[redacted]

Z65·11345

DO NOT REMOVE THIS COPY

Return to MAP/Sullivan

CCN

X71-73504
(ACCESSION NUMBER)

(THRU)

231
(PAGES)

None
(CODE)

NASA-CR-116666
(NASA CR OR TMX OR AD NUMBER)

(CATEGORY)

FF No. 602(A)

AVAILABLE TO NASA OFFICES AND NASA RESEARCH CENTERS ONLY

CLASSIFICATION CHANGE

To UNCLASSIFIED

By authority of NASA L. By. Ltr

Changed by E. L. Merritt 11/11/74

Classified Document Master Control Station, NASA

Scientific and Technical Information Facility

DO NOT REMOVE THIS COPY

DEC 19
RECEIVED
NASA STI FACILITY
INPUT BRANCH

NORTH AMERICAN AVIATION, INC.

SPACE and INFORMATION SYSTEMS DIVISION

(NASA-CR-116666) GENERAL TEST PLAN RESEARCH AND DEVELOPMENT FOR PROJECT APOLLO SPACECRAFT. VOLUME 1: GENERAL TEST PLAN SUMMARY (North American Aviation, Inc.)

N75-70667

Unclas

06141

[redacted]

Z65·11345

[redacted]

This issue replaces and supersedes all previous issues of this book.

Copy No. Accession No. 27006

(cy 39)

SID 62-109-1-R-3

GENERAL TEST PLAN RESEARCH AND DEVELOPMENT FOR PROJECT APOLLO SPACECRAFT (U)

NAS9-150

Volume 1. General Test Plan Summary

Reissued 30 June 1963 Rev 30 September 1963

[redacted] information affecting the national defense of the United [redacted] Section 793 and 794. Its [redacted] manner to an [redacted] prohibited by law.

NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

[redacted]

[redacted]

[redacted]

List of Revised Pages*

iii
v
vii
viii
xiii
1-1 through 1-52
2-1
2-3
2-6
2-7
2-9
2-10
2-22
2-23
2-25
2-28 through 2-36
2-38
2-39
2-40
2-41
2-45
2-46
2-47 through 2-54
3-1
3-7
3-8
3-13
3-15
4-5
5-2 through 5-6
5-9
5-11 through 5-15
5-17 through 5-20
5-22 through 5-25
5-27
5-31
5-33 through 5-36
5-38 through 5-41
5-43 through 5-53
7-1
7-10
7-12
8-1
8-2

*Includes revised, reissued, and new pages. Revisions in original test are indicated by a bar on margin of page next to revised material.

[redacted]

FOREWORD

The General Test Plan for the Project Apollo spacecraft is required by Contract NAS 9-150, Article I-A, and is presented in accordance with Paragraph 4.5.3.1.3 of the Statement of Work. Program status is as of 31 August 1963.

The General Test Plan is presented in five volumes. Volume I of the General Test Plan presents the over-all test logic for the Apollo spacecraft and gives a management-oriented summary of all tests to be performed. Volume II contains the test plans for Apollo individual systems, such as service propulsion system, reaction control system, etc. Volume III describes the Apollo ground qualification test program, including ground support equipment. Volume IV describes the acceptance criteria for each level of Apollo equipment assembly. Volume V contains the detailed test plans for the multiple systems tests, including ground and flight tests.

General Test Plan revisions will be made quarterly, as required by state-of-the-art advances and program adjustments.

S&ID actions resulting from NASA-MSC comments on the 30 June 1963 issue of the Apollo General Test Plan (Refer to NASA-MSC letter, SCE/L53/63-389, dated 4 June 1963) are embodied in this issue of the General Test Plan. Detailed conclusions reached as a result of study and review of the NASA-MSC comments are itemized in S&ID letter 63-MA-13455, to Mr. R.O. Piland, deputy Manager, Apollo Spacecraft Project office.

[redacted]

[redacted]

CONTENTS

Section		Page
	INTRODUCTION	xiii
1.0	TEST LOGIC	1-1
	1.1 Service Propulsion System	1-39
	1.2 Reaction Control System	1-40
	1.3 Launch Escape System	1-40
	1.4 Earth Landing System	1-41
	1.5 Environmental Control System	1-42
	1.6 Electrical Power System	1-43
	1.7 Guidance and Navigation System	1-43
	1.8 Stabilization and Control System	1-44
	1.9 Communications and Instrumentation System	1-45
	1.10 Life Systems	1-45
	1.11 Ground Support Equipment	1-46
	1.12 Structural Tests	1-47
	1.13 Mechanical and Ordnance Devices	1-48
	1.14 Materials, Processes, and Producibility	1-48
	1.15 Wind Tunnel Test Program	1-49
	1.16 Thermal Protection System	1-49
	1.17 In-Flight Test System	1-50
	1.18 Displays and Controls	1-51
	1.19 Simulation Test Program	1-52
2.0	INDIVIDUAL SYSTEM TESTS	2-1
	2.1 Service Propulsion System	2-1
	2.1.1 Scope	2-1
	2.1.2 Objectives	2-1
	2.1.3 Requirements	2-1
	2.1.4 Subcontractor Test Plan (Aerojet Corporation)	2-1
	2.1.5 S&ID Test Plan	2-2
	2.1.6 Facilities	2-3
	2.1.7 Schedule	2-3
	2.2 Reaction Control System	2-3
	2.2.1 Scope	2-3
	2.2.2 Objectives	2-4
	2.2.3 Requirements	2-4
	2.2.4 Subcontractor Test Plan	2-4
	2.2.5 S&ID Test Plan	2-4
	2.2.6 Facilities	2-5
	2.2.7 Schedule	2-6

[redacted]

[redacted]

Section | Page

2.3 Launch Escape System 2-6
2.3.1 Scope 2-6
2.3.2 Objectives 2-6
2.3.3 Requirements 2-6
2.3.4 Subcontractor Test Plan 2-6
2.3.5 S&ID Test Plan 2-11
2.4 Earth Landing System 2-11
2.4.1 Scope 2-11
2.4.2 Objectives 2-11
2.4.3 Requirements 2-11
2.4.4 Subcontractor Test Plan (Northrop-Ventura) . 2-11
2.4.5 S&ID Test Plan 2-11
2.4.6 Facilities 2-12
2.4.7 Schedule 2-12
2.5 Environmental Control System 2-12
2.5.1 Scope 2-12
2.5.2 Objectives 2-12
2.5.3 Requirements 2-13
2.5.4 Subcontractor Test Plan (AiResearch) . . 2-13
2.5.5 S&ID Test Plan 2-13
2.5.6 Facilities 2-14
2.5.7 Schedule 2-14
2.6 Electrical Power System 2-15
2.6.1 Subcontractor Test Plan 2-15
2.6.2 S&ID Test Plan 2-16
2.6.3 Schedule 2-17
2.7 Guidance and Navigation System 2-17
2.7.1 Scope 2-17
2.7.2 Objectives 2-17
2.7.3 Requirements 2-17
2.7.4 Associate Contractor Test Plan (MIT) . . 2-17
2.7.5 S&ID Test Plan 2-19
2.7.6 Facilities 2-20
2.7.7 Schedule 2-21
2.8 Stabilization and Control System 2-21
2.8.1 Scope 2-21
2.8.2 Objective. 2-21
2.8.3 Requirements 2-21
2.8.4 Subcontractor Test Plan (Minneapolis-Honeywell) 2-21
2.8.5 S&ID Test Plan 2-21
2.8.6 Facilities 2-23
2.8.7 Schedule 2-23

[redacted]

Section | Page

2.9 Communications and Instrumentation System . . 2-23
2.9.1 Communications System 2-23
2.9.2 Instrumentation System 2-26
2.10 Life Systems 2-28
2.10.1 Scope 2-28
2.10.2 Objectives 2-29
2.10.3 Requirements 2-29
2.10.4 S&ID Test Plan 2-31
2.10.5 Facilities 2-32
2.10.6 Schedule 2-33
2.11 Ground Support Equipment 2-33
2.11.1 Scope 2-33
2.11.2 Objectives 2-33
2.11.3 Requirements 2-33
2.11.4 Subcontractor Test Plan 2-33
2.11.5 S&ID Test Plan 2-33
2.11.6 Facilities 2-34
2.11.7 Schedule 2-34
2.12 Structural Tests 2-34
2.12.1 Scope 2-34
2.12.2 Objectives 2-34
2.12.3 Requirements 2-34
2.12.4 S&ID Test Plan 2-34
2.12.5 Facilities 2-38
2.12.6 Schedule 2-38
2.13 Mechanical and Ordnance Devices 2-38
2.13.1 Scope 2-38
2.13.2 Objectives 2-38
2.13.3 Requirements 2-38
2.13.4 S&ID Test Plan 2-38
2.13.5 Facilities 2-40
2.13.6 Schedule 2-40
2.14 Materials, Processes, and Producibility . . 2-40
2.14.1 Subcontractor Test Plan 2-40
2.14.2 S&ID Test Plan 2-40
2.14.3 Schedule 2-42
2.15 Wind Tunnel 2-42
2.15.1 Scope 2-42
2.15.2 Objectives 2-42
2.15.3 Requirements 2-42
2.15.4 S&ID Test Plan 2-42
2.15.5 Facilities 2-44
2.15.6 Schedule 2-44

[redacted]

[redacted]

Section | Page

2.16 Thermal Protection System 2-44
2.16.1 Scope 2-44
2.16.2 Objectives 2-44
2.16.3 Requirements 2-45
2.16.4 Subcontractor Test Plan (AVCO) . . . 2-45
2.16.5 S&ID Test Plan 2-45
2.16.6 Facilities 2-46
2.16.7 Schedule 2-46
2.17 In-Flight Test System 2-47
2.17.1 Scope 2-47
2.17.2 Objectives 2-47
2.17.3 Requirements 2-47
2.17.4 Subcontractor Test Plan 2-47
2.17.5 S&ID Test Plan 2-47
2.17.6 Facilities 2-48
2.18 Displays and Controls 2-48
2.18.1 Scope 2-48
2.18.2 Objectives 2-49
2.18.3 Requirements 2-49
2.18.4 Subcontractor Test Plan 2-49
2.18.5 S&ID Test Plan 2-49
2.19 Simulation Test Plans 2-50
2.19.1 Scope 2-50
2.19.2 Objectives 2-50
2.19.3 Requirements 2-51
2.19.4 S&ID Test Plan 2-52
2.19.5 Facilities 2-53
2.19.6 Test Schedule 2-53

3.0 GROUND QUALIFICATION TESTS 3-1
3.1 Scope 3-1
3.2 Ground Qualification Program—Spacecraft . . 3-2
3.2.1 Program Logic 3-2
3.2.2 Reliability Assessment 3-3
3.2.3 Subsystem Qualification Phases . . . 3-3
3.2.4 The Concept of Criticality 3-5
3.2.5 Minimum Qualification Program . . . 3-6
3.2.6 Program Considerations 3-9
3.3 Qualification Schedules—Spacecraft Subsystems . 3-9
3.3.1 Concept 3-9
3.3.2 Application 3-10
3.4 Environmental Criteria—Spacecraft Subsystems . 3-10
3.4.1 Environmental Criteria 3-10
3.4.2 Test Criteria 3-13
3.4.3 Waiver of Test 3-13

[redacted]AL

[redacted]

Section Page

3.5 Spacecraft Subsystem Qualification Tests . . . 3-14
3.5.1 Scope 3-14
3.5.2 Reliability Logic Diagram 3-14
3.5.3 System Parameters for Qualification Testing 3-14
3.5.4 Qualification Test Schedule 3-15
3.6 Ground Support Equipment 3-15
3.6.1 Scope 3-15
3.6.2 Concept 3-15
3.6.3 Considerations 3-17
3.6.4 Implementation 3-19
3.7 Integrated Systems Qualification 3-22
3.7.1 Scope 3-22
3.7.2 Purpose 3-22
3.7.3 Method 3-22

4.0 ACCEPTANCE TEST PLANS 4-1
4.1 Scope 4-1
4.2 Concept 4-1
4.2.1 General 4-1
4.2.2 Premise 4-3
4.2.3 Implementation 4-3
4.3 Techniques 4-6

5.0 MULTIPLE SYSTEMS TESTS 5-1
5.1 Pad Abort Tests 5-1
5.1.1 Scope 5-1
5.1.2 Objectives 5-1
5.1.3 Requirements for Pad Abort Boilerplate 6 and Airframe 010 5-2
5.1.4 Test Description 5-3
5.1.5 Facilities 5-5
5.1.6 Test Schedule 5-5
5.2 Little Joe II Tests 5-5
5.2.1 Scope 5-5
5.2.2 Objectives 5-6
5.2.3 Requirements 5-9
5.2.4 Test Description 5-10
5.2.5 Facilities 5-15
5.2.6 Test Schedule 5-15
5.3 Apollo/Saturn Test Plans 5-15
5.3.1 Scope 5-15
5.3.2 Objectives 5-17
5.3.3 Requirements 5-21

[redacted]

[redacted]

Section | Page

5.3.4 Test Description 5-21
5.3.5 Facilities 5-25
5.3.6 Test Schedule 5-26
5.4 Propulsion Test Program 5-26
5.4.1 Scope 5-26
5.4.2 Objectives 5-28
5.4.3 Requirements 5-29
5.4.4 Test Description 5-29
5.4.5 Facility 5-32
5.4.6 Test Schedule 5-32
5.5 Spacecraft Environmental Proof Test Plans . . 5-32
5.5.1 Scope 5-34
5.5.2 Objectives 5-34
5.5.3 Test Description 5-35
5.5.4 Facilities 5-38
5.5.5 Test Schedule 5-38
5.6 House Spacecraft Test Plans 5-38
5.6.1 Scope 5-38
5.6.2 Objectives 5-38
5.6.3 Requirements 5-41
5.6.4 Test Description 5-41
5.6.5 Facilities 5-43
5.6.6 Test Schedule 5-43
5.7 Spacecraft Test Preparation Plans 5-44
5.7.1 Scope 5-44
5.7.2 Objectives 5-44
5.7.3 Requirements 5-45
5.7.4 Test Description 5-45
5.7.5 Facilities 5-48
5.7.6 Test Schedule 5-48
5.7.7 Data Handling and Analysis 5-48
5.7.8 Reliability Engineering Support . . . 5-52

NOMENCLATURE 6-1

DEFINITION OF TERMS 7-1

REFERENCES 8-1

[redacted]HAL

[redacted]

ILLUSTRATIONS

Figure		Page
1	Apollo General Test Schedule	xv
1-1	Apollo Test Logic (All Systems)	1-2
1-2	Apollo Test Logic (Service Propulsion System)	1-3
1-3	Apollo Test Logic (Reaction Control Systems)	1-4
1-4	Apollo Test Logic (Launch Escape System)	1-5
1-5	Apollo Test Logic (Earth Landing System)	1-6
1-6	Apollo Test Logic (Environmental Control System)	1-7
1-7	Apollo Test Logic (Electrical Power System)	1-8
1-8	Apollo Test Logic (Guidance and Navigation System)	1-9
1-9	Apollo Test Logic (Stabilization and Control System)	1-10
1-10	Apollo Test Logic (Communication and Instrumentation System)	1-11
1-11	Apollo Test Logic (Life Systems)	1-12
1-12	Apollo Test Logic (Structural Systems)	1-13
1-13	Apollo Test Logic (Mechanical Systems)	1-14
1-14	Apollo Test Logic (Thermal Protection System)	1-15
2-1	Service Propulsion System Test Schedule	2-3
2-2	Reaction Control System Test Schedule	2-7
2-3	Launch Escape System Rocket Motor Development Test Schedules	2-10
2-4	Earth Landing System Test Schedule	2-12
2-5	Environmental Control System Test Schedule	2-15
2-6	Electrical Power System Test Schedule	2-18
2-7	Guidance and Navigation System Test Schedule	2-22
2-8	Stabilization and Control System Test Schedule	2-24
2-9	Communications Equipment Test Schedule	2-27
2-10	Human Engineering Test Program, Crew Equipment, and Spacecraft Systems General Schedule	2-35
2-11	Ground Support Equipment Test Schedule	2-37
2-12	Structural Test Schedule	2-39
2-13	Mechanical and Ordnances Devices Test Schedule	2-41
2-14	Materials, Processes, and Producibility Test Schedule	2-43
2-15	Wind Tunnel Test Schedule	2-45
2-16	Thermal Protection System Test Schedule	2-46
2-17	Simulation Schedule	2-54
2-18	Simulator/Evaluator Schedule	2-54
3-1	Spacecraft Zones	3-11
4-1	Equipment Test Flow Chart	4-2

[redacted]

[redacted]

[redacted]

Figure		Page
4-2	Stress-Strength Function	4-4
4-3	Parameter Distribution	4-5
5-1	Pad Abort Test Schedule	5-6
5-2	Little Joe II Abort Test Schedule	5-16
5-3	Apollo/Saturn Test Schedule	5-27
5-4	Propulsion Test Schedule	5-33
5-5	Spacecraft Environmental Proof Test Schedule	5-39
5-6	House Spacecraft Test Schedule	5-43
5-7	Typical Boilerplate Sequence of Operations During Test Preparation	5-46
5-8	Typical Airframe Sequence of Operations During Test Preparation	5-47
5-9	Interim Boilerplate Test Preparation Area, Bldg 1, Downey	5-49
5-10	Spacecraft Test Preparation Schedule	5-51

TABLES

Table		Page
1-1	Test Logic System Breakdown	1-16
3-1	Criticality Classifications	3-6
3-2	Minimum Hardware per System	3-8
3-3	Environmental Tests and Their Applicability to S/C Zone and to Test Phase	3-12
3-4	GSE Classifications	3-16
3-5	GSE Qualification Test Catalog	3-18

[redacted]

[redacted]

INTRODUCTION

The General Test Plan for Project Apollo spacecraft defines the manner in which the testing will be accomplished to qualify the spacecraft for manned earth-orbital flight. The test program for flights beyond earth orbit will be presented in future issues of this document.

This volume presents the over-all test logic for Project Apollo and provides a management-oriented summary of all testing activities. The general test schedule for this project is shown in Figure 1. The dates shown for the Apollo boilerplate missions are in the process of being rescheduled.

This volume is divided into five sections. Section 1.0, Test Logic, delineates and explains the sequence of tests for each Apollo spacecraft system from earliest component testing through system development, qualification, and integrated systems tests. Certain categories of testing, such as wind tunnel, are treated in the same manner as system tests. The over-all test logic, phasing of equipment, system integration, and vehicle development are summarized on logic diagrams.

Section 2.0, Individual System Tests, contains brief descriptions of the individual system tests conducted to evaluate materials, components, and system performance. Information concerning objectives, procedures, schedules, and facilities is included with information regarding subcontractor equipment tests, requirements, and schedules. The manner in which this equipment is integrated with S&ID schedules also is specified.

Section 3.0, Ground Qualification Tests, summarizes the Apollo ground qualification program. Information concerning objectives, procedures, schedules, scope, and facilities is included with an integrated picture of the program.

Section 4.0, Acceptance Test Plans, contains a description of the acceptance criteria of each subsystem and associated ground support equipment. The acceptance philosophy is discussed with its many requirements.

Section 5.0, Multiple Systems Tests, contains brief descriptions of major test programs in which more than one system is involved. Information concerning test preparation, objectives, procedures, schedules, and facilities is included in condensed form.

[redacted]

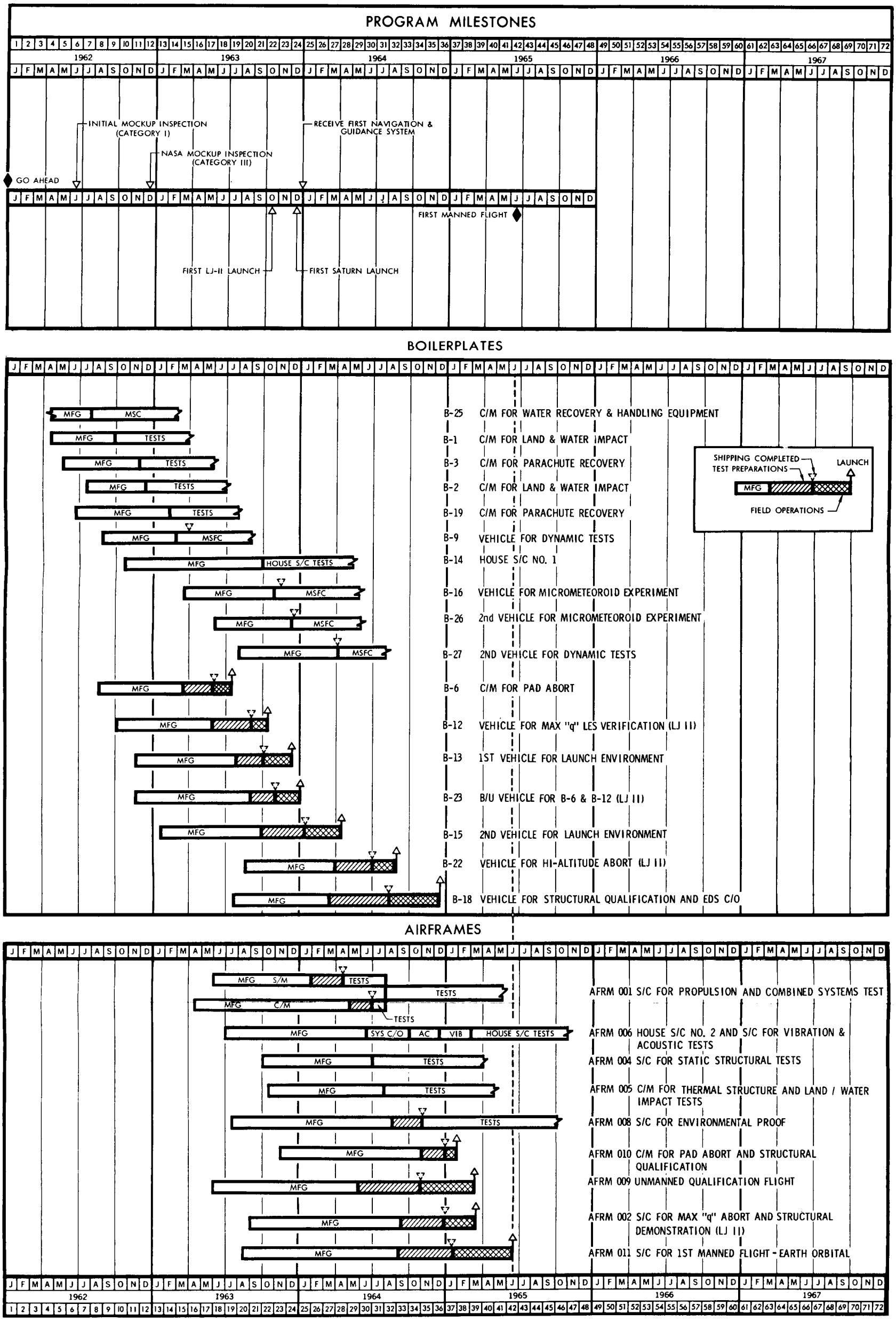


Figure 1. Apollo General Test Schedule

NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

C[redacted]

[redacted]

1.0 TEST LOGIC*

This section describes the time-sequenced development test logic to be employed in the testing of each Apollo system and traces concisely the progression of each system. The interim objective of all testing is qualification for manned earth-orbital flight; the ultimate objective is qualification for safe manned lunar flight.

The reoriented qualification program was developed to provide a logical step from the development test program into the boilerplate and spacecraft test program. It presents the various phases planned to qualify each subsystem to be used in the multiple systems tests. The qualification program provides the integrating medium required to assure complete qualification of all subsystems by phase as each step in the program is accomplished.

Acceptance test planning is designed to eliminate as many factors contributing to unreliability as possible on a unit by unit basis. In fact, the program is being designed to predict the reliability potentials of each individual component and assembly.

Figure 1-1 shows the test phasing of Apollo systems from the first boilerplate configuration through airframe 011, a manned earth-orbital vehicle. Similar logic diagrams for individual system utilization and test progression are shown in Figures 1-2 through 1-14. Table 1-1 gives a group key number to be used with individual systems diagrams and identifies agencies that supply Apollo subsystems.

The mock-ups and boilerplate vehicles appear on the diagrams as hexagons and squares, respectively. Trainers and airframe vehicles are shown as triangles: trainers with point down and airframes with point up. Numbers within the symbol correspond to the mock-up, boilerplate, trainer, of airframe numbers. Flight articles are distinguished from ground test articles by a small triangle within the symbol to indicate the launch date of the flight article and a "bullet" within the symbol to indicate the date of the test start on the ground test article. Dates are referenced to the calendar on the chart.

Multiple system tests, such as air drops and Little Joe II launches, are on the same level as shown by the index on the right margin. The individual systems being tested with the Apollo program are shown on the arrow leading into the test article by circled group numbers. The group numbers are explained in the system breakdown (Table 1-1).

Arrows trace test support or development, and in cases where no systems are shown on an arrow between two test items, the two test items have the same systems aboard. In the case of mock-ups and trainers, only support and development are shown.

*Entire section reissued.

[redacted]

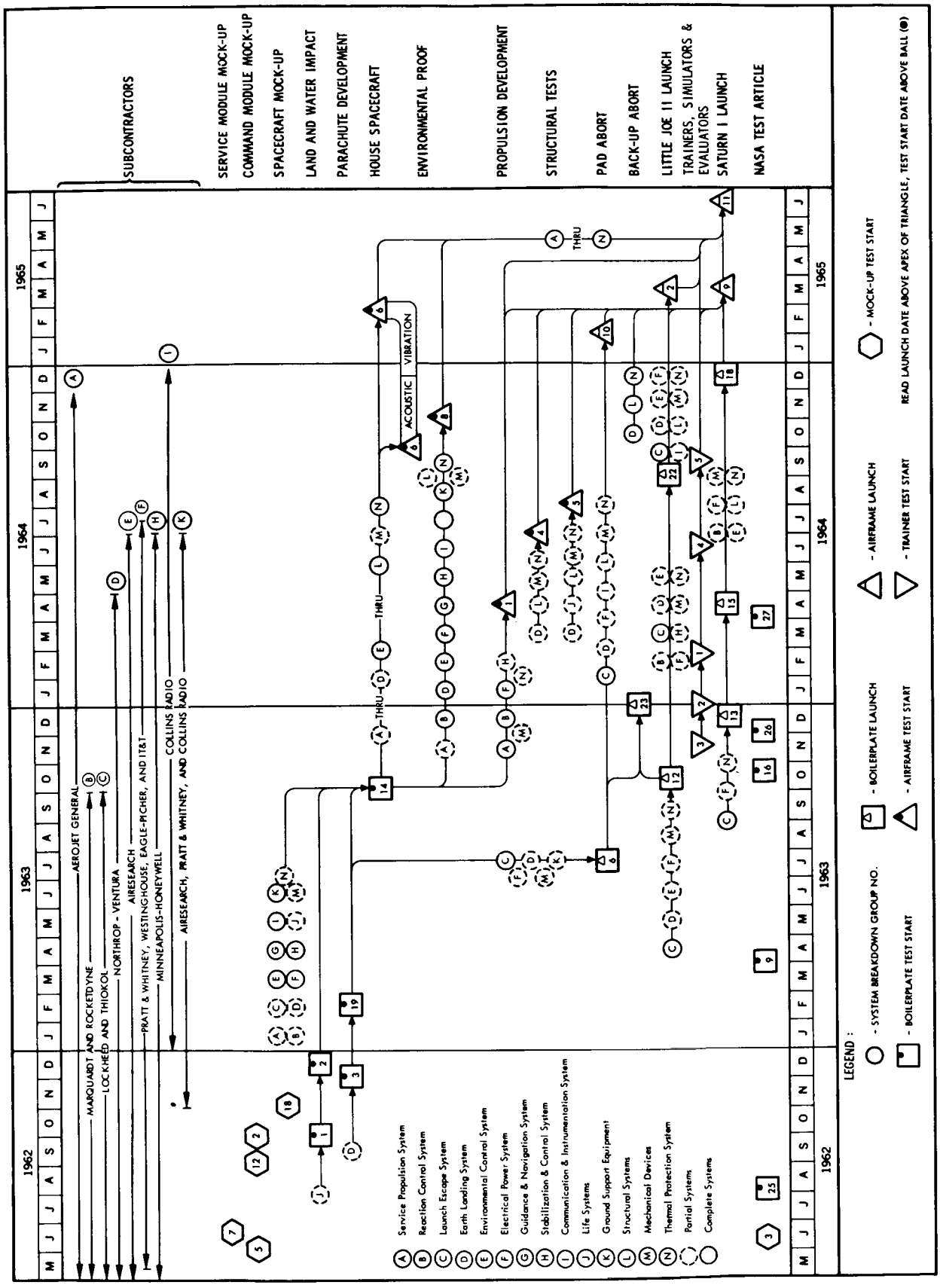


Figure 1-1. Apollo Test Logic (All Systems)

[redacted]TIAL

[redacted]

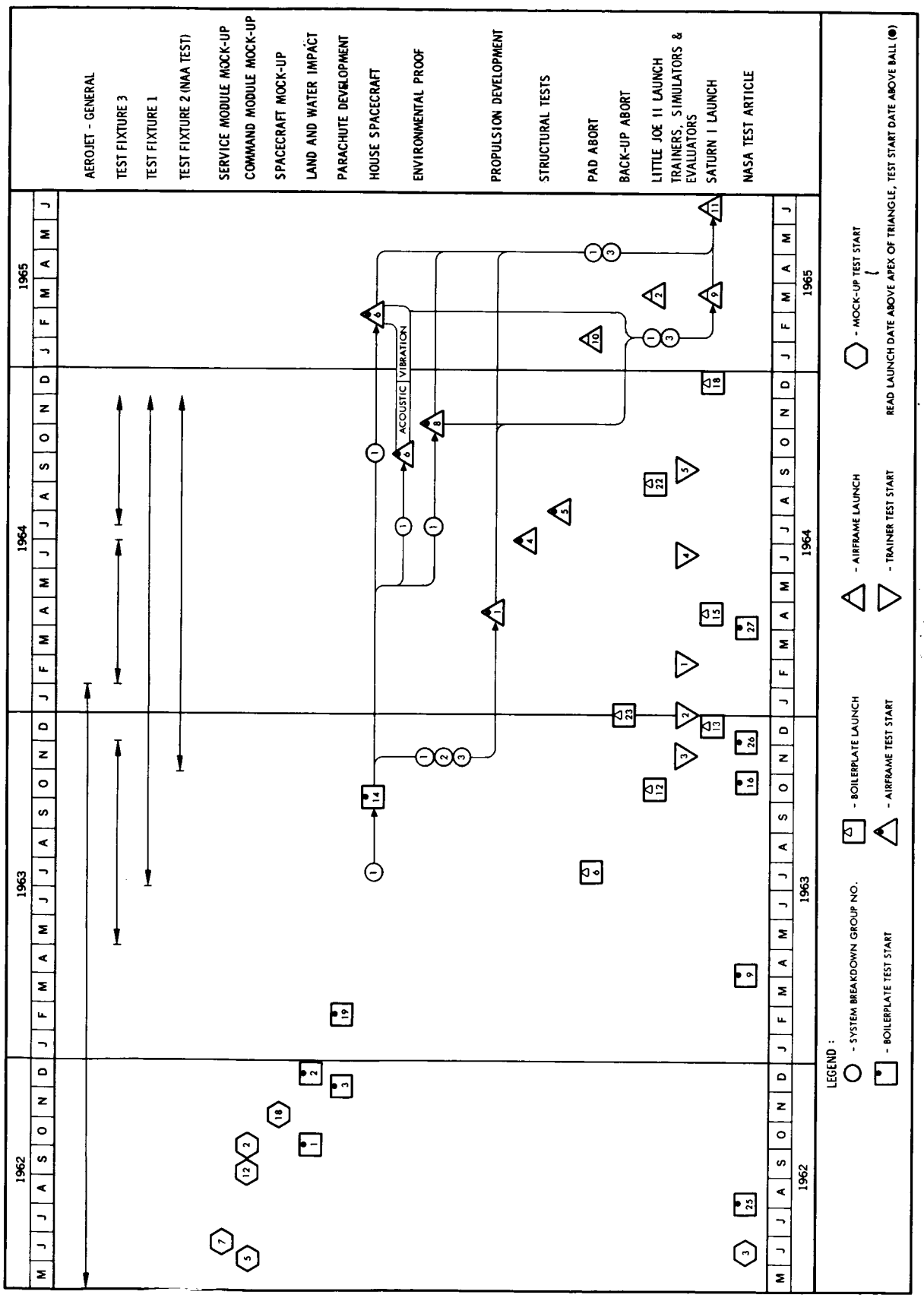


Figure 1-2. Apollo Test Logic (Service Propulsion System)

[redacted]

[redacted]

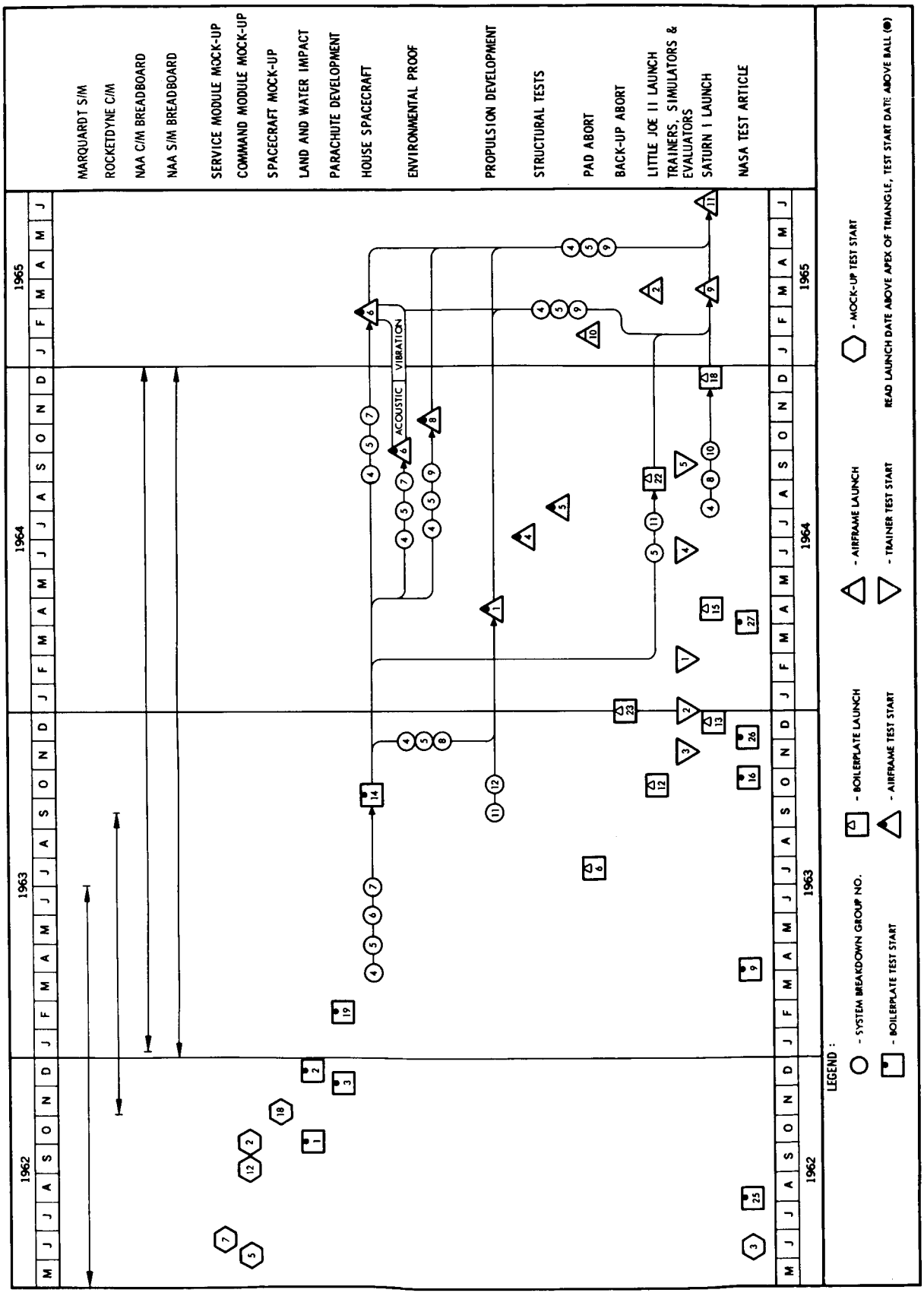


Figure 1-3. Apollo Test Logic (Reaction Control Systems)

[redacted]NTIAL

CO[redacted]

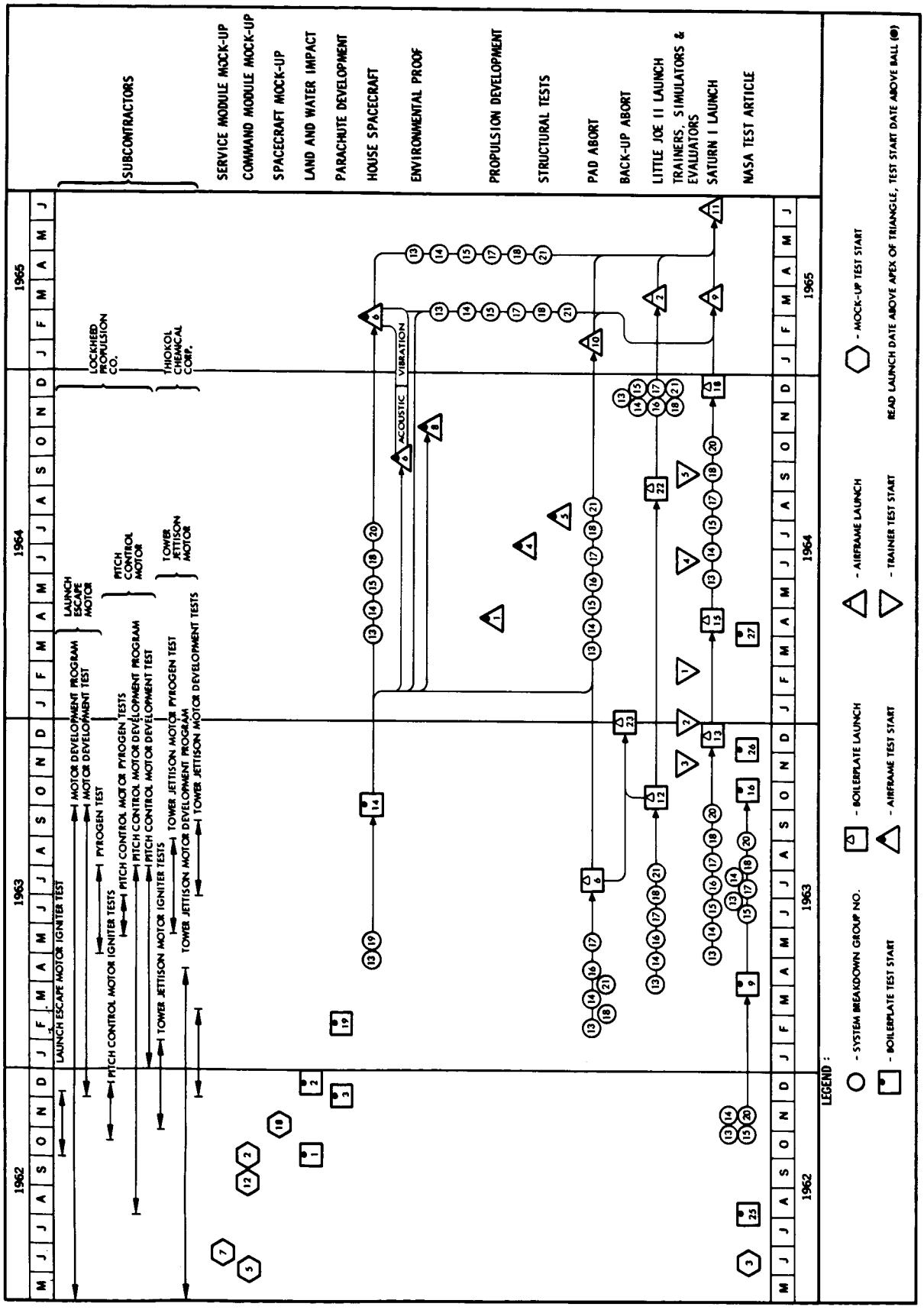


Figure 1-4. Apollo Test Logic (Launch Escape System)

[redacted]

[redacted]

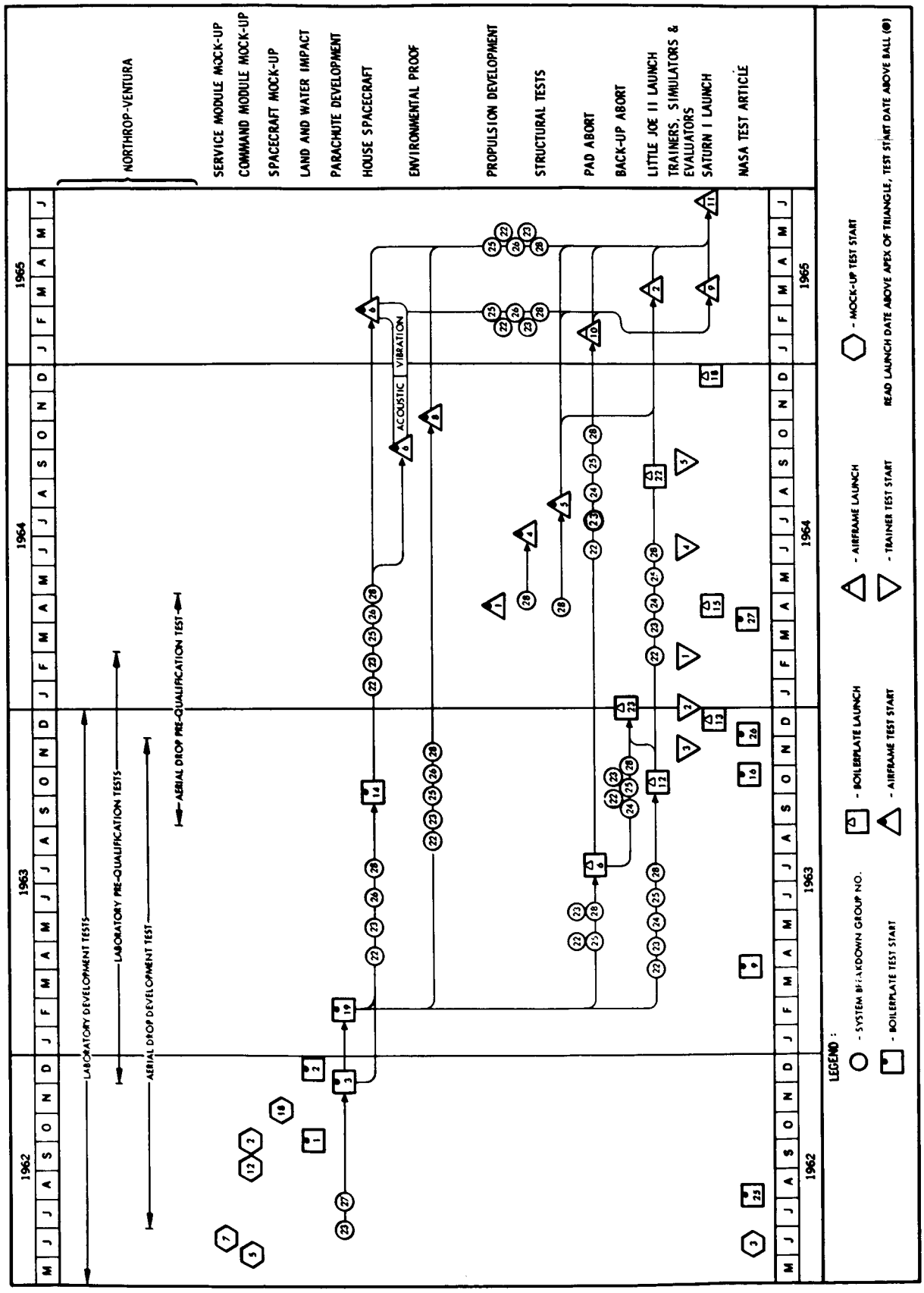


Figure 1-5. Apollo Test Logic (Earth Landing System)

[redacted]

CO[redacted]

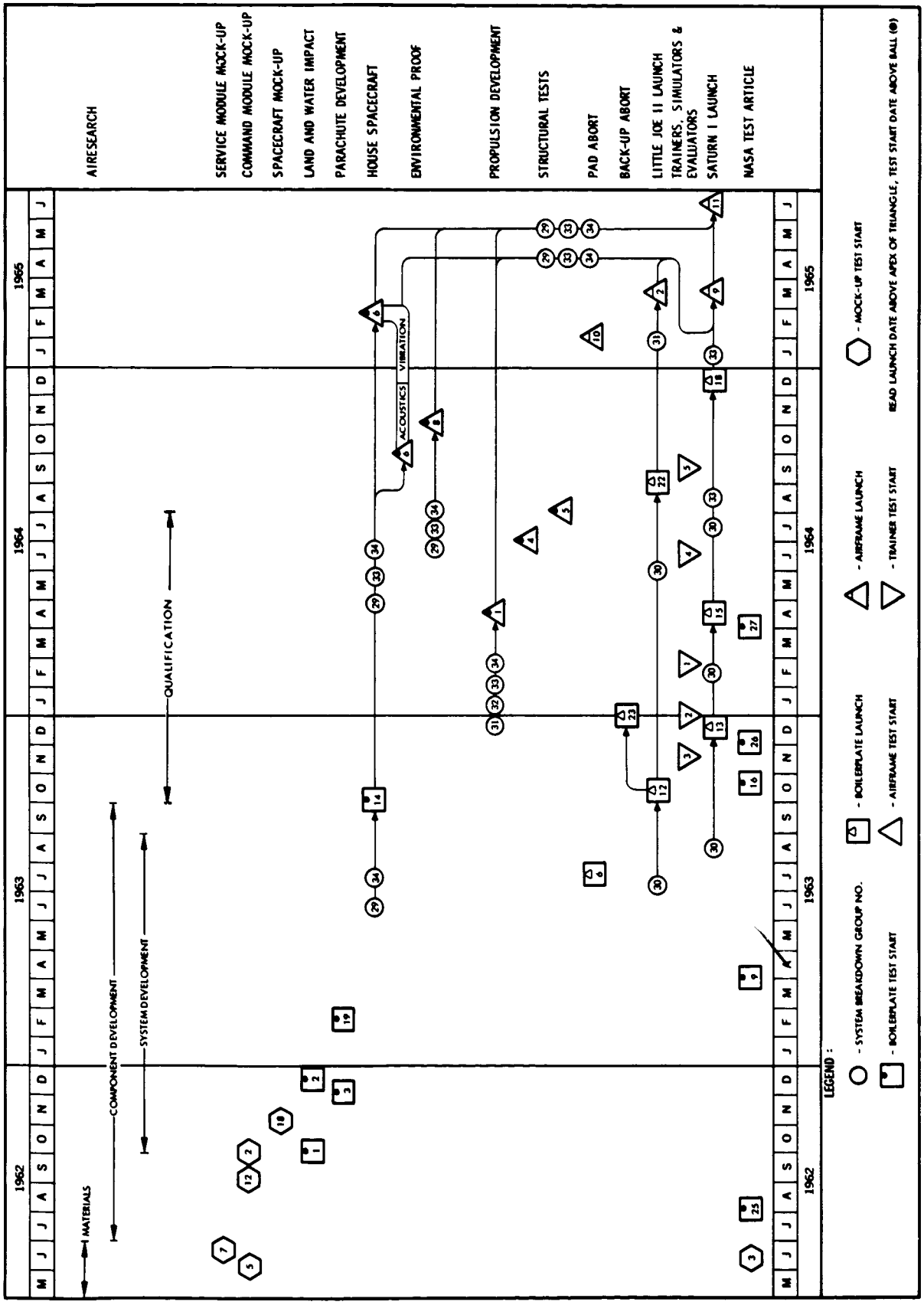


Figure 1-6. Apollo Test Logic (Environmental Control System)

[redacted]

[redacted]

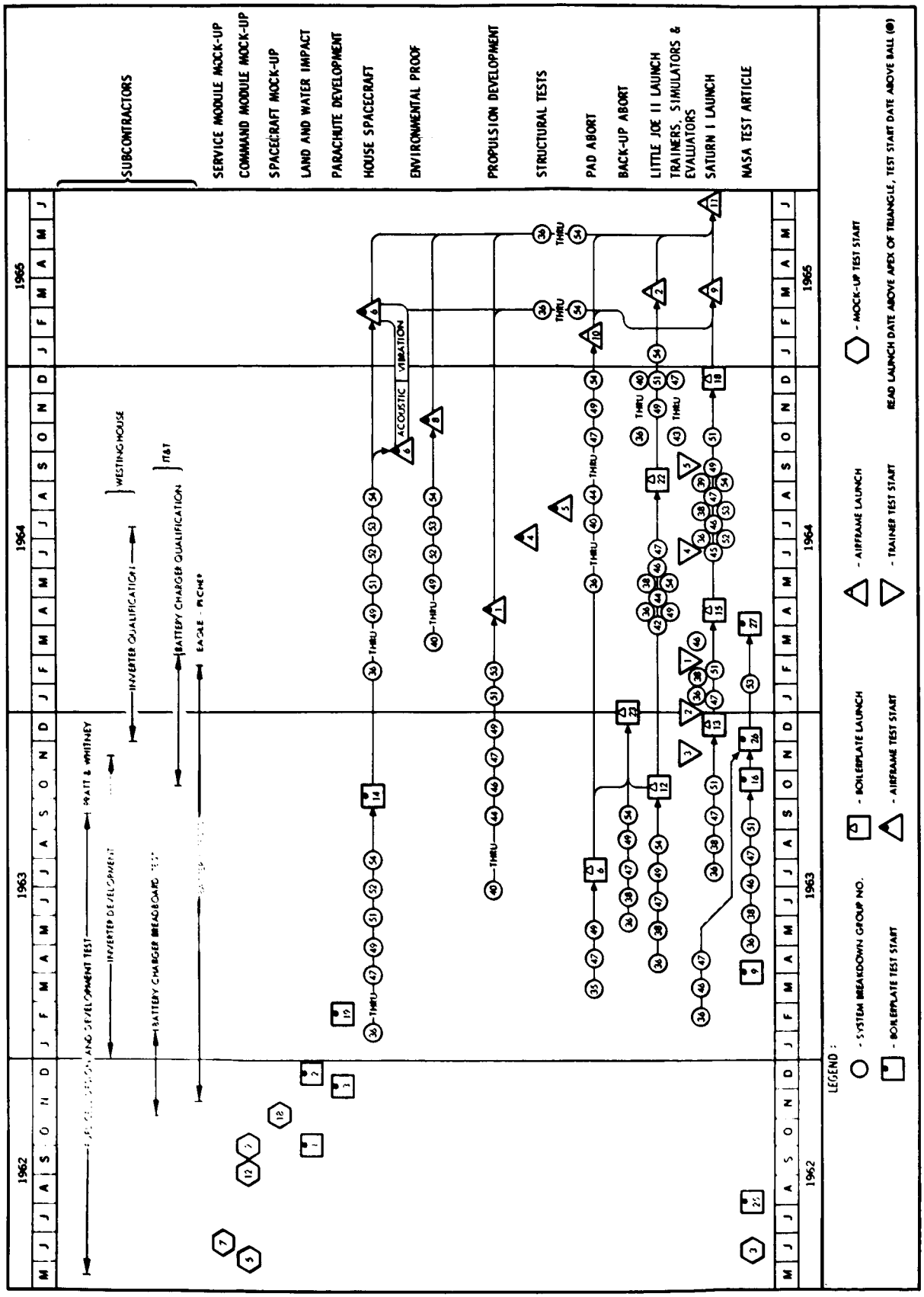


Figure 1-7. Apollo Test Logic (Electrical Power System)

[redacted]DENTIAL

CO[redacted]

