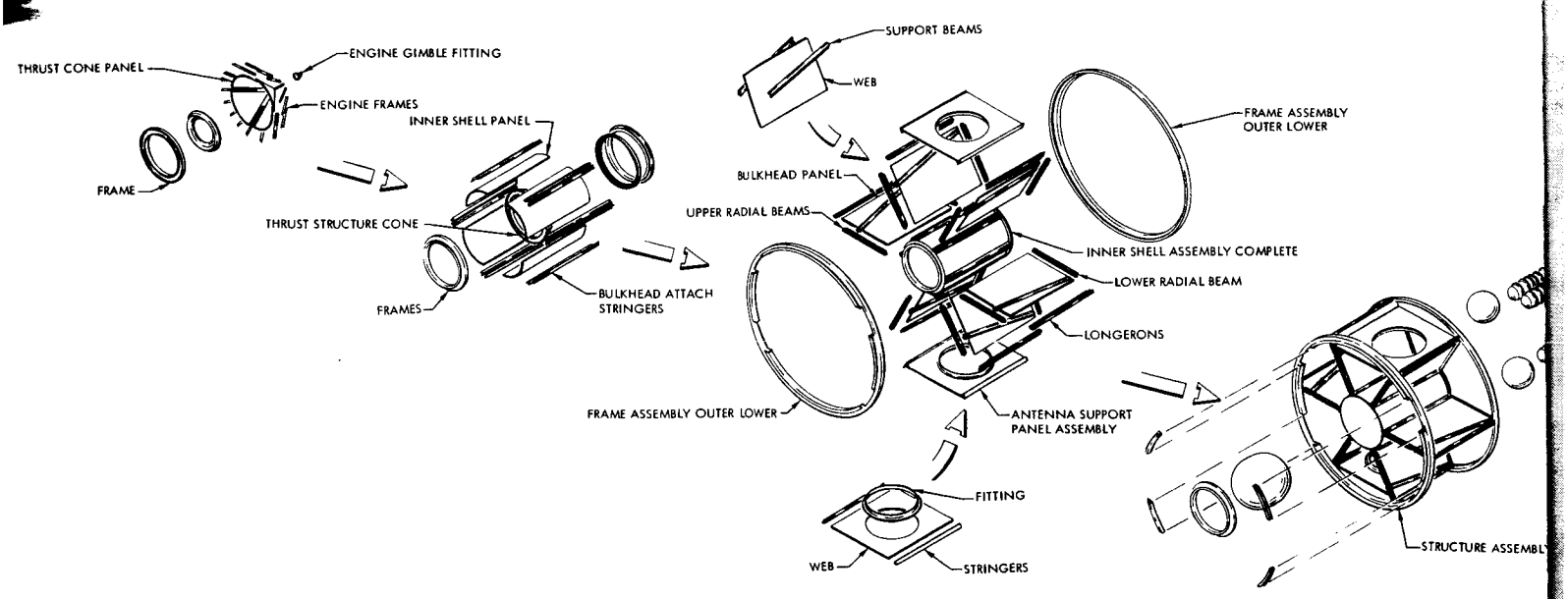
THRUST CONE PANEL
ENGINE GIMBLE FITTING
ENGINE FRAMES
FRAME
INNER SHELL PANEL
THRUST STRUCTURE CONE
FRAMES
BULKHEAD ATTACH STRINGERS
SUPPORT BEAMS
WEB
BULKHEAD PANEL
UPPER RADIAL BEAMS
FRAME ASSEMBLY OUTER LOWER
INNER SHELL ASSEMBLY COMPLETE
LOWER RADIAL BEAM
LONGERONS
FRAME ASSEMBLY OUTER LOWER
ANTENNA SUPPORT PANEL ASSEMBLY
FITTING
WEB
STRINGERS
STRUCTURE ASSEMBL

