M69000489

[redacted]

This reissue supercedes and
replaces the 1 March 1962 issue.

Copy No. 347

[redacted]

347

REFERENCE ONLY

SID 62-223

APOLLO
PROGRAM PLAN

[redacted]

NAS9-150

Reissued 28 November 1962

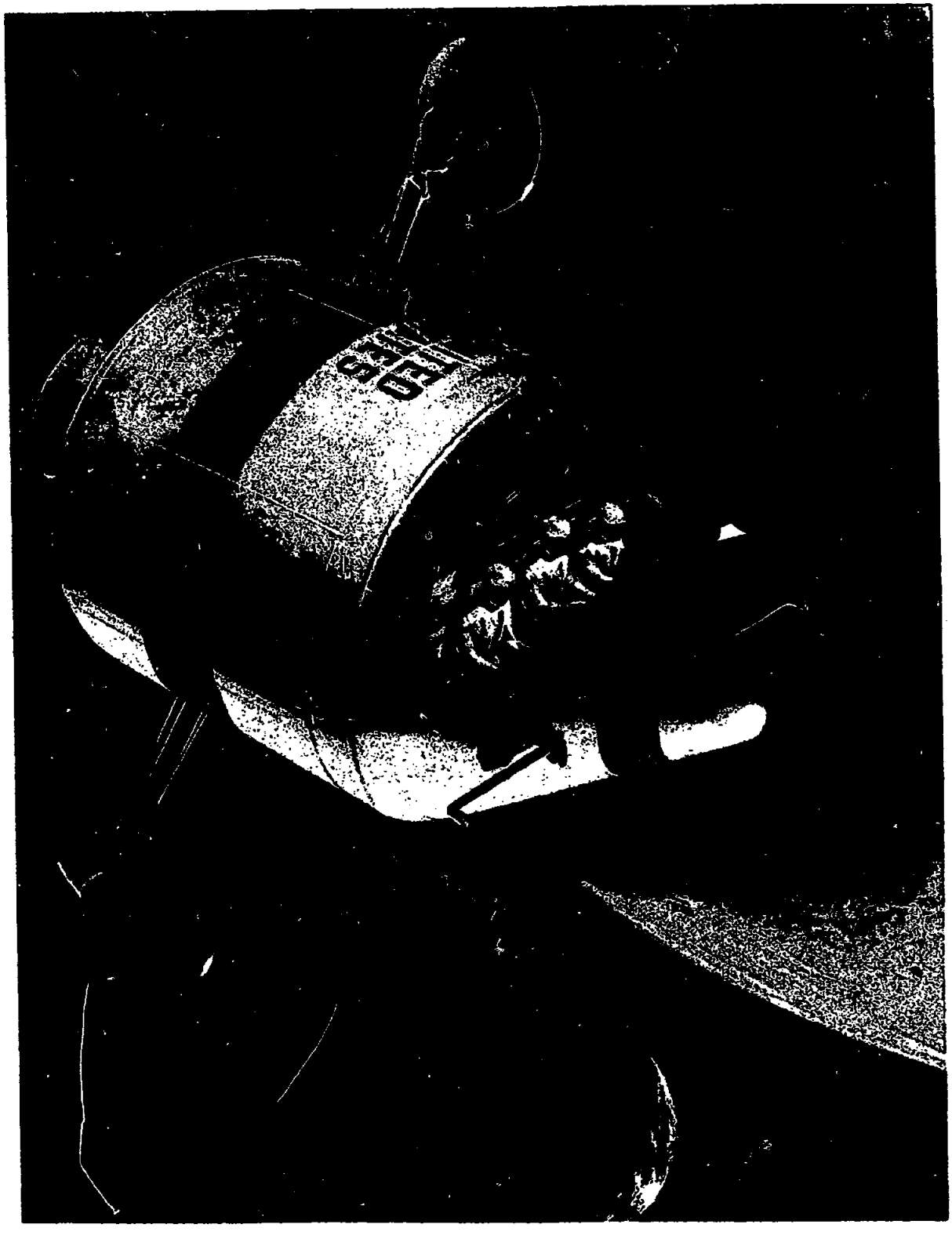
The classification of this report has
been changed from Conf to Unc
per Apollo downgrading list from
letter or
contract no Security
Date 10/69 D Killian
SCG-11 Rev. 1

[redacted]

NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

[redacted]

[redacted]



Artist's Conception of Apollo Spacecraft in Lunar Orbit

[redacted]

PRECEDING PAGES BLANK-NOT FILMED

[redacted]

CONTENTS

Section		Page
	INTRODUCTION	1
I	MANAGEMENT	3
	MANAGEMENT PLAN	3
	Introduction	3
	Organization	3
	Planning	9
	Program Performance	11
	Cost Control	13
	S&ID Manpower Loading	16
	Change Control	16
	Major Subcontractor Control	22
	Associate Contractor Administration	26
	Interdivisional Work Authorization	28
	NASA-S&ID Interface	28
	MASTER DEVELOPMENT SCHEDULE	31
	VEHICLE PHASING PLANS	35
	PROCEDURES	83
	General	83
	Contracts	83
	Engineering	84
	Accounting	84
	Personnel	85
	Manufacturing and Facilities	85
	Material	85
	Industrial Security	86
	Quality Assurance	86
	Logistics	86
II	TECHNICAL DEVELOPMENT PLAN	87
	INTRODUCTION	87
	APOLLO DEVELOPMENT PLAN	89
	SPACECRAFT CONFIGURATION	97
	SYSTEMS ENGINEERING	99
	Mission Requirements	99
	Mission Engineering	99
	Mission Analysis	112

PRECEDING PAGES BLANK-NOT FILMED

[redacted]

[redacted]

Section | Page

System Design Analysis 118
System Integration 119
Test Integration 121
Ground Operational Support System 121
FLIGHT TECHNOLOGY 123
Aerodynamics 123
Performance and Trajectories 131
Flight Dynamics 138
Wind Tunnel Test Program 143
LIFE SYSTEMS 151
Introduction 151
Objectives and Responsibilities 151
THERMO AND FLUID DYNAMICS 179
Propulsion Systems Analysis 179
Thermal Analysis 184
Aerodynamics 189
Environmental and Power Systems Analysis . . . 197
SIMULATION—TRAINING EQUIPMENT 205
Simulation and Evaluation 205
Training Equipment 222
Objective 222
STRUCTURAL DESIGN 227
Command Module 227
Service Module 232
Spacecraft Adapter 233
Spacecraft Mechanical Devices 233
Spacecraft Heat Protection 234
Development Studies 234
Development Tests 239
Problem Areas 243
Manufacturing 245
Documentation 245
Subcontractors' Efforts 245
SPACECRAFT SYSTEMS 247
Guidance and Navigation 247
Stabilization and Control 249
Reaction Control System 251
Service Propulsion System Development Plan . . 265
Launch Escape Motors Development Plan . . . 270
Environmental Control System 273
Electrical Power System 285
Communications Subsystem 293
Instrumentation 301
Electronics Interfaces 305

[redacted]

[redacted]

Section | Page

GROUND SUPPORT EQUIPMENT 311
GSE Objectives 311
Referenced Documents 311
Program Plan 312
HARDWARE DEFINITIONS AND OBJECTIVES . . 317
Mock-Ups 317
Boilerplates 321
Spacecraft 336
TEST LOGIC 351
Service Propulsion System 351
Reaction Control System 352
Launch Escape System 352
Earth Landing System 353
Environmental Control System 354
Electrical Power System 355
Guidance and Navigation System 355
Stabilization and Control System 356
Communications and Instrumentation System . . 356
Life Systems 357
Ground Support Equipment 358
Structural Tests 358
Mechanical Devices 359
Materials, Processes, and Producibility . . . 360
Wind Tunnel Test Program 360
Thermal Protection System 361
RELIABILITY 363
Reliability Program 363
Organization 363
Requirements 364
Apportionment 364
Design Reliability 368
Reliability, Crew Safety, and Design Reviews . . 371
Reliability Monitoring and Documentation . . 372
Subcontractor Relationships 373
Reliability Measurement and Assessments . . . 373
Failure and Problem Reporting, Analysis, and Feedback 376
Manufacturing Reliability 378
Reliability Indoctrination and Training . . . 378
Human Engineering 379

[redacted]

[redacted]

Section		Page
III	SUMMARIES OF PLANS	381
	TEST OPERATIONS	381
	Requirements	381
	Spacecraft Test Preparation Program	387
	Prequalification Flight Drop Test Program (Boilerplates 3 and 19)	389
	Mission Abort Tests	392
	Spacecraft Environmental Proof Test Program	393
	Service Propulsion Program	398
	House Spacecraft Tests	402
	Apollo-Saturn Test Programs	405
	QUALITY CONTROL	409
	Management	409
	Documentation	409
	Organization	410
	Quality Engineering	410
	Quality Control Laboratory	412
	Procurement Quality Control	413
	Fabrication Quality Control	414
	Space and Missile Systems Inspection	415
	Off-Site Testing—AMR	417
	Other Off-Site Testing	419
	MANUFACTURING	421
	Tooling	421
	Spacecraft Fabrication and Assembly Procedures	422
	Launch Escape Tower	427
	Spacecraft Service Module	427
	Spacecraft Adapter	431
	Assembly Mating	431
	Test and Checkout	431
	Systems Integration Assurance Test	433
	Ground Support Equipment	437
	FACILITIES	451
	Division Laboratories	451
	Aerothermodynamic Testing	454
	Computer and Simulation Facility	454
	Propulsion Systems Development Facility	455
	Data Ground Station	456
	Bonding and Test Facility	458
	Training Equipment Fabrication	458
	Subassembly, Assembly, and Mock-Up	459
	Radiographic Facility	459
	Plaster Master Facility	460
	Ground Support Equipment Fabrication	460

[redacted]

[redacted]

Section | Page

Systems Integration and Checkout Facility 461
Program Management 462
Engineering 462
Training Area and Classrooms 462
Mock-Up Display Area 465
Atlantic Missile Range 465
Ground Operation Support Systems 466
LOGISTICS 467
Maintenance Concept 467
Maintenance Plan 467
Support Plan 468
Training Plan 473

APPENDIX
MASTER DEVELOPMENT PLAN 483

[redacted]

[redacted]

Figure		Page
29	AFRM 009 Spacecraft for First Manned Flight and Service Module Qualifications (SA-111)	77
30	AFRM 010 Command Module for Pad Abort	79
31	AFRM 011 Spacecraft for Second Manned Flight, Earth Orbital (SA-112)	81
32	Apollo Development Program	90
33	Apollo Spacecraft Development Schematic	91
34	Mockups	93
35	Spacecraft Configuration and Specifications for Lunar Orbital Rendezvous	97
36	Space Vehicle Configuration Earth Orbital Mission	101
37	Earth Orbital Mission	102
38	Circumlunar Mission	104
39	Circumlunar Mission Operational Sequence	105
40	Lunar Orbital Mission Translunar Flight	108
41	Lunar Orbital Mission Transearth Flight	109
42	Lunar Orbital Mission Operational Sequence	110
43	Space Vehicle Configuration Lunar Mission	111
44	Lunar Landing Mission—Lunar Orbital Rendezvous Technique	113
45	Optimization Tasks Flow Diagram	117
46	Wind Tunnel Testing Schedule	129
47	Life Systems Personnel	153
48	Crew Equipment Design Development Plan	154
49	Crew Couch Panel	157
50	Crew Function Testing	158
51	Crew Function Testing	159
52	Life Systems Crew Simulation Activity	160
53	Life Systems Crew Test Activity	161
54	Human Factors Design Criteria Initiation and Flow Chart	163
55	Functions of the Task Design and Analysis Unit	165
56	Crew Performance and Training Functions	166
57	Crew Operations Unit Functional Flow Diagram	169
58	Simulation Phasing Schedule	209
59	Analog Amplifier Requirements	214
60	Master Simulation Phasing Plan	216
61	Trainer Mission Simulator	224
62	Structures Development Plan	236
63	Mechanical Systems Development Plan	237
64	Earth Landing Systems Development Plan	238
65	Flow of Materials and Producibility Information	241
66	Stabilization and Control Systems Over-All Block Diagram	250
67	Stabilization and Control Development Plan	253

[redacted]

PRECEDING PAGES BLANK-NOT FILMED

[redacted]

Figure		Page
68	Perspective Layout - Installation, Command Module Reaction Control System	255
69	Command Module Reaction Control System Development Plan	257
70	Propellants of the Service Propulsion System	260
71	Service Module Reaction Control System Development Plan	263
72	Service Propulsion System Installation (Perspective Sketch)	266
73	Service Propulsion System Development Plan	267
74	Launch Escape Motors Development Plan	271
75	Environmental Control System	275
76	Cryogenic Storage Tank	279
77	Waste Management System	280
78	Airesearch Program Milestones	286
79	Beech Program Milestones (Completion Dates)	287
80	Electrical Power System Development Plan	289
81	Electrical Power System	290
82	Development Plan, Communications Subsystem	295
83	Ground Support Development Plan	313
84	B-1 and B-2 Command Module for Land and Water Impact Test	322
85	B-3 Command Module for Parachute Recovery	323
86	B-6 Command Module and Launch Escape System for Pad Abort	325
87	B-9 Spacecraft for Dynamic Test and Second Spacecraft for Booster Compatibility Test	326
88	B-12 Command Module and Launch Escape System for Max q LES Verification	327
89	B-13 First Spacecraft for Booster Compatibility	329
90	B-14 House Spacecraft No. 1	330
91	B-15 Third Spacecraft for Booster Compatibility	332
92	B-16, B-18 Spacecraft for Booster Compatibility Verification	333
93	B-19 Command Module for Parachute Recovery	334
94	B-22 Command Module for High Altitude LES Verification	335
95	B-25 Command Module for Recovery Procedures and Handling Equipment Development	337
96	AFRM 001 Spacecraft for Propulsion System Qualification	338
97	AFRM 002 Command Module and Launch Escape System for Max q LES Verification	340
98	AFRM 004 Spacecraft for Static Test No. 1	341

[redacted]

[redacted]

Figure		Page
99	AFRM 005 Command Module for Static Test No. 2	342
100	AFRM 006 House Spacecraft No. 2	343
101	AFRM 008 Spacecraft for Environmental Proof	346
102	AFRM 009 Spacecraft for First Manned Flight and Service Module Propulsion Verification	347
103	AFRM 010 Command Module and Launch Escape System for Pad Abort	348
104	AFRM 011 Spacecraft for Second Manned Flight—Earth Orbital Qualification	349
105	Apollo Test Plan	374
106	Flyable and Nonflyable Test Hardware	383
107	Spacecraft Test Missions	385
108	Inner Structure Assembly Sequence	423
109	Heat Shield Assembly Sequence	425
110	Launch Escape Tower Assembly Sequence	428
111	Service Module Assembly Sequence	429
112	Prototype Spacecraft Adapter Assembly Sequence	432
113	Spacecraft White Room Assembly Sequence	435
114	Apollo Mock-up and Evaluator Schedule	438
115	Apollo Boilerplate Command Module No. 1 Master Schedule (9 August 1962)	439
116	Apollo Boilerplate Service Module No. 1 Master Schedule (19 September 1962)	440
117	Apollo Boilerplate Adapter No. 1, Boilerplate No. 9 (19 September 1962)	441
118	Apollo Boilerplate Launch Escape Tower (Static No. 1) Master Schedule (19 September 1962)	442
119	Apollo Spacecraft Command Module AFRM 001 Master Schedule (9 August 1962)	443
120	Apollo Spacecraft Service Module Master Curve	445
121	Apollo Spacecraft Adapter Master Schedule AFRM 009 (19 September 1962)	447
122	Apollo Training Equipment (19 September 1962)	448
123	Apollo GSE Time Spans	449
124	S&ID Complex at Downey, California	452
125	Data Ground Station Location in Building No. 6	457
126	First-Floor Layout of Building No. 6 Addition	463
127	Second-Floor Layout of Building No. 6 Addition	464
128	Sequence of Programmed Data for Flight Crew and Systems Monitoring Personnel	475
129	Training Analysis of Programmed Data	476
130	Examples of Apollo Flight Crew Training Units	478

[redacted]

[redacted]

TABLES

Table		Page
1	Recommended Test Facilities	146
2	Engineering Simulator Complex Comparison	218
3	Problem Areas	244
4	Preliminary Major Element Reliability Apportionment (Lunar Landing Mission)	365
5	Preliminary Command and Service Module Reliability Apportionment to Mission Phase	366
6	Preliminary Command and Service Module Reliability Apportionment to Subsystem Level	366
7	Preliminary Subsystem Reliability Apportionment to Subassembly Level	367
8	Preliminary Subsystem Reliability Apportionment to Mission Phase	369
9	Simulated Orbital Phase Test Conditions	396

[redacted]

[redacted]

INTRODUCTION

The objective of this document is to describe the effort planned (as of 31 October 1962) to design and develop the Apollo command module, service module, and spacecraft adapter, and to integrate the lunar excursion module (LEM) into the total spacecraft design. During the period through 15 May 1965, effort will be concentrated on development of the basic spacecraft systems. This effort will culminate in manned earth-orbital flights.

Specific plans for integration of the LEM and development testing of the complete spacecraft will be added in a revision after the LEM associate contractor, NASA, and S&ID representatives have established requirements for this phase of the program.

The plans and schedules presented in this revision of the Program Plan also reflect the effort included in the firm cost proposal dated 30 October 1962. This proposal is based on optimum design and development of the assigned spacecraft modules to be compatible with the lunar orbital rendezvous technique. Hardware requirements for this phase of the program are based on the following:

1. NASA's TWX P1014452 and P082100Z from T. Markley, Project Officer to E.E. Sack dated 10 September 1962.

2. A S&ID management briefing of MSC-ASPO management on 19 September 1962 at MSC. This briefing proposed a reduction of hardware quantities and certain simplifications.

3. A reduction of system weight as submitted in SID 62-99-8 weight reduction report to NASA dated 10 September 1962. This information was also presented at the briefing at MSC on 19 September 1962.

This Program Plan is divided into three major sections: management plans, technical development plan, and summaries of plans. Management plans contain organization charts, management concepts, master schedule data, and sections on subcontractor control and associate contractor interface procedures. The technical development plan describes the effort and programs planned by each of the technical departments within engineering. These plans are included in considerable detail, because they are not contained in any other document. Summaries of plans contain condensations of plans for test and operations, quality control, manufacturing, facilities, and logistics. These plans reflect complete documents, but are included herein to provide a comprehensive program plan.

[redacted]

[redacted]

1. MANAGEMENT

MANAGEMENT PLAN

INTRODUCTION

The purpose of the Apollo management function is to direct the organization, planning, and performance necessary to accomplish program objectives on schedule and within authorized funds. This section of the Apollo Program Plan discusses and illustrates the concepts and plans that have been formulated to carry out the S&ID Apollo program management function. It includes explanations of Apollo and S&ID organization, planning, performance concepts, the S&ID procedural framework, and some special techniques and procedures that are planned for use in maintaining a high level of visibility and control of the S&ID Apollo Program.

ORGANIZATION

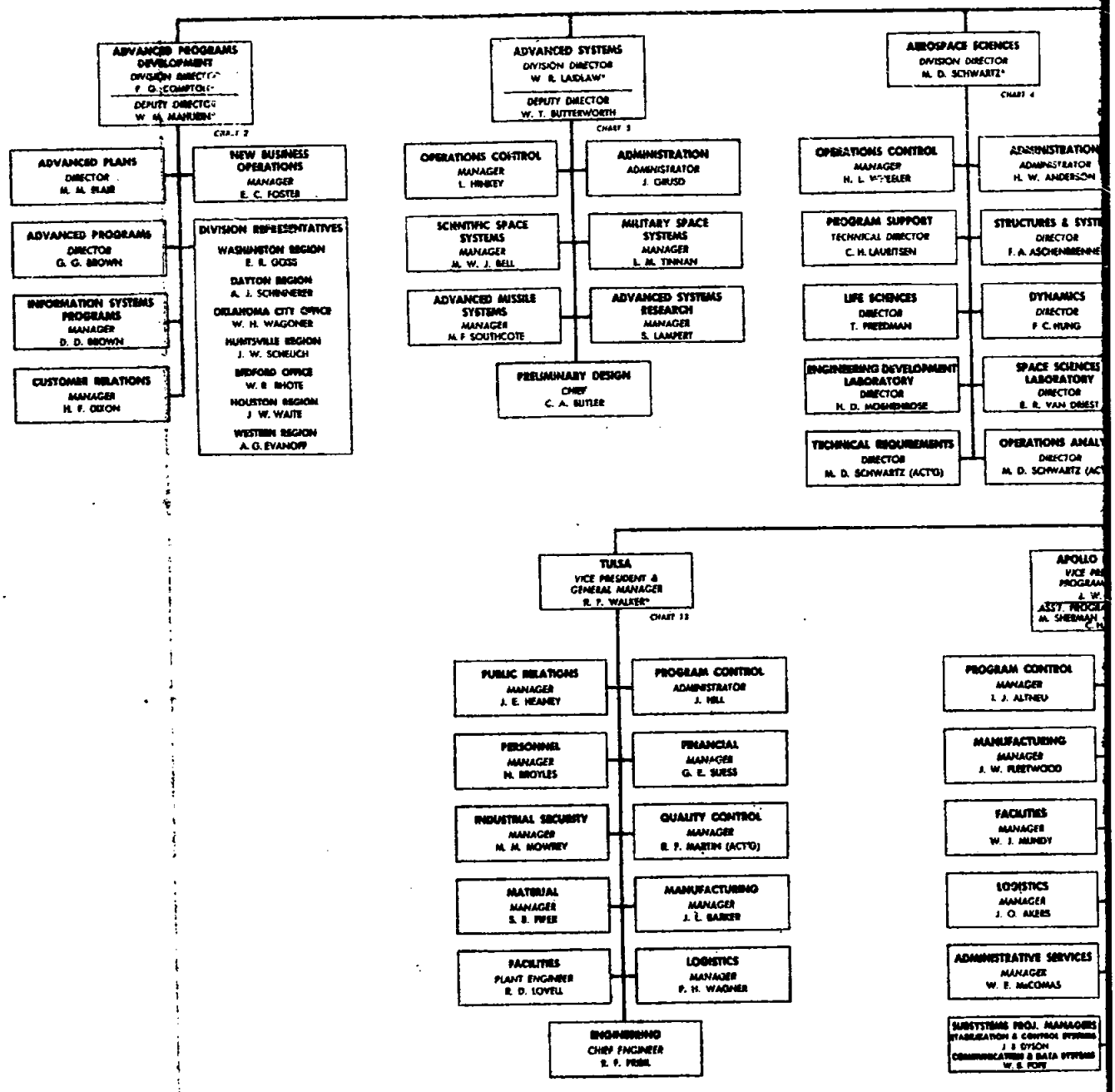
The Space and Information Systems Division (S&ID) of North American Aviation, Inc., is organized to undertake tasks which range from study programs to the development, production, and testing of complex space, missile, and information systems. For a large program, such as Apollo, a special program-oriented division is established. A special division is headed by a program manager and contains representation from all major functional elements that are required for contract performance. The overall organization of S&ID is shown in Figure 1. It will be noted that several program divisions exist at the present time, including the Apollo Program Division. This division is headed by Mr. J. Paup, a vice president of S&ID, who is responsible for the direction and integration of all program functions. A detailed delineation of the Apollo Program Division is contained in Figure 2.

A complete capability has been provided by combining the talents of eight major subcontractors with those of S&ID. The major subcontractors will be responsible for development and fabrication of the major spacecraft

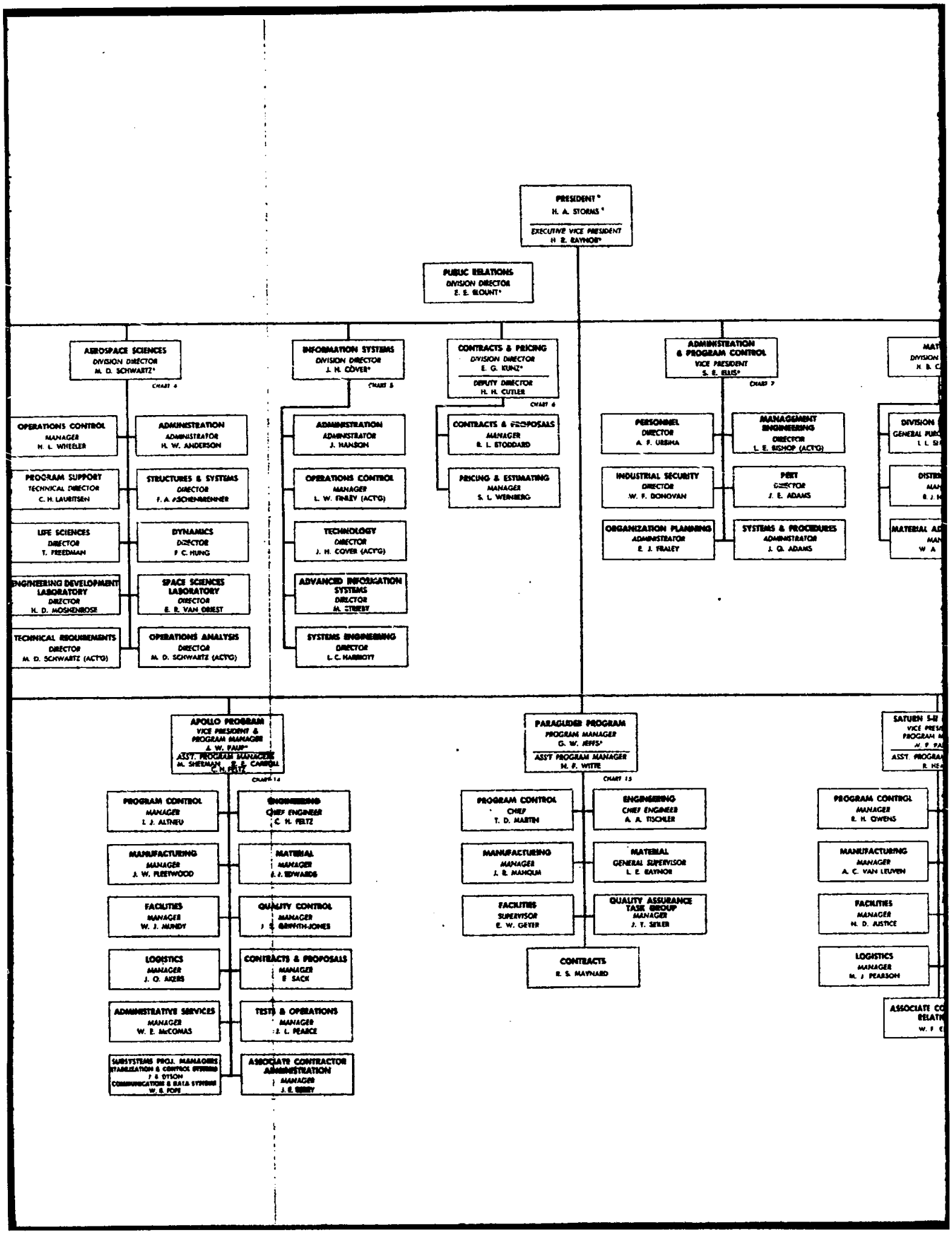
PRECEDING PAGE BLANK-NOT FILMED

[redacted]

[redacted]



PRECEDING PAGE BLANK-NOT FILMED


PRESIDENT
H. A. STORMS
EXECUTIVE VICE PRESIDENT
H. R. RAYNOR
PUBLIC RELATIONS
DIVISION DIRECTOR
E. E. BLOUNT
AEROSPACE SCIENCES
DIVISION DIRECTOR
M. D. SCHWARTZ
CHART 4
OPERATIONS CONTROL
MANAGER
H. L. WHEELER
ADMINISTRATION
ADMINISTRATOR
H. W. ANDERSON
PROGRAM SUPPORT
TECHNICAL DIRECTOR
C. H. LAURITSEN
STRUCTURES & SYSTEMS
DIRECTOR
F. A. ASCHENBRENNER
LIFE SCIENCES
DIRECTOR
T. FREEDMAN
DYNAMICS
DIRECTOR
F. C. HUNG
ENGINEERING DEVELOPMENT LABORATORY
DIRECTOR
H. D. MOSHENROSE
SPACE SCIENCES LABORATORY
DIRECTOR
E. R. VAN DRIEST
TECHNICAL REQUIREMENTS
DIRECTOR
M. D. SCHWARTZ (ACT'G)
OPERATIONS ANALYSIS
DIRECTOR
M. D. SCHWARTZ (ACT'G)
INFORMATION SYSTEMS
DIVISION DIRECTOR
J. H. COVER
CHART 5
ADMINISTRATION
ADMINISTRATOR
J. HANSON
OPERATIONS CONTROL
MANAGER
L. W. FINLEY (ACT'G)
TECHNOLOGY
DIRECTOR
J. H. COVER (ACT'G)
ADVANCED INFORMATION SYSTEMS
DIRECTOR
M. STREBY
SYSTEMS ENGINEERING
DIRECTOR
L. C. HARRIOTT
CONTRACTS & PRICING
DIVISION DIRECTOR
E. G. KUNZ
DEPUTY DIRECTOR
H. H. CUTLER
CHART 6
CONTRACTS & PROPOSALS
MANAGER
R. L. STODDARD
PRICING & ESTIMATING
MANAGER
S. L. WEINBERG
ADMINISTRATION & PROGRAM CONTROL
VICE PRESIDENT
S. E. ELLIS
CHART 7
PERSONNEL
DIRECTOR
A. F. URBINA
MANAGEMENT ENGINEERING
DIRECTOR
L. E. BISHOP (ACT'G)
INDUSTRIAL SECURITY
DIRECTOR
W. F. DONOVAN
PERT
DIRECTOR
J. E. ADAMS
ORGANIZATION PLANNING
ADMINISTRATOR
E. J. FRALEY
SYSTEMS & PROCEDURES
ADMINISTRATOR
J. O. ADAMS
APOLLO PROGRAM
VICE PRESIDENT & PROGRAM MANAGER
J. W. PAUP
ASST. PROGRAM MANAGER
M. SHERMAN
R. E. CARROLL
C. H. FELTZ
CHART 14
PROGRAM CONTROL
MANAGER
I. J. ALTNEU
ENGINEERING
CHIEF ENGINEER
C. H. FELTZ
MANUFACTURING
MANAGER
J. W. FLEETWOOD
MATERIAL
MANAGER
E. J. EDWARDS
FACILITIES
MANAGER
W. J. MUNDY
QUALITY CONTROL
MANAGER
J. S. GRIFFITH-JONES
LOGISTICS
MANAGER
J. O. AKERS
CONTRACTS & PROPOSALS
MANAGER
E. SACK
ADMINISTRATIVE SERVICES
MANAGER
W. E. McCONAS
TEST & OPERATIONS
MANAGER
J. L. PEARCE
SUBSYSTEMS PROJ. MANAGERS
STABILIZATION & CONTROL SYSTEMS
J. B. DYSON
COMMUNICATIONS & DATA SYSTEMS
W. B. POPE
ASSOCIATE CONTRACTOR ADMINISTRATION
MANAGER
J. E. BERRY
PARAGLIDER PROGRAM
PROGRAM MANAGER
G. W. JEFFS
ASST PROGRAM MANAGER
H. F. WITTE
CHART 15
PROGRAM CONTROL
CHIEF
T. D. MARTIN
ENGINEERING
CHIEF ENGINEER
A. A. TISCHLER
MANUFACTURING
MANAGER
J. B. MANQUM
MATERIAL
GENERAL SUPERVISOR
L. E. RAYNOR
FACILITIES
SUPERVISOR
E. W. GEYER
QUALITY ASSURANCE TASK GROUP
MANAGER
J. T. SIELER
CONTRACTS
R. S. MAYNARD
SATURN S-II
VICE PRESIDENT
PROGRAM MANAGER
ASST. PROGRAM
PROGRAM CONTROL
MANAGER
R. H. OWENS
MANUFACTURING
MANAGER
A. C. VAN LEUVEN
FACILITIES
MANAGER
H. D. JUSTICE
LOGISTICS
MANAGER
M. J. PEARSON
ASSOCIATE CO
RELATI

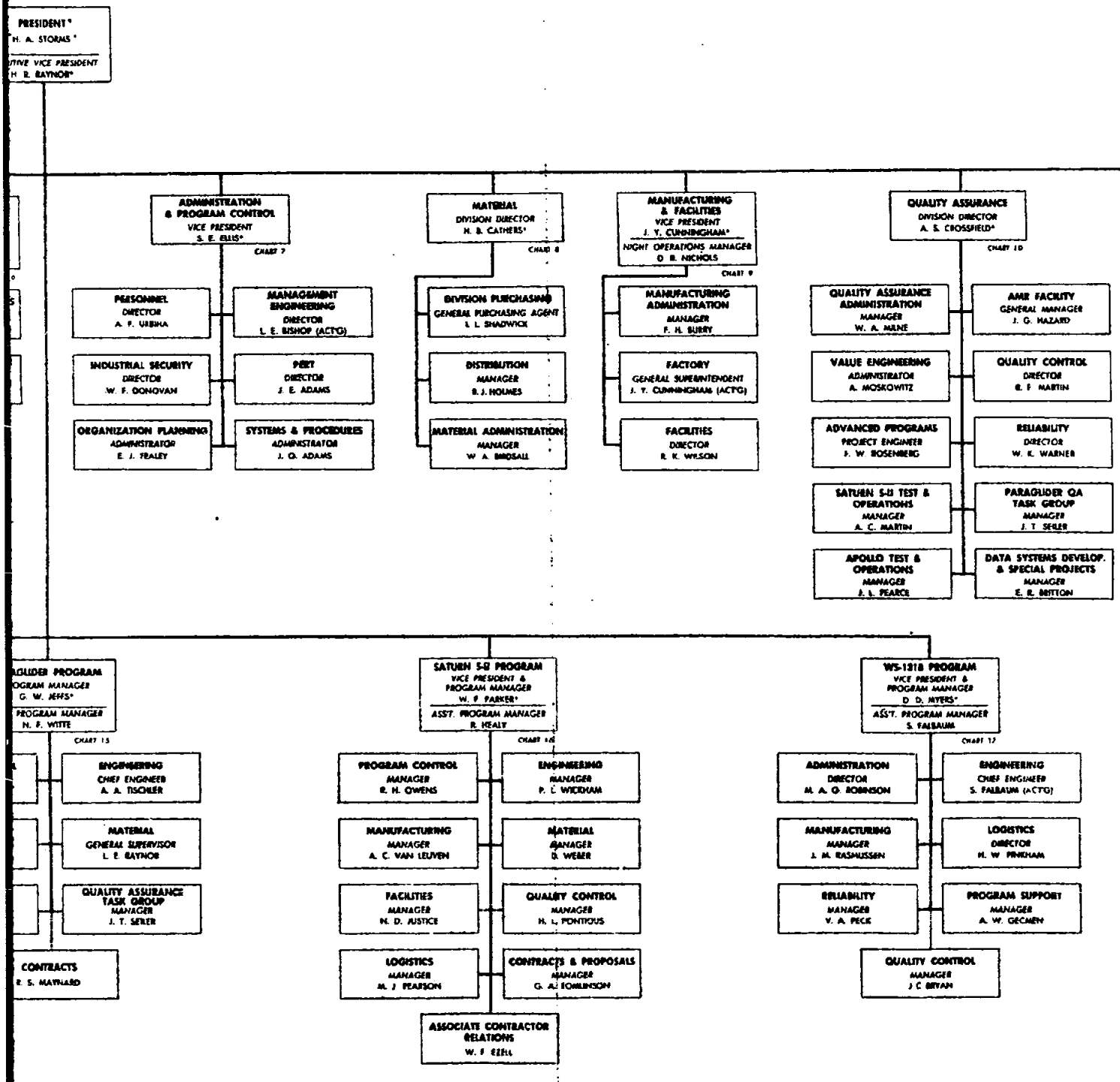


Figure 1. S&ID Org

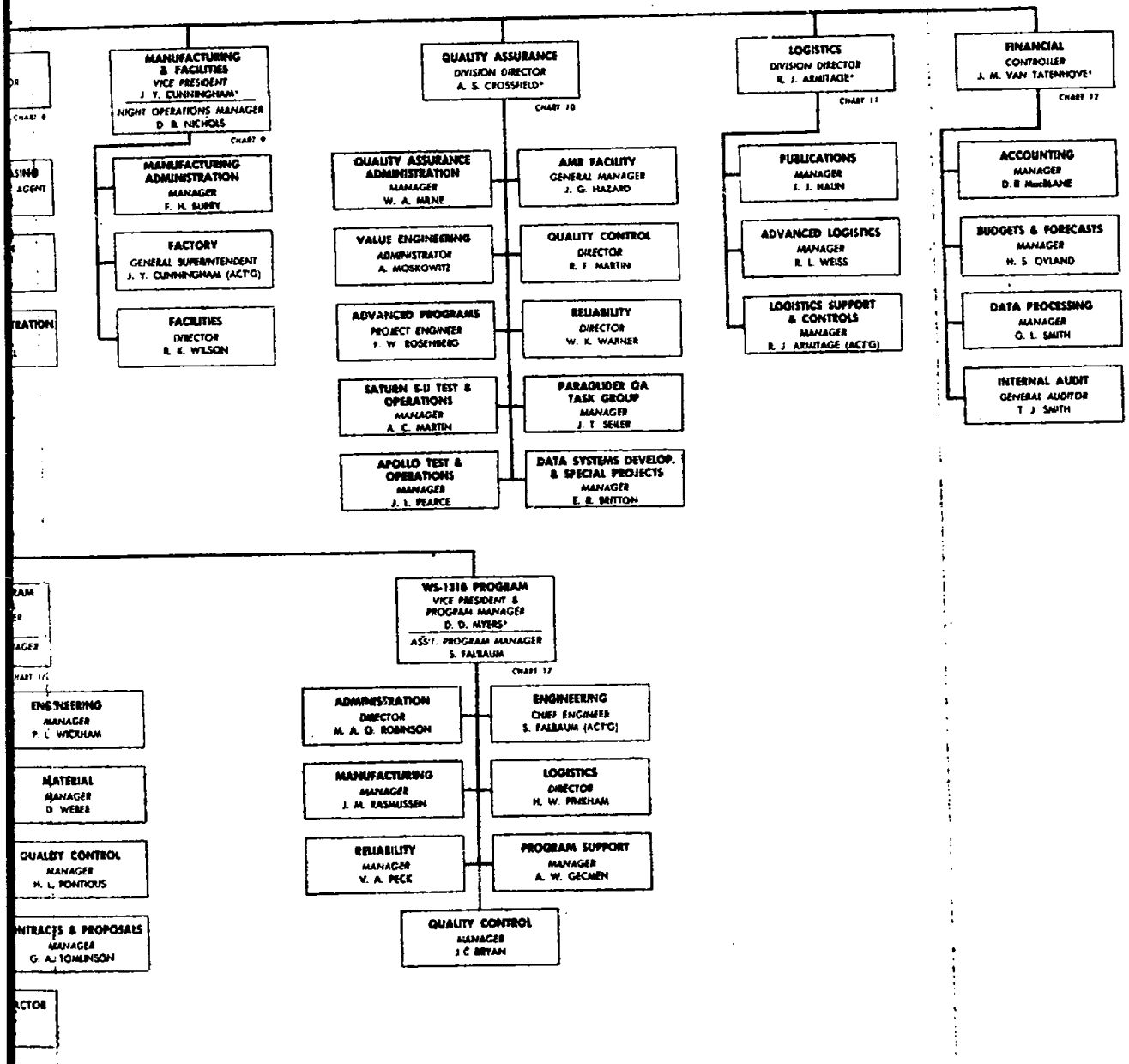
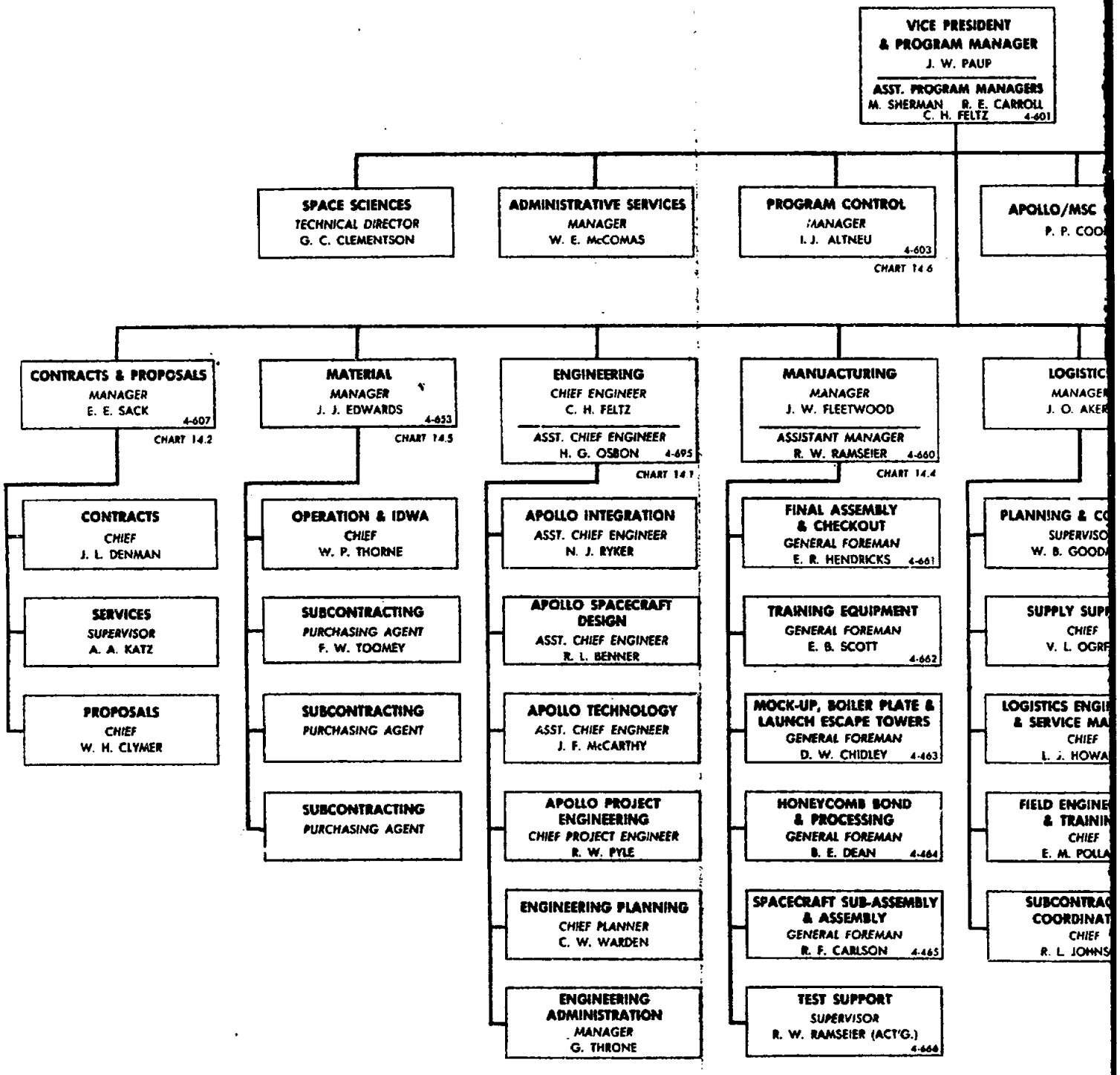


Figure 1. S&ID Organization

[redacted]


VICE PRESIDENT & PROGRAM MANAGER
J. W. PAUP
ASST. PROGRAM MANAGERS
M. SHERMAN R. E. CARROLL
C. H. FELTZ 4-601
SPACE SCIENCES
TECHNICAL DIRECTOR
G. C. CLEMENTSON
ADMINISTRATIVE SERVICES
MANAGER
W. E. McCOMAS
PROGRAM CONTROL
MANAGER
I. J. ALTNEU 4-603
CHART 14.6
APOLLO/MSC
P. P. COO
CONTRACTS & PROPOSALS
MANAGER
E. E. SACK 4-607
CHART 14.2
MATERIAL
MANAGER
J. J. EDWARDS 4-653
CHART 14.5
ENGINEERING
CHIEF ENGINEER
C. H. FELTZ
ASST. CHIEF ENGINEER
H. G. OSBON 4-695
CHART 14.1
MANUACTURING
MANAGER
J. W. FLEETWOOD
ASSISTANT MANAGER
R. W. RAMSEIER 4-660
CHART 14.4
LOGISTIC
MANAGER
J. O. AKER
CONTRACTS
CHIEF
J. L. DENMAN
SERVICES
SUPERVISOR
A. A. KATZ
PROPOSALS
CHIEF
W. H. CLYMER
OPERATION & IDWA
CHIEF
W. P. THORNE
SUBCONTRACTING
PURCHASING AGENT
F. W. TOOMEY
SUBCONTRACTING
PURCHASING AGENT
SUBCONTRACTING
PURCHASING AGENT
APOLLO INTEGRATION
ASST. CHIEF ENGINEER
N. J. RYKER
APOLLO SPACECRAFT DESIGN
ASST. CHIEF ENGINEER
R. L. BENNER
APOLLO TECHNOLOGY
ASST. CHIEF ENGINEER
J. F. McCARTHY
APOLLO PROJECT ENGINEERING
CHIEF PROJECT ENGINEER
R. W. PYLE
ENGINEERING PLANNING
CHIEF PLANNER
C. W. WARDEN
ENGINEERING ADMINISTRATION
MANAGER
G. THRONE
FINAL ASSEMBLY & CHECKOUT
GENERAL FOREMAN
E. R. HENDRICKS 4-661
TRAINING EQUIPMENT
GENERAL FOREMAN
E. B. SCOTT 4-662
MOCK-UP, BOILER PLATE & LAUNCH ESCAPE TOWERS
GENERAL FOREMAN
D. W. CHIDLEY 4-463
HONEYCOMB BOND & PROCESSING
GENERAL FOREMAN
B. E. DEAN 4-464
SPACECRAFT SUB-ASSEMBLY & ASSEMBLY
GENERAL FOREMAN
R. F. CARLSON 4-465
TEST SUPPORT
SUPERVISOR
R. W. RAMSEIER (ACT'G.) 4-666
PLANNING & C
SUPERVISO
W. B. GOOD
SUPPLY SUP
CHIEF
V. L. OGRF
LOGISTICS ENGI
& SERVICE MA
CHIEF
L. J. HOWA
FIELD ENGINE
& TRAININ
CHIEF
E. M. POLLA
SUBCONTRAC
COORDINAT
CHIEF
R. L. JOHNS

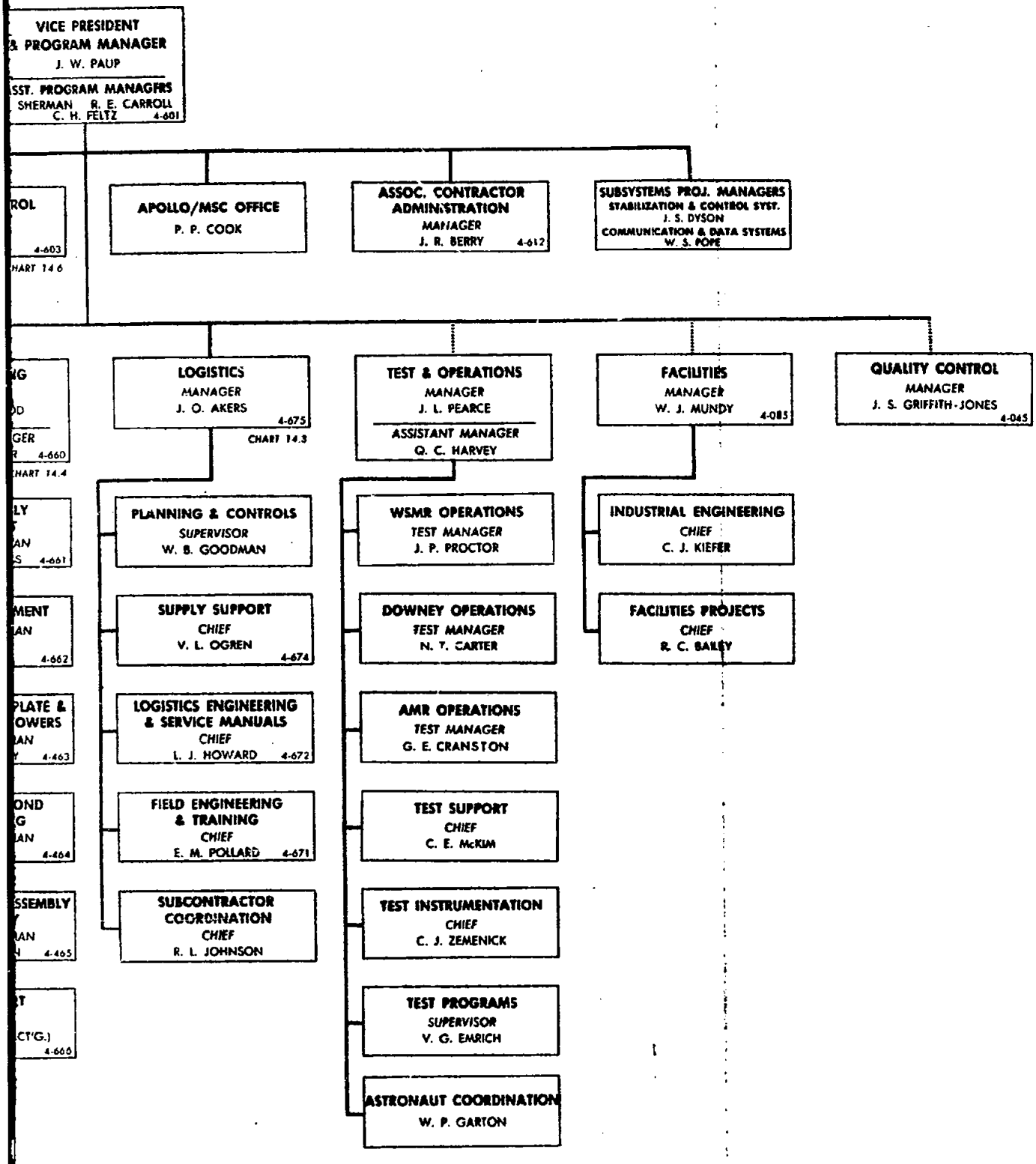


Figure 2. Apollo Program Organization

[redacted]

systems. S&ID will provide surveillance and will integrate the systems into the design of the command and service modules of the Apollo spacecraft. These major subcontractors are as follows:

Stabilization and control system	Minneapolis-Honeywell
Service module reaction control	The Marquardt Corporation
Service propulsion system	Aerojet-General Corporation
Launch escape motor	Lockheed Propulsion Center
Environmental control system	AiResearch
Electrical power fuel cells	Pratt & Whitney Aircraft
Communications system	Collins Radio Company
Earth landing system	Northrop-Ventura

Development of the guidance and navigation system will be accomplished by Massachusetts Institute of Technology (MIT) under a separate contract. S&ID will maintain close coordination with MIT and will integrate the guidance and navigation system into the spacecraft design. The Rocketdyne Division of NAA will develop and fabricate the command module reaction control system. Additional subcontractors who will develop and supply important subsystems are as follows:

Ablative heat shield	Avco Corporation
Earth and post-landing battery	Eagle Picher
Jettison motor	Thiokol
Super critical gas storage	Beech Aircraft
Anthropomorphic dummies	Alderson Laboratory
R & D beacon antenna	Melpar
Static inverter	Westinghouse Electric Corporation
R & D telemetry	Transco

Administration of the subcontractors and all interdivision work assignments will be done by the Apollo Material Department. The Associate Contractor Administration Office will coordinate S&ID activities with those of the associate contractors.

PLANNING

Management level planning for the S&ID Apollo Program includes the development of a program logic upon which each of the functional departments can base its detailed planning. Over-all program requirements were established by teams of NASA and S&ID technical management personnel

[redacted]

[redacted]

and reviewed and approved by NASA and S&ID program management. The Technical Development Plan, Section II of the Apollo Program Plan, delineates the plans made by the various functional groups within the Apollo Engineering Department in support of the over-all development logic. The plans of other Apollo functions are summarized in Section III of the Apollo Program Plan, but are detailed in the following documents:

Apollo Manufacturing Plan	SID 62-102
Apollo Facilities Plan	SID 62-153
Apollo General Test Plan	SID 62-109
Apollo Support Plan	SID 62-702-1
Apollo Maintenance Plan	SID 62-702-2
Apollo Training Plan	SID 62-162

The S&ID Apollo task consists of translating a spacecraft system concept into a workable hardware design. While there is considerable analytical and experimental effort that precedes the detail design, much of the planned program effort is associated with the spacecraft system design, fabrication, and developmental testing which includes the major ground and flight test programs. Management level planning has produced the Master Development Schedule which is included in this document as Figure 7. This schedule serves as a base for all detailed functional planning. A centralized planning group, part of Apollo Program Control, is responsible for coordinating the preparation of the Master Development Schedule to ensure that the requirements thus produced are within practical limits of performance from all functional viewpoints.

The scheduling concept, which has been adopted by Apollo management, will also employ the use of Vehicle Phasing Plans. One such plan is prepared for each major test vehicle, showing more detailed requirements than can be placed on the Master Development Schedule. These plans show engineering support dates, detailed manufacturing phasing, systems delivery requirements, test phasing, and launch requirements. Vehicle Phasing Plans for all planned boilerplate and spacecraft articles are included in the Program Plan as Figures 8 through 31.

After development logic and master schedules have been released, each functional group is able to develop detailed planning information. One key document published by Engineering further defines the mission and

[redacted]

configuration of each test vehicle. With this information, all functional departments prepare detailed plans and obtain manpower and material estimates for each task and sub-task. The resulting data is used to prepare the firm cost proposal. The Apollo Contracts and Proposal Department coordinates the preparation of all cost proposals. Ground rules and specific guidelines for the preparation of cost proposals are communicated to all concerned departments through the use of a plan of action document. This document contains or references all applicable schedules and plans to be used as a base for preparing cost estimates. A cost proposal coordination committee reviews inputs from each functional department. When costs appear to be excessive, this committee establishes and evaluates cost reduction possibilities and recommends program changes to program management. The Apollo Program Manager and Apollo Assistant Program Managers review and evaluate the cost proposal and any changes that have been recommended by the cost proposal coordination committee. The program manager approves the cost proposal prior to submittal to NASA. Program changes are communicated to the affected departments and re-planning is initiated as applicable.

PROGRAM PERFORMANCE

The third and probably the most difficult task of program management is to ensure a high level of program performance. The groundwork for good performance is set by organizational planning, selection of competent managers, and clear-cut delineation of responsibilities and tasks. Managers are expected to organize, staff, and direct their respective functional activities and make decisions within their scope of responsibility. Because of the complexity of the Apollo spacecraft and its mission, the efforts of many functional groups must be coordinated to ensure a high level of contract performance. Frequently, program management must make decisions where the consideration of two or more managerial functions are involved. Sound management decisions and positive program direction require an understanding of the over-all development logic and a comprehensive reporting system. The reporting system must yield objective status information and provide the necessary base to measure progress and assess performance throughout all stages of the program. One of the major functions of Apollo Program Control is to develop and implement a concept and techniques that will provide the high level of program visibility necessary for management to maintain control over all program elements that contribute to performance.

Program performance is measured in terms of (1) technical performance, (2) schedule performance, and (3) cost performance. These

[redacted]

[redacted]

three are not independent; however, it is entirely possible to show good performance in one and relatively poor performance in one or both of the others. For the most effective management, visibility and status concepts have been established. These procedures will permit early identification of problem areas which, if not resolved, will contribute to poor performance in one or more of the three major performance criteria factors. The techniques involve the accumulation and display of various types of current information in a centralized location which has been named the Apollo Program Operations Center. Some of the techniques to be employed in this center are discussed in the succeeding paragraphs.

Program Evaluation and Review Technique (PERT)

One of the basic tools to be used in maintaining program visibility and assessing performance will be the Program Evaluation and Review Technique (PERT). A master visibility PERT-type network is planned for display on a time-oriented magnetic board. This network will contain the most significant events occurring throughout the program. The format of this chart is a modification of the NASA/PERT system, and it affords the viewer an over-all view of the program logic. Close examination of the chart will reveal the sequences of integral program activities and the interrelationship and constraints between events. The program, as displayed, will cover a six-year time span, with considerable detail in the first three years. Periodic updating of activity status will be accomplished by program control with the aid of reports from the various functional departments. This information will be interpreted for its effect on corresponding sections of the visibility chart. The magnetic character of the board will permit immediate changes of displayed information, providing management with timely advice concerning program progress and problem areas.

Hardware Status

A large portion of total program effort will be associated with the major hardware fabrication and testing programs. Charts for each class of hardware have been established to show engineering design and manufacturing completion status in relation to the schedule.

Facilities Status

The completion of facilities on schedule will be vital to the development, fabrication, and testing effort. A chart showing major facilities status will be updated frequently to provide management with detailed visibility in this area.

[redacted]

[redacted]

Cost Status

Funding curves and actual expenditures for each general order will be displayed and maintained. Authorized expenditures and actual expenditures for each functional department will be shown.

Critical Problems

Critical technical and administrative problems will be displayed. Impact on the program and current action to solve the problem will also appear, along with the names of the personnel who are responsible for developing a solution.

Subcontractor Status

Major systems delivery requirements will be included in the management level visibility network. Additional cost, schedule, technical, and administrative status charts for each subcontractor will be displayed in the operations center.

Miscellaneous

Additional information, such as basic spacecraft configuration, weight, and performance data, will be displayed for ready reference. Scheduled meetings and related outside events will also be displayed. Other information, pertinent to the maintenance of management visibility and control, will be added when it is required by the developing program.

COST CONTROL

S&ID constantly monitors the financial status of its contracts through the use of highly mechanized control and reporting systems. Coordinated procedures for program and burden budgets, combined with intra-departmental labor and burden controls, provide a comprehensive and effective cost control program.

Program Budgets

Program cost control is implemented at the inception of each major program by the establishment of a budget and reporting system adapted to the needs of program control groups, program and functional management, and the division management. Management financial responsibilities are affirmed at each stage of the budget process. A program budget administrator is established by the controller as a service to the Program Manager.

[redacted]

[redacted]

Budget Establishment

Contractual funding is used as a basis for program budgets which are established for each functional group or department. The budgets are developed from the latest contractual documents for firm business and from cost proposals or management approved plans for business not yet negotiated. Budget allowances are revised for responsibility or task changes within the framework of the original contract, as well as for changes in the contract itself. All budget allocations are reviewed by and receive the approval of the Program Manager.

Program Cost Plans

Functional responsibility areas provide forecasts of costs to contract completion for incorporation into the program budget performance reports. Forecast direct labor loads, projections of material and other direct costs, and cumulative recorded cost information are fed into 1401 and 1410 computers for processing, in conjunction with the latest approved forecasted rates for direct labor, labor burden, material procurement costs, and general and administrative costs. A resulting tabulated report, Con-Bud, provides (1) cumulative costs to date, (2) forecasts to completion by month and quarter, and (3) total estimated costs at completion.

Budget Reports

A merging of the program cost plans (as reflected in the Con-Bud Report) and the program budgets (determined from the budget documents) provides the data required for the preparation of program budget performance reports. These reports are issued for total program hours and dollars and for each functional responsibility area by hours and other cost dollars. They provide the following information:

1. Program costs to date
2. Budgeted costs for all work effort
3. Estimated costs to complete
4. Total estimated cost at completion
5. Variance from program budget
6. Funding limitations and requirements

Reports are distributed to the Program Manager, to the manager of each of the functional responsibility areas, to the program budget administrator, and to others concerned with the program's financial status.

 [redacted]

[redacted]

B-X System

Currently in development is a revised program of data processing and reporting called the "B-X" (Budgets and Expenditures) system. Essentially, the system combines the concepts of a data bank, responsibility accounting, mechanized budgeting, and current reporting of interdivision effort on S&ID contracts. It will permit a broader spectrum of customized control reports for each area of responsibility, prepared from standard source data. The ultimate objective is complete mechanization of contract cost reporting from initial input to final reports.

Burden Budgets

Cost control is also provided for burden costs applicable to all programs by means of a comprehensive burden budgeting and reporting system. Burden budgets encompass all operating departments. The system employs flexible budgets, accomplished by means of a fixed and variable trend allowance applied to direct labor base hours as they are realized.

Trend allowances are determined statistically from past experience, adjusted for organizational, cost, and task changes. Budget allowances are limited by burden cost plans. These plans in turn are subject to burden rate limitations imposed by negotiated rates on current firm contracts and the necessity for maintaining competitive rates on future business.

Burden budget performance reports are provided on a weekly basis for burden labor and on a monthly basis for total burden costs. These reports are shaped to each level of management and successively summarized according to their areas of responsibility. The top executive officers receive reports reflecting budgetary performance for the entire division, delineated by functional and program area.

The net effect of the burden budget system is to provide effective burden cost controls, closely integrated with division profit and cost plans.

Intra-Departmental Controls

Functional and program areas also maintain control over direct labor hours, direct costs, and burden effort in greater detail than is provided in the published budgetary performance reports. Adapted to their own requirements, these controls measure performance against established departmental standards in such areas as Manufacturing, Quality Assurance, Engineering Laboratory, Engineering, and Logistics. Mechanized reporting systems have been developed to meet some of these intra-departmental control activities. Such programs supplement the division-wide financial reins provided by the program budget and burden budget systems.

[redacted]

[redacted]

S&ID MANPOWER LOADING

Planned manpower versus time for the S&ID Apollo program is shown graphically in Figure 3. Total program requirements are represented by the dotted line. Functional requirements which result in this total are stacked in the following order:

Engineering

Manufacturing

Logistics

Quality Assurance

Quality Control

All functional manpower requirements include both planned on-site effort as well as effort planned for Tulsa, Atlantic Missile Range (AMR), Tullahoma, and White Sands Missile Range (WSMR).

Manpower is computed on the basis of 160 hours per man-month and is representative of the total hours planned for the contract.

CHANGE CONTROL

As the program progresses, changes in the established systems, spacecraft design, mission concepts and schedule objectives may be necessary. One of the major management tasks is to determine the effects of proposed changes on overall program performance objectives. Also, from a contractual viewpoint, all proposed changes must be assessed to determine whether or not they fall within the scope of contract provisions. Many of the proposed changes will be in the category of engineering design changes. These proposed changes will be processed at S&ID in accordance with the divisional procedure entitled "Engineering Change Control." This procedure is summarized in the following paragraphs:

Engineering Change Control

S&ID management decisions to approve or reject proposed engineering changes are based on evaluation of technical descriptions. Requirements for the development of these technical descriptions are outlined in detail in SID Procedure C-432. This change control procedure will be applicable to

[redacted]

[redacted]

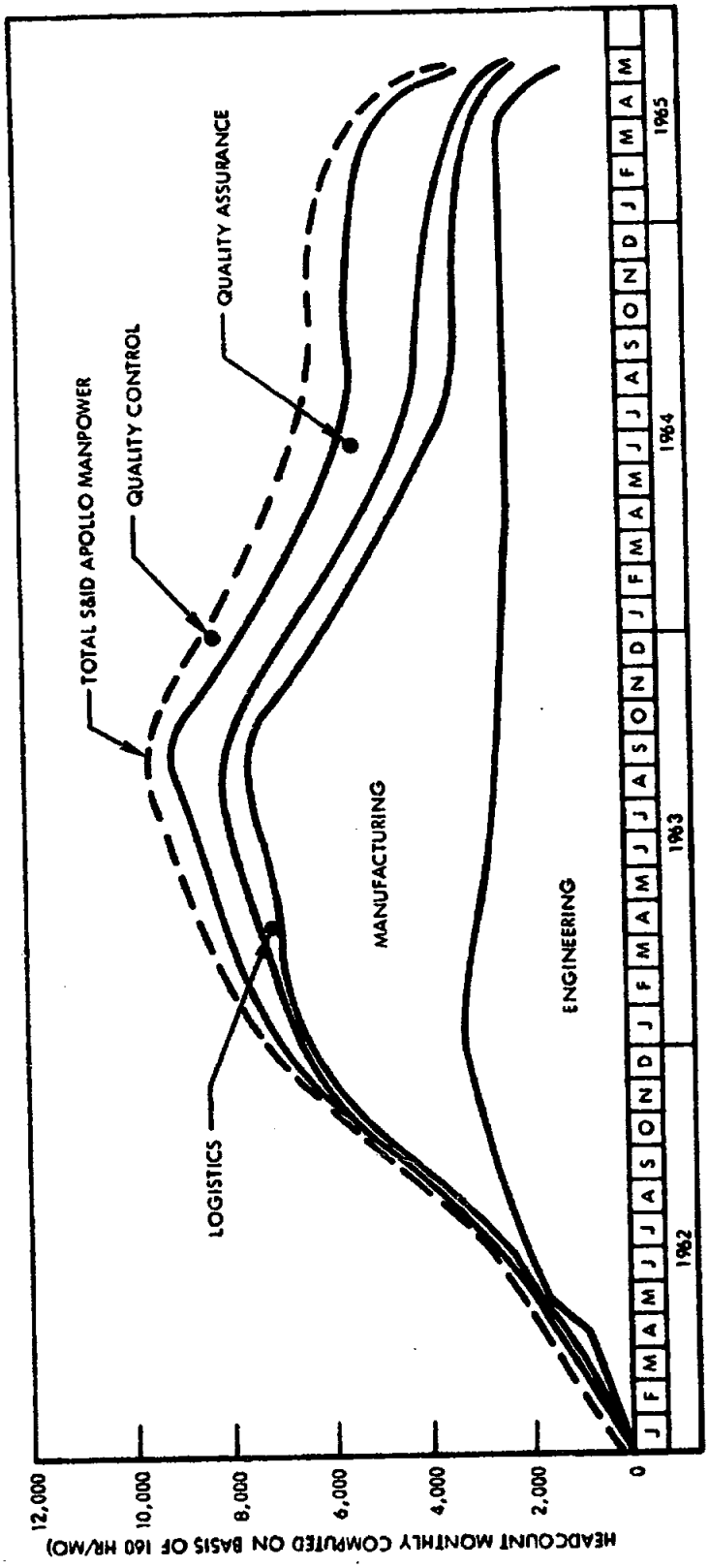


Figure 3. Total Contract Manpower Loading

[redacted]

[redacted]

all proposed engineering changes which affect approved performance specifications or other documents defining configurations, safety, interchangeability, reliability, costs, delivery schedules, or those which require retrofit or rework of delivered articles.

All requirements for engineering design changes, regardless of source, are directed to the responsible engineering design group for study prior to the initiation of documentation and coordination effort. An engineering change control function will be the focal point for all technical information relating to engineering changes for the Apollo program.

Figure 4 illustrates the flow specified for processing technical descriptions. It will be noted that regardless of where a change requirement originates, it will flow through the responsible engineering design group. Engineering Change Control will coordinate the change requirements with other design groups, collect data, and prepare a technical change package. Upon approval of the package by the chief engineer, Engineering Change Control forwards the change package to the chairman of the Change Control Board. The Change Control Board consists of representatives from Program Contracts, Program Control, Engineering, Logistics, Manufacturing, Quality Assurance, Administrative Support, Industrial Planning, Program Purchasing, Specifications, and Integrated Facilities, as required. This board determines (1) the effect of the change on work in process, spares, material and equipment procurement, publications, program schedules, etc.; (2) establishes the method for implementing the change; and (3) authorizes immediate release of the change, if the change is within scope of the contract. If the change is determined by the board to be out-of-scope of the contract, the board will authorize preparation of a proposal to the customer.

Authorization for Engineering Changes

Engineering effort to perform studies, prepare change proposals to the customer or release engineering changes that affect approved performance specifications, or other documents defining configurations, safety, interchangeability, reliability, costs, delivery schedules, or those which require retrofit or rework of delivered articles, is accomplished only when authorized by Apollo/S&ID management. An S&ID procedure, "Authorization for Engineering Changes," establishes the requirements for the issuance of such authorizations and delineates the resultant actions. The Master Change Record (MCR) is the basic form used in this procedure; it provides complete documentary coverage of all phases of activity related to a given change. When authorized by the chief engineer, the engineering change control function prepares an MCR. The MCR delineates the effort to be expended and specifies information submittal schedules or completion dates.

[redacted]

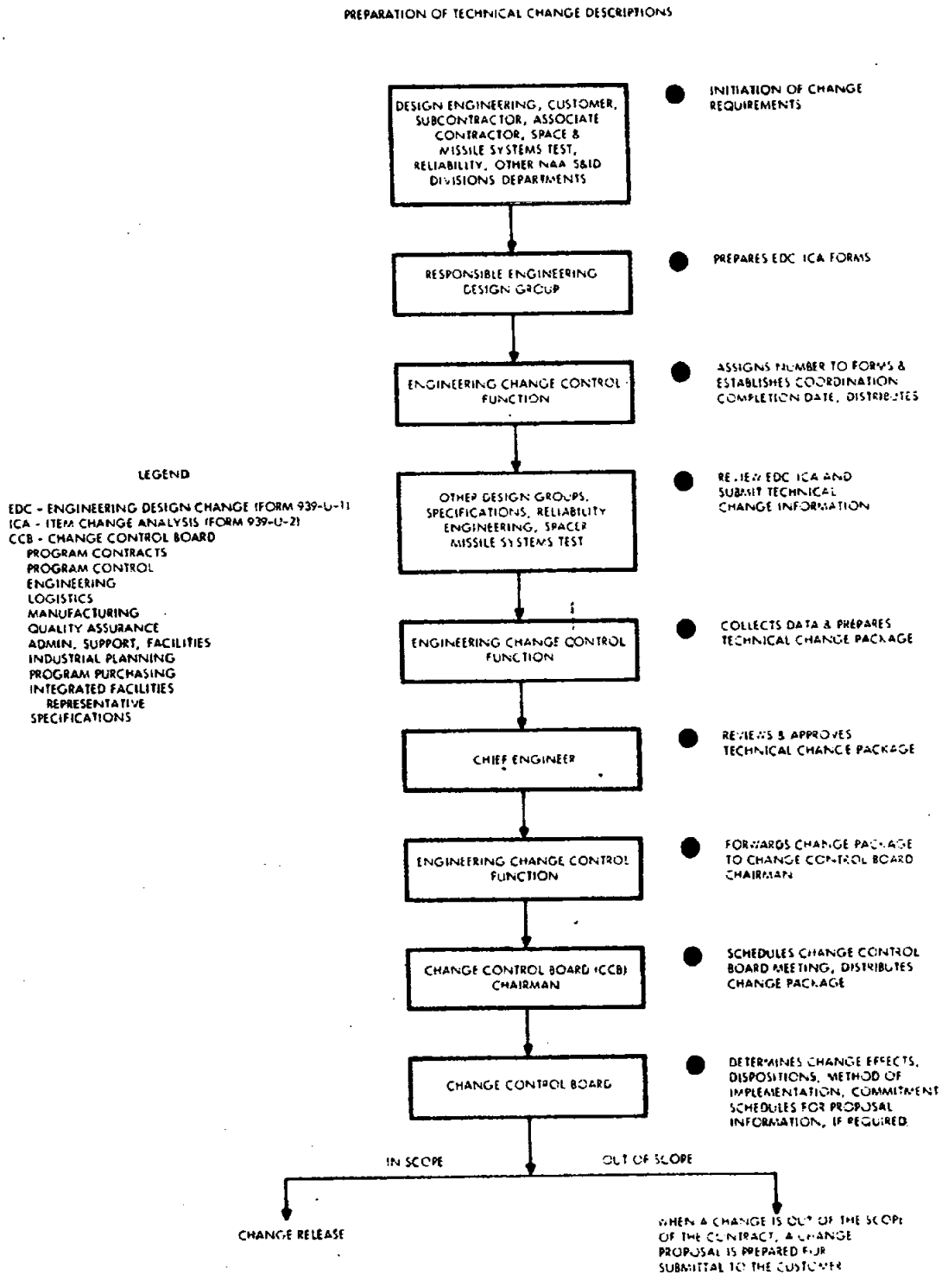


Figure 4. Engineering Change Flow Chart

[redacted]

[redacted]

Completed MCR's are distributed using a standard list, including the groups affected (Engineering, Logistics, Manufacturing, Contracts and Pricing, Quality Assurance, Material, Program Control, etc.). When the chief engineer authorizes immediate release of a change (within contractual scope) or upon receipt of customer authorization to incorporate a change (outside of contractual scope), the engineering change control function obtains confirmation of change points from Production Planning, Manufacturing. If subcontractor equipment is affected, Engineering Change Control coordinates with Program Material/Purchasing, to obtain confirmation of subcontractor delivery schedules. Upon receipt of confirmations, a new or revised MCR is issued, showing the approved change points and authorizing release of engineering designs. Upon receipt of an authorizing MCR, engineering design groups prepare and release the required engineering orders, drawings, and specifications. All engineering orders released reference the authorizing MCR number. Other departments, upon receipt of engineering orders, drawings, and specifications, function to ensure proper incorporation of the change in accordance with established policies and procedures.

Schedule Change Control

As part of the overall performance evaluation and control, Apollo program management has established a mechanism for processing, evaluating, and approving those schedule changes which do not reflect poor performance and which will not jeopardize completion of major milestones. Figure 5 illustrates the processing of all requests for formal schedule changes. Requirements for schedule changes will usually originate in a functional department, which completes a Schedule Change Request form and forwards it to Program Control. Program Control conducts a preliminary review to determine the impact of the proposed schedule change on the program. Next, Program Contracts reviews the change request and the Program Control comments to determine the effect of the proposed change on contractual requirements.

The Schedule Change Request is then placed on the agenda for the next meeting of the Change Control Board. At this meeting, the Schedule Change Request is introduced and the results of the preliminary investigations are discussed. The effect of the adoption of the schedule change is noted by applicable functional representatives. Each Change Control Board member receives a copy of the change request for review and approval or disapproval by the cognizant manager. If all managers approve the change, Program Control prepares and distributes a Schedule Change Notice. When one or more of the functional managers disapprove the change, a special review is scheduled by Program Control. If no approval is forthcoming at this review, the Schedule Change Request file is forwarded to the program manager's office for resolution.

[redacted]

[redacted]

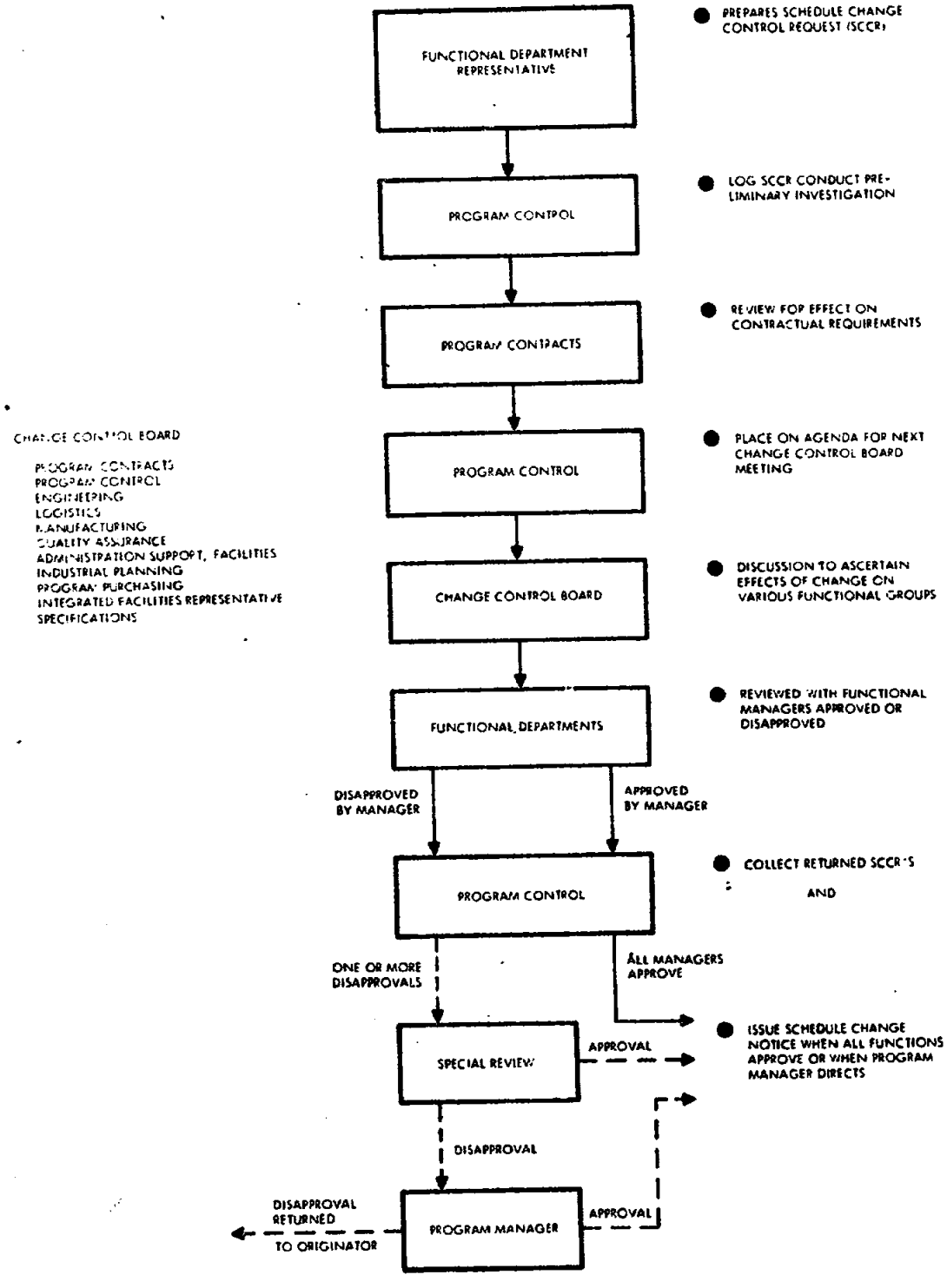


Figure 5. Schedule Change Control Flow Chart

[redacted]

[redacted]

Contract Change Proposals (CCP's)

When desired program changes are found by the Change Control Board to be outside of the contractual scope and provisions, a Contract Change Proposal is prepared upon instructions from the Change Control Board chairman. The basic procedure governing the preparation and submittal is contained in an S&ID procedure entitled "Preparation and Submittal of Engineering Changes to the Customer." A flow chart for processing CCP's is shown in Figure 6. This same basic procedural framework will be used for all types of contract changes that are proposed by S&ID.

MAJOR SUBCONTRACTOR CONTROL

Control of the major Apollo subcontractors is achieved by continuous surveillance over the program activities through the utilization of monitoring methods and procedures. Before the finalization of a definitive contract and firm technical base-line, the following documents control the subcontractor effort:

1. A letter contract is written, as a preliminary contractual instrument, which authorizes immediate commencement of manufacture of supplies or performance of services, including but not limited to, preproduction planning or the purchase of necessary material.

2. A work statement and a procurement specification are prepared by S&ID, outlining the scope of work and the system performance requirements.

3. The subcontractor is required to prepare documentation reports in the general categories of:

   a. Contractual planning reports (program, test, manufacturing, facilities, qualification-reliability, etc.)

   b. Contractual management reports (financial, PERT, progress, milestone, testing status, etc.)

   c. Data reports (as required to provide program visibility)

This documentation is processed for an efficient and timely flow of information to include in parallel documents required from S&ID by NASA. Additionally, the subcontractor is responsible for the maintenance of these reports through a revision system.

[redacted]

[redacted]

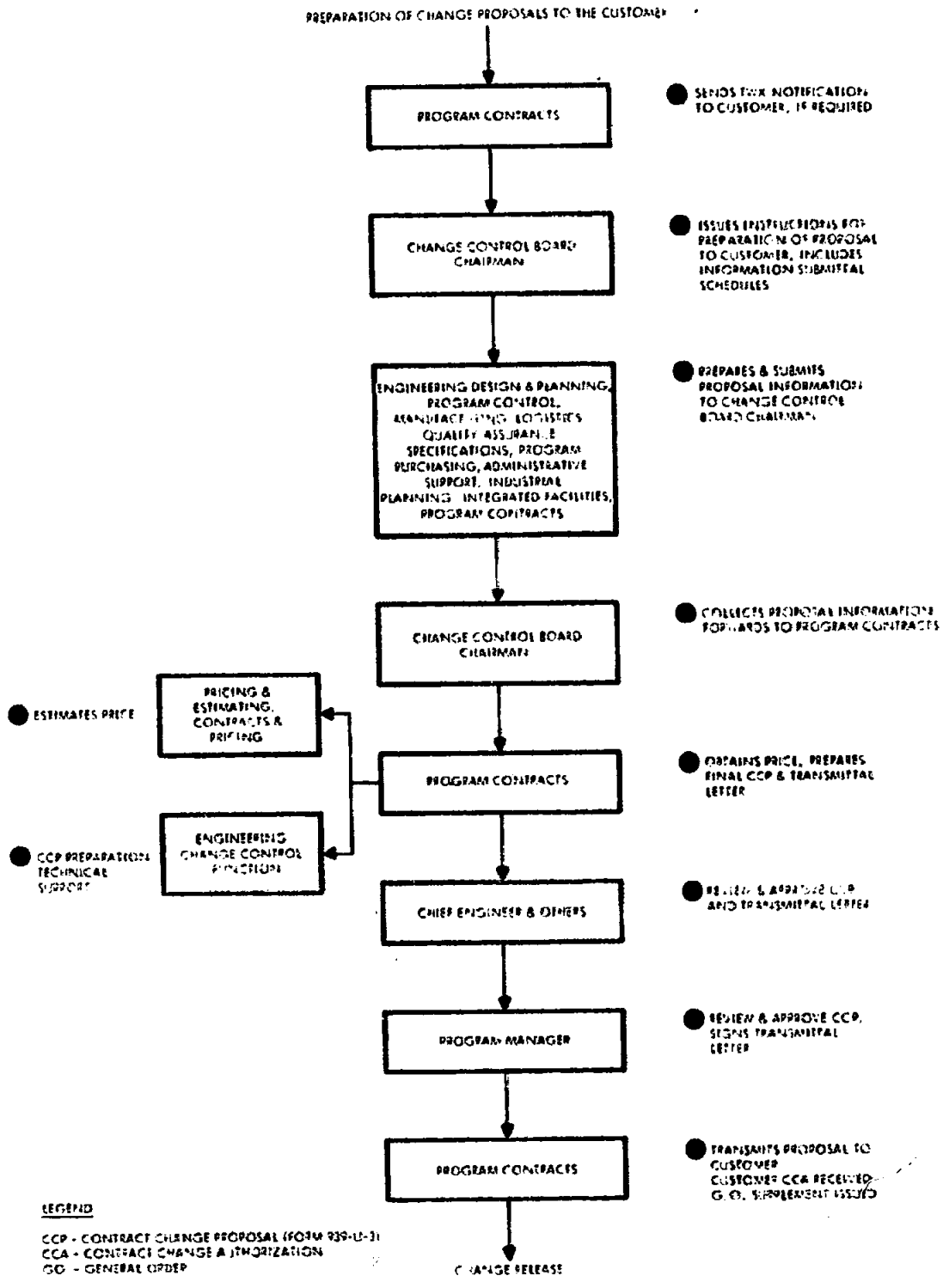


Figure 6. Contract Change Proposal Flow Chart

[redacted]

[redacted]

During the initial stages of the program, while the supplier is working under a letter contract and specific funding, any changes outside the scope of the technical statement of work must be authorized by the cognizant project manager, as required by S&ID policies and procedures. All changes are incorporated by amendment with NASA approval, according to S&ID policies and procedures and the material department manual. During this stage, the supplier submits the following types of management control data to the material department:

1. Funding data: projections, expenditures, commitments

2. Progress reports

3. Milestone status and narrative variance reports

4. PERT Networks, narrative and variance reports

Liaison is maintained through regularly programmed status briefings and monthly coordination meetings with the subcontractors. These meetings afford Apollo management and technical personnel insight into, and understanding of, the overall project development. Particular emphasis is placed on discussing problems related to end-item delivery requirements of S&ID.

Subsequent to the establishment of a definitive contract and firm technical base, supplier control is accomplished by monitoring performance by means of the project management team concept, which includes the following key personnel:

1. A buyer functions as the subcontract administrator, and as such, he is the focal point of supplier contact. In the performance of this function the buyer surveys, negotiates, and administers the contract. He calls upon functional team members to solidify the S&ID position and strives for bilateral agreements upon which to definitize and negotiate changes to the contract.

2. A project manager is responsible to S&ID Apollo management for over-all direction of the supplier's program. He is charged with providing technical direction and, where necessary, is the decision-making source for technical, as well as administrative, matters. It is his responsibility to ensure the delivery of functionally qualified hardware on schedule and within authorized funds.

[redacted]

[redacted]

3. A design engineer is the focal point for all technical matters. He will advise the project manager of the supplier's technical activity.

4. A quality assurance engineer is responsible for reviewing and approving supplier quality inputs and maintaining quality assurance standards compatible with prime contract requirements. He will monitor all quality aspects of the program and refer to the project manager those problems that require his attention.

5. The reliability engineer is responsible for performing the reliability functions.

6. The team coordinator determines status through management control and technical liaison effort. He is responsible for analyzing subcontractor reports and data, correlating technical accomplishments with costs and calendar schedule, detecting problem areas, recommending corrective action, and coordinating solutions.

A resident subcontractor management office is maintained at each subcontractor location. The objective of this office is to utilize professional contract management to ensure on-schedule performance within the terms of the contract. This is accomplished by providing a coordinated team of highly-qualified professional personnel at the subcontractor location. This team is comprised of the following representatives: material, program control, engineering, quality control, and others determined by Apollo management. Functioning with the project management team, this group provides on-the-spot surveillance of the subcontractor effort. The project management team is informed of progress, status, and subcontractor problems through the resident subcontractor management office. Formal documentation is also required. This documentation is reviewed by, and made accessible to, S&ID functional groups, as indicated in the following paragraphs.

Documentation requirements stipulate that the supplier submit to S&ID various types of engineering documentation for review, cognizance, and appraisal. The project manager and his staff are informed, step-by-step, on design development and test effort being performed at the supplier's facility. Further engineering coordination is accomplished through design evaluations, design review boards, constant evaluation by the design engineer of the supplier's technical staff, technical representation at the supplier's facility, monthly technical coordination meetings, and special meetings.

[redacted]

[redacted]

S&ID manufacturing personnel review and approve the subcontractor's manufacturing plan to assure the economical application of fabrication processes.

Quality and reliability procedures and test plans are submitted for approval to S&ID. Surveillance is maintained through reference test reports and technical exchange meetings. Through inspection and acceptance test criteria, personnel assure that the supplier delivers specified equipment.

S&ID GSE requirements personnel review and approve supplier's recommendations for GSE and also GSE hardware specificattions. Coordination is effected through technical exchange meetings and drawing reviews.

Training and maintenance data and spares are reviewd by logistics personnel. Hardware lists are reviewed by a spares review board for buy determinations. Subsequent to these determinations, hardware releases are effected. Periodic provisioning and coordination conferences are scheduled, as required.

The Apollo contract department coordinates, negotiates, and administers the prime contract; and the Apollo material department is responsible for guaranteeing that the subcontracts are compatible with, and support, the prime contract.

ASSOCIATE CONTRACTOR ADMINISTRATION

NAA relations with associate contractors are administered through a staff, Associate Contractor Administration (ACA), established as a part of the Program Manager's office. The function of ACA is to ensure that the program technical requirements are met and the business policies of NASA and the Company are observed in all relations with associates. Present operating concepts and procedures, as outlined in the following paragraphs, have proved effective and form the basis for future ACA operations.

ACA is the principal point of contact with the associate contractors and with NASA on associate contractor matters. Representatives are assigned to specific areas of associate effort; each representative is responsible for maintaining effective communication channels with NASA, the associate contractors, and elements of the S&ID organization for the exchange of technical and management information. The policies and procedures under

[redacted]

[redacted]

which these representatives operate provide for keeping S&ID effort within contract scope and for identifying the possible need for NASA direction on specific matters.

The Manned Spacecraft Center (MSC) and S&ID are currently developing an Apollo interface procedure which, it is planned, will be applicable to the interface coordination activities of MSC and the Apollo contractors. Subordinate procedures, applicable to S&ID's coordination with specific associate contractors and approved by MSC, S&ID, and the respective associates, will be issued as memorandums of understanding. With MSC and MIT concurrence, S&ID will soon propose to replace the present MIT/S&ID interface procedures reports, SID 62-270 and SID 62-271, with a single memorandum of understanding. Such a memorandum has already been proposed for the Convair/S&ID interface with respect to the Little Joe II effort. At this time, coordination with the Manned Space Flight Center (MSFC) and its contractors is governed by the procedure set forth in MSC letter, ASPO/CSM 62-4, dated 21 September 1962. The letter, together with procedures pertaining to MSC/MSFC Coordination Panels, appears to satisfy present needs.

At Downey, an ACA representative is assigned for each of the following associate contractor programs:

Navigation and guidance

Launch vehicles (Saturn and Little Joe II)

NASA Furnished crew equipment and instrumentation

Integration, checkout and GOSS

Lunar excursion module

In addition to the ACA personnel at Downey, the senior representative in residence at MIT is provided by ACA. MIT also has a senior resident representative at S&ID. It is planned that a similar exchange of senior resident representatives will be effected with Grumman.

Where the need exists for continuous coordination between functional elements of the S&ID and contractor's organizations, specialists will be assigned as resident representatives to the contractor's sites. One such

[redacted]

[redacted]

assignment—Engineering representative to MIT—has been made. A similar requirement will be necessary for the S&ID/Grumman effort. This requirement will probably be met through a series of short term assignments, providing continuous engineering coverage by specialists with current knowledge of spacecraft design progress.

INTERDIVISIONAL WORK AUTHORIZATION

NAA skills and available equipment will be utilized in the Apollo Program. Currently, there are approximately 100 interdivisional work authorizations (IDWA) issued in the S&ID Apollo Program. These range from a minor IDWA for several hundred fabrication hours to a major IDWA of approximately five million dollars for the reaction control motor.

S&ID Procedure B-401, dated 1 December 1961, is the basic procedure governing authorization and control of interdivisional effort. The Apollo material department is responsible for monitoring and coordinating all Apollo IDWA effort and receives weekly and monthly reports of the hours and dollars status. Each IDWA has a designated coordinator responsible for the effort at each division. Close control is exercised to assure that task completions follow prescribed schedule. Open capacity and available skills are maintained by the IDWA group to take advantage of special equipment possessed by other divisions and which are not available at S&ID.

Copies of all IDWA's are supplied weekly to the NASA resident Apollo project office.

NASA-S&ID INTERFACE

NASA has established a resident Apollo project office at the S&ID Downey facility. This office is analogous to the resident subcontractor management offices maintained by S&ID at the various subcontractor locations. Responsibilities of the resident Apollo project office include the following:

1. To serve as a focal point of coordination between S&ID and MSC on the Apollo spacecraft

2. To administer and direct S&ID's technical effort in accordance with technical guidelines established by the Apollo Spacecraft Project Office (ASPO) in Houston

3. Be directly responsible for Apollo spacecraft reliability and quality assurance programs

[redacted]

4. To administer and direct S&ID's program management effort in accordance with the management guidelines established by the ASPO

5. Represent ASPO in negotiations or contacts with the Western Operations Resident Office.

The Resident Apollo Project Office is divided into four major functional groups which report to the resident project manager. These groups are (1) administration, (2) engineering, (3) reliability and quality assurance, and (4) manufacturing.

The administrative office serves as a point of contact between MSC Financial Management and Contracts and S&ID and coordinates with NASA-O on accounting, overhead, special direct costs, and other pricing and contractual policies. This office also recommends cost control procedures and monitors financial reporting with the objective of evaluating cost versus performance for S&ID and their subcontractors. Additional functions include monitoring documentation and the activities of the S&ID Associate Contractor Relations Office.

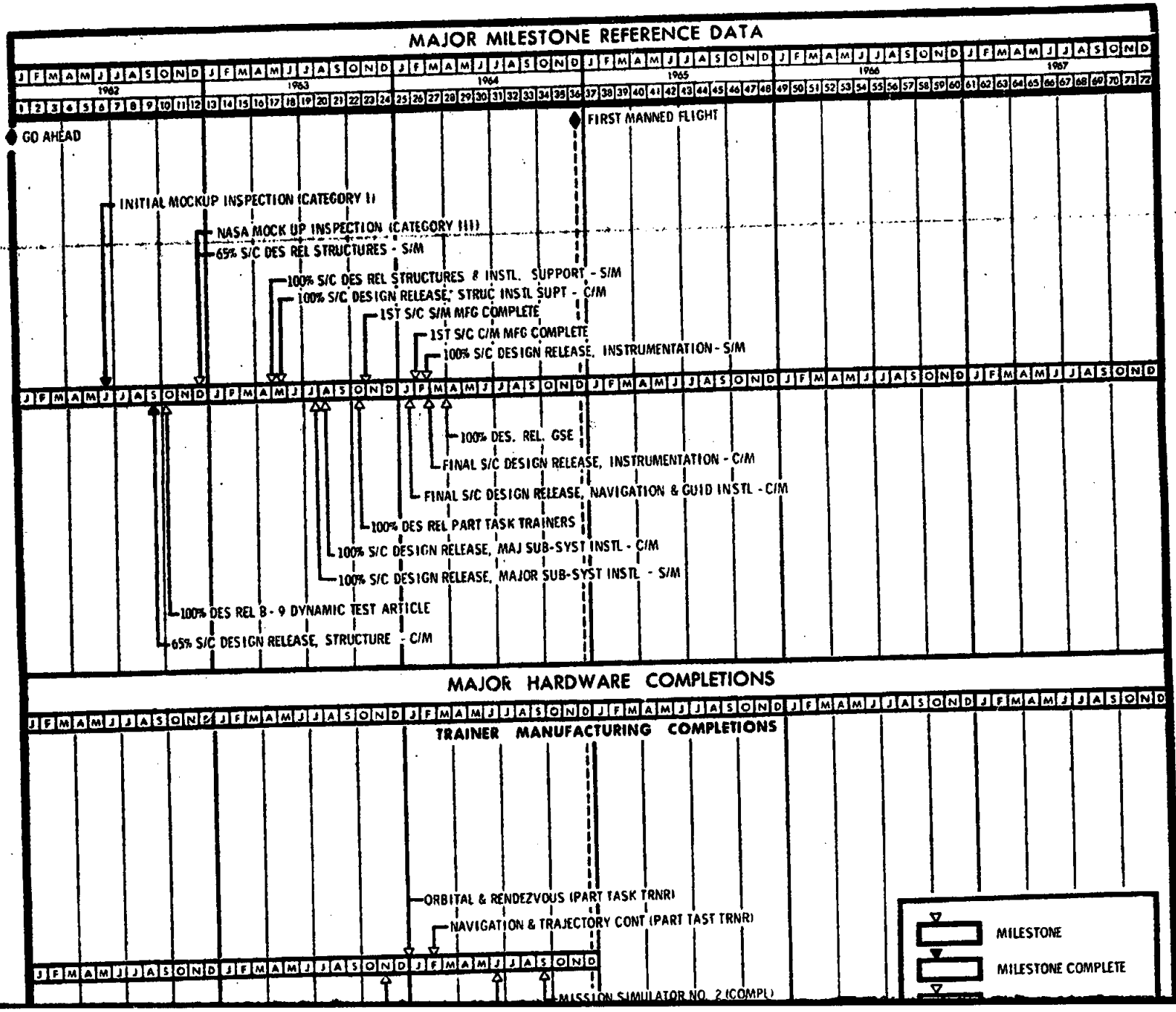
The engineering office is responsible for monitoring S&ID's engineering effort and evaluating their compliance with Apollo design criteria established by the ASPO. This includes monitoring of systems design concepts and informing ASPO of S&ID's design and systems integration effort and designating problem areas that could affect schedule or performance. A second major responsibility of this group is to provide assurance that NASA experience applicable to Apollo is used by S&ID.

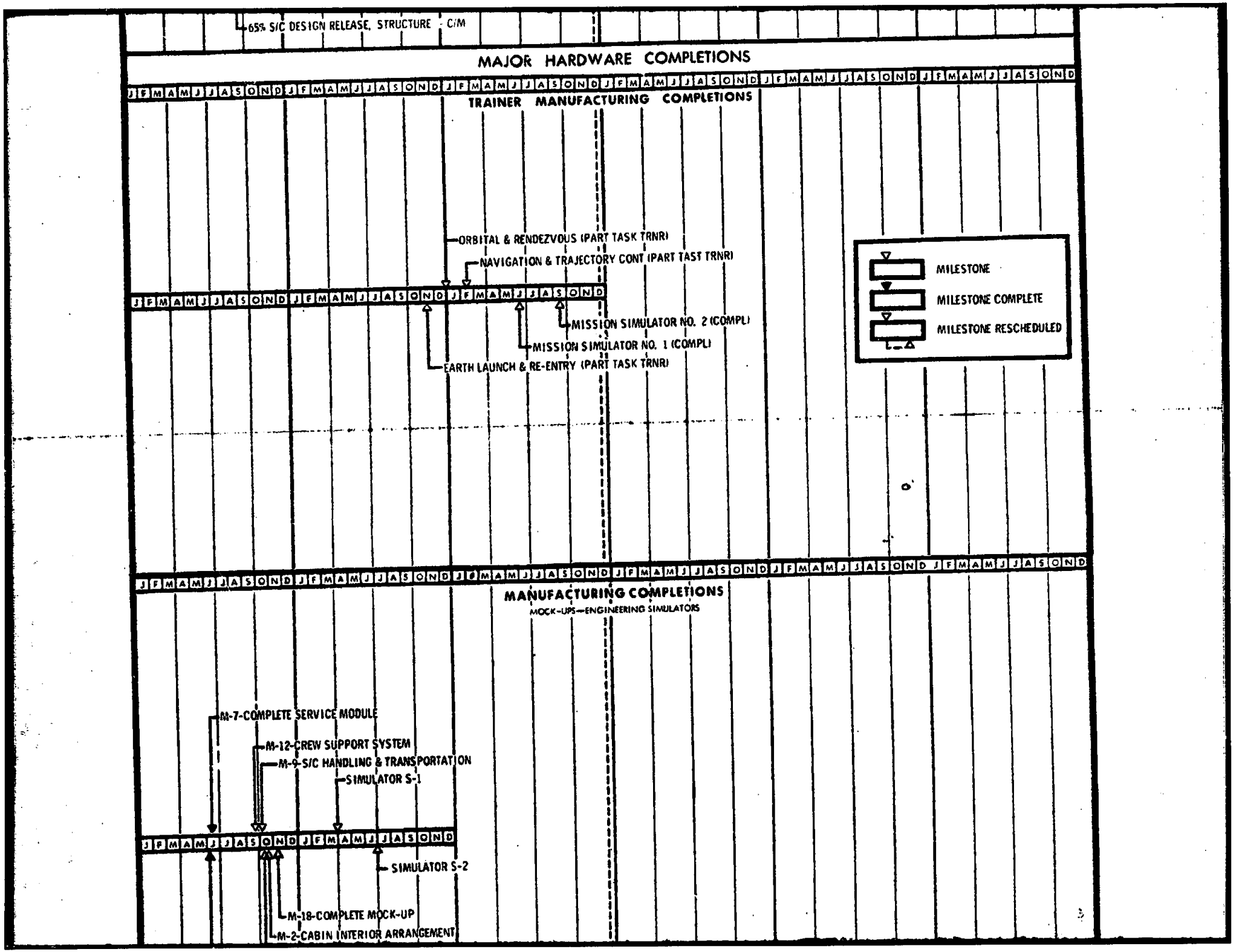
The reliability and quality assurance office will participate in the preparation and approval of all quality control inspection plans and will develop, document, and maintain a quality control inspection plan that will be used by NASA-O inspectors for product verification of all phases of inspection and testing of NASA articles used in the Apollo spacecraft. The quality control group will continuously monitor and assess the effectivity of S&ID inspection activity through personal investigations, and will review Western Operations Office and other inspection agency evaluation. The quality assurance group will participate with MSC operations and project flight groups in establishing requirements for system and spacecraft checkout procedures. The group will also monitor and evaluate adequacy of all S&ID articles during checkout of all components, subsystems, systems, and completed spacecraft. The engineering reliability group will monitor and evaluate the reliability and quality assurance efforts of S&ID and their subcontractors during subsystem and component design activities and will prepare periodic summary status reports to MSC.

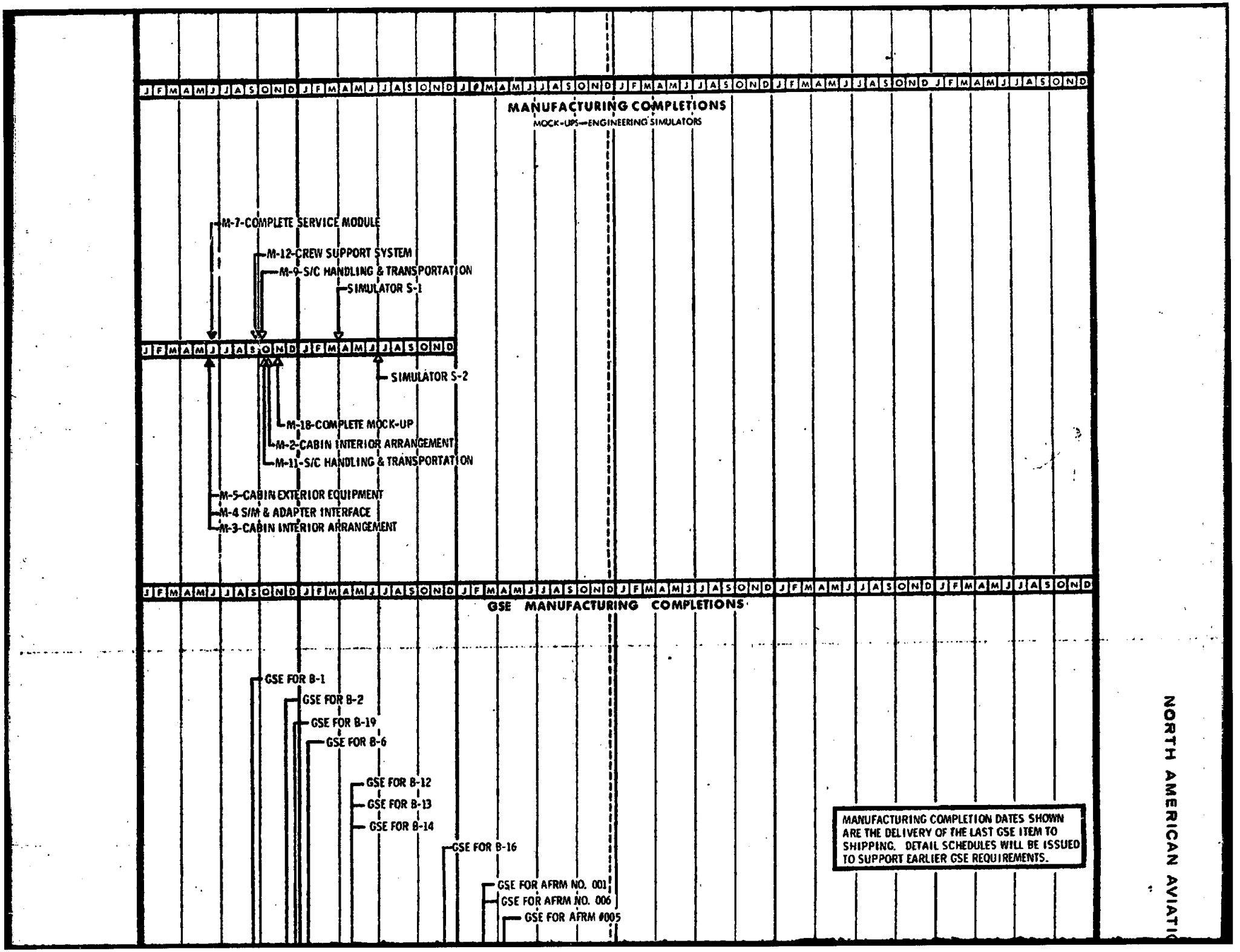
[redacted]

The manufacturing office will be responsible for the review and evaluation of S&ID's plans and operations in the areas of (1) production control and programming; (2) tool policy, design, and manufacturing; (3) manufacturing facilities; and (4) manufacturing operations. The second major responsibility of this group is to inform the ASPO of the status and progress of S&ID's manufacturing effort.

[redacted]


MAJOR MILESTONE REFERENCE DATA
1962
1963
1964
1965
1966
1967
GO AHEAD
FIRST MANNED FLIGHT
INITIAL MOCKUP INSPECTION (CATEGORY I)
NASA MOCK UP INSPECTION (CATEGORY III)
65% S/C DES REL STRUCTURES - S/M
100% S/C DES REL STRUCTURES & INSTL. SUPPORT - S/M
100% S/C DESIGN RELEASE, STRUC INSTL SUPT - C/M
1ST S/C S/M MFG COMPLETE
1ST S/C C/M MFG COMPLETE
100% S/C DESIGN RELEASE, INSTRUMENTATION - S/M
100% DES. REL. GSE
FINAL S/C DESIGN RELEASE, INSTRUMENTATION - C/M
FINAL S/C DESIGN RELEASE, NAVIGATION & GUID INSTL - C/M
100% DES REL PART TASK TRAINERS
100% S/C DESIGN RELEASE, MAJ SUB-SYST INSTL - C/M
100% S/C DESIGN RELEASE, MAJOR SUB-SYST INSTL - S/M
100% DES REL B - 9 DYNAMIC TEST ARTICLE
65% S/C DESIGN RELEASE, STRUCTURE - C/M
MAJOR HARDWARE COMPLETIONS
TRAINER MANUFACTURING COMPLETIONS
ORBITAL & RENDEZVOUS (PART TASK TRNR)
NAVIGATION & TRAJECTORY CONT (PART TAST TRNR)
MISSION SIMULATOR NO. 2 (COMPL)
MILESTONE
MILESTONE COMPLETE


65% S/C DESIGN RELEASE, STRUCTURE - C/M
MAJOR HARDWARE COMPLETIONS
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
TRAINER MANUFACTURING COMPLETIONS
ORBITAL & RENDEZVOUS (PART TASK TRNR)
NAVIGATION & TRAJECTORY CONT (PART TAST TRNR)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
MISSION SIMULATOR NO. 2 (COMPL)
MISSION SIMULATOR NO. 1 (COMPL)
EARTH LAUNCH & RE-ENTRY (PART TASK TRNR)
MILESTONE
MILESTONE COMPLETE
MILESTONE RESCHEDULED
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
MANUFACTURING COMPLETIONS
MOCK-UPS—ENGINEERING SIMULATORS
M-7-COMPLETE SERVICE MODULE
M-12-CREW SUPPORT SYSTEM
M-9-S/C HANDLING & TRANSPORTATION
SIMULATOR S-1
J F M A M J J A S O N D J F M A M J J A S O N D
SIMULATOR S-2
M-18-COMPLETE MOCK-UP
M-2-CABIN INTERIOR ARRANGEMENT



NORTH AMERICAN AVIATI

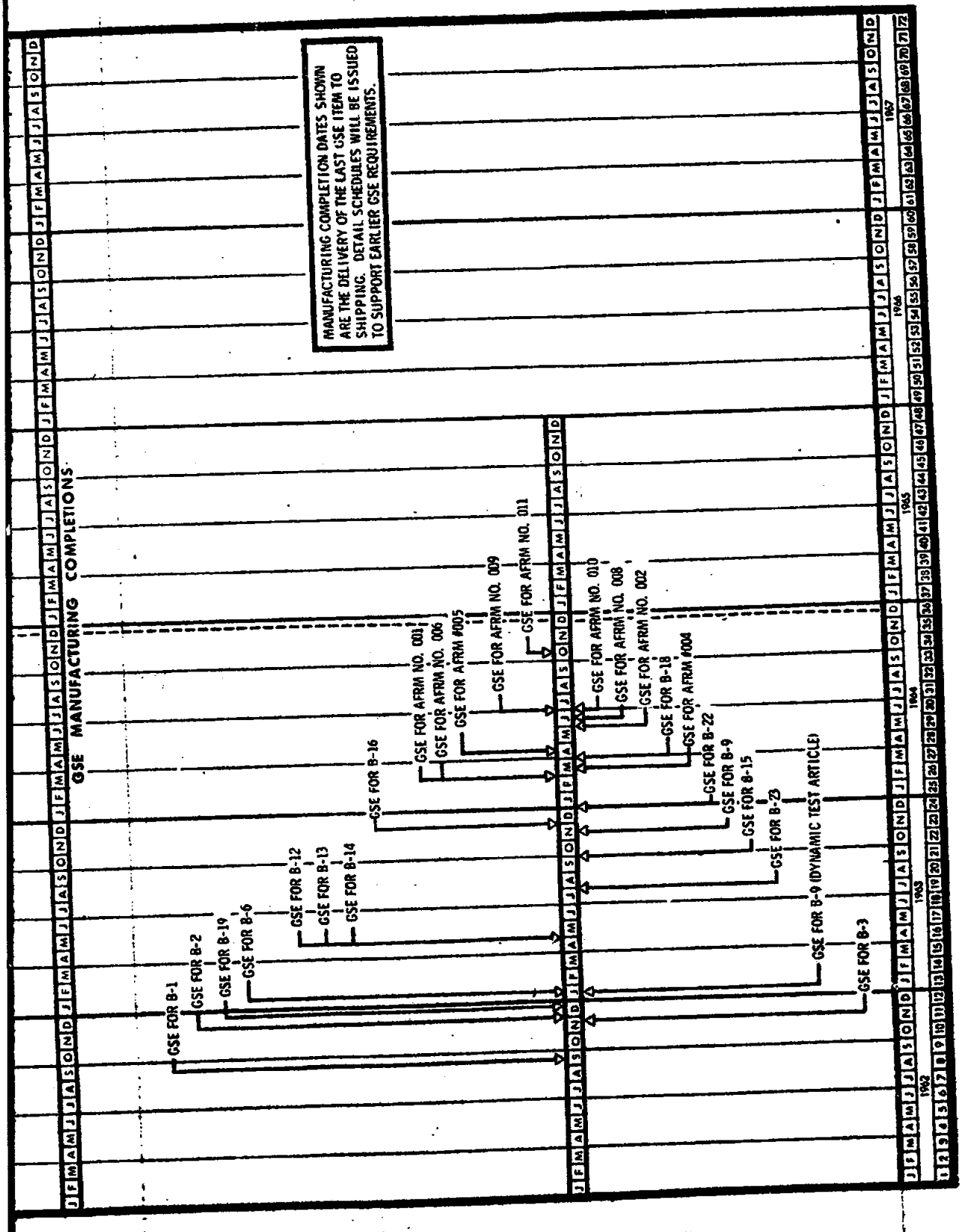
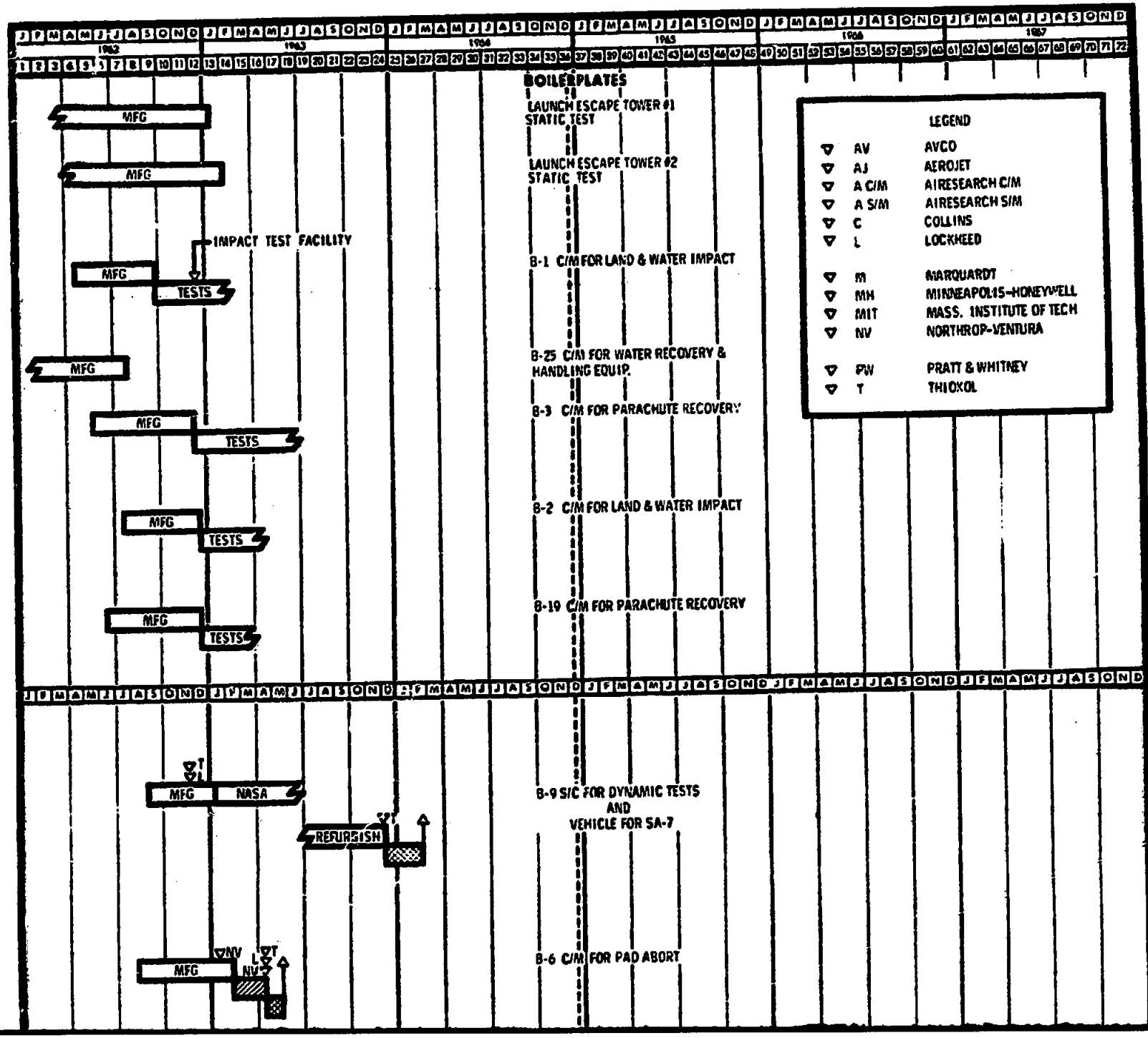
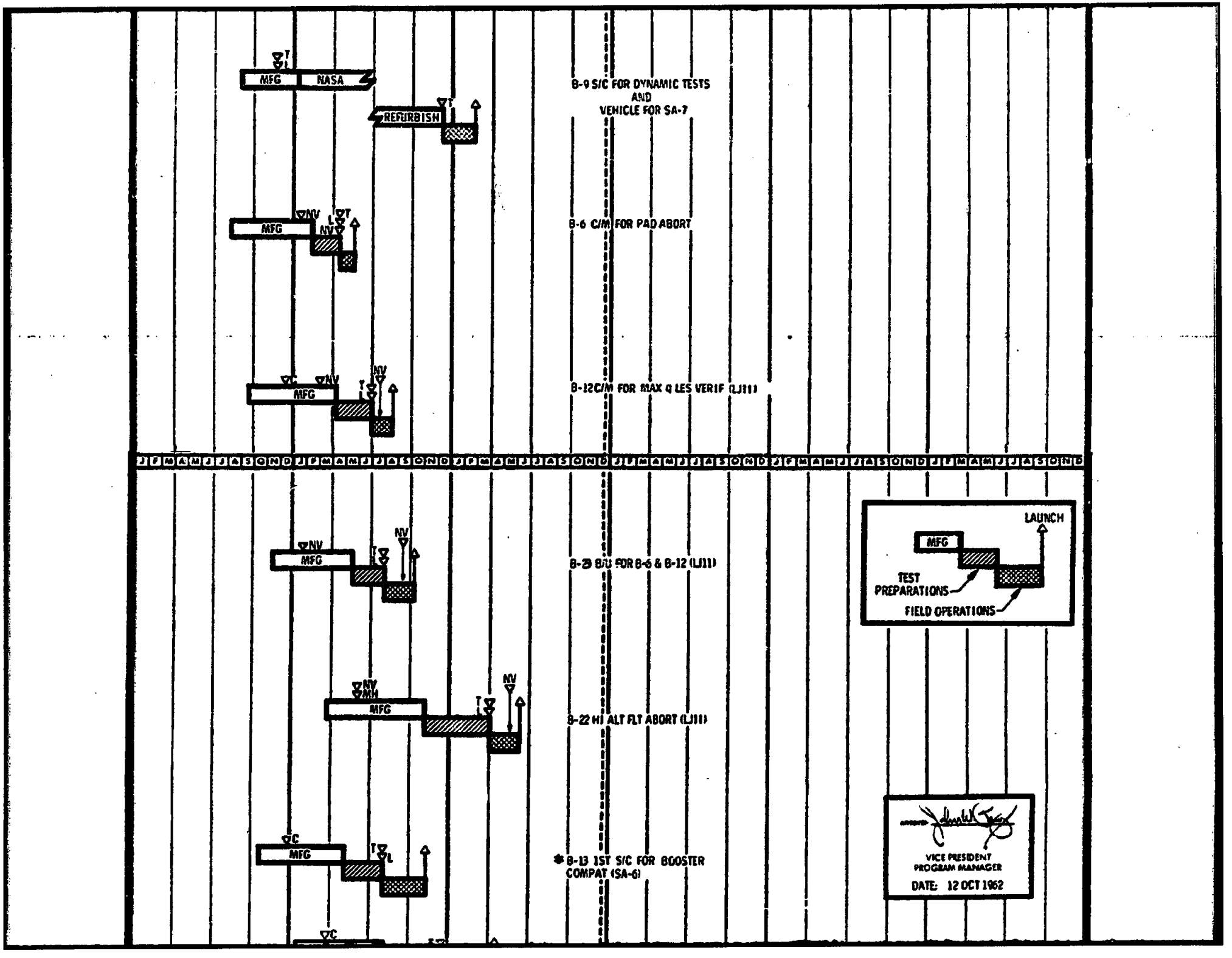
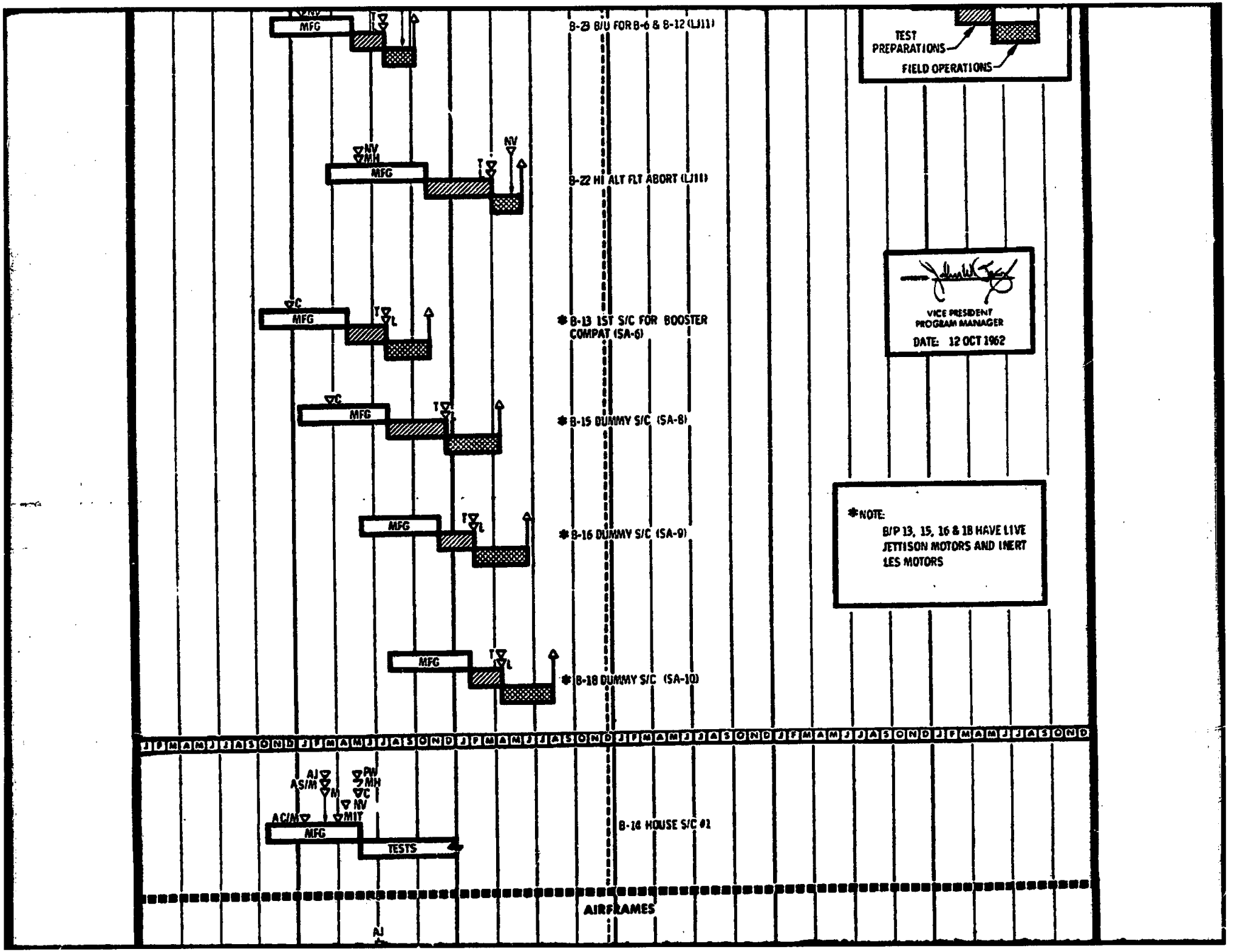
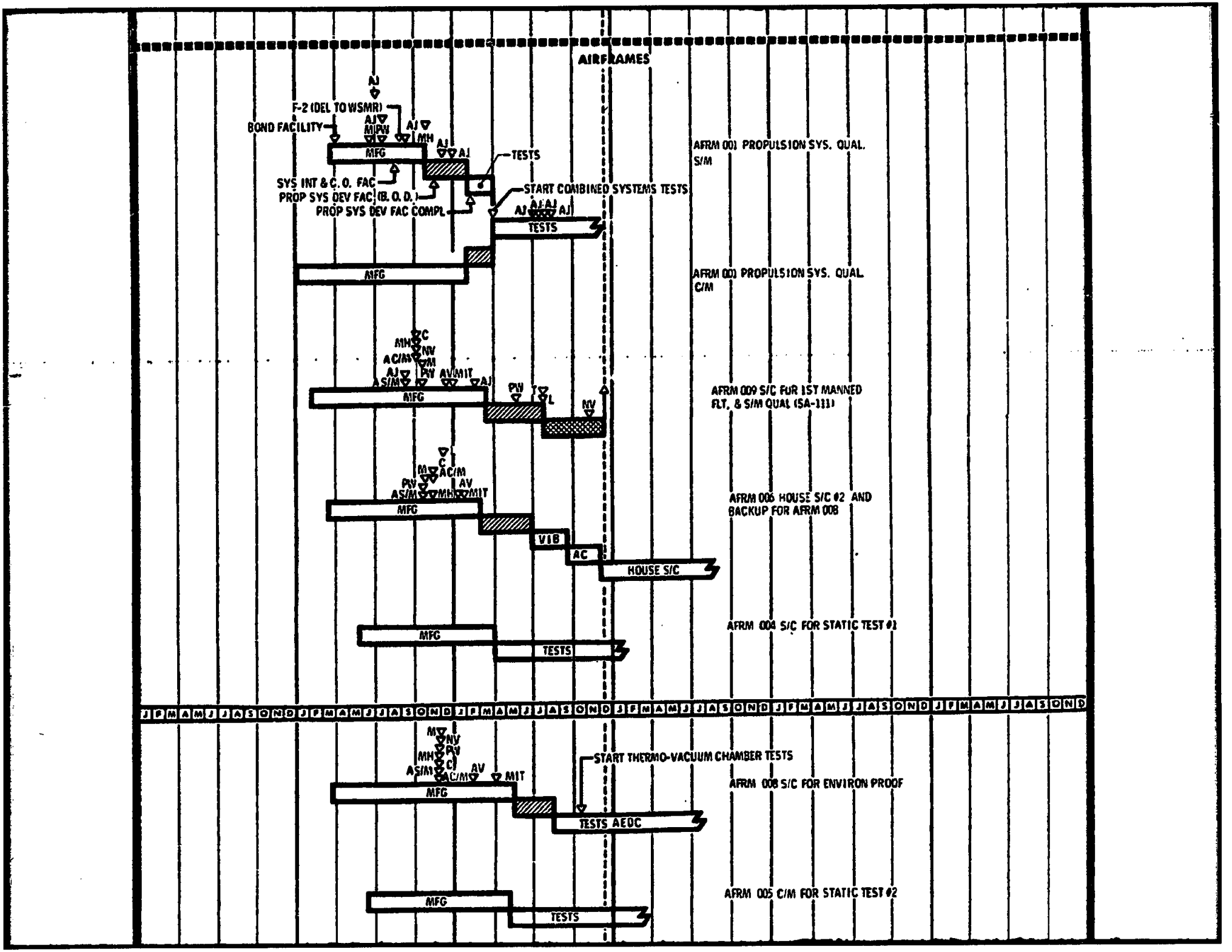


Figure 7. Apollo Master Development Schedule (Sheet 1 of 2)


1962
1963
1964
1965
1966
1967
BOILERPLATES
LAUNCH ESCAPE TOWER #1 STATIC TEST
LAUNCH ESCAPE TOWER #2 STATIC TEST
B-1 C/M FOR LAND & WATER IMPACT
B-25 C/M FOR WATER RECOVERY & HANDLING EQUIP.
B-3 C/M FOR PARACHUTE RECOVERY
B-2 C/M FOR LAND & WATER IMPACT
B-19 C/M FOR PARACHUTE RECOVERY
B-9 S/C FOR DYNAMIC TESTS AND VEHICLE FOR SA-7
B-6 C/M FOR PAD ABORT
MFG
TESTS
NASA
REFURBISH
IMPACT TEST FACILITY
LEGEND
AV AVCO
AJ AEROJET
A C/M AIRESEARCH C/M
A S/M AIRESEARCH S/M
C COLLINS
L LOCKHEED
M MARQUARDT
MH MINNEAPOLIS-HONEYWELL
MIT MASS. INSTITUTE OF TECH
NV NORTHROP-VENTURA
PW PRATT & WHITNEY
T THIOXOL


MFG
NASA
REFURBISH
B-9 S/C FOR DYNAMIC TESTS AND VEHICLE FOR SA-7
B-6 C/M FOR PAD ABORT
B-12 C/M FOR MAX Q LES VERIF (LJ11)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
B-23 B/U FOR B-6 & B-12 (LJ11)
B-22 HI ALT FLT ABORT (LJ11)
B-13 1ST S/C FOR BOOSTER COMPAT (SA-6)
LAUNCH
TEST PREPARATIONS
FIELD OPERATIONS
VICE PRESIDENT PROGRAM MANAGER
DATE: 12 OCT 1962


MFG
B-23 B/U FOR B-6 & B-12 (LJ11)
TEST PREPARATIONS
FIELD OPERATIONS
NV
MH
T
B-22 HI ALT FLT ABORT (LJ11)
C
L
* B-13 1ST S/C FOR BOOSTER COMPAT (SA-6)
VICE PRESIDENT PROGRAM MANAGER
DATE: 12 OCT 1962
* B-15 DUMMY S/C (SA-8)
* B-16 DUMMY S/C (SA-9)
* NOTE:
B/P 13, 15, 16 & 18 HAVE LIVE JETTISON MOTORS AND INERT LES MOTORS
* B-18 DUMMY S/C (SA-10)
J F M A M J J A S O N D
AJ
AS/M
M
PW
MH
C
NV
AC/M
MIT
B-14 HOUSE S/C #1
TESTS
AIRFRAMES


AIRFRAMES
AJ
F-2 (DEL TO WSMR)
BOND FACILITY
AJ
MI PW
AJ
MH
AJ
AJ
MFG
TESTS
SYS INT & C. O. FAC
PROP SYS DEV FAC (B. O. D.)
PROP SYS DEV FAC COMPL
START COMBINED SYSTEMS TESTS
AJ AJ AJ AJ
TESTS
AFRM 001 PROPULSION SYS. QUAL. S/M
MFG
AFRM 001 PROPULSION SYS. QUAL. C/M
MH C
NV
AC/M M
AJ PW AV/MIT
AS/M AJ
MFG
PW T
L
NV
AFRM 009 S/C FOR 1ST MANNED FLT. & S/M QUAL (SA-111)
L
C
M AC/M
PW AV
AS/M MH MIT
MFG
AFRM 006 HOUSE S/C #2 AND BACKUP FOR AFRM 008
VIB
AC
HOUSE S/C
MFG
TESTS
AFRM 004 S/C FOR STATIC TEST #1
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
M NV
PW
MH C
AS/M AC/M AV MIT
START THERMO-VACUUM CHAMBER TESTS
MFG
AFRM 008 S/C FOR ENVIRON PROOF
TESTS AEDC
MFG
TESTS
AFRM 005 C/M FOR STATIC TEST #2

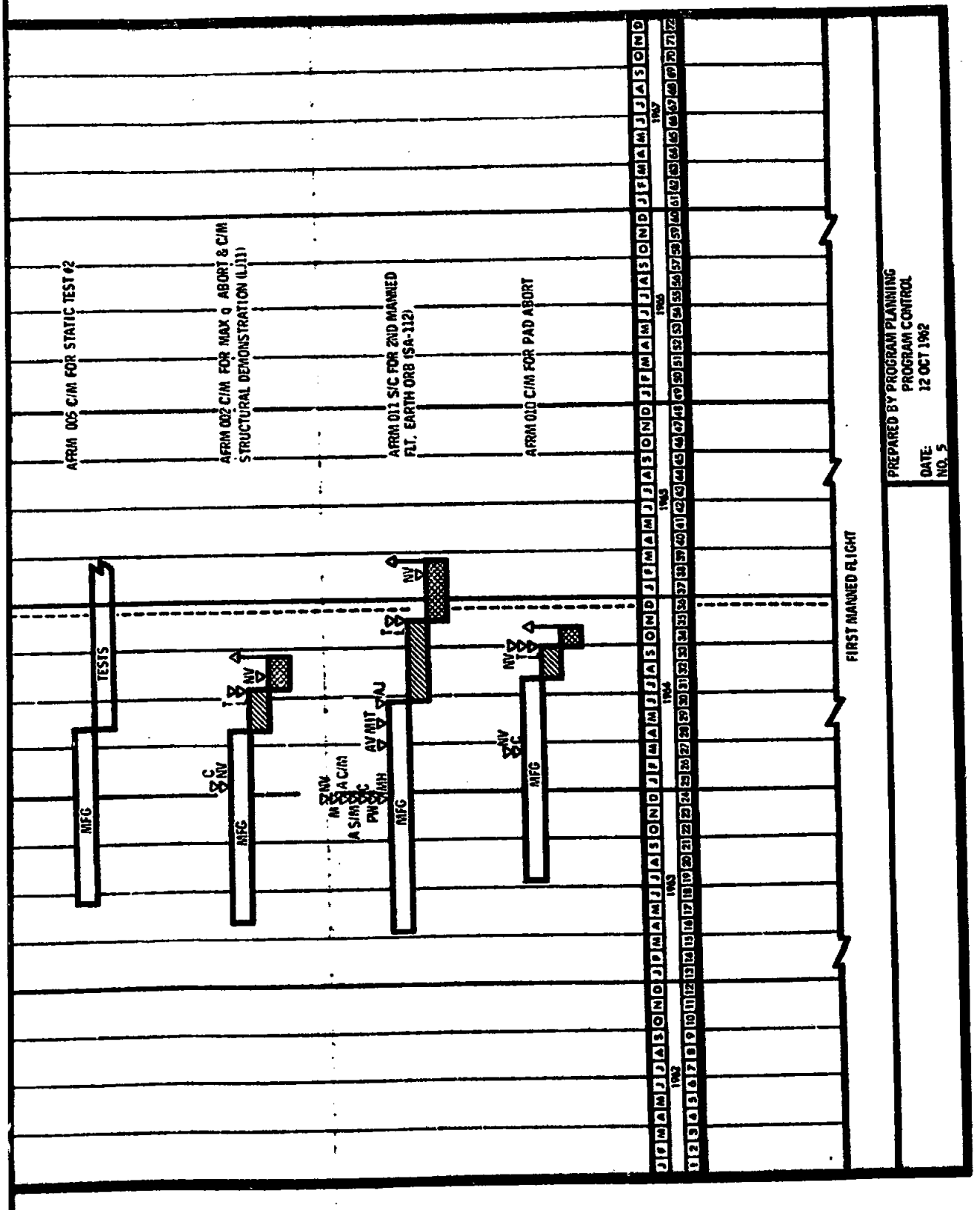
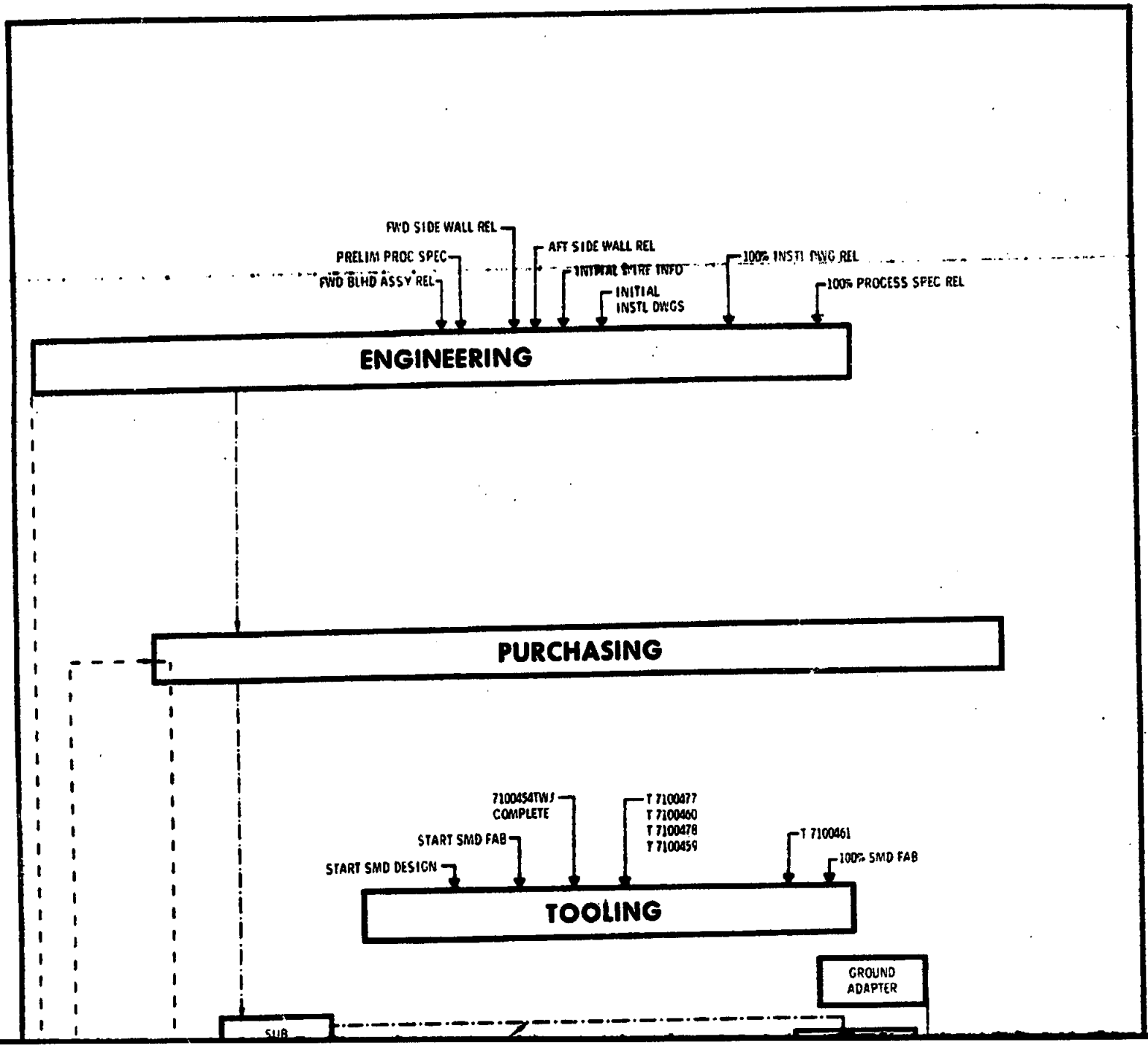
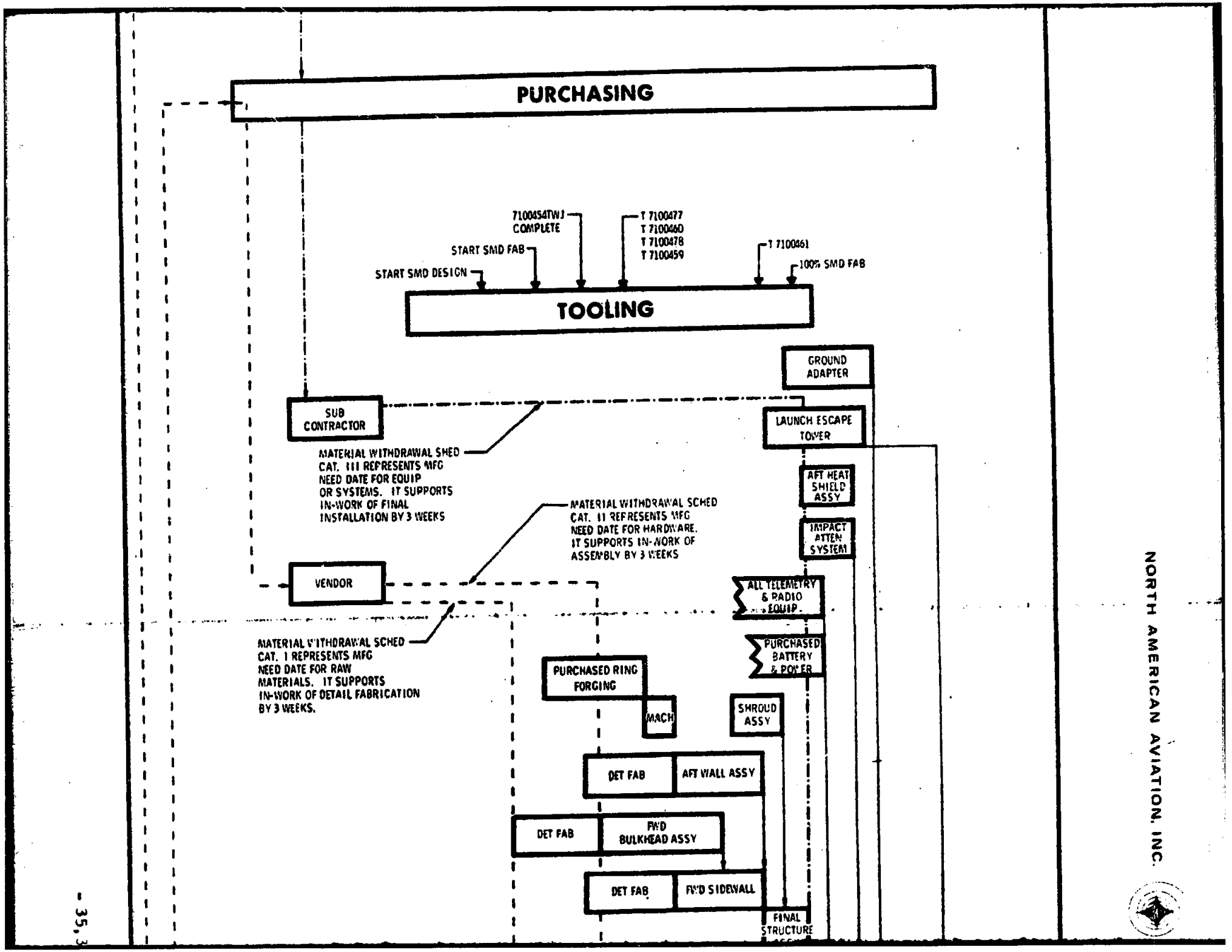


Figure 7. Apollo Master Development Schedule (Sheet 2 of 2)


FWD SIDE WALL REL
PRELIM PROC SPEC
FWD BLHD ASSY REL
AFT SIDE WALL REL
INITIAL SMRF INFO
INITIAL
INSTL DWGS
100% INSTL DWG REL
100% PROCESS SPEC REL
ENGINEERING
PURCHASING
7100454TWJ
COMPLETE
START SMD FAB
START SMD DESIGN
T 7100477
T 7100460
T 7100478
T 7100459
T 7100461
100% SMD FAB
TOOLING
GROUND
ADAPTER
SUB



NORTH AMERICAN AVIATION, INC.