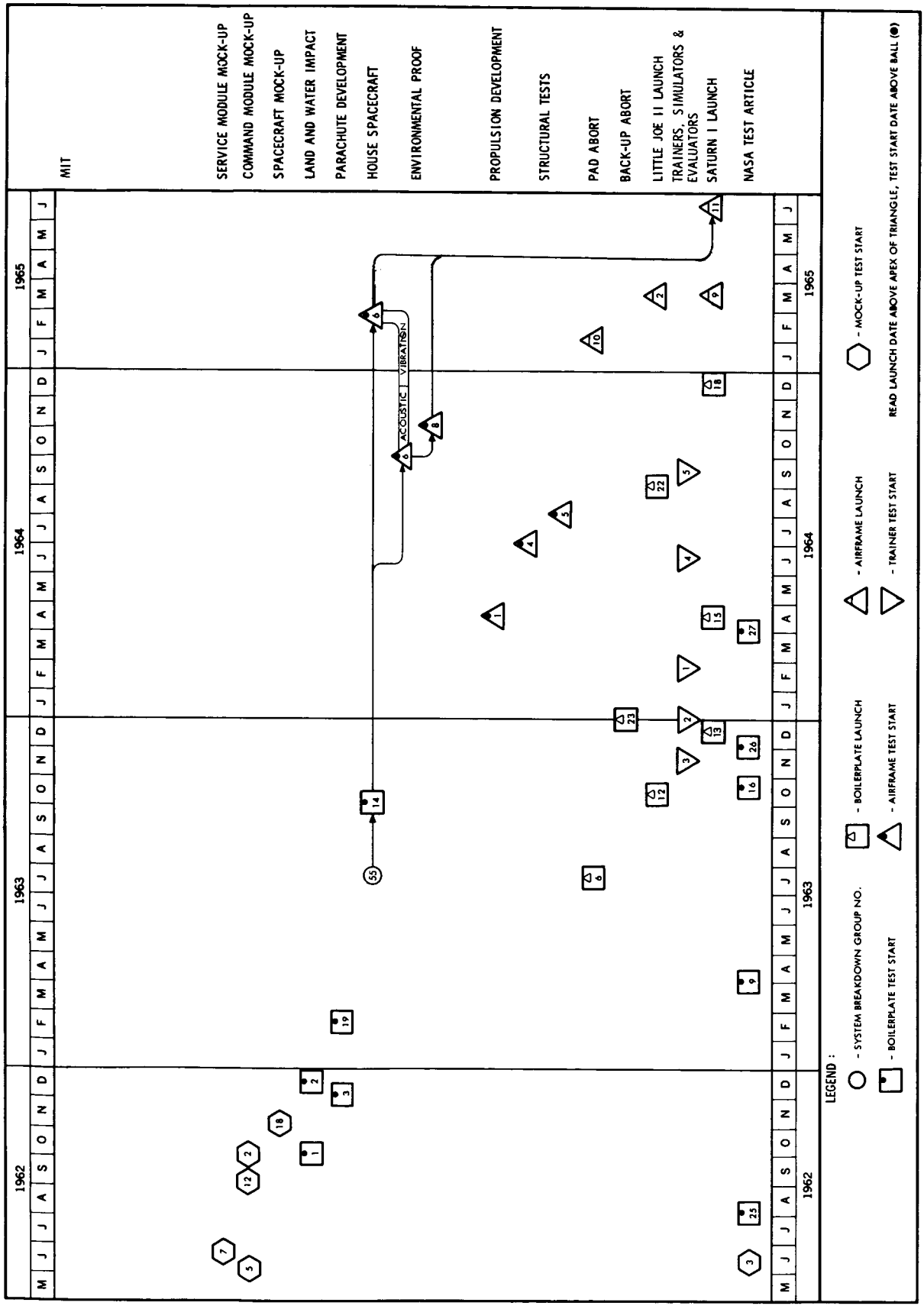


Figure 1-8. Apollo Test Logic (Guidance and Navigation System)

[redacted]

[redacted]

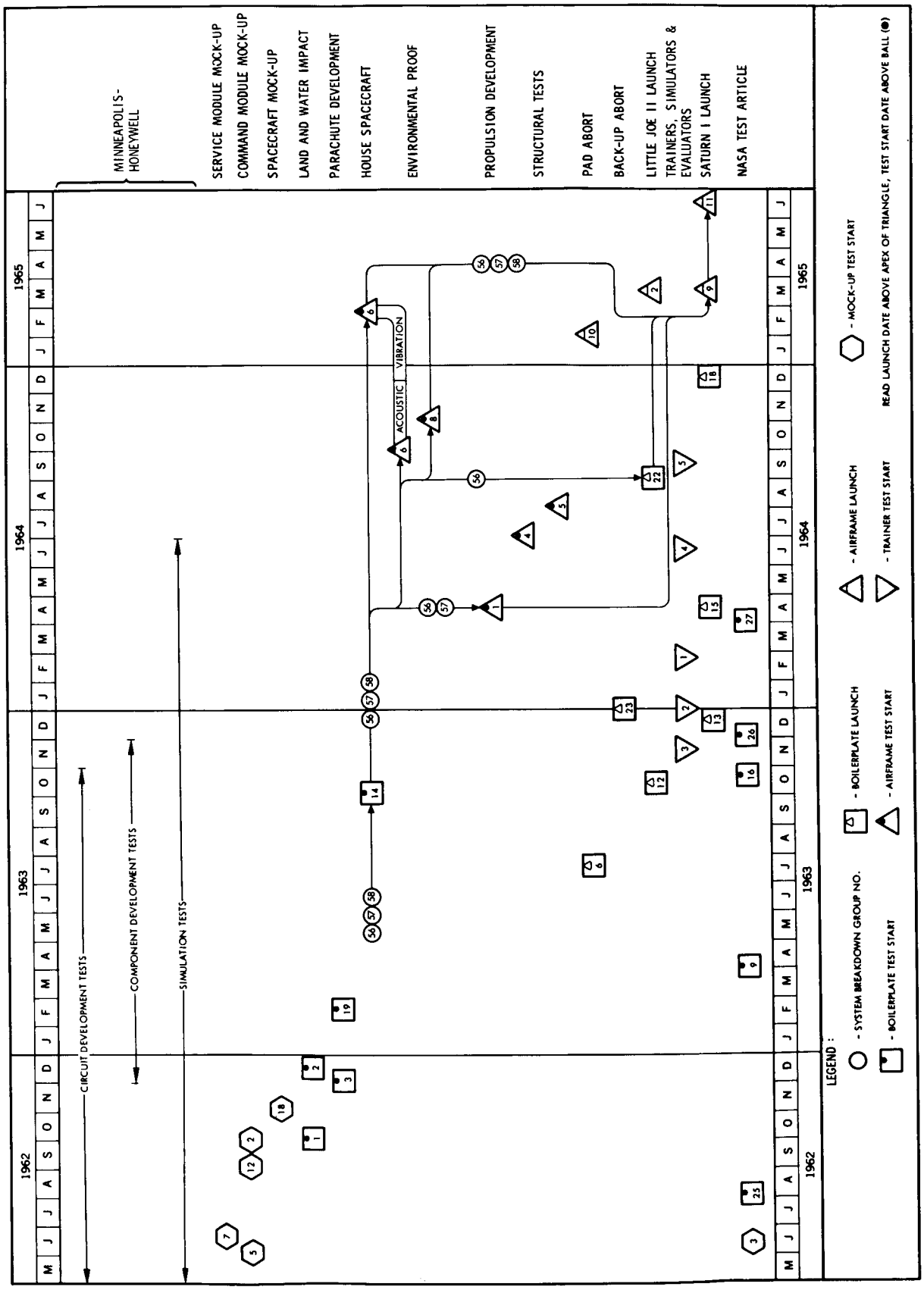


Figure 1-9. Apollo Test Logic (Stabilization and Control System)

[redacted]DENTIAL

CO[redacted]

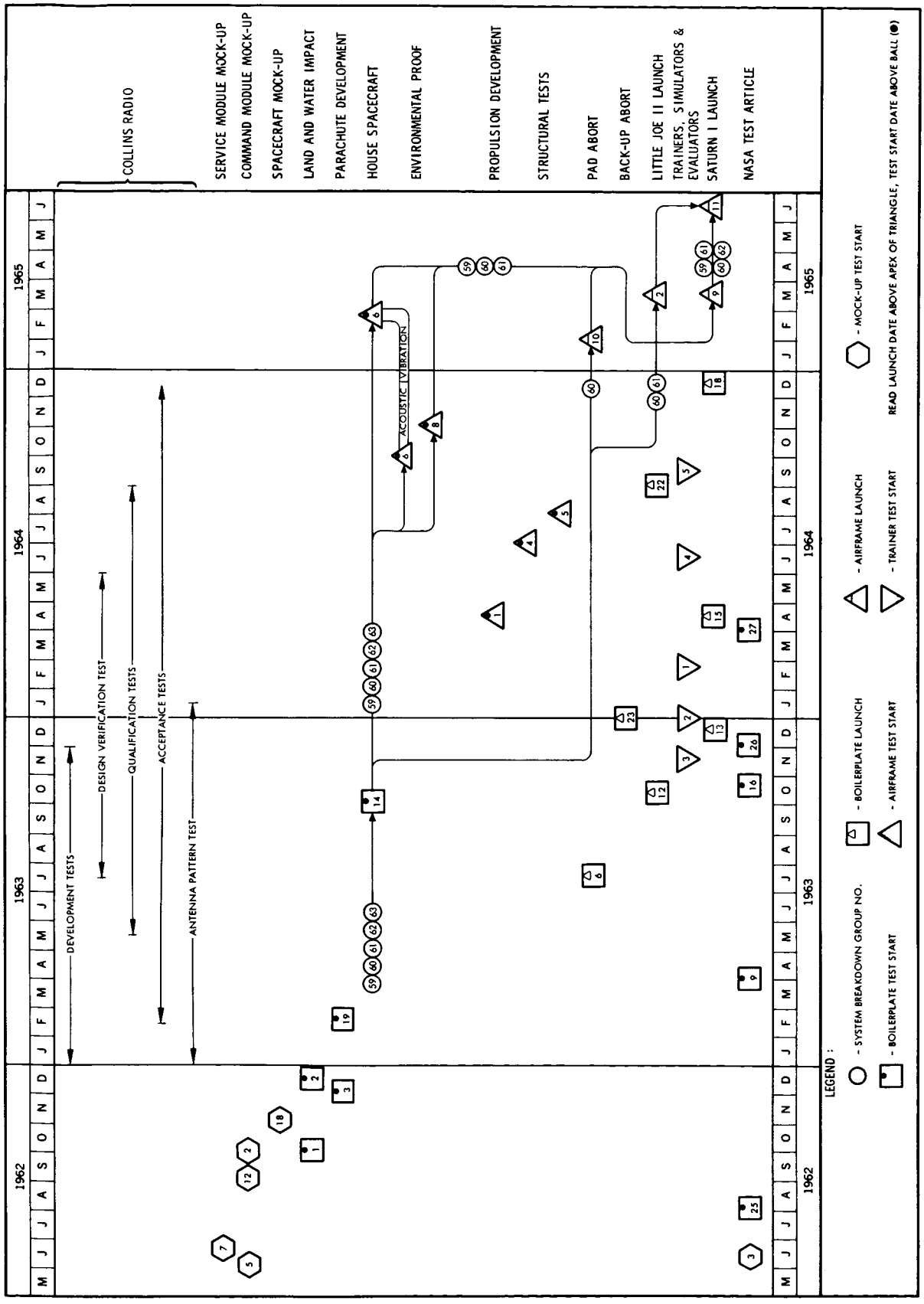


Figure 1-10. Apollo Test Logic (Communication and Instrumentation System)

[redacted]

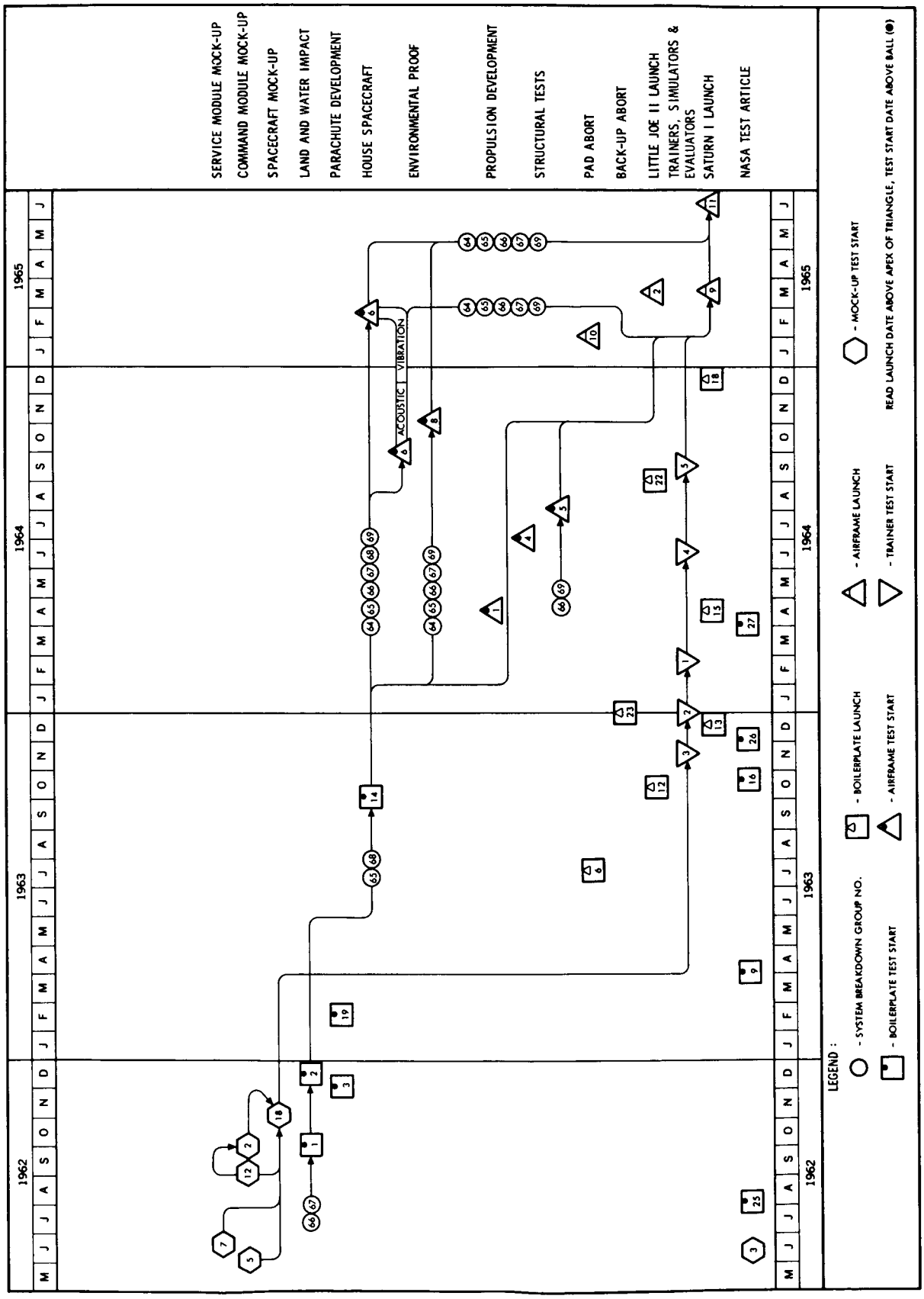


Figure 1-11. Apollo Test Logic (Life Systems)

[redacted]ENTIAL

C[redacted]

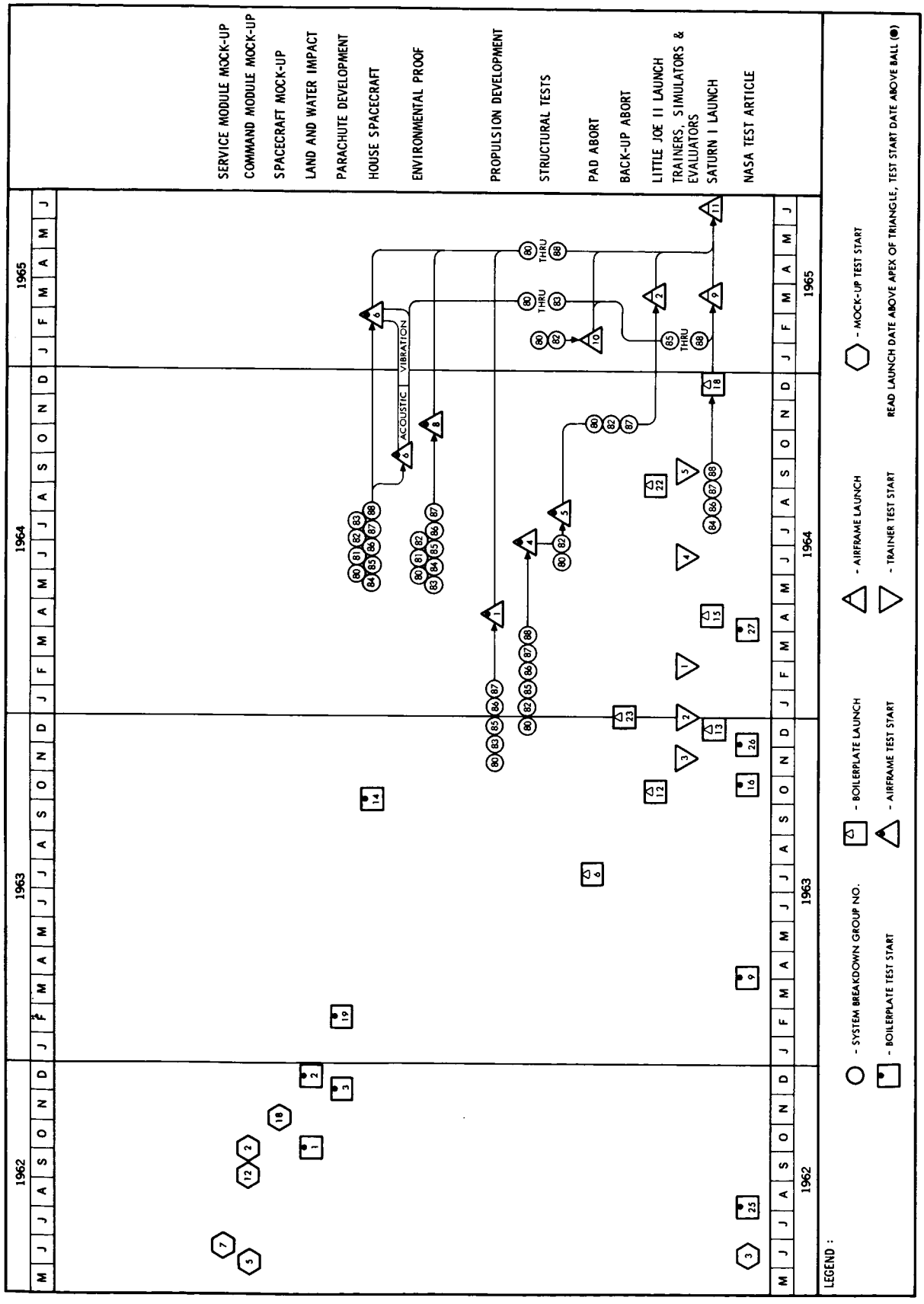


Figure 1-12. Apollo Test Logic (Structural Systems)

[redacted]

[redacted]

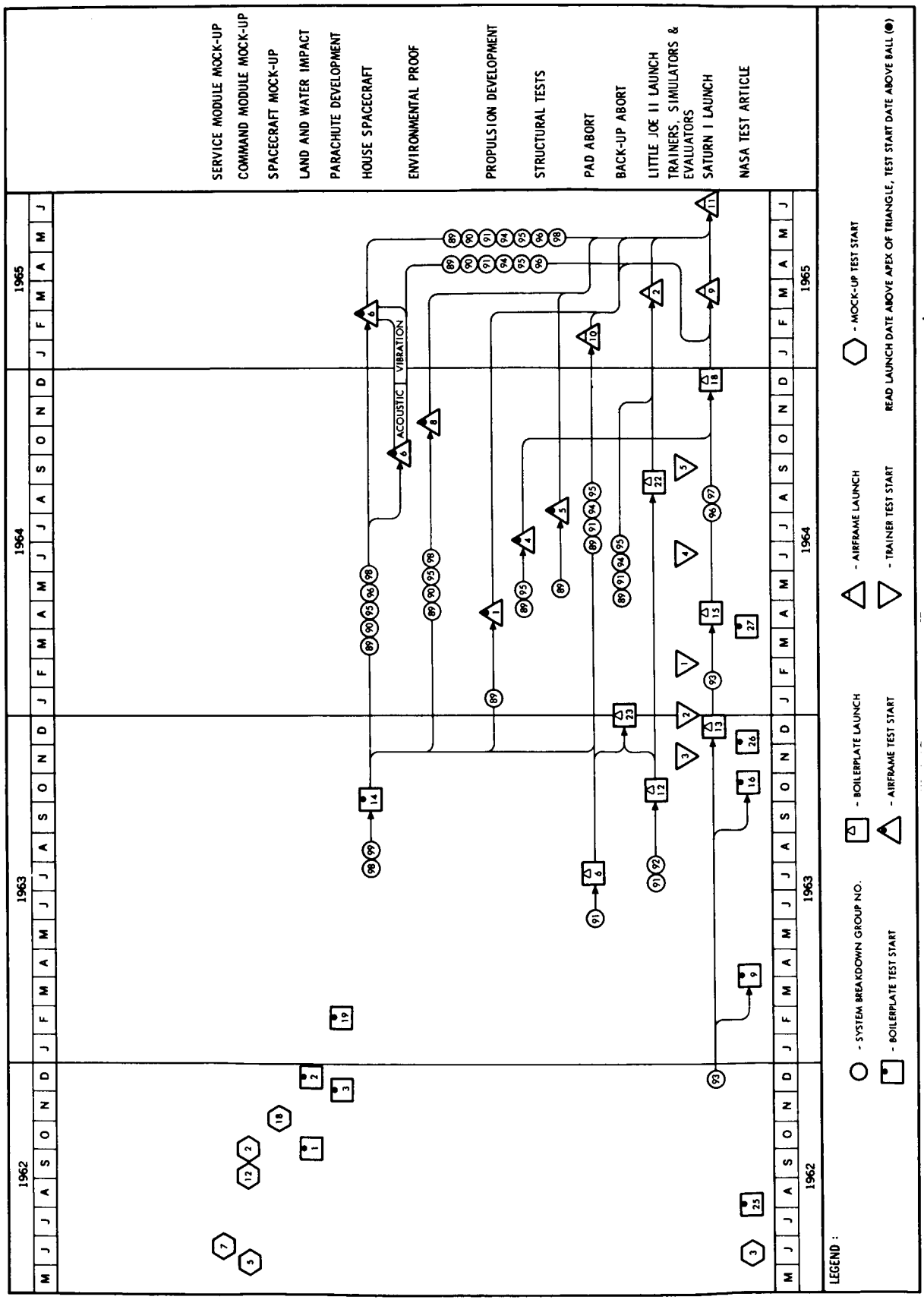


Figure 1-13. Apollo Test Logic (Mechanical Systems)

[redacted]ENTIAL

CO[redacted]

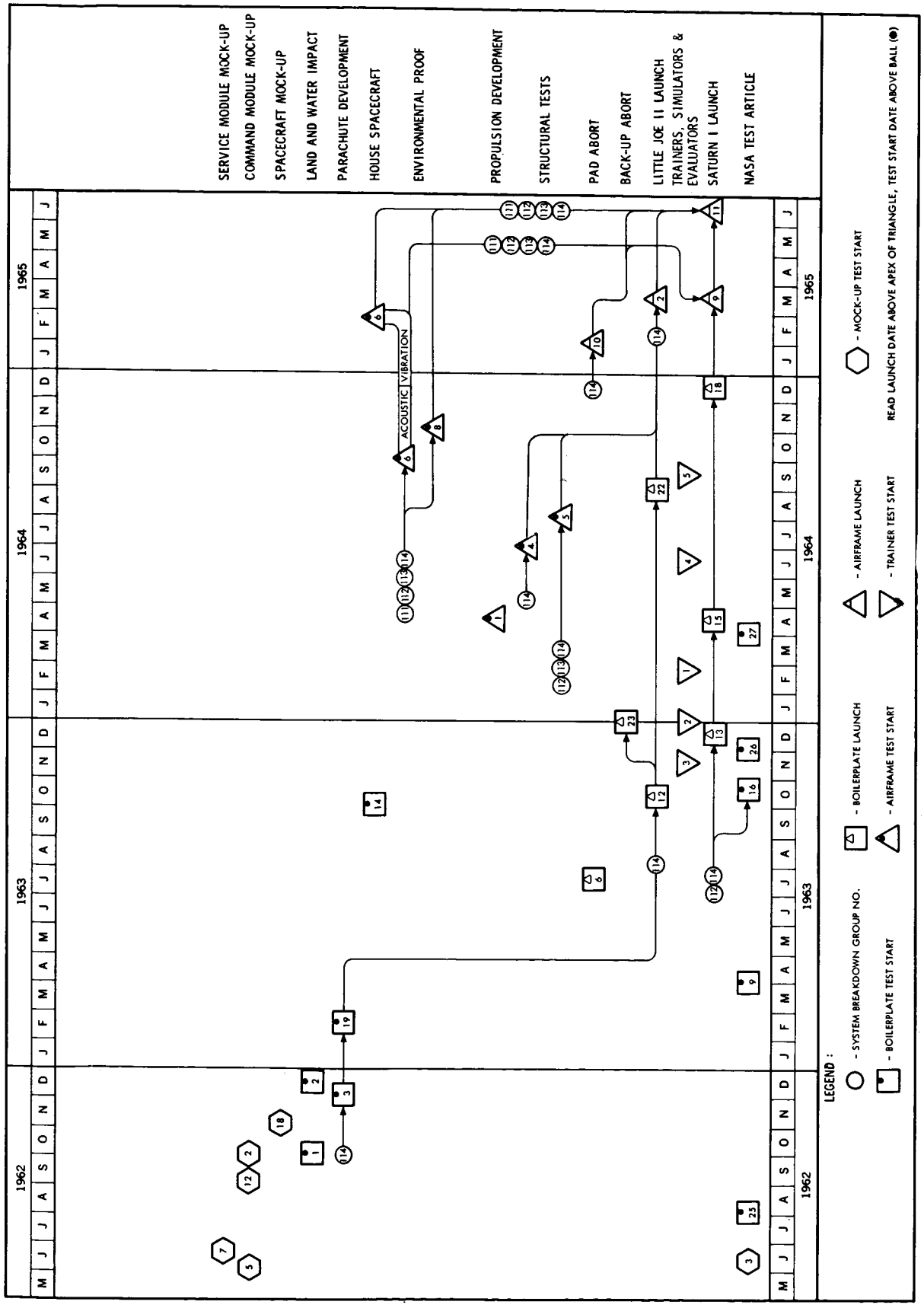


Figure 1-14. Apollo Test Logic (Thermal Protection System)

[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown

Group	Subsystem	Responsibility	Item
SERVICE PROPULSION SYSTEM			
1	Engine	Aerojet	Rocket engine, simulated
	Fuel	Allison	Fuel tank
		S&ID	Disconnect, fill
		S&ID	Heat exchanger
		S&ID	Disconnect, vent
		S&ID	Flex connector
	Oxidizer	Allison	Oxidizer tank
		S&ID	Disconnect, fill
		S&ID	Flex connector
		S&ID	Heat exchanger
		S&ID	Qunatity gauging system
		S&ID	Disconnect, vent
		S&ID	Mixture ratio control valve
	Helium	Airite	Helium tank
		S&ID	Disconnect, fill
		S&ID	He isolation valve, solenoid (normally closed)
		S&ID	Regulator, pressure
		S&ID	Valve, check
		S&ID	Valve, relief
		S&ID	Disconnect, test
2	Engine	Aerojet	Rocket engine, unqualified
		Aerojet	Chamber, unqualified
3	Engine	Aerojet	Rocket engine, fully qualified
REACTION CONTROL SYSTEM			
4	Fuel (S/M)	Bell	Fuel tank
		S&ID	Disconnect, fill
		S&ID	Valve, solenoid (normally open)
		S&ID	Disconnect, vent
		S&ID	Disconnect, test
	Oxidizer (S/M)	Bell	Oxidizer tank
		S&ID	Disconnect, fill
		S&ID	Valve, solenoid (normally open)
		Giannini	Quantity indicating system
		S&ID	Disconnect, vent
		S&ID	Disconnect, test

[redacted]DENTIAL

CO[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
4	Helium (S/M)	Menasco	Helium tank
		S&ID	Disconnect, fill
		S&ID	Valve, solenoid (normally open)
		S&ID	Valve, check
		S&ID	Valve, relief
		S&ID	Disconnect, test
		S&ID	Regulator, pressure
5	Fuel (C/M)	Bell	Fuel tank
		S&ID	Disconnect, fill
		S&ID	Diaphragm, burst
		S&ID	Valve, solenoid (normally open)
		S&ID	Disconnect, test
		S&ID	Disconnect, vent
		S&ID	Valve, squib
	Oxidizer (C/M)	Bell	Oxidizer tank
		S&ID	Disconnect, fill
		S&ID	Diaphragm, burst
		S&ID	Valve, solenoid (normally open)
		S&ID	Disconnect, test
		S&ID	Disconnect, vent
		S&ID	Valve, squib
	Helium (C/M)	Menasco	Helium tank
		S&ID	Disconnect, fill
		S&ID	Valve, squib
		S&ID	Valve, solenoid (normally open)
		S&ID	Regulator, pressure
		S&ID	Valve, check
		S&ID	Valve, relief
		S&ID	Disconnect, test
6	Engine	Marquardt	Unqualified solenoid valve
7	Engine	Marquardt	Simulated rocket engine
		Rocketdyne	Simulated rocket engine

[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
8	Engine	Marquardt	R & D unqualified rocket engine
9	Engine	Marquardt Rocketdyne	Qualified rocket engine Qualified rocket engine
10	Engine	S&ID	Simulated rocket engine
11	Engine	Rocketdyne	Unqualified rocket engine
12	Engine	Marquardt	R & D rocket engine
LAUNCH ESCAPE SYSTEM			
13	Structure	S&ID S&ID	Tower structure Aft skirt
14	Structure	S&ID S&ID	Pitch motor structure Ballast enclosure
15	Structure	S&ID	Nose cone
16	Structure	Nortronics (NASA for BP 13 & 15)	Q ball
17	Mechanical devices	S&ID	LES tower to C/M separation system, ordnance installation
		S&ID	LES tower to C/M explosive bolt cartridge
	Rocket motors	Thiokol	Live tower jettison motor
18	Mechanical devices	S&ID	LES tower to C/M explosive bolt body
19	Mechanical devices	S&ID	Bolt installation, inert explosive, LES tower to C/M

[redacted]DENTIAL

CO[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
20	Rocket motors	Lockheed	Inert launch escape motor
		Lockheed	Inert pitch control motor
21	Rocket motors	Lockheed	Live launch escape motor
		Lockheed	Live pitch control motor
EARTH LANDING SYSTEM			
22	Mechanical devices	Northrop-Ventura	Drogue chute system
		Northrop-Ventura	Pilot chute system
		Northrop-Ventura	Pack assembly, main chute, right
		Northrop-Ventura	Pack assembly, main chute, center
		Northrop-Ventura	Pack assembly, main chute, left
		Northrop-Ventura	Harness assembly, spacecraft main chute
		Northrop-Ventura	Riser, main cluster
		Northrop-Ventura	Controller, sequence
		Northrop-Ventura	Cartridge, pyro, drogue, mortar
		Northrop-Ventura	Cartridge, pyro, pilot, mortar
		Northrop-Ventura	Main chute disconnect assembly
23	Mechanical devices	S&ID	Assembly, drogue disconnect
		S&ID	Detonator, electrical, shaped charge
24	Mechanical devices	Northrop-Ventura	Chute release impact switch
25	Mechanical devices	Northrop-Ventura	Explosive, main chute disconnect assembly

[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
26	Location aids	Vendor	Sea marker assembly
		Vendor	Light, flashing
		Vendor	Bomb, sofar
27	Mechanical devices	S&ID	Separation system installation, forward compartment heat shield
28	Mechanical devices	S&ID	Installation, mechanical equipment, forward compartment heat shield
ENVIRONMENTAL CONTROL SYSTEM			
29	Pressure suit circuit	AiResearch	Suit circuit return air check valve assembly
		AiResearch	Debris trap
		AiResearch	Suit compressor
		AiResearch	Suit compressor check valve
		AiResearch	CO_2 and odor absorber removable container (26 replacements)
		AiResearch	CO_2 and odor absorber package
		AiResearch	Suit bypass valve
		AiResearch	Suit compressor selector switch
		AiResearch	Suit air temperature sensor
		AiResearch	Suit air temperature control
		AiResearch	Suit air temperature selector
		AiResearch	Suit evaporator temperature sensor
		AiResearch	Suit evaporator temperature control

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
29		AiResearch	Heat exchanger package a. Regenerative heat exchanger b. Regenerative heat exchanger bypass valve c. Suit evaporator d. Glycol-to-suit air heat exchanger e. Water separator f. Water separator pump assembly
		AiResearch	Suit hose connector package a. Suit shutoff valve b. Suit supply connection c. Suit return d. Check valve
		AiResearch	Suit flow limiter
	Water - glycol circuit	AiResearch	Glycol check valve
		AiResearch	Glycol evaporator
		AiResearch	Cabin temperature control valve
		AiResearch	Glycol pump selector switch
		AiResearch	Glycol temperature control
		AiResearch	Glycol temperature sensor
		AiResearch	Glycol quick disconnect
		AiResearch	Manual shutoff valve
		AiResearch	Glycol shutoff valve
		AiResearch	Glycol reservoir
		AiResearch	Glycol pump assembly
		AiResearch	Accumulator
		AiResearch	Isolation valve
		AiResearch	Pump (2)
		AiResearch	Check valve (2)
		AiResearch	Filter
		AiResearch	Glycol temperature control valve

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
29	Command module pressure and temperature control	AiResearch	Cabin outflow pressure regulator and negative relief valve
		AiResearch	Cabin heat exchanger
		AiResearch	Cabin temperature selector
		AiResearch	Cabin temperature anticipator
		AiResearch	Cabin temperature control
		AiResearch	Cabin temperature sensor
		AiResearch	Cabin blower diverter valve
		AiResearch	Cabin blower selector switch
		AiResearch	Cabin recirculating blower
		AiResearch	Cabin vent valve
		AiResearch	Cabin pressure regulator
	Oxygen supply	AiResearch	Backpack supply shutoff and pressure relief valve
		AiResearch	Backpack supply cap
		AiResearch	Demand pressure regulator and relief valve
		AiResearch	Manual O_2 supply valve
		AiResearch	Oxygen quick disconnect
		AiResearch	Emergency O_2 inflow control valve
		AiResearch	O_2 pressure regulator assembly a. Shutoff valve b. Pressure regulator c. Relief valve d. Check valve
	Water supply	AiResearch	Water check valve
		AiResearch	Suit evaporator water inflow control valve
		AiResearch	Combined water tank
		AiResearch	Water chiller
		AiResearch	Water shutoff valve

[redacted]ENTIAL

CO[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
29		AiResearch	Water tank pressure relief valve
		AiResearch	Potable water supply assembly a. Supply valve b. Heater
		AiResearch	Water pressure relief valve
		AiResearch	Tank pressure control and relief valve
	Waste management	Vendor	Waste disposal control unit
		Vendor	Urine disposal lock
		Vendor	Bacteria control unit
		Vendor	Urine flex hose
		Vendor	Vacuum cleaner assembly
		Vendor	Ventilation check valves
		Vendor	Waste management blower
		Vendor	Backup valves
	Cold plate	S&ID	Cold plate assembly
	Pressure suit instrumentation	AiResearch	Transducer, temperature, inlet, suit supply manifold a. Sensor b. Amplifier
		AiResearch	Transducer, pressure, inlet, suit supply manifold
		AiResearch	Transducer, differential pressure, suit compressor
		Vendor	Transducer, partial pressure, CO_2
	Water glycol Instrumentation	AiResearch	Transducer, temperature, gaseous, outlet, glycol evaporator a. Sensor b. Amplifier

[redacted]

[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
29		AiResearch	Transducer, temperature, liquid outlet, glycol evaporator a. Sensor b. Amplifier
		AiResearch	Transducer, pressure, quantity measurement, glycol accumulator
		AiResearch	Transducer, pressure, gaseous, outlet, glycol evaporator
		AiResearch	Transducer, temperature, outlet, space radiator a. Sensor b. Amplifier
	Oxygen supply instrumentation	AiResearch	Transducer, flow, oxygen supply
		AiResearch	Transducer, pressure, outlet, regulator, oxygen supply
		AiResearch	Transducer, temperature, command module, air, cabin average a. Sensor b. Amplifier
	Command module pressure and temperature instrumentation	AiResearch	Transducer, pressure, cabin total, command module
	Water supply system instrumentation	AiResearch	Transducer, pressure, quantity measurement, waste water tank
	Power supply	AiResearch	Power supply transducer, temperature
	Water-glycol circuit	AiResearch	Space radiator outlet check valve
		AiResearch	Glycol pressure relief valve
		AiResearch	Glycol check valve

CO[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
29		AiResearch	Glycol shutoff valve (P/N827570-1-1)
		AiResearch	Glycol shutoff valve (P/N827580-1-1)
		AiResearch	Space radiator isolation valve
		AiResearch	Glycol fill and vent connection
30	Special equipment	Vendor	Special cooling equipment
31	Special equipment	Vendor	Special glycol cooling system
32	Special equipment	Vendor	Pressure suit environmental unit
33	Water-glycol circuit	S&ID	Space radiators
	CRYOGENIC STORAGE SYSTEM		
34	Oxygen	Beech	Storage tank
		Beech	Valve package (complete)
		Beech	Fill or purge valve
		Beech	Vent valve
		Vendor	Relief disconnect coupling
		Beech	Fuel cell reactant supply shutoff valve package
		Beech	Signal Conditioner
		Beech	Electrical Connecter
	Hydrogen	Beech	Storage tank
		Beech	Valve package (complete)
		Vendor	Relief disconnect coupling
		Beech	Fuel cell reactant supply shutoff valve package
		Beech	Signal conditioner
		Beech	Electrical connecter
	ELECTRICAL POWER SYSTEM		
35	Launch escape tower	Vendor	Explosive bridgewire initiator
		Vendor	Explosive bridgewire firing unit

[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
36	Launch escape tower	Vendor	Hot wire initiator
37	Launch escape tower	Vendor	C/M to LES tower electrical umbilical plug
38	Launch escape tower	Vendor	Loomed cable
39	Launch escape tower	S&ID	Sequencer
40	Command module	Eagle-Picher	Battery, entry and post landing
		Vendor	Circuit breaker, d-c push-pull
		Vendor	Electrical circuit interrupter
		Vendor	Connector, special purpose
41	Command module	S&ID	PLSS battery charge control
		ITT	Battery charger
		S&ID	Under voltage sensing assembly
		S&ID	AC power failure sensing assembly
	Service module	Pratt & Whitney	Fuel cell modules
		Vendor	Power transfer switch, fuel cell
		Vendor	S/M to GSE umbilical disconnect
		Vendor	Adapter interface connector
		Vendor	Switch, motor operated, DPST
42	Command module	Westinghouse	Static inverter
		Vendor	Power transfer switch .G. P., types II and III

[redacted]DENTIAL

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
42		Vendor	Relay, 4PDT, 5A
	Service module	Vendor	Switch, transfer, RCS, motor operated
43	Command module	Vendor	Circuit breaker, 1 PH-AC and 3 PH-AC
		Vendor	Relay 2PDT, 2A
		Vendor	Connector, forward compartment umbilical
	Service module	Vendor	Connector, S/M termination
		Vendor	Switch, overcurrent relay, motor operated
44	Command module	Vendor	Power transfer switch, G. P., type I
45	Command module	S&ID	Mission sequencer (BP 14)
		S&ID	Relay, magnetic latch (internal part of S/C mission sequencer)
46	Command module	Eagle-Picher	Battery, pyrotechnic
47	Command module	Vendor	Bulkhead feedthrough, types I and II
		Vendor	Connector G. P., 3 types, 3 classes
48	Command module	Vendor	Circuit breakers 1 to 5 amp DC
		Vendor	Circuit breakers 50 to 100 amp DC
49	Command module	Vendor	Hot wire initiators
50	Service module	NASA	R & D battery
51	Service module	Vendor	Ribbon cable, type I

[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
52	Service module	S&ID	Sequencer
	Adapter	Vendor	Hot wire initiator
53	Service module	S&ID	Radiator panels
54	Service module	Vendor	Hot wire initiator
GUIDANCE AND NAVIGATION SYSTEM			
55	Command module	MIT	Sextant
		MIT	Scanning telescope
		MIT	Navigation base
		MIT	Inertial measuring unit
		MIT	Computer
		MIT	Power and servo assembly
		MIT	Map and data viewer
		MIT	Coupling display unit
		MIT	Navigation display and control panels
		MIT	Computer display and control panels
		MIT	Optics base
		MIT	PSA junction box
		MIT	Electronic control assembly
		MIT	Optics eyepieces
		MIT	Bellows assembly
		MIT	Photometer
		MIT	Signal conditioning module
		MIT	Display and control electronics
STABILIZATION AND CONTROL SYSTEM			
56	Command module	Minneapolis-Honeywell	Rate gyro package (includes baseplate)
		Minneapolis-Honeywell	Pitch channel electronic control assembly
		Minneapolis-Honeywell	Roll channel electronic control assembly

CO[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
56		Minneapolis-Honeywell	Yaw channel electronic control assembly
57	Command module	Minneapolis-Honeywell	Attitude gyro, accelerometer package (includes baseplate)
		Minneapolis-Honeywell	Auxiliary electronic control assembly
		Minneapolis-Honeywell	Display/AGAP electronic control assembly
		Minneapolis-Honeywell	Translation control
		Minneapolis-Honeywell	Three-axis rotation control
58	Command module	Minneapolis-Honeywell	Delta V display
		Minneapolis-Honeywell	Attitude set/gimbal position display
		Minneapolis-Honeywell	Flight director attitude indicator
		Minneapolis-Honeywell	SCS control panel
COMMUNICATIONS AND INSTRUMENTATION			
59	Antenna	Airborne Instruments Laboratory	Recovery antenna release mechanism
		Airborne Instruments Laboratory	Back-up recovery antenna
		Airborne Instruments Laboratory	Recovery antenna
		Airborne Instruments Laboratory	HF/VHF diplexer
		S&ID	Associated coaxial cables
		Collins	Multiplexer

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
59		Vendor	VHF/UHF diplexer
		Vendor	Associated coaxial cables
		S&ID	VHF antenna switch
		Radcom	C-Band antennas
		S&ID	Associated coaxial cables
	RF Electronics	Collins	C-Band transponder equipment
		Collins	VHF/AM transmitter-receiver equipment
		Collins	VHF recovery beacon equipment
		Collins	VHF/FM transmitter equipment
		Collins	HF transceiver equipment
	Main display console	S&ID	Communications control panel
		S&ID	Audio control panel (3 panels)
	Intercommunications	Collins	Audio center equipment
	Data	Collins	PCM telemetry equipment
		Collins	Signal conditioning equipment
		Collins	Data storage equipment
		Collins	Pre-modulation processor equipment
		Elgin	Central timing equipment
60	Antenna	S&ID	VHF/2KMC scimitar antennas
		S&ID	Associated coaxial cables
61	Antennas	S&ID	Multiplexer coaxial cables
62	Antennas	Vendor	2KMC antenna switch
		S&ID	Associated coaxial cables
	RF Electronics	Collins	Unified S-band equipment
		Collins	S-band power amplifier

CO[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
62	Data	Motorola	Up-data link equipment
		RCA	Television equipment
	In-flight test	Vendor	In-flight test system
	Antenna	Avien	Earth sensor
		Avien	Gimbals and gimbal drives
		Avien	High-gain antenna
		S&ID	Associated transmission lines
63	Instrumentation	Vendor	Proton detection equipment
		Vendor	Type IV radio noise alert equipment
LIFE SYSTEMS			
64	Crew accessories	Vendor	Manual set, crewman
		Vendor	Logbook assembly, crewman
		S&ID	Lapboard assembly, crewman
		Vendor	Tool set, in-flight maintenance, crewman
		Vendor	Egress accessories, hatch
		Vendor	Map set, crewman
	Crew couch and restraint	S&ID	Restraint assembly, rest station, crewman
		S&ID	Restraint assembly, lower equipment bay, crewman
	Lighting	Vendor	Filter assembly, forward viewing window
		Vendor	Filter assembly, side viewing window
		Vendor	Filter assembly, hatch window
	Crewman equipment	Vendor	Shoestraps assembly, personal

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
64		Vendor	Hose assembly, umbilical, crewman
		Vendor	Belt assembly, in-flight maintenance, crewman
		Vendor	Hose assembly, recharging, backpack
	Government furnished equipment	NASA	Constant wear garment
		NASA	Checkout instrument assembly, pressure garment, in-flight
		NASA	Coverall, thermal insulation overgarment
	Food	Vendor	Food
		Vendor	Package set, food
	Waste management	S&ID	Receptacle assembly, relief, crewman
		Vendor	Liner set, relief receptacle crewman
		Vendor	Bag set, fecal/emesis
65	Crew accessories	S&ID	Case assembly, map and manual, crewman
	Lighting	Vendor	Fixture assembly, lighting, primary area (type III)
		Vendor	Fixture assembly, lighting, secondary area (type I)
		Vendor	Fixture assembly, lighting, secondary area (type II)
		Vendor	Light assembly, portable, crewman
		Vendor	Fixture assembly, light, rendezvous position
		Vendor	Fixture assembly, light, rendezvous flashing

CO[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
65		Vendor	Fixture assembly, light, rendezvous flood (docking)
	Survival provisions	Vendor	Provisions assembly, crewman survival (collective)
	Government furnished equipment	NASA	Portable life support system
	Food	Vendor	Mouthpiece, food, personal
		Vendor	Delivery assembly, water, personal
		Vendor	Shelf assembly, work/ food preparation
	Waste management	S&ID	Canister assembly, fecal
	Personal communication	Vendor	Communications assembly, personal (headset, microphone, constant wear hat)
66	Crew support	S&ID	X-X Axis (foot) attenuator
		S&ID	X-X Axis (head) attenuator
		S&ID	Y-Y Axis attenuator
		S&ID	Z-Z Axis attenuator
	Crew couch and restraint	S&ID	Pad assembly, couch, crewman
		S&ID	Harness assembly, restraint, crewman
67	Government furnished equipment	NASA	Pressure garment assembly (PGA)
68	Personal communications	Vendor	Base station, communications personal
69	Crew support	S&ID	Crew couch assembly, pilots structural
		S&ID	Crew couch assembly, co-pilots structural

[redacted]

[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
69		S&ID	Crew couch assembly, engineer's structural
	GROUND SUPPORT EQUIPMENT		
70 to 79			(To be supplied at a later date
	STRUCTURAL TESTS		
80	C/M spacecraft inner structure	S&ID	Inner structure assembly
		S&ID	Forward access hatch
		S&ID	Crew access hatch
	C/M heat shield	S&ID	Outer structure, crew, forward, and aft compartments
	C/M equipment supports	S&ID	Forward compartment
		S&ID	Aft compartment
		S&ID	Food and storage compartment, aft
		S&ID	Frame X_c 42.665
		S&ID	Crew area equipment support
		S&ID	Right hand bay, aft section
		S&ID	Right hand bay, forward section
		S&ID	Left hand bay
		S&ID	Lower bay, forward section
		S&ID	Lower bay, aft section
		S&ID	Main display console equipment support
81	C/M equipment supports	S&ID	CO_2 absorber cartridge, storage support structure, aft
	S/M equipment supports	S&ID	Insulation panels installation, mounting provision

[redacted]ENTIAL

CO[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
81		S&ID	Heat shield assembly sectors II, III, V, and VI
82	C/M equipment support	S&ID	Left hand forward compartment
		S&ID	Right hand forward compartment
83	S/M equipment support	S&ID	Environmental control system installation, mounting provisions
		S&ID	Electrical power system installation, mounting provisions
84	S/M equipment support	S&ID	Communications system installation, mounting provisions
85	S/M equipment support	S&ID	Fuel cell shear web structure
		S&ID	Support shelf assembly, O_2 tank, upper
		S&ID	Support shelf assembly, O_2 tank, lower
		S&ID	Support shelf assembly, H_2 tank, upper
		S&ID	Service propellant system mounting installation
		S&ID	Pressurization system mounting installation
86	S/M equipment support	S&ID	Reaction control system module installation
		S&ID	Pressurization system panel assembly
87	S/M	S&ID	Service module structure a. Outer shell structure b. Hatch cover

[redacted]

[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
87		S&ID	c. Aft bulkhead d. Radial shear web e. Service propulsion system propellant tank cover door f. Equipment support fittings g. Service module manhole door h. Service module manhole door seal
88	Adapter	S&ID	S-IV adapter
MECHANICAL DEVICES			
89	Mechanical controls	S&ID	Latching subassembly, crew hatch
		S&ID	Latching subassembly, heat shield hatch
		Vendor	Actuator, harmonic drive, crew hatch
	Sextant doors	S&ID	Latching subassembly
		S&ID	Hinging subassembly
		S&ID	Manual input
		Vendor	Gearbox (harmonic and differential)
		Vendor	Flex drive
		Vendor	Screwjack
90	Mechanical controls	Vendor	Mechanical control, cabin air pressure valve, ECS
91	Separation	Vendor	Cartridge assembly, electrical initiated hot wire
92	Separation	S&ID	Boilerplate ordnance installation, C/M to S/M separation system

[redacted]DENTIAL

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
92		S&ID	Boilerplate separation system installation, C/M to S/M
93	Separation	S&ID	Boilerplate tension tie installation, C/M to S/M
94	Separation	S&ID	Spacecraft ordnance installation, C/M to S/M separation
95	Separation	S&ID	Spacecraft separation system installation, C/M to S/M
96	Separation	S&ID	Ordnance installation, spacecraft adapter
97	Separation	S&ID	Boilerplate ordnance installation C/M to S/M separation system
		S&ID	Boilerplate system installation C/M to S/M separation
98	Separation	S&ID	Deployment system, unified S-band antenna installation
99	Separation	S&ID	Installation, inert tension tie, C/M to S/M Installation, S/M to Saturn-IV adapter separation system
MATERIALS, PROCESSES AND PRODUCIBILITY			
100 to 105			(To be supplied at a later date)

[redacted]

[redacted]

Table 1-1. Test Logic System Breakdown (Cont)

Group	Subsystem	Responsibility	Item
WIND TUNNEL TEST PROGRAM			
106 to 110			(To be supplied at a later date)
THERMAL PROTECTION SYSTEM			
111	Ablative material	Avco	Forward compartment, C/M
		Avco	Crew compartment
		Avco	Aft compartment
112	Insulation	S&ID	Forward compartment
113	Insulation	S&ID	Crew compartment
		S&ID	Aft compartment
114	Insulation	S&ID	Aerodynamic strake

1.1 SERVICE PROPULSION SYSTEM (See Figure 1-3)

The service propulsion system (SPS) will provide the propulsion for mission abort, major midcourse velocity corrections, lunar capture, and escape velocities. The system, pressure-fed and using storable hypergolic propellants, is controlled automatically through the guidance and navigation and stabilization and control systems, but it can be controlled manually in the event of automatic control failure. The system consists of a gimbaled rocket engine, helium-pressurized fuel, and oxidizer storage and distribution subsystems.

The test program will begin at the subcontractor's test facility on the component and subsystem level and will progress to the boilerplate and spacecraft level using prototype hardware as it becomes available. The rocket engine manufacturer will use test fixture F-1 to conduct qualification tests, to evaluate basic design parameters and performance, to certify safe usage, and to evaluate the propellant system at sea level. Test fixture F-3 will be used for the supplier qualification tests at simulated altitudes and space environments. Test fixture F-2 will be used at the WSMR to determine engine, propellant, and pressurization system interaction effects and over-all compatibility, and will permit continuance of SPS tests when airframe 001 is out of service for modification or repairs. These tests will be conducted under S&ID surveillance. Testing of the integrated subsystems with a propellant collection fixture to simulate the rocket engine will be conducted by S&ID to provide the essential design development, evaluation, and verification data. This test will use off-the-shelf components initially, but will use qualified components in the final phases.

Testing of the SPS on an integrated system level to determine system compatibility will begin with house spacecraft 1 (boilerplate 14). Prototype hardware will be used if it is available. House spacecraft 2 (airframe 006) will confirm development design changes and systems compatibility using prototype hardware. The propulsion spacecraft (airframe 001) test at the WSMR will be conducted to evaluate SPS performance, heat transfer, and fuel handling and storage problems under conditions at sea level. The need for further testing of the SPS for its ultimate mission will be determined by system interaction tests on airframe 008 as well as operational experience on flight vehicles. For data concerning additional propulsion system testing, see Subsection 2.1 and 5.4 in this volume, Section 1.0 in Volume II, and Section 4.0 in Volume V.

[redacted]

1.2 REACTION CONTROL SYSTEM (See Figure 1-3)

The reaction control system (RCS) provides for attitude control and stabilization of the Apollo spacecraft. (The command module and service module have similar reaction control systems.) The RCS is pulse-modulated and pressure-fed and uses storable hypergolic propellants. It consists of a helium pressurized storage and distribution subsystem, an oxidizer storage and distribution subsystem, a fuel storage and distribution subsystem, propellant control valves, and a thrust chamber subsystem.

The test program will begin at the subcontractor's or component supplier's test facility on the rocket engine component or subsystem level and will progress to integrated system tests using prototype hardware as it becomes available. In general, all system components will be tested to the requirements of the detailed specifications. S&ID will conduct performance evaluation tests to verify the component supplier's test results. The rocket engine manufacturers (Marquardt and Rocketdyne) will perform experimental tests, prototype development tests, and qualification tests. S&ID will monitor all subcontractor major tests.