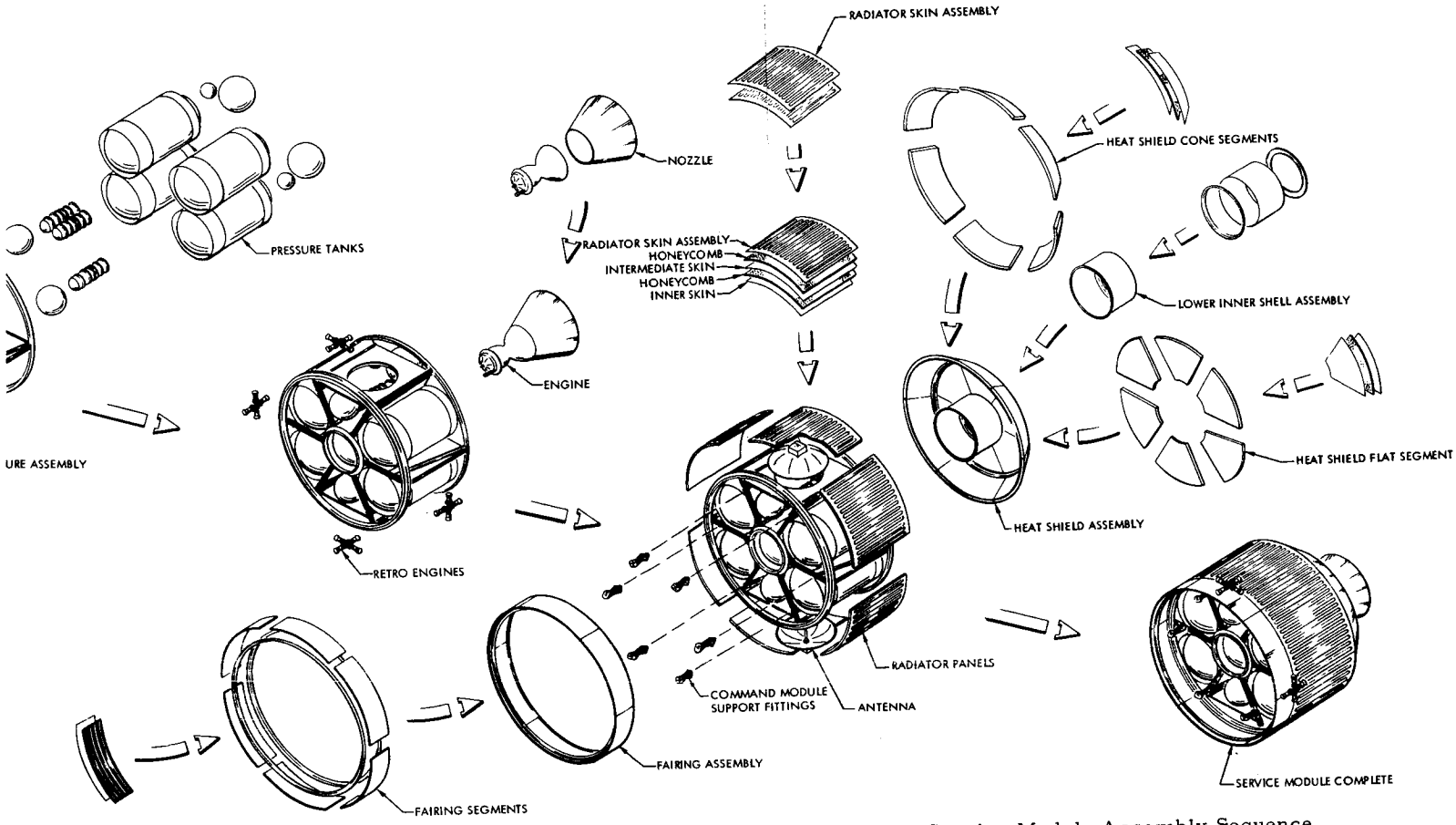

Figure 58. Apollo Service Module Assembly Sequence

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LOGISTICS PLANS SUMMARY

This section summarizes three Logistics plans: Maintenance, Support, and Training. The Preliminary Apollo Maintenance Plan is a viable way of implementing a systematically integrated maintenance system for a successful Apollo program. The Preliminary Apollo Support Plan is a workable means of implementing the test program; it identifies the materials and services that will be required to ensure adequate support for the Apollo Program. The Preliminary Apollo Training Plan encompasses training requirements for the flight crew, the ground operations personnel, and the maintenance personnel. The plan supports the maintenance support system and the Apollo spacecraft system with a formal training program.

APOLLO MAINTENANCE PLAN SUMMARY

The scope and general outline of material to be included in the Apollo Maintenance Plan are presented in this section; the actual maintenance plan will be submitted in April 1962.

Scope

The preliminary Apollo maintenance plan describes methods for systematically implementating a maintenance system conceived to meet the stringent requirements of the Apollo Program. Data developed from this plan, when compiled, analyzed, evaluated, and properly applied to the Apollo operational program, will provide the precise information necessary for a realistic, flexible, and expeditious maintenance plan.

The data compiled and the analyses made in the maintenance plan will supply personnel information, training requirements, data for compiling support manuals, facility requirements, levels of maintenance, end-item selection, source coding,

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and provisioning. This information will be oriented with respect to both maintenance and supply.

Objectives

The principal objectives of the Apollo Maintenance Plan are as follows:

1. To establish a systematic maintenance system through use of maintenance functional drawings.

2. To provide a means for S&ID and NASA to establish a pool of pertinent and validated information on the various elements of the spacecraft, trainers, and ground support equipment at the earliest possible date following publication of the Apollo System Test Plan.

3. To provide the means for continuously up-dating and validating information as the development of the spacecraft, trainers, and GSE proceeds.

4. To provide data for NASA to analyze at an early date to evaluate S&ID's interpretation of maintenance concepts.

5. To provide a means by which hardware, tools, personnel, training, and other pertinent data may be identified at a very early time and maintained current with the state of Apollo hardware development.

6. To provide a management control tool relative to support manual data development and publication.

7. To provide a management tool to assist in programming, budgetary, and procurement actions relative to equipment and facilities, both qualitatively and quantitatively, on a realistic and economical basis.

8. To provide basic data which can be expanded into many internal management control areas through electrical accounting and electronic data processing systems.

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Objectives

A maintenance support plan without precedent is required for an Apollo operational capability using R & D and/or prototype equipment. This plan concerns determination of skills, manning, training, tools and equipment, facilities, maintenance levels and policies, support manuals, and supply requirements. In order to accomplish this, it is necessary to develop and satisfy the logistic and support requirements concurrently with the release of the System Test Plan and S&ID engineering drawings.