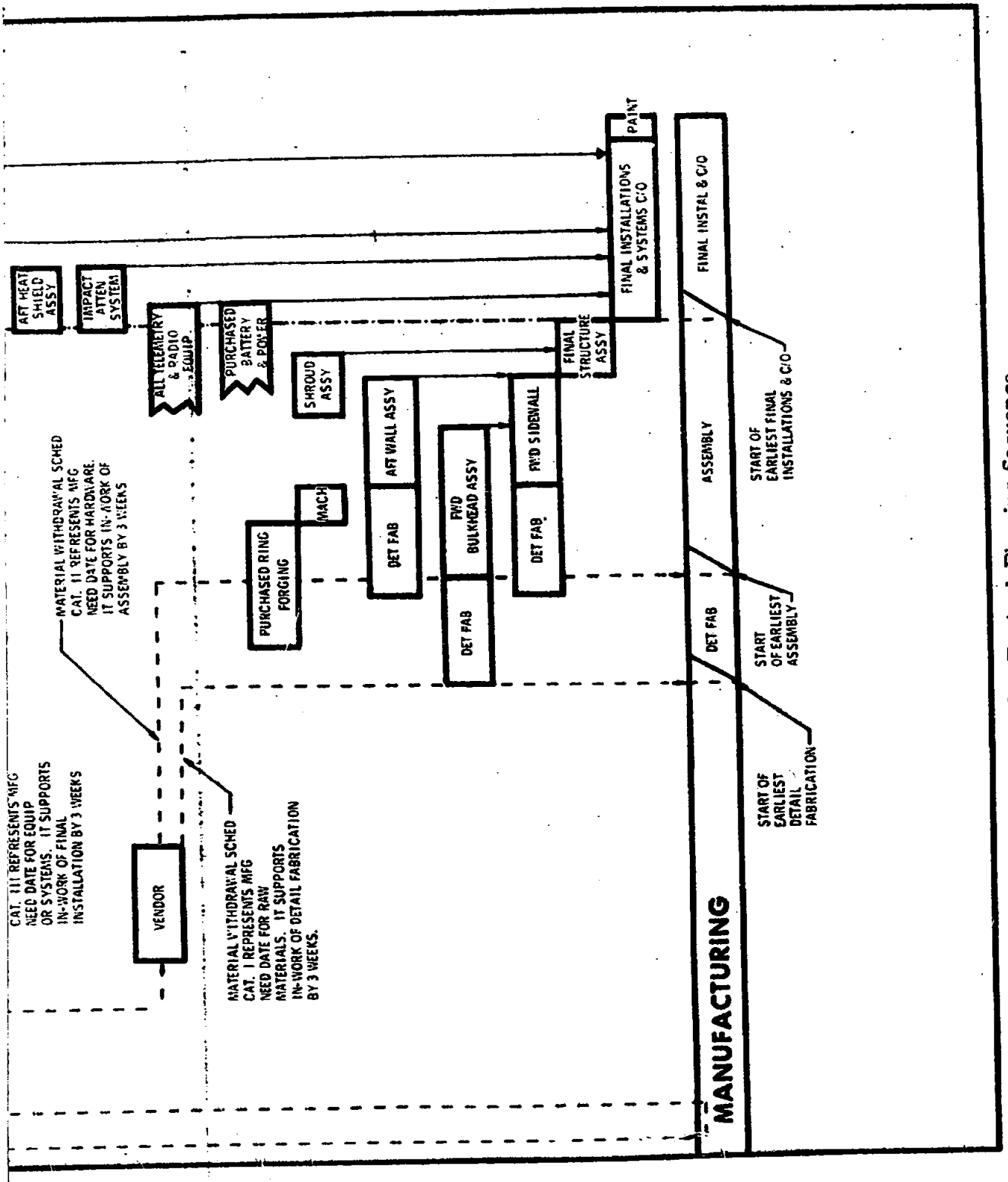
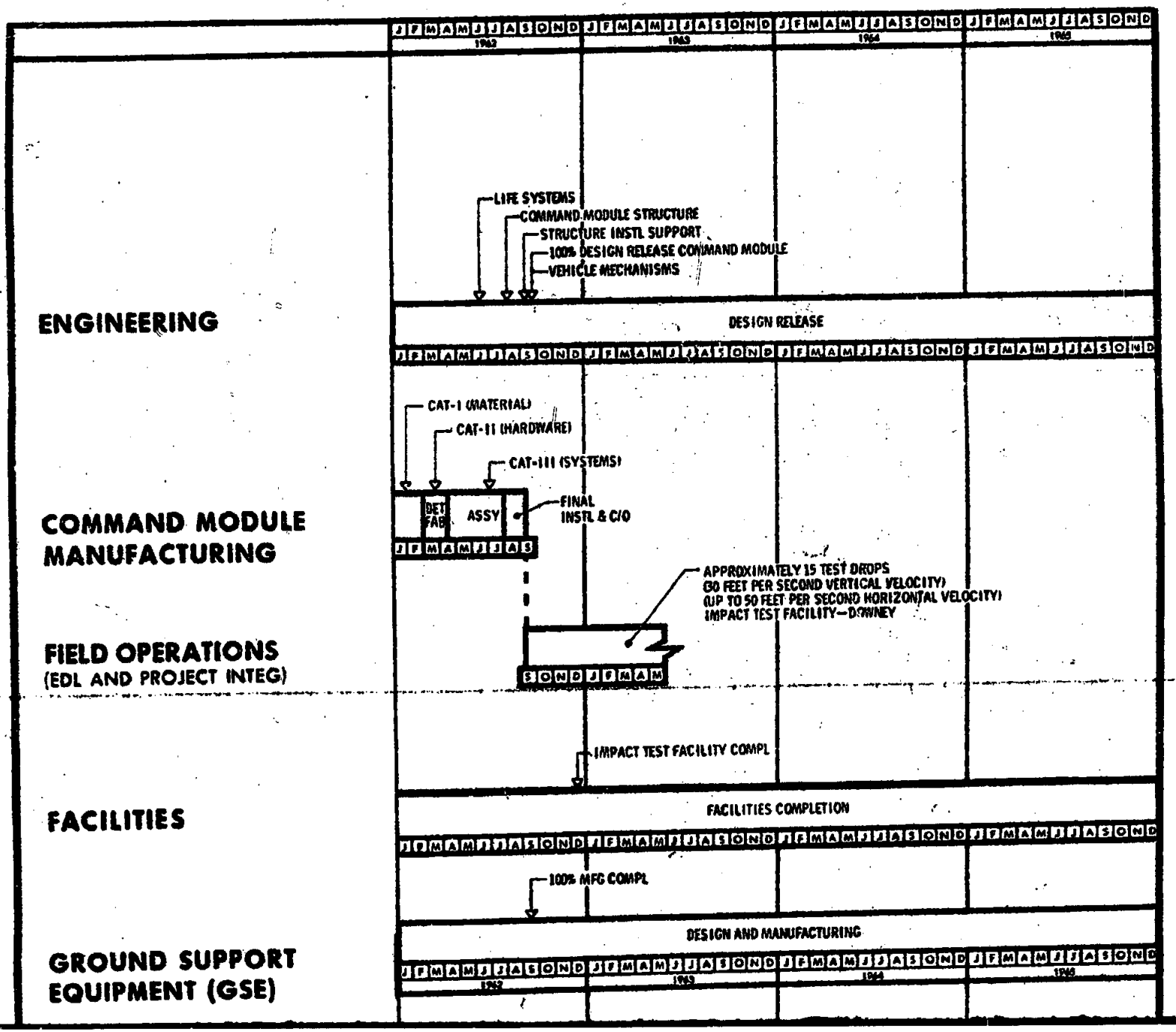
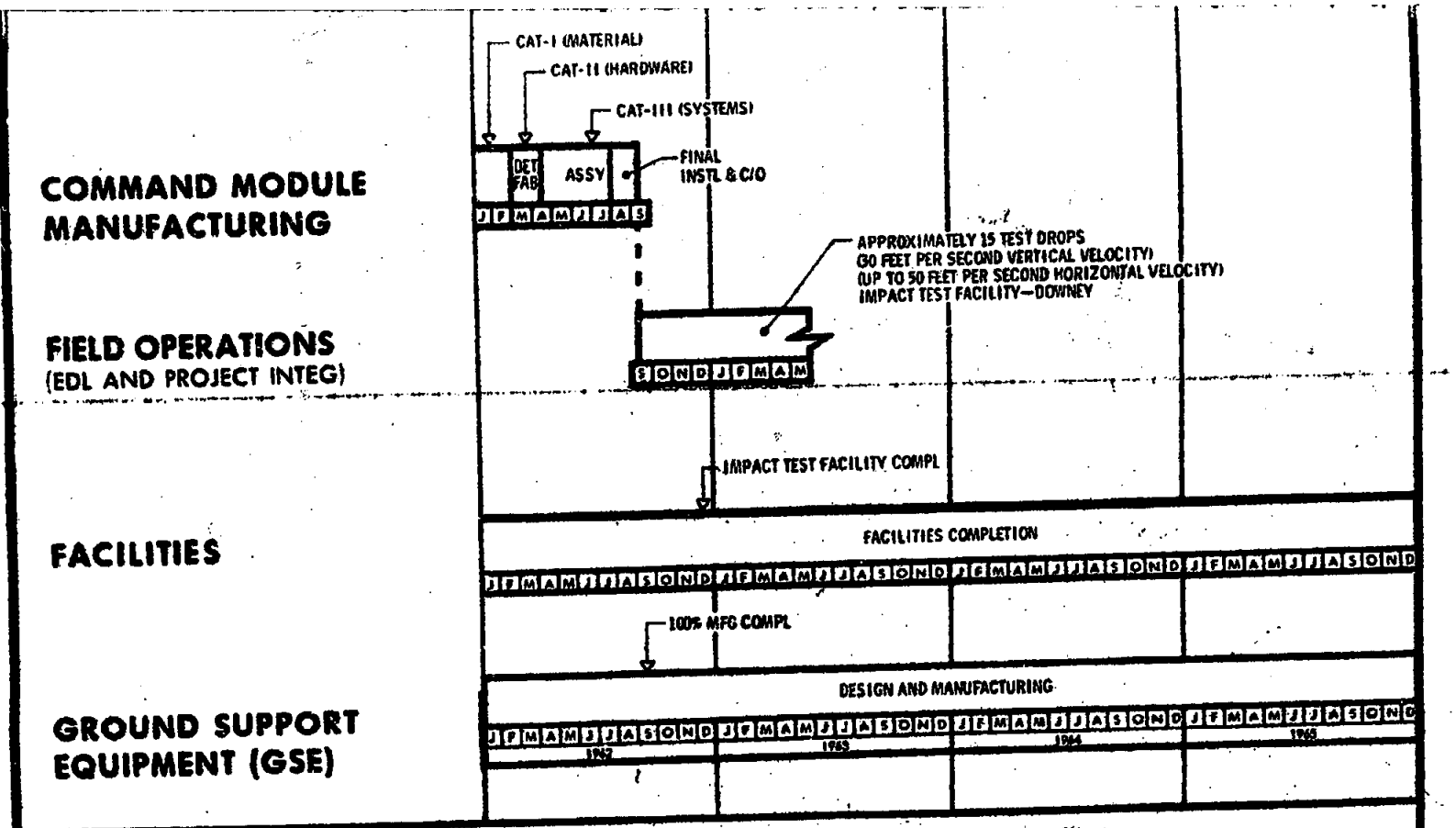


Figure 8. Typical Phasing Sequence



NORTH AMERICAN AVIATION, INC.



DEFINITION:

WILL CONSIST OF A BOILERPLATE COMMAND MODULE SIMULATING SIZE, SHAPE, WEIGHT AND CENTER OF GRAVITY OF THE SPACECRAFT TO EVALUATE AND DEVELOP THE EARTH IMPACT ATTENUATION SYSTEM AND CREW SHOCK ABSORPTION SYSTEMS.

TEST OBJECTIVES:

EVALUATE EARTH IMPACT ATTENUATION SYSTEM AT LAND IMPACT, CREW SHOCK ABSORPTION SYSTEM AT LAND IMPACT, VERTICAL AND TRANSVERSE ACCELERATION LOADS AT LAND IMPACT, 'g' FORCES, DIRECTIONAL AND TIME LIMIT ON ANTHROPOMORPHIC DUMMIES; VERIFY FLOTATION STABILITY.

MISSION:

TO BE USED ON SITE BY NAA/S&ID FOR THE DEVELOPMENT AND EVALUATION OF: (A) THE EARTH IMPACT ATTENUATION SYSTEM DURING LAND AND WATER IMPACTS (B) THE CREW SHOCK ABSORPTION SYSTEM FROM LAND AND WATER IMPACT TO A STABILIZED CONDITION (C) THE STABILITY CHARACTERISTICS OF THE COMMAND MODULE ON LAND AND WATER DURING AND AFTER TOUCHDOWN IMPACT.

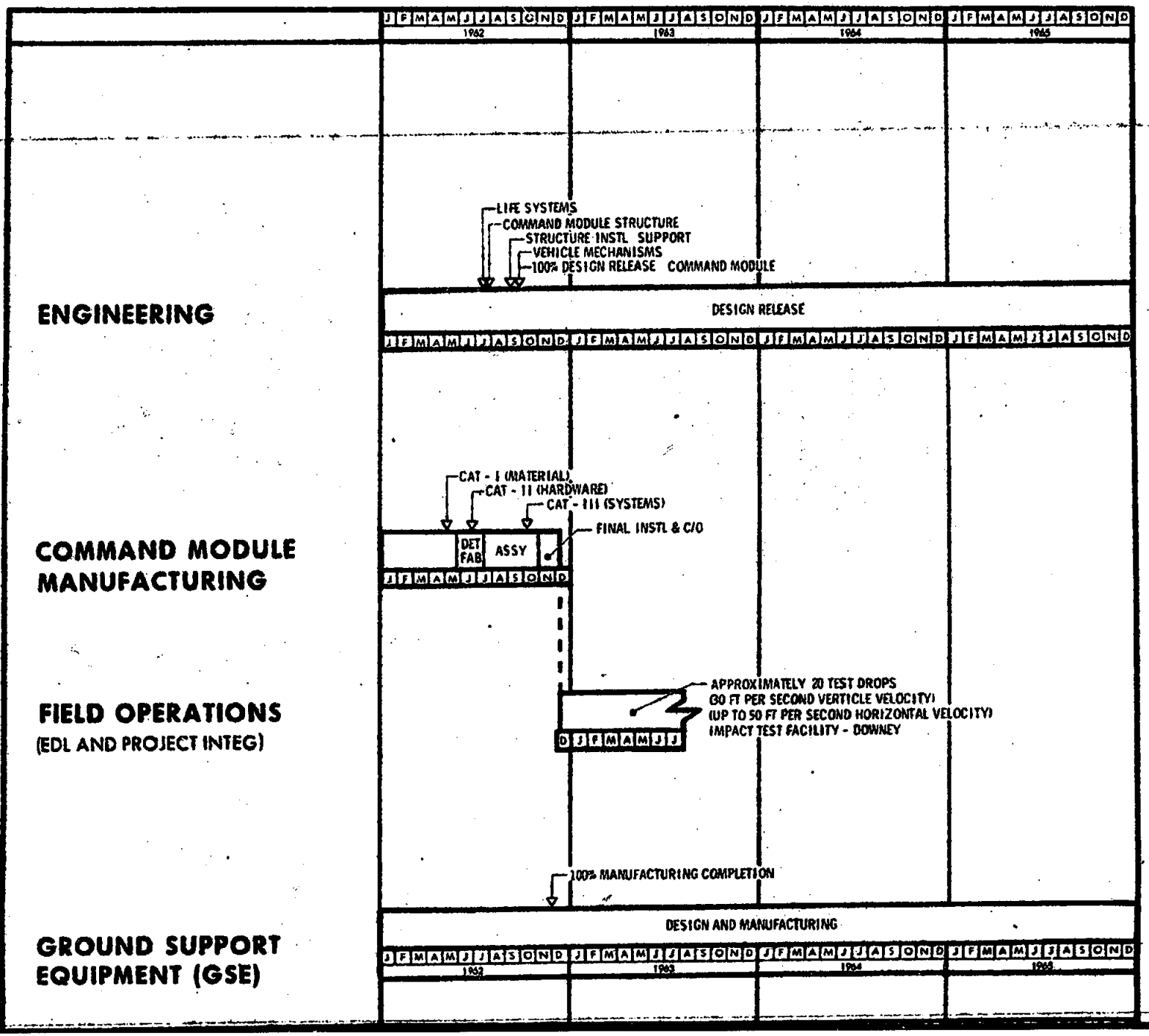
NOTES

1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS TO BE INCLUDED IN SUBSEQUENT REVISIONS.

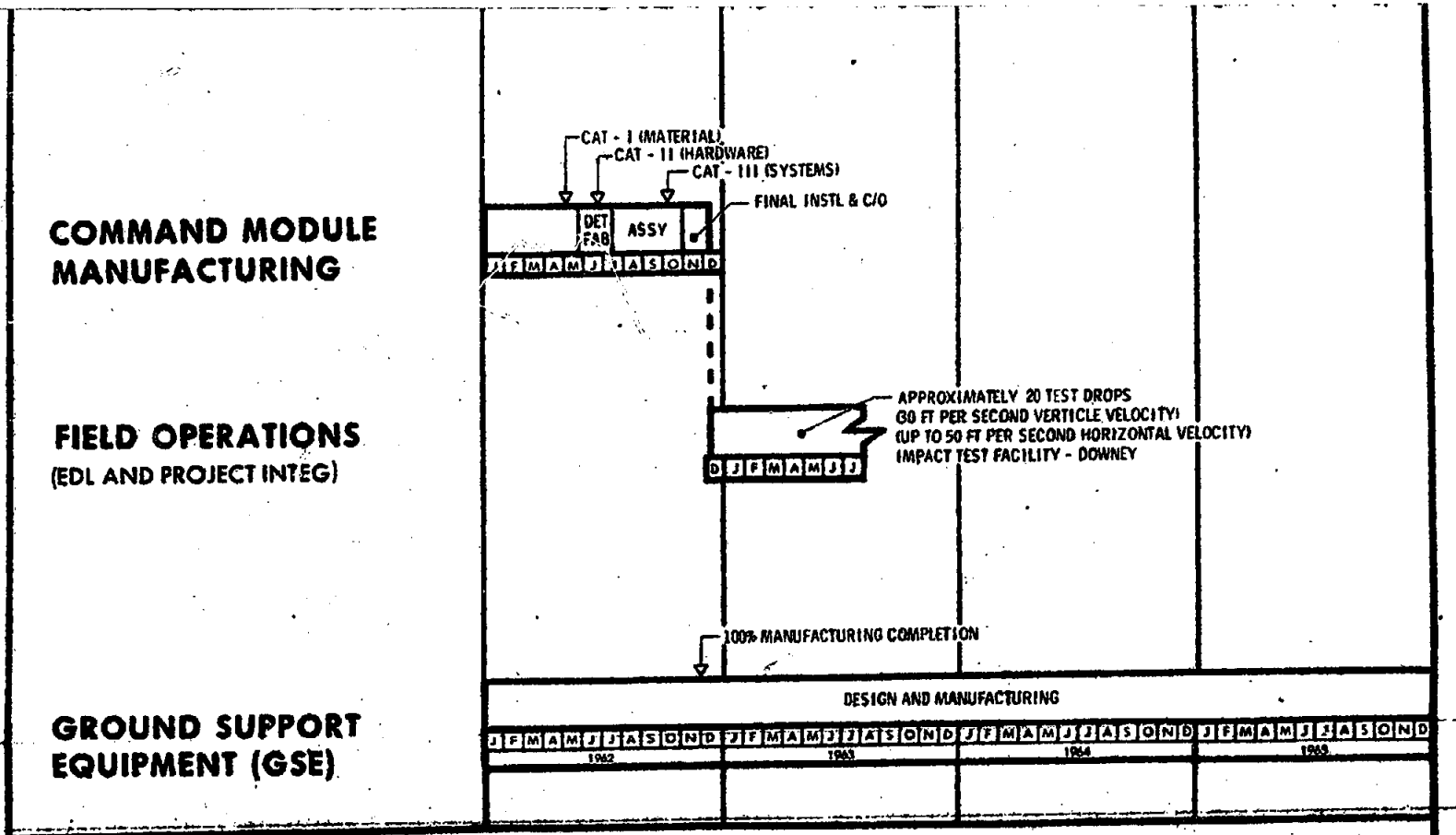
APPROVED BY
APOLLO PROGRAM CONTROL

DATE: 12 OCT 1962

Figure 9. Boilerplate 1 Command Module for Land and Water Impact



NORTH AMERICAN AVIATION, INC.



DEFINITION:

WILL CONSIST OF A BOILERPLATE COMMAND MODULE SIMULATING SIZE, SHAPE, WEIGHT AND CENTER OF GRAVITY OF THE SPACECRAFT TO EVALUATE AND DEVELOP THE EARTH IMPACT ATTENUATION SYSTEM AND CREW SHOCK ABSORPTION SYSTEMS.

TEST OBJECTIVES:

EVALUATE EARTH IMPACT ATTENUATION SYSTEM AT LAND IMPACT, CREW SHOCK ABSORPTION SYSTEM AT LAND IMPACT, VERTICAL AND TRANSVERSE ACCELERATION LOADS AT LAND IMPACT, "g" FORCES, DIRECTIONAL AND TIME LIMIT ON ANTHROPOMORPHIC DUMMIES; VERIFY FLOTATION STABILITY.

MISSION:

TO BE USED ON SITE BY NAA/S&ID FOR THE DEVELOPMENT AND EVALUATION OF: (A) THE EARTH IMPACT ATTENUATION SYSTEM DURING LAND AND WATER IMPACTS; (B) THE CREW SHOCK ABSORPTION SYSTEM FROM LAND AND WATER IMPACT TO A STABILIZED CONDITION; (C) THE STABILITY CHARACTERISTICS OF THE COMMAND MODULE ON LAND AND WATER DURING AND AFTER TOUCHDOWN IMPACT.

NOTES

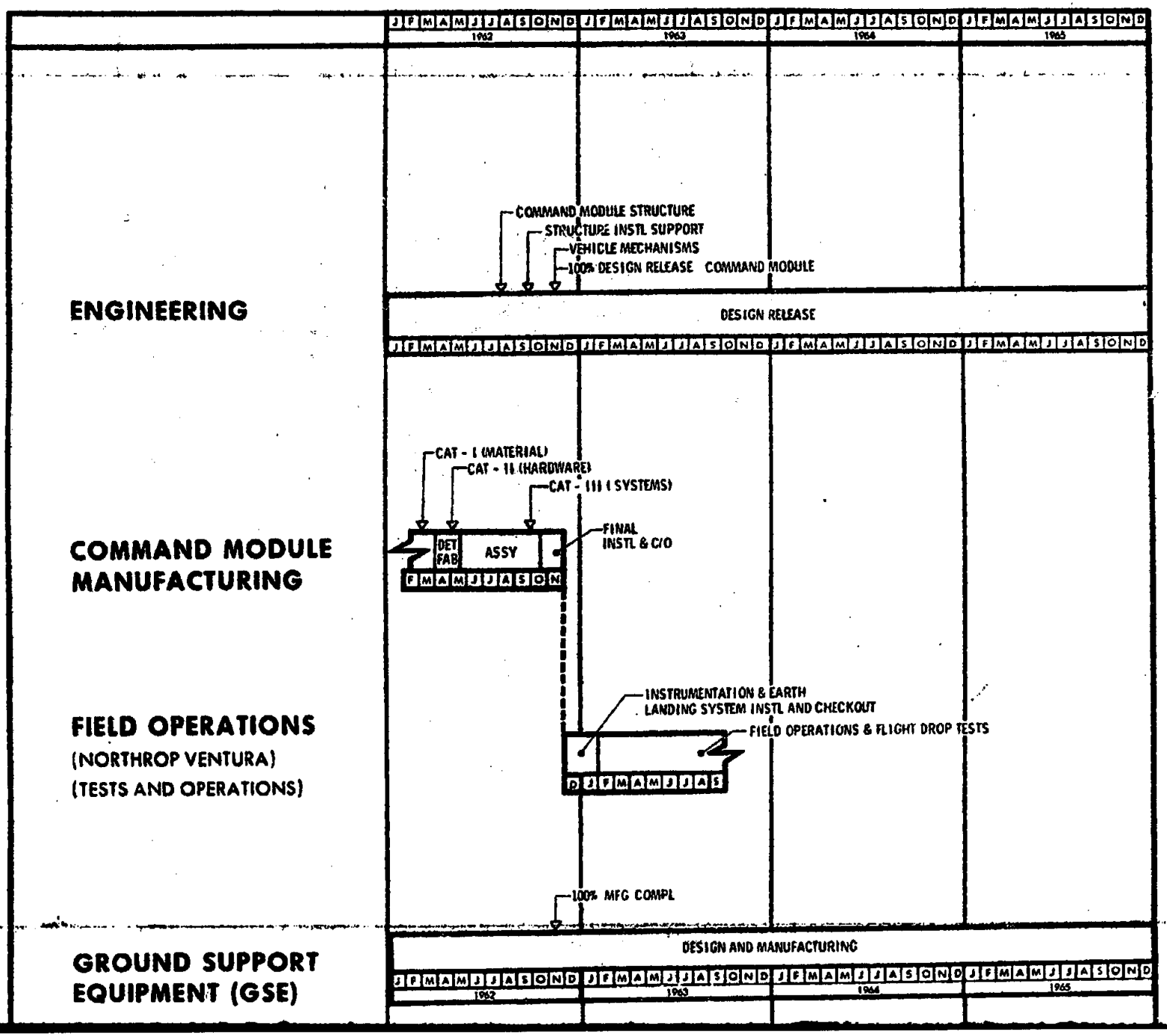
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS TO BE INCLUDED IN SUBSEQUENT REVISIONS.

APPROVED BY
APOLLO PROGRAM CONTROL

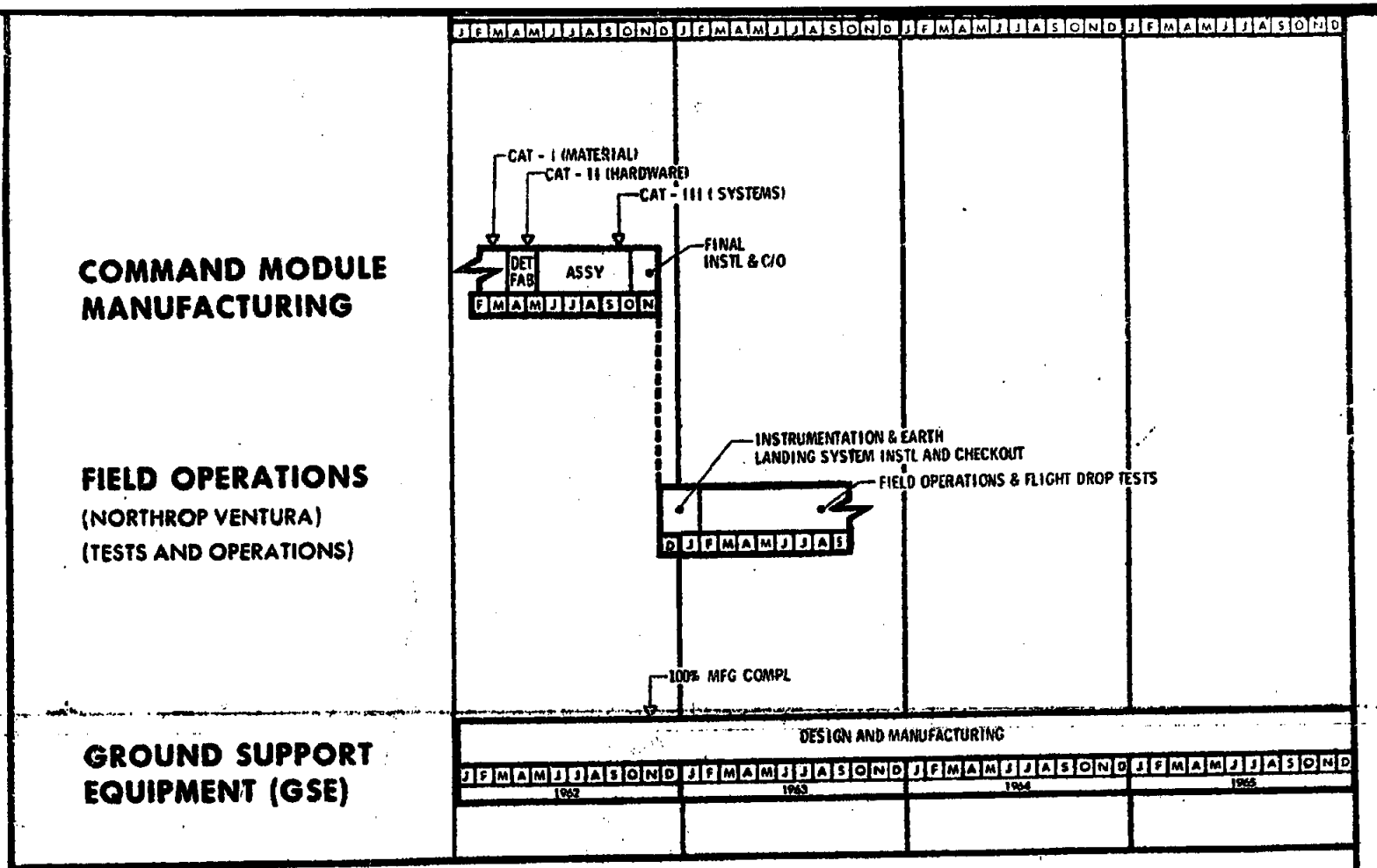
M. Shannon

DATE: 12 OCT 1962

Figure 10. Boilerplate 2 Command Module for Land and Water Impact



NORTH AMERICAN AVIATION, INC.



DEFINITION:

WILL CONSIST OF A BOILERPLATE COMMAND MODULE SIMULATING SIZE, SHAPE, STRUCTURAL SOUNDNESS, MASS AND CENTER OF GRAVITY OF THE SPACECRAFT. SYSTEMS AND INSTRUMENTATION AS REQUIRED FOR TESTS WILL BE INSTALLED.

TEST OBJECTIVES:

TO EVALUATE THE PARACHUTE RECOVERY SYSTEM OPERATION IN THE AIR BY HIGH ALTITUDE FLIGHT DROPS FROM C-133 AIRCRAFT OVER THE EL CENTRO TEST SITE. APPROXIMATELY FIFTEEN (15) HIGH ALTITUDE DROP TESTS WILL BE CONDUCTED.

MISSION:

DEVELOPMENT AND QUALIFICATION TESTING OF THE PARACHUTE RECOVERY SYSTEM.

NOTES

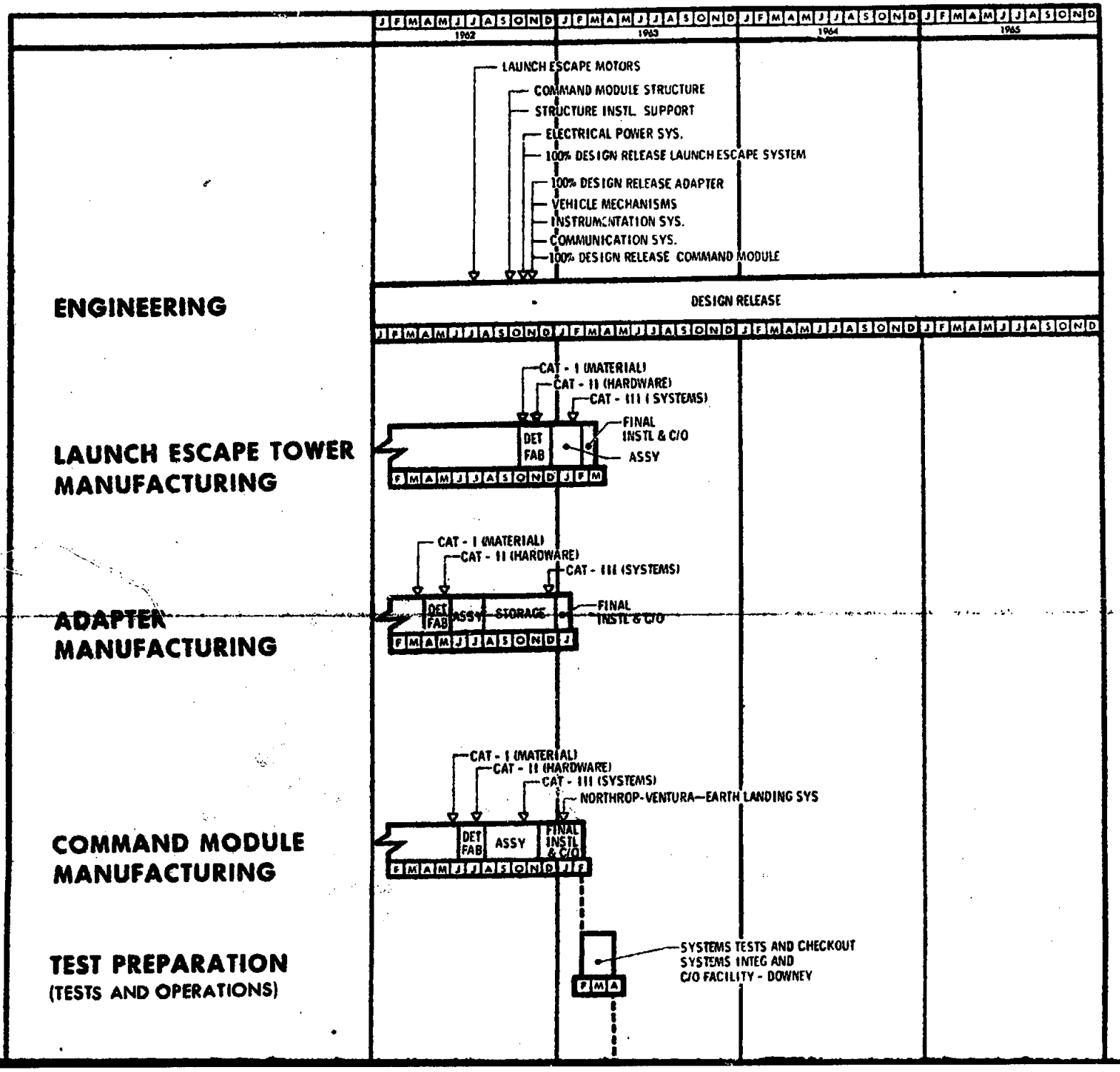
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS TO BE INCLUDED IN SUBSEQUENT REVISIONS.

APPROVED BY
APOLLO PROGRAM CONTROL

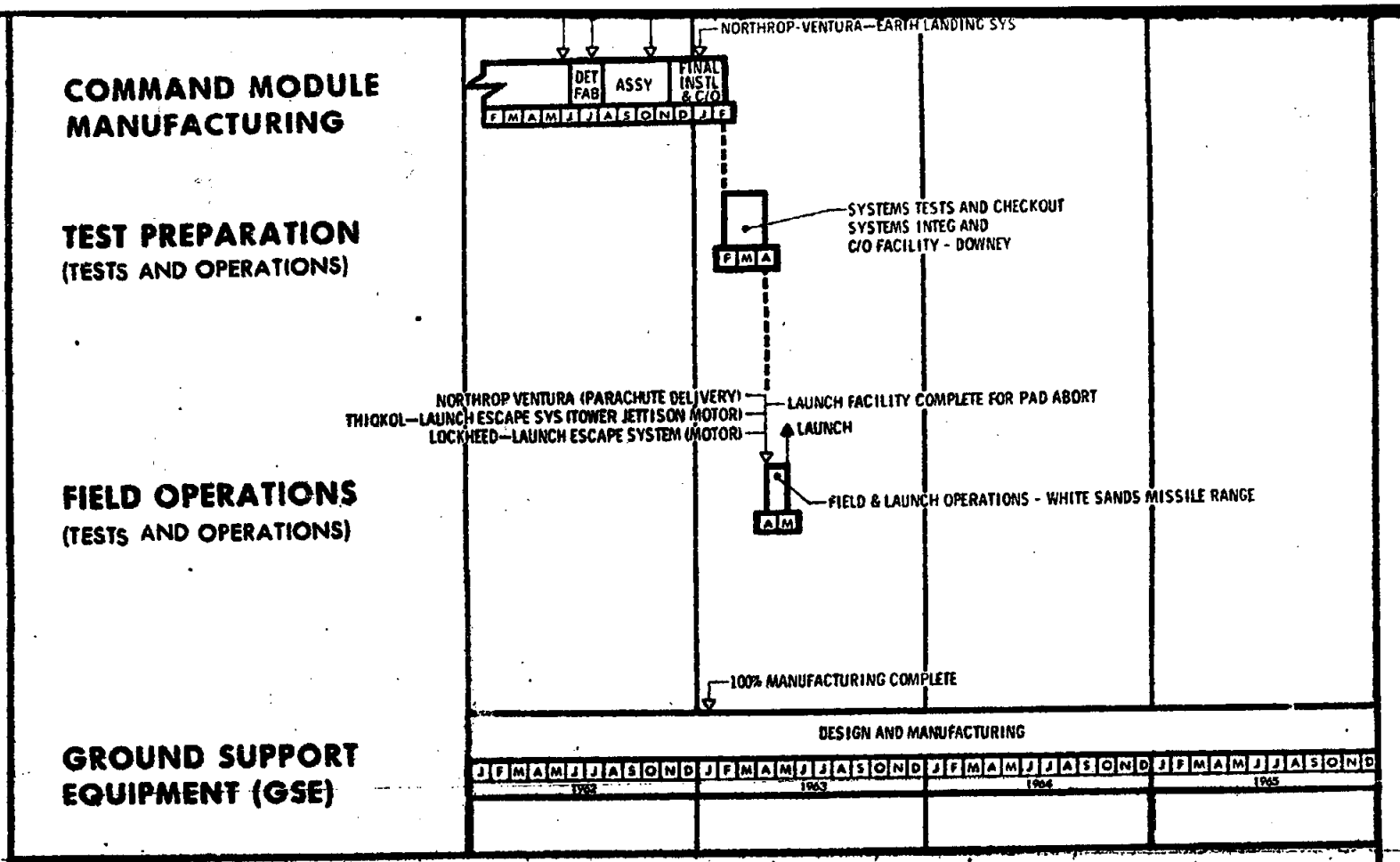
M. Sherman

DATE: 12 OCT 1962

Figure 11. Boilerplate 3 Command Module for Parachute Recovery


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
LAUNCH ESCAPE MOTORS
COMMAND MODULE STRUCTURE
STRUCTURE INSTL. SUPPORT
ELECTRICAL POWER SYS.
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
100% DESIGN RELEASE ADAPTER
VEHICLE MECHANISMS
INSTRUMENTATION SYS.
COMMUNICATION SYS.
100% DESIGN RELEASE COMMAND MODULE
ENGINEERING
DESIGN RELEASE
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
FINAL INSTL & C/O
ASSY
LAUNCH ESCAPE TOWER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
ASSY
STORAGE
FINAL INSTL & C/O
ADAPTER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
NORTHROP-VENTURA—EARTH LANDING SYS
DET FAB
ASSY
FINAL INSTL & C/O
COMMAND MODULE MANUFACTURING
SYSTEMS TESTS AND CHECKOUT
SYSTEMS INTEG AND
C/O FACILITY - DOWNEY
TEST PREPARATION
(TESTS AND OPERATIONS)

NORTH



DEFINITION:

CONSISTS OF A COMMAND MODULE (BOILERPLATE WITH SIMULATED AFT HEAT SHIELD WITH NO ABLATIVE MATERIAL); A GROUND ADAPTER FOR THE COMMAND MODULE WHICH INCLUDES SEPARATION SYSTEM FROM SERVICE MODULE TO COMMAND MODULE; A LAUNCH ESCAPE TOWER (SPACECRAFT STRUCTURE) WITH LIVE JETTISON AND LAUNCH ESCAPE MOTORS.

TEST OBJECTIVES:

TO EVALUATE AND QUALIFY THE LAUNCH ESCAPE SYSTEM FOR PAD ABORT; TO EVALUATE THE STABILITY MARGINS, THE LAUNCH ESCAPE TOWER JETTISON DYNAMICS, LAUNCH ESCAPE CONTROL SYSTEM OPERATION, STRUCTURAL INTEGRITY OF LAUNCH ESCAPE TOWER; TO DEMONSTRATE RECOVERY SYSTEM FROM PAD ABORT; TO DETERMINE THE JET EFFECTS ON THE COMMAND MODULE.

MISSION:

EARLY QUALIFICATION OF LAUNCH ESCAPE SYSTEM.

NOTES

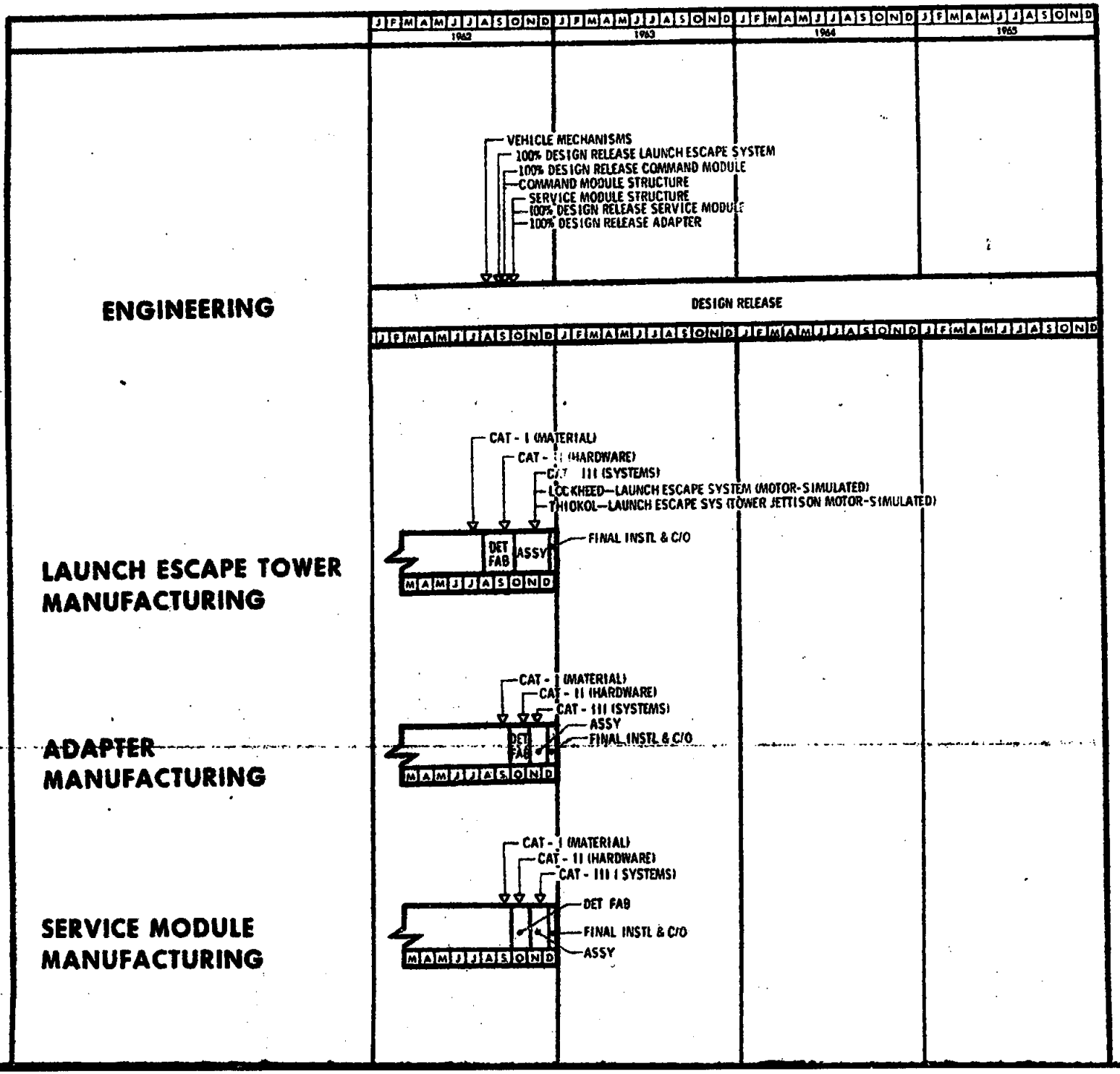
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS TO BE INCLUDED IN SUBSEQUENT REVISIONS.

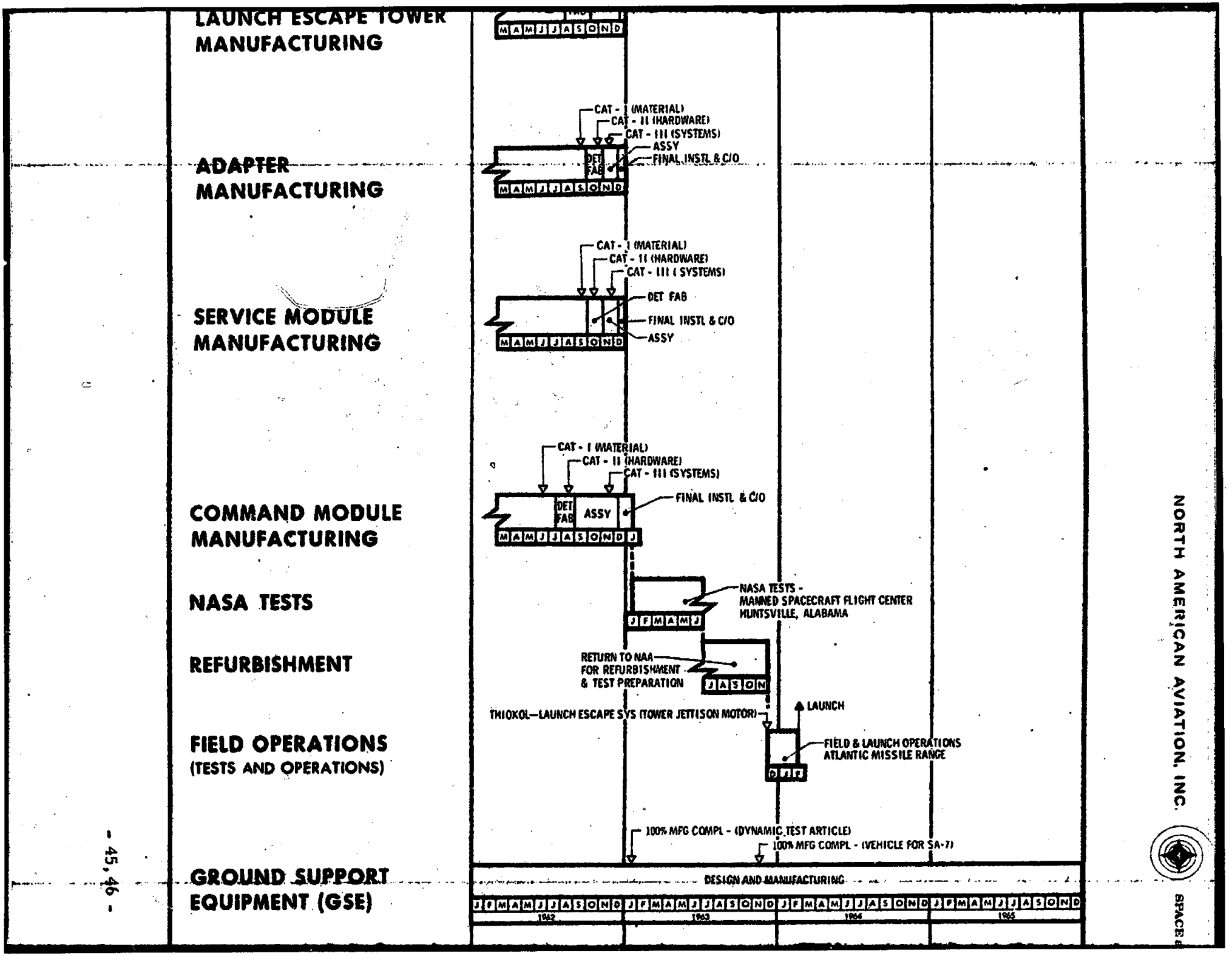
APPROVED BY
APOLLO PROGRAM CONTROL

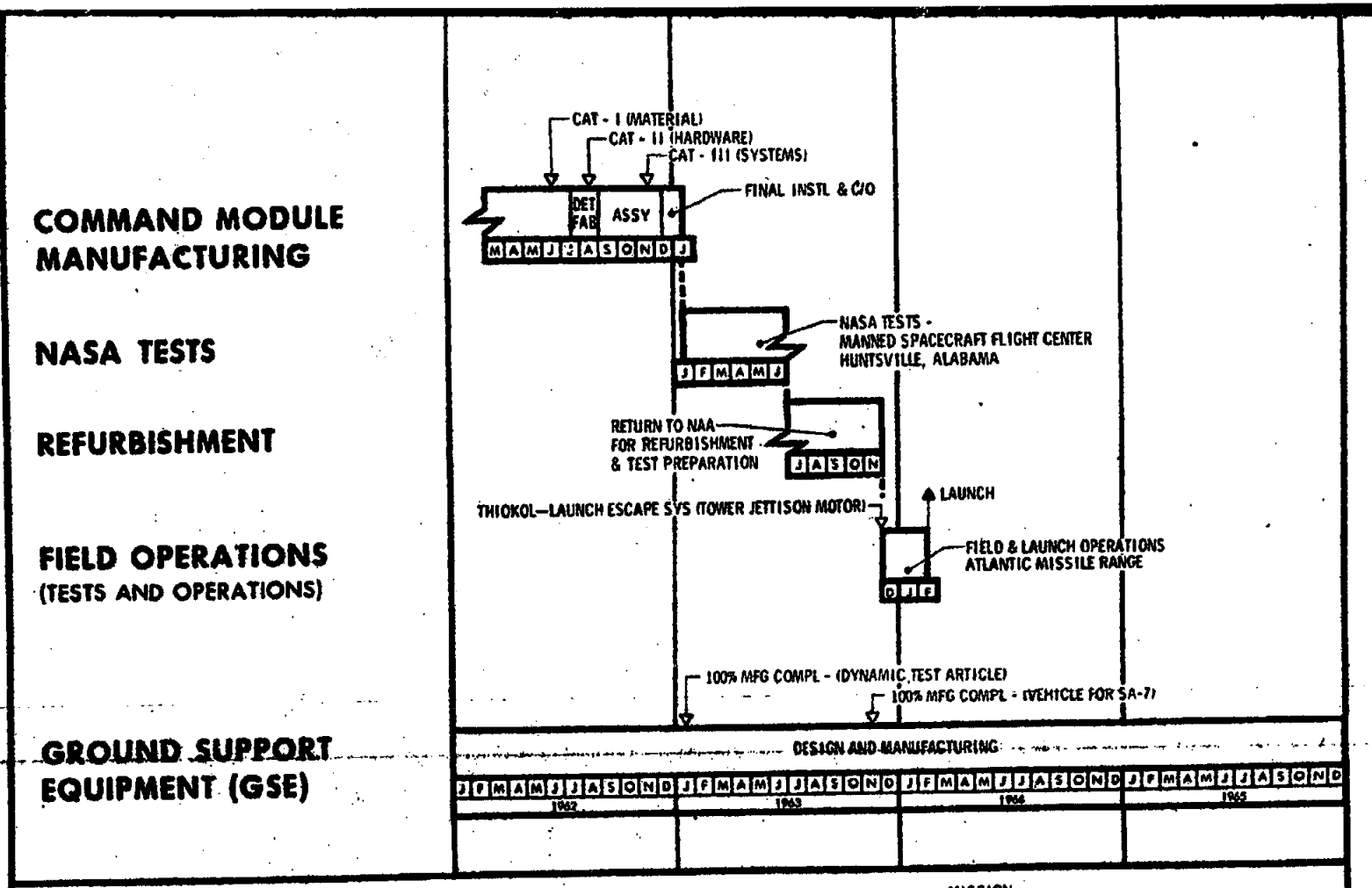
M. Sherman

DATE: 12 OCT 1962

Figure 12. Boilerplate 6 Command Module for Pad Abort


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
ENGINEERING
VEHICLE MECHANISMS
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
100% DESIGN RELEASE COMMAND MODULE
COMMAND MODULE STRUCTURE
SERVICE MODULE STRUCTURE
100% DESIGN RELEASE SERVICE MODULE
100% DESIGN RELEASE ADAPTER
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
LOCKHEED—LAUNCH ESCAPE SYSTEM (MOTOR-SIMULATED)
THIOKOL—LAUNCH ESCAPE SYS (TOWER JETTISON MOTOR-SIMULATED)
DET FAB
ASSY
FINAL INSTL & C/O
M A M J J A S O N D
ADAPTER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
ASSY
FINAL INSTL & C/O
M A M J J A S O N D
SERVICE MODULE MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
FINAL INSTL & C/O
ASSY
M A M J J A S O N D


LAUNCH ESCAPE TOWER MANUFACTURING
ADAPTER MANUFACTURING
SERVICE MODULE MANUFACTURING
COMMAND MODULE MANUFACTURING
NASA TESTS
REFURBISHMENT
FIELD OPERATIONS (TESTS AND OPERATIONS)
GROUND SUPPORT EQUIPMENT (GSE)
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
ASSY
FINAL INSTL & C/O
DET FAB
NASA TESTS - MANNED SPACECRAFT FLIGHT CENTER HUNTSVILLE, ALABAMA
RETURN TO NAA FOR REFURBISHMENT & TEST PREPARATION
THIOKOL—LAUNCH ESCAPE SYS (TOWER JETTISON MOTOR)
LAUNCH
FIELD & LAUNCH OPERATIONS ATLANTIC MISSILE RANGE
100% MFG COMPL - (DYNAMIC TEST ARTICLE)
100% MFG COMPL - (VEHICLE FOR SA-7)
DESIGN AND MANUFACTURING
1962
1963
1964
1965
NORTH AMERICAN AVIATION, INC.
SPACE



DEFINITION:

THE DYNAMIC TEST ARTICLE WILL CONSIST OF A BOILERPLATE COMMAND MODULE AND SERVICE MODULE, ADAPTER, AND LAUNCH ESCAPE TOWER FOR INCORPORATION OF DYNAMIC TESTS TO BE PERFORMED AT MANNED SPACECRAFT FLIGHT CENTER WITH A LAUNCH VEHICLE.

TEST OBJECTIVES:

PRIMARY TEST OBJECTIVES WILL BE DETERMINED BY NASA. THE SECONDARY TEST OBJECTIVE WILL BE TO DEMONSTRATE COMPATIBILITY OF SPACECRAFT AND BOOSTER.

MISSION:

DETERMINATION OF DYNAMIC STRUCTURAL COMPATIBILITY WITH A LAUNCH VEHICLE AND OBTAIN ORBIT OF THE COMMAND AND SERVICE MODULES.

NOTES

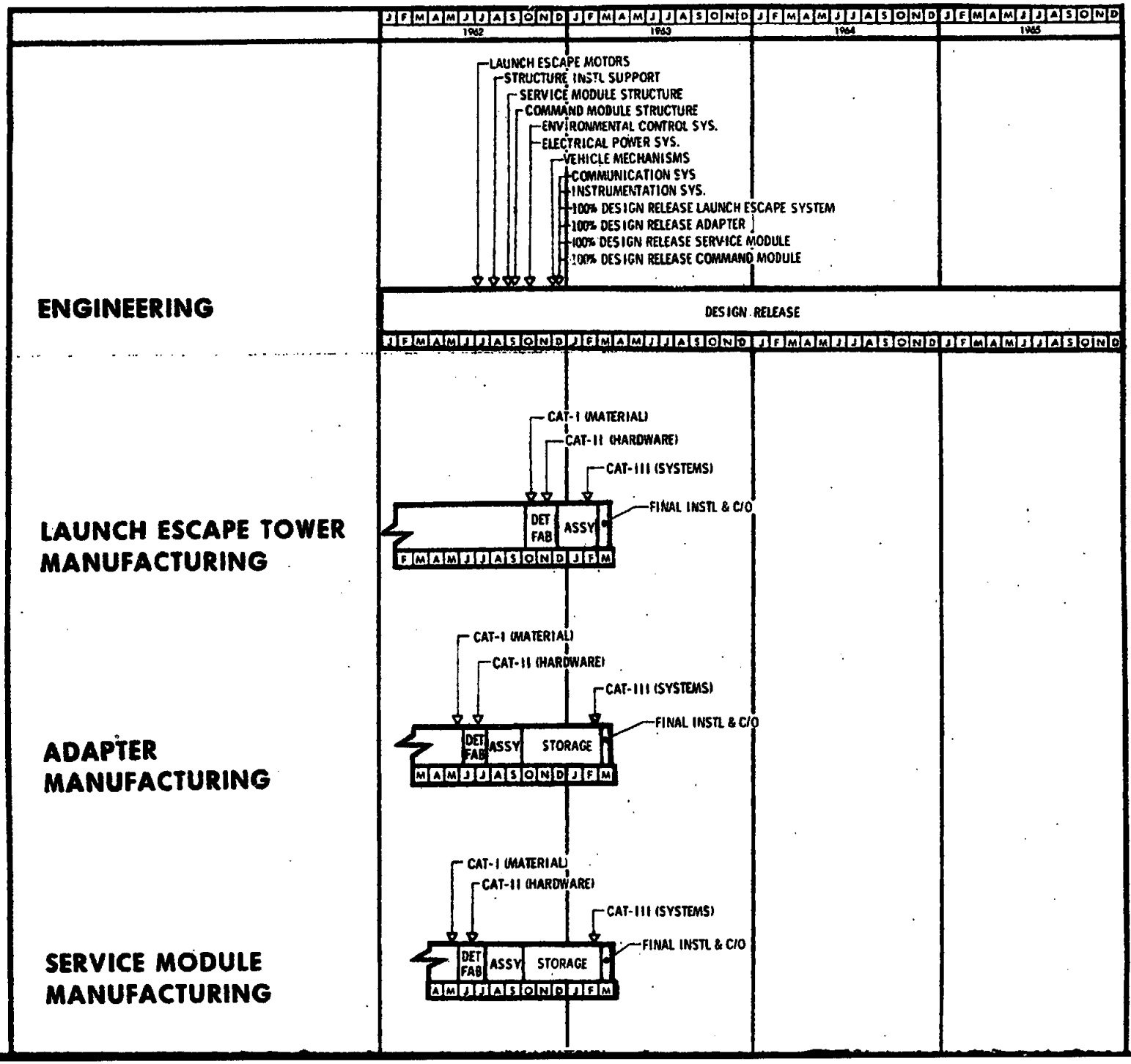
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS AND AMR LAUNCH SITE COMPLETION TO BE INCLUDED IN SUBSEQUENT REVISIONS.

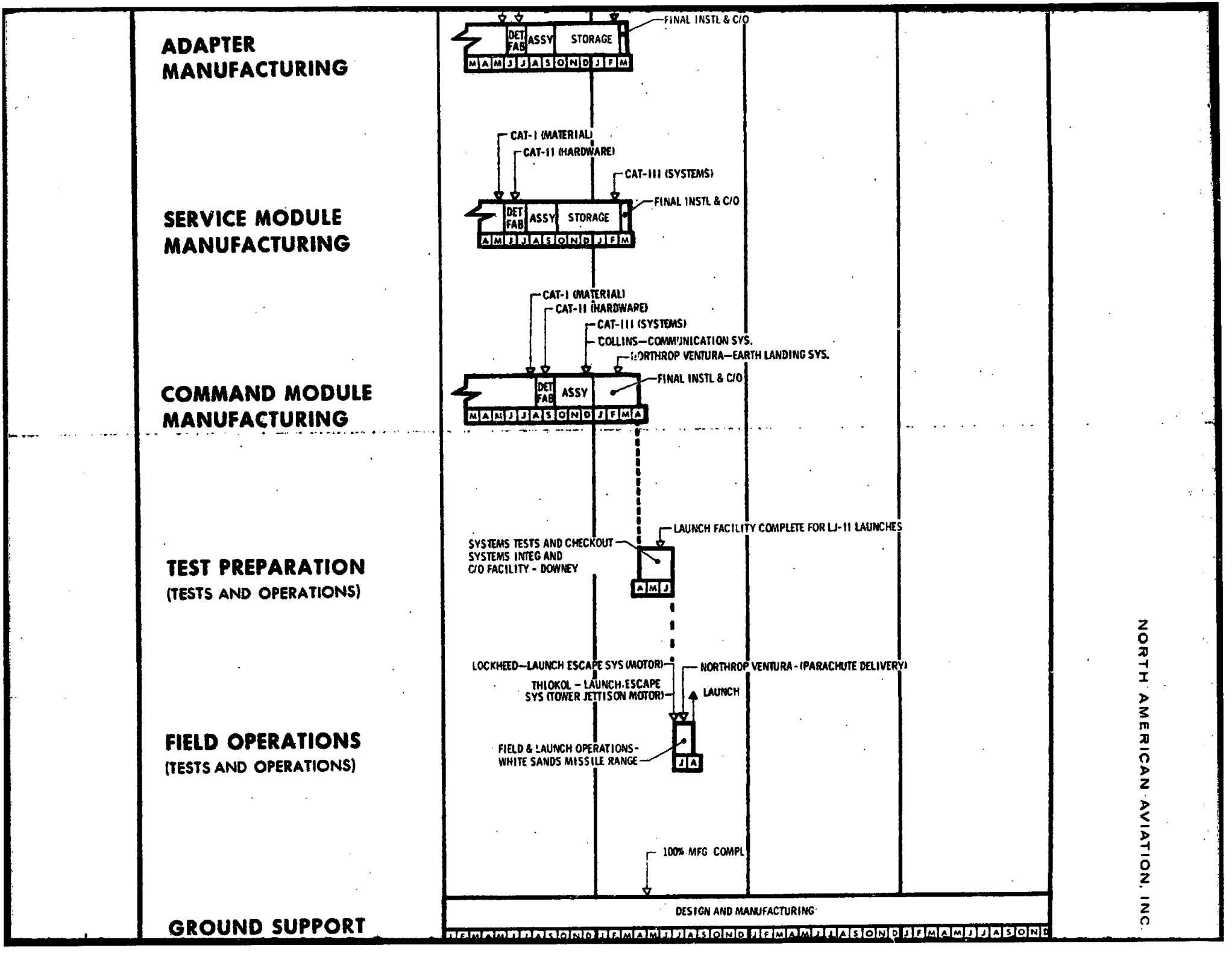
APPROVED BY
APOLLO PROGRAM CONTROL

M. Shuman

DATE: 12 OCT 1962

Figure 13. Boilerplate 9 Spacecraft for Dynamic Tests and Vehicle (SA-7)


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
LAUNCH ESCAPE MOTORS
STRUCTURE INSTL SUPPORT
SERVICE MODULE STRUCTURE
COMMAND MODULE STRUCTURE
ENVIRONMENTAL CONTROL SYS.
ELECTRICAL POWER SYS.
VEHICLE MECHANISMS
COMMUNICATION SYS
INSTRUMENTATION SYS.
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
100% DESIGN RELEASE ADAPTER
100% DESIGN RELEASE SERVICE MODULE
100% DESIGN RELEASE COMMAND MODULE
ENGINEERING
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT-I (MATERIAL)
CAT-II (HARDWARE)
CAT-III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
ADAPTER MANUFACTURING
CAT-I (MATERIAL)
CAT-II (HARDWARE)
CAT-III (SYSTEMS)
DET FAB
ASSY
STORAGE
FINAL INSTL & C/O
SERVICE MODULE MANUFACTURING
CAT-I (MATERIAL)
CAT-II (HARDWARE)
CAT-III (SYSTEMS)
DET FAB
ASSY
STORAGE
FINAL INSTL & C/O


ADAPTER MANUFACTURING
DET FAB
ASSY
STORAGE
FINAL INSTL & C/O
M A M J J A S O N D J F M
SERVICE MODULE MANUFACTURING
CAT-I (MATERIAL)
CAT-II (HARDWARE)
CAT-III (SYSTEMS)
DET FAB
ASSY
STORAGE
FINAL INSTL & C/O
A M J J A S O N D J F M
COMMAND MODULE MANUFACTURING
CAT-I (MATERIAL)
CAT-II (HARDWARE)
CAT-III (SYSTEMS)
COLLINS—COMMUNICATION SYS.
NORTHROP VENTURA—EARTH LANDING SYS.
DET FAB
ASSY
FINAL INSTL & C/O
M A M J J A S O N D J F M A
TEST PREPARATION
(TESTS AND OPERATIONS)
LAUNCH FACILITY COMPLETE FOR LJ-11 LAUNCHES
SYSTEMS TESTS AND CHECKOUT
SYSTEMS INTEG AND
C/O FACILITY - DOWNEY
A M J
FIELD OPERATIONS
(TESTS AND OPERATIONS)
LOCKHEED—LAUNCH ESCAPE SYS (MOTOR)
NORTHROP VENTURA - (PARACHUTE DELIVERY)
THIOKOL - LAUNCH ESCAPE
SYS (TOWER JETTISON MOTOR)
LAUNCH
FIELD & LAUNCH OPERATIONS -
WHITE SANDS MISSILE RANGE
J A
100% MFG COMPL
GROUND SUPPORT
DESIGN AND MANUFACTURING
NORTH AMERICAN AVIATION, INC.

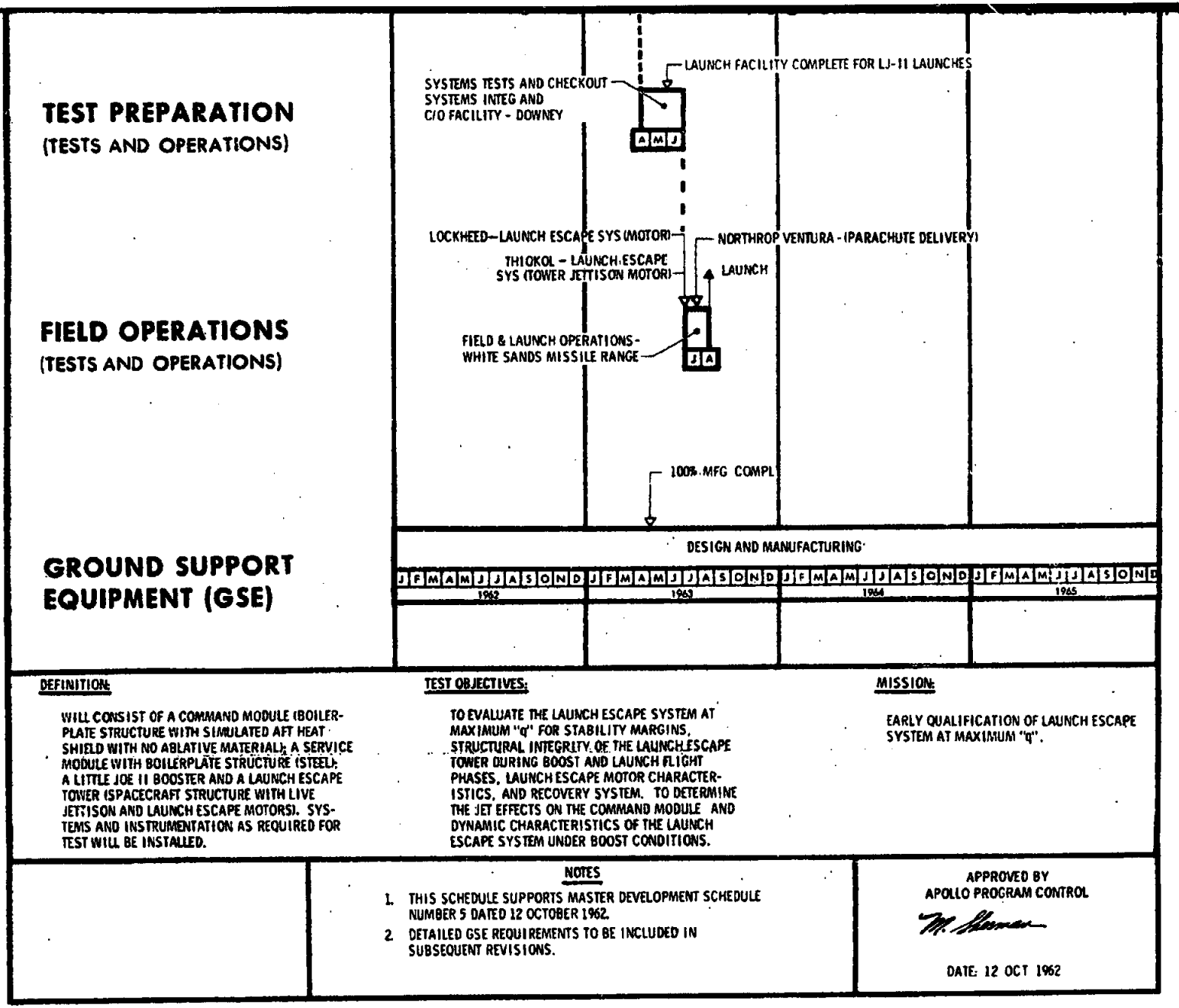
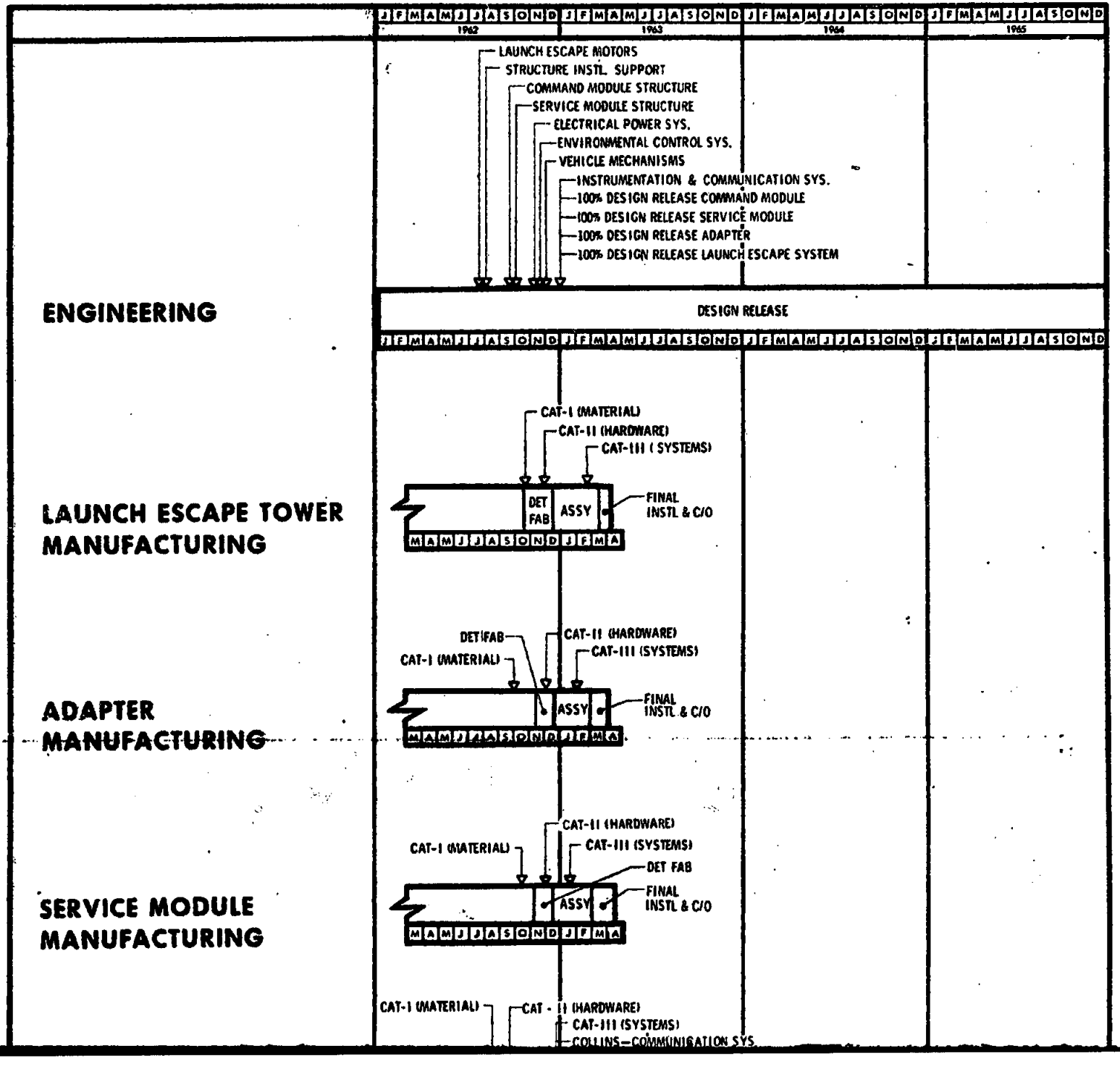
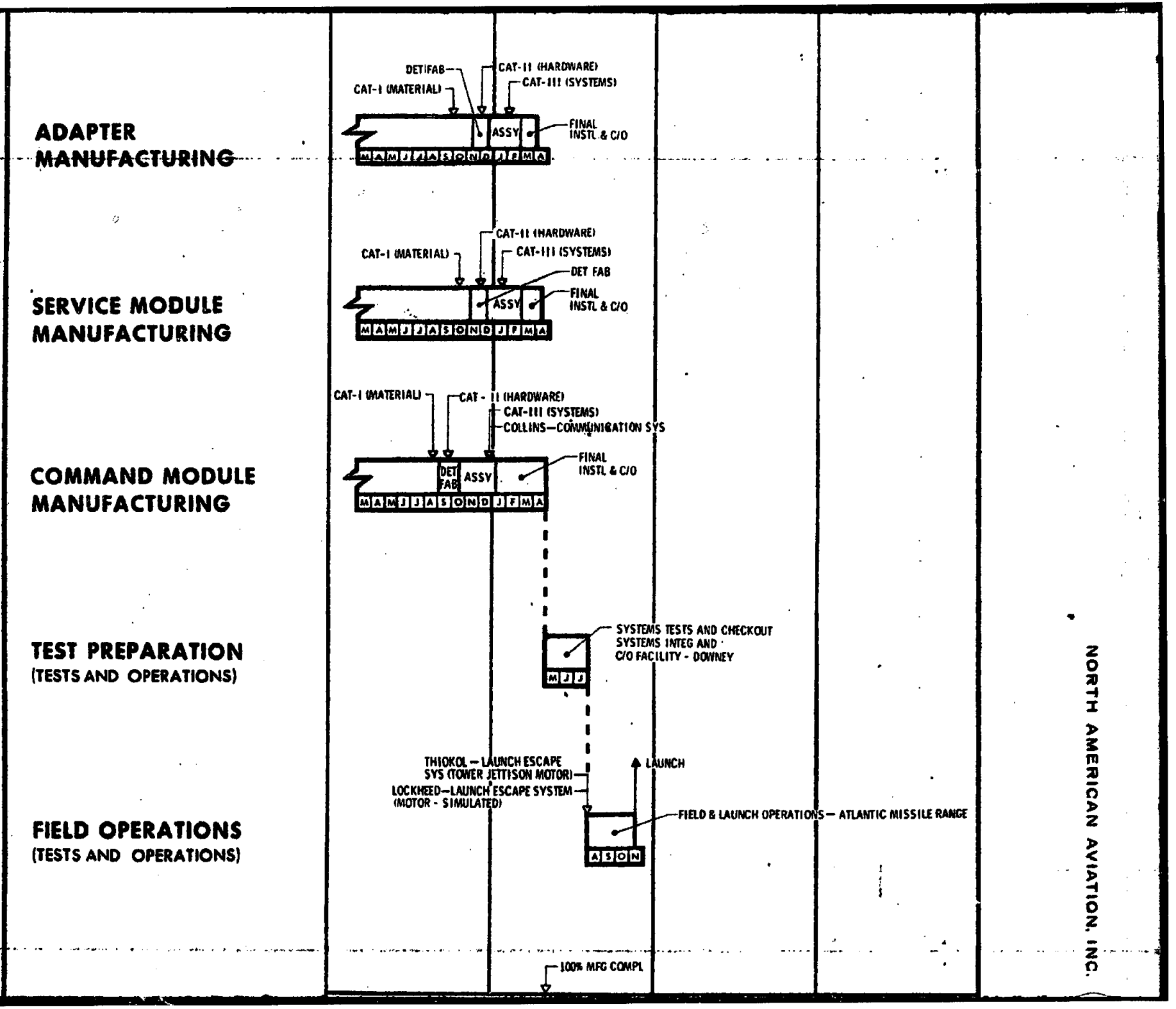


Figure 14. Boilerplate 12 Command Module for Maximum q Launch Escape System Verification (Little Joe II)


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
LAUNCH ESCAPE MOTORS
STRUCTURE INSTL. SUPPORT
COMMAND MODULE STRUCTURE
SERVICE MODULE STRUCTURE
ELECTRICAL POWER SYS.
ENVIRONMENTAL CONTROL SYS.
VEHICLE MECHANISMS
INSTRUMENTATION & COMMUNICATION SYS.
100% DESIGN RELEASE COMMAND MODULE
100% DESIGN RELEASE SERVICE MODULE
100% DESIGN RELEASE ADAPTER
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
ENGINEERING
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT-I (MATERIAL)
CAT-II (HARDWARE)
CAT-III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
M A M J J A S O N D J F M A
ADAPTER MANUFACTURING
DET/FAB
CAT-I (MATERIAL)
CAT-II (HARDWARE)
CAT-III (SYSTEMS)
ASSY
FINAL INSTL & C/O
M A M J J A S O N D J F M A
SERVICE MODULE MANUFACTURING
CAT-I (MATERIAL)
CAT-II (HARDWARE)
CAT-III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
M A M J J A S O N D J F M A
CAT-I (MATERIAL)
CAT - II (HARDWARE)
CAT-III (SYSTEMS)
COLLINS—COMMUNICATION SYS.



NORTH AMERICAN AVIATION, INC.

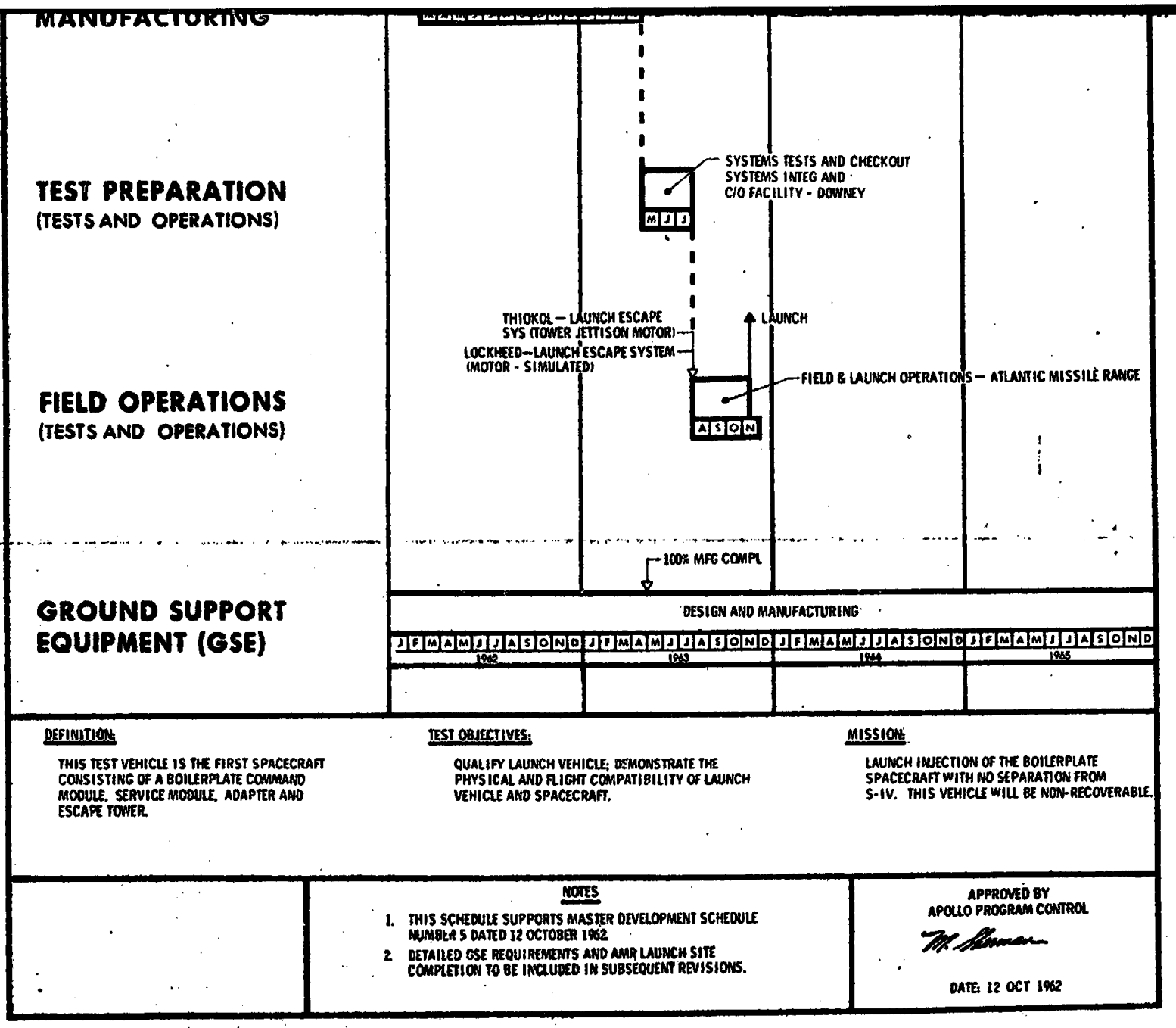
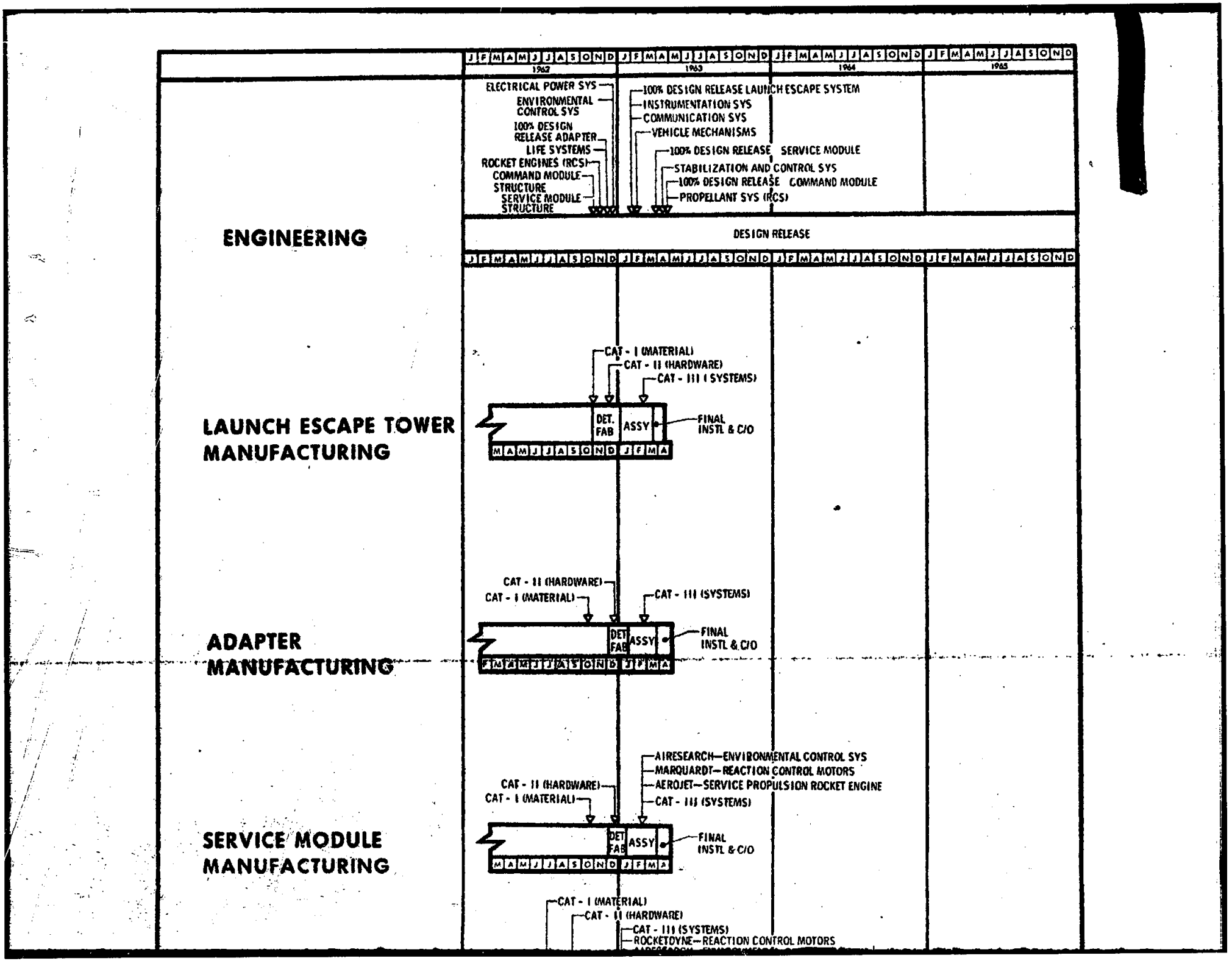
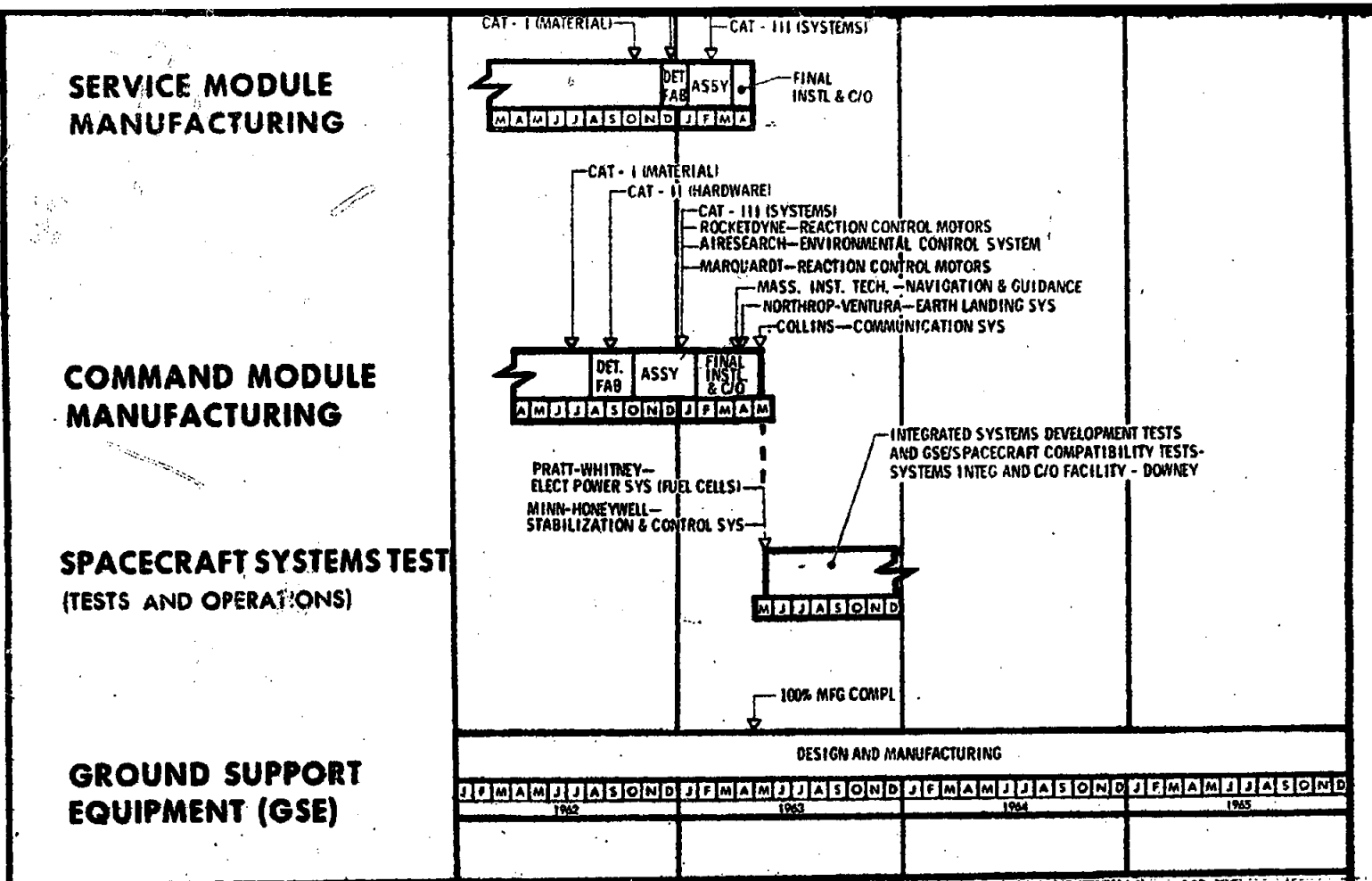


Figure 15. Boilerplate 13 First Spacecraft for Booster Compatibility (SA-6)


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
ELECTRICAL POWER SYS
ENVIRONMENTAL CONTROL SYS
100% DESIGN RELEASE ADAPTER
LIFE SYSTEMS
ROCKET ENGINES (RCS)
COMMAND MODULE STRUCTURE
SERVICE MODULE STRUCTURE
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
INSTRUMENTATION SYS
COMMUNICATION SYS
VEHICLE MECHANISMS
100% DESIGN RELEASE SERVICE MODULE
STABILIZATION AND CONTROL SYS
100% DESIGN RELEASE COMMAND MODULE
PROPELLANT SYS (RCS)
ENGINEERING
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET. FAB
ASSY
FINAL INSTL & C/O
ADAPTER MANUFACTURING
CAT - II (HARDWARE)
CAT - I (MATERIAL)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
SERVICE MODULE MANUFACTURING
AIRESEARCH—ENVIRONMENTAL CONTROL SYS
MARQUARDT—REACTION CONTROL MOTORS
AEROJET—SERVICE PROPULSION ROCKET ENGINE
CAT - II (HARDWARE)
CAT - I (MATERIAL)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
ROCKETDYNE—REACTION CONTROL MOTORS



DEFINITION:

HOUSE SPACECRAFT NO. 1 IS A TEST PLATFORM FOR THE MOUNTING OF PRIMARY SYSTEMS TO EVALUATE SYSTEMS COMPATIBILITY. WILL CONSIST OF A COMMAND MODULE AND A SERVICE MODULE (SKELETAL STRUCTURE FOR MOUNTING SYSTEMS IN THEIR PROPER GEOMETRY WITH REMOVABLE SKIN ON OUTER STRUCTURE); A SPACECRAFT ADAPTER AND A LAUNCH ESCAPE TOWER (SPACECRAFT). COMPLETE SYSTEMS WILL BE REQUIRED, EXCEPT LIVE ROCKET MOTORS.

TEST OBJECTIVES:

DEVELOP PRIMARY SYSTEMS TO PROTOTYPE STATUS; EVALUATE THE INTERACTION OF SYSTEMS, GROUND SUPPORT EQUIPMENT DESIGN AND OPERATION WITH SPACECRAFT; ESTABLISH PRELIMINARY OPERATIONAL PROCEDURES.

MISSION:

A DEVELOPMENTAL TOOL FOR USE IN THE DEVELOPMENT OF SYSTEMS AND A PRELIMINARY CHECK IN INTEGRATED SYSTEMS COMPATIBILITY.

NOTES:

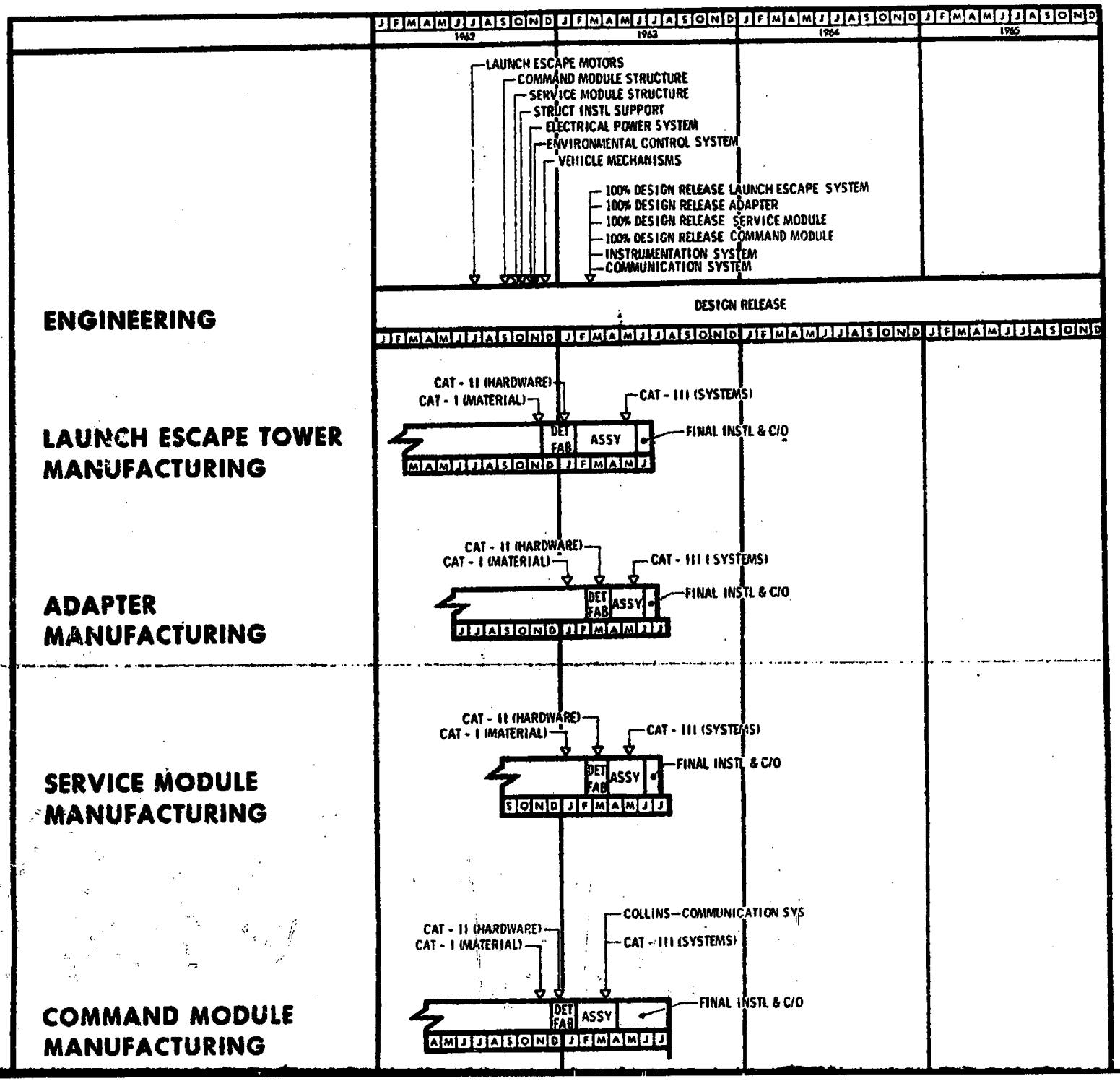
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS TO BE INCLUDED IN SUBSEQUENT REVISIONS.

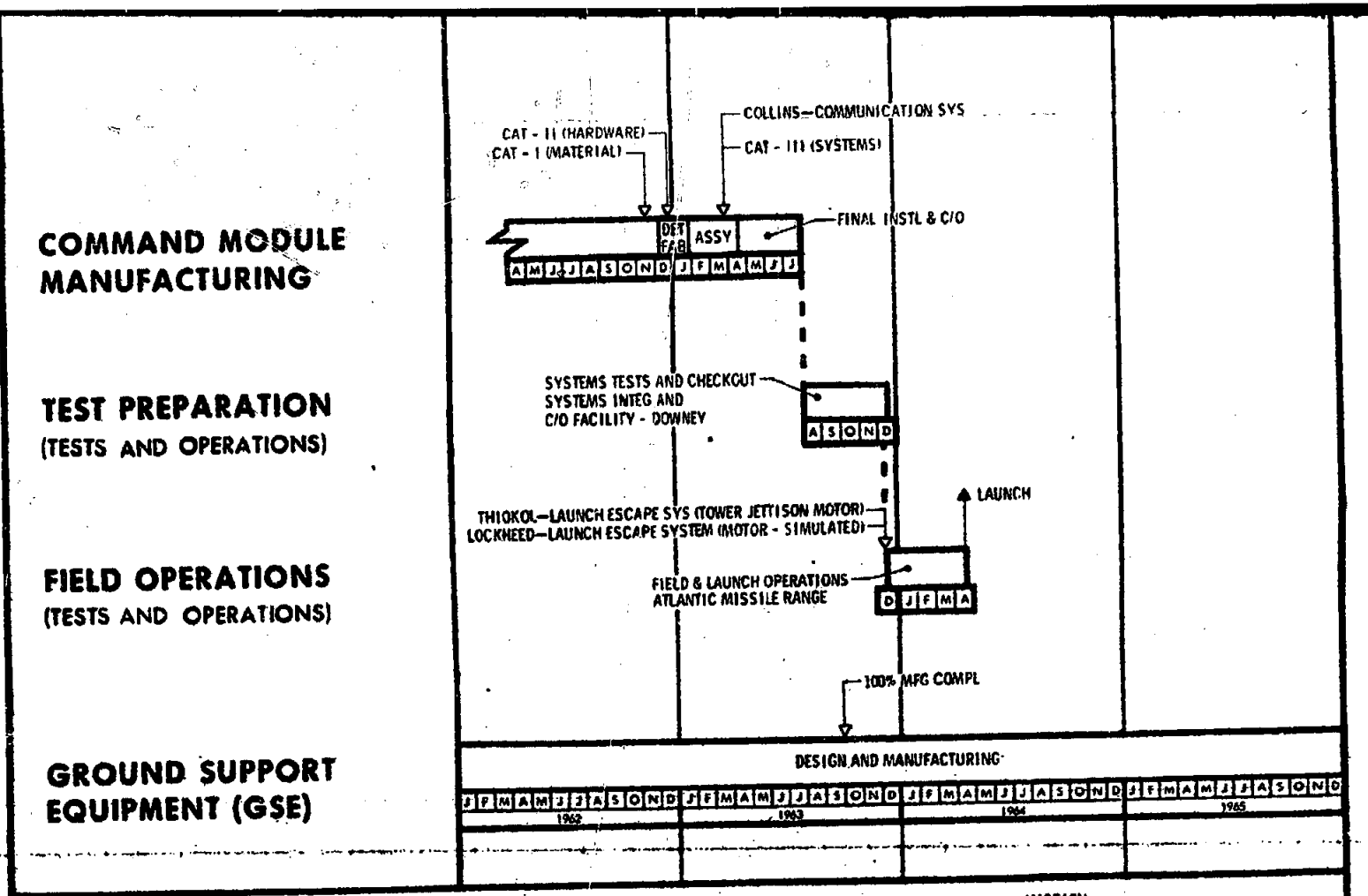
APPROVED BY
APOLLO PROGRAM CONTROL

M. Shuman

DATE: 12 OCT 1962

Figure 16. Boilerplate 14 House Spacecraft No. 1


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
LAUNCH ESCAPE MOTORS
COMMAND MODULE STRUCTURE
SERVICE MODULE STRUCTURE
STRUCT INSTL SUPPORT
ELECTRICAL POWER SYSTEM
ENVIRONMENTAL CONTROL SYSTEM
VEHICLE MECHANISMS
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
100% DESIGN RELEASE ADAPTER
100% DESIGN RELEASE SERVICE MODULE
100% DESIGN RELEASE COMMAND MODULE
INSTRUMENTATION SYSTEM
COMMUNICATION SYSTEM
ENGINEERING
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT - II (HARDWARE)
CAT - I (MATERIAL)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
M A M J J A S O N D J F M A M J
ADAPTER MANUFACTURING
CAT - II (HARDWARE)
CAT - I (MATERIAL)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
J J A S O N D J F M A M J J
SERVICE MODULE MANUFACTURING
CAT - II (HARDWARE)
CAT - I (MATERIAL)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
S O N D J F M A M J J
COMMAND MODULE MANUFACTURING
COLLINS—COMMUNICATION SYS
CAT - II (HARDWARE)
CAT - I (MATERIAL)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
A M J J A S O N D J F M A M J J



DEFINITION:

THIS TEST VEHICLE IS THE THIRD SPACECRAFT CONSISTING OF A BOILERPLATE COMMAND MODULE, SERVICE MODULE, ADAPTER AND ESCAPE TOWER.

TEST OBJECTIVES:

QUALIFY LAUNCH VEHICLE; DEMONSTRATE THE PHYSICAL AND FLIGHT COMPATIBILITY OF LAUNCH VEHICLE AND SPACECRAFT. DEMONSTRATE THE COMPATIBILITY OF THE R&D INSTRUMENTATION WITH THE LAUNCH VEHICLE.

MISSION:

LAUNCH INJECTION OF THE BOILERPLATE SPACECRAFT WITH NO SEPARATION FROM S-IV. THIS VEHICLE WILL BE NON-RECOVERABLE.

NOTES

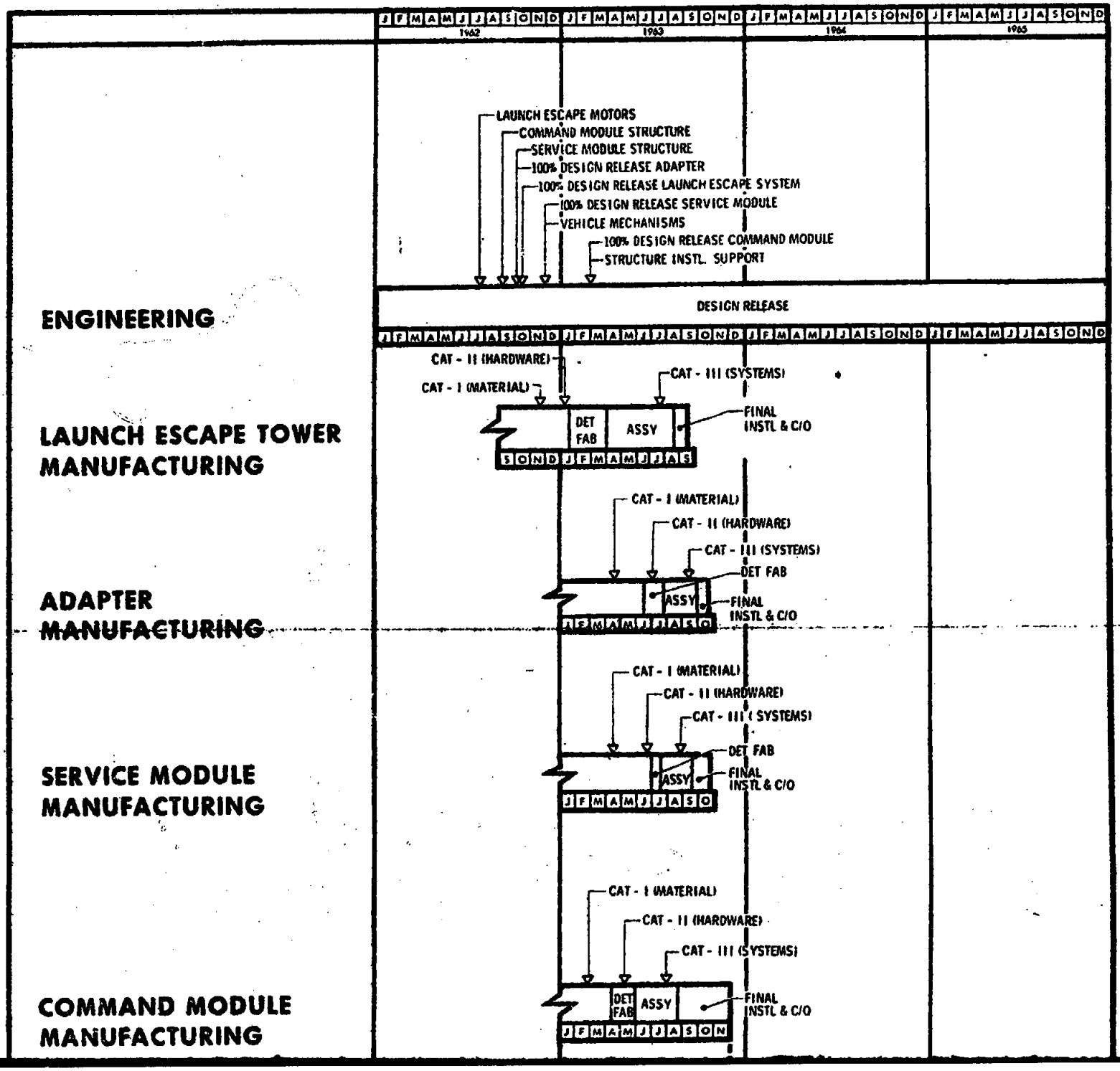
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS AND AMR LAUNCH SITE COMPLETION TO BE INCLUDED IN SUBSEQUENT REVISIONS.