S&ID will conduct development tests on the helium and propellant storage and distribution subsystems. The test will be initiated on the subsystem level and will progress to a complete RCS test on the breadboard level to determine the compatibility of the subsystems and to obtain essential development data.

Initial testing of the RCS to determine preliminary operational procedures will be conducted in house spacecraft 1 (boilerplate 14) and will use simulated propellants. The RCS performance will be evaluated in propulsion spacecraft airframe 001 using actual propellants. House spacecraft 2 (airframe 006) will confirm development design changes, evaluate systems compatibility, and evaluate and develop operational procedures. The RCS will be subjected to space environment on airframe 008 and further tested on boilerplate 22 and airframe 009 to determine its readiness for the ultimate mission. For data concerning additional reaction control system testing, see Subsection 2.2 and 5.4 in this volume, Section 2.0 in Volume II, and Section 4.0 in Volume V.

1.3 LAUNCH ESCAPE SYSTEM (See Figure 1-2)

The launch escape system (LES) consists essentially of the pitch control motor, tower jettison motor, launch escape motor, tower structure, and tower release device. Two release devices are provided; a method of releasing the tower structure from the command module at the appropriate time in normal or abort operation, and a method of releasing the command module from the service module and launch vehicle in the event of an abort condition.

CO[redacted]

[redacted]

During the subcontractor development programs for the three rocket motors, the igniters will be tested in an inert motor, and their performance will be evaluated. The pitch control, tower jettison, and launch escape motors will be static fired 27, 23, and 15 times, respectively, to evaluate motor, propellant, and igniter characteristics. During the subcontractor development programs for the launch escape and tower jettison motors, two simulated altitude performance tests at AEDC for each will be required to verify the design prior to flight tests.

Pad abort test of boilerplate 6 and airframe 010 will be conducted to evaluate the launch escape system flight dynamic characteristics. The trajectory for the pad abort test will be controlled by the pitch control motor to insure landing at a safe distance from the pad.

Little Joe II LES tests performed on boilerplate 12 and airframe 002 will demonstrate and evaluate system performance at maximum q (maximum dynamic pressure) conditions. Additional data will be obtained from escape tower structural verification and operation of the parachute system during abort tests. Further structural integrity tests (including related LES tests) of the tower will be conducted on boilerplates 9, 13, 15, 16, 18, and 26; also on boilerplate 23, if used as back-up for 6 and 12.

High-altitude LES tests, including recovery system tests, will be performed on boilerplate 22. The tower structural and mechanical release components will be subjected to functional and environmental tests by S&ID prior to boilerplate evaluation tests. Partial LES tests involving the tower structure and separation system will be performed on airframes 004, 006, and 008, while tests involving live motors will be performed on boilerplates 6, 12, and 22 and airframes 002 and 010. Tests of the tower structure and release mechanism are included on boilerplates 6, 9, 12, 13, 14, 15, 16, 18, 22, 23, and 26, and on airframes 002, 004, 006, 008, 010. Additional LES information is presented in Subsection 2.3 of this volume and in Section 3.0 of Volume II.

1.4 EARTH LANDING SYSTEM (See Figure 1-7)

The earth landing system (ELS) for the Apollo vehicle consists of drogue parachutes and deployment devices, main parachutes and deployment devices, and location aids.

Components will be initially tested by the subcontractor or the contractor and will progress through complete system hardware testing. Tests emphasizing interface areas will be conducted to explore complete system problems thoroughly. Prototype components will be subjected to the Apollo mission environment and will be tested for proper functioning.

[redacted]

[redacted]

The drogue parachutes, main parachutes, means of deployment, and mechanical location aids will be developed and tested by the subcontractor. S&ID and the subcontractor will conduct verification tests by air drops using boilerplates 3 and 19. The airframe shock attenuation subsystem will be used on boilerplates 3 and 19 for reuse of the articles only.

The ELS will be installed on the environmental proof spacecraft, airframe 006 and 008, to verify the capability of the system to withstand the environmental conditions of the Apollo missions.

The ELS will be further evaluated for command module earth-recovery requirements as included in the following tests:

1. Pad abort escape test for boilerplate 6 and airframe 010

2. Escape at maximum q test for boilerplate 12 and for airframe 002

3. High-altitude abort for boilerplate 22.

Further assurance of operating capabilities will result from recovery of boilerplate 23 and airframe 009. Additional ELS testing is described in Subsection 2.4 in this volume and Section 4.0 in Volume II.

1.5 ENVIRONMENTAL CONTROL SYSTEM (See Figure 1-6)

The environmental control system (ECS) consists of materials, components, and subsystems pertinent to environmental conditions within the command and service modules. The system provides for temperature, humidity, oxygen, and pressure control; equipment cooling; and CO_2, toxic gases, and other contaminant removal.

Materials will be investigated by the subcontractor for their integrity and reliability under Apollo environments. Components will be tested by the subcontractor to confirm performance requirements of the ECS and to determine design modifications through employment of simulated environmental and/or dynamic conditions to verify flow rates, pressure drops, electrical and thermal characteristics, functional performance, and response times. The subcontractor will test subsystems and systems assembled with material and components to determine if interaction between the connecting media reveals any malfunctions.

S&ID will perform integrated systems tests on a breadboard ECS and will have limited subcontractor back-up testing of components and subsystems. The breadboard will be maintained for supporting tests of associated systems and new components that result from design improvements or changes in

system requirements. Other related activities to be undertaken are subsystem interaction and compatibility, preflight and inflight testing and monitoring, and GSE interaction and compatibility.

Major tests on the ECS will be performed on the house spacecraft, airframe 006, and the environmental proof spacecraft, airframe 008. Initial flight performance of the ECS will be tested on airframe 009. Flight performance verification will be obtained on instrumented and manned orbital spacecraft airframe 011. For data concerning additional system testing, refer to Subsection 2.5 in this volume, Section 5.0 in Volume II, and Section 5.0 in Volume V.

1.6 ELECTRICAL POWER SYSTEM (See Figure 1-6)

The electrical power system (EPS) consists of the following major components and subsystems: fuel cells, mechanical accessories, pyrotechnics, solid-state inverters, sequencers, secondary-type zinc-silver oxide batteries, battery chargers, distribution subsystems, control subsystems, and illumination subsystems.

In general, the subcontractors will perform developmental tests on the component and subsystem level. S&ID will conduct performance evaluation tests on the components and subsystems to assure conformance to procurement specifications. S&ID will also conduct the system and integrated system level tests on breadboards, boilerplates, and spacecraft.

Operational characteristics of the sequence subsystem and electroexplosive devices will be evaluated in the pad abort tests (boilerplate 6 and airframe 010) and in airborne abort tests (boilerplates 12 and 22, and airframe 002). Compatibility of the EPS on the subsystem, system, and integrated system level will be determined by the house spacecraft tests (boilerplate 14 and airframe 006) and airframe 009. Effects of heat and vibration on the EPS will be determined by the propulsion spacecraft test (airframe 001). The environmental test will be conducted to determine the operational characteristics of the EPS in simulated mission environments (airframe 008).

For additional test information, refer to Subsection 2.6 in this volume and Section 6.0 in Volume II.

1.7 GUIDANCE AND NAVIGATION SYSTEM (See Figure 1-5)

The guidance and navigation system consists of the inertial measurement unit, sextant and scanning telescope assembly, guidance computer, power and servo-assembly, and various displays and controls required for operation of these equipments.

[redacted]

The design and development testing will be accomplished by the associate contractor and his subcontractors. This phase of the test program will continue to program completion. Testing accomplished by S&ID will cover the areas of interface requirements, computer simulation to verify system design and performance, systems and operational compatibility and evaluation of over-all system performance. This testing will constitute a ground qualification test program and will include testing carried out on house spacecraft and environmental proof spacecraft.

Flight qualification will be accomplished as part of a flight operations test program to demonstrate controlled earth-atmosphere reentry. System operation in the spacecraft environment will be confirmed in early orbital or suborbital flight, while full demonstration of most functions with relationship to manned control will be carried out on subsequent earth orbital flight. Integrated system testing is further described in Subsection 2. 7 of this volume and Section 7. 0 of Volume II.

1. 8 STABILIZATION AND CONTROL SYSTEM (See Figure 1-3)

The stabilization and control system (SCS) for the Apollo vehicle consists of the sensing elements, electronic circuitry, and control elements necessary to stabilize and control the vehicle through all flight phases. Major components include the rate and displacement gyros, longitudinal accelerometer, mission programmer (unmanned only), control panels, electronic control assemblies, command module reaction controls, service module reaction controls, and propulsion system gimbaling controls.

Components and subassemblies will be initially tested at the subcontractor's facility and will progress through complete system hardware testing using reaction control motors and analog simulation. Additional tests emphasizing interface areas will be conducted by S&ID to explore complete system problems thoroughly. Reference Volume II, paragraphs 2. 3. 1. 2. 4 and 2. 3. 1. 2. 5.

Initial testing with other systems will start in the house spacecraft, boilerplate 14, where systems will be operated in various combinations to assure compatibility and to develop combined operating procedures. Testing of combined operations will be done under various environmental conditions in the environmental spacecraft, airframe 008; testing in conjunction with mission propulsion motor and reaction control motor systems will be conducted in the propulsion spacecraft, airframe 001.

The ability of the SCS to produce the needed control to maintain proper entry conditions will be verified on spacecraft airframes 009 and 011, which will be tested from a Saturn launch vehicle. Further testing is described in Subsection 2. 8 in this volume and Section 8. 0 in Volume II.

CO[redacted]

1.9 COMMUNICATIONS AND INSTRUMENTATION SYSTEM (See Figure 1-5)

The communications and instrumentation system comprises the rf and data handling equipment, antenna subsystem, and instrumentation procured by S&ID from subcontractors, and the R & D instrumentation supplied by NASA-MSC. Much of the procured equipment is being manufactured or procured by a major subcontractor (Collins Radio Company).

The procured equipment will be designed, developed, and tested by the subcontractors prior to delivery to S&ID. The NASA-supplied equipment will also be tested prior to delivery to S&ID for installation in the spacecraft.

S&ID tests will consist mainly of procured equipment receiving inspection, evaluation tests, system integration tests, and acceptance tests of both procured and the NASA-supplied equipment. S&ID will also conduct full-scale antenna tests.

Integrated subsystem tests will be conducted on house spacecraft 1 (boilerplate 14), house spacecraft 2 (airframe 006), and the environmental proof spacecraft (airframe 008).

Partial antenna equipment group flight evaluation tests will be conducted on airframes 002 and 010 if required. Further testing is described in Subsection 2.9 in this volume and in Section 9.0 of Volume II.

1.10 LIFE SYSTEMS (See Figure 1-8)

The success of each Apollo flight is contingent upon the safety of the astronaut, and his ability to perform his functions and duties. A life systems test program will be conducted to provide a positive evaluation of all factors affecting crew reliability and safety, and to demonstrate that the crew can perform the required tasks, at the required level of proficiency, under the anticipated conditions of the mission. The life systems consists of such items as crew couches, a restraint system, pressure suits, food and water provisions, etc.

The life systems program will evaluate crew performance as an integral function of Apollo system design. The primary emphasis will be directed toward achieving the required reliability and safety goals by assuring a thorough integration of human capabilities and limitations with systems design.

The life systems test program will follow the logical progression of systems evaluation, beginning with individual systems tests and progressing through multiple systems test and flight test. Test activities will be carried

[redacted]

[redacted]

out in the areas of man-machine, man-man, and man-environment interactions. Crew systems qualification and reliability criteria will be evaluated by crew performance tests under partial- and full-task simulations.

Evaluation of individual systems operation will be employed to determine the adequacy of life systems criteria and specifications at the detailed design level on simulators 1 and 2 and mock-up 12. Man-machine (human engineering) tests will be conducted to evaluate preliminary spacecraft and related GSE subsystems man-machine interface designs.

Where tests indicate a lack of life sciences data, NASA will be advised of the problem areas and their probable influence on vehicle design and mission reliability. As systems design, crew requirements, and procedures become firm, test activity will follow the typical design-development progression, from design-development activities to first-run and prototype hardware installed in boilerplates 1, 2, and 14 and in airframes 006 and 008.

A crew simulation test program will be conducted for development and evaluation of crew-operated systems to determine optimum crew procedures, task distribution, work-rest cycle, and to verify the Apollo mission as being within the range of human capability in the environmental conditions anticipated. The major emphasis during this phase will be placed on crew performance validation during partial- and full-task simulation studies.

Further testing information is contained in Subsection 2. 10 of this volume and in Section 10. 0 of Volume II.

1. 11 GROUND SUPPORT EQUIPMENT

Ground support equipment (GSE) has been defined as all equipment required to inspect, test, adjust, calibrate, appriase, gage, measure, repair, overhaul, assemble, disassemble, transport, safeguard, record, store, actuate, service, maintain, launch, and otherwise support the end article. GSE for the Apollo vehicle has four basic categories: handling, servicing, auxiliary, and checkout equipment. Detail equipment may consist of items such as hoists, slings, adapters, dollies, winches, electromechanical subassemblies, bench maintenance equipment, covers, computers, and complete checkout consoles. Because of the diversity of tests, many pieces of GSE hardware will be used concurrently with various system tests throughout the Apollo development phases. The ground support equipment for ground tests should be the same configuration as the GSE which is to be utilized for flight operations, except for functions unique to the particular test.

Components and subassemblies, initially developed and tested at S&ID and at several subcontractor's facilities, will progress to complete subsystem

test development. Additional in-house GSE breadboard tests will be conducted by S&ID to emphasize interface areas for satisfactorily resolving complete system problems. Commercial "off-the-shelf" test equipment will not be included in developmental testing as end items. This equipment may be included in developmental testing of complete checkout consoles.

GSE employment will start with boilerplate 1 and will continue through all boilerplates and airframes. The category and quantity of GSE will be determined during tests. For example, servicing equipment will start, significantly, with boilerplate 6 and continue through follow on boilerplates as required. Auxiliary equipment that cannot be defined as handling, servicing, or checkout will be used as needed on major tests. Combined checkout and handling GSE hardware will be used on boilerplate 12. A complete set of GSE will be required on boilerplate 14 and airframes 009 and 011.

Partial prototype GSE of one or more categories will undergo evaluation tests conducted on airframes 001, 002, 004, and 005. Complete sets of GSE prototype will be used and tested on airframes 006, 008, 009, 010, and 011.

Further test data is presented in Subsection 2. 11 of this volume and in Section 11. 0 of Volume II.

1. 12 STRUCTURAL TESTS (See Figure 1-4)

Structural tests will be conducted on the components, subassemblies, assemblies, and combined assemblies of the launch escape tower, command module, service module, spacecraft adapter, and ground support handling equipment.

The test program will begin with laboratory tests to provide design and development information under combined flight environments and loads for spacecraft structural components. Criteria of static and aerodynamic loads, hard vacuum, heat, meteoroid impact, vibration, and acoustics will be applied. Included are dynamic tests of the crew couch impact attenuation system struts, acoustic and vibration tests of typical panels of the modules, and miscellaneous load tests on fittings. Subassemblies and assemblies will be tested to design and ultimate loads under critical environments for design verification. Included are dynamic tests of boilerplate and spacecraft structure and bracketry. Boilerplates 9 and 27 will be shipped to the Marshall Space Flight Center, Huntsville, Alabama, where they will be subjected to simulated dynamic flight stresses under the direction of NASA.

The boilerplate and spacecraft flight test program will provide design information for verification of flight environments, evaluation of structural components and assemblies, and prequalification data for the final design configurations.

[redacted]

Ground handling slings, dollies, trailers, etc., will be proof-load tested for conformance to applicable specifications.

Further testing data is presented in Subsection 2.12 of this volume and in Section 12.0 of Volume II.

1.13 MECHANICAL AND ORDNANCE DEVICES

Development tests will be conducted on mechanisms for separation, release, deployment, positioning, and shock attenuation.

Components of each device, viz., latches, release units, shock struts, adjustments, pivot points, and the like will be development tested for conformance to Apollo mission environments and will be evaluated for design suitability. Flight body loads will be applied, and critical measurements of travel, stress distribution, response time, and deflection during operation will be compared with design requirements. Thus, a design will be verified, or a modification or redesign will be indicated. Conventional static and dynamic load and operational tests will be conducted in the laboratory under the hyperenvironments of reentry, hard vacuum, radiation, and meteoroid impact where applicable.

Mechanical devices will be installed in house spacecraft 1 (boilerplate 14) and 2 (airframe 006) to evaluate performance and compatibility for continuing improvement of design. No live ordnance units will be installed.

Further verification and eventual qualification of the devices will result from ground and flight testing of the boilerplates and spacecraft which use these mechanical and ordnance devices. For example, the recoverable command modules will provide operational data when the forward compartment cover and heat shield release mechanisms and shock struts are subjected to flight loads. Separation devices for the launch escape tower and modular interfaces will be evaluated during test flight missions. Additional mechanical and ordnance tests are given in Subsection 2.13 of this volume and in Section 13.0 of Volume II.

1.14 MATERIALS, PROCESSES, AND PRODUCIBILITY

Producibility and the selection of materials and processes will be investigated primarily through research and study of pertinent and authoritative technical literature. If studies are inconclusive, laboratory tests will be conducted until conclusive evidence is obtained for an objective engineering decision. Of primary interest is the selection of materials and processes that offer superior strength-to-weight properties: reliability, weldability or bondability, and high resistance to critical mission environment such as radiation, pure oxygen environment, hard vacuum, meteoroid impact, and reentry.

[redacted]IDENTIAL

CON[redacted]

[redacted]

The major criteria for design and material selection for early spacecraft will be airworthiness and spaceworthiness as demonstrated on other programs. The final proof for selection will be the demonstration of prequalification on integrated ground tests and qualification on unmanned spacecraft prior to incorporation of material into the design of a spacecraft intended for a manned mission. Additional discussion is given in Subsection 2. 14 of this volume and in Section 14. 0 of Volume II.

1. 15 WIND TUNNEL TEST PROGRAM

Data from the wind tunnel test program will provide a basis for evaluation of the design and performance of the space vehicle, of the spacecraft with LES, and of the command module during flight from reentry through main parachute deployment. These configurations will be examined for aerodynamic stability, pressure distribution, and air loads, heat transfer, and structural dynamics.

The wind tunnel test program can be roughly divided into four phases that culminate in providing information for a man-rated spacecraft.

1. Preliminary design data that uses idealized aerodynamic configurations for models

2. Design confirmation in which models are updated to include effects of small asymmetries and surface irregularities that have been included in the vehicle design

3. Production configuration evaluation in which models are updated to include the final production vehicle design

4. Flight test support and modifications that are specifically designed to support flight tests or to evaluate recommended vehicle modifications as a result of flight test data

Wind tunnel tests with the drogue parachute also will be conducted to provide stability, drag, and parachute-module dynamics data. Additional system tests are outlined in this volume in Subsection 2. 15 and in Section 15. 0 of Volume II.

1. 16 THERMAL PROTECTION SYSTEM (See Figure 1-4)

The thermal protection system for the command module consists of three basic elements: the ablative material, the brazed steel honeycomb substructure, and the thermal insulation. In general, the tests of this system will be designed to simulate the anticipated flight environment of the Apollo spacecraft during boost, abort, earth orbit, translunar and lunar orbit, earth return, and earth atmosphere reentry.

[redacted]

[redacted]

[redacted]

Developmental test will be conducted by the heat-shield subcontractor to evaluate the ablative material and the composite heat-shield components. In the early stages of development, these tests will consist of small-scale tests on the individual materials for thermal and mechanical properties. Subsequent tests are performed on composite panels 2 by 3 feet in size. S&ID will conduct performance evaluation tests to assure conformance to the procurement specifications. These tests will consist of design data tests and analysis verification tests.

Among the developmental and evaluation tests planned for the thermal protection system are mechanical and physical tests, dynamic tests, structural integrity tests, and thermodynamic tests. Tensile, shear, flexure, compressive strength, specific heat, thermal expansion coefficient, and thermal conductivity properties of the ablative materials will be determined. Acoustical and vibrational environments will be simulated. Adhesive bond, and large composite panel thermal exposure tests to verify the structural integrity of the heat-shield ablative material and substructure will form an integral part of the development program. Thermodynamic tests will be conducted in plasma-arc tunnels to determine the performance of the ablative material when exposed to the thermal environments applicable to the Apollo program. Space environment tests will be performed according to the capabilities of the available test facilities.

The spacecraft flight and static test program relevant to the thermal protection system includes airframes 006, 005, 008, and 009. Design information will be obtained for verification of flight environments, for evaluation of ablative and structural components and assemblies, and for confirmation of the final design configuration.

The thermal and mechanical properties of the antenna window material, cryogenic insulation, and structural materials will be determined, as required, for thermal analysis for the Apollo spacecraft and Apollo systems.

Further system testing is outlined in Subsection 2. 16 of this volume and in Section 16. 0 of Volume II.

1. 17 IN-FLIGHT TEST SYSTEM

The in-flight test system (IFTS), located in the upper right hand equipment bay of the command module, consists of the following packaged assemblies: indicator lights, voltage comparators, power supplies, multi-range voltmeter, stimulus generator, GSE access connectors, INPUT-OUTPUT connectors, and such controls and switches as are necessary for proper operation of the equipment.

[redacted]IDENTIAL

CO[redacted]

The design and development testing will be accomplished by the subcontractors. This phase of the test program will continue to program completion. Testing accomplished by S&ID will cover areas of interface requirements, simulation test to verify system design and performance, system and operational compatibility, and evaluation of over-all ground qualification. This testing will constitute a ground qualification test program, and will include testing carried out on house spacecraft and environmental proof spacecraft.

Flight qualification will be accomplished as part of a flight operations test program to demonstrate earth-atmosphere spacecraft performance. System operation in the spacecraft environment will be confirmed in the first orbital flight. Most of the other functions will be demonstrated fully in subsequent orbital flights.

IFTS system testing is described further in Subsection 2. 17 of this volume and Section 17. 0 of Volume II.

1. 18 DISPLAYS AND CONTROLS

The displays and controls system comprises the interface by which the crew exercises intelligent control of the Apollo mission. These displays and controls consist of units and panel assemblies mounted on the main display console. With the exception of the caution warning system, entry monitor display system, clocks and timers, emergency detection system, and barometric indicator, the displays and controls are integral parts of the preceding major systems in Subsections 1. 1 through 1. 9.

The procured equipment will be designed, developed, and tested by the associate contractors, sub-contractors and vendors prior to delivery to S&ID.

S&ID will perform receiving inspection, in-house acceptance tests, qualification tests, and systems integration tests of both vendor and NAA manufactured panels.

The various displays and controls will be tested as individual components and sub-assemblies, as well as in combined systems and integrated systems to determine system compatibility as indicated in paragraphs 1. 1 through 1. 9. Integrated systems tests will be conducted on house spacecraft 1 and 2 (B-14 and AFRM 006), and environmental-proof spacecraft (AFRM 008).

Displays and controls are described further in Subsection 2. 18 of this volume, and Section 17. 0 of Volume II.

[redacted]

[redacted]

1.19 SIMULATION TEST PROGRAM

The simulation test program is a continuous effort of obtaining data from the simulation test plan. This data is used to provide design specifications for the various systems and subsystems, and to determine system compatibility in the integrated configuration. This includes the evaluation of the performance of the man-machine combination.

Additional program tests are outlined in Subsection 2.19 of this volume.

CO[redacted]

[redacted]

2.0 INDIVIDUAL SYSTEM TESTS

Tests for information and development are conducted to select and coordinate design concepts, to create the best component design, and to prove the design soundness and value. The compatibility of components will also be ensured; operational characteristics of the system will be determined under simulated environmental and demand conditions; and suitability of the system for integration into the spacecraft will be verified.

2.1 SERVICE PROPULSION SYSTEM

2.1.1 Scope

This section consists of the development test program for the service propulsion system. It is divided into two main sections: (1) the subcontractor (Aerojet General) test program and (2) S&ID's development test program. The section is limited to engineering development, evaluation, and design verification tests.

2.1.2 Objectives

The objectives of this test plan are to develop, optimize, and verify performance and configuration of a rocket engine and, with the use of the F-1 test fixture, to develop and evaluate the propellant system.

2.1.3 Requirements

Tests will be performed using experimental injectors, steel test chambers, and steel chamber sections. Additional requirements will include thrust measuring stands, tankage, altitude chambers, and high-response recording and measuring instruments.

2.1.4 Subcontractor Test Plan (Aerojet Corporation)

The rocket engine test plan is divided into three phases. The development test phase is to demonstrate compliance with the detail design criteria and to determine the optimum component configuration. The program will encompass component environmental and life cyclic tests and will provide a large portion of the reliability demonstration information. The simulated high-altitude phase will provide performance and durability verification at simulated altitude and pressure conditions and will verify

[redacted]

[redacted]

[redacted]

component compatibility in low-pressure environments. The development evaluation tests will demonstrate chamber durability, ability to perform mission duty cycles, and intermittent restarts. Duration testing of thrust chamber valves and gimbal actuators will be accomplished during this phase.

2.1.5 S&ID Test Plan

S&ID will conduct the following types of tests on the service propulsion system.

2.1.5.1 Design Detail Development Tests

The following design details will be investigated: welding or brazing of system plumbing and components, advanced metallic and plastic seal designs, compatibility of system materials with the hypergolic propellants, and high-pressure tank design. Because of the similarity between the SPS and the RCS, many of the tests listed will provide data for all the systems and will be conducted for this objective.

2.1.5.2 Back-up Tests on Purchased Components

The prime contractor shall ensure that subcontractor test results are adequate by prescribing or approving the details of the test procedures and means of obtaining data, observing tests, and evaluating test data. Selected evaluation tests on representative samples of purchased components will be performed, as required, provided that such tests will not require duplication of special test equipment at the S&ID facility that is available elsewhere. Maximum use will be made of existing government test facilities.

2.1.5.3 Propellant Utilization Subsystem Tests

The individual components of the SPS, with the exception of the rocket engine, will be assembled on a special test fixture and tested extensively to provide development and verification data. The program will be divided into two phases. The initial tests will employ an experimental propellant utilization subsystem and pressurization and propellant distribution subsystems that are composed of readily available components. The second phase of testing will employ a qualified propellant utilization subsystem. A simulated propellant will be used during both phases of testing.

2.1.5.4 Component Test

Additional subcontractors will be called upon to develop and furnish components, such as valves, tanks, regulators, etc. A statement of objectives and a test program for these items will appear in the September 1963 revision of this document.

[redacted]NTIAL

[redacted]

2.1.6 Facilities

The SPS Engine testing will be accomplished at the Sacramento and Azusa testing facilities of Aerojet General Corporation. Propellant Testing will be conducted at the S&ID Facilities, Downey.

2.1.7 Schedule

The service propulsion system test schedule is shown in Figure 2-1.

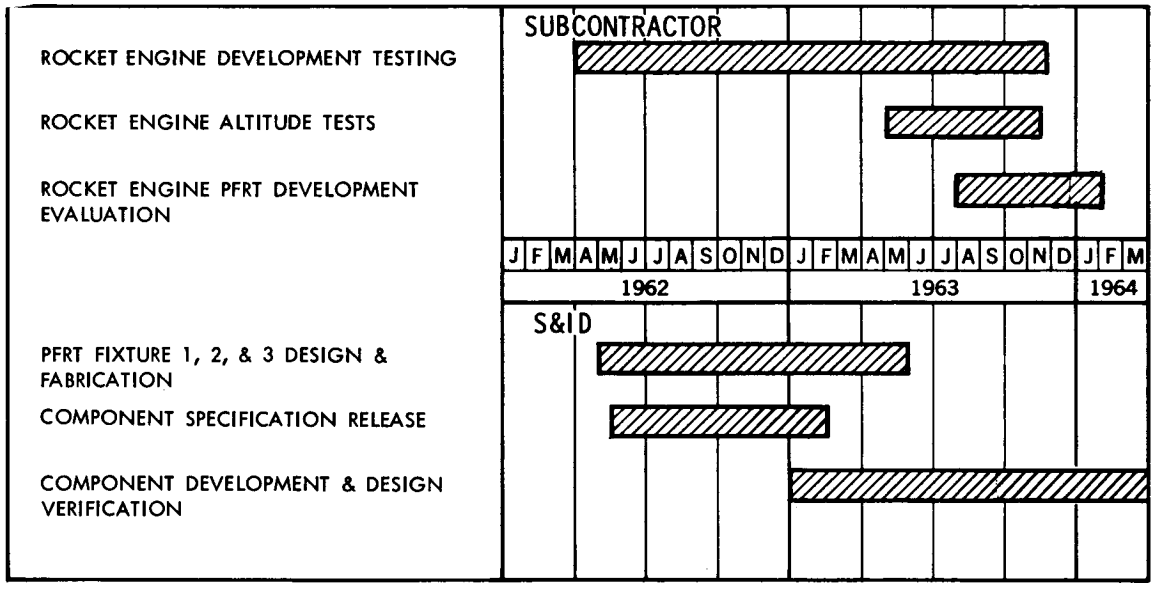


Figure 2-1. Service Propulsion System Test Schedule

2.2 REACTION CONTROL SYSTEM

2.2.1 Scope

The RCS for the command module and service module development program will include engineering development, evaluation, and design verification tests conducted by the subcontractor and S&ID. The subcontractor development test program consists of experimental tests and prototype development tests. The development test program of S&ID consists of different phases of tests at the breadboard level to evaluate the system before the integrated system tests.

[redacted]

2.2.2 Objectives

The objectives of this test plan are to develop and verify the design configuration of the Apollo spacecraft reaction control system and to ensure compatibility with its propellant system.

2.2.3 Requirements

The development tests will be performed using environmental simulation equipment, thrust measuring equipment, and ultra-high response recording and measuring instruments.

2.2.4 Subcontractor Test Plan

2.2.4.1 Rocket Engine Tests (Marquardt)

The test plan is divided into two major phases of development testing. The experimental test phase will establish the detail design criteria for the prototype design and determine the optimum component configuration. The prototype development test phase will include minimum impulse performance tests, life tests, and environmental tests on individual components and/or complete prototype engines.

2.2.4.2 Rocket Engine Tests (Rocketdyne)

The engine development test plan as proposed by Rocketdyne is divided into two major phases. The experimental test phase, conducted concurrent with the prototype phase, will be directed toward the investigation of problem areas discovered during limited testing conducted to date on the boilerplate Gemini 100 pound orbit attitude and maneuver system (OAMS) engine.

The prototype test phase will include mission cycle testing, engine performance testing, minimum impulse tests, operating limits testing, heat transfer testing, and malfunction testing on the prototype engine design, which is based on the as yet untested Gemini 100 pound OAMS flight configuration.

2.2.5 S&ID Test Plan

S&ID tests will be divided into the following general categories.

2.2.5.1 Design Detail Development and Verification Tests

Included in this category are tests to investigate welding or brazing of system plumbing and components, advanced metallic and plastic seal

[redacted]DENTIAL

designs, positive-expulsion bladder design, compatibility of system materials with the hypergolic propellants, high-pressure tank design, rocket nozzle temperature distribution, and rocket exhaust plume impingement heating and erosion.

2.2.5.2 Back-up Tests on Purchased Components

The prime contractor shall ensure that subcontractor test results are adequate and accurate by prescribing or approving the details of the test procedures and means of obtaining data, observing tests, and evaluating test data. Selected evaluation tests on representative samples of purchased components will be performed as required, provided that such tests will not require duplication of special test equipment at the S&ID facility that is available elsewhere. Maximum use will be made of existing government test facilities.

2.2.5.3 Testing of the Complete RCS at the Breadboard Level

The individual components of the RCS will be assembled on a breadboard test stand and will be tested extensively to provide essential development data, such as verification of flow and pressure data, determination of leakage rates, and simulation of component failures. The test stands will be full-scale replicas of the reaction control equipment compartments that will simulate the complete internal configuration of the compartments. The program will be divided into three progressive phases. The initial tests will employ readily available components and substitute fluid media; the system configuration will be updated for each successive phase of testing; the final phase will employ the prototype system design. Each phase will include the actuating or firing of the rocket engines individually and collectively for continuous and pulsated periods of operation.

2.2.5.4 Component Test

Additional subcontractors will be called upon at a later date to develop and furnish components, such as valves, tanks, regulators, etc. A statement of objectives and a test program for these items will appear in the September 1963 revision of this document.

2.2.6 Facilities

Test chambers to produce altitude pressure simulation, located at Marquardt Jet Laboratory in Van Nuys, and a special test facility including explosion control buildings, noise abatement equipment, etc. at S&ID in Downey, California, will be used for these tests. The Rocketdyne Propulsion Field Laboratory in the Santa Susana Mountains will also be used.

[redacted]

2.2.7 Schedule

The RCS test schedule is shown in Figure 2-2.

2.3 LAUNCH ESCAPE SYSTEM

2.3.1 Scope

During the LES development program, the igniters will be tested in a test chamber and evaluated. The launch escape, pitch control, and tower jettison motors will be static fired to verify the motor hardware design and to evaluate the solid propellant characteristics.

As part of the tower jettison motor development program, two simulated altitude performance tests will be required to attain the optimum design before flight testing. Flight test evaluation will be accomplished by means of abort tests.

This section covers LES rocket motors only. Development of the tower structure will be found in Section 2.12 (Structural Tests). Development of the separation subsystem will be found in Section 2.13 (Mechanical Devices).

2.3.2 Objectives

Since this section covers rocket motors only, the objectives of each individual motor test plan appear under the individual subcontractor test plan.

2.3.3 Requirements

Requirements are also included under the individual subcontractor test plan.

2.3.4 Subcontractor Test Plan

2.3.4.1 Launch Escape Rocket Motor Tests (Lockheed Propulsion Company)

2.3.4.1.1 Objective. Development testing will verify the design of the rocket motor and will help to produce the components and performance desired. A total of 17 motor tests will be conducted in the development phase.

Igniter test firings will serve to verify ignition performance (ignition delay, heat release, and flame pattern) and the basic design features of the igniter.

[redacted]ENTIAL

C[redacted]

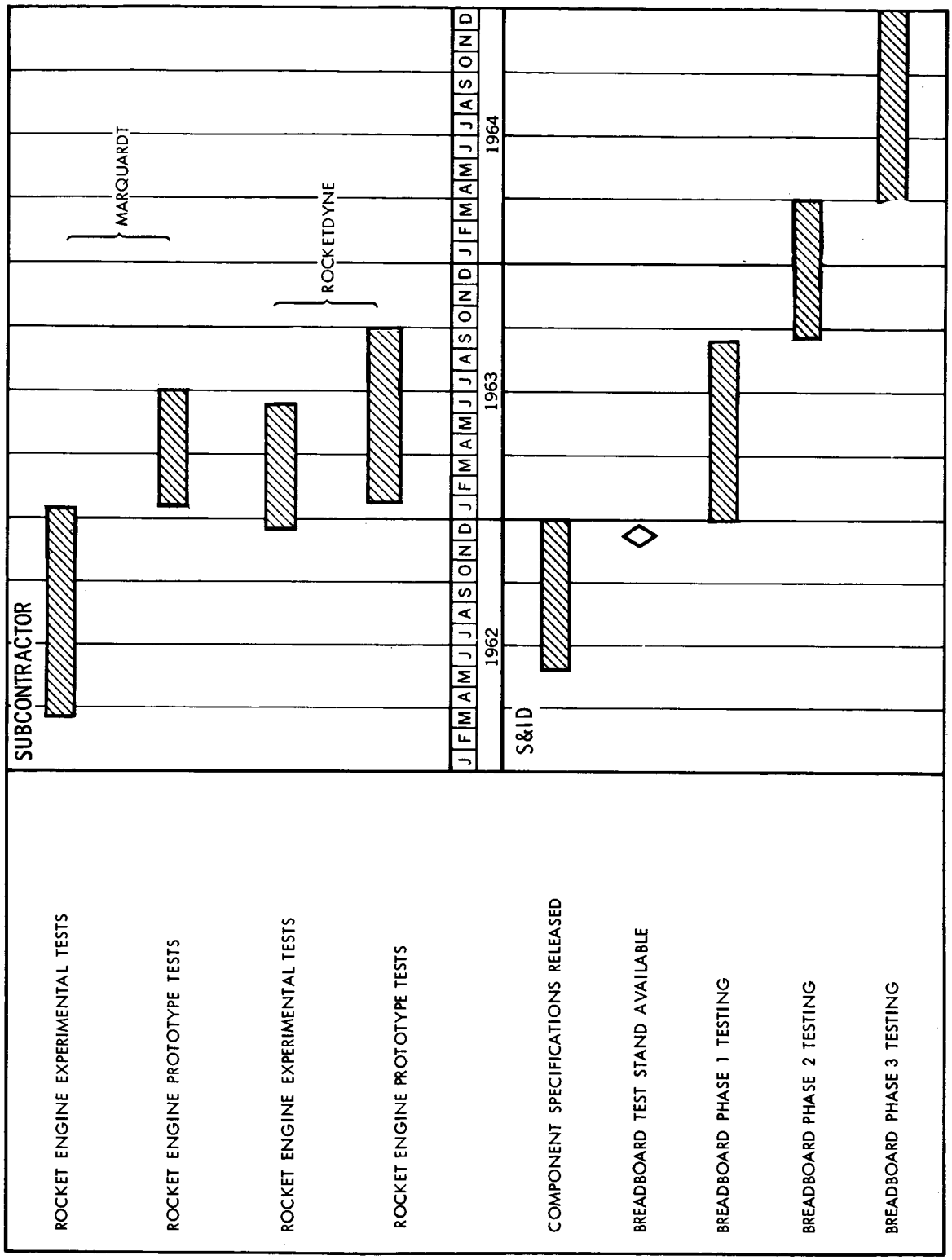


Figure 2-2. Reaction Control System Test Schedule

[redacted]

[redacted]

The first of several live motor firing tests will provide data needed to effect optimum igniter and motor ballistic performance throughout the operating temperature range and optimum propellant process control.

2.3.4.1.2 Test Program. The rocket motor igniter will undergo preliminary development testing in open air firings and firings into test chambers simulating internal motor volume.

After several preliminary live motor firing tests, and following any necessary design refinements, the motor will be tested under increasingly severe single and combined environmental stresses. A total of 17 motor tests will be conducted during this phase.

2.3.4.1.3 Facilities. All motor development testing will be accomplished at the subcontractor's static test facilities at Potrero, near Beaumont, California.

2.3.4.1.4 Equipment. Test equipment for the launch escape program will consist of a three-component thrust stand, motor conditioning equipment, motor handling equipment, and a data acquisition system. Altitude-ignition simulation equipment, hydrotest, and vibration equipment will also be required.

2.3.4.1.5 Schedule - The subcontractor development test schedules are shown in Figure 2-3.

2.3.4.2 Pitch Control Motor Tests (Lockheed Propulsion Company)

2.3.4.2.1 Objective. Completion of development tests of the pitch control motor will verify the design of the rocket motor components and the performance expected of the rocket motor propellant. Also, development tests will substantiate the conception of varying the total impulse of the motor within the design range without motor redesign.

2.3.4.2.2 Test Program. The pitch control motor development program will encompass 28 test units. An expected final value of total impulse will then be established. All further development tests will be conducted using motors having this impulse.

Twenty-four full-scale, maximum-impulse motor firings will commence with static tests designed to gain ballistic performance data. Several static tests will be performed with the motor containing the minimum required impulse. Environmental treatments with single and combined stresses will be applied to further develop motors.

[redacted]DENTIAL

2.3.4.2.3 Facilities. All motor development tests will be performed at the subcontractor's static test facilities at the Redlands, California plant.

2.3.4.2.4 Equipment. The test equipment utilized for the pitch control motor development program will include a single-component thrust fixture, an instrumentation and data acquisition system, and temperature conditioning equipment. Hydrotest fixtures and equipment, vibration equipment, and vacuum equipment for the altitude ignition test will also be required.

2.3.4.2.5 Schedule. The subcontractor development test schedules are shown in Figure 2-3.

2.3.4.3 Tower Jettison Motor Tests (Thiokol Chemical Corporation)

2.3.4.3.1 Objective. Completion of development tests of the tower jettison motor will verify the design of the rocket motor components and the performance expected of the rocket motor propellant. This testing serves the same purpose as the conventional preliminary flight rating test program and provides reliability data.

2.3.4.3.2 Test Program. Open-air development tests of the igniter subassembly, to verify its design and basic performance, will precede the first live motor firing. Ignition delay, heat release, and flame pattern reproducibility will be evaluated. Refinement of the igniter will be accomplished during the initial series of live motor tests, which will also serve to improve the ballistic performance of the motor and to establish exact nozzle sizes and insulation requirements. The remainder of the live motor firings will verify the refined design. Single and combined environments will be imposed to permit evaluation of the motor with respect to the criteria for shipping, handling, and use. A total of 24 tests are scheduled in the tower jettison motor development program.

2.3.4.3.3 Facilities. All tests are to be performed by the subcontractor, who will utilize the static test facilities of the Thiokol Chemical Corporation at the Elkton, Maryland plant. The support of Arnold Engineering Development Center will be required for two tests of motor performance at simulated altitude conditions.

2.3.4.3.4 Equipment. Test equipment utilized in the tower jettison motor development program will include one three-component thrust stand, instrumentation and data acquisition systems, temperature conditioning equipment, and vibration equipment. Hydrotest equipment, vacuum equipment for simulated altitude-ignition testing, and motor handling equipment will also be used.

[redacted]

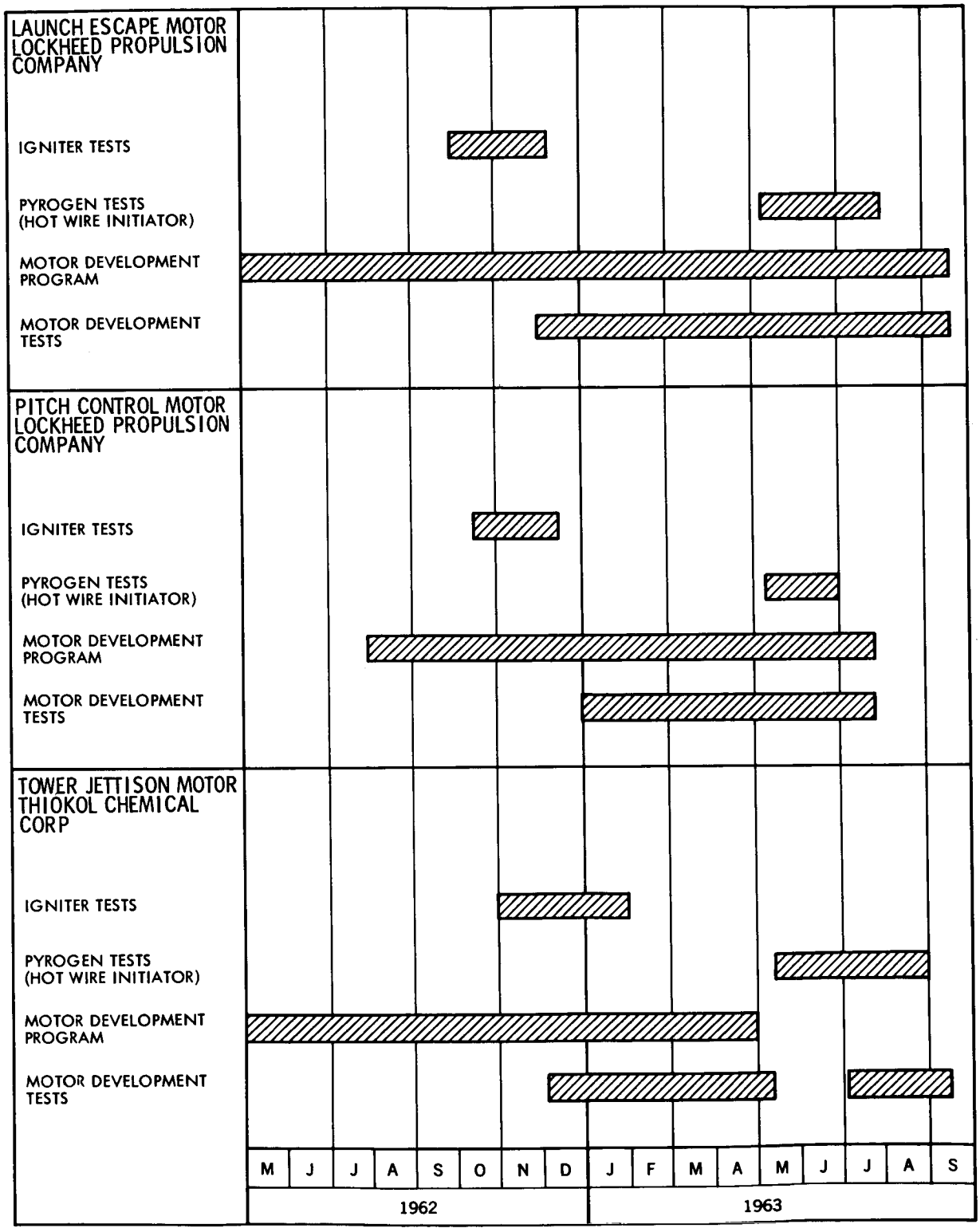


Figure 2-3. Launch Escape System Rocket Motor Development Test Schedules

[redacted]ENTIAL

C[redacted]

2.3.4.3.5 Schedule. The subcontractor development test schedules are shown in Figure 2-3.

2.3.5 S&ID Test Plan

As noted in subsection 2.3.1 this section covers LES rocket motors only. S&ID development of the tower structure is outlined in Section 2.12, and development of the separation subsystem is outlined in Section 2.13.

2.4 EARTH LANDING SYSTEM

2.4.1 Scope

This section consists of the parachute subsystem development test plan for Northrop Ventura and the crew shock-attenuation subsystem test plan of S&ID. The plans include laboratory development testing, ground and flight demonstration testing, and design evaluation and prequalification tests.

2.4.2 Objectives

The objectives of the test plans are to develop, optimize, and verify the configuration and performance of the parachute design and materials and crew seat attenuation mechanical system by functional testing.

2.4.3 Requirements

Tests will be performed using material specimens, single and multiple parachute flight drops, wind tunnel model testing, component tests, and environmental evaluation tests. Laboratory equipment, support aircraft and dummy drop weights, boilerplates 3 and 19, command modules, and photographic and test support instruments and recorders will be required.

2.4.4 Subcontractor Test Plan (Northrop-Ventura)

The subcontractor's test program will be submitted upon approval of Northrop Ventura's Report 2523, Test Plan-Apollo Earth Landing System.

2.4.5 S&ID Test Plan

S&ID will conduct materials evaluation, crew strut component selection and development tests, subsystem demonstration tests, and evaluation tests with boilerplates 1 and 2 during the impact program.

[redacted]

2.4.6 Facilities

The testing will be accomplished at Northrop Ventura and at the El Centro facilities for the parachute subsystem, and at Downey for the crew seat attenuation development.

2.4.7 Schedule

The earth landing system test schedule is shown in Figure 2-4.

2.5 ENVIRONMENTAL CONTROL SYSTEM

2.5.1 Scope

The test program for the environmental control system is divided into two major sections: (1) the subcontractor tests, covering the design, development, evaluation, and qualification of the subcontracted subsystems and systems, and (2) the S&ID testing program, encompassing design, development, evaluation, materials, coating, supplier confirmation, component, subsystem, system and integrated system tests.

2.5.2 Objectives

Subcontractor test program objectives are to establish the optimum material, components, subsystem, and system. Development testing will be followed by operational and qualification testing. The S&ID test program consists of confirming subcontractor and supplier tests, development of component, subsystem, and integrated systems, and the evaluation of operation. The integrated system tests will substantiate design criteria of the ECS, radiator, and the coldplate. The breadboard tests will be used to show operation on the complete flight profile. Sufficient manned tests will be

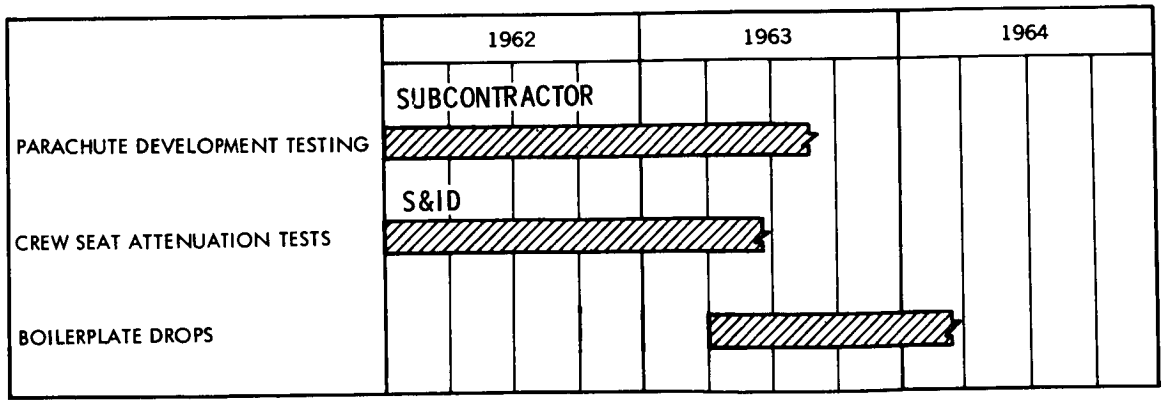


Figure 2-4. Earth Landing System Test Schedule

[redacted]DENTIAL

CO[redacted]

performed at altitude in the vacuum chamber to verify the crew ECS interface under both normal and various emergency operating conditions.

2.5.3 Requirements

The test articles include a complete ECS breadboard, radiator and coldplates (all to be mounted in a pressure vessel simulating the command module) and a servicing unit. Black boxes will simulate the electronic equipment packages, and a metabolic simulator will simulate three crewmen under different degrees of exertion and dress. The altitude chamber will be constructed to simulate the complete Apollo mission through all modes. Adequate support facilities are required, such as vacuum pumps, an ethylene-glycol-water refrigeration and pumping system, an oxygen regulated supply, and an electrical source. Pressure, flow, electrical controls, and monitoring equipment will be required. Provisions must also be made to assure crew comfort and safety during the manned phase of these tests.

2.5.4 Subcontractor Test Plan (AiResearch)

2.5.4.1 Component Testing

The subcontractor will conduct the component test program to meet the applicable specification requirements. The component tests cover the flow rates; proof pressure; pressure drop; electrical, thermal, environmental or dynamic characteristics; and response time. Stress, material, and finish tests are to be performed. A test is to be run for toxic gas released from the raw materials under operational conditions. Component compatibility checks are to be determined. Functional performance tests will be accomplished.

2.5.4.2 Subsystems Test Plan

Subsystems will be assembled in as near the flight configuration as possible and tested with respect to the following considerations: interaction of components, compliance with operating criteria (thermal, pressure drop, etc.), and interaction with other systems.

2.5.5 S&ID Test Plan

2.5.5.1 Material and Components

Material and component tests will be performed to check specification conformance and compatibility with other components in the system. Materials are to be tested for strength, corrosion, and outgassing at operating conditions. Finishes and coatings will be tested for compatibility

[redacted]

[redacted]

and the program requirement limits. The development, evaluation, operational, and qualification testing will be accomplished on S&ID units, and substantiation tests performed on the subcontractor components, subsystems, and systems.

2.5.5.2 Subsystem and System Test Plans

Subsystem and system testing will be performed to confirm specification compliance, material compatibility, performance and integrated system interaction. The tests will be accomplished under room ambient, elevated, and depressed temperatures and pressures simulating all modes of an Apollo mission. These tests will utilize simulated electronic units, metabolic simulator, simulated solar heat loads, and flight altitude pressures programmed to simulate flight time. Considerable testing with human occupancy will also be performed. A breadboard ECS will be used in conjunction with space radiators and coldplates. Facilities will include the altitude chamber, coolant oxygen, and electrical supplies.

The breadboard and facilities for flight simulation will be maintained to facilitate design improvement and system follow-up on maintenance.

2.5.6 Facilities

2.5.6.1 Subcontractor

The subcontractor (AiResearch Corp.) will supply evacuation, pressurization media, instrumentation sensing, readout and recording equipment. The media required to support the tests are gaseous oxygen, ethylene glycol, and water (heated and cooled). Electrical and ambient conditions for testing are to be supplied by the subcontractor, monitored by S&ID.

2.5.6.2 S&ID

The tests by S&ID will utilize a complete breadboard ECS, radiator and coldplates, a pressure vessel of Apollo flight configuration, an altitude chamber with adequate support facilities, and simulation equipment to simulate loads of the crew, electronic equipment, solar and flight ambient heats, and flight pressures. The altitude chamber will be suitable for manned tests, and suitable support facilities will be provided to support such tests. These items will permit the simulation of a complete mission profile for integrated systems compatibility and operation. The breadboard with the support facilities will be used for system design improvement and maintenance, following development and integrated system testing.

2.5.7 Schedule

The test schedule for the environmental control system is shown in Figure 2-5.