Operational spacecraft development requires that identical basic factors must be itemized. The characteristics, limitations, configurations, and capabilities inherent in the hardware design are factors from which are derived skills, personnel, training, tools and equipment, ground support facilities, maintenance level determination and policies, support manual data, and supply requirements. Detailed analyses of each item of hardware and a summation of these analyses, properly evaluated, establish the total dimensions for all of these requirements, none of which can be independently developed. These can and must be developed concomitantly with the hardware system. Once defined, the detailed information collected in each category may be utilized in many different combinations to accomplish programming, planning, and implementing actions.

APOLLO SUPPORT PLAN SUMMARY

Material (Spares) Support

The Contractor will identify and provide the material and services to support the Apollo Test Program as specified in the NASA Statement of Work. The objective is to ensure that complete material and spares support is available to the level determined by the Maintenance and Test Plans. Policies and procedures developed for in-house control of this effort will be similar to those required at off-site facilities.

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To ensure adequate and timely support of the development program, S&ID Apollo Logistics will administer and provide surveillance for the overall material effort. Policies and procedures will provide efficient methods of provisioning, expediting, accountability, and control of material support. Through daily, weekly, and monthly reports, originated at off-site locations and S&ID, Apollo Logistics will have adequate information to initiate instantaneous resolution of impending problems and to ensure that assets are provided as required.

The scope of the contractor's responsibilities at off-site facilities will comply with existing company policies and procedures. The greatest level of support will be required for the operations at the Atlantic Missile Range. Time will be a critical factor, and the nature of the test operation will demand immediate response to requirements for maintenance, parts replacement, and emergency test support material. The Apollo test program at AMR and other test sites will require an adequate number of qualified supply support personnel. A complete stock of spares and material, based on maintenance concepts and test parameters, will be provided at each site. Direct air transport service will provide minimum turn-around time for hardware items. An immediate response communication system for in-house and vendor support will be established. This system will be designed to fulfill all requests for replacement parts and emergency test support.

In compliance with the Apollo test program objectives, the warehouse will receive, store, and disburse the materials and will maintain proper and related accountability records.

Records of issue rates, consumption data, and parts on hand will be maintained. The stock room will be supplied with spares, GSE, supporting parts, and a current list of these items. Quantities, item numbers, part numbers, nomenclature, and date of receipt will be recorded.

Packaging, Handling, and Transportation

The contractor will provide for packaging, handling, and transportation which will effect safe and timely delivery of all hardware developed under the

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Apollo program. To achieve this goal, the following policies will be complied with:

1. Maximum reliability and performance will be assured by preventing deterioration and physical or mechanical damage during transport, handling, and storage.

2. Protection of equipment will be provided as economically and efficiently as is consistent with anticipated hazards of shipment and storage.

3. Handling costs will be minimized by use of packaging methods and containers of minimum weight and cubic displacement.

4. Packaging, handling, and transporation manuals will control the procedures for preservation, packaging, marking, handling, loading, transport, unloading, and storage.

5. The method of transportation selected will be compatible with the delivery schedule and the environmental requirements of the hardware to be delivered. Delivery on schedule will be a prime requisite of this support plan.

A manual will be provided which will specify methods and procedures for packaging, handling, and transporting modules, major components delivered separately, major items of GSE, and training equipment. The manual will also specify procedures for preservation and environmental protection, speed and handling of transporters, procedures for truck loading and unloading, method of tie down, including points of attachment and type of snubbers, alignment of C-133B, preparation of aircraft, functions of loading personnel, and other procedures. These detailed methods and procedures will be based upon the environmental, shock, and vibration limitations of the items being delivered and will ensure that the handling, transport, and storage environments are controlled within established limits.

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Modification, Repair, and Overhaul

To attain Project Apollo reliability goals and prevent costly duplication of test equipment, the Contractor will perform modification, repair, and overhaul using the same resources and personnel as for manufacture wherever practicable. Hardware items that affect program reliability and require corrective maintenance will generally be returned to S&ID manufacturing.

The scope of repair and modification accomplished outside of S&ID will depend on the test program criteria, the level of repair determined by the maintenance plan, or the magnitude of the contemplated change. Test program criteria include those tests which do not possess end items that will actually be used in the Apollo space missions, such as breadboard or boiler plate equipment.

All S&ID, subcontractor, or vendor components that are within S&ID responsibility and that are damaged or that malfunction or become obsolete will be replaced through normal material supply support channels. When replacement occurs at a test site, disposition will be determined by a material review board; and components that are beyond the repair capability of local facilities will be returned to S&ID with a Parts Replacement Request (PRR).

To minimize flow time of components through the repair cycle, each responsible modification, repair, and overhaul section will maintain a sufficient shelf stock of major spare parts, subassemblies, and modification and overhaul (M/O) details. Stocked items will be continuously replenished through normal requisition procedures.

Repair or modification of Government furnished equipment (GFE) will not be initiated without the prior approval of the responsible Government agency. GFE rework will be accomplished by the manufacturer's representative or, with approval, by the supplier's service representative. All overhaul, modification, or repair of subcontracted or vended components will be accomplished in close coordination with the supplier or his representative.

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Accurate consumption-data reporting will be required from each modification, repair, and overhaul section so that reliability engineering can analyze the causes of failure and determine methods for increasing reliability without making unacceptable sacrifices to other equipment characteristics. The causes of failure may involve basic design deficiences, environmental factors, methods of operation, interaction with other equipment, handling, and fabricatiing techniques. Accurate consumption data reporting will also provide the spares disposition team with proper qualitative and quantitative information to maintain realistic stock balances.