APPROVED BY
APOLLO PROGRAM CONTROL

M. Shannon

DATE: 12 OCT 1962

Figure 17. Boilerplate 15 Dummy Spacecraft (SA-8)


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
LAUNCH ESCAPE MOTORS
COMMAND MODULE STRUCTURE
SERVICE MODULE STRUCTURE
100% DESIGN RELEASE ADAPTER
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
100% DESIGN RELEASE SERVICE MODULE
VEHICLE MECHANISMS
100% DESIGN RELEASE COMMAND MODULE
STRUCTURE INSTL. SUPPORT
ENGINEERING
DESIGN RELEASE
CAT - II (HARDWARE)
CAT - I (MATERIAL)
CAT - III (SYSTEMS)
LAUNCH ESCAPE TOWER MANUFACTURING
DET FAB
ASSY
FINAL INSTL & C/O
S O N D J F M A M J J A S
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
ADAPTER MANUFACTURING
ASSY
FINAL INSTL & C/O
J F M A M J J A S O
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
SERVICE MODULE MANUFACTURING
ASSY
FINAL INSTL & C/O
J F M A M J J A S O
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
COMMAND MODULE MANUFACTURING
DET FAB
ASSY
FINAL INSTL & C/O
J F M A M J J A S O N

NORT

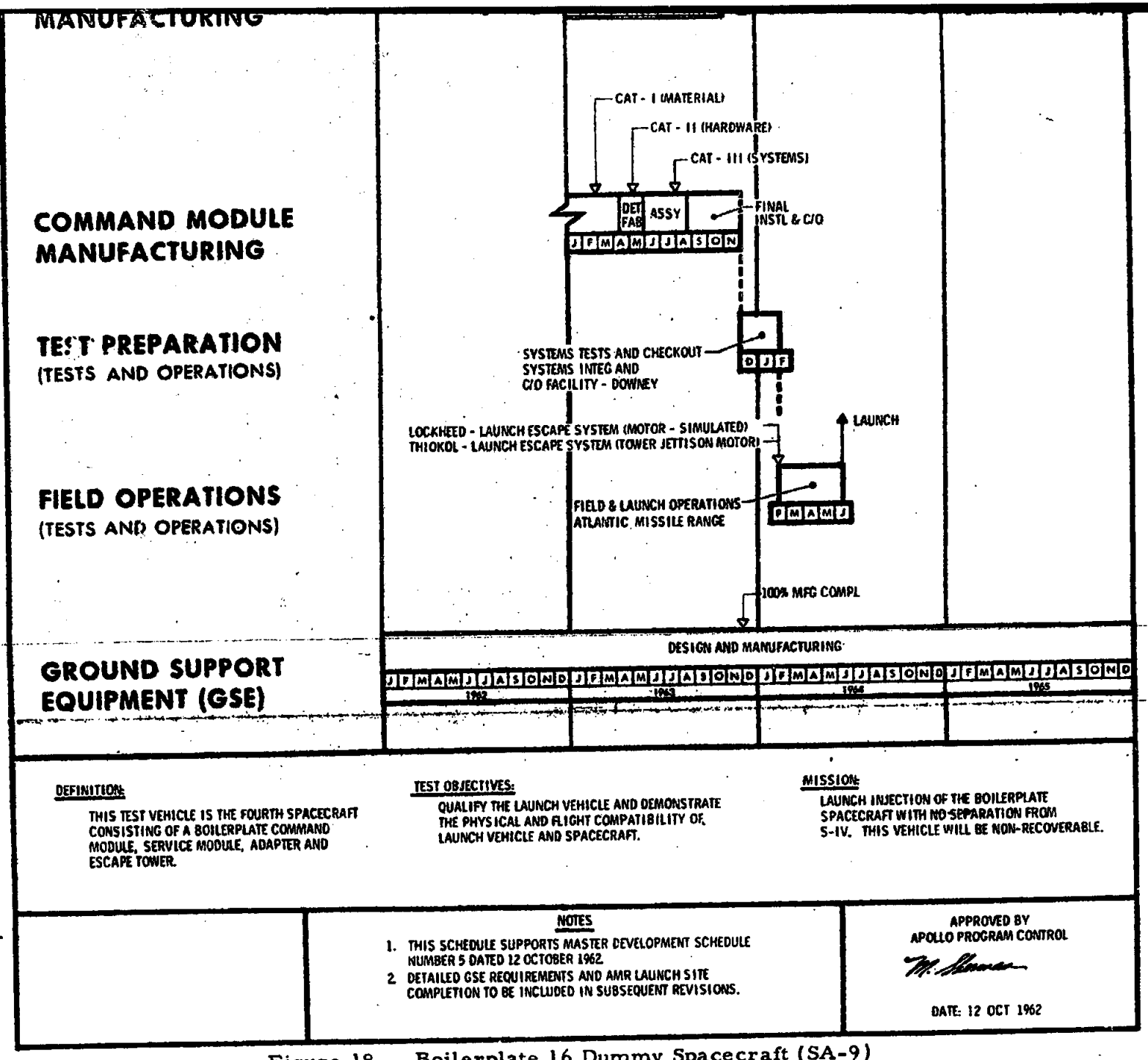
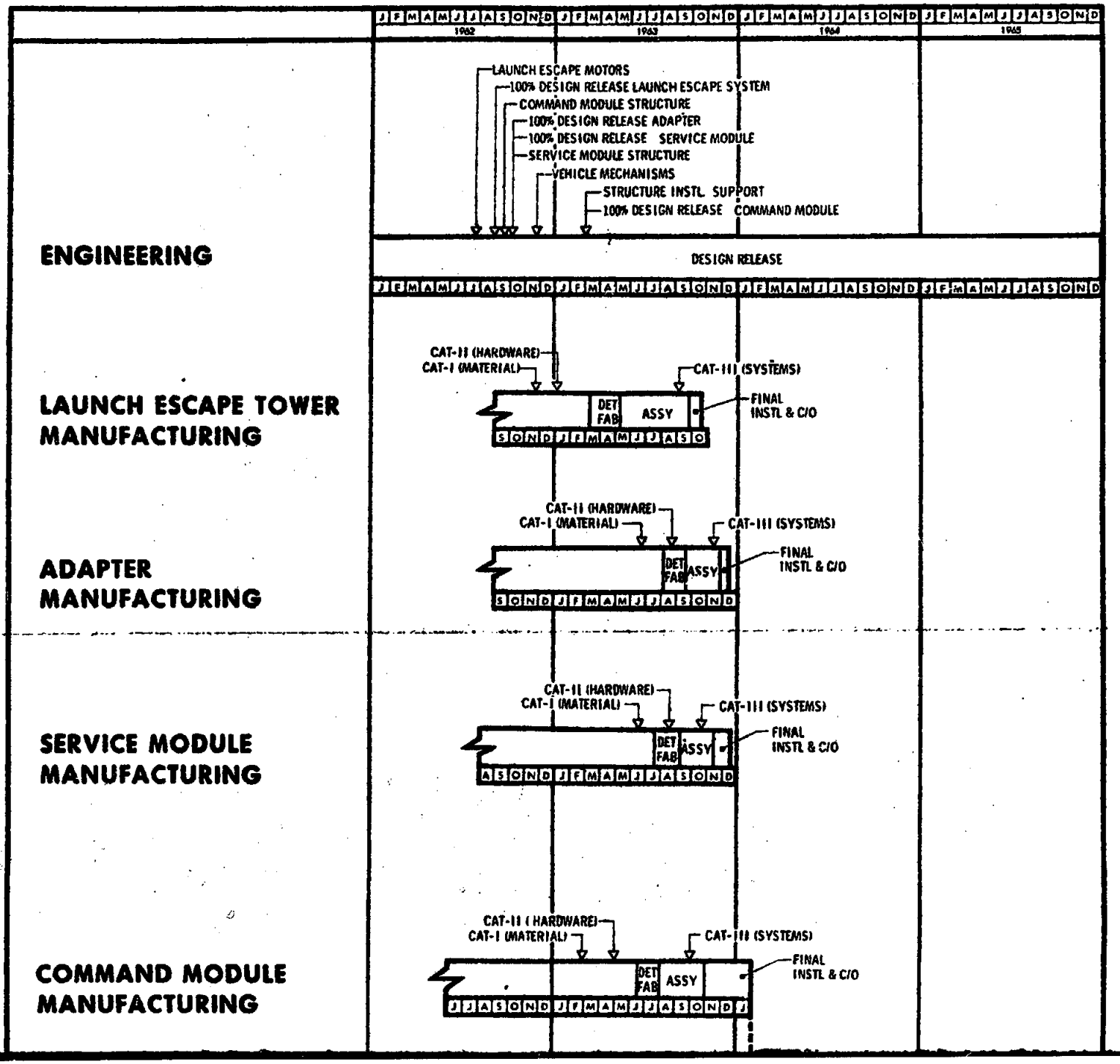


Figure 18. Boilerplate 16 Dummy Spacecraft (SA-9)


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
LAUNCH ESCAPE MOTORS
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
COMMAND MODULE STRUCTURE
100% DESIGN RELEASE ADAPTER
100% DESIGN RELEASE SERVICE MODULE
SERVICE MODULE STRUCTURE
VEHICLE MECHANISMS
STRUCTURE INSTL SUPPORT
100% DESIGN RELEASE COMMAND MODULE
ENGINEERING
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT-II (HARDWARE)
CAT-I (MATERIAL)
CAT-III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
ADAPTER MANUFACTURING
SERVICE MODULE MANUFACTURING
COMMAND MODULE MANUFACTURING

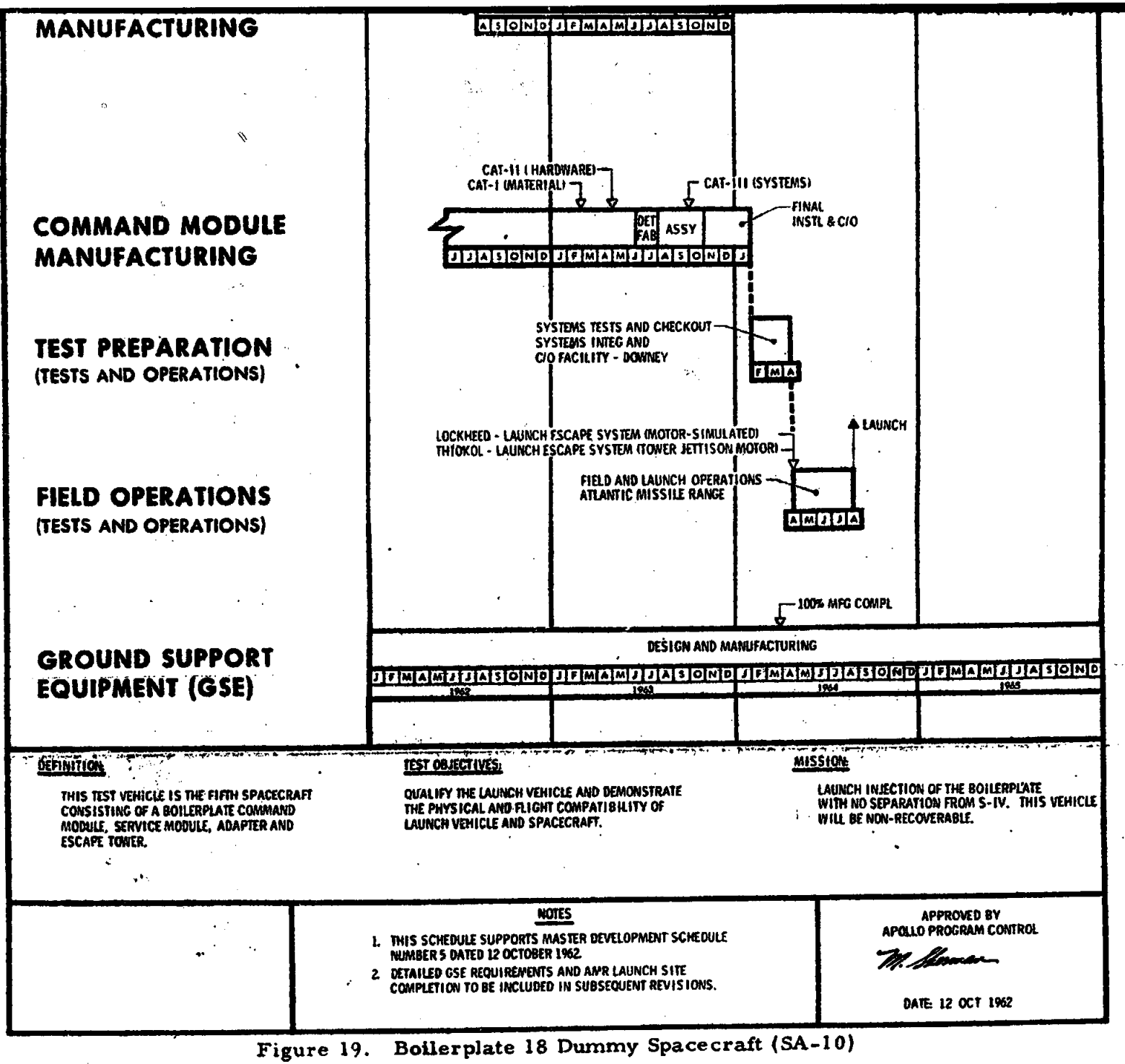
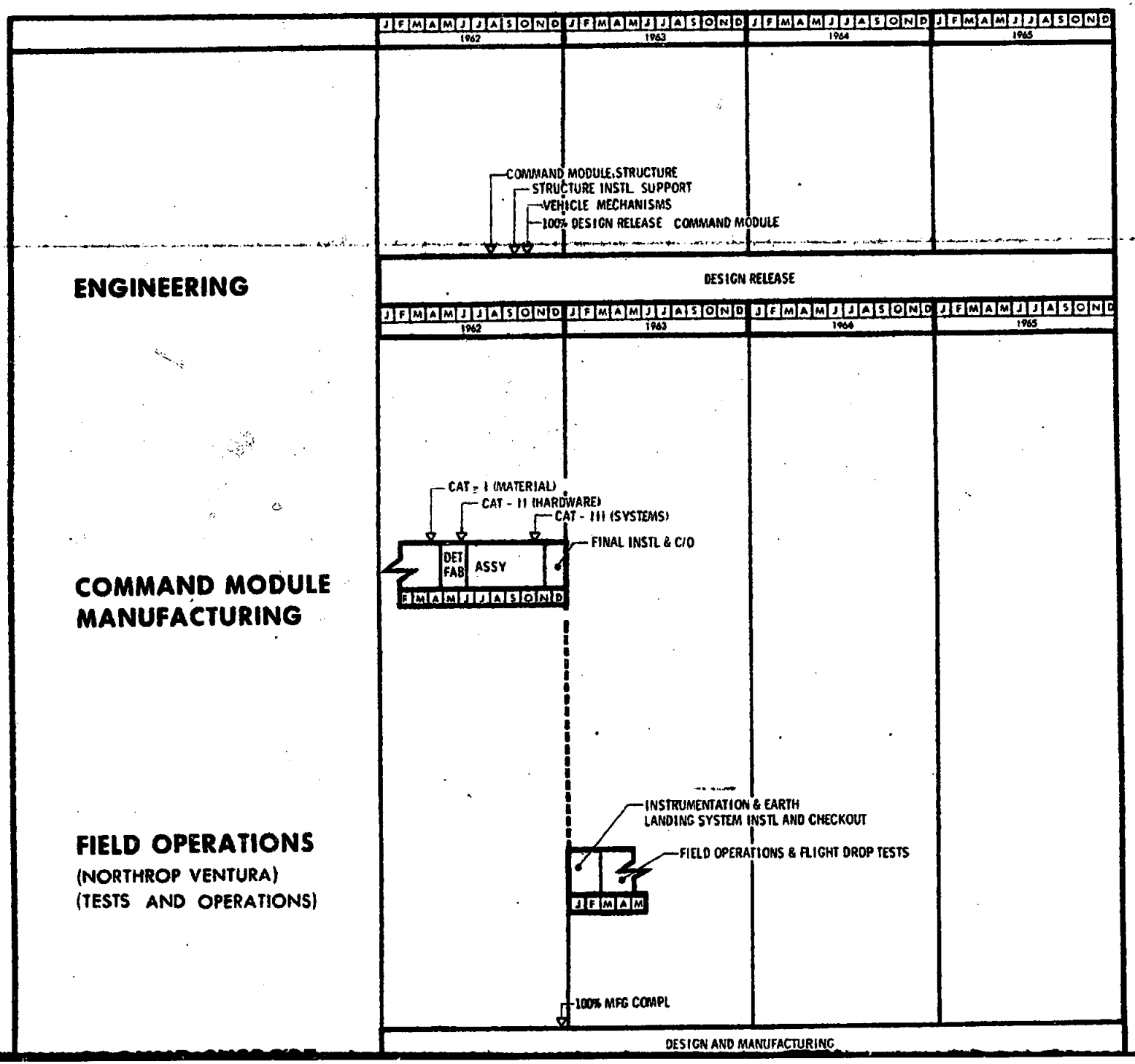
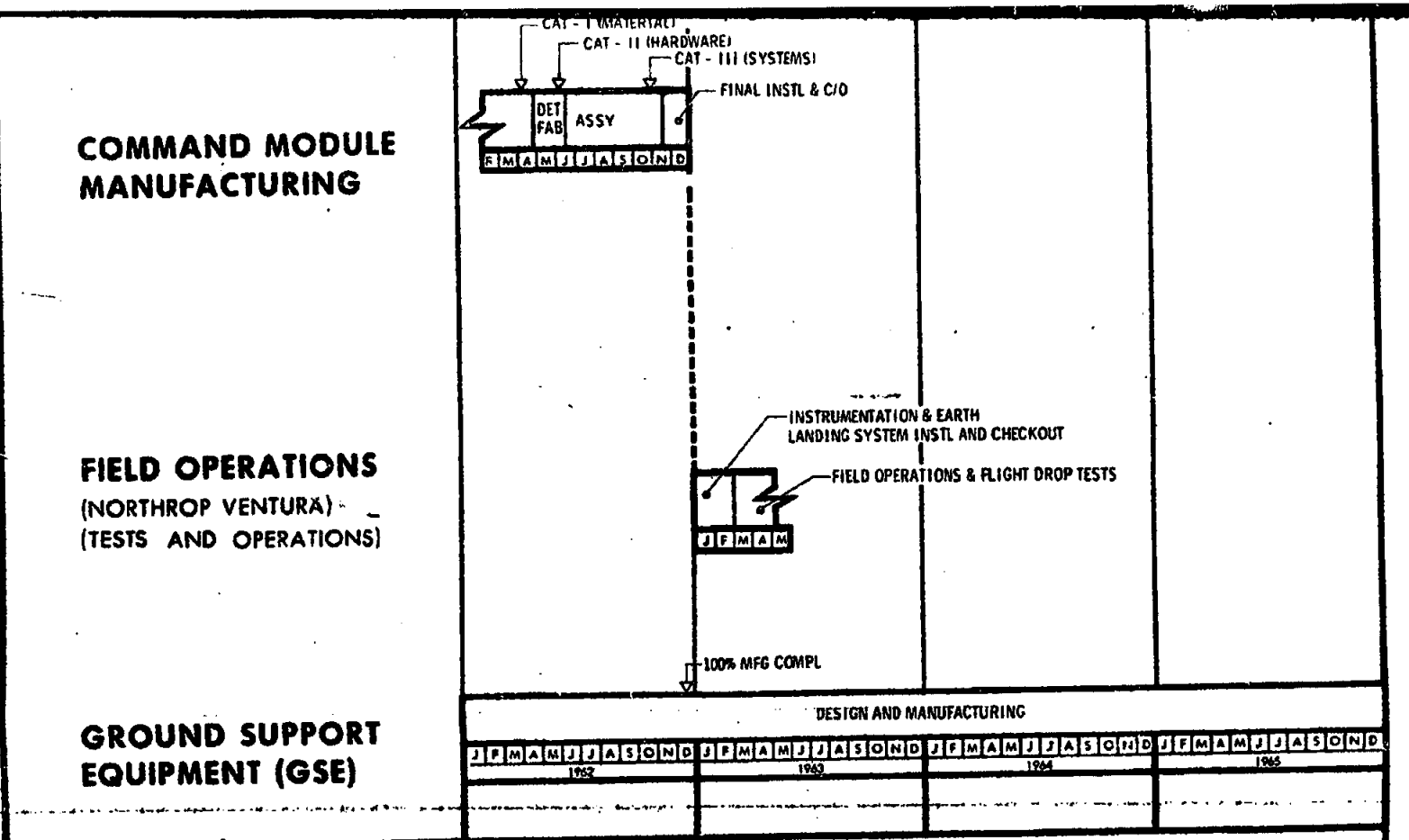


Figure 19. Boilerplate 18 Dummy Spacecraft (SA-10)



NORTH AMERICAN AVIATION, INC.



DEFINITION:

WILL CONSIST OF A BOILERPLATE COMMAND MODULE SIMULATING SIZE, SHAPE, STRUCTURAL SOUNDNESS, MASS AND CENTER OF GRAVITY OF THE SPACECRAFT. SYSTEMS AND INSTRUMENTATION AS REQUIRED FOR TESTS WILL BE INSTALLED.

TEST OBJECTIVES:

TO EVALUATE THE PARACHUTE RECOVERY SYSTEM OPERATION IN THE AIR BY HIGH ALTITUDE FLIGHT DROPS FROM C-133 AIRCRAFT OVER THE EL CENTRO TEST SITE. APPROXIMATELY FIFTEEN (15) HIGH ALTITUDE DROP TESTS WILL BE CONDUCTED.

MISSION:

DEVELOPMENT AND QUALIFICATION TESTING OF THE PARACHUTE RECOVERY SYSTEM.

NOTES

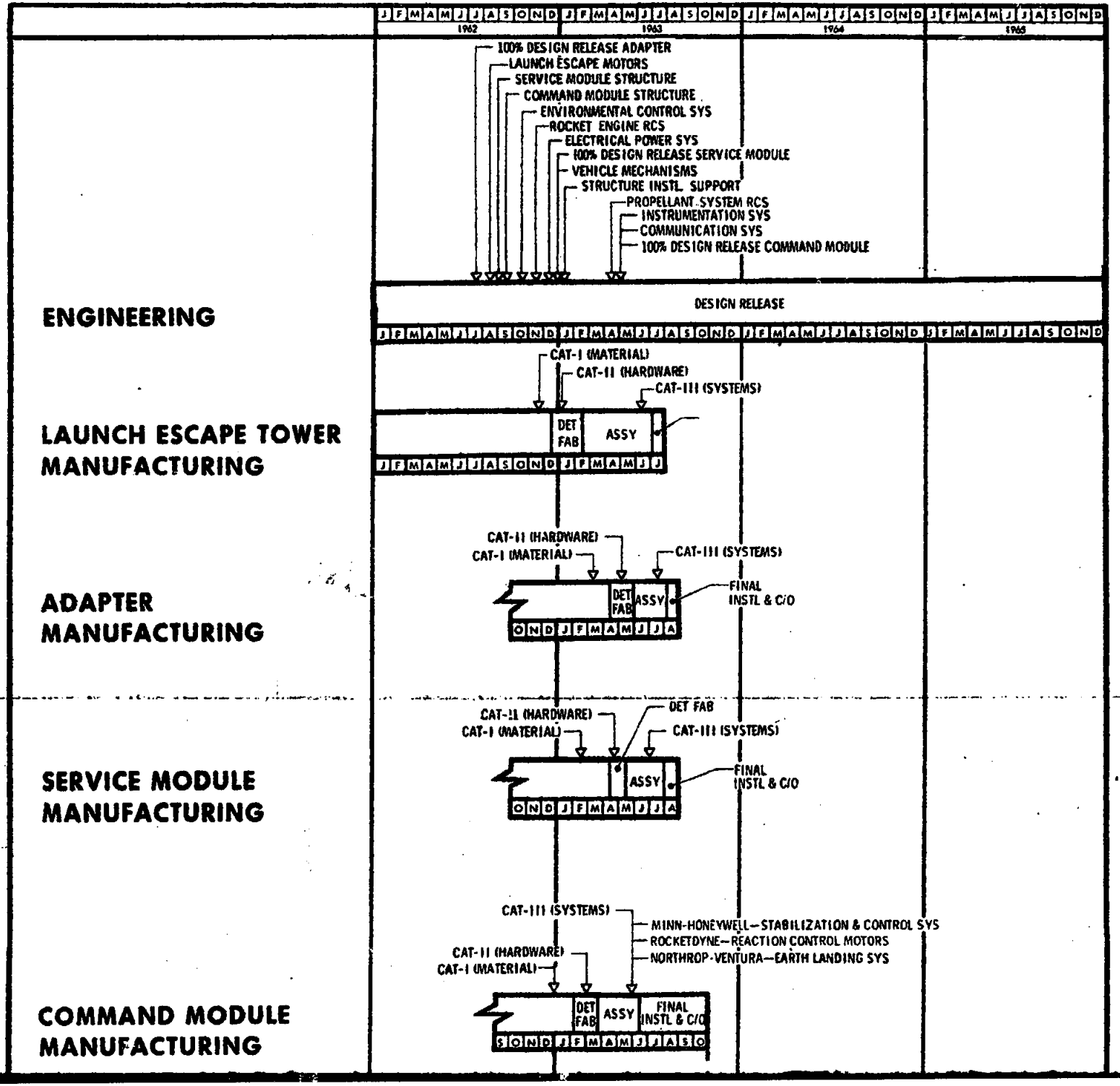
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS TO BE INCLUDED IN SUBSEQUENT REVISIONS.

APPROVED BY
APOLLO PROGRAM CONTROL

M. Sherman

DATE: 12 OCT 1962

Figure 20. Boilerplate 19 Command Module for Parachute Recovery


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
100% DESIGN RELEASE ADAPTER
LAUNCH ESCAPE MOTORS
SERVICE MODULE STRUCTURE
COMMAND MODULE STRUCTURE
ENVIRONMENTAL CONTROL SYS
ROCKET ENGINE RCS
ELECTRICAL POWER SYS
100% DESIGN RELEASE SERVICE MODULE
VEHICLE MECHANISMS
STRUCTURE INSTL. SUPPORT
PROPELLANT SYSTEM RCS
INSTRUMENTATION SYS
COMMUNICATION SYS
100% DESIGN RELEASE COMMAND MODULE
ENGINEERING
DESIGN RELEASE
CAT-I (MATERIAL)
CAT-II (HARDWARE)
CAT-III (SYSTEMS)
LAUNCH ESCAPE TOWER MANUFACTURING
DET FAB
ASSY
CAT-II (HARDWARE)
CAT-I (MATERIAL)
CAT-III (SYSTEMS)
ADAPTER MANUFACTURING
DET FAB
ASSY
FINAL INSTL & C/O
CAT-II (HARDWARE)
CAT-I (MATERIAL)
DET FAB
CAT-III (SYSTEMS)
SERVICE MODULE MANUFACTURING
ASSY
FINAL INSTL & C/O
CAT-III (SYSTEMS)
MINN-HONEYWELL—STABILIZATION & CONTROL SYS
ROCKETDYNE—REACTION CONTROL MOTORS
NORTHROP-VENTURA—EARTH LANDING SYS
CAT-II (HARDWARE)
CAT-I (MATERIAL)
COMMAND MODULE MANUFACTURING
DET FAB
ASSY
FINAL INSTL & C/O

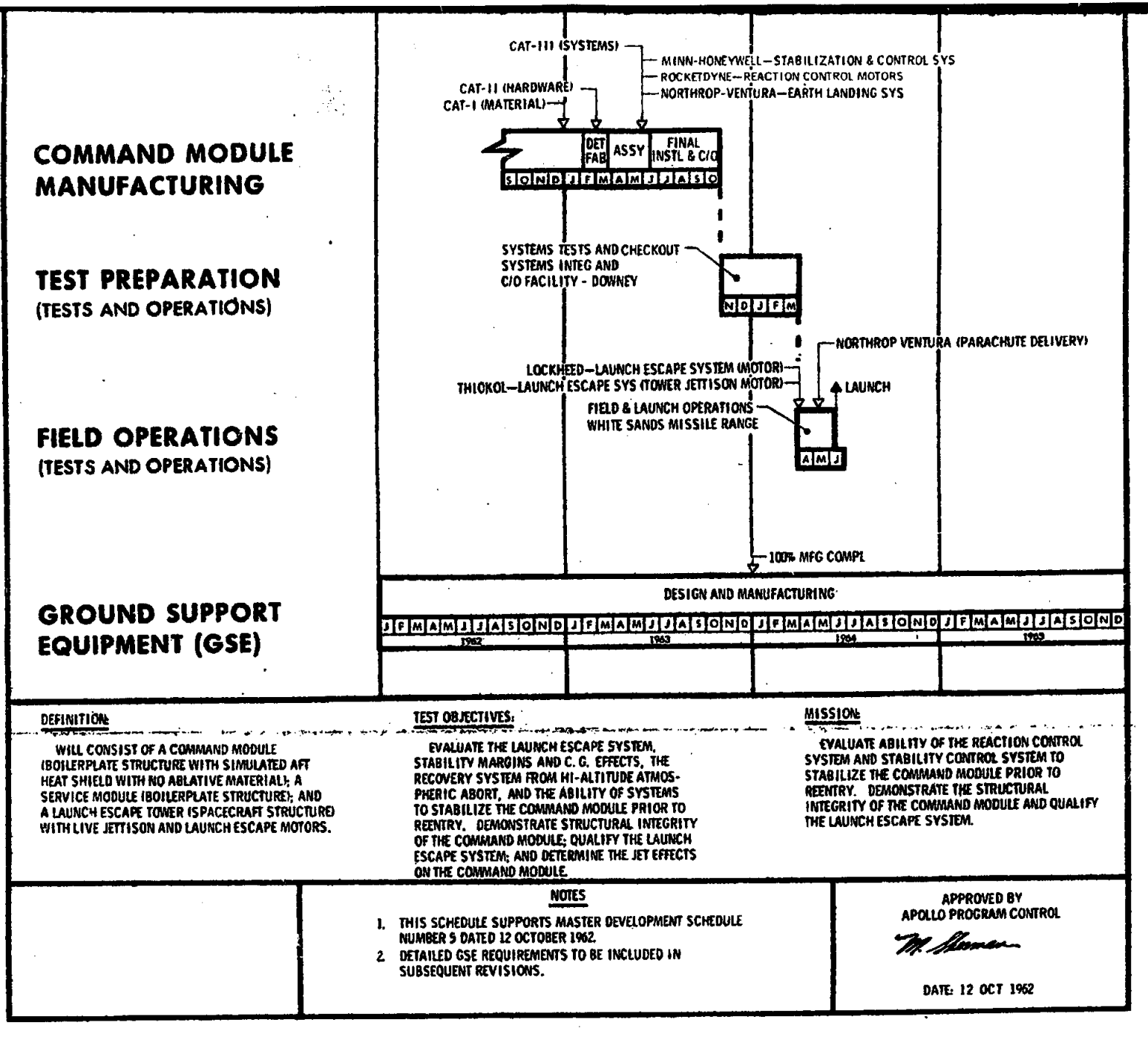
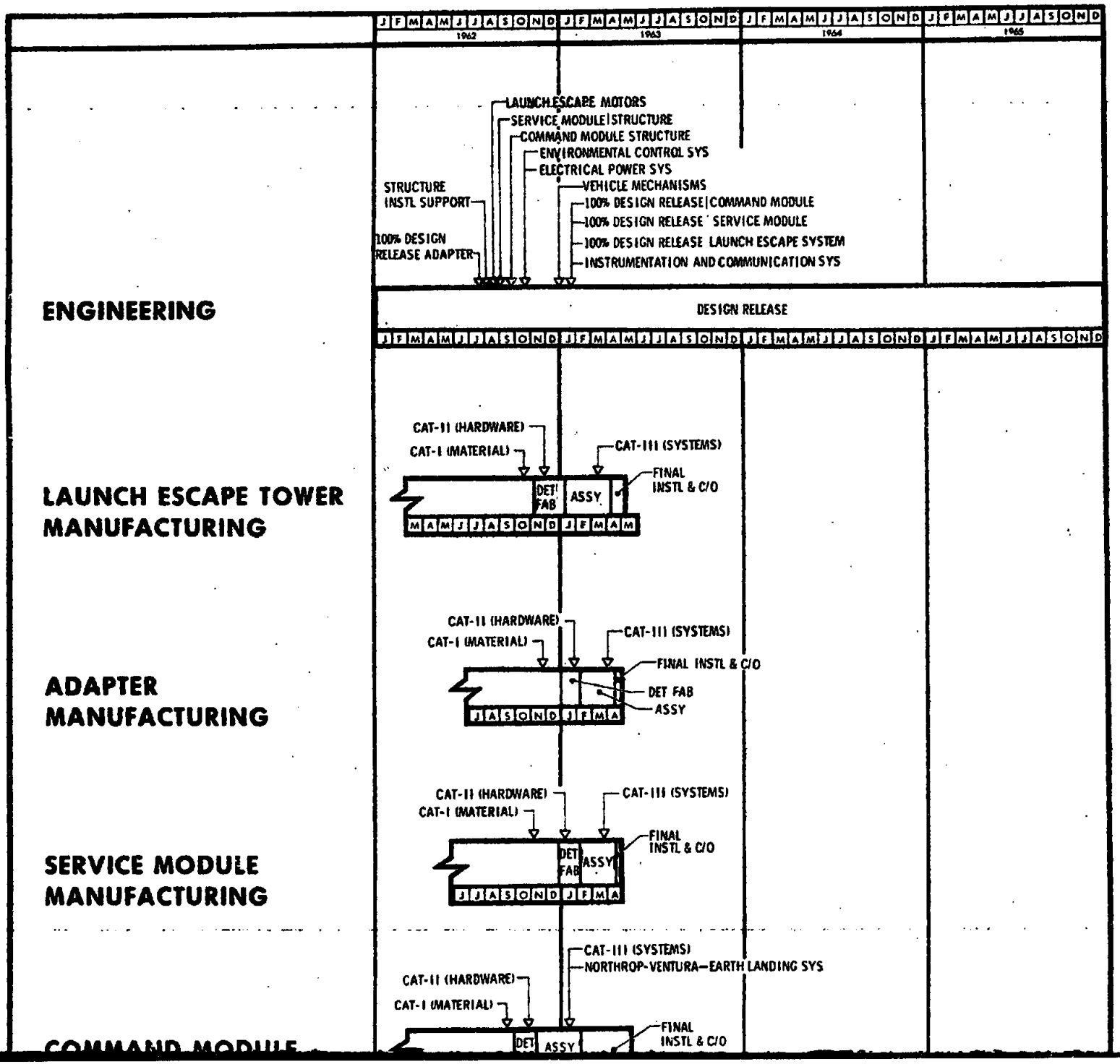
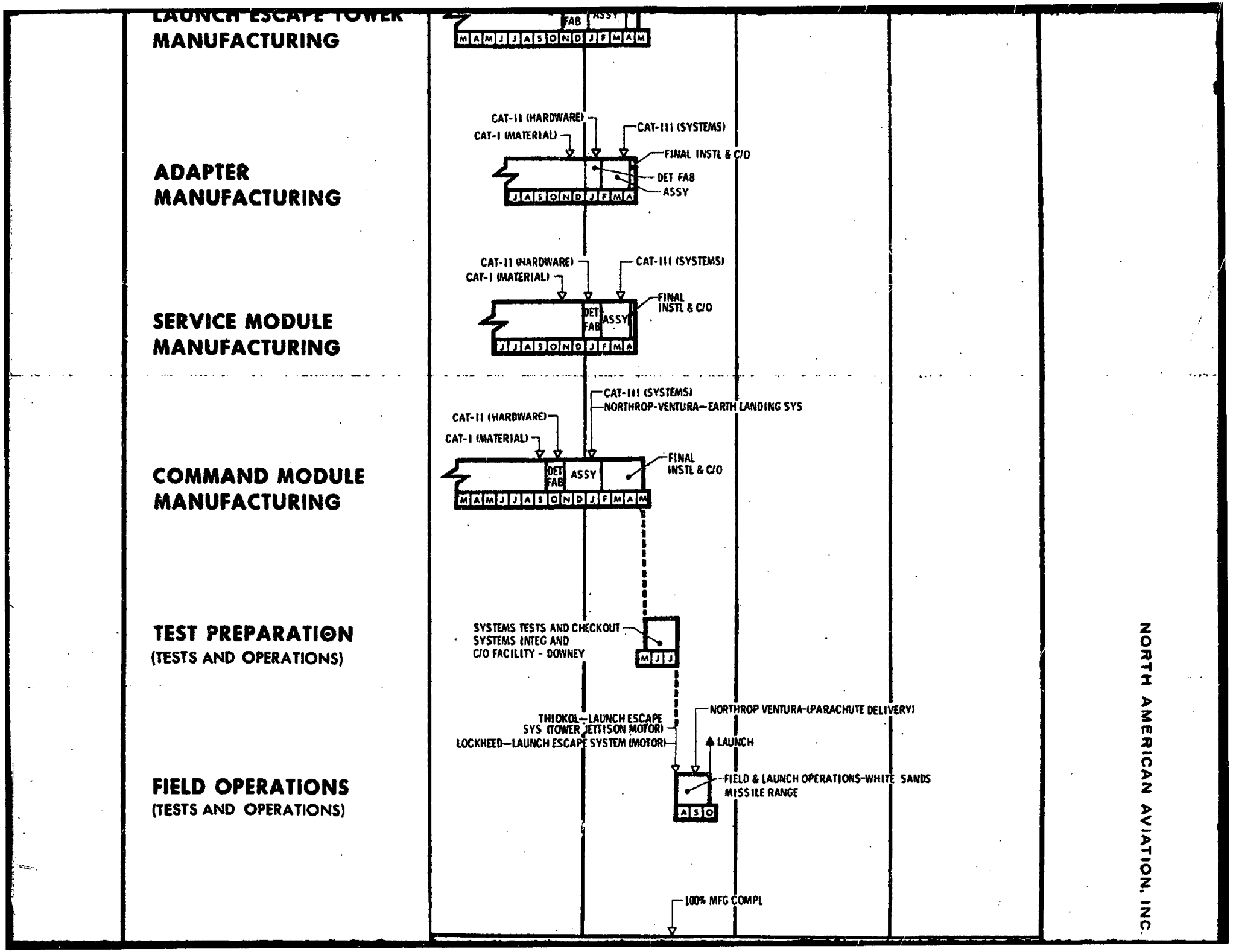
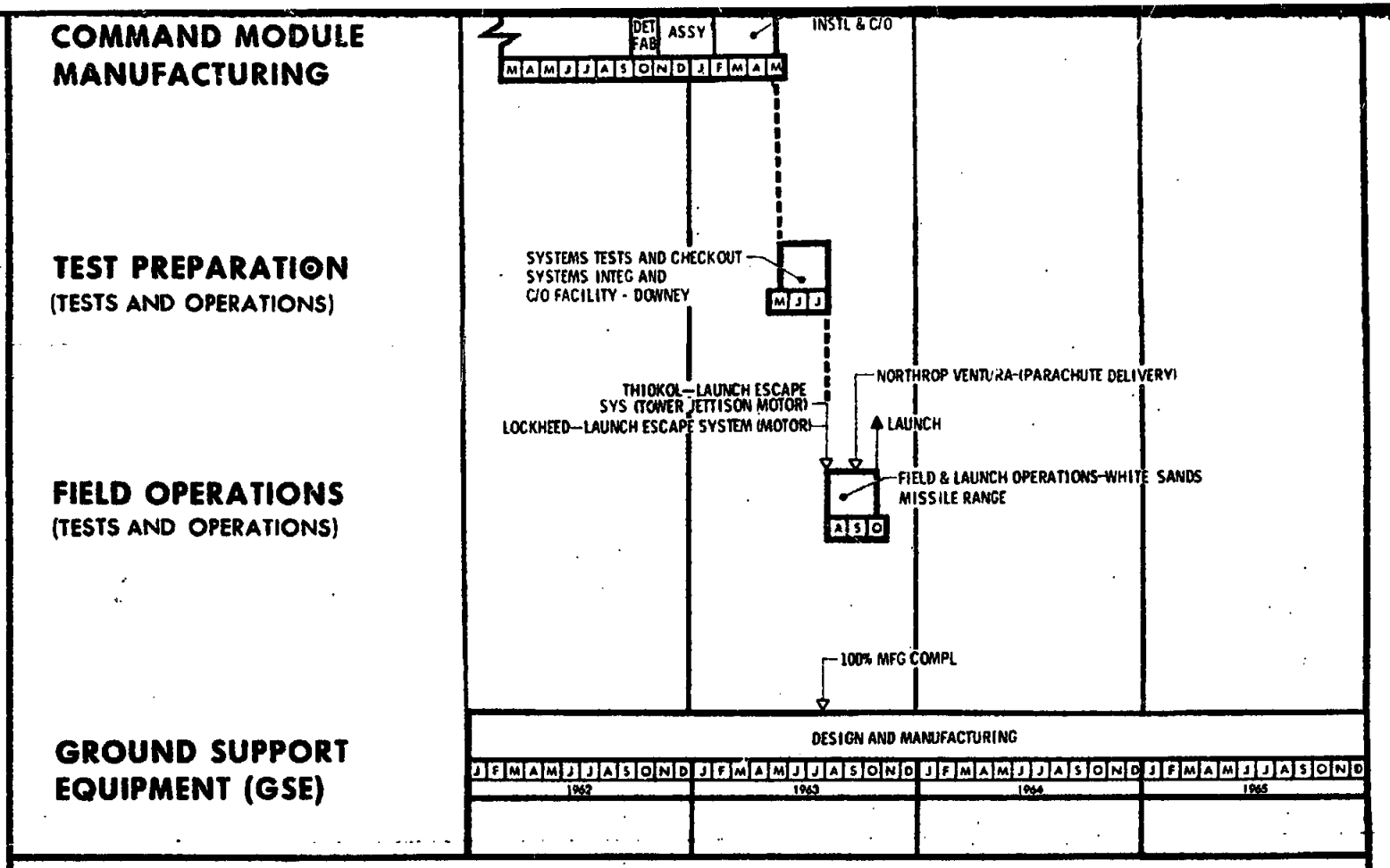


Figure 21. Boilerplate 22 High Altitude Flight Abort (Little Joe II)


J F M A M J J A S O N D
1962
1963
1964
1965
ENGINEERING
LAUNCH ESCAPE MOTORS
SERVICE MODULE STRUCTURE
COMMAND MODULE STRUCTURE
ENVIRONMENTAL CONTROL SYS
ELECTRICAL POWER SYS
VEHICLE MECHANISMS
STRUCTURE INSTL SUPPORT
100% DESIGN RELEASE COMMAND MODULE
100% DESIGN RELEASE SERVICE MODULE
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
100% DESIGN RELEASE ADAPTER
INSTRUMENTATION AND COMMUNICATION SYS
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT-II (HARDWARE)
CAT-I (MATERIAL)
CAT-III (SYSTEMS)
FINAL INSTL & C/O
DET FAB
ASSY
ADAPTER MANUFACTURING
CAT-II (HARDWARE)
CAT-I (MATERIAL)
CAT-III (SYSTEMS)
FINAL INSTL & C/O
DET FAB
ASSY
SERVICE MODULE MANUFACTURING
CAT-II (HARDWARE)
CAT-I (MATERIAL)
CAT-III (SYSTEMS)
FINAL INSTL & C/O
DET FAB
ASSY
CAT-III (SYSTEMS)
NORTHROP-VENTURA—EARTH LANDING SYS
CAT-II (HARDWARE)
CAT-I (MATERIAL)
FINAL INSTL & C/O
DET
ASSY
COMMAND MODULE



NORTH AMERICAN AVIATION, INC.



DEFINITION:

WILL CONSIST OF A COMMAND MODULE (BOILERPLATE STRUCTURE WITH SIMULATED AFT HEAT SHIELD - NO ABLATIVE MATERIAL); A SERVICE MODULE (BOILERPLATE STRUCTURE - STEEL); A LAUNCH ESCAPE TOWER (SPACECRAFT STRUCTURE) WITH LIVE JETTISON AND LAUNCH ESCAPE MOTORS; A SPACECRAFT ADAPTER (BOILERPLATE STRUCTURE); AND A LITTLE JOE II BOOSTER.

TEST OBJECTIVES - FOR PAD ABORT

EVALUATE THE STABILITY MARGINS AND CENTER OF GRAVITY EFFECTS AND EVALUATE AND QUALIFY THE LAUNCH ESCAPE SYSTEM. DEMONSTRATE COMMAND MODULE STRUCTURAL INTEGRITY AND DETERMINE THE JET THRUST EFFECTS ON THE COMMAND MODULE.

TEST OBJECTIVES - FOR MAX "q"

EVALUATE THE STABILITY MARGINS, THE LAUNCH ESCAPE SYSTEM, THE LAUNCH ESCAPE MOTOR CHARACTERISTICS, AND THE STRUCTURAL INTEGRITY OF THE LAUNCH ESCAPE TOWER. DETERMINE THE DYNAMIC CHARACTERISTICS OF A LAUNCH ESCAPE SYSTEM AND THE JET EFFECTS ON THE COMMAND MODULE.

MISSION:

EARLY QUALIFICATION OF LAUNCH ESCAPE SYSTEM AT PAD ABORT AND MAX "q". PROVIDE MISSION BACKUP FOR BOILERPLATE #6 AND BOILERPLATE #12.

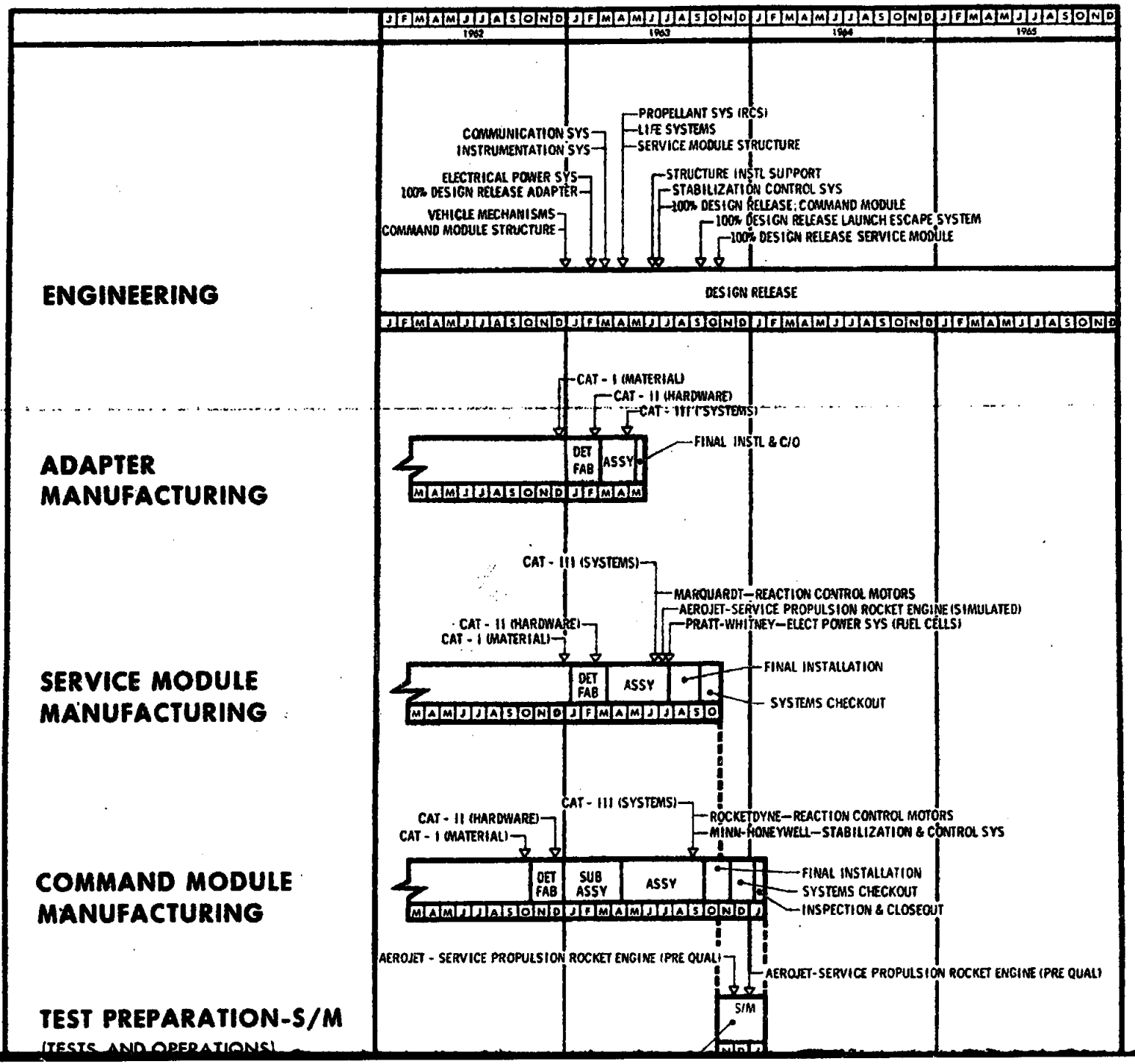
NOTES

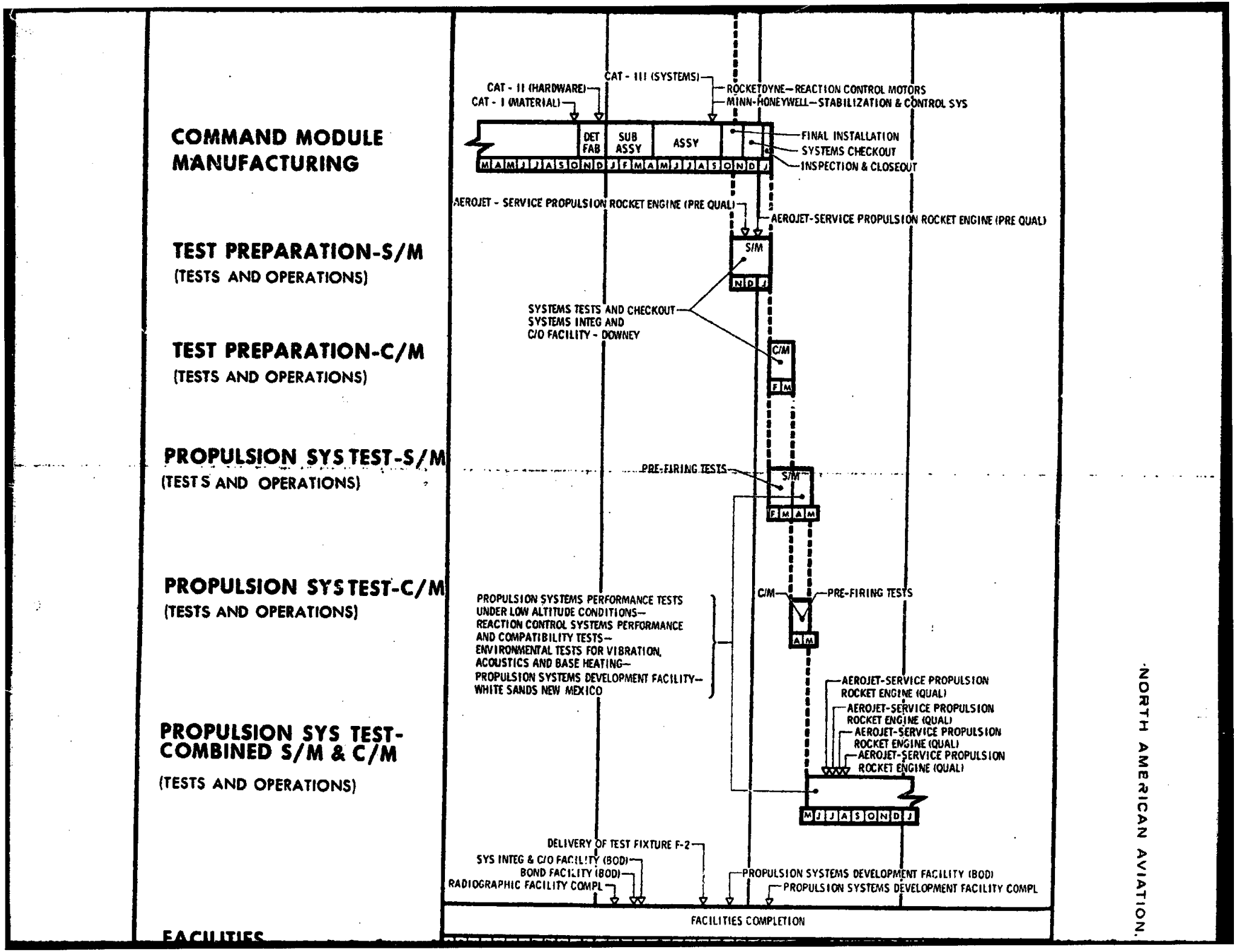
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS TO BE INCLUDED IN SUBSEQUENT REVISIONS.

APPROVED BY
APOLLO PROGRAM CONTROL

DATE: 12 OCT 1962

Figure 22. Boilerplate 23 Back-up for Boilerplate 6 and Boilerplate 12 (LJ II)


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
ENGINEERING
COMMUNICATION SYS
INSTRUMENTATION SYS
ELECTRICAL POWER SYS
100% DESIGN RELEASE ADAPTER
VEHICLE MECHANISMS
COMMAND MODULE STRUCTURE
PROPELLANT SYS (RCS)
LIFE SYSTEMS
SERVICE MODULE STRUCTURE
STRUCTURE INSTL SUPPORT
STABILIZATION CONTROL SYS
100% DESIGN RELEASE: COMMAND MODULE
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
100% DESIGN RELEASE SERVICE MODULE
DESIGN RELEASE
ADAPTER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
SERVICE MODULE MANUFACTURING
CAT - III (SYSTEMS)
MARQUARDT—REACTION CONTROL MOTORS
AEROJET-SERVICE PROPULSION ROCKET ENGINE (SIMULATED)
PRATT-WHITNEY—ELECT POWER SYS (FUEL CELLS)
CAT - II (HARDWARE)
CAT - I (MATERIAL)
DET FAB
ASSY
FINAL INSTALLATION
SYSTEMS CHECKOUT
COMMAND MODULE MANUFACTURING
CAT - III (SYSTEMS)
CAT - II (HARDWARE)
CAT - I (MATERIAL)
ROCKETDYNE—REACTION CONTROL MOTORS
MINN-HONEYWELL—STABILIZATION & CONTROL SYS
DET FAB
SUB ASSY
ASSY
FINAL INSTALLATION
SYSTEMS CHECKOUT
INSPECTION & CLOSEOUT
TEST PREPARATION-S/M
(TESTS AND OPERATIONS)
AEROJET - SERVICE PROPULSION ROCKET ENGINE (PRE QUAL)
AEROJET-SERVICE PROPULSION ROCKET ENGINE (PRE QUAL)
S/M



NORTH AMERICAN AVIATION

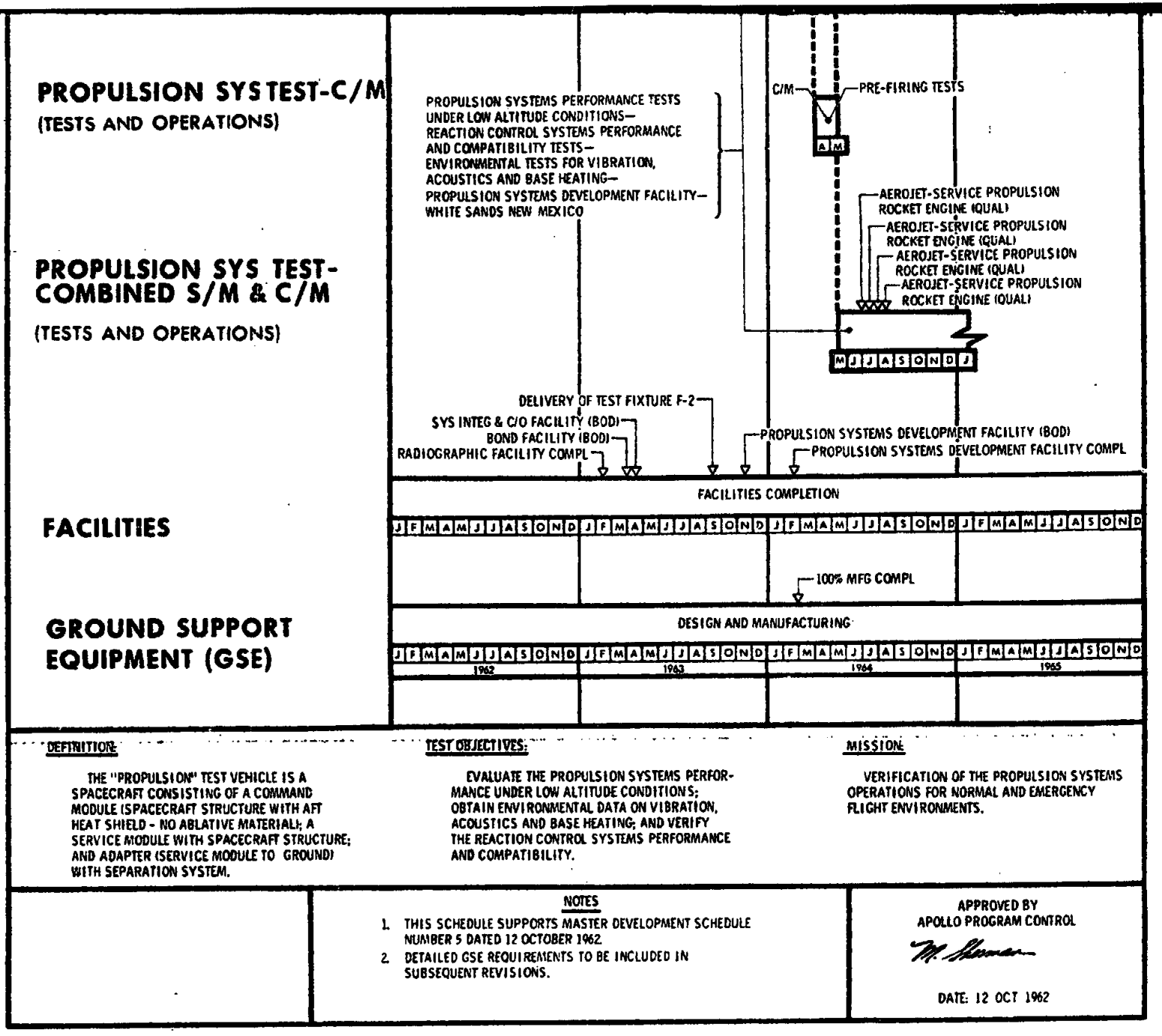
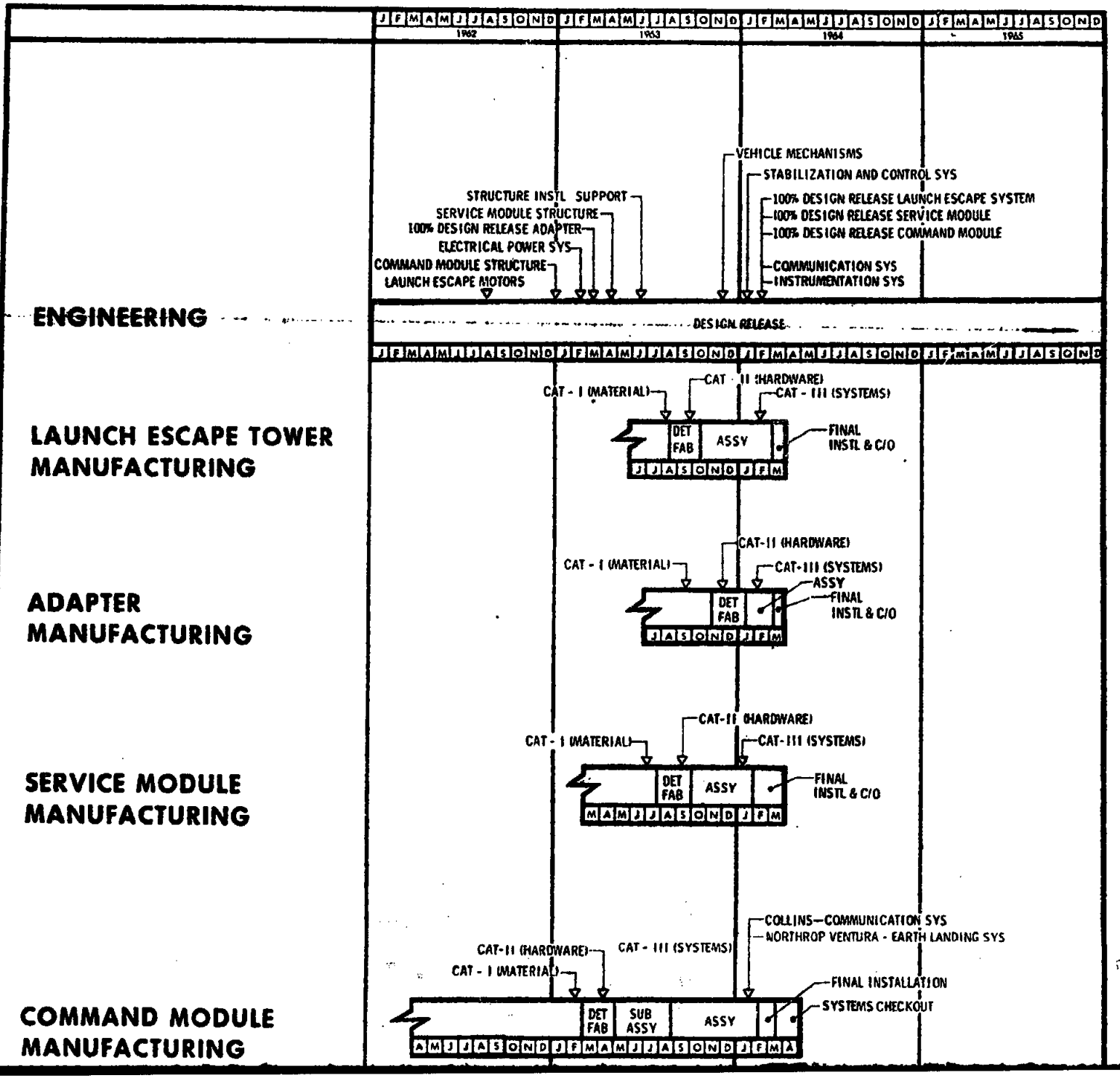
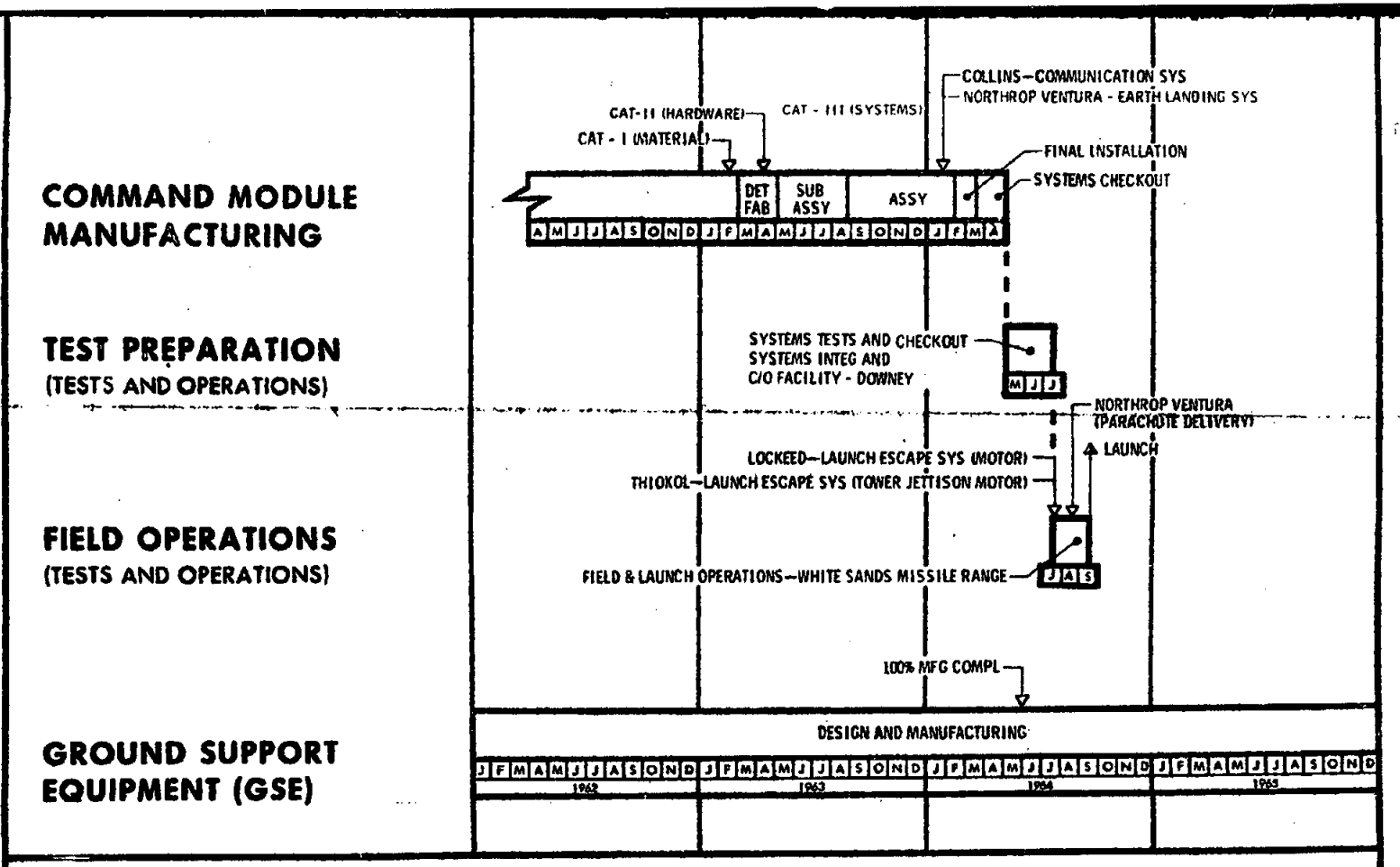


Figure 23. AFRM 001 Propulsion System Qualification


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
VEHICLE MECHANISMS
STABILIZATION AND CONTROL SYS
STRUCTURE INSTL SUPPORT
SERVICE MODULE STRUCTURE
100% DESIGN RELEASE ADAPTER
ELECTRICAL POWER SYS
COMMAND MODULE STRUCTURE
LAUNCH ESCAPE MOTORS
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
100% DESIGN RELEASE SERVICE MODULE
100% DESIGN RELEASE COMMAND MODULE
COMMUNICATION SYS
INSTRUMENTATION SYS
ENGINEERING
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
ADAPTER MANUFACTURING
CAT-II (HARDWARE)
CAT - I (MATERIAL)
CAT-III (SYSTEMS)
ASSY
FINAL INSTL & C/O
SERVICE MODULE MANUFACTURING
CAT-II (HARDWARE)
CAT - I (MATERIAL)
CAT-III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
COMMAND MODULE MANUFACTURING
COLLINS—COMMUNICATION SYS
NORTHROP VENTURA - EARTH LANDING SYS
CAT-II (HARDWARE)
CAT - III (SYSTEMS)
CAT - I (MATERIAL)
FINAL INSTALLATION
SYSTEMS CHECKOUT
DET FAB
SUB ASSY
ASSY



DEFINITION:

THE LAUNCH ESCAPE MAX "q" SPACECRAFT CONSISTS OF A COMMAND MODULE (SPACECRAFT STRUCTURE WITH AFT HEAT SHIELD - NO ABLATIVE MATERIAL); A SERVICE MODULE (OPTIMIZED TO LOR CONFIGURATION - SPACECRAFT STRUCTURE); A SPACECRAFT ADAPTER (FOR SERVICE MODULE TO LITTLE JOE II - SPACECRAFT STRUCTURE - WITH AIR BARRIER); AND A SPACECRAFT LAUNCH ESCAPE SYSTEM WITH LIVE JETTISON AND LAUNCH ESCAPE MOTORS.

TEST OBJECTIVES:

DEMONSTRATE STRUCTURAL INTEGRITY OF THE COMMAND MODULE; EVALUATE AND QUALIFY THE LAUNCH ESCAPE SYSTEM AT MAX "q"; DETERMINE THE JET EFFECTS ON THE COMMAND MODULE; EVALUATE THE PITCH CONTROL SYSTEM, THE STABILITY MARGINS AND EFFECT OF THE PITCH CONTROL ROCKET MOTOR; EVALUATE THE RECOVERY SYSTEM AND TOWER SEPARATION.

MISSION:

DEMONSTRATION OF COMMAND MODULE STRUCTURAL INTEGRITY AND EVALUATION OF PITCH CONTROL AND RECOVERY SYSTEMS.

NOTES

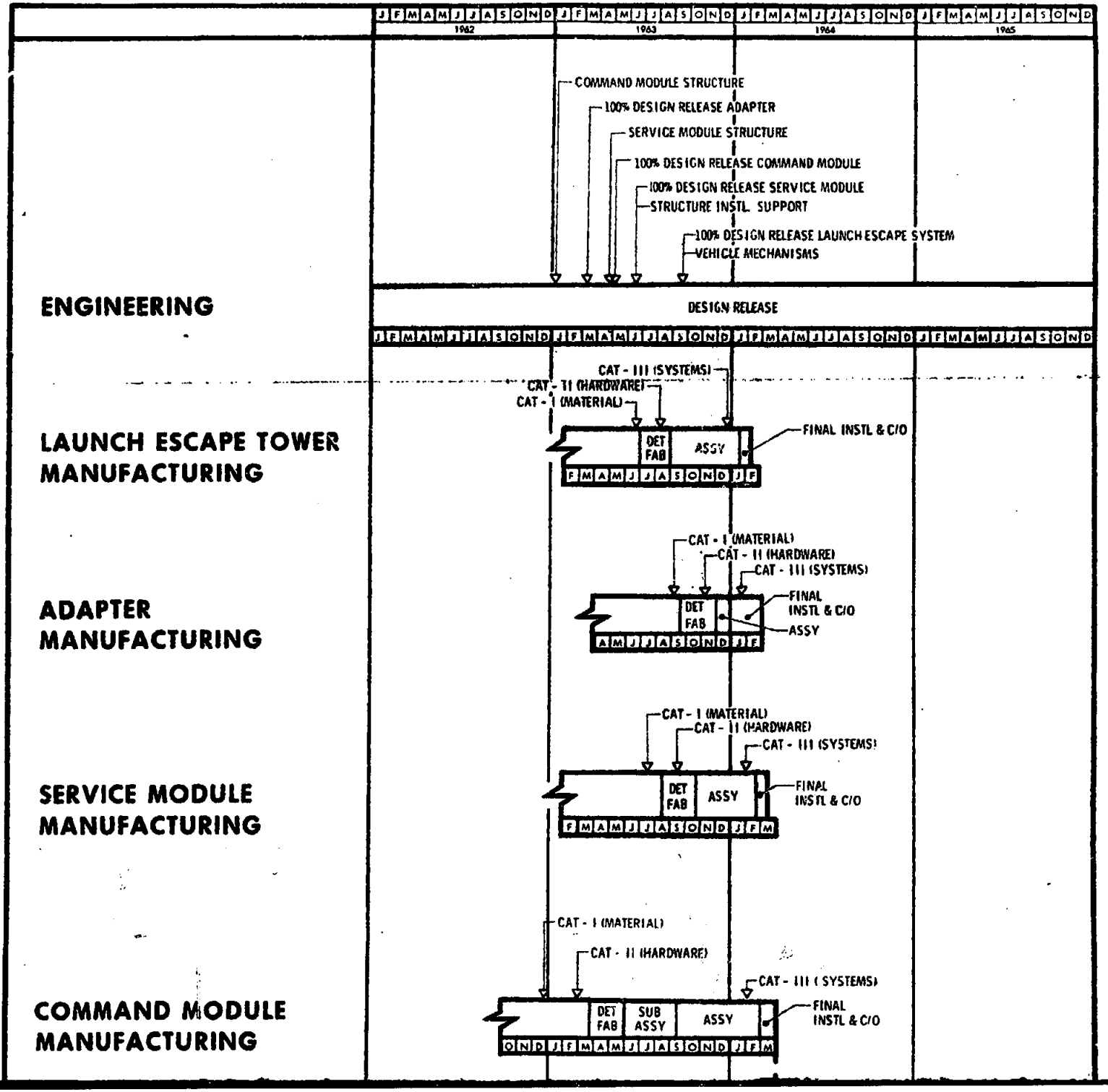
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS TO BE INCLUDED IN SUBSEQUENT REVISIONS.

APPROVED BY
APOLLO PROGRAM CONTROL

M. Sherman

DATE: 12 OCT 1962

Figure 24. AFRM 002 Command Module for Maximum q Abort and Command Module Structural Demonstration (Little Joe II)


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
COMMAND MODULE STRUCTURE
100% DESIGN RELEASE ADAPTER
SERVICE MODULE STRUCTURE
100% DESIGN RELEASE COMMAND MODULE
100% DESIGN RELEASE SERVICE MODULE
STRUCTURE INSTL. SUPPORT
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
VEHICLE MECHANISMS
ENGINEERING
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT - III (SYSTEMS)
CAT - II (HARDWARE)
CAT - I (MATERIAL)
DET FAB
ASSY
FINAL INSTL & C/O
ADAPTER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
FINAL INSTL & C/O
ASSY
SERVICE MODULE MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
COMMAND MODULE MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
SUB ASSY
ASSY
FINAL INSTL & C/O

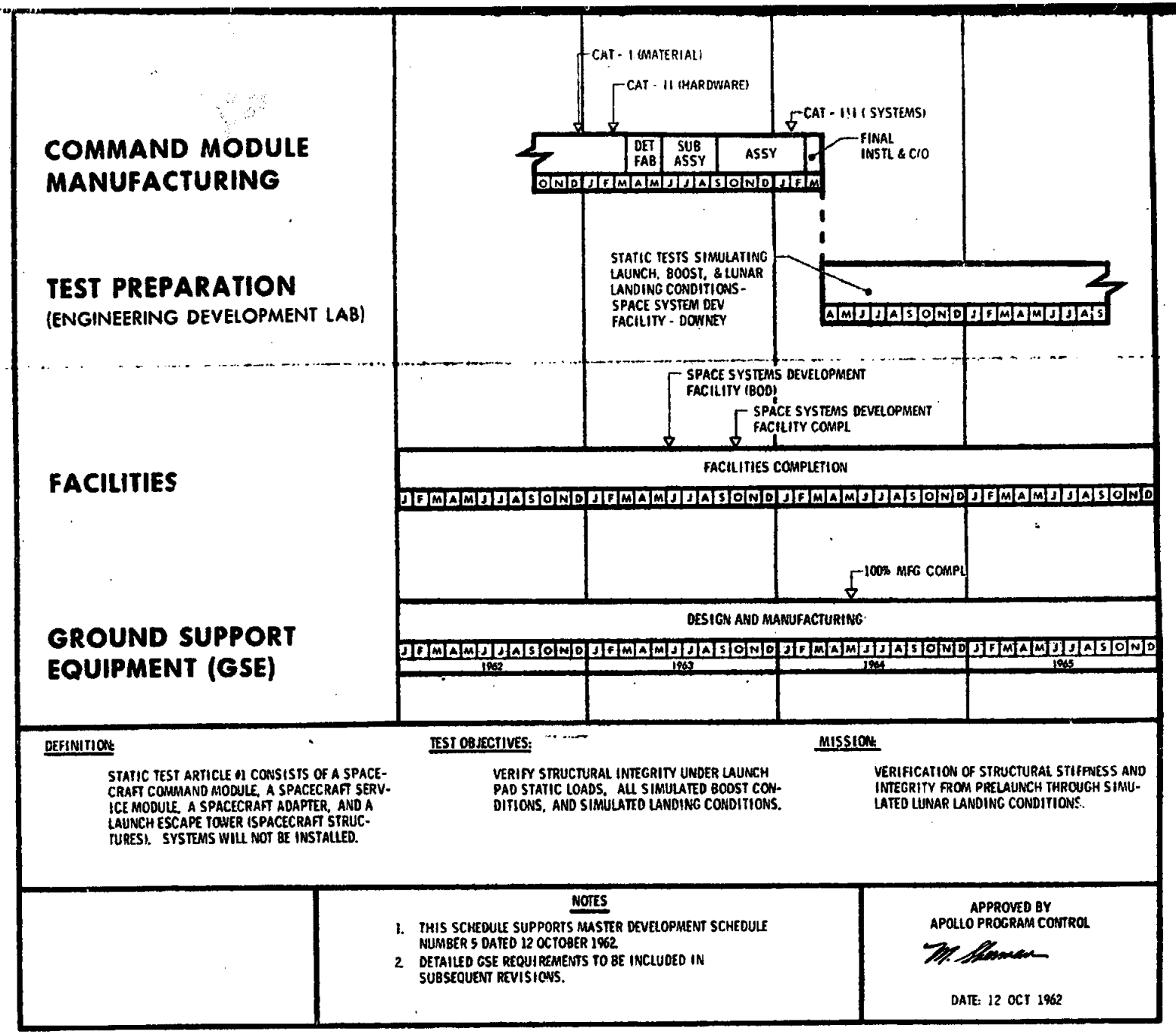
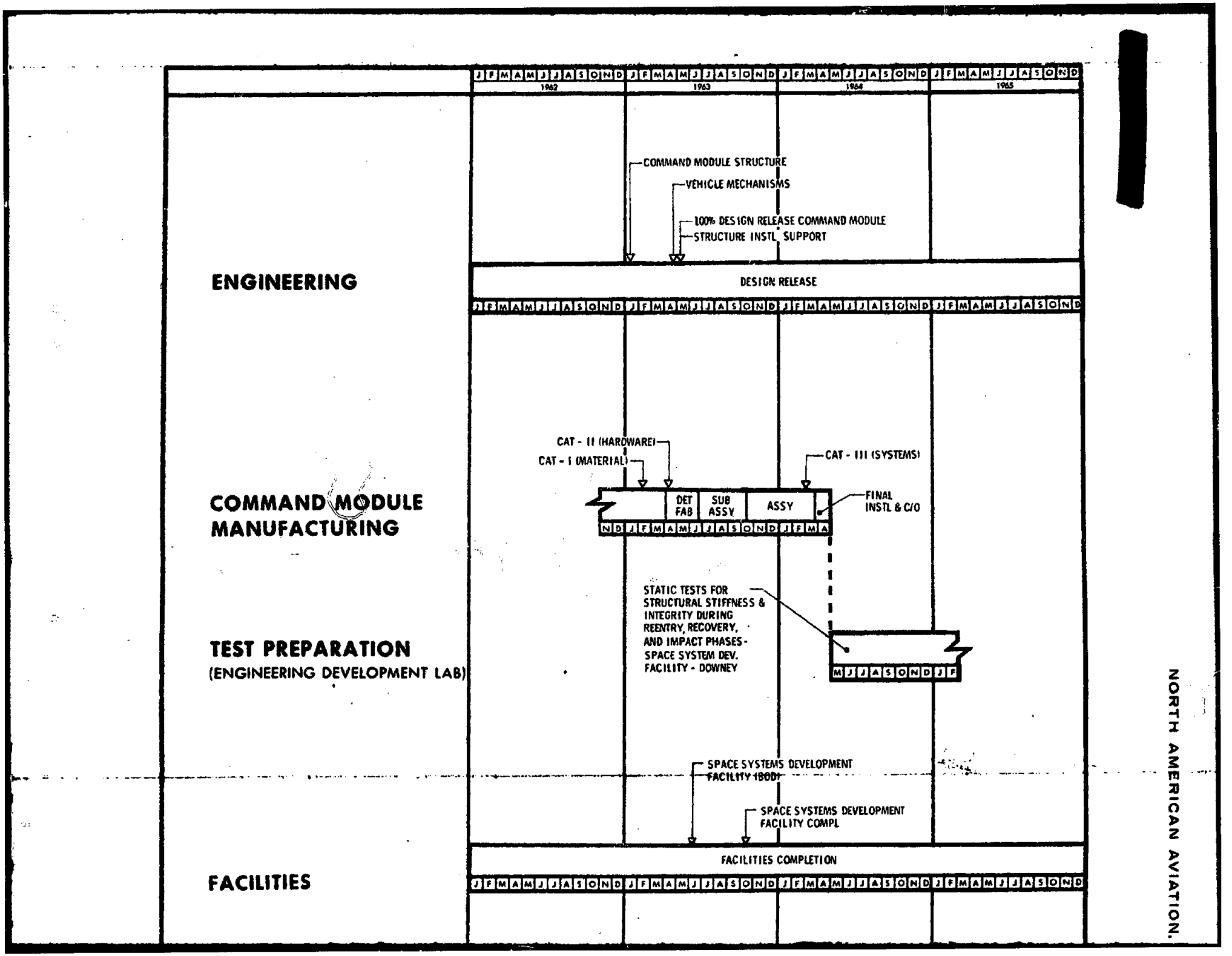
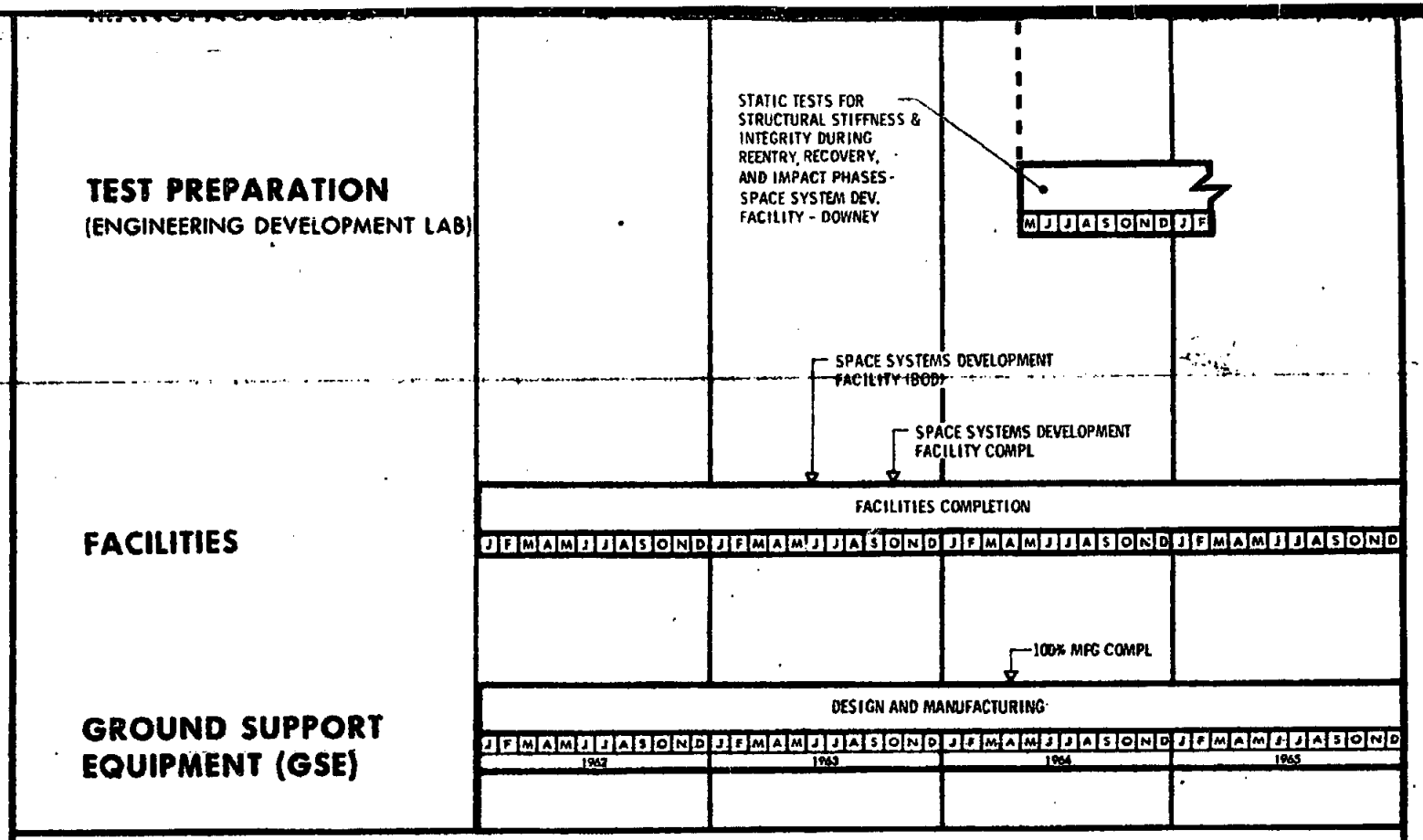


Figure 25. AFRM 004 Spacecraft for Static Test No. 1



NORTH AMERICAN AVIATION.



DEFINITION:

THIS SPACECRAFT IS THE SECOND STATIC TEST ARTICLE AND CONSISTS OF A SPACECRAFT COMMAND MODULE WITH HEAT SHIELD STRUCTURE AND NO ABLATIVE MATERIAL. INSTALLATION OF SYSTEMS ARE NOT REQUIRED.

TEST OBJECTIVES:

VERIFY STRUCTURAL INTEGRITY UNDER SIMULATED THERMAL ENVIRONMENT AT REENTRY, UNDER SIMULATED SHOCK CONDITIONS DURING AIR PHASE OF RECOVERY, AND UNDER SIMULATED SHOCK LOADS AT EARTH IMPACT (LAND AND WATER SIMULATION).

MISSION:

VERIFICATION OF STRUCTURAL STIFFNESS AND INTEGRITY DURING REENTRY AND RECOVERY PHASES.

NOTES

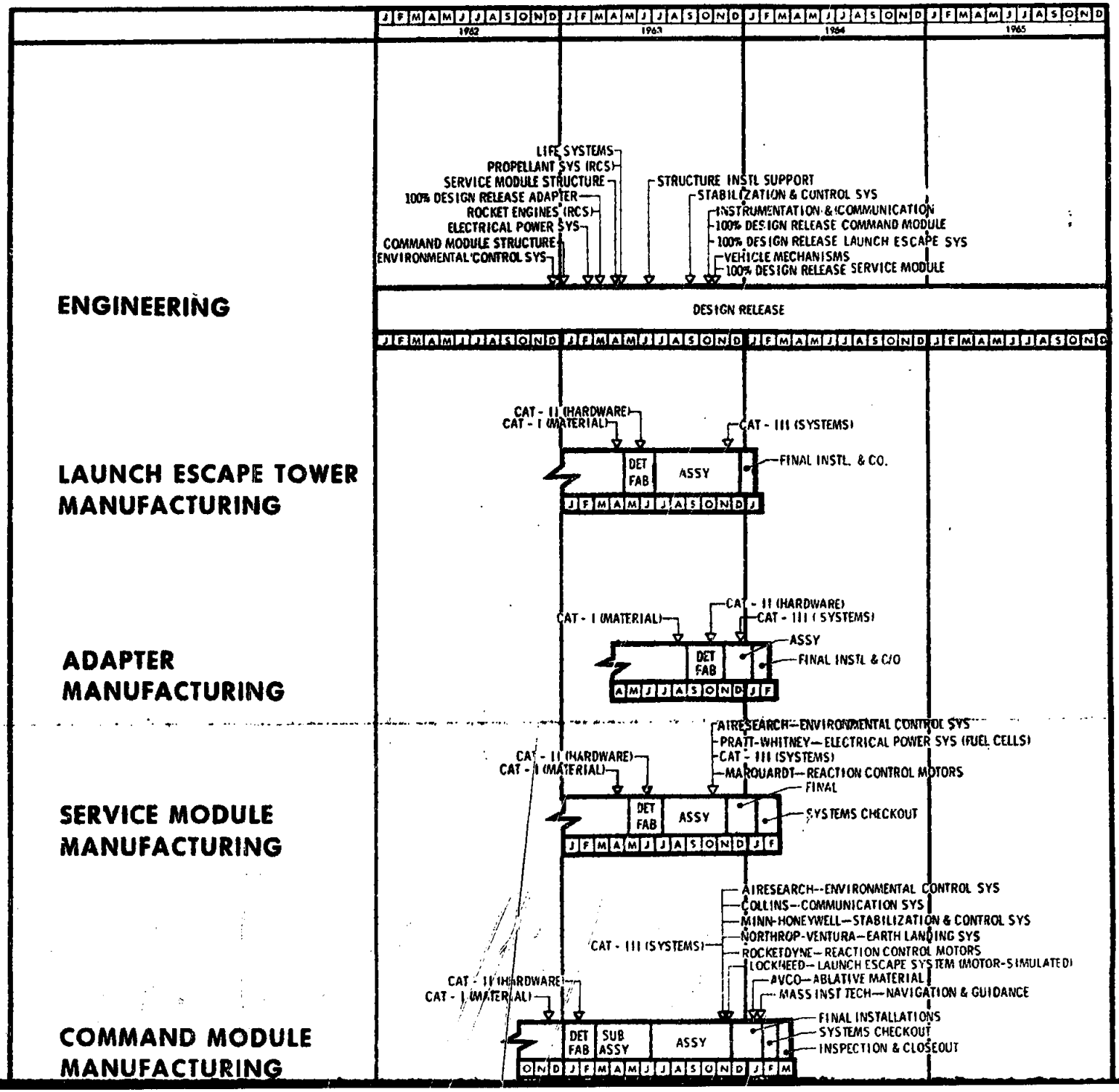
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS TO BE INCLUDED IN SUBSEQUENT REVISIONS.

APPROVED BY
APOLLO PROGRAM CONTROL

M. Shannon

DATE: 12 OCT 1962

Figure 26. AFRM 005 Command Module for Static Test No. 2


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
ENGINEERING
LIFE SYSTEMS
PROPELLANT SYS (RCS)
SERVICE MODULE STRUCTURE
100% DESIGN RELEASE ADAPTER
ROCKET ENGINES (RCS)
ELECTRICAL POWER SYS
COMMAND MODULE STRUCTURE
ENVIRONMENTAL CONTROL SYS
STRUCTURE INSTL SUPPORT
STABILIZATION & CONTROL SYS
INSTRUMENTATION & COMMUNICATION
100% DESIGN RELEASE COMMAND MODULE
100% DESIGN RELEASE LAUNCH ESCAPE SYS
VEHICLE MECHANISMS
100% DESIGN RELEASE SERVICE MODULE
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT - II (HARDWARE)
CAT - I (MATERIAL)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL. & CO.
ADAPTER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
ASSY
DET FAB
FINAL INSTL & C/O
SERVICE MODULE MANUFACTURING
AIRESEARCH—ENVIRONMENTAL CONTROL SYS
PRATT-WHITNEY—ELECTRICAL POWER SYS (FUEL CELLS)
CAT - III (SYSTEMS)
MARQUARDT—REACTION CONTROL MOTORS
CAT - II (HARDWARE)
CAT - I (MATERIAL)
FINAL
DET FAB
ASSY
SYSTEMS CHECKOUT
COMMAND MODULE MANUFACTURING
AIRESEARCH—ENVIRONMENTAL CONTROL SYS
COLLINS—COMMUNICATION SYS
MINN-HONEYWELL—STABILIZATION & CONTROL SYS
NORTHROP-VENTURA—EARTH LANDING SYS
CAT - III (SYSTEMS)
ROCKETDYNE—REACTION CONTROL MOTORS
LOCKHEED—LAUNCH ESCAPE SYSTEM (MOTOR-SIMULATED)
AVCO—ABLATIVE MATERIAL
MASS INST TECH—NAVIGATION & GUIDANCE
CAT - II (HARDWARE)
CAT - I (MATERIAL)
FINAL INSTALLATIONS
SYSTEMS CHECKOUT
INSPECTION & CLOSEOUT
DET FAB
SUB ASSY
ASSY

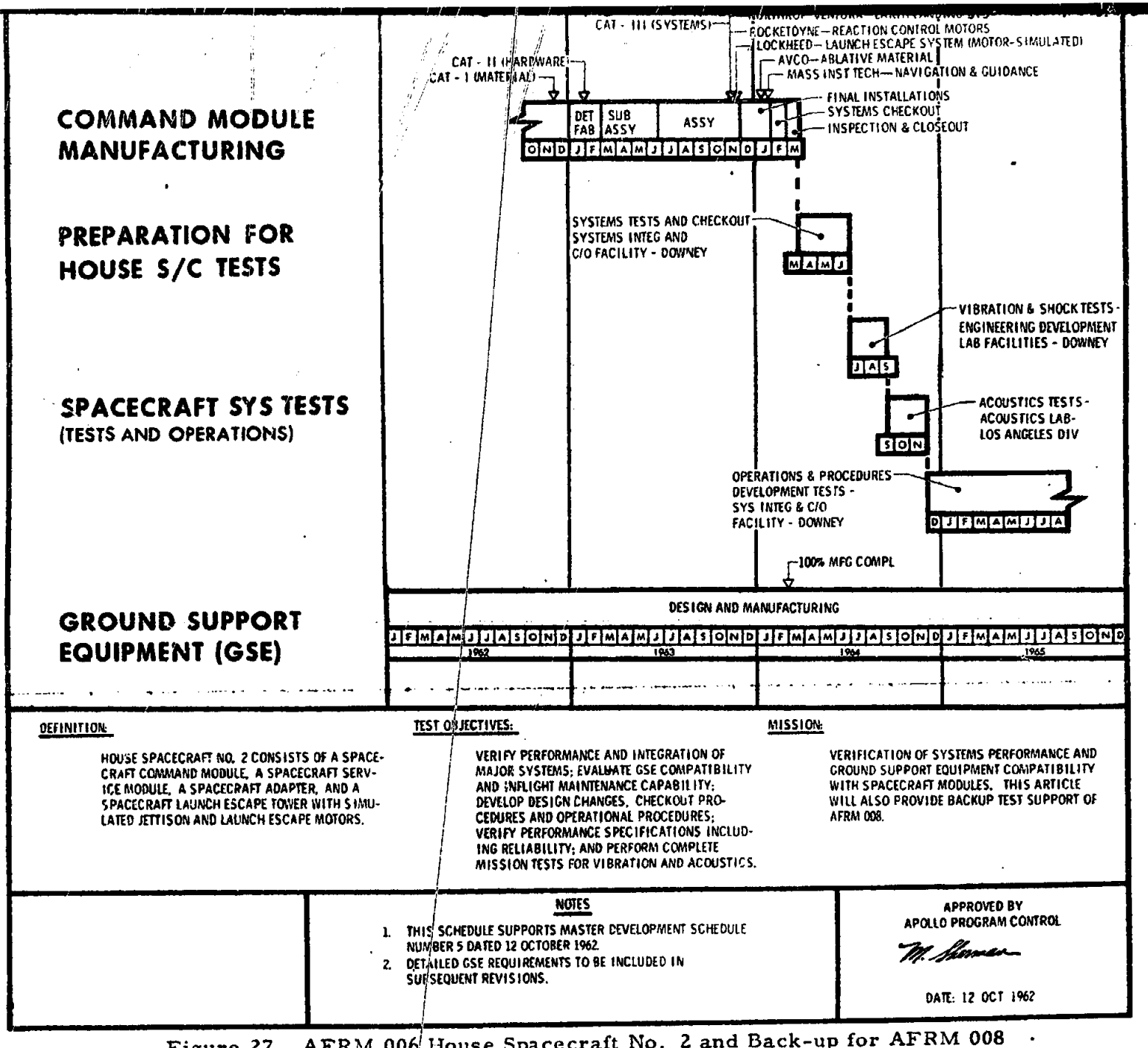
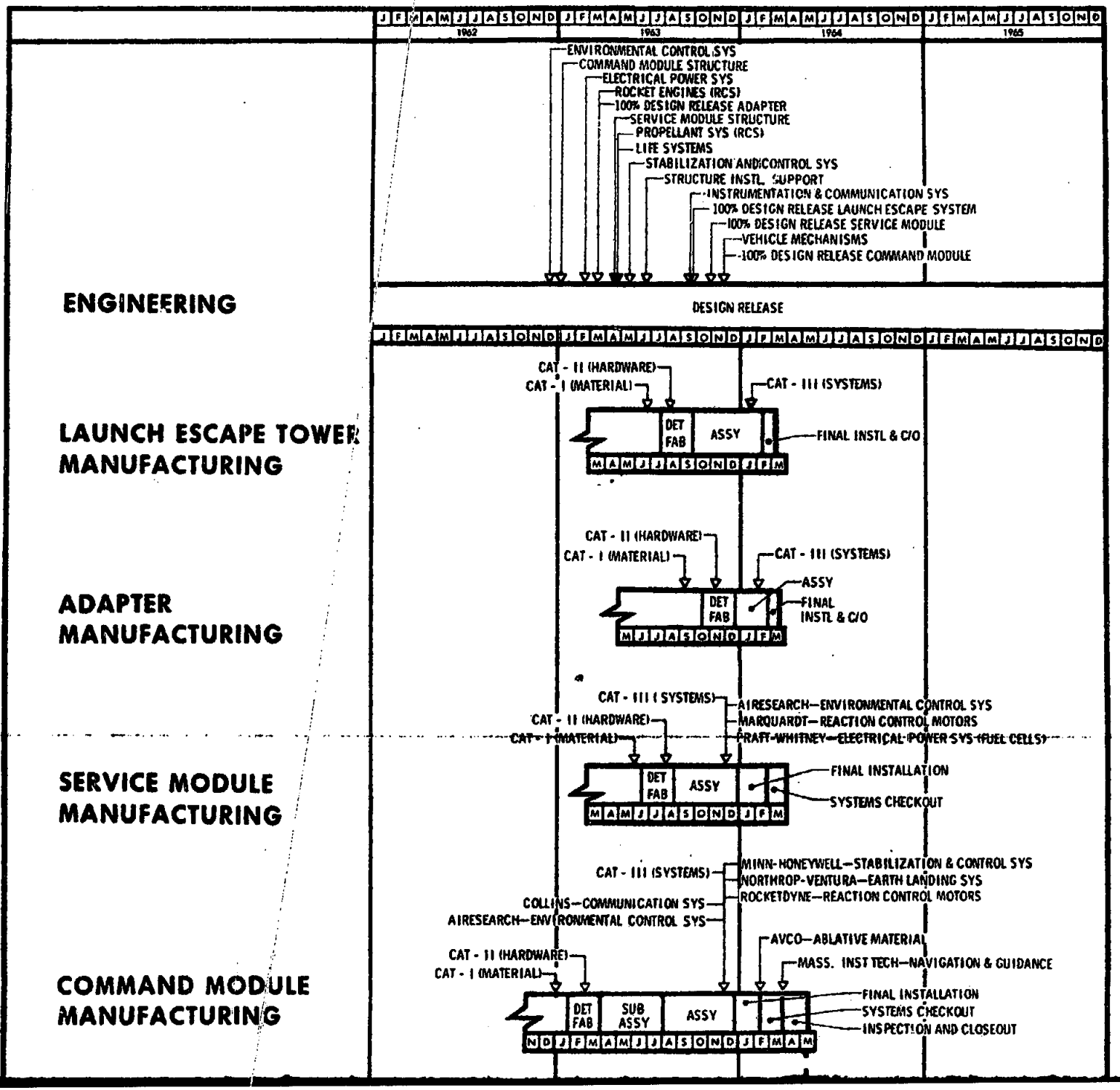
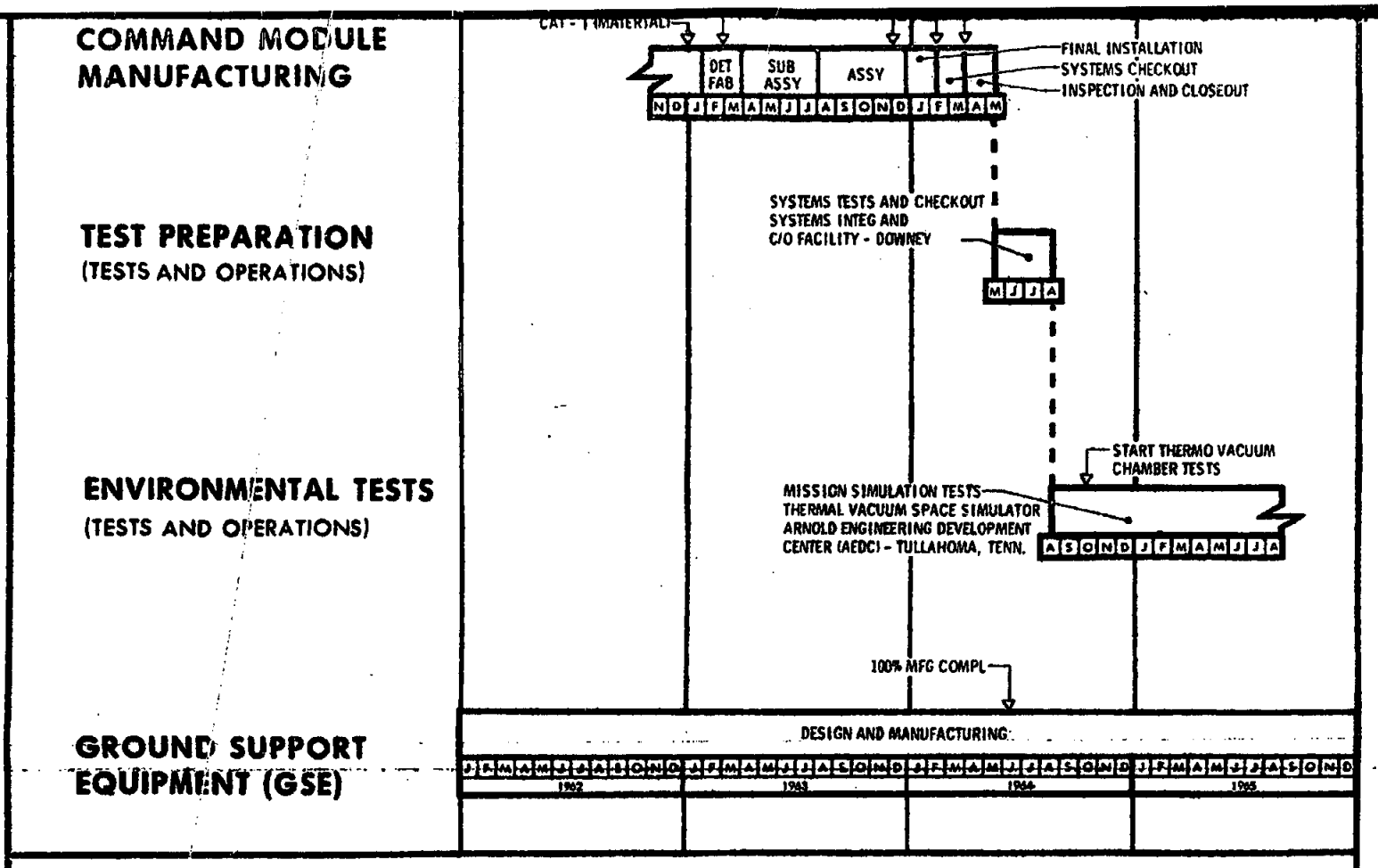


Figure 27. AFRM 006 House Spacecraft No. 2 and Back-up for AFRM 008


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
ENVIRONMENTAL CONTROL SYS
COMMAND MODULE STRUCTURE
ELECTRICAL POWER SYS
ROCKET ENGINES (RCS)
100% DESIGN RELEASE ADAPTER
SERVICE MODULE STRUCTURE
PROPELLANT SYS (RCS)
LIFE SYSTEMS
STABILIZATION AND CONTROL SYS
STRUCTURE INSTL. SUPPORT
INSTRUMENTATION & COMMUNICATION SYS
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
100% DESIGN RELEASE SERVICE MODULE
VEHICLE MECHANISMS
100% DESIGN RELEASE COMMAND MODULE
ENGINEERING
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT - II (HARDWARE)
CAT - I (MATERIAL)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
ADAPTER MANUFACTURING
CAT - II (HARDWARE)
CAT - I (MATERIAL)
CAT - III (SYSTEMS)
ASSY
DET FAB
FINAL INSTL & C/O
SERVICE MODULE MANUFACTURING
CAT - III (SYSTEMS)
AIRESEARCH—ENVIRONMENTAL CONTROL SYS
MARQUARDT—REACTION CONTROL MOTORS
PRATT-WHITNEY—ELECTRICAL POWER SYS (FUEL CELLS)
CAT - II (HARDWARE)
CAT - I (MATERIAL)
DET FAB
ASSY
FINAL INSTALLATION
SYSTEMS CHECKOUT
COMMAND MODULE MANUFACTURING
CAT - III (SYSTEMS)
MINN-HONEYWELL—STABILIZATION & CONTROL SYS
NORTHROP-VENTURA—EARTH LANDING SYS
ROCKETDYNE—REACTION CONTROL MOTORS
COLLINS—COMMUNICATION SYS
AIRESEARCH—ENVIRONMENTAL CONTROL SYS
AVCO—ABLATIVE MATERIAL
MASS. INST TECH—NAVIGATION & GUIDANCE
CAT - II (HARDWARE)
CAT - I (MATERIAL)
DET FAB
SUB ASSY
ASSY
FINAL INSTALLATION
SYSTEMS CHECKOUT
INSPECTION AND CLOSEOUT



DEFINITION:

THE ENVIRONMENT PROOF SPACECRAFT CONSISTS OF A SPACECRAFT COMMAND MODULE, A SPACECRAFT SERVICE MODULE, AND A SPACECRAFT ADAPTER. THIS ARTICLE SHALL HAVE COMPLETE SPACECRAFT SYSTEMS.

TEST OBJECTIVES:

QUALITY DESIGN OF THE ASSEMBLED SPACECRAFT SYSTEMS TO WITHSTAND ENVIRONMENTAL CONDITIONS DURING THE FOLLOWING PHASES: PRE-LAUNCH, LAUNCH, BOOST, SEPARATION, EARTH ORBIT, REENTRY, EARTH LANDING, AND RECOVERY. SUBSEQUENT TO THE FIRST MANNED FLIGHT, ADDITIONAL TESTS WILL BE CONDUCTED SIMULATING LUNAR AND CISLUNAR ENVIRONMENTS.

MISSION:

VERIFICATION OF SPACECRAFT SYSTEMS FOR THE COMPLETE SPACECRAFT UNDER SIMULATED MISSION ENVIRONMENTS.

NOTES

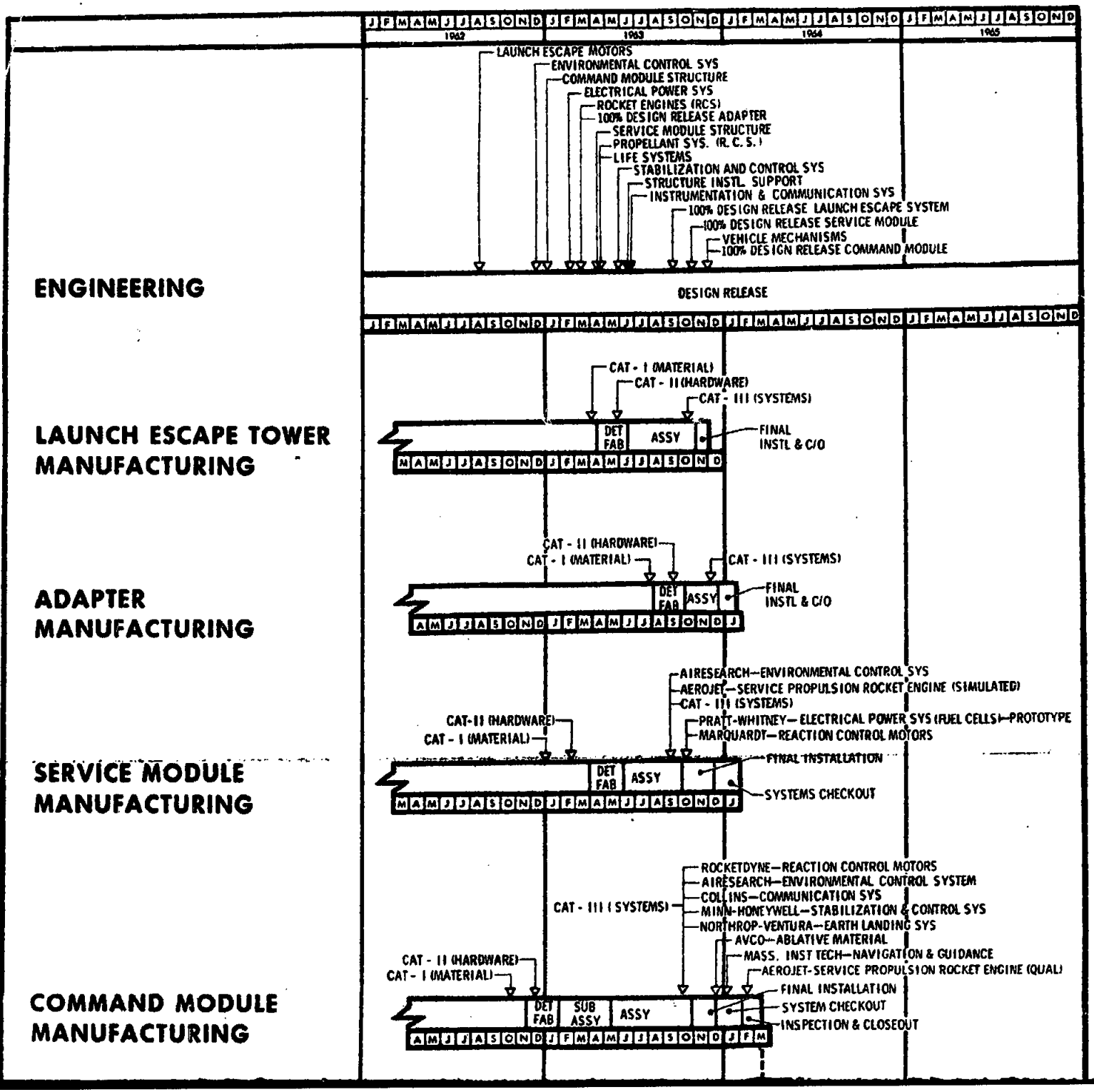
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS TO BE INCLUDED IN SUBSEQUENT REVISIONS.

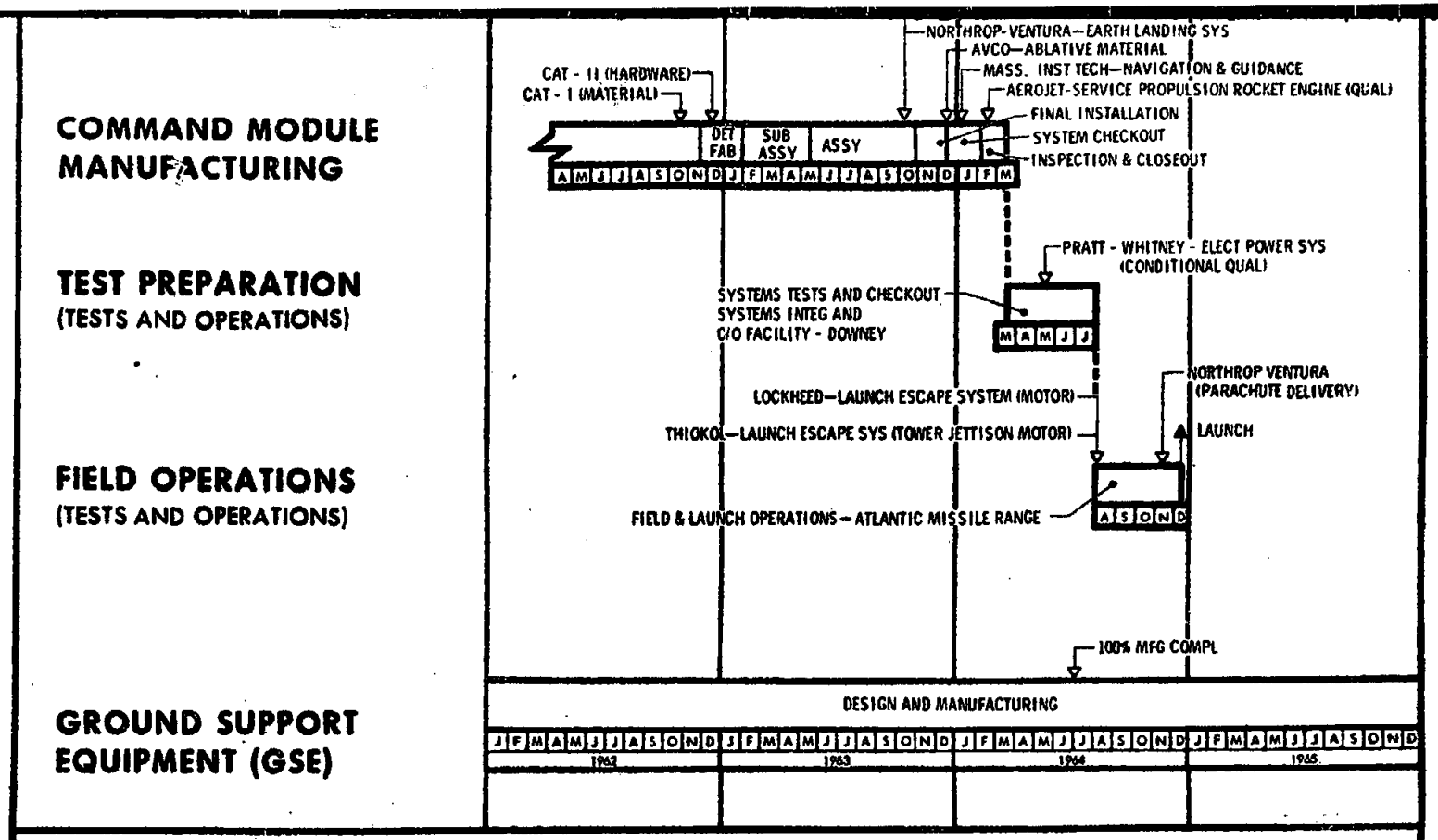
APPROVED BY
APOLLO PROGRAM CONTROL

M. Sherman

DATE: 12 OCT 1962

Figure 28. AFRM 008 Spacecraft for Environmental Proof


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
LAUNCH ESCAPE MOTORS
ENVIRONMENTAL CONTROL SYS
COMMAND MODULE STRUCTURE
ELECTRICAL POWER SYS
ROCKET ENGINES (RCS)
100% DESIGN RELEASE ADAPTER
SERVICE MODULE STRUCTURE
PROPELLANT SYS. (R. C. S.)
LIFE SYSTEMS
STABILIZATION AND CONTROL SYS
STRUCTURE INSTL. SUPPORT
INSTRUMENTATION & COMMUNICATION SYS
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
100% DESIGN RELEASE SERVICE MODULE
VEHICLE MECHANISMS
100% DESIGN RELEASE COMMAND MODULE
ENGINEERING
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
ADAPTER MANUFACTURING
CAT - II (HARDWARE)
CAT - I (MATERIAL)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
SERVICE MODULE MANUFACTURING
AIRESEARCH—ENVIRONMENTAL CONTROL SYS
AEROJET—SERVICE PROPULSION ROCKET ENGINE (SIMULATED)
CAT - III (SYSTEMS)
PRATT-WHITNEY—ELECTRICAL POWER SYS (FUEL CELLS)—PROTOTYPE
MARQUARDT—REACTION CONTROL MOTORS
CAT-II (HARDWARE)
CAT - I (MATERIAL)
DET FAB
ASSY
FINAL INSTALLATION
SYSTEMS CHECKOUT
COMMAND MODULE MANUFACTURING
ROCKETDYNE—REACTION CONTROL MOTORS
AIRESEARCH—ENVIRONMENTAL CONTROL SYSTEM
COLLINS—COMMUNICATION SYS
CAT - III (SYSTEMS)
MINN-HONEYWELL—STABILIZATION & CONTROL SYS
NORTHROP-VENTURA—EARTH LANDING SYS
AVCO—ABLATIVE MATERIAL
MASS. INST TECH—NAVIGATION & GUIDANCE
AEROJET-SERVICE PROPULSION ROCKET ENGINE (QUAL)
CAT - II (HARDWARE)
CAT - I (MATERIAL)
DET FAB
SUB ASSY
ASSY
FINAL INSTALLATION
SYSTEM CHECKOUT
INSPECTION & CLOSEOUT



DEFINITION:

THIS VEHICLE IS THE FIRST MANNED SPACECRAFT SUBORBITAL FLIGHT FOR QUALIFICATION OF SPACECRAFT SYSTEMS. IT WILL CONSIST OF A COMMAND MODULE, SERVICE MODULE, ADAPTER, LAUNCH ESCAPE SYSTEM, AND A SATURN C-1 BOOSTER.

TEST OBJECTIVES:

PRIMARY:
DEMONSTRATE C-1 LAUNCH VEHICLE AND SPACECRAFT READINESS FOR MANNED PARTICIPATION IN ORBITAL FLIGHT AND RECOVERY OPERATION; DEMONSTRATE AND EVALUATE READINESS OF THE RECOVERY COMPLEX; EVALUATE VIBRATION MODES OF THE SPACECRAFT; QUALIFY THE SERVICE MODULE PROPULSION SYSTEM IN SPACE FLIGHT, AND HEAT SHIELD FOR REENTRY.

SECONDARY:
DEMONSTRATE SEPARATION CAPABILITY FOR ORBITAL FLIGHT; EVALUATE AND QUALIFY THE ABORT CAPABILITY USING SERVICE MODULE PROPULSION SYSTEM; EVALUATE CREW SHOCK ABSORPTION SYSTEM; EVALUATE STABILITY, CONTROL, AND REACTION CONTROL SYSTEMS, AND EVALUATE FUEL CELL MODULE UNDER ZERO "g".

MISSION:

QUALIFICATION OF THE LAUNCH VEHICLE, THE SPACECRAFT AND ESSENTIAL SPACECRAFT SYSTEMS FOR MANNED ORBITAL FLIGHT.

NOTES

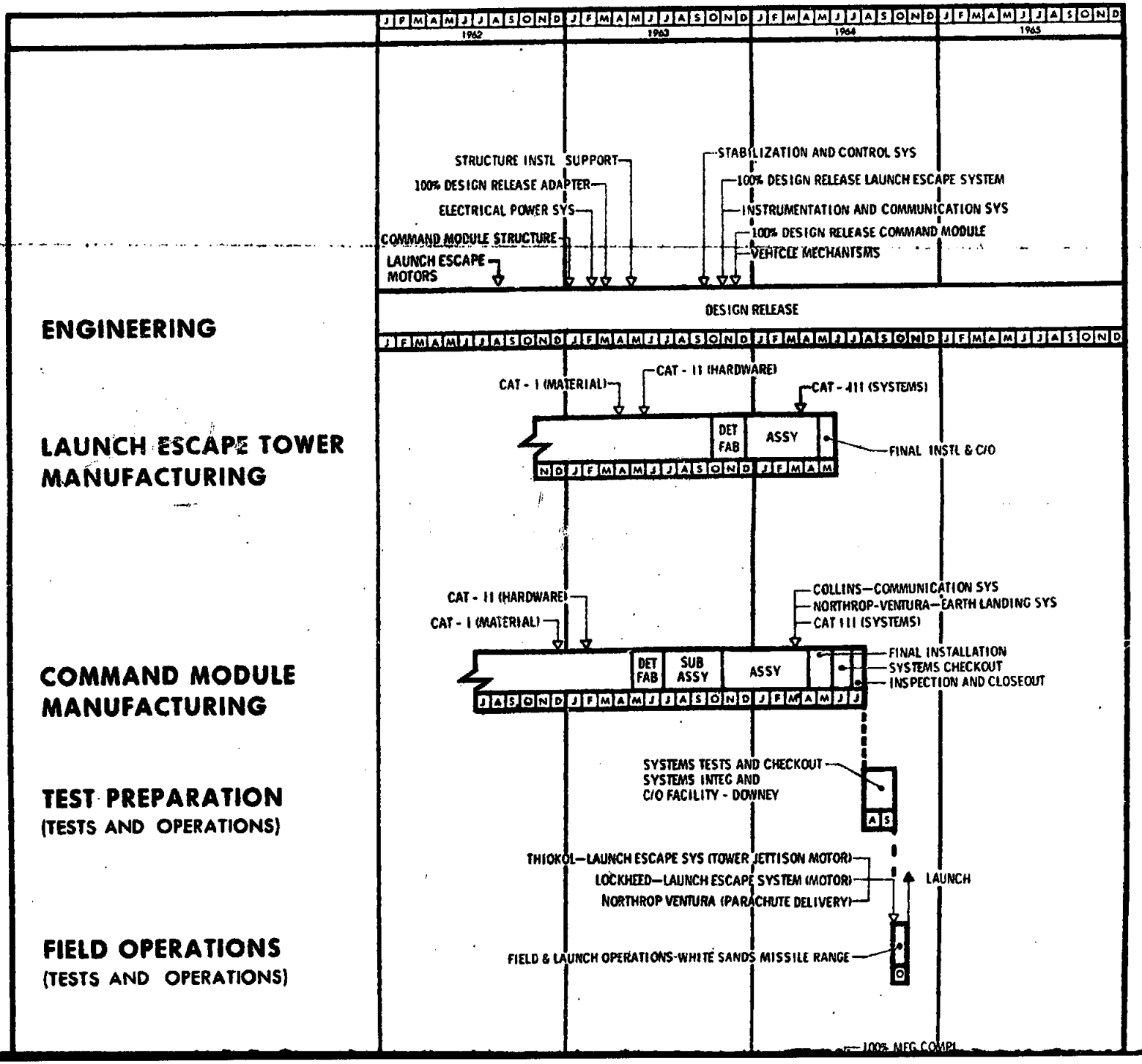
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS AND AMR LAUNCH SITE COMPLETION TO BE INCLUDED IN SUBSEQUENT REVISIONS.

APPROVED BY
APOLLO PROGRAM CONTROL

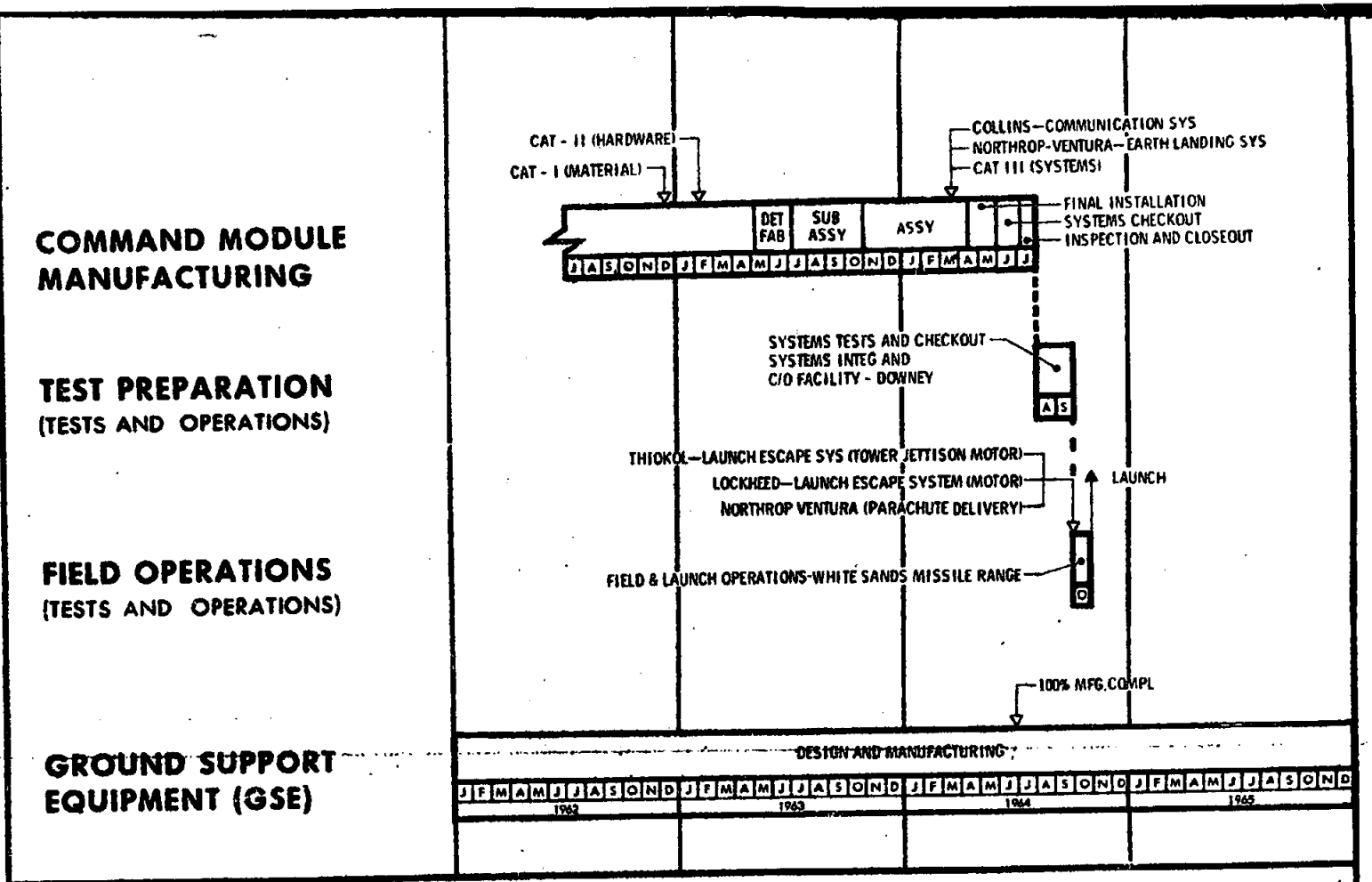
M. Sherman

DATE: 12 OCT 1962

Figure 29. AFRM 009 Spacecraft for First Manned Flight and Service Model Qualifications (SA-111)



NORTH AMERICAN AVIATION, INC.



DEFINITION:

THE PAD ABORT SPACECRAFT CONSISTS OF A COMMAND MODULE (SPACECRAFT STRUCTURE WITH AFT HEAT SHIELD - NO ABLATIVE MATERIAL); A GROUND ADAPTER; AND A SPACECRAFT LAUNCH ESCAPE TOWER WITH LIVE JETTISON AND LAUNCH ESCAPE MOTORS.

TEST OBJECTIVES:

EVALUATE AND QUALIFY THE LAUNCH ESCAPE SYSTEM BY DETERMINATION OF THE JET EFFECTS ON THE COMMAND MODULE; EVALUATION OF STABILITY MARGINS, LAUNCH ESCAPE TOWER JETTISON DYNAMICS, CONTROL SYSTEM OPERATIONS AND STRUCTURAL INTEGRITY.

MISSION:

QUALIFICATION OF LAUNCH ESCAPE SYSTEM FOR PAD ABORT.