[redacted]IDENTIAL

CO[redacted]

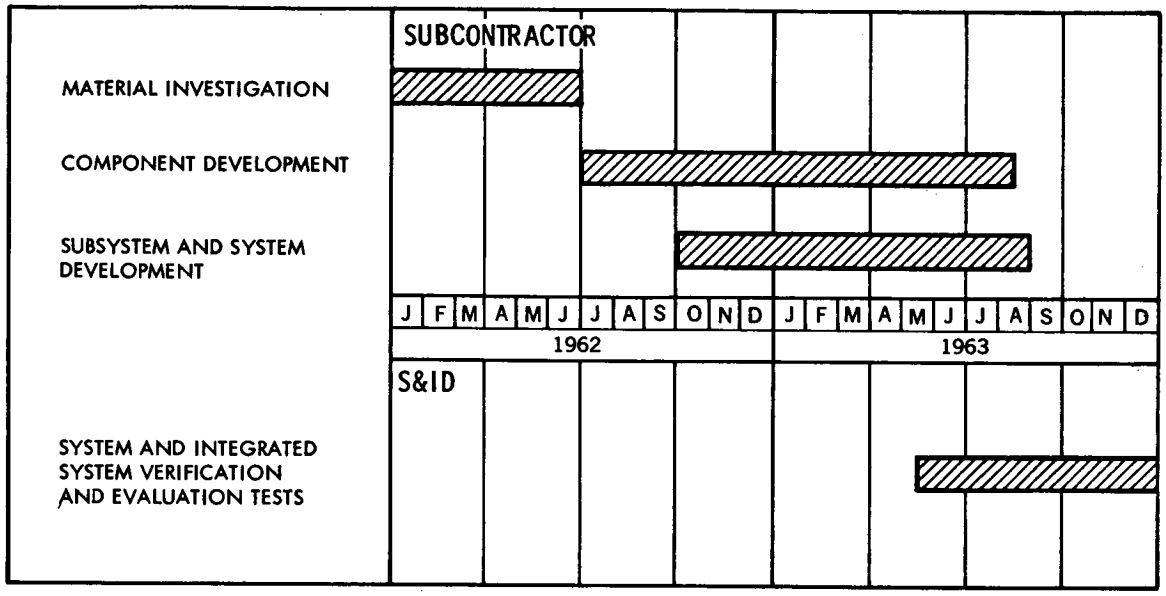


Figure 2-5. Environmental Control System Test Schedule

2.6 ELECTRICAL POWER SYSTEM

2.6.1 Subcontractor Test Plan

The test plan will encompass the general evaluation of design approach, materials, sealing techniques, and performance on the component and subsystem levels. The following specific evaluation tests will be conducted by the various subcontractors to assure the development of reliable equipment.

1. Multiphase tests on fuel cells to encompass design development, multiple cell, single module, and qualification testing. This development and qualification program will include testing of such components as electrodes, pressure regulators, pump separators, glycol pumps, etc., to design and off-design conditions. Single module tests will be performed to evaluate thermodynamic and power output characteristics of operating systems under selected simulated environments (vacuum, vibration, acceleration, etc.)

2. Sealing of the insert to the metallic body umbilicals and pressure barrier electrical feed-throughs

3. Heat rejection of electrical components (not coldplate cooled) when operated for extended periods of time in a vacuum environment.

4. Charge and discharge characteristics of zinc-silver oxide batteries

5. Arming and safing characteristics of electro-explosive devices and their associated hardware

[redacted]

[redacted]

6. Efficiency characteristics of static inverter and battery charger

7. Techniques for the reduction and shielding of electromagnetic interference generation

2.6.2 S&ID Test Plan

The test plan encompasses the evaluation of off-the-shelf components to derive a design approach for the static inverter, evaluate the operation of illuminating elements in a vacuum atmosphere, develop the technique for determining the state of charge of the zinc-silver oxide battery, and to evaluate various electro-explosive devices in the preliminary design stage. Performance evaluation tests will be conducted on various subsystems to further explore the problems associated with interface areas encountered within the spacecraft. The tests performed by the prime contractor will be conducted on a breadboard and prototype at the component, subsystem, and integrated subsystem levels. Component tests will be performed on vendor-supplied items.

The S&ID fuel cell tests will be divided into the following general categories.

2.6.2.1 Laboratory Tests (S&ID, Downey)

Inasmuch as Pratt & Whitney's fuel cell tests will be concerned with tests on single fuel cell modules, power output characteristics of two and three fuel cell modules connected in parallel will be evaluated under operating conditions. Data on such parameters as thermodynamic characteristics, load sharing, reactant regulation, etc., will be evaluated by the S&ID Engineering Development Laboratories.

Heat rejection characteristics on scale model radiators, heat transfer characteristics of cooling fluids, and combined environmental control (ECS) and electrical power systems (EPS) will also be evaluated in the Downey laboratories. Solutions to reactant control problems will be the primary objective of the integrated EPS and ECS tests.

2.6.2.2 Vehicle Tests

Various tests will be made on house spacecrafts 1 and 2 and airframes 001 and 008 to solve operational problems on complete fuel cell systems when integrated in the spacecraft and subjected to various operational modes. Such parameters as mechanical vibration, electro-magnetic interference, heat rejection under simulated or actual mission environments, mechanical and electrical interface problems as related to spacecraft, and water separation will be evaluated.

[redacted]DENTIAL

Successful completion of this series of tests and operational experience on flight tests will verify the fuel cells as being satisfactory as a power source for Apollo missions.

2.6.3 Schedule

The electrical power system test schedule is shown in Figure 2-6.

2.7 GUIDANCE AND NAVIGATION SYSTEM

2.7.1 Scope

Both the associate contractor and S&ID have an integral part in the development of the guidance and navigation system. The associate contractor will perform design, qualification, and reliability demonstration tests on the guidance and navigation system and its associated ground support equipment. S&ID will perform interface tests, systems compatibility tests, operational compatibility tests, and simulation tests.

2.7.2 Objectives

The objective of the associate contractor tests is to demonstrate proper design, operation, qualification, and reliability of the guidance and navigation system. The objective of the S&ID test program is to insure proper design and operational integration of the G & N system with the spacecraft.

2.7.3 Requirements

The program requirements for the associate contractor are negotiated between MIT and NASA and are not a part of this plan.

In order to fulfill the tests of the prime contractor, GFP guidance and navigation systems must be available. Laboratory equipment will be limited to a standard array of oscilloscopes, meters, etc. Special test equipment essential to the evaluation of the total integrated guidance crew tasks will consist of a star simulator (reproduction of stars and star fields by optical means, noncritical), a landmark simulator consisting of several clear photographs of the moon, a precision tilt table, liquid coolant source, a flight simulator table, and an analog and digital computer center.

2.7.4 Associate Contractor Test Plan (MIT)

The design, development, and qualification and reliability demonstration of the guidance and navigation system and the associated ground support equipment will be performed by the guidance and navigation associate contractor and his subcontractors. MIT documents E-1078, Apollo Guidance and Navigation Development Plan, and E-1097, Work Statement for Industrial Support, describe the test plans for the associate and subcontractors.

[redacted]

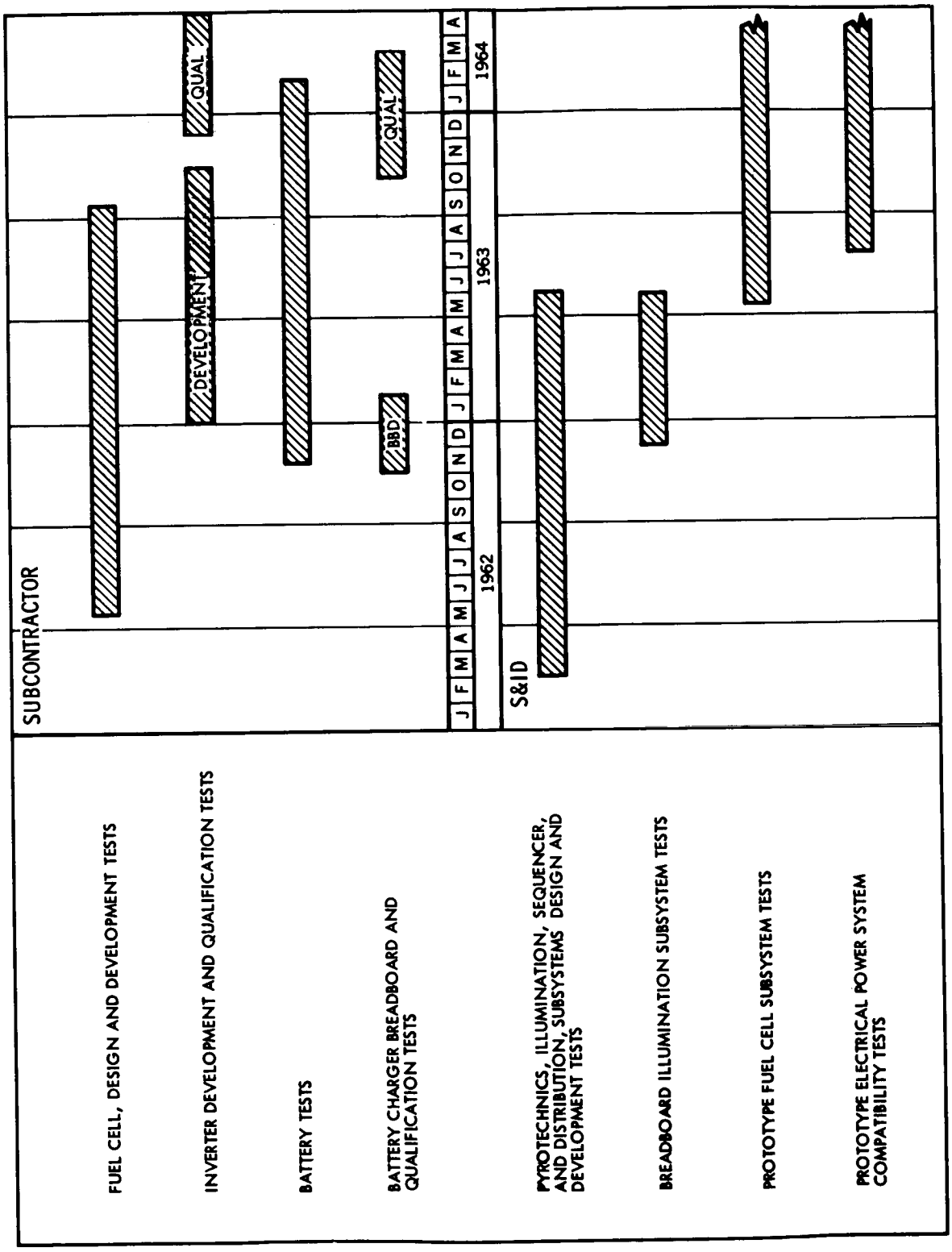


Figure 2-6. Electrical Power System Test Schedule

[redacted]IDENTIAL

CO[redacted]

[redacted]

2.7.5 S&ID Test Plan

S&ID will perform command module and combined systems tests in fulfillment of the design integration of the guidance and navigation system with the spacecraft. The guidance and navigation associate contractor or his representatives will provide technical assistance as required. The following categories of tests will be conducted by S&ID in fulfillment of the design integration of the guidance and navigation system with the spacecraft.

2.7.5.1 Interface Requirements

An analysis of system operations and interrelations with other spacecraft- and ground-installed equipment will be performed. Tests will be conducted to establish and define the interface areas and to determine the requirements for the necessary interface hardware. The necessary equipment will be developed, and intersystem tests will be scheduled to verify and evaluate hardware design. This effort will include the interfaces between the guidance and navigation system, on the one hand, and the environmental control system, electrical power system, stabilization and control system, rendezvous system, and controls and displays on the other.

2.7.5.2 Systems Compatibility

The electrical, mechanical, and functional relationships between the guidance and navigation system and other systems will be investigated. Noise and transient studies will be performed in both the laboratory and the command module to permit definition of the electrical environment in which the system must operate. The studies will evaluate system susceptibility to noise and transients, detect noise generated by the system, and arrive at an optimum cabling configuration for minimum intersystem interference. Compatibility tests will be conducted to develop and evaluate the in-flight test and maintenance hardware and the procedures associated with the guidance and navigation system.

2.7.5.3 Operational Compatibility

S&ID will conduct such studies and tests as are necessary to evaluate and confirm the operational modes of the guidance and navigation system from the total-spacecraft viewpoint and to optimize the role of the astronauts in performing guidance and navigation functions in conjunction with all other spacecraft events. These studies and tests will include investigation of various malfunctions and failure modes, measurement of the effects of such malfunctions on interconnecting systems, and the interacting effect of other systems malfunctions upon the guidance system. The results will provide valuable system operating characteristics for the astronaut's use in coping with a wide variety of emergency conditions.

[redacted]

2.7.5.4 Computer Simulation Studies

As the prototype hardware becomes available, comprehensive testing of the guidance and navigation system will be conducted. Analog and/or digital computers will be used to close the spacecraft dynamics loop around the guidance system being tested. This portion of the test program is designed to investigate the effects of hardware nonlinearities, guidance computer program assumptions, and associated variations of stability and limit-cycle characteristics for various flight cases. It will also investigate system interaction and effectiveness under simulated nominal and perturbational flight conditions. Because of the schedule and the lead-time required to procure system hardware, the simulation tests are divided into three phases.

Phase I will consist of pure synthesis, in which guidance and nagigation system hardware, with the vehicle parameters and guidance computer program mechanization, will be simulated on the digital computer. During these studies, guidance and navigation hardware characteristics will be represented as accurately as they can be, within the capability of normal programming. The results of these studies will form the basis for the establishement of performance acceptance criteria of the fundamental system design and of hardware development and fabrication necessary to achieve the required Apollo emergency- and normal-mission success.

Phase II will be similar to Phase I except that it will utilize analog computers and a level two-language guidance computer simulation to assist in simulation of the vehicle dynamics and the stabilization and control system. This study will serve to simulate the guidance and navigation system in real time for a natural progression to Phase III.

Phase III will be similar to Phase II except that each simulated subsytem will be replaced with its actual prototype, which will be identical to the subsystem employed for manned flight. These tests will serve as a means of determining and evaluating the effects of the hardware characteristics and the interfaces of the guidance and navigation system. All flight cases will be studied and new computer programs written to include mechanization of significant nonlinearities, noise characteristics, discontinuities, guidance computer program mechanization, etc.

2.7.6 Facilities

S&ID testing of the guidance and navigation system will be carried out in the guidance and control engineering laboratory.

[redacted]NTIAL

2.7.7 Schedules

See Figure 2-7.

2.8 STABILIZATION AND CONTROL SYSTEM

2.8.1 Scope

Design verification, evaluation, prequalification, interface, and acceptance testing of the stabilization and control system will be performed jointly by the subcontractor and the prime contractor. The test program will be conducted to ensure minimum redundancies but provide maximum confidence and reliability. Specific qualification test and reliability test programs will be reported separately.

2.8.2 Objective

The objective of the subcontractor's test program is to verify design and performance of the prototype stabilization and control system as defined by the specifications. The prime contractor's test will thoroughly explore the complete-system and combined-systems problems, with emphasis upon all major interface areas encountered in the spacecraft.

2.8.3 Requirements

The program requirements for the subcontractor include breadboards for circuit development tests and dynamic flight simulators for satisfying system performance. The prime contractor will require prototype stabilization and control subsystems or systems.

2.8.4 Subcontractor Test Plan (Minneapolis-Honeywell)

The prototype system tests will verify design and development concepts and system performance. Included in these tests will be circuit development, component development, system breadboard testing, computer simulator testing, radio interference testing, environmental testing, design improvement testing, and system acceptance tests.

2.8.5 S&ID Test Plan

The prime contractor's tests are designed to augment the subcontractor test results. They will place emphasis upon all major interface areas and will thoroughly explore the system problem areas. The general approach consists of subsystem testing through the use of analog simulation and available hardware, progressing in length and intensity through a smooth transition to complete system hardware testing. The tests performed will

[redacted]

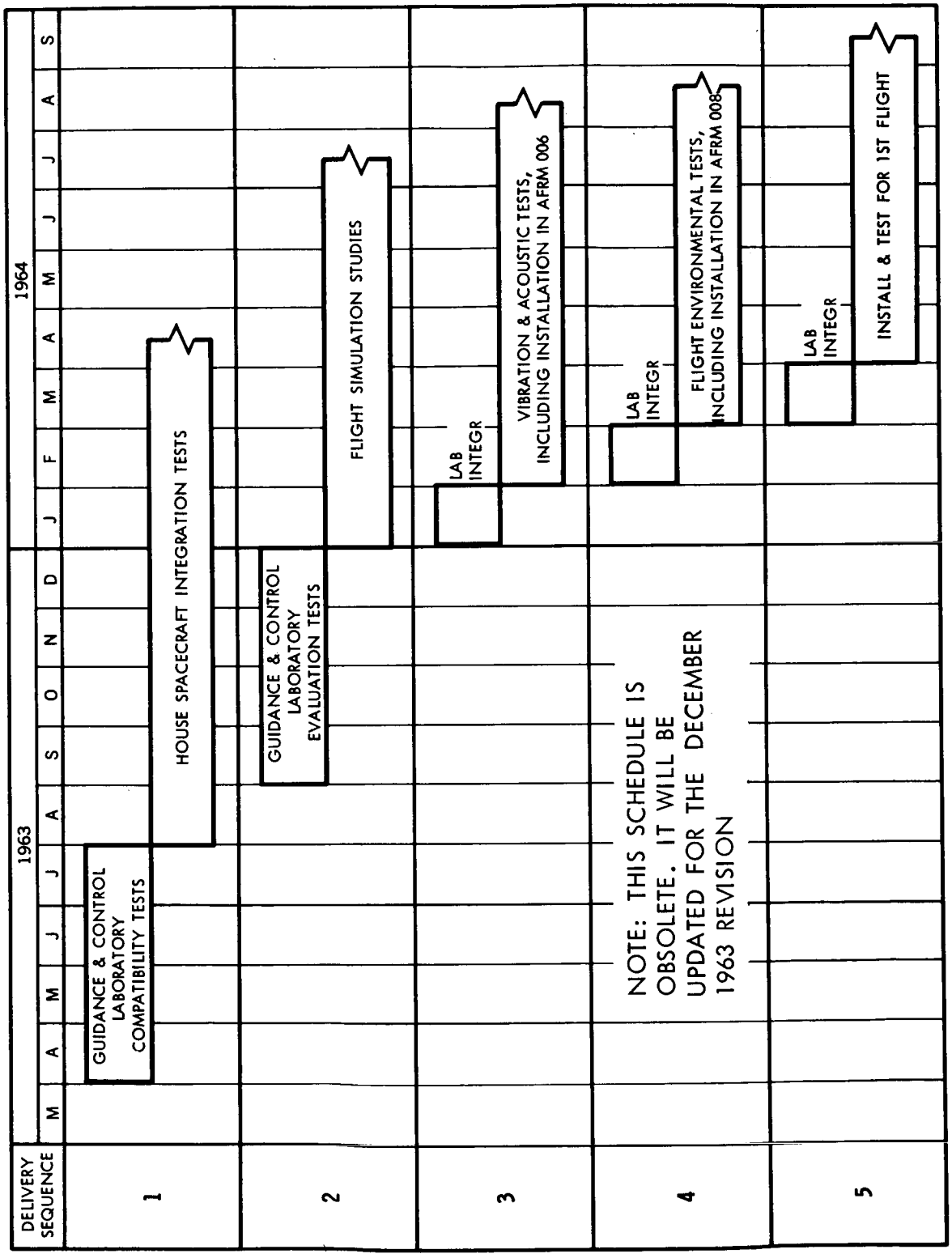


Figure 2-7. Guidance and Navigation System Test Schedule

[redacted]DENTIAL

CO[redacted]

include subsystem and system evaluation testing under simulated operational environment, for reliability purposes.

2.8.6 Facilities

Testing will be carried out in the G & C Engineering Laboratory of S&ID at Downey, California.

2.8.7 Schedule

The stabilization and control system test schedule is shown in Figure 2-8.

2.9 COMMUNICATIONS AND INSTRUMENTATION SYSTEM

2.9.1 Communications System

2.9.1.1 Scope

The subcontractors will perform development, design verification, qualification, and acceptance tests. The major subcontractor (Collins Radio Co.) will also perform systems-type tests on one set of prototype equipment of that portion of the communications system which is covered by the Collins subcontract. S&ID will verify specified equipment, perform evaluation tests on the complete communications system and explore interface problems. Development, qualification, and acceptance tests will be performed on the S&ID - fabricated antennas, and the 2-KMC high-gain antenna will be calibrated and aligned. Detailed equipment tests will be performed by using bench maintenance equipment necessary for performance verification and maintenance.

2.9.1.2 Objectives

The objectives of the subcontractor's tests are to establish the feasibility of the design approach, develop the design to operational maturity, and ensure that the equipment delivered will comply with the design specifications. The objectives of the S&ID tests are to verify performance of the equipment and explore any interface problems.

2.9.1.3 Requirements

The subcontractors will require breadboard models, engineering models, and prototypes for development, and production models for qualification. S&ID will require prototype models for simulators and house spacecraft 1, and production models for house spacecraft 2 and the other spacecraft.

[redacted]

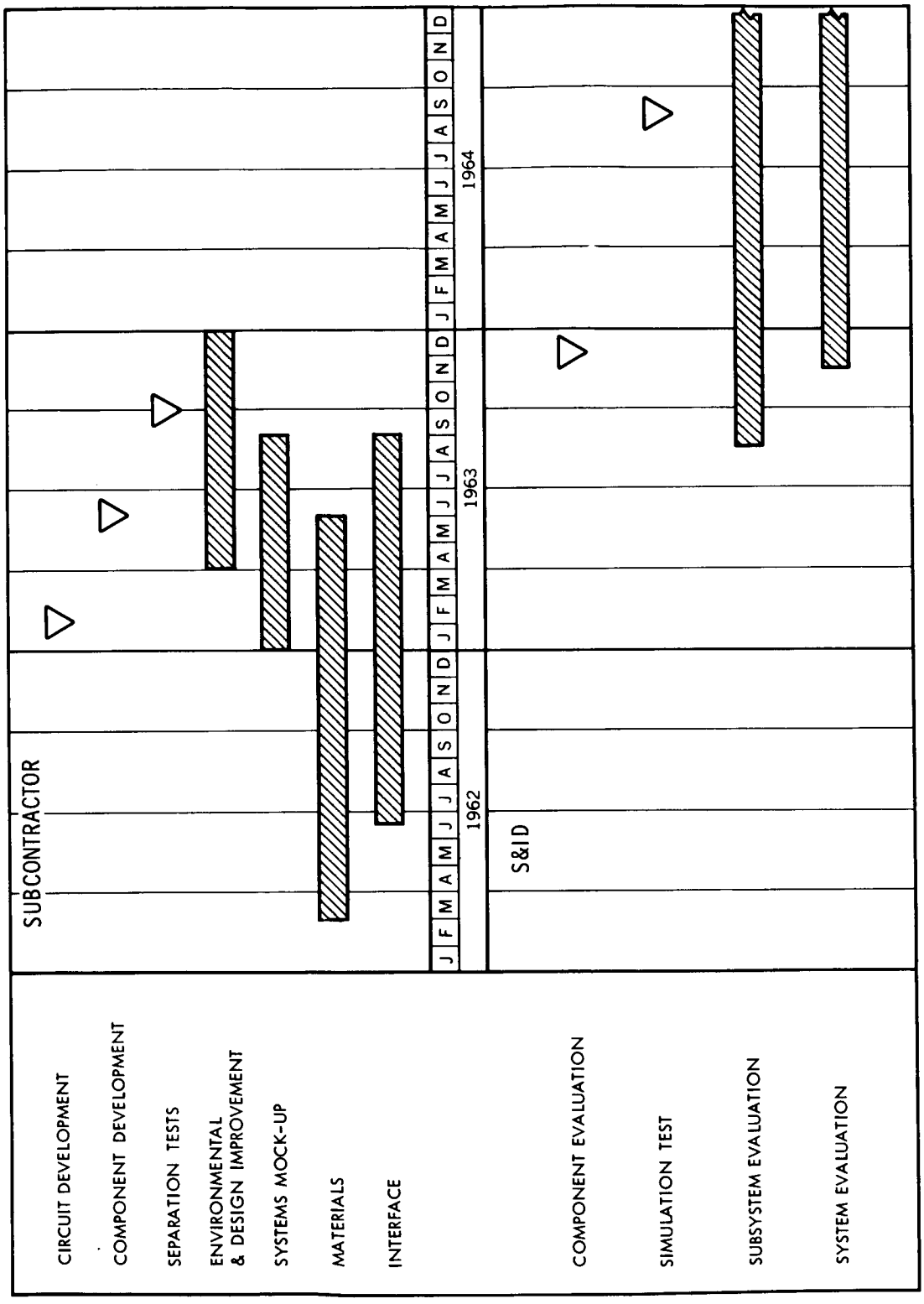


Figure 2-8. Stabilization and Control System Test Schedule

CO[redacted]

[redacted]

2.9.1.4 Subcontractor Test Plan

2.9.1.4.1 Major Subcontractor Test Plan (Collins Radio). The major communciations subcontractor and its subcontractors will conduct an extensive test program during the design, development, and manufacture of the equipment. The tests will include part application, development, design verification, qualification, and acceptance tests. The major subcontractor will conduct system-type tests on one set of prototype equipment that it or its subcontractors manufacture.

2.9.1.4.2 Antenna Subcontractors Test Plan. The subcontractors supplying antenna equipment will conduct an extensive test program during the design, development, and manufacture of the equipment. The antenna equipment will be divided into two classes: R&D antenna equipment and operational antenna equipment. The R&D antenna equipment will be used on early boilerplate and prototype spacecraft. These antennas will be used for several reasons, such as less severe spacecraft environments, schedule difficulties in obtaining operational antennas, and requirements for handling the additional NASA-supplied transmitters for the R&D program. The tests to be conducted by the subcontractors will include model antenna patterns, development, design verification, qualification, and acceptance tests. In addition to these tests, full-scale pattern tests will be conducted on the operational antenna equipment.

2.9.1.4.3 Other Subcontractors Test Plan. The subcontractors supplying the balance of the communications equipment will conduct an extensive test program during the design, development, and manufacture of the equipment. The tests will include part application, development, design verification, qualification, and acceptance tests.

2.9.1.5 S&ID Test Plan

S&ID will conduct equipment tests on the communications system equipment to verify that performance is within specified limits, and system tests to determine any interface problems. Detailed equipment tests will be performed as necessary for maintenance and spare equipment status verification. These equipment tests will be conducted on the bench maintenance equipment and will be equivalent to the functional portion of the acceptance tests. S&ID will conduct an extensive test program on the VHF and 2-KMC scimitar antennas during their design, development, and manufacture. The tests will include development, qualification, and acceptance tests. Calibration and alignment tests will be conducted on the 2-KMC high-gain antenna prior to its installation on the S/M.

[redacted]

[redacted]

[redacted]

2.9.1.6 Facilities

Facilities for the subcontractor's tests will be provided by the subcontractors. S&ID testing of the communications system will use the S&ID facilities at Downey.

2.9.1.7 Schedule

The communications system test schedule is shown in Figure 2-9.

2.9.2 Instrumentation System

2.9.2.1 Scope

The test program consists of qualification tests, subsystem tests, and combined system tests. The items to be tested include sensors and their associated equipment, subsystems, and special instrumentation—optical, scientific, and biomedical.

2.9.2.2 Objective

The objective of the instrumentation system tests is to demonstrate the system's capability to furnish the required information, in specified form, from the source to the designated utilization points, under the specified environmental conditions, without interfering with and without interference from the designed function of other systems.

2.9.2.3 Requirements

The test articles are transducers, signal conditioners, associated installation hardware, wiring, instrumentation subsystems, and instrumentation systems.

Data recording is accomplished by the use of oscillographs, oscilloscope cameras, tape recorders, and other data logging devices.

2.9.2.4 Subcontractor Test Plan

Subcontractor tests are not included in the instrumentation testing program.

2.9.2.5 S&ID Test Plan

S&ID will conduct the following tests.

CO[redacted]

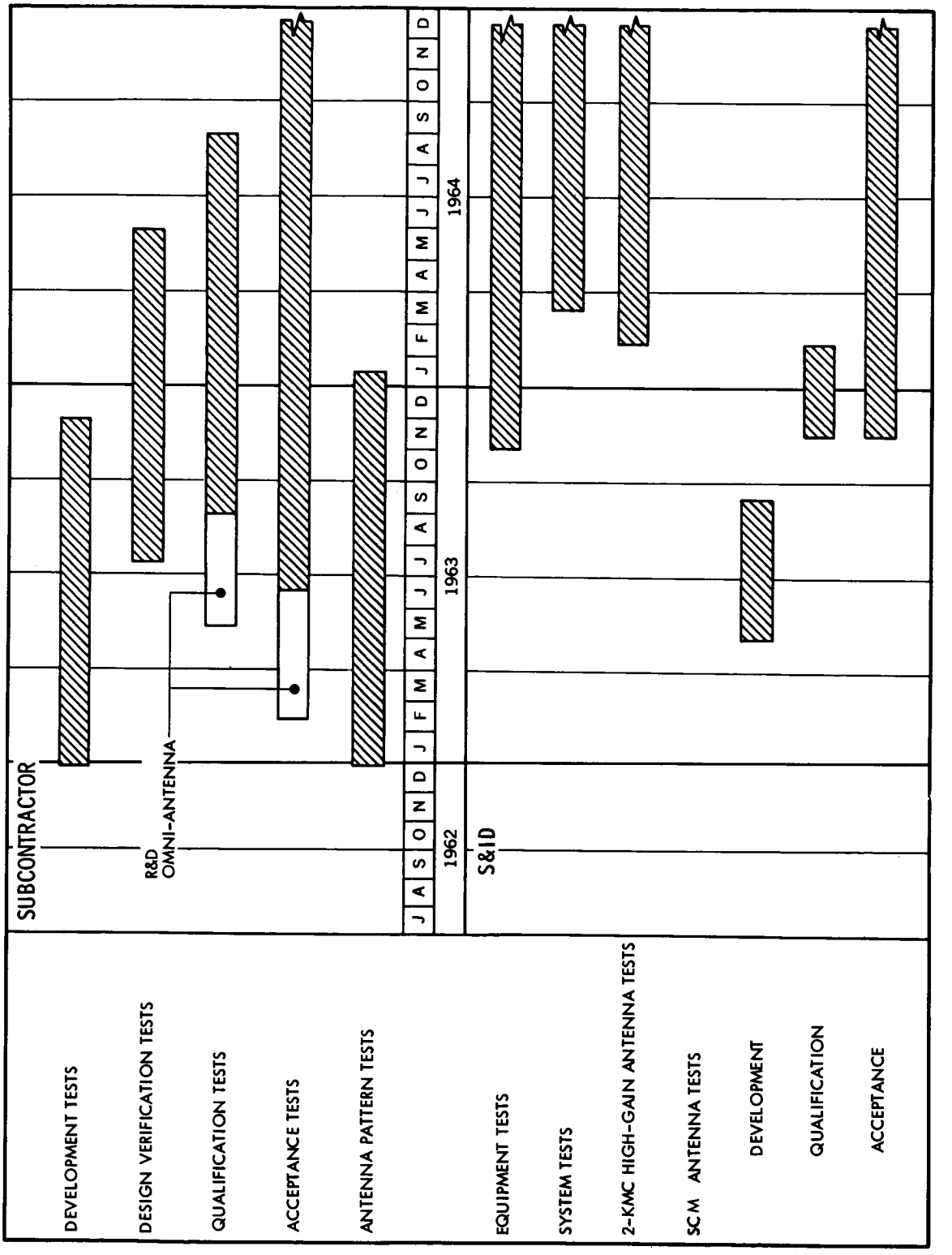


Figure 2-9. Communications Equipment Test Schedule

[redacted]

[redacted]

2.9.2.5.1 Acceptance Tests. Acceptance tests, consisting of a receiving inspection, a calibration, and an operational checkout, and a pre-installation test will be conducted on each component item received to insure that it is in satisfactory operating condition and that it is capable of performance in accordance with the specifications.

2.9.2.5.2 Subsystem Tests. Subsystem tests will be conducted to determine the interaction of the components when they are functioning as a part of the complete subsystem.

2.9.2.6 Facilities

The test facility for the acceptance tests consists of a complete evaluation laboratory equipped with environmental chambers, measurement standards, recording equipment, and typical test equipment located at S&ID, Downey, California.

The test facilities for the subsystem and combined system tests are the designated test vehciles, and these tests will be conducted at the manufacturing site for each vehicle.

2.9.2.7 Schedule

The test schedules for acceptance testing vary for each component, depending upon the type of component, number of each type being tested, and test vehicle for which it is intended.

Test start dates for the subsystem and combined system tests occur toward the end of the manufacturing phase for each test vehicle involved.

2.10 LIFE SYSTEMS

2.10.1 Scope

The life systems test program consists of human engineering design evaluation tests, crew performance, and flight simulation tests to assure an optimum man-machine relationship and successful accomplishment of the Apollo missions. Tests will be conducted in mock-ups, simulators, evaluators, boilerplates, house spacecraft, and airframe vehicles. Testing will also include dynamic conditions, such as acceleration profiles (boost and reentry), impact drop loads (land and water), shock loads, parachute recovery loads, zero-g flights, vibration, and acoustic tests. The tests are planned to verify that all equipment meets life systems criteria for all anticipated operational and environmental conditions.

[redacted]ENTIAL

2.10.2 Objectives

The objectives of the test program are to conduct those tests necessary to evaluate equipment design, systems design, operating procedures, crew performance, and crew environments through a systems development procedure in order to ensure that the crew can reliably and safely perform their tasks with the required level of proficiency under the anticipated conditions of the Apollo mission, and that the equipments are designed to fulfill the needs of a manned mission.

2.10.3 Requirements

2.10.3.1 Crew Equipment and Spacecraft Systems Testing

Crew equipment systems and spacecraft systems human engineering development design evaluation tests will be conducted in mock-ups 2, 12, 18 and in house spacecraft B-14. The qualification tests will be conducted in airframes 008, 006, and 001. Timing devices, motion picture coverage, still photography, provisions for pressurizing and venting pressure suits, biomedical monitoring facilities, and intercommunications between test subjects and test operating personnel will be required.

Developmental land and water impact tests will be conducted with boilerplates 1 and 2 and a drop test fixture. Qualification tests will be conducted with AFRM 005. Fully instrumented anthropomorphic dummies with the Life Systems Self-Contained Instrumentation Package (SCIP) will be required.

Boost and reentry g-profile tests will be conducted on a centrifuge. Human subjects, motion picture and still photographic coverage, television coverage, provisions for pressurizing and venting pressure suits, biomedical monitoring, intercommunications, g load-time measuring and recording will be required.

Parachute shock opening load tests are recommended to be conducted with anthropomorphic dummies onboard boilerplate 3 and 19 if the results of the early C/M parachute tests dictate the necessity by indicating possible critical dynamic conditions. (Refer to Volume II, Section 4.0.) Photographic coverage and instrumentation will be required.

Zero-g flights with a partial C/M mock-up onboard a C-135 aircraft will be conducted to interface crew equipment and systems to the zero-g environment. Still- and movie-camera coverage, human subjects,

provisions for pressurizing pressure suits, biomedical instrumentation, and intercommunications will be required.

Developmental vibration testing of crew equipment and systems interfaces will be conducted with a test fixture and other necessary equipment. Qualification tests will be conducted concurrently with airframe 006. A vibration shake table and instrumentation will be required for developmental tests.

Altitude chamber tests will be conducted using the ECS high-vacuum test facility and the B/P command module pressure vessel. These tests will be conducted concurrently with the ECS test program. (Refer to Volume II, Section 5.0.) Human subjects will be monitored physiologically and biochemically to evaluate reactions to the normal command module environment and during numerous predictable emergency conditions. Spacecraft hardware will be utilized for systems such as the environmental control system, space suit assembly, waste management system, and food and water system. All crew provisions will be qualified to the atmospheric and thermal parameters involved.

2.10.3.2 Crew Engineering and Environmental Simulation Tests

Systems development tests will be conducted with evaluators E-1 and E-2. Human subjects, activated star field, 6-degree-of-freedom analog computer program, communications, 18-channel pen recorders, analog-to-digital converter, card punch write-out, closed circuit television, and photographic coverage will be required. These tests are integrated with the simulation program required by Apollo flight performance and control. A centrifuge and vibration and acoustic test requirements are stipulated in paragraph 2.10.3.1.

Crew integration and task allocation tests will be conducted in evaluator E-1 and simulator 1. Equipment requirements are similar to those previously mentioned.

Crew environments tests will be conducted in the crew systems analyzer in the early stages. Performance and physiological instrumentation, food and water supply, television monitoring, communications, input instrumentation, and digital readout and recording instrumentations will be required. Altitude chamber, centrifuge tests, and vibration and acoustic equipment requirements will be as specified in paragraph 2.10.3.1.

Integrated crew analysis qualification tests will be conducted in evaluator E-5, airframes 001, 006, and 008, and centrifuge, vibration, and acoustic test equipment. Equipment requirements will be similar to other respective vehicle tests specified in this paragraph and in paragraph 2.10.3.1.

CO[redacted]

[redacted]

2.10.4 S&ID Test Plan

The life systems test program will be conducted throughout Apollo design development and qualification. Testing will be carried out in two concurrent test areas. Human engineering design evaluation testing will be conducted to evaluate and qualify the Apollo system man-machine interfaces. The second test area will consist of crew performance and flight simulation testing to evaluate and qualify the interactive effects of human performance and systems performance.

2.10.4.1 Crew Evaluation (Human Engineering) Test Plan

Life systems design-evaluation (human-engineering) tests will be conducted to evaluate crew equipment, spacecraft systems, and related GSE systems machine interface designs. Initial tests will be conducted to evaluate life systems design concepts and functions and to obtain an early insight into problem areas or deficiencies of man-machine relationships. Design evaluation tests will begin with the preliminary drawing release. Testing will progress from breadboard equipment models installed in mock-ups and simulators and will continue throughout design development, major ground tests, boilerplate tests, and the flight-test program. A comprehensive dynamic test program will be conducted to test the crew couch and suspension and restraint system. Qualification testing will consist of tests conducted with AFRM vehicles or production quality equipment. To facilitate identification of specific test requirements, the life systems design evaluation program is divided into equipment and system categories as follows:

1. Crew equipment tests

   (a) Crew support (couch and attenuation) system

   (b) Restraint system

   (c) Space suit assembly

   (d) Crew assesories

   (e) Survival equipment

   (f) Biomedical equipment and provisions

2. Spacecraft (Crew) systems tests

   (a) Control-display systems

   (b) Crew systems tests

[redacted]

[redacted]

(c) Illumination systems

(d) Food and water provisions

(e) Waste management systems

(f) Environmental control system

(g) GSE (checkout, auxiliary servicing, and handling) systems

2.10.4.2 Crew Engineering and Environmental Simulation Test Program

The test program will be conducted to develop the crew-operated flight control systems, to determine crew operating procedures, task distribution, work-rest cycles, and to verify that the Apollo missions are within the range of human capability under the environmental conditions anticipated. The crew engineering and environmental test programs will be conducted in seven major areas as follows:

1. Mission phases
2. Dynamic base
3. Qualification testing
4. Crew integration
5. Habitability - environment
6. Transposition, seeking, rendezvous, and LEM interface
7. Navigational studies

The test program follows a logical developmental schedule. During the systems development tests, the basic flight control and systems management procedures are developed concurrently with systems dynamics. These systems are then combined in the crew integration studies (along with environmental data from the habitability tests) into an integrated evaluation of man/machine and man/man performance capabilities. The culmination of events will be accomplished during the qualification tests when all Apollo systems, environments, and procedures are combined in final qualification of the crew system. The criticality of the transposition, docking, rendezvous, and navigational phases makes it desirable to examine these phases separately and intensively.

2.10.5 Facilities

All crew performance and flight simulation tests and human engineering crew equipment and crew systems tests performed in evaluators, simulators, crew performance analyzers, mock-ups, or test fixtures will be conducted at S&ID Downey. All boilerplate and airframe vehicle tests will be conducted in conjunction with other S&ID multiple systems tests. Zero-g flights will be performed at Wright-Patterson Air Force Base in the C-135 flight laboratory. Centrifuge tests will be conducted at Johnsville, Pennsylvania.

[redacted]DENTIAL

CO[redacted]

[redacted]

2.10.6 Schedule

The test schedule for the life systems test program is shown in Figure 2-10.

2.11 GROUND SUPPORT EQUIPMENT

2.11.1 Scope

The ground support equipment (GSE) test program encompasses the systematic testing of the checkout, servicing, handling, and auxiliary ground support equipment used in all phases of the Apollo Program.

2.11.2 Objectives

The objectives of this test program are to establish, verify, and qualify the design of the ground support equipment.

2.11.3 Requirements

The equipment used to support the various GSE tests will vary as the nature of the GSE varies. In addition to the conventional laboratory type equipment, the program will require vibration machines, environmental chambers, bench maintenance equipment, shock machines, digital computers, spacecraft substitute units, and the house spacecraft.

2.11.4 Subcontractor Test Plan

The ground support equipment subcontractor development test phase will include testing of mechanical, structural, electrical, and electromechanical components, subassemblies, and assemblies, including complete consoles. GSE tests will include environmental and complete functional parameters that will satisfy normal operating conditions.

2.11.5 S&ID Test Plan

Checkout systems tests will be performed on combined system test units, prelaunch automatic checkout equipment, and bench maintenance equipment. These tests will include development qualification and acceptance tests. Development test will establish materials, design concepts, and hardware for final design. Qualification test will be conducted to demonstrate that the design will meet the performance and environmental requirements. Acceptance tests will be performed on each deliverable end item. Except for the integrated GSE test which demonstrates compatibility with the spacecraft equipment associated GSE and peripheral equipment.

Handling equipment tests will be performed on stands and dollies and on equipment installation or removal fixtures. Those tests will utilize

[redacted]

mock-ups, boilerplates, and spacecraft. Primary objectives of these tests are to determine adequacy of design, rigidity, feasibility, maintainability, and compatibility with the Apollo vehicle.

Servicing equipment tests will be performed on fluid transfer units, conditioning units, and storage units. These tests will be designed to demonstrate compatibility and suitability of end-item systems with the system they are designed to support.

2.11.6 Facilities

Those tests outlined in the S&ID test program will be conducted insofar as possible by S&ID, using S&ID facilities. The various subcontractor tests will be performed by the respective subcontractor using subcontractor facilities.

2.11.7 Schedule

The GSE test schedule is shown in Figure 2-11.

2.12 STRUCTURAL TESTS

2.12.1 Scope

This section consists of the structural test plan, including the development testing of components, subassemblies, complete spacecraft module structures, and combined structures of the command module, service module, adapter, launch escape tower, and GSE handling equipment.

2.12.2 Objectives

The objectives of the plan are to develop, optimize, and verify the structural integrity and analytic methods used in the design of the spacecraft components and in the complete structural design.

2.12.3 Requirements

Tests will be performed using components of the structure, the complete spacecraft, AFRM 004 and AFRM 005, and boilerplates 1, 2, and 28 Laboratory equipment, the S&ID impact facility, photographic and test support instrumentation, and recorders will be required.

2.12.4 S&ID Test Plan

S&ID will conduct component structural tests on the command module base, side wall, apex, windows, hatches, heat shield, and associated parts. These tests include vibration and sonic tests of typical panels, development of internal honeycomb sandwich structure, quarter-scale model impact

[redacted]

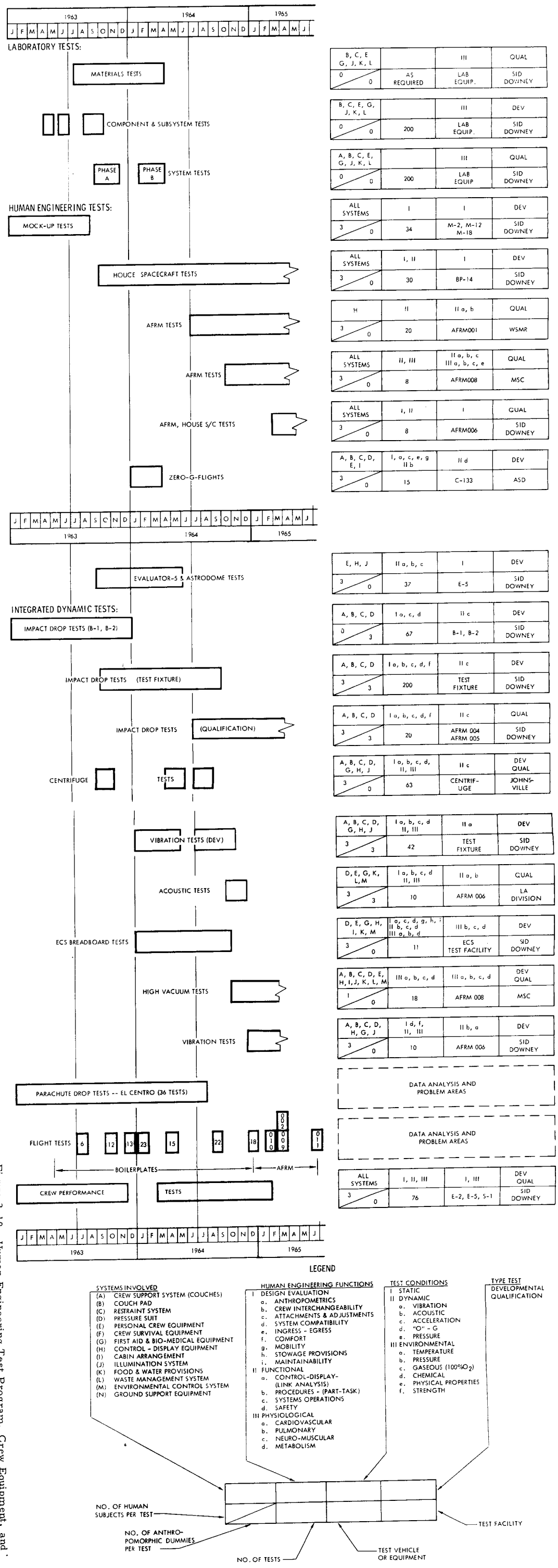


Figure 2-10. Human Engineering Test Program, Crew Equipment, and Spacecraft Systems General Schedule

CO[redacted]

[redacted]

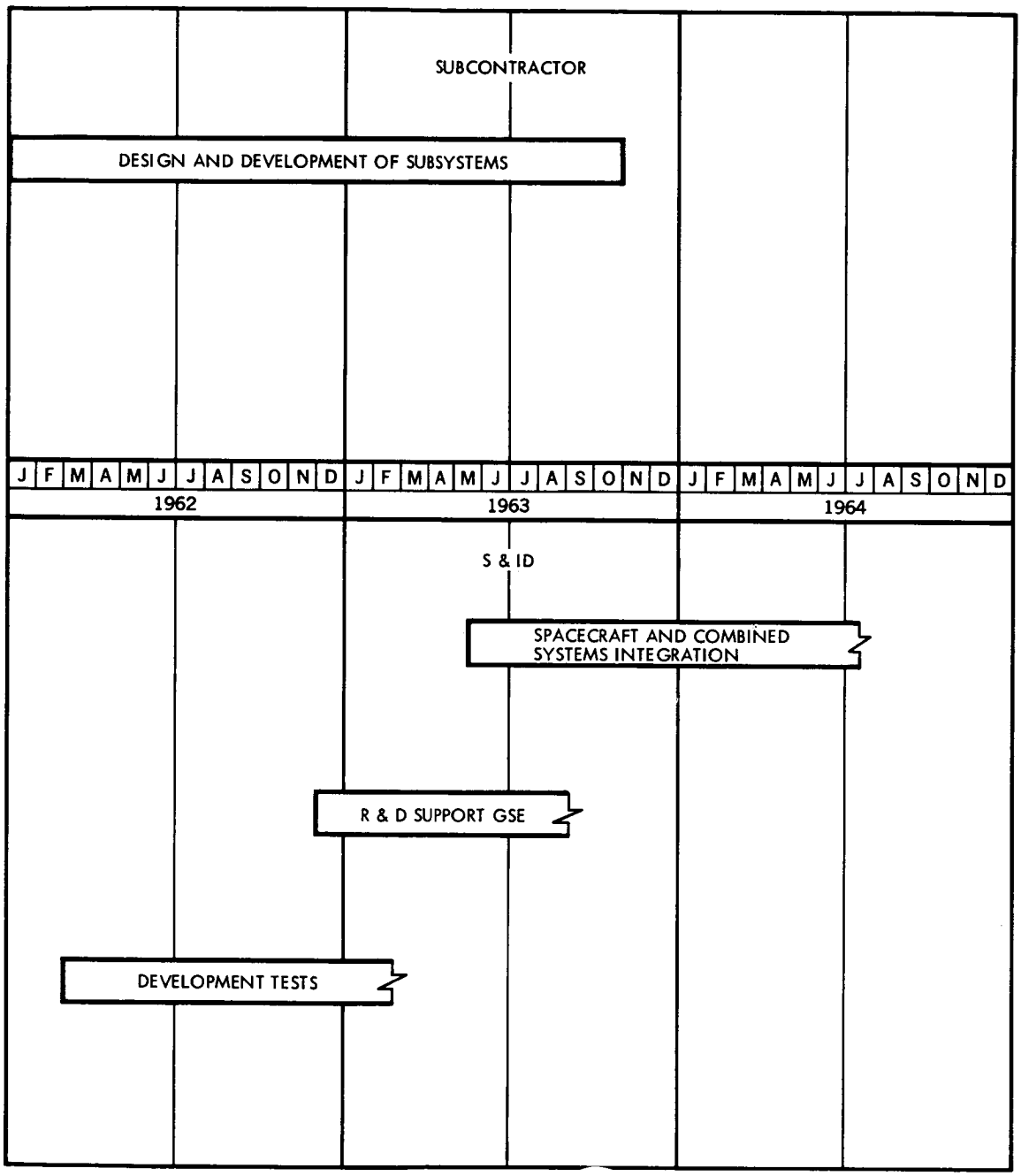


Figure 2-11. Ground Support Equipment Test Schedule

[redacted]

tests, and full-scale tests of boilerplates 1, 2, and 28, and airframes 004 and 005. The service module structural tests consist of pressure vessel tests, bulkhead, fire wall, heat shield, radial shear web, and associated parts. Additional tests include meteoroid shielding and spacecraft tests of AFRM 004. The launch escape tower structural tests include welded tubing cluster joints, sonic and vibration environment determination, static firing tests, and complete structural load tests.

2.12.5 Facilities

The tests will be accomplished at S&ID, other NAA division laboratories, NASA Langley, subcontractor's facilities, and at the Lockheed Propulsion Company facility.

2.12.6 Schedule

The structural test schedule is shown in Figure 2-12.

2.13 MECHANICAL AND ORDNANCE DEVICES

2.13.1 Scope

This section consists of the development plan for actuation, separation, release, deployment, positioning, and shock attenuation devices and components. The plans include laboratory development testing and design evaluation and prequalification tests.

2.13.2 Objectives

The objectives of the plan are to select, develop, optimize, and verify the configuration and performance of the mechanical and ordnance devices by structural and functional testing.

2.13.3 Requirements

Tests will be performed using spacecraft design components under environmental conditions for performance evaluation. Laboratory equipment, component and subsystem spacecraft devices, and photographic and test support instruments and recorders will be required.

2.13.4 S&ID Test Plan

S&ID will conduct laboratory tests in fixtures that simulate spacecraft installations. Initially, static and dynamic loads will be applied during operation at room temperature to evaluate design characteristics. Extensive testing of the spacecraft design configurations will be conducted under critical environmental conditions.