Apollo Support Manuals

The Apollo spacecraft development contractor will manage the preparation and procurement of all support manuals for Project Apollo. The support manuals will provide technical instructions covering all (except depot) levels of maintenance and operation of the spacecraft, spacecraft systems, and major items of ground support equipment.

Text of the manuals will be written for skilled technicians and engineering personnel. Levels of maintenance covered in the manuals will be dictated by the maintenance plan.

The Contractor will provide technical accuracy certification of all data included in Contractor prepared support manuals.

The Contractor will verify the utility of the technical instructions (not information as distinguished from instructions) by performing as much of the operations, either actually or by simulation, in true or reverse order of assembly, disassembly, installation, removal, adjustment, calibration, or by other procedures as will reasonably assure or prove the overall accuracy and sufficiency of the instructions.

The contractor will develop a system for making necessary changes and revisions to the manuals to reflect equipment design, production and modification changes, to correct errors, and to expand and improve coverage, if necessary.

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A change system for expediting verification and documentation by quality assurance and technical writing personnel will be instigated by the Contractor to cover data change requirements originating at test sites. On-the-spot changes will be verified by qualified engineering test personnel and will be immediately documented for inclusion in the normal revision cycle.

The manual will cover all delivered equipment and include all production changes which have been made. The initial manual should provide the most complete coverage possible at the scheduled date of delivery and should not be delayed for inclusion of material which can be added by supplements, changes, or revisions.

Supplementary manuals will normally be used to provide additional new data, when it is considered more expedient or practicable to issue such a supplement than it is to change pages, or to isolate classified information.

APOLLO TRAINING PLAN SUMMARY

The Apollo Preliminary Training Plan encompasses an overall consideration of the training requirements for flight crew, ground operations, and maintenance personnel for Apollo Phase A accomplishment. The plan has been developed on the basis of available data and in advance of more definitive and descriptive data to be provided by subsequent personnel performance specification documentation, system description data, and maintenance planning documents. For this reason, the present training plan must be considered as preliminary and tentative. However, it provides a basic framework for development of a definitive plan for a formalized Apollo training program. The training plan is envisioned to be a progressively changing document with continuing definition of scope and content throughout the Apollo program.

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The major content areas of the Apollo Training Plan are the following:

1. Program Scope and Approach
2. Flight Crew Training
3. Ground Training
4. Training Equipment
5. Training Documentation
6. Facilities
7. Bibliography

The Program Scope and Approach section briefly defines the requirement for training flight crew personnel, ground monitoring personnel, and NAA maintenance and checkout personnel associated with the Apollo spacecraft operations. An overall training phasing schedule is presented in this section. This section briefly defines the basic methods to be used in development of training analysis, the development of training materials and equipment, and the conduct of training.

Flight Crew Training objectives and requirements are described and preliminary scheduling charts presented to depict the training of initial manned Apollo spacecraft crews and subsequent crew training. Flight crew training is envisioned to include background preparation training, vehicle systems training, operations performance training, mission specific training (preflight training), and debriefing training. In addition, the requirements for mission environment training and physical fitness training are described.

The Ground Training section requirements are briefly described with accompanying schedules and includes a description of ground control and remote site personnel training in addition to maintenance and checkout personnel.

Training Equipment requirements are discussed for three types of training: maintenance operations, part-task, and mission simulation. A list of required training equipments in each category is provided. In addition, a brief descriptive summary of three training devices, one from each category is presented. The need for other training support equipments such as training aids is discussed.

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The Training Documentation section presents a brief discussion of the content to be provided in the training plan, trainer utilization manuals, training exercises, and other supporting documentation.

In the Facilities section, the requirements for the Apollo training program are identified and described for the S&ID, MSC, and AMR sites.

Finally, a bibliography of selected, pertinent documents is presented.

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FACILITIES PLAN SUMMARY

The Preliminary Facilities Plan is an outline documentation of planned facilities required for the Apollo Spacecraft Program. The Space and Information Systems Division has at its disposal specialized facilities available in other NAA operating divisions.

The facilities and capabilities of the subcontractors and associate contractors will be utilized to the maximum extent possible in accordance with the requirements of the program.

The Apollo spacecraft and its support equipment will be developed, designed, and manufactured by S&ID at Air Force Plant No. 16 in Downey, California. The development, fabrication, assembly, test, and checkout of the Apollo spacecraft program will involve the plant facilities described in the following pages.

The Apollo project management office and the Apollo engineering operations offices and design areas will be located in the Downey plant. Office space will also be provided for the NASA representative and his staff, as well as representatives of major S&ID contractors.

DIVISION LABORATORIES

S&ID's Space Science, Engineering Development, Life Sciences, and Information Systems Laboratories will expand to support the Apollo program requirements. Some laboratory functions will be relocated to permit expansion of adjacent laboratory areas. New facilities will be required to house some of the advanced and expanded laboratory functions. Maximum utilization practicable will be made of existing laboratory facilities of North American. The Aerospace Laboratory and the highly specialized laboratory facilities of other NAA Divisions

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Figure 59. S&ID Facilities at Downey, California

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will be utilized as required. North American's sonic testing facility at the Aerospace Laboratory in El Segundo, California, is planned to be modified to produce pressure levels up to 190 db for Apollo testing. This acoustic chamber housing the world's largest catenary horn will provide simultaneously acoustical and mechanical vibration at elevated temperatures for Apollo development tests.