NOTES

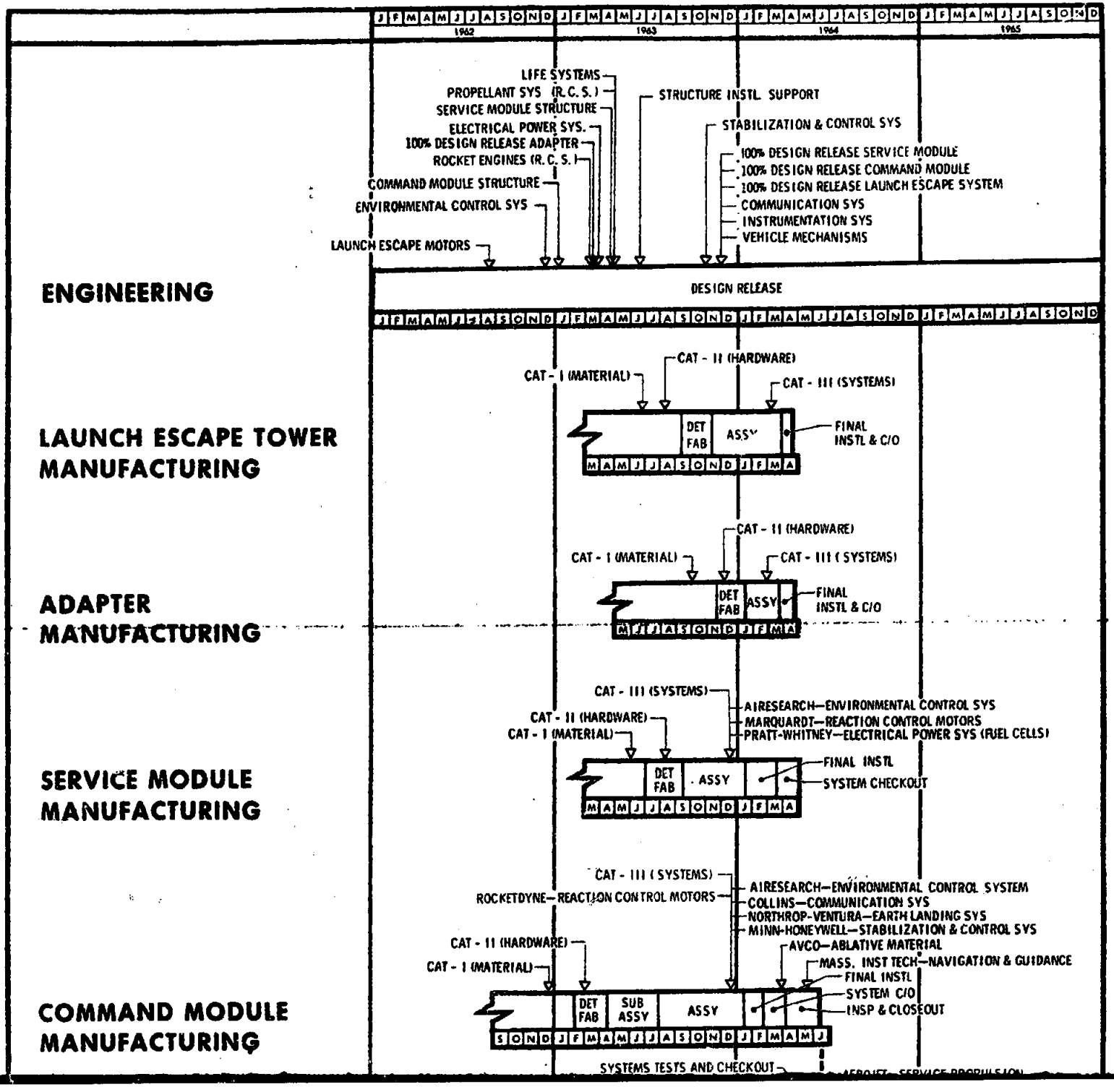
1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS TO BE INCLUDED IN SUBSEQUENT REVISIONS.
3. PAD ABORT ADAPTER FOR B-6 WILL BE REFURBISHED FOR USE WITH AFRM 010.

APPROVED BY
APOLLO PROGRAM CONTROL

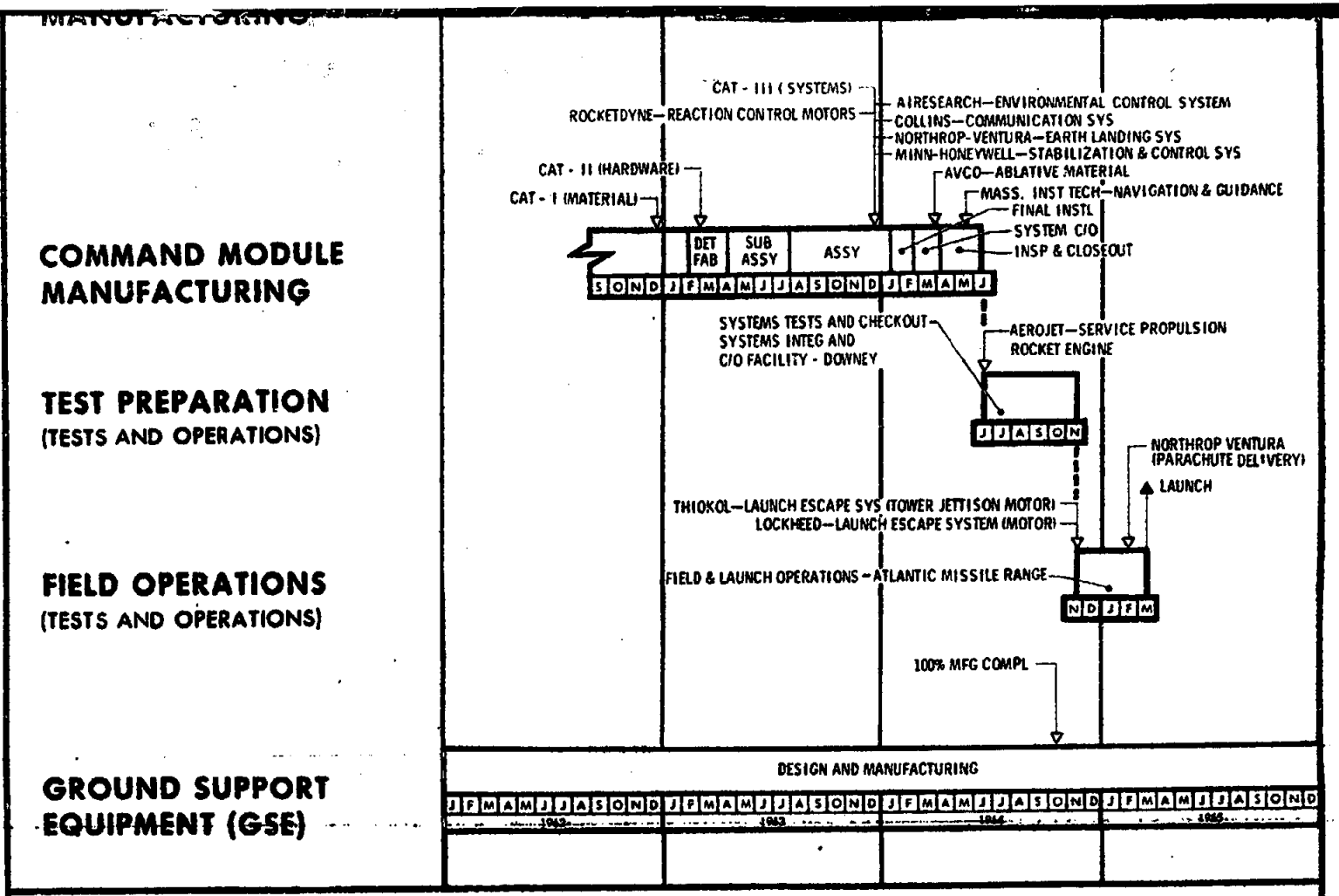
M. Sherman

DATE: 12 OCT 1962

Figure 30. AFRM 010 Command Module for Pad Abort


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
LIFE SYSTEMS
PROPELLANT SYS (R.C.S.)
SERVICE MODULE STRUCTURE
ELECTRICAL POWER SYS.
100% DESIGN RELEASE ADAPTER
ROCKET ENGINES (R.C.S.)
COMMAND MODULE STRUCTURE
ENVIRONMENTAL CONTROL SYS
LAUNCH ESCAPE MOTORS
STRUCTURE INSTL. SUPPORT
STABILIZATION & CONTROL SYS
100% DESIGN RELEASE SERVICE MODULE
100% DESIGN RELEASE COMMAND MODULE
100% DESIGN RELEASE LAUNCH ESCAPE SYSTEM
COMMUNICATION SYS
INSTRUMENTATION SYS
VEHICLE MECHANISMS
ENGINEERING
DESIGN RELEASE
LAUNCH ESCAPE TOWER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
ADAPTER MANUFACTURING
CAT - I (MATERIAL)
CAT - II (HARDWARE)
CAT - III (SYSTEMS)
DET FAB
ASSY
FINAL INSTL & C/O
SERVICE MODULE MANUFACTURING
CAT - III (SYSTEMS)
CAT - II (HARDWARE)
CAT - I (MATERIAL)
AIRESEARCH—ENVIRONMENTAL CONTROL SYS
MARQUARDT—REACTION CONTROL MOTORS
PRATT-WHITNEY—ELECTRICAL POWER SYS (FUEL CELLS)
DET FAB
ASSY
FINAL INSTL
SYSTEM CHECKOUT
COMMAND MODULE MANUFACTURING
CAT - III (SYSTEMS)
ROCKETDYNE—REACTION CONTROL MOTORS
AIRESEARCH—ENVIRONMENTAL CONTROL SYSTEM
COLLINS—COMMUNICATION SYS
NORTHROP-VENTURA—EARTH LANDING SYS
MINN-HONEYWELL—STABILIZATION & CONTROL SYS
AVCO—ABLATIVE MATERIAL
MASS. INST TECH—NAVIGATION & GUIDANCE
CAT - II (HARDWARE)
CAT - I (MATERIAL)
FINAL INSTL
SYSTEM C/O
INSP & CLOSEOUT
DET FAB
SUB ASSY
ASSY
SYSTEMS TESTS AND CHECKOUT
AEROJET—SERVICE PROPULSION

NORTH



DEFINITION:

THE SECOND MANNED EARTH ORBITAL RECOVERABLE SPACECRAFT CONSISTS OF A SPACECRAFT COMMAND MODULE, A SPACECRAFT SERVICE MODULE (OPTIMIZED FOR LOR CONFIGURATION), A SPACECRAFT ADAPTER, AND A SPACECRAFT LAUNCH ESCAPE SYSTEM. COMPLETE SPACECRAFT SYSTEMS WILL BE INSTALLED.

TEST OBJECTIVES:

VERIFY THE CAPABILITY OF A MANNED SPACECRAFT TO COMPLETE AN ORBITAL MISSION; VERIFY THE OPERATION OF GOSS WITH MANNED SPACECRAFT; EVALUATE MULTIMAN INFLIGHT CREW REACTION; AND VERIFY THE CAPABILITY OF THE MANNED SPACECRAFT RECOVERY COMPLEX.

MISSION:

VERIFICATION OF FEASIBILITY FOR MULTIMANNED ORBITAL SPACE FLIGHT AND SAFE EARTH RECOVERY.

NOTES

1. THIS SCHEDULE SUPPORTS MASTER DEVELOPMENT SCHEDULE NUMBER 5 DATED 12 OCTOBER 1962.
2. DETAILED GSE REQUIREMENTS AND AMR LAUNCH SITE COMPLETION TO BE INCLUDED IN SUBSEQUENT REVISIONS.

APPROVED BY
APOLLO PROGRAM CONTROL

M. Sherman

DATE: 12 OCT 1962

Figure 31. AFRM 011 Spacecraft for Second Manned Flight, Earth Orbital (SA-112)

[redacted]

PROCEDURES

Clearly stated, fully applied policies and procedures improve performance, reduce costs, save time, and promote effective use of management ability by reducing the number of problems created through inconsistent methods of operation. Written procedures are particularly beneficial when an inflow of new personnel must be planned to meet program schedule objectives. Particular attention has been given to reviewing and updating established S&ID procedures to reflect the most recent concepts of organization and control and to meet the requirements of new programs, such as Apollo.

Since the procedural framework is an important part of the overall management plan, a partial list of S&ID procedures is included for reference. These procedures are effective for all programs including Apollo, except where specific conflicts exist with the negotiated contract provisions.

GENERAL

A-401	S&ID Policies and Procedures
A-401.1	NAA Company Directives
A-401.2	Central Functional Area Manuals
A-402	Organizational Planning
A-404.2	Transmittal of Technical Data
A-407	S&ID Forms
A-410	Company Addresses
A-422	Government Reports Coordination
A-424	S&ID Reliability Program
A-424.1	Malfunction and Problem Reporting
A-424.2	Supplier Analysis of Components
A-426	Release of Technical Information
A-429	S&ID PERT Programs

CONTRACTS

B-401	Interdivision Work Authorization
B-403	Transfer of Work to Integrated Facilities
B-406	General Orders and Sales Orders

[redacted]

[redacted]

B-411	Government Property
B-411.1	Establishing Requirements
B-411.2	Procurement
B-411.3	Receiving
B-411.4	Warehousing
B-411.5	Maintenance and Calibration
B-411.6	Property Control Records
B-411.7	Physical Inventory
B-411.8	Disposition
B-413	Government Property in Possession of Subcontractors
B-419	Loss, Damage, Destruction, or Consumption of Government Property

ENGINEERING

C-401	S&ID Drawing Systems
C-401.1	Standard Drawing Release System
C-401.2	Control Print System
C-401.3	Block Time System
C-403	Process Specifications
C-403.1	Quality Control Specifications
C-404	Procured Parts and Equipment Documentation
C-404.1	Military and Standard Equipment Specifications
C-404.2	Specification Control Drawings
C-404.3	Procurement Specifications
C-404.4	Approved Source Lists
C-405	Material Specifications
C-405.1	Qualified Source List
C-407	Request for Drawing Change
C-409	Preparation and Release of the Interchangeability and Replaceability Report
C-413	Laboratory Notebooks
C-417	Preparation, Release, and Distribution of Technical Reports
C-431	S&ID Engineering Memos to Subcontractors
C-432	Engineering Change Control
C-432.1	Authorization for Engineering Changes (MCR)
C-432.2	Preparation and Submittal of Engineering Changes to the Customer

ACCOUNTING

D-402	General Order Bulletins
D-410	Budgetary Controls

[redacted]

[redacted]

PERSONNEL

E-407	Recruiting of Personnel
E-410	Equal Employment Opportunity
E-411	Standard Work Periods and Pay Provisions
E-414	Vacation, Sick Leave, and Holiday Allowances
E-417	Trips and Expense Reports
E-417.1	Domestic Assignments
E-417.2	Domestic Field Service Assignments
E-417.3	Foreign Field Service and Related Assignments
E-417.4	Foreign Assignments
E-417.5	Down Range Assignment
E-417.8	Sea Assignments
E-418	New Hire Travel and Moving Allowances
E-422	Training and Certification
E-422.7	Product Support - Training
E-432	Presentation and Appeal of Employee Grievances

MANUFACTURING AND FACILITIES

F-403	Change Verification Record
F-403.1	Verification of Changes to Internal Parts of Assemblies
F-405	Functional Testing of Division Products
F-406	System Measuring Devices
F-408	Production Control Policy
F-408.1	Fabrication, Assembly, and Inspection Records (Fair)
F-408.2	Withholding and Processing Defective Parts
F-413	Control of Dimensional Tooling
F-413.2	Manufacture and Control of Contract Tooling Master Parts
F-417	Control of Government-Owned Aircraft on Bailment Contracts
F-419	Master Blueprint Station
F-420	Procurement Control of Bailment Property

MATERIAL

G-401	Material Operations
G-402.1	Procurement and Control of Nondimensional Tooling
G-408	Procurement Requests
G-410	Make or Buy Policies and Decisions
G-410.1	Subcontracting of Major Assembly Units
G-410.2	Minor Subcontracted Parts
G-410.5	Purchased Labor
G-410.6	Supplier Pre-Award Survey
G-410.7	Major Subcontracting Source Selection and Proposal Evaluation

[redacted]

G-410.8	Evaluation and Selection of Suppliers for Minor Subcontracts
G-412	Receiving Material
G-417	Sales of Government-Owned Property
G-421	Acquisitions and Receipt of Property Under Facilities Contracts

INDUSTRIAL SECURITY

H-401	Security Regulations and Responsibilities
H-401.2	Control of Classified Documents
H-403	Dissemination of Technical Information to Other Companies
H-405	Closed Area Control
H-407	Identification Cards and Badges
H-408	Removal of Property From Company Premises
H-419	Locking Equipment

QUALITY ASSURANCE

J-405	Corrective Action
J-405.1	Quality Verification Testing
J-406	Product Serial Numbers
J-412	Withholding Items From Use
J-413	Quality Performance
J-415	Inspection Records
J-416	Material Review Board
J-417	Quality Control Purchase Order Review

LOGISTICS

K-406	Stock replenishment Spares

[redacted]

[redacted]

II. TECHNICAL DEVELOPMENT PLAN

INTRODUCTION

The Technical Development Plan is an integral part of the Program Plan and is presented in accordance with part 4 of the Project Apollo Spacecraft Development Statement of work, 18 December 1961. In the present issue of the plan, emphasis is placed on approaches to systems design and development. Other technical areas associated with Project Apollo are presented to acquaint the reader with the technical scope of this project.

This issue includes a complete revision of the Technical Development Plan incorporating the approaches of technical development in flight technology, simulation, life systems, flight systems, GSE, training equipment, GOSS, and testing.

The general hardware makeup of the Apollo design analysis and test article development program will consist of 2 engineering simulators, 8 mock-ups, 15 boilerplates, and 9 spacecraft, through a second manned flight (airframe 011). This makeup is a result of direct negotiations with NASA.

[redacted]

APOLLO DEVELOPMENT PLAN

The objective of the Apollo spacecraft is manned lunar landing and lunar surface exploration through the use of the lunar orbital rendezvous technique. The spacecraft will be designed to accommodate a lunar landing mission duration of 14 days maximum, including a maximum lunar orbit duration of seven days.

As illustrated in Figure 32, the program to accomplish this objective is multiphase with firm short-term and tentative long-term developmental approaches for manned landing on the lunar surface and return to earth. This Technical Development Plan encompasses a firm plan for the Apollo spacecraft development and qualification through first manned earth-orbital flight and tentative plans for succeeding effort.

Utilization of the various launch vehicles for Apollo spacecraft qualifications is illustrated in this plan to demonstrate the developmental format for manned lunar landing and exploration.

The Apollo development consists of three consecutive, closely related phases to accomplish manned lunar landing and exploration. These are (1) manned earth-orbital qualification, (2) lunar qualification, and (3) lunar missions.

A firm program has been established for the earth-orbital qualification phase, during which the spacecraft systems will be developed and qualified prior to the first manned orbital flight. Prior to full systems qualification, intermediate technical development operations must be performed to ensure meeting the required high mission reliability. Spacecraft simulators, mock-ups (Figure 34), boilerplates, and spacecraft test articles for systems and structural evaluation, module compatibility demonstration, operational procedure and technique development, and systems qualifications will be employed during this phase. Subsequent effort to be performed for the other development phases are illustrated in Figure 33. Launch vehicles presently programmed for this phase are Little Joe II and Saturn C-1.

The program will include a series of ground tests and launch flights, fully integrated in both function and schedule, leading to complete qualification for the manned flight.

Ground tests, using boilerplate-type spacecraft began on 17 September 1962 with a series of land-water impact tests.

[redacted]

[redacted]

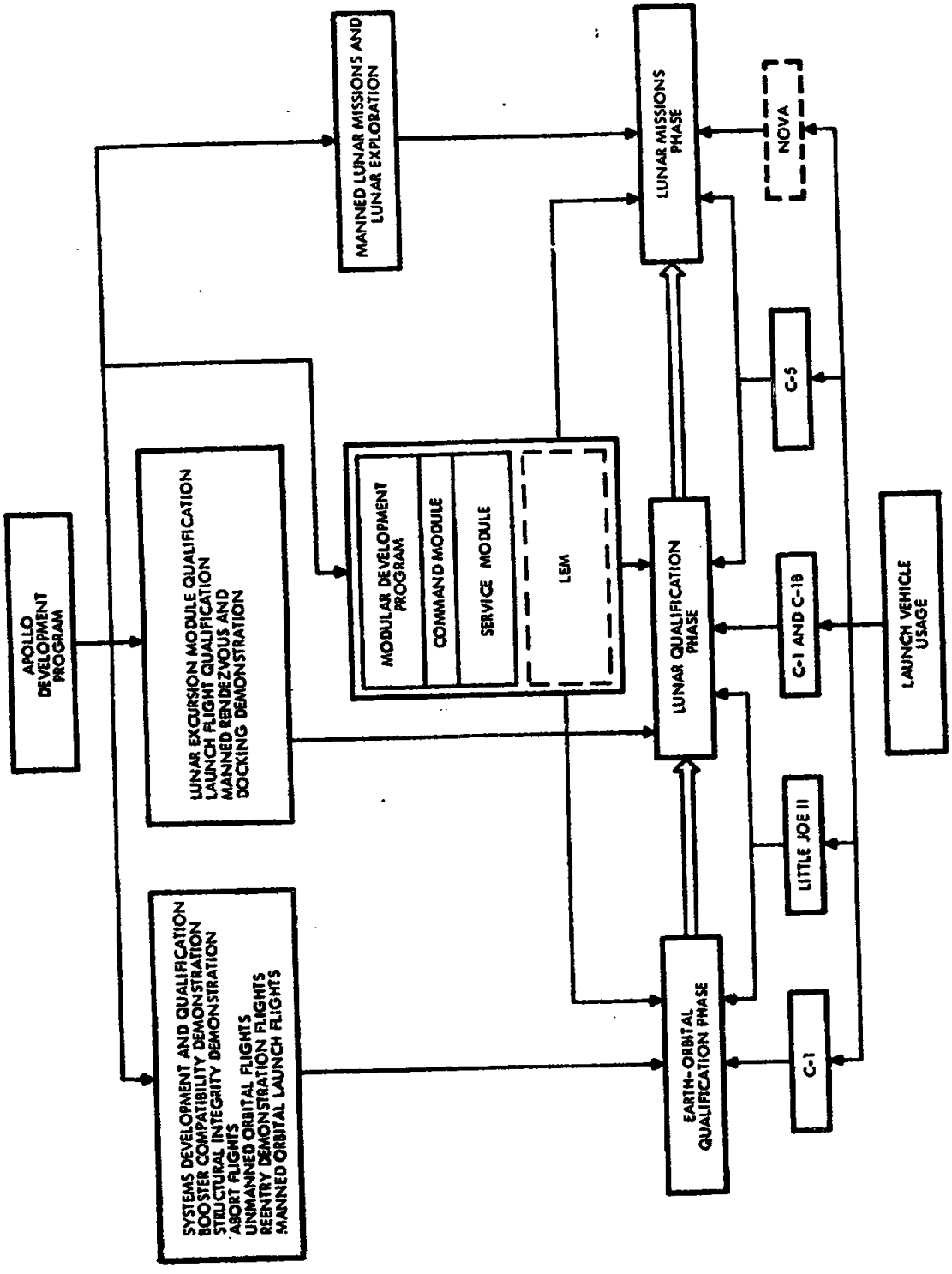


Figure 32. Apollo Development Program

[redacted]

[redacted]

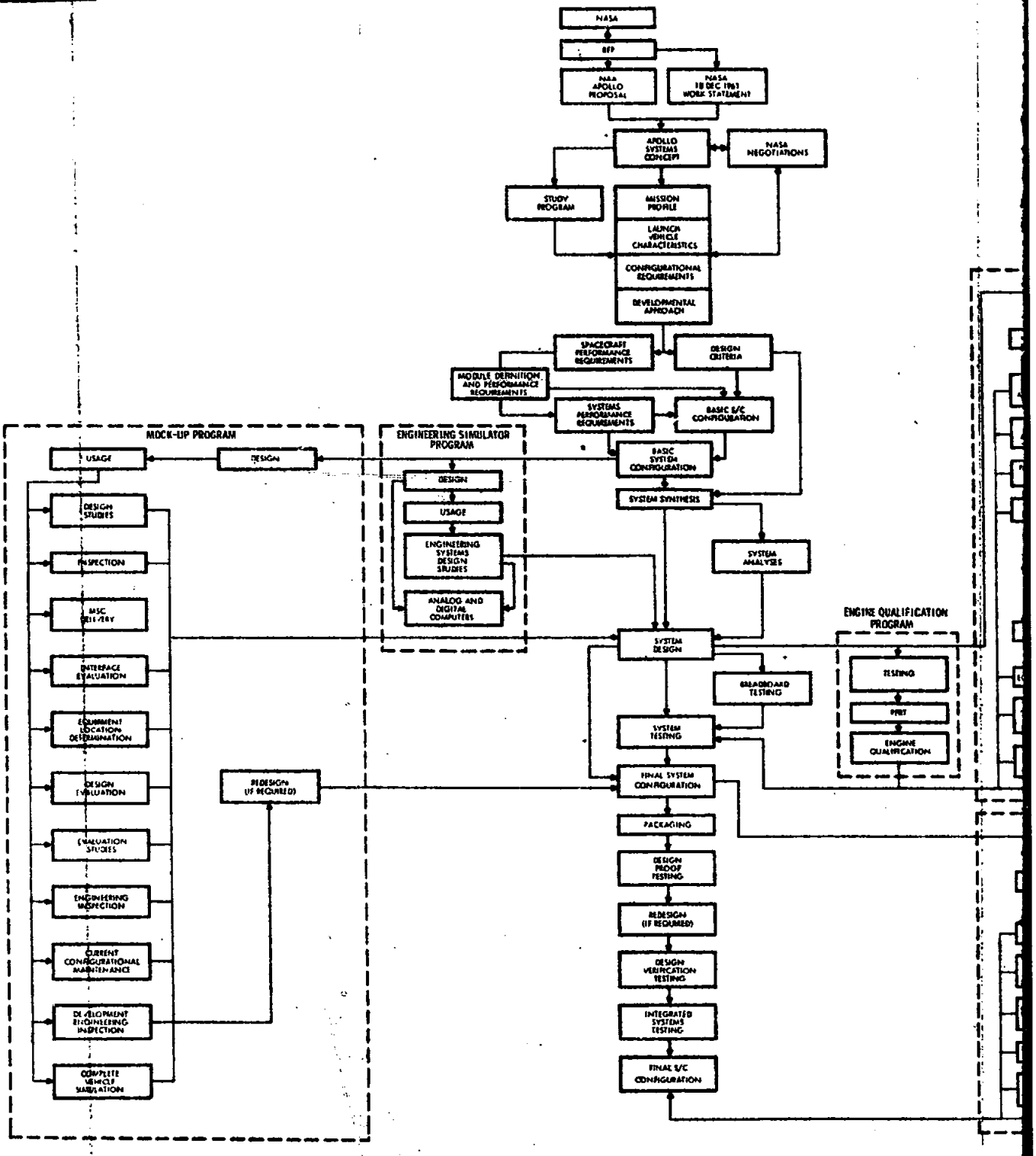


Figure 33. Apollo Spacecraft

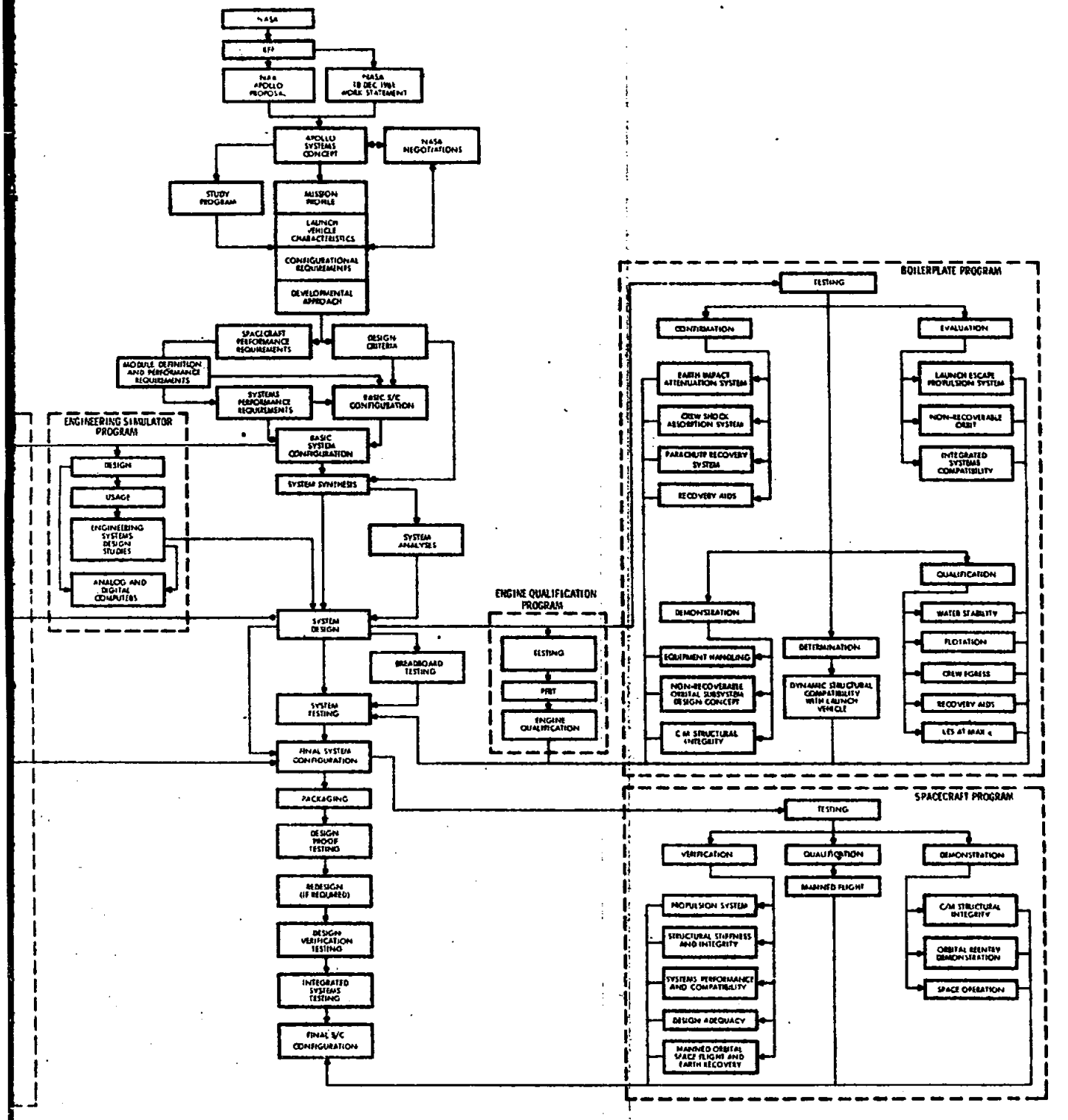


Figure 33. Apollo Spacecraft Development Schematic

[redacted]

[redacted]

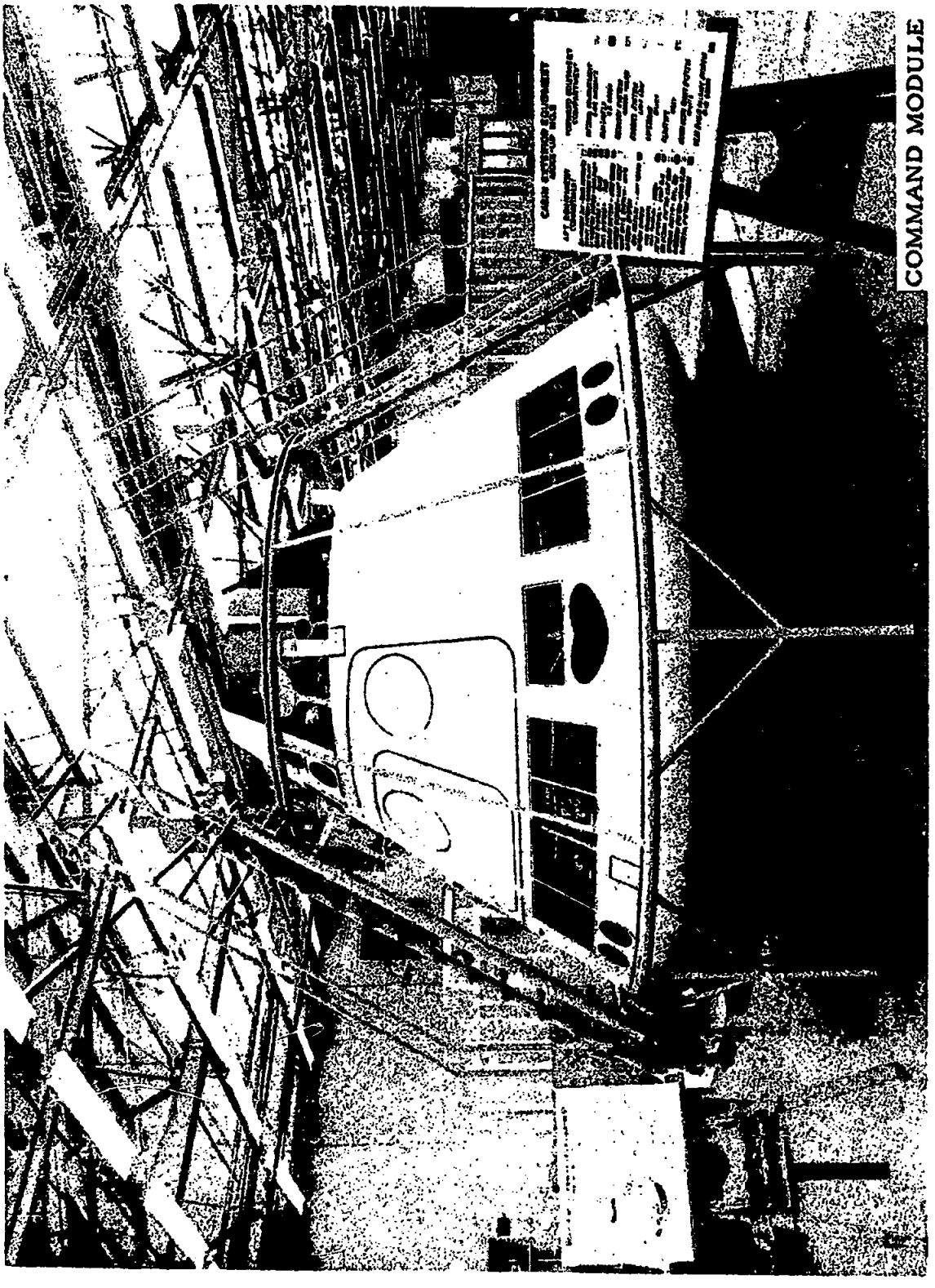


Figure 34. Mock-ups (Sheet 1 of 2)

[redacted]

[redacted]

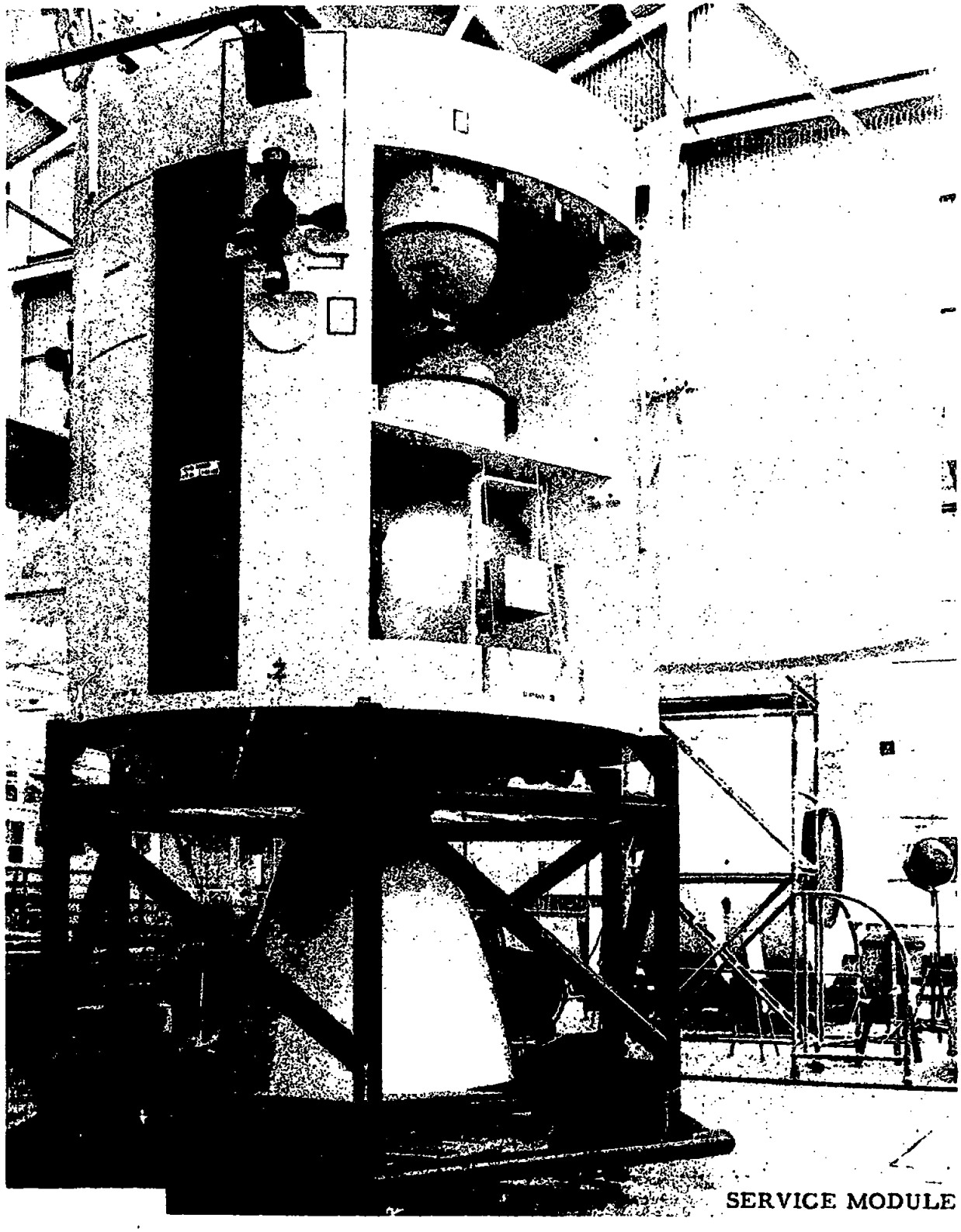


Figure 34. Mock-ups (Sheet 2 of 2)

[redacted]

[redacted]

The long series of abort tests will begin in mid-1963. This phase will be conducted using both boilerplates and spacecraft. The program will begin with the abort tests, which will include the pad abort and max q high-altitude aborts to evaluate and qualify the structural integrity of the command module and launch escape system function using Little Joe II at the White Sands Missile Range.

Coincident with the abort tests which start in May 1963, the flight tests to develop and qualify all the modules and systems of the spacecraft will begin. The modules qualified will be the command and service module. All the systems will be qualified not only for function and reliability, but for integration and compatibility. This series of tests will culminate in the first manned orbital flight in March, 1965.

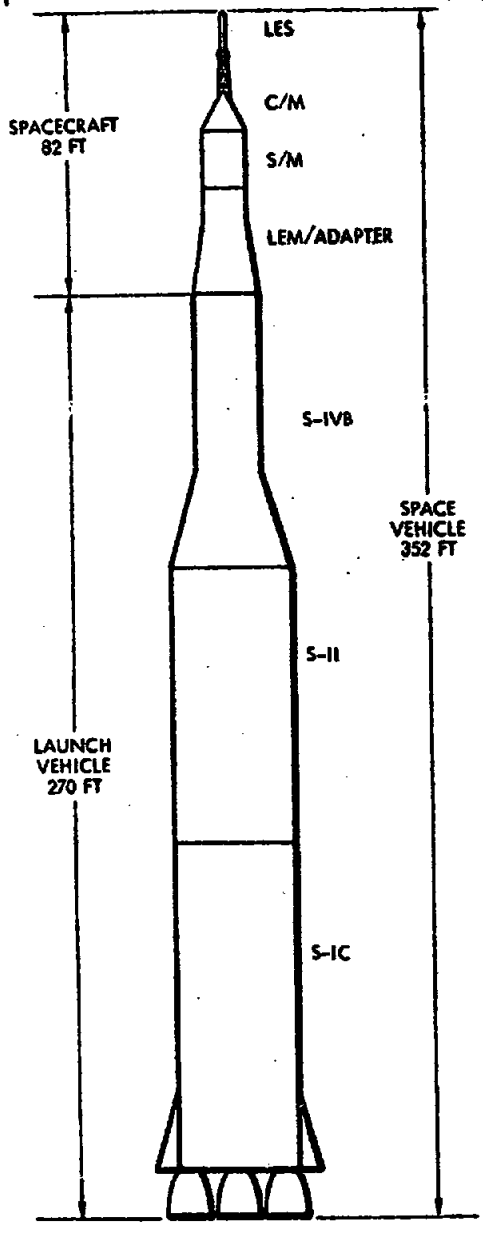
Initial manned earth-orbital missions will consist of low-altitude orbital flights of up to two weeks' duration. In the lunar qualification phase, the lunar excursion module will be employed to develop rendezvous, docking, and escape transition operations in space.

The lunar mission phase will involve further development of the command and service modules, closeup reconnaissance of the lunar surface, and lunar landing. The C-5 launch vehicle will be employed for these manned lunar missions. The lunar landing mission will utilize the lunar-orbital-rendezvous technique, and will involve the command module, service module, adapter, lunar excursion module, and a C-5 launch vehicle. Spacecraft configuration and specification information for this mission is shown in Figure 35.

Manned lunar missions will start in early 1967. The target date for the manned lunar landing is mid-1967.

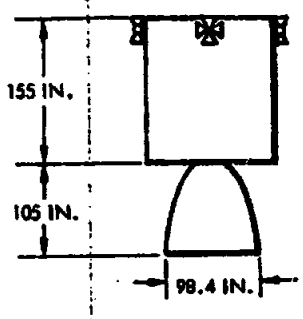
[redacted]

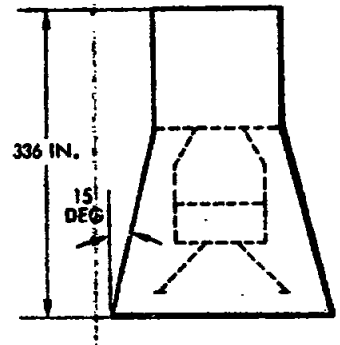
APOLLO SPACE VEHICLE



LAUNCH VEHICLE: SATURN C-5

STAGE	THRUST (LB)	I_{SP} (SEC)
S-IC	7,500,000 (SL)	263.58 (SL)
S-II	1,000,000	424
S-IVB	200,000	424





SERVICE MODULE:

GROSS TAKE-OFF WE
PROPELLANT (MAX)

S/M SYSTEMS:

SERVICE PROPULSI
NON-THROTTLE
VECTOR CONTR
PROPELLANTS:
OXIDIZER
FUEL
REACTION CONTR
TRANSLUNAR IN
CONSISTS OF:
QUAD SYSTEM
HELIUM PRESS
OXIDIZER
FUEL
THRUST
COMMUNICATIO
HIGH-GAIN AN
VOICE, TELEMET
STRUCTURAL - DE
ENVIRONMENTAL
SYSTEMS S/M C
SUPPLY, ASSOC
ELECTRICAL POWE
CONTAINS 3 FU

LUNAR EXCURSION

WEIGHT (W/O ADAP
ADAPTER
USABLE PROPELLANT

LEM SYSTEMS:

CREW
G&N
ECS
RCS
PROPULSION
C & I
SCS
SEPARATION
IN-FLIGHT TEST
STRUCTURAL
ELECTRICAL POW

PERFORMANCE

MISSION PHASE	PROPULSION	(FT/SEC)	S/C WEIGHT (LB)
EARTH BOOST TO ORBIT (100 NAUT MI)	C-5 (STAGES 1,2,3)	29,540	6,000,000
TRANSLUNAR INJECTION (MAX)	C-5 (STAGE 3)	10,446	275,531
TRANSLUNAR MIDCOURSE	S/M	310	86,740
LUNAR ORBIT INJECTION	S/M	4,028	84,160
LUNAR ORBIT TRANSFER	LEM	415	25,000
DE-ORBIT AND LANDING	LEM	7,330	23,996
LUNAR BOOST TO ORBIT	LEM	6,660	8,768
ORBIT TRANSFER AND RENDEZVOUS	LEM	220	4,545
S/C RENDEZVOUS (LEM PICKUP)	S/M	660	31,770
TRANSEARTH INJECTION	S/M	4,395	29,400
TRANSEARTH MIDCOURSE	S/M	310	19,820

PRECEDING PAGE BLANK-NOT FILMED

SERVICE MODULE:

GROSS TAKE-OFF WEIGHT	53,290 LB
PROPELLANT (MAX)	41,790 LB

S/M SYSTEMS:

SERVICE PROPULSION - LIQUID-FUELED, PRESSURE-FED, NON-THROTTLEABLE ENGINE WITH GIMBALS FOR THRUST VECTOR CONTROL, EXPANSION RATIO 60:1

PROPELLANTS:

OXIDIZER	NITROGEN TETROXIDE N_2O_4
FUEL	50/50 UDMH AND N_2H_4

REACTION CONTROL - PROVIDES 3-AXIS CONTROL FROM TRANSLUNAR INJECTION TO ENTRY. THE SYSTEM CONSISTS OF:

QUAD SYSTEM	4 ROCKET ENGINES/SYSTEM
HELIUM PRESS	4500 PSIG
OXIDIZER	N_2O_4
FUEL	MMH
THRUST	100 LB

COMMUNICATION AND INSTRUMENTATION - HIGH-GAIN ANTENNA FOR 2-WAY VOICE, TELEMETRY, TV, 2-WAY TRACKING AND RANGING

STRUCTURAL - DESIGNED TO WITHSTAND BOOST LOADS

ENVIRONMENTAL CONTROL - DEFINED UNDER S/C SYSTEMS S/M CONTAINS SPACE RADIATORS, WATER SUPPLY, ASSOCIATED COMPONENTS

ELECTRICAL POWER - DEFINED UNDER S/C SYSTEMS S/M CONTAINS 3 FUEL CELLS

LUNAR EXCURSION MODULE/ADAPTER

WEIGHT (W/O ADAPTER)	24,460 LB (UNMANNED)
ADAPTER	3,260 LB
USABLE PROPELLANT (LEM)	15,880 LB (ESTIMATED)

LEM SYSTEMS:

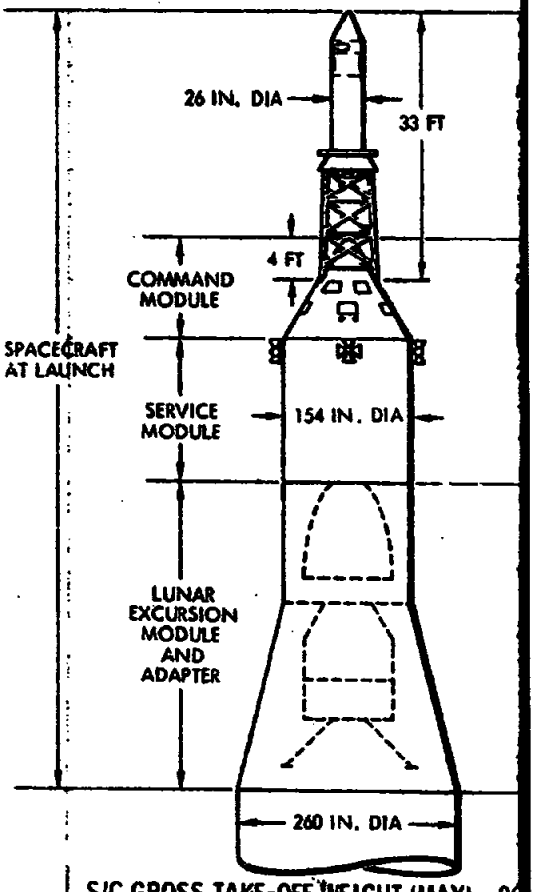
CREW
G&N
ECS
RCS
PROPULSION
C & I
SCS
SEPARATION
IN-FLIGHT TEST
STRUCTURAL
ELECTRICAL POWER

ADAPTER SYSTEMS:

POSIGRADE ROCKETS (4 AT 2K LB THRUST EACH)
INSTRUMENTATION
ELECTRICAL
STRUCTURAL

MISSION:

LUNAR LANDING MISSION UTILIZING THE LUNAR ORBITAL



S/C GROSS TAKE-OFF WEIGHT (MAX) = 96
S/C CROSS INJECTED WEIGHT (MAX) = 90

ANCE

LSION	(FT/SEC)	S/C WEIGHT (LB)
GES 1,2,3)	29,540	6,000,000
GE 3)	10,446	275,531
	310	86,740
	4,028	84,160
	415	25,000
	7,330	23,996
	6,660	8,768
	220	4,545
	660	31,770
	4,395	29,400
	310	19,820

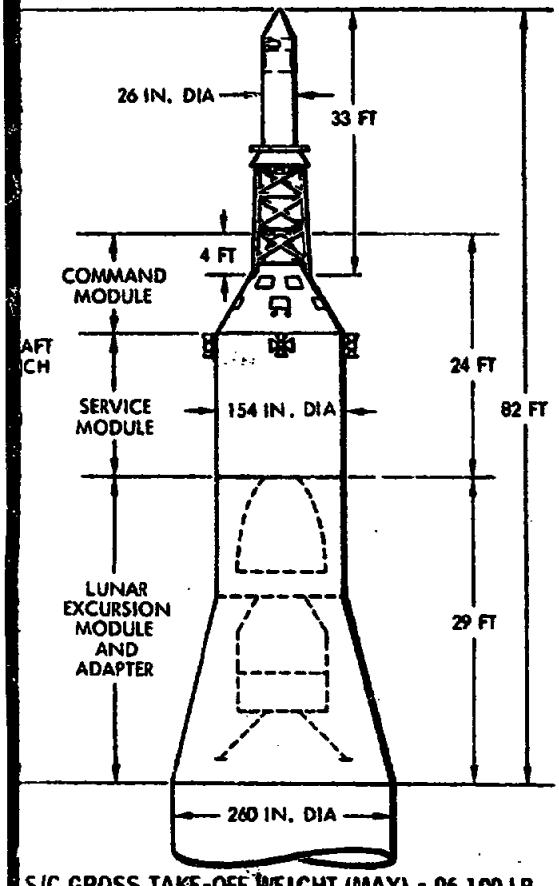
COMMUNICATIONS AND INSTRUMENTATION

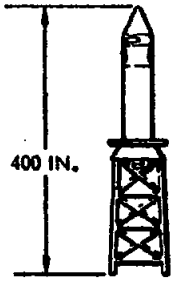
VHF-FM TRANSMITTER	225-260 MC	10 W
VHF-AM TRANSCEIVER	243-300 MC	10 W
DSIF TRANSPONDER		
RECEIVER (PM & FM/PM)	2110-2120 MC	
TRANSMITTER (PM OR FM)	2200-2400 MC	200 MW
POWER AMPLIFIER		20 W
PERSONAL COMMUNICATIONS (PARTIALLY NASA SUPPLIED)		
VOICE	243 MC	10 MW
OPTIONAL POWER AMP	243 MC	5 MW
TELEVISION	225-250 MC	200 MW
C-BAND TRANSPONDER	5.4-5.9 KMC	2.5 KW
VHF RECOVERY BEACON	243 MC(100 W PULSED)	1 W (CW)
HF TRANSCEIVER (VOICE)	2-10 MC	10 W PEAK ENVELOPE POWER
RECEIVER (TONE)	2-10 MC	5 W PEAK

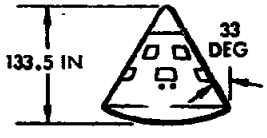
TV
TEL
TA
ELEC
FUE
TO
TO
WA
IN
OU

APOLLO SPACECRAFT

ING MISSION UTILIZING THE LUNAR ORBITAL RENDEZVOUS (LOR) MODE







S/C GROSS TAKE-OFF WEIGHT (MAX) = 96,100 LB
S/C CROSS INJECTED WEIGHT (MAX) = 90,000 LB

LAUNCH ESCAPE SYSTEM (ASSOCIATED WITH C/M):

TAKE-OFF WEIGHT 6600 LB

CAPABLE OF PAD ABORT UP TO 4000-FT ALTITUDE AND 300
SYSTEM CONSISTS OF:

NOSE CONE	
TOWER ASSEMBLY	
PITCH CONTROL MOTOR	4,000 LB THRUST
JETTISON MOTOR	40,000 LB THRUST
LAUNCH ESCAPE MOTOR	120,000 LB THRUST
BALLAST	277 LB WEIGHT

COMMAND MODULE:

GROSS TAKE-OFF WEIGHT 8490 LB (WITHOUT CREW

SYSTEMS:

- LAUNCH ESCAPE SYSTEM - DEFINED ABOVE
- STRUCTURAL AND HEAT PROTECTION-DESIGNED TO WITHSTAND BOOST AND ENTRY LOADS.
- HEAT SHIELD
  - CHARRING-TYPE ABLATIVE MATERIAL
- CREW SYSTEM -
  - PERMITS CREW TO CONTROL S/C, COMMUNICATE W EACH OTHER, GOSS AND THE LEM AS NECESSARY
  - THE SYSTEM CONSISTS OF:
    - CONTROLS AND DISPLAYS (3 PANELS)
    - AURAL EQUIPMENT (VHF/DSIF)
    - LIGHTING (FIXED AND PORTABLE)
    - COUCHES (3 REQD, 1 REMOVABLE)
    - FOOD MANAGEMENT (INCL. DISPOSAL)
    - PERSONAL HYGIENE
    - BIOMEDICAL EQUIPMENT
    - WATER MANAGEMENT (ECS)
    - WASTE MANAGEMENT (SOLID AND LIQUID)
    - SURVIVAL EQUIPMENT (COLLECTIVE)
    - SPACE SUIT ASSEMBLY CONSISTING OF:
      - PORTABLE LIFE SUPPORT SYSTEM
      - PRESSURE GARMENT ASSEMBLY
      - CONSTANT WEAR GARMENT
- ENVIRONMENTAL CONTROL SYSTEM (ECS)
  - DEFINED UNDER SPACECRAFT SYSTEMS
- IN FLIGHT TEST SYSTEM (IFTS)
  - DEFINED UNDER SPACECRAFT SYSTEMS

S/C SYSTEMS

TV	REP. RATE 12 FRAMES/SEC RESOLUTION 500 LINES/FRAME TRANSMITS THROUGH DSIF
TELEMETRY	PCM 8-BIT WORDS AT 32K BITS/SEC
TAPE RECORDER	14 CHANNELS

10 W
10 W

200 MW
20 W

ELECTRICAL POWER

FUEL CELLS	3 CELLS TOTAL
TOTAL REACTANTS	H_2 (80 LB)
	O_2 (580 LB)
TOTAL OUTPUT POWER (28 V DC)	4500 W MAX
WATER PRODUCTION	1.7 LB/HR (AVG)
INVERTERS (3 REQD)	3 PHASE, 400 CPS, Y
OUTPUT POWER	115 VAC 1 KVA EACH

10 MW
5 MW
200 MW
2.5 KW
1 W (CW)
10 W PEAK ENVELOPE POWER
5 W PEAK

ENVIRONMENTAL CONTROL SYSTEM

MISSION	14 DAYS (M
CABIN PRESSURE (ECS ACTIVE)	5 TO 15 PSI
CABIN TEMPERATURE	75 ± 5 F
RELATIVE HUMIDITY	40-70%
TOTAL HEAT ABSORPTION RATE	10,000 BTU/
O_2 PARTIAL PRESSURE	233 MM HG
CO_2 PARTIAL PRESSURE	7.6 MM HG
O_2 OUTPUT RATE	5.4 LBS/DAY
CO_2 INPUT ABSORPTION RATE	6.9 LBS/DAY

Fig

ESCAPE SYSTEM (ASSOCIATED WITH C/M):

FF WEIGHT 6600 LB

E OF PAD ABORT UP TO 4000-FT ALTITUDE AND 3000-FT DISPLACEMENT AT APOGEE
CONSISTS OF:

E CONE
ER ASSEMBLY
H CONTROL MOTOR 4,000 LB THRUST
SON MOTOR 40,000 LB THRUST
NCH ESCAPE MOTOR 120,000 LB THRUST
AST 277 LB WEIGHT

D MODULE:

TAKE-OFF WEIGHT 8490 LB (WITHOUT CREW AND WITHOUT LES)

S:

NCH ESCAPE SYSTEM - DEFINED ABOVE
CTURAL AND HEAT PROTECTION-DESIGNED TO
ITHSTAND BOOST AND ENTRY LOADS.
T SHIELD
HARRING-TYPE ABLATIVE MATERIAL
V SYSTEM -
ERMITS CREW TO CONTROL S/C, COMMUNICATE WITH
ACH OTHER, GOSS AND THE LEM AS NECESSARY
HE SYSTEM CONSISTS OF:
CONTROLS AND DISPLAYS (3 PANELS)
AURAL EQUIPMENT (VHF/DSIF)
LIGHTING (FIXED AND PORTABLE)
COUCHES (3 REQD, 1 REMOVABLE)
FOOD MANAGEMENT (INCL. DISPOSAL)
PERSONAL HYGIENE
BIOMEDICAL EQUIPMENT
WATER MANAGEMENT (ECS)
WASTE MANAGEMENT (SOLID AND LIQUID)
SURVIVAL EQUIPMENT (COLLECTIVE)
SPACE SUIT ASSEMBLY CONSISTING OF:
PORTABLE LIFE SUPPORT SYSTEM
PRESSURE GARMENT ASSEMBLY
CONSTANT WEAR GARMENT
IRONMENTAL CONTROL SYSTEM (ECS)
EFINED UNDER SPACECRAFT SYSTEMS
LIGHT TEST SYSTEM (IFTS)
EFINED UNDER SPACECRAFT SYSTEMS

GUIDANCE AND NAVIGATION (G&N)
MAJOR FUNCTIONS ARE:
PRIMARY INERTIAL REFERENCE
ACCELERATION, VELOCITY, AND POSITION DETERMINATION
G & N COMPUTATION AND PREDICTION
COMPUTATION FOR OTHER S/C SYSTEMS
ABORT - COMPUTATION
COMMUNICATIONS AND INSTRUMENTATION (C&I)
TWO-WAY VOICE COMMUNICATION CAPABILITY BETWEEN CREW MEMBERS, S/C AND GOSS, AND S/C AND LEM
REACTION CONTROL SYSTEM (RCS)
PROVIDES 3-AXIS CONTROL DURING PRE-ENTRY, ENTRY, RECOVERY, AND ABORT MANEUVERS. THE SYSTEM CONSISTS OF THE FOLLOWING:

DUAL SYSTEM	6 ROCKET ENGINES/SYSTEM
HELIUM PRESSURIZATION	4500 PSIG
OXIDIZER	N_2O_4
FUEL	MMH
THRUST	100 ± 5 LB
EARTH LANDING-	
PARACHUTES	3 MAIN, 1 DROGUE
DESCENT VELOCITY	30 FT/SEC (MAX)
HORIZONTAL VELOCITY	50 FT/SEC (MAX)
COUCH ATTENUATION	40 G (MAX)
ELECTRICAL POWER SYSTEM	DEFINED UNDER S/C SYSTEMS
C/M SCS	DEFINED UNDER S/C SYSTEMS

RONMENTAL CONTROL SYSTEM

SSION	14 DAYS (MAX)
BIN PRESSURE (ECS ACTIVE)	5 TO 15 PSIA
BIN TEMPERATURE	75 ± 5 F
ATIVE HUMIDITY	40-70%
TAL HEAT ABSORPTION RATE	10,000 BTU/HR (MAX)
PARTIAL PRESSURE	233 MM HG (NOM)
O_2 PARTIAL PRESSURE	7.6 MM HG (MAX)
OUTPUT RATE	5.4 LBS/DAY (NOM)
O_2 INPUT ABSORPTION RATE	6.9 LBS/DAY (NOM)

IN FLIGHT TEST SYSTEM (IFTS)

GO-NO-GO TEST SYSTEM TO PROVIDE CHECK OF SPACECRAFT SYSTEMS AND MALFUNCTION ISOLATION FOR IMPROVEMENTS IN MISSION RELIABILITY. OPERATING PRINCIPLE UTILIZES A PROGRAMMER, COMPARATOR, STIMULI GENERATOR, ETC.

STABILIZATION AND CONTROL SYSTEM

THE SCS IS AN INERTIAL SYSTEM WHICH PROVIDES STABILIZATION AND CONTROL SIGNALS TO PULSE THE RCS SYSTEM AND IGNITE THE PROPULSION SYSTEM OF THE S/M.

Figure 35. Spacecraft Configuration and Specifications for Lunar Orbital Rendezvous

[redacted]

SYSTEMS ENGINEERING

The systems engineering responsibility is to translate mission objectives into descriptions and hardware concepts, insuring that the systems developed are compatible in philosophy, in design, in physical integration, and in performance capability and reliability. Systems engineering, emphasizing the urgency of time, will concern itself, not only with the mission, but also with the development of a simple, straightforward program. Finally, the systems engineering function must cover the planning of adequate capability in the system to cope with unforeseen environmental conditions, operational factors, and equipment failures, or to adjust to deliberate changes in operational plans.

Systems engineering functions include the analytical and experimental activities that precede the detail design effort and subsequently support the active design and development programs. In order to define completely the requirements of the program, these activities must be closely integrated. The established requirements are analyzed for overall compatibility and reduced to usable design criteria. A continuing effort of investigation and resolution of existing and impending problem areas is carried on as a function of Systems Design Analysis. These and other plans are delineated in the succeeding paragraphs.

MISSION REQUIREMENTS

The ultimate objective of Project Apollo is to land men on the moon for limited observation and exploration in the landing area, and subsequently, to return them safely to earth. Intermediate objectives include scientific observation in the earth-moon space and reconnaissance of the moon prior to landing. It is expected that these objectives will be accomplished in a sequence of earth orbital, circumlunar, lunar orbital, and lunar landing missions. In addition to achieving these objectives, it is intended that the Apollo space vehicle be designed so that it will be adaptable for use as an earth orbital vehicle for conducting a variety of scientific and technological flights.

MISSION ENGINEERING

Nominal Mission Description

The Apollo spacecraft will be designed for the lunar orbital rendezvous technique for accomplishing the lunar landing mission. The intermediate and lunar landing mission plans and operational sequences are described in the succeeding paragraphs.

[redacted]

[redacted]

Earth Orbital Mission

The earth orbital mission will be to place an Apollo spacecraft into 90- to 400-nautical-mile, circular, earth orbits by means of the Saturn C-1 booster. Figure 36 illustrates the spacecraft and booster configuration for this mission.

Ascent

Ascent is defined as the period from launch vehicle lift-off through earth orbit injection. The ascent flight phase includes first-stage boost, first-stage separation, and second-stage boost into earth orbit. The spacecraft will be launched into orbit by the eight-engine C-1 booster. Figure 37 illustrates the typical earth orbital mission.

Orbital inclination will be selected on the basis of minimum ejection requirements for a velocity differential that satisfies the recovery (three consecutive passes) requirements for the latitude of the selected landing site. Since the optimum inclination is also related to orbit altitude, the design inclinations will be based on the maximum and minimum attainable orbital altitude.

The maximum allowable injection altitude is defined by an optimum boost trajectory (maximum payload) having the following constraint: The combination velocity-altitude-path angle, at any time during boost, will be consistent with those flight conditions necessary for a safe abort corridor. The allowable entry condition for abort is a 20 g-load factor.

Orbit

The nominal orbital altitude will be reached with the eight-engine propulsion system of the C-1 configuration. Orbital altitudes in excess of 100, but not greater than 400, nautical miles will be accomplished by an orbital transfer utilizing the service module propulsion system. A circular orbital altitude of 139 nautical miles or more will be necessary to meet the 14-day orbit requirement.

Orbit Ejection

Orbit ejection is defined as the retrograde flight phase. The spacecraft will be capable of operating satisfactorily under retro-powered flight within the ejection window boundaries determined by the following conditions: (1) orbital altitudes between 90 and 400 nautical miles, (2) maximum aerodynamic maneuver envelope, (3) minimum ejection propulsion, and (4) range sensitivity.

[redacted]

[redacted]

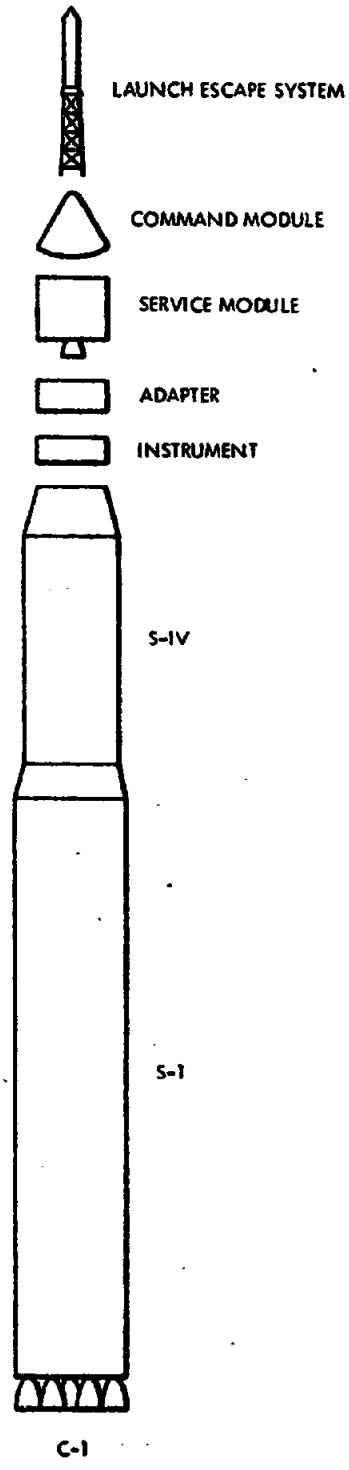


Figure 36. Space Vehicle Configuration - Earth-Orbital Mission

[redacted]

[redacted]

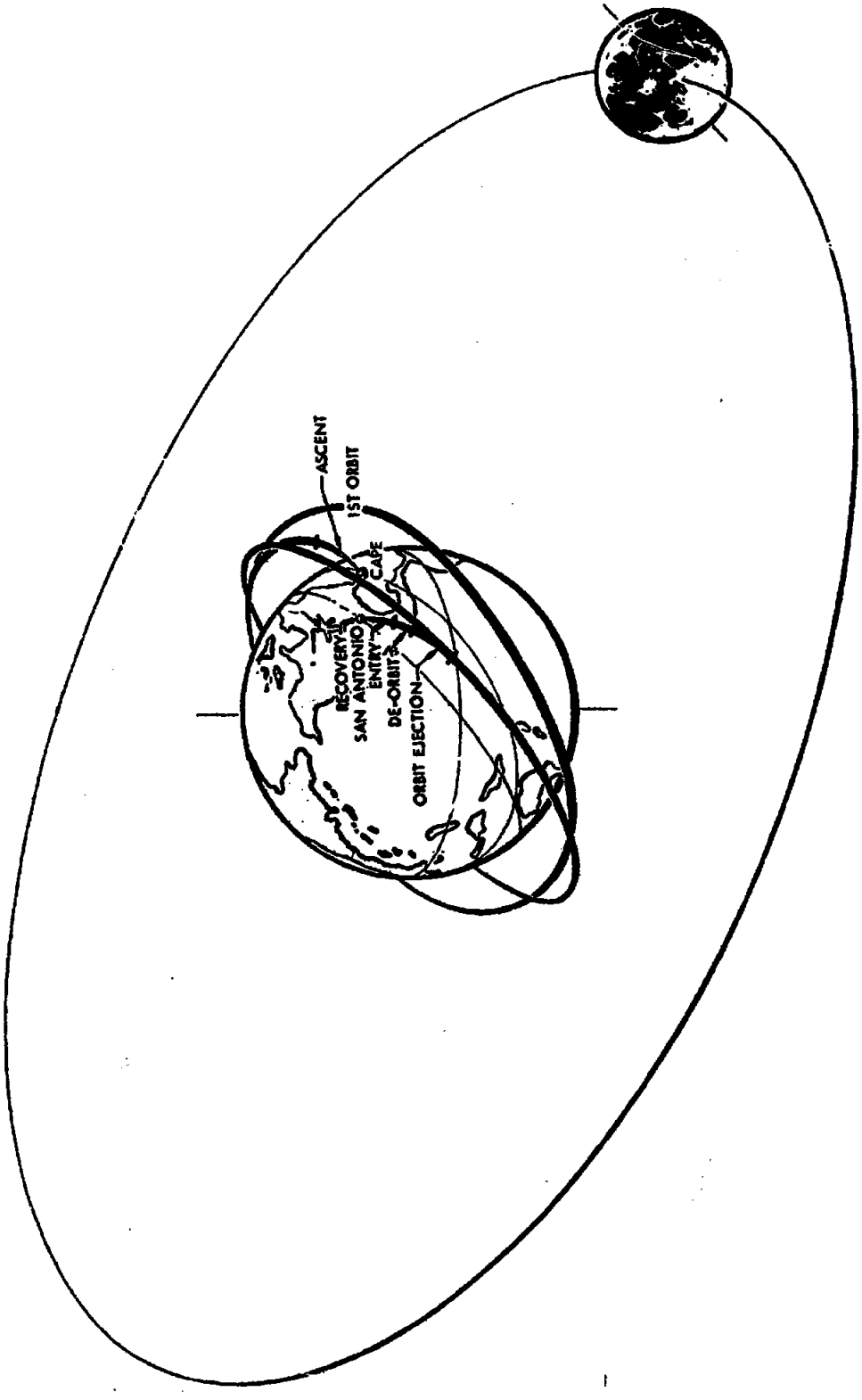


Figure 37. Earth-Orbital Mission

[redacted]

[redacted]

De-Orbit Coast

This flight segment will follow orbit ejection and terminate at the entry point (400,000 feet altitude). The command module will be separated from the service module prior to reaching the entry interface. The command module will be oriented for entry during this operation.

Entry

The command module will be capable of performing satisfactorily during an atmospheric entry, which includes pull-up to horizontal flight, transition from pull-up to glide, and glide to the recovery interface. The entry flight phase will begin at 400,000 feet altitude and end at 40,000 feet.

Recovery

The command module will be capable of recovery and touchdown on land or water. Recovery deployment will begin at 40,000 feet altitude and include glide to drogue chute deployment, drogue chute deployment and stabilized descent, and main chute deployment to touchdown.

Post-Flight Operations

The post-flight operations will consist of command module touchdown and all air and ground operations required to reach the module, pick up the crew and spacecraft and transport them to the nearest operational base.

Circumlunar Mission

The spacecraft and booster configuration for the circumlunar mission is shown in Figure 43. The circumlunar mission will consist of placing the spacecraft and the launch vehicle in the inertial space position required for translunar injection, establishing the spacecraft in a circumlunar trajectory having a specified perilune altitude and returning the command module safely to a selected earth landing site. The spacecraft will circumnavigate the moon (Figure 38). Figure 39 illustrates the operational sequence, as described in the following paragraphs.

Ascent

Ascent is the period from lift-off of the launch vehicle through parking orbit injection. Range safety azimuths at the launch site limit the launch delay period to a maximum of 5.5 hours, two hours of which will provide for possible delays.

[redacted]

[redacted]

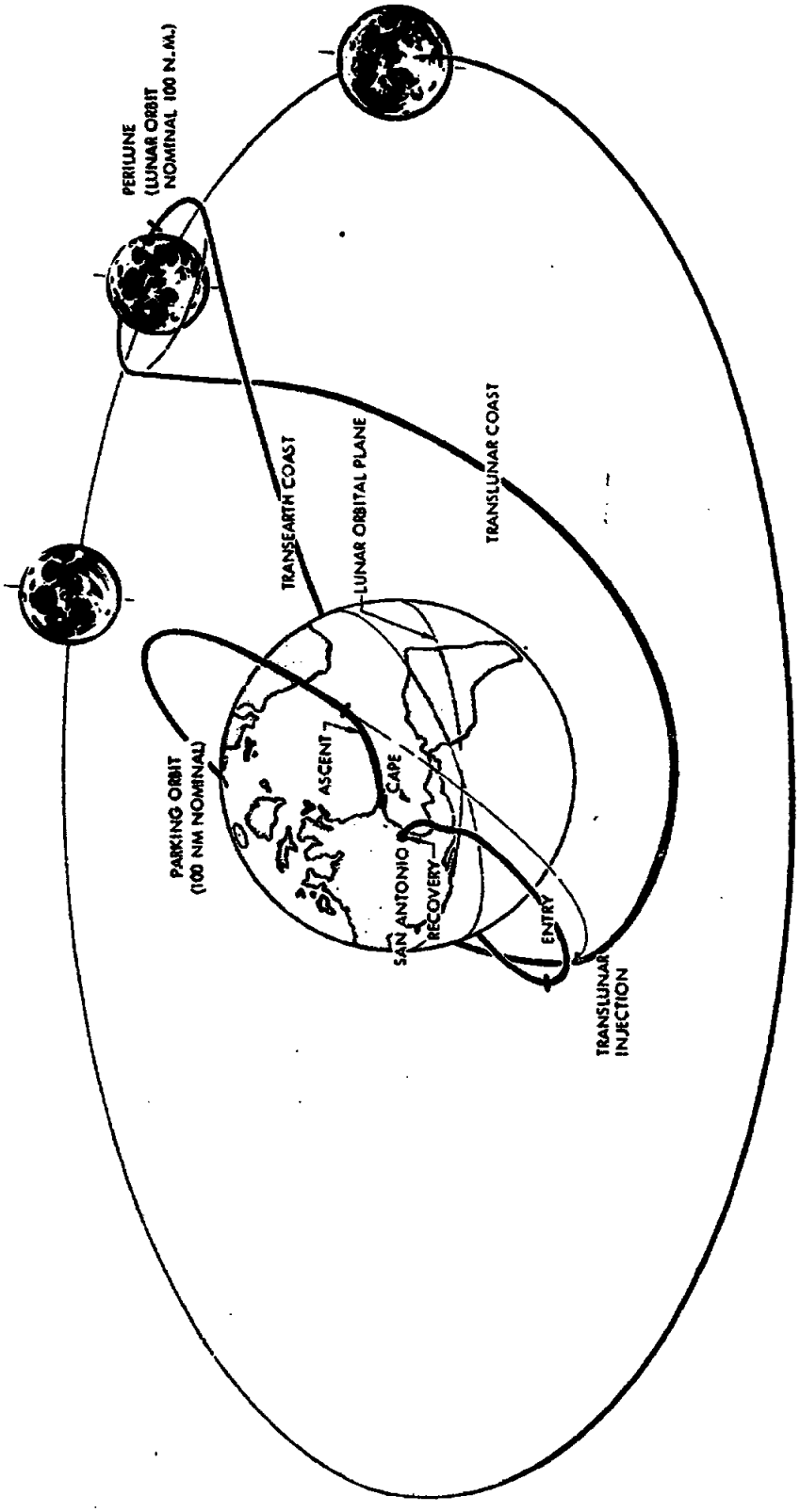


Figure 38. Circumlunar Mission

[redacted]

[redacted]

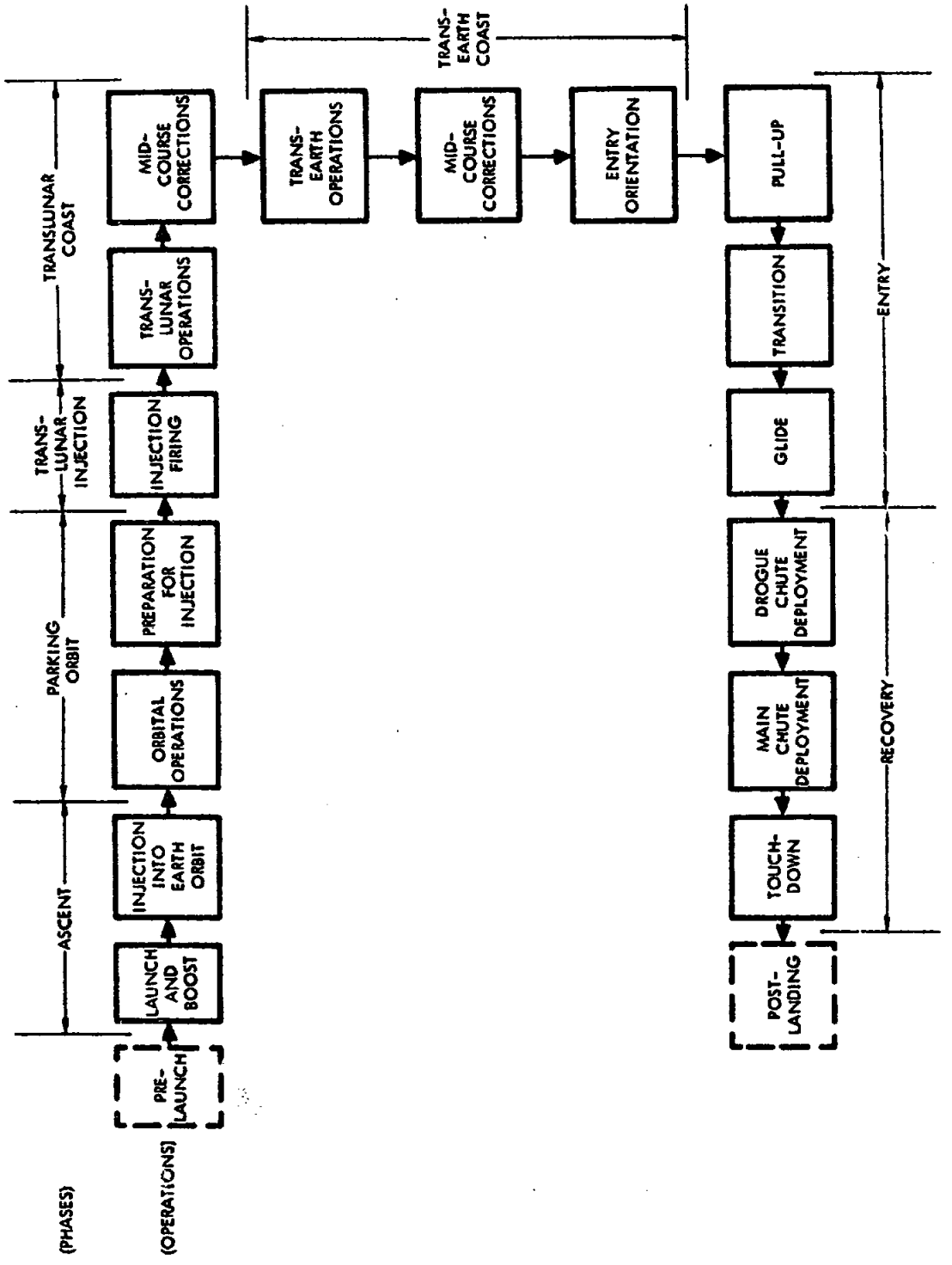


Figure 39. Circumlunar Mission Operational Sequence

[redacted]

[redacted]

Parking Orbit

The parking orbit is a circular earth orbit with a nominal altitude of 100 nautical miles. The purpose of the parking orbit will be to establish an accurate space positioning of the spacecraft and verify the satisfactory operation of spacecraft systems prior to translunar injection.

Translunar Injection

Translunar injection is the acceleration of the spacecraft from earth orbit to escape velocity along a translunar trajectory. It is accomplished by firing the launch vehicle final stage. The velocity vector at shutdown shall provide a free return circumlunar trajectory.

Translunar Coast

Translunar coast is the period between translunar injection and perilune.

The perilune altitude (the point on the lunicentric orbit nearest the center of the moon) for the circumlunar trajectory will be a nominal altitude.

Transearth Coast

The transearth coast flight phase will commence at perilune and terminate at entry into the earth's atmosphere. The command module will be separated from the service module just prior to entry.

Entry

The location of the command module at the entry interface, in respect to the preselected landing site, will be dependent upon the lunar declination, time of launch, and entry inclination angle. After arriving at the designated location, the command module will be capable of operating satisfactorily during the following entry maneuvers: (1) pull-up, (2) transition, and (3) glide.

Recovery and Post-Flight Operations

Recovery and post-flight operations are the same as those described for the earth-orbital mission.

Lunar Orbital Mission

The spacecraft and booster configuration for the lunar orbital mission is shown in Figure 43. This mission will consist of placing the spacecraft in a lunar orbit at the perilune altitude and returning the command module safely to a selected landing site on earth.

[redacted]

[redacted]

Figures 40 and 41 illustrate the lunar orbital mission. Figure 42 presents the operational sequence which is described in the following paragraphs. (Ascent, parking orbit, translunar injection, and translunar coast operations are the same as those described for the circumlunar mission.)

Lunar Injection

Injection of the spacecraft into a circular lunar orbit will begin at perilune of the circumlunar trajectory. Velocity requirements for injection will be based upon the following conditions: (1) The moon is to be at apogee at the time the spacecraft reaches perilune, (2) The inclination of the transearth trajectory plane to the lunar orbital plane is to be maximum. The spacecraft will be capable of performing an out-of-plane maneuver at injection.

Lunar Orbit

The lunar orbit will be circular and at a nominal altitude of 100 nautical miles. A minimum of one orbit will be made about the moon; the maximum number of orbits will be dependent upon the planned duration of the mission. Total lunar orbital duration shall be a minimum of 48 hours and a maximum of 7 days.

Transearth Injection

Injection of the spacecraft into the transearth trajectory will be possible at least once during each orbit of the moon. The velocity increment required for injection will be supplied by the service module. The transearth injection conditions (velocity and position) are dependent upon required entry corridor parameters, earth approach conic inclination, and time of earth entry.

Transearth Coast

The transearth coast flight phase will commence at transearth injection and terminate at entry. The command module will be separated from the service module just prior to entry.

Entry, Recovery and Post-Flight Operations

Entry, recovery and post-recovery operations are the same as those described earlier for the circumlunar mission.

Lunar Landing Mission

The spacecraft and booster configuration for the lunar orbital rendezvous mission is illustrated in Figure 43. The command module/service module will remain in lunar orbit, while a manned lunar excursion module

[redacted]

[redacted]

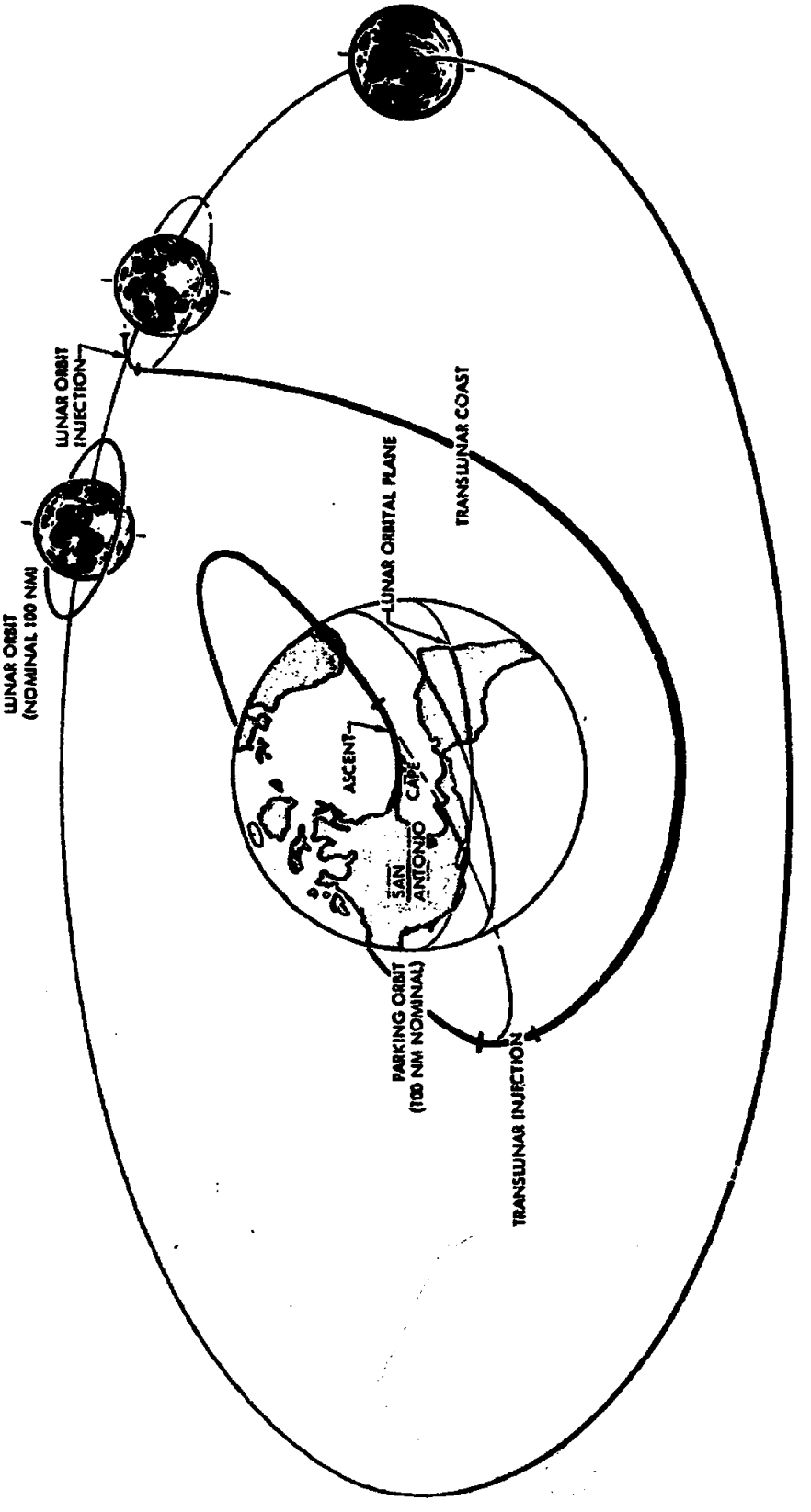


Figure 40. Lunar Orbital Mission - Translunar Flight

[redacted]

[redacted]

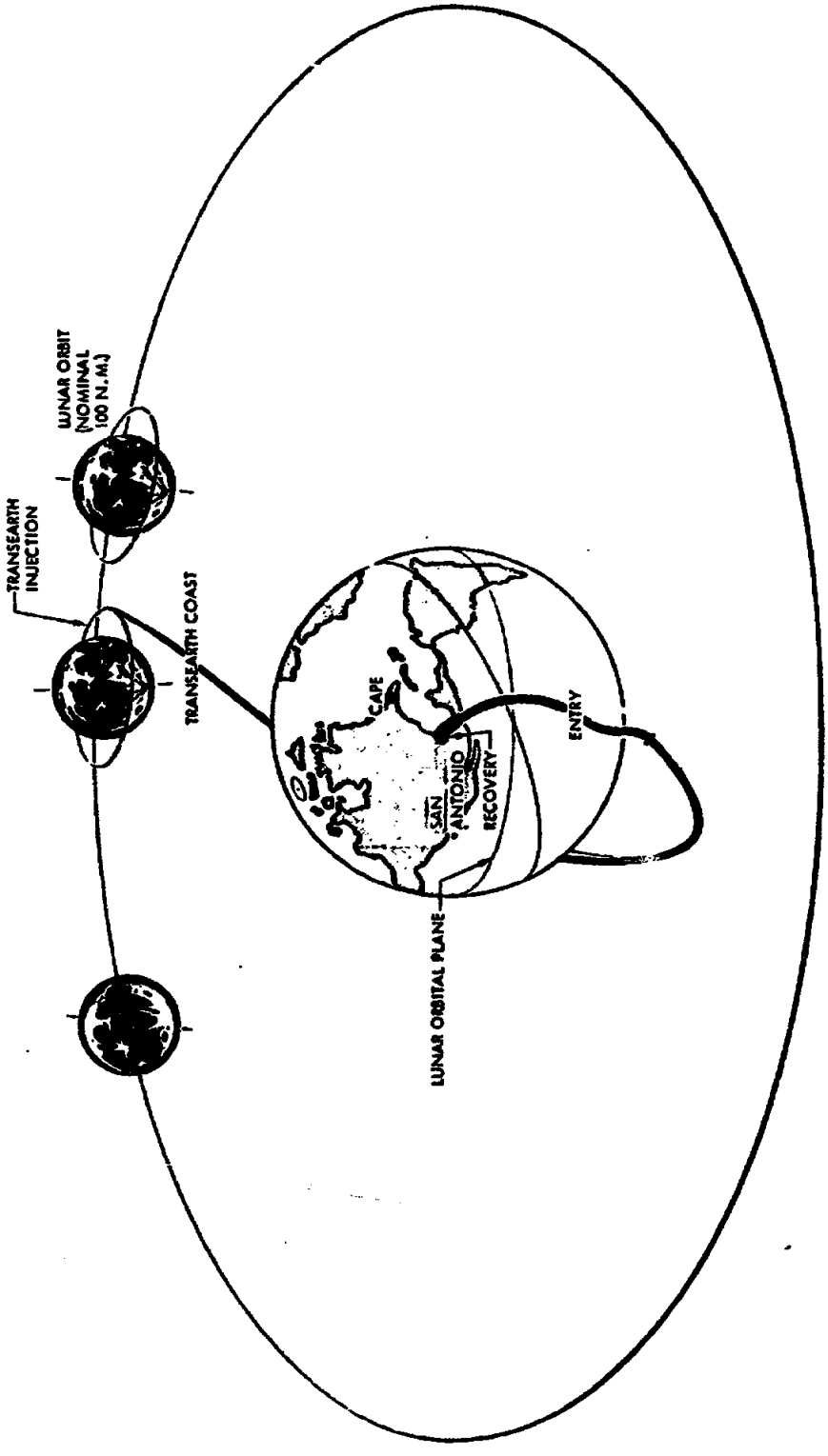


Figure 41. Lunar Orbital Mission - Transearth Flight

[redacted]

[redacted]

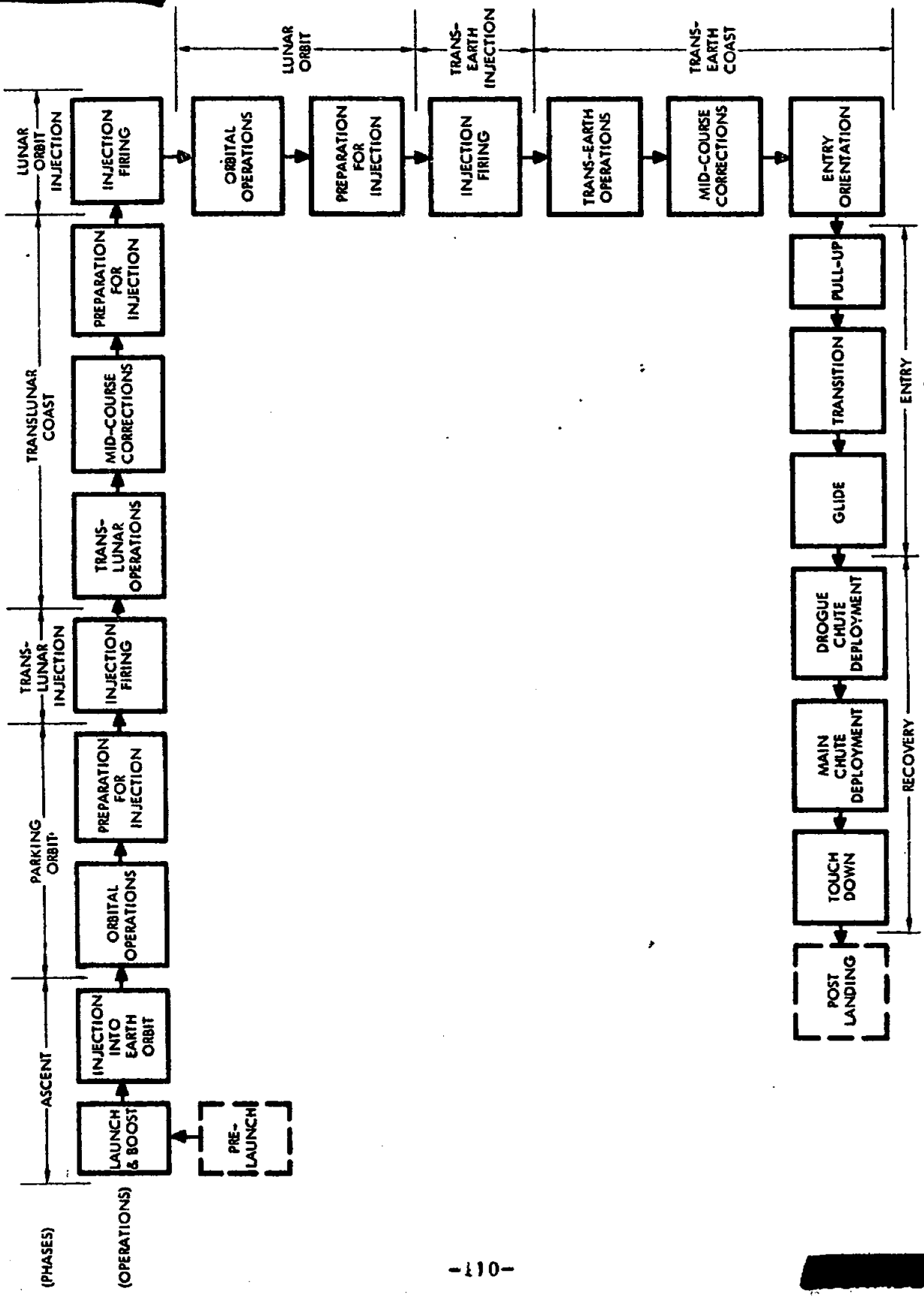


Figure 42. Lunar Orbital Mission Operational Sequence

[redacted]

[redacted]

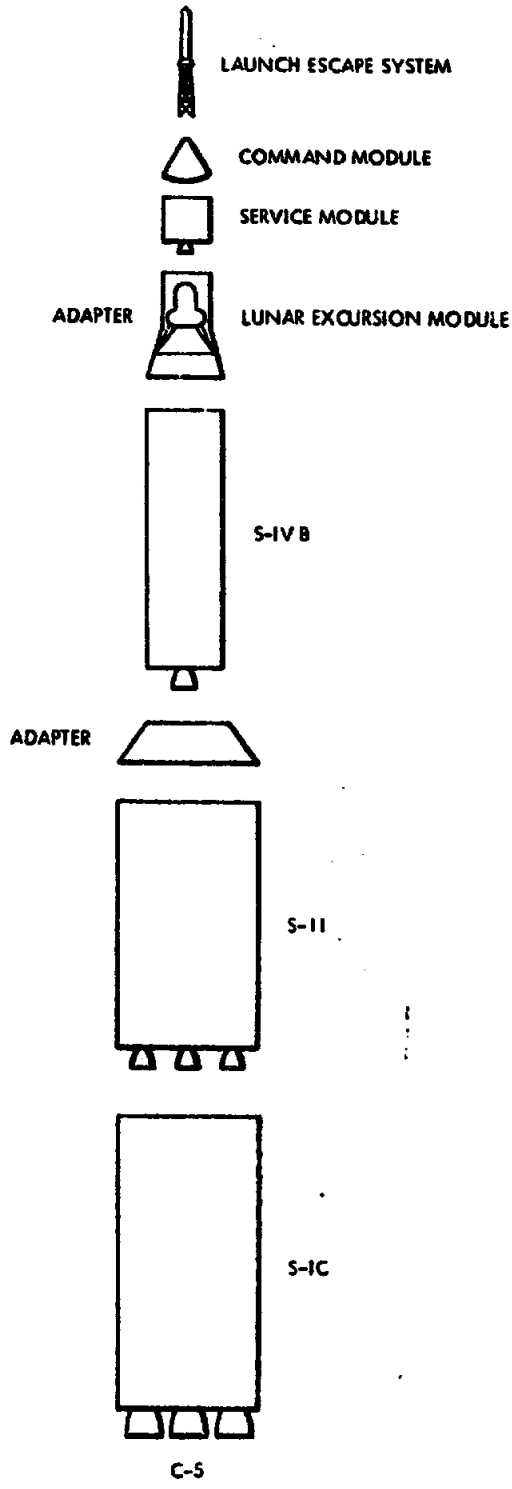


Figure 43. Space Vehicle Configuration - Lunar Missions

[redacted]

[redacted]

departs from the spacecraft and lands on the moon. The launching of the excursion module from the moon will be synchronized with the orbiting spacecraft, so that a rendezvous can be accomplished. Figure 44 illustrates the mission. The transearth injection, transearth coast, entry, recovery, and post-recovery operations are the same as those described for the lunar orbital mission.

MISSION ANALYSIS

The mission analysis activity performs analytic investigations of interactions between the mission and the Apollo systems by evaluating performances of given systems for various missions. Determination of optimum systems is fulfilled by mission analysis, which provides methods for laying out in logic form the performance of the Apollo system in executing the steps of a given mission; for finding the margins or criticality in operations and in systems functioning; and for evaluating modifications of systems, crew functions, or the mission itself. Analyses are performed as required to determine recommended functional and performance requirements for crew and total system as well as for subsystems for the establishment of operations and functional criteria.

Although these analyses are primarily performed for the normal mission, mission analysis must evaluate the requirements of off-normal situations and operations and integrate them with those of the normal mission to enhance crew safety confidence factors.

Normal Missions

To define the normal mission and the crew and systems requirements, mission analysis will first consider the effects of program objectives on mission concept. For instance, reliability and scheduling for the lunar landing mission concept has led to specification of a single Saturn C-5 launch vehicle. Other aspects of the mission concept might be subject to variation and will be studied.

Program objectives and system concepts are limited by constraints and ground rules. Some of these, such as natural environments, cannot be changed but require analysis to determine their effects and possible means of control.

The Apollo mission concept and program definition have proceeded to a point where change may not be feasible. However, in certain areas, such as operations with the Lunar Excursion Module, various concepts and the relative importance of possible performance or design requirements must be analyzed. Variations of Lunar Excursion Module transposition, docking,

[redacted]

[redacted]

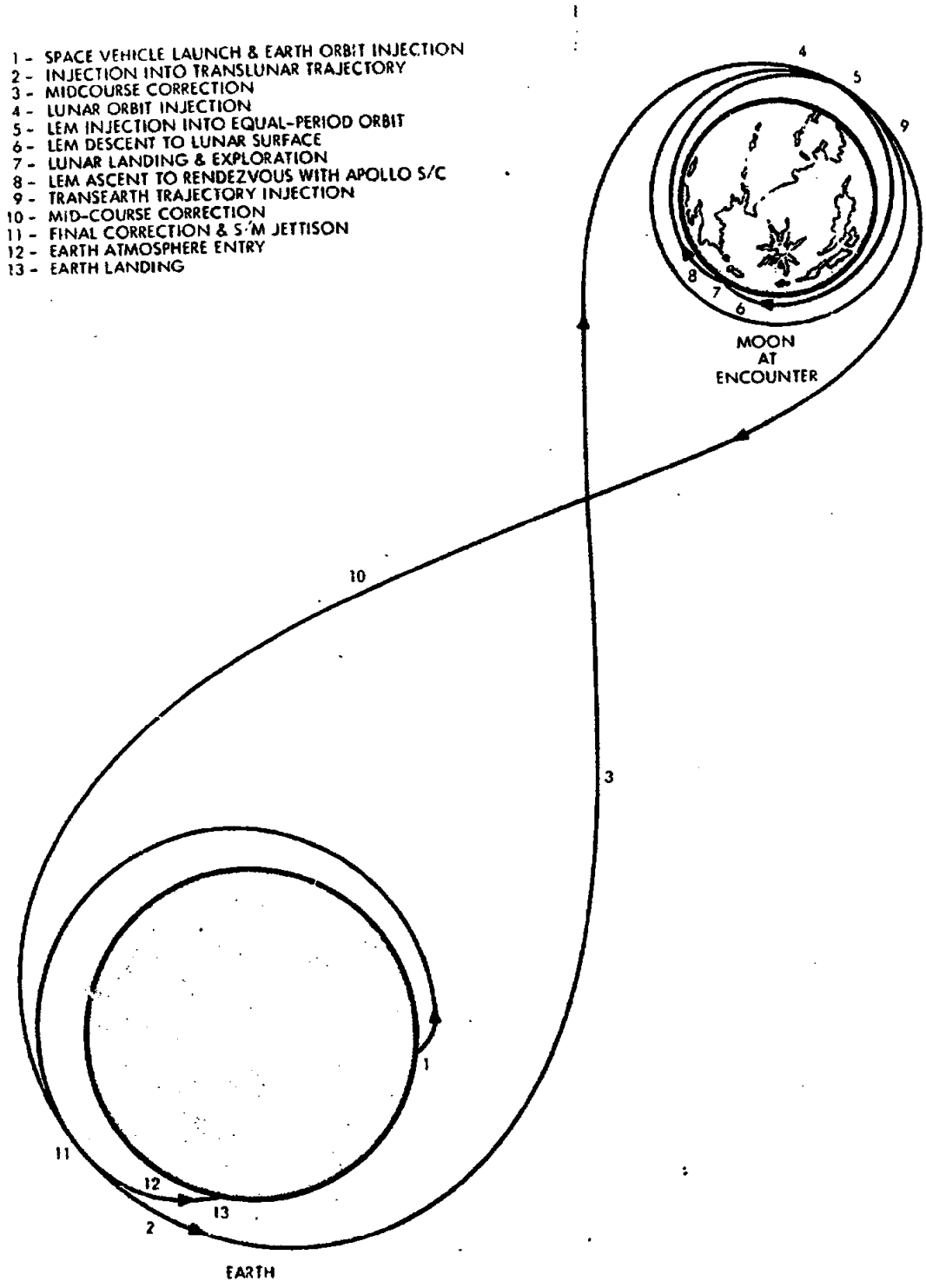


Figure 44. Lunar Landing Mission—Lunar Orbital Rendezvous Technique

[redacted]

[redacted]

and all of the lunar operations will be evaluated to provide definitive guidelines.

For a given mission concept, it is the role of mission analysis to determine performance requirements on specific systems. These performance requirements may differ with each mission phase and must be analyzed to determine the most compatible and least demanding requirements. In operations, careful analysis must be made of sequencing in systems and of crew participation. These analyses are used by design groups to detail appropriate systems, which must then be reviewed as to reliability and mission suitability. The output performance and the input requirements of proposed systems must be evaluated relative to the specific aspects of the mission. Passive systems, such as structure, radiation shield, or heat shield, affect the total system as to weight and environment. Active systems have additional input requirements, such as electrical power, fluids, stabilization and temperature control, which may impose conditions on the mission not previously anticipated. Requirements and performance of systems for the mission will be fed back for an iteration to study mutual compatibility among all systems and possible modifications of the mission to relax some of the requirements.

An operations profile and time-line for the complete mission will be used to study the compatibility of all the mission requirements, the development of the mission by test-flight stages, and to develop a computer mission simulation for evaluation of the effects of system tolerances or off-normal performance. It will also indicate the requirements for information flow and permit evaluation of the requirements for a crew to exercise the necessary control. Sequencing of operations, particularly time-critical operations, is an important part of the operations profile.

Another important task of mission analysis is to define the requirements of the mission on crew functions. The crew is in control of the mission. They have significant functions and contributions that cannot be programmed automatically or effectively performed by remote control. It is not logical to require the crew to perform tasks that are better programmed, such as controlling a thrusting maneuver; however, it may be desirable to give the crew initiation, negation, or quantitative control capability. Further, the information requirements must be studied for establishing crew performance requirements, such as displays and controls and in-flight test and maintenance. While the requirements for performance of basic crew functions should be as specific as possible, certain alternative or optional requirements may be studied by the Life Systems group to define crew tasks and methods of execution.

[redacted]

[redacted]

Mission analysis must evaluate the effect of the crew safety requirements on spacecraft and mission design, and on selection of alternative modes of operation or alternative mission profiles. The requirements for crew functions in this area must be studied in detail, and data must be generated to preplan safety provisions or effective use of safety procedures on the actual mission.

Mission analysis will cover preparations for the mission and its support from the earth and possibly certain preparations on the moon. Mission analysis must be concerned with the hardware development program and the flight program leading up to the final mission. Obtaining necessary information from the ground and flight tests will be a large part of mission analysis work. Information from other space programs, particularly Mercury and Gemini, must be evaluated for the Apollo mission.

Requirements for preparation of plans for specific missions will be analyzed. Typical requirements include trajectories, flight dynamics, systems functioning, expected environment, crew tasks, alternate operations, and abort plans for all phases. Crew training requirements for the mission will be evolved and put into concrete recommendations by the Life Systems group.

Mission planning will analyze requirements for systems qualification and for flight-readiness certification. The latter must be performed in different degrees at different mission stages. Requirements for an in-flight test system and for telemetered information to the earth will be included.

Mission Variations

Although the basic portion of mission analysis is for normal missions, considerable effort must be devoted to off-normal missions and off-normal conditions or operations. Part of this analysis comes through providing assurance of mission performance and crew safety and part from deliberate mission variations. The latter may be diverted missions selected after evaluation indicates that the planned mission cannot be performed or they may be selected variations, such as landing at a different region on the moon in either lunar day or night.

Off-normal conditions in the environment or in systems performance require detailed study to evaluate assurance and procedures. Systems margins of performance, redundancy, and sequencing of operations must be evaluated by analysts and computers to ensure that adequate provisions have been made. A criticality index for systems and a criticality line for the logic sequence in operations (comparable to the critical path in PERT) will be studied. Alternative modes of operation and back-up provisions will be studied.

[redacted]

Abort situations and provisions for all phases of the mission must be evaluated. The analysis will include modes of failure of systems and effects of failure, and their time-criticality when in the mission they occur and how quickly they will have serious implications. Requirements must be set for on-board detection and isolation equipment, for spares and repair, for crew functions, for abort systems.

In addition to the normal mission time-line charts, detailed logic diagrams of early mission flight phases will define all contingent situations. Similar logic diagrams covering all phases of the basic missions will be made up according to a development sequence. Detailed time analyses will be conducted into two basic areas. The first analysis will determine nominal and extreme times for restoration of a contingency to a stable situation and will include detection, isolation, evaluation, and resolution of the contingency. The second analysis will estimate nominal and extreme time for deterioration of the contingent situation and will include emergency abort. Comparison of these two analyses will permit refinement of the logic diagrams and the reference of contingent operations to the normal mission time scale. Consideration will be given to establishment of a statistical multicontingency occurrence and its analysis on the IBM 7090 computer.

Apollo Optimization Effectiveness

Efforts to optimize Apollo effectiveness will be based on the planned expansion of previous mission engineering activity. Whereas mission engineering will be concerned with functional capabilities, Apollo effectiveness optimization efforts will include the following trade-off factors:

1. Reliability and crew safety
2. Probability of mission success
3. Date of first lunar landing and safe return
4. Relative program cost

The objective of this effort will be to prepare the necessary trade-off information with which a logical selection can be made of the Apollo requirements that make best use of time and available resources.

Apollo effectiveness optimization is illustrated in Figure 45. A specific model system and basic mission will be defined and will be used to establish the first complete set of reference data. With the model and mission defined, duty cycles will be determined and existing time-line charts will be revised as necessary and detailed to the next lower subsystem

[redacted]

[redacted]

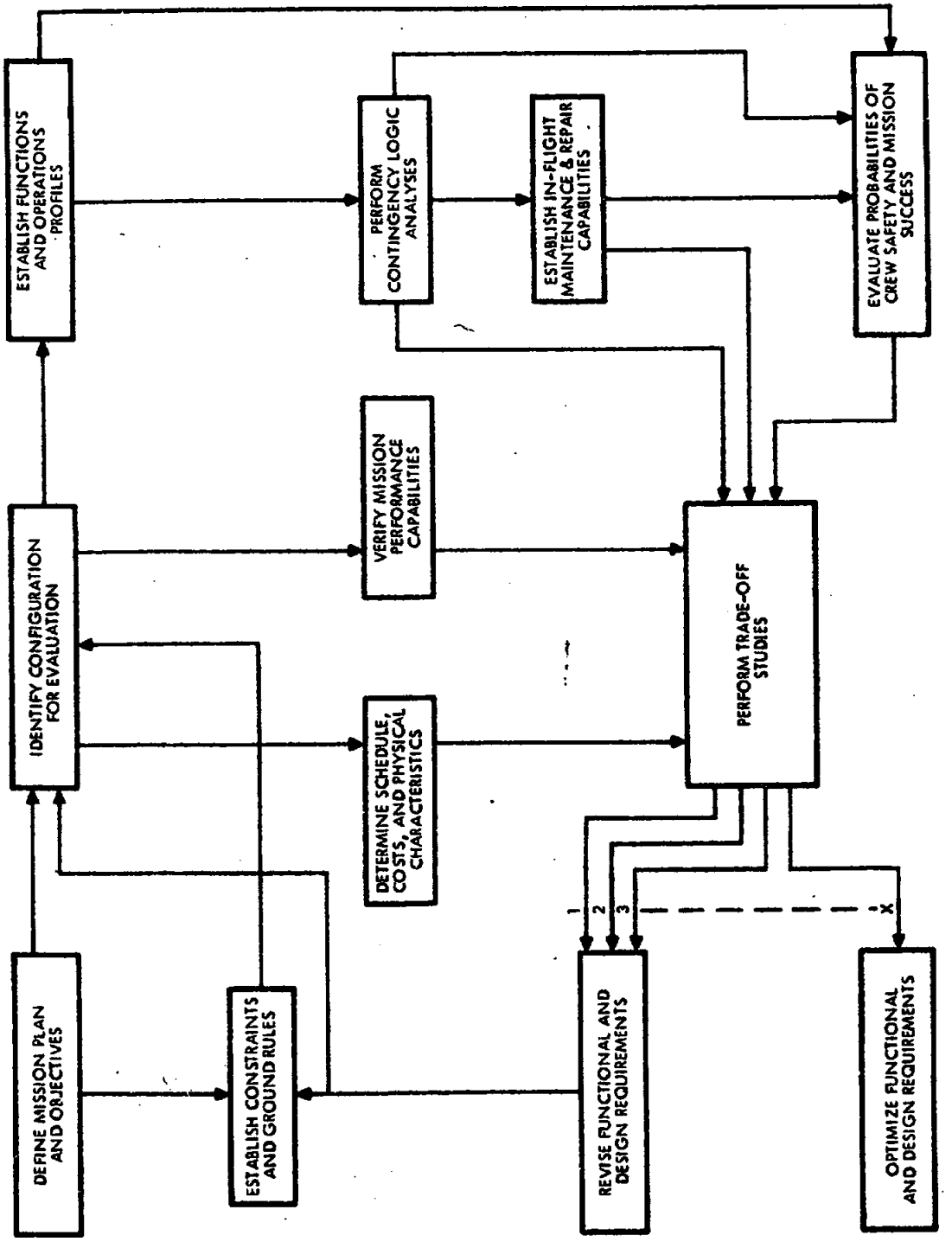


Figure 45. Optimization Tasks Flow Diagram

[redacted]

[redacted]

level. At the same time, mission performance capabilities of the model will be verified, and schedule, costs, and physical characteristics associated with the model will be determined.

Based on the inputs described, existing reliability assessments will be reviewed and revised as necessary, and computations will be made of the probabilities of reliability and crew safety and of mission success.

SYSTEM DESIGN ANALYSIS

As the Apollo program progresses, many areas will require additional investigation and study to assure that the program is proceeding in the optimum path. These investigations and studies may originate from design review meetings, internal and with NASA; requests from NASA; direction from the Chief Engineer; and other S&ID sources depending on the type of problem involved. System Integration personnel will direct and integrate these studies and investigations using assigned persons from the affected functional and support groups. Groups outside of Apollo Engineering, Contracts, Facilities, and Manufacturing will provide the necessary assistance.

Integration studies are those involving several systems in the spacecraft. These studies may or may not be within the established design objectives. A study of the electrical loads throughout the mission to determine the compatibility of the present supply system with the requirements of all spacecraft systems might be an example of this type of investigation.

Trade-off studies involve determining the optimum of various requirements and may be made with existing concepts or may serve to introduce new ideas into the program. The study on the lunar landing mission by lunar orbital rendezvous or earth orbital rendezvous to determine the most efficient program within the limits of the present boosters is an example of this type of study. Another example is the study requested by NASA to compare the various methods for achieving lunar excursion module rendezvous and docking and to give a preliminary examination of the types of hardware and actions required in completing this operation.

Feasibility studies involve the study and investigation of new ideas and concepts outside of the established program. A study requested by NASA to determine the feasibility of increasing the service module base diameter to 260 inches is an example of the feasibility studies that will be undertaken.

Studies are required to evaluate the effect of new or revised requirements on the spacecraft design. An example of this type of study is

[redacted]

[redacted]

Integrated Systems Schematic Drawings

An indispensable tool that graphically presents the interrelationship of systems is the integrated systems schematic - a composite of all individual airborne and GSE systems. It establishes continuity of line and functions between individual systems as well as between each system and the respective GSE. In one drawing is a pictorial presentation of all functions as they relate to each other. Design and Systems Integration Engineering use this tool for tracing through functions during interface compatibility studies; for circuit analyses; for troubleshooting; and as a training aid for factory, test, and field technicians responsible for assembly, checkout, and maintenance of the Apollo spacecraft. Checkout procedures are verified by use of the schematic for procedure dry runs. The schematic will be developed to include complete system details down to the component level. Every electrical and fluid connection of the Apollo spacecraft combination and launch vehicle interface will be incorporated.

Electromagnetic Interference Control

Electromagnetic interference has been demonstrated as a cause for malfunction in many sophisticated vehicle systems using electrical and electronic units. Therefore, every known expedient will be employed to reduce the probability of Apollo spacecraft system failure as a result of stray electrical currents or rf fields. During the design and development period, established design methods will be employed to maintain all electrical currents and voltages within desired tolerances and flow channels. Electrical interference will be reduced to a minimum by suppressing transients through control of grounding, loading, shielding, wire routing, and component packaging.

An electromagnetic interference control program including criteria for reduction of electromagnetic interference in the Apollo spacecraft and associated electrical-electronic equipment will be established to ensure electromagnetic interference compatibility of the over-all spacecraft vehicle.

Electromagnetic interference control will include the following:

1. Preparation of the electromagnetic interference control specification for the Apollo spacecraft program

2. Preparation and implementation of an interference control plan for spacecraft and associated ground support electrical-electronic equipment

PRECEDING PAGE BLANK-NOT FILMED

[redacted]

[redacted]

3. Preparation and implementation of an interference test plan for electrical-electronic system compatibility

4. Determination of proper corrective action to maintain EMI within required limits

TEST INTEGRATION

Test Integration engineering will establish and document the engineering requirements for the Apollo Test Program with emphasis on integrated and interface test requirements. Test conduct surveillance will be provided. Overall cognizance of engineering test analysis and evaluation reports will be accomplished. Specific tasks are:

1. Evaluate all individual system test plans to assure a well integrated test program properly aligned to Apollo goals.

2. Provide engineering requirements including measurement lists for all multiple system tests including both major ground tests and flight tests.

3. Provide engineering surveillance during major tests particularly with respect to compliance with engineering requirements.

4. Conduct an engineering analysis of all integrated system tests together with a review of all systems test analysis as accomplished by responsible design groups. Prepare appropriate engineering reports.

GROUND OPERATIONAL SUPPORT SYSTEM

The ground operational support system (GOSS) is required to support a spacecraft conforming to the Apollo Spacecraft General Requirements Specification, SID 62-700-2, and a spacecraft crew. GOSS will be used to enhance assurance of mission accomplishment and crew safety for each Apollo mission.

The basic GOSS functions are spacecraft support and mission evaluation.

GOSS will support the spacecraft crew by monitoring mission progress, by providing backup diagnostic assistance in checking spacecraft systems performance, and by providing backup to the guidance and navigation system, as required.

[redacted]

[redacted]

GOSS consists of an integrated mission control center including computational and communications switching facilities, a world-wide communications and tracking network, a launch control center, and recovery facilities for planned or contingency landing areas. Deep Space Instrumentation Facilities provide data to the GOSS and supplement its capability.

GOSS will provide evaluations of mission and alternate missions performance capability. This will include evaluating computations from spacecraft and/or GOSS tracking data, predicting trajectories and impact, and making recommendations for alternative missions as required. The communications network will link the spacecraft with the Integrated Mission Control Center by means of radar, telemetry and television (spacecraft to earth), and voice communications.

S&ID will establish liaison through appropriate NASA agencies with GOSS contractors to assure compatibility between interface requirements and capabilities. Support of the space system design shall be rendered by analysis of performance, status, and capability data regarding spacecraft systems, GOSS communications and tracking networks, computational facilities, launch and recovery systems, and operational concepts to determine GOSS support required by the spacecraft.

Current files of GOSS-oriented information on spacecraft design and GOSS development, operational concept, and mission planning will be maintained to allow timely publication of GOSS interface and performance specifications.

Mission analysis and other appropriate studies including an analysis of systems information flow will be performed. This analysis will lead to identification and definition of GOSS interfaces with the spacecraft, delineation of performance requirements, and determination of GOSS coverage requirements. Spacecraft system measurements and other information required by GOSS will be determined so that predicted values, current values, and time histories may be combined and so that extrapolation of future requirements and capabilities can be modified by determined probabilities and confidence factors.

Logical time sequence diagrams will be produced relating missions and abort intervals with GOSS to illustrate the flow of data and/or information from the spacecraft to GOSS. These diagrams will make possible predictions and analysis of flight conditions.

[redacted]

[redacted]

FLIGHT TECHNOLOGY

The effort of Flight Technology will encompass four separate program activities:

1. Aerodynamics
2. Performance and trajectories
3. Flight dynamics
4. Wind tunnel test program

These analytical and experimental activities will support structure and system design and major test programs. Reports and manuals will be prepared to document the following functions:

1. Determining requirements for the design of structure and systems
2. Preparing data for others to use in the design process
3. Evaluating designs for suitability to performance of the missions
4. Documenting overall vehicle flight characteristics for mission planning
5. Evaluating specific flight plans
6. Evaluating specific flight data

The detail programs for accomplishing these ends are reported separately for each of the functional areas.

AERODYNAMICS

The aerodynamics activities will include basic objectives and functions performed for other groups. Basic objectives in aerodynamics will be (1) to assure the aerodynamic soundness of the design, and (2) to determine and publish the aerodynamic characteristics and the aerothermodynamic environment of various configurations.

[redacted]

[redacted]

Relation to Others in the Apollo Program

1. Functions performed for structure and systems design

   a. Determine preliminary guide lines and configuration requirements for structural design

   b. Issue data as follows:

      (1) Air pressure and loads for structural design

      (2) Lift and drag characteristics for performance and trajectories

      (3) Stability and control characteristics for flight dynamics

      (4) Flow field descriptions for aerothermodynamic analysis and radio attenuation studies

      (5) Flight environment for structural design and for performance analyses

2. Functions performed for the development test program

   a. Establish requirements for wind tunnel program

   b. Prepare summary analyses of wind tunnel test results

   c. Establish aerodynamic requirements for boilerplate and unmanned prototype flight programs

   d. Analyze results of flight program

3. Functions performed for manned operations

   a. Maintain continued surveillance of configuration changes

   b. Determine aerodynamic characteristics of emergency configurations

[redacted]

[redacted]

Technical Study Plan

Entry Aerodynamics

The general entry configuration has been established at contract go-ahead. Initial aerodynamic studies will emphasize the determination of design criteria and the identification of critical problem areas. Estimates of command module aerodynamic forces and damping derivatives will be made utilizing Newtonian flow theory programmed for digital computer calculations. These estimates will be supplemented by analysis of preliminary NASA test data released in Apollo working papers. The results will be assembled in the Preliminary Aero Data and Loads Report and will provide the basis for initial trajectory and flight dynamics studies.

Concurrent with this effort, work will be initiated to obtain the aerodynamic characteristics of the specific command module configuration evolving from structural design studies. Wind tunnel test requirements will be determined and tests conducted. To permit early testing, small simple models will be utilized. Parametric data obtained will be used in studies to determine the effects on command module aerodynamics of variations in heat shield radius, corner radius, and afterbody angle. Center-of-gravity tolerances will also be established.

Subsequent studies will include the effects on stability of asymmetric ablation of the heat shield. Wind tunnel data will be used in conjunction with Newtonian predictions of the perturbations in forces due to local geometry changes. The effects on stability of the reaction jets interacting with the free stream flow will be determined from analysis of wind tunnel results. Digital programs will be established to aid in calculation of the nozzle flow field and its interaction with the adjacent structure.

Preliminary aerodynamic damping characteristics of the entry body will be predicted using Newtonian estimates of the forces on the command module. Analog studies will establish the relative importance of the damping terms to control system design. Wind tunnel programs will be conducted using the forced oscillation and decaying oscillation techniques. The forced oscillation tests give a measure of the longitudinal damping parameter, whereas the decaying oscillation tests provide a measure of the overall stability (both static and dynamic) during an oscillatory motion. Analysis of the results will provide an evaluation of damping derivatives as affected by Mach number, dynamic pressure, and center-of-gravity location.

Preliminary command module loads will be estimated using Newtonian flow. Final loads will be determined through wind tunnel tests which provide measured pressure distributions. A digital program will be developed to compute loadings by integration of local pressure distributions.

[redacted]

[redacted]

Methods will be developed for approximate and refined analyses of the flow fields about the Apollo vehicle. Primary emphasis will be on hypersonic blunt body flow fields. Digital programs will be developed to compute real gas equilibrium and nonequilibrium flow, and extended to include angle-of-attack effects. Results of these studies will define local surface conditions for design purposes, and the aerothermodynamic properties of the flow field for use in radio attenuation studies.

Final evaluation of orbital entry aerodynamics will be made from results obtained in the flight test program. The flights of SA-9 and SA-10 will provide the first flight test evaluation of the entry configuration.

Launch Escape System

Initial studies of the launch escape system will determine configuration arrangements which will provide the required stability characteristics. These characteristics can be significantly affected by operation of the escape motor. Early design will be based on analysis of wind tunnel results (jets off) combined with analytical estimates of the interactions between the jet plumes and free stream flow fields. An experimental program will be formulated, and methods of simulating the jet effects in wind tunnel tests will be evaluated. These methods include solid plumes, cold jets, and rocket operation. Evaluation of the system will be established from analysis of the pad abort and high-altitude aborts conducted in the flight test program.

Dynamic stability characteristics will be obtained from analysis of wind tunnel data. Damping derivatives will be determined from analysis of forced-oscillation tests conducted at the Langley Research Center. The effects of Mach number, Reynolds number, center-of-gravity location, and angle of attack will be determined.

Launch escape system loads will be determined from wind tunnel data. Preliminary results will be obtained in early tests with small scale models. More extensive data will be acquired with large scale models in the NASA Unitary Tunnels. Measurements of steady and unsteady pressure distributions will be obtained, including the effects of simulated escape motor operation.

Recovery System Aerodynamics

The aerodynamic characteristic of the command module at subsonic Mach numbers with the parachute cover heat shield removed will be determined from analysis of wind tunnel data.

[redacted]

[redacted]

Launch Vehicle Aerodynamics

The aerodynamic characteristics of the various booster vehicles will be determined by theoretical estimates and through wind tunnel data. Tests will be conducted of the C-1 and C-5 configurations to establish total booster aerodynamics and the characteristics of the booster alone after separation of Apollo. These data will be used in performance studies and in studies of miss distance during abort from boost.

Studies will be conducted to determine the air loadings due to buffet effects during boost. Data will be assembled from other programs and from NASA studies at the Langley and Ames Research Centers. Wind tunnel measurements will be made of buffet pressures and aerodynamic noise on the launch vehicle with emphasis on the command module, service module, and adapter. Analysis of the results will provide design criteria for buffet loads. Flight test measurements will provide in-flight evaluation of buffet effects.

Figure 46 presents the aerodynamics testing schedule.

Reports and Manuals to be Issued

Aerodynamic Data Manual (First Issue 1 April 1962)

Basic force and moment data are presented for all Apollo vehicles. This report is the official source document for all design and performance studies and will be revised as more current data become available.