CO[redacted]

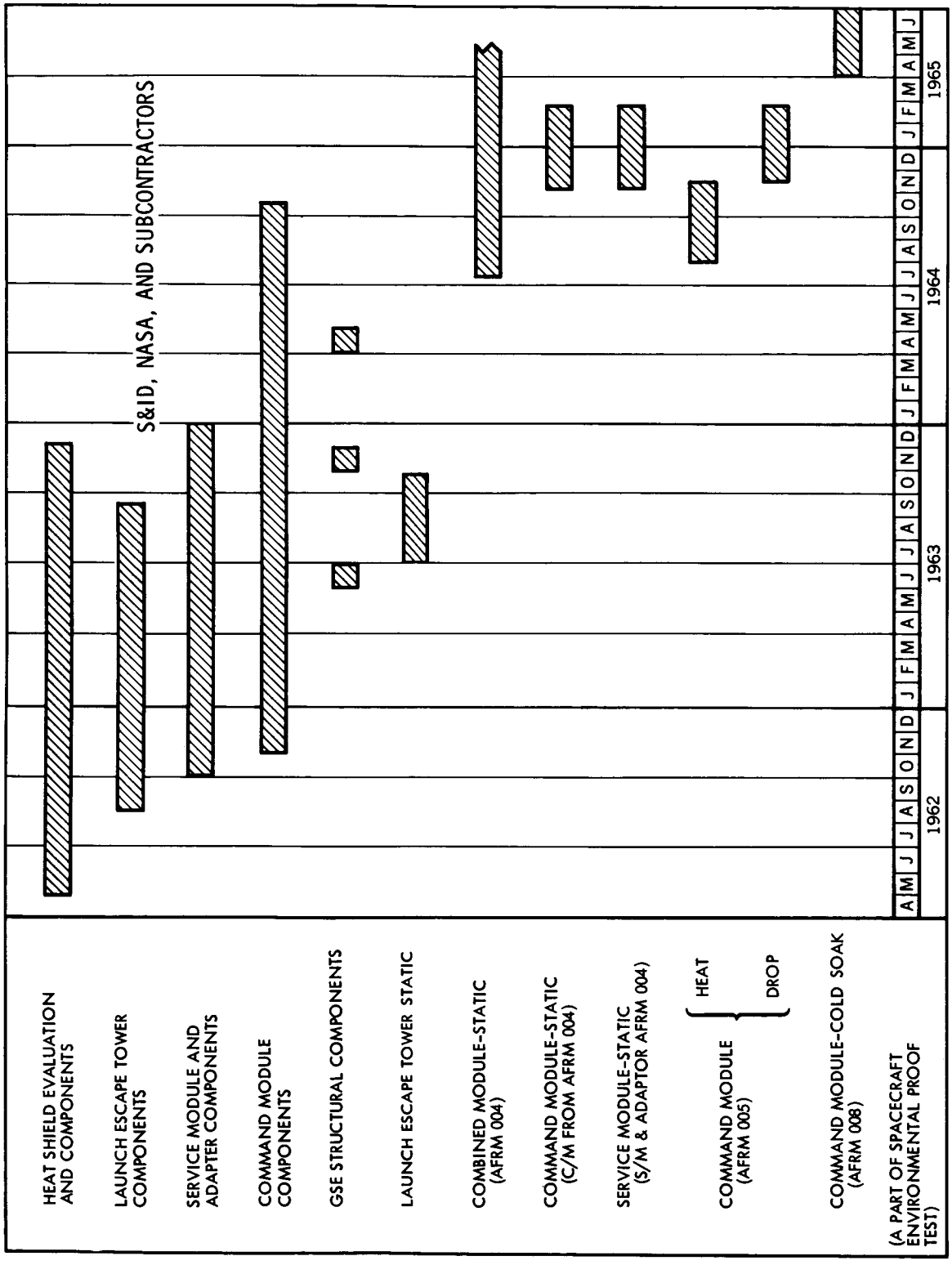


Figure 2-12. Structural Test Schedule

[redacted]

[redacted]

2.13.5 Facilities

The testing will be accomplished at S&ID, other NAA division laboratories, and subcontractor facilities.

2.13.6 Schedule

The mechanical and ordnance device schedule is shown in Figure 2-13.

2.14 MATERIALS, PROCESSES, AND PRODUCIBILITY

2.14.1 Subcontractor Test Plan

Development testing of certain materials and processes used in the heat shield, honeycomb sandwich, antenna window, etc., will be conducted jointly by the subcontractors and S&ID. In such matters as protective coatings and the effects of vacuum and radiation on bonded aluminum honeycomb, S&ID will determine and specify requirements, and a subcontractor will develop or conduct the testing.

2.14.2 S&ID Test Plan

This program will result in the selection of materials and processes necessary for the development of the Apollo spacecraft. The selection will result from research into authoritative technical and scientific literature and/or from test data concerning existing or newly developed materials and processes.

Tests will be conducted under environmental conditions to evaluate certain properties, such as sublimation rates of organic materials for obnoxious and toxic fumes and mechanical and physical characteristics, and to evaluate the effects of radiation, meteoroid impact, space environment, and fire hazard susceptibility on electrical insulators and conductors. Materials for thermal insulation, temperature control coatings, radar windows, seals, etc., and a family of suitable lubricants for mechanisms will be developed.

[redacted]TIAL

CO[redacted]

[redacted]

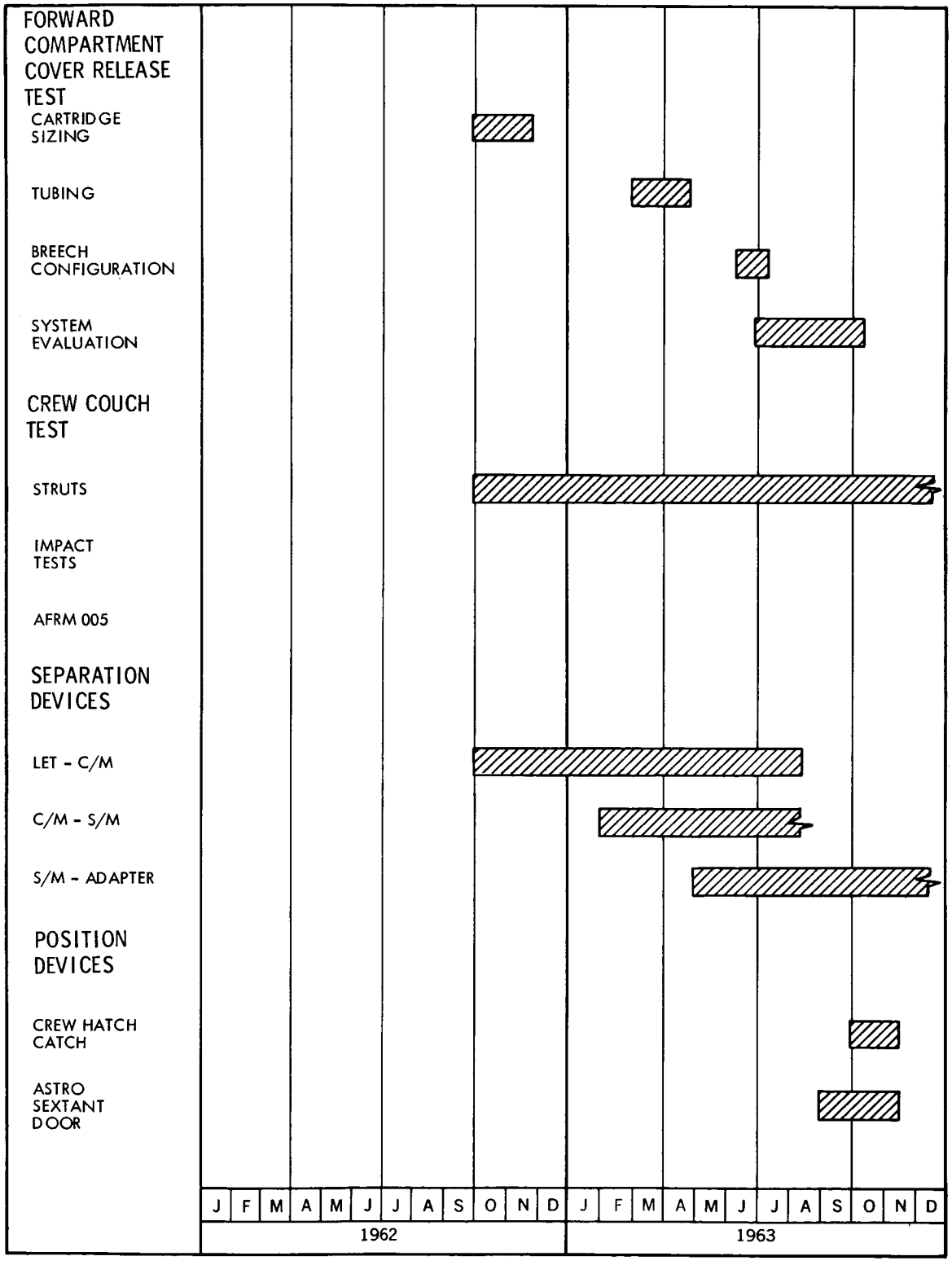


Figure 2-13. Mechanical and Ordnance Devices Test Schedule

[redacted]

[redacted]

Methods for leak detection, location, and repair, and for treating materials by or for cleaning, descaling, deoxidizing, pickling, coating, etc., are to be determined. Processes will be developed for welding, brazing, metal spraying, and bonding. Fabrication techniques for complex honeycomb shapes will be established.

2.14.3 Schedule

The materials, processes, and producibility test schedule is shown in Figure 2-14.

2.15 WIND TUNNEL

2.15.1 Scope

The Apollo wind tunnel test program has been devised to obtain aerodynamic stability, force, and heating data throughout the atmospheric flight regimes of Apollo missions and abort trajectories.

2.15.2 Objectives

The results from the test data analyses will be used to validate or modify the theoretical analyses that contribute to the design of the Apollo vehicles.

2.15.3 Requirements

The primary requirement for the wind tunnel test program is to obtain data applicable to Apollo design or flight planning activities. The model designs and the selection of the test facilities and conditions are, therefore, controlled by this requirement. A second requirement is to obtain data of value commensurate with the cost of the particular test program.

2.15.4 S&ID Test Plan

The wind tunnel test program can be divided into four categories: aerodynamic stability testing, aerodynamic loads and pressures testing, aerodynamic heat transfer testing, and structural dynamics. Data from the program provide a basis for evaluation of the design and performance of the launch escape vehicle, the entry configuration, and the space vehicle. Balance force data are obtained to determine both the static and the dynamic

[redacted]ENTIAL

[redacted]

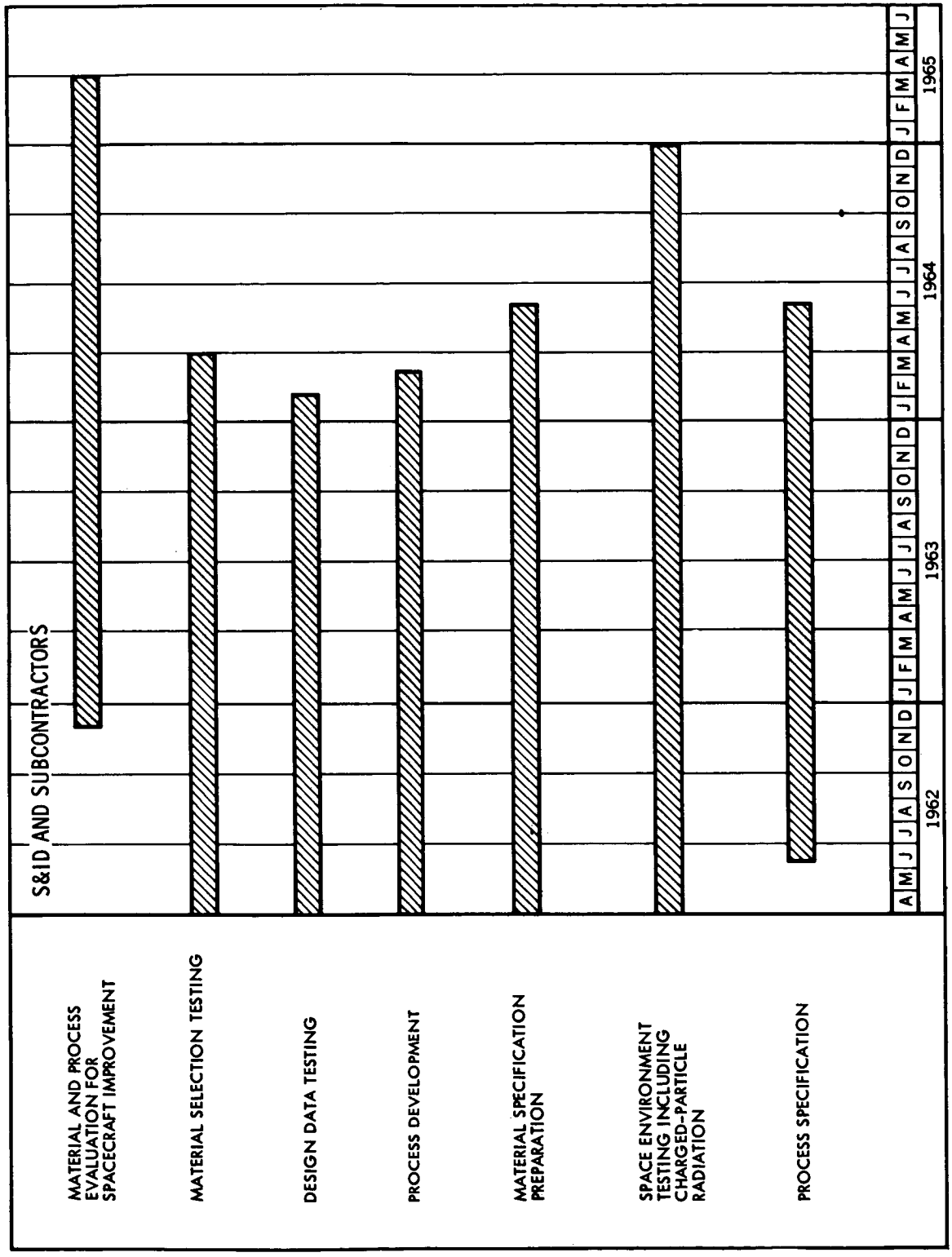


Figure 2-14. Materials, Processes, and Producibility Test Schedule

[redacted]

[redacted]

derivatives of the spacecraft configurations. Aerodynamic buffet and noise data as well as data concerning steady state pressures on the spacecraft configurations are assembled for the space vehicle.

Heat transfer testing includes the special area of heat generated by the service module propulsion system or by the reaction control system thrust chambers.

Several types of ground test facilities, both private and governmental, are to be used. Testing of large models in continuous flow tunnels will provide most of the data. Impulse and ballistic range facilities will be used to investigate aerodynamics at entry velocities and temperatures.

2.15.5 Facilities

Facilities used in the wind tunnel program include the NASA wind tunnels at the Ames, Langley, and Lewis Research Centers; the Jet Propulsion Laboratory; AEDC Air Force facilities; privately-owned facilities at the Cornell Aeronautical Laboratory; and the NAA-owned tunnels.

2.15.6 Schedule

The wind tunnel test program schedule is shown in Figure 2-15.

2.16 THERMAL PROTECTION SYSTEM

2.16.1 Scope

This section consists of the development test program for the thermal protection system. It is divided into heat shield development, antenna window development, and surface control coating development. This section is limited to laboratory development, evaluation, and design verification tests.

2.16.2 Objectives

The objectives of the plans are to select, develop, optimize, and verify configuration and performance of the thermal protection system. This will be accomplished by material property tests and environmental simulations on components including vibration, flexure, and acoustic tests. Preflight qualification testing will be performed on AFRM 006 and AFRM 008.

[redacted]

CO[redacted]

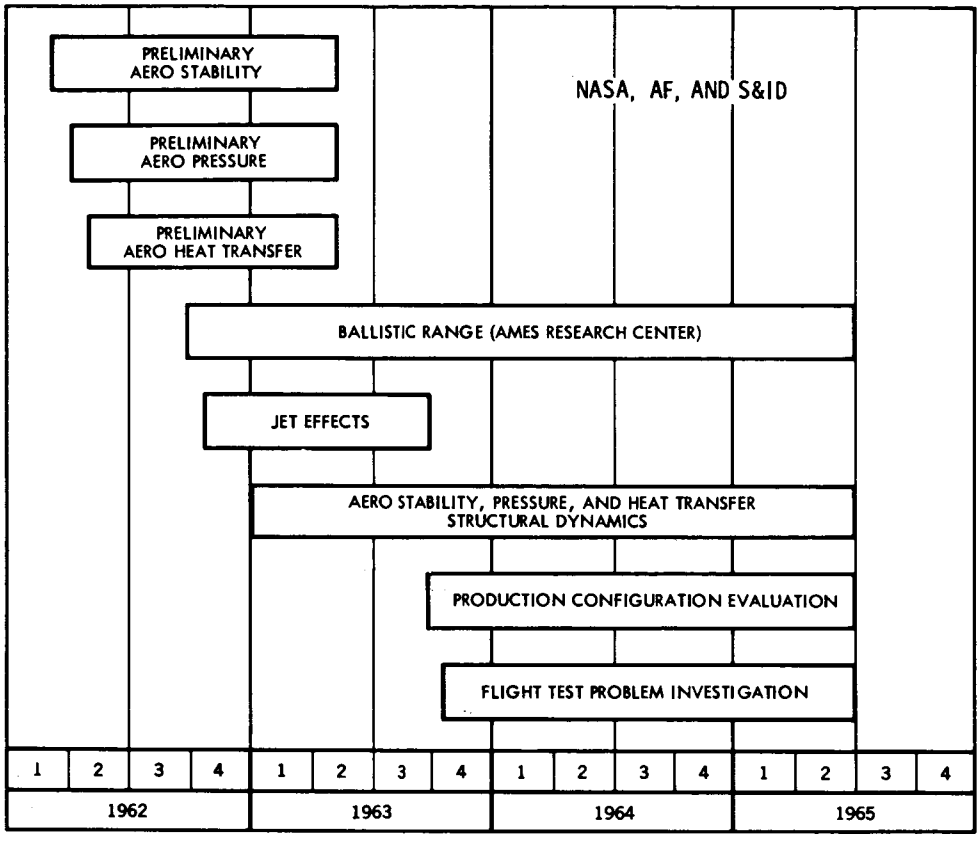


Figure 2-15. Wind Tunnel Test Schedule

2.16.3 Requirements

Tests will be performed using material specimen, substructural panels, composite panels with ablative material and substructure, and the two AFRM vehicles. Laboratory equipment, material specimens, AFRM 006 and 008, and photographic and test specimen instrumentation and recorders will be required.

2.16.4 Subcontractor Test Plan (AVCO)

The AVCO ablative materials will be evaluated under flight environmental conditions, and composite panels will be fabricated and tested for thermostructural evaluations.

2.16.5 S&ID Test Plan

S&ID will conduct substructure material evaluation, composite and substructure panel testing, antenna window material tests, surface control

[redacted]

[redacted]

evaluation of spacecraft insulation materials including a full-scale test of an insulated service module sextent, and full-scale preflight qualification tests of AFRM 006 and 008. Feasibility testing was conducted for the alternate heat shield to the AVCO program.

2.16.6 Facilities

The testing will be accomplished at AVCO facilities, at subcontractor arc jet tunnels, and at Downey and other NAA laboratory facilities.

2.16.7 Schedule

The thermal protection system development schedule for evaluation of insulation materials is shown in Figure 2-16.

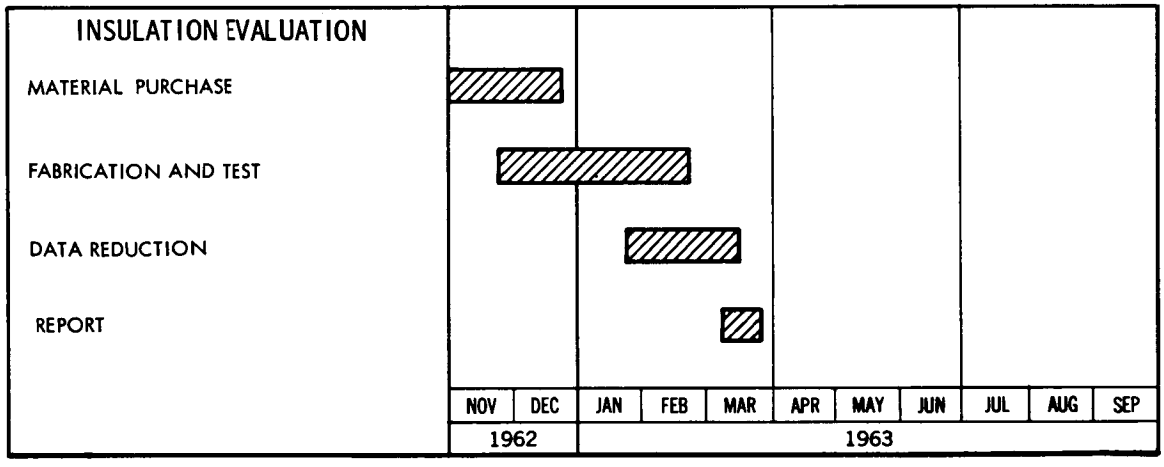


Figure 2-16. Thermal Protection System Test Schedule

CO[redacted]

2.17 IN-FLIGHT TEST SYSTEM

2.17.1 Scope

Both the subcontractor and S&ID have an integral part in the development of the in-flight test system. The subcontractor will perform design, qualification, and reliability demonstration tests on the in-flight test system and its associated ground support equipment. S&ID will perform interface tests, systems compatibility test, operational compatibility test, and simulation tests.

2.17.2 Objectives

The objective of the subcontractor tests is to demonstrate proper design, operation, qualification, and reliability of the in-flight test system. The objective of the S&ID test program is to insure proper design and operational integration of the in-flight system with the spacecraft.

2.17.3 Requirements

Tests will be performed using qualified and semiqualified in-flight test systems. Laboratory equipment will consist of a standard array of oscilloscopes, meters, etc. Special test equipment essential to the evaluation of the total integrated in-flight test system tasks (GSE) will be a parallel development.

2.17.4 Subcontractor Test Plan

The design, development, qualification and reliability demonstration of the in-flight test system and the associated ground support (bench maintenance equipment), will be performed by the in-flight test system subcontractor.

2.17.5 S&ID Test Plan

S&ID will perform command module and systems test in fulfillment of the design integration of the in-flight test system with the spacecraft. The in-flight test system subcontractor or his representative will provide technical assistance as required. The following categories of tests will be conducted by S&ID in fulfillment of the design integration of the in-flight test system with the spacecraft.

2.17.5.1 Interface Requirements

An analysis of system operations and interrelations with other spacecraft and ground-installed equipment will be performed. Tests will be

[redacted]

conducted to establish and define the interface areas and to determine the requirements, if necessary, for interface hardware. The necessary equipment will be developed, and intersystem tests will be scheduled to verify and evaluate hardware design. This effort will include the interfaces between the in-flight test system, on the one hand, and the communications system, environmental control system, electrical power system, stabilization and control system, LEM system, and controls and displays on the other.

2.17.5.2 System Compatibility

The electrical, mechanical, and functional relationships between the in-flight test system and other systems will be investigated. Noise and transient studies will be performed in both the laboratory and the command module to permit definition of the electrical environment in which the system must operate. The studies will evaluate system susceptibility to noise and transients, detect noise generated by the system and arrive at an optimum cabling configuration for minimum intersystem interference. Compatibility tests will be conducted to develop and evaluate the in-flight test, maintenance hardware and the procedures associated with the in-flight test system.

2.17.5.3 Operational Compatibility

S&ID will conduct such studies and tests as are necessary to evaluate and confirm the operational modes of the in-flight test system from the total-spacecraft viewpoint and to optimize the role of the astronauts in performing in-flight test functions in conjunction with all other spacecraft events. These studies and tests will include investigation of various malfunctions and failure modes, measurement of the effects of such malfunctions on interconnecting systems, and the interacting effect of other systems malfunctions upon the in-flight test system. The results will provide valuable system operating characteristics for the astronaut's use in coping with a wide variety of emergency conditions.

2.17.6 Facilities

S&ID testing of the in-flight test system will be carried out in the in-flight test system laboratory and S&ID.

2.18 DISPLAYS AND CONTROLS

2.18.1 Scope

The displays and controls are divided into three categories for purposes of test and checkout. Category one consists of those panel assemblies supplied complete and ready to install by the associate contractor or

CON[redacted]

subcontractor. Test and checkout is controlled entirely by the responsible system group, with D&C (Displays & Controls) having jurisdiction only over configuration and installation. Category two consists of those panel assemblies purchased in their entirety to NAA (D&C) specification. Qualification and acceptance tests are the joint responsibility of the supplier and D&C. Those panel assemblies which are system entities, such as the entry monitor display system, are the test responsibility of D&C through the mission phase. Category three consists of those panel assemblies which, after installation, become an extension of the parent system. These panel assemblies, up to installation in the S/C, are the test responsibility of D&C. After installation in the S/C, the test functions of the panel assemblies become a part of the test and checkout of the parent systems, and become the responsibility of the respective system group.

2.18.2 Objectives

Regardless of the source of the panel assembly, the spacecraft tests are conducted to demonstrate proper design, operation, qualification, and reliability of the equipment, and are performed to insure proper design and operational integration of the panels with the spacecraft.

2.18.3 Requirements

To fulfill the test requirements, standard test equipment will be used. Special test equipment for manufacturing installation tests and combined and integrated systems tests will be used in the laboratory. This special test equipment for manufacturing installation tests and combined and integrated systems tests will be developed by the responsible area groups.

2.18.4 Subcontractor Test Plan

In category one, the design, development, qualification, and reliability demonstration of the panel assembly, and development of associated ground support equipment will be performed by the responsible associate or subcontractor.

2.18.5 S&ID Test Plan

In category two (2.18.1), the sub-contractor and S&ID are jointly responsible for the design, development, qualification, and reliability demonstration of the panel assembly, and the development of associated GSE. S&ID has further responsibility, with the technical support of the subcontractor, for the compatibility with the S/C, and the interface area with the associated system for total test and checkout of the S/C.

[redacted]

In category three (2.18.1), S&ID is responsible through the respective design groups for the design, development, qualification, reliability demonstration of the panel assembly, and development of associated GSE. S&ID has further responsibility for performing compatibility and interface tests for the total test and checkout of the S/C.

2.18.5.1 Interface Area Tests

All panel assemblies, with the exception of the entry monitor display system, the caution-warning display system, the barometric indicator, the emergency detection system and the clocks and timers, are display and control extensions of their parent system. As such, combined systems tests and integrated systems tests of the panel assemblies become a functional part of the tests of the parent systems and will necessarily be integrated with those tests by the responsible systems group.

2.19 SIMULATION TEST PLANS

2.19.1 Scope

Simulation testing is a continuing effort which is divisible into three main phases: initially, preliminary and conceptual design are performed utilizing computational equipment. The next phase is concerned with evaluation of the several systems affecting the vehicle dynamics utilizing computational equipment and the evaluator complexes. The final phase of the simulation test plan will consist of a series of studies for the purpose of system design verification utilizing prototype hardware, computational equipment, engine simulators, and a flight table.

The data obtained from the simulation test plan provides design specifications for the various systems and subsystems and determines system compatibility in the integrated configuration including evaluation of the performance of the man-machine combination. Both preflight and post flight evaluation and verification and duplication of dynamic operations for the various missions will be performed as required to support flight test operations.

2.19.2 Objectives

2.19.2.1 Preliminary and Conceptual Evaluation (Phase I)

1. Determine design concepts for systems and subsystems.

2. Determine specifications and transfer functions for various systems and subsystems.

CO[redacted]

3. Determine engineering feasibility of operational procedures.

2.19.2.2 System Evaluation (Phase II)

1. Evaluate design specifications for the various systems.

2. Evaluate effect of system gains, dead-bands, hystersis loops, limits, and tolerances on system performance.

3. Evaluate interface requirements for guidance and navigation system.

4. Evaluate procedures and engineering trade-off techniques to be utilized in event of system malfunctions.

5. Evaluate man-in-the-loop performance.

6. Evaluate accuracy of the various systems and subsystems.

7. Evaluate relative capabilities of various manual and automatic backup modes.

8. Evaluate abort procedures for determination of operational requirements.

9. Evaluate controls and displays.

2.19.2.3 System Verification (Phase III)

1. Verify dynamic compatibility and performance of integrated systems.

2. Verify system specification.

3. Verify mission profiles for the several unmanned and manned tests.

4. Verify and evaluate flight test results.

5. Verify operational procedures.

2.19.3 Requirements

To accomplish the above objectives, certain equipment is necessary. The required equipment includes, but is not limited to the following.

[redacted]

[redacted]

1. Computational equipment including general purpose analog and digital computer, special logic consoles, and certain specialized interface gear

2. Three evaluators

3. Two simulators

4. Various prototype systems including the stabilization and control system, the guidance and navigation system, the entry survival system, the reaction control system, and certain communication equipment

5. External visual display equipment including simulated sextant and telescope to provide appropriate visual cues

6. Appropriate equipment for obtaining, processing, and storing required data

7. Special simulation devices such as the service module engine simulator and flight table

2.19.4 S&ID Test Plan

The schedule for the various phases of simulation test plan is shown in Figure 2-17.

Phase I of the simulation test is presently in progress and has been continually in operation since early 1962. Phase II of the program was initiated in July 1963 and will continue at least through 1965. The final phase of the study will be initiated during spring of 1964 and will continue in accordance with the program efforts.

The simulation test plan utilizes analog and/or hybrid computers for total simulation studies or is utilized in combination with simplified desk-top control panels for the initial phase of the plan. The evaluators, which are required for the second phase of the program, are mock-ups of the command module with simulated controls, panels, and visual cues. Continuous updating of the controls and displays and of the simulated systems will be conducted during the final phase of the program utilizing boilerplates. These are copies of Boilerplate 14 with provisions for integrating prototype hardware. In cases where prototype hardware is not available, breadboarded systems will be utilized wherever possible.

Provisions for monitoring the controls and displays during the conduct of any test will be provided through use of closed circuit television and duplicate display panels. A data acquisition system will be provided for both on-line and off-line processing and storing of data. Control and direction of the test will be provided by a test conductor utilizing a central control console which is integral to each simulator/evaluator complex.

2.19.5 Facilities

The simulators/evaluators complexes will be located in Building 4 of the Downey facility, S&ID. The computational devices, both analog and digital, will be located in a central area in proximity to the simulator/evaluator area. Other required specialized devices will be provided in the immediate area including data acquisition equipment, visual cues, and special test equipment.

2.19.6 Test Schedule

Figure 2-18 presents the present simulation test schedule for the simulator/evaluator complexes.

[redacted]

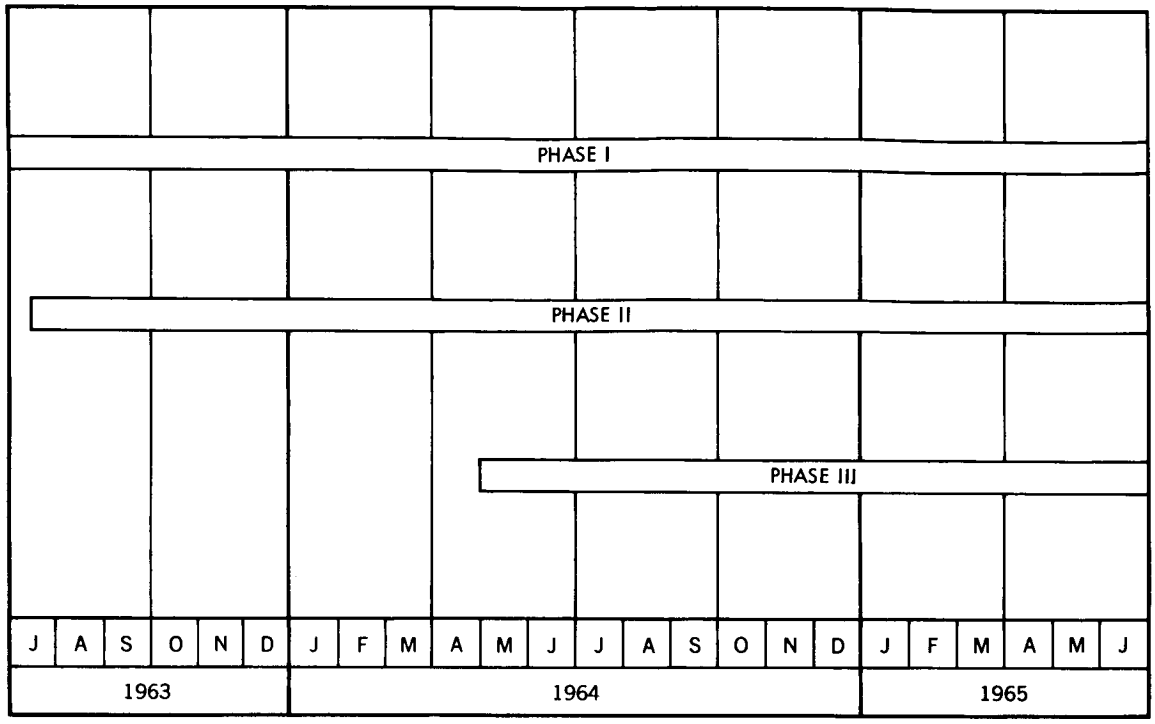


Figure 2-17. Simulation Schedule

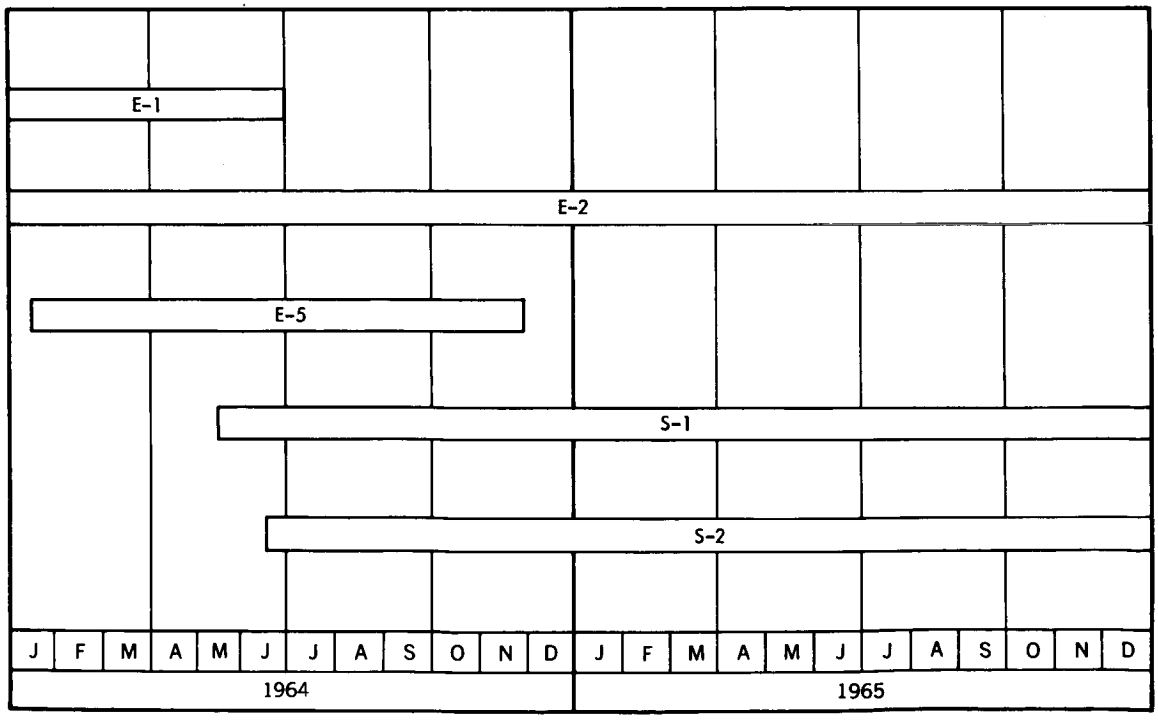


Figure 2-18. Simulator/Evaluator Schedule

[redacted]

CO[redacted]

3.0 GROUND QUALIFICATION TESTS

This section describes the Apollo ground qualification test plan presented more fully in Volume III. The ground qualification program has been designed to enable each subsystem to achieve mission essential product qualification, with a minimum testing of hardware, through the delineation of subcontractor requirements and their integration with program responsibilities of S&ID at successively increased levels of system qualification. This approach will enable all system components to be qualified in simulated mission environments to the extent of mission requirements, while eliminating any duplication of testing to identical levels of qualification. The separate qualification test plans define the manner in which the approved subcontractor and S&ID will accomplish the testing required to qualify the subsystems and the associated ground support equipment. The integrated system qualification test plan defines the manner in which S&ID with subcontractor support will accomplish the next successive level of qualification for the Apollo Systems. Integrated system qualification tests include system interface and compatibility testing and boilerplate and airframe testing leading to flight qualification tests. An inherent objective of this ground qualification test plan is maximum utilization of design, development, and qualification data from all test areas for the purposes of equipment qualification and reliability assessment.

3.1 SCOPE

The purpose of this program is to prove flight-worthiness of each subsystem to and beyond specification limits of functional and environmental stresses by ground simulation of established mission requirements. The objective of the ground qualification test plan will be to verify the results of the research and development of the Project Apollo spacecraft, as it progresses from engineering design and development testing to the flight qualification phase. Ground qualification will be achieved by demonstration of system capability to perform within specification requirements and demonstration that performance, functional, and quality provisions are repeatable on randomly selected test articles. As a consequence, the demonstration of system reliability cannot be a prerequisite for qualification.

Program objectives, schedules, and environmental criteria are delineated for all Apollo spacecraft subsystems.

The individual qualification of each subsystem is meticulously planned by clearly defining the scope of each test program, delineating the tests to be performed with the hardware required, and establishing the minimum test criteria consistent with component criticality.

[redacted]

[redacted]

The ground qualification test plan is applied to all the various types and classes of ground support equipment required to support the Apollo Project within the responsibility of S&ID.

The ground qualification test plan culminates in the operational integration of all subsystems as an entity, to assure dimensional and functional system compatibility.

3.2 GROUND QUALIFICATION PROGRAM-SPACECRAFT

The ground qualification program has been designed to provide an optimum compromise from a statistically rigorous demonstration of all the required design parameters at impossibly high reliability objectives to a reasonable program that can be accomplished within the many constraints imposed on the program. The program consists of a logical combination of tests designed to explore all potential weak points or "failure modes" in every component and then demonstrate the design margin relevant to these weak points both in the environment and time domains.

3.2.1 Program Logic

The environmental capabilities are explored and verified during the design proof phase of the tests. These are conducted at the component level and basically designed to verify that the component is capable of surviving the levels of a given environment. The off-limit test goes a step further and determines the design margin relative to the potential and/or critical failure modes. The mission life tests are conducted at the subsystem level and are designed to explore these parameters in the time domain. They are conducted under natural combinations of environments to be expected during a "normal" space flight. The term "normal" is herein defined as that condition wherein no critical malfunctions or combinations of circumstances exist that might cause a malfunction and prejudice mission success or crew survival. These tests provide data on the repeatability of the design parameters with time and between like items and subsystems.

Since the over-all qualification program is designed to explore all of the potential causes of unreliability, a reliability test program is derived by inference but not in the manner normally expected. Reliability demonstration is a statistically rigorous form and for the Apollo objective is impossible, at least within existing program constraints. However, in this program a logical application of good engineering principles and an

[redacted]IDENTIAL

CO[redacted]

examination of potential failure modes under all the anticipated conditions, including time, have yielded a new concept of reliability assurance, where calculating failure rates as a function of reliability tests becomes a second-order function.

3.2.2 Reliability Assessment

Since the Apollo qualification program does not yield the data necessary to demonstrate the over-all program reliability objectives to any assessable degree of confidence, a base line of reference must be established in order to make an assessment of reliability at any given point in time. Further, it must be applicable down to each separable functional area at least, in order to estimate the potential reliability of any given function and correlate it with failures if they do occur. The expression "mean (or average) time to failure" seems to provide the most applicable term to describe the failure characteristics of a function for Apollo. If this must be related to the reliability number associated with mission success (i.e., 0.96), it can be accomplished only by applying this number down to the functional level, for example, deep-space communications, propulsion, d-c power, etc. In most cases, this is actually below the subsystem level. This would impose an 8400 hours mean-time-to-failure for a group of components making up a function, where no redundancy exists exclusive of the group.

With the foregoing constraints in mind, it is now possible to state the ramifications relevant to the assessment of reliability within the qualification program. This assessment will be accomplished without the use of any additional test time or equipments. The assessment program will be based on the use of attribute data from all phases of the testing activity, from the moment of design freeze to the moment before the final launch.

3.2.3 Subsystem Qualification Phases

3.2.3.1 Design Proof for Apollo

The design proof tests, as applied to the Apollo, are a series of environmental tests conducted in sequence and at the maximum levels anticipated for a given environment anywhere and/or at any time during a normal or abnormal mission if it is within the design criteria. "Abnormal" may be considered a situation, such as Max-q abort, where crew safety is essential and subsystem integration, a secondary consideration. The test safety margin applied in these tests is about 1.33 times the level anticipated in more than 95 percent of the possible situations.

[redacted]

The design proof tests are imposed in a modified MIL-E-5272 manner, except that explosion-proof tests will be in a simulated spacecraft atmosphere rather than conventional aircraft. Electromagnetic interference tests will conform to S&ID specification MC 999-0002B. Further, by NASA instruction, the tests imposed to qualify Apollo for the transportation and handling phase have been modified to conform with the premise that all components, subsystems, and spacecraft will receive special handling up to the time of vehicle launch.

3.2.3.2 Off-Limit Test

The off-limit test is actually considered a part of the design proof phase, but successful demonstration of any given characteristic is not held as a contingency for qualification of any component under test. The tests are designed to determine the actual design margin relevant to any possible failure mode. The intent is to provide data necessary for the redesign of those characteristics that the tests indicate may contribute to unreliability.

The off-limit test is used to determine design margins and to enable the engineer to predict the potential reliability of a given characteristic or component. The test may involve stress to destruction. This is accomplished by determining the stress-strength margins related to each characteristic or failure mode and then algebraically summing them. Most of this work will be performed in the development program on the lower levels of assembly, but there is a definite need to verify these premises and to examine the effects of interfaces.

The exact characteristics to be tested for, by off-limit stressing or test to destruction, are a function of the failure mode analysis, which is to be performed on every component used in the Apollo spacecraft. The more critical modes will be analyzed by the off-limit techniques.

3.2.3.3 Mission Simulation Life Test

The mission simulation life test, as designed for Apollo, is a test phase established to simulate the normalized value of expected environments and the operational duty cycle for all phases of the equipment life from the first checkout through to recovery. The tests are to be conducted at subsystem or functional level to insure that there are no component interface problems. They will include a natural combination of environments wherever practical. Implementation of this will be limited only by availability of facilities and, to some extent, by scheduling.

[redacted]

CO[redacted]

The mission life cycle is composed of two phases—one simulates any activity which may have an effect on reliability during the prelaunch operations from the time a unit completes fabrication until launch is initiated, and the second phase simulates the postlaunch period up to and including recovery operation.

A total of at least four full-mission life cycles will be imposed on each complete system to be used in this test series. To qualify, however, each system must have successfully completed the first two full cycles. Limited life items will be replaced as required, but only after the second cycle is well along. Successful completion, as herein applied, implies that the subsystem must not have experienced any failures prior to reaching the approved life limit. Failures other than wear-out probably will necessitate redesign and retest. The second series of two cycles is required to establish repeatability between like subsystems and between like components, particularly on critical functions.

3.2.4 The Concept of Criticality

The logic employed to derive numerical values for criticality and the functional relationship between criticality and test time is predicated on the following assumptions:

1. Product integrity, as measured by the mean time before failure (MTBF), may be extended as the amount of experience acquired from testing is increased. MTBF may therefore be considered some function of the test time. This presupposes that testing reveals information which leads to design improvements, process, or quality changes, etc., all of which result in improved design integrity.

2. More test data is required on systems of higher criticality than on those of lesser criticality.

3. More test data is required on systems which cannot be improved through analytical techniques and those limited by relation to state of the art.

4. Criticality is a function of the relative orders of redundancy, alternate modes of operation, spares incorporated in a given subsystem design, and their effect on crew survival or mission success. Therefore, test time on subsystems composed mainly of series components must be greater than that required for subsystems with parallel components or where spares and/or alternate modes of operation are provided.

[redacted]

[redacted]

The intent is to reduce the risk that high-criticality or series components will cause or contribute to loss of the crew or failure to accomplish the mission. The program provides a test in which there is no greater risk factor with critical items than there is with hardware of lesser criticality. Equalization, or establishing constant risk factor and, therefore, an optimum approach, is the objective of the ground qualification test plan.

The derivation of criticality and examples of its application are presented in Section 2.0 of Volume III. The classification of criticality is shown in Table 3-1.

Table 3-1. Criticality Classifications

Class	Effect on Mission	Functional Relation
1	Impair crew survival (catastrophic)	No redundancy
2	Impair mission success or abort	Dual redundancy
3	Maintenance problem or nuisance	Triple redundancy of some form or nonessential equipment

There is no magical or mathematically rigorous way of making the transition from the criticality classification to the choice of an optimum test time; it must be based on sound engineering practice and program requirements.

3.2.5 Minimum Qualification Program

Reference is made to the AGREE report of the Advisory Group on Reliability, Electronic Equipment Office of the Assistant Secretary of Defense (Research and Engineering): "Reliability of Military Electronic Equipment" (4 June 1957), US Government Printing Office. The AGREE report recommends that the minimum test time be equal to, or greater than, three times the MTBF, in order to (1) "provide additional data in case of dispute" and (2) "provide information for corrective action in case equipment is rejected." This level is also subscribed to by industry as a whole. It is based on the premise that, if the reliability or mean time before failure (MTBF) is much greater than the level at which it is operated, the

CON[redacted]

chances of a failure occurring during the prescribed test cycle are negligibly small. All subsystems associated with Apollo fall into this category, since the required reliability is between one and three orders of magnitude greater than the proposed test level.

A minimum qualification program has been established and is considered by S&ID to be a base point. Anything less than this would compromise the objectives of the mission and yield insufficient data for meaningful qualification of the subsystems. An effective program depends on optimum and multiple usage of the hardware. Further, no "random" or unknown failures can be tolerated. All failures must be designed out of the system. The tests are planned and scheduled carefully to insure that a previous test conducted on a component will not prejudice the results of a following test. Refurbishment of components and systems is planned when multiple tests are scheduled or detrimental effects are expected during the early phases.

3.2.5.1 Hardware Requirements

The minimum qualification program has been defined to include two component or lower levels of assembly, for sequential single environmental, explosion-proof, and electromagnetic interference tests; one component or lower level of assembly for off-limit tests; and one subsystem for mission simulation and life tests. Replacements are necessary on highly critical, limited-life, or other items which require refurbishment prior to completion of this test phase. Table 3-2 summarizes the minimum hardware utilization.

Requirements for hardware, over and above this minimum program, are justified on the basis of criticality, expected mission life, and service life. Hardware tested to non-prejudicial environments during design proof tests may be utilized for off-limit environmental or functional testing. Refurbishment may be employed in other instances to make hardware from design proof suitable for off-limit testing. The number of subsystems to be subjected to the mission-life cycles is determined by the criticality classification of the function provided. The number of components required to support the systems in mission-life tests is based on the expected life of the component; where any component within a given subsystem would wear out before completion of the test, a replacement has been planned to assure four full cycles of mission-life tests.

3.2.5.2 Test Time

The Apollo General Test Plan applies the minimum program proposed by AGREE on the most critical items, i.e., a minimum test time of three

[redacted]

[redacted]

Table 3-2. Minimum Hardware per System

Test Phase	No. Black Boxes and Lower Assemblies	No. of Subsystems
Phase A: Design proof	3	0
Part 1, environmental	(2)	(0)
Part 2, off-limit	(1)	(0)
Phase B: Mission simulation and life tests	0	1*
Total	3	1*

*Plus replacements on critical and limited-life items; refurbish items requiring such action

times the required MTBF for items of criticality Class 1. A test time equal to the required MTBF was established for items of criticality Class 3. As a reasonable compromise, one and a half times the required MTBF was selected for criticality Class 2 items. The justification for reduced programs for items of lesser criticality is established in Section 2.0 of Volume III. The import of that work can be seen by inspection of Table 3-1.

The time required to qualify a system under the mission-life concept was determined to be a function of its criticality to the system and/or the total operating time accumulated throughout its expected life. The higher the criticality index, the more test data is required, and the higher the operating hours expected to accumulate in a synthesized cycle, the more test time is required to qualify the system. Much of the required operational time required to qualify under the mission-life phase will be derived from "attribute data" obtained from many other phases of the Apollo test program. It was found necessary to use this data because of the magnitude of data required to qualify Apollo for the lunar flight.

The operating hours accumulated on a system from its fabrication to recovery was synthesized by considering every step a component undergoes. A mission profile was drawn, depicting the prior-to-launch phases and the postlaunch phases. From the mission profile, individual subsystems or function "operated time" for prelaunch and "duty cycle" for postlaunch were derived. The total operating time to be imposed during

CO[redacted]

each mission-life cycle on a given subsystem is the sum of both. The total for any given subsystem will vary and is given in the related paragraph of Section 5.0, Volume III.

The total test time is determined by multiplying the appropriate MTBF by the MTBF multiplier obtained from the criticality classification of the item under consideration. The time for qualification tests is derived by subtracting applicable cumulative times from development tests, other qualification tests, and the flight program; the remainder comprises the objective for the mission-life tests.

3.2.6 Program Considerations

The ground qualification test plan proposed for Apollo is considered a bare minimum and must be carefully controlled. Fast reaction cycles must be established between NASA and S&ID to provide for the contingencies that are not included in the program and to prevent serious slippages in schedules. The probability and effects of a failure have not been provided for in the selection of numbers of hardware or in the tests and facilities planning. Any failure during qualification is, therefore, considered a contingency that will necessitate additional hardware, test time, and facilities.

Reliability demonstration is not considered a requirement for qualification, and no statistically rigorous reliability assessment will be made. Enough data probably will never be available to make an assessment relevant to the basic program objectives, either for crew safety or mission success, at any time during the program. However, an assessment will be made as a byproduct, using as much data as is available and to the degree possible at the given point in time.

3.3 QUALIFICATION SCHEDULES-SPACECRAFT SUBSYSTEMS

3.3.1 Concept

The qualification schedules are a graphical presentation of the test status for the components of all the Apollo subsystems. They display the time phasing of the development and qualification tests with respect to boilerplate and airframe vehicle milestones and the phasing of component qualification relative to system qualification. The intent is to present test schedules and the number of tests performed to facilitate the generation of launch constraints for each flight article. These constraints are the criteria by which the component degree of success is specified in development and qualification tests to assure a sufficiently high probability of success for each boilerplate or airframe mission. The schedules appear by subsystem in Section 3.0, Volume III.

[redacted]

3.3.2 Application

The qualification schedules assist in the generation of launch constraints for any given mission. The component in question is located in the applicable system schedule. The boilerplate or airframe launch date is drawn on the applicable system schedule and compared with the phase of component development. If this date line falls within the component's development testing phase, constraints consisting of a minimum standard to be achieved, such as a success to failure ratio, will establish the degree of qualification required for that component. A launch date falling within the qualification test phase would require similar constraints to be established for components in question. If a component has completed qualification prior to the launch date in question, no schedule constraints are required.

3.4 ENVIRONMENTAL CRITERIA–SPACECRAFT SUBSYSTEMS

Section 4.0 of Volume III defines the Apollo Program requirements as they relate to environmental criteria. The environments have been separated into two major areas, prelaunch and postlaunch, and are defined in their order of occurrence. The specific environments, combinations, and levels of severity to be encountered by the subsystems are detailed for the prelaunch and postlaunch phases.

3.4.1 Environmental Criteria

The qualification tests are designed in accordance with the environments that the subsystems will encounter, dependent upon the location of the equipment in the spacecraft. For this purpose, the spacecraft has been divided into four zones. These zones are illustrated in Figure 3-1. In addition to specific mission assignments and separable physical properties, each zone possesses characteristic combinations of environments and discrete variations in severity levels.

The environmental considerations, from completion of equipment manufacture to the actual point of launch (prelaunch phase), the mission environments as they occur successively, and the duration of each from the point of launch to command module recovery (postlaunch phase), are detailed in Section 4.0, Volume III. Generally, they exist as combined environments and are treated accordingly in the specific subsystem qualification test plans of Section 5.0, Volume III. The environmental tests pertinent to the Apollo Program are summarized in Table 3-3, which depicts their applicability to S/C zones and the test phases described in paragraph 3.2.3.