The division laboratories will provide testing services for research and development to advance the state of the art in prototype, design proof, qualification, reliability, and quality verification. Equipment and spacecraft systems in new and existing North American Aviation and government facilities will be subjected to simulated service environments: static and dynamic loads, transient temperatures, acoustics, acceleration, shock, salt spray, humidity, fungus, sand and dust, solar radiation, cold sink of space, and altitude. Division laboratories for conducting analytical and experimental studies on physiological processes, behavioral processes, and bio-astronautics, and for developing specialized hardware and techniques for life support, space systems, and flight sciences will be provided. Division laboratories for conducting applied research and development in the fields of sensors and pattern recognition, and laboratories for developing displays to develop components for detection, tracking, and data processing will also be provided.

Laboratory facilities will be required for Guidance and Navigation Engineering, and they will be used to evaluate components and subsystems of the Apollo guidance and navigation systems. The Laboratories will be used for design evaluation of all interface problems and equipment, for mechanical and functional compatibility checks, and for malfunction analysis. A stabilization and control systems laboratory to synthesize breadboard tests, to evaluate modulation schemes, to analyze tests, and to evaluate switch logic is required. This laboratory will be used for verification, trouble-shooting, bench maintenance; for evaluation of prototype GSE; and for development evaluation. An anechoic chamber and acoustic facilities are planned. A space system development laboratory is planned to house special vibration and shock equipment, hazardous tests cells for ultra-high temperatures, and pressurization systems.

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Plans for the construction of a company-financed, hard-vacuum space chamber at North American Aerospace Laboratory are nearly complete. As soon as the facility is completed, it will be used to support the Apollo spacecraft program. Scheduled date of completion is September 1962. The stainless steel chamber will be 15 feet in diameter and 26 feet long, and it will be housed in a 50- by 60-foot building. Its ultimate vacuum pressure will be 1×10^{-8} mm of mercury. Additional space environment equipment including a solar and thermal simulator is planned to be housed at this facility.

ELECTRICAL POWER SYSTEM TEST FACILITY

A new facility for hazardous tests will be provided for electrical systems development tests. The test cell will be constructed for fire and pressure relief, and the necessary equipment will be incorporated as a part of the test cell. The facility will be approximately 2025 square feet. It will include a 500 square foot test cell flanked by two 200 square foot storage areas for gaseous oxygen and hydrogen, and liquid nitrogen. Explosion proof viewing ports will be installed in the protective wall between the test cell and the control room. Power requirements demand 28-volt DC; 100-volt, 60-cycle AC; and 400-volt, 60-cycle AC with explosion proof electrical outlets.

WATER IMPACT, FLOTATION, AND RECOVERY TESTS

From August 1962 through September 1963, a test site is required to complete land and water impact, recovery aids, water egress, flotation, and logistics recovery tests. The conduct of the water impact tests under conditions approximating expected water landing environments will require actual ocean testing. Preliminary investigation of local test facilities indicates the possibility of using the Naval test site at Point Mugu, California, for conducting these tests. At least one of the test sequences will consist of monitoring post-landing recovery and performance of survival aids and checking vehicle seaworthiness for 7 days.

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COMPUTER AND SIMULATION FACILITY

Although S&ID's present computer facility is well-balanced from an operational and environmental standpoint, and additional IBM 7090 digital computer and five additional sections of an analog computer will be provided on the site until a planned simulation and information processing center is completed.

Prior to the completion of this new facility, an area will be allocated next to the existing computer facility to allow analog computer tie-in with the semi-hard mockup and with the life science mockup. These computers and simulators will be relocated to the new simulation and information processing center which will also have the following additional simulation facilities. Two engineering simulators of Apollo command modules will be provided for mission simulation including rendezvous, earth and lunar orbit, and lunar landing. A planetarium, visual simulation laboratory, observation room, environmental chamber, attitude control simulator, navigational aids area, aero ground equipment area, flight table area, fabrication calibration area, an attitude and control systems test cell, and a control center area are planned to support the total mission simulation studies.

DATA GROUND STATION

A new PCM/PAM data acquisition and processing system will be installed in Building No. 6 adjacent to the final assembly and systems integration facility. The ground station and computer-plotter area will be noise-controlled and will have a raised floor for cable distribution and for installation of air-conditioning plenum chambers. An observation area will be provided for display of realtime data. The adjacent area will be provided for data review and storage rooms, projection and dark rooms, spare parts and raw material storage, and offices. The building modification for the new ground station will include the installation of the raised floor; air conditioning for clean, temperature- and humidity-controlled air; acoustic walls and ceilings for noise control; and regulated and unregulated power.

SUBASSEMBLY, ASSEMBLY, AND MOCKUP

Approximately 20 mockups of various configurations for engineering evaluation will be fabricated in the high-bay manufacturing area. The mockups will be used to evaluate physical size and space provisions of each design objective.

A separate area will be provided for mockups after fabrication for design engineering evaluation review. Mockups will be up-dated to reflect the latest engineering changes and concepts.

The mockup area will be equipped with modern shop equipment and facilities required to build and maintain mockups of wood, fiberglass, and metal.