Aerodynamic Loads Manual (First Issue 1 April 1962)

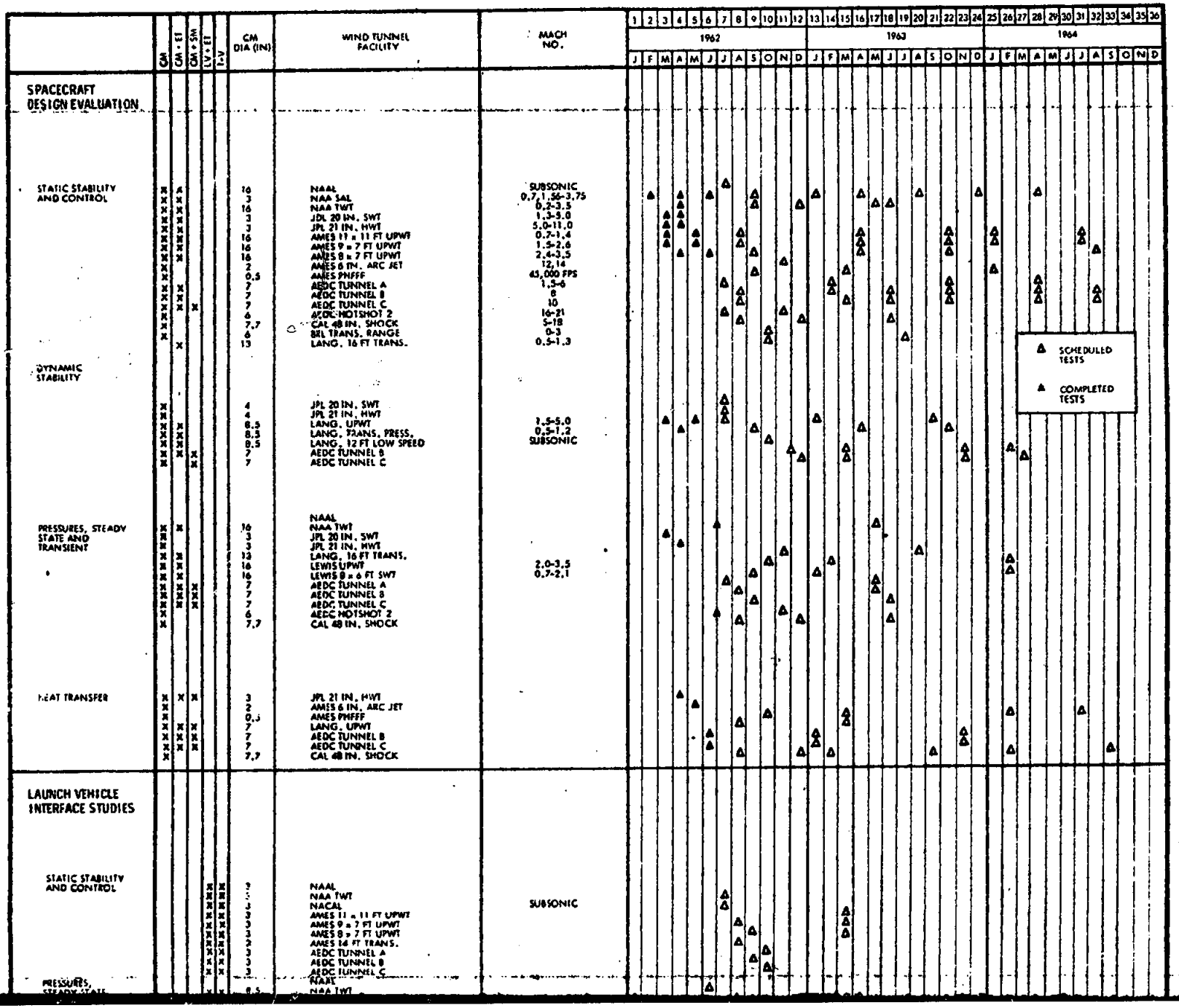
Loads trajectories are presented for boost, abort, and entry. Total and component pressure, force, and moment distributions are presented for all Apollo vehicles. This report serves as the official source document for all air loads design data and will be revised as more current data become available.

Aerodynamic Dimensional Data Manual (First Issue 1 July 1962)

Aerodynamic configuration arrangements, surface contour tolerances, alignment tolerances, center-of-gravity requirements, and weight and balance summaries will be presented for all Apollo vehicles. This report will be revised continually to reflect the most current configurations.

[redacted]

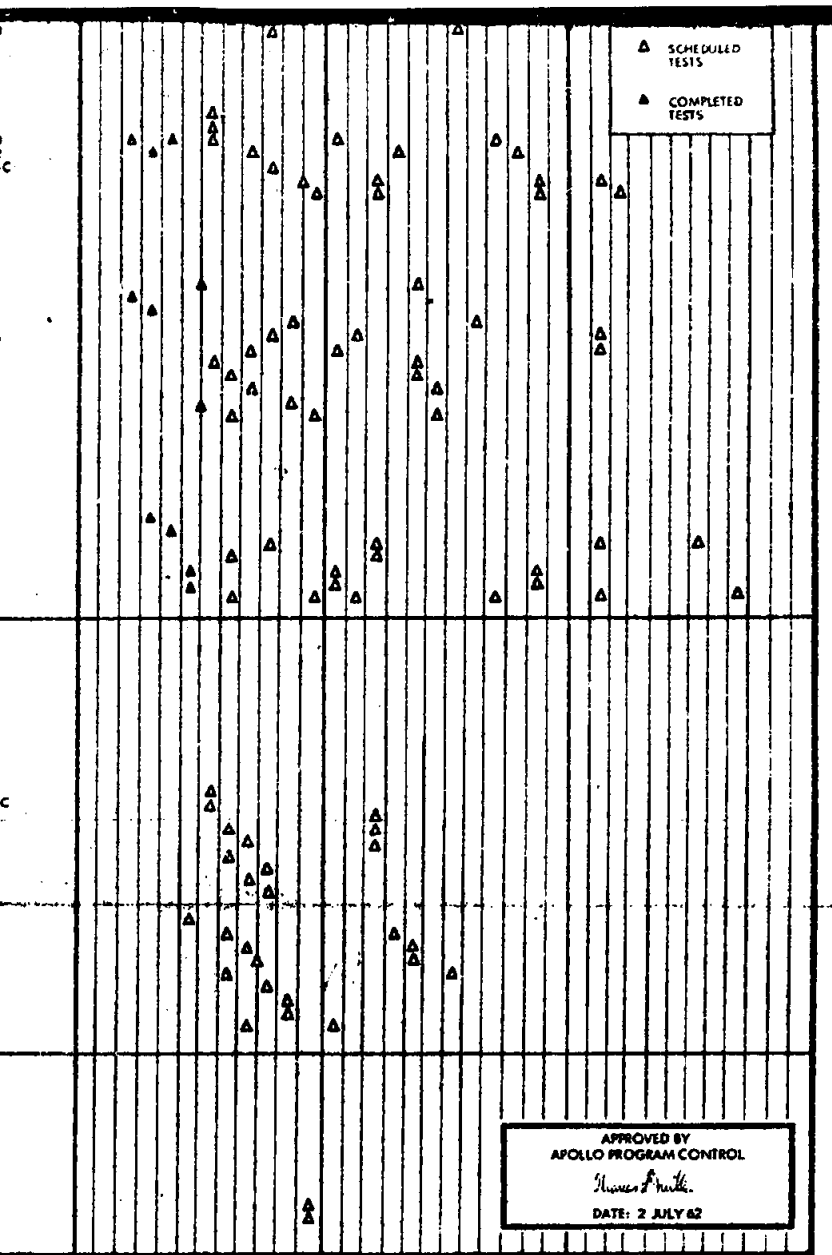
	CM	CM + ET	CM + SM	LV + ET	T-V	CM DIA (IN)	WIND TUNNEL FACILITY	MACH NO.
SPACECRAFT DESIGN EVALUATION								
STATIC STABILITY AND CONTROL	X	X				16	NAAL	SUBSONIC
	X	X				3	NAA SAL	0.7, 1.56-3.75
	X	X				16	NAA TWT	0.2-3.5
	X	X				3	JDL 20 IN. SWT	1.3-5.0
	X	X				3	JPL 21 IN. HWT	5.0-11.0
	X	X				16	AMES 11 x 11 FT UPWT	0.7-1.4
	X	X				16	AMES 9 x 7 FT UPWT	1.5-2.6
	X	X				16	AMES 8 x 7 FT UPWT	2.4-3.5
	X					2	AMES 6 IN. ARC JET	12, 14
	X					0.5	AMES PHFFF	45,000 FPS
	X	X				7	AEDC TUNNEL A	1.5-6
	X	X				7	AEDC TUNNEL B	8
	X	X	X			7	AEDC TUNNEL C	10
	X					6	AEDC HOTSHOT 2	16-21
	X					7.7	CAL 48 IN. SHOCK	5-18
	X					6	BRL TRANS. RANGE	0-3
		X				13	LANG. 16 FT TRANS.	0.5-1.3
DYNAMIC STABILITY								
	X					4	JPL 20 IN. SWT	
	X					4	JPL 21 IN. HWT	
	X	X				8.5	LANG. UPWT	1.5-5.0
	X	X				8.5	LANG. TRANS. PRESS.	0.5-1.2
	X	X				8.5	LANG. 12 FT LOW SPEED	SUBSONIC
	X	X	X			7	AEDC TUNNEL B	
	X		X			7	AEDC TUNNEL C	
PRESSURES, STEADY STATE AND TRANSIENT							NAAL	
	X	X				16	NAA TWT	
	X					3	JPL 20 IN. SWT	
	X					3	JPL 21 IN. HWT	
	X	X				13	LANG. 16 FT TRANS.	
	X	X				16	LEWIS UPWT	2.0-3.5
	X	X				16	LEWIS 8 x 6 FT SWT	0.7-2.1
	X	X	X			7	AEDC TUNNEL A	
	X	X	X			7	AEDC TUNNEL B	
	X	X	X			7	AEDC TUNNEL C	
	X					6	AEDC HOTSHOT 2	
	X					7.7	CAL 48 IN. SHOCK	
HEAT TRANSFER	X	X	X			3	JPL 21 IN. HWT	
	X					2	AMES 6 IN. ARC JET	
	X					0.5	AMES PHFFF	
	X	X	X			7	LANG. UPWT	
	X	X	X			7	AEDC TUNNEL B	
	X	X	X			7	AEDC TUNNEL C	
	X					7.7	CAL 48 IN. SHOCK	
LAUNCH VEHICLE INTERFACE STUDIES								
STATIC STABILITY AND CONTROL				X	X	?	NAAL	
				X	X	?	NAA TWT	
				X	X	3	NACAL	SUBSONIC
				X	X	3	AMES 11 x 11 FT UPWT	
				X	X	3	AMES 9 x 7 FT UPWT	
				X	X	3	AMES 8 x 7 FT UPWT	
				X	X	2	AMES 16 FT TRANS.	
				X	X	3	AEDC TUNNEL A	
				X	X	3	AEDC TUNNEL B	
				X	X	3	AEDC TUNNEL C	
PRESSURES, STEADY STATE				X	X	8.5	NAAL	
							NAA TWT	



PRECEDING PAGE BLANK-NOT FILMED

NORTH AMERICAN AVIATION, INC.

						13	LANG. 16 FT TRANS.	0.5-1.3	
DYNAMIC STABILITY									
	X					4	JPL 20 IN. SWT		
	X					4	JPL 21 IN. HWT		
	X	X				8.5	LANG. UPWT	1.5-5.0	
	X	X				8.5	LANG. TRANS. PRESS.	0.5-1.2	
	X	X				8.5	LANG. 12 FT LOW SPEED	SUBSONIC	
	X	X	X			7	AEDC TUNNEL B		
	X		X			7	AEDC TUNNEL C		
							NAAL		
PRESSURES, STEADY STATE AND TRANSIENT	X	X				16	NAA TWT		
	X					3	JPL 20 IN. SWT		
	X					3	JPL 21 IN. HWT		
	X	X				13	LANG. 16 FT TRANS.		
	X	X				16	LEWIS UPWT	2.0-3.5	
	X	X				16	LEWIS 8 x 6 FT SWT	0.7-2.1	
	X	X	X			7	AEDC TUNNEL A		
	X	X	X			7	AEDC TUNNEL B		
	X	X	X			7	AEDC TUNNEL C		
	X					6	AEDC NOTSHOT 2		
	X					7.7	CAL 48 IN. SHOCK		
HEAT TRANSFER	X	X	X			3	JPL 21 IN. HWT		
	X					2	AMES 6 IN. ARC JET		
	X					0.3	AMES PHFFF		
	X	X	X			7	LANG. UPWT		
	X	X	X			7	AEDC TUNNEL B		
	X	X	X			7	AEDC TUNNEL C		
	X					7.7	CAL 48 IN. SHOCK		
LAUNCH VEHICLE INTERFACE STUDIES									
STATIC STABILITY AND CONTROL				X	X	3	NAAL		
				X	X	[illegible]	NAA TWT		
				X	X	3	NACAL	SUBSONIC	
				X	X	3	AMES 11 x 11 FT UPWT		
				X	X	3	AMES 9 x 7 FT UPWT		
				X	X	3	AMES 8 x 7 FT UPWT		
				X	X	3	AMES 14 FT TRANS.		
				X	X	3	AEDC TUNNEL A		
				X	X	3	AEDC TUNNEL B		
				X	X	3	AEDC TUNNEL C		
							NAAL		
PRESSURES, STEADY STATE AND TRANSIENT				X	X	8.5	NAA TWT		
				X	X	8.5	AMES 11 x 11 FT UPWT		
				X	X	8.5	AMES 9 x 7 FT UPWT		
				X	X	8.5	AMES 8 x 7 FT UPWT		
				X	X	8.5	AMES 14 FT TRANS.		
HEAT TRANSFER				X	X	3	LANG. UPWT		
				X	X	3	AEDC TUNNEL B		
				X	X	3	AEDC TUNNEL C		
STRUCTURAL DYN.				X		12	LANG. TRANS. DYN	0.3-1.2	
JET REACTION STUDIES									
CONTROL EFFECTIVENESS (REACTION JETS)	X					7	AEDC TUNNEL B		
	X					7	AEDC TUNNEL C		
SERVICE MODULE BASE HEATING							AEDC J2		



APPROVED BY
APOLLO PROGRAM CONTROL
DATE: 2 JULY 62

Figure 46. Wind Tunnel Testing Schedule

[redacted]

Command Module Aerodynamic Summary Report (First Issue 1 July 1963)

Static and dynamic stability characteristics of the operational command module will be presented for flight from entry through recovery. The first issue of this report will be based on analyses of wind tunnel data. Subsequent issues will incorporate flight test program results.

Launch Escape System Aerodynamics Summary Report (Issued 1 January 1964)

A description and evaluation of the static and dynamic characteristics of the launch escape system will be presented. Conditions from rocket ignition to tower jettison will be covered.

Aerodynamics of Apollo Launch Vehicles (First Issue 1 March 1963)

This report will contain a documentation and analysis of the aerodynamic characteristics of Apollo launch vehicles for performance and trajectory studies. Results of wind tunnel tests simulating conditions before and after separation of the Apollo vehicle will be included. The report will be revised as required.

Flight Test Program Report (First Issue 1 July 1962)

Objectives and instrumentation requirements will be presented for aerodynamic evaluation of the spacecraft during the flight test program.

Flight Test Summary Analysis Report (First Issued 1 October 1964)

An evaluation and summary of aerodynamic characteristics of the Apollo vehicle will be presented as determined in flight test.

PERFORMANCE AND TRAJECTORIES

The basic objectives of performance and trajectories will be (1) to establish performance capabilities and limitations of the Apollo spacecraft, (2) to generate detail trajectory data for specific missions, (3) to provide data for operational analysis covering interaction of trajectory, navigation and guidance requirements, ground operations support system, and operational flexibility (i.e., launch and landing sites and mission dates, and (4) to supply digital programming service for flight technology and associated areas.

In addition, performance and trajectories will support structure and systems design, development test program, and manned operations.

[redacted]

[redacted]

Functions performed for structure and systems design will include:

Prepare preliminary trajectories and performance estimates as guidelines for structural design

Integrate energy management among navigation and guidance, propulsion, and selected flight plan

Determine trade-offs among flight plan trajectories, fuel requirements, and position and velocity accuracies

Determine design envelope trajectories for loads and heat shield analysis and guidance system design

Determine propulsion system and propellant requirements

Evaluate the complete spacecraft system to determine capability for performing various missions

Analyze effects of malfunctions and set requirements for safe abort in space

Develop digital programs for flight technology and associated areas

Publish the Flight Performance Manual

The following functions will be performed for the development test program and manned operations.

1. Estimate preflight performance for each flight to determine the flight plans

2. Prepare data relating to detail flight plans for flight test operations.

3. Produce detail trajectories for each flight

4. Determine contingency flight plans in case of malfunction for each flight including detail abort flight schemes

Technical Study Plan

Booster Analysis

Analog and digital computer studies will be made to determine generalized launch vehicle performance and trade-offs for the Apollo payloads. These will include general and specific reference boost trajectories and the

[redacted]

launch vehicle malfunction performance. Launch vehicles for which this data will be determined include Little Joe II, Saturn C-1 and C-1B, Saturn C-5, and possible Nova. Trajectory and performance data will be determined for each Apollo development test and operational Apollo mission. This requirement is established to account for weight variations in each boilerplate and prototype Apollo payload.

Preliminary analysis and general performance requirements for the service module will be specified. Based upon the selected design point, performance and propellant propulsion requirements will be determined for each service module mission. This also includes reference trajectories for each burning maneuver and abort situations occurring in trajectories to or from the moon and during lunar landing and take-off where applicable.

Special analyses will be conducted to determine optimum lunar orbit injection, ejection, and rendezvous trajectories. From these studies, propulsion requirements and system weight optimizations will be determined for the appropriate selection of thrust level and propellant system weight.

Space Operations

Mathematical formulas will be derived to permit precision cislunar trajectory calculations using optional coordinate systems.

Physical and apparent lunar librations will be determined to calculate selenographic coordinates. The effects of nonspherical earth and moon will be evaluated to obtain geodetic and selenodetic coordinates. Additional relationships will be derived to determine tracking parameters from the earth to the spacecraft and from the spacecraft to selected celestial bodies.

Iteration (SEARCH) logic will be formulated to solve the two-point boundary-type problem for five classes of lunar trajectories. These include circumlunar trajectories, translunar trajectories, transearth trajectories from lunar orbit, and cislunar abort trajectories.

Reference trajectories will be calculated for the earth-orbital, the circumlunar, the lunar-orbital, and the lunar landing missions. Characteristic velocities will be determined for these missions as a function of the required operational flexibility (i. e., launch windows, lunar declinations, etc.). Earth and lunar lighting data will be calculated to evaluate the lighting constraints on mission flexibility.

Trajectories and propulsion requirements will be established for the lunar landing mission to consider Apollo lunar excursion module integration of lunar orbital and in-phase and out-of-plane landing and ascent maneuvers.

[redacted]

Perturbation studies will be made to determine the variation of earth and lunar orbital elements (as a function of time) due to a nonspherical earth or moon, the gravitational attraction of secondary bodies, etc.

Abort trajectory analyses will be conducted for all phases of Apollo flight. Simplified and precision analyses will be used to determine propulsion requirements for abort. Consideration will be given to emergency landing site selection, transit time, radiation hazards, landing approach azimuths, and glide range requirements.

Entry Phase

Entry trajectory and performance analyses will result in the establishment of guaranteed mission performance, systems performance requirements, and flight constraints for (1) earth orbit ejection and atmospheric entry, (2) atmospheric entry and recovery from lunar missions, and (3) aborted missions.

These analyses will consist in part in the establishment and evaluation of flight modes and range control techniques during atmospheric entry. That technique which is least sensitive to system errors and vehicle design constraints and which meets the required mission performance will be defined. Secondly, design criteria will be established from which design trajectories, trajectory and interface envelopes, and systems performance requirements will result. Further, trajectory sensitivities and path constraints during orbital and atmospheric flight will be defined. These, combined with performance evaluation studies, will aid in the formulation of such items as flight placards and displays, ejection propulsion system requirements, guidance and control systems requirements, and guaranteed mission performance.

Performance Interface Tasks

Performance interface efforts will consist of two major task areas: (1) interfaces with test plans and (2) interfaces with guidance and navigation.

The test planning interface will be concerned with coordination of boost, space, and entry trajectory analyses with test planning functions to establish reference trajectories and performance estimates for all test flights. Additional related tasks will include coordination of trajectory and performance test measurement requirements with Systems Integration and Systems Test groups, and the reduction of flight test data to be included in the trajectory and performance section of the Spacecraft Flight Report.

The guidance and navigation interface tasks will be concerned with investigations of the interrelationships between spacecraft performance

[redacted]

requirements and guidance accuracies for all flight phases within the operational and mission constraints of the Apollo program. These tasks will be extended to include analysis of performance requirements for degraded levels of guidance and maneuvering precision associated with potential backup modes of operation. Further related activities in this area will include the representation of trajectories and performance functions in exploring the performance-reliability interface as reflected in mission success and crew safety probabilities. This will involve the establishment of safe entry criteria and potential abort trajectory envelopes with their expected dispersions as a function of primary and degraded levels of guidance and control precision.

Digital Programming

Digital programs for performance and trajectory, flight dynamics, aerodynamics, thermodynamics, and utility routines are presently in the developmental or operational stage.

The performance and trajectory efforts will be concerned with (1) boosts and reentry, (2) orbital, (3) space trajectories, and (4) error analysis.

Boost and reentry will have the following programs:

1. Longitudinal trajectory multi-stage two degree of freedom. Calculates the trajectory for a ballistic missile including the effects of horizontal headwind or tailwind profile

2. Three degree of freedom. Computes the three-dimensional trajectory of a multi-stage vehicle on a rotating spherical or oblate earth

3. Trans-earth injection requirements for daylight landing. Calculates the landing parameters for a given injection time

4. Trajectory optimization. Minimizes fuel requirements or maximizes payload for given initial and final trajectory parameters.

Orbital programs will include:

1. Parking orbit program with ephemeris. Computes an approximate trajectory from a known launch site on the earth to the moon.

2. Two-impulse abort or transfer and rendezvous. Solves specific time solution of abort from initial conic; with second impulse, it will perform rendezvous with second conic; geometrically attached to landing site.

[redacted]

3. Class 1 in-transit abort. Generates geographic contours of abort range, total impulsive velocity required, and landing azimuth for major constraint of minimum time of abort to landing

4. Earth-orbital mission geometry. Investigates the orbital abort maneuvers from a circular parking orbit to a series of selected emergency landing sites with a view to the compatibility of the spacecraft propulsion capability

Space trajectories efforts will include:

1. Cowell lunar trajectory. N-body space trajectory program which numerically integrates the equations of motion by Cowell's method

2. Circumlunar trajectory analysis. Determines the orientation of the radius vector required for a translunar trajectory which has a perilune radius of approximately zero. This program will modify these initial conditions and go through an iteration process in order to go circumlunar and satisfy perigee radius and flight path angle at entry.

3. Conic 3-D. Restricted two-body equations of motion for elliptic and hyperbolic orbits in three dimensions. Elements and orientation of conic, position, velocity and time at a specified radius and at perifocus will be computed.

4. Circumlunar trajectory Encke's method. Using Encke's method with true anomaly as the independent variable, this program will compute a precision trajectory for transearth, transmoon, and circumlunar flights, and will incorporate maneuver capabilities.

The error analysis program 16 body error analysis will compute one (6 by 6) injection-terminal error-matrix and up to 50 (6 by 3) midcourse velocity-terminal error matrices. It also will compute partials of 23 observation and tracking variables, and for each of these variables, a (6 by 6) symmetric matrix which relates measurement deviations due to injection deviations.

The program for flight dynamics is the generalized six degrees of freedom analysis. This program will include oblate rotating earth with staging, winds, gravity, heating, heating control, accelerometer, autopilot, aerodynamics, rotating machinery, and guidance.

[redacted]

The program which supports aerodynamics will include:

1. Newtonian coefficients. Determine static and dynamic hypersonic aerodynamic coefficients for a body of revolution with an offset center-of-gravity.

2. Method of characteristics. Calculate supersonic flow fields by method of characteristics with improved numerical methods.

The thermodynamics program will include:

1. Heat shield analysis. Make a complete evaluation of the temperature distribution of the Apollo heat shield.

2. Flow field. Compute a rocket exhaust gas flow field in a vacuum.

The Utility routines program will include:

1. Integration routine. Integrates a set of differential equations using a variable computing interval. It employs a Runge-Kutta starter and will accept any predictor-corrector method up to the sixth order. The program is designed to stop on the independent or any dependent variable.

2. Read routine. A relative read routine, which reads and stores data and curves into preassigned common locations, writes out the input data and input curves, selects the proper curve for each stage, and plots the input curves.

3. Multidimensional curve evaluation. Evaluates a curve, family, or set of families (two, three, or four dimensional curves).

4. Search routine. Computes the inverse of any function

Reports and Manuals to be Issued

The performance and trajectories section will prepare the reports and manuals which are identified and listed below along with pertinent publications data.

1. Contribution to spacecraft performance specification, February 1962

2. Trajectory analysis summary report, first issue, 15 March 1962; periodic revision roughly every six months

[redacted]

3. Detail trajectory analysis reports, covering the following phases of flight: entry analysis, space operations, navigation and guidance - performance studies, and booster analysis studies.

4. Performance and trajectories manual. Internal document covering a complete history of the pertinent flight mechanics and performance and trajectory studies in developing the Apollo spacecraft to perform the lunar landing mission.

5. Individual trajectory and flight plan reports for each of the development test series will include maximum q, Little Joe II abort series high-altitude abort - Little Joe series, earth orbital tests - nonrecovery series, orbital tests - recovery series, and manned orbital flights.

6. Flight contributions to the flight analysis reports, which will be submitted 30 days after each test flight.

FLIGHT DYNAMICS

The basic objectives of flight dynamics will be to ensure adequate stability and control for the spacecraft; to define and issue dynamics requirements for the stabilization and control system, launch escape system, reaction control system, and recovery system; and to issue stability and control design data.

In addition to these objectives, flight dynamics will support structure and systems design, and development test program and manned operations. The structure and systems design program will include two groups of functions.

Functions performed for structure and systems design are as follows:

1. Publish stability and control data for the design of the stabilization and control system and for the recovery system

2. Determine design requirements for the launch escape, reaction control, recovery, and stabilization and control systems

3. Analyze the dynamics of each flight segment to evaluate the complete dynamic system

4. Develop analog and digital computer methods for the study of stability and control

[redacted]

[redacted]

The functions performed for the development test program and manned operations will include:

1. Conduct preflight evaluations of flights to establish placards, limitations, and detail test plans

2. Conduct postflight analyses to correlate test data with theoretical analysis and to provide data for use on evaluations for subsequent flights

Technical Study Plan

Space Dynamics

The basic systems affecting the motion of the vehicle in space and during maneuvers will be the service module reaction control system and the service module propulsion system. Flight dynamics requirements that include the desired configuration, thrust level, response, gimbal travel, duty cycle, and control propellant will be specified for these systems based on preliminary engineering analysis and the use of analog computers to simulate the systems. When component hardware characteristics become available from the vendor, the systems will be evaluated in detail with analog simulations.

The flight phases under consideration will be investigated in general in the following manner. Each flight phase will be divided into subphases, and criteria established for each. Concurrently, equations of motion applicable to the respective flight phase and compatible with both analog and digital computers will be written. Simplified engineering analyses will be performed to depict pertinent problem areas and establish computer study objectives and study schedules. Computer studies will then be made with data based on current estimates. Results from the computer studies will be analyzed and documented and the basic governing criteria and concepts reevaluated.

Flight test support will be provided in the form of test objectives, required instrumentation, test planning, and mission simulation both preceding and subsequent to the flight. A flight description handbook will be provided as will test site support. After correlation of flight test data and analytical results, the mathematical model of each of the flight phases and hardware components will be updated.

Data from the Mercury and Gemini programs will be integrated into all studies where these data are applicable.

[redacted]

Other problems which will be studied are the effect of propellant slosh on control dynamics and precision attitude hold, and the allotting of control modes between manual and automatic control while maintaining acceptable performance.

Preentry Flight Phase

A six-degree-of-freedom combined analog-DDA simulation will be utilized to investigate problem areas associated with the preentry flight phase. A six-degree-of-freedom digital program is being formulated and coded as a backup for the analog mechanization.

Primary problem areas to be investigated are (1) separation dynamics and modules' clearance subsequent to separation, (2) heat shield forward positioning about the pitch axis, (3) orientation of the command module as required for entry using three-axis attitude control, (4) determination of proper time or distance prior to entry at which to initiate separation, and (5) control system logic and propellant requirements.

Entry Flight Phase

The combined analog-digital entry simulation will be utilized to investigate problem areas associated with the entry phase of flight. This mechanization describes complete six-degree-of-freedom motion of the command module traversing a three-dimensional trajectory over a spherical rotating earth and includes the attitude control system logic together with a predictive guidance system. It is tied to a cockpit which displays the vehicle environment in the form of an instrument display.

Problem areas to be investigated using this mechanization are (1) reaction control system requirements, namely, motor thrust levels, amount of propellant, control system configuration and parameters, and reaction motor duty cycles, (2) steering logic required for mission flexibility, terminal accuracy, and low error sensitivity, (3) emergency entry technique, system malfunctions, and subsystems compatibility, and (4) simulation of all test conditions.

Investigation of the above problem areas will be augmented by use of simplified computer studies and theoretical analysis. Some of these efforts will be (1) stability analysis employing topological methods, (2) feasibility and comparison studies of various trajectory shaping techniques using special purpose digital computer studies, and (3) evaluation of short-period dynamic characteristics by use of analog and digital computers.

In addition, effort will be directed toward formulation and coding of a generalized six-degree-of-freedom digital program based on building-block

[redacted]

[redacted]

logic. The ultimate aim of this effort will be to provide a library of building blocks conducive to rapid assembly of programs for any vehicle configuration, control system, and flight regime.

Recovery Flight Phase

A six-degree-of-freedom digital program will be used in investigating problem areas associated with the recovery phase of flight. Problem areas to be investigated are (1) freeflight stability characteristics and trajectory motion of the recovery vehicle, (2) formulation and test verification of mathematical models of drogue and main parachute load characteristics, (3) stabilizing effects of the drogue parachute on command module motion, (4) criteria and parachute landing system design justification and evaluation, (5) dynamic characteristics of recovery system for abort and normal entry conditions, and (6) simulation of all test conditions.

Investigation of the above problem areas utilizing computer models will be augmented by theoretical analysis. Some of these efforts will be: (1) stability analysis using topological methods and (2) recovery system weight tradeoff approximations between design criteria and system requirements.

Escape Dynamics

Parametric studies of the dynamic characteristics of the launch escape system will be carried out using both analog and digital computers. Parameters which will be varied include

1. Destabilizing jet effects from the launch escape system motor
2. Ballast weight to alter the static margin
3. Launch escape motor alignment tolerance
4. Gust and wind shear disturbances
5. Control system characteristics.

The purpose of these studies will be to determine whether or not a control system will be required for the launch escape system, and, if so, what characteristics will be required of it. A range of aerodynamic configurations will be studied, and various initial conditions for abort arising from possible booster control system failure cases will be considered.

As jet effect data will not be available until shortly before the first boilerplate launch escape system test, it will be necessary to define the optimum control system characteristics (authority, gains) based on the

[redacted]

parametric studies which will be undertaken in advance. As wind tunnel data become available, the estimates of the optimum system can be refined.

A postflight technical assessment of each boilerplate test will be made by comparing observed results with correlation studies to be run on a computer. The boilerplate tests using the launch escape system fall into three categories: pad abort tests, max q tests, and high-altitude tests.

The information gained from each test will be used to reevaluate the dynamics of the system during escape.

Reports and Manuals to be Issued

Data relating to the reports and manuals to be prepared by Flight Dynamics are presented below.

1. Stability and Control Data Manual (First Issue 1 May 1962)

   This report will contain basic stability and control data. It will be the official source document for stability and control data used in the design of the stabilization and control system and the recovery system, and will be revised periodically as later data becomes available.

2. Drogue Chute Design Evaluation (First Issue 1 June 1962)

3. Main Chute Design Evaluation (First Issue 1 August 1962)

4. Postflight Analysis of Boilerplate Recovery Tests (First Issue 1 May 1963)

5. Thrust Vector Control Design Evaluation (First Issue 1 July 1962)

6. Preflight Pad Abort Simulation (First Issue 1 January 1963)

7. Pad Abort Test Evaluation (First Issue 1 June 1963)

8. Max q Preflight Abort Simulation (First Issue 1 May 1963)

9. Max q Abort Test Evaluation (First Issue 1 September 1963)

10. Final Launch Escape System Evaluation (First Issue 1 January 1964)

11. Service Module Reaction Control System Evaluation (First Issue 1 February 1963)

[redacted]

[redacted]

12. Service Module Main Propulsion Control Evaluation (First Issue 1 March 1963)

13. Preflight Service Module Abort Simulation (First Issue 1 April 1964)

14. Service Module Abort Test Evaluation (First Issue 15 June 1964)

15. Detail Entry Control Requirements (First Issue 1 August 1962)

16. Entry Range Control Evaluation (First Issue 1 January 1963)

17. Preflight Simulation of Service Module Orbit Ejection and Entry (First Issue 15 February 1964)

18. Entry and Service Module Control Postflight Analysis (First Issue 15 July 1964)

WIND TUNNEL TEST PROGRAM

The basic objectives of the wind tunnel test program will be to provide information on the (1) aerodynamic forces and environment on the various configurations, (2) aerodynamic heating data, and (3) aeroelastic data. In addition to these objectives, the wind tunnel test program will support structure and systems design and development test program and manned operations.

The Aerodynamics section of the Flight Technology department manages the Apollo wind tunnel program. Tests are conducted for aerodynamics, thermodynamics, and structural dynamics. Based on requirements received from these activities, models are designed and constructed, and tests are planned and conducted. Upon completion of each test, a data report is issued to the test requestor for analysis.

As data become available from the development test program and from manned flights, further tests, which cannot be defined at this stage, will be performed to investigate discrepancies which become apparent between flight results and earlier wind tunnel tests.

Technical Study Plan

Test Objectives

The test objectives of the proposed wind tunnel test program will provide the following data:

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

[redacted]

[redacted]

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

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

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

5. Reaction jet effects on stability of the entry configuration

6. Steady-state pressure distributions on launch escape and entry configuration

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

8. Buffet loads effect on the bending mode shapes of the space vehicle structure

9. Aerodynamic heat transfer distributions on the launch vehicle, launch escape system, and entry configuration

10. Heating of service module by attitude control rocket exhaust

11. Service module base heating

Spacecraft Design and Evaluation Tests

Static stability and control data will be obtained in wind tunnel tests conducted over a Mach number ranges from 0.2 to 20. Data at higher velocities will be obtained in ballistic ranges and free flight facilities. Actual flight Reynolds numbers will be duplicated for most tests of the command module during entry.

Escape rocket motor jet effects on the stability of the launch escape system will be obtained by testing a model with a hydrogen peroxide monopropellant rocket to simulate jet effects.

Dynamic stability will be evaluated in transonic and supersonic wind tunnels by means of a dynamic balance. Free damped oscillation techniques also will be used to determine damping derivatives.

[redacted]

[redacted]

Structural design information will be obtained from model static pressure measurements in the 1.5 to 10 Mach number range. Transient pressures, due to aerodynamic noise and buffet on a large scale model, will be obtained in the subsonic, transonic, and supersonic regimes up to M = 3.5.

Aerodynamic heating rates will be determined from rate-change measurements of surface temperature by using thin-film or variable reluctance heat-transfer gauges, or by measuring the output of thermocouples mounted on the inner surface of a thin-walled model. Data will be obtained in impulse, continuous flow, and free-flight wind tunnels. In free-flight wind tunnels, heating measurements will be made by either picking up the output of a single thermocouple inductively, or using a miniature FM telemeter transmitter.

Launch Vehicle Interface Studies

The static stability and control effectiveness at the lower ranges of velocity and altitude encountered by the launch vehicle will be investigated by means of well established wind tunnel techniques. Steady-state and transient pressure distributions will be obtained for loads calculations over a Mach number range from subsonic to 3.5. Aerodynamic heating rates will be determined for a Mach number range from 1.5 to 10.

Aeroelasticity Tests

Transonic tests of a structurally simulated 0.08 scale model will be conducted to determine the effect of buffet loads on the bending mode shape of the structure.

Jet Reaction Studies

The effectiveness of the reaction jet controls of the entry configuration will be investigated in the Mach number range from 8 to 10. Gas under high pressure will be exhausted from model posts to simulate the reaction jets.

Service Module Base Heating

Rocket heating data associated with the service module attitude control and propulsion systems will be obtained by the use of scaled motors in rocket test facilities.

Test Facilities

A list of the test facilities planned to be used is given in Table 1.

Table 1. Recommended Test Facilities

Facility	Abbreviation	Mach Range	Stag. Press. (psia)	Stag. Temp. (°F)	Re/Ft x 10^{-6}	Type	Test Section
1. North American Aerodynamics Laboratory	NAAL	Subsonic	15	70	1.9	Continuous	8' x 11'
2. North American Aviation Supersonic Aerophysics Laboratory	SAL	0.7, 1.6 - 3.25	15	70	2 - 4.6	Blowdown	16" x 16"
3. North American Aviation Trisonic Wind Tunnel	TWT	0.2 - 3.5	15 - 110	70	5 - 14	Blowdown	7' x 7'
4. North American Aviation Shock Tunnel	NAA ST	16 - 20	6,000	4,500	0.02 - 0.05	Impulse	12" dia
5. Jet Propulsion Laboratory 20-Inch Supersonic	JPL 20"	1.3 - 5	2 - 60	110	0.4 - 6	Continuous	20" x 20"
6. Jet Propulsion Laboratory 21-Inch Hypersonic	JPL 21"	5 - 9.5	20 - 600	100 - 1200	0.25 - 3.6	Continuous	21" dia
7. Langley 8-Foot Transonic Tunnel	LTPT	0.25 - 1.2	5 - 15	125	0.6 - 2.5	Continuous	8' x 8'
8. Langley Unitary Plan Wind Tunnel	LUPWT	1.4 - 5	30 - 55	150	5 - 11	Continuous	4' x 4'
9. Langley Transonic Dynamics Tunnel	LTDT	0.4 - 1.2	0.07 - 15	150	0.3 - 2.8	Continuous	14' x 14'
10. Langley Low-Speed Tunnel	LST	0 - 0.4	15	40 - 110	0 - 2.5	Continuous	7' x 10'
11. Langley 16-Foot Transonic Tunnel	L16'	0.2 - 1.3	15	40 - 180	1.2 - 4.0	Continuous	15.5' octagonal
12. Ames Unitary Plan Wind Tunnel	AUP	0.7 - 3.5	29 - 35	120	3 - 9	Continuous	11' x 11', 9' x 7', 8' x 7'

Table 1. Recommended Test Facilities (Cont.)

Facility	Abbreviation	Mach Range	Stag. Press. (psia)	Stag. Temp. (°F)	Re/Ft x 10^{-6}	Type	Test Section
13. Ames 14-Foot Transonic Wind Tunnel	A14 ft	0.6 - 1.2	15	180	2.8 - 3.7	Continuous	14' x 14'
14. Ames Prototype Hypersonic Free Flight Facility	APHFFF	30,000 fps	-	-	-	Ballistic range	0.45" dia model
15. Ames 6-Inch Arc Jet	A6" AJ	12, 14	-	900 Btu/lb	-	Continuous	6" dia
16. AEDC Tunnel A-40	AEDC A	1.5 - 6	1 - 200	70 - 310	0.3 - 9.5	Continuous	40" x 40"
17. AEDC Tunnel B-50	AEDC B	8	100 - 800	900	0.4 - 3.3	Continuous	50" dia
18. AEDC Tunnel C-50	AEDC C	10, 12	175 - 2400	1,500	0.3 - 3.1	Continuous	50" dia
19. Arnold Engineering Development Center Hotshot II	AEDC HSII	16 - 21	16,100	5,400	0.21 - 0.55	Impulse	50" dia
20. Arnold Engineering Development Center Engine Test Facility J-2	AEDC J-2	0	-	-	-	Vacuum chamber	-
21. Ballistic Research Laboratory Transonic Range	BRL T	0.5 - 2.0	-	-	0.5 - 1.0	Ballistic range	6" dia model
22. Cornell Aeronautical Laboratory 48-Inch Shock Tunnel	CAL 48" ST	6 - 20	-	-	0.002 - 28	Impulse	24" dia
23. Cornell Aeronautical Laboratory 6-Foot Shock Tunnel	CAL 6' ST	15 - 25	30,000	14,000	0.002 - 2	Impulse	72" dia
24. Lewis 10' x 10'	L10' x 10'	2 - 3.5	14 - 0.35	120 - 330	2.2 - 3.2	Continuous	10' x 10'
25. Lewis 8' x 6'	L8' x 6'	0.7 - 2.2	15.6 - 25	138 - 200	4.2 - 4.8	Continuous	8' x 6'

[redacted]

These facilities cover the full range of flight conditions encountered from launch to entry and recovery. They fall into four general categories:

1. Continuous tunnels, covering a range of Mach numbers from subsonic to 14

2. Blowdown tunnels, at subsonic, transonic, and supersonic Mach numbers

3. Impulse tunnels. These are either arc driven (hotshot) or shock tube driven (shock tunnel), and provide Mach numbers above 15.

4. Ballistic ranges. Superorbital velocities can be reached in these. Also, tests free of sting interference can be performed at lower speeds in these for comparison purposes.

Reports and Manuals to be Issued

The following reports and manuals will be issued to document the wind tunnel test program.

Apollo Wind Tunnel Program Report (First Issue 30 January 1962)

Test objectives, test facilities, models required, and tunnel test hours for the Apollo program are discussed in this report. Also included are the proposed schedule of wind tunnel tests, tests completed, reports published, and the relationship of the test program to the design phases of the vehicle development. This report will be updated and issued quarterly beginning 1 April 1962.

Pretest Reports

Test objectives, configurations to be tested, test conditions, and the run schedule are presented in these reports. Instrumentation requirements and data reduction and presentation are also included. A pretest report will be published for each of the tests which are scheduled. The report is published approximately four weeks prior to the test depending upon the requirements of the particular facility.

Data Reports

The wind tunnel test results are presented in tabular and plotted format in the data report. Model and Schlieren photographs plus dimensional data are also included. These reports will be issued 30 days after the completion of each test.

[redacted]

[redacted]

Apollo Wind Tunnel Summary Report (First Issue 1 October 1964)

Upon completion of the Apollo wind tunnel program a report will be published summarizing the tests by test hours, facilities, and models. A summary of all pertinent reports also will be included.

[redacted]

[redacted]

LIFE SYSTEMS

INTRODUCTION

Beyond the normal equipment engineering problems associated with manned space flight, the capability of man to survive in space, as well as his ability to function efficiently as part of a complex integrated system, looms large as a major problem in the performance and success of the Apollo mission. He must carry his habitable environment with him. He will be faced with medical, physiological, and psychological problems which can lead to performance failure. Yet, the Apollo mission must provide a safety probability of 0.999 and a completion probability of 0.90.

The close coordination of man and machine demands the exact determination of equipment requirements and human capabilities for man and equipment integration within the Apollo program and places man in a unique situation. He becomes a system in a loop of systems, while retaining his status as controller of overall systems performance.

OBJECTIVES AND RESPONSIBILITIES

The purpose of the Life Systems Group is to recognize, analyze, and resolve those problems pertaining to the man in the loop. Life Systems responsibilities include the incorporation of these problem solutions into equipment design, establishment of compatible man-system interfaces required between the Apollo astronauts and the Apollo spacecraft within the constraints of weight and volume requirements, and the establishment of criteria for those systems needed to provide the environment which will allow the astronaut to perform effectively throughout the mission. The cycle for incorporating solutions into equipment design is comprised of (1) human engineering design and evaluation of design for both flight crew and ground crew systems, (2) simulation, (3) testing and verification, (4) human factors analysis, (5) task design and analysis, and (6) establishment of medical parameters.

To accomplish Life Systems responsibilities within the Apollo program the group is divided into three major sections, composed of ten functional units, as follows:

1. Human Engineering Section
   - Crew Equipment Unit
   - Personal Equipment Requirements Unit

PRECEDING PAGE BLANK-NOT FILMED

[redacted]

[redacted]

Spacecraft Design Support Unit

Ground Control and Support Unit

2. Crew Simulation and Testing Section

Crew Simulation Requirements Unit

Technical Coordination and Support Unit

3. Human Factors Analysis Section

Task Design and Analysis Unit

Crew Performance and Training Unit

Crew Operations Unit

Biomedical Unit

The development cycle is illustrated in Figure 47.

Human Engineering

Human Engineering analyzes requirements, prepares designs, and develops and specifies tests for crew system equipment and components. This section also develops the basic criteria and layouts for flight crew living and work-space arrangement, crew seating and restraints, interior lighting and color, visibility provisions, optical systems, ingress-egress provisions, controls and displays, food and water management, as well as various other items of personal equipment. This section provides support to GSE and Training Equipment Design through direct coordination with these groups on all human engineering problems.

Crew Equipment Unit

The Crew Equipment Unit develops and designs crew arrangement layouts, controls and displays layouts, vision layouts, interior lighting details, restraint and couch pad details, rest station provisions, and weightlessness control methods and equipment. Figure 48 shows the flow pattern of the development plan.

Personal equipment includes couch pad and restraint equipment, which must be designed to allow maximum movement and comfort, while providing proper restraint during periods of acceleration and vibration and under conditions of weightlessness. The crewman must be accommodated while he

[redacted]

[redacted]

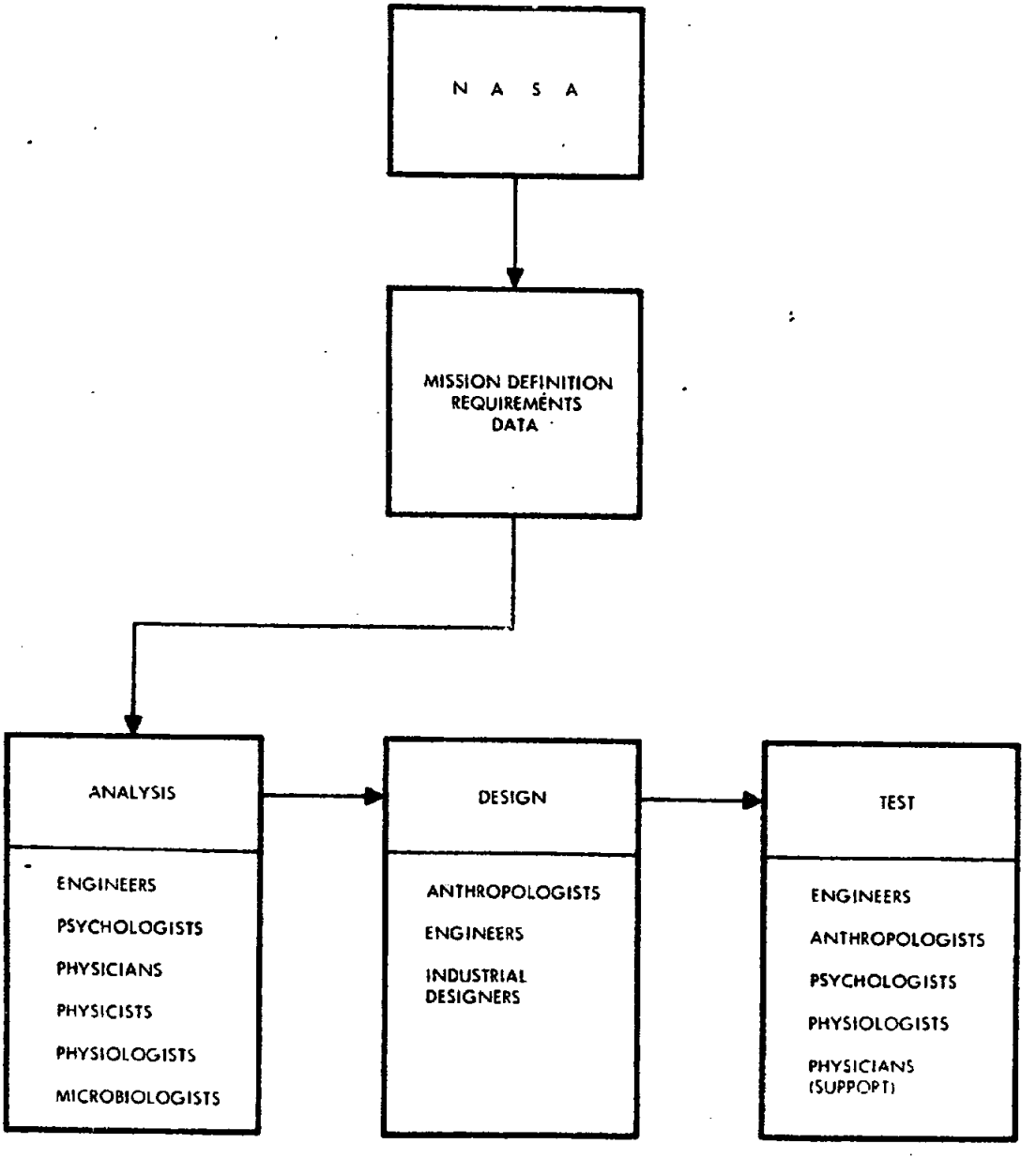


Figure 47. Life Systems Personnel

[redacted]

[redacted]

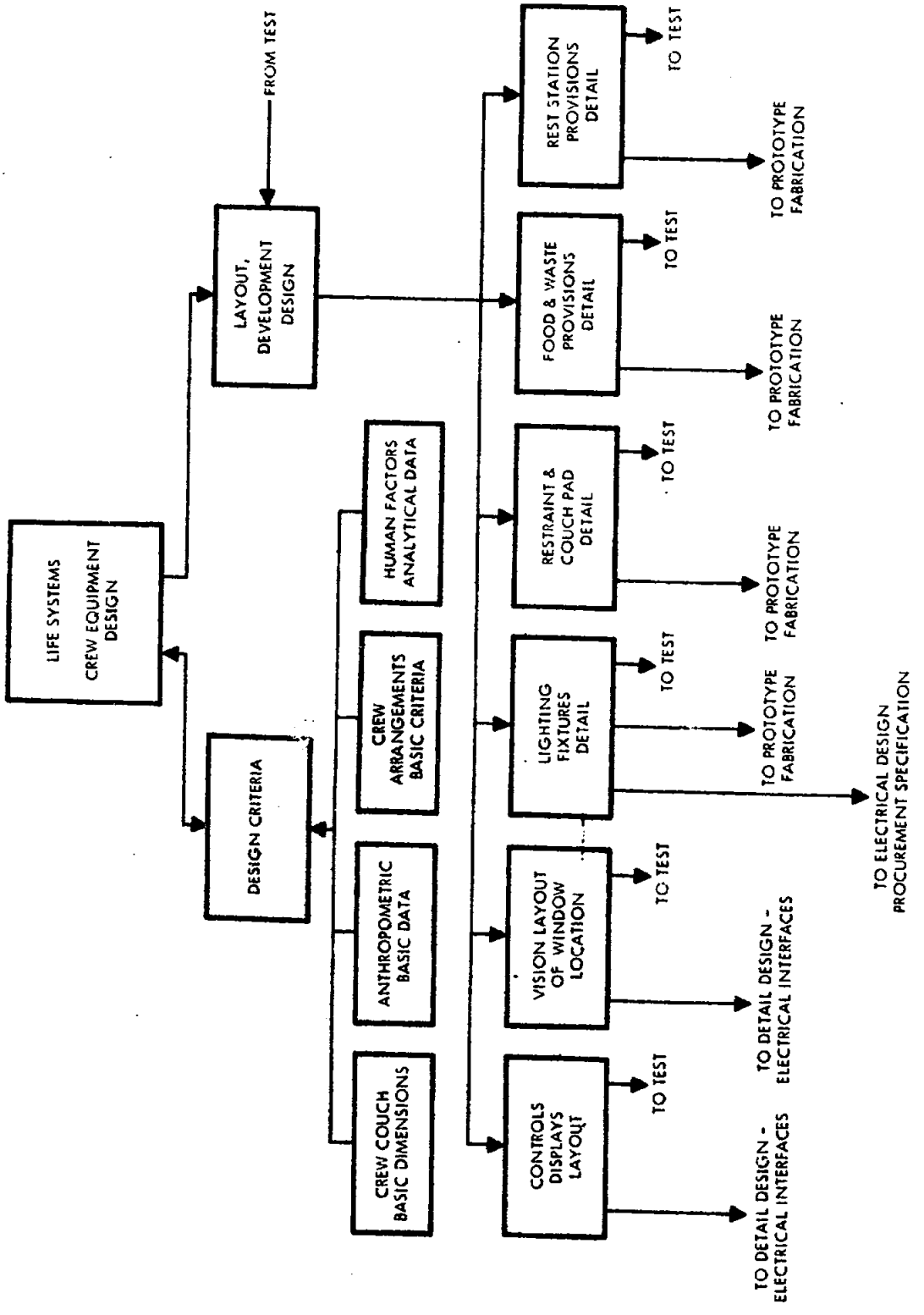


Figure 48. Crew Equipment Design Development Plan

[redacted]

[redacted]

is in the pressurized garment assembly or the constant-wear garment. Couch liners will be made to improve load distribution. Comfort liners will overlay the couch liner. Couches are to be adjustable, so that they can be utilized by the 10th through the 90th percentile man. Couch design will utilize the internal spacecraft dimensions to maximum effectiveness. For example, the center couch will be stowed under the left hand couch and used as a bed and sleeping area while in flight. Design problems of eliminating cabin light, reducing the noise level for the sleeping crewman, and providing air circulation and freedom of movement during sleep will be resolved through simulator and evaluator studies.

Mock-up and anthropometric studies being conducted will determine the most practical use of storage space and of methods to confine the contents of drawers and cabinets within the spacecraft while it is in zero and negative g conditions. Alternative designs will be investigated to determine which types of equipment are least likely to cause damage to pressure suits or injury to personnel. Handles, latch mechanisms, maintenance tools, and cleaning equipment will require special designs for safety.

Personal Equipment Requirements Unit

The Personal Equipment Requirements Unit is concerned with achieving the most compatible relationship between the astronaut and the spacecraft and systems. Eating, drinking, defecation, urination, regurgitation, personal hygiene, communication, and mobility become problems under zero g conditions. Anthropometric and mock-up studies will determine the configuration of the toilet and associated equipment, and methods of use. The disposal of noxious odors and the methods of handling, storing, and disposing of urine and feces are problems requiring investigation. The physical and chemical properties of personal equipment must be examined to determine the usefulness of such items under thermal variables, electromagnetic influences, galactic conditions, and Van Allen and solar radiation exposures. Specific equipment, such as film, semiconductors, fluid elements, medical and first aid kits, individual survival equipment, and low-power batteries must be protected from all types of radiation. Temporary fastening of equipment to places handy and accessible for use and reuse must be provided.

Tests will be conducted to determine the appropriateness of given designs and their applications in personal equipment. Coordination with other activities will produce overall design compatibility.

Spacecraft Design Support Unit

The Spacecraft Design Support Unit has the basic objective of expediting and coordinating human engineering design criteria into Apollo

[redacted]

[redacted]

spacecraft systems and equipment development. This unit also provides a systematic flow of life systems criteria to support Apollo engineering design groups in the development and implementation of life systems designs (Figure 49).

Ground Control and Support Unit

The Ground Control and Support Unit has the objective of establishing and maintaining human engineering criteria for ground support and training equipment. This unit monitors and reviews all design prerelease drawings, proof and system tests, and checkout procedures to determine the compatibility of the man-machine relationship. Results to be expected from the work of this unit are standardization of instrumentation, maximum console panel utilization and reliability, and safe man-machine interfaces.

Crew Simulation and Testing Section

The Crew Simulation and Testing Section develops the planning, organization, direction, and operation of all life systems crew testing and simulation. The test program being developed by this unit considers man-equipment, man-environment, and man-man interactions within Apollo mission profiles. In addition, this group will conduct all manned simulation that is required for the Apollo test program (Figures 50 and 51).

Crew Simulation Requirements Unit

The Crew Simulation Test Requirements Unit will procure equipment and facilities for tests, coordinate and conduct tests in accordance with life systems requirements, direct all life systems test participation in boilerplate and spacecraft programs, and compile data and records of such tests. It will plan, organize, and operate all Apollo life systems crew simulation activity, including crew performance tests, system development studies, crew task tests, biomedical tests, and other physiological and environmental simulations. These tests will be conducted in work-space analyzers, simulators, evaluators, and mockups. The life systems crew testing program and test requirements are illustrated in Figures 52 and 53.

A life systems test program will provide an evaluation of all factors affecting crew reliability and safety and will demonstrate that the crew can perform the required tasks at the necessary level of proficiency under the anticipated conditions of the mission. 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

[redacted]

[redacted]

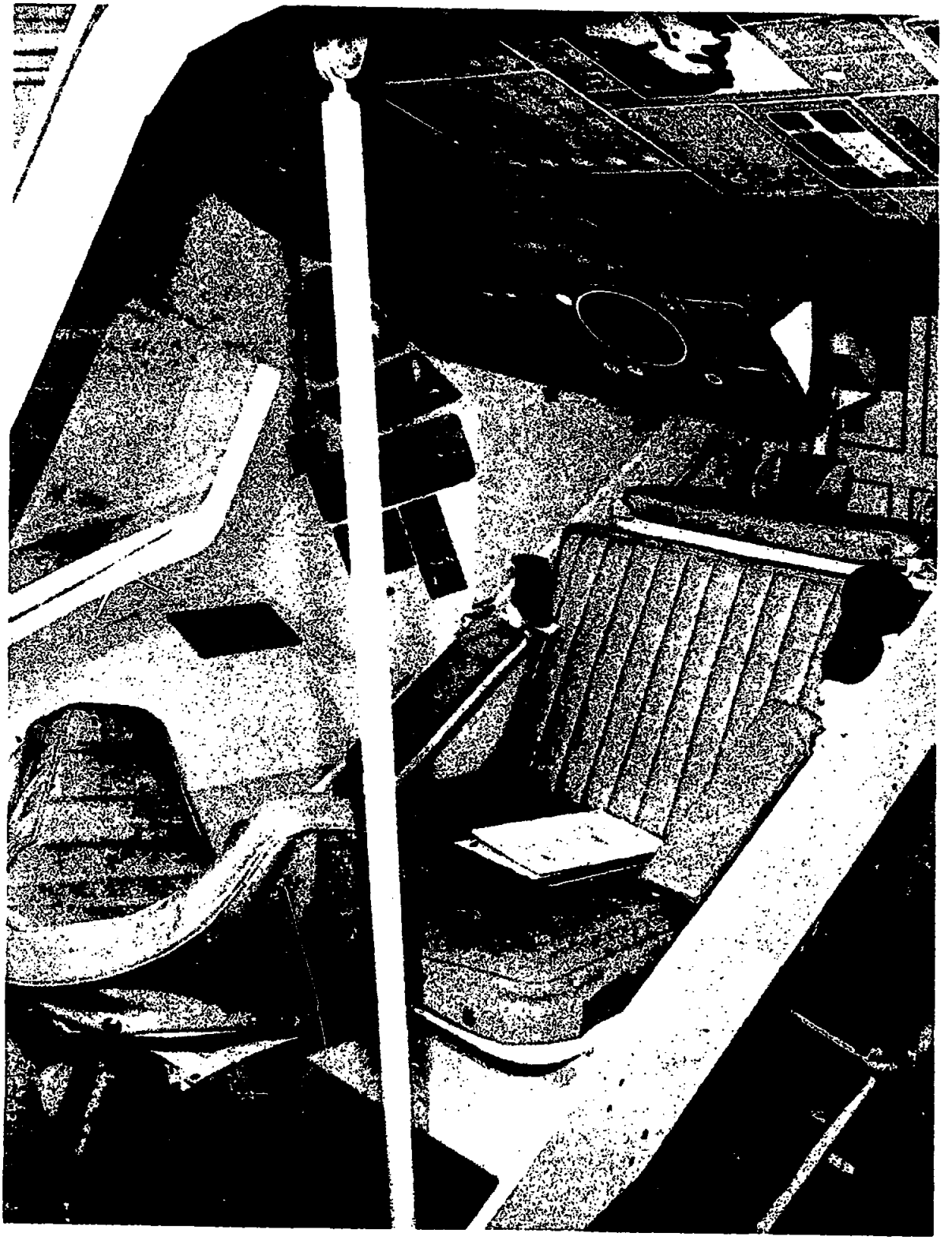


Figure 49. Crew Couch Panel

[redacted]

[redacted]

Figure 50. Crew Function Testing

[redacted]

[redacted]

Figure 51. Crew Function Testing

[redacted]

[redacted]

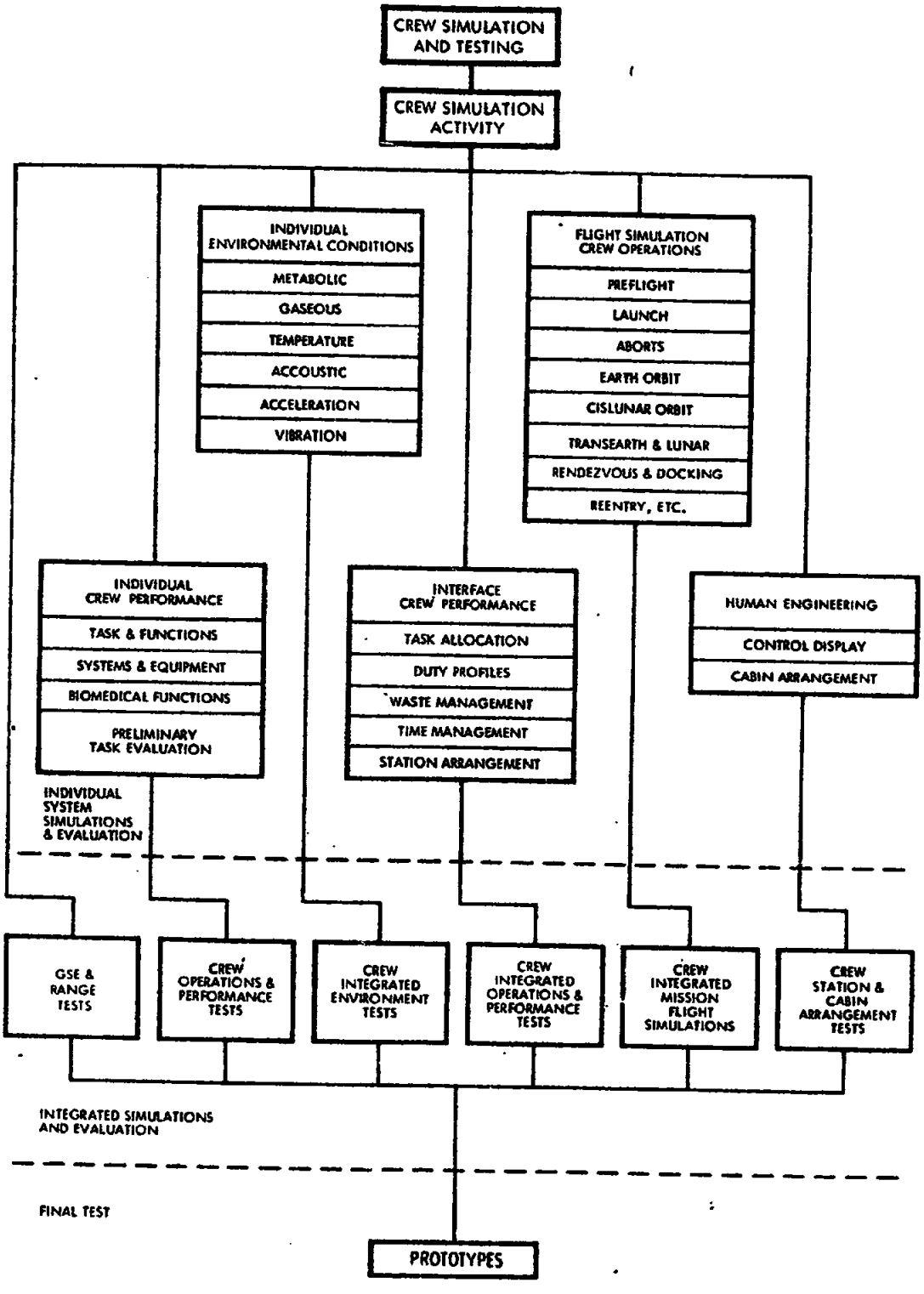


Figure 52. Life Systems Crew Simulation Activity

[redacted]

[redacted]

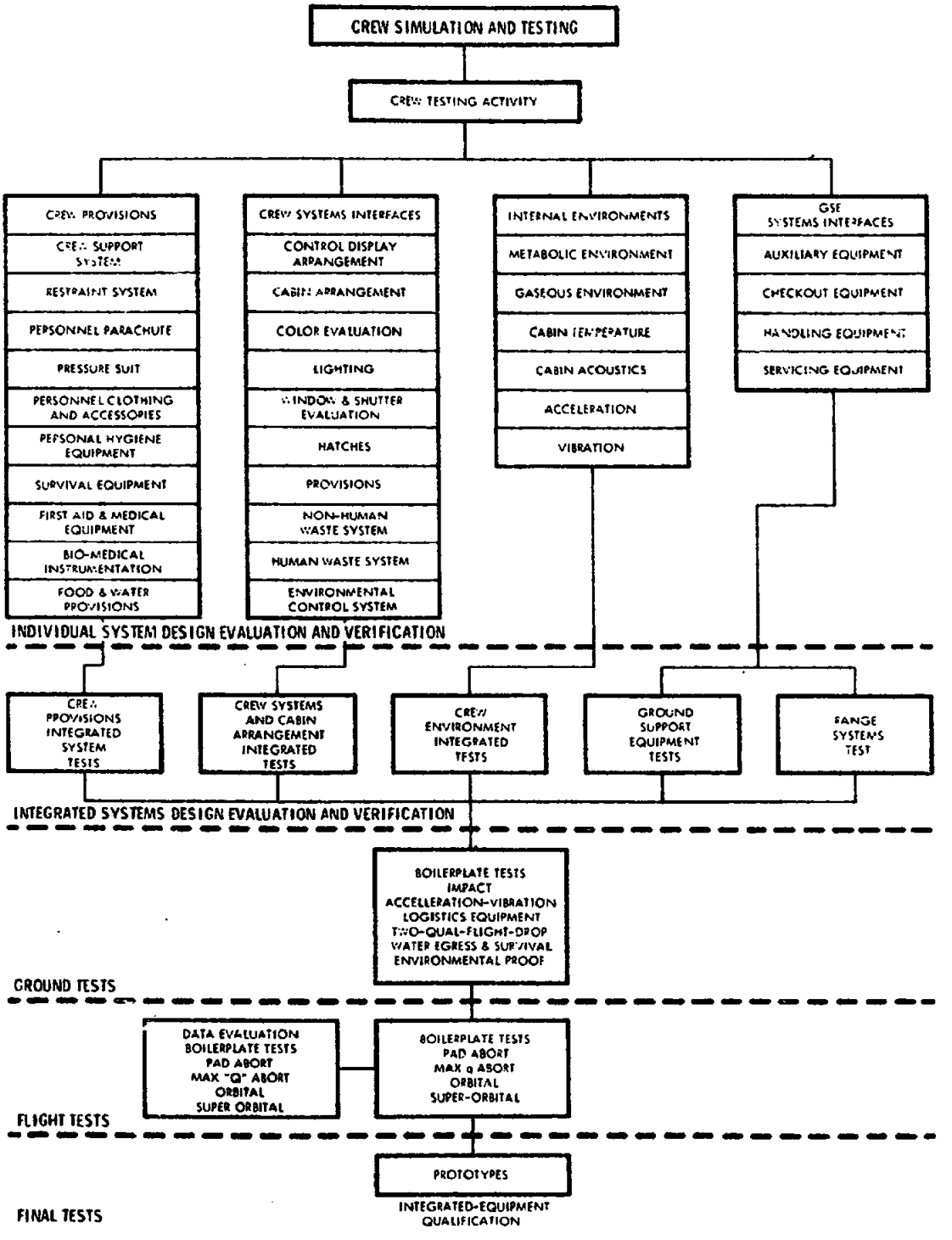


Figure 53. Life Systems Crew Test Activity

[redacted]

[redacted]

reliability and safety goals by assuring a thorough integration of human capabilities and limitations with systems design.

The life systems crew simulation and testing program will follow the logical progression of systems evaluation, beginning with individual components and systems tests and progressing through multiple systems tests and in-flight tests. Test activities will be carried 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-mission simulations.

Evaluation of individual systems operation will be employed to determine the adequacy of life systems criteria and specifications at the detailed design level in the crew performance analyzer, in simulators No. 1 and No. 2, evaluators 1, 2 and 5, and the mockup. Man-machine (human engineering) tests will be conducted to evaluate preliminary spacecraft and related GSE subsystem man-machine interface designs.

As systems design, crew requirements, and mission procedures become firm, test activity will follow the typical progression from design-development activities to first-run and prototype hardware installed in boilerplates B-1, B-2, and B-14 and AFRM 001, 006, and 008. The major emphasis during this latter phase will be placed on crew performance validation during partial- and full-mission simulation studies.

Human Factors Analysis Section

The Human Factors Analysis Section will develop task and performance analysis requirements for test and simulation and interpret test and simulation data pertaining to human factors in flight and ground crew performance and training, crew operations, and biomedicine. This section will resolve these requirements into safe and effective operational values to assist in life systems design, development, and test criteria determinations. Figure 54 shows the flow plan for human factors design criteria.

Task Design and Analysis Unit

Task Design and Analysis personnel will establish man-machine function allocations, crew flight information, and communications requirements. They will prepare crew task analyses and descriptions, integrate crews, and allocate tasks. In addition, they will establish human factors information requirements for all GSE and GOSS. Task-equipment data will be updated and tabulated by electronic data processing. Specialized analyses will be applied to critical man-machine system design problems; these analysis include link, time-line, and second-by-second operations analysis. This

[redacted]

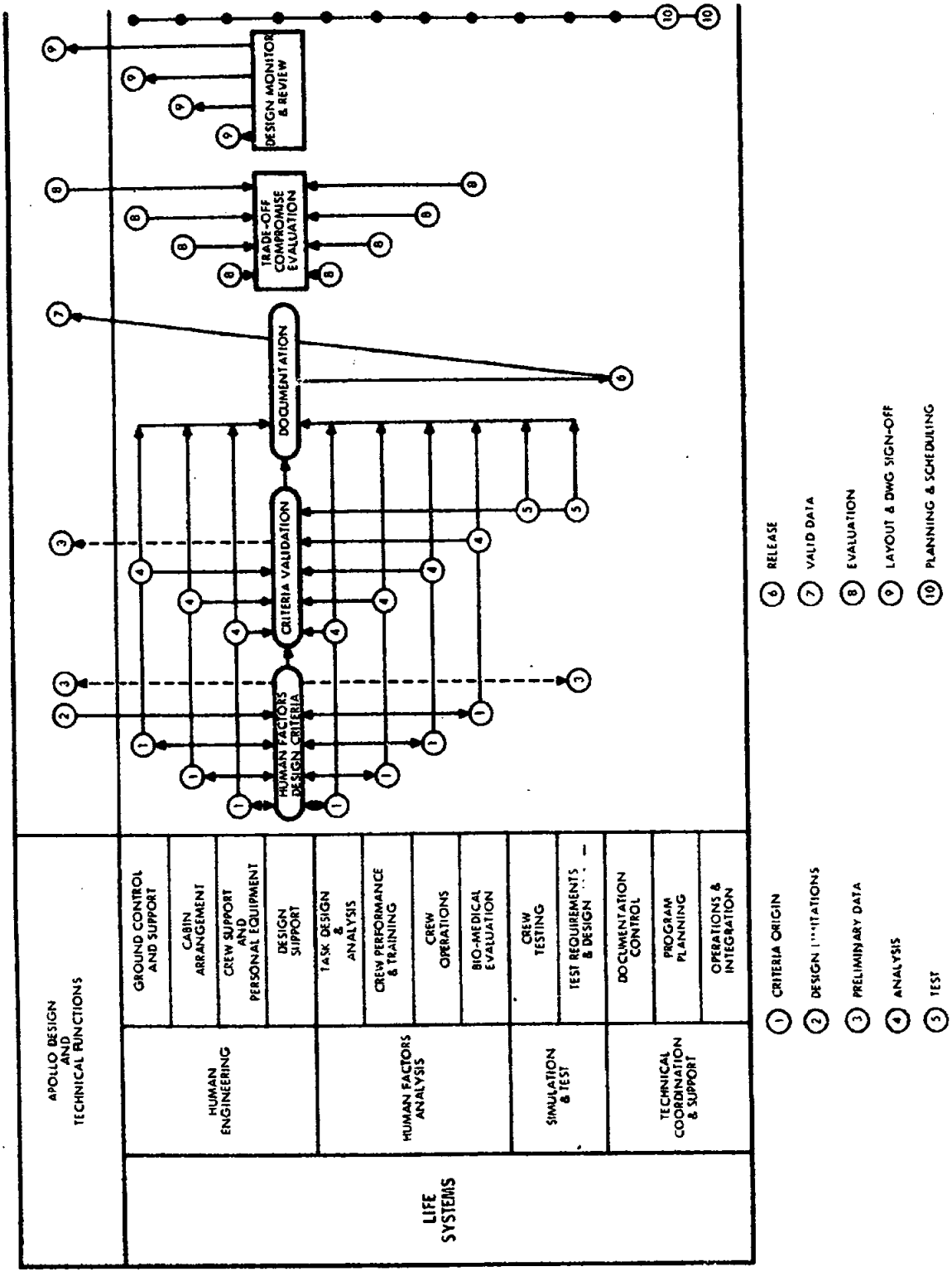


Figure 54. Human Factors Design Criteria Initiation and Flow Chart

[redacted]

[redacted]

unit also will establish life systems in-flight maintenance procedures criteria and design trade-off data. During the course of system testing, it will analyze reliability failure reports to identify human-initiated malfunctions and recommend corrective action. The section will also provide task data for operations and maintenance manual preparation. Figure 55 illustrates the functions of the Task Design and Analysis Unit.

Task Design and Analysis will conduct analysis of human factors requirements for in-flight maintenance. Generally, the problems involved are (1) performing maintenance activities during weightlessness and (2) involving the optimum human factor in systems to improve reliability. Specifically, the problem areas will encompass the design of controls, displays, work-space layout, and also, the anticipation of man-machine difficulties in the operation and maintenance of equipment.

The work will be done according to the requirements derived from analysis of missions, operational environments, and failure modes to determine the contribution the crew can make to reliability. The results of analysis will help effective utilization of on-board resources to assure reliability through a more realistic human factors design prior to hardware design effort.

Crew Performance and Training Unit

Crew Performance and Training will design, develop, and test methods for evaluating flight crew performance in training. This unit will establish performance criteria for GSE and GOSS operators. It will assist in the designing of, and support the conducting of, tests and simulations to identify areas needing performance validation.

Crew Performance and Training will continue the analysis of airborne and ground crew task data developed by the Task Design Analysis Unit to ascertain that the performance required of the system's human components is within expected human capabilities. Figure 56 illustrates the functions of the unit.

Performance Criteria. Performance criteria will, at first, be based on the observation of air and ground crews' performance of simulated missions. As ground support equipment becomes available, crew performance analysis will be made of operational units.

Though based on conventional methods and techniques, the validation measures developed will be intended for the Apollo spacecraft and will have to be altered to best serve continuous development of the Apollo vehicle and its supporting equipment.

[redacted]

[redacted]

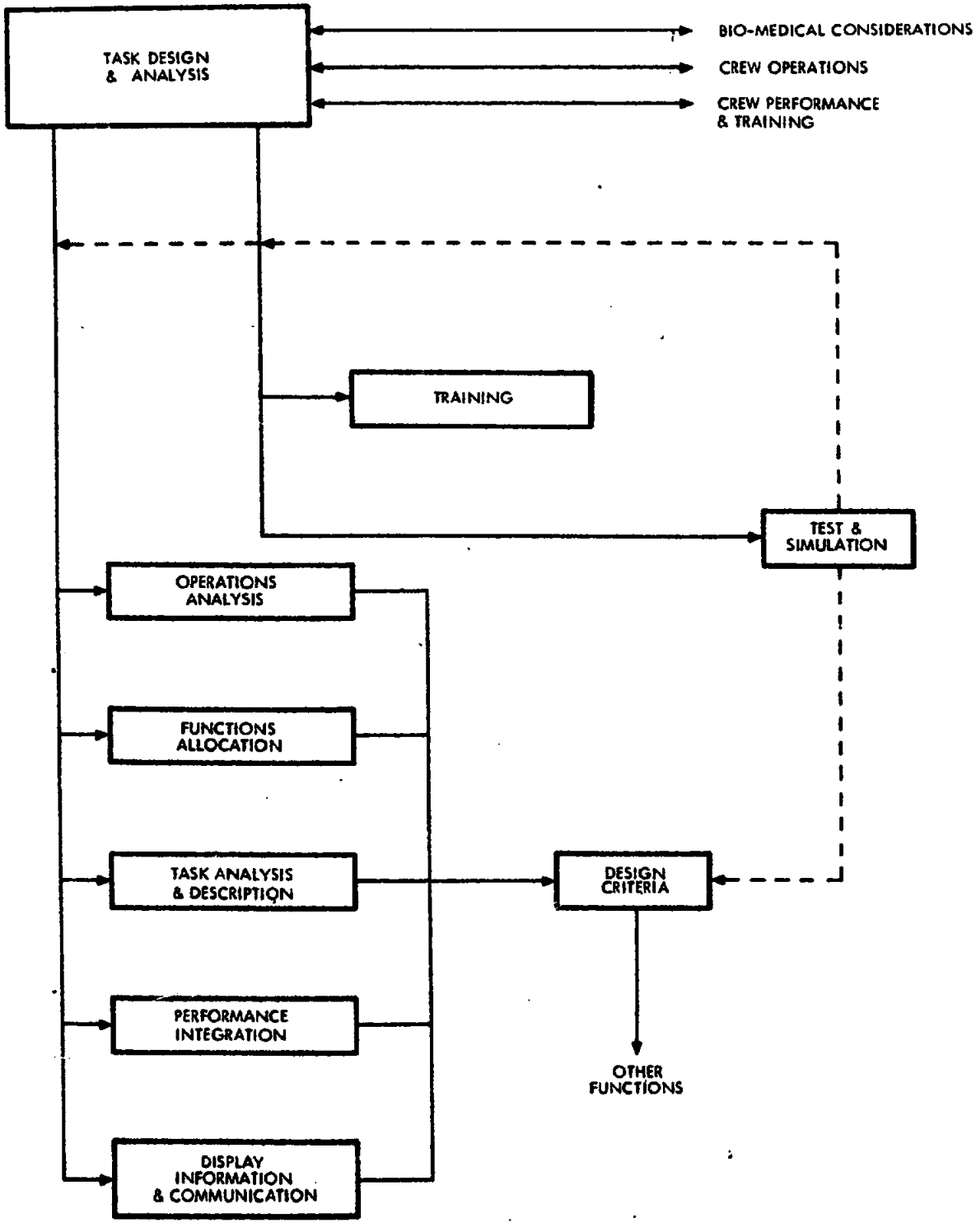


Figure 55. Functions of the Task Design and Analysis Unit

[redacted]

[redacted]

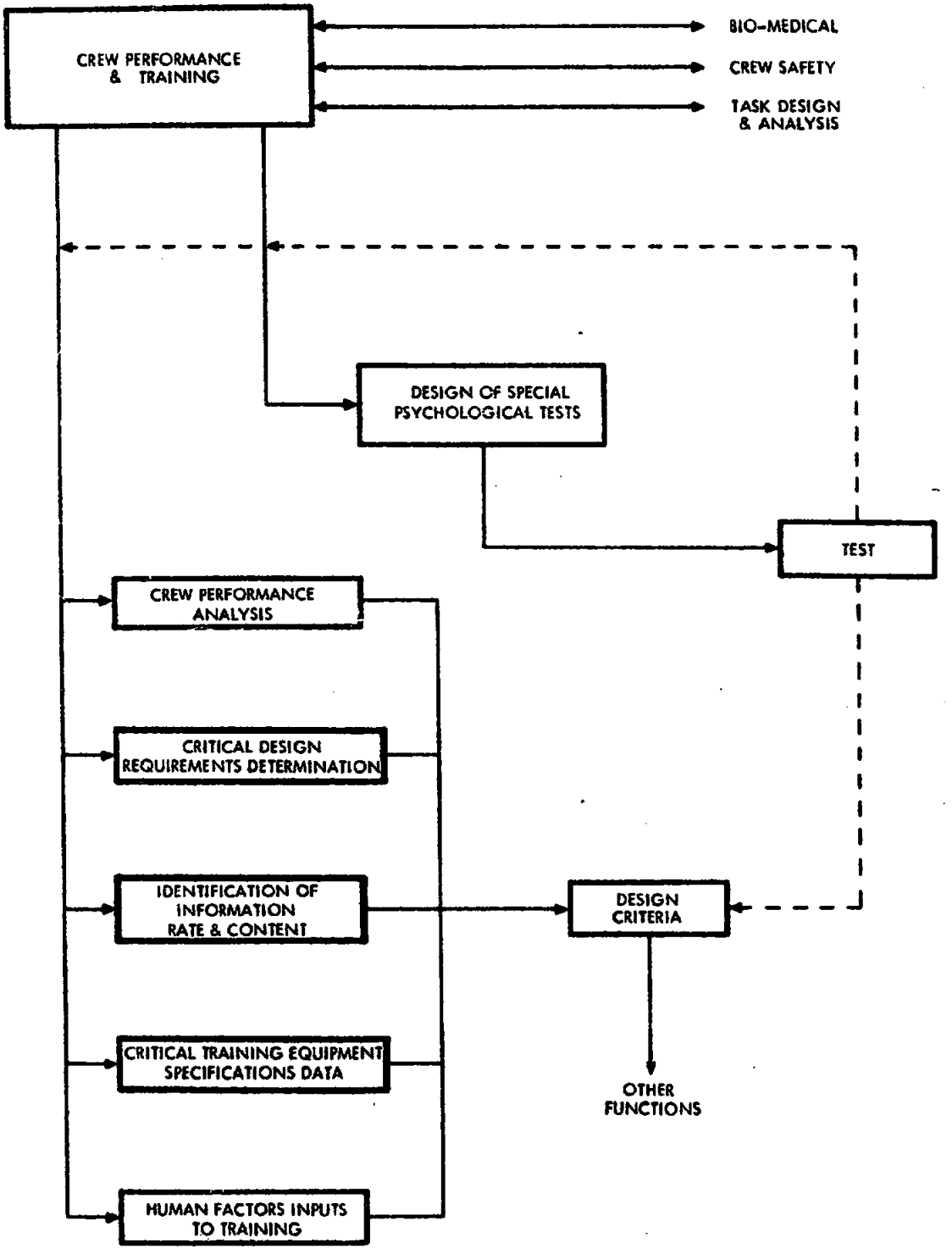


Figure 56. Crew Performance and Training Functions

[redacted]

[redacted]

Some of the factors for investigation of crew performance are:

1. The effects of environmental stresses; such as, confinement, vibration, and noise

2. The capacity of the crew to increase reliability by the manual control of malfunctions in an automatic system

3. The capacity of the crew to perform tasks on more than one system during any particular time period

4. The effect of a malfunction in relation to its time of occurrence in the mission profile.

5. The estimation and verification of human reliability under manual, maintenance, and emergency conditions.

From this analysis, certain areas of task design can be specified for simulation or test to provide validation. Crew Performance and Training personnel analyze the resultant data and report to Task Design and Analysis Unit, to Training Program Development, and to Training Equipment Design.

Effects of Variables. The effects of such variables as confinement, noise level, and work load on selected performance parameters will be analyzed. Studies are presently underway to determine how the confinement of the crew in an Apollo mock-up will affect human ability to track, monitor the panel, and make simple decisions. A battery of psychomotor and reasoning ability tests will be administered before and after the confinement period to further assess the effects of confinement on the psychological functions of the crew.

As hardware and crew functions are defined in more detail, specific problems may appear which are related to work loads, human constant tracking error, and problem solving ability. For example, a constant tracking error will be apparent in the navigation procedure. Methods for correcting this error, as well as the determination of the amount of error as a function of confinement, fatigue, stress, etc., will be investigated by Crew Performance and Training. The study of human error will be particularly crucial for determining the feasibility of manual back-up procedures.

Crew Operations Unit

The Crew Operations Unit is concerned with the interpretation of crew task schedules and performance variables, correlated to the analyses of spacecraft equipment and corresponding systems performance fundamentals.

[redacted]

The objective is to establish operationally effective and safe crew-equipment-mission interface parameters. This will result from continued configurations analyses, mission profile and time-line examinations, spacecraft systems investigations, procedural activity studies, crew performance measurement evaluations, and the effective accumulation and integration of operational inputs and evaluations. Figure 57 illustrates the function of the unit.

Operational Factors Studies and Determinations. By evaluations of prior manned spacecraft performance data analysis and man-machine studies of the spacecraft control-display subsystems, on-board systems command and control variables (automatic versus manual), operator vision and visual support aids, and crew support equipment hardware design specification outputs, this unit will specify and integrate critical and non-critical operational considerations. In consonance with this effort, continued up-dating and revision of crew operational requirements by coordination of pilot and astronaut operational inputs will be undertaken. This timely and technically effective procedure will comprise a major and important portion of the overall effort of this unit.

These evaluations will entail detailed examinations of spacecraft mock-ups, evaluators, simulators, and boilerplate tests, as well as systems and hardware mechanization investigations and configuration analyses. The products of these efforts are the determination of operational requirements for spacecraft advanced and state-of-the-art basic control and display, crew support aids development, operator vision parameters, and establishment of human factors criteria.

Aerospace Safety Determination. This unit studies safety factors connected with ground test, launch, flight, and recovery operations. These operations are analyzed, using the projection of requirements from life systems criteria. From these analyses, further life systems criteria are obtained.

Studies of GSE, site and recovery equipment, and flight article equipment, when there is a direct connection with the ground or command module crew operation, will concern life systems safety requirements determinations. These criteria will involve configuration analyses, procedural development, and crew operational limitation involvement studies.

The development and implementation of life systems safety requirements will entail participation of this unit in periodic meetings of the Life Systems Hazards Review Board (LSHRB) and direction of the activities of a Life Systems Aerospace Safety Committee (LSASC). The purpose of the LSHRB is to review simulation and test programs in which human subjects

[redacted]

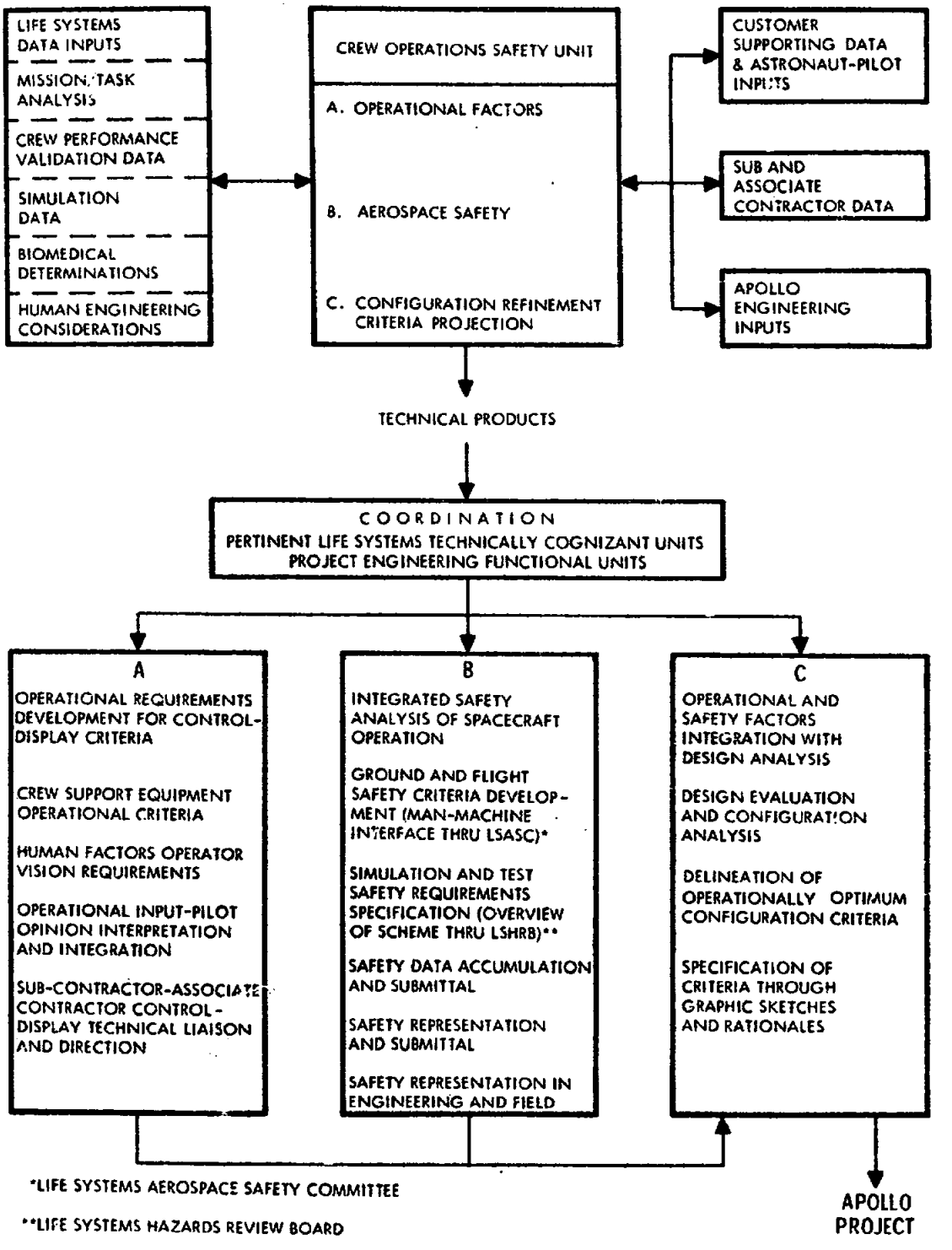


Figure 57. Crew Operations Unit Functional Flow Diagram

[redacted]

[redacted]

and monitoring personnel are involved, so that safety requirements may be developed and implemented for these tests. The purpose of the LSASC is to review spacecraft GSE and flight article crew-equipment coordination and submit life systems safety requirements to cognizant project personnel.

The requirements and criteria associated with aerospace safety will be developed in consonance with, and be compatible with, reliability assessments or equipment-mission-success data and with crew performance measured values.

Configuration Refinement Criteria Development. This unit will provide human factors design criteria, graphic and written rationales to support developmental design efforts, and design change considerations for mock-ups, evaluators and simulators, boilerplate, and spacecraft articles. From this information, operator procedures, mission phasing plans, and system equipment contingencies are developed. In addition, Criteria Development investigates the effectiveness of overall man-machine cross-relationships.

Biomedical Unit

The Biomedical Unit has the objective of providing biomedical support to the design units and establishing medical parameters for human tolerance limits under conditions of stress. This unit must establish the human environmental parameters and analyze and define the physiological and medical stresses on crew members. It is concerned with major problems involving astronaut safety and well-being and with the prevention of direct injuries to the crew.

The functional breakdown for biomedical program planning is listed below, followed by a discussion of typical activities of the Biomedical Unit.

1. Analysis to Determine Tolerances, Hazards, and Requirements

   a. Environmental conditions

      Acceleration
      Vibration
      Noise
      Temperature
      Oxygen
      Carbon dioxide
      Radiation
      Toxic contaminants

[redacted]

b. Metabolic conditions

Physiological effects on performance
Food and water
Cardiovascular
Responsiveness
Inner ear
Biochemical
Health

c. Crew systems

Waste management
Food
Personal hygiene
Restraint and support
Medical supplies
Survival equipment
Human instrumentation

2. Analysis and Review of Specifications

Interface
Pressure suit
Spacecraft systems
Safety
Crew systems
Test
GSE

3. Support of Tests and Evaluations

Medical testing
Laboratory testing
Test instrumentation

Analysis of Hazards: Human Tolerance and Response to Stress. The initial approach is to survey the literature on human tolerance to stress. Stress can be divided into (1) physical stress, (2) toxicity or chemical stress, (3) mechanical stress, and (4) radiation. The physiological and psychological responses to stress are the main fields of biomedical interest.

The several categories of physical stress are acceleration, continuous g-forces, impact, weightlessness, tumbling, pressure, decompression, noise, vibration, and thermal stress.

[redacted]

[redacted]

Toxicity can be divided into endogenous and exogenous toxicity. Endogenous toxic products come from fuel leakage, highly reactive free radicals formed by interaction of radiation with molecules of matter, leakage gases, and combustion products from spacecraft equipment. Exogenous sources include toxic products that affect metabolism, such as carbon dioxide and acetone.

Mechanical stress occurs from the impact of micrometeors on the cabin and consequent explosive decompression of the interior.

Various types of radiation are to be considered, including those of the Van Allen belt, the artificial belt from nuclear weapon detonations, galactic or cosmic rays, ultraviolet rays, solar storm radiation, microwaves, intense visible light, and Bremsstrahlung (gamma rays secondary to the slowing down of incident electrons in matter).

Examples of physiological effects on the body and psychological responses to these stresses lie in the following areas:

1. Disorientation, e.g., changes occur in the orientation in space of the otoliths and semicircular canals of the inner ear.

2. Cardiovascular adaptability, e.g., impairment of venous return to the heart by certain accelerations tends to pool the blood in the extremities. In this condition the heart does not have sufficient blood input to function at its full capability—the cardiac output decreases, insufficient blood flows to the brain and other vital areas, oxygen transfer to tissues is slowed, and vision and consciousness are ultimately lost.

3. Visual responses, e.g., under conditions of heavy vibrations, and especially with dim lighting and crowded conditions, the reading of instruments is hindered.

4. Loss of muscle tone in the weightless state requires specially devised exercises and training.

5. Alternation of the normal human work-rest cycle falls out of step with the usual daily variations in psychological and physiological parameters.

6. Confinement in limited space and isolation from the normal multiple sensory inputs of everyday life affects responses.

7. The general deterioration in overall performance of man reflects many combined stresses.

[redacted]

[redacted]

Information from these areas is analyzed in terms of the best estimate of the stresses inherent in the Apollo mission. Data are obtained on mission profiles and design. Design specifications are obtained from groups responsible for the crew support and restraint system, survival and personal equipment, environmental control system, flight dynamics, communication, instruments and electronics, structures and materials, ground support and control systems, and others. Design criteria and limits are established, which are employed by engineering design. Final design is checked for its fulfillment of biomedical requirements. Results of tests, such as confinement simulation tests, are evaluated and, if necessary, additional requirements are established.

Test Support and Evaluation. Several series of tests involving confinement, pressure suit operation, environmental control system function, and human centrifugation are contemplated over the next several months.

1. Test objectives and procedures, as well as potential hazards, will be surveyed.

2. Emergency facilities will be set up and procedures instituted for test programs involving human volunteers. (A medical monitor will be present whenever necessary.)

3. Subjects will be evaluated medically, qualified for the test, and medically examined pre- and post-test.

4. Bioinstrumentation facilities for programs will constitute another major responsibility. This involves procurement and operation of gear for securing such data, as electrocardiogram, heart rate, respiratory rate and volume, on several subjects at one time and over extended time periods.

5. Needs for further testing will be established.

Vision.

1. The Biomedical Unit will survey literature to define visual hazards (e.g., the effects of acceleration, vibration, illumination, etc., on visual performance) and determine limits of human tolerance to the stresses which affect vision. These activities will be coordinated with the Crew Performance Unit.

2. Physiological requirements will be established.

[redacted]

[redacted]

3. Biomedical requirements for simulation and tests will be defined.

4. Test subjects will be monitored.

5. Test results will be evaluated and requirements, formulated from test results, will be reviewed.

6. Data will be obtained from other Apollo groups on mission profiles and design plans.

7. Analyses will be made of above activities for compliance with physiological requirements, and biomedical specifications will be defined for final design, based on test results and updated physiological requirements.

Ground Support Crew Health.

1. Studies of ground support operations will be made by the Biomedical Unit.

2. Data will be obtained from other Apollo groups, i. e., Ground Support Design and Operation.

3. The need for medical support of ground support crews will be evaluated.

4. Biomedical requirements will be submitted to ground support groups.

5. Requirements will be defined for the replacement of disabled personnel, diagnosis and treatment facilities, and medical personnel to support ground support crews.

Crew Health.

1. Specifications for bioinstrumentation will be determined.

2. Biomedical requirements will be established for training of ground support crews involved in physiological monitoring.

3. Studies will be made of possible medical emergencies which may arise in flight.

4. The course of action to be taken in case emergencies arise will be outlined.

[redacted]

5. Requirements for medical emergency supplies in the command module will be determined.

6. Requirements for medical training of astronauts will be determined.

7. Training and operational medical manuals will be written.

Personal Hygiene - Sanitation. This area of work defines parameters, provides procurement requirements, and evaluates materials and methods to maintain acceptable levels of crew hygiene and spacecraft sanitation.

Sanitation can be defined as the process of keeping the interior of the vehicle and its equipment free of noxious odors and particles potentially injurious to health. Personal hygiene encompasses the processes of maintaining body cleanliness, removing surplus hairs and nails, providing clean clothing and dental care.

The initial effort in personal hygiene-sanitation is to evaluate currently available commercial products, as they relate to the promotion of overall sanitary conditions, physiological compatibility, and psychological acceptance. Items considered for personal hygiene include razor, ingestible dentifrice, constant-wear garment, cleansing pads, deodorizer pads, toilet tissue, and defecation-emesis containers. Spacecraft sanitation is integrated with areas of food, water, solid and liquid waste, and environmental control management systems.

Information received from simulator tests is analyzed to determine further design requirements and refinements needed for personal hygiene and sanitation equipment. It is anticipated that future effort will be largely devoted to determining chemical formulations, methodology of use, and the effectiveness of sanitation and personal hygiene materials.

Spacecraft Microbiology. Measures are necessary to prevent and control microbial action during the Apollo mission that could be detrimental to the health of the crewmen and the performance of the spacecraft. Microbiological populations are involved in the following areas of consideration:

1. Items and procedures for personal hygiene

2. Sources and types of contamination—aerosols, food, water, clothing, human flora, wastes, and equipment

3. Preservation and safety of food and water

4. Methods of decontamination and control

[redacted]

[redacted]

5. Transmission and control of infectious diseases

6. General crew health

7. Microbial action on equipment

8. Toxic or offensive gas production from wastes

9. Mutagenic effects on micro-organisms after exposure to radiation

The effects of environmental conditions during space flight, such as, temperature, relative humidity, light, partial pressure, gravity, gaseous atmosphere, and radiation, which morphologically and physiologically affect biological entities, are largely unknown. The Mercury space flights presently offer the best opportunities for studying the interaction of man, spacecraft, and micro-organisms. In addition to qualitative and quantitative assays during simulator tests, microbiological experiments will be performed on the Mercury and other flights preceding the Apollo mission. An evaluation of the results in conjunction with our present knowledge will lead to establishment of microbiological requirements for the Apollo mission.

Toxicology. The Apollo Work Statement (paragraph 4.5.2.6) states that the contractor "... shall define the complete design criteria for the spacecraft and spacecraft systems and for all ground equipment. The design criteria shall incorporate the guidelines of Part 3 of the Statement of Work, where applicable." The only guide line provided for atmospheric contaminants is for carbon dioxide. Accordingly, toxicological work of the Biomedical Unit is concerned with the following tasks:

1. Assistance will be provided to other cooperating groups to evaluate the toxic hazards of various materials used in the interior of the command module. Biomedicine will contribute toxicological information, the Materials and Producibility Unit will supply information on the chemical nature of the materials and of the atmospheric contaminants, and the Environmental Control Analysis Unit will offer information on the levels to which atmospheric contaminants can be controlled. All of this information is required to evaluate toxic hazards.

2. Permissible continuous (for 2 weeks) exposure limits will be determined for atmospheric contaminants expected to be in the command module interior.

3. Emergency (short time) exposure limits will be determined for such contaminants as may be expected to present such a problem.

[redacted]

4. Support will be provided in the design and evaluation of tests of contamination in the command module atmosphere.

5. Support will be provided in the evaluation of the potability of water from fuel cells by supplying toxicological information.

6. Other toxicological information will be furnished as needed.

7. Apollo design criteria specifications pertaining to toxicological aspects of Apollo design will be developed.

8. While most of this information will be obtained from existing literature, testing, when it is directly applicable and necessary to the above objectives, will be subcontracted.

Radiation. In the absence of guidelines, Biomedicine normally would establish radiation tolerance design criteria. Since NASA has furnished such criteria, Biomedicine has set itself two basic goals regarding space radiation: (1) continued evaluation of this problem and (2) monitoring of the Apollo system design, including operations, to insure that the final criteria are not compromised. In line with the above goals, the following tasks are planned:

1. Continuing review of the biological effects of ionizing radiation, with special reference to factors of dose effectiveness; such as, dose rate, dose distribution, partial-body shielding, recovery rates, drugs, etc.

2. Continuing study of ionizing radiation exposures in the Apollo mission

3. Continuing evaluation of permissible ionizing radiation doses for the Apollo crew (routine and emergency)

4. Reviewing and studying the effects of ionized gases with special reference to Apollo

5. Providing liaison with the Radiation Shielding Section and supporting their effort

6. Studying vehicle and personnel dosimeter requirements and aiding in dosimeter evaluation and integration

7. Reviewing and evaluating simulator test results

[redacted]

[redacted]

8. Developing Apollo design criteria specifications pertaining to ionizing space radiations

Nutritional Requirements. To provide adequate foods for the Apollo mission, a developmental program involving simulator studies and orbital flights is necessary. Selection of food items should occur primarily through testing in 14-day simulator runs, using an ECS and parameter tolerances identical to those planned for the Apollo mission. Validation of such items will require use in earth orbital missions, providing a minimum of seven days utilization under space conditions.

Some of the food items can be checked out under controlled dietary studies being conducted in simulation runs at USAF SAM, USAS ASD, Ames, etc., by consultation with other space effort groups at research centers and universities, and through literature surveys. However, a total nutritional evaluation within the Apollo configuration, involving complete diets of freeze-dried and high caloric density foods (and optimal dietary combinations thereof), should eventually be performed, either by NAA or NASA.

Concepts planned for inclusion in the Apollo nutritional program are:

1. Freeze-dried foods, to be reconstituted either in the plastic packaging or in the mouth

2. Dehydrated foods, compressed into modified bar form without loss of rehydration capability

3. Edible packaging, which also has nutritional value, thereby eliminating or reducing unnecessary weight and volume

4. Foods with high palatibility and acceptability

5. Maximum physiological availability to reduce fecal output

6. Variety to minimize monotony effects

7. Survival requirements: study of the minimum metabolic requirements to aid in determining a reasonable margin of safety in provisioning the Apollo

[redacted]

[redacted]

THERMO AND FLUID DYNAMICS

The Thermo and Fluid Dynamics Section is responsible for analyses of thermodynamic performance, heat transfer, and external and internal fluid dynamics of all Apollo systems for all spacecraft and test vehicle missions. This section makes extensive use of high-speed digital computers to perform analyses for all design groups to supply design criteria for components, vehicle systems, and test articles. To provide realistic analyses, basic data are gathered from the literature and through laboratory tests. Through continuing analyses, recommendations are made to the design organizations for improvements of both in-house and subcontractor-supplied components and systems. In addition, verification of system designs and recommendations for design modifications result from analyses of laboratory and flight vehicle tests conducted by North American, subcontractors, and the NASA. All these activities are closely coordinated with the S&ID design groups concerned, the appropriate subcontractors, and the NASA Apollo Project Office.

Activities performed in the Thermo and Fluid Dynamics Section are organized into four basic areas: Propulsion Analysis, Thermal Analysis, Aerodynamics, and Environmental and Power Analysis.

PROPULSION SYSTEMS ANALYSIS

Basic Objectives

The basic objectives for this group are as follows:

1. To provide technical direction and analytical support to the Apollo propulsion effort in the areas of propellant systems, rocket engines, and rocket plume evaluation

2. To analyze the requirements and performance of Apollo propulsion systems and components as to their effectiveness in carrying out the missions from the propulsion viewpoint (inputs received from design and mission analysis groups)

3. To generate, after suitable analysis and component testing, detailed reports on performance features for distribution to all S&ID, NASA, and subcontractor personnel concerned

4. To conduct test programs for obtaining or verifying basic data required for analysis and supplementing and verifying analytical results

[redacted]

[redacted]

Organizational Relationships

This group will coordinate with design and analysis personnel to define required areas of analysis or aid in the solution of other problems, and will publish completed analysis for distribution to requesting groups and/or other groups concerned so the necessary design or performance changes can be made.

Within the Thermo and Fluid Dynamics Section, this group will obtain specific technical data from other groups, analyze various heat transfer and aerothermodynamics problems associated with rocket systems, and coordinate such areas as heating of associated structures and engine heating as a function of boost or reentry conditions.

During the Development Test Program, the Propulsion System Analysis group will coordinate with system test personnel and other groups to monitor test results of qualified hardware received from various subcontractors and will ensure satisfactory engine performance by analysis of test results. In its relationship with subcontractors, this group will maintain a close relationship with engine contractors during the various phases of the development program. This group will also evaluate test performance and engine design for compatibility with over-all design requirements and identify possible problem areas using subcontractor information.

This group will coordinate with NASA where analyses indicate a change in design or performance requirements is necessary and will schedule periodic technical discussion on pertinent engine analyses.

Technical Activities

Activities performed in the Propulsion Systems Analysis group are organized into three units: propellant system analysis, engine analysis, and plume analysis.

Propellant Systems Analysis

This unit will perform the following tasks:

1. Conduct propellant system analyses to verify compatability with engine and mission requirements. Determine the operating requirements for the propellant feed systems. Conduct analysis of the effects of the thermal environment on operation of the propellant and components. Conduct analysis of operation of the propellant system at zero. Provide analysis to support preparation of procurement specifications and to support the design of GSE.

[redacted]

2. Evaluate the effect of propulsion system changes and mission changes on control system performance or requirements. Develop digital or electrical analog for transient analysis of the control system. Provide analysis to support control system procurement specifications.

3. Conduct studies and analyses to determine system variations required to improve system operation, improve reliability, reduce weight, reduce cost, or to enhance mission capability. Determine changes required for system optimization.

4. Develop test programs to obtain basic data, such as propellant properties, that can be used to improve analysis of system and component design and performance. Conduct tests of models to obtain early verification of analytical methods. Participate in S&ID and subcontractor breadboard and prototype test of systems and components. Develop test programs to obtain maximum benefits from boilerplate and spacecraft testing.

Engine Analysis

This unit will perform the following tasks:

1. Conduct performance analyses of main service module engine and support formulation of specification requirements. Verify engine manufacturers predicted performance, and determine effects of variables such as mixture ratio, operating time, and propellant inlet pressure.

2. Conduct analyses of installation and environment effects on engine performance and engine heating. Conduct failure analyses of engine system and components to verify satisfactory operation.

3. Evaluate engine materials of construction (ablatives, coatings, etc.) from the standpoint of engine operation and environment effects.

4. Provide support to monitor engine suppliers' program. Conduct analyses of engine component and system performance, as needed. Assist engine supplier in test operations and evaluate results. Coordinate engine/motor performance and requirements with NASA and S&ID groups.

5. Develop necessary test programs to obtain basic engine performance data and to verify or improve analyses of system and component design and performance.

[redacted]

[redacted]

6. Conduct analyses to determine system variations as a function of engine design and performance to improve system operation, to improve reliability, to reduce weight, to reduce cost and to enhance system compatability. Determine optimum propulsion system configurations.

7. Participate in S&ID and subcontractor breadboard and prototype tests of systems and components. Evaluate development, ground test, and flight test engine data and compare the results with predicted performance.

8. Perform analyses of all solid propellant rocket motors (launch escape motor, tower jettison motor, pitch control motor, and posigrade motor) to insure compatability with system requirements. Analyse motor performance under various environmental conditions, and study its effect on performance, safety and reliability.

9. Perform analyses of heating effects on adjacent structures resulting from rocket engine operation. Coordinate results of analyses with other groups.

10. Provide analytical support for engine/motor problems associated with guidance and navigation (engine pulsing operation) and stage separation.

Plume Analysis Tasks

This unit will perform the following activities:

1. Characterize rocket nozzle exhaust plumes for altitude and space conditions.

2. Conduct internal aerodynamics and thermodynamics analyses of nozzle flows to determine thrust losses and boundary value data for plume analyses.

3. Conduct experimental and analytical studies of nozzle flow interface effects such as separating space craft from booster with fire-in-the-hole and posigrade systems.

4. Characterize electrical and radiation properties of exhaust plumes to determine effects on communications, tracking and thermal loads on the system.

5. Investigate shock structures and boundary layers resulting from plume impingement on spacecraft surfaces.

[redacted]

[redacted]

6. Investigate analytically the effects of plume after burning for altitude conditions.

7. Coordinate results of the above analyses with Thermal Analysis, Aerodynamics, Structural Design, Systems Integration, and Propulsion Analysis personnel to ensure proper input data is used for heating analysis, component location, plume effects on engine or propellant feed performance, and problems associated with communications and tracking.

8. Determine the ballistics of uncombusted carbon particles to determine possible impingement effects on radiators and antenna.

9. Translate results of the foregoing analyses to computer programs to perform parametric studies as required.

Test Programs

This unit will conduct water table simulation stage separation tests for preliminary evaluation of stage separation techniques to assure that impinging surfaces of the service propulsion engine exhaust are designed and constructed so that a smooth separation can reliably be executed between Apollo and the S-IV stage.

A wind tunnel scale model stage separation test program will be conducted to aid in selection of important criteria to successfully accomplish stage separation of Apollo from S-IV. Objectives of the program are to obtain proper shape and location of blowout panels for exhausting service module main engine combustion gases.

A rocket engine exhaust plume effects test program will be conducted to determine the effects of the reaction control engine exhaust plume on the flight stability and skin design integrity of the Apollo service module. This will be accomplished by determining the pressure and temperature pattern on the surface due to the impingement of the plume under space simulated conditions.

Tests of the propellant tank heat exhangers will be conducted to evaluate the possible methods of adding heat to the propellants. An effort will be made to prevent the pressurizing helium gas from becoming progressively colder because of tank environment.

Investigation and tests will be conducted on the specific propellant used in the service propulsion system to determine its behavior when exposed to conditions of zero or low gravity. The ability to analyze and specify the internal design of the propellant tanks will be enhanced to such a degree that the utilization of the propellants will fulfill the predicted requirements.

[redacted]

[redacted]

Tests will be conducted to determine the degree of compatability of all materials used in the lubrication of the rocket engines that will be installed on the Apollo modules. The materials will be exposed to high vacuum, high temperature, thermo shock, propellants, and combustion of propellants of the same parameters to which they will be exposed during the lunar excursion mission.

The following limited scope tests will be conducted to obtain preliminary data that will assist in determining parameters and defining direction of efforts when executing the preceding large scope tests. The effect of introducing propellants into an evacuated line at temperatures representative of the command module reaction control system environment at reentry will be determined. Service propulsion system ullage blowdown tests will be conducted to determine the temperature and pressure time history of the ullage gas in a N_2O_4 tank during ullage blowdown. The expansion process in the pressure regulator will be investigated to determine the magnitude of isenthalpic temperature rise in helium as it passes through a pressure regulator. Changes in electrical properties due to vacuum mixtures, water content, impurities, dissolved helium, and density will be determined over a controlled temperature and pressure range. The contact angle of A-50, N_2O_4, and NMH propellant when contained within a cylindrical vessel will be determined.

THERMAL ANALYSIS

Basic Objectives

The basic objectives of the Thermal Analysis group are as follows:

1. To predict heating rates to the vehicle components resulting from the boost, abort, space, and atmospheric entry mission phases of the system

2. To determine the optimum thermal protection for the vehicle components required for each phase of the mission

3. To predict steady-state and transient structural heat transfers and temperatures resulting from the heating rates experienced during each phase of the mission including the effects of the thermal protection system and the thermal characteristics of the structure

[redacted]

[redacted]

Organizational Relationships

This group will coordinate with other Design, Structures, Aerodynamics, Trajectory Analysis groups to obtain proper vehicle configurations for analysis; provide predictions of the temperature-time histories for the various vehicle configurations to design groups concerned; and coordinate with the model shop for the construction of wind tunnel models.

Within the Thermo and Fluid Dynamics Section, this group will supply heating rates and temperature histories to other groups as required, coordinate with the propulsion group to obtain exhaust flow field data for the launch escape system rocket and reaction control system rockets, coordinate with Aerodynamics to help establish the aerothermodynamic wind tunnel test program, and coordinate with the model design group throughout the design of the models to be tested.

During the development test program, the Thermal Analysis group will specify instrumentation and test methods for the flight test plan in conjunction with the testing group to accomplish the objectives of the tests applicable to aerothermodynamics and heat transfer analysis. The group will also coordinate with wind tunnel test personnel during aerothermodynamic tests and provide analytical support for proof and developmental testing as related to heat transfer.

The responsibilities of this group in subcontractor relations will be to supply estimates of non-blowing aerodynamic heating rates to the heat shield subcontractor and to coordinate and monitor the effort of the heat shield subcontractor to ensure compatibility with over-all design and performance requirements.

This group will coordinate analyses with NASA personnel conducting similar research, conduct periodic reviews with NASA personnel concerning analyses results, and coordinate with NASA recommended basic design or flight requirement changes.

Technical Activities

Activities performed in the Thermal Analysis group are organized into three units: aerothermodynamics, atmospheric heat transfer, and space heat transfer.

[redacted]

[redacted]

Aerothermodynamics

The activities of this unit include the following tasks:

1. Predict heat transfer rates encountered in all flight modes due to aerodynamic heating and the combined effect of rocket engine exhaust impingement.

2. Develop and refine analytical methods of predicting heat transfer based on existing theories and correlation of data obtained in an extensive experimental program.

3. Establish the performance limits of the complete Apollo system in terms of launch time tolerances and lunar return tolerances by studying the effect of various entry trajectories on heat shield weight.

4. Conduct an extensive wind tunnel program encompassing tests of models of the Apollo components under conditions simulating heating encountered during launch, entry, and abort, and investigate the effects of jet impingement on vehicle components. Specify wind tunnel model design requirements, instrumentation, and test plans.

5. Analyze test data obtained to correlate model data with actual flight conditions to develop analytical methods that will satisfactorily predict actual aerodynamic heating rates.

6. Specify the test instrumentation methods to accomplish the objectives of the tests applicable to aerothermodynamic design problems for the flight test plan to establish the reliability and performance of the Apollo system.

7. Conduct a literature survey relative to state-of-the-art techniques for evaluating invisoid flow field and non-blowing aerodynamic heating rates for Apollo vehicle during all flight phases.

8. Analyze the environmental and geometrical phenomena that influence aerodynamic heating (convective and radiative) to the Apollo reentry configuration (e.g., ionization, nonequilibrium flow, boundary layer transistion criteria in the presence of an ablating surface, cross-flow, and separated flow).

9. Compile a set of theories for predicting non-blowing aerodynamic heating rates to the Apollo vehicle for all flight conditions based on the results of tasks 7 and 8.

[redacted]

[redacted]

10. Compile and maintain through coordination with the digital programs group automatic computing programs to permit mass production of aerodynamic heating estimates.

11. Supply estimates of non-blowing aerodynamic heating rates to all organizations concerned including the heat shield subcontractor.

12. Analyze and supply estimates of heat transfer rates to surfaces exposed to rocket exhaust environment.

13. Establish the detailed specifications for a wind-tunnel program that will be used to evaluate the proposed aerodynamic heating theories. Determine important flow parameters and range of those which must be simulated in tests. Evaluate, through direct contact, reports, and experience, the capability of existing facilities to perform the desired tests. Propose a test program including selection of facilities, schedule, number, and types of models, and location of end-point instrumentation for models.

14. Monitor and direct each aerodynamic heating test by providing an engineer at the test facility.

15. Plot, evaluate, and compare test data with theory.

16. Realign, adjust, and correct theories with experimental data if such data are construed to be reliable.

Atmospheric Heat Transfer

This unit will perform the following tasks:

1. Provide predicted temperature-time histories for all structures and components during atmospheric flight mission phases. Provide prediction of the temperature-time histories for all structures and components on the command module. This effort includes determining the inter-dependency of the temperature of each of the components on all the other components in the equipment bays. Provide predictions of the temperature-time histories for all structures and components on the service module. This provides temperature-time predictions for all structures on the launch escape system. Because this system does not continue the mission beyond the boost phase, only the boost trajectory plus possible abort trajectories are considered.

2. Predict the thermal protection requirements for each modular system during all mission phases.

[redacted]

3. Evaluate the atmospheric heating protection requirements for each of the modules including the effect of heating due to exhaust gas impingement.

4. Evaluate the changes of aerodynamic shape and center-of-gravity location that occur during the entry due to the ablation of the heat shield.

5. Design the protective shield for the antenna regions on the command module. This portion of the heat shield is not considered to be part of the subcontract for the ablative heat shield.

6. Determine the thermal insulation requirements for each of the modules to protect the vehicle during atmospheric heating.

7. Determine the ablation characteristics of these materials proposed for use as the reentry heat shield. Include the thermal properties of the materials concerned.

8. Determine the thermal properties of super insulations, honeycomb panels, and temperature control coatings.

9. Help establish flight test requirements and evaluate applicable flight test data as it is made available.

Space Heat Transfer

The tasks to be performed by this unit are as follows:

1. Provide temperature predictions for spacecraft structures and components for all space mission phases including earth orbit, translunar, lunar orbit, and transearth.

2. Determine the insulation and/or heater requirements for all spacecraft structure and components.

3. Request and coordinate material properties testing of all insulation material under consideration for use in the spacecraft.

4. Apply results of materials property testing to spacecraft thermal protection design.

5. Help determine thermal space flight test criteria to support the design and analysis of the command module and service module.

[redacted]

[redacted]

6. Evaluate results of space flight tests where they concern thermal design.

7. Predict temperature histories and gradients of the heat shield ablative layer and substructure for all space mission phases.

8. Perform analytical studies to determine temperature histories and thermal protection requirements for all boilerplate vehicles during earth orbit.

9. Provide analytical support for the development of computer programs required for heat transfer analysis.

AERODYNAMICS

Basic Objectives

The basic objectives for the Aerodynamics group are as follows:

1. To assure the aerodynamic soundness of the design

2. To determine and publish the aerodynamic characteristics and the aerothermodynamic environment of various configurations

3. To manage the Apollo wind tunnel program and determine aerodynamic forces and environment on the various configurations, aerodynamic heating data, and aeroelastic data

Organizational Relationships

This group will determine preliminary guide lines and configuration requirements for structural design, design and construct wind tunnel models, and plan and conduct the associated tests based on requirements received from other sections.

The Aerodynamics group will issue the following data to other design sections:

Air pressure and loads for structural design

Lift-and-drag characteristics for performance and trajectories

Stability and control characteristics for flight dynamics

Flow field descriptions for radio attenuation studies

[redacted]

[redacted]

Flight environment for structural design and performance analysis

Results of wind tunnel tests

Within the Thermo and Fluid Dynamics Section, the Aerodynamics group will determine and issue flow field descriptions of aerothermodynamic analysis studies, design and test models for required analysis of other groups within the sections, and issue test reports.

During the development test program, this group will establish requirements for the wind tunnel program, prepare summary analyses of wind tunnel test results, establish aerodynamic requirements for boilerplate and unmanned prototype flight programs, evaluate flight plans, analyze results of flight program, and investigate discrepancies that become apparent between flight results and wind tunnel tests.

For manned operations, this group will maintain continued surveillance of configuration changes, determine aerodynamic characteristics of emergency configurations, and evaluate flight plans and analyze results.

In relationship with NASA, the Aerodynamics group will obtain approval for wind tunnel test objectives and test scheduling, maintain cognizance of NASA research programs as applicable to Apollo, and maintain technical liaison for concurrence with design and analysis results.

Technical Activities

Activities performed in the Aerodynamics group are organized into aerodynamics analysis and wind tunnel model testing and design.

Aerodynamics Analysis

This unit will be responsible for entry Aerodynamics (the general entry configuration is established at contract go-ahead) as follows:

1. Initially determine design criteria and identify critical problem areas. Estimate command module aerodynamic forces and damping derivatives using Newtonian flow theory programmed for digital computer calculations. Supplement these estimates by analysis of preliminary NASA test data released in Apollo working papers. Assemble the results in the Preliminary Aero Data and Loads Report and provide the basis for initial trajectory and flight dynamics studies.

[redacted]

[redacted]

2. Obtain the aerodynamic characteristics of the specific command module configuration evolving from structural design studies. Determine wind tunnel test requirements and conduct tests. (To permit early testing, small simple models are used.) Use the parametric data obtained in studies to determine the effects on command module aerodynamics of variations in heat shield radius, corner radius, and afterbody angle. Establish center-of-gravity tolerances.

3. Determine the effects on stability of asymmetric ablation of the heat shield. Use wind tunnel data in conjunction with Newtonian predictions of the perturbations in forces due to local geometry changes. Determine from the analysis of wind tunnel results the effects on stability of the reaction jets interacting with the free-stream flow. Establish digital programs to aid in the calculation of the nozzle flow field and its interaction with the adjacent structure.

4. Predict preliminary aerodynamic damping characteristics of the entry body using Newtonian estimates of the forces on the command module. Prepare analog studies to establish the relative importance of the damping terms to control system design. Conduct wind tunnel programs using the forced oscillation and decaying oscillation techniques. (The forced oscillation tests give a measure of the longitudinal damping parameter, whereas the decaying oscillation tests provide a measure of the overall stability (both static and dynamic) during an oscillatory motion.). Analyze the results to provide an evaluation of damping derivatives as affected by Mach number, dynamic pressure, and center-of-gravity location.

5. Estimate preliminary command module loads using Newtonian flow. Determine final loads through wind tunnel tests that provide measured pressure distributions. Develop a digital program to compute loadings by integration of local pressure distributions.

6. Develop methods for approximate and refined analyses of the flow fields about the Apollo vehicle. (Primary emphasis is on hypersonic blunt body fields.) Develop digital programs to compute real gas equilibrium and nonequilibrium flow and extend them to include angle-of-attack effects. Define local surface conditions for design purposes and the aerothermodynamic properties of the flow field for use in radio attenuation studies using the results of these studies.

7. Evaluate actual orbital entry aerodynamics from results obtained in the flight test program.

[redacted]

[redacted]

This unit will perform the following activities in regard to the launch escape system:

1. Initially determine configuration arrangements that provide the required stability characteristics. (These characteristics can be significantly affected by operation of the escape motor.) Base early design on analysis of wind tunnel results (jets off) combined with analytical estimates of the interactions between the jet plumes and free-stream flow fields. Formulate an experimental program and evaluate methods of simulating the jet effects in wind tunnel tests. (These methods include solid plumes, cold jets, and rocket operation.) Evaluate the system from analysis of the pad abort and high-altitude aborts conducted in the flight test program.

2. Obtain dynamic stability characteristics from analysis of wind tunnel data. Determine damping derivatives from analysis of forced-oscillation tests conducted at the Langley Research Center. Determine effects of Mach number, Reynolds number, center-of-gravity location, and angle of attack.

3. Determine launch escape system loads from wind tunnel data. Obtain preliminary results in early tests with small-scale models. Obtain more extensive data with large-scale models in the NASA unitary tunnels. Obtain measurements of steady and unsteady pressure distributions including the effects of simulated escape motor operation.

This unit will perform the following recovery system aerodynamics activities:

1. Develop the entry configuration to meet requirements for parachute deployment. Give support to design and development of the recovery system including the aerodynamic design of the pressure sensore for drogue deployment.

2. Determine the aerodynamic characteristic of the command module at subsonic Mach numbers, with the parachute cover heat shield removed, from analysis of wind tunnel data.

The following launch vehicle aerodynamics activities will be performed by this unit:

1. Determine the aerodynamic characteristics of the various booster vehicles by theoretical estimates and through wind tunnel data. Conduct tests of the C-1 and C-5 configurations to establish

[redacted]

[redacted]

total booster aerodynamics and the characteristics of the booster alone after separation of Apollo. Use these data in performance studies and in studies of miss distance during abort from boost.

2. Conduct studies to determine the air loadings due to buffet effects during boost. Assemble data from other programs and from NASA studies at the Langley and Ames research centers. Make wind tunnel measurements of buffet pressures and aerodynamic noise on the launch vehicle with emphasis on the command module, service module, and adapter. Analyze the results to provide design criteria for buffet loads. Analyze flight test measurements to provide in-flight evaluation of buffet effects.

Wind Tunnel Model Design and Testing

The proposed testing schedule shown in Figure 46 will be revised as the program progresses and needs for specific data change. A current schedule is found in the Wind Tunnel Program Report, SID 62-170.