C[redacted]

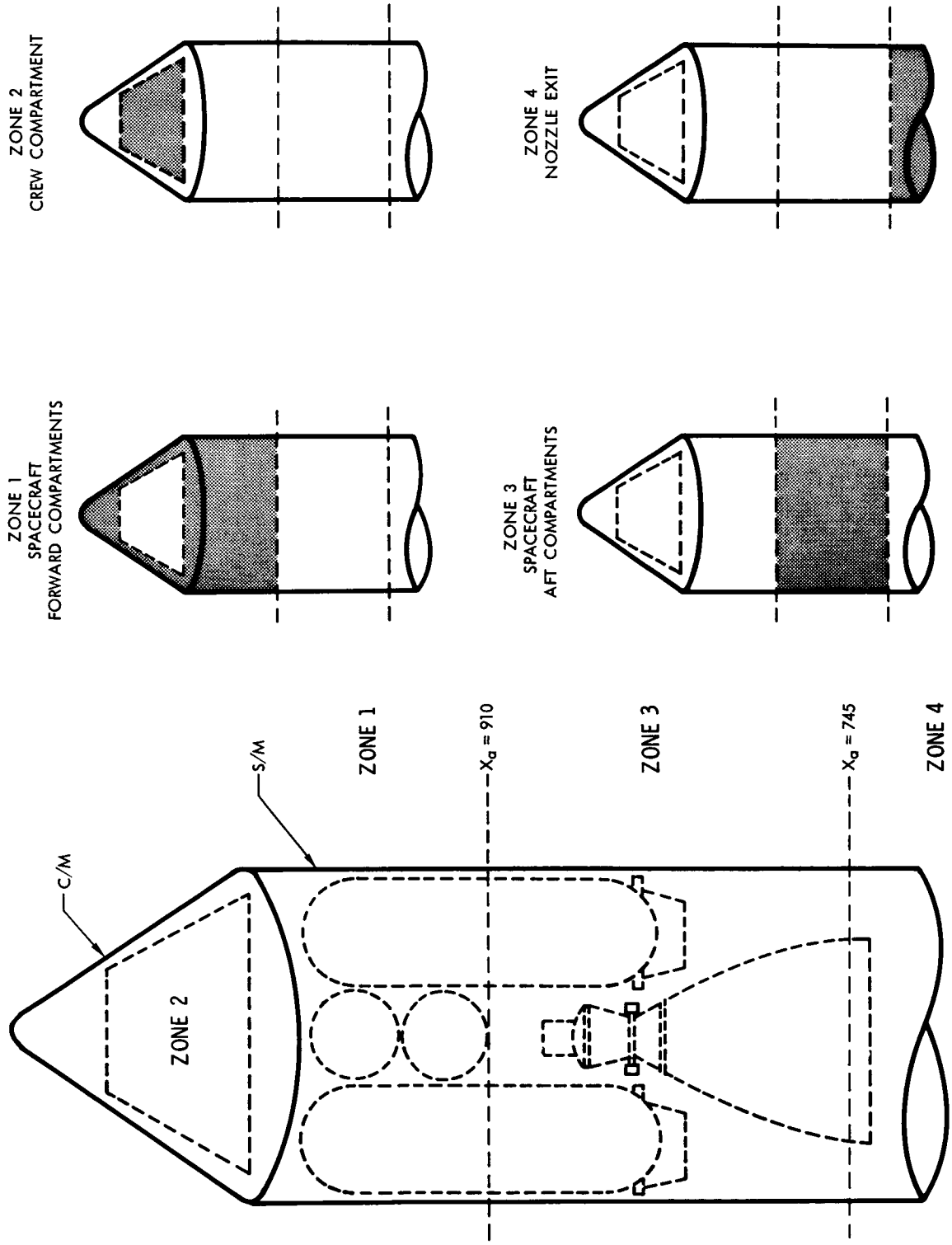


Figure 3-1. Spacecraft Zones

[redacted]

[redacted]

Table 3-3. Environmental Tests and Their Applicability to S/C Zone and to Test Phase

Test Phase	Environmental Test Title	Applicable S/C Zones (See Figure 3-1)
Climatics and checkout	Humidity	(1) (2) (3) (4)
	Sand and dust	(Exterior of S/C only)
	Salt fog	(Exterior of S/C only)
	Explosion	(1) (2) (3) (4)
	Electromagnetic Interference	(1) (2) (3) (4)
Design proof Mission sequential maximum level	Acceleration	(1) (2)
	Vibration	(1) (2) (3) (4)
	Acoustics	(1) (2) (3) (4)
	High temperature	(1) (2) (3) (4)
	Low temperature	(1) (2) (3) (4)
	Vacuum	(1) (2) (3) (4)
	O_2 atmosphere	(2)
	Thermal shock	(1) (2) (3) (4)
	Shock	(2)
Phase A Off-limit	Vibration	(1) (2) (3) (4)
	High temperature	(1) (2) (3) (4)
	Low temperature	(1) (2) (3) (4)
	Shock	(2)
Phase B - Life Mission sequential normal levels	Checkout life	(1) (2) (3) (4)
	Acceleration	(1) (2) (3) (4)
	Vibration	(1) (2) (3) (4)
	Acoustics	(1) (2) (3) (4)
	Vacuum high temperature	(1) (2) (3) (4)
	Vacuum low temperature	(1) (2) (3) (4)
	O_2 atmosphere	(2)
	Thermal shock	(1) (2) (3) (4)
	Shock	(2)

CON[redacted]

3.4.2 Test Criteria

S&ID will be advised not less than 48 hours in advance of a scheduled test. S&ID will notify MSC-ASPD of all tests and will witness any test, in whole or in part, or designate witnesses (in addition to those selected by the supplier) who have a "need to know" (e.g., consultants or government agencies). Test data will be required concurrent with or prior to delivery of the tested item. No tests will be delayed if the S&ID representation is not available. Pretest analysis, trends in testing and analysis of test results throughout the development, qualification and acceptance test phases will be employed to determine the critical tests to be witnessed by S&ID representatives.

Equipment used to measure item parameters should not introduce an error greater than 10 percent of the tolerance on the parameter; e.g., if a parameter tolerance is plus or minus 10 percent, the equipment error will not be greater than plus or minus 1 percent of the parameter nominal value.

No adjustments, repairs, or maintenance will be allowed during tests, unless they are a part of scheduled maintenance.

The failure reporting, analysis, and feedback system is planned to be in accordance with paragraph 3.5.12 of MIL-R-27542. Failure data will be reported in accordance with S&ID MC 999-0025, paragraph 3.5. All failures will be analyzed and corrective action implemented subject to S&ID approval and NASA review.

The applicability of one or more of the environmental tests and procedures will be determined by S&ID. Operational tests that are to be performed prior to, during, and after the tests will be included in the procedures.

3.4.3 Waiver of Test

If the supplier can furnish evidence of equipment or component compliance to the conditions and requirements of the qualification tests or evidence certifying that similar equipment or components have successfully passed tests equivalent to, or more stringent than, those required (i.e., during development on other programs), that portion of the qualification tests may be waived. Any test waiver will be subject to the discretion of S&ID. Evidence to be submitted in support of request for a test waiver should include the following:

1. Complete description of similar items, including photographs, drawings, and performance data

2. Test reports on test data of previously conducted functional and environmental tests (actual and similar equipment)

[redacted]

3. Supplier's comparison of the proposed article with that to which similarity is claimed, listing reasons and justifications to establish validity of similarity.

3.5 SPACECRAFT SUBSYSTEM QUALIFICATION TESTS

Section 5.0 of Volume III presents the individual subsystem qualification test plan and treats the physical characteristics and unique mission requirements of each subsystem. Each test plan has been designed to verify system capability to perform within design specification requirements for a sufficient length of time to accomplish its mission operational requirements. On a repeatable basis, with equipment selected at random, each test plan will establish as a minimum that inherent equipment capability exists to meet the subsystem reliability goals. Further, each test plan has been designed to qualify the respective equipment in ground simulation within the program requirements presented in paragraph 3.2, within the schedule constraints mentioned in paragraph 3.3, and within the environmental criteria summarized in paragraph 3.4. Test oriented reliability logic diagrams, listings of system parameters for qualification testing, and qualification test schedules constitute the subsystem test plans of Volume III.

In general, ground qualification of the subsystem, subassemblies, or components peculiar to the subsystem will be performed by the subcontractor. Responsibility for ground qualification of system compatibility and integration will remain with S&ID.

3.5.1 Scope

The purpose and objectives of the individual qualification test plan are defined specifically for each subsystem. Extent of testing and ramifications peculiar to the subsystem are delineated in Section 5.0 of Volume III.

3.5.2 Reliability Logic Diagram

A reliability logic diagram oriented toward qualification testing is shown in Volume III for each subsystem. The logic diagrams will be helpful in performing system studies to establish continuity of test, malfunction analysis, and collection of data for reliability assessment.

3.5.3 System Parameters for Qualification Testing

The criticality index described in paragraph 3.2, the spacecraft zone location illustrated in Figure 3-1, the total hardware requirements,

and the test utilization of the hardware have been tabulated for the components of each subsystem in Volume III. The environmental tests, the levels of severity, and the time of duration are applied to the hardware in accordance with the criticality index, the zone location, and the number of components available.

3.5.4 Qualification Test Schedule

A qualification test schedule has been established for each subsystem to achieve the objectives of the ground qualification test plan as they relate to the individual system within the constraints of the Apollo Project. The schedules define the test utilization and availability of components, sub-assemblies and subsystems, the application and duration of environmental tests, combination environments, and functional checkouts by dates of accomplishment.

3.6 GROUND SUPPORT EQUIPMENT

3.6.1 Scope

The ground qualification test plan will be applied to the various types and classes of ground support equipment required to support the Apollo Project within the responsibility of S&ID.

The quantity of ground support equipment, the diversity of functions, and the nuances in qualification testing demand the establishment of a unique qualification program tailored to meet the specific requirements of GSE. The development and application of the ground qualification test plan as they relate to GSE are summarized here and presented in detail in Section 6.0, Volume III.

3.6.2 Concept

There are many categories of tests, classes of GSE, environmental and criticality considerations, and functional groupings of equipment which must be organized into a comprehensive test plan with firm and logical criteria established to make each classification distinct and useful within itself. Table 3-4 illustrates the factors and their interaction to be considered.

[redacted]

Table 3-4. GSE Classifications

Classifications	Functional Grouping	Test Categories
A. Equipment	1. Checkout	A. Development
Class I - Mission essential	2. Auxiliary	B. Qualification
Class II - Mission non-essential	3. Servicing	1. Design proof
B. Environmental	4. Bench maintenance	2. Life
Class I - Controlled	5. Handling	C. Acceptance
Class II - Noncontrolled	6. SCD's	
C. Criticality		
Class I - Prejudice crew survival		
Class II - Cause pad or In-flight abort		
Class III - Cause count-down recycle		

GSE, initially, was divided into mission essential and mission non-essential, equipment determined on the basis of its individual contribution to the mission. This division placed 10 percent of the GSE in Class I (MEE) and 90 percent in Class II (MNEE). A criticality classification determined by analysis of effects on crew survival and mission assignments was then imposed on mission essential equipment to establish maximum and minimum levels of MEE qualification consistent with reliability requirements and test program cost optimization. For the same reason, an environmental classification was imposed on the complete GSE to reduce the number of environmental test types required. Finally, a functional grouping of the GSE was made to complete the requirements analysis and assure the most effective test effort. Of the functional groups the MEE classification is limited to the first three groups; MNEE includes the six groups.

[redacted]

These concepts are fully defined in Section 6.0 of Volume III. Their application is briefly illustrated in paragraph 3.6.4 below.

Although the terminology may be self-defining, mission essential will be defined here to promote understanding of the GSE qualification program. A piece of GSE will be classified as mission essential if it is in a closed loop with the spacecraft any time just prior to or during countdown so that it may be involved in one of the following:

1. Fail to detect a malfunction.

2. Introduce a malfunction.

3. Cause a complete countdown recycle, short delays not included.

Similarly, the classification of environment should be defined. The GSE is expected to be subjected to two classes of environments as a function of equipment use and location. The types of environment to be applied as a function of equipment classification are presented in Table 3-5. Sand, dust, and salt fog are applied only to equipments expected to be unsheltered, or in an uncontrolled environment. As in the spacecraft tests, it has been assumed, with NASA concurrence, that the equipment will receive special handling. The specific levels of environmental tests are presented in Section 6.0 of Volume III.

3.6.3 Considerations

The GSE program has many considerations which govern the extent of the qualification test plan. The test planning has therefore been limited and designed to work within these bounds.

The sample size is limited in most cases to one item. In some cases that item is also the end item to be delivered. Additional items will be required for certain mission essential equipment. The time available for qualification testing is often limited to such an extent that only a conventional acceptance test can be accomplished.

The environmental limits applied to the GSE are very different from the spacecraft applications, being basically limited to those specified in MIL-E-4970, which applies only to those components that undergo a comprehensive qualification program. One-of-a-kind items are considered special cases and are evaluated by an expanded acceptance test only. As in the spacecraft tests, electromagnetic interference is checked in accordance with S&ID specification MC 999-0002B.

 [redacted]

[redacted]

Table 3-5. GSE Qualification Test Catalog

Environmental Tests By Test Category	*Mission-Essential		*Mission Nonessential	
	** Cont Environment	**Uncont Environment	** Cont Environment	**Uncont Environment
A. Development	1	1	1	1
B. Qualification				
High temperature	4	4	4	4
Low temperature	3	3	3	3
Low pressure	2	2	2	2
Humidity	7***	7	7***	7***
Vibration	6	6	6	6
Shock	5	5	5	5
Salt spray		8*		
Sand and dust		9*		
Rain		10*		
Operating temperature		11		8
Tilted position	8***	12***	8***	9***
Electromagnetic interference	9	13	9	10
Noise	10***	14***	10***	11***
Lifting	11***	15***	11***	12***
Dielectric	12	16	12***	13***
Insulation	13	17	13***	14***
Continuity	14	18	14***	15***
Life	15	19	15	16
C. Acceptance				
Examination of product	16	20	16	17
Nondestructive tests	17***	21***	17***	18***
Continuity	18	22	18	19
Functional checkout	19	23	19	20

*Component classification
**Environmental classification
***Where applicable

The numbers indicate the suggested sequence of application.

[redacted]DENTIAL

CO[redacted]

Other constraints, such as facilities scheduling and varied environments at the point of application, complicate the program planning. However, the program presented is considered a reasonable compromise.

3.6.4 Implementation

The over-all GSE test program has been divided into three categories. To the greatest extent possible, all testing performed within the scope of this program, and data resulting therefrom, will be integrated to provide the maximum applicable information for qualification and assessment of reliability.

The three categories are: (1) Development tests, (2) Qualification tests, and (3) Acceptance tests.

3.6.4.1 Test Category

3.6.4.1.1 Development Tests. These tests are conducted for the following purposes:

1. Evaluation of materials, parts, components, and circuits to determine their application suitability

2. Acquisition of design or process information

3. Assurance that the product will successfully complete the qualification tests

These tests will be designed to locate significant failure modes and to determine effects of critical single and combined environmental and/or functional stresses and combinations of tolerances.

3.6.4.1.2 Qualification Tests. Qualification tests of appropriate parts, components, subassemblies, and higher levels of assembly will demonstrate that the design is inherently capable of meeting the performance and environmental requirements. The tests will be performed at the most practical level of assembly. The qualification tests are divided into two phases: Phase A, Design Proof; and Phase B, Life Tests.

3.6.4.1.2.1 Phase A. Design proof testing includes the following:

Transportation and handling	MIL-E-4970A
Electromagnetic interference	S&ID specification MC-999-0002B
Off-limit tests	Functional and nondestructive

[redacted]

[redacted]

The off-limit test, as applied to Apollo GSE, is a functional off-limit test, designed to explore critical failure modes, which was the reason the equipment was classified MEE. The specific application of this test will therefore be determined by the failure mode and effect analysis. Specific data will be supplied in later revisions of this document. The tests will be applied only to mission essential equipment in GSE criticality Classes I and II. They will be designed to be nondestructive in nature.

3.6.4.1.2.2 Phase B. Life tests will be applied to mission-essential units and certain other long-life components. They will consist of exposure to natural environments. Each unit assigned to life tests will be required to complete a given number of simulated use-operation cycles without any failures. The number of cycles are determined as a function of criticality. The use of spares will not be permitted. Upon completion of the prescribed cycles, critical and limited life items may be replaced and the equipment will then be subjected to the additional cycles required to make up at least four cycles. Only the first series of operational tests will be utilized to determined compliance with qualification requirements.

The following times imposed for GSE one-cycle use-operation are based on past experience extrapolated to what is defined and anticipated for Apollo. These are average times and not considered rigorous.

Factory checkout and acceptance	65 hours
S&ID Downey use	110 hours
On-site (prior to launch ops)	125 hours
Pad use (includes 3 countdown recycles) (Applied to MEE only)	100 hours
Total	400 hours

3.6.4.1.3 Acceptance Tests. Acceptance tests are those tests necessary to meet the functional and operational requirements of the procurement specification. The tests will be performed on each item of equipment submitted for qualification to assess the acceptance test procedure effectiveness. These tests are not within the scope of this section except as used for qualification. (See Volume IV.)

3.6.4.2 Test Criteria

Equipment used to measure item parameters will not introduce an error greater than 10 percent of the tolerance on the parameter; e.g., if a parameter tolerance is ±10 percent, the equipment error will not be greater than ±1 percent of the parameter nominal value.

[redacted]

No adjustments, repairs, or maintenance will be performed during tests, unless they are a part of scheduled maintenance or such adjustments, repairs and/or maintenance are not due to faults in design, materials, workmanship, or to the test conditions imposed.

Detailed malfunction data will be recorded as a part of the normal equipment testing operations. All failures will be analyzed and a corrective action implemented. The designation, "Retest OK," will not be considered acceptable; a complete analysis will be accomplished for all failures.

If evidence can be furnished of equipment or component compliance to the conditions and requirements of the procurement specification or certifying that similar equipment or components have successfully passed tests of criteria equivalent to or greater than those required, the applicable portion of these tests will be waived. Evidence submitted to support the above will include the following:

1. Complete description of similar item, including photographs, drawings, and performance data

2. Test reports and test data of previously conducted functional and environmental tests (actual and similar equipment)

3. Suppliers comparison of the proposed article with which similarity is claimed, listing reasons for such similar claims

The hardware requirements and the extent of testing are a function of the particular equipment's contribution to the mission, its criticality, and environmental classifications. Specific test programs are detailed in Section 6.0 of Volume III.

3.6.4.3 Assessment of Reliability

The reliability assessment program will be planned in accordance with the spacecraft program, except that no additional hardware will be programmed to assess reliability. The program includes specific ground rules for choice and application of data from all areas of test. The actual assessment of reliability will be accomplished by an analytical treatment of data from tests designed to determine design margins and life versus failure rate characteristics. Qualification testing will be monitored and controlled to the greatest possible extent, to assure maximum usefulness of the derived data for reliability assessment.

[redacted]

[redacted]

3.7 INTEGRATED SYSTEMS QUALIFICATION

3.7.1 Scope

Qualification and reliability program requirements to be accomplished prior to and in support of any and all phases of integrated systems testing must be established in order that component and subsystem qualification or flight worthiness for each boilerplate or airframe test may be assured. These test objectives are determined by preflight analysis of vehicle readiness and establishment of success criteria, termed "Interim Qualification Requirements". These are based on the mission objectives which in turn form the control measures to be satisfied before a given flight should be attempted. Section 7 of Volume III, therefore, confines itself to the program requirements and objectives relevant to the qualification and reliability aspects of integrated systems testing.

3.7.2 Purpose

Qualification and reliability requirements are established for each integrated systems test in order to assess the flight readiness of the test vehicle and its components as well as to predict the probability of success of the mission relative to its objectives. The assessment of flight readiness and the prediction relevant to test success serve to optimize the extent and interaction of each test objective with respect to the over-all qualification program.

3.7.3 Method

A flight/qualification flow chart appears in Volume III, Section 7, showing the philosophy and implementation of integrated systems testing. Interim qualification requirements are delineated in tabular form for each flight vehicle in ascending order of severity concurrent with the mission objectives as they become more and more complex and extensive. The intent is to insure a reasonable probability of accomplishing the mission objectives.

[redacted]

4.0 ACCEPTANCE TEST PLANS

Since the Apollo Program is a high-reliability effort and the constraints are such that a detailed, extensive reliability demonstration program is impractical, a vigorous and achievable effort will be incorporated in the design, development, qualification, reliability, production, and acceptance test areas. Emphasis will be placed in the acceptance area (supplier and S&ID) for the basic reason that, although reliability cannot be tested into a unit, a properly planned acceptance test program will maintain the standard achieved by Apollo Engineering and will prevent the high reliability of qualified units from being degraded during the production process. This is accomplished by designing the tests to assure a narrow distribution of tolerances. It must be emphasized that in order to be effective, any analysis of the acceptance data must include data accumulated during various in-process tests of the production stages.

4.1 SCOPE

This section presents the acceptance test program as it is to be applied to the Apollo spacecraft and its associated ground support equipment (GSE). This section was generated to delineate the basis for the acceptance test program and to present the philosophy of application. Subsequent revisions of this section will present a more complete picture of the program from the point of view of concept and its application to any subsystem or relevant level of assembly.

Acceptance testing, as presented in this section, will be performed, where practical, at the supplier's facility immediately upon completion of the in-process tests of the production area. At the S&ID facilities, receiving and/or system checkout will be accomplished only when no comprehensive and acceptable tests were accomplished prior to receipt by S&ID. The equipment test flow chart, relevant to acceptance tests, is presented in Figure 4-1. For further discussion of acceptance criteria, see Volume IV of the General Test Plan.

4.2 CONCEPT

4.2.1 General

The acceptance test program is based on the premise that rigorous control and limitation of all measureable quantities that affect system performance by the introduction of variances about some mean (usually the

[redacted]

[redacted]

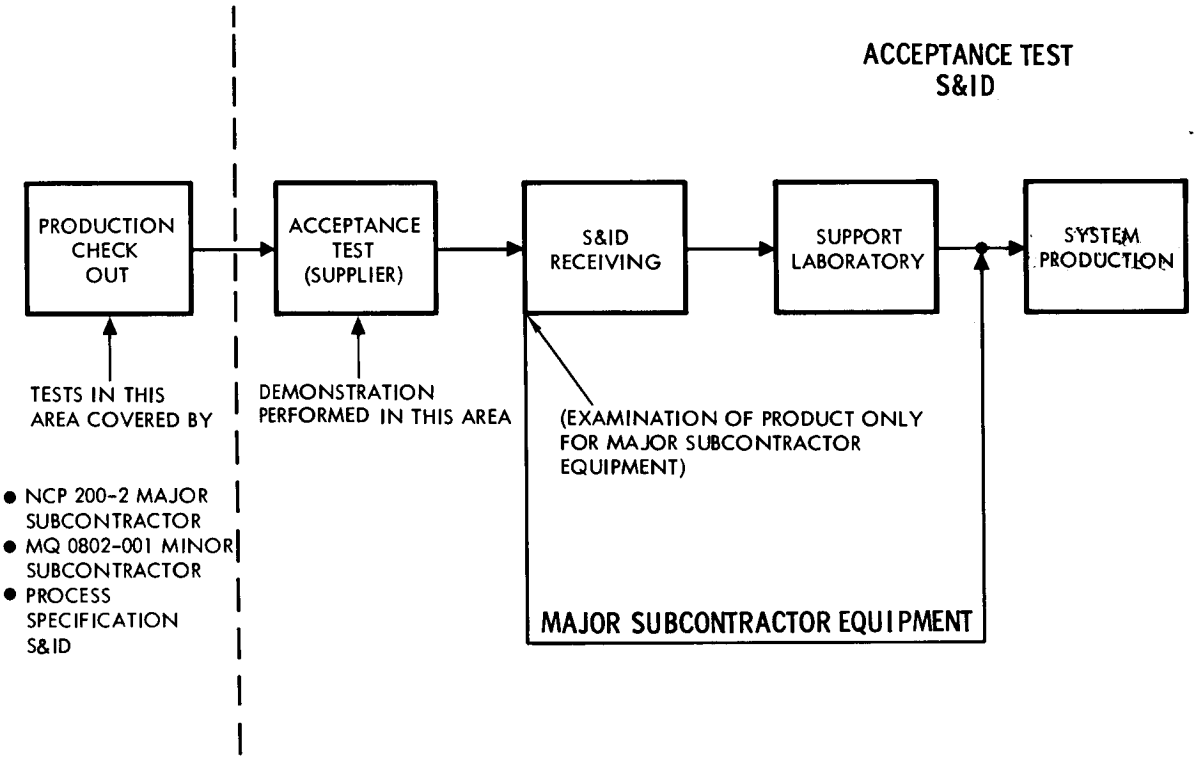


Figure 4-1. Equipment Test Flow Chart

[redacted]IAL

absolute desired value of the parameter) can make the attainment of a reliability that approaches the inherent reliability of the product possible. In order to understand this concept and to establish the validity of the premise, it is necessary to understand the physics of failure as it is affected and controlled by a screening process such as planned for Apollo acceptance testing.

It must be emphasized that this is not the "normal" acceptance test program when an end product is evaluated on its own merits with no consideration given to relevant prior data. Rather, this program requires an evaluation of prior data gathered at different stages of the production process, plus an extensive test program designed to evaluate the end product's functional capabilities in a nonprejudicial environment. A final engineering decision is required on the merits and potential reliability of a given component on an individual basis.

4.2.2 Premise

The program objective must be to limit the distribution of variances for any given parameter within safe tolerances. It is obvious that as the distribution of stress approaches the distribution of strength the probability of failure increases (see Figure 4-2). It is less obvious that as the distribution of strengths about a given mean increases the probability of failure (strength 2) increases. If the foregoing follows, steps must be taken to compensate and control this potentiality. S&ID proposes to do this during the Apollo Program. It is Apollo Engineering's basic responsibility to incorporate an adequate margin between stress and strength in its designs. This responsibility is being implemented, and further discussion is contained in Volume III of the General Test Plan. It is also Engineering's responsibility to describe tolerances for parameter variation. This has also been accomplished, but the analysis and control of the parameter variations can be accomplished only by the acceptance test program.

4.2.3 Implementation

Supplier acceptance tests will be monitored by S&ID Quality Assurance personnel or their representatives. Data obtained during these tests (successful or not) will be carefully monitored and assessed by an Apollo Engineering representative. Acceptance tests will include functional, vibration, and special nondestructive tests, as delineated in pertinent specifications, to eliminate poor workmanship and excessive parameter variation. The criteria for acceptance will consider past history, the in-process data transmitted with the unit from the production area, and the data obtained during the acceptance test. If a unit is marginal in any of the applied tests, a review of all in-process data is required to determine the specific area where rework will be required. These same acceptance tests will also be

[redacted]

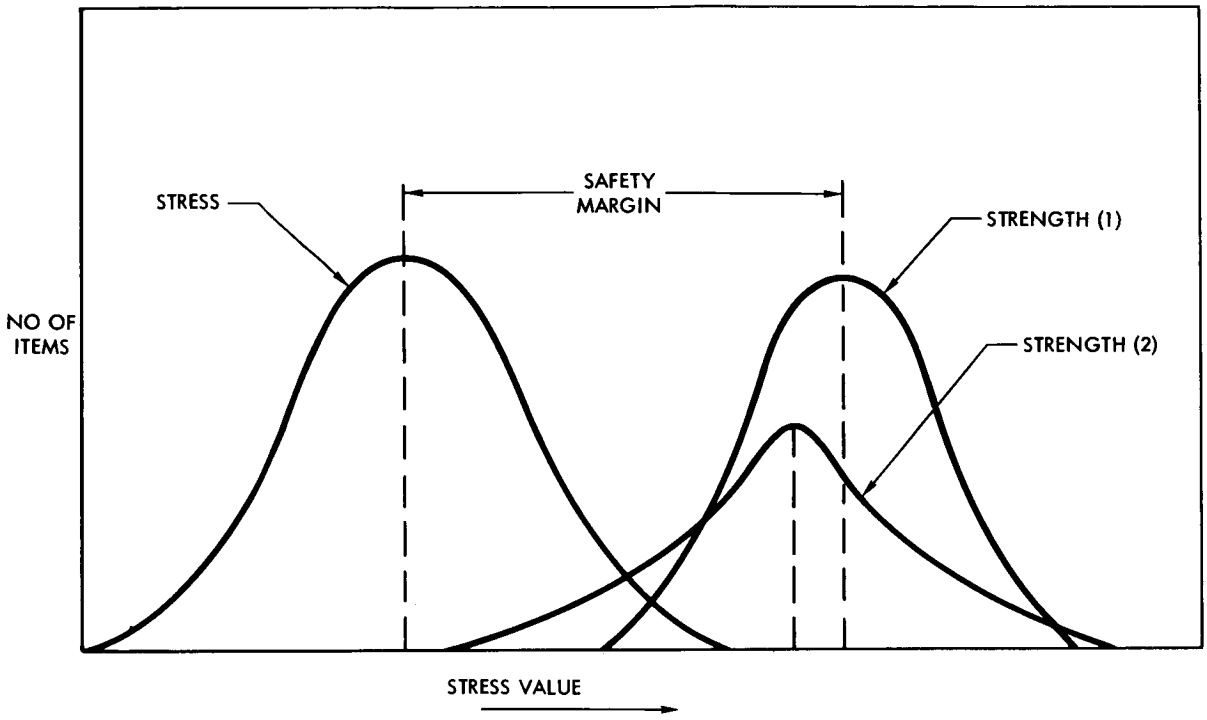


Figure 4-2. Stress-Strength Function

[redacted]

performed on units that are to be subjected to Qualification Tests to evaluate the effectiveness of the acceptance procedure and to reject poor equipment. The rejection of units after assignment to internal or commercial test laboratories will present problems in logistics and time.

S&ID will also conduct or grant a waiver of acceptance tests on spacecraft parts. These acceptance tests will be performed either in the receiving area, in a test laboratory that supports the receiving area and has the complex equipment required for checkout, in the system checkout area after the unit has been installed as a subsystem in the space vehicle, or in an acceptance test area (for equipment fabricated in-house). The S&ID tests on equipment obtained from suppliers must be compatible with the tests performed by the suppliers at their facilities. Compatibility of test will be accomplished by S&ID approval or preparation of supplier test procedures.

Equipment parameters monitored and recorded during the acceptance test are assumed to be distributed normally. The effect of field stresses such as time and wear on the parameters is also assumed to cause a normal distribution of these same parameters in a normal manner. This process is shown in Figure 4-3.

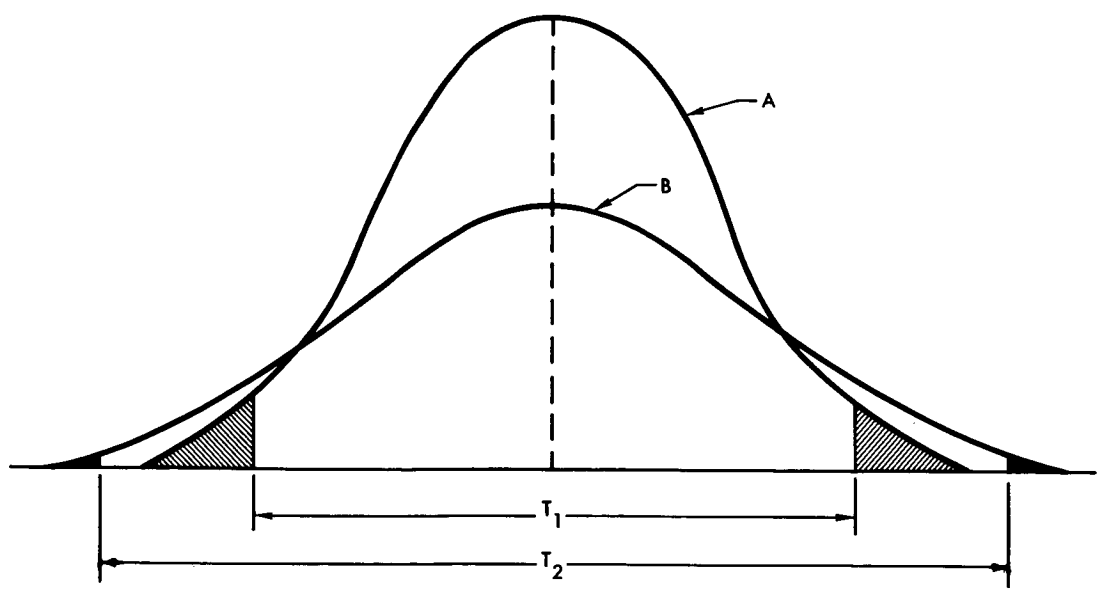


Figure 4-3. Parameter Distribution

T_1 is the tolerance limit set for acceptance or rejection during the acceptance test. T_2 is the maximum tolerance limit to which the equipment can be expected to degrade in the field without causing an unacceptable increase in the probability of failure of the system. Any variation of the

[redacted]

[redacted]

standard deviation of Curve A will be reflected directly in a change of the standard deviation of Curve B. Therefore, it can be seen that in the controlled acceptance test program any drift in the standard deviation of Curve A can be anticipated, controlled, and limited. The effect of this program will be to control the probability of mission failures. This control of the probability of mission failures is the intent of the Acceptance Test Program as described in this report. It will be accomplished by limiting the parameter distributions to narrow margins.

4.3 TECHNIQUES

The techniques used in performing acceptance tests will include, but not be limited to, visual inspection, functional tests (mechanical, electrical, or electromechanical), and vibration, X-ray, infrared, ultrasonics, and magnaflux tests.

[redacted]

[redacted] [redacted]

5.0 MULTIPLE SYSTEMS TESTS

5.1 PAD ABORT TESTS

5.1.1 Scope

The purpose of the pad abort tests is to accomplish the first phase of the mission abort test program. This is to evaluate the capability of returning a command module to earth from pad abort when the launch escape system is used. The pad abort tests will provide performance data at one extreme of the launch envelope, i.e., the static condition prior to first motion of the mated spacecraft and launch vehicle.

5.1.2 Objectives

5.1.2.1 Test Objectives for Boilerplate 6 Pad Abort

The first-order test objectives for boilerplate 6 are to:

1. Determine aerodynamic stability characteristics of the Apollo escape configuration during a pad abort
2. Demonstrate capability of the escape system to propel the command module to a safe distance from the launch vehicle during a pad abort
3. Demonstrate launch escape tower release system
4. Demonstrate operation of tower jettison motor
5. Demonstrate parachute subsystem of the earth landing system

The second-order test objectives for boilerplate 6 are to:

1. Demonstrate abort and recovery timing sequence
2. Determine dynamics of the command module during jettisoning of escape tower
3. Determine escape tower vibration during a pad abort

[redacted]

4. Demonstrate operation of research and development instrumentation and communications equipment to be used on subsequent flights

5. Demonstrate compatibility of prototype handling ground support equipment

6. Determine initial separation trajectory of the LES

5.1 2.2 Test Objectives for Airframe 010 Pad Abort

The test objectives for airframe 010 are to:

1. Demonstrate the structural integrity of the command module during a pad abort

2. Determine the operational characteristics of the spacecraft subsystems during a pad abort

3. Demonstrate abort and recovery sequences

4. Demonstrate the parachute subsystem of the earth landing system

5. Demonstrate the crew impact attenuation system

5.1.3 Requirements for Pad Abort Boilerplate 6 and Airframe 010

The test requirements for these vehicles are divided into four phases: manufacturing tests, in-house test preparation, prelaunch checkout, and flight testing.

The flight test requirements consist of determination through in-flight measurements of structural, event, and aerodynamic data; radar tracking of the test vehicle to provide elevation, azimuth, and slant range data; phototheodolite and high-speed camera coverage of the flight to provide acceleration, position, attitude, and velocity data as well as tower/command module separation characteristics and miss distance; and the monitoring, through camera coverage, of the recovery system sequence and operation.

The test will consist of the application of an abort signal to the test vehicle and the measurement of the event times and parameters associated with an abort sequence.

It is required that a time history of all events and parameters measurements, trajectories of command module and launch escape tower, and camera coverage of the complete test from launch to impact be submitted to engineering for the final test report.

[redacted]

Ground support equipment is required for handling and checking out the test vehicle prior to launch activities.

5.1.4 Test Description

5.1.4.1 Configuration

5.1.4.1.1 Boilerplate 6. Boilerplate 6 shall consist of:

1. Command module (boilerplate with simulated aft head shield)
2. Forward heat shield without ablative coating
3. Pad adapter
4. Escape tower (spacecraft structure)
5. Explosive separation system between escape tower/apex heat shield and command module (spacecraft)
6. Jettison motor (spacecraft)
7. Battery power system
8. R & D telemetry system and antenna
9. End instrumentation and signal conditioners
10. Abort system sequencer (boilerplate)
11. Parachute subsystem of the earth landing system (spacecraft)
12. On board tape recorder and recorder electronics
13. Pitch control motor (spacecraft)
14. Launch escape motor (spacecraft)

5.1.4.1.2 Airframe 010. Airframe 010 shall consist of:

1. Command module (airframe structure with aft heat shield, no ablative material)
2. Forward heat shield without ablative coating

[redacted]

3. Pad adapter (includes separation system from service module to command module airframe)

4. Escape tower (spacecraft structure)

5. Launch escape motor (spacecraft)

6. Explosive separation system between escape tower/apex heat shield and command module (spacecraft)

7. Jettison motor (spacecraft)

8. Battery power system

9. R & D telemetry system

10. End instrumentation and signal conditioners

11. Abort system sequencer (spacecraft)

12. Separation system between command module and command module to pad adapter (spacecraft)

13. Parachute subsystem of the earth landing system (spacecraft)

14. On-board tape recorder and recorder electronics

15. Pitch control motor (spacecraft)

16. Spacecraft antenna system

17. Boilerplate environmental control system

18. Crew couches, supports and impact attenuation system

19. Uninstrumented anthropomorphic dummies

5.1.4.2 Flight Plan for Pad Abort Boilerplate 6 and Airframe 010

The flight consists of the following phases:

1. Launch abort escape

2. LES separation from command module

3. Command module orientation, descent, and recovery

The vehicle will be launched vertically from White Sands Missile Range (WSMR) which is approximately 4000 feet above mean sea level. A ground

[redacted]TIAL

CON[redacted]

command abort signal will be transmitted to the launch escape vehicle and will activate the abort sequencer in the command module. Launch escape motor ignition and pitch control motor ignition occur simultaneously. After a timed interval, jettison motor ignition and launch escape tower/apex heat shield release occur simultaneously. The expended escape system follows a free fall trajectory to earth impact. After a timed interval the drogue parachute is deployed. The drogue parachute assists in orienting the command module blunt end forward for main parachute deployment. After a timed interval, the drogue parachute is released and the pilot parachutes deploy the three main parachutes, which are inflated to a reefed condition, to reduce the opening shock to the parachutes. After another timed interval, the three main parachutes are disreefed, fully inflated, and establish an equilibrium descent velocity of approximately 24 feet per second. The main parachutes are released upon earth impact of the command module.

5.1.5 Facilities

The pad abort tests will be conducted at the WSMR. A launch area designated by the WSMR as ALA-3, consisting of a launch pad, a barricade structure for the trailer, and a blockhouse, will be employed for checkout and launch of the test vehicle.

A vehicle assembly building will be utilized for assembly, weighing, and alignment operations required with respect to the launch escape system and the command module. Administrative and storage areas will be utilized to provide office space for the personnel of the test group and to store equipment prior to use in the testing. The existing WSMR tracking and telemetry recording facilities will be utilized to monitor the tests.

5.1.6 Test Schedule

The pad abort test schedule is shown in Figure 5-1.

5.2 LITTLE JOE II TESTS

5.2.1 Scope

The purpose of the Little Joe II tests is to accomplish the second phase of the mission abort test program. This is to evaluate the capability of returning a command module to earth from a portion of the launch envelope where the launch escape system is used. The Little Joe II tests will provide data at two points in the launch envelope. The first point is based on the high dynamic pressure anticipated to be encountered during the boost phase of the Saturn-Apollo vehicle. The second point is the high altitude extreme at which the launch escape system is to serve as the

[redacted]

[redacted]

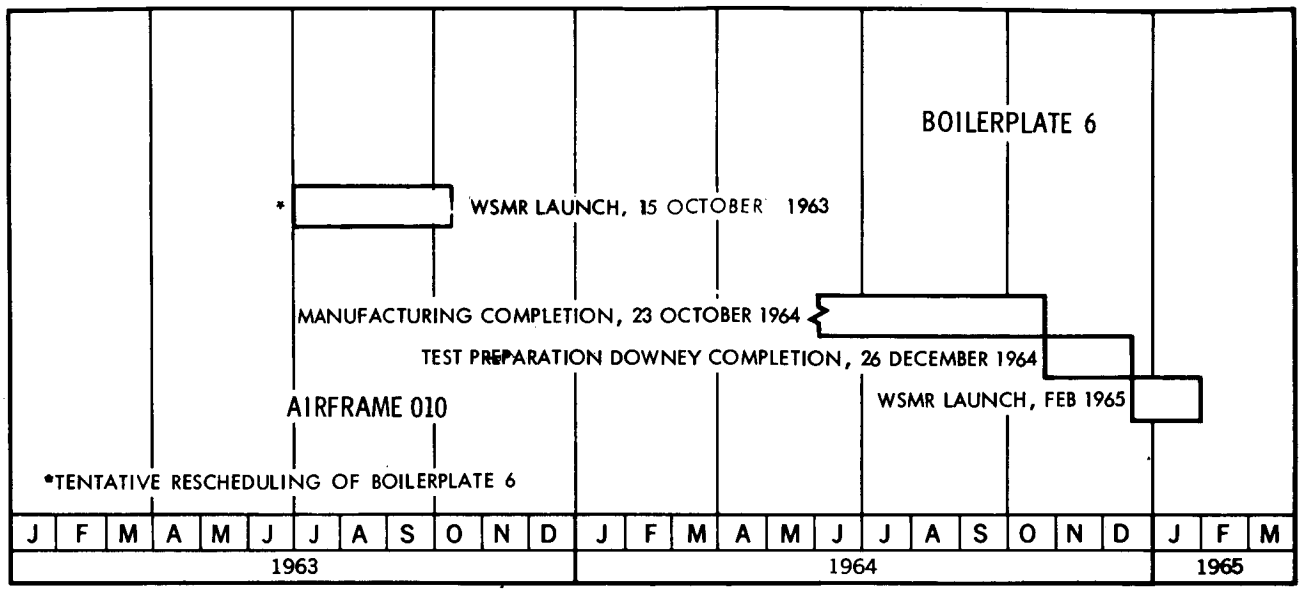


Figure 5-1. Pad Abort Test Schedule

mode of escape. A total of four test articles are programmed from 1963 to 1964, including the launching of one back-up vehicle, if required.

5.2.2 Objectives

5.2.2.1 Test Objectives for Little Joe II-1 (High q Boilerplate 12)

The first-order test objectives are to:

1. Demonstrate the structural integrity of the escape tower

2. Demonstrate the capability of the escape system to propel the command module to a predetermined distance from the launch vehicle

3. Determine aerodynamic stability characteristics of the escape configuration for this abort condition

4. Demonstrate proper operation of the command module to service module separation mechanism

[redacted]

5. Demonstrate proper operation of the parachute recovery system

The second-order test objectives are to:

1. Demonstrate Little Joe II spacecraft compatibility

2. Determine aerodynamic loads due to the fluctuating pressures on the command module and service module during a Little Joe II launch

3. Demonstrate satisfactory abort and recovery timing sequence

5.2.2.2 Test Objectives for Little Joe II-2 (Back-up Boilerplate 23)

The first-order test objectives are to:

1. Demonstrate capability of the escape system to propel the command module to a safe distance from the launch vehicle

2. Determine aerodynamic stability characteristics of the Apollo escape configuration during a high q abort

3. Demonstrate structural integrity of the escape tower during a high q abort

4. Demonstrate abort and recovery sequence

5. Demonstrate parachute subsystem of the earth landing system

[redacted]

[redacted]

The second-order test objectives are to:

1. Demonstrate Little Joe II spacecraft compatibility

2. Determine aerodynamic loads due to the fluctuating pressures on the spacecraft during a Little Joe-II launch

5.2.2.3 Test Objectives for Little Joe II-3 (High Altitude Atmospheric B-22)

1. Determine the aerodynamic stability characteristics of the launch escape vehicle during an abort, simulating an abort from a C-1 launch vehicle just prior to tower jettison

2. Demonstrate the capability of the launch escape system to propel the boilerplate spacecraft to a safe distance from the launch vehicle and to jettison the tower

3. Demonstrate the operation of the earth landing system during conditions simulating a lunar return

4. Evaluate the ability of the partial SCS and the RCS to provide rate damping and rate stabilization for the command module after tower jettison

5. Demonstrate operation of the CM/service module and CM/launch escape tower release systems

6. Demonstrate the operation of the forward compartment cover jettison system

7. Evaluate the altitude ignition characteristics of the launch escape and pitch control motors

8. Demonstrate the effectiveness of strakes to provide aft heat shield forward orientation for the command module

9. Evaluate the launch escape motor plume heating and pressure effects on the command module and tower

10. Demonstrate separation and space envelope of the tower after jettison from a tumbling launch escape vehicle

[redacted]

5.2.2.4 Test Objectives for Little Joe II-4 (High q Airframe 002)

The test objectives are to:

1. Demonstrate structural integrity of the production command module under the high q incurred by the escape configuration, simulating an abort from the Saturn C-1 launch vehicle

2. Determine dynamics of the command module during an abort resulting in high q on the escape configuration

3. Determine the operational characteristics of spacecraft subsystems during a high q abort

4. Demonstrate abort and recovery sequences

5. Demonstrate parachute subsystem of the earth landing system

6. Evaluate the ability of the partial SCS and the RCS to provide rate damping and rate stabilization for the command module after tower jettison

5.2.3 Requirements

5.2.3.1 Little Joe II-1 Boilerplate-12

The test requirements for this vehicle are divided into four phases: manufacturing tests, in-house test preparation, prelaunch checkout, and flight testing.

The flight test requirements for this vehicle consist of determination through in-flight measurements of structural, event, and aerodynamic data; radar tracking of the test vehicle to provide elevation, azimuth, and slant range data; phototheodolite and high-speed camera coverage of the flight to provide acceleration, position, attitude and velocity data as well as the tower/command module separation characteristic and miss distance; and the monitoring, through camera coverage, of the recovery system sequence and operation.

The test shall consist of a demonstration of an in-flight abort from atop a Little Joe II launch vehicle under Saturn C-1 high q conditions, and the measurement of the event times and parameters associated with an in-flight abort. It is required that a time history of all events and parameter measurements, trajectories of command module and launch escape tower, and camera coverage of the complete flight, from launch to impact, be submitted to engineering for the final test report.

[redacted]

[redacted]

Ground support equipment is required for handling and checkout of the test vehicle prior to launch.

5.2.3.2 Little Joe II-2 Back-up Boilerplate 23

These test requirementes are identical to those of the Little Joe II-1 high q test requirements. Boilerplate 23 will be launched only in the event of a need for additional data pertaining to high q abort.

5.2.3.3 Little Joe II-3 Boilerplate 22

This section is to be added December 1963

5.2.3.4 Little Joe II-4 Airframe 002

This section is to be added December 1963

5.2.4 Test Description

5.2.4.1 Configuration

5.2.4.1.1 Little Joe II-1 Boilerplate 12. The configuration consists of:

1. Command module (boilerplate structure with simulated aft heat shield)

2. Forward heat shield without ablative coating (boilerplate structure) and forward heat shield separation system

3. Service module 148.6 inches in length plus a 10-inch extension (boilerplate structure, steel)

4. Little Joe II booster

5. Escape tower (spacecraft structure)

6. Pitch control motor (spacecraft)

7. Launch escape motor (spacecraft)

8. Jettison motor (spacecraft)

9. Explosive separation system between escape tower and command module (spacecraft)

[redacted]

CONFIDENTIAL

10. Battery power system

11. R & D telemetry system and antennas

12. End instrumentation and signal conditioners

13. Radar beacon and antennas

14. Explosive separation system between command module and service module (spacecraft)

15. On-board tape recorder and recorder electronics

16. Liquid cooling system for instrumentation

17. Parachute subsystem of the earth landing system

18. Abort system sequencer

19. Service module bulkhead

20. On-board camera subsystems

5.2.4.1.2 Little Joe II-2 Back-up Boilerplate 23. The configuration consists of:

1. Command module (boilerplate structure with simulated aft heat shield)

2. Forward heat shield without ablative coating (boilerplate structure) and forward heat shield separation system

3. Service module 148.6 inches in length plus a 10-inch extension (boilerplate structure, steel)

4. Little Joe II booster

5. Escape tower (spacecraft structure)

6. Pitch control motor (spacecraft)

7. Launch escape motor (spacecraft)

8. Jettison motor (spacecraft)

9. Explosive separation system between escape tower and command module (spacecraft)

[redacted]

[redacted]

10. Battery power system

11. R & D telemetry system and antennas

12. End instrumentation and signal conditioners

13. Radar beacon and antennas

14. Explosive separation system between command module and service module (spacecraft)

15. On-board tape recorder and recorder electronics

16. Liquid cooling system for instrumentation

17. Parachute subsystem of the earth landing system

18. Abort system sequencer

19. Service module bulkhead

20. On-board camera subsystems

5.2.4.1.3 Little Joe II-3 Boilerplate 22. The configuration consists of:

1. Command module (boilerplate structure with simulated aft heat shield)

2. Forward heat shield without ablative coating

3. Service module 148.6 inches in length plus a 10-inch insert (boilerplate structure, steel)

4. Little Joe II booster

5. Escape tower (spacecraft structure)

6. Launch escape motor (spacecraft)

7. Explosive separation system between escape tower and command module (spacecraft)

8. Jettison motor (spacecraft)

9. Battery power system

[redacted]IAL

[redacted]

10. R & D telemetry system and antennas

11. End instrumentation and signal conditioners

12. Radar beacon

13. Separation system between command module and service module (spacecraft)

14. Parachute subsystem of the earth landing system

15. Command module reaction control system

16. Stabilization and control system (partial)

17. Liquid cooling system for instrumentation

18. Pitch control motor (spacecraft)

19. On-board tape recorder and recorder electronics

5.2.4.1.4 Little Joe II-4 Airframe 002. The configuration consists of:

1. Command module (airframe structure with aft heat shield, no ablative material)

2. Forward heat shield without ablative material

3. Service module 148.6 inches in length plus a 10-inch insert (boilerplate structure steel)

4. Little Joe II booster

5. Escape tower (spacecraft)

6. Launch escape motor (spacecraft)

7. Explosive separation circuit between tower and command module (spacecraft)

8. Jettison motor (spacecraft)

9. Battery power system

10. R & D telemetry system

[redacted]

[redacted]

11. End instrumentation and signal conditioners

12. Radar beacon

13. Parachute subsystem of the earth landing system (spacecraft)

14. Liquid cooling system for instrumentation

15. Separation circuit between command module and service module (spacecraft)

16. Recovery aids

17. Pitch control motor (spacecraft)

18. Stabilization and control system (partial)

19. Command module reaction control system

5.2.4.2 Flight Plan

5.2.4.2.1 Little Joe II-1 Boilerplate 12. The flight consists of the following phases:

1. Little Joe II boost

2. High q abort/CM-SM separation

3. LES separation from command module

4. Command module orientation, descent, and recovery

The vehicle will be launched from White Sands Missile Range, which is approximately 4000 feet above mean sea level. The vehicle will be oriented in a northern direction and at an angle of approximately 82 degrees with respect to the launch pad. The signal to launch, which will be transmitted via land line from the blockhouse, will ignite all Little Joe II solid rocket engines. Command module separation from the service module-Little Joe II combination will occur at an altitude of approximately 18,000 feet above sea level. A radio command signal, transmitted by ground control and received by a redundant receiver in Little Joe II at approximately 29.0±.5 seconds after launch, will initiate the separation. This signal will also simultaneously fire the launch escape motor and the pitch control motor. The combined thrust of the pitch control motor and the launch escape motor will propel the command module away from the launch vehicle. During the propulsive portion of the abort phase, dynamic pressure will increase to approximately 950 pounds per square foot. After an elapsed interval of 15.5 seconds from command module separation, jettison motor ignition and launch escape tower separation will occur simultaneously. The expended escape system

[redacted]

follows a free-fall fall trajectory to earth impact. A time-delay relay provides a 3-second interval after jettison motor ignition for release of the forward compartment cover. One second later, the drogue parachute will be deployed to stabilize and decelerate the command module for main chute deployment. As the command module passes 15,000 feet, the drogue parachute will be released and three pilot parachutes will be deployed. The pilot parachutes in turn will extract the three main parachutes which are inflated in the reefed condition to reduce opening shock. After a 6-second delay, the main parachutes are disreefed and fully inflated, establishing an equilibrium descent rate of 24 feet per second. The main chutes are automatically released from the command module upon earth impact.

5.2.4.2.2 Little Joe II-2 Back-up Boilerplate 23. This flight plan will be the same as that for high q boilerplate 12, if it is used.

5.2.4.2.3 Little Joe II-3 Boilerplate 22. This section is to be added December 1963.

5.2.4.2.4 Little Joe II-4 Airframe 002. This section is to be added December 1963.

5.2.5 Facilities

All Little Joe II airborne abort tests will be conducted at White Sands Missile Range and will use the same facilities. A launch area designated by the WSMR as ALA-3 consisting of a launch pad with a service tower to support checkout, a barricade building for the checkout trailer, and a blockhouse will be employed for checkout and launch of the test vehicle. On boilerplate 22, a portion of the launch pad will be equipped with servicing and safety equipment to accomplish a static firing of the command module reaction control system. A vehicle assembly building will be utilized for required assembly, weighing, and alignment operations with respect to the launch escape system and the command module. Administrative and storage areas will be utilized to provide office space for the personnel of the test group and the storage of equipment prior to use in the testing. The existing WSMR tracking and telemetry recording facilities will be used to monitor the tests.

5.2.6 Test Schedule

See Figure 5-2 for the Little Joe II test schedule.