Fabrication and refurbishment of the boilerplate and prototype command modules, service modules, spacecraft adapters, and launch escape tower systems will be accomplished in the high-bay manufacturing area of Building No. 1 under an existing 14,000-pound bridge crane system. This will permit the utilization of existing facilities and equipment.

BOILERPLATE FINAL ASSEMBLY AND CHECKOUT

Bench maintenance, boilerplate subsystems assembly, boilerplate final assembly, and checkout operations will be initially performed in Building No. 1. The bench maintenance operation will be located in an existing, clean, temperature-controlled area adjacent to manufacturing. Systems verification tests will be conducted in this area. This operation will be relocated adjacent to the manufacturing final assembly area when the addition to Building No. 6 is completed.

Subsystems assembly operations will be conducted in the adjacent low-bay area. Mechanical and electrical subsystems will be assembled in this area prior to installing them in the boilerplate modules.

The installation of subsystems and components will be accomplished in an existing high-bay manufacturing area. Bridge cranes to support this operation are available.

The mating of the modules and escape tower, the checkout of the various systems, and the checkout of the instrumentation are planned to be accomplished by using the existing hydrostatic test tower. This 110-foot tower is equipped with a bridge crane capable of handling the modules. Power and equipment will be provided to checkout the subsystems and instrumentation for this operation.

ELECTRICAL AND ELECTRONIC ASSEMBLY, TUBING, AND GSE

Electrical and electronic assembly, tubing, and GSE fabrication are planned to be accomplished at the Slauson Facility, an NAA leased facility.

The function of this area will be to assemble electronic modules and electrical wire assemblies. This includes all soldering, harness jigging, module and black box assembling, functional checkout, and environmental checkout.

Fabrication of GSE includes the fabrication of consoles (welding, riveting, and metal fitting), the assembly of electrical and mechanical modules which become a part of the consoles, the functional checkout of these modules, and the installation of modules into the consoles. The complete functional GSE includes slings, dollies, transporters, check fixtures, adapters, and specific packaging items.

Fabricating tubing includes such operations as cutting, bending, flaring, welding, and cleaning.

This facility will have electronic, hydraulic, and pneumatic calibration equipment and environmentally controlled areas to comply with design specifications.

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TRAINING EQUIPMENT

It is planned that Apollo training equipment will be fabricated and checked out in the manufacturing areas in Building No. 1. Both 20- and 30-foot bay height areas will be required for equipment installation, mating, and checkout.

Subassembly and checkout of electrical, pneumatic, and hydraulic systems will be accomplished in clean enclosed areas to preclude contamination of systems. Fabrication of trainer structures will be accomplished with the newest types of equipment and facilities available to maintain the lowest costs possible and to maintain quality assurance.

Final assembly and checkout will be performed in a high-bay area with bridge crane coverage for mating operations and material handling. Special power requirements compatible with design specifications for trainer operations and checkout will be provided.

It is planned to provide space in Building No. 3 for training operations, which will include training classrooms and an area to house maintenance trainers with associated ground support equipment.

BONDING AND TEST FACILITY

A new building will be constructed to house the Apollo bonding and test operations. This new 23,400-square-foot building will consist of structural steel framing with insulated corrugated metal siding and a reinforced concrete floor. Bridge crane coverage will be provided. This building will be 100 by 180 by 30 feet and will have an adjacent office and support area, 30 by 180 by 24 feet. This facility will be used for cleaning the aluminum honeycomb and facing sheets, prebond priming, preparation of honeycomb and adhesives prior to bonding, layup of honeycomb panels, bonding, and ultrasonic inspection of the bond. An area will also be included for hydrostatic and helium leak checking the command modules. The bonding area will be temperature and humidity controlled and will contain autoclaves and adequate refrigeration for storing adhesives.

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RADIOGRAPHIC FACILITY

The existing 1920-square-foot X-ray facility will require a 1920-square-foot addition to support the Apollo radiographic inspection requirements. This addition will be a 24- by 80-foot corrugated metal building with a 15- by 15-foot sliding door at each end. All four walls will be lead-lined from the floor to a 10-foot height, and will conform to AEC Handbook 60. This expanded facility will be utilized for all radiographic inspection for production fusion welds, purchased electrical and electronic components, and assemblies and will also be utilized by Materials Review for evaluation of suspect areas or items. Complete X-ray film processing, evaluation, and storage capabilities are part of this facility and will be employed for Apollo support.

SYSTEMS INTEGRATION, MANUFACTURING, AND CHECKOUT FACILITY

The planned facilities for supporting the flight acceptance, systems integration, and manufacturing final assembly activities will be combined into a new addition to Building No. 6, USAF Plant No. 16.

The final assembly operation will consist of components and systems installation in the command modules, the service modules, and the space adapters. Functional checkout of components and systems on an individual basis will be conducted as required. The installation and operations will be conducted in an environmentally controlled area as required by applicable specifications.

Subsystems assembly will consist of manufacturing assembly operations, such as components and subsystems which require a controlled environment. This operation will be located to provide transfer of assemblies directly into final assembly. Air showers and clean rooms will prevent component and systems degradation.

Combined systems checkout will be conducted upon completion of the individual modules in an environmentally controlled area. This area will contain equipment for conducting simulated flight attitudes.