The wind tunnel test objectives of this unit are to provide the following:

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

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

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

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

5. Reaction jet effects on stability of the entry configuration

6. Steady-state pressure distributions on launch escape and entry configuration

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

[redacted]

[redacted]

8. Buffet loads effect on the bending mode shapes of the space vehicle structure

9. Aerodynamic heat transfer distributions on the launch vehicle, launch escape system, and entry configuration

10. Heating of service module by attitude control rocket exhaust

11. Service module base heating

Spacecraft design and evaluation wind tunnel tests will be conducted by this unit to attain the following objectives:

1. Obtain static stability and control data in wind tunnel tests conducted over a Mach number ranges from 0.2 to 20. Obtain data at higher velocities in ballistic ranges and free-flight facilities. (Actual flight Reynolds numbers will be duplicated for most tests of the command module during entry.)

2. Obtain escape rocket motor jet effects on the stability of the launch escape system by testing a model with a hydrogen peroxide mono-propellant rocket to simulate jet effects.

3. Evaluate dynamic stability in transonic and supersonic wind tunnels by means of a dynamic balance. Use free damped oscillation techniques to determine damping derivatives.

4. Obtain structural design information from model static pressure measurements in the 0.7 to 10 Mach number range. Obtain transient pressures due to aerodynamic noise and buffet on a large-scale model in the subsonic, transonic, and supersonic regimes up to Mach number 3.5.

5. Determine aerodynamic heating rates from rate change measurements of surface temperature by using thin film or variable reluctance heat transfer gages, or by measuring the output of thermocouples mounted on the inner surface of a thin-walled model. Obtain data in impulse, continuous flow, and free-flight wind tunnels. Make heating measurements in free-flight wind tunnels by either picking up the output of a single thermocouple inductively or by using a miniature FM telemeter transmitter.

[redacted]

[redacted]

Wind tunnel launch vehicle interface studies will be conducted by this unit to accomplish the following:

1. Investigate the static stability and control effectiveness at the lower ranges of velocity and altitude encountered by the launch vehicle by means of well-established wind tunnel techniques. Obtain steady-state and transient pressure distributions for loads calculations over a Mach number range from subsonic to 3.5. Determine aerodynamic heating rates for a Mach number range. from 1.5 to 10.

Wind tunnel aeroelasticity tests will be conducted in the form of transonic tests of a structurally simulated 0.08-scale model to determine the effect of buffet loads on the bending mode shape of the structure.

Jet reaction studies will be made to investigate the effectiveness of the reaction jet controls of the entry configuration in the Mach number range from 8 to 10. Exhaust gas under high-pressure from model posts will be used to simulate the reaction jets.

Service module base heating studies will be made to obtain rocket heating data associated with the service module attitude control and propulsion systems by the use of scaled motors in rocket test facilities.

Wind Tunnel Test Facilities

A list of the test facilities which it is planned to use is given in Table 1. These facilities cover the full range of flight conditions encountered from launch to entry and recovery. They fall into four general categories:

1. Continuous tunnels covering a range of Mach numbers from subsonic to 14

2. Blowdown tunnels at subsonic, transonic, and supersonic Mach numbers

3. Impulse tunnels either arc driven (hotshot) or shock tube driven (shock tunnel) that provide Mach numbers above 15

4. Ballistic ranges by which superorbital velocities can be reached and tests free of sting interference can be performed at lower speeds for comparison purposes

[redacted]

[redacted]

Reports and Manuals

The following reports and manuals will be published by the Aerodynamics group:

1. Aerodynamic Data Manual (First Issue 1 April 1962).
   Basic force and moment data are presented for all Apollo vehicles. This report is the official source document for all design and performance studies and is revised as more data become available.

2. Aerodynamic Loads Manual (First Issue 1 April 1962).
   Loads trajectories are presented for boost, abort, and entry. Total and component pressure, force, and moment distributions are presented for all Apollo vehicles. This report serves as the official source document for all air loads design data and is revised as more data become available.

3. Aerodynamic Dimensional Data Manual (First Issue 1 July 1962).
   Aerodynamic configuration arrangements, surface contour tolerances, alignment tolerances, center-of-gravity requirements, and weight and balance summaries are presented for all Apollo vehicles. This report is continually revised to reflect the most current configurations.

4. Command Module Aerodynamic Summary Report (First Issue 1 July 1963).
   Static and dynamic stability characteristics of the operational command module are presented for flight from entry through recovery. The first issue of this report is based on analyses of wind tunnel data. Subsequent issues incorporate flight test program results.

5. Launch Escape System Aerodynamics Summary Report (Issued 1 January 1964).
   A description and evaluation of the static and dynamic characteristics of the launch escape system are presented. Conditions from rocket ignition to tower jettison are covered.

6. Aerodynamics of Apollo Launch Vehicles (First Issue 1 March 1963).
   This report contains a documentation and analysis of the aerodynamic characteristics of Apollo launch vehicles for performance and trajectory studies. Results of wind tunnel tests simulating conditions before and after separation of the Apollo vehicle are included. The report is revised as required.

[redacted]

[redacted]

7. Flight Test Program Report (First Issue 1 January 1963). Objectives and instrumentation requirements are presented for aerodynamic evaluation of the spacecraft during the flight test program.

8. Flight Test Summary Analysis Report (First Issue 1 October 1964). An evaluation and summary of aerodynamic characteristics of the Apollo vehicle are presented as determined in flight test.

9. Apollo Wind Tunnel Program Report (First Issue 30 January 1962). Test objectives, test facilities, models required, and tunnel test hours for the Apollo program are discussed in this report. Also included are the proposed schedule of wind tunnel tests, tests completed, reports published, and the relationship of the test program to the design phases of the vehicle development. This report is updated and issued quarterly beginning 1 April 1962.

10. Pretest Reports.
Test objectives, configurations to be tested, test conditions, and the run schedule are presented in these reports. Instrumentation requirements and data reduction and presentation are also included. A pretest report is published approximately four weeks prior to the test depending upon the requirements of the particular facility.

11. Data Reports.
The wind tunnel test results are presented in tabular and plotted format in the data report. Model and Schlieren photographs and dimensional data are also included. These reports are issued 30 days after the completion of each test.

12. Apollo Wind Tunnel Summary Report (First Issue 1 October 1964). Upon completion of the Apollo wind tunnel program, a report is published that summarizes the tests by test hours, facilities, and models. A summary of all pertinent reports is included.

ENVIRONMENTAL AND POWER SYSTEMS ANALYSIS

Basic Objectives

The basic objectives of this group are as follows:

1. To establish system performance criteria and provide both technical direction and analytical support to environmental control, electrical power, and nuclear radiation protection systems for Apollo

[redacted]

[redacted]

2. To conduct tests to verify or to obtain basic data used in analysis

3. To acquire system component test data from both ground and flight testing and to reduce, analyze, interpret, and formulate this test data into detailed reports of systems performance features

Organizational Relationships

This group will maintain continuous coordination with the Environmental Control and Electrical Power Systems groups to define areas where analysis and/or technical direction is required and will publish completed analyses and distribute to the associated or affected design group, as well as other groups that may be concerned. In this manner, results of analyses are incorporated into current systems or component designs.

Within the Thermo and Fluid Dynamics Section, this group will maintain a constant interchange of technical data between the other groups within the section. This will obtain, for example, such information as heat transfer through the vehicle wall, internal wall temperature distribution, and environmental temperatures for various system components from the Heat Transfer group for incorporation in system analyses.

During the development test program, the Environmental and Power Systems Analysis group will maintain a continuous coordination with systems test personnel during the combined systems testing phase for ground testing and flight testing (including boilerplates and system analysis vehicles). Test data required to establish system performance verification will be acquired.

This group will maintain a close relationship with associated subcontractors to ensure "in-house" analyses incorporate the most up-to-date information, evaluate component and system performance by monitoring subcontractor and analyses of all phases of development, and maintain a continuous information and data exchange between S&ID and the subcontractors to provide for rapid identification of problem areas that will lead to expedient problem solutions.

This group will maintain close coordination with NASA during all analyses that affect system concepts or performance as they are presently incorporated into current design requirements. NASA will be presented with the results of pertinent analytical investigations at regularly scheduled meetings.

Technical Activities

Activities performed in the Environmental and Power Systems Analysis group are organized into three units: power systems analysis, nuclear radiation protection systems, and environmental control systems analysis.

[redacted]

[redacted]

Power Systems Analysis

This unit will perform the following tasks:

1. By analysis, establish, verify, and determine the optimum design criteria for the environmental control system and electrical power system space radiators and for fuel cell and cryogenic storage subsystems.

2. Analyze the power system performance and establish and define system operating parameters. Conduct system heat balance analyses and develop a computer program to describe the steady-state and transient performance characteristics of the system. Verify and determine optimum design configurations and evaluate their effects on system performance and interfaces with other vehicle systems.

3. Aid in the planning and monitoring of all system component tests. Analyze, interpret, and evaluate the results and make suitable recommendations. Coordinate the tests with all groups and subcontractors involved.

4. Aid in defining and establishing the testing plans and procedures for all power system and subsystem monitor tests. Analyze and evaluate results and make recommendations as required. Cooperate in the development of the over-all system qualification test and the interpretation of its results.

5. Analyze the fuel cell subsystem and evaluate all test data. Evaluate preprototype, breadboard, units to determine temperatures, required heat rejection rates, operating pressures, and pressure drops. Formulate and operate computer programs to describe the subsystem operation.

6. Analyze the cryogenic storage subsystem. Determine performance requirements and operating characteristics and design and checkout computer programs to describe system operations. Provide criteria to aid in defining optimum design configurations. Determine the weight and volume necessary to support the mission with the required system reliability, heat required to maintain proper pressure and flow rates, and variations in system temperatures.

7. Establish thermodynamic and fluid dynamic design requirements for electrical power systems and environmental control system space radiators. Determine operating parameters for temperature, heat rejection rate, flow rate, system pressure, pressure drop, etc.

[redacted]

Develop transfer functions to describe steady-state and transient performance. Employ computer programs to determine optimum configurations and performance characteristics.

8. Plan, monitor, and evaluate tests to determine realistic temperature control coating properties for use on radiator heat rejection surfaces. Conduct a survey of literature and industry to select candidate coatings. Arrange for actual and simulated space environment tests and coordinate test requirements with NASA to facilitate the acquisition of test space on vehicles for some of these tests. Collect, reduce, and evaluate test data. Analyze effects of space environment on the candidate coatings and select coating. Generate special handling requirements and coordinate these with manufacturing, system integration, and logistic groups.

Nuclear Radiation Protection Systems

This unit will perform the following tasks:

1. Investigate solar cosmic ray events to determine the magnitude, physical phenomena, spectral distribution, frequency of occurrence, and probability of encounter. Determine radiation sources for all mission modes and flight trajectories.

2. Conduct shielding investigations and develop an IBM computer program to determine the inherent shielding of vehicle and radiation dose received by men and equipment associated with the radiation sources encountered on all missions. Establish, where required, the additional shielding system concepts and configurations to reduce radiation dose to allowable limits for crew and equipment. Maintain and update computer programs.

3. Investigate various methods of radiation detection to determine optimum sensor configuration from the standpoint of type of radiation, range, accuracy, weight, volume, and compatibility with both radiation protection system and other vehicle systems. Establish the nuclear radiation instrumentation sensor requirements for all mission trajectories for both exterior and interior environments.

4. Combine the concepts, operating limitations, and design data generated by these activities with the over-all vehicle operations to establish the optimum nuclear radiation protection.

[redacted]

[redacted]

Environmental Control Systems Analysis

This unit will perform the following tasks:

1. Analyze the crew requirements to establish the performance parameters for the pressure suit circuit subsystem components for all mission modes. Establish and maintain a computer program to assist in the analysis.

2. Analyze the coolant loop to establish the performance parameters for the subsystem components for all mission modes. Establish and maintain computer programs to assist in the analysis.

3. Analyze the crew compartment requirements to maintain a shirt-sleeve atmosphere regarding temperature, pressure, and composition control. Consider all mission modes for both normal and emergency operation.

4. Integrate the suit circuit, coolant loop, and compartment subsystem analysis to determine performance of the complete environmental control system for all mission modes including transient conditions as well as varying electronic cooling loads. Establish a computer program for the integrated system.

5. Establish and monitor subcontractor and in-house efforts in the evaluation and test of materials for possible atmospheric contamination properties. Coordinate this effort with Bio-engineering for toxic effects and allowable concentrations.

6. Conduct analysis on food storage and waste management systems to determine line size and component performance and to establish compatibility with the environmental control system for all modes of operation.

7. Conduct analyses to determine on-board water requirements for various mission phases and times. Establish line sizes and tankage requirements. Ensure compatibility with the ESP fuel cell water production system and rates.

8. Monitor component and system testing at the subcontractor for compliance with component performance. Assist and monitor qualification, R &D, and reliability testing for performance verification and establish performance criteria.

[redacted]

9. Establish performance criteria and environmental test conditions for integrated systems breadboard and house spacecraft tests. Assist in establishing instrumentation requirements (type and location) for performance reports. Integrate the test data into computer programs established for system analysis and system optimization studies.

10. Conduct trade-off studies to determine optimum component arrangements and usage. Conduct studies to determine optimum use of on-board water quantities, heat sources, and heat sinks. Conduct trade-off studies to establish configuration and concept for changes in mission requirements and program scope.

11. Conduct environmental control system analysis to support ground support equipment groups. Provide GSE/spacecraft interface requirements for both normal and test operations.

12. Perform analytical studies required to determine the environmental control system concept and performance requirements for each boilerplate test vehicle consistent with mission profile and operational ground rules.

13. Establish environmental control system component and system requirements and assist the design group with component procurement for the boilerplate test program.

14. Reduce and analyze data from boilerplate tests and incorporate this into spacecraft environmental control system performance where applicable. Support the test program as required.

15. Conduct a preliminary analysis of cold plate design parameters to define limits for more refined parametric analysis.

16. Perform analysis, on a single-plate basis, to establish interrelationships of package dissipation, environmental heat loads, temperature limits of coolant and components, coolant flow patterns, heat transfer coefficients, pressure drop, and contact resistance. Establish a computer program for these analyses.

17. Investigate materials and techniques of contact resistance control.

18. Specify and coordinate laboratory tests of single plates to confirm analytical assumptions and results and replace certain long, tedious analytical methods.

[redacted]

[redacted]

19. Include the consideration of subsequent building-block assembly of individual plates into the modular system and requirements of miscellaneous equipment to establish parameters such as cooling capacity, temperature profiles, and interchassis effects. Determine the effects of structural attachments and evaluate effects of environmental loads. Expand the initial computer program to supplement these objectives.

20. Specify tests on a system basis and evaluate test results to provide back-up to the single cold plate tests.

21. Determine equipment that may be temperature controlled by passive means and the optimum method for such control.

[redacted]

[redacted]

SIMULATION—TRAINING EQUIPMENT

SIMULATION AND EVALUATION

The Apollo engineering simulation program is oriented specifically to evaluate designs by means of closed-loop, dynamic, and simulated flight operations.

In order to meet this objective, an expanding simulation facility is necessary. The initial facility, which performs analytical design studies to minimize the use of a man in the loop, will grow in complexity to a complete man-machine simulation facility. In the latter simulation facility, the crew will be placed within an environment duplicating the actual flight environment in order that engineering design may be evaluated.

Initially, all subsystems will be simulated by means of analog and digital computers. As the program continues, individual items of hardware will be substituted until important subsystems are in actual use. The build-up in systems complexity also will be paralleled by the build-up in the simulated environment of the crew. Simulation of visual, aural, and kinesthetic environments will proceed from the simple to the complete simulation of the actual environment as required and practical. The command module used during these studies will proceed from semi-hard engineering evaluators to completely hard engineering simulators that duplicate, in all interior respects, latest configurations of the Apollo spacecraft.

The complexity of the simulated mission flights also will be built up from simple studies to complete flight phase simulations. When the final evaluation stage is approached, there will be two engineering simulator complexes available that will provide the necessary environment with a complete simulation. Actual systems will be used in the command module for final engineering evaluations of the total man-machine system. As a concurrent operation, other simulators and evaluators will be used for the continuing and advanced system development that is necessary in any major program.

The engineering simulator complexes will be used for the usual preflight and postflight system evaluation studies. In addition, they will provide the experience necessary for designing, checking out, and evaluating new or compensatory procedures and tactics to be followed during actual flight if unusual or emergency conditions should develop.

The S&ID engineering simulation program provides a natural foundation for the training activity of General Order 7125. This technical combination,

PRECEDING PAGE BLANK-NOT FILMED

[redacted]

[redacted]

paralleling related engineering simulation and crew-mission training activities of NASA, will provide the balanced and adaptive concept necessary to accomplish this phase of the Apollo project.

Program Format

The simulation and trainers branch is divided into four sections: Flight simulation-evaluation, spacecraft simulation, training equipment engineering, and digital programs.

The engineering simulation program for Apollo will be a highly organized and coordinated plan to ensure schedule compliance, economy, and valid engineering information. The responsibility for this effort is that of the flight simulation-evaluation and spacecraft simulation sections of the simulation and trainers branch. The bulk of this activity will be project-oriented within Apollo technology but will utilize S&ID functional facilities. S&ID function capabilities, and outside consultants in a supporting role.

The flight simulation and spacecraft simulation sections establish, continuously update, and coordinate Apollo simulation program requirements necessary to accomplish engineering evaluations and flight phase simulations, support life systems engineering evaluations, and to support each preflight and postflight systems evaluation.

To implement this activity, SID 62-1303, "Apollo Simulation Evaluation Summary," was issued in November 1962. This report presents the following:

The master simulation phasing plan (Figure 60).

Facility schedule summary

Definition and philosophy of each simulation study

Simulation equipment

Simulation facility descriptions

A second report, also published in November 1962, "Apollo Simulator Program Plan," SID 62-787, presents the requirements, definitions, and phasing schedules for hardware-oriented equipment.

This development plan summarizes portions of the two previous reports. Simulation schedules from SID 62-1303 are presented (Figure 58) for boost and abort, entry and recovery, orbital and space mechanics, lunar development operations, special facility tests, systems tests, earth orbital boilerplate flights, earth orbital prototype flights, and lunar flight operations.

[redacted]

[redacted]

Simulation evaluation milestones (Figure 58) include schedules for various boilerplate and airframe launchings and simulator and evaluator completion dates. Similar completion dates for the latter two are listed in Figure 60.

Flight simulation coordinates computer schedules for Apollo simulation evaluations and controls cost and obtains machine time. The section assimilates simulation data for all phases of flight from cognizant branches and establishes and maintains the Apollo simulation data manual. In particular, flight simulation performs the following technical functions:

Integrates simulation equations of motion, control and guidance transfer functions, and hardware; and establishes analog or analog-digital combined operation techniques

Performs flight control and guidance and dynamic systems evaluations to ensure simulation compatibility and validity

Conducts engineering and flight phase simulation evaluations and assists project branches and computer personnel in simulation activities and evaluation of data

Establishes equations of motion and other data, such as engineering flight placards and interpretation of mission flight plans specific to a given preliminary crew engineering training objective or program

Supports crew-training activities as required

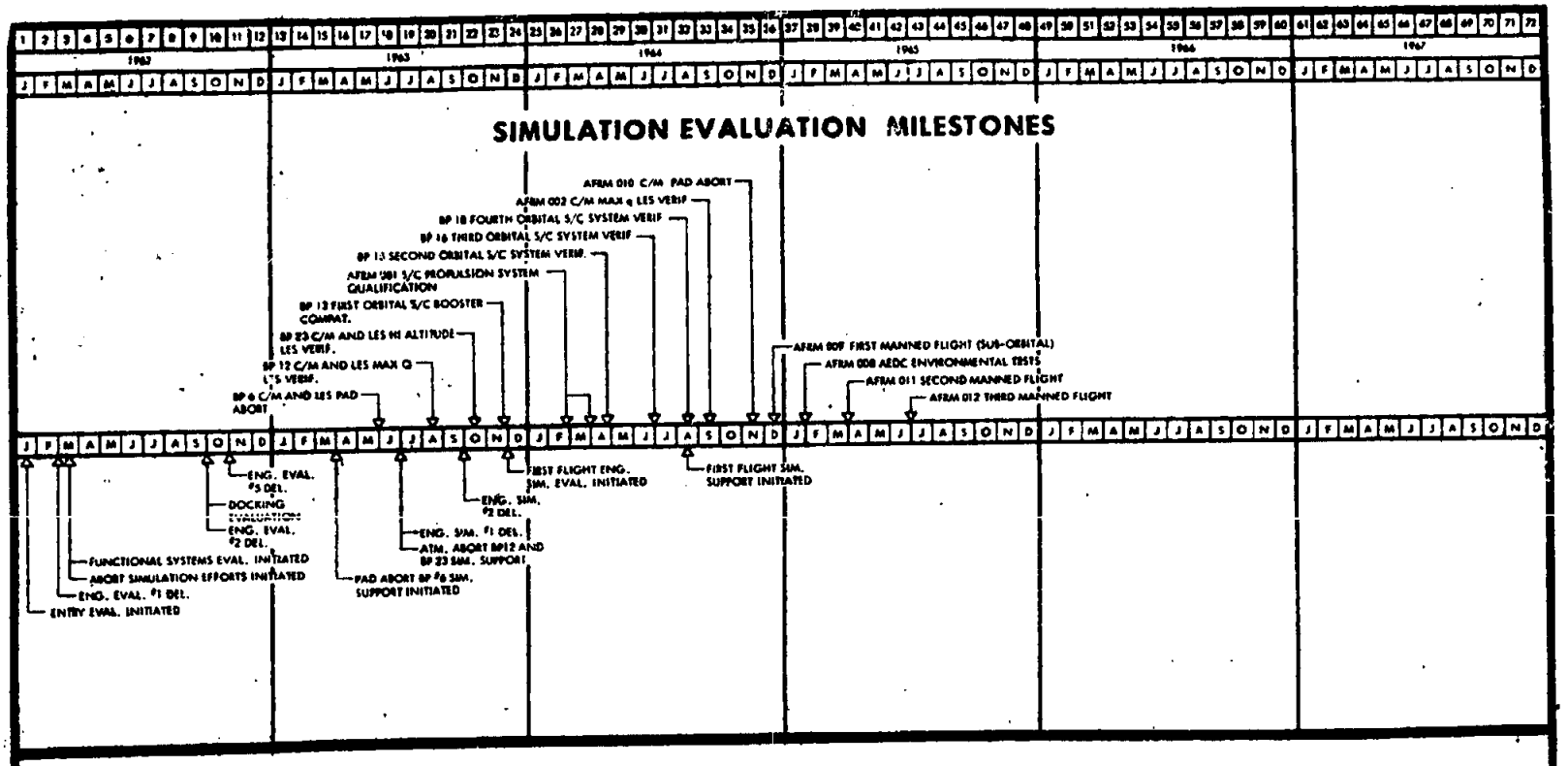
The spacecraft simulation section is responsible for all phases of engineering simulation equipment design and specifications and coordination required to accomplish engineering studies and flight phase simulation to support life systems engineering evaluations and preflight and postflight systems evaluation. This effort includes computer equipment, engineering evaluators, engineering simulators, visual environment simulators, models, and star-field simulation. In addition, this section performs the following functions:

Establishes and lays out design configurations

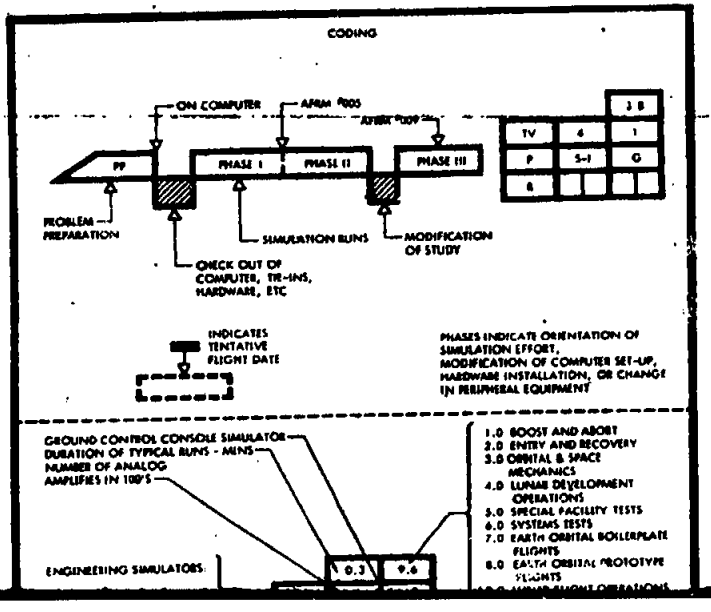
Prepares schematics, assembly and detail drawings, and necessary harness wiring diagrams

Establishes simulation equipment, test requirements, equipment specifications, and test procedures

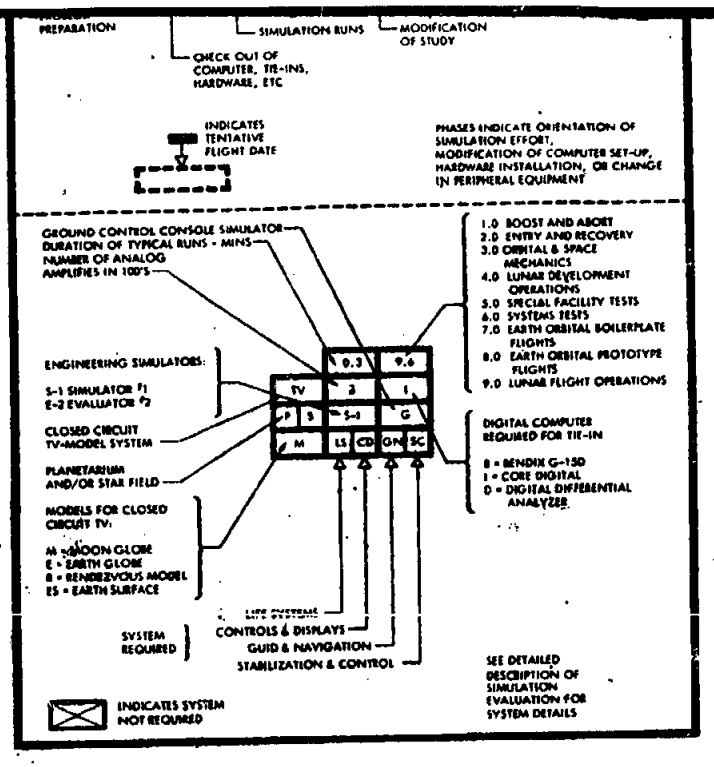
[redacted]

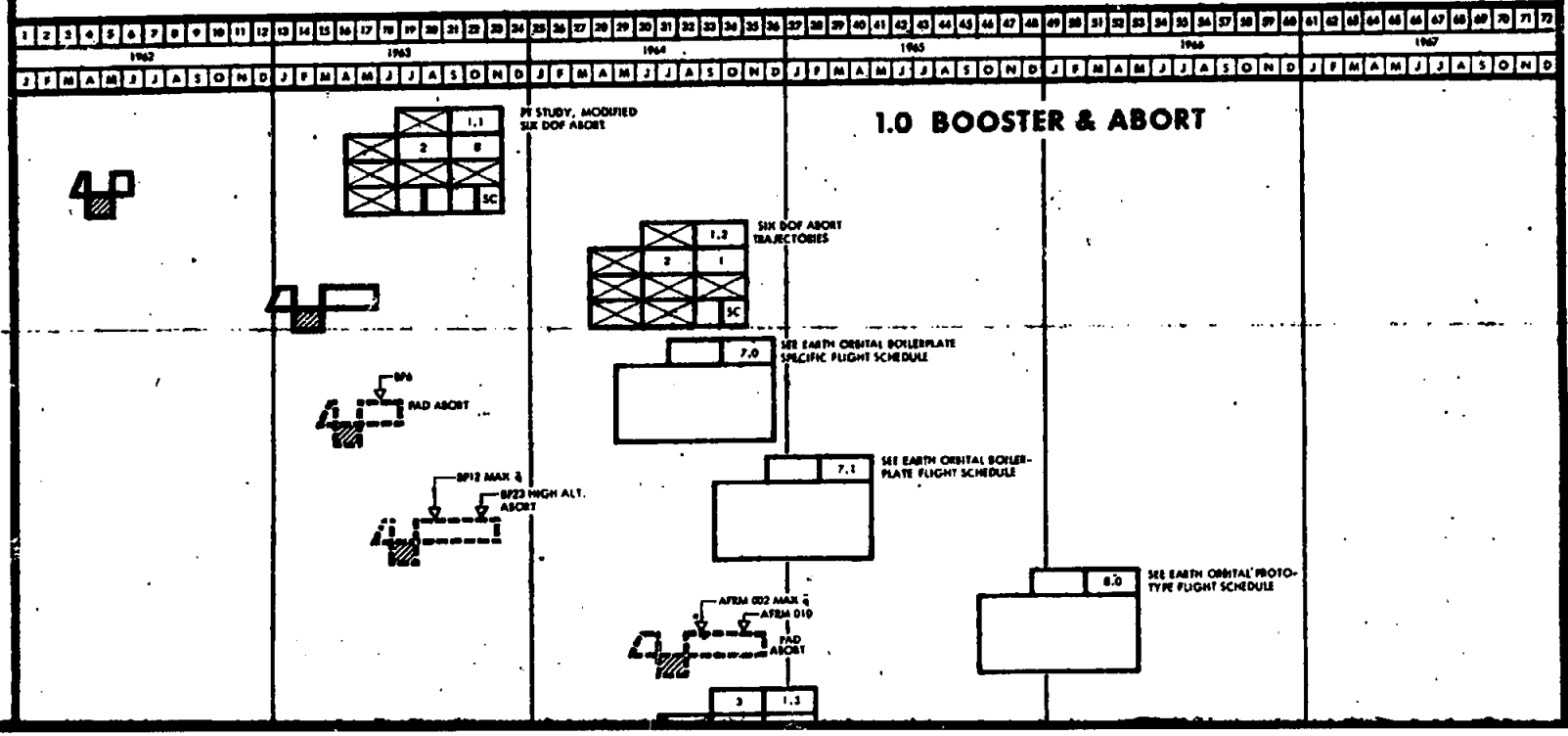


CODING

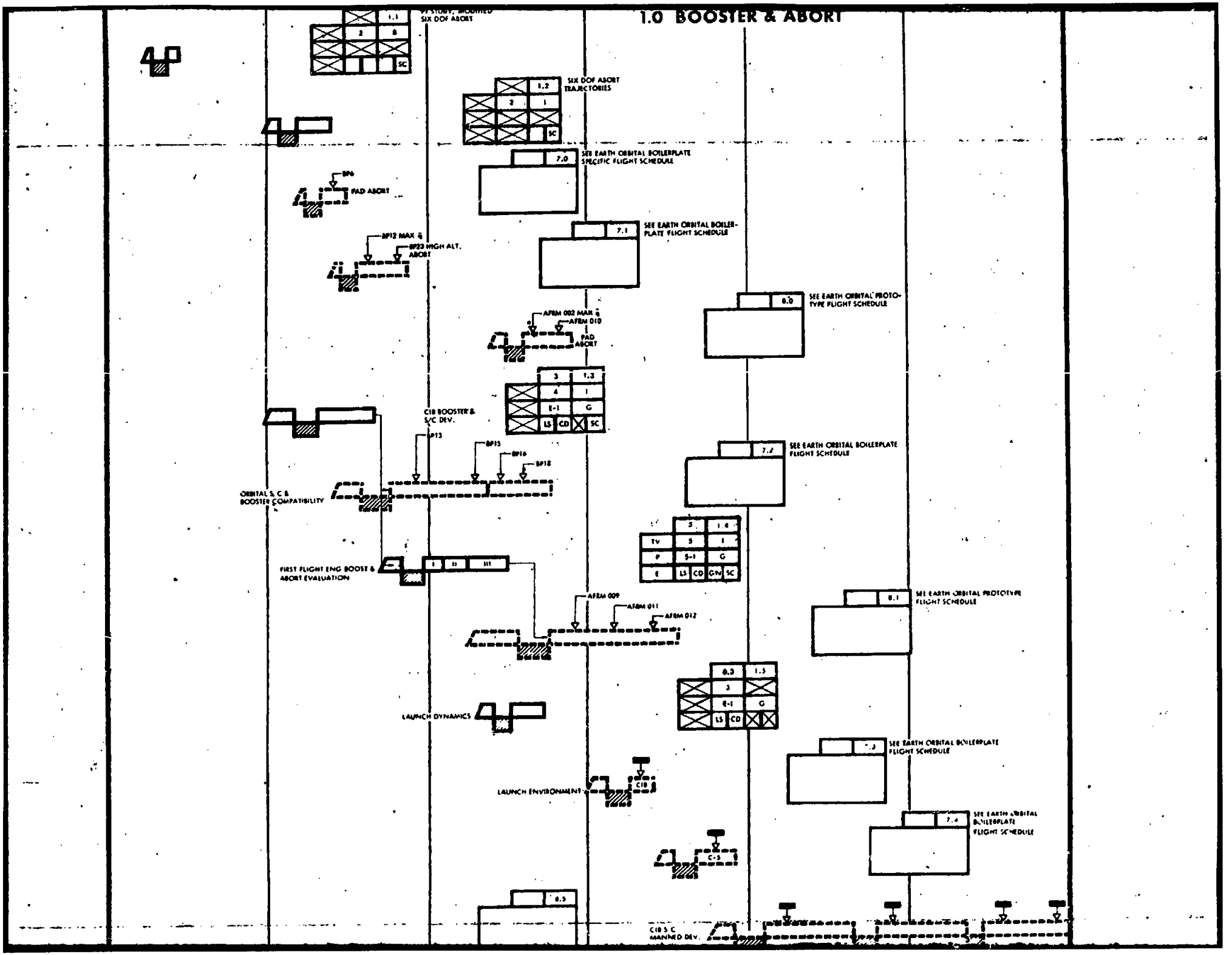


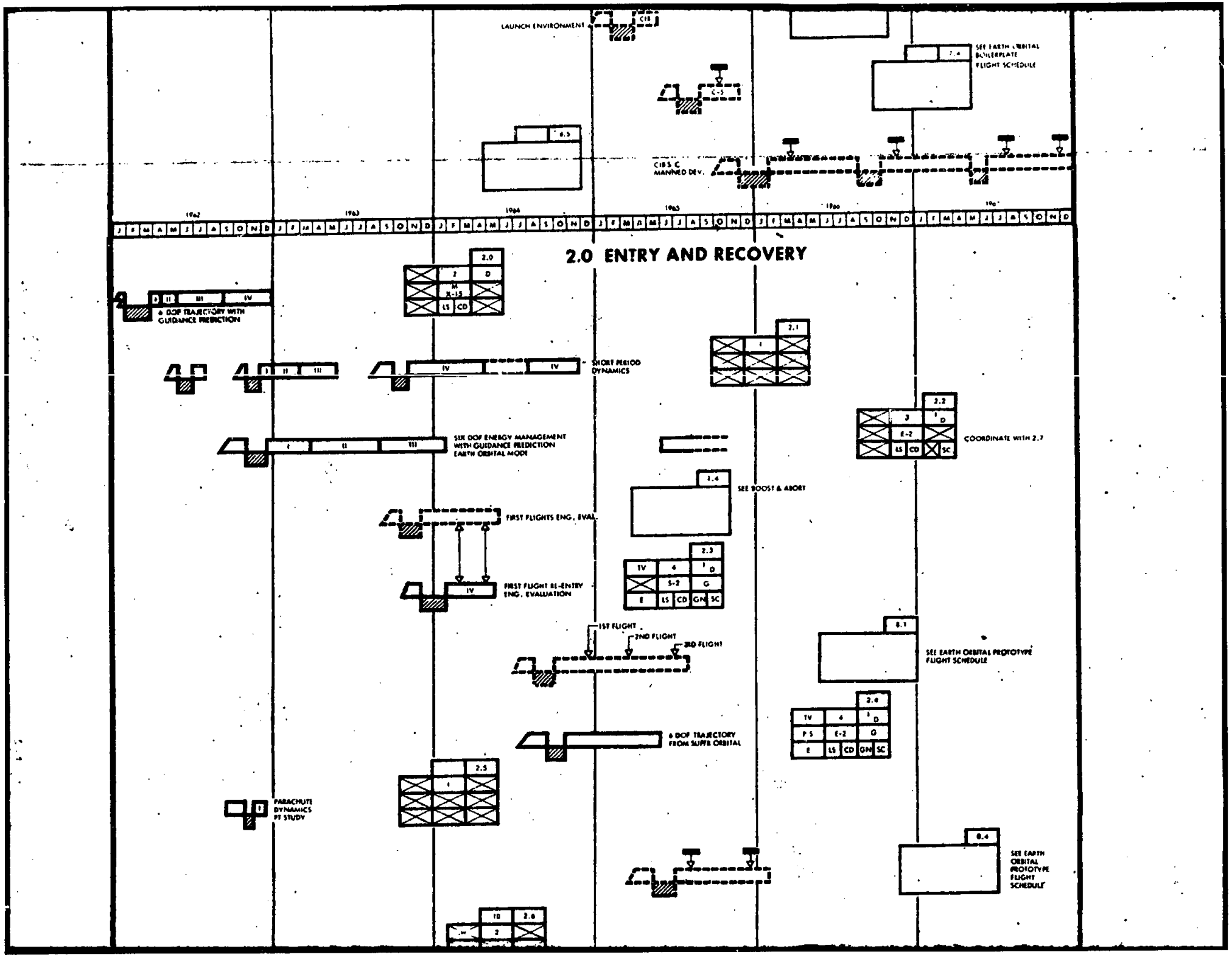
PRECEDING PAGE BLANK-NOT FILMED

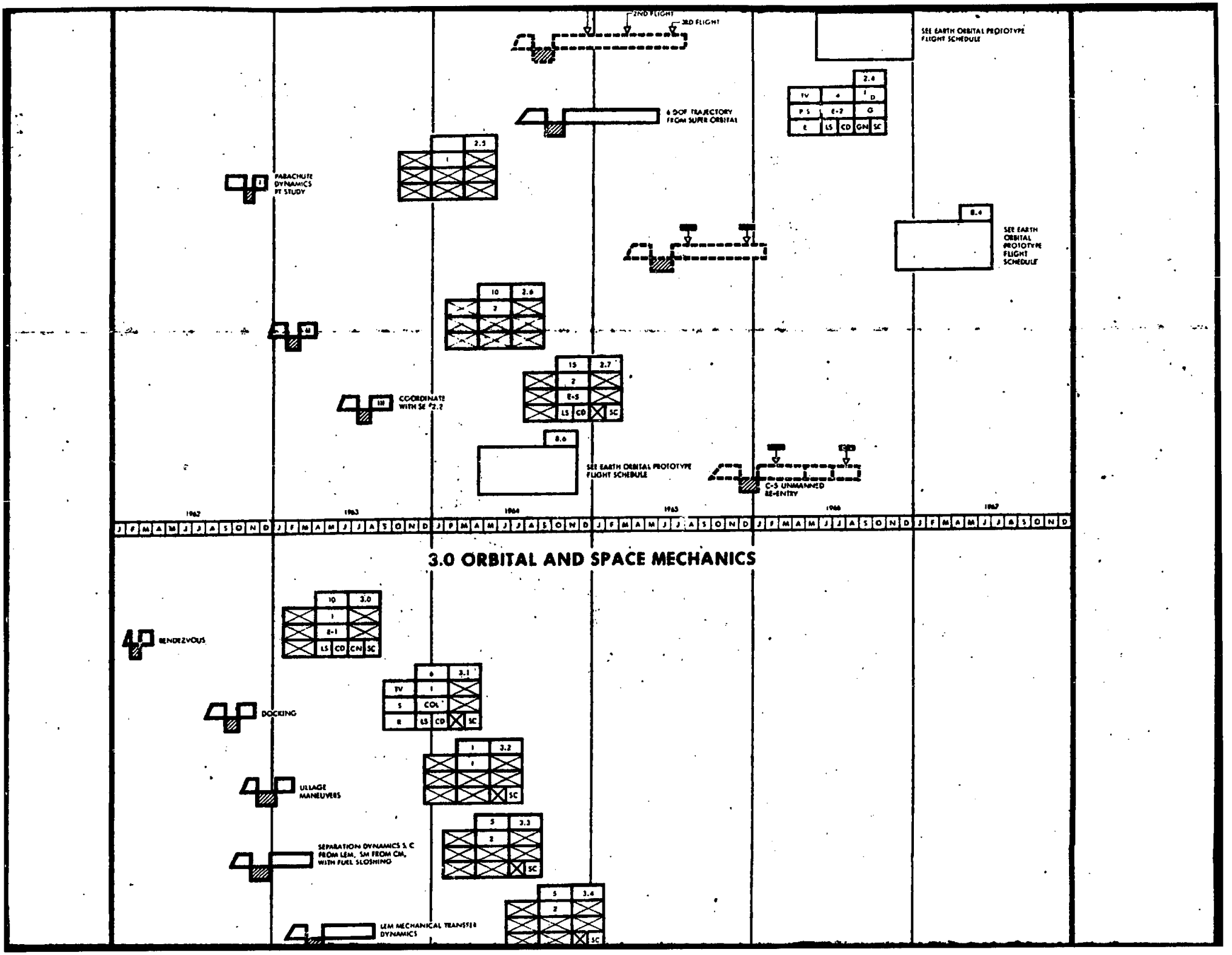

PREPARATION
CHECK OUT OF COMPUTER, TIE-INS, HARDWARE, ETC
SIMULATION RUNS
MODIFICATION OF STUDY
INDICATES TENTATIVE FLIGHT DATE
PHASES INDICATE ORIENTATION OF SIMULATION EFFORT, MODIFICATION OF COMPUTER SET-UP, HARDWARE INSTALLATION, OR CHANGE IN PERIPHERAL EQUIPMENT
GROUND CONTROL CONSOLE SIMULATOR
DURATION OF TYPICAL RUNS - MINS
NUMBER OF ANALOG AMPLIFIES IN 100'S
ENGINEERING SIMULATORS:
S-1 SIMULATOR #1
E-2 EVALUATOR #2
CLOSED CIRCUIT TV-MODEL SYSTEM
PLANETARIUM AND/OR STAR FIELD
MODELS FOR CLOSED CIRCUIT TV:
M = MOON GLOBE
E = EARTH GLOBE
R = RENDEZVOUS MODEL
ES = EARTH SURFACE
SYSTEM REQUIRED
CONTROLS & DISPLAYS
GUID & NAVIGATION
STABILIZATION & CONTROL
INDICATES SYSTEM NOT REQUIRED
1.0 BOOST AND ABORT
2.0 ENTRY AND RECOVERY
3.0 ORBITAL & SPACE MECHANICS
4.0 LUNAR DEVELOPMENT OPERATIONS
5.0 SPECIAL FACILITY TESTS
6.0 SYSTEMS TESTS
7.0 EARTH ORBITAL BOILERPLATE FLIGHTS
8.0 EARTH ORBITAL PROTOTYPE FLIGHTS
9.0 LUNAR FLIGHT OPERATIONS
DIGITAL COMPUTER REQUIRED FOR TIE-IN
B = BENDIX G-150
I = CORE DIGITAL
D = DIGITAL DIFFERENTIAL ANALYZER
SEE DETAILED DESCRIPTION OF SIMULATION EVALUATION FOR SYSTEM DETAILS

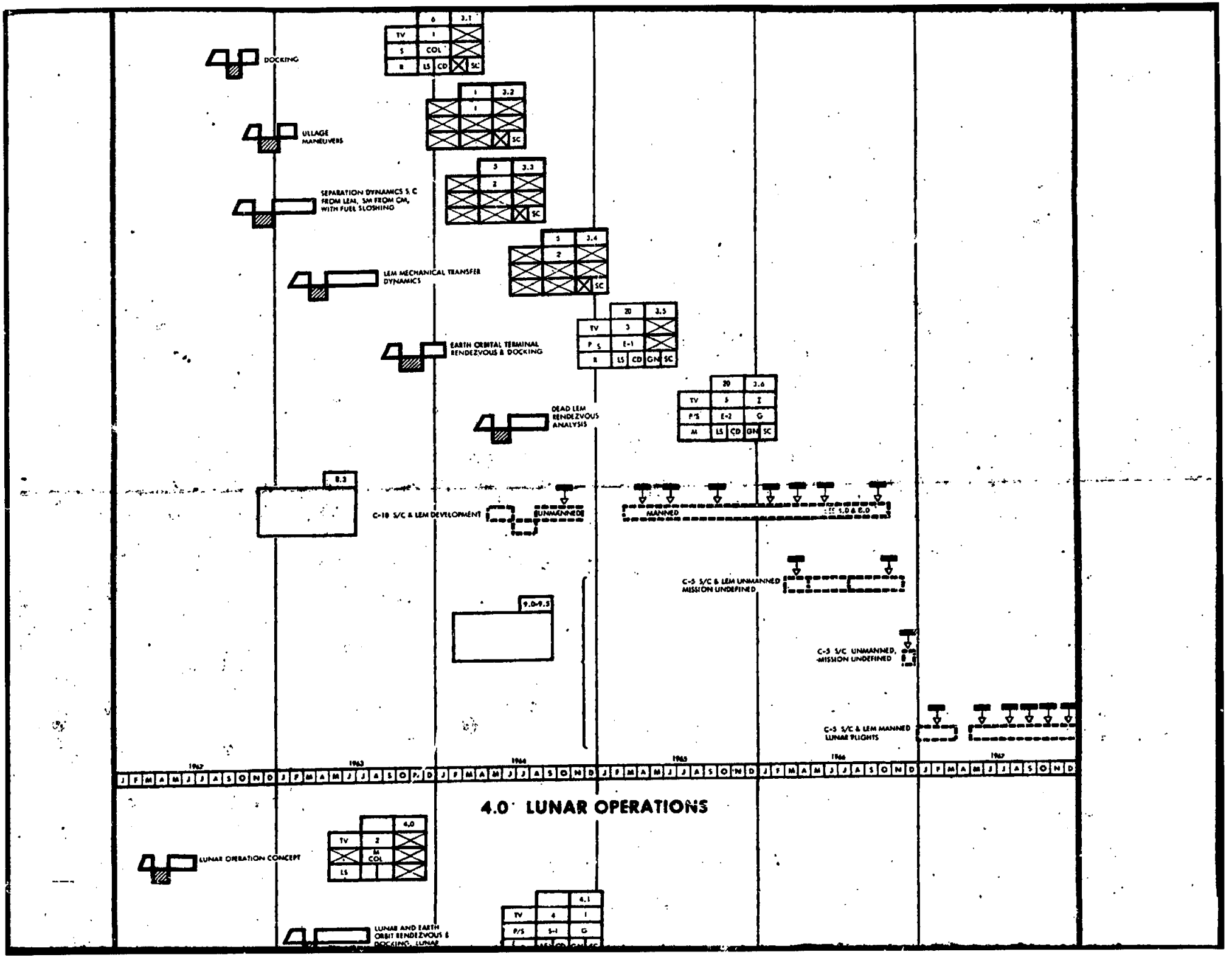

1962
1963
1964
1965
1966
1967
1.0 BOOSTER & ABORT
PI STUDY, MODIFIED SIX DOF ABORT
SIX DOF ABORT TRAJECTORIES
SEE EARTH ORBITAL BOILERPLATE SPECIFIC FLIGHT SCHEDULE
PAD ABORT
SEE EARTH ORBITAL BOILER-PLATE FLIGHT SCHEDULE
HIGH ALT. ABORT
SEE EARTH ORBITAL PROTO-TYPE FLIGHT SCHEDULE
PAD ABORT

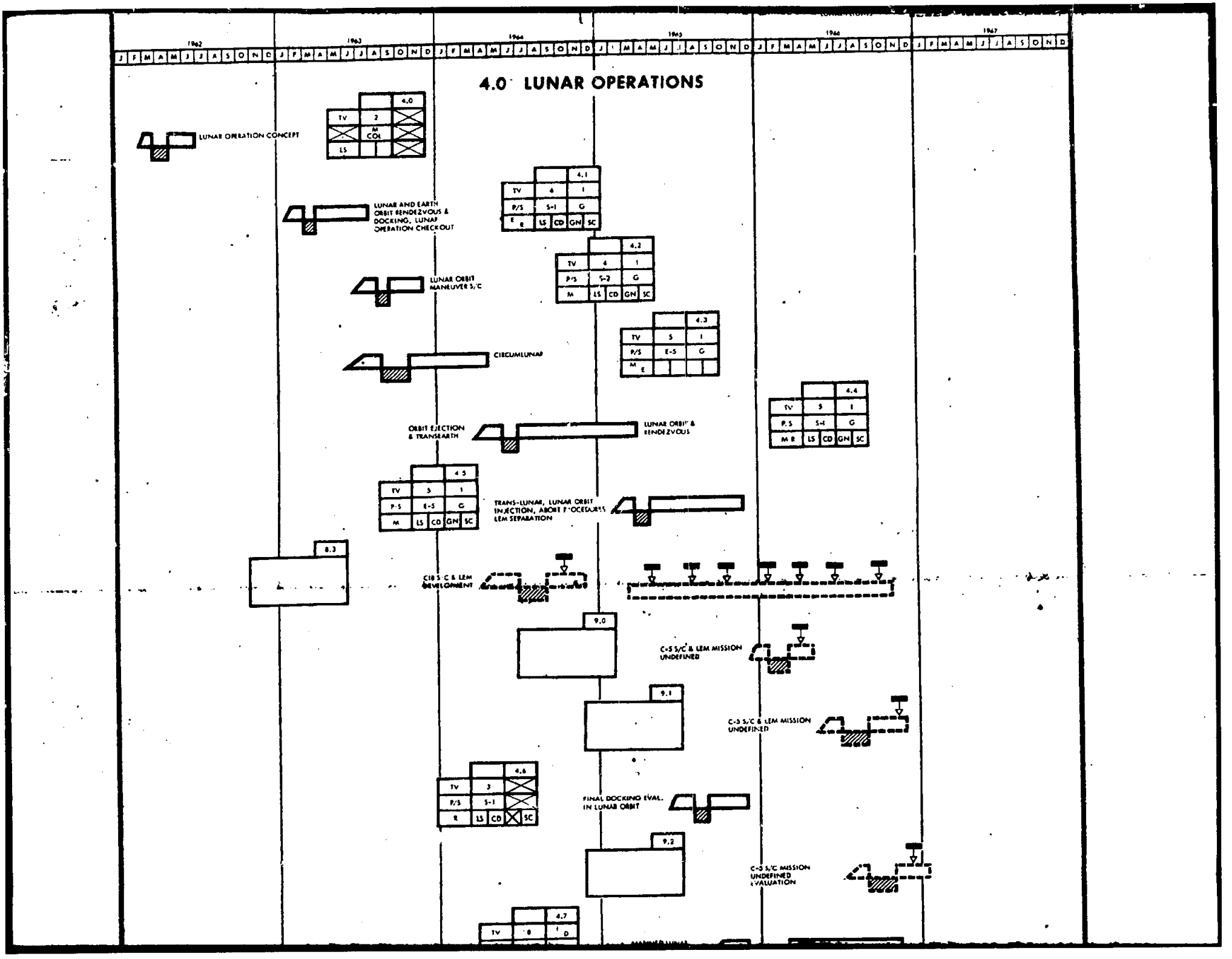
1.0 BOOSTER & ABORT

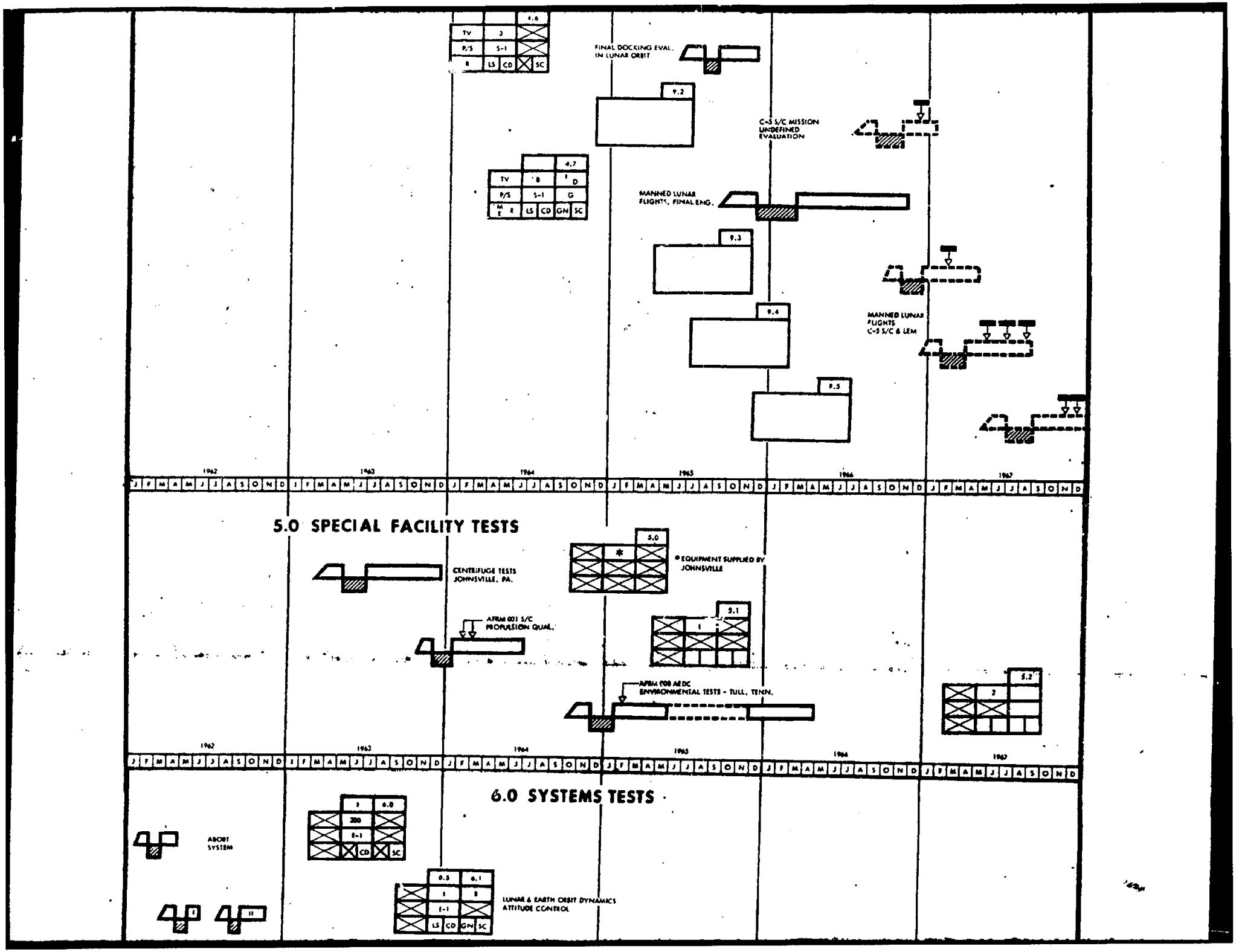


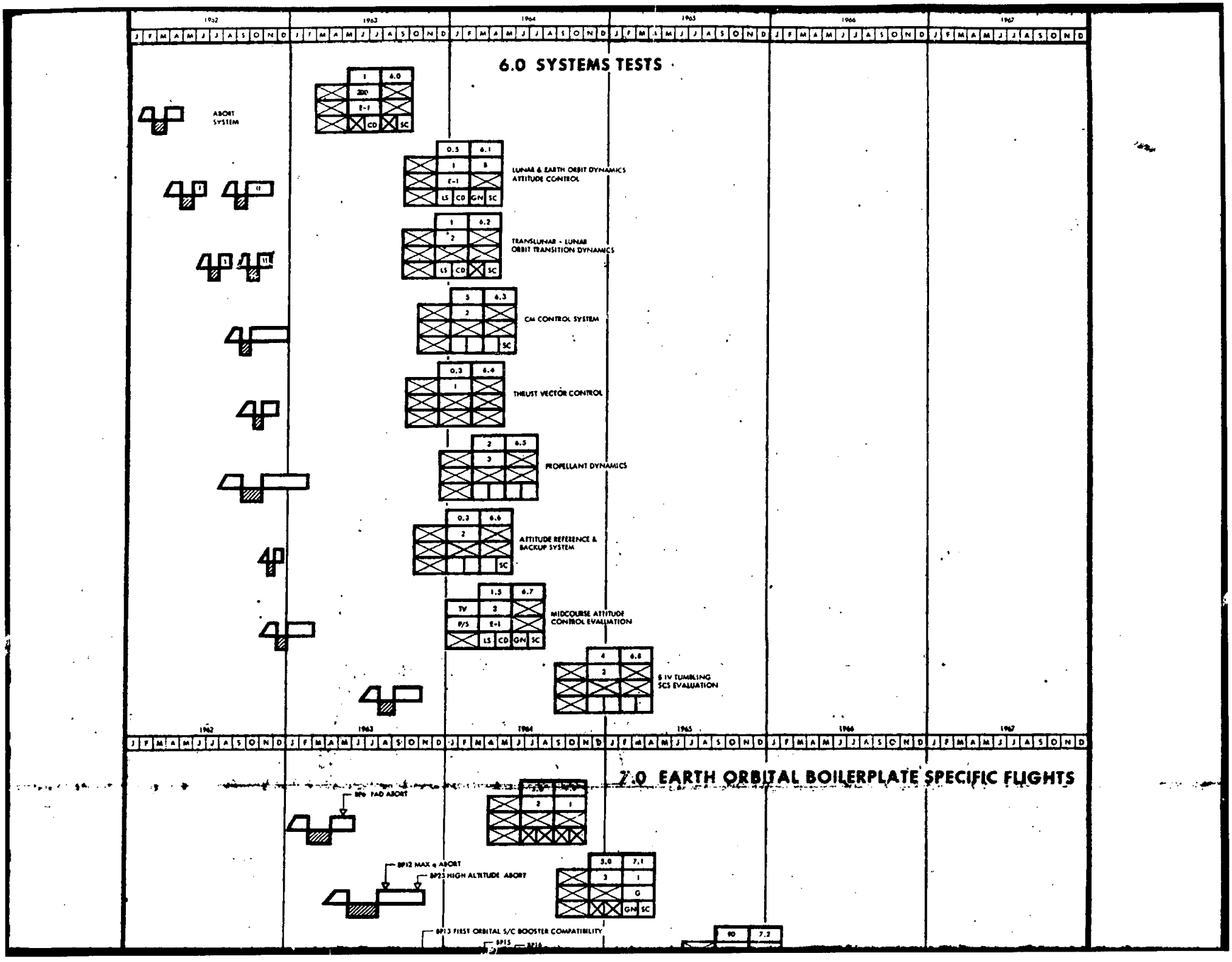

2.0 ENTRY AND RECOVERY
1962
1963
1964
1965
1966
1967
LAUNCH ENVIRONMENT
SEE EARTH ORBITAL BOILERPLATE FLIGHT SCHEDULE
CIBS C MANNED DEV.
6 DOF TRAJECTORY WITH GUIDANCE PREDICTION
SHORT PERIOD DYNAMICS
SIX DOF ENERGY MANAGEMENT WITH GUIDANCE PREDICTION EARTH ORBITAL MODE
COORDINATE WITH 2.7
SEE BOOST & ABORT
FIRST FLIGHTS ENG. EVAL.
FIRST FLIGHT RE-ENTRY ENG. EVALUATION
1ST FLIGHT
2ND FLIGHT
3RD FLIGHT
SEE EARTH ORBITAL PROTOTYPE FLIGHT SCHEDULE
6 DOF TRAJECTORY FROM SUPER ORBITAL
PARACHUTE DYNAMICS PT STUDY
SEE EARTH ORBITAL PROTOTYPE FLIGHT SCHEDULE

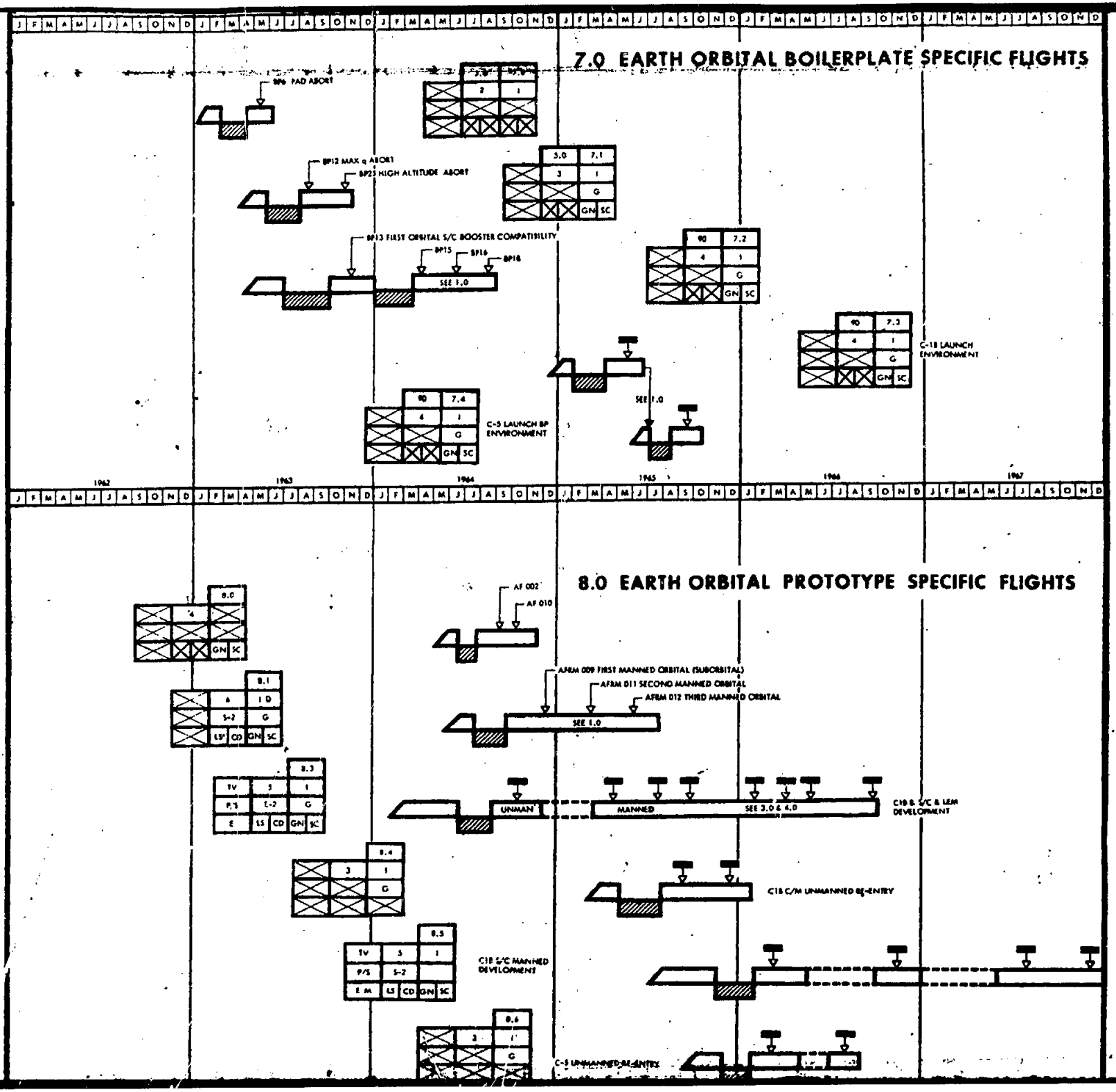

2ND FLIGHT
3RD FLIGHT
SEE EARTH ORBITAL PROTOTYPE FLIGHT SCHEDULE
6 DOF TRAJECTORY FROM SUPER ORBITAL
PARACHUTE DYNAMICS PT STUDY
SEE EARTH ORBITAL PROTOTYPE FLIGHT SCHEDULE
COORDINATE WITH SE #2.2
SEE EARTH ORBITAL PROTOTYPE FLIGHT SCHEDULE
C-5 UNMANNED RE-ENTRY
1962
1963
1964
1965
1966
1967
3.0 ORBITAL AND SPACE MECHANICS
RENDEZVOUS
DOCKING
ULLAGE MANEUVERS
SEPARATION DYNAMICS S. C FROM LEM, SM FROM CM, WITH FUEL SLOSHING
LEM MECHANICAL TRANSFER DYNAMICS


DOCKING
ULLAGE MANEUVERS
SEPARATION DYNAMICS S. C FROM LEM, SM FROM CM, WITH FUEL SLOSHING
LEM MECHANICAL TRANSFER DYNAMICS
EARTH ORBITAL TERMINAL RENDEZVOUS & DOCKING
DEAD LEM RENDEZVOUS ANALYSIS
C-10 S/C & LEM DEVELOPMENT
UNMANNED
MANNED
C-5 S/C & LEM UNMANNED MISSION UNDEFINED
C-5 S/C UNMANNED, MISSION UNDEFINED
C-5 S/C & LEM MANNED LUNAR FLIGHTS
1962
1963
1964
1965
1966
1967
4.0 LUNAR OPERATIONS
LUNAR OPERATION CONCEPT
LUNAR AND EARTH ORBIT RENDEZVOUS & DOCKING, LUNAR


1962
1963
1964
1965
1966
1967
J F M A M J J A S O N D
4.0 LUNAR OPERATIONS
LUNAR OPERATION CONCEPT
LUNAR AND EARTH ORBIT RENDEZVOUS & DOCKING, LUNAR OPERATION CHECKOUT
LUNAR ORBIT MANEUVER S/C
CIRCUMLUNAR
ORBIT EJECTION & TRANSEARTH
LUNAR ORBIT & RENDEZVOUS
TRANS-LUNAR, LUNAR ORBIT INJECTION, ABORT PROCEDURES LEM SEPARATION
C-5 S/C & LEM DEVELOPMENT
C-5 S/C & LEM MISSION UNDEFINED
C-5 S/C & LEM MISSION UNDEFINED
FINAL DOCKING EVAL. IN LUNAR ORBIT
C-5 S/C MISSION UNDEFINED EVALUATION
4.0
TV 2
M COL
LS
4.1
TV 4 1
P/S S-1 G
E R LS CD GN SC
4.2
TV 4 1
P/S S-2 G
M LS CD GN SC
4.3
TV S 1
P/S E-S G
M E
4.4
TV S 1
P/S S-1 G
M R LS CD GN SC
4.5
TV S 1
P/S E-S G
M LS CD GN SC
8.3
9.0
9.1
4.6
TV 3
P/S S-1
R LS CD SC
9.2
4.7
TV 8 1
D


FINAL DOCKING EVAL. IN LUNAR ORBIT
C-5 S/C MISSION UNDEFINED EVALUATION
MANNED LUNAR FLIGHTS, FINAL ENG.
MANNED LUNAR FLIGHTS C-5 S/C & LEM
1962
1963
1964
1965
1966
1967
5.0 SPECIAL FACILITY TESTS
CENTRIFUGE TESTS JOHNSVILLE, PA.
* EQUIPMENT SUPPLIED BY JOHNSVILLE
AFRM 001 S/C PROPULSION QUAL.
AFRM 008 AEDC ENVIRONMENTAL TESTS - TULL, TENN.
6.0 SYSTEMS TESTS
ABORT SYSTEM
LUNAR & EARTH ORBIT DYNAMICS ATTITUDE CONTROL


1962
1963
1964
1965
1966
1967
6.0 SYSTEMS TESTS
ABORT SYSTEM
LUNAR & EARTH ORBIT DYNAMICS ATTITUDE CONTROL
TRANSLUNAR - LUNAR ORBIT TRANSITION DYNAMICS
CM CONTROL SYSTEM
THRUST VECTOR CONTROL
PROPELLANT DYNAMICS
ATTITUDE REFERENCE & BACKUP SYSTEM
MIDCOURSE ATTITUDE CONTROL EVALUATION
S IV TUMBLING SCS EVALUATION
7.0 EARTH ORBITAL BOILERPLATE SPECIFIC FLIGHTS
BP6 PAD ABORT
BP12 MAX q ABORT
BP23 HIGH ALTITUDE ABORT
BP13 FIRST ORBITAL S/C BOOSTER COMPATIBILITY
BP15


7.0 EARTH ORBITAL BOILERPLATE SPECIFIC FLIGHTS
BP6 PAD ABORT
BP12 MAX q ABORT
BP23 HIGH ALTITUDE ABORT
BP13 FIRST ORBITAL S/C BOOSTER COMPATIBILITY
BP15
BP16
BP18
SEE 1.0
C-5 LAUNCH BP ENVIRONMENT
C-1B LAUNCH ENVIRONMENT
8.0 EARTH ORBITAL PROTOTYPE SPECIFIC FLIGHTS
AF 002
AF 010
AFRM 009 FIRST MANNED ORBITAL (SUBORBITAL)
AFRM 011 SECOND MANNED ORBITAL
AFRM 012 THIRD MANNED ORBITAL
SEE 1.0
UNMAN
MANNED
SEE 3.0 & 4.0
C1B & S/C & LEM DEVELOPMENT
C1B C/M UNMANNED RE-ENTRY
C1B S/C MANNED DEVELOPMENT
C-5 UNMANNED RE-ENTRY
1962
1963
1964
1965
1966
1967

NORTH AM

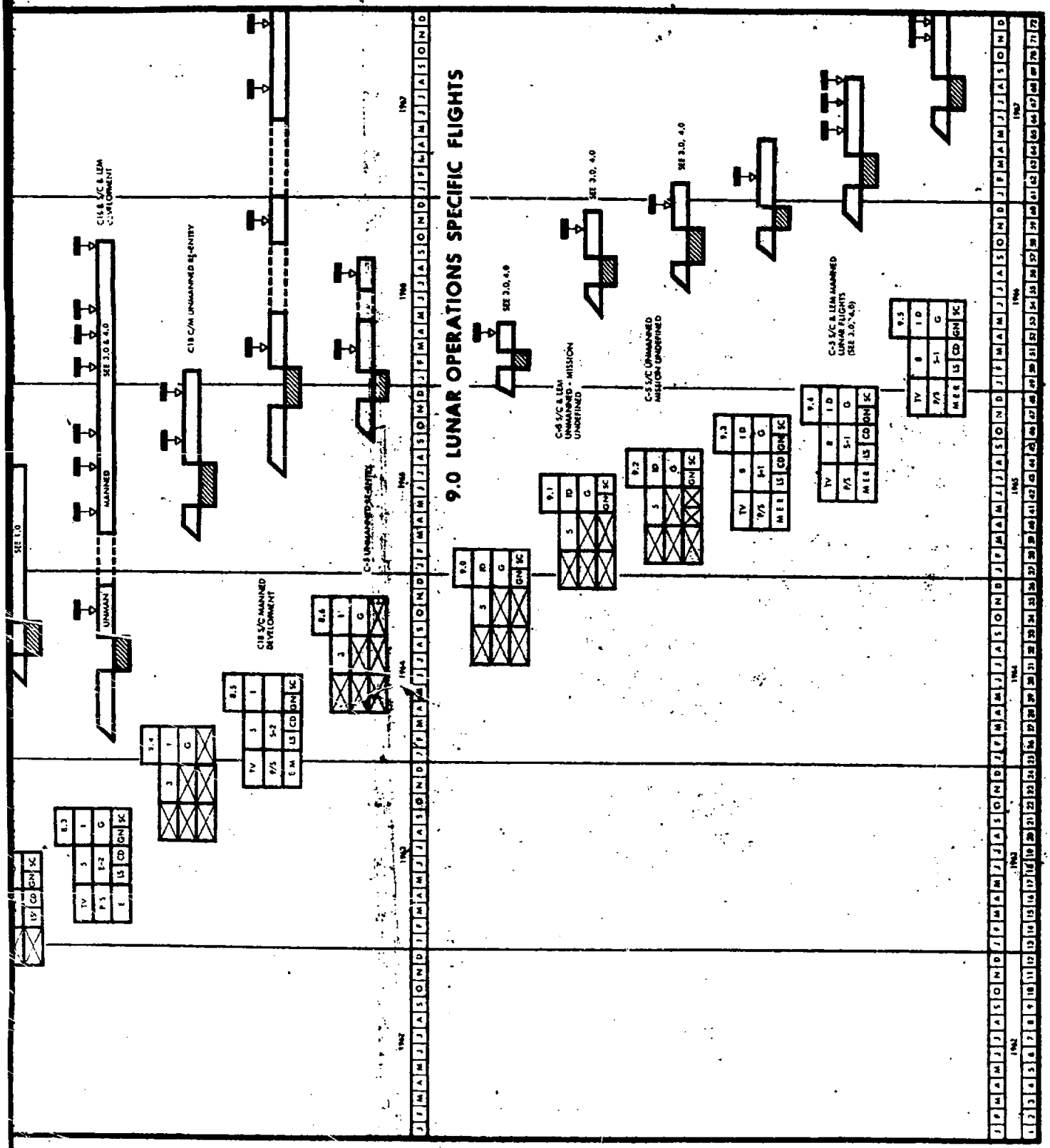


Figure 58. Simulation Phasing Schedule

[redacted]

Is responsible for installation, modifications, maintenance, and redesign of engineering evaluators, engineering simulators, peripheral simulation equipment, visual display equipment, and simulation breadboard and prototype equipment

Is responsible for operation, interrelated equipment tie-in, and data evaluation support relating to engineering simulation equipment for all engineering simulation activities

Functional support facilities and capabilities will provide the following:

Computer support, programming techniques, numerical analysis techniques, and special computer applications to engineering simulation problems as applied to combined analog-digital computer operations

Support to install, checkout, and modify equipment of engineering evaluators and engineering simulators; support functional maintenance of flight control system, displays, and visual environment simulators

Support analog and digital general-purpose computer as applied to basic engineering studies and man-machine simulation studies

Consultant services will be used for the following:

To optimize, from a technical and economic standpoint, the preferred analog-digital equipment necessary to accomplish the engineering simulation program

To analyze and aid the initiation of combined analog-digital computer techniques and the application of hybrid computer systems

Project Team Concept

A simulation-evaluation team concept has been established in order to effectively integrate the technological skills associated with the Apollo engineering simulation program. As such, each simulation study of Figure 58 is organized under a project study leader from the flight simulation-evaluation or spacecraft simulation sections.

The teams are composed of engineers from the following allied technical areas:

Primary technical branches, commensurate with the objectives of the study

Supporting technical branches

[redacted]

[redacted]

Functional computer center

Simulation

Under the direction of a team leader, all coordination, scheduling, simulation, related evaluation, and general study integration pertaining to a given simulation are carried out. In this way the main technical branch is not burdened with details unrelated to the basis of the study.

This concept is suitable especially for study efforts carried out at other facilities as well as studies in which S&ID and a subcontractor have a joint interest. This concept has been applied successfully in conducting Apollo simulation evaluations at the S&ID Columbus division. The project leader and team concept also offer a concentrated single source of engineering support for engineering evaluations and mission crew-training operations established by NASA and participated in by S&ID.

Simulation Equipment

An engineering design-evaluation complex must include analog computers, digital-computer conversion equipment, duplication or simulation (at least partially) of the visual, aural, kinesthetic, and physical environment for the man and the equipment. Also included are command-module evaluators and simulators, simulation master control stations, actual hardware and simulated hardware, and buffer equipment. The basic plan of action presently established and implemented is as follows:

Utilization of appropriate existing simulation facilities throughout the country as required by the design program

Establishment of an interim simulation facility in early 1963, to be used for the initial engineering design activities

Establishment of a more refined simulation facility based upon exact engineering technology requirements, experience obtained with the interim facility, and the technical and cost optimization study effort (it is expected that this facility will not require a major revision of the interim facility)

All details of the simulation equipment plan of action are not complete. However, a basic computer, evaluator, simulator, and system hardware requirement-procurement program has been established.

[redacted]

Analog-Digital Computer Complex

The heart of the simulation will be the analog-digital computer complex required to provide the following:

Simulation of vehicle motion and dynamics in all flight phases

Simulation of spaceborne equipment

Simulation of GSE

Monitoring of crew performance

Simulation of communications

Driving signals for visual display equipment

Instrument display driving signals

Data reduction

The final computer complex must be designed carefully to provide integration of all requirements efficiently and economically. To accomplish this, the Apollo simulation sections have initiated a program for continuing study of computer complex equipment requirements. The initial study and evaluation will result in the choice and procurement of computing equipment that will most nearly satisfy technical and economic considerations.

In order to fulfill immediate simulation needs of the program, an interim plan will provide the necessary computer equipment for at least the first one and one-half years of the program. In this way the optimum equipment can be integrated into the facility at normal procurement rates.

The interim buildup of in-house general purpose analog computing capability is scheduled to meet the simulation study requirements buildup of Figure 59. This interim buildup will result in a total operational amplifier count of 896 in October 1962, and 1400 in January 1963. In addition to the general purpose analog computer equipment, an F86 simulator has been procured to satisfy the immediate simulation need of the program.

Benefits to the engineering program from this approach are not limited to the computer capabilities of the F86 simulation equipment, but also include the acquisition of flight instruments that are compatible with the computer complex and would not require special buffer equipment. Minor modifications will have to be made to the computer portion of the F86 simulator to adapt it to the Apollo project.

[redacted]

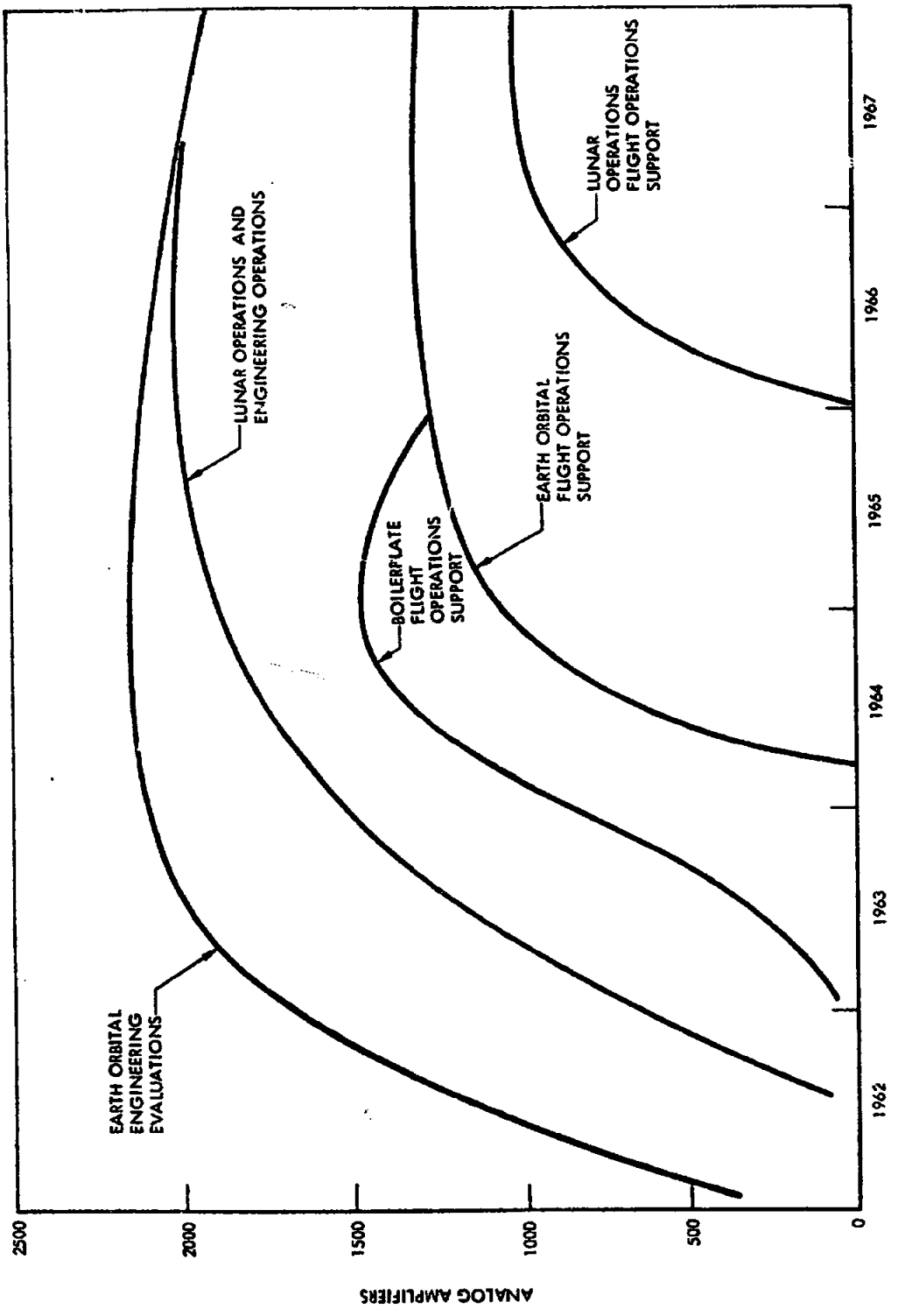


Figure 59. Analog Amplifier Requirements

[redacted]

[redacted]

The interim plans also include the tie-in of an IBM 7090 digital computer to the general analog computers. An existing analog-digital conversion system is being expanded to accommodate the Apollo simulation requirements and a second unit has been procured to meet the multiplicity of operations requirements.

In the development of the optimum simulation equipment plans, several possibilities are being investigated concurrently. The approaches chosen include the following:

Utilization of general-purpose analog computer equipment tied in with general-purpose digital computer equipment

A mixture of general-purpose analog equipment, general-purpose hybrid equipment, digital differential analyzer equipment, and general-purpose digital equipment

Special-purpose digital equipment connected to general-purpose or special-purpose analog and digital differential analyzer equipment

Since the Apollo simulation program needs are extensive and will continue to grow with time, the simulation facility simultaneously may require more than one of the above approaches.

Engineering Evaluators—Simulators

With the prevailing viewpoint that the Apollo will be man-oriented, it is necessary to provide the proper command module environment. Several phases in this requirement are evident.

Because the spacecraft will be undergoing continuous design modifications, it will be impractical to utilize hard simulators in the initial phases. The choice, therefore, is simple: wooden shells. In order to provide some electrical continuity, a metal lining will be used; hence, the term, semi-hard. These units are denoted as engineering evaluators. The final simulators must be, in all interior respects, replicas of the flight articles, and, moreover, must ensure proper operation of the installed spacecraft equipment prototypes. These simulators are denoted as engineering simulators.

It is necessary to have more than one simulator at one time to permit updating, as well as to accommodate peak workloads. These requirements then can be translated into the schedule shown in Figure 60, which gives a total of three command-module engineering evaluators and two engineering simulator complexes.

[redacted]

[redacted]

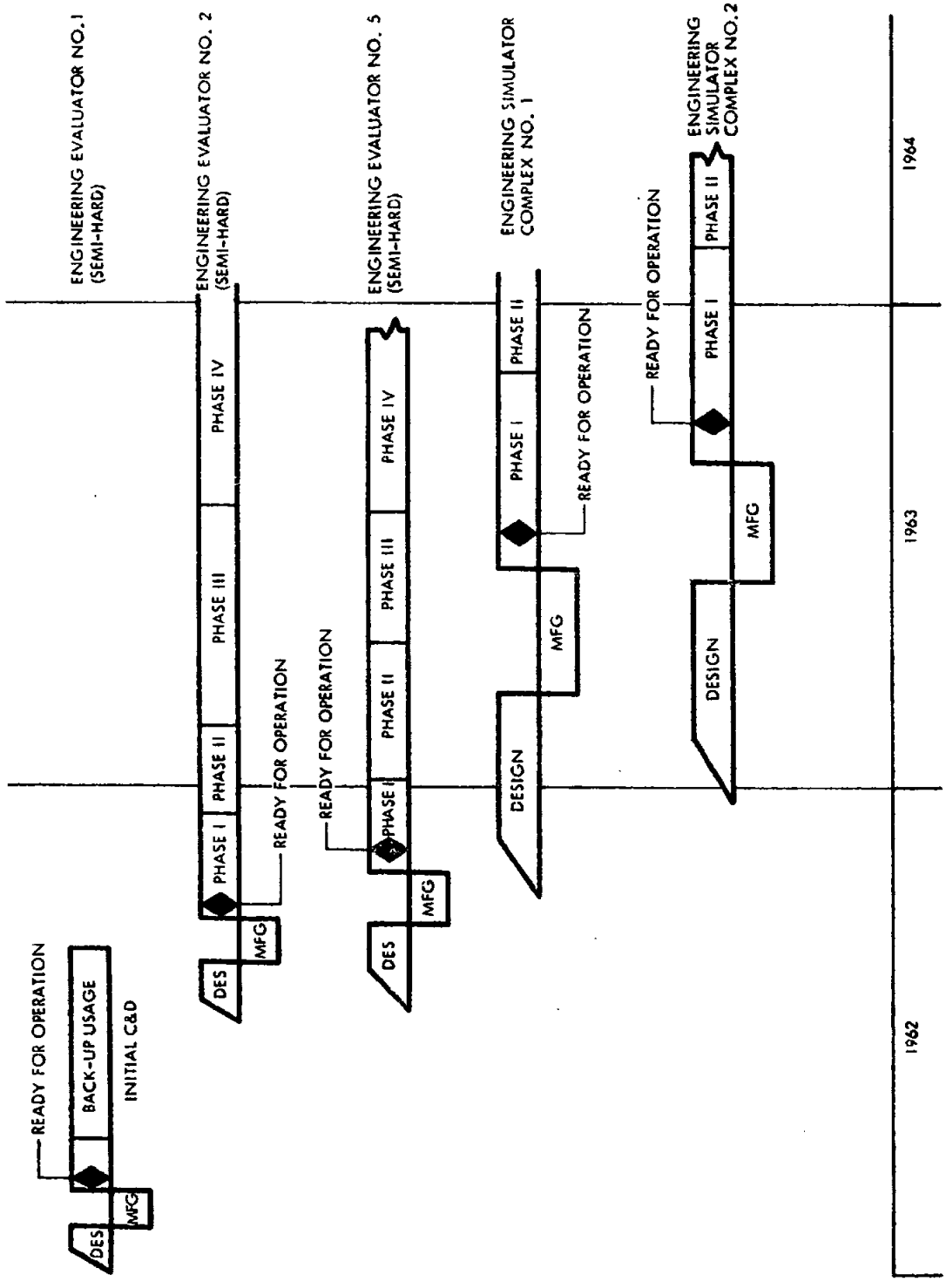


Figure 60. Master Simulation Phasing Plan

[redacted]

[redacted]

The three semi-hard engineering evaluators are used for man-machine computer tie-in studies, human factors analyses, and electronic systems synthesis. Scheduling of these units (Figure 60) is based on the phasing plan for simulator evaluations (Figure 58).

The Engineering simulator complexes are planned to include replicas of the command-module configuration and will be identical to the spacecraft with respect to the following:

Interior volume

Controls and displays

Crew stations and equipment, e.g., drawers, refrigerators, and waste management

Stabilization and control components

Guidance and navigation components, including the on-board digital computer

Secondary lighting and ventilation systems

Secondary power systems

The exterior construction will preserve the appearance of the spacecraft as seen by the crew through windows and other aids. Installation, maintenance, or removal of the systems may be accomplished from either the inside or the outside of the simulator through hatches, doors, or panels.

The complexes are simulation-oriented by means of a full-time tie-in with the analog and digital computer equipment, visual environment simulators, and ground control simulators. Engineering simulator complex No. 1 is scheduled to handle the preeminent simulation evaluations and, as such, is designed for greater simulation capability than complex No. 2. Table 2 presents a comparative summary of the equipment associated with each complex. A full description of each complex is contained in class 2 documentation related to boilerplates, airframes, evaluators, and simulators.

[redacted]

[redacted]

Table 2. Engineering Simulator Complex Comparison

Equipment	1	2
Simulator control	Yes	Yes
Visual simulation	Full	Partial
Computers	Yes	Yes
Command module	Boilerplate 26	Boilerplate 27
Structure	Yes	Yes
Environmental control system	Full	Partial
Electric power system	Prototype	Operational, partial
Wiring	Yes	Yes
Crew provisions	Full	Partial
Couches	Yes	Yes
Impact attenuation	Yes	Yes
Miscellaneous mechanization system	Yes	Yes
Telecommunications	Yes	Yes
Guidance and navigation system	Full	Simulate or breadboard with provision to accept hardware
Stabilization and control system	Full	Simulate or breadboard with provision to accept hardware
Controls and displays	Yes	Yes
Communication	Partial	Partial
Service module engine + gimbal system	Yes	No
Flight table	Yes	No
GSE	Yes	No

[redacted]

[redacted]

Visual Environment Simulation

The simulation of a visual environment for design-evaluation simulation effort is not required to be as refined as that required for the crew training complete-mission simulation. However, because the project is man-oriented, it is necessary to include in the engineering evaluation program such visual environment simulation necessary to meet design objectives.

The visual simulation systems in design will provide the crew with realistic visual displays to represent earth launch, earth and lunar rendezvous and docking, earth orbit, earth landings, and transearth-translunar trajectories. Closed-loop TV systems, in conjunction with optical methods, are indicated for the facility, rather than direct optical viewing. The control signals to the visual simulation equipment will originate from the real time solution of the spacecraft flight problem.

The visual system associated with engineering simulator complex No. 1 will support the more involved simulation evaluations, while the system for complex No. 2 will handle the bulk of the limited flight phase evaluations. For example, a celestial sphere is associated with complex No. 1 and a projector-screen arrangement is adequate for complex No. 2. Visual environment equipment is as follows:

Engineering Complex No. 1

Earth models with cameras

Lunar models with cameras

Rendezvous models with cameras

Day and night models

Celestial sphere with cameras

Film projector

Sextant model (with selected star field)

Visual loop adapter

Full projection dome (planetarium)

Visual display checkout equipment

[redacted]

[redacted]

Engineering Complex No. 2

Earth models with cameras

Lunar models with cameras

Rendezvous models with cameras

Day-night display systems

Visual display adapter and projector

Portable projection screens

Visual display checkout equipment

The earth orbital flight phase requires earth models, while the circumlunar, rendezvous, and lunar operation flight phases requires earth and moon globes and rendezvous models for orientation information. The size of such models has been determined tentatively, and it may prove possible to use relatively small models in conjunction with variable focus lenses on the TV system.

For landing phases it appears necessary to have at least two terrain models. Scales set at perhaps 1000 to 1 and 50,000 to 1 would be tentative choices, but they cannot be fully defined until the actual trajectories are determined. It is likely that the terrain models used will be changed during the program in order to study different landing sites and to accommodate different trajectories.

Conventional TV pickup tubes seem to respond best to natural colors. Therefore, it is recommended that, in lieu of an extensive research program, natural coloring be used rather than shades of gray.

Buffer Equipment

Buffer equipment is required to tie-in all of the separate portions of the simulation complex. Signal conditioning and buffering are required in the interfaces between any two of the following:

Computers

Instrument displays

Controls

[redacted]

Airborne hardware

Visual display equipment

Automatic checkout system

Master control station

Readily available commercial equipment will be used insofar as is practical. The special-purpose buffer equipment required will be designed and incorporated in the usual fashion.

Master Control

A master simulation control station will be provided to control and monitor the operation of each portion of the simulation facility and provide the simulation of the GOSS system. It will provide quick-look, real-time data reduction necessary to monitor the progress of the simulation study.

These requirements are under study and will be implemented by the purchase of commercial equipment and by the design and construction of the necessary special purpose equipment.

Data Reduction

The extensive data reduction requirements of simulations will be met by a combination of special analog and digital programs to provide on-line data reduction and analysis. This also will be accomplished by the usual off-line techniques.

Automatic Checkout System

The requirements for checkout of the simulation complex are more severe in many ways than the checkout of the actual system, because the facility must be used nearly full time to meet the Apollo design schedules; not only must the spaceborne hardware be checked out, but also the computer complex, buffer equipment, and visual display equipment. These requirements can be met efficiently and economically only by an automatic checkout system for the simulation equipment. These requirements will be satisfied by a combination of subcontracts, Apollo GSE equipment, and specially designed equipment operating in conjunction with the digital computer portion of the simulation complex.

[redacted]

[redacted]

TRAINING EQUIPMENT

Introduction

The training equipment development program for the Apollo spacecraft project consists of two types of trainers: the complete mission simulators and part-task trainers. The part-task trainers used are navigation and trajectory control, orbital and rendezvous, and earth launch and reentry. It is intended that one trainer mission simulator and the three part-task trainers be located at the Manned Spacecraft Center, Houston. One trainer mission simulator will be located at the Atlantic Missile Range.

OBJECTIVE

The objective of the training equipment is to provide integrated, realistic, crew training for the three crew members in all phases of the mission, including prelaunch, launch, orbit, translunar, lunar orbit, rendezvous, transearth, entry, and landing.

Requirements

The trainer requirements to fulfill the stated objectives should:

1. Provide a realistic presentation of command module equipment, instruments, and displays

2. Provide a means of instructing and monitoring flight crew

3. Provide a method for degrading or malfunctioning in the command module equipment for crew experience

4. Provide opportunities for the crew to be exposed to simulated emergency operations, abort, etc.

5. Provide simulation of command module weight and center of gravity changes, dynamics, buffeting, sound and external visual stimuli

6. Provide the trainer with the facilities to be linked to the GOSS network

7. Provide automatic self-check and malfunction detection and evaluation to the black box level, where applicable

8. Provide sufficient flexibility in design to allow rapid and inexpensive modification and growth

[redacted]

Description of Training Equipment

Typically, the trainer mission simulator and each of the part-task trainers will consist of the following subsystems:

1. A simulated command module
2. Computing and peripheral equipment
3. Support equipment
4. Visual simulation equipment
5. An instructor's console
6. Air conditioning equipment
7. Power equipment

The view of the trainer mission simulator (Figure 61) is also typical of the part task trainers. The trainers will provide realistic representations of all equipment in the command module which is used, either in normal operation or in emergency operation of the spacecraft, during the particular phase the trainer is designed to simulate. The following discussion describes the major subsystems.

Simulated Command Module

The command module system will consist of the controls and displays necessary to simulate the Apollo system. The control and display panels will be identical in appearance to those in the Apollo spacecraft. The equipment in the spacecraft not required to perform the simulation will be "mock-up" to preserve realism. The instruments will perform with the same response, scale, time delay, and accuracy as those in the spacecraft. On-board maintenance responsibilities will be the same in the simulator as they will be in the spacecraft, in order to provide malfunction detection and maintenance experience for the flight crew.

Computing and Peripheral Equipment

The digital computing equipment will accept program control routine and subroutine functions and will serve as the master control of the computer complex.

[redacted]

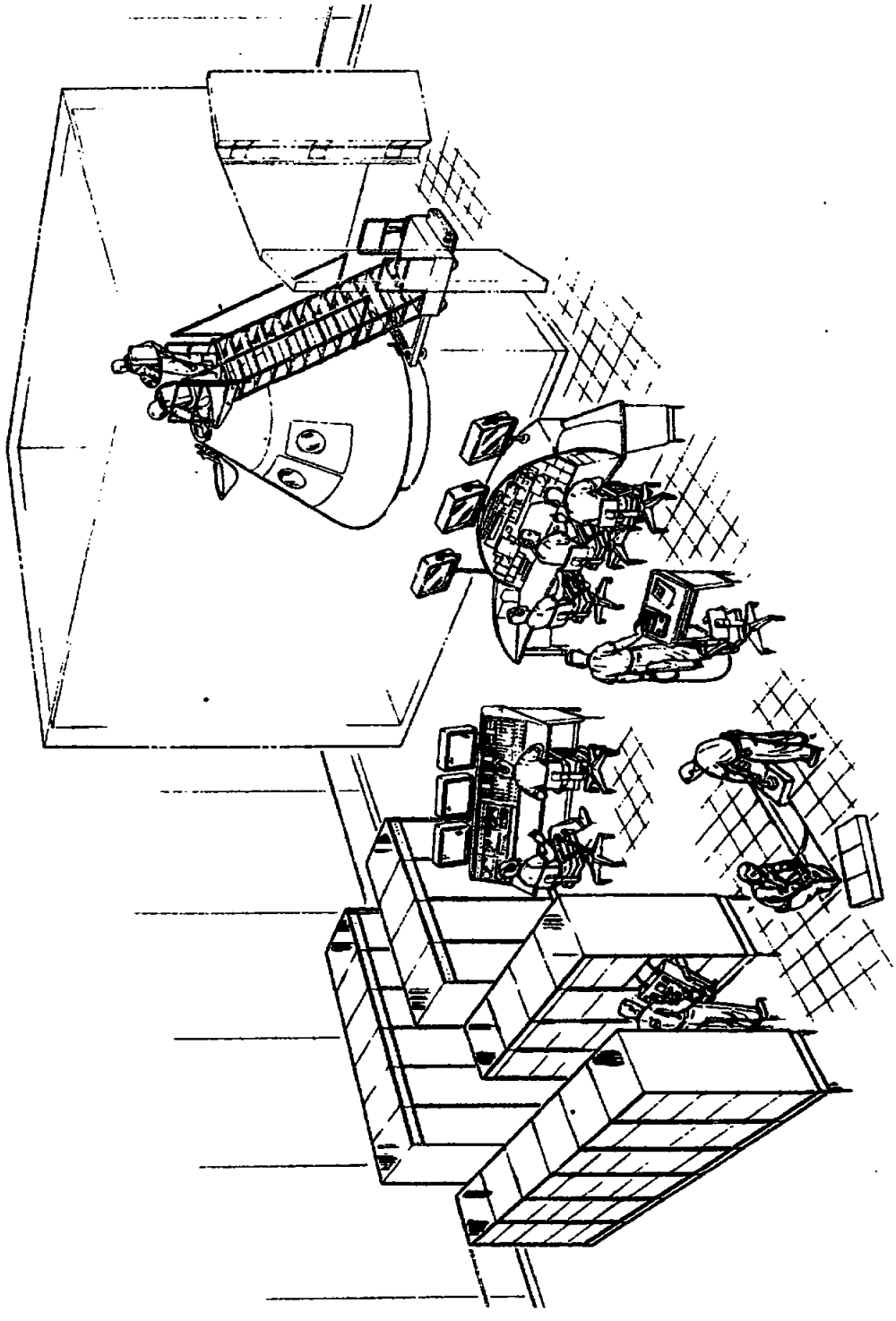


Figure 61. Mission Simulator Trainer

[redacted]

[redacted]

The central digital computer with specific analog equipment, where needed, will be utilized to mechanize the trainer equations. The computer complex will perform all trajectory computations, simulate the guidance and control system, present the necessary position data for the visual simulation system, perform malfunction insertion and correction, execute self-check, and assess the performance of the astronauts.

The computer complex will include the necessary peripheral equipment for signal conversion and processing.

Support Equipment

The support system will include the following equipment:

1. The audio and vibration simulator will reproduce the noise of reaction jets, thrust engines, and any other meaningful sounds. The presence or absence of these sounds is an indication of a possible system malfunction or emergency condition.

2. The communication simulator will simulate all communication channels between the Apollo spacecraft and ground stations. Time delays, noise, fading, and special interference (such as, solar flares) will be introduced to lend realism.

3. The interface equipment will link the trainers to NASA integrated mission control complex.

Visual Simulation Equipment

The visual simulation system will present simulated external views to the flight crew. These views whether through windows or through the scanning telescope, will be in natural color, with magnification factors the same, as if they were seen from the actual spacecraft. Accurate star-earth or star-moon, and other angular relationships required for navigational purposes, will be provided by visual cues through the sextant. The motion of the visual simulation system in response to attitude changes of the spacecraft will be automatic, being controlled by the computer complex.

Instructor Console

The instructor's console will maintain a set of repeater instruments, so that the instructors can monitor the performance of the flight crew. All control of the trainer will be initiated by the instructors at the console.

[redacted]

Development Approach

To achieve the program planned for the training equipment, the developmental approach will be based on a thorough and complete study of flight and ground crew tasks, an analysis of the relative difficulty of these tasks, and the development of a training plan to assure that all personnel may achieve the proficiency required for successful missions. After the determination of the training requirements, the training equipment to implement these requirements will be developed as follows:

1. Methods of mechanizing spacecraft trajectory equations and system performance simulation will be analyzed. This encompasses studies of vehicle dynamics, attitudes, trajectories, system electronics, thrust characteristics, etc.; the development of mathematical models for simulation of these characteristics; and the determination of optimum methods for real-time simulation.

2. The visual and aural simulation systems will be analyzed and defined. This includes studies of various methods of presenting visual and aural cues, determination of degree of fidelity required for training, and cost studies of various systems.

3. Trainer and trainee evaluation methods will be analyzed and developed. This involves study of the methods for determining the trainee's proficiency in learning required responses and the trainer's proficiency in developing teaching procedures.

4. Computer requirements will be defined. This involves defining the digital and analog computer functions and determining the computer sizes and capabilities.

5. Normal and emergency mission training computer programs will be developed.

6. Trainers will be designed and manufactured. This activity concerns the design of structure, the development of simulated controls and displays and activating mechanisms, electrical and electronic design of trainer-to-computer interfaces and computer-to-NASA equipment interfaces.

7. Test methods will be developed in the form of test outlines and checkout procedures.

[redacted]

STRUCTURAL DESIGN

The structure and mechanical systems of the spacecraft include all spaceborne structure of the modules, mechanical devices, and system mounting interfaces. Study areas included are spacecraft weights, structural dynamics, materials, producibility, and strength determination.

Concurrent with the basic study efforts by other functional engineering groups, design will begin on layouts and production drawings of a vehicle configuration that can perform the specified missions. This effort will be carried out in close coordination with all of the Apollo technical disciplines. The design groups will establish the basic load paths, select the material and manufacturing processes, and determine the major assembly sequences. The design groups also will support manufacturing in material review, salvage and rework, drawing maintenance, and redesign.

COMMAND MODULE

The command module is the major unit of the Apollo spacecraft. It houses the crew and contains all equipment necessary for crew support and for control and recovery of the spacecraft. This configuration satisfies the requirements for aerodynamic shape, center-of-gravity location, interior volume, and crew and equipment disposition. The maximum diameter of 154 inches was established for the nominal overall size, while a diameter of 151.50 inches was established and frozen for the working design size of the primary structure. Difference in diameter is in the ablation material. The final thickness of the material will be determined by Avco or NAA during its development program. With the basic configuration proposed, thickness changes can be made in the ablation material without affecting the essential structure.

The command module consists of an inner structure enveloped by an external heat shield composed of an outer structure and ablative material. Between the inner and outer structure is a layer of insulation. Both the inner and outer structure are symmetrical about a common center line, which is coincident with the launch vehicle center line.

The command module contains three compartments: the forward unpressurized compartment, the pressurized crew compartment, and the aft unpressurized compartment. The inner structure is the crew compartment; the external heat shield and the insulation form the thermal protection system for the module.

[redacted]

[redacted]

At the forward end of the command module, the launch escape system will be attached at four points by tension fittings, which include individual release mechanisms actuated by a single device.

At the aft end of the command module are three tension connections (used to attach the service module directly to the command module), and six compression pads, three of which will take shear loads. Umbilical connections (electrical, coaxial and hard line) and direct tension connections will be located on the aft compartment heat shield.

Inner Structure

The inner structure will carry the primary load for the command module and will be fabricated from bonded aluminum honeycomb. The welded, inner skin will form the integral, pressurized crew compartment. The inner skin is made up of chem-milled panels welded together and also welded to all the load-carrying or distribution members, such as longerons, access door frames, window frames, and penetration fitting frames. The outer skin and core are bonded together and to all the load-carrying members. In turn, the core is bonded to the welded inner skin.

The structure will consist of a forward bulkhead, forward and aft sidewalls, and the aft bulkhead. Four continuous longerons will support the launch escape system at the forward ends and react the service module booster loads at the aft ends. Additional longerons in the aft sidewall will react the remainder of the booster thrust loads. Special bulkhead penetration fittings will allow passage of the electrical, coaxial wiring, and hard lines through the sealed wall and into the pressurized compartment.

The forward sidewall will contain the side access crew hatch and four observation windows, and the crew hatch will contain the additional fifth window. The forward bulkhead will house the forward cylinder; the forward crew access hatch is located at the extreme forward end of the forward cylinder. Four structural beams (attached to the forward bulkhead) and the forward cylinder are used to react the internal pressure loads, forward compartment heat shield jettison loads, drogue mortar loads, docking loads, and the parachute attachment loads.

All crew access hatches are designed as internal opening hatches to minimize the pressure-sealing problem. All penetrations through the pressure wall will be welded in place, if possible; otherwise, the penetrations will be mounted to flanges which are gasket-sealed to the inside of the pressure wall.

[redacted]

[redacted]

Heat Shield

The external heat shield (which is also a primary structure) consists of the outer structure, the ablative material, and the insulation to form the thermal protection system for the command module. The ablative material will be designed and installed by Avco.

Charring ablative materials are used as the primary means of providing entry heating protection for the command module substructure. No active cooling of the cabin walls will be required. The ablative material will be installed in a honeycomb matrix previously bonded to the outer structure. In addition, the ablative material will be bonded to the outer structure. The bond attachment will react the thermal stresses caused by thermal expansion of the two materials. Penetrations through the ablative material will be suitably spaced and designed to minimize heat influx through the heat shield.

The outer structure is a brazed honeycomb of PH15-7 Mo steel assembled in constant-depth panels. The panels are welded to each other to form a continuous substructure for each compartment heat shield. The skins are chem-milled to provide lands for welding or local reinforcements for attachments or penetrations.

The heat shield consists of three major components: the forward compartment, the crew compartment, and the aft compartment heat shields.

The forward heat shield is a complete conical unit with the discone antenna attached at its forward end. The antenna is hinged sideways to allow access to the docking mechanism and the forward crew access hatch. The aft end of the heat shield contains four local recessed fittings which allow the launch escape system to be attached directly to the primary inner structure by four tension fittings. These recessed fittings also are used to attach the heat shield to the inner structure by the use of additional tension fittings. Forward ejection of the heat shield is accomplished by four ejectors mounted to the forward end of the heat shield. A small access door is provided for local area service within the compartment. Removal of the entire heat shield provides installation and major service access to the equipment within.

Stringers and frames are used to attach the crew compartment heat shield directly to the inner structure. The heat shield assembly is fabricated as a major unit, and is lowered over the inner structure; the stringers are installed by inserting them in a set of guide fittings. The frames are riveted and bolted to prepared angle attachments which are bonded to the inner structure and brazed to the outer structure.

[redacted]

The crew compartment heat shield contains numerous maintenance and access doors which lead to the equipment in the aft compartment. Other cover doors, actuated by crewmen or remotely driven mechanisms, provide visibility through the five observation windows and the MIT guidance equipment. A hatch cover, which may be removed externally, is used over the side access hatch. C-band antennae in the heat shield are mounted flush with the ablative material.

The aft compartment heat shield is a continuous unit fastened to the inner structure by 56 tension bolt connections. The service module booster loads are transmitted directly through the heat shield to the inner structure. Removal of the heat shield allows for the installation and service of all equipment located within the aft compartment. The outward corner of the heat shield substructure has been designed as a sheet metal assembly (rather than honeycomb) to simplify the manufacturing problem for this double curvature area.

Systems Installation and Structural Support

The forward compartment of the command module contains the three main parachutes, drogue chute and mortar, and remaining elements of the recovery system. It also contains the tower and heat shield release mechanism, docking mechanism, and the forward crew access hatch and tunnel. Two of the pitch engines also are installed in this compartment.

The crew compartment consists of a crew area and the equipment bays surrounding this area. The three crewmen are positioned in three, side-by-side couches. The center couch, when relocated below the left-hand couch, forms the sleeping area. When the center couch is removed it provides a passageway within the command module.

Equipment bays, located about the crew area, contain the various systems components. The forward equipment bay consists of the main instrument panel, plus some environmental control equipment and the in-flight test checkout panel. The aft equipment bay contains the crewmen's food and fecal canister. The left-hand equipment bay consists of the major components of the environmental control system, while the right-hand equipment bay contains medical supplies, scientific equipment and the life support equipment.

The lower equipment bay contains the greatest amount of serviceability for in-flight maintenance. Equipment in this bay is most likely to require service. High density is an additional requirement for equipment in this bay because final center of gravity of the command module must be located properly

[redacted]

[redacted]

toward the +Z axis. Equipment located in this bay includes telecommunications, stability and control, scientific equipment, guidance and navigation, and the environmental control system Lithium Hydroxide cannisters.

A series of secondary support structure will bolster the equipment within the bays. This structure will be bonded to the inner wall of the inner structure for proper load distribution. The structure will incorporate the "cold plates" as part of the structure and will contain built-in passages for the wiring harness and the environmental control system fluid lines. These passages are located at the front face of the secondary structure for ease of harness installation. The design for the installation of all equipment and its secondary support will be for easy equipment installation, service, or removal.

The aft compartment contains the reaction control system components and water management system, plus the structural tension bolts between the heat shield and the inner structure. These systems contain the reaction control engines, the tankage, lines and control system units for the dual propellants, storage containers, lines and control system units for the propellant pressurization lines, cooling and drinking water tanks, and the electrical and hard line umbilical connection between the aft heat shield and the inner structure.

Tankage equipment is supported by the aft compartment frames. The propellant pressurization lines and electrical harness are fastened to prebonded members attached to the inner structure. Field access to the aft compartment equipment is obtained by removing the service and maintenance doors. To install or remove equipment, the aft heat shield is removed.

Launch Escape Tower

The launch escape system consists of a series of structures attached to both ends of the integrally structured launch escape motor. The sequential assembly consists of the nose cone, the ballast enclosure (containing appropriate ballast and the pitch control motor), the jettison motor with adapter structure at both ends, launch escape motor, flow separator and structural skirt, and the launch escape tower.

The nose cone is constructed from spun Inconel X material. The ballast enclosure, fabricated from riveted 4130 steel, contains the internal support provision for varying amounts of ballast as well as the thrust structure for the pitch control motor.

Both the flow separator and the structural skirt are constructed of riveted 6Al-4V titanium sheet and forging stock covered by a thermal

[redacted]

[redacted]

protection material applied to the outside surfaces. The flow separator is designed for ready removal in the field before the launch escape system is installed on the command module.

The launch escape tower is a four-legged, welded 6Al-4V tubular construction with the attachment to the command module at the aft end and adjustable fittings at the forward end. The fittings will adjust the thrust vector of the launch escape motor to the center-of-gravity location of the combined command module and launch escape system. The aft end of the tower contains a sheet metal "bent," which also is used to house the separation control mechanism and the actuating cablecutters. Service to this mechanism is provided by access doors in the "bent."

SERVICE MODULE

The service module will be attached to the command module for all phases of operation except earth landing (it will be jettisoned prior to entering the earth's atmosphere). The service module will house the mission propulsion and reaction control systems and major portions of the environmental control, electrical power supply, and communication systems. The spacecraft adapter will attach the service module to the launch vehicle for all types of missions, except lunar landing. The service module propulsion system engine will extend into the spacecraft adapter.

The service module will consist of seven compartments (six spaced around a center compartment) for housing service propulsion system tanks and systems or major portions of systems. Two environmental control system radiator panels and three fuel cell radiator panels will encircle the outer compartments of the module.

The structure will include six radial beams and two perforated bulkheads. The external shell will include two large environmental control system radiator panels, and three fuel cell radiator panels mounted around the cylindrical periphery of the module. The external shell of the module will be constructed of six aluminum sandwich panels attached to the outboard ends of the six radial beams. These beams will include fittings at the forward end to mate with the command module ablative material contour.

Tension loads between the service and command modules will be reacted by three tension ties. The lower surface of the aft bulkhead will react a uniformly distributed load around the periphery of module, which is imposed by the spacecraft adapter.

The service module primary-load-carrying structure will provide adequate load paths for vehicle thrust loads, service module propulsion loads, tankage inertia loads, and command-module-to-service-module, or service-module-to-adapter staging loads.

[redacted]

[redacted]

Fuel, oxidizer, and helium tanks will be designed to include installation provisions. Coordinated tank designs will evolve from consulations with propulsion and electrical personnel in order that interfaces of plumbing, wiring, and expulsion systems will be provided by the structural designs.

All mounting bracketry for installation of equipment in the service module will be designed and coordinated with all system design groups to arrive at a final design for the mounting interfaces. Structural design and mounting of the radiators for the environmental control system and the electrical power system will be provided to include adequate stiffness and insulation.

SPACECRAFT ADAPTER

The spacecraft adapter will be used to connect the service module to the launch vehicle or to the LEM in the lunar-landing mission and to enclose the service module propulsion engine nozzle. An umbilical between the adapter and the service module will connect circuits providing launch vehicle propulsion, control, and abort information to the instrument panel in the command module. The connection will automatically separate upon pull-away of the spacecraft from the launch vehicle. The adapter also will contain instrumentation consisting of sensors and associate signal conditioners for providing structural data. The spacecraft adapter for the C-1 will be separate and distinct from the lunar excursion module adapter.

The spacecraft adapter will be constructed of aluminum sandwich panels and will be reinforced at both ends by two frames. The upper, or forward end of the adapter will contain a machined fitting which will bear uniformly against the service module. The lower, or aft end of the adapter likewise will terminate in a continuous, uniform joint that will be part of the circumferential mating ring.

SPACECRAFT MECHANICAL DEVICES

The spacecraft will include mechanisms to be used in combination with electromechanical and pyrotechnic actuation devices. These mechanisms will position, lock, or release various assemblies of the spacecraft. The interstage separation mechanisms will separate the spacecraft modules and/or adapters by remote command during launch, orbit, lunar entry phase, lunar launch, and earth entry phase. In the earth-orbital mission, separation will occur at the interfaces between the spacecraft adapter and the launch

[redacted]

vehicle, the command module and the launch escape tower, the service module and the spacecraft adapter, and the command module and the service module.

SPACECRAFT HEAT PROTECTION

A layer of microfiber will insulate the cabin structure from the heat shield. The substructure of the heat shield will consist of brazed corrosive-resistant steel to which ablative material is bonded and, if required, fastened by mechanical fasteners. The heat shield substructure will be attached to the primary structure in a manner that will allow thermal expansion without introducing thermal stresses in the cabin structure. Charring ablative materials will be utilized as the primary means of providing entry heating protection for the command module substructure. No active cooling of the cabin wall will be necessary.

DEVELOPMENT STUDIES

The orderly development of qualified and efficient structure and mechanical devices capable of withstanding the Apollo mission environments will be accomplished as described below.

Weights

Component and vehicle estimates based on parametric analyses of preliminary layouts will precede the preparation of calculated weights from layouts and released spacecraft drawings. Centers of gravity, inertias, and three-axes mass distributions will be computed for use in load and dynamic analyses. Weight trade-offs will be performed for various design evaluations and final selections.

Continuous efforts for the program will include preparation of weight status, centers of gravity, inertia, AMPR and cost analyses, and the weight and balance data.

Structural Dynamics

The three major task study areas included within the category of dynamics are loads and criteria, dynamic response and shock, vibration, and acoustics.

Loads and criteria efforts will consider the ground conditions for impact, atmospheric and space flight, abort, entry, and recovery conditions. Studies will be conducted relative to safety factors and material selection, shock, vibration, noise, temperature, pressures, acceleration, radiation, and meteoroid environments.

[redacted]

Dynamic response study efforts will include calculations of model analyses of individual modules and the complete spacecraft, selection studies including wind tunnel tests for the recovery, landing system and response analyses for acoustic and aerodynamic environments.

Shock, vibration, and acoustic design and test criteria will be established from studies of the anticipated environments. Shock and vibration isolation requirements will be determined for the mounting of spacecraft systems. Flight and ground test dynamic measurements will be acquired for use in structural evaluation.

Structural Methods

In support of the structural analysis effort, original structural analysis methods will be developed. Emphasis will be placed on determining the deflections and stress of conical and spherical shells under unsymmetrical load and nonuniform thermal gradients. An analysis will be made to determine the effects on the spacecraft of the micrometeoroid environment.

Original structural analysis methods will be developed to support the structural analysis effort. Emphasis will be placed on determining the deflections and stress of conical and spherical shells under unsymmetrical load and nonuniform thermal gradients. An analysis will be made to determine the effects of the micrometeoroid environment on the spacecraft.

Ground Support Equipment

The design of boilerplates and mock-ups will include all necessary attachments for ground support fittings and the structure required to carry loads resulting from ground handling operations. The spacecraft structure will be designed on the basis that ground handling operations will be performed by normal spacecraft interface systems, and that loads (due to ground handling operations) will not require addition of structure to the spacecraft. Continuous monitoring of handling procedures and the resulting loads to the spacecraft structure will assist in accomplishing this.

To provide reliability confidence in GSE, structural analysis of GSE designs will be performed and manufactured parts will be structurally tested. Coordination with GSE design will assure compatibility of ground support and checkout equipment with the spacecraft interface systems.

Development plans for structures, mechanical systems, and earth landing systems are illustrated in Figures 62 through 64.

[redacted]

[redacted]

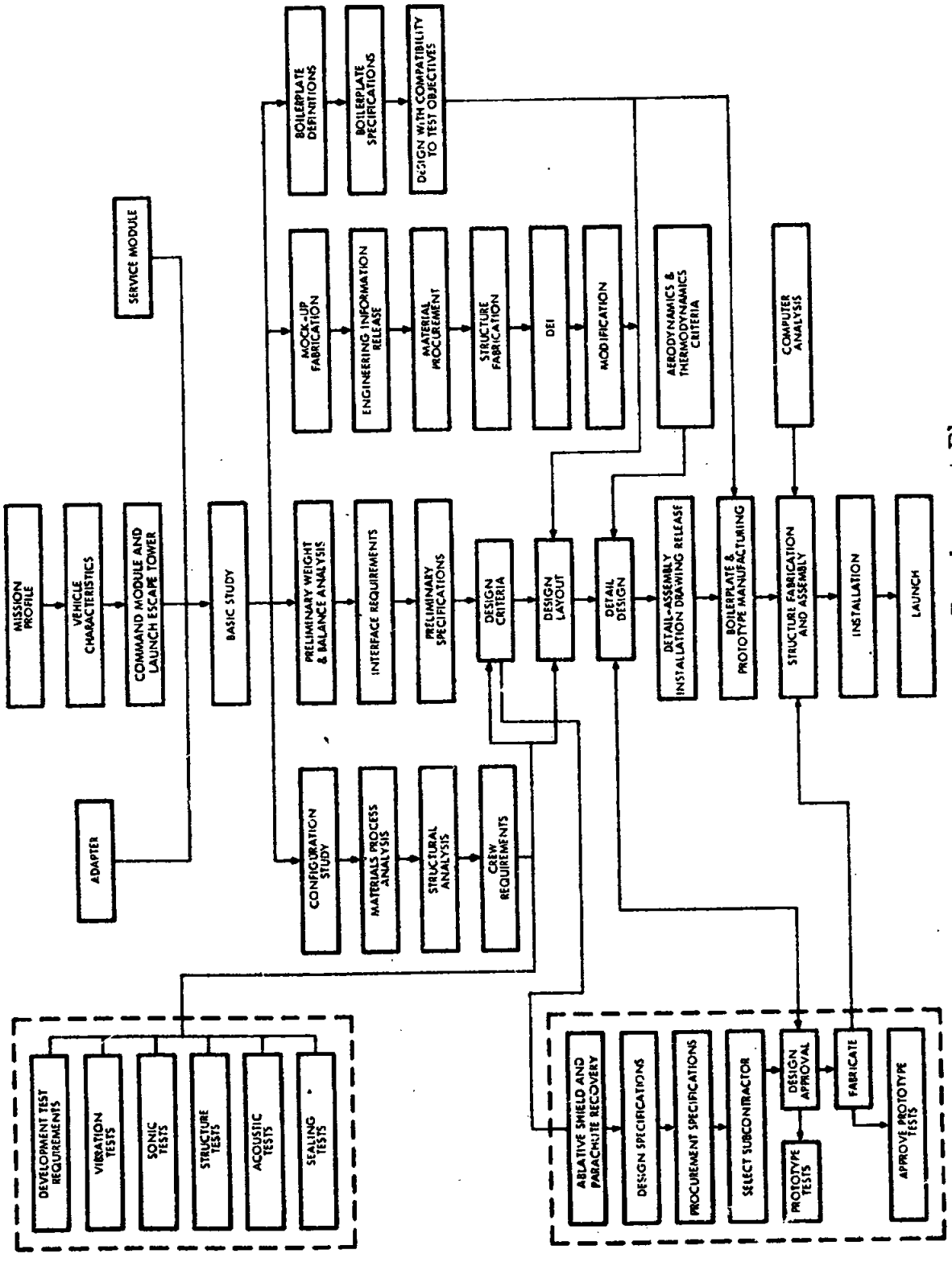


Figure 62. Structures Development Plan

[redacted]

[redacted]

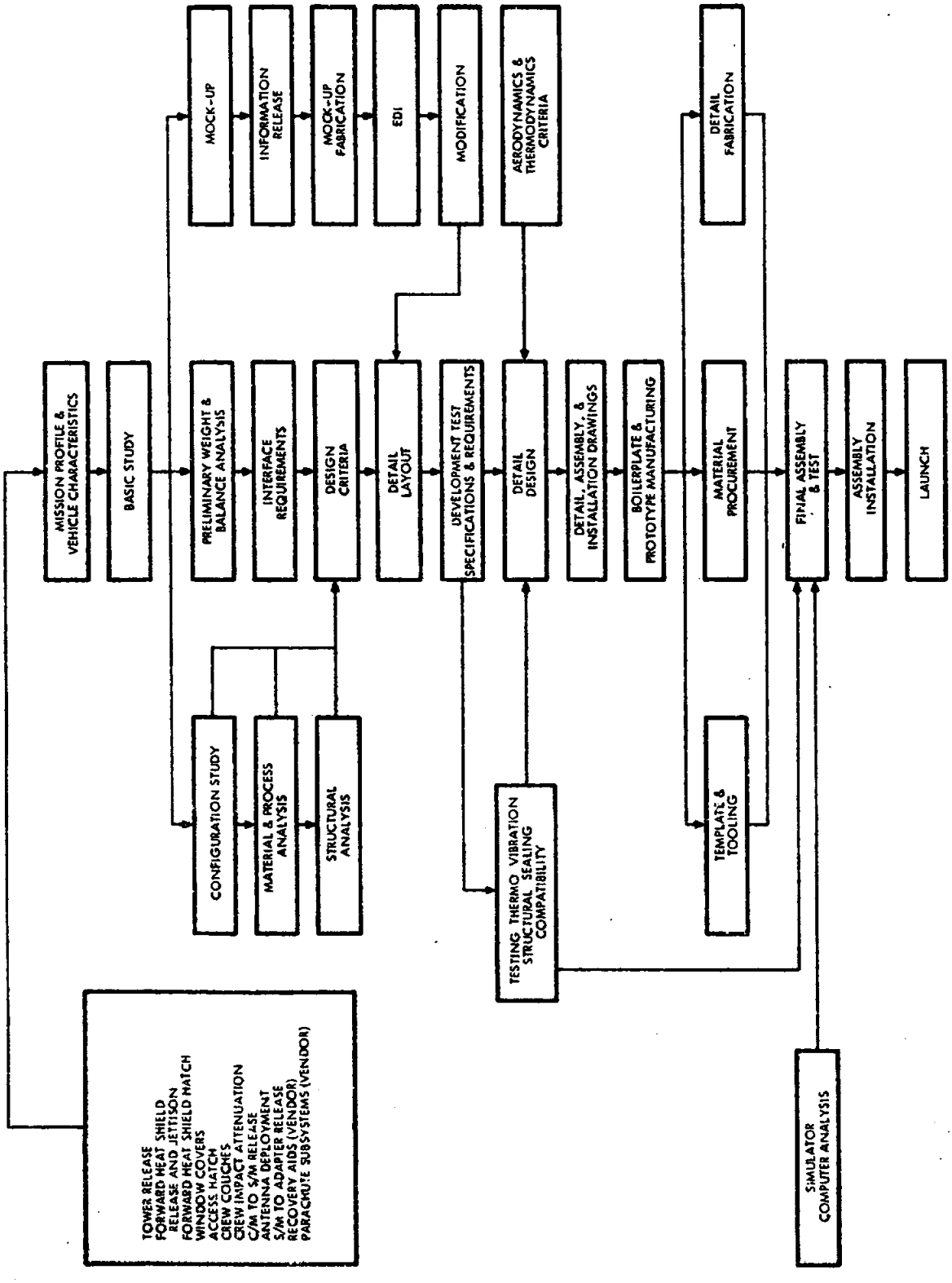


Figure 63. Mechanical Systems Development Plan

[redacted]

[redacted]

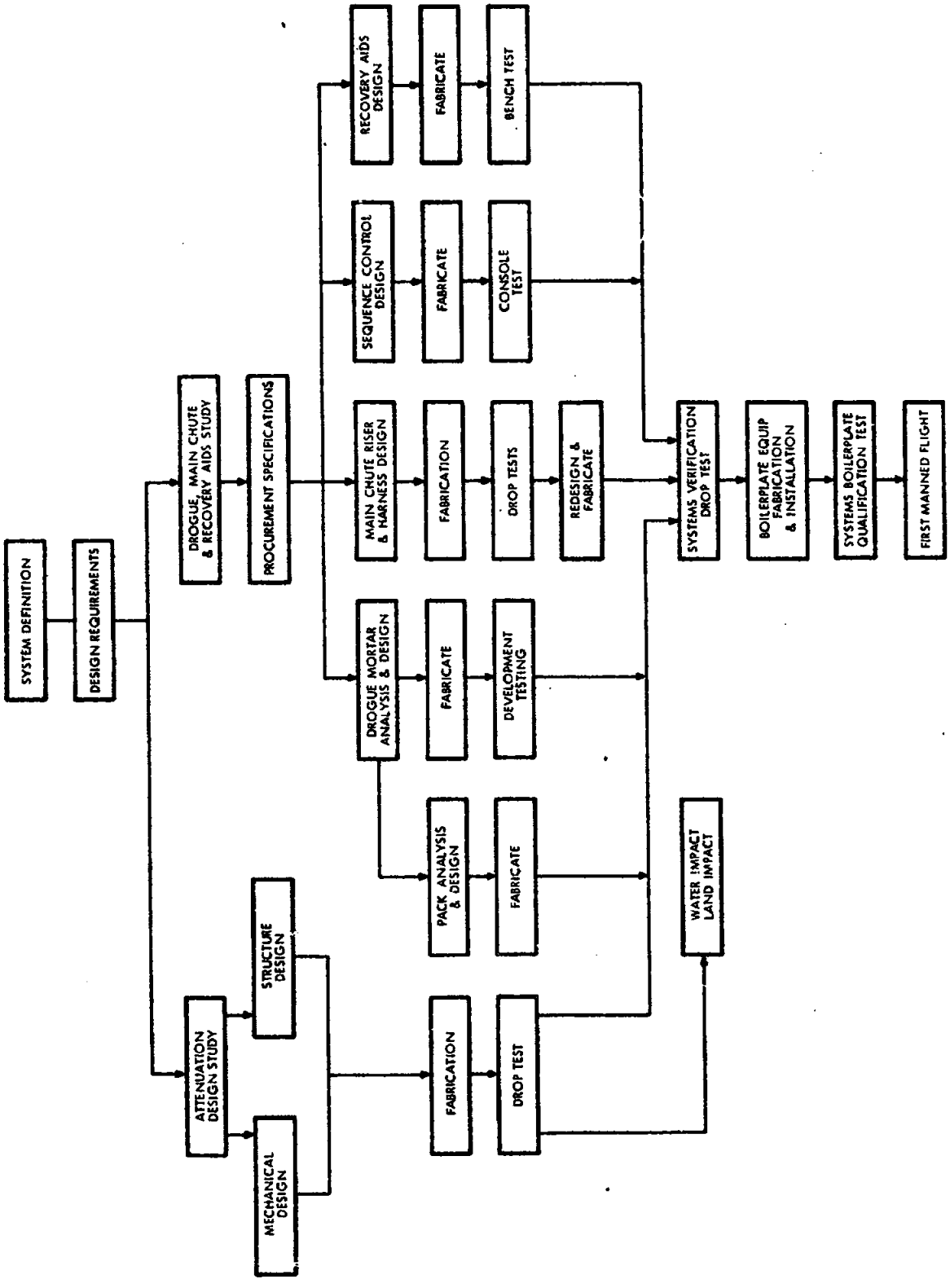


Figure 64. Earth Landing Systems Development Plan

[redacted]

[redacted]

DEVELOPMENT TESTS

Structures

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 equipment handling equipment.