5.3 APOLLO/SATURN TEST PLANS

5.3.1 Scope

[redacted]

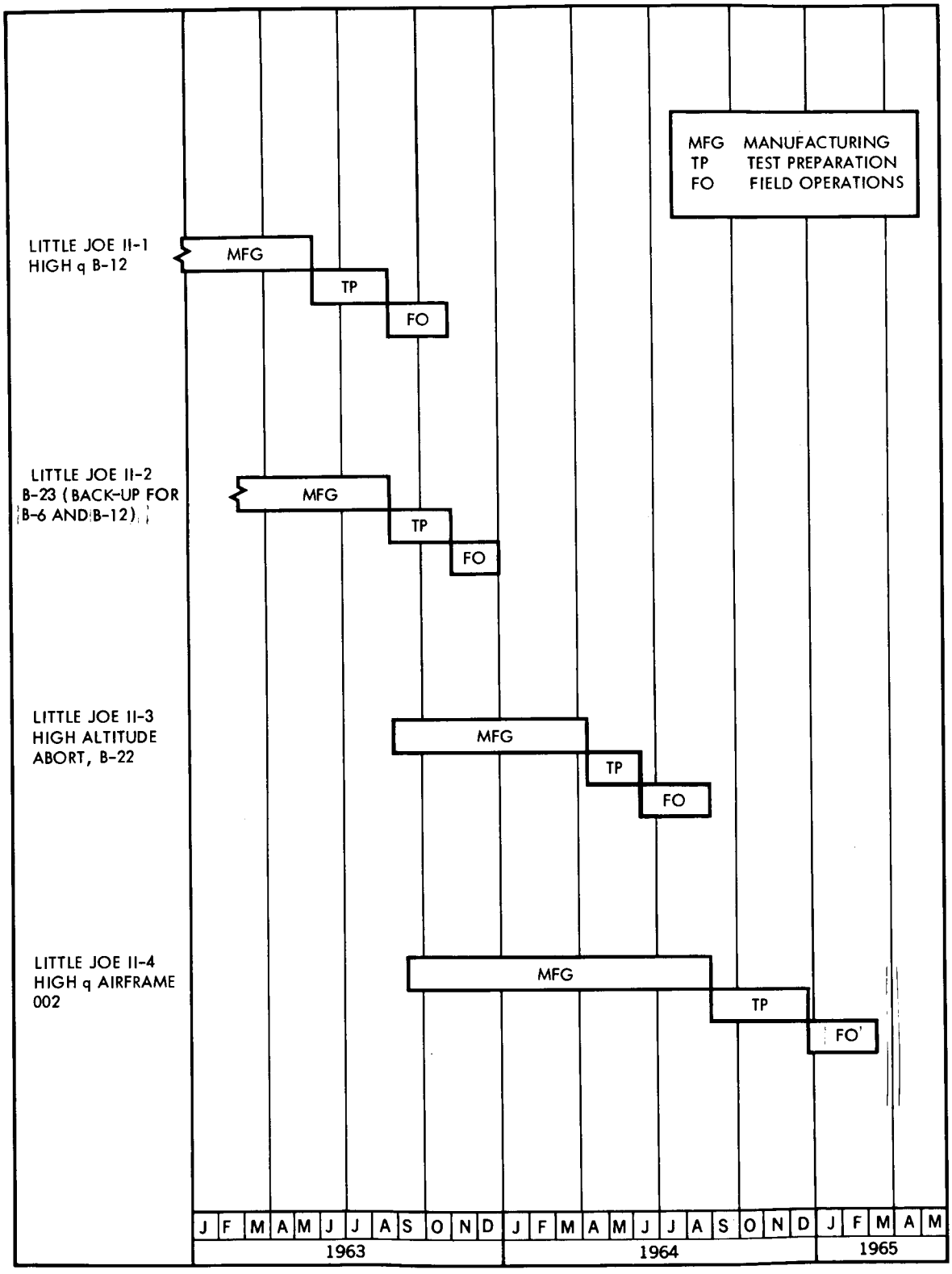


Figure 5-2. Little Joe II Abort Test Schedule

[redacted]

The purpose of the Apollo/Saturn test program is to evaluate, qualify, and demonstrate the capability of the complete Apollo spacecraft system to perform a manned earth-orbital mission. A total of five flight tests are programmed, utilizing Saturn I launch vehicles. Early flights will be programmed for launch vehicle - spacecraft compatibility and environmental investigations. Demonstration of a manned earth-orbital mission will conclude this phase of the test program.

5.3.2 Objectives

5.3.2.1 Spacecraft and Launch Vehicle Development Test

Boilerplate 13 is scheduled for this test.

The first-order test objectives are as follows:

1. Demonstrate the physical compatibility of the launch vehicle and boilerplate spacecraft under flight loading conditions

2. Determine the launch and exit environmental parameters to verify design criteria

3. Demonstrate the primary mode of launch escape-tower jettison using the tower jettison motor

The second-order test objectives are as follows:

1. Demonstrate the structural integrity of the launch escape system under flight loading conditions

2. Demonstrate the compatibility of the R & D telecommunications system with the launch vehicle systems

3. Determine the spacecraft flight trajectory and orbital parameters

5.3.2.2 Second Spacecraft and Launch Vehicle Development Test

Boilerplate 15 is scheduled for this test.

The first-order test objectives are as follows:

1. Demonstrate the physical compatibility of the launch vehicle and boilerplate spacecraft under flight loading conditions

[redacted]

[redacted]

2. Determine the launch and exit environmental parameters to verify design criteria

3. Demonstrate the alternate mode of launch escape tower jettison using the launch escape and pitch control motors

The second-order test objectives are as follows:

1. Demonstrate the structural integrity of the launch escape system under flight loading conditions

2. Demonstrate the compatibility of the R & D telecommunications system with the launch vehicle systems

3. Determine the spacecraft flight trajectory and orbital parameters

5.3.2.3 Spacecraft Structures and Separation Systems Qualification - Boilerplate 18

The first-order objectives of this flight are as follows:

1. Demonstrate a system that is designed to provide adequate separation of the spacecraft from the Saturn I launch vehicle at S-IV burnout

2. Evaluate the structural integrity of the adapter and SM structures for flight loads to be encountered on manned Saturn I flights

3. Evaluate the operation of the spacecraft crew safety system in relation to the launch vehicle emergency detection system

4. Demonstrate the C/M - S/M flight trajectory and orbital parameters

The second-order test objectives are as follows:

1. Demonstrate satisfactory launch escape tower jettison

5.3.2.4 Suborbital Spacecraft Systems Demonstration - Airframe 009

The first-order objectives of this test are as follows:

1. Demonstrate the physical compatibility of the launch vehicle and production spacecraft under flight loading conditions

2. Evaluate the structural integrity of the spacecraft in suborbital flight environments including boost, zero g, entry, water impact, and recovery

3. Determine the C/M suborbital entry trajectory

[redacted]

4. Determine operational characteristics of the production spacecraft systems under unmanned suborbital flight conditions

5. Evaluate the operation on the SM SPS and RCS under zero g conditions including the SPS restart capability

6. Evaluate the operation of the fuel cell and ECS under zero g conditions

7. Determine C/M aerodynamic stability characteristics during a lifting entry

8. Evaluate the operation of the SCS during space flight

9. Evaluate the thermal protection system at conditions approaching orbital entry

10. Evaluate the capability of the RCS and SCS to control the C/M during entry

11. Evaluate the operation of the crew safety system

12. Demonstrate the satisfactory separation of the SM from the C/M

13. Evaluate the performance of the spacecraft communications and instrumentation system and compatibility with the launch vehicle systems

14. Demonstrate satisfactory performance of the complete recovery operation

15. Demonstrate satisfactory operation of the earth landing system after suborbital flight conditions

The second-order test objectives are as follows:

1. Evaluate the launch countdown operation

5.3.2.5 Manned Earth-Orbital Demonstration - Airframe 011

The first-order objectives of this test are as follows:

1. Demonstrate the structural integrity of the spacecraft in the orbital flight environments including boost, earth orbit, entry, water impact, and recovery

2. Determine the C/M orbital entry trajectory

[redacted]

[redacted]

3. Demonstrate satisfactory operation of the production spacecraft systems under manned orbital flight conditions

4. Demonstrate satisfactory operation of the crew safety system

5. Demonstrate proper operation of spacecraft systems with manual control

6. Demonstrate the compatibility of the manned spacecraft with the GOSS

7. Demonstrate the maneuvering capability of the CM using the RCS during orbital entry

8. Demonstrate satisfactory performance of the complete recovery operation

9. Demonstrate the orbital attitude control capability using the SM RCS

10. Demonstrate satisfactory separation of the SM from the CM

11. Demonstrate satisfactory performance of the thermal protection system under ascent, orbital, and entry conditions

The second-order objectives of this test are as follows:

1. Evaluate multiman crew performance under orbital flight conditions

2. Evaluate start and restart capabilities of the SM SPS and RCS under orbital flight conditions

3. Evaluate the operational characteristics of the spacecraft systems under orbital flight conditions

4. Evaluate guidance and navigation system closed loop operation and inflight navigational sighting techniques

5. Evaluate the operation of the ECS during manned orbital flight

6. Evaluate the launch countdown operation

[redacted]

[redacted]

5.3.3 Requirements

Included in the test requirements will be the following:

1. Individual operational checkout procedure requirements for individual, multiple, and integrated systems tests

2. Prelaunch and launch checkout procedure requirements

3. Lists of applicable design specifications, process specifications, drawings, special data requirements, and special test requirements

4. Reference documents defining primary and secondary test objectives, vehicle and GSE configuration, including primary and secondary systems trajectories, structural design criteria, instrumentation measurement list, aerodynamic stability of the vehicle, hazards associated with the vehicle or GSE, and placards and limitations

These test requirements will be available on the following dates:

Airframe 009	15 September 1963
Airframe 011	15 December 1963

5.3.4 Test Description

5.3.4.1 Spacecraft Configuration

5.3.4.1.1 Boilerplate 13. The basic configuration will consist of boilerplate structures to simulate the command module, service module, and spacecraft adapter. A production launch escape tower will be provided with an inert launch escape propulsion motor, an inert pitch control rocket motor, and a live tower jettison motor. Spacecraft systems will include a minimum number of support systems necessary to carry out the assigned objectives. Examples of these systems are: R & D telemetry, instrumentation, radar beacon, Q-ball, associated battery power system, and a limited temperature control system.

5.3.4.1.2 Boilerplate 15. The configuration of Boilerplate 15 will be identical to Boilerplate 13 except that a complete launch escape system will be provided, including a live tower jettison motor, live pitch control motor, and live launch escape motor.

[redacted]

[redacted]

5.3.4.1.3 Boilerplate 18. The structural configuration for this test will consist of a boilerplate command module and production-type launch escape tower, service module, and spacecraft adapter. A complete launch escape system will be provided. Major systems to be installed in the command module include the following:

R & D instrumentation and telemetry

C-band beacon

Electrical power system (battery)

R & D environmental control system

Emergency detection system (C/M display and control equipment and associated wiring, including umbilical to launch vehicle)

Mission sequencer

CM/SM separation system

The service module will include a reaction control system with only the aft thrusting engines of each quad package operable, a service propulsion system bell, instrumentation, electrical distribution subsystem, and inoperable EPS and ECS radiators. Separation systems will be provided for separation of the adapter from the S-IV instrument package and from the service module.

5.3.4.1.4 Airframe 009. The configuration for this test will consist of a prototype Spacecraft structure conforming to production design and equipped with essentially all systems except those noted below. The basic prototype components will consist of a command module equipped with an ablative heat shield, a service module including a service propulsion system, a service module adapter, and a launch escape system equipped with live launch escape, pitch control, and tower jettison motors. There will be a battery power system, which will be sufficient to accommodate the power requirements of all Spacecraft systems. One fuel cell module will be on-board for checkout, but will not supply electrical power for critical systems. The following systems will not be installed for this test.

1. MIT guidance and navigation system

2. One cryogenic system

3. Two fuel cells

[redacted]IAL

4. Water management system associated with the fuel cells

5. Up-data link

6. Television camera

7. Crew provisions

8. DSIF system

5.3.4.1.5 Airframe 011. The configuration for this test will include a complete flight configured Spacecraft with all systems required to support a manned orbital mission. The basic prototype components will consist of a command module with an ablative heat shield, a service module including the SPS, a service module adapter, and a launch escape system equipped with live launch escape, pitch control, and tower jettison motors. Electrical power will be supplied by three fuel cells in a prototype electrical power system. There will be a sufficient battery power onboard to provide emergency power to ensure safe return of the crew in the event of a fuel cell failure.

5.3.4.2 Tests

Final qualification testing of those Apollo spacecraft scheduled for flight operations with Saturn launch vehicles will be initiated with the completion of manufacturing final assembly, and will continue through flight operation. The test operations will be divided into readiness test, launch operation, flight operations and recovery.

5.3.4.2.1 Readiness Tests.

5.3.4.2.1.1 Downey Test Preparation. Test preparation effort will consist of planning and implementing engineering acceptance tests of each Apollo spacecraft. The purpose of these tests is to verify satisfactory operation of the individual and integrated systems prior to delivery of the spacecraft to the field. Acceptance preparation, acceptance tests, GSE integration, test procedures development, and mission support define the entire scope of functions performed during this period.

5.3.4.2.1.2 Field Site Prelaunch Tests. The purpose of the field site prelaunch tests is to further verify spacecraft readiness for flight operation. Individual and integrated systems tests will be conducted in the same manner as the Downey test preparation. These tests will verify spacecraft flight readiness following the transportation to the field site and will supply additional data for establishing system reliability

[redacted]

levels prior to launch operations. Additional tests to be performed will include static firings of the reaction control and service propulsion systems, vacuum chamber tests, and all hazardous testing requiring special remote facilities. The prelaunch test operation will culminate with the final launch pad integrated checkout of the launch vehicle, spacecraft, control centers, and support activities, including simulated countdown and simulated flight operations.

5.3.4.2.2 Launch Operation. The initial phase of the launch operation will be the final preparation of all airborne systems, GSE, and facilities for the launch countdown and flight operation. This will include such items as servicing of the spacecraft systems and GSE, electrical hook-up of certain ordnance items, and final instrumentation checks. Completion of the actual countdown will conclude this phase of testing.

5.3.4.2.3 Flight Operations

5.3.4.2.3.1 Boilerplates 13 and 15. Flight operations will begin with the launch of the spacecraft using the Saturn I launch vehicle consisting of the S-I and S-IV boost stages. Following separation from the S-1 stage and approximately ten seconds after S-IV ignition, the launch escape tower will be jettisoned. The S-IV stage will be programmed to inject the entire combination of command module, service module, spacecraft adapter, and S-IV into a 90 to 120 nautical-mile perigee orbit. Recovery capability is not a test requirement; therefore, there is no planned recovery operation.

5.3.4.2.3.2 Boilerplate 18. The test will commence with a Saturn I launch of the spacecraft. During the powered portion of flight, the emergency detection system will be evaluated. An abort capability utilizing the launch escape system is provided up to 10 seconds after S-IV ignition. Following orbit insertion, the spacecraft and adapter combination will be separated from the S-IV instrument package through the sequential operation of the separation system and service module reaction control motors. Upon completion of this operation, the adapter will then be separated from the service module. There will be no planned recovery operation.

5.3.4.2.3.3 Airframe 009. The Saturn I Launch Vehicle will boost the unmanned Apollo spacecraft into a sub-orbital trajectory terminating near Ascension Island. The boost trajectory will be designed to inject a payload into a 100 nautical mile earth orbit. However, after a normal S-IV ignition and launch escape tower jettison, the S-IV stage will be prematurely shutdown to insure sub-orbital flight. Following S-IV separation the spacecraft will be rotated in pitch (nose upward) approximately 115 degrees and two firings of the SPS conducted. Upon completion of the second SPS firing, the spacecraft will be oriented for S/M separation. Following Service Module separation the Command Module will be oriented

[redacted]

for entry by use of the C/M RCS. The Command Module RCS will damp out separation transients, and rotate the C/M 90 degrees in pitch and 180 degrees in roll to achieve the desired attitude for a lifting entry. The roll attitude will remain fixed until drogue chute deployment. Flight Operations will be concluded following impact of the C/M in the Atlantic near Ascension Island.

5.3.4.2.3.4 Flight Plan for Airframe 011.

Following the S-I boost phase and normal jettisoning of the launch escape tower, the S-IV will inject the manned Apollo spacecraft into a 100 nautical-mile earth orbit. The spacecraft will separate from the S-IV in orbit and the SM adapter will be jettisoned. The flight objective is a three orbit mission. During orbital flight the crew will perform designated tasks to fully test the various spacecraft systems. To initiate the entry with the required retrovelocity input, the crew will first orient the spacecraft to the proper attitude and then ignite the SM SPS engine. Upon SPS cutoff, the crew will reorient the spacecraft, jettison the SM, then orient the CM for entry. The entry maneuver will consist of a 45 degree modulated lifting trajectory. Flight operations will be concluded following water impact of the CM near Ascension Island.

5.3.5 Facilities

5.3.5.1 Launch Facilities

The Apollo/Saturn tests will be conducted at the AFMTC, Cape Canaveral, Florida. Pending completion of presently planned Apollo spacecraft checkout facilities, interim facilities will be required for early test articles. Launch operations will be conducted utilizing pads 34 and/or 37.

5.3.5.2 Ground Operational Support System (GOSS)

The Apollo/Saturn test program will be supported by the GOSS, which consists of a world-wide network of communication, tracking, and control stations. Approximately 21 strategically located stations throughout the world will, through the direction of the Integrated Mission Control Center (IMCC), monitor the spacecraft flight progress, the flight crew status on manned missions, and the on-board systems. The GOSS will continually monitor certain portions of the flight such as boost, orbit injection, and re-entry through recovery. The coverage that will be maintained during other portions of the flight will be as complete as possible.

[redacted]

[redacted]

The GOSS facilities will include control centers, remote stations, tracking ships, and deep-space instrumentation facilities (DSIF). The support capability of these facilities or sites will vary; however, the majority of them will provide voice communications with the spacecraft and IMCC, space position tracking, telemetry reception, data processing, and data transmission to the IMCC. The DSIF will be provided, primarily, for lunar distance tracking. The extent to which each of the GOSS facilities will be required to support the Phase A test program will depend upon the individual spacecraft missions.

Information and data will be transmitted within the GOSS network by teletype, voice, computer code, and video systems. Selected stations and the IMCC will be equipped with high-speed equipment to minimize data acquisition and transmission delays.

5.3.6 Test Schedule

The Apollo/Saturn test schedule, shown in Figure 5-3, reflects time-phasing relationships for Apollo/Saturn flight tests.

5.4 PROPULSION TEST PROGRAM

5.4.1 Scope

The spacecraft propulsion test program will be conducted to verify the conformance of the combined propellant-rocket engine propulsion systems with design specifications and to evaluate the interactions of the related spacecraft systems during propulsion operations. Static-firing tests will be performed on the service propulsion, service module reaction control and command module reaction control systems in their installed configuration. Data will be collected to demonstrate the reliable performance of propulsion systems for both normal and design limit parameters. Compatibility testing during propulsion systems tests will include spacecraft systems associated with control or monitoring of the propulsion systems, GSE and launch site service systems, and the applicable operating procedures.

The principal test vehicle will be an actual spacecraft service module and command module with the necessary flight-configuration systems. However, the service module main propulsion system will be initially evaluated with an F-2 service propulsion test fixture to provide early assessment of the pressurization, propellant, and rocket engine subsystem interfaces and to certify the system for flight-weight ground test firing operations. The F-2 fixture will be of battleship construction, simulating the service propulsion flight configuration. Plumbing and valving will be

[redacted]

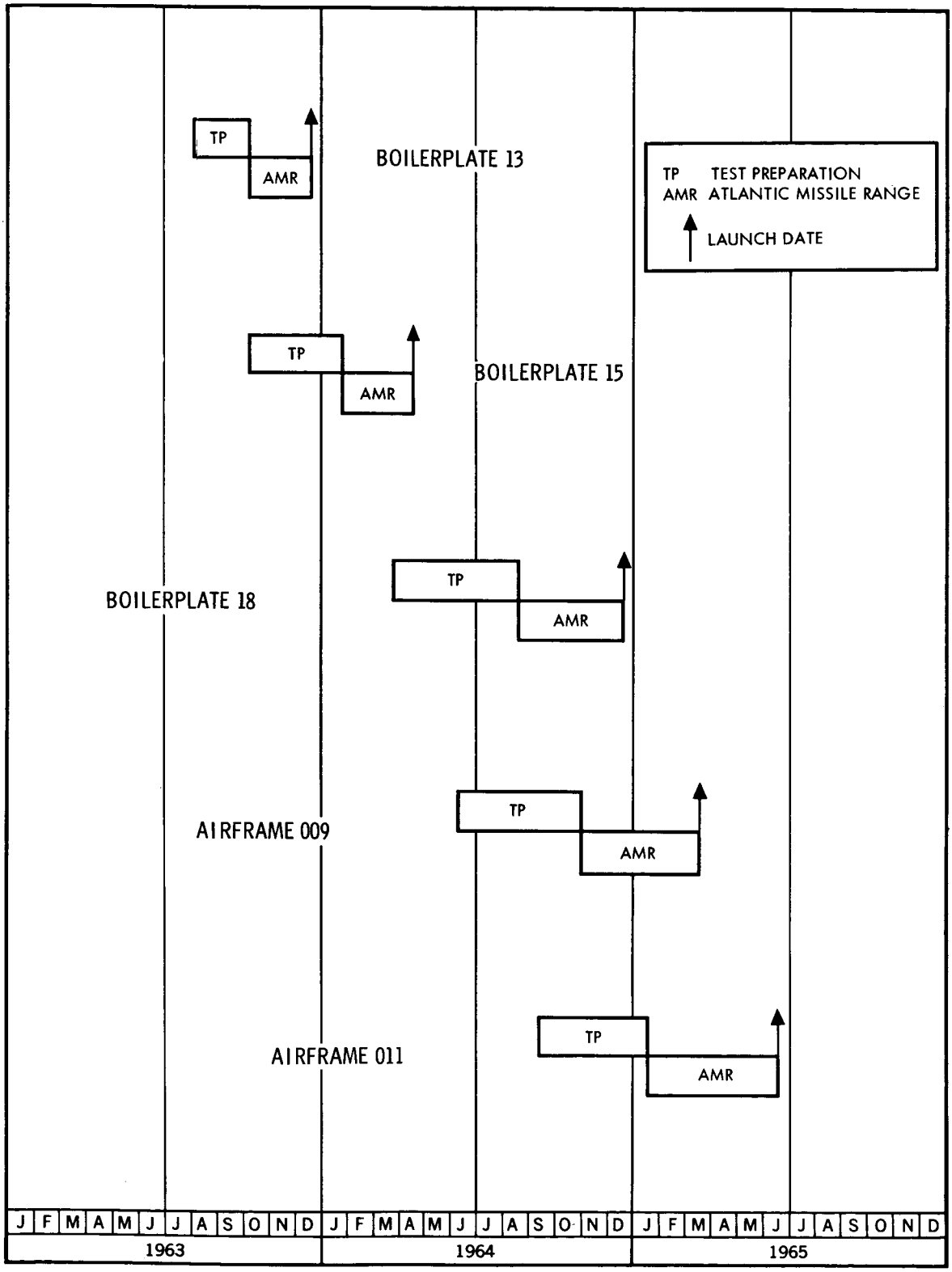


Figure 5-3. Apollo/Saturn Test Schedule

[redacted]

[redacted]

replaced with spacecraft hardware as it becomes available. The F-2 test program will continue for problem investigation and design improvement tests in support of the propulsion test spacecraft (airframe 001) program.

The propulsion test program will be conducted at PSDF. The environment will be the ambient variable climatic conditions.

The first operational tests of the electrical power system, i.e., the fuel cells and their associated cryogenic systems, require access to a hazardous area. Airframe 001 will provide the test facility on which a performance test program will be conducted.

Safety and operational procedures will be evaluated and refined throughout the propulsion test program. Where practicable, GSE and facilities systems will be identical to, or will simulate, those to be used in the test preparation and prelaunch operations for the flight spacecraft.

5.4.2 Objectives

5.4.2.1 Airframe 001 Test Objectives

The test objectives to be accomplished with airframe 001, within the limitations of ground test at ambient environment, are as follows:

1. Evaluation and demonstration of the service module service propulsion integrated pressurization, propellant, and rocket engine system performance under normal and off-limit conditions

2. Evaluation and demonstration of the performance of the command module and the service module reaction control combined propellant-engine systems for normal and off-limit propellant inlet conditions

3. Evaluation of Apollo propellant handling, thermal conditioning, and transfer equipment and procedures

4. Evaluation of leak detection, purge, checkout, maintenance, and servicing of the propulsion systems

5. Evaluation of techniques and procedures for flight-vehicle acceptance static firings

6. Evaluation of interactions between the propulsion systems and all associated control and monitor systems during hot propulsion operation

[redacted]IAL

[redacted]

7. Demonstration of the structural integrity of the S/M and C/M when subjected to vibration, shock, and acoustics under simultaneous but variable hot firing of the SPS and RCS engines

8. Evaluation of servicing and maintenance for the electrical power fuel cell and cryogenic systems installed in the service module

9. Evaluation of the operation and performance of the complete electrical power system when operating in a spacecraft under the influence of other spacecraft systems

5.4.2.2 F-2 Test Objectives

Test objectives to be accomplished with the F-2 fixture in support of airframe 001 are as follows:

1. Evaluation of the operation and performance of the service module service propulsion combined propellant-rocket engine systems under normal and off-limit conditions.

2. Determination of the compatibility of the service module main propulsion system, facility, and GSE.

3. Develop checkout, servicing, operating, and maintenance procedures for the SPS.

4. Investigation of problems and/or malfunctions evidenced on airframe 001 test vehicle and flight vehicles.

5.4.3 Requirements

The spacecraft propulsion test program provides for an evaluation and qualification of the combined propellant-rocket engine systems and an evaluation of the interactions of the related spacecraft systems during propulsion operations. Test requirements for airframe 001 and the F-2 fixture are presented in the detail test plan, Section 4.0, Volume V. The test objectives reflect the test requirements that are applicable to each test vehicle.

5.4.4 Test Description

5.4.4.1 Service Propulsion F-2 Test Fixture

5.4.4.1.1 Description. The service module main propulsion systems tests will be initiated with the F-2 test fixture. This vehicle will be of battleship construction simulating the internal size and shape of the flight-

[redacted]

[redacted]

configuration service propulsion systems. Corrosion-resistant tanks, propellant feed system, and a preliminary flight-rated engine will be mounted in a structural steel frame. Plumbing and components will be replaced with spacecraft hardware as it becomes available. A rack-mounted pressurization system will be used.

5.4.4.1.2 Test Operations. Before installing the F-2 fixture on the firing stand, functional checkouts, leak tests, and instrumentation preparation will be completed. After installation of the vehicle on the stand, facility/GSE/test vehicle compatibility testing and instrumentation and control calibration will be accomplished. Following systems checkout and familiarization tests, propellant handling tests and system functional operation tests will be completed.

Functional test firings will be conducted to investigate start-stop transients, systems response, and repeatability for normal and malfunction mode operations.

Firing tests conducted with a failed injector valve and both high-and low-propellant delivery pressures will be followed by tests with oxidizer-fuel ratios both above and below the normal 2 to 1 ratio.

Mission profile tests will be conducted in simulation of high-altitude abort, earth orbital, circumlunar, lunar orbital, and translunar abort missions. Sufficient tests will be accomplished to demonstrate reliable repeated performance.

It is intended that the F-2 fixture be continuously used for analysis of malfunctions and problems resulting from difficulties encountered during propulsion systems tests and during actual spacecraft flight missions. The test fixture will be used to develop and prove out modifications to the spacecraft throughout the program.

5.4.4.2 Propulsion Test Spacecraft Airframe 001

5.4.4.2.1 Description. Airframe 001 will be a prototype spacecraft containing systems of flight configuration, except that the main service module engine flight nozzle will not be employed, and sea-level nozzles will be used on some RCS tests.

The primary systems to be tested in the spacecraft are as follows: (The functional description of the system in this volume is given in the appended references.)

1. Service propulsion – Section 1.1

[redacted]

[redacted]

2. Service module reaction control propulsion — Section 1.2

3. Command module reaction control propulsion — Section 1.2

4. Propulsion control and display

5. Electrical power systems — Section 1.6

The systems subjected to interaction testing during the propulsion test program are as follows:

1. Stabilization and control system: Partial system available for propulsion system evaluation under actual firings — Section 1.8

2. Control and display system: applicable controls and displays will be installed to support operations of the previously mentioned systems and to determine interactions with other systems

The supporting systems required during the propulsion test program are as follows:

1. Command module environmental control: to support equipment operation when a closed command module is required during service module firings — Section 1.5.

5.4.4.2.2 Test Operations. As a result of present scheduling, the service module will be available for delivery to the test site prior to the command module. Therefore, upon the arrival of each module at the test site, separate testing will be initiated, which will phase into a combined spacecraft operation.

The service module, airframe 001, firing tests will be preceded by a thorough test preparation and cold-test period for the vehicle and the assoicated ground support systems. The service module will be instrumented and checked out in the test preparation area at Downey prior to shipment to the test site. Upon arrival at the test site, a receiving inspection and validation checkout will be performed. The service module will then be installed on the test stand for final preparation, compatibility tests, and instrumentation calibration with the facility. Propellant and engine system leak, purge, and servicing

[redacted]

[redacted]

techniques and procedures will be investigated. Simulated service module firings will be accomplished from the blockhouse for procedure and test control verification.

Test firings will be conducted to obtain normal reaction control system and service propulsion system performance. In addition, firings will be performed with failed injector, off-limit engine propellant inlet pressures, and varied oxidizer-fuel mixture ratios and temperatures. Start, restart, steady-state, and mission profile tests will be performed.

The command module, airframe 001, will be prepared for test prior to delivery to the field and will be processed as specified for the service module. Initial tests will consist of RCS firing tests using manual remote control. The stabilization control system will then be activated, and an evaluation of the integrated systems will be performed. Programming and GSE equipment will be used to simulate inertial elements signals so that flight modes can be investigated.

The service module propulsion systems will be tested using blockhouse control until the command module becomes available. Subsequent testing will be sequenced to progressively demonstrate the development of the systems and man-machine compatibility. Present plans are to use the command module as a remote hard-wire control station, and then progress to electrically mated spacecraft operations.

Scheduling requires the propulsion test program to be phased to specific flight programs requirements. The tests will provide the confidence level necessary to qualify the systems for airframe 009 and airframe 011. Thereafter, testing will be extended to demonstrate systems operation and reliability for extended earth-orbital and lunar mission profiles.

5.4.5 Facility

The hot propulsion test program will be conducted at the propulsion test facility being provided by NASA at PSDF.

5.4.6 Test Schedule

The propulsion test program to be conducted on F-2 test fixture and airframe 001 is shown in Figure 5-4. This schedule reflects vehicle test operations phasing.

5.5 SPACECRAFT ENVIRONMENTAL PROOF TEST PLANS

[redacted]

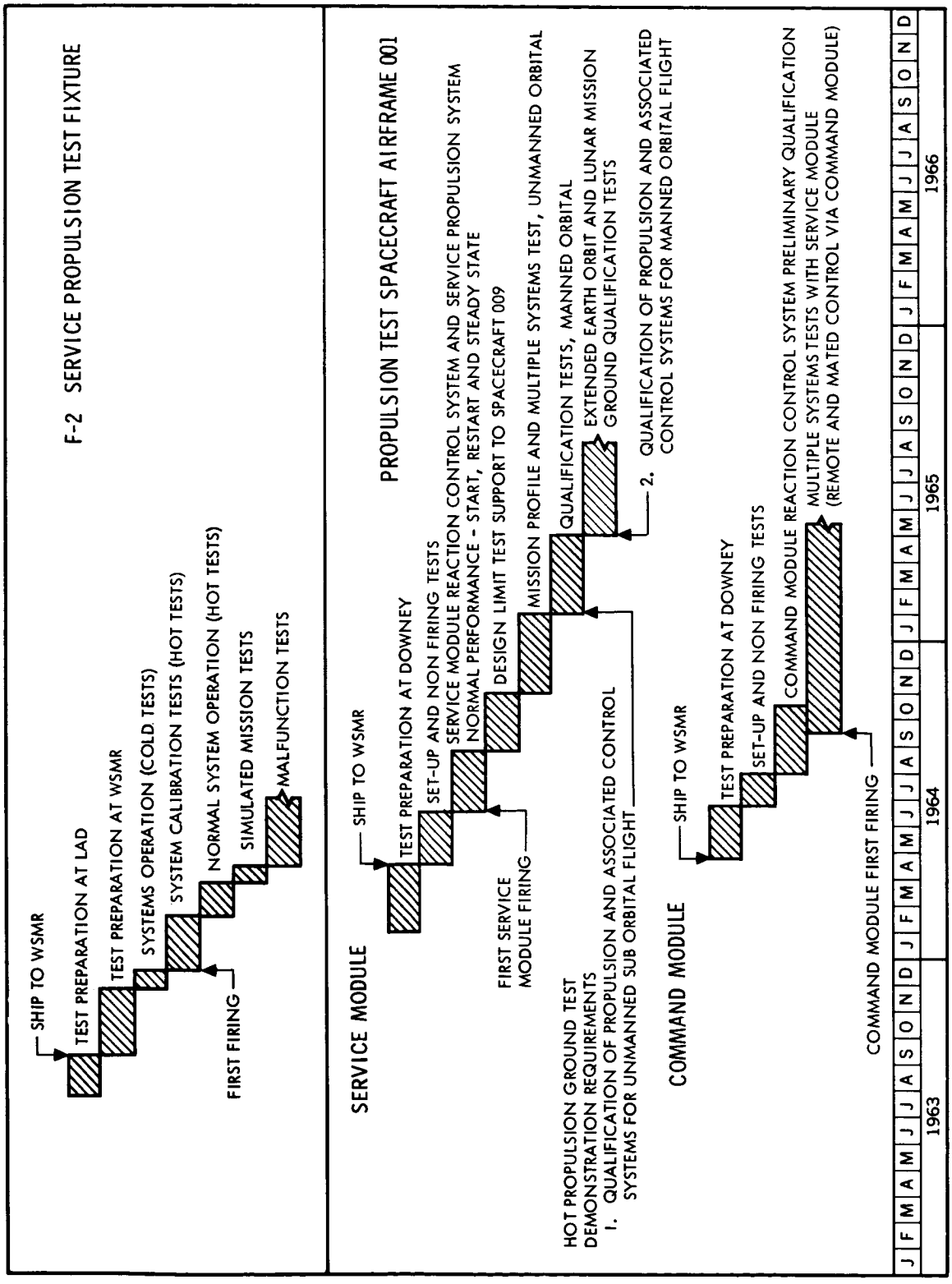


Figure 5-4. Propulsion Test Schedule

[redacted]

[redacted]

5.5.1 Scope

The environmental proof test program is designed to provide an evaluation of the spacecraft, including component systems, under simulated mission environmental conditions. Proof level tests, within practical limits of test facilities and economy, will be conducted to verify that the spacecraft can be expected to meet reliably the critical environments to which it will be exposed during an actual mission as well as during ground handling. These tests will be conducted in a sequence providing progressive levels of qualification commensurate with the various flight phases. Since no one facility can provide all environmental parameters, a series of separate tests will be conducted. These tests, in conjunction with subsystem and system-level testing, will provide the desired assurance of the spacecraft's suitability for flight operation. Test categories are space simulation (thermal-vacuum chamber) and vibration and acoustic tests. Compound stresses will be imposed whenever possible to provide the maximum attainable reliability confidence.

5.5.2 Objectives

5.5.2.1 Space Simulation (Thermal-Vacuum Chamber)

This category is directed toward the following objectives:

1. Demonstrate the operational suitability of the flight spacecraft configuration under simulated space environmental conditions of launch, earth orbit, and reentry.

2. Demonstrate the design adequacy of the flight spacecraft configuration under simulated space environmental conditions and the suitability of the vehicle for manned flight operations.

3. Determine the heat balance and equilibrium temperature distributions for earth orbit conditions.

4. Evaluate the effects of outgassing during systems operation.

5. Evaluate the effects of cyclic heating and cooling on the structure and systems operations.

6. Demonstrate the spacecraft capability to provide a life supporting environment during earth orbit mission simulations.

7. Demonstrate satisfactory manned spacecraft operation, including alternate mode systems operation.

8. Evaluate spacecraft operation under normal, extreme, and emergency operational conditions while the spacecraft is subjected to earth orbit environmental conditions.

[redacted]

[redacted]

5.5.2.2 Vibration and Acoustic

The following objectives are sought:

1. Determine susceptibility to failure of the structure, operating systems, and equipment when subjected to simulated service vibration environment

2. Verify proper operation of the spacecraft systems when they are subjected to simulated service vibration environment

3. Determine nonstressed noise and vibration levels in spacecraft

4. Determine the susceptibility of structure and equipment support to failure when subjected to ground handling and transportation vibration

5. Determine acoustic transmissibility of command module and service module structures and determine vibration response of primary and secondary structures in command module, service module, and adapter when they are exposed to sonic excitation equivalent to that expected from booster engines, abort system engines, and aerodynamic noise (launch and atmospheric reentry)

It must be noted that acoustic testing of the entire spacecraft is not scheduled because interaction between modules will be at frequencies below the excitation capabilities of the test facilities, and interaction between internal systems can be evaluated during acoustic tests of those systems.

5.5.3 Test Description

5.5.3.1 Space Simulation (Thermal-Vacuum Chamber)

The spacecraft will be installed vertically in the MSC Space Environmental Simulation Chamber and subjected to flight simulations of vacuum, heat, and cold approximating earth orbit conditions wherein the top, bottom, and side of the spacecraft are subjected to solar heating and space cooling.

Since Airframe 008 is the first flight configured spacecraft to be subjected to space conditions, verification of its ability to provide a safe environment for manned testing must be accomplished prior to conducting manned operations under simulated space conditions.

Therefore, the initial tests are oriented to qualifying the spacecraft for manned operation and to obtaining gross spacecraft operating information.

[redacted]

[redacted]

Subsequent tests allow complete manned operation of the spacecraft systems in all operating modes in a non-hazardous reduced pressure condition. Manned tests in support of Airframe 011 with particular emphasis on removal of the flight constraints will then be conducted under conditions simulating earth orbit.

Simulation of an earth orbit flight mission will be accomplished in the following manner:

1. Launch - commence pumpdown of chamber (requires approximately 24 hours to achieve orbit altitude) and operate systems accordingly.

2. Earth orbit - with environmental chamber walls at deep space cooling conditions and spacecraft at orbit injection conditions, cycle the three solar simulators in the following duty cycle:

   2.1 Top Simulator - ON for 14 minutes - OFF

   2.2 Side Simulator - ON for 22 minutes - OFF

   2.3 Bottom Simulator - ON for 14 minutes - OFF

   2.4 All three simulators OFF for 40 minutes

   2.5 Repeat steps 2.1 through 2.4

   This cyclic operation of the solar simulators will approximate the conditions of the spacecraft emerging from the earth's shadow, traversing between sun and earth, and reentering the earth's shadow.

3. Atmospheric reentry - chamber pressure is to be increased in accordance with flight profile.

4. Spacecraft roll - the lunar plane (spacecraft mounting table) will be rotated to simulate spacecraft roll during orbit simulation.

The propellant systems will operate with a water-glycol fluid in lieu of hypergolic propellants. The off-loaded fluid will be ducted to the chamber exterior. Operational prelaunch, post test, and recovery duty cycle procedures will be utilized as applicable.

Detailed environmental test plans are presented in Volume V, Section 5.

5.5.3.2 Vibration and Acoustic Tests

5.5.3.2.1 Vibration Test of Spacecraft Modules. The individual modules and the entire spacecraft (with systems operating) will be subjected to service vibration spectrums through inputs in the lateral and transverse

[redacted]

CONFIDENTIAL

[redacted]

axes. The operations will be monitored for system malfunctions and structure and equipment failures. The individual modules and the entire spacecraft (systems non-operating will be subjected to ground handling and transportation vibration spectrums to determine susceptibility to failure of the structure, equipment, and equipment supports.

5.5.3.2.2 Acoustic Tests of Modules. The modules will be mounted in holding jigs to orient the modules in the acoustic field and to isolate the modules from vibration greater than 5 cps. Internal and external acoustic levels and panel vibration will be measured for use in space flight noise rating analysis. Acoustic, vibration, and strain measurement systems will be utilized to determine acoustic transmissibility of the module structure and to determine vibration and strain response of primary and secondary structures in the modules and adapter when they are exposed to random broadband and narrow-band excitation.

5.5.3.2.3 Space Flight Noise and Vibration Rating Tests. The command module will be mounted in a quiet room facility and noise and vibration levels, with systems operating, will be determined. These data, in coordination with the other vibration test data, will be used to evaluate the space-flight nonstressed acoustic and vibration levels.

5.5.3.3 Configuration

The spacecraft tests will involve the following Apollo systems. Reference is also made to the section of this volume wherein a system functional description appears.

System	Reference
SPS	1.1
RCS	1.2
LES	1.3
ELS	1.4
ECS	1.5
EPS	1.6
G&NS	1.7
SCS	1.8
C&IS	1.9
Life systems	1.10
Structures	1.12
Mechanical devices	1.13
Thermal protection system	1.16

[redacted]

[redacted]

5.5.4 Facilities

5.5.4.1 Space Simulation

The space simulation tests are to be conducted at the NASA MSC Space Environmental Facility utilizing airframe 008.

5.5.4.2 Vibration and Acoustics

These tests are to be conducted at the S&ID Engineering Development Laboratory and the Los Angeles Division acoustic test facility using airframe 006 (house spacecraft 2) with flight configuration systems.

5.5.5 Test Schedule

The spacecraft environmental proof test schedule is shown in Figure 5-5.

5.6 HOUSE SPACECRAFT TEST PLANS

5.6.1 Scope

House spacecraft testing will be a continuous effort that will have three main phases. These phases are systems and GSE evaluation, operations development, and design support. Systems to be tested will include all command module systems and the major portion of the service module systems (excluding actual firing tests of mission propulsion and reaction control motors). During these test phases, GSE will be evaluated for adequacy of design to test the systems concerned and for determining the ability of the GSE to detect and isolate critical system failures. Systems testing with the house spacecraft will be accomplished with major emphasis on integrated systems testing.

Data obtained from the continual testing of the house spacecraft systems will be used in determining suitability of design specifications, reliability and safety factors in design, and mission success probabilities. Simulated mission tests will be performed to establish specific reliability, crew safety assessments, confidence levels, and man-machine interfaces. The vibration and acoustic portions of the environmental proof test program will be accomplished with the second house spacecraft (airframe 006).

5.6.2 Objectives

5.6.2.1 Systems and GSE Evaluation

Objectives for the system and GSE evaluations are as follows:

[redacted]

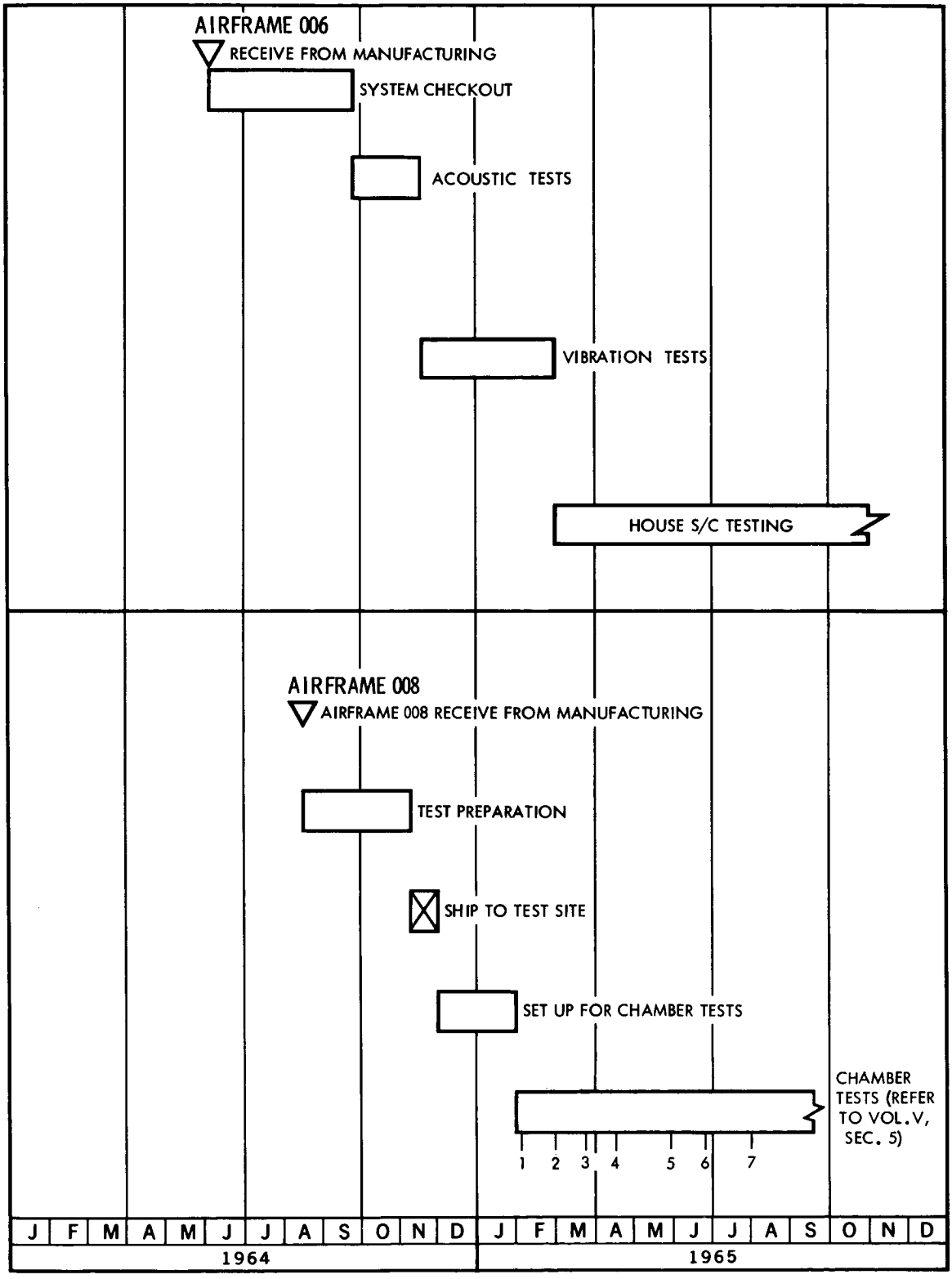


Figure 5-5. Spacecraft Environmental Proof Test Schedule

[redacted]

[redacted]

1. Assure proper performance of components and subsystems

2. Verify individual major systems performance under ambient and certain vibration and acoustic environments

3. Verify system conformance to design specifications

4. Assess GSE (including PACE and STU) compatibility with systems

5. Evaluate requested design modifications

5.6.2.2 Operations Development

Objectives for the operations development program are as follows:

1. Verify systems integration in and between major modules

2. Determine adequacy of GSE to detect and isolate system failure

3. Determine in-flight maintenance capability

4. Determine electromagnetic susceptibility levels

5. Confirm development design modifications

6. Determine suitability of design specifications

7. Verify human performance criteria (handling, checkout, and maintenance operations)

8. Determine system performance as a function of operating time, specific functional inputs, and environmental conditions

9. Develop handling and integrated systems checkout procedures

10. Develop operational procedures for vehicle and mission (ground and flight crews)

11. Verify that all equipments, procedures, and checkout environments are designed for optimum safety

5.6.2.3 Design Support

Design support objectives for the house spacecraft test program are as follows:

[redacted] [redacted]

1. Evaluate design development changes prior to inclusion in the flight systems

2. Determine malfunction modes, limits, and trends

3. Evaluate design changes to automatic checkout equipment or techniques

4. Analyze system malfunctions occurring during test preparation

5. Evaluate systems control and information display for optimum checkout and flight crew performance

5.6.3 Requirements

To accomplish the objectives, certain special test equipment requirements must be met. These requirements include, but are not limited to, the following:

1. GSE for checkout, servicing, and handling (include all direct interface GSE, i.e., PACE equipment)

2. Functional up-dating of all boilerplate 14 systems to operational status

3. Facilities for handling and storage of all equipment fluids and gases except those whose use is not permitted under the existing safety requirements at Downey

4. Exhaust and venting systems for gaseous operations (e.g., fuel cell operation)

5. Continuous up-dating of all systems on boilerplate 14 and airframe 006 to maintain current mission phase configurations

6. Special facilities for excitation of the spacecraft during full systems operation in vibration and acoustic environments (present plans are to utilize facilities at Downey and at Los Angeles Division of NAA)

5.6.4 Test Description

House spacecraft testing will begin with boilerplate 14 (designated house spacecraft 1), which is scheduled for delivery in October 1963. House spacecraft 1 will be a skeletal structure with removable skin. This spacecraft will permit installation of spacecraft systems in their proper geometric relations to each other to determine actual operating characteristics.

[redacted]

This testing will permit on-site modification assessment within working systems to properly assess developmental systems prior to time of prototype manufacturing. Much of the system installation will be of temporary nature (packaged breadboard) until prototype systems are firmly established. The initial systems will be up-dated to full prototype as soon as systems availability will permit.

The second house spacecraft (airframe 006) will be a full prototype structure and systems for developing integrated systems checkout and procedures. It is scheduled for delivery in March 1964. This vehicle will be used to accomplish the vibration and acoustic portions of the environmental proof test program, resolve interface problems, verify intersystem compatibility, develop and evaluate operational procedures, and perform malfunction mode analysis as the over-all test program proceeds. House spacecraft 1 will be integrated into this phase of testing as the prototype systems are installed. However, house spacecraft 1 will be limited in that the removable skin will not permit cabin pressurization testing in the command module.

The house spacecraft configuration will consist of those systems noted below; reference is also made to sections of this volume which contain a functional description of these systems.

Systems	Reference
SPS	1.1
RCS	1.2
LES	1.3
ECS	1.5
EPS	1.6
G&NS	1.7
SCS	1.8
C&IS	1.9
Life systems	1.10
GSE	1.11
Mechanical devices	1.13
Thermal protection system	1.16

During all phases of the testing program, the prototype systems will be up-dated by modification or actual replacement with production hardware to ensure that test data will be valid for the current flight hardware reliability criteria.

For further details on this test program, refer to Volume V, Section 6.0.

[redacted]

5.6.5 Facilities

The house spacecraft testing program will be accomplished primarily in Building 290 at Downey. Certain specific tests that require excitation of the complete spacecraft in the expected vibration and acoustic environments will be done in facilities under the cognizance of the S&ID Engineering Development Laboratories at Downey and the Los Angeles Division of NAA. A complete set of GSE will be required to accomplish test operations on all systems with the exception of actual firing of mission propulsion, reaction control, and pyrotechnic devices. These systems will be tested with non-toxic liquids, gases, or simulators to assess control of the systems without violating local safety ordinances.

5.6.6 Test Schedule

Figure 5-6 shows the house spacecraft test schedule.

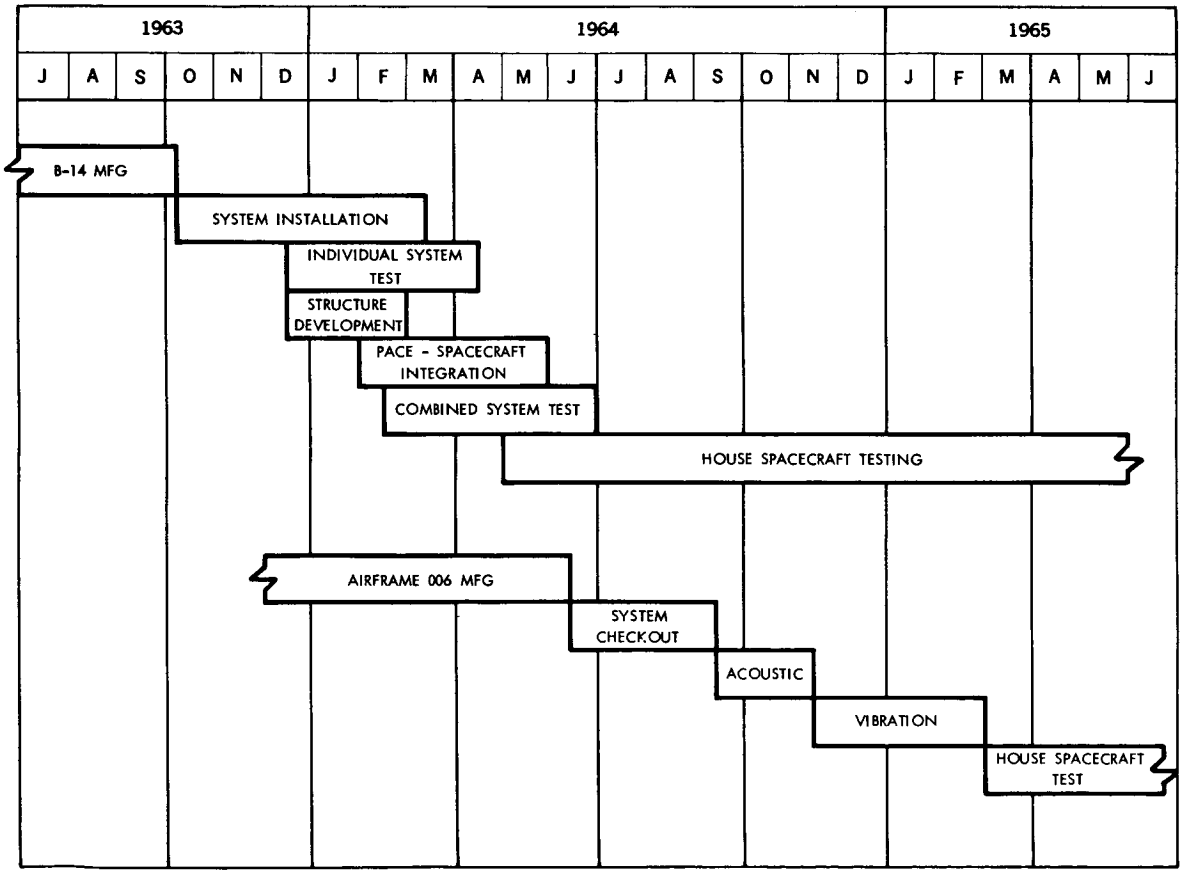


Figure 5-6. House Spacecraft Test Schedule

[redacted]

[redacted]

5.7 SPACECRAFT TEST PREPARATION PLANS

5.7.1 Scope

The spacecraft test preparation program consists of planning, scheduling, implementing, performing, reporting, and evaluating checkouts on the Apollo spacecraft at the Downey facility beginning with boilerplate 6. Present schedule estimates indicate 14 boilerplates and airframes to be processed through the test preparation area up to February 1965. The test program is designed to verify satisfactory operation of individual and integrated systems according to the S&ID specifications. The major goal is to have the vehicle flight ready with an extremely high degree of reliability in all components and systems.