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Systems integration will be conducted in an area adjacent to combined systems checkout operations. This operation will include mating of the individual modules. All mating and breakaway points will be checked, and electromechanical continuity will be established. This area will also be environmentally controlled.

Systems verification tests will be conducted in the bench maintenance area to determine the extent of the rework required on systems or components (vendor and GFAE) that have been removed from the modules for maintenance operations. This area will contain environmentally controlled areas for systems checkout. Areas to house vendor representatives will be provided.

The control rooms, which will house test equipment complexes for the checkout operations, will be adjacent to the specified operational areas. These rooms will be temperature and humidity controlled.

A calibration room will be provided for calibrating test equipment to be used in support of final assembly, combined systems checkout, and integrated systems checkout. A stockroom will be provided to house all components and systems required for final assembly and checkout. Air showers will be placed adjacent to this room to inhibit or prevent degradation to the environmentally controlled rooms.

The planned location of the Flight Acceptance and Systems Integration area will be adjacent to the manufacturing final assembly area, and will permit minimum handling of the modules under controlled environment and maximum utilization of the high-bay area. Adjacent support areas will be dust and temperature-humidity controlled to eliminate possible contamination. Air locks will be provided at all entrances and exits to controlled areas.

Control rooms will be located to provide visual check as well as data monitoring of instrumentation calibration and checkout. Electronic laboratories and shielded areas will be designed and located for maximum utilization and radiation control.

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PROPULSION SYSTEMS DEVELOPMENT FACILITY

This facility is to be located in an existing area at North American's Solid Propulsion Plant at McGregor, Texas (USAF Plant No. 66). Major facility requirements are described in the following paragraphs.

Test Stand

A new structure will be constructed to support the Apollo spacecraft and/or systems during the various tests. Facilities will be provided to support complete systems compatibility testing under hot-firing conditions. Provisions will be made to contain the escape tower following jettisoning from the spacecraft during development tests. An umbilical boom will be installed to service the spacecraft and provide umbilical connections to simulate launch conditions. A bridge crane will be provided to position the spacecraft with a hoist to place the escape tower. A terminal room will be constructed at the stand to provide for short-run cables connecting the long-run cables from the control center to the spacecraft. An adapter will be installed over the flame bucket to support the spacecraft, and thrust measuring devices will be added to measure engine reaction and thrust. The stand will permit full engine gimbaling. An airlock chamber will be installed on the bridge crane to provide crew access to the command module. An emergency exit will be positioned by the escape hatch in case of danger. A ground control station will be constructed to house the propellant transfer units that will be used to check out the spacecraft propulsion systems prior to static firing tests. A Firex system will be installed to protect the spacecraft and stand from damage resulting from spillage, fire, and explosions.

Control and Instrumentation Center

A new building will be constructed for test conduction and data acquisition equipment and activities. Room will be provided for 20 two-bay consoles. A closed-circuit television system for observation of the test stand during actual firing will be installed. Provisions will be made for recording equipment to handle approximately 500 measurements from external power on the spacecraft

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during the test runs. This building will be air-conditioned to provide for proper operation of equipment and personnel.

Service Building

A new 22,000-square-foot general purpose building will be constructed to provide facilities for spacecraft and ground support equipment preparation and maintenance and office space for personnel. It will be located at a safe distance from the stand.

Liquid and Gas Storage and Transfer

Facilities will be installed to store and transfer all liquid and gas propellants, pressurants, fuels, and refrigerants for the usage required with the necessary transfer equipment for loading the spacecraft. Adequate protection will be provided for both personnel and equipment at the transfer points.

Solid-Engine and Igniter Storage

A facility will be provided at a safe distance from the complex for the storage of solid engines, solid propellants, and igniters. This facility will be in accordance with the presently accepted criteria for this type of storage and will include the necessary safety considerations.

Facilities

The necessary roads, grading, embankments, water, sewage, and electrical services will be provided for this test facility. Standard safety considerations will be followed.

TEST AND RANGE FACILITIES

The test facilities presently available at NAA, vendors, suppliers, and subcontractors will be utilized to the fullest extent during the development test program. These facilities will be augmented, where necessary, by existing government facilities and by new test facilities.

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AEROTHERMODYNAMIC TESTING

A highly concentrated, aerothermodynamic test program is proposed for the Apollo spacecraft design and development. The recommended wind tunnel facilities required to accomplish this program are listed in Table 6.

PROPULSION SYSTEM DEVELOPMENT

An altitude-simulation firing facility is required for propulsion systems development and proof-test hot firing tests. The present plan is to use the new AEDCJ-4 altitude test cell, which is scheduled for completion in early 1963. The complete spacecraft, including the launch escape system, will be tested in the chamber under firing conditions using flight nozzles. The chamber is approximately 90 feet in diameter and 200 feet in length. The basic facility elements required for the spacecraft testing will be similar to the sea-level facility with the following two exceptions:

1. Tethered launch escape system testing will not be performed.

2. Crew-loading capsule environment will not be required.

The AEDC facility is an Air Force facility; therefore, coordination through Apollo program channels will be required.

ATLANTIC MISSILE RANGE

Preparation and checkout operations on the spacecraft are divided into six general categories.