The test program will begin with laboratory tests to provide design and development information under combined flight environments and loads for prototype components of structure. Criteria of static and aerodynamic loads, hard vacuum, heat, meteoroid impact, vibration, and acoustics will be applied. Included are dynamic tests of the impact attenuation subsystem struts, acoustic and vibration tests of typical panels of the modules, thermal tests of the heat shield, 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 thermal testing of the command module base and heat shield and dynamic tests of boilerplate and prototype structure and bracketry.

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 configuration.

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

Mechanical Devices

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

Components of each device (i. e., latches, cable-cutting release units, shock struts, adjustments, pivot points, etc.) will be development tested for conformance to Apollo mission environments and evaluated for design suitability. Flight body loads will be applied and critical measurements of travel, stress distributors, response time, and deflection during operation will be compared with design requirements, thus verifying a design or indicating a modification or redesign. Conventional static and dynamic load and operational tests will be conducted in the laboratory under hyperenvironments of entry, hard vacuum, radiation, and meteoroid impact, where applicable.

[redacted]

Mechanical devices will be installed in house spacecraft 1 (B-14) and 2 (airframe 006) to evaluate performance and compatibility for continuing improvement of design.

Further verification and eventual qualification of the devices will result from ground and flight testing of the boilerplates and spacecraft which use these mechanical devices. For example, the recoverable command modules will provide operational data when the forward compartment cover and its release mechanism are subjected to flight loads. Separation devices for the launch escape tower and modular interfaces will be evaluated during test flight missions.

Materials and Producibility

The investigation and selection of materials and processes for design of Apollo will be accomplished by literature search, analyses, and test. In the event that required data is not found in the literature, or that studies are inconclusive, tests will be conducted until sufficient data is acquired to document objective engineering decisions. The general plan for implementing and disseminating this information is diagrammed in Figure 65.

The following items are considered of paramount importance in the selection of materials for the design, fabrication, and operation of the Apollo spacecraft:

Optimum strength-to-weight characteristics

High reliability

Resistance to natural environments

Resistance to induced environments

High quality at minimum cost within confines of the schedule.

Generally, tests will be conducted either in the S&ID Engineering Development Laboratories, other North American Aviation research facilities, or major government or commercial research facilities.

Available equipment and schedule requirements will dictate facility choice and utilization. Data will be obtained promptly and economically. Each test project will be monitored by the responsible Apollo material and producibility unit. Apollo quality control and Apollo manufacturing will be assisted as necessary.

[redacted]

[redacted]

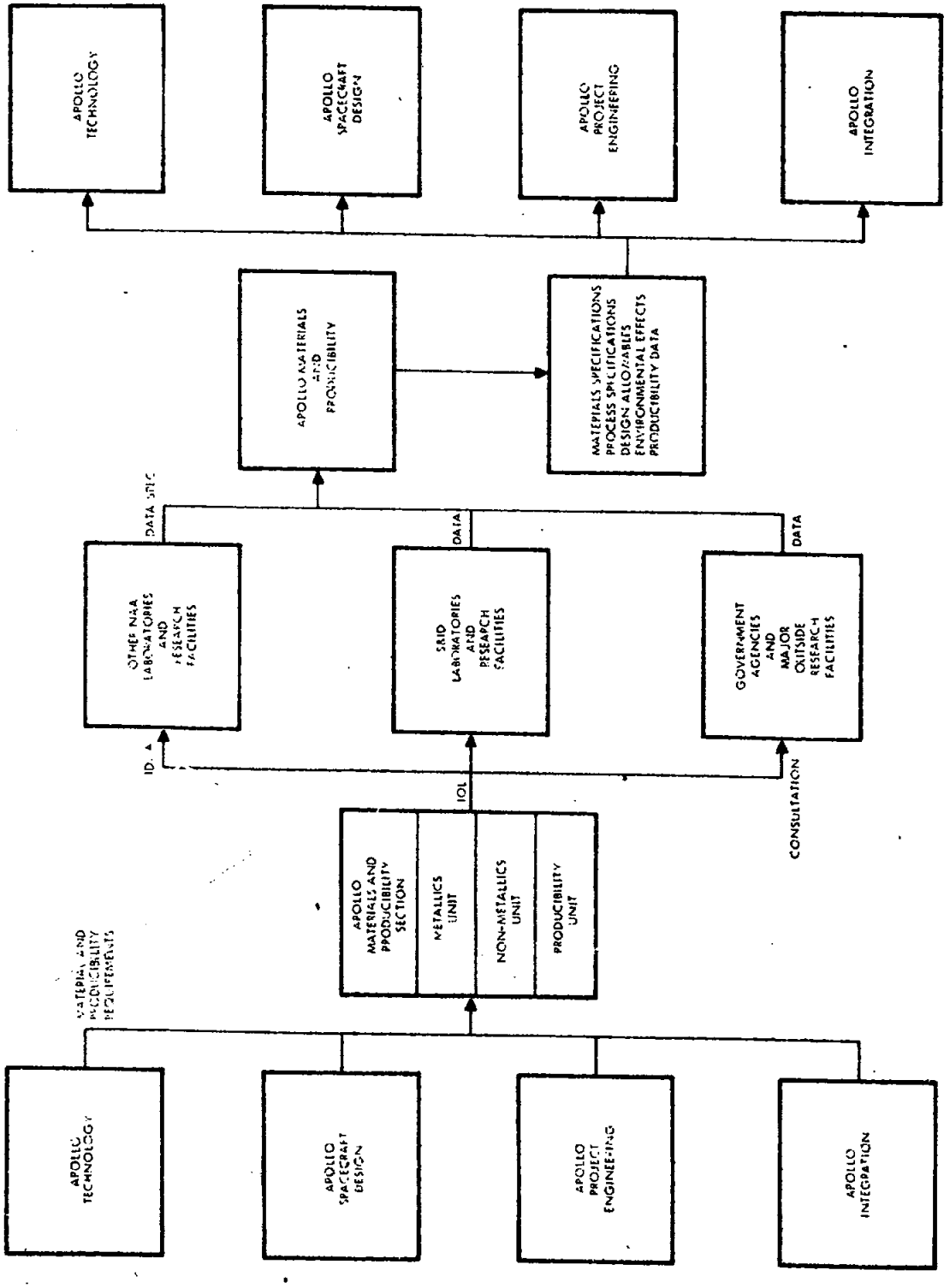


Figure 65. Flow of Materials and Producibility Information

[redacted]

[redacted]

Major criteria for selection of design and material on the early spacecraft will be the result of proven successes in air and space vehicle usage. Ultimate selection of materials and process will be determined by (1) successful prequalification on integrated ground tests, and (2) qualification on an unmanned spacecraft before final acceptance in the design of a spacecraft destined for manned missions.

Earth Landing System

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

The crew support, suspension, restraint subsystem will be developed, tested, and prequalified using B-1 and B-2 and the NAA water and land impact test facility. Final verification will be accomplished using prototypes of these systems with an airframe 005 command module to be reprogrammed following completion of its prime static test objective. The drogue parachutes, main parachutes, and means of deployment and mechanical location aids will be developed and tested by the subcontractor. NAA and the subcontractor will conduct verification tests in the form of air drops using B-3 and B-19.

The environmental proof spacecraft, airframe 008, will include the installation of the earth landing system and will verify the capability of the system to withstand the environmental conditions of the Apollo missions.

In addition, the earth landing system will be further tested by the requirement for the earth recovery of the command module in the following:

Pad abort escape test: B-6

Escape at maximum q test: B-12 and airframe 002

High-altitude abort: B-22

Very high-altitude abort: airframe 009

Further assurance of operating capabilities will result from recovery of the following: B-23, airframe 007, 010 (recovery qualification), and 012 (back-up).

[redacted]

[redacted]

Launch Escape System

During the subcontractor development program, the igniters will be tested in an inert motor and evaluated. The launch escape motor will be static fired 18 times and the jettison motor will be static fired 30 times to evaluate engine and solid propellant characteristics. At the end of the subcontractor development programs for both motors, two simulated altitude performance tests will be required to optimize the design before flight tests.

The tower structural and mechanical release components will undergo functional and environmental tests by S&ID prior to boilerplate evaluation tests.

S&ID prime contractor pad abort test on B-6 will be made to evaluate the tower jettison and launch escape motor flight dynamic characteristics.

Little Joe II launch escape system tests performed on B-12 and airframe 002 at max q conditions will demonstrate and evaluate maximum dynamic pressure. Additional data obtained during abort tests will be escape tower structural verification, vector thrust analysis, programmed controls, and operation of the parachute system. (Further structural integrity of the tower, including related launch escape motor tests, will be conducted on B-13, B-14, B-15, and B-18.)

High- and very high-altitude launch escape motor system testing will be done on B-22 and airframe 009 (airframe 012 back-up) including recovery system tests. Partial launch escape system tests (tower or motors) will be performed on airframe 004, 006, 007, 008, 010, and 011 because of configurational requirements. (Tower release mechanism tests are included in B-6, B-9, B-14, B-15, B-16, B-22, and airframe 002, 004, 006, 007, 008, 009, and 011.)

PROBLEM AREAS

Problem areas associated with development of spacecraft structures and mechanical systems, along with approaches which will be taken to obtain resolution are listed in Table 2.9-1.

[redacted]

[redacted]

Table 3. Problem Areas

Problem Source	Problem Area	Approach
Radome for command module antennas	Selection of adequate radome material for space environment	Material investigation is currently in progress.
Command module heat shield	Convective and radiative heat transfer during atmosphere reentry	Wind tunnel test program supported by extensive analyses.
	Adequate structural protection	Development, evaluation, and qualification tests.
Space radiator (Electrical and Environmental Control)	Optimization of weight and reliability	Investigation of heat pump utilization and movable radiator.
Structural implications during S/M abort	Engine start	Studies of problem.
Micrometeoroid space environment	Establishment of confidence levels in the space environment for micrometeorite frequency, density, and size	Additional astronomical studies and actual satellite meteorite measurement tests. Development of better hypervelocity guns and analytical techniques.
	Analytical and experimental determination of penetration mechanics	
Entry heating	Simulating entry environment on large structural components during ground tests	Further studies on such heat sources as ramjet engines, rocket engines, and radiant heat facilities.

[redacted]

[redacted]

Table 3. Problem Areas (Cont.)

Problem Source	Problem Area	Approach
Hatch and access openings through the heat protection system	Development of effective heat shield enclosures	Design and testing of a door that will be effective against heat leakage.
Command module leakage	Maintain below critical leakage rate	Develop highly reliable sealant techniques, and leakage rate tests.
Visibility	Crew visibility	Mock-up studies.

MANUFACTURING

Throughout the design and engineering maintenance of the mock-ups, boilerplates, and spacecraft, coordination and consultation will be provided by the design group with the manufacturing department.

DOCUMENTATION

Documentation efforts will include contribution to the Test Plan, Spacecraft Familiarization Manual, the Program Plan, the Weight and Balance Report, and various structural analyses, materials and processes, and test documents.

SUBCONTRACTORS' EFFORTS

Monitoring of subcontractors will be provided by the design and structures department. Subcontractors include AVCO for heat protection system, Northrop-Ventura for the landing system, and various structural subcontractors for honeycomb panels and similar items. Approval and surveillance will be provided on the Test Plan and development plan documentation of the subcontractor.

[redacted]

SPACECRAFT SYSTEMS

GUIDANCE AND NAVIGATION

The primary objective of the Guidance and Navigation group will be to coordinate Apollo spacecraft requirements during all mission phases. This objective will be attained via the development of the guidance and navigation system—establishing, defining, and resolving the interface areas to assure complete compatibility in all ground and inflight operations.

Initial projects will include the following: a lunar mission review to determine the guidance and navigation system functions during various mission phases; analyses of earth orbit, circumlunar, and lunar orbit trajectories to establish accuracy and performance requirements; and definition of environmental conditions in which the system must operate. These efforts will generate a guidance and navigation system performance requirements specification.

Close coordination will be maintained with the associate contractor during preliminary system design. This will delineate the equipment necessary for guidance and navigation functions; it will also define the restraints, constraints, maintainability, and environmental control reliability factors relevant to the system.

Various Guidance and Navigation system modes and operations will be investigated to ensure mechanical and functional compatibility as well as the operational facility of the crew. These investigations will consist of analyses and subsystem and combined system tests conducted at the laboratory and house spacecraft levels; these tests will verify analytical studies and evaluate deliverable hardware.

Operating procedures for the guidance and navigation system will be important considerations in two interface areas. The location of the system components will be determined, in part, by which equipment must be made available to the astronauts during mission phases—either for operation or display. Also, these requirements will be integrated with those of other systems to maintain the spacecraft center of gravity and structural integrity as well as to permit mission completion under emergency conditions. The step-by-step, inflight procedures for navigational sightings, inertial platform alignment, and related guidance operations will be integrated with other manual operations to develop an operational profile.

PRECEDING PAGE BLANK-NOT FILMED

[redacted]

[redacted]

Other analyses will be performed in the following interface areas:

1. Installation design analysis of optical and inertial alignment, rigidity, and mechanical integrity of the guidance and navigation system with the command module structure.

2. Generation of spacecraft attitude error signals within the guidance and navigation system—including the method of transmission to the stabilization and control system; signal characteristics - voltage level, linearity, scale factor, waveshape, display, etc.

3. Integration of the guidance and navigation system's ground support equipment and checkout procedures into the spacecraft checkout concept—from factory verification to launch-pad countdown—and the inflight telemetry requirements.

4. Integration of the guidance and navigation system inflight maintenance procedures into the inflight test and maintenance system; integration of guidance and navigation crew tasks into the total crew task requirements under a series of defined environments.

5. Analysis of system operation to determine other interface areas requiring development of additional interface equipment.

6. Evaluation of the combined optical and inertial modes of guidance and navigation operation which consists of inflight alignment, orbit determination, and attitude orientation.

Laboratory tests of the actual hardware will be conducted to define the interface areas, determine requirements and parameters for the necessary interface hardware, and verify and evaluate equipment design. Other studies and tests will be conducted to investigate various malfunction and failure interactions between guidance and interconnected systems; these studies and tests will also evaluate astronaut effectiveness in coping with a wide variety of emergency situations.

Details of each interface configuration will be documented to convey interface design to all concerned parties. Both installation and integrated operational procedures will be developed, refined, and maintained to assure efficient and accurate operation of the guidance and navigation system for all mission phases and modes of operation.

Combined systems operating procedures will be developed for operational testing of the guidance and navigation system in conjunction with stabilization and control and other interconnected systems; this will permit the effective evaluation and test of the guidance and navigation system and associated components during factory, combined system, and prelaunch operations.

[redacted]

[redacted]

STABILIZATION AND CONTROL

The Apollo stabilization and control system (SCS) includes SCS components and related displays necessary for the following operations: high-altitude, tower-abort flight; manned earth-orbital flights; and the circumlunar, lunar orbit, and lunar landing missions.

The design of all SCS components, comprised of highly reliable elements, (e.g., Minuteman parts) will enhance system reliability, in-flight checkout, and maintenance capability.

The SCS equipment, subject to crew monitor and control, is presented below:

1. Manual translational controls
2. Manual three-axis rotational controls
3. SCS control panel (includes SCS mode select, deadband adjust, and channel disable)
4. SCS displays (includes flight-director attitude indicator, gimbal position indicator and [illegible]just), and ΔV Display (includes on-off thrust, emergency ullage, tail-off correction, ΔV required and ΔV remaining)

Other SCS components, located in the lower equipment bay, are presented below:

1. Rate gyro package
2. Body-mounted attitude gyro package
3. Accelerometer package
4. Electronic control assemblies (three)
5. Display electronics package
6. Spare attitude gyros (two)
7. Spare rate gyro

An SCS over-all block diagram is shown in Figure 66.

[redacted]

[redacted]

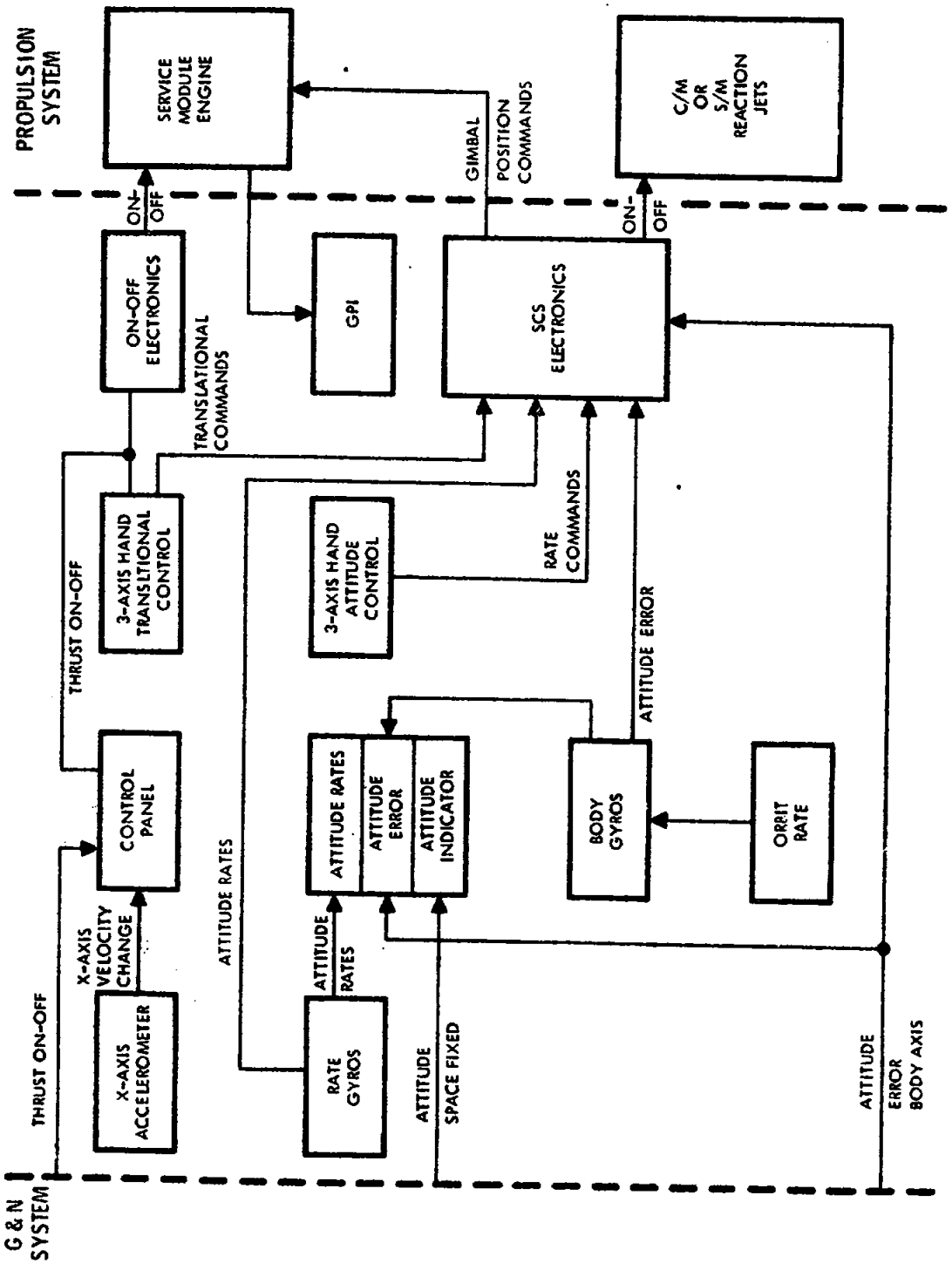


Figure 66. Stabilization and Control

[redacted]

[redacted]

The display elements are an integral part of the SCS; these will meet the necessary stability and control requirements for the entire Apollo mission. The displays, commensurate with crew requirements, will minimally consist of elements capable of presenting actual and commanded attitudes and rates of one or more reference sets.

Panel controls will permit the crew to select the operating mode and perform certain selections or adjustments. Development, design verification, evaluation, qualification, and reliability testing of SCS components, subsystems, and systems will be performed jointly by the subcontractor and the prime contractor. (See Figure 67.)

The overall test plan is designed to meet lunar orbit, return and re-entry requirements insofar as hardware is concerned; this will be accomplished by progressively increasing the severity of the environment. The SCS will be subjected to various tests: circuit development; component development; system mock-up; computer simulation; radio interference; environmental evaluation; design improvement; acceptance; materials; parameter variation system development; and qualification reliability tests.

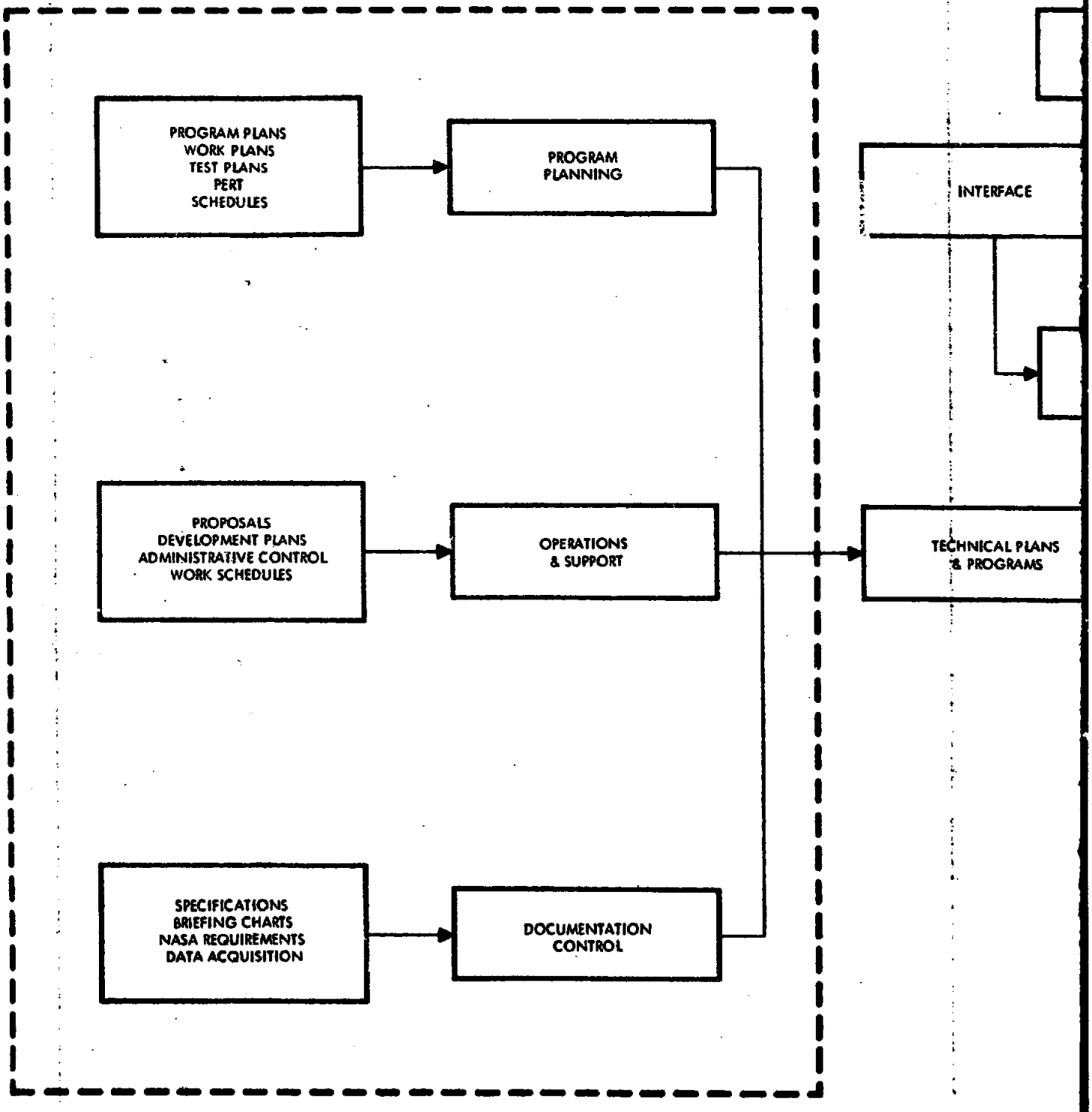
Components and subassemblies will be initially tested by the subcontractor's facility; they will be subjected to various tests which culminate in a complete system hardware test which will utilize reaction control motors, SM engine gimbal actuators, and analog simulation. Additional tests, conducted by S&ID, will focus on interface areas to thoroughly explore complete system problems.

Initial testing with other systems will commence in the House Spacecraft (Boilerplate 14). To assure systems compatibility and develop combined operating procedures every system except propulsion will be operated in various combinations. In addition, combined operations test will be conducted under various environmental conditions in the Environmental Spacecraft, Airframe 008. Tests of the mission propulsion motor system and the reaction control motor systems will be conducted in the Propulsion System Test Airframe 001.

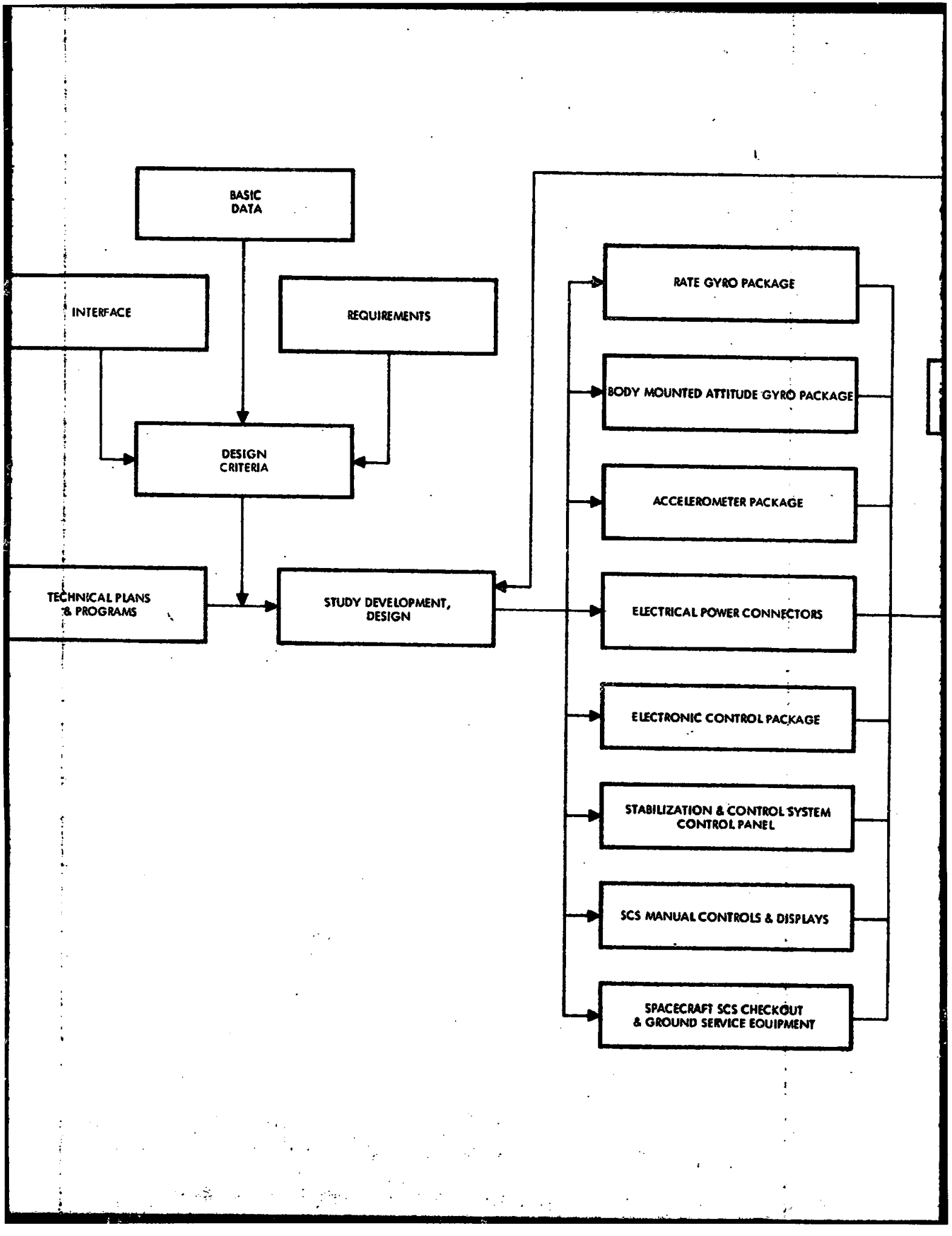
REACTION CONTROL SYSTEM

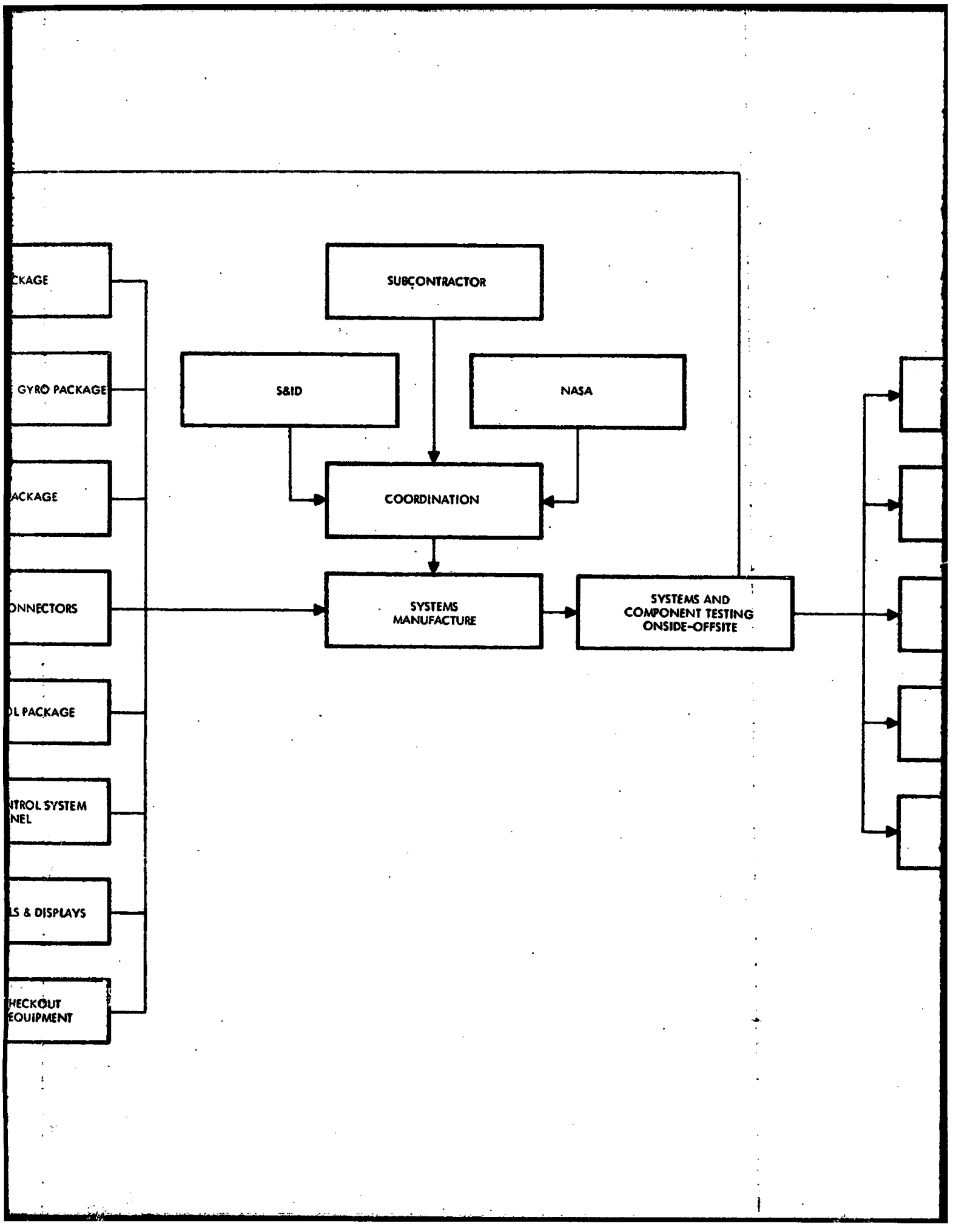
Command Module Reaction Control System Development Plan

The reaction control system of the command module will provide the impulses for three-axis attitude control prior to entering the atmosphere, for roll control during entry and during the earth landing maneuver, and for attitude and stabilization control during a high-altitude atmospheric abort. (See Figure 68.)



PRECEDING PAGE BLANK-NOT FILMED


BASIC DATA
INTERFACE
REQUIREMENTS
DESIGN CRITERIA
TECHNICAL PLANS & PROGRAMS
STUDY DEVELOPMENT, DESIGN
RATE GYRO PACKAGE
BODY MOUNTED ATTITUDE GYRO PACKAGE
ACCELEROMETER PACKAGE
ELECTRICAL POWER CONNECTORS
ELECTRONIC CONTROL PACKAGE
STABILIZATION & CONTROL SYSTEM CONTROL PANEL
SCS MANUAL CONTROLS & DISPLAYS
SPACECRAFT SCS CHECKOUT & GROUND SERVICE EQUIPMENT


CKAGE
GYRO PACKAGE
ACKAGE
ONNECTORS
L PACKAGE
NTROL SYSTEM
NEL
LS & DISPLAYS
HECKOUT
EQUIPMENT
SUBCONTRACTOR
S&ID
NASA
COORDINATION
SYSTEMS
MANUFACTURE
SYSTEMS AND
COMPONENT TESTING
ONSIDE-OFFSITE

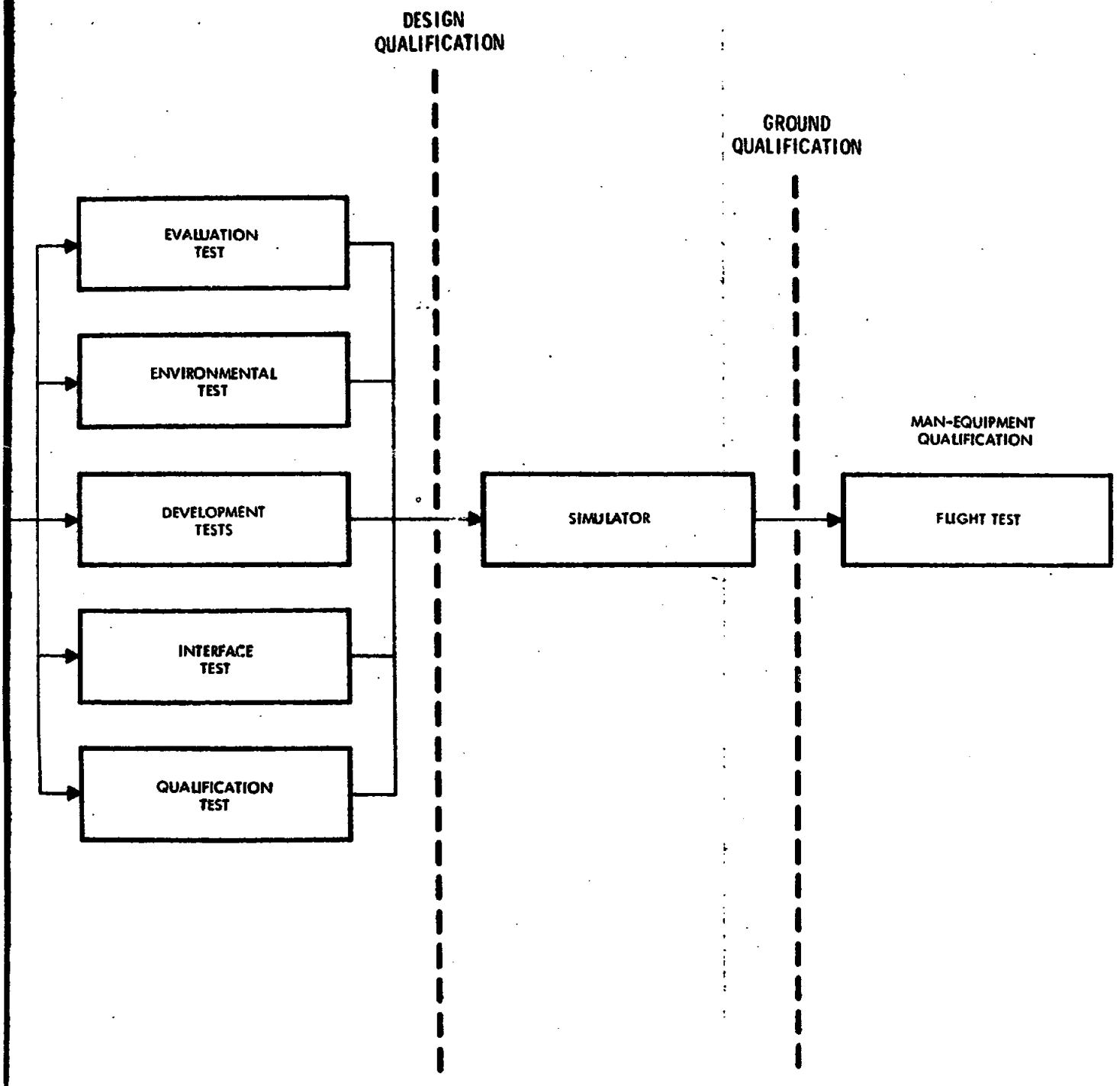


Figure 67. Stabilization and Control Development Plan

[redacted]

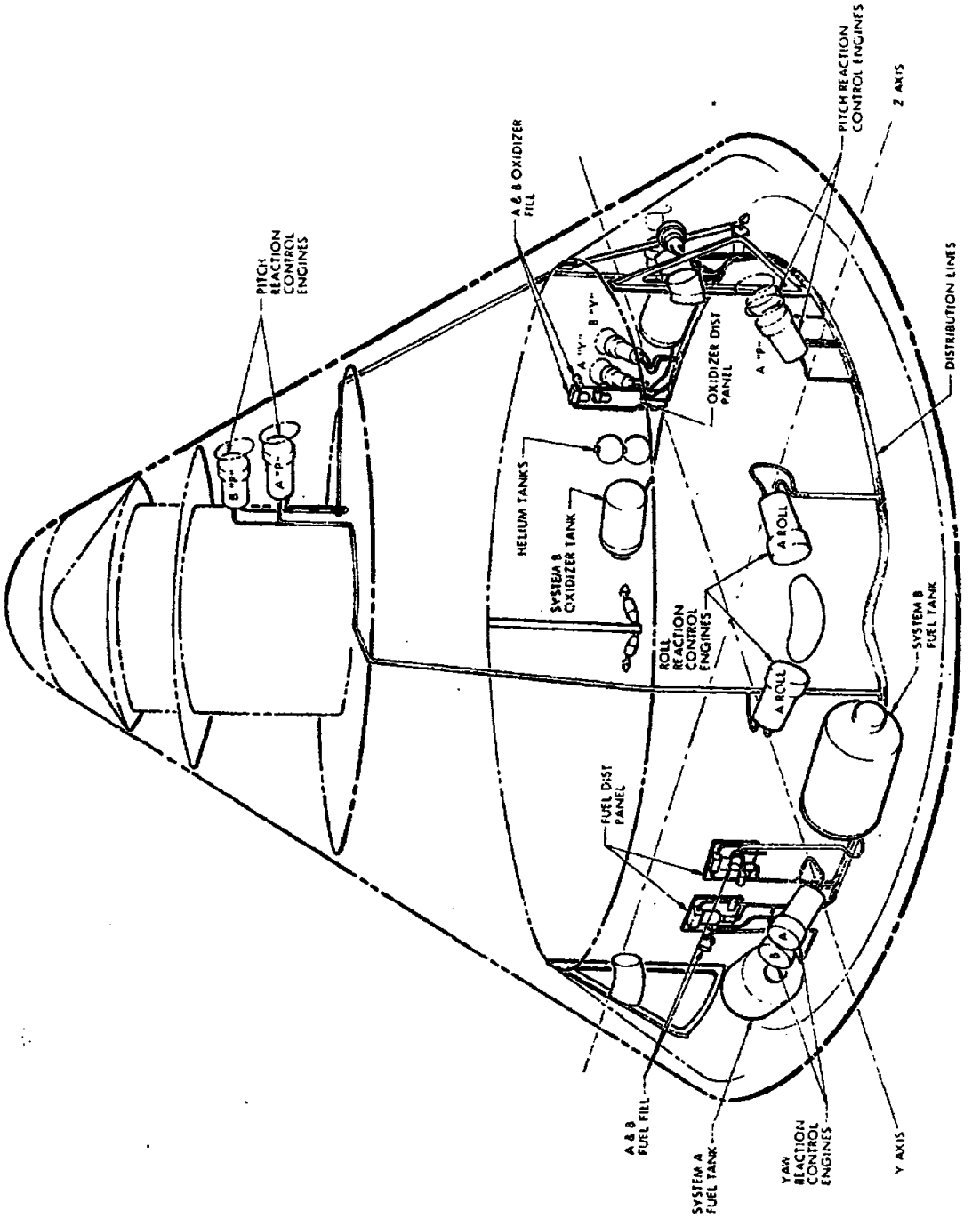


Figure 68. Perspective Layout - Installation, Command Module Reaction Control System

[redacted]

[redacted]

The command module reaction control system is pulse-modulated and pressure-fed by helium gas. The system utilizes earth-storable hypergolic propellants consisting of nitrogen tetroxide (N_2O_4) as the oxidizer and a 50-50 blend of unsymmetrical-dimethylhydrazine (UDMH) and hydrazine (N_2H_4) as fuel.

Two similar, independent systems comprise the command module reaction control system. Each system will have the capability of providing all the required control impulses in the event of failure of the other system.

Development of the command module reaction control system is shown schematically in Figure 69.

NAA/S&ID Specification SID 62-700-1 and -2 defines the preliminary mission, design, and performance requirements for the command module reaction control system. Utilizing SID 62-700-1 and -2 as a basis for design, studies will be conducted to further define the mission profile, design criteria, and performance requirements for the system. From these studies, a basic system configuration will be established.

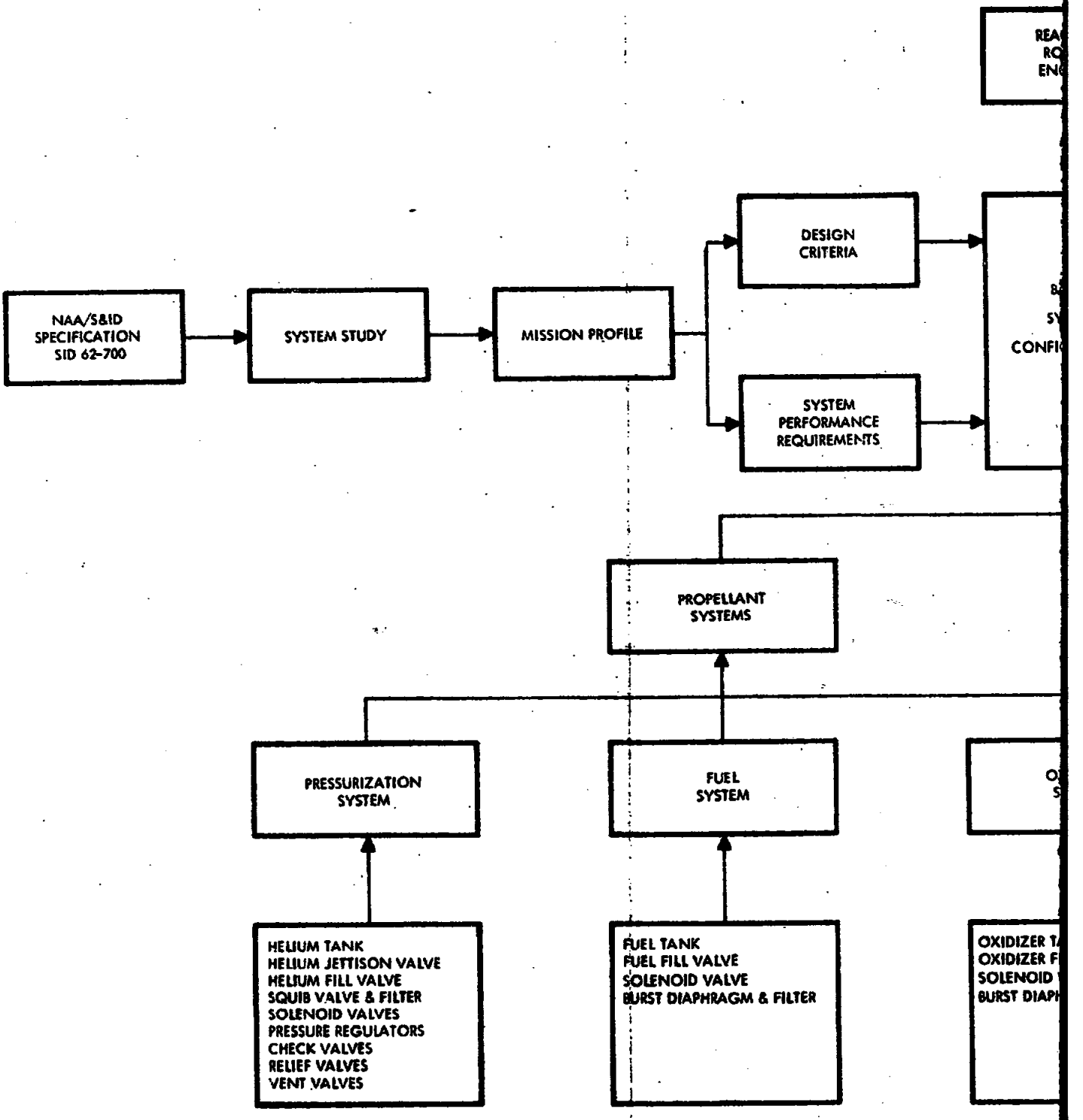
Each of the two independent reaction control systems will consist of a pressurized helium storage and distribution system, a fuel storage and distribution system, an oxidizer storage and distribution system, and six reaction rocket engine assemblies. Each pressurized helium system will be composed of a helium storage tank, a helium jettison valve, a helium fill valve, a squib valve and filter assembly, solenoid valves, pressure regulators, check valves, relief valves, and vent valves. Each fuel system will contain a positive expulsion fuel tank, a fuel fill valve, a burst diaphragm and filter assembly, and a solenoid valve. Each oxidizer system will be composed of a positive expulsion oxidizer tank, an oxidizer fill valve, a burst diaphragm and filter assembly, and a solenoid valve.

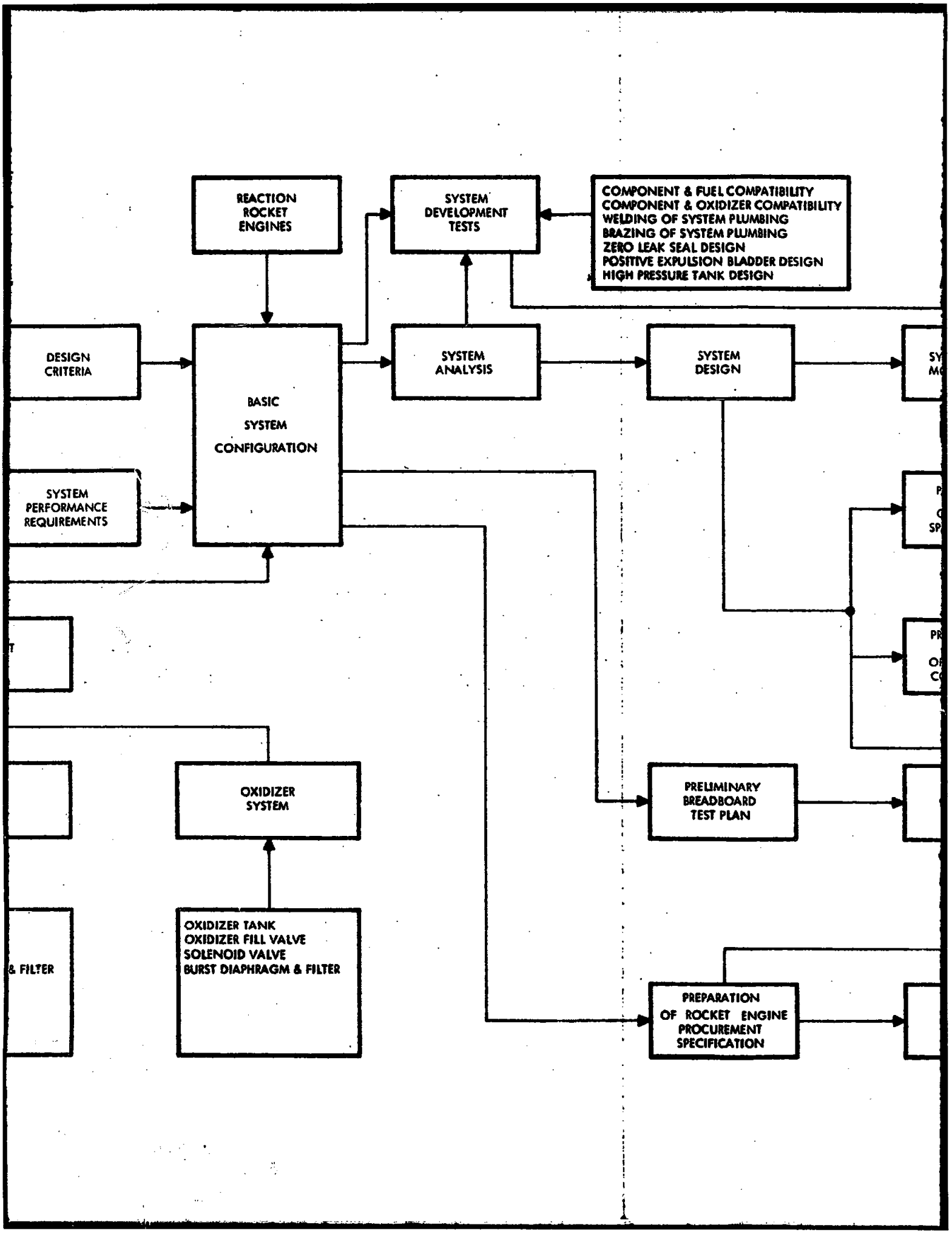
When a basic system configuration is determined for the command module reaction control system, preparation of the reaction engine specification will begin and a subcontractor will be selected. Additionally, a preliminary breadboard test plan and the design of a breadboard test stand will be prepared, test stand fabrication and system development tests will be initiated, and a comprehensive analysis of the system configuration will be accomplished. In certain instances, these phases will be parallel to and interdependent of each other. Criteria resulting from system analysis and system development tests will provide guidelines for detailed system design and completion of the breadboard test plan. Requirements for propellant system components, dictated by the system design, also will be defined in component procurement specifications.

The reaction engine will be designed and tested by a subcontractor. The tests will include engine development and qualification tests. At specific

[redacted]

[redacted]


NAA/S&ID SPECIFICATION SID 62-700
SYSTEM STUDY
MISSION PROFILE
DESIGN CRITERIA
SYSTEM PERFORMANCE REQUIREMENTS
PROPELLANT SYSTEMS
PRESSURIZATION SYSTEM
FUEL SYSTEM
HELIUM TANK
HELIUM JETTISON VALVE
HELIUM FILL VALVE
SQUIB VALVE & FILTER
SOLENOID VALVES
PRESSURE REGULATORS
CHECK VALVES
RELIEF VALVES
VENT VALVES
FUEL TANK
FUEL FILL VALVE
SOLENOID VALVE
BURST DIAPHRAGM & FILTER


REACTION ROCKET ENGINES
SYSTEM DEVELOPMENT TESTS
COMPONENT & FUEL COMPATIBILITY
COMPONENT & OXIDIZER COMPATIBILITY
WELDING OF SYSTEM PLUMBING
BRAZING OF SYSTEM PLUMBING
ZERO LEAK SEAL DESIGN
POSITIVE EXPULSION BLADDER DESIGN
HIGH PRESSURE TANK DESIGN
DESIGN CRITERIA
BASIC SYSTEM CONFIGURATION
SYSTEM ANALYSIS
SYSTEM DESIGN
SYSTEM PERFORMANCE REQUIREMENTS
OXIDIZER SYSTEM
PRELIMINARY BREADBOARD TEST PLAN
OXIDIZER TANK
OXIDIZER FILL VALVE
SOLENOID VALVE
BURST DIAPHRAGM & FILTER
PREPARATION OF ROCKET ENGINE PROCUREMENT SPECIFICATION

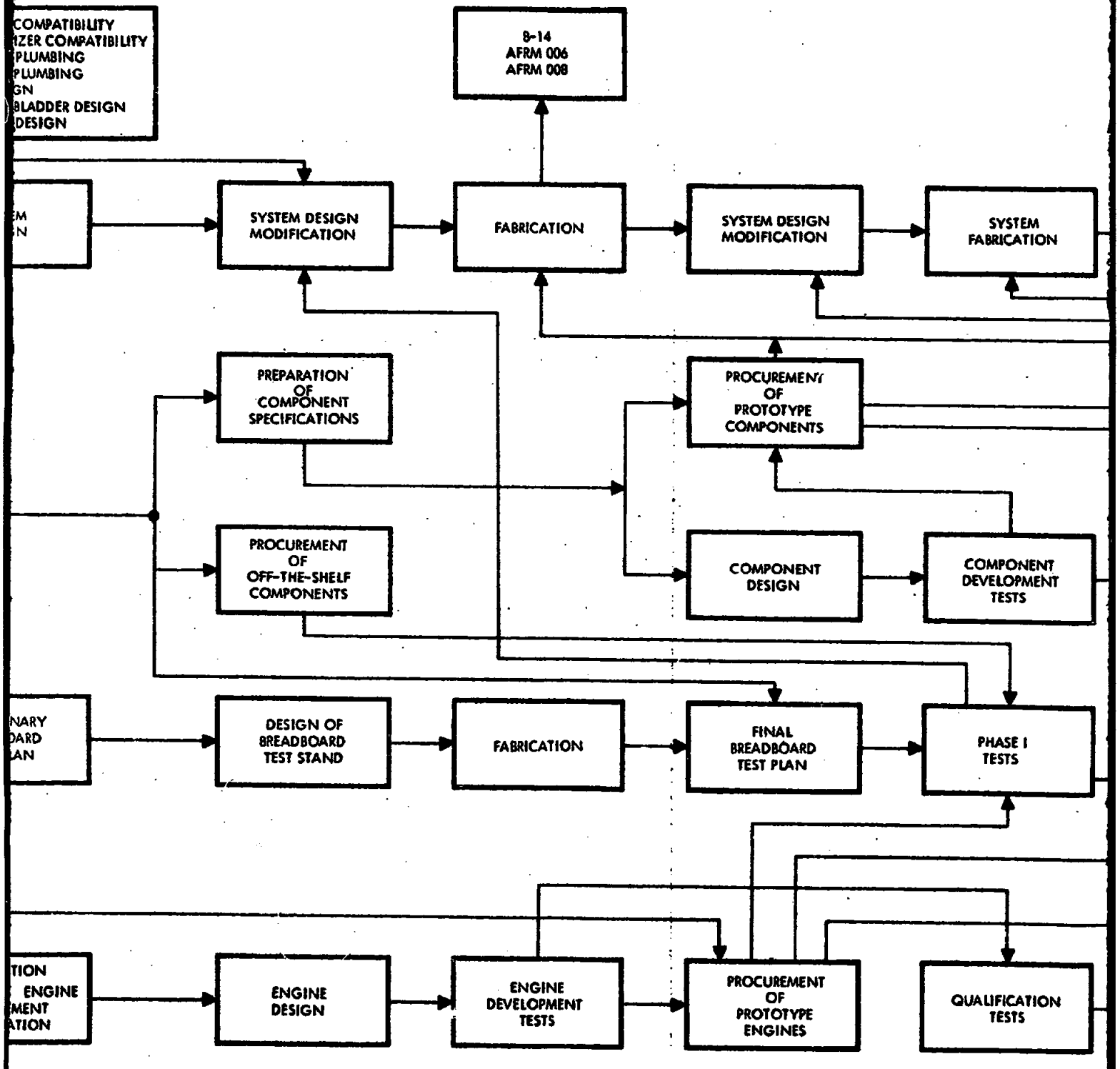


Figure 69. Comman

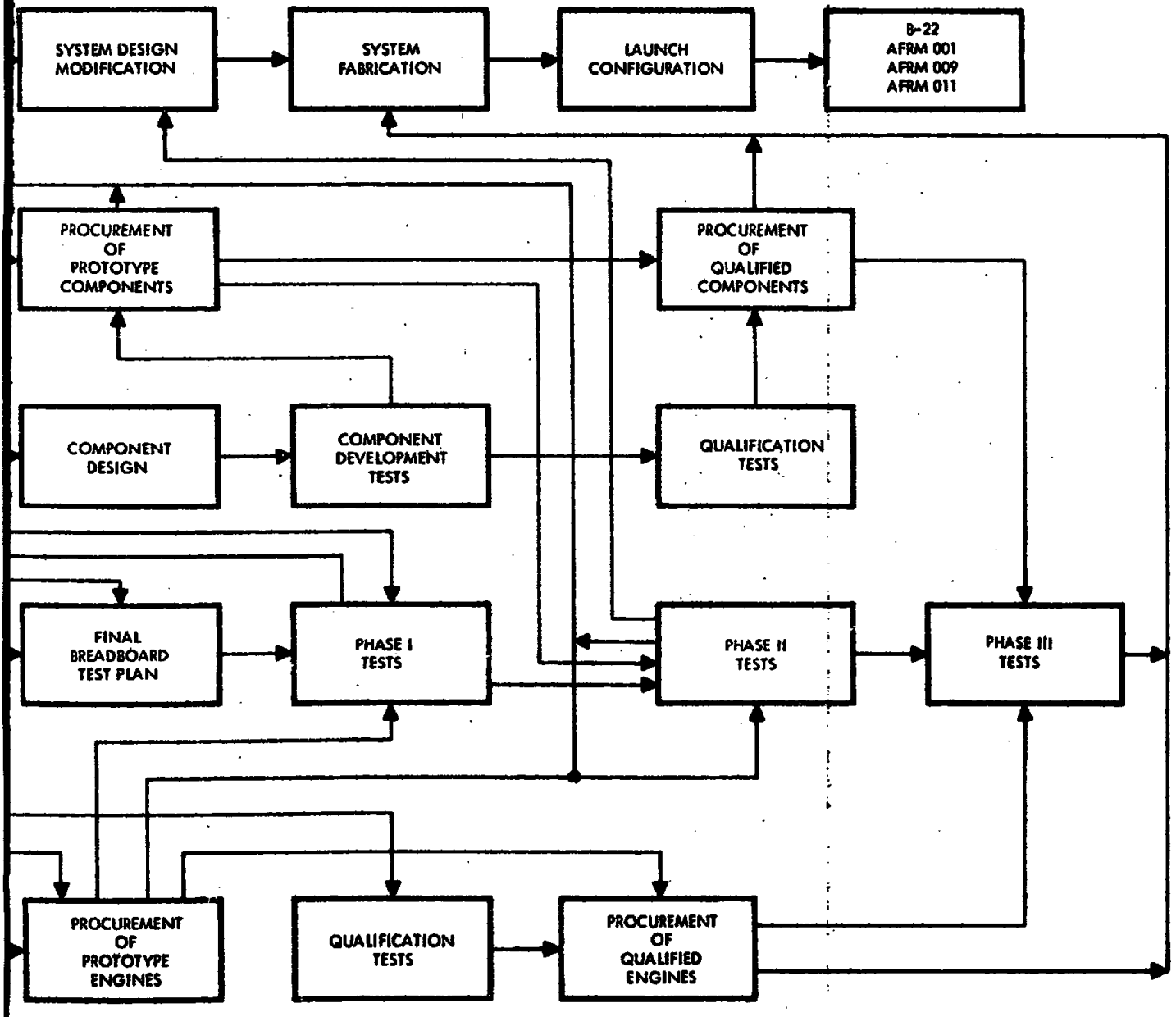


Figure 69. Command Module Reaction Control System Development Plan

[redacted]

stages in the engine development and qualification program, the subcontractor will supply engines for the breadboard test program, house spacecraft program, and various environmental, static test and flight spacecraft programs. Similarly, propellant system components will be designed, tested, and supplied (at various stages of development) by subcontractors.

The breadboard test program will be divided into three phases, designated as phase I, phase II, and phase III. Major differences between these phases will be in the types of components used in the test setup and the fluid media used during the test runs. Phase I testing will employ readily available off-the-shelf propellant system components and prototype nonfirable engines. Fluid media to be used during phase I tests will be water and nitrogen or suitable nontoxic, nonflammable fluids which simulate the density and viscosity of the hypergolic propellants. Prototype propellant system components and engines will be used in phase II testing, while phase III testing will employ qualified components and engines. The actual hypergolic propellants will be used during phase II and phase III propellant system and engine firing tests.

A preliminary system configuration will support B-14 (house spacecraft 1) airframe 006 (house spacecraft 2), and airframe 008 (environmental proof spacecraft). This preliminary system will be composed of prototype propellant system components and engines.

Results of the reaction engine development program, the propellant system component development program, and the breadboard test program will determine the spacecraft launch configuration. This configuration, will include qualified propellant system components and engines and will be installed in B-22 (High altitude abort spacecraft), airframe 001 (propulsion spacecraft), airframe 009, airframe 011, and all subsequent operational spacecraft.

Service Module Reaction Control System Development Plan

The reaction control system of the service module will provide the impulses for three-axis attitude control and stabilization of the spacecraft in the lunar parking orbit and during all spacecraft flight phases. These phases will include translunar and transearth phases, except when the service propulsion system is active. In all flight phases, the reaction control system also will provide minor translational velocity increments to the spacecraft. This function will be used to accomplish minor midcourse corrections, terminal rendezvous, and docking. It also will provide an initial, positive acceleration force on the propellants of the service propulsion system during zero-g engine starts. (See Figure 70.)

The service module reaction control system is pulse-modulated and pressure-fed by helium gas. The system uses earth-storable hypergolic

[redacted]

[redacted]

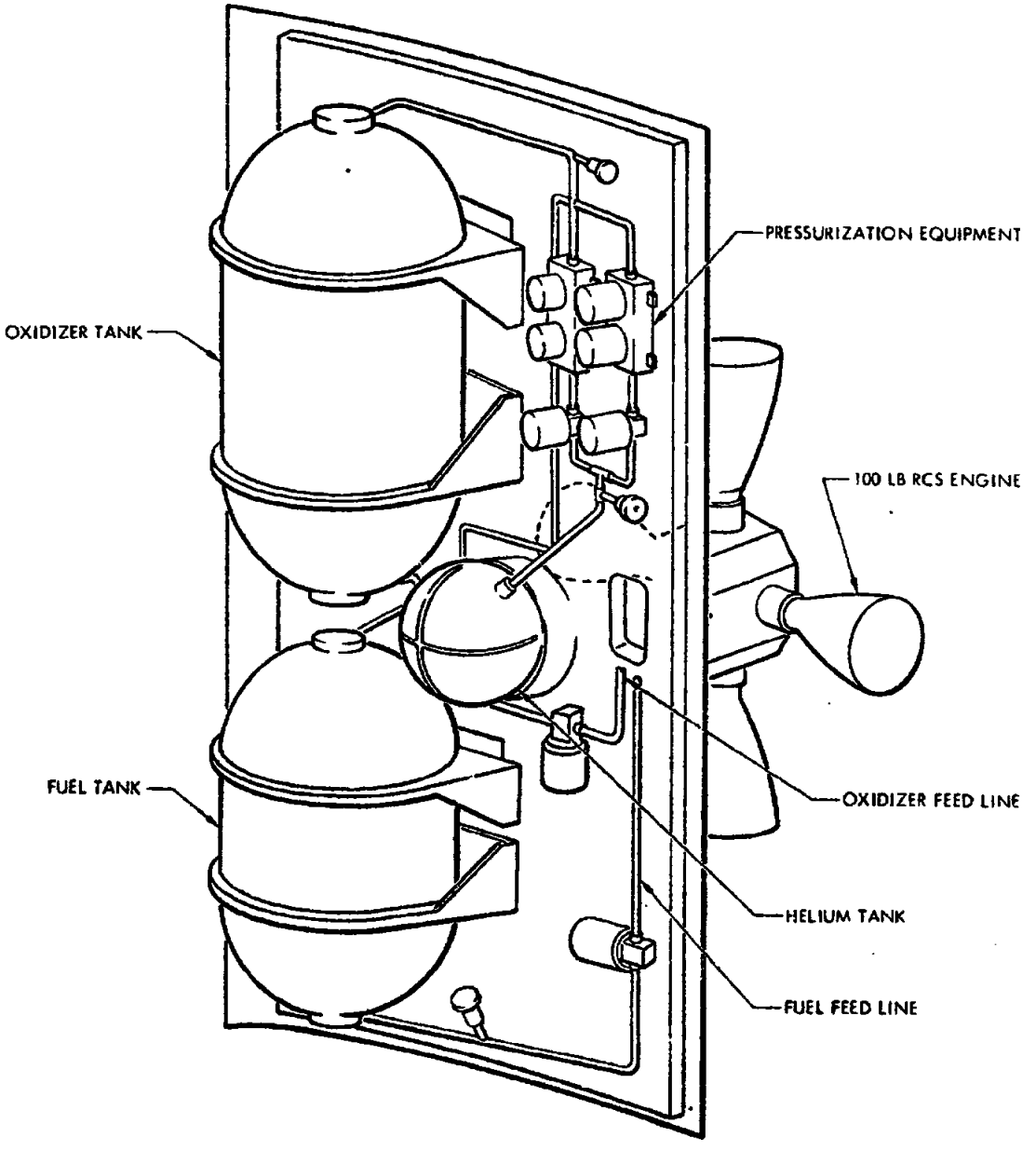


Figure 70. Propellants of the Service Module Reaction Control System

[redacted]

[redacted]

propellants consisting of nitrogen tetroxide (N_2O_4) as the oxidizer and a 50-50 blend of unsymmetrical dimethylhydrazine (UDMH) and hydrazine (N_2H_4) as fuel.

The complete service module reaction control system consists of four similar, independent systems located 90 degrees apart. Any three of the systems will have the capability of providing all the required control impulses.

Development of the service module reaction control system is represented schematically in Figure 71.

NAA/S&ID Specification SID 62-700-1 and -2 defines the preliminary mission, design, and performance requirements for the service module reaction control system. Utilizing SID 62-700-1 and -2 as a basis for design, studies will be conducted to further define the mission profile, design criteria, and performance requirements for the system. A basic system configuration will be estabilished from these studies.

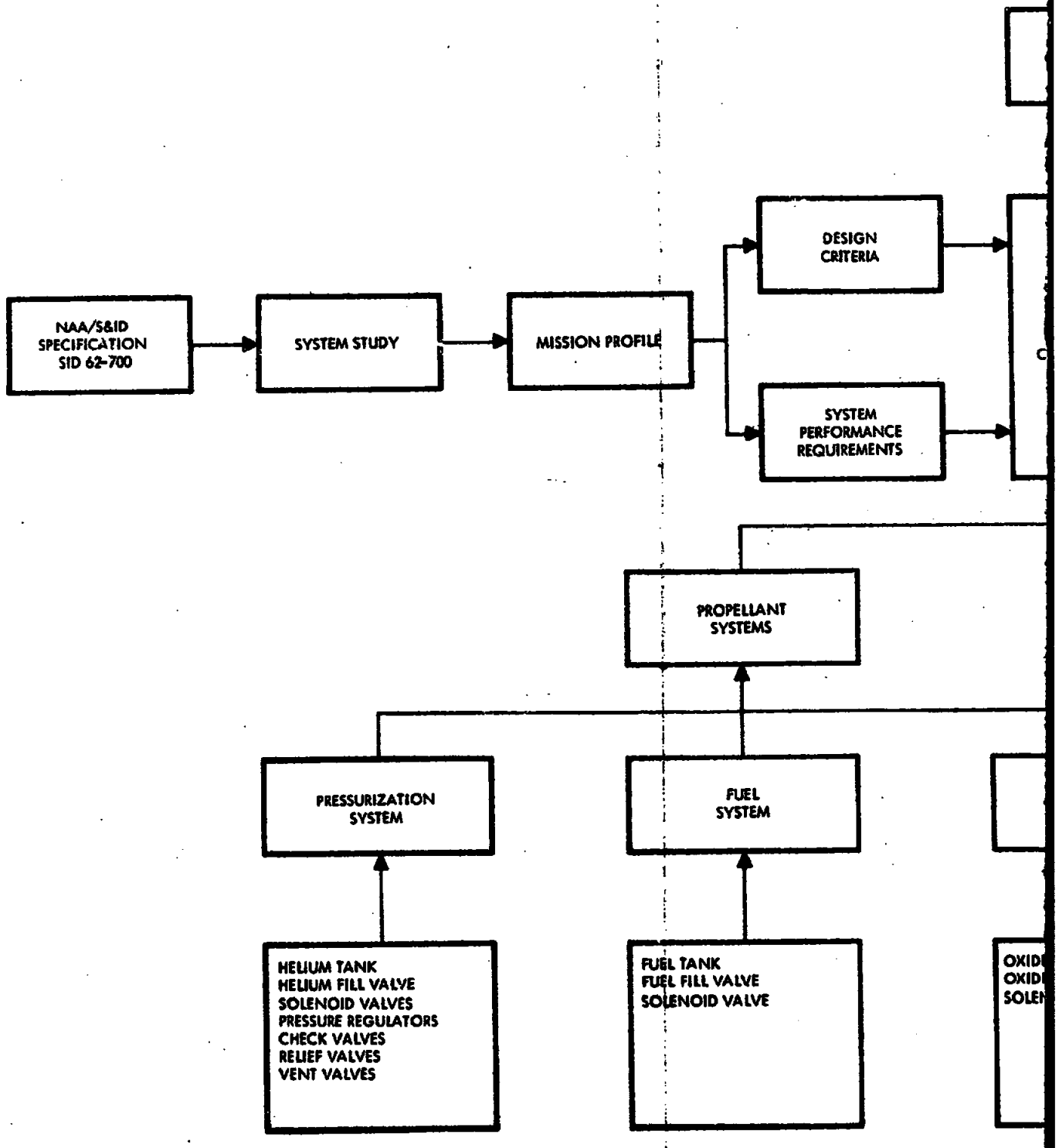
Each of the four independent reaction control systems will consist of a pressurized helium storage and distribution system, a fuel storage and distribution system, an oxidizer storage and distribution system, and four reaction rocket engine assemblies. Each pressurized helium system will be composed of a helium storage tank, a helium fill valve, solenoid valves, pressure regulators, check valves, relief valves, and vent valves. Each fuel system will be comprised of a positive expulsion fuel tank, a fuel fill valve, and a solenoid valve. Each oxidizer system will be composed of a positive expulsion oxidizer tank, oxidizer fill valve, and a solenoid valve.

When a basic configuration is determined for the service module reaction control system, preparation will begin on the reaction engine specification and a subcontractor will be selected. In addition, a preliminary breadboard test plan and the design of a breadboard test stand will be prepared, test stand fabrication and system development tests will be initiated, and a comprehensive analysis of the system configuration will be accomplished. These phases will parallel each other and will be interdependent in certain instances. Criteria obtained from system analysis and system development tests will provide the guidelines required for detailed system design and finalization of the breadboard test plan. Requirements for propellant system components, dictated by system design, also will be defined in component procurement specifications.

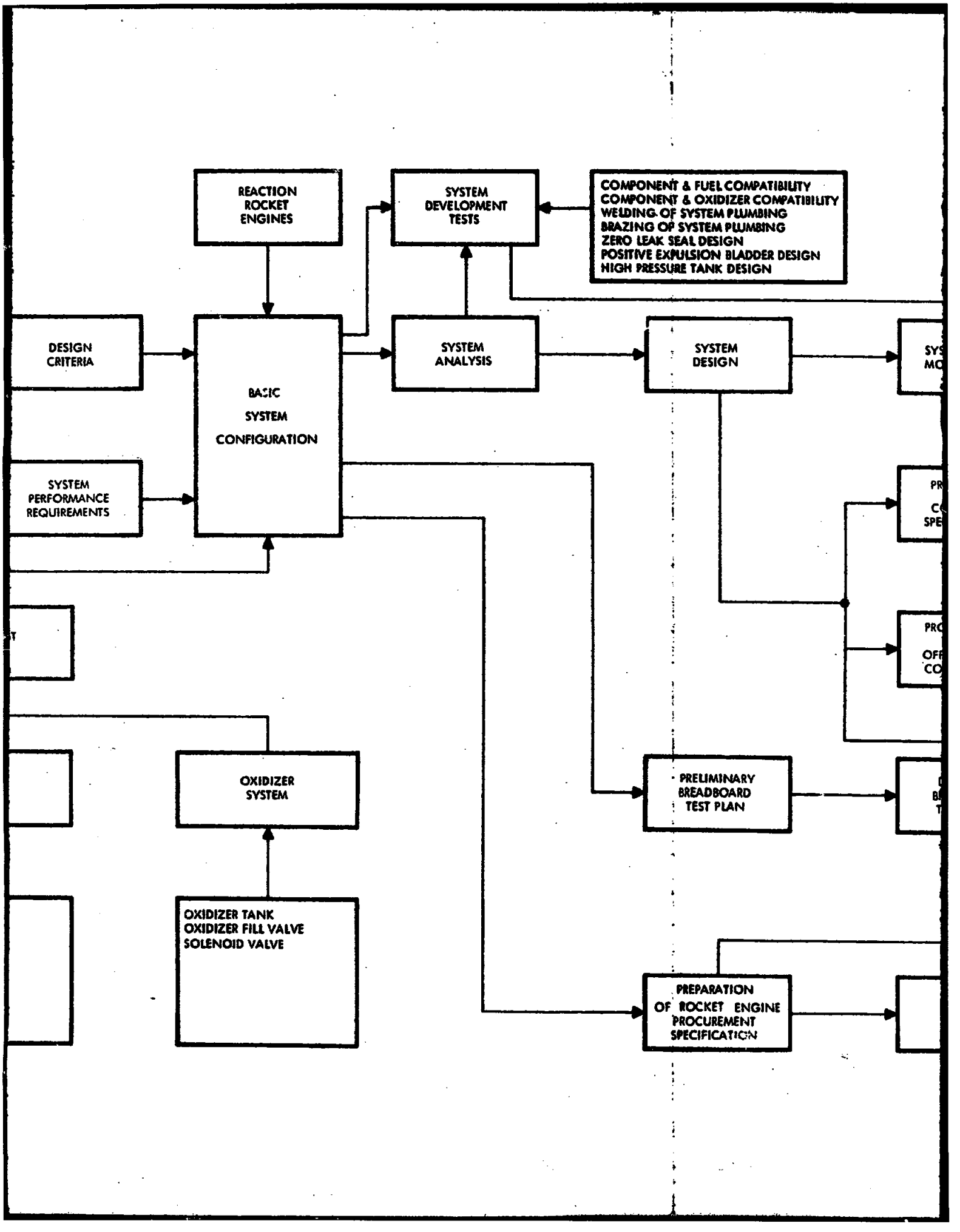
The reaction engine will be designed and tested by a subcontractor. The tests will include engine development and qualification tests. At specific stages in the engine development and qualification program, the subcontractor

[redacted]

[redacted]



PRECEDING PAGE BLANK-NOT FILMED


REACTION ROCKET ENGINES
SYSTEM DEVELOPMENT TESTS
COMPONENT & FUEL COMPATIBILITY
COMPONENT & OXIDIZER COMPATIBILITY
WELDING OF SYSTEM PLUMBING
BRAZING OF SYSTEM PLUMBING
ZERO LEAK SEAL DESIGN
POSITIVE EXPULSION BLADDER DESIGN
HIGH PRESSURE TANK DESIGN
DESIGN CRITERIA
BASIC SYSTEM CONFIGURATION
SYSTEM ANALYSIS
SYSTEM DESIGN
SYSTEM PERFORMANCE REQUIREMENTS
OXIDIZER SYSTEM
OXIDIZER TANK
OXIDIZER FILL VALVE
SOLENOID VALVE
PRELIMINARY BREADBOARD TEST PLAN
PREPARATION OF ROCKET ENGINE PROCUREMENT SPECIFICATION

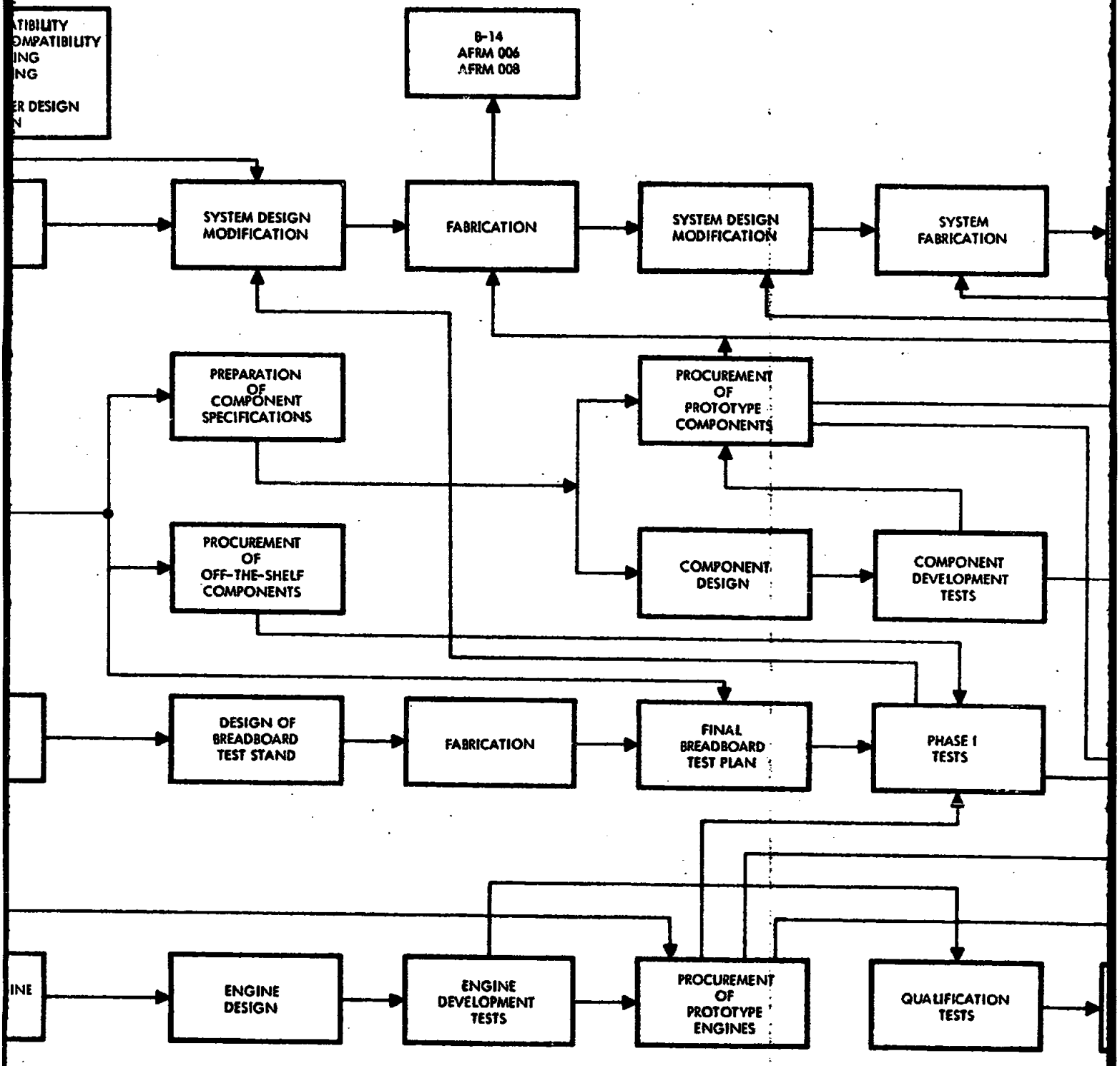


Figure 71. Service Mod

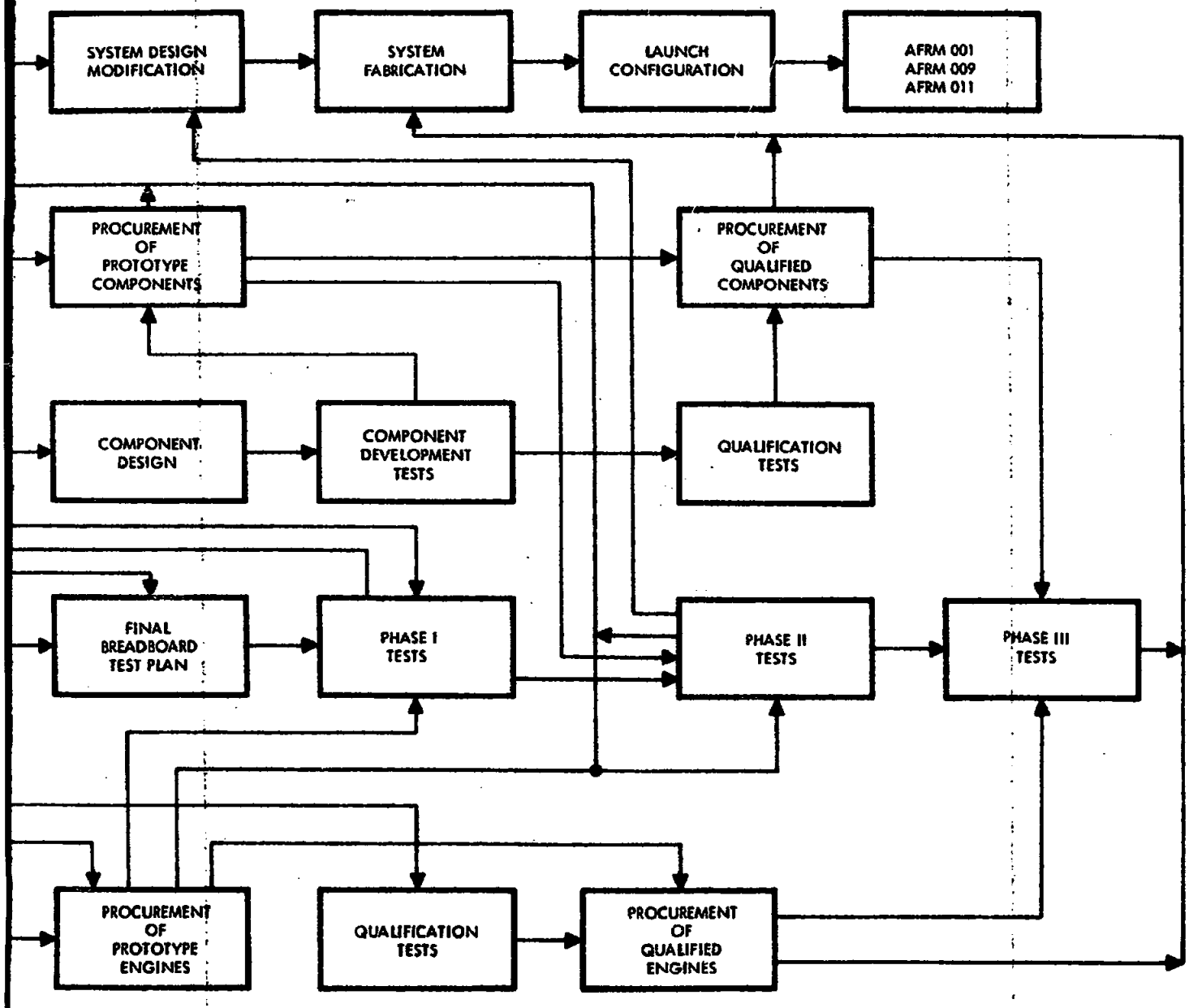


Figure 71. Service Module Reaction Control System Development Plan

[redacted]

will supply engines to support the breadboard test program, house spacecraft program, and various environmental, static test and flight spacecraft programs. Similarly, propellant system components will be designed, tested, and supplied (at various stages of development) by subcontractors.

The breadboard test program will be divided into three phases: phase I, phase II, and phase III. These phases will differ in the types of components used in the test setup and the fluid media used during the test runs. Phase I tests will employ readily available off-the-shelf propellant system components and prototype, nonfireable engines. Fluid media to be used during phase I tests will be water and nitrogen or suitable nontoxic, nonflammable fluids which will simulate the density and viscosity of the hypergolic propellants. Phase II tests will be conducted with prototype propellant system components and engines, while phase III tests will use qualified components and engines. Actual hypergolic propellants will be used during phase II and phase III propellant system and engine firing tests.

A preliminary system configuration (composed of prototype propellant system components and engines) will be fabricated to support B-14, airframe 006, and airframe 008.

The spacecraft launch configuration will be determined by the results of the reaction engine development program, the propellant system component development program, and the breadboard test program. The configuration, which will include qualified propellant system components and engines, will be installed in airframe 001, airframe 009, airframe 011, and all subsequent operational spacecraft.

SERVICE PROPULSION SYSTEM DEVELOPMENT PLAN

The service propulsion system will be located in the service module of the Apollo spacecraft and will furnish the impulse for the earth orbital mission retrograde, major midcourse velocity correction, lunar orbit injection, and ejection and post-atmospheric abort. (See Figure 72.)

The engine will utilize earth-storable hypergolic propellants consisting of nitrogen tetroxide (N_2O_4) as the oxidizer and a 50-50 blend of hydrazine (N_2H_4) and unsymmetrical-dimethylhydrazine (UDMH) as the fuel. The propellants will be pressure-fed to the engine by means of helium gas. The engine will be of fixed thrust and will utilize a gimbal and a gimbal-actuator system for thrust vector control.

Development of the service propulsion system is shown schematically in Figure 73.

[redacted]

[redacted]

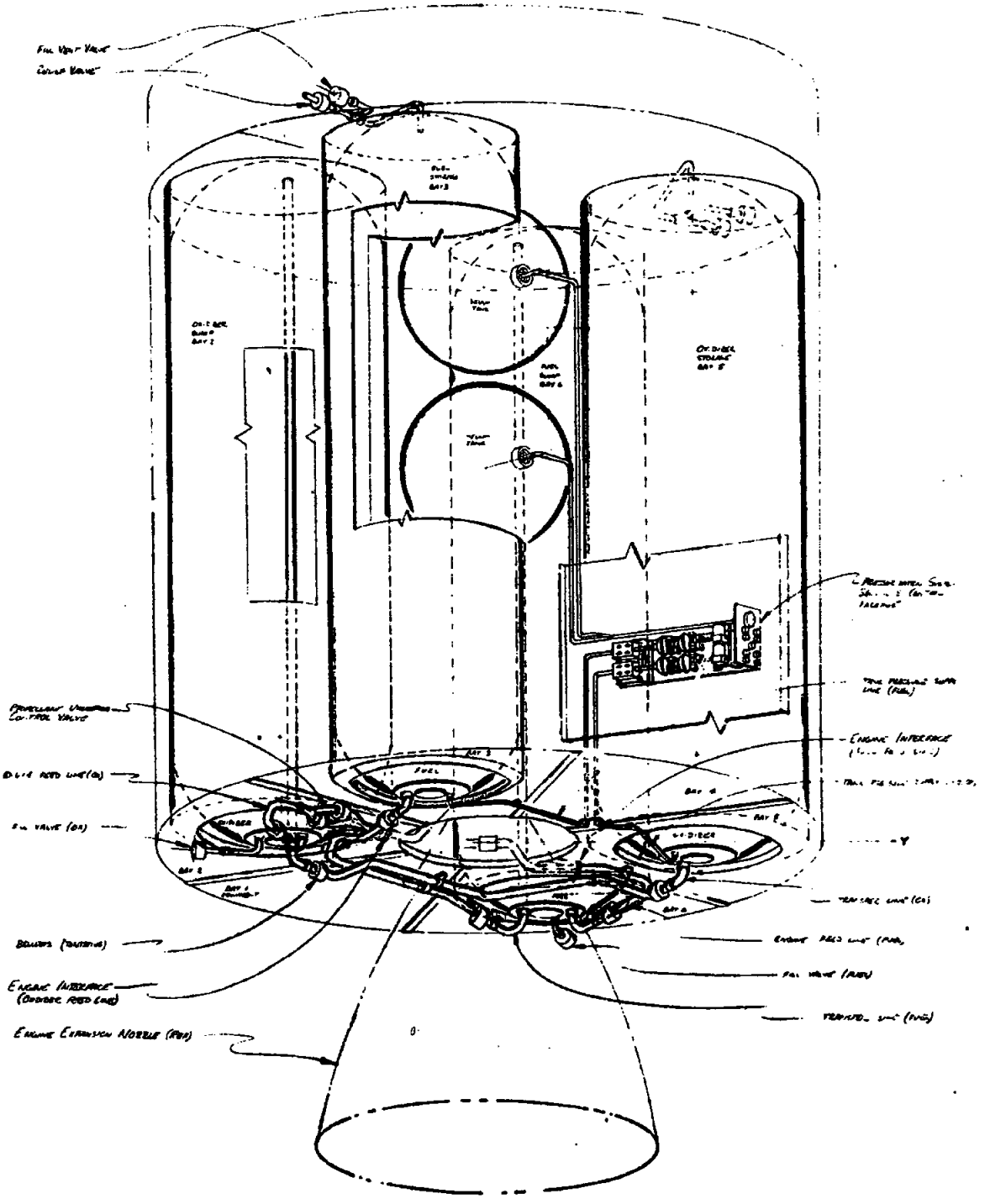
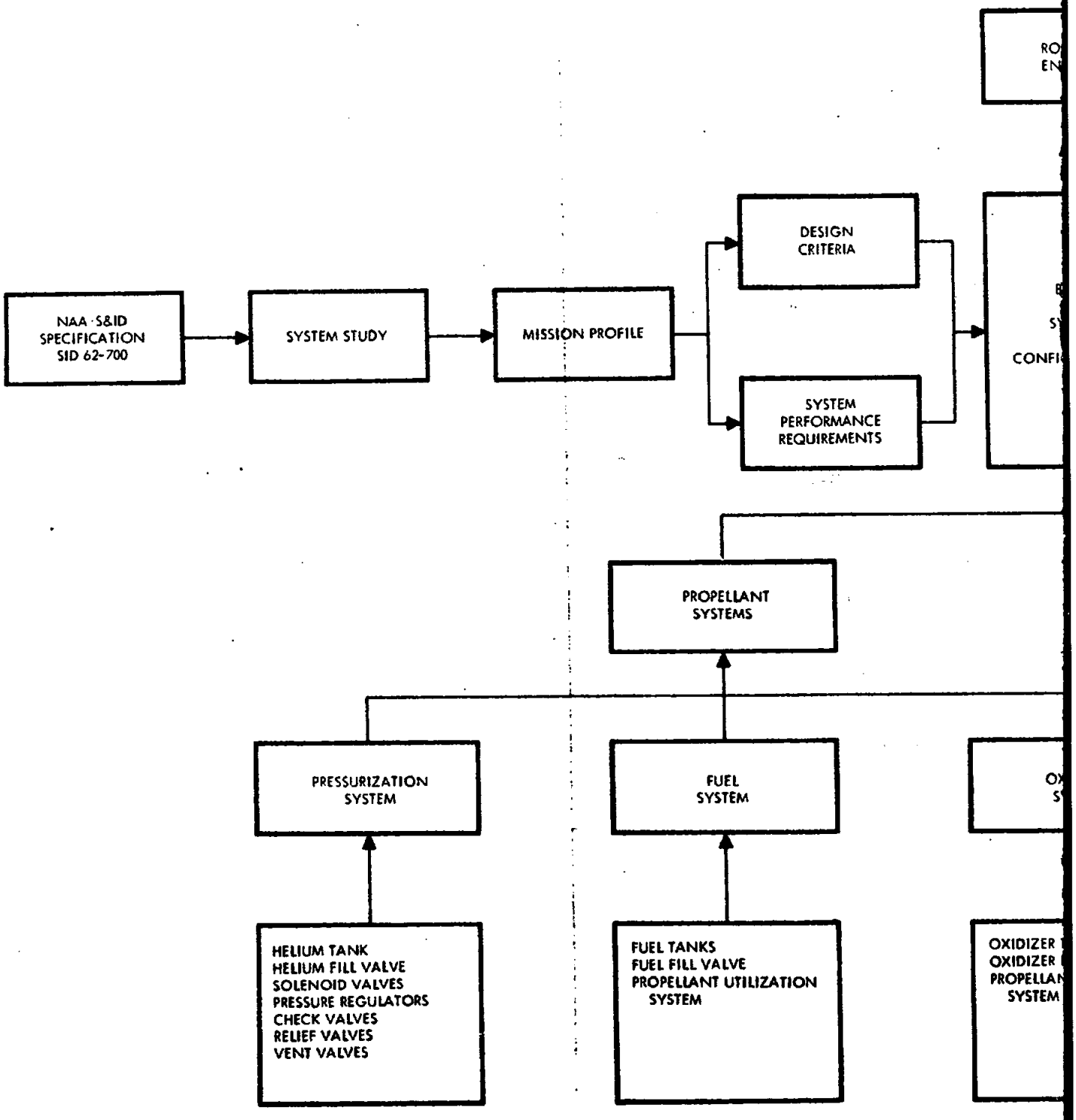
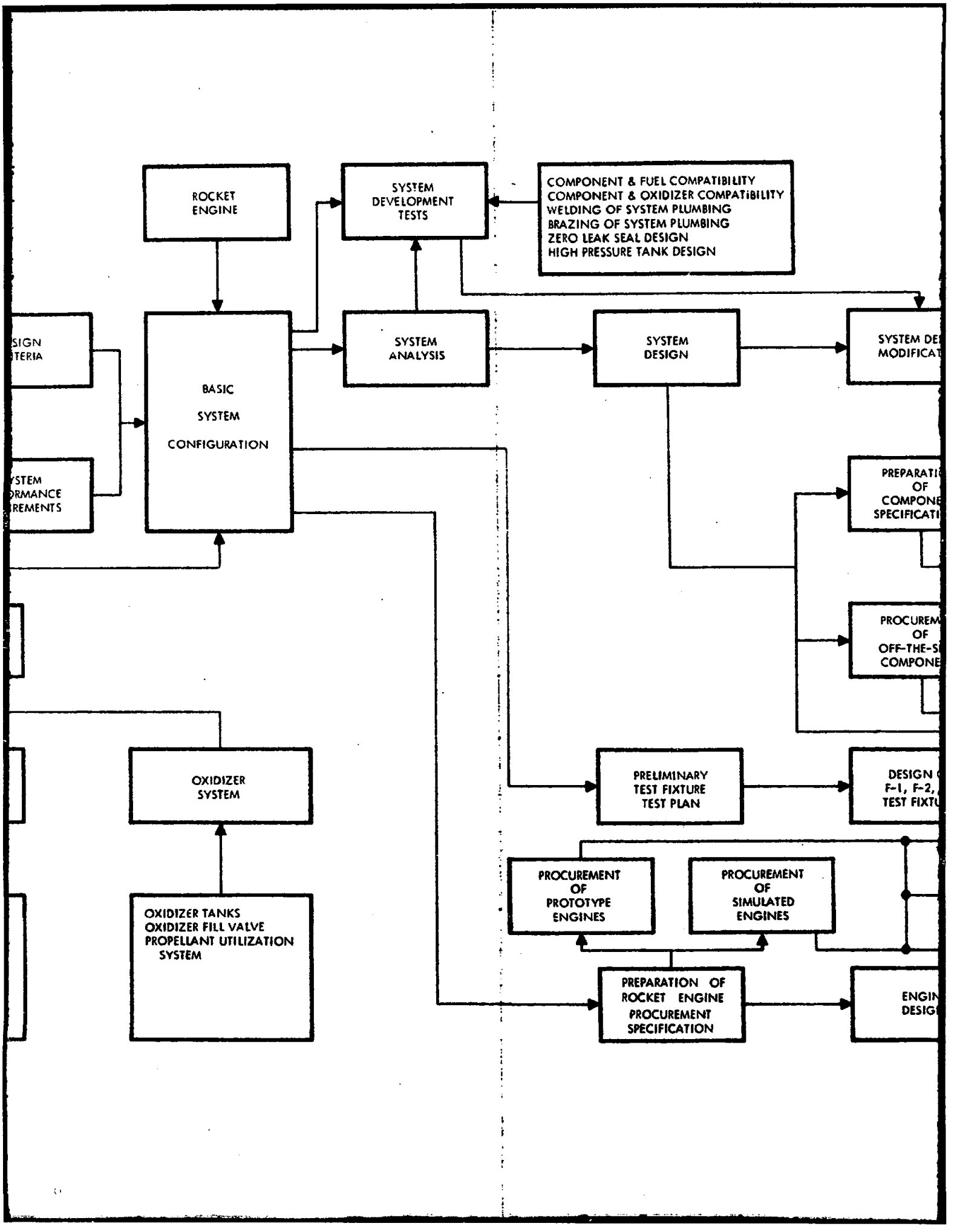


Figure 72. Service Propulsion System Installation (Perspective Sketch)

[redacted]

[redacted]


NAA S&ID SPECIFICATION SID 62-700
SYSTEM STUDY
MISSION PROFILE
DESIGN CRITERIA
SYSTEM PERFORMANCE REQUIREMENTS
PROPELLANT SYSTEMS
PRESSURIZATION SYSTEM
FUEL SYSTEM
HELIUM TANK
HELIUM FILL VALVE
SOLENOID VALVES
PRESSURE REGULATORS
CHECK VALVES
RELIEF VALVES
VENT VALVES
FUEL TANKS
FUEL FILL VALVE
PROPELLANT UTILIZATION SYSTEM


ROCKET ENGINE
SYSTEM DEVELOPMENT TESTS
COMPONENT & FUEL COMPATIBILITY
COMPONENT & OXIDIZER COMPATIBILITY
WELDING OF SYSTEM PLUMBING
BRAZING OF SYSTEM PLUMBING
ZERO LEAK SEAL DESIGN
HIGH PRESSURE TANK DESIGN
SIGN
TERIA
BASIC SYSTEM CONFIGURATION
SYSTEM ANALYSIS
SYSTEM DESIGN
SYSTEM DE
MODIFICAT
YSTEM
ORMANCE
REMENTS
PREPARATI
OF
COMPONE
SPECIFICATI
PROCUREM
OF
OFF-THE-S
COMPONE
OXIDIZER SYSTEM
PRELIMINARY TEST FIXTURE TEST PLAN
DESIGN
F-1, F-2,
TEST FIXTU
PROCUREMENT OF PROTOTYPE ENGINES
PROCUREMENT OF SIMULATED ENGINES
OXIDIZER TANKS
OXIDIZER FILL VALVE
PROPELLANT UTILIZATION SYSTEM
PREPARATION OF ROCKET ENGINE PROCUREMENT SPECIFICATION
ENGIN
DESIG

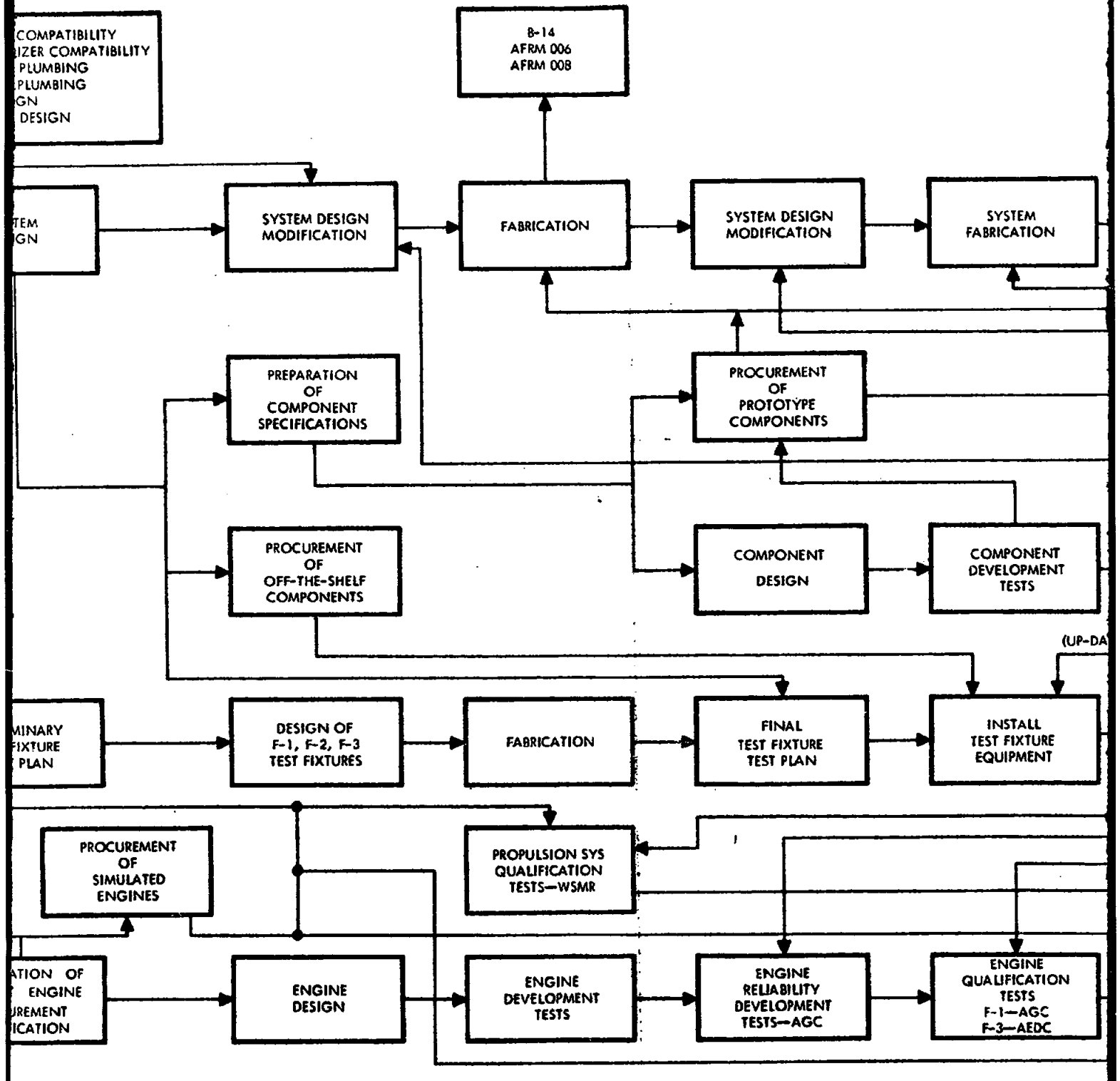

COMPATIBILITY
IZER COMPATIBILITY
PLUMBING
PLUMBING
GN
DESIGN
B-14
AFRM 006
AFRM 008
TEM
GN
SYSTEM DESIGN MODIFICATION
FABRICATION
SYSTEM DESIGN MODIFICATION
SYSTEM FABRICATION
PREPARATION OF COMPONENT SPECIFICATIONS
PROCUREMENT OF PROTOTYPE COMPONENTS
PROCUREMENT OF OFF-THE-SHELF COMPONENTS
COMPONENT DESIGN
COMPONENT DEVELOPMENT TESTS
(UP-DA
MINARY
FIXTURE
PLAN
DESIGN OF F-1, F-2, F-3 TEST FIXTURES
FABRICATION
FINAL TEST FIXTURE TEST PLAN
INSTALL TEST FIXTURE EQUIPMENT
PROCUREMENT OF SIMULATED ENGINES
PROPULSION SYS QUALIFICATION TESTS—WSMR
ATION OF
ENGINE
UREMENT
ICATION
ENGINE DESIGN
ENGINE DEVELOPMENT TESTS
ENGINE RELIABILITY DEVELOPMENT TESTS—AGC
ENGINE QUALIFICATION TESTS F-1—AGC F-3—AEDC

Figure 73.

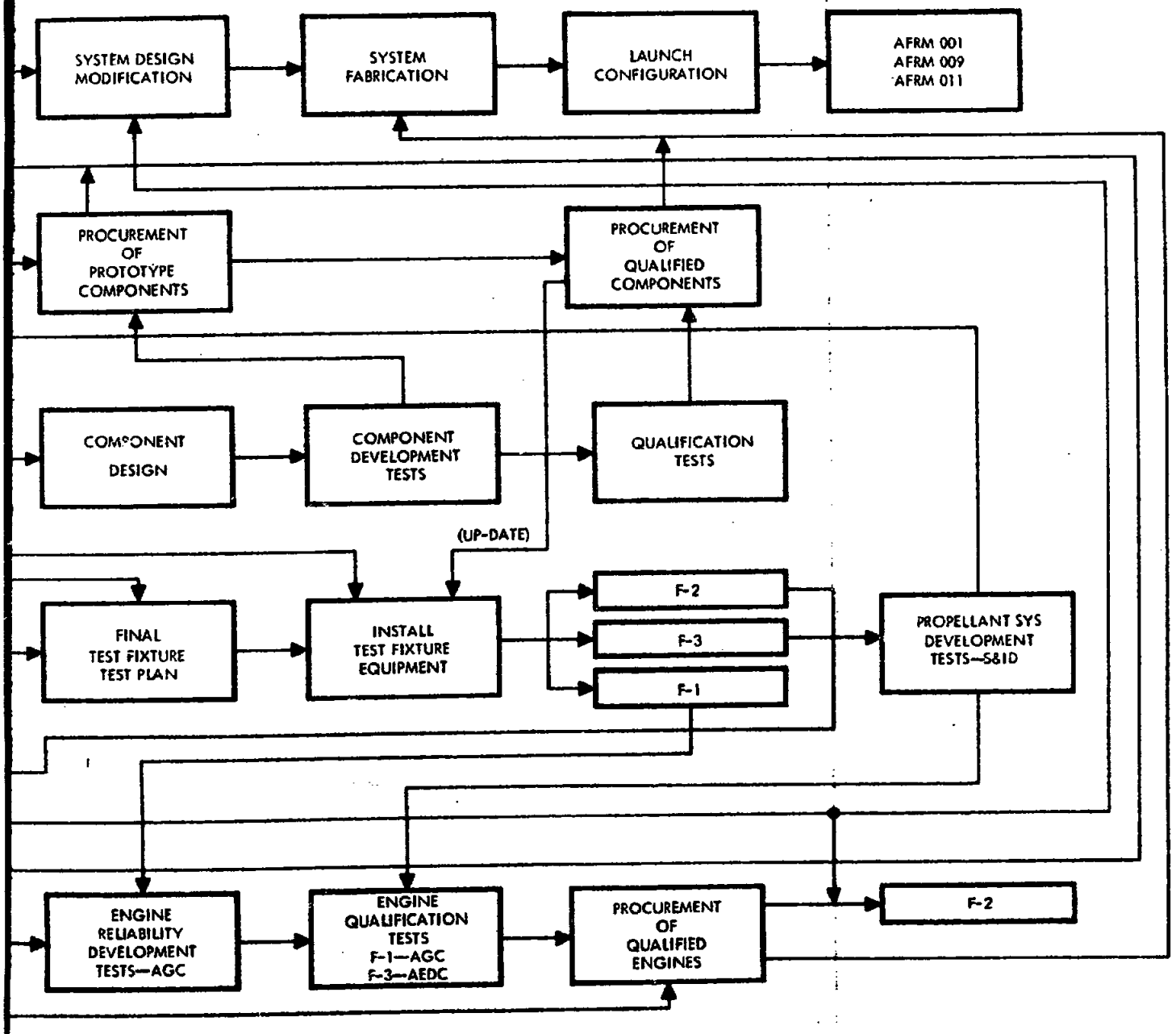


Figure 73. Service Propulsion System Development Plan

[redacted]

The preliminary mission and design and performance requirements for the Service Propulsion System, are defined in NAA/S&ID Specifications SID 62-700-1 and -2. SID 62-700-1 and -2 will provide a design basis for studies to further define the mission profile, design criteria, and performance requirements for the system. These studies will establish a basic system configuration.

The service propulsion system will consist of a pressurized helium storage and distribution system, a fuel storage and distribution system, an oxidizer storage and distribution system, and a single engine assembly. The pressurized helium system will contain a dual helium tankage system, helium fill valve, solenoid valves, pressure regulators, check valves, relief valves, and vent valves. The fuel system will incorporate a dual fuel tankage system and a fuel fill valve. The oxidizer system will be comprised of a dual oxidizer tankage system, an oxidizer fill valve, and a propellant utilization and quantity gauging system. The engine assembly will consist of a thrust chamber assembly, propellant valve system, gimbal, gimbal actuator system, engine mount, and instrumentation.

A basic configuration for the service propulsion system is determined, preparation of the rocket engine specification will begin and a subcontractor will be selected. A preliminary test fixture test plan and design of the F-1, F-2 and F-3 test fixtures will be prepared, test fixture fabrication and system development tests will begin, and a comprehensive analysis of the system configuration will be completed. In some instances these phases will be parallel to and interdependent of each other. Results obtained from the system analysis and system development tests will provide guidelines for detailed system design and finalization of the test fixture test plan. Propellant system component requirements, dictated by the system design, also will be defined in component procurement specifications.

The rocket engine will be designed and tested by a subcontractor. The tests will be conducted for engine development, reliability development, and qualification. Testing will be done at ground level and under simulated altitude conditions at Arnold Engineering Development Center. At specific stages in the engine development and qualification program the subcontractor will supply engines to support the test fixture test program, house spacecraft program, and various environmental, static test and flight spacecraft programs. Propellant system components will be designed, tested, and supplied in the same manner by contracted suppliers.

In order to begin test fixture testing at the earliest possible date, readily available off-the-shelf propellant system components will be procured for installation on the F-1, F-2, and F-3 test fixtures. As the development program progresses, the test fixtures will be updated with qualified components as these items become available.

[redacted]

The F-1 test fixture will be utilized for engine reliability development and qualification testing. The F-2 test fixture will be used for in-house propulsion system qualification tests and also as a back-up test system for airframe 001. The F-3 test fixture will be used for propellant system development tests prior to engine qualification tests under simulated altitude conditions. With the exception of the F-3 propellant system development tests the actual hypergolic propellants will be used for all test fixture operations, including engine firing tests. F-3 propellant system development tests will employ water or suitable nontoxic, nonflammable fluids which will simulate the density and viscosity of the hypergolic propellants.

A preliminary system configuration will support B-14, airframe 006, and airframe 008. This preliminary system will be composed of prototype propellant system components and a simulated engine.

Results of the rocket engine development program, propellant system component development program, and the test fixture test program will determine the spacecraft launch configuration. The launch configuration, which will include qualified propellant system components and a qualified engine, will be installed in airframe 001, airframe 009, airframe 011, and all subsequent operational spacecraft.

LAUNCH ESCAPE MOTORS DEVELOPMENT PLAN

The launch escape system will contain three solid propellant motors, launch escape motor, tower jettison motor, and the pitch control motor.

The launch escape motor will be mounted on the launch escape tower of the Apollo command module. It will be used to separate the Apollo command module from the service module in an abort sequence.

The tower jettison motor will be mounted on top of the Apollo launch escape motor. Under normal conditions the jettison motor will separate the launch escape tower from the command module after ignition of the second stage booster. In an emergency operation (after the launch escape motor has separated the command module from the service module), the tower jettison motor will separate the launch escape tower from the command module under launch pad, maximum dynamic pressure, and maximum altitude abort conditions.

The pitch control motor will be located between the tower jettison motor and the nose cone. After the ignition of the launch escape motor (in an abort sequence), the pitch control motor will ignite and place the vehicle in the correct flight altitude for a successful escape.

[redacted]

[redacted]

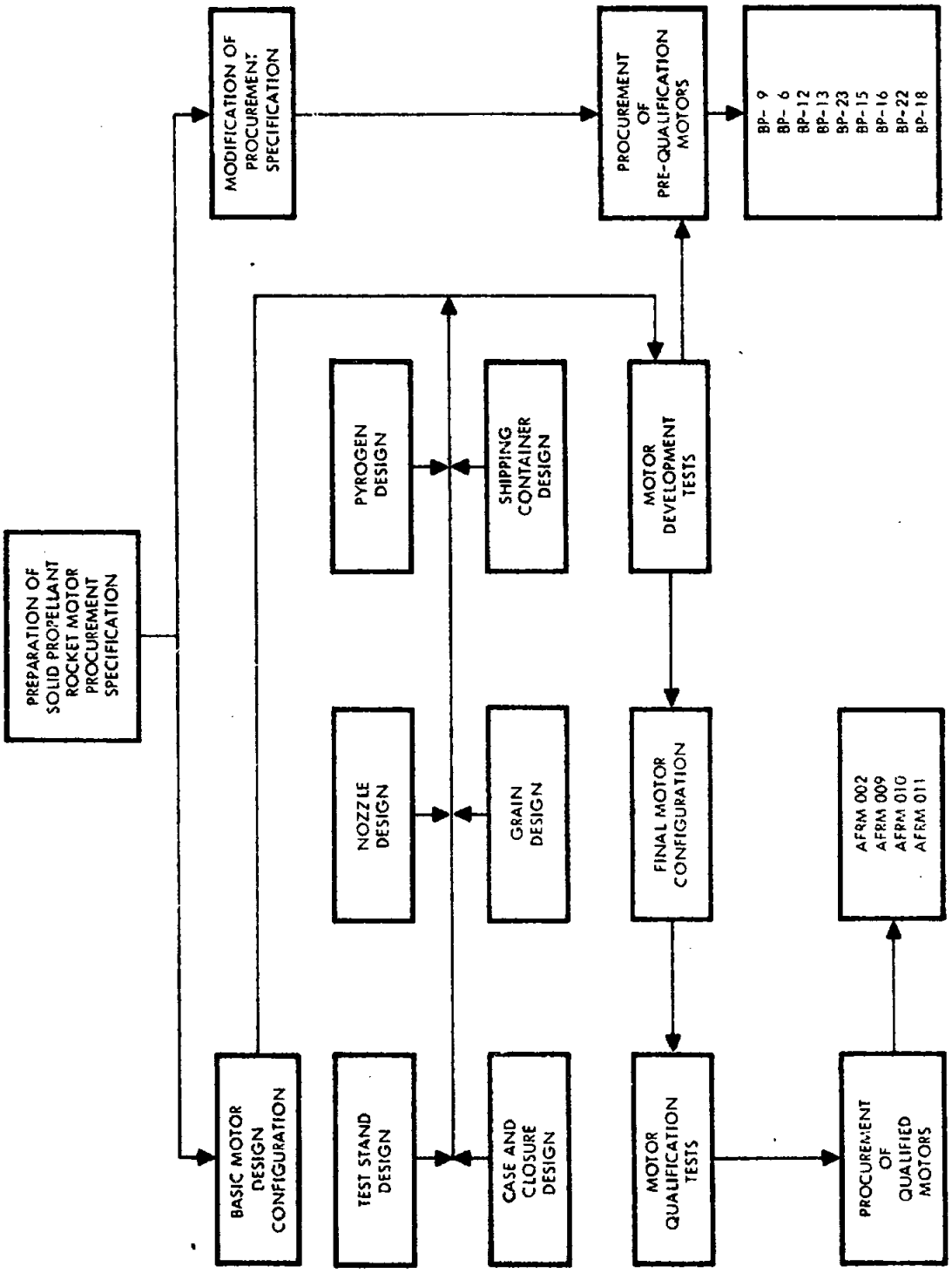


Figure 74. Launch Escape Motors Development Plan

[redacted]

[redacted]

The launch escape motor is 185.63 inches in length and 26.0 inches in diameter. It is equipped with four nozzles, canted at 35 degrees from the motor centerline. Unequal nozzle throat sizes will provide a thrust offset of 2 degrees 45 minutes from the motor centerline.

The launch escape motor propellant consists of a polysulfide ammonium perchlorate grain with an eight-point star design.

The propellant grain is designed to meet a 120,000-pound thrust level at 20 F and 36,000 feet elevation. This thrust level has a growth potential to 150,000 pounds.

The tower jettison motor is 55 inches in length and 26 inches in diameter. It contains two scarfed nozzles canted at 30 degrees from the motor centerline. The scarfed nozzle is required for the nozzle exit cone to fit the mold line of the interstage structure, which is located between the tower jettison motor and the launch escape motor. Unequal nozzle throat sizes will provide a thrust offset of 2 degrees 30 minutes from the motor centerline.

The propellant consists of a polysulfide ammonium perchlorate grain with a 10-point star design. The propellant grain is designed to meet a 31,500-pound thrust level at 20 F, sea level.

The pitch control motor is 22 inches in length and 8.79 inches in diameter and contains one nozzle centered along the motor centerline. The propellant consists of a polysulfide ammonium perchlorate grain with a 14-point star design. The motor is designed to meet a 5500-pound thrust level at 20 F, sea level.

Development testing of the launch escape, tower jettison, and the pitch control motors will verify the design of the rocket motors and determine optimum performance and selection of components. (See Figure 74.)

The development program will combine development and conventional preliminary flight-rating tests in order to provide extensive reliability data. All tests will be performed by the subcontractors at their own static test facilities. The development program will consist of 17, 23, and 28 development motors for the launch escape, tower jettison, and pitch control motors. Initial static rounds will be temperature conditioned and fired to verify motor design and ballistic performance. Environmental treatments, increasingly severe in nature, will be applied to the remaining motors before static testing.

Following completion of the development programs, motor designs will be finalized and the motors will enter a qualification program. Objective of the qualification programs is to qualify the launch escape, tower jettison, and pitch control motors for man-rated flight. The rocket motors will be static tested under single and combined environments at the subcontractors' facilities.

[redacted]

[redacted]

ENVIRONMENTAL CONTROL SYSTEM

Introduction

The complete environmental control system for Project Apollo consists of the environmental control system proper (ECS), the cryogenic storage system (CSS), and the waste management system (WMS). The CSS will furnish oxygen to the ECS; the ECS will process this oxygen and supply it to the cabin and crew. The ECS will also receive waste gases from the WMS, process it, and provide a return flow of purified air to ventilate the food, wastes, and personal equipment storage compartments.

Environmental Control System Description (Figure 75)

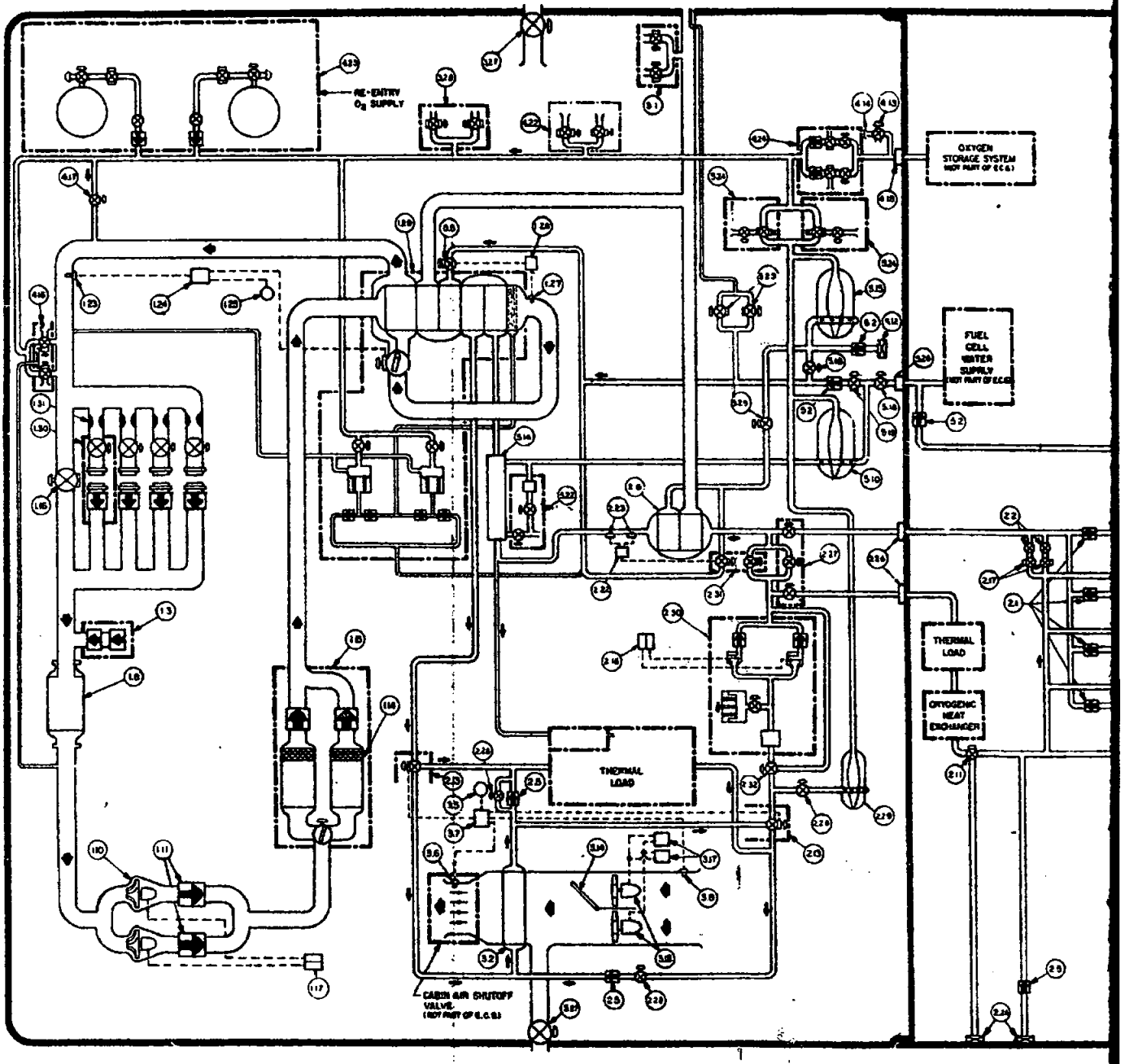
The environmental control system (ECS) will be designed to provide the necessary environmental requirements in the spacecraft for earth orbital and earth-to-moon missions. The function of the system will be as follows: the ECS will provide a control of the flow, pressure, temperature, and composition of the gases for command module shirtsleeve atmosphere. Also, these gases will be utilized in the operation of the three pressure suits used by the crewmen during the escape and entry phases, and during emergency conditions. The system will provide thermal control of the equipment used in the command and service module, where required. Facilities will be provided for charging the back-packs, which are used for lunar exploration in connection with the lunar orbital rendezvous (LOR) or emergency conditions. Also provided will be a water supply system to be used for crew water consumption and emergency or supplementary heat transfer operations.