5.7.2 Objectives

The objectives of the spacecraft test preparation program are as follows:

5.7.2.1 First-Order Checkout Objectives

1. Perform checkouts for evaluation of individual system and integrated systems performance and flight readiness, utilizing field test procedures and techniques

2. Determine malfunctions and off-limit performance and perform malfunction analysis to permit corrective action before delivery to the field test site

3. Demonstrate test vehicle/GSE compatibility

4. Determine necessary procedures, data, and statistics to assure that the test preparation requirements and objectives have been accomplished prior to shipment to a field test site

5. Determine man-machine interface criteria

5.7.2.2 Second-Order Checkout Objectives

1. Demonstrate a logical development of techniques, procedures, and facilities

2. Demonstrate crew in-flight capabilities associated with mission simulation checkouts

[redacted]

5.7.3 Requirements

Test requirements for individual and combined systems tests and integrated systems tests for the various boilerplates and airframes will be included in the detailed test plan. The test requirements will reflect the test objectives, which will be tailored for each spacecraft configuration and mission.

5.7.4 Test Description

Spacecraft flight readiness sequences will be accomplished in two parts. The first part of the sequence will be performed in the spacecraft test preparation area at the Downey facility, and the second part of the sequence will be completed at either the WSMR or the AMR.

The spacecraft test preparation area at the Downey facility will receive the boilerplates and airframes from manufacturing final assembly and process them through the typical sequence shown in Figures 5-7 and 5-8.

A complete examination of the spacecraft systems and subsystems will be performed in the preparation area to ensure conformance with the latest configuration, specifications, and engineering orders and to ensure the readiness of the hardware for test operations.

Modification and updating of the spacecraft to the latest mandatory engineering orders will be completed before the spacecraft goes to the tumble station. Modifications will also be accomplished prior to shipment of the spacecraft to the field. R & D instrumentation equipment will be installed according to the NASA's requirements.

Individual systems checks will be conducted on each spacecraft system to ensure functional operation and to verify performance within engineering specification limits. Combined and integrated systems checks will be conducted to ensure satisfactory operation of all spacecraft systems. Integrated systems checks will include a mission sequence simulation to demonstrate functional capability of the entire spacecraft before shipment to the field test site.

Spacecraft systems will be flushed and purged as required. After adequate examination and cleaning, individual modules will be weighed and the center of gravity determined. The gross center of gravity for the spacecraft will be computed.

Modifications to the spacecraft will be further accomplished depending on the NASA and/or the S&ID requirements. Additional checkout subsequent

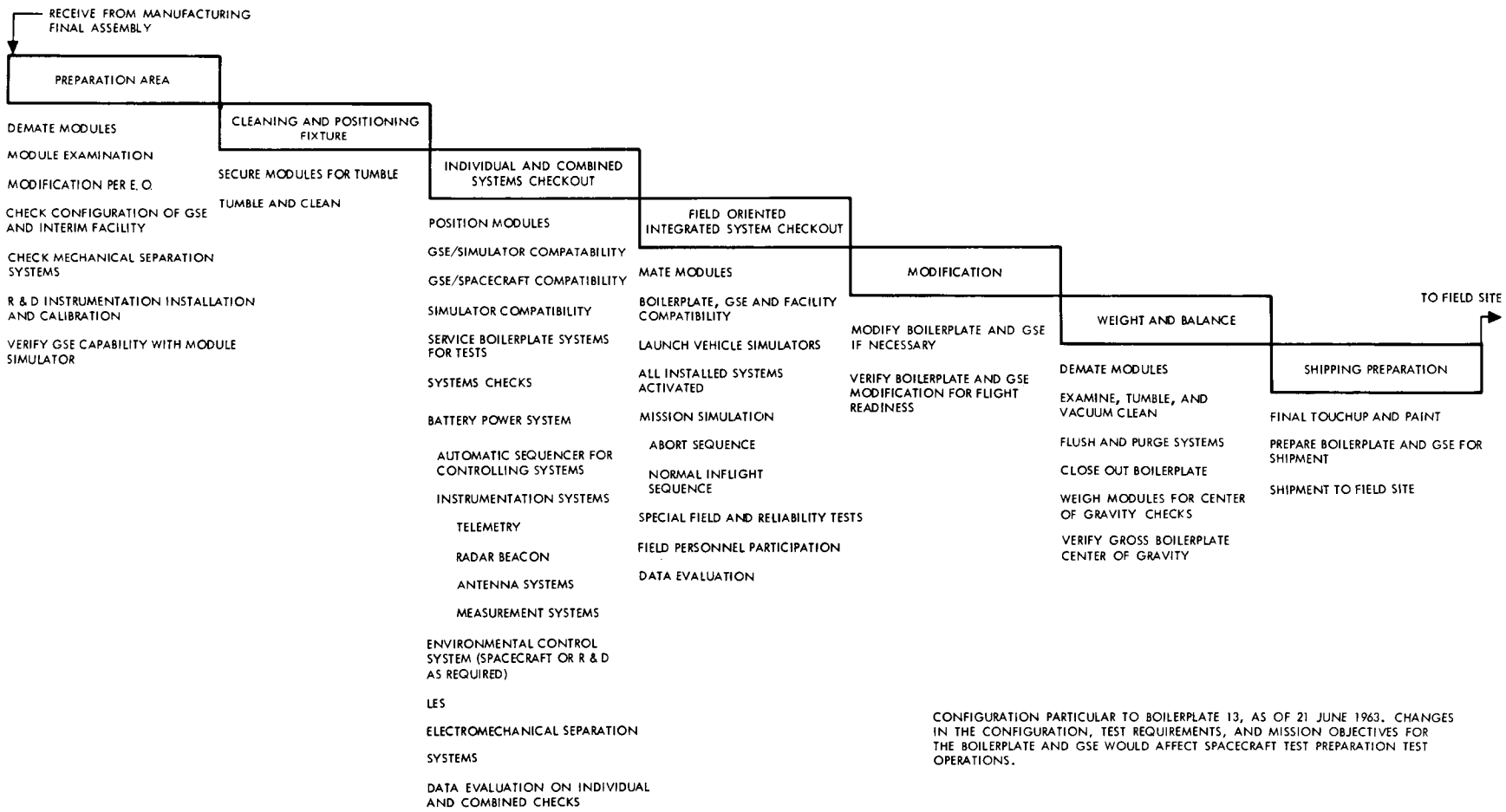
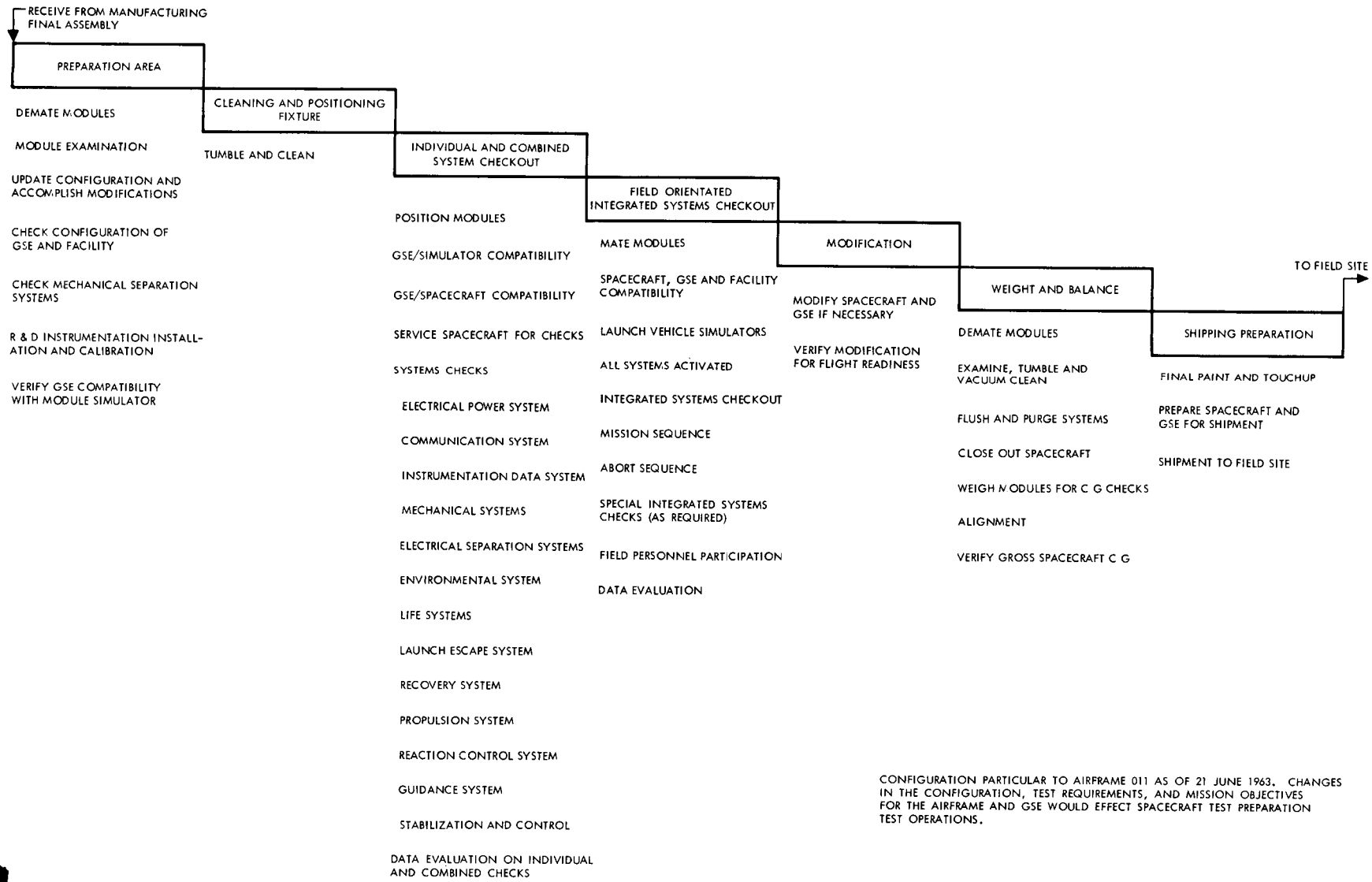


Figure 5-7. Typical Boilerplate Sequence of Operations During Test Preparation



CONFIGURATION PARTICULAR TO AIRFRAME 011 AS OF 21 JUNE 1963. CHANGES IN THE CONFIGURATION, TEST REQUIREMENTS, AND MISSION OBJECTIVES FOR THE AIRFRAME AND GSE WOULD EFFECT SPACECRAFT TEST PREPARATION TEST OPERATIONS.

Figure 5-8. Typical Airframe Sequence of Operations During Test Preparation

[redacted]

to these modifications will be performed on systems affected by the modifications to verify and substantiate satisfactory performance.

5.7.5 Facilities

The revised plan for the interim test facility indicates that the checkout of boilerplates 6 through 15 is based on the use of the area in Building 1 (Figure 5-9) at the Downey USAF Plant 16 facility.

Airframe 001 and subsequent spacecraft will be checked in Building 290. Present estimate on the beneficial occupancy date for Building 290 is 22 November 1963. For additional test facility information, refer to SID 62-153, Facilities Plan for Project Apollo Spacecraft.

Completion of Downey facility Building 290 will enable using the operational GSE and checkout facility to accomplish spacecraft test preparation with the exceptions of actual firing of the propulsion and reaction control systems, space condition operation of the environmental control system, and the usage of supercritical gases for operation of the spacecraft fuel cell. However, the operation of the fuel cell will be accomplished by using gases without violating state or local safety ordinances and codes.

5.7.6 Test Schedule

The spacecraft test preparation program schedule shown in Figure 5-10 reflects the sequence through airframe 010, which is the command module pad abort qualification flight. Further programming and scheduling will continue in compliance with subsequent manned space flight missions.

5.7.7 Data Handling and Analysis

5.7.7.1 Analysis and Evaluation

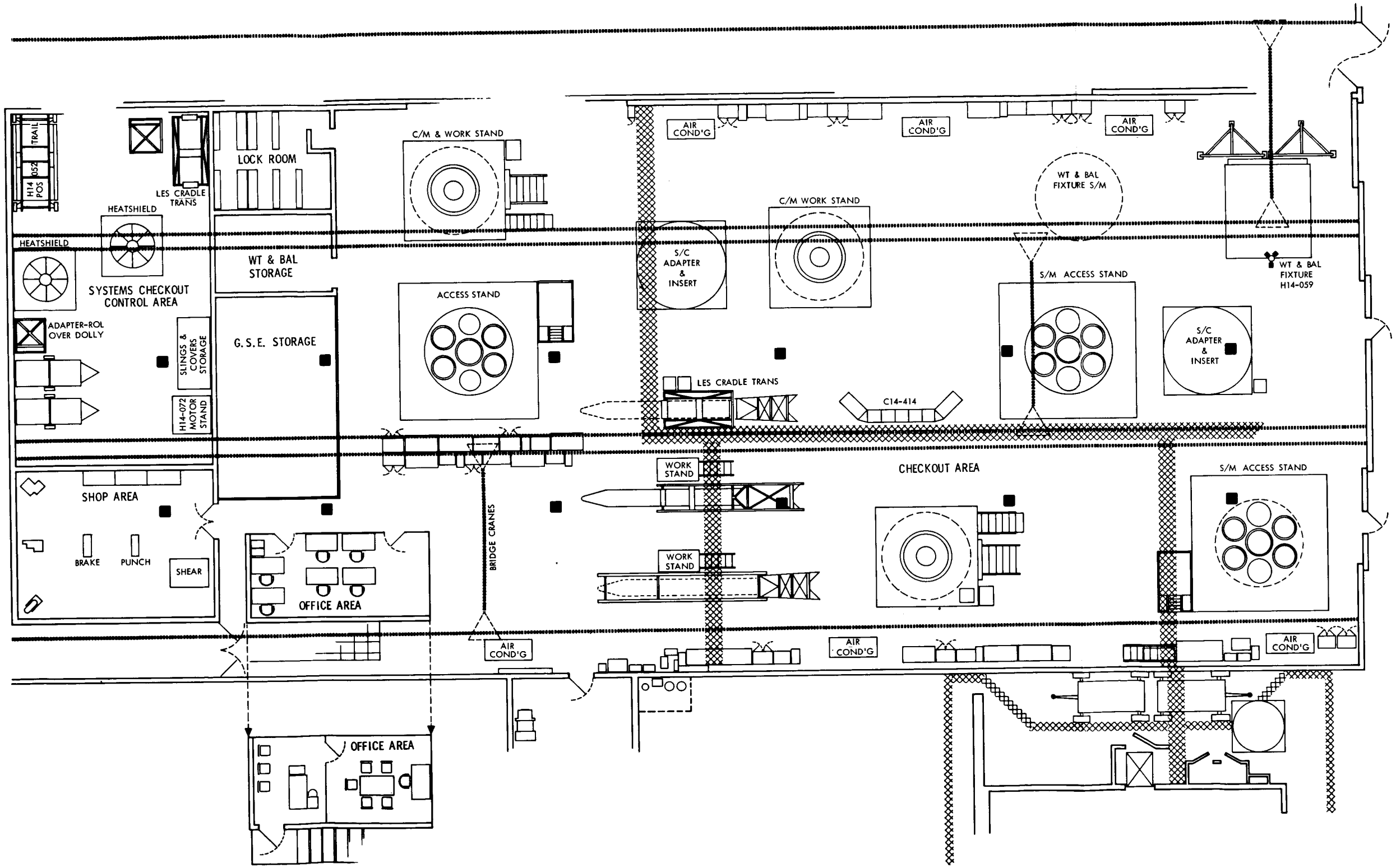
Test data will be analyzed and evaluated by personnel from the spacecraft test preparation group and the data engineering group. Data from tape recordings will be utilized, and computerized data will be used to a depth compatible with the required evaluation. Data support will be provided to the project engineer during checkout in any manner needed.

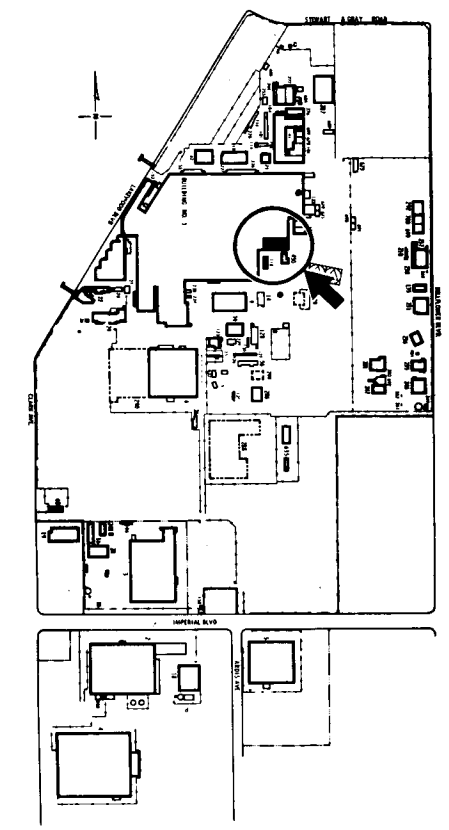
5.7.7.2 Checkout Reporting

All checkouts will be documented. The documentation will include a thorough description of the checkout, a presentation of the checkout data, and evaluation of these data. Preliminary reports will be issued on all checkout results that indicate need for immediate engineering action. Final

[redacted]

[redacted]





ORIENTATION PLAN

Figure 5-9. Interim Boilerplate Test Preparation Area, Bldg 1, Downey

[redacted]

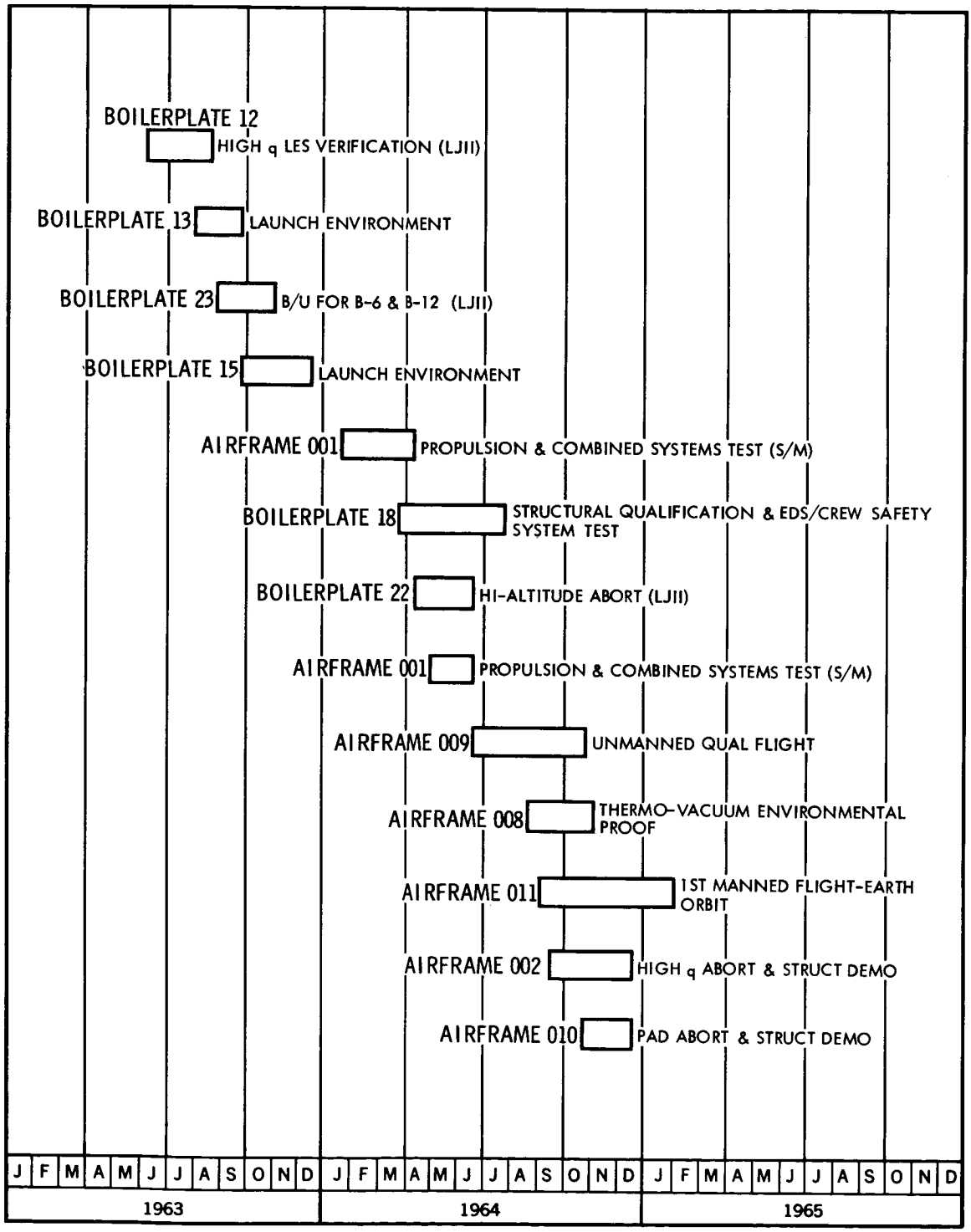


Figure 5-10. Spacecraft Test Preparation Schedule

[redacted]

formal checkout reports will be issued that will include a presentation of the results obtained by the Apollo groups responsible for analysis and evaluation.

5.7.7.3 Data Handling and Flow

Data will be acquired by hard line and r-f link during the tests. These data will be recorded on magnetic tape for subsequent playback. Quick-look oscillograph and strip-chart records will be prepared during and immediately after a test to establish trends, obtain relative magnitudes, and detect problem areas.

Upon completion of each individual checkout, data will be prepared for preliminary engineering review. These data will be completely identified so that trends can be confirmed and areas of further reduction can be selected and initiated. Final processing will entail absolute magnitudes and computations for distribution and for formal reporting. Physical data storage will include provisions for ready access and rapid retrieval.

5.7.7.4 Calibration Data

Calibrations are required for scaling of data. Instrument calibration data will accompany each piece of instrumentation delivered to test preparation. These data will be verified upon installation of the instrumentation in the test vehicle. The up-dated calibration data will then be supplied to the data engineer for utilization in data reduction.

These data will be processed through a computer to produce a fitted calibration curve and an oscillograph reading card and to up-date the master calibration tape. The curves and cards will be utilized for quick look and preliminary review of test data. The tape will be utilized for automatic data reduction.

5.7.7.5 Data Retention and Control

Magnetic tape will be retained for future data reduction if needed. Control and distribution of all data (films, records, tape, etc.) will be maintained.

5.7.8 Reliability Engineering Support

Reliability Engineering will act as a checkout historian and accumulate all applicable data on spacecraft checks, plans, and performance from preparation areas through to delivery. The data will be used in qualitative and

[redacted]

quantitative assessments of reliability and performance of each subsystem, and of the spacecraft as a whole. This data, together with other appropriate data, such as acceptance data, both from the subcontractor and in-house, will be integrated with that accumulated from prior checks to form interim assessments at appropriate times. Thus, a probability of success can be provided for any given phase. The reliability data can also be compared with program objectives in order to assure that these have been attained at any time.

This data will also be compared with the flight constraints generated for each multiple system checkout to determine whether or not a launch can be attempted.

[redacted]

NOMENCLATURE

A listing of the special nomenclature and abbreviations used in this report is presented. These listings may appear interchangeably with their full definitions in the text. Accepted abbreviations for units of physical measurement such as volts, ohms, etc. are not included.

Abbreviation	Definition
AEDC	Arnold Engineering Development Center
AFMTC	Air Force Missile Test Center
AFRM	Airframe
AGAP	Attitude gyro and accelerometer package
AGC	Aerojet-General Corporation
AGC	Automatic gain control
AGREE	Advisory group on reliability of electronic equipment
AMR	Atlantic Missile Range
ATO	Apollo Test and Operations
BAL	Balance
BCD	Binary coded decimal
B-#	Boilerplate - # (with specific number)
B/M	Bench maintenance
BMAG	Body-mounted attitude gyros
BOD	Beneficial occupancy date
B/P	Boilerplate

[redacted]

[redacted]

Abbreviation	Definition
CCMTA	Cape Canaveral Missile Test Annex
C&D	Controls and displays
CDS	Communications and data subsystems
CDU	Coupling display unit
CG	Center of gravity
C&IS	Communications and instrumentation system
C/M	Command module
C/O	Checkout
C-O	Crew operated
CP	Control panel
CTU	Central timing unit
CVR	Change verification record
DEA	Display electronic assemblies
DF	Direction finding
DOD	Department of Defense
DOF	Degrees of freedom
DP	Design proof
DPT	Design proof test
DSIF	Deep Space Instrumentation Facility

[redacted]

[redacted]

Abbreviation	Definition
DVD	Differential velocity display
EBW	Exploding bridge wire
ECA	Electronic control assembly
ECS	Environmental control system
EDL	Engineering Development Laboratory (S&ID Dny)
ELS	Earth landing system
EMI	Electromagnetic interference
EPS	Electrical power system
ET	Escape tower
FDAI	Flight director attitude indicator
FM	Frequency modulation
FAX	Facsimile transmission
G, g	Acceleration of gravity
G&NS	Guidance and navigation system
GOSS	Ground operational support system
GP	General purpose
GPI	Gimbal position indicator
GSE	Ground support equipment
HAA	High-altitude abort
HBW	Hot bridge wire
H/A	Hazardous area

[redacted]

[redacted]

Abbreviation	Definition
IFT&M	In-flight test and maintenance
IMCC	Integrated Mission Control Center
IMU	Inertial measurements unit
INT	Interior
INST REF	Instrument reference
IRIG	Inter-range instrumentation group
L-	Time before launch (days)
LAD	Los Angeles Division (or NAA)
L/D	Length-diameter ratio
LEM	Lunar excursion module
LEV	Launch escape vehicle
LES	Launch escape system
LJII	Little Joe II
LOR	Lunar orbit rendezvous
LSS	Life support system
L/V	Launch vehicle
MDSS	Mission data support system
M-#	Mock-up - # (with specific number)
Max q	Maximum dynamic pressure
MEE	Mission essential equipment

[redacted]

[redacted]

Abbreviation	Definition
MIT	Massachusetts Institute of Technology
MLT	Mission life test
MNEE	Mission non-essential equipment
MSC	Manned Spacecraft Center (NASA, Houston, Texas)
MTBF	Mean time before failure
MTTR	Mean time to repair
NAA	North American Aviation
NASA	National Aeronautics and Space Administration
O/F	Oxidizer-to-fuel ratio
OPS	Operations
OTP	Operational test procedure
PA	Power amplifier
PACE-S/C	Prelaunch automatic checkout equipment - spacecraft
PAM	Pulse amplitude modulation
PCM	Pulse coded modulation
PCM	Pulse code modulator
PDM	Pulse duration modulation
P_f	Probability of failure
P_{f_p}	Probability of performance failure
P_{f_s}	Probability of stress failure
PFRT	Preliminary flight rating test
POD	Prelaunch Operations Division (NASA)

[redacted]

[redacted]

Abbreviation	Definition
P_s	Probability of success
PSA	Power and servo assembly
PTT	Push to talk
PUCS	Propellant utilization control system
P&WA	Pratt & Whitney Aircraft
R/B	Radar beacon
R/C	Radio command
RCC	Range control center
RCS	Reaction control system
R&D	Research and development
REG	Regulator
RF	Radio frequency
RFI	Radio frequency interference
RFWAR	Requirements for work and resources
RGP	Rate gyro package
R&Z	Range and zero
SA	Saturn Apollo
SCAT	Space communications and tracking
SCD	Specification control drawing
SCIP	Self-contained instrumentation package
SCO	Subcarrier oscillator
SCR	Silicon-controlled rectifier

[redacted]

[redacted]

Abbreviation	Definition
SCT	Scanning telescope
S/C	Spacecraft
S/C_a	Spacecraft adapter
SCS	Stabilization and control system
SEP	Space electronic package
S&ID	Space and Information Systems Division (of NAA)
S/M	Service module
SOL	Solenoid
SOFAR	Sound fixing and ranging
SPS	Service propulsion system
STU	Systems test unit
SXT	Sextant
T-	Time before launch
T-O	Time of launch
T+	Time after launch
T/M	Telemeter
TP	Test point
TPA	Test preparation area
TPS	Thermal protection system
T/R	Transmitter receiver (combination in two packages)
TWT	Traveling wave tube
TWX	Teletype wire transmission
UDMH	Unsymmetrical dimethyl hydrazine

[redacted]

Abbreviation	Definition
VCO	Voltage controlled oscillator
VLF	Vertical launch facility
VSWR	Voltage standing wave ratio
WSMR	White Sands Missile Range
XCVR	Transceiver (transmitter receiver in one package)

[redacted]

DEFINITION OF TERMS

ABLATE	To carry away; to remove by cutting or erosion, melting or evaporation. To undergo ablation; to become melted or vaporized and removed at a very high temperature.
ABORT	An uncompleted missile flight or an uncompleted hold-down test resulting from a failure of equipment or of a system other than the one undergoing test. In a tactical operation (simulated or real) a missile failure either on the ground or in flight; a missile that fails to complete a programmed flight.
ADAPTER	Flange or extension of a vehicle stage or section providing a means of fitting another stage or section to it.
AEROBALLISTICS	Term derived from aerodynamics and ballistics, dealing primarily with the motion of bodies whose flight path is determined by applying the principle of both sciences to different portions of the path.
AEROTHERMODYNAMIC BORDER	Area above an altitude of about 100 miles where the atmosphere becomes so rarefied that there is no longer any significant heat-generating air friction on the skin of vehicles.
AIRFRAME	Assembled structural and aerodynamic components of an aircraft or missile.
ALBEDO	The ratio of light reflecting from an unpolished surface to the light falling upon it. Term is used in reference to light reflected from the moon or planets.
AMBIENT CONDITIONS	Environmental conditions such as pressure or temperature; naturally existing conditions.
ANTHROPOMORPHIC	Human-like; related to or designed for the human body.

[redacted]

[redacted]

[redacted]

APOLLO	NASA designation for follow-up manned space-flight program to Project Mercury manned orbital mission. Apollo spacecraft is to be suitable for manned earth-orbiting laboratory, manned circumlunar flight, manned lunar landing, and return.
ATLANTIC MISSILE RANGE (AMR)	A 5000- to 6000-mile instrumented range for testing ballistic and guided missiles located between Cape Canaveral, Florida, and a point beyond Ascension Auxiliary AFB, near the middle of the South Atlantic.
ATTITUDE	Orientation of an air vehicle as determined by the inclination of its axis to a frame of reference, usually the earth.
ATTITUDE JETS	Sometimes called steering jets, attitude-control jets or roll, pitch, and yaw jets; fixed or movable gas nozzles on a rocket, missile, or satellite operated continuously or intermittently to change attitude or position.
AXIS, AXES	Reference axes in the Apollo spacecraft are as follows:
X-axis	The X-axis is parallel to the nominal launch axis and is positive in the direction of initial flight.
Y-axis	The Y-axis is normal to the X-axis and is positive to the right of a crewman when the crewman is in his seat facing toward positive "X."
Z-axis	The Z-axis is normal to both the X- and Y-axes and is positive in the direction of the crewman's feet when he is in his seat.
BACKUP	Designed to immediately follow an earlier space system or a project to complement the latter or take advantage of new techniques and processes; a system that can replace a failed system.

[redacted]

BENCH MAINTENANCE EQUIPMENT	Equipment supporting component and subsystem testing; facilities capable of isolating, defining, and providing remedial action to malfunctions.
BIOMEDICINE	Combined discipline of biology and medicine for analysis of human tolerances to and protection against environmental variances.
BOILERPLATE	Simulated module for predevelopmental and developmental tests leading to the design of the spacecraft module.
BOOSTER ENGINE	An engine, especially a booster rocket, that adds thrust to the thrust of the sustainer engine, or provides propulsion for a special phase of flight.
BREADBOARD MODEL	An assembly of preliminary circuits and parts to prove the feasibility of a device, circuits, equipment, system or principle in rough or breadboard form without regard to the eventual over-all design or form of parts.
BRIDGE WIRE	The ignition resistor filament. The bridge wire heats the primary explosive to initiate the explosion.
CELESTIAL GUIDANCE	Mechanically or electrically recorded navigational tables, computers, and other instruments and devices that sight stars, calculate position, direct, and control the spacecraft.
CENTRIFUGE	A large motor-driven apparatus with a long rotating arm at the end of which human and animal subjects or equipment can be revolved at various speeds to simulate accelerations encountered in high-performance vehicles.
CHECKOUT	A sequence of operational and calibrational tests needed to determine the condition and status of a required operation or function.

[redacted]

[redacted]

COASTING FLIGHT	The flight of a rocket or other vehicle between burnout or thrust cutoff of one stage and ignition of another, or between final burnout and summit altitude or maximum range. Also the unpowered portion of an interplanetary flight.
COMMAND MODULE	Personnel and control vehicle in the Apollo spacecraft configuration containing command and communication facilities and crew provisions.
COMPATIBILITY	The quality that permits an item to function in harmony with other equipment and fulfill all design objectives.
CONFIGURATION	The physical nature of an item; the physical arrangement of components which comprise a spacecraft and its dimensions.
CONSOLE	Master instrument panel from which rocket and missile launchings and test are controlled; a group of controls, indicators, and similar electrical or mechanical equipment that is used to monitor readiness of and/or control specific functions such as missile checkout, countdown and launch operations.
COUNTDOWN	Series of numbered events and checks that take place from the start of rocket-launching operations until the rocket lifts off the launch stand.
CRYOGENIC FUEL	A rocket fuel that either in itself is kept at very low temperatures or combines with an oxidizer kept at very low temperatures.
CUTOFF	The shutting off of a liquid or solid-propellant combustion process of a rocket engine, causing a rapid drop toward zero thrust (intentional command action).
DEEP SPACE INSTRUMENTATION FACILITY (DSIF)	Communication equipment capable of contacting and tracking spacecraft beyond normal ranges. DSIF facilities are located at Woomera, Australia; Johannesburg, South Africa; and Goldstone, California

[redacted]AL

[redacted]

DEMONSTRATE	Denotes the occurrence of an action or an event during a test. The accomplishment of this type of objective requires a qualitative answer. The answer will be derived through the relation of this action or event to some other known information or occurrence. This category of objectives implies a minimum of system instrumentation and/or that information be obtained external to the test vehicle.
DESIGN VERIFICATION TEST	Basic development test used to determine the adequacy of the design over the anticipated operating conditions. A design verification test is always conducted by Engineering and on a breadboard level.
DETERMINE	Denotes the measuring of performance of any unit or system. This category implies the quantitative investigation of over-all operation, which includes, generally, instrumentation for measuring basic inputs and outputs of the unit or system. The information obtained should indicate to what extent the system is operating as designed. The instrumentation should allow performance deficiencies to be isolated to either the system or the system inputs.
DRAG	The resistance of a body to motion in a medium such as air.
DRY WEIGHT	Weight of a rocket vehicle without its fuel and usually without payload.
EARTH LANDING SUBSYSTEM (ELS)	Acceleration-decreasing equipment for return to the earth's surface after atmospheric reentry; may consist of a parachute system, a flexible aerodynamic glider configuration, or both.
ENGINEERING DEVELOPMENT PART	A part or unit to be employed in a breadboard design.
ENVIRONMENTAL CONTROL SUBSYSTEM (ECS)	The components controlling crew conditions in the spacecraft; governing factors of atmosphere, pressure, and temperature; and providing support for spacesuit conditions in event of cabin decompression or extra vehicular operations.

[redacted]

[redacted]

ESTABLISH	Denotes gathering information for the development of ground procedures and operating techniques. Objectives in this category are not necessarily dependent on analytic studies.
EVALUATE	Denotes the measuring of performance of any unit or system, as well as the performance and/or interaction of its sections or subsystems that are under investigation. The accomplishment of objectives of this type requires quantitative data on the performance of both the unit or system, and its sections or subsystems will be analyzed for their contribution toward performance of the unit or system. This category will provide the most detailed information of any of these categories.
FALLAWAY SECTION	Any section of a rocket vehicle that is cast off and falls away from the vehicle during flight, especially such a section that falls back to earth.
FIRST MOTION	First indication of motion of the missile or test vehicle from its launcher. Synonymous with "takeoff" for vertically launched missiles.
FLIGHT READINESS FIRINGS (FRF)	A missile system test consisting of the complete firing of the liquid-propellant engines of a rocket missile while it is restrained in its launching stand to verify the readiness of the missile for a flight test or mission.
FREE-FLIGHT TRAJECTORY (Free Fall Ellipse)	That part of a ballistic missile's trajectory that begins with thrust cutoff and ends at reentry.
FUEL CELL	A source of electrical power analogous to a common electrical cell with the reactants continually replenished from an external supply.
GAMMA RADIATION	Electromagnetic radiation having a high degree of penetration similar to X-rays originating from the nucleus.

[redacted]AL

[redacted]

GEMINI	NASA follow-up program to Mercury; a two-man spacecraft to demonstrate rendezvous and docking techniques, longer orbital flights (to 14 days), controlled reentry, and landing.
GIMBALED MOTOR	A rocket motor mounted on a gimbal, i. e., on a contrivance having two mutually perpendicular axes of rotation so as to correct pitching and yawing.
GODDARD SPACE FLIGHT CENTER (GSFC)	NASA research center at Greenbelt, Maryland, named for Robert H. Goddard, American rocket pioneer.
GOLDSTONE TRACKING FACILITY	A deep space instrumentation facility located at Army's Camp Irvin, Barstow, California, using a radiotelescope and operated for NASA by Jet Propulsion Laboratory (JPL).
GO NO-GO	A missile launch controlled at the end of the countdown as to permit an instantaneous change in decision on whether or not to launch.
GROUND OPERATIONAL SUPPORT SYSTEM (GOSS)	Network of tracking stations, fixed and mobile, air, ground, and seaborne to communicate with, track, and telemeter spacecraft and satellites.
GROUND SUPPORT EQUIPMENT (GSE)	All ground equipment that is part of the complete spacecraft system and that must be furnished to ensure its support. All implements or devices required to maintain the functional operational status of the spacecraft are included. In the Apollo program, bench maintenance equipment, combined system test unit, and prelaunch automatic checkout equipment comprise the GSE.
GUIDANCE	(1) The process of intelligent gathering and maneuvering required by a missile, probe, or space ship to reach a specified destination. (2) General term includes entire scheme: sensing devices, computers, and servo systems.

[redacted]

 [redacted]

[redacted]

HEAT SHIELD	An ablative protective covering to ensure spacecraft and crew survival through the hypertemperatures of atmospheric reentry.
HEAT SINK	A device that absorbs heat energy.
HOT TEST	Propulsion system test conducted by actually firing the propellants. A hot test may be live, static, or conducted in a confined place.
INERTIAL GUIDANCE	An onboard guidance system for space and satellite vehicles where gyros, accelerometers, and possibly a gyro-stabilized platform satisfy guidance requirements without use of any ground-located components. The system is entirely automatic, following predetermined trajectory.
INFRARED LIGHT	Light in which the rays lie just below the red end of the visible spectrum.
INITIATOR	A primary explosive mixture used as a primer, detonator for caps which initiates the explosion of blasting propellant, bursting explosives at the desired moment.
INTERIM QUALIFIED	A term used to describe the status of a component or system scheduled for use in early flights wherein the basically essential qualification tests have been successfully completed as related to the specific flight objectives.
INVERTER	A converter to a-c power from a d-c source.
JET STEERING	The use of fixed or movable gas jets on a space weapon, ballistic missile, or sounding rocket for thrust vector control to steer it along a desired trajectory, during both propelled flight and after thrust cutoff.
KELVIN SCALE (K)	A temperature scale that used Centigrade degrees as gradients and absolute zero for zero. Zero Kelvin equals -460 F or -273 C.

[redacted]

LANGLEY RESEARCH CENTER	NASA installation in Hampton, Virginia, responsible for technical research in development and improvement in both atmospheric and space flight.
LAUNCH WINDOW	The allowable limits of launch time that will allow a spacecraft to achieve successful injection into programmed flight path.
LAUNCH ESCAPE SUBSYSTEM (LES)	The components for command module recovery in case of mission abort after launch and prior to orbit. The system consists of the launch escape motor, the launch escape tower, and the tower jettison motor.
LIQUID HYDROGEN	Liquid rocket fuel that develops a specific impulse, when oxidized by liquid oxygen, ranging between 317 and 364 seconds depending upon the mixture ratio.
LIQUID OXYGEN	Oxygen supercooled and kept under pressure so that its physical state is liquid. Used as an oxidizer in a liquid-fuel rocket.
LITTLE JOE (I, II)	A solid-rocket test vehicle developed by General Dynamics. I was used especially to test the Mercury capsule, and II will be used to test the Apollo spacecraft.
LUNAR EXCURSION MODULE	The two-man vehicle that will land on the moon after the Apollo spacecraft enters lunar orbit.
LUNAR ORBITAL RENDEZVOUS	The concept for manned lunar landing adopted by NASA wherein the lunar excursion module leaves the spacecraft, lands on the moon, and later returns to the orbiting spacecraft. The excursion module will be jettisoned as the spacecraft leaves lunar orbit.
MANNED SPACECRAFT CENTER (MSC)	NASA headquarters responsible for development and operation of manned space vehicles (Mercury, Gemini, Apollo), located in Houston, Texas.

[redacted]

MARSHALL SPACE FLIGHT CENTER (MSFC)	NASA operation responsible for design and development of space launch vehicles (Saturn, Advanced Saturn, Nova), located in Huntsville, Alabama.
MOCK-UP	A full-scale, three-dimensional representation of a complete spacecraft, individual module, and/or related equipment. Based on permanence and difficulty of alteration, mock-ups are graded as "soft," "semi-hard," and "hard."
MODULE	A combination of components, contained in one package or so arranged that together they are common to one mounting, which provides a complete function. (See command module, service module, lunar excursion module, etc.)
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)	Civilian agency, sponsored by the U. S. Government, with research and development jurisdiction in aeronautical and space activities except those activities peculiar to or primarily associated with the development of weapon systems, military operations, or the defense of the United States.
NAUTICAL MILE (NM)	A measure of distance equal to 6,076.103 feet or approximately 1.15 mile.
OBTAIN DATA	Denotes gathering engineering information that is to be measured to augment the general knowledge required in the development of the over-all spacecraft. This category may also be used for supplemental investigation, such as environmental studies, ground equipment studies, etc. The degree of instrumentation is not implied by this definition.
OPTICAL STAR TRACKER	A star tracker that locks onto the light of a particular celestial body. Distinguished from a radiometric star tracker. (See star tracker.)
OXIDIZER	A rocket propellant component, such as liquid oxygen, nitric acid, fluorine, and others, that supports the combustion of a fuel.

[redacted]

PAD	A permanent or semipermanent load-bearing surface constructed or designed as a base upon which a launcher can be placed. Short for launch pad.
PITCH	The movement about an axis that is at once perpendicular to the Apollo longitudinal axis and horizontal to the Y-axis of the spacecraft.
PRE-QUALIFIED	A pre-qualified part or component is one that has been scheduled as the one most likely to succeed in the qualification program and will be used in production runs as well as during developmental test or early flight test prior to qualification.
PRESSURIZED SUIT	A garment designed to provide pressure upon the body so that respiratory and circulatory functions may continue normally, or nearly so, under low-pressure conditions, such as occur at high altitudes or in space without benefit of a pressurized cabin.
PROGRAMMED ROLL	An automatically controlled roll of a ballistic missile or satellite, usually executed during its vertical ascent before pitch-over.
PROGRAMMED TURN	The turn of a ballistic missile from vertical motion, after lift-off, to a curved path approximating the desired powered flight trajectory prior to the initiation of guidance.
PROPELLANT	A liquid or solid substance burned in a rocket for the purpose of developing thrust.
PROTOTYPE	A model suitable for complete evaluation of mechanical and electrical form, design, and performance. It is in final mechanical and electrical form, employing approved parts, and completely representative of the final equipment.
QUALIFICATION OF PART, COMPONENT, OR SYSTEM	A part, component, or system is considered qualified by definition after it has successfully completed all of the prescribed tests associated with relevant control specifications.

[redacted]

[redacted]

READOUT	A radio transmitter transmitting data either instantaneously with computation of the data or by play of a magnetic tape on which the data have been recorded.
RECOVERY	The act of retrieving a portion of a launched missile or satellite that has survived reentry.
REENTRY	Return of a part of a space vehicle to the atmosphere after flight above the sensible atmosphere.
RELIABILITY	Reliability is the probability of performing without failure a specified function, under given conditions, for a specified period of time. It deals with failure rates in time of specified items.
RETROROCKET	Relatively small rocket unit, usually solid propellant, installed on a rocket-propelled vehicle and fired in a direction opposite to the main motion to decelerate main unit.
ROLL	The movement of Apollo about its longitudinal (X) axis.
SATURN	The sun's sixth planet. A NASA rocket engine cluster in research and development expected to develop some 1,500,000 pounds of first-stage thrust. The Apollo launch vehicle.
SEPARATION	Moment when a full stage, half stage, a warhead, or a nose cone is separated from the remainder of the rocket vehicle; the moment when staging is accomplished.
SERVICE MODULE	Apollo module carrying propulsion equipment, fuel, reaction control systems, and communications power. It is used for thrust after booster separation, mid-course correction, lunar orbit, lunar orbit ejection, and earth return midcourse correction. It is jettisoned prior to reentry.
SERVICE PROPULSION SYSTEM	Engine and associated equipment providing thrust for service module functions. (See SERVICE MODULE.)

[redacted]

C[redacted]

SOFT LANDING	Landing on the moon or other spatial body at such slow speed as to avoid damage of landing vehicle. Soft landings on moon are anticipated by use of retrorockets.
SOLAR FLARE	Solar phenomenon that gives rise to intense ultraviolet and corpuscular emission from the associated region of the sun. This affects the structure of the ionosphere and interferes with communications.
SOLID PROPELLANT	A propellant in solid condition including all the ingredients necessary for sustained chemical combustion, such as a compound of fuel and oxidizer, usually in plastic caked form. It burns on its exposed surface, generating hot exhaust gases to produce a reaction force.
SPACECRAFT	In the Apollo program, any component or combined components of the flight vehicle not part of the launch vehicle: launch escape subsystem, command module, service module, adapter, or any combination of these.
SPECIFIC IMPULSE	The thrust produced by a jet-reaction engine per unit weight of propellant burned per unit time, or per mass of working fluid passing through the engine in unit time. It is equal to thrust in pounds divided by weight flow rate in pounds per second.
STABILIZATION AND CONTROL SUBSYSTEM (SCS)	An Apollo monitor system linked to navigation and guidance system, display system, and reaction control subsystem indicating spacecraft attitude (roll, yaw, or pitch).
STAGE	In a rocket vehicle powered by successive units, one or other of the separate propulsion units.
STAGNATION POINT	The location on a surface in an airstream where the air flow is zero.

[redacted]

STAR TRACKER	A telescopic instrument on a missile or spacecraft that locks onto a celestial body and gives guidance to the missile or other object during flight.
STATIC TESTING	Testing of a missile or other device in a stationary or holddown position, to verify structural integrity, to determine the effects of limit loads, or to measure thrust.
SYSTEMS ENGINEERING	Process of applying science and technology to the study and planning of an over-all aerospace vehicle system, whereby relationships of various parts of the system and the use of various subsystems are fully planned and integrated prior to time hardware designs are committed.
TELEMETERING	The technique of recording space data by radioing an instrument reading from a rocket to a recording machine on the ground.
THEODOLITE	A sighting and measuring telescopic instrument that gives a reading on horizontal or vertical angles.
TRAJECTORY	The path described by a missile or a space vehicle.
TRANSFER ELLIPSE	Path followed by a body moving from one elliptical orbit to another.
ULLAGE	The amount of fluid by which a tank falls short of being full; the loss through evaporation, spilling, or consumption; the amount remaining that cannot be drained from an emptied tank or container.
UMBILICAL	Any one of several electrical or fluid lines connected between the ground support operation and an uprighted rocket missile or space vehicle before launch.
UNSYMMETRICAL DIMETHYLHYDRAZINE (UDMH)	Rocket fuel which with aerozine will power the Apollo spacecraft.

CO[redacted]

VECTOR STEERING	Vernacular for a steering method where one or more thrust chambers are gimbal mounted so that the direction of the thrust force (thrust vector) may be tilted in relation to the center of gravity of the missile to produce turning.
VELOCITY VECTOR	Combination of two ballistic missile trajectory values: the speed of the missile's center of gravity at a designated point on the trajectory and angle between local vertical and the direction of the speed.
WHITE SANDS MISSILE RANGE (WSMR)	A proving ground in New Mexico under the control of the Army Ordnance Missile Command; supports Apollo abort tests.
YAW	Lateral movement of the Apollo spacecraft along the Z-axis in line of flight.

[redacted]

REFERENCES*

S&ID REPORTS

1. SID 61-460 — Contract Data Requirements - R & D Project Apollo
2. SID 62-50 — Apollo GSE Specification
3. SID 62-65 — Apollo Design Criteria Specifications
4. SID 62-99 — Monthly Weight and Balance Report
5. SID 62-109 — General Test Plan Research and Development for Project Apollo Spacecraft

   SID 62-109-1 Volume I General Test Plan Summary
   SID 62-109-2 Volume II Individual System Tests
   SID 62-109-3 Volume III Ground Qualification Tests
   SID 62-109-4 Volume IV Acceptance Test Plans
   SID 62-109-5 Volume V Multiple Systems Tests

6. SID 62-153 — Facilities Plan
7. SID 62-154 — Quality Control Program Plan
8. SID 62-243 — GSE End Items - Apollo
9. SID 62-244 — Spares, Systems and GSE Documentation - Apollo
10. SID 62-417 — GSE Planning and Requirements
11. SID 62-564 — GSE Requirements and Utilization for Apollo Development Program
12. SID 62-585 — Apollo Hardware Utilization List
13. SID 62-651 — Apollo Engineering Test Requirements on Test Fixture 2 and Airframe 001
14. SID 62-700-1, -2, -3 — Apollo Mission and Spacecraft General Performance Requirements and Specifications
15. SID 62-702 — Apollo Maintenance Plan

*Entire section reissued.

[redacted]

16. SID 62-931 — Requirement for Work and Resources, White Sands Missile Range

17. SID 62-972 — Apollo Test and Operations Mission Abort Test Program - Test Support Requirements

18. SID 62-975 — Apollo Test and Operations Environmental Proof Test Support Requirements

19. SID 62-1003 — Preliminary Specification NASA-Furnished Crew Equipment Interface Requirements Project Apollo

20. SID 62-1005 — GOSS Performance and Interface Specifications

21. SID 62-1014 — Definitions and Objectives Apollo GSE

22. SID 62-1145-1 — Apollo Integrated Systems GSE Concept Boilerplate No. 6

23. SID 62-1367 — Apollo Checkout and GSE Concept

24. SID 62-1408-1, -2, -3 — Apollo Measurement Requirements

25. SID 62-1450 — Apollo GSE Plan

26. SID 63-501 — Apollo Measurement Requirements, Airframe 001 and Test Fixture 2

27. SID 63-508 — Apollo C/M and S/M Measurement Requirements Airframe 008

28. SID 63-565 — Apollo Measurement Requirements, Boilerplate 15

29. SID 63-1040 — Apollo Simulation Plan

NASA REPORTS

Project Apollo Flight Mission Directive for Pad Abort I, NASA Project Apollo Working Paper 1049A, 24 January 1963.

Project Apollo Flight Mission Directive for Mission A-001, NASA Project Apollo Working Paper 1065, dated 31 January 1963.

Project Apollo Flight Mission Directive for Mission A-101, NASA Project Apollo Working Paper 1085, dated 31 July 1963.