Preparation for Checkout and Receiving Inspection

The modules will first enter the receiving inspection and preparation area for checkout. A receiving inspection and configuration review, down to the

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Table 6. Recommended Wind Tunnel Test Facilities

Facility	Abbreviation	Mach Range	Stagnation Pressure (psia)	Stagnation Temperature (°F)	Re/Ft x 15^6	Type	Test Section
North American Aerodynamics Laboratory	NAAL	Subsonic	15	70	1.9	Continuous	8 by 11 ft
North American Aviation, Supersonic Aerophysics Laboratory	SAL	0.7, 1.6 to 3.25	15	70	2 to 4.6	Blowdown	16 by 16 in.
North American Aviation, Trisonic Wind Tunnel	TWT	0.2 to 3.5	15 to 110	70	5 to 14	Blowdown	7 by 7 ft
Jet Propulsion Laboratory 20-in. Supersonic	JPL 20 in.	1.3 to 5	2 to 60	110	0.4 to 6	Continuous	20 by 20 in.
Jet Propulsion Laboratory 21-in. Hypersonic	JPL 21 in.	5 to 9.5	20 to 600	100 to 1200	0.25 to 3.6	Continuous	21 in. diameter
Langley 8-ft Transonic Tunnel	LTPT	0.25 to 1.2	5 to 15	125	0.6 to 2.5	Continuous	8 by 8 ft
Langley Unitary Plan Wind Tunnel	LUPWT	1.4 to 5	30 to 55	150	5 to 11	Continuous	4 by 4 ft
Ames Unitary Plan Wind Tunnel	AUP	0.7 to 3.5	29 to 35	120	3 to 9	Continuous	11 by 11 ft 9 by 7 ft 8 by 7 ft

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Table 6. Recommended Wind Tunnel Test Facilities (Cont)

Facility	Abbreviation	Mach Range	Stagnation Pressure (psia)	Stagnation Temperature (°F)	Re/Ft x 15^6	Type	Test Section
Ames Prototype Hypersonic Free Flight Facility	ABR	30,000 fps				Free-flight	0.45 in. diameter model
Ames 6-in. Arc Jet	A6 in. AJ	12, 14		900 Btu/lb		Continuous	6 in. diameter
AEDC Tunnel A-40	AEDC A	1.5 to 6	1 to 200	70 to 310	0.3 to 9.5	Continuous	40 by 40 in.
AEDC Tunnel B-50	AEDC B	8	100 to 800	900	0.4 to 3.3	Continuous	50 in. diameter
AEDC Tunnel C-50	AEDC C	10, 12	175 to 2400	1500	0.3 to 3.1	Continuous	50 in. diameter
Arnold Engineering Development Center Hot-shot II	AEDC HSII	16 to 21	16,100	5400	0.21 to 0.55	Impulse	50 in. diameter
Ballistic Research Laboratory Transonic Range	BRL T	0.5 to 2.0			0.5 to 1.0	Free-flight	6 in. diameter model
Cornell Aeronautical Laboratory Shock Tunnel	CAL ST	6 to 20			0.002 to 28	Impulse	24 in. diameter
Lewis 10 by 10 ft	L10 by 10 ft	2 to 3.5	14 to 0.35	120 to 330	2.2 to 3.2	Continuous	10 by 10 ft
Lewis 8 by 6 ft	L8 by 6 ft	0.7 to 2.2	15.6 to 25	138 to 200	4.2 to 4.8	Continuous	8 by 6 ft

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subsystem module level, will be performed in this area. Ground support equipment will also undergo similar checks. A clear "white-room" area is required for this operation.

Functional Checkout

Functional checkout operations will require horizontal mating or interconnecting of the spacecraft modules, and ground support equipment required for service, command, and system analysis. A clear area with "white-room" specifications is required for this area. Approximately 10,000 square feet will be required for functional checkout.

Altitude Chamber Checks

The spacecraft will undergo a series of checks in an altitude chamber to verify the hermetic property of the command module before and after static-firing. Two altitude chambers with control areas and vibration stations will be required.

Static Firing

After the altitude chamber checks have been completed, the spacecraft will be moved to the static firing area. A test stand will be required for the vertical mated module firing. Storage will be required for propellants, cryogenics, gas, etc. A control room will be required with the capability to run firings from the control room or the command module.

Simulated Countdown

Following static firing and altitude chamber checks, the spacecraft will be moved to the vertical checkout facility. The test configuration will consist of an S-I simulator, an S-IV simulator, the adapter, service module, command module, and escape tower. A simulated countdown will be performed and will be followed by a simulated flight.

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Launch Pad Operations

Contractor requirements at the launch site include space in the control center for ground support equipment peculiar to the operation for the spacecraft, and provisions on the gantry and umbilical towers for the handling and servicing functions.

GROUND OPERATION SUPPORT SYSTEMS

Ground operation support systems will provide support to Apollo flight operations by predicting and monitoring vehicle trajectories from launch to recovery, by monitoring crew status and vehicle systems performance, by maintaining the vehicle-earth communication and data links, and by maintaining centralized control of the GOSS stations.

GOSS stations will be located and equipped to provide maximum contact with manned orbital flights and to supply tracking and communications during injection and re-entry. The stations at the primary recovery sites will be prepared for landing and recovery operations for a three-orbit flight. Alternate sites will be prepared for one- or two-orbit flights.

GOSS performance and equipment requirements will be specified to NASA by S&ID and implemented by a NASA subcontractor.