The ECS will have a number of functions. Carbon dioxide and various odors will be removed by lithium hydroxide and activated charcoal. The atmospheric makeup gas will be supplied from supercritically-stored oxygen. Equipment and crew heat loads will be rejected to space through a radiator, and emergency or supplementary cooling will be provided by evaporating water. A command module nominal ambient pressure of 5.0 psia will be maintained during normal system operation and 14.7 psia (ambient) during ground operation; a suit pressure of 3.5 psia will be maintained if cabin pressure is lost.

Subsystem Functions

The functions of the subsystems are described in the following paragraphs.

[redacted]



MANUAL SHUTOFF VALVE

ELECTRICALLY ACTUATED VALVE

ELECTRICALLY ACTUATED CONTROL VALVE WITH MANUAL OVERRIDE

PRESSURE REGULATOR

PRESSURE REGULATOR AND RELIEF VALVE

PRESSURE RELIEF VALVE

PRESSURE RELIEF VALVE WITH MANUAL OVERRIDE

ELECTRICALLY ACTUATED 3-WAY VALVE

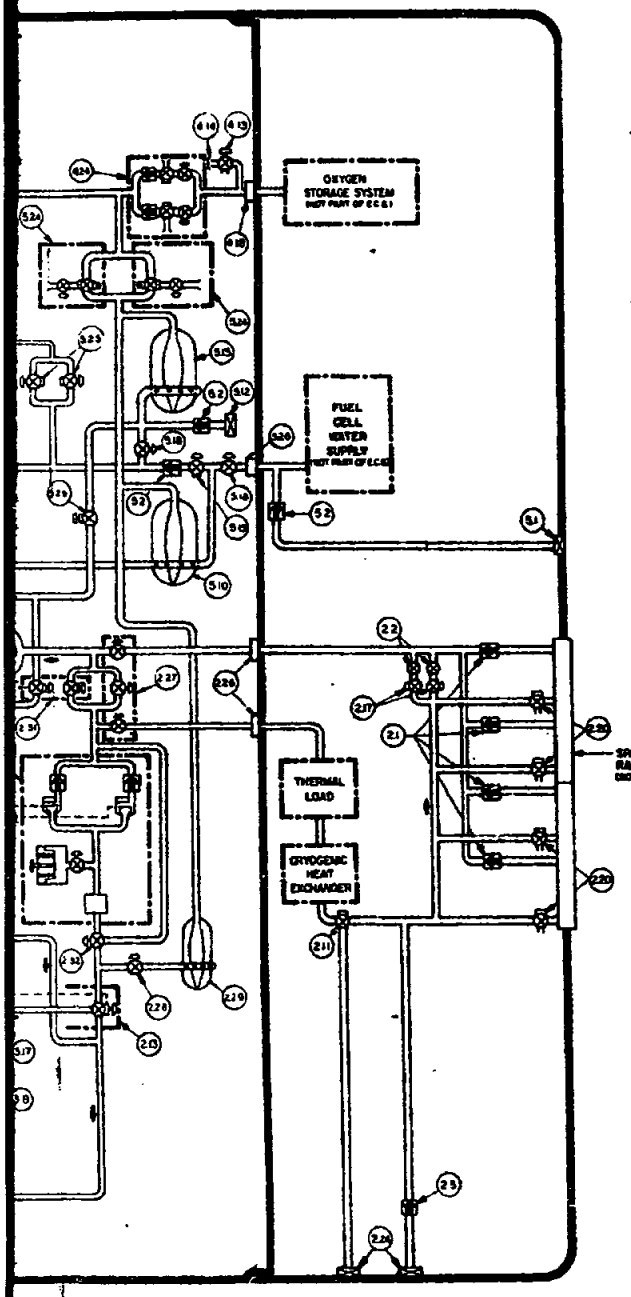
ELECTRICALLY ACTUATED 3-WAY VALVE WITH MANUAL OVERRIDE

CHECK VALVE

SELF SEALING QUICK DISCONNECT

QUICK DISCONNECT

PRECEDING PAGE BLANK-NOT FILMED



ITEM NO	NO REQ	DESCRIPTION
		GROUP I - PRESSURE SUIT CIRCUIT
1.3	1	SUIT CIRCUIT RETURN AIR CHECK VALVE ASSEMBLY
1.6	1	DEBRIS TRAP
1.10	2	SUIT COMPRESSOR
1.11	2	SUIT COMPRESSOR CHECK VALVE
1.14	20	CO_2 AND ODOR ABSORBER-REMOVABLE CONTAINER (20 REPLACEMENTS)
1.15	1	CO_2 & ODOR ABSORBER PACKAGE LiOH CANISTER (2) CHECK VALVE (2) ISOLATION VALVE
1.16	1	SUIT BYPASS VALVE
1.17	2	SUIT COMPRESSOR SELECTOR SWITCH
1.23	1	SUIT AIR TEMPERATURE SENSOR
1.24	1	SUIT AIR TEMPERATURE CONTROL
1.25	1	SUIT AIR TEMPERATURE SELECTOR
1.27	1	SUIT EVAPORATOR TEMPERATURE SENSOR
1.28	1	SUIT EVAPORATOR TEMPERATURE CONTROL
1.29	1	HEAT EXCHANGER PACKAGE REGENERATIVE HEAT EXCHANGER REGENERATIVE HEAT EXCHANGER BYPASS VALVE SUIT EVAPORATOR GLYCOL-TO-SUIT AIR HEAT EXCHANGER WATER SEPARATOR WATER SEPARATOR PUMP ASSEMBLY
1.30	4	SUIT HOSE CONNECTOR PACKAGE SUIT SHUTOFF VALVE SUIT SUPPLY CONNECTION SUIT RETURN CHECK VALVE
1.31	4	SUIT FLOW LIMITER
		GROUP II - WATER-GLYCOL-CIRCUIT
2.1	4	SPACE RADIATOR OUTLET CHECK VALVE
2.2	2	GLYCOL PRESSURE RELIEF VALVE
2.5	3	GLYCOL CHECK VALVE
2.6	1	GLYCOL EVAPORATOR
2.11	1	GLYCOL SHUTOFF VALVE
2.15	1	CABIN TEMPERATURE CONTROL VALVE
2.16	2	GLYCOL PUMP SELECTOR SWITCH
2.17	2	GLYCOL SHUTOFF VALVE
2.20	4	SPACE RADIATOR ISOLATION & VENT VALVE
2.22	1	GLYCOL TEMPERATURE CONTROL
2.23	2	GLYCOL TEMPERATURE SENSOR
2.24	2	GLYCOL FILL & VENT CONNECTION
2.25	2	GLYCOL QUICK DISCONNECT
2.27	1	MANUAL SHUTOFF VALVE
2.28	5	GLYCOL SHUTOFF VALVE
2.29	1	GLYCOL RESERVOIR
2.30	1	GLYCOL PUMP ASSEMBLY ACCUMULATOR ISOLATION VALVE PUMP (2) CHECK VALVE (2) FILTER
2.31	1	GLYCOL TEMPERATURE CONTROL VALVE
2.32	1	GLYCOL PUMP DIVERTER VALVE
		GROUP III - COMMAND MODULE PRESS. & TEMP CONTROL SYSTEM
3.1	1	CABIN OUTFLOW, PRESS REG & NEGATIVE RELIEF VALVE
3.2	1	CABIN HEAT EXCHANGER
3.3	1	CABIN TEMPERATURE SELECTOR
3.4	1	CABIN TEMPERATURE ANTICIPATOR
3.7	1	CABIN TEMPERATURE CONTROL
3.8	1	CABIN TEMPERATURE SENSOR
3.14	1	CABIN BLOWER DIVERTER VALVE
3.17	2	CABIN BLOWER SELECTOR SWITCH
3.18	2	CABIN RECIRCULATING BLOWER
3.27	2	CABIN VENT VALVE
3.28	1	CABIN PRESSURE REGULATOR
		GROUP IV - OXYGEN SUPPLY
4.13	1	BACK PACK SUPPLY SHUTOFF & PRESSURE RELIEF VALVE
4.14	1	BACK PACK SUPPLY CAP
4.16	1	DEMAND PRESSURE REGULATOR & RELIEF VALVE
4.17	1	MANUAL O_2 SUPPLY VALVE
4.18	1	WATER QUICK DISCONNECT
4.22	1	EMERGENCY O_2 INFLOW CONTROL VALVE
4.23	1	RE-ENTRY O_2 SUPPLY SYSTEM O_2 TANK (2) O_2 FILL PORT (2) VALVE ASSEMBLY (2) PRESSURE REGULATOR (2) RELIEF VALVE (2) CHECK VALVE (2)
4.24	1	O_2 PRESSURE REGULATOR ASSEMBLY SHUTOFF VALVE (2) PRESSURE REGULATOR (2) RELIEF VALVE (2) CHECK VALVE (2)
		GROUP V - WATER SUPPLY SYSTEM
5.1	1	WATER SUPPLY QUICK DISCONNECT
5.2	3	WATER CHECK VALVE
5.5	1	SUIT EVAPORATOR WATER INFLOW CONTROL VALVE
5.10	1	POTABLE WATER TANK
5.12	1	FREON QUICK DISCONNECT VALVE
5.14	1	WATER CHILLER
5.15	1	WASTE WATER TANK
5.18	2	WATER SHUTOFF VALVE
5.19	1	WATER TANK PRESSURE RELIEF VALVE
5.22	1	POTABLE WATER SUPPLY ASSEMBLY SUPPLY VALVE (2) HEATER
5.23	2	WATER PRESSURE RELIEF VALVE
5.24	2	TANK PRESSURE CONTROL & RELIEF VALVE
5.25	1	FREON FLOW VALVE
5.26	1	WATER QUICK DISCONNECT

F VALVE WITH MANUAL OVERRIDE

CTUATED 3-WAY VALVE

CTUATED 3-WAY VALVE
VERRIDE

CHECK VALVE

SELF SEALING QUICK DISCONNECT

QUICK DISCONNECT

Figure 75. Environmental Control System

[redacted]

Pressure Suit Circuit Subsystem

The purpose of the pressure suit circuit is to automatically control the flow, pressure, temperature, and composition of the pressure-suit gas. This system, in conjunction with the command module pressure and temperature control subsystems, will also control these environmental conditions in the command module when any or all the crew are out of their pressure suits.

These functions will be provided by a water separator, a regenerative heat exchanger, oxygen demand regulators, a debris trap, air compressors, CO_2 and odor absorbers, and an air cooler. Component redundancies will be provided as required to obtain the necessary reliability for the Apollo missions.

Water-Glycol Coolant Subsystem

The water-glycol coolant subsystem is basically a closed intermediate heat-transfer loop which permits heat to be transferred from the space vehicle interior to the space radiators. A primary purpose of this subsystem is to provide cooling for the crew and the electronic equipment. This function will be accomplished by pumps, coldplates, heat exchangers, valves, and controls as required.

Command Module Pressure and Temperature Control Subsystem

The primary purpose of this subsystem is to automatically maintain the pressure and temperature of the command module interior within prescribed limits. This function will be accomplished in conjunction with the pressure-suit circuit subsystem by means of regulated oxygen inflow, recirculation blowers, a heat exchanger, a temperature control and sensor, command module pressure relief valve, and various other valves and controls.

Oxygen Supply Subsystem

The oxygen supply subsystem consists of the normal oxygen supply system and the reentry oxygen supply system.

The normal oxygen supply system is capable of supplying all of the required oxygen for the entire mission up to the reentry phase. The system functions by reducing the pressure of the space vehicle oxygen supply system to the nominal working pressure required by the suit circuit, coolant reservoir potable water tank, and water separator pump pressure controls. This function will be performed by suitable pressure regulators, demand regulators, and shutoff and check valves. This system will also provide for the recharging of the back-packs in the command module.

[redacted]

The reentry oxygen supply system will supply the oxygen required for mission completion after separation of the service module from the command module. This system will store gaseous oxygen at a high pressure. During system operation, the high pressure will be reduced to the nominal working pressure of the various suit circuit pressure controls. This function will be accomplished by oxygen storage tanks, pressure regulators, and valves.

Water Supply Subsystem

The water supply subsystem will provide water for emergency heat transfer operation in the event of malfunction of the water-glycol heat transfer loop, supplementary heat transfer during orbital mission modes, and potable hot and cold water for consumption by the crew members. Potable water will be stored prior to take-off and will be replenished from the fuel cells. These functions will be accomplished by utilizing water tanks, pressure controls, and valves as required. This subsystem will also provide for Freon cooling during launch and boost.

Cryogenic Storage System Description (Figure 76)

The cryogenic storage system (CSS) will be composed of two subsystems—oxygen and hydrogen. Each subsystem will consist of two tanks and interconnecting plumbing. Oxygen will be used for the spacecraft cabin and pressure-suit atmosphere, while oxygen and hydrogen will be supplied for fuel-cell operation.

An internal electric heater will be required for each tank to maintain operating pressure above the critical pressure of the fluid. The fill and vent valves will be of the quick-disconnect type. Relief valves for each tank will consist of one valve for high pressure and high flow in direct connection with the tank, and one valve for low pressure and low flow located between the check valve and the system shutoff valve. The shutoff valves will control the flow and routing of the operating medium. The quantity will be measured by a platinum resistor, and the pressure will be monitored by a pressure transducer.

Waste Management System Description (Figure 77)

The waste management system (WMS) is designed to remove the gaseous, solid, and liquid wastes from within the command module of the Apollo. The system will remove objectionable odors from the food, refuse, and personal equipment storage compartments. Wastes, in the form of fecal odors, urine, particulate matter, food and water spillage, and results of unanticipated bodily functions, will be removed by a vacuum cleaner, urine disposal system, and fecal odor lines. The resultant gaseous wastes will be transferred to the ECS for further processing. These functions will be accomplished by a blower, switch, flexible lines, urine separator, chemical tank, and valves.

[redacted]

[redacted]

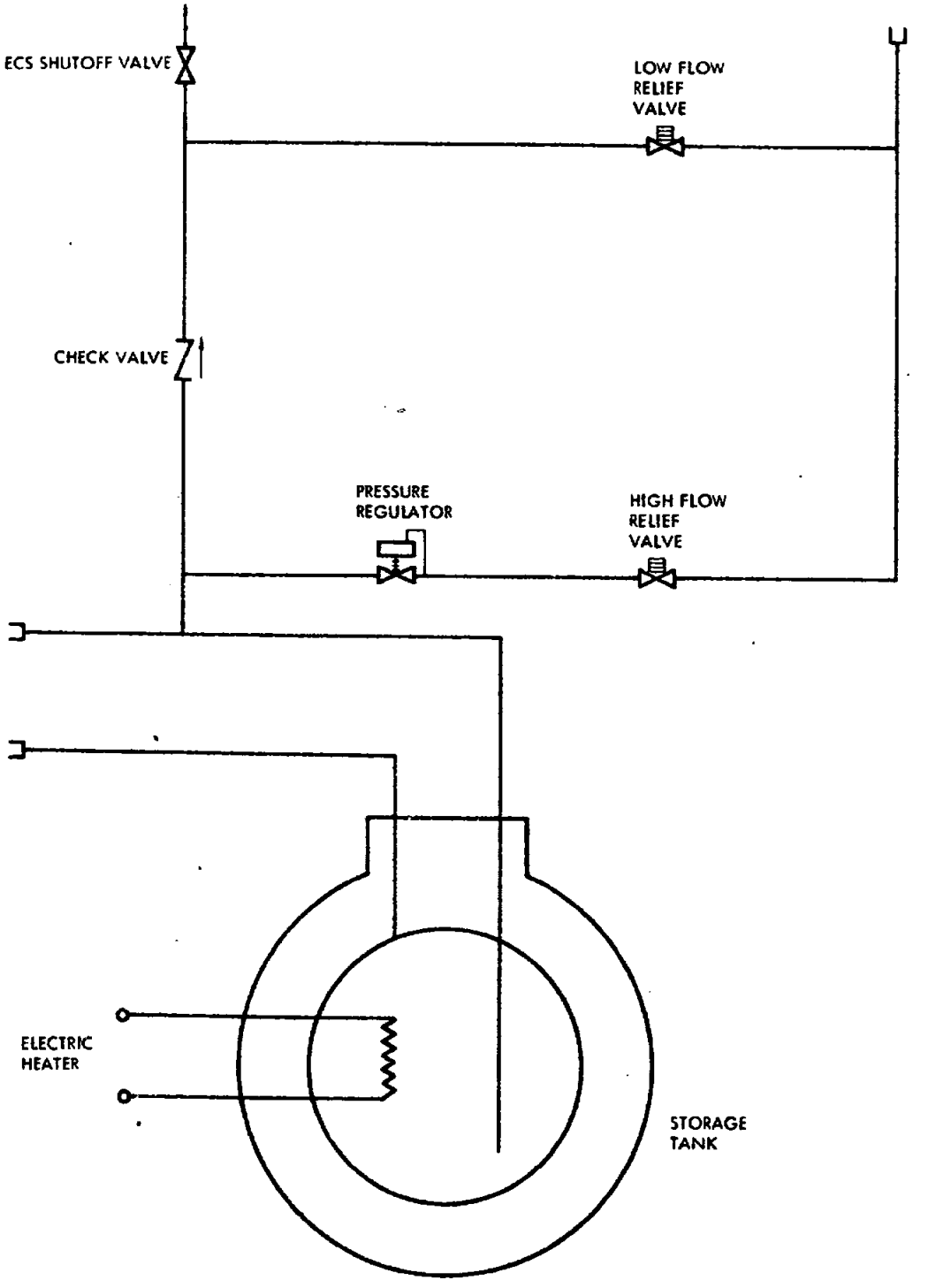


Figure 76. Cryogenic Storage Tank

[redacted]

[redacted]

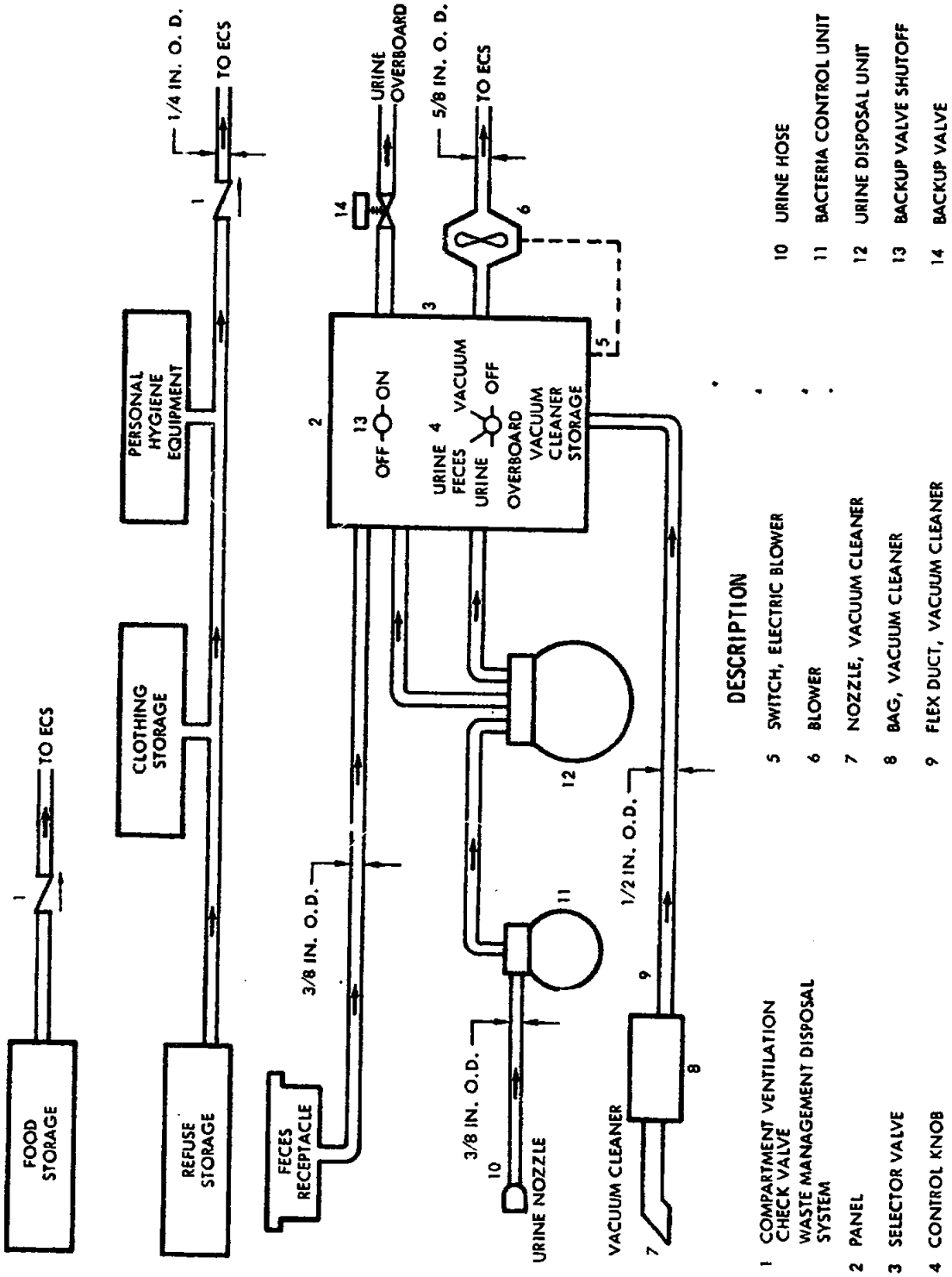


Figure 77. Waste Management System

[redacted]

[redacted]

Development Plan

The project scope includes study, design, and development of the system; liaison between NASA and the subcontractor; supervision of manufacture and assembly; approval of required documentation; establishment of a program of tests and test observation; and an analysis of collected data for reliability. The CSS and a large portion of the ECS are each being developed by a subcontractor; components of the WMS are being prepared for submittal for bids. Certain other parts of the system, such as electronic component cold plates and the space radiators, are being designed and developed by S&ID.

Studies

Studies are constantly being conducted to provide optimum solutions to problems that may arise during performance of tasks assigned to the subcontractor.

Design and Development

The detailed requirements of the system are established by S&ID. Two major components of the system are designed and developed in-house; these components are the ECS space radiators and the electronic component cold plates. The CSS is subcontracted to Beech Aircraft. The remaining, and largest, portion of the CSS is subcontracted to AiResearch Manufacturing Company. This subcontractor also produces most of the bench maintenance items of GSE which are associated with the ECS. These two major subcontractors are under the technical direction of Apollo Engineering, and they perform all development and qualification testing of their portions of the system. The installation of the system in the vehicle is designed and coordinated by Apollo Engineering.

Manufacturing

The quality of all equipment manufactured by the subcontractor is controlled in compliance with a quality control program established by S&ID.

Program Control

Since the Apollo program is an advanced space and development project, all specified tasks may vary in significance as the program progresses. For this reason, changes will occur occasionally, requiring the initiation, curtailment, or termination of tasks. A reliability program is implemented to ensure compliance with mission reliability and safety requirements.

[redacted]

[redacted]

Documentation

S&ID authorizes and approves the required documentation prepared and submitted by the subcontractors in accordance with delivery schedules, type, classification, and quantities specified in the ECS Work Statement. The required documentation is generally of the types and classification as that which NASA requires of S&ID.

Requirements

The design and performance requirements of the ECS are as follows:

1. The subsystems will meet the prescribed performance parameters.

2. All components will be subjected to the full environmental conditions to determine deficiencies in design and fabrication.

3. All components will operate at their design ambient operating pressures.

4. A separate set of components will be cycled or operated to determine the unit's wear-out characteristics.

5. Cycling will be performed under the most severe conditions under which the unit may expect to operate.

Problem Areas

A program for anticipating and identifying problem areas parallels design and development. By this means, problems may be resolved or introduced in phase with the program. Design studies of problem areas include those generated by NASA, as well as those developed internally. The objective of these studies is to increase system reliability and reduce hardware weight, volume, and cost. Some of the areas investigated are as follows:

1. Evaluation of component backup and alternate functions

2. Multiple use of common components

3. Simplification of controls

4. Conservation of power

5. Integration with other systems

6. Advantage of changing performance requirements

[redacted]

[redacted]

7. Minimization of weight

Results of some of the investigations which have already been carried out are:

1. Water separator. A study of an alternate separator design has resulted in the development of the wick-type separator. This unit has been accepted and is now included in the ECS.

2. Atmosphere. The 5.0 psia, 100 percent oxygen atmosphere has been substituted for the originally proposed 7.0 psia mixture of oxygen and nitrogen.

3. Catalytic burner. The feasibility of completely eliminating the catalytic burner has been studied, with the result that this component has now been deleted from the system.

4. Snorkel. The decision to use cabin vent valves instead of snorkels has eliminated the need for a snorkel improvement study.

5. Water glycol. Water glycol was selected over other coolant fluids tested.

Specific problem areas that will require continued investigation are as follows:

1. Space radiator. Trade-offs of radiator effectiveness versus weight and complexity

2. Water glycol. Investigation of more effective water-glycol mixtures

3. Back-packs. Studies of back-pack charging techniques, cryogenic or gaseous

4. Material breakdown. Studies of a breakdown of materials within the module that may produce toxic gases under extreme temperatures or low pressures

5. Radiation protection. Further investigation of the dangers of radiation and methods of protection

6. Lithium hydroxide. A consideration of media other than lithium hydroxide to remove CO_2

7. Pressure suits. A continued study of required flow rates based on the metabolic processes within the pressure suits

[redacted]

[redacted]

8. LEM cooling. The feasibility of storing and transferring urine and water to the lunar excursion module (LEM) for cooling requirements

9. LEM pressurization. Methods of pressurization of LEM for lunar mission

10. Radiation shielding. The storage and use of water, urine, and other fluids for radiation shielding

11. Cryogenic gas tank insulation. Methods of maintaining heat leaks in tank walls at an acceptable level

12. Cryogenic fluid temperature. Limitations on accuracy of instrumentation due to stratification during zero-g condition

13. Sensing.

14. Tank wall resistance to noise. Effects of acoustics on outer shell of cryogenic tanks

15. Cabin pressure versus ambient pressure. Methods of maintaining required cabin pressure schedule due to the variation of ambient pressures during boost and reentry

Subsystem Compatibility

A complete system will be assembled and operated under all modes of the mission profile in order to ascertain the compatibility of the subsystems. This system will be installed in a geometric mock-up of the mission module, with all of its associated plumbing and environmental conditions.

Testing

Development, qualification, and reliability tests are performed on all systems, subsystems, and components. Designs are modified to correct any deficiencies manifested during the tests. Tests are then repeated, after modification of design, to ensure compliance with the applicable specifications.

Compatibility and evaluation testing will be conducted on boilerplate 14, house spacecraft No. 1. System performance and compatibility tests will be conducted on airframe 006, house spacecraft No. 2. Environmental proof tests verifying the design adequacy under simulated mission environments will be performed on airframe 008. Initial flight performance will be conducted on the first manned recoverable spacecraft airframe 009 and flight performance verification on the manned orbital spacecraft airframe 011.

[redacted]

[redacted]

Subcontractor Milestone Schedules

The subcontractor milestone development schedules are shown in Figures 78 and 79. The WMS schedules are not included, since supplier selection is in the initial stages. The WMS equipment will be procured by components and will consist of one or more suppliers.

ELECTRICAL POWER SYSTEM

System Description

The primary power source for the Apollo spacecraft will be a fuel cell system. The fuel cell system will consist of three fuel cell modules, plus the following mechanical and electrical accessories: reactant tankage, piping, controls and radiator.

Each fuel cell module will consist of a battery of non-regenerative hydrogen-oxygen fuel cells connected in series. The fuel cells will be low-pressure, intermediate-temperature, Bacon type, using potassium hydroxide electrolyte.

Each reactant will be stored in the supercritical cryogenic state in two tanks of equal volume.

A space radiator system will be designed to be capable of operation in deep space, earth and lunar orbits. Condensed water will be separated and supplied to the environmental control system in potable form.

Additional electrical power will be provided by three silver-zinc storage batteries. Two of these batteries will supply all power during entry snd recovery flight phases, as well as supplementary power during peak-load periods on the fuel cell system. The third battery will be isolated from the electrical power system and will supply only post-landing loads.

All fuel cell modules and both entry batteries will be connected to a dual, redundant, essential bus system supplying all essential loads redundantly, so that power to all essential systems will be maintained in the event of failure of one or two fuel cell modules, one entry battery, or one essential bus. Non-essential loads will be connected to a separate bus, which can be disconnected from the essential bus in the event of failure of two fuel cells or one entry battery. (Essential loads are defined as those essential to safety of flight, and non-essential loads as those necessary to successful completion of mission.)

Circuit protection for the power distribution system will be provided by a system of circuit breakers and diodes so that power will not be interrupted to any single essential load due to short circuits in the power source, feeder circuit, or either essential bus.

[redacted]

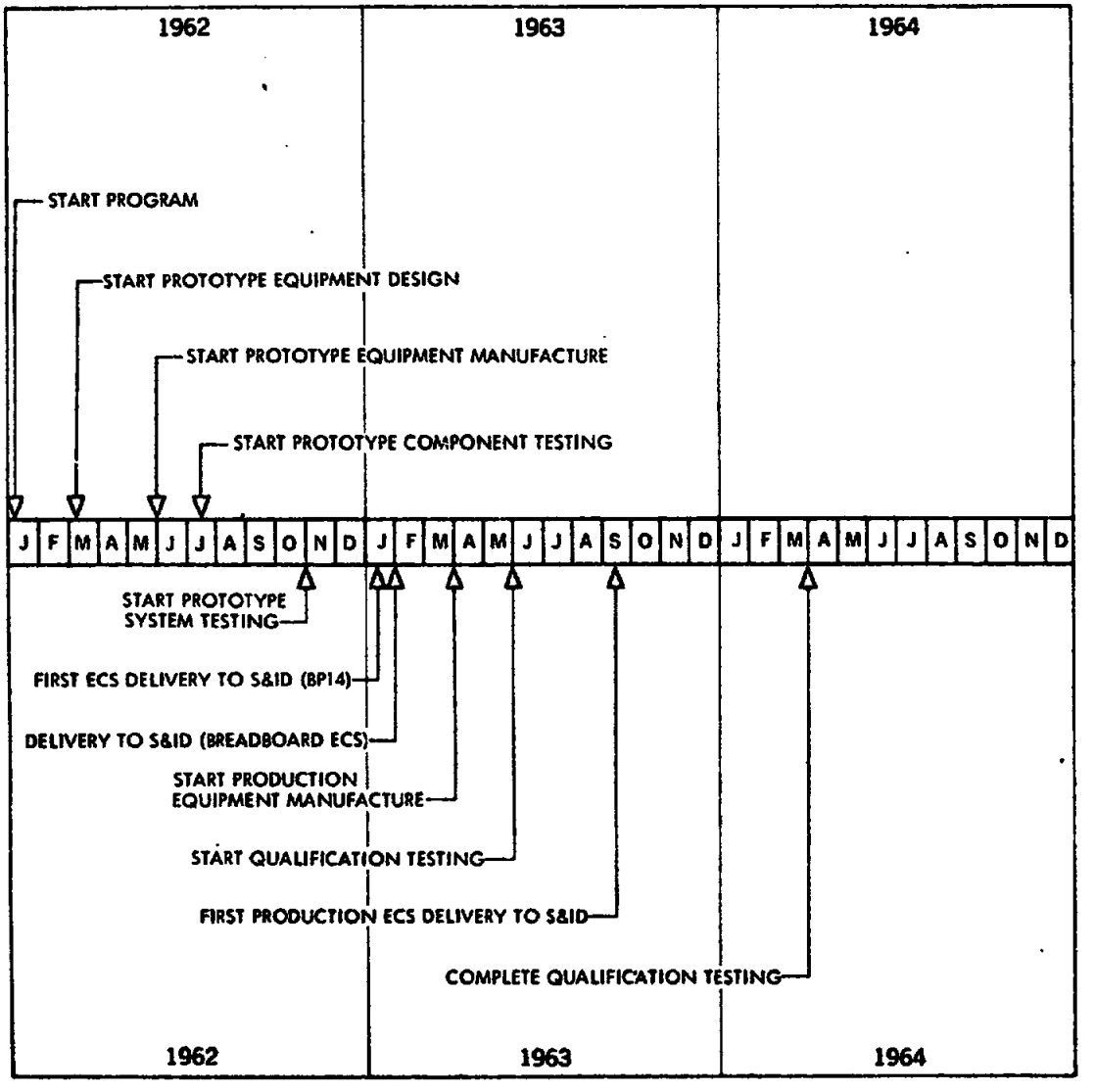


Figure 78. AiResearch Program Milestones

[redacted]

[redacted]

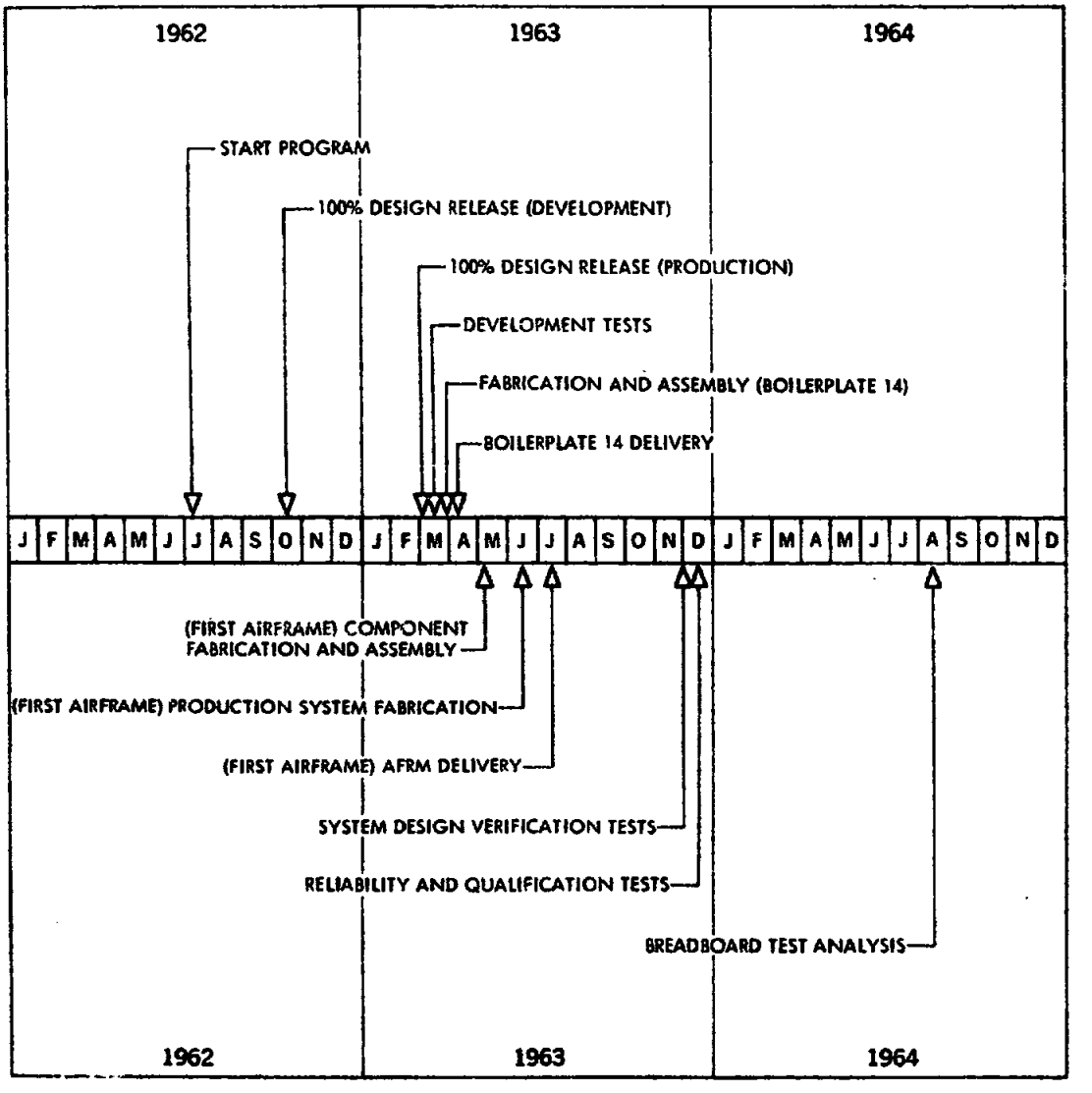


Figure 79. Beech Program Milestones (Completion Dates)

[redacted]

[redacted]

Three static inverters will supply 400 cps, three-phase ac power. One inverter only will operate, with the other two acting as standby units.

One battery charger will be provided to recharge, prior to earth reentry, any of the three batteries after normal or emergency discharge.

Two independent sequencing systems will be provided to control the sequential operation of the pyrotechnic and related systems for abort and separation operations. A block diagram of the electrical system is shown in Figure 81.

Development Approach

Development, design verification, evaluation, and qualification testing of electrical power system components, subsystems, and systems will be performed by S&ID and various subcontractors. A test program of functional and environmental tests at each level will be designed to provide reliable hardware and systems. See Figure 80 for a block diagram of the development plan.

Fuel Cell Subsystem - Subcontractor Tests

The fuel cell subcontractor will perform the following development and qualification tests on the fuel cell components and system:

1. Major component development tests

   a. Development experiments to determine manufacturing processes and performance parameters will be performed on single cells, pumps, regulators, and control valves.

   b. Application suitability and design qualification tests will be performed on all major components and major modules.

   c. Accelerated life tests will be performed on critical modules and components such as single cells, pumps, regulators, and valves.

2. Fuel cell module testing

The concept of a system composed of three independent modules allows most development and test work to be done on modules, rather than

[redacted]

[redacted]

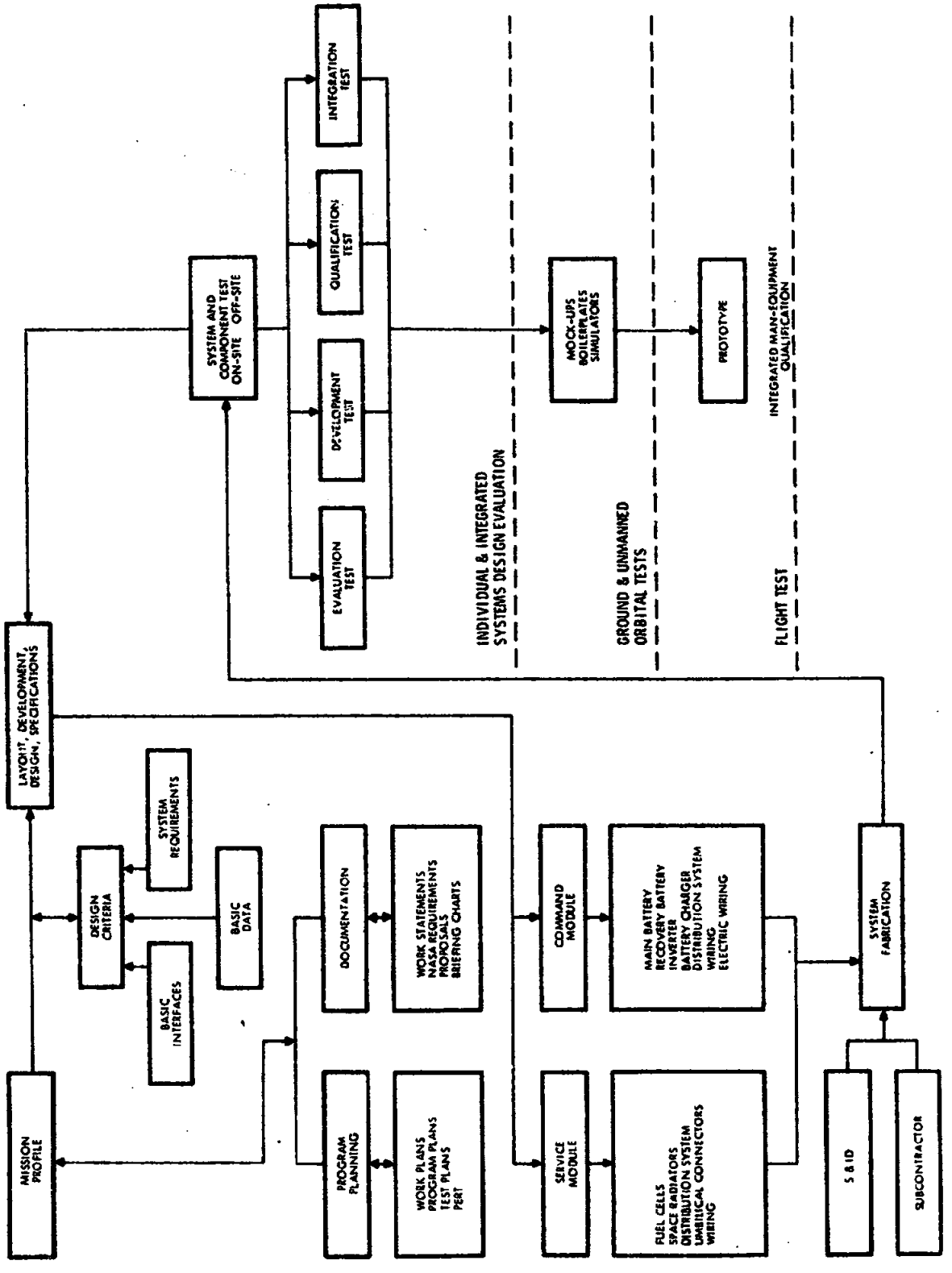


Figure 80.. Electrical Power System Development Plan

[redacted]

[redacted]

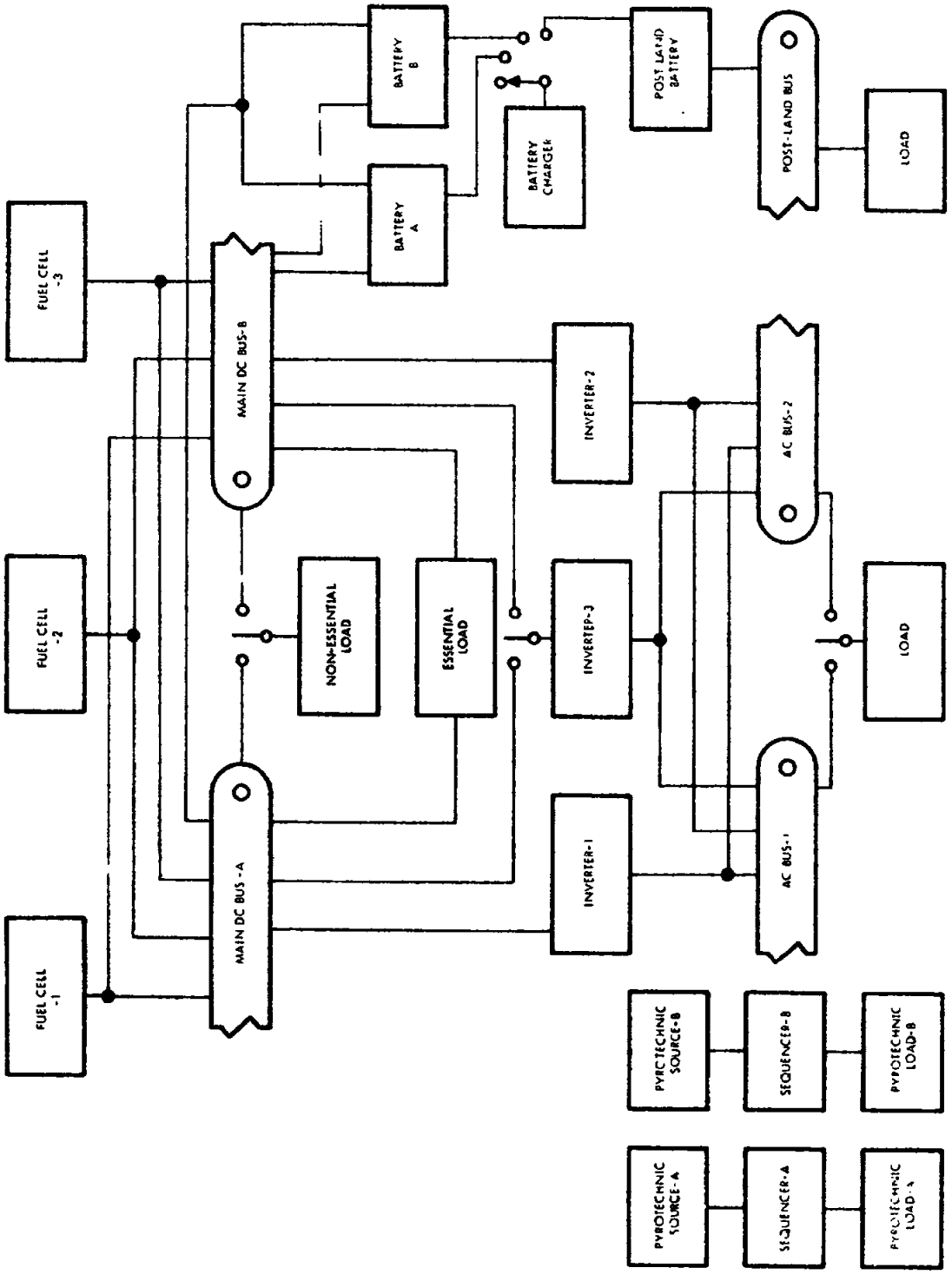


Figure 81. Electrical Power System

[redacted]

[redacted]

on complete fuel cell systems. Modules will be operated independently for the qualification tests.

During development, active experimental modules and systems will be utilized in tests to demonstrate performance, compatibility with vehicle equipment, and durability under simulated environments. Final formal qualification and reliability tests will be made with prototype production modules in which all improvements will be incorporated.

S&ID Fuel Cell Subsystem Tests

Certain S&ID fuel cell subsystem tests will be redundant with those performed by the subcontractor, but most tests will augment the subcontractor's program with evaluation and performance verification to thoroughly explore systems interface problems. The S&ID fuel cell subsystem tests will combine the following subsystems for the first time and test them for performance and compatibility:

1. Subcontractor's fuel cell modules
2. Radiator system
3. Reactant tankage and control system
4. Environmental control system
5. Electrical power distribution and control subsystem

Test objectives will be:

1. To obtain reactant consumption, pressure, temperatures, and water generation data on fuel cells
2. To assess the performance of heat exchangers, water separators, and other mechanical accessories
3. To assess thermal vacuum performance of fuel cell radiators with fuel cells
4. To determine minimum, maximum, transient, and specific power output and load sharing characteristics of the fuel cell power system

[redacted]

[redacted]

5. To determine steady-state and transient voltage response of the complete system

6. To determine off-design performance, such as

   a. Short-circuit conditions and system protective interaction

   b. Radiator damage effects

   c. Leak detection in reactant tanks and lines

Electrical Power Distribution Subsystem

Major Equipment

S&ID will perform evaluation tests to determine the optimum technical approach and component types for static inverters, batteries, battery chargers, lighting systems, sequencers, and pyrotechnic systems. Subcontracts to equipment suppliers will specify development, qualification, and reliability tests for performance and environmental conditions to qualify equipment to the system level. These tests will be performed by the subcontractor before delivery of prototype equipment.

Components and Materials

S&ID will perform evaluation tests to determine optimum materials, manufacturing techniques, and technical approaches for wire, connectors, circuit breakers, relays, timing devices, diodes, and other components and materials to be used in the Apollo electrical power system. Material and component specifications will specify the necessary qualification and reliability testing to be performed by the supplier.

Electrical Power Distribution Subsystem Testing

S&ID will first assemble prototype components and equipment into a complete breadboard electrical power distribution subsystem, which will electrically duplicate the final spacecraft system. Electrical loads will be simulated by load banks where necessary and by actual equipment where practical. Initially, storage batteries will be used to duplicate the fuel cell subsystem power source. After the breadboard and prototype fuel cell systems are delivered, they will be used with the power distribution subsystem to test the entire electrical power system performance, as described above, under fuel cell system testing.

[redacted]

[redacted]

Electric Power Flight Testing

Performance characteristics of the sequencer and pyrotechnic devices will be evaluated in pad abort (boilerplate 6 and airframe 10) and airborne abort tests (boilerplates 12, 22, 23, and airframe 2). The compatibility of the electric power system with the utilizing systems will be evaluated and characteristics determined on boilerplate 14 (house spacecraft 1) and airframe 6 (house spacecraft 2). In addition, preliminary performance data will be obtained from breadboard tests conducted in the laboratory test facility. Dynamic and environmental effects will be determined on airframes 1 and 8; propulsion and environmental spacecraft, respectively. Flight testing will occur on airframes 9 and 11 to qualify the electric power system.

COMMUNICATIONS SUBSYSTEM

Objectives

The communications subsystem will be designed to provide the following capabilities:

1. Convert optical data to electrical signals through the use of TV equipment

2. Condition electrical signals to a common level to allow convenient display, recording, and transmission

3. Provide stable frequencies for synchronization of time-dependent spacecraft subsystems and equipment, except for the guidance and navigation subsystem, and provide a time reference for all time-dependent spacecraft operations

4. Assemble and encode in suitable form for transmission, the data required by the Mission Control Center during spacecraft missions

5. Store for future read-out that data which cannot be transmitted to the ground in real time

6. Provide for voice communication between crew members and provide for the transfer of audio signals to and from transmitters and receivers

7. Provide omnidirectional and high-gain antennas as required to transmit and receive electromagnetic signals.

[redacted]

[redacted]

8. Transmit voice, telemetry, stored-data, and TV signals to the ground operational support stations

9. Provide for two-way voice communication with the lunar excursion module (LEM) and with the crew during extra-vehicular activities of the crew

10. Receive and demodulate voice transmissions from the ground operational support stations

11. Provide for reception of limited biomedical data from the crew during extra-vehicular activities and from the LEM when in transit to and from the lunar surface

12. Receive and transmit in phase coherence a DSIF-type signal to enable the ground operational support stations to track the spacecraft in angle, velocity, and range

13. Receive and respond to interrogating radar signals

14. Provide electronic recovery aids in the location and recovery of the spacecraft following entry

Development Plan

The S&ID project scope of the Apollo communications subsystem will include the study, design, and development of the subsystem, the liaison between NASA and the subcontractors, the supervision of manufacturing and assembling, the approval of required documentation, the establishment of a program of tests and test observation, and the analysis of collected data for reliability. (See Figure 82.)

In addition to the design of the subsystem, S&ID will assume the responsibility of directing this project to its successful completion. While a large portion of the subsystem will be developed or procured by a major subcontractor, the remaining equipment such as spacecraft central timing equipment, and the major portion of the antenna equipment will be procured from other subcontractors.

Design Analysis and Optimization

S&ID with support from the major subcontractor will conduct studies to determine the optimum subsystem configuration and the resulting equipment requirements. Studies will be conducted as necessary by S&ID to provide optimum solutions to problems that may arise in the subsystem during the Apollo program.

[redacted]

[redacted]

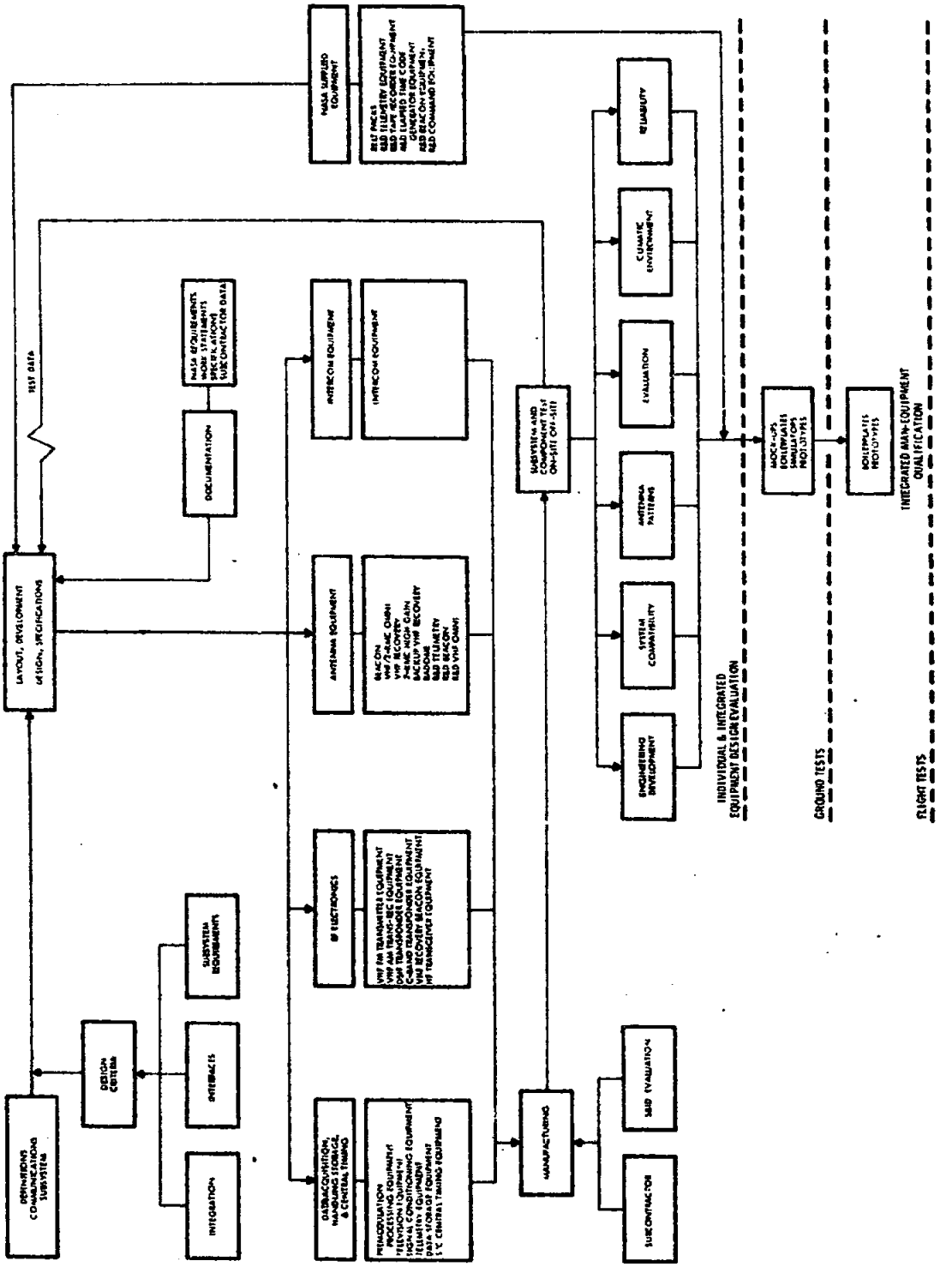


Figure 82. Development Plan, Communications Subsystem

[redacted]

[redacted]

Design and Development

Using the equipment requirements generated from the studies and from NASA inputs, specifications will be prepared for the procurement of the equipment. These specifications will be submitted by S&ID or by the major subcontractor to prospective subcontractors for bids, with the exception of those specifications on the equipment which NASA and S&ID agree should be manufactured by the major subcontractor. After the subcontractors have been selected, the development program will begin with the design and development of breadboards. As soon as breadboard development has progressed to a point that ensures basic performance requirements, the development of prototype equipment will be initiated.

The design and qualification of the communications subsystem will be based upon the following:

1. The subsystem will meet the required performance parameters.

2. All equipment will be subjected to a level of environmental conditions required to determine deficiencies in design and fabrication.

3. A separate set of components will be cycled or operated to determine the reliability characteristics.

4. Cycling will be performed under programmed environmental conditions consistent with mission requirements.

Each subcontractor will be responsible for the design and development of ground support equipment for the equipment that they supply, but the equipment must be approved by S&ID. The design of this equipment must be compatible with the designs of the spacecraft and the ground support equipment of the Apollo project.

Manufacturing

The quality of all equipment manufactured by the subcontractors is controlled by the quality control program established by S&ID.

Since the Apollo project is an advanced space and development project, all specified tasks may vary in significance as the program progresses. It will be a responsibility of S&ID to make the appropriate decisions when it becomes apparent that the initiation, curtailment, or termination of a task is required. A reliability program will be implemented to ensure mission reliability and safety requirements.

[redacted]

[redacted]

Documentation

S&ID will authorize and approve the required documentation prepared and submitted by the subcontractors.

Types of Equipment

The communications subsystem will consist of equipment described in the following paragraphs.

1. VHF/FM transmitter equipment. The VHF/FM transmitter equipment will be used for transmission of telemetry during near-earth phases of the missions.

2. VHF/AM transmitter-receiver equipment. The VHF/AM transmitter-receiver will be used for two-way voice communications between spacecraft and earth during earth-orbital missions and near-earth phases of lunar missions, between spacecraft and the LEM, between spacecraft and the belt-pack transceiver, and between spacecraft and rescue aircraft. The transmitter-receiver will be capable of transmitting on one frequency and receiving on either of two frequencies. A capability of receiving biomedical data from the LEM or from the belt-pack transceiver during extra-vehicular activities of the crew will be included. The transmitter-receiver operates in the 260- to 300-mc band.

3. DSIF transponder equipment. The DSIF transponder equipment will provide for transmission of telemetry data and TV, pseudo-random noise (PRN) ranging, two-way voice, and coherent doppler tracking during cislunar phases of the missions. During near-earth phases of the missions, it can provide the same operation when within line-of-sight of suitably equipped ground stations. A 100 percent spare transponder will be provided.

4. C-band transponder equipment. The C-band transponder will be used for radar tracking during the near-earth phases of the mission and will be compatible with the AN/FPS-16 radar system.

5. VHF recovery beacon equipment. The VHF recovery beacon will be used to aid rescue aircraft in locating the spacecraft during the post-landing phase of the mission and will be compatible with the radio direction finding systems presently available.

[redacted]

[redacted]

6. HF transceiver equipment. The HF transceiver will be used to aid rescue forces in localizing the spacecraft during the post-landing phase of the mission to an area within which the VHF radio direction-finding equipment can operate and locate the spacecraft.

7. Beacon antenna equipment. The beacon antenna equipment will be used with the C-band transponder for near-earth radar tracking.

8. VHF/2-KMC omni-antenna equipment. The VHF/2-kmc omni-antenna will consist of a VHF omni-antenna capable of broadband operation to be used for all VHF functions from lift-off to the recovery phase, and a 2-kmc omni-antenna to be used with the DSIF transponder for near-earth operation or for emergency cislunar operation. The VHF/2-kmc omni-antenna will be jettisoned prior to the drogue parachute deployment.

9. VHF recovery antenna equipment. A VHF recovery antenna will be provided for all VHF functions from recovery through the post-landing phase. It will be automatically extended after the main parachute is deployed.

10. Back-up VHF recovery antenna equipment. A back-up VHF recovery antenna will be provided for all VHF functions during the post-landing phase in the event that the VHF recovery antenna should be damaged during the landing. It can be extended after the landing has been completed.

11. HF recovery antenna equipment. The HF recovery antenna will be used with the HF transceiver during the post-landing phase. It will be extended after the landing has been completed.

12. 2-KMC high gain antenna equipment. The 2-kmc high-gain antenna will be used with the DSIF transponder. The antenna will normally be stored in the service module and will be extended during cislunar communication operations. The antenna will be provided with gimbal drives which permit rotation of the antenna for hemispherical coverage.

13. Radome equipment. A radome will be provided to cover the VHF/2-kmc omni-antenna.

[redacted]

[redacted]

14. R&D antenna equipment. The following R&D antenna equipment will be provided on certain boilerplate and prototype spacecraft for use with NASA furnished R&D instrumentation equipment:

    R&D beacon antenna equipment

    R&D telemetry antenna equipment

    R&D VHF omni-antenna equipment

15. Intercommunication equipment. The intercommunication equipment will provide the crew with intercommunication in both pressure-suit and shirt-sleeve environments, and will permit flexibility of voice communication over the various spacecraft transmitters and receivers.

16. Television equipment. A televison camera will be used to provide real time video information for transmission to the ground operational support stations. Video information will be transmitted to earth via the DSIF transponder for observation of the crew and flight operations. The camera will be portable.

17. Signal conditioning equipment. Signal conditioning equipment will be used where required to condition signals to a standard level and form before commutation in the telemetry equipment.

18. Telemetry equipment. The telemetry equipment will process spacecraft data into forms suitable for transmission to earth. Conditioned analog data will be commutated and digitized. This information and other digital data will be coded into PCM format and transmitted to earth during cislunar phases via the DSIF transponder. During near-earth phases of all missions, data will normally be transmitted over the VHF/FM transmitter.

19. Premodulation processing equipment. Premodulation processing equipment will be provided to process and combine the outputs of the intercommunication, data storage, television, and telemetry equipment for the various modes of modulating the rf equipment.

20. Data storage equipment. A magnetic tape recorder will be provided for onboard storage and playback of analog and digital data. Data can be stored during critical periods and during communication blackouts and played back later for transmission to earth, or data can be stored for playback after recovery of the spacecraft. Erase capability is also provided.

[redacted]

[redacted]

21. Spacecraft central timing equipment. Spacecraft central timing equipment will be used to provide a time reference for the electrical power subsystem, telemetry equipment, data storage equipment, television equipment, and photographic cameras and to present time information to the crew. This equipment will be synchronized to the guidance and navigation subsystem.

Problem Areas

A number of problem areas are anticipated in the communications subsystem and these have been incorporated in the study program to be conducted by S&ID. New problems will be phased into the study program as they arise. The problem areas that affect the subsystem configuration or equipment design and development will be given special consideration. The major problem areas as now envisioned are listed below.

Equipment or Area	Problem
Reentry blackout effects	Determination of the characteristics of the reentry ionization effects and feasibility of plasma sheath tracking.
Frequency allocations	The large number of rf links required for the launch vehicle may cause problems such as interference, multiplexer design problems, and difficulty in obtaining the desired frequency assignments for the spacecraft.
Interface with LEM	Assurance of adequate GOSS coverage during the transfer of the LEM to the docking position after translunar injection. Possible effect of the method of LEM transfer and docking upon the ability to deploy the 2-kmc high gain antenna.
	Effect of docked LEM upon the patterns of the VHF omni-antenna and the 2-kmc omni-antenna.
Modulation techniques	Determination of efficient and practical modulation methods to be used with the rf equipment in the different modes of information transfer. Perform trade-offs of power, complexity, reliability, weight.

[redacted]

[redacted]

Equipment or Area	Problem
Telemetry	Implementation of the spacecraft prelaunch automatic checkout equipment (SPACE) checkout approach will cause changes in the telemetry equipment requirements.
Reliability	Determination of the reliability characteristics and demonstration that the apportioned reliability has been achieved within the limitations of cost and schedule.

In addition to the above problem areas, each piece of equipment will be subjected to a design study program. The final objective of this program is to increase subsystem reliability and reduce hardware weight and volume. Subject matter will consist initially of the following:

1. Evaluation of equipment back-up and alternate functions
2. Multiple use of common components
3. Simplification of controls
4. Conservation of power
5. Integration with other subsystems

INSTRUMENTATION

Objectives

The objectives of the instrumentation subsystem will include the following:

Sense and convert to electrical signals those physical parameters which must be displayed, stored, or transmitted.

Condition electrical signals to a common level convenient for display, storage, or transmission.

Provide adequate means for connecting electrical signals to display, storage, and transmitting equipment.

Obtain photographic records of events occurring within or outside the spacecraft.

[redacted]

Types of Equipment

Sensor Equipment

The sensor equipment will sense various physical phenomena of the spacecraft and its subsystems, convert them into electrical signals for telemetry, data storage, and data display for the crew.

Signal Conditioning Equipment

Signal conditioning equipment will convert electrical signals to a standard level and form prior to display, storage, or commutation in the telemetry equipment.

Data Distribution Equipment

Distribution panels or other cross-connection devices will permit connection of signal inputs to the proper signal conditioner input and permit connection of signal conditioner outputs to the telemeter, the display, to GSE, or the data storage equipment.

Photographic Equipment

Photographic equipment will consist of one 16 mm cine camera and one still camera. Both cameras will operate inside and outside the spacecraft and will be equipped with wide angle and telephoto lenses. A window with characteristics compatible with the photographic requirements will be provided.

Radiation Detection Equipment

Radiation detection equipment will measure radiation rates and total dosages of various types of particles. Data will be displayed for the crew and transmitted to earth for analysis.

Development Plan

Project scope of the Apollo instrumentation subsystem of the contractor (S&ID) includes the analysis, design, and development of the subsystem; the liaison between NASA and the subcontractors, the supervision of manufacturing and assembly; approval of required documentation; establishment of a program of tests and test support, and an analysis of collected data for reliability.

In addition to the design of the subsystem, the contractor will assume the responsibility of directing this project to its successful completion.

[redacted]

[redacted]

Design Analysis and Optimization

The contractor, with support from the major subcontractor, will analyze the subsystem design to determine the optimum configuration and the resulting equipment requirements. Necessary analyses will be performed by the contractor to provide optimum solutions to subsystem problems arising during the Apollo Program.

Design and Development

The contractor, upon request by subcontractors, will arrange for the use of NASA or other government facilities where appropriate. The detailed requirements will be established by the contractor and supported by NASA and the subcontractors for the subsystem. Each subcontractor will be responsible for design and development of GSE that they supply, but equipment must be approved by the contractor. Design of this equipment must be compatible with designs of the spacecraft and the Project Apollo GSE.

The development program will begin with individual component performance determinations. As soon as component development progresses to a point that ensures basic performance requirements, the development of the required equipment will begin. All equipment will be subjected to environmental conditions to determine whether deficiencies in design and fabrication exist.

Each piece of equipment will undergo a design analysis program. Final objective of this program is to increase subsystem reliability and reduce hardware weight and volume. Initial subject matter will consist of the following:

Evaluation of equipment back-up and alternate functions

Multiple use of common components

Simplification of controls

Conservation of power

Integration with other subsystems

Manufacturing

The quality of all equipment manufactured by the subcontractors is controlled by the quality control program established by the prime contractor.

[redacted]

[redacted]

Since the Apollo project is an advanced space and development project, tasks may vary in significance as the program progresses. It will be a responsibility of the contractor to make appropriate decisions when it becomes apparent that initiation, curtailment, or termination of a task is required. A reliability program will be implemented to ensure mission reliability and safety requirements.

Documentation

The contractor will authorize and approve the required documentation prepared and submitted by the subcontractors in accordance with delivery schedules, type classification, and quantities specified in the delivery schedule.

Tests

Tests will be performed on the subsystem and on all equipment and components. Designs will be modified to correct any deficiencies revealed during the tests. Tests will be repeated after modification of design to ensure compliance with applicable specifications.

The types of tests required are defined in the following paragraphs.

Development Tests

Development tests will support the design of the subsystem, equipment, and components. These tests will be conducted under simulated, selected, and critical in-service environments.

Qualification Tests

Qualification tests of the fully developed subsystem and components will be performed to ensure their compliance with instrumentation subsystem requirements. The tests will be conducted under extended, simulated, and actual mission environments.

Reliability Tests

Reliability tests will be performed to ensure that the subsystem, equipment, and components will meet the high reliability requirements of the instrumentation subsystem. Reliability will be confined by a statistical analysis, where required, using data collected from all tests, including those conducted on a quantity of units under the reliability testing plan.

[redacted]

[redacted]

Quality Assurance Tests

Quality assurance tests to confirm nominal performance will be made on the subsystem, equipment, and components prior to delivery from the subcontractor to the contractor.

Compatibility Tests

A complete subsystem will be assembled and operated under all modes of the mission profile to assure compatibility of the equipment. This subsystem will be installed in a geometric mock-up of the spacecraft.

ELECTRONICS INTERFACES

Electronic Systems Installation

Controls and Displays

Main Display Console. Instruments are mounted on cold plates by using thermal contact material and wedge and clamp latches. Horizontal and vertical structural members carry loads from the cold plates to the forward bulkhead. The overall appearance resembles that of a rack and panel installation. Since the volume of the main display console is broken by the permanently installed cold plates, conventional rear wiring harnesses cannot be employed. Front wiring is installed immediately aft of the structural members. Connectors are mounted on extensions of the subpanel bezels and are mated manually to the center screw lock harness connectors.

In addition to conventional environmental tests, a rigorous testing program is required to verify the compressible thermal contact material, especially as it affects the design of the wedge and clamp latch.

Side Display Consoles. Hardware mounted on the side consoles consists largely of conventional switches and circuit breakers and will not require cold plate mounting. Conventional panel installation techniques are employed.

Lower Equipment Bay - Standard

Electronic systems units installed in the lower equipment bay are modular in construction and, for the most part, are standard in cross section. The units are mounted on both sides of horizontal cold plates by wedge and clamp latches which compress the thermal contact material between the units and the cold plates. Front wiring harnesses are installed immediately inboard of the cold plates and structural members. Connectors are mounted on extensions of the unit front panels and are mated manually to the center screw lock connectors in the wiring panels.

[redacted]

Conventional environmental tests and a rigorous testing program are required for this equipment.

Lower Equipment Bay - Nonstandard

Nonstandard electronic units, belonging to both the guidance and navigation and stabilization and control systems, require individual mounting techniques, although the cold plate-thermal contact material-latch technique is employed wherever possible. Units are shaped to accept coolant lines where the cold plates and compressible contact material are incompatible with precision mounting or internal structure of the units.

In-Flight Test System

The in-flight test system is installed in the right-hand, forward equipment bay. The data wiring, consisting of a center-core harness with rack and panel connectors, is installed as part of the overall spacecraft wiring and is located adjacent to the permanently installed structure and cold plates. Rack and panel electronic units, including the in-flight test system panel and manual test unit, are clamped to the cold plates.

Apollo Controls and Displays

Scope

The Apollo controls and displays subsystem presents information to and accommodates control action inputs from the spacecraft crew for manual initiation and supervision of vehicle maneuvers, event sequences, spacecraft systems operation, and energy and condition management.

Objectives

Maximum use of the crewman within the control loop is a basic requirement in Apollo control/display design. To accomplish this, the controls and displays subsystem must provide the crewman with sufficient information from the monitored spacecraft systems so he may evaluate their performance and condition and recognize malfunctions. Whether the systems are controlled automatically or manually, he must have sufficient command access to the controlled spacecraft systems to effect manual operation, override or use automatic control if required and, in event of malfunction, to select alternate operating methods or to safely shutdown the controlled system.

Both the Apollo vehicle and the Apollo mission depart significantly from prior concepts. A major objective in development of the control/display

[redacted]

system will be to suit the peculiarities of the Apollo mission and, at the same time, maintain a minimum departure from equipment configuration and operating procedures established in prior space vehicle programs.

System Requirements

The controls and displays subsystem must provide information and command access to the following spacecraft systems:

1. Flight Control
   - Stabilization and control
   - Guidance and navigation
2. Propulsion
   - Command module and service module reaction control
   - Service propulsion
3. Environmental/cryogenic
   - Environmental control
   - Cryogenic storage
4. Electrical Power
   - Fuel cells
   - Electrical distribution
   - Lighting
5. Communications and instrumentation
   - Communications
   - Data handling
   - Television
   - Antennas
   - Central timing
6. Mission/Vehicle Support
   - Abort sequence control
   - Earth landing sequence control
   - Mission sequence control

[redacted]

[redacted]

7. Special Instruments

Radiation warning

General event/condition indication

Visual information display

In-flight test

System General Description

The primary location of Apollo controls and displays is the spacecraft main display console and adjacent side panels within the command module. The crew couches, located immediately below the main display console, accommodate demountable hand controllers for spacecraft maneuvering.

Viewing and control access to the optical measuring unit and automatic guidance equipment of the guidance and navigation system is provided at the lower equipment bay in the command module.

Development Activities

Initial elements of the development plan include definition of crew tasks (which involve interaction with the spacecraft controls and displays), definition of the information/response requirements, and deduction therefrom of initial control-display panel composition and arrangement.

Due to the uniqueness of the Apollo mission, there will be subsystem requirements that have not occurred before and their feasibility will have to be investigated.

Paralleling the investigation of mechanization feasibility and the development of new control/display items will be a concurrent effort to select and optimize component hardware for more conventional applications.

The first significant activity is to define the initial composition of controls and displays in an arrangement known to be feasible, and which will satisfy mission requirements.

The next major activity is the detailed definition of hardware, and will include preparation of component and subsystem element specifications for procurement of mock-up, prototype, and flyable hardware.

Since many of the control/display equipment requirements will be new and will have to meet specifications more severe than ever before, suppliers are expected to require at least 1-1/2 years to deliver fully qualified equipment. However, plans call for acceptance of partially qualified equipment, which will be available about six months after order.

[redacted]

[redacted]

After the unqualified supplier hardware is tested, final specifications will be prepared for each item of equipment and will define specific tests to be made by the supplier before delivery. A quality assurance program will be carried out by each supplier as specified by S&ID.

The partially qualified hardware (delivery will begin on it in the spring of 1963) will be assigned to simulators, engineering development laboratories, boilerplate house spacecraft, first trainers, propulsion spacecraft, and to reliability, providing enough equipment for all parallel testing is delivered on time. Meanwhile, suppliers will proceed on their own development programs.

The foregoing tests may result in some major equipment changes, and delivery of these changed instruments is expected to begin in the spring of 1964.

Constraints

Significant constraints expected to be encountered in display development include provision for safe return of the vehicle by one man, pressuresuit induced motion and vision constraints, and equipment environment which ranges from vacuum to pure oxygen and from free fall to high-g with vibration.

Problem Areas

Current problems requiring substantial investigation include (1) means for providing information assuring safe rendezvous in the event of lunar excursion module propulsion failure, (2) assurance of survival and safe impact on entry, and (3) effective display integration to provide higher intelligibility of information at a lower cost in weight, power, and volume.

Other general problem areas are integration of optics and displays; volume, weight, and power conservation; instrument cooling in vacuum environment, and maintainability.

In-Flight Test System

The in-flight test system will provide automatic monitoring and manual testing of the spacecraft systems. The present design allows for 400 system test points to be monitored using a "No-Go" readout which informs the crew of subsystem status. Diagnostic testing to isolate and maintain defective subsystem modules is accomplished with a manual test unit which is composed of an on-board oscilloscope and meter.

[redacted]

[redacted]

Basic specifications for purchase of the automatic monitoring subsystem and the manual test unit are nearing engineering release. After a subcontractor is selected, a pilot model of the in-flight test system is expected to be completed by mid-1963. A fully qualified in-flight test system can be obtained by mid-1964, which satisfies the early manned earth orbital spacecraft schedule.

Present and future tasks include a system engineering approach to firm up maintenance or trouble-shooting for each spacecraft system. This will result in test procedures to be used when the in-flight test system is in operation. These tasks will further define the test parameters to be measured and corrective action to be taken in the use of on-board spares and system adjustment procedures. Gross spacecraft checkout procedures, associated with the spacecraft prelaunch automatic checkout equipment concept and the telemetry information while in-flight, must be further integrated with the in-flight test system into a logical checkout procedure.

A parallel effort that requires additional follow-up is the phasing of microelectronics into the in-flight test system development. In this manner the in-flight test system can realize a weight- and power-saving that can become effective at the time of Apollo lunar mission assignment in early 1968.

[redacted]

[redacted]

GROUND SUPPORT EQUIPMENT*

GSE OBJECTIVES

The primary objective of Apollo GSE is to provide equipment necessary to checkout, service, and launch the Apollo spacecraft. The checkout of the Apollo spacecraft will be an integrated systems checkout to utilize and implement the NASA spacecraft prelaunch automatic checkout equipment (SPACE) concept. All airframe checkout operations at Atlantic Missile Range will be geared to the SPACE concept, and the equipment conceived will follow the SPACE requirement for integrated flight and GSE hardware.

The "Apollo Test Plan" (SID 62-109) is the guideline for determining the GSE required to support boilerplate and airframe test vehicles. The S&ID Apollo checkout concept and the NASA-SPACE concept provide the direction for determining checkout requirements of the integrated spacecraft systems. The basic configuration of boilerplate and airframe test articles will dictate requirements for handling-, storage-, and transportation-type GSE. Close coordination between NASA, the S&ID spacecraft systems design groups, and GSE will provide the interface control required for effective and timely determination of GSE requirements and changes.

The integrated systems concepts will be analyzed to determine the requirements for subcontractor-furnished GSE, GFP, and S&ID in-house equipment. Close engineering management and technical direction of subcontractor's efforts will ensure that objectives, costs, and schedules of the Apollo program are met.

REFERENCED DOCUMENTS

The documents referenced in the following paragraphs reflect the basis followed in determining the requirements for GSE. This list of references is basic and will be expanded periodically as concepts are formulated and more information becomes available.

Government Documents (NASA)

Quality Assurance Provisions for Space Systems Components (NCP 200-2)

---

*This section is for information purposes only and does not represent GSE as defined in the 12 October 1962 firm cost proposal which did not include the SPACE concept.

[redacted]

[redacted]

Non-Government Documents (S&ID)

Apollo Test Plan (SID 62-109)

Reliability Program Plan (SID 62-203)

PROGRAM PLAN

Determination of Requirements

Requirements will be determined for GSE based upon the integrated systems concepts prepared by systems integration and containing mechanical, electrical, electronic, fluid, and pneumatic spacecraft systems parameters. Interface requirements, as well as information to evaluate integration of flight and GSE hardware, will be obtained from integrated systems concepts. The GSE development plan (Figure 83) illustrates the evolution of GSE from the concept development stage through manufacturing and logistics support.

For early boilerplate test articles, the basic spacecraft on-board systems configuration will dictate the degree of sophistication required for checkout. For later airframe vehicles to be tested at Atlantic Missile Range, SPACE will be employed with a manually operated, back-up checkout system.

Handling, servicing, and auxiliary equipment requirements will be determined concurrently with checkout requirements.

Establishment of requirements for checkout, handling, servicing, and auxiliary equipment will lead to firm definitions of individual GSE items. As checkout systems requirements and equipment are determined, the preparation of programs and methods for the SPACE computer will be initiated. At the same time, evaluation and control of interfaces will begin and progress concurrently with determination of requirements and definition of individual GSE items. Close coordination with the spacecraft systems design groups, associate and subcontractors, and NASA will be maintained to achieve interface control.

Extensive investigation of the availability and use of GFP will be made to reduce costs and implement schedules to the fullest extent. Coordination with NASA and other NASA contractors will be necessary in order to make use of available equipment in the most economical manner. To carry out this effort, detailed data covering non-S&ID equipment will be required.

[redacted]

[redacted]

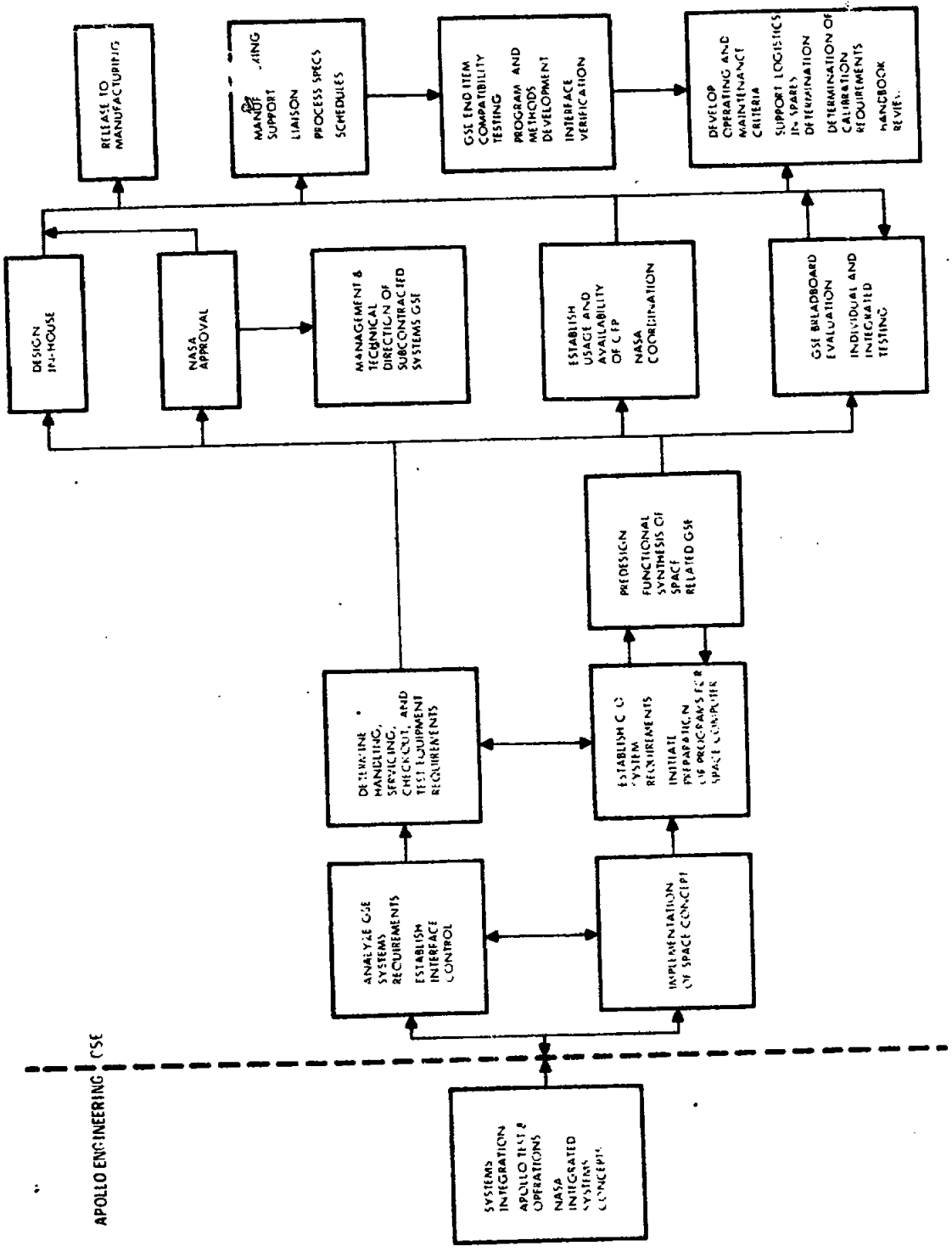


Figure 83. Ground Support Development Plan

[redacted]

[redacted]

Preliminary Design of SPACE Related GSE

Overall requirements for SPACE related checkout GSE will be determined simultaneously with functional synthesis and preliminary design of Apollo SPACE subsystems and other subsystems related to Apollo checkout, including carry-on equipment, simulators, servicing equipment control units, and line terminal equipment.

Specifications, logic diagrams, timing charts, and other documentation describing functional characteristics of the subsystem functional design will be prepared for use toward detailed design effort. Results of investigations and descriptions of resulting functional designs will be documented in technical reports for transmittal to the NASA.

Design

Design effort for GSE will be conducted in two major areas: (1) in-house design and (2) subcontracted systems design. Concurrent with these efforts will be the investigation of the availability and possible use of GFP.

In-House Design

The GSE design sections will prepare concept plans compatible to the integrated systems concepts. Th· ·oncept plans will result in the identification of GSE items which conform to requirements of the integrated systems concepts.

Basic layouts of overall configuration and preliminary analyses will establish detail design parameters. The progress of detail design will follow coordination with the spacecraft systems design groups, ATO and systems integration, and approval by NASA of the concept plan.

The design effort will consist of detail design for the manufacture of end items, preparation of procurement specifications for the purchase of end items and components, and preparation of process specifications for the manufacturing and checkout of GSE end items and components. Close coordination with various vendors during the design, fabrication, and testing of subcontracted end items and assemblies will be conducted to ensure compliance with specifications.

Preliminary design circuits will be breadboarded and verified to determine their applicability and capability to perform required functions. The breadboarded circuits also will aid in determining components and parts which meet specific reliability and quality-assurance requirements.

[redacted]

[redacted]

Reliability requirements, as set forth in the Reliability Program Plan (SID 62-203) and the Qualification-Reliability Test Plan (SID 62-204), will establish reliability criteria and will be used in all design, both in-house and subcontracted.

Engineering schedules will be prepared and coordinated with manufacturing to ensure the release of engineering data compatible with manufacturing required dates.

Subcontracted Systems GSE Design

Engineering management and technical direction will be provided for all GSE built by the Apollo major subcontractors. Specifications, drawings, and other subcontractor documents will be reviewed for approval. GSE design, development, and manufacture by subcontractors will be monitored at the subcontractors' facilities to ensure that the objectives of the Apollo Program are met from the standpoint of cost schedules and engineering standards.

Testing and Support

Testing of GSE will verify circuit designs, load capability, compatibility with spacecraft systems design and interfaces, and reliability. GSE handling items will be proof-loaded to verify load capability and minimize the possibility of damage to any test vehicle during handling operations. Interface points also will be verified by the compatibility of the equipment with the test vehicles.

After GSE end items are manufactured, they will be tested and interface compatibility will be checked through the use of various GSE-type substitute units which simulate the spacecraft system interfaces. A set of pertinent GSE will be maintained and utilized for (1) the development of computer methods and tape programs for checkout procedures, (2) certification of these programs and new programs or methods as required, and (3) testing and verification of GSE changes resulting from spacecraft systems changes prior to their release to the field.

The determination of spares requirements by logistics will be supported by the GSE design unit. Operating and maintenance criteria will be developed in addition to procedures for servicing GSE. Handbooks relative to GSE will be reviewed for technical accuracy and adequacy of coverage.

[redacted]

[redacted]

HARDWARE DEFINITIONS AND OBJECTIVES

The Apollo Spacecraft Development Plan includes requirements for hardware articles for evaluation and test purposes. These articles fall into three categories: (1) mock-ups, (2) boilerplates, and (3) spacecraft.

Mock-ups are used to display configuration and design detail for study and evaluation, and will be important technical tools in the development of the spacecraft design. In the early stages of development, mock-ups will be made of materials that can easily be modified to reflect design improvements. As the design progresses, mock-ups will simulate the finalized spacecraft configuration.

Boilerplates are simulated spacecraft or modules used for developmental tests leading to the final spacecraft design. Boilerplates will simulate the following characteristics of the final spacecraft design:

External size and shape
Structural soundness
Mass and center of gravity
Stiffness (with respect to impact absorption)
Systems as required
Instrumentation as required

Spacecraft articles will incorporate final design features and will be used for unmanned flight, ground qualification tests, and manned flight.

Mock-ups, boilerplates, and spacecraft articles that are planned for the time period through December 1964 are defined in the subsequent paragraphs. It will be noted that each boilerplate and spacecraft will contain one or more of the three major components: (1) the launch escape system, (2) the command module, and (3) the service module.

MOCK-UPS

M-2—Command Module for Cabin Interior Arrangement

This mock-up is built specifically for the purpose of displaying the command module interior arrangement, and will be used by S&ID as the official configuration control mock-up. The exterior of the mock-up will be of minimum design, utilizing only the interior for simulated equipment installation.

PRECEDING PAGE BLANK-NOT FILMED

[redacted]

[redacted]

Present objectives are to develop the best arrangement of crew equipment for maximum accessibility and optimum utilization. Future objectives are to maintain configuration control on all installed equipment and to conduct various tests on crew equipment for accessibility and arrangement.

The command module interior skin will be fabricated of plywood and will be framed with a suitable external structure. An outer plywood skin will be provided. The following equipment items will be simulated:

Ingress and egress hatches
Windows and/or viewing ports (with plexiglas)
Crew support and life system
Control panel
Upper and lower equipment bays
Left- and right-hand equipment bays
Environmental control system
All interior mechanical and electrical equipment
All lighting fixtures

M-3—Command Module for Cabin Interior Arrangement

This mock-up is a duplicate of M-2 in all respects, and was delivered to the Manned Space Center (MSC), Houston, Texas, in September 1962. This mock-up presents the interior configuration of the command module for MSC observance.

M-4—Partial Service Module and Partial Adapter Interface

This mock-up will reflect the service module and the adapter interface. Its specific purpose is to simulate the interface and disconnect mechanisms that are applicable. The mock-up will be made of metal to hold the relative positions of the interface with minimum movement for more nearly perfect simulation.

Design objectives will be the evaluation of mechanical and electrical mating characteristics and compatibility between components, and the evaluation of physical size and space provisions for installed equipment.

The portions of the service module and adapter that mate will be built of metal, with only sufficient external structure to maintain integrity while meeting mock-up design objectives.

M-5—Command Module for Cabin Exterior Equipment

This mock-up will depicf the exterior of the command module and all details that are relevant to configuration control. As such, it will be the

[redacted]

official configuration control mock-up used for continual updating to the latest configuration and will only involve tests on the mock-up exterior.

Present objectives will be to establish the location and to determine the compatibility of all equipment, as well as to establish accessibility of equipment for maintenance. Future objectives will be to maintain configuration control of all installed and simulated equipment with evaluation of accessibility for maintenance.

The mock-up will be constructed of wood with the space between the pressure shell outer mold line and the heat shield structure inner mold line simulated along with antennas, reaction control system, windows and/or viewing ports, mechanical and electrical disconnects, environmental control system, and the parachute storage area.

It will have a minimum amount of interior structure, as needed for support. Design of the exterior configuration includes all equipment and bays exterior to the interior command module mold line.

M-7—Complete Service Module

This mock-up will reflect a complete configuration of the service module. It will depict propulsion components for display and design support necessary to integrate the subcontractor's propulsion system into the service module.

Present objectives are to evaluate space for personnel movement within the module, to provide for accessibility of component modules for in-flight and ground maintenance, and to evaluate the interface design between the command module and the service module. The future objectives will be to study and evaluate space requirements and the compatibility of the various systems and equipment.

The service module mock-up will be of sufficient strength to withstand handling and transportation at S&ID and comply with design objectives. A complete reaction control system, propulsion system, and environmental control system, with major electrical and mechanical systems supplied with disconnects, will be simulated and installed.

M-9—Spacecraft for Handling and Transportation

This spacecraft handling and transportation mock-up will be a hard mock-up of the launch escape system, command module, service module, and adapter, which will be used by S&ID for evaluation studies involving size, weight, and center of gravity of the Apollo spacecraft. The mock-up will also

[redacted]

aid in the design of handling and transportation equipment for the launch escape system, command module, service module, and adapter.

The mock-up will have the capability of holding extra weights as required to make various weight and center-of-gravity tests and the capability to sustain a transportation load. The external configuration of the Apollo spacecraft, all hoisting and jacking provisions, and all other connections associated with handling and transportation will be simulated. Reaction control rocket engines in the service module, connection and separation points, and external items, such as hatches, ports, and antenna, will be simulated.

M-11—Spacecraft for Handling and Transportation

This mock-up will be used in the same manner as Mock-up 9, and is required to ensure that a mock-up of this nature will be present at S&ID for ground support evaluation in the event that Mock-up 9 is being used for transportation feasibility studies. One handling and transportation mock-up is, therefore, assured of being at S&ID for ground support equipment studies.

M-12—Partial Command Module for Crew Support Equipment

This mock-up will reflect only the minimum interior and exterior configuration required to demonstrate the restraint system and vibration mitigation system as these systems are developed on Simulators 1 and 2.

Design objectives will be to maintain current design information concerning crew support and restraint systems, current anthropometric requirements, the current restraint system, the shock and vibration mitigation system, and the current requirements for crew protection.

The mock-up will consist of the command module interior, along with the crew support systems, equipment bays, and instrument panels in a configuration that will include simulated couches, shock and vibration mitigation systems, personal parachute system, restraint system, and support system.

M-18—Spacecraft Complete

This mock-up will reflect as closely as possible, a complete configuration of the spacecraft, which will include the launch escape system, command module, service module, and adapter. Information that has been compiled from all mock-ups prior to completion of Mock-up 18 will be included on this mock-up.

The mock-up will be a simulation of the complete spacecraft vehicle consisting of the launch escape system, command module, service module, and adapter. Mock-up 18 will remain at S&ID for future studies and DEI use.

[redacted]

The mock-up will be made as complete as possible including all systems and incorporating all changes and refinements obtained from data compiled from previously built mock-ups.

BOILERPLATES

Fifteen boilerplates are planned to provide early system confirmation, system overall evaluation, qualification of spacecraft design, structural and systems compatibility, and booster compatibility verification.

B-1 and B-2—Command Module for Land and Water Impact Test

The mission of B-1 and B-2 (Figure 84) will be the early confirmation of the crew shock absorption system and stability characteristics of the command module during and after touchdown impact.

Test objectives of this mission will be to evaluate the crew shock absorption system, and the vertical and transverse acceleration loads during land and water impact. Verification of the maximum emergency limit g forces, flotation stability, and the evaluation of time limit and directional g forces on anthropomorphic dummies will be carried out. The configuration will consist of the command module only, equipped with a crew shock absorption system, anthropomorphic dummies, and a simulated heat shield with no ablative material. On-board instrumentation to external recorders by direct wire will also be used along with high-speed cameras.

There is a probability that 20 drops on each boilerplate will be conducted at S&ID, Downey facility. In at least one test each on land and water, the command module must impact under the following conditions:

1. Impact angle of minus 15 degrees

2. Crew positioned feet first

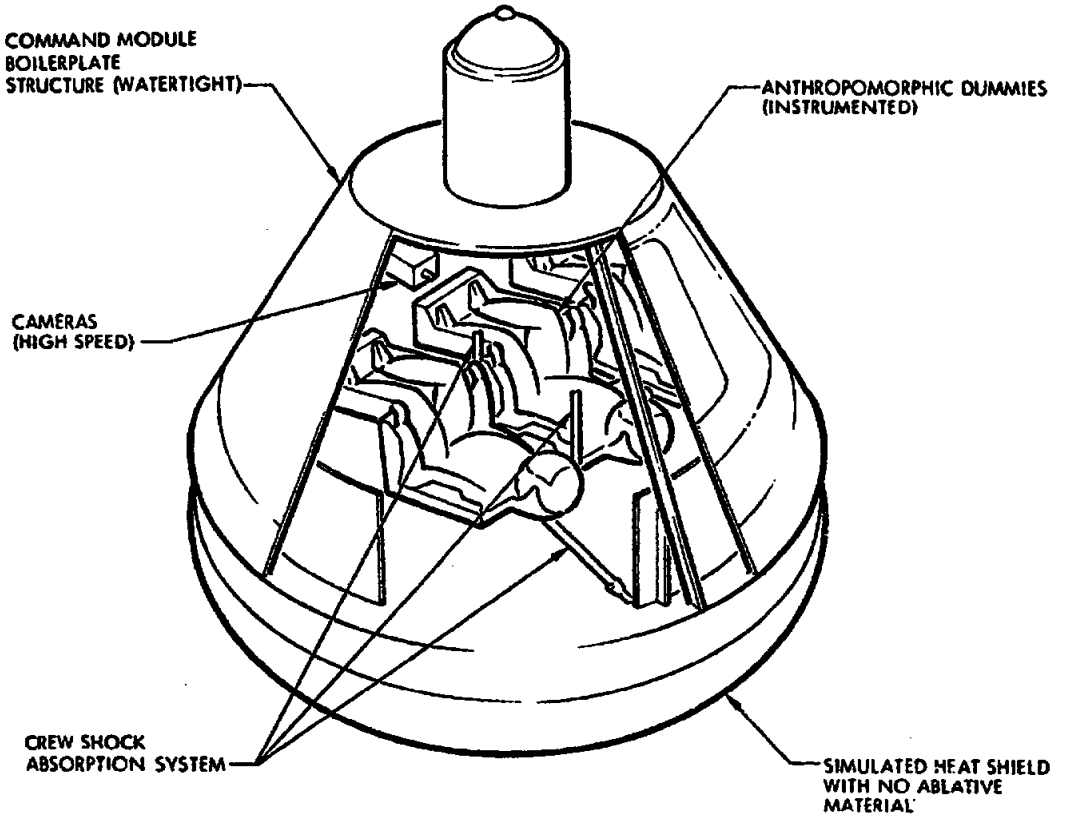
3. Equivalent vertical velocity of 30 feet per second at impact in combination with up to 50 feet per second horizontal velocity

B-3—Command Module for Parachute Recovery

The mission of B-3 (Figure 85) will be the early confirmation of the parachute recovery system using a C-133 airplane for drops on land and water. Tests will be conducted at El Centro, California.

The boilerplate will consist of a command module only, equipped with a drogue parachute, landing parachute, and an earth impact attenuation system. The sequence control subsystems, battery power system, instrumentation,

[redacted]



MISSION - GENERAL: EARLY CONFIRMATION OF CREW SHOCK ABSORPTION SYSTEMS

Figure 84. B-1 and B-2 Command Module for Land Water Impact Test

[redacted]

[redacted]

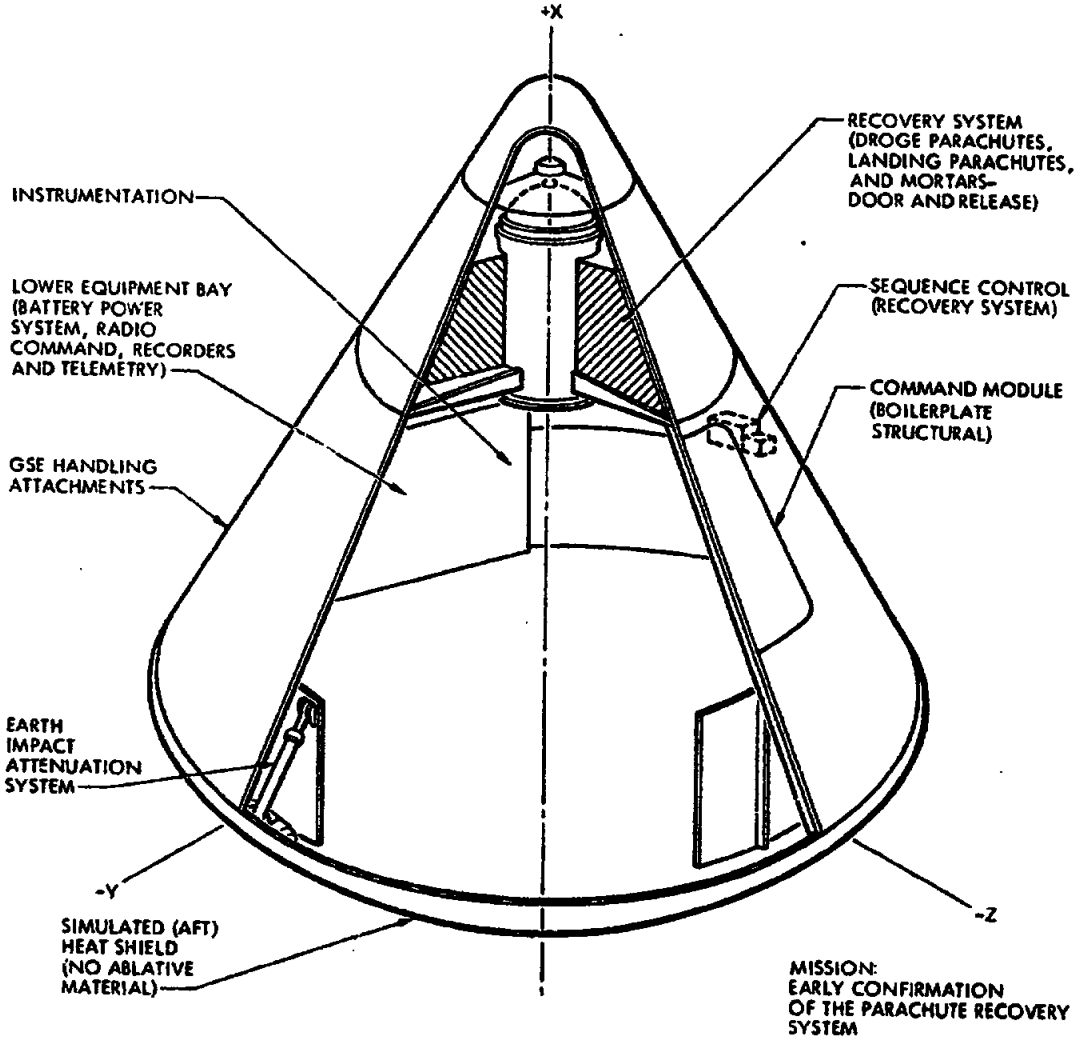


Figure 85. B-3 Command Module for Parachute Recovery

[redacted]

[redacted]

radio command, and on-board recorders will be used. Partial telecommunications and recovery systems will also be required.

B-6—Command Module and Launch Escape System for Pad Abort

The mission and test objectives of B-6 (Figure 86) will be evaluation of the launch escape propulsion system, launch escape tower jettison release mechanism, recovery system, and verification of structural integrity of the launch escape tower. Tests will be conducted at the White Sands Missile Range, New Mexico.

The configuration of this boilerplate will include a command module, ground adapter, launch escape tower, launch escape motor, pitch control rocket motor, and a jettison motor. The on-board systems will include a battery power system, R & D telemetry system, instrumentation, and abort system sequencer. Recovery parachute, drogue chute, mortar, sequencer, and provisions for impact attenuation system will also be required.

B-9—Spacecraft for Dynamic Test and Second Spacecraft for Booster Compatibility Test

B-9 (Figure 87) will consist of a boilerplate command module, service module, spacecraft adapter, and launch escape tower for dynamic tests to be performed at MSFC in conjunction with a launch vehicle. This boilerplate will be used for the determination of dynamic structural compatibility with a launch vehicle. The configurational requirements will be as follows:

Command module—structure same as B-13
Service module—structure same as B-13
Spacecraft adapter-service module to C-1—structure same as B-13
Launch escape and jettison motors (simulated)—structure same as B-13
Escape tower—prototype structure same as B-13

After completion of dynamic testing at MSFC, the boilerplate will be refurbished and a live jettison motor installed. The boilerplate will then be launched by a C-1 launch vehicle for a booster compatibility test. The boilerplate is non-recoverable.

B-12—Command Module and LES for Max q LES Verification

The objective of B-12 (Figure 88) will be the evaluation of the launch escape system at maximum dynamic pressure (max q). This will include evaluation of stability margins, structural integrity of the launch escape

[redacted]

[redacted]

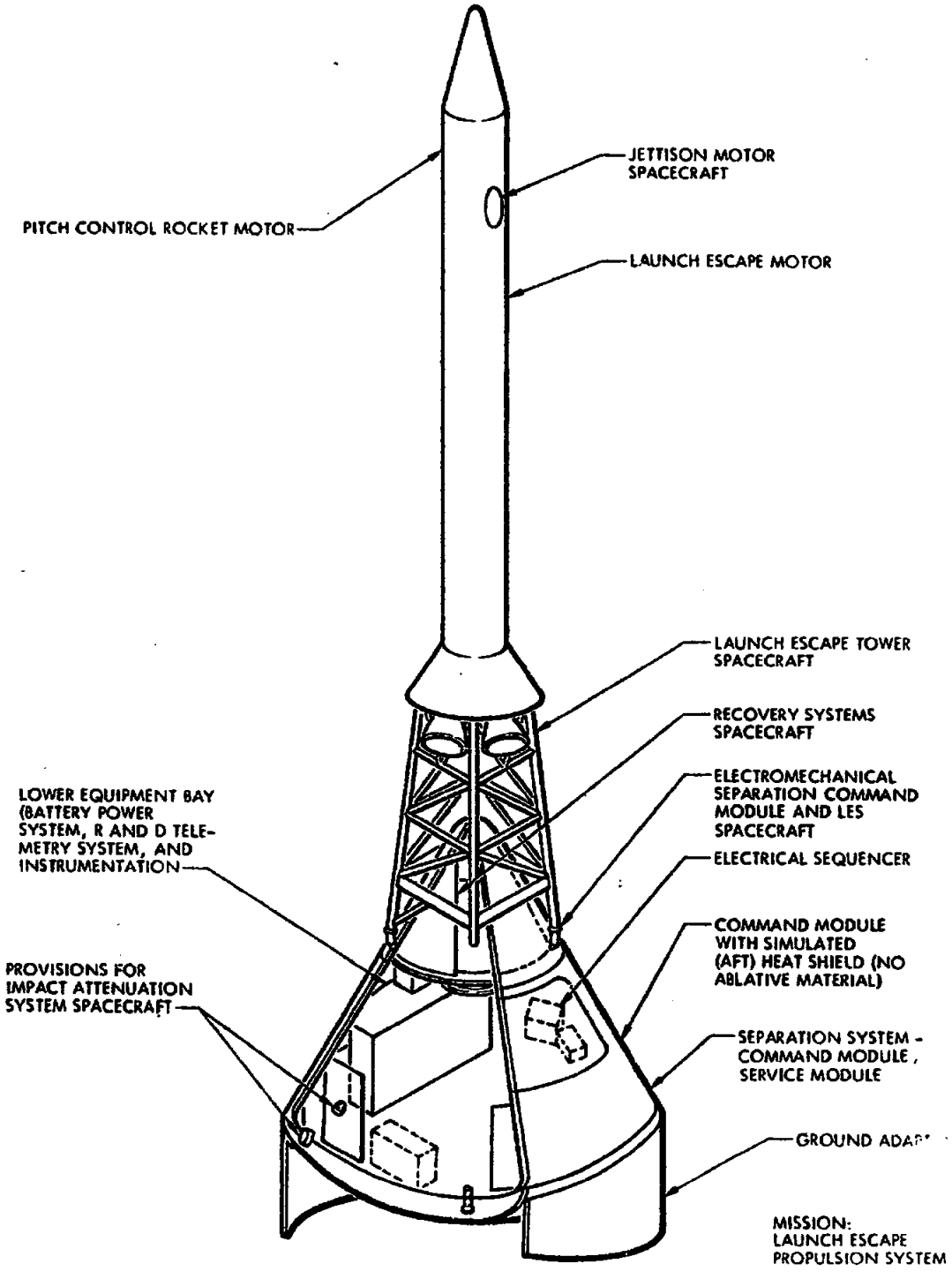


Figure 86. B-6 Command Module and Launch Escape System for Pad Abort

[redacted]

[redacted]

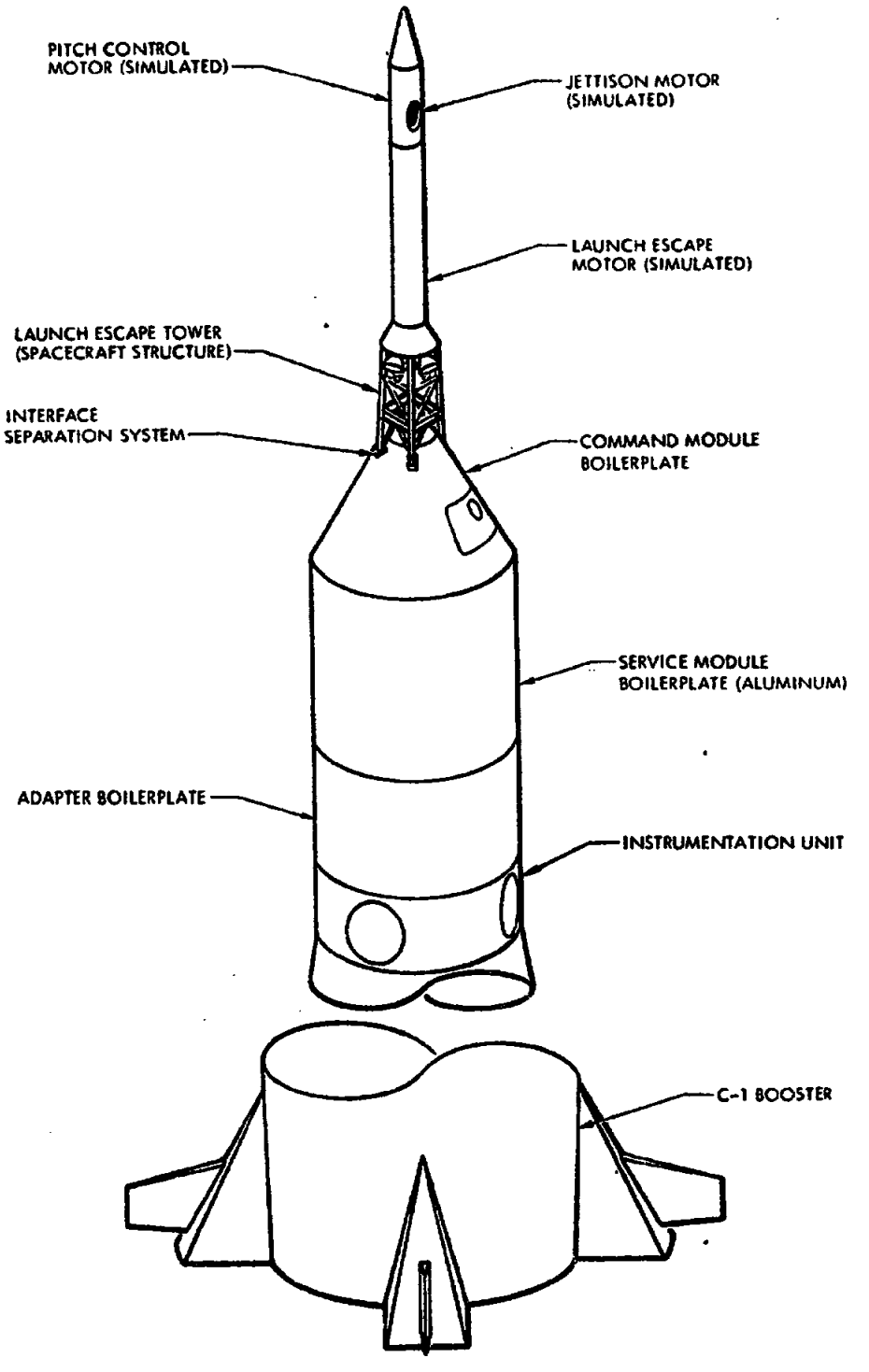


Figure 87. B-9 Spacecraft for Dynamic Test and Second Spacecraft for Booster Compatibility Test

[redacted]

[redacted]

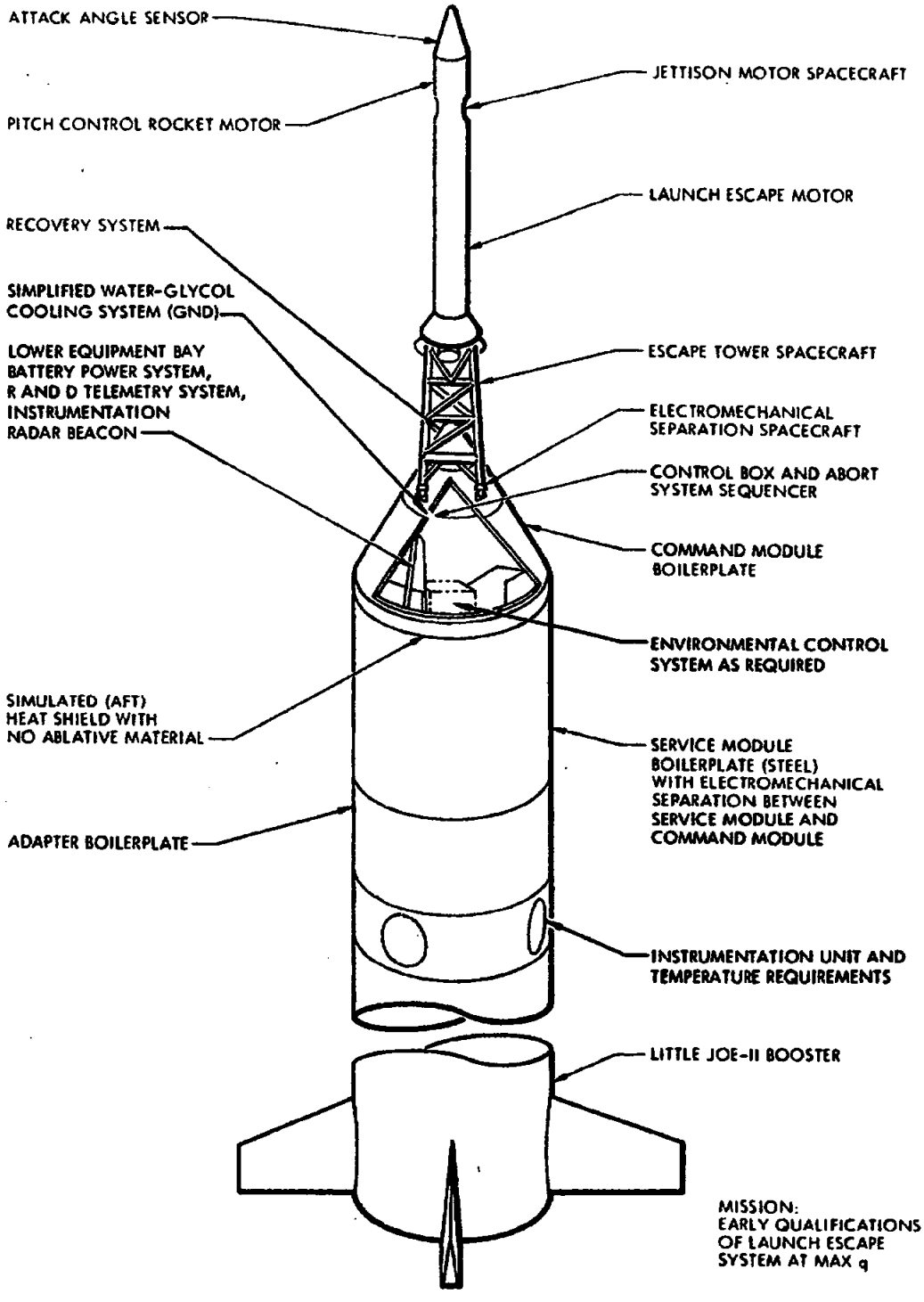


Figure 88. B-12 Command Module and Launch Escape System for Max q LES Verification

[redacted]

[redacted]

tower, launch escape motor characteristics at max q, and the recovery system. The test will be conducted at the White Sands Missile Range, New Mexico.

The configuration will include a command module, launch escape tower, service module, and adapter. The launch escape tower will be equipped with a launch escape motor, pitch control, and a jettison motor. A Little Joe II booster will be used to launch this boilerplate. Systems needed include battery power, R & D telemetry, abort system sequencer, and a recovery system.

B-13—First Spacecraft for Booster Compatibility

This test vehicle (Figure 89) is a spacecraft consisting of a boilerplate command module, service module, spacecraft adapter, and escape tower. The mission will be a launch injection of the spacecraft with a C-1 launch vehicle. There will be no separation from S-IV booster and the boilerplate is non-recoverable.

The prime object of this flight will be to demonstrate compatibility of the spacecraft and booster. Additional objectives will include evaluation of the structures under flight loads and the R & D instrumentation system, including telemetry and tracking.

The vehicle will consist of a command module, service module, and launch escape tower equipped with inert launch escape and pitch control motors and a live jettison motor. The service module will be attached to the C-1 booster with a spacecraft adapter. Battery power, R & D telemetry, and instrumentation systems will be needed.

B-14—House Spacecraft No. 1

B-14 (Figure 90), designated as House Spacecraft No. 1, is a test platform for mounting primary systems to evaluate systems compatibility. It will be used mainly as a tool in development of systems, and a preliminary check of integrated systems compatibility. House Spacecraft No. 1 will also be used to establish operational procedures and to evaluate GSE design and operation. B-14 will remain at S&ID, Downey facility.

The basic configuration will include a command module, service module, launch escape tower, and a ground adapter. These will be skeletal structures for mounting systems in their proper geometry with removable skin on the outer structure. These modules will be equipped with complete systems with the exception of live rocket motors.

[redacted]

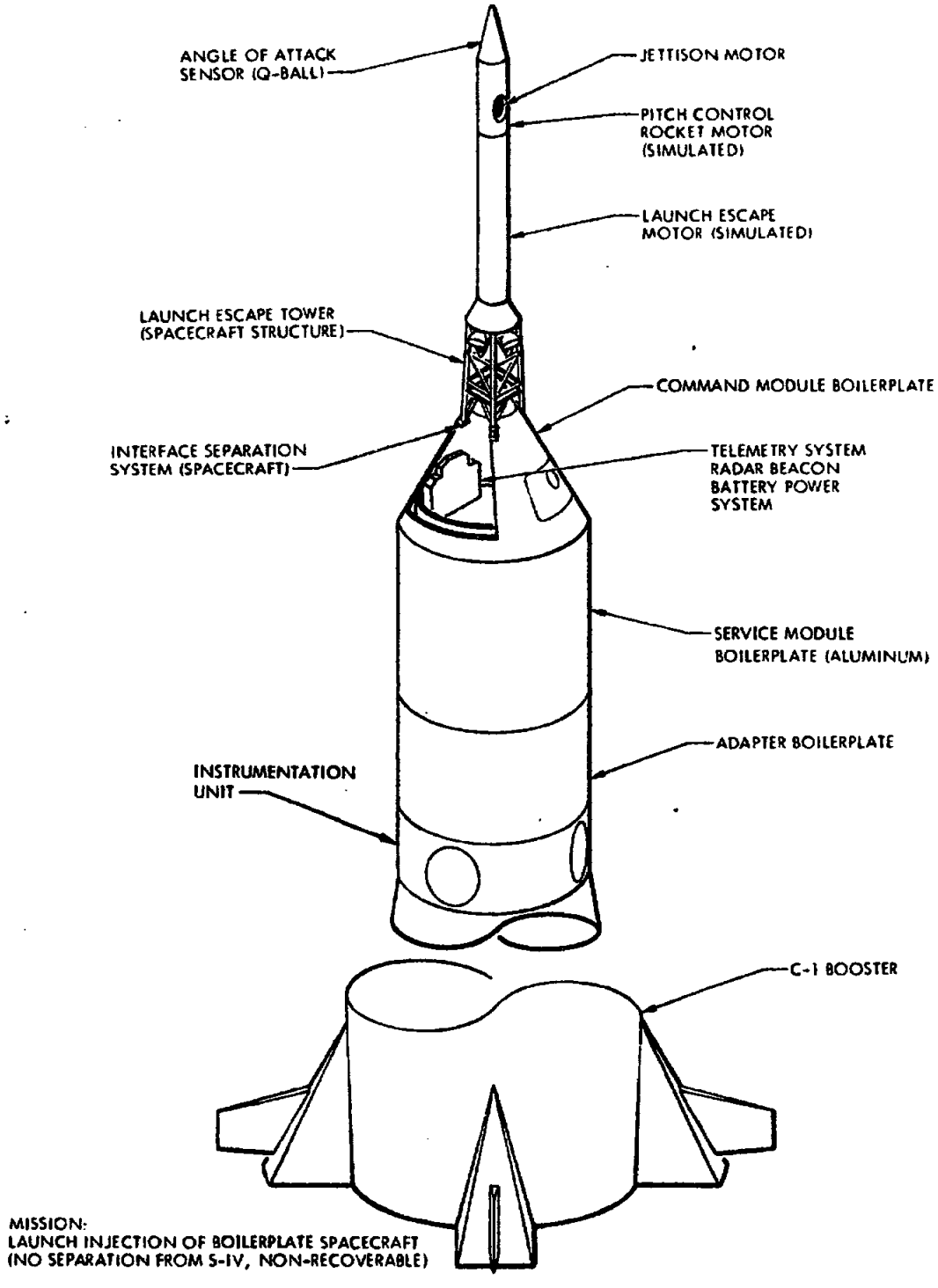


Figure 89. B-13 First Spacecraft for Booster Compatibility

[redacted]

[redacted]

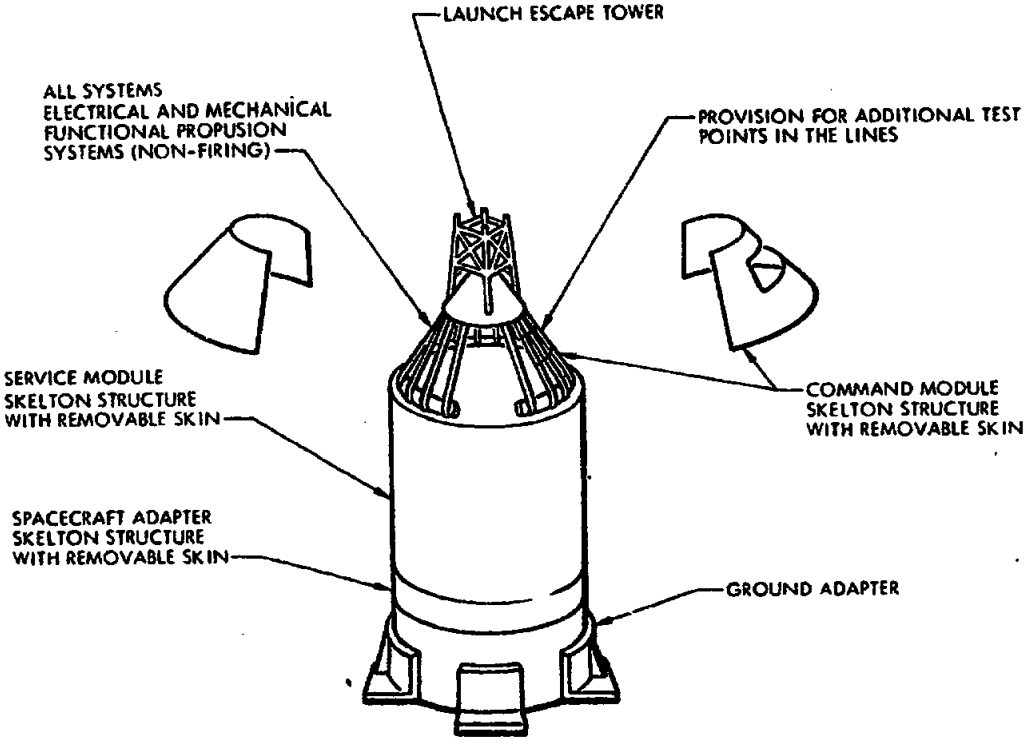


Figure 90. B-14 House Spacecraft No. 1

[redacted]

[redacted]

B-15—Third Spacecraft for Booster Compatibility

B-15 (Figure 91) is the third spacecraft for booster compatibility test consisting of a boilerplate command module, service module, spacecraft adapter, and a launch escape system. The primary objective of this flight will be to demonstrate the compatibility of the spacecraft and booster by launch injection of the boilerplate with a C-1 launch vehicle. Data will be gained for evaluation of the structure under flight loads and compatibility of the R & D instrumentation system with the launch vehicle. B-15 will not separate from the S-IV booster and is non-recoverable.

During this flight, the vehicle will utilize a launch escape system with an inert launch escape motor, inert pitch control motors, and a live jettison motor. A battery power system, an R & D telemetry system, a radar beacon, and an instrumentation system will be carried aboard this spacecraft.

B-16 and B-18—Spacecraft for Booster Compatibility Verification

These test vehicles (Figure 92) will be the fourth and fifth spacecraft for booster compatibility verification. They will be launched from a C-1 launch vehicle. The boilerplates will not separate from the S-IV and are non-recoverable. The mission objectives will be to qualify the launch vehicle and to demonstrate the physical and flight compatibility of the launch vehicle and spacecraft.

The vehicle will consist of a launch escape system, command module, service module, and adapter. The launch escape system will have inert launch escape and pitch control motors and a live tower jettison motor. Battery power and sequencer will be required for launch tower jettison.

B-19—Command Module for Parachute Recovery

The mission of B-19 (Figure 93) will be the early confirmation of the recovery system using a C-133 airplane for drops on land and water. Tests will be conducted at El Centro, California.

The boilerplate will consist of a command module only, equipped with a drogue parachute, landing parachute, and an earth impact attenuation system. The sequence control subsystem, battery power system, instrumentation system, radio command and on-board recorders will be used. Partial telecommunications and recovery systems will also be required.

B-22—Command Module for LES for High-Altitude RCS Verification

The mission of B-22 (Figure 94) will be to determine the aerodynamic stability characteristics of the Apollo escape configuration during an

[redacted]

[redacted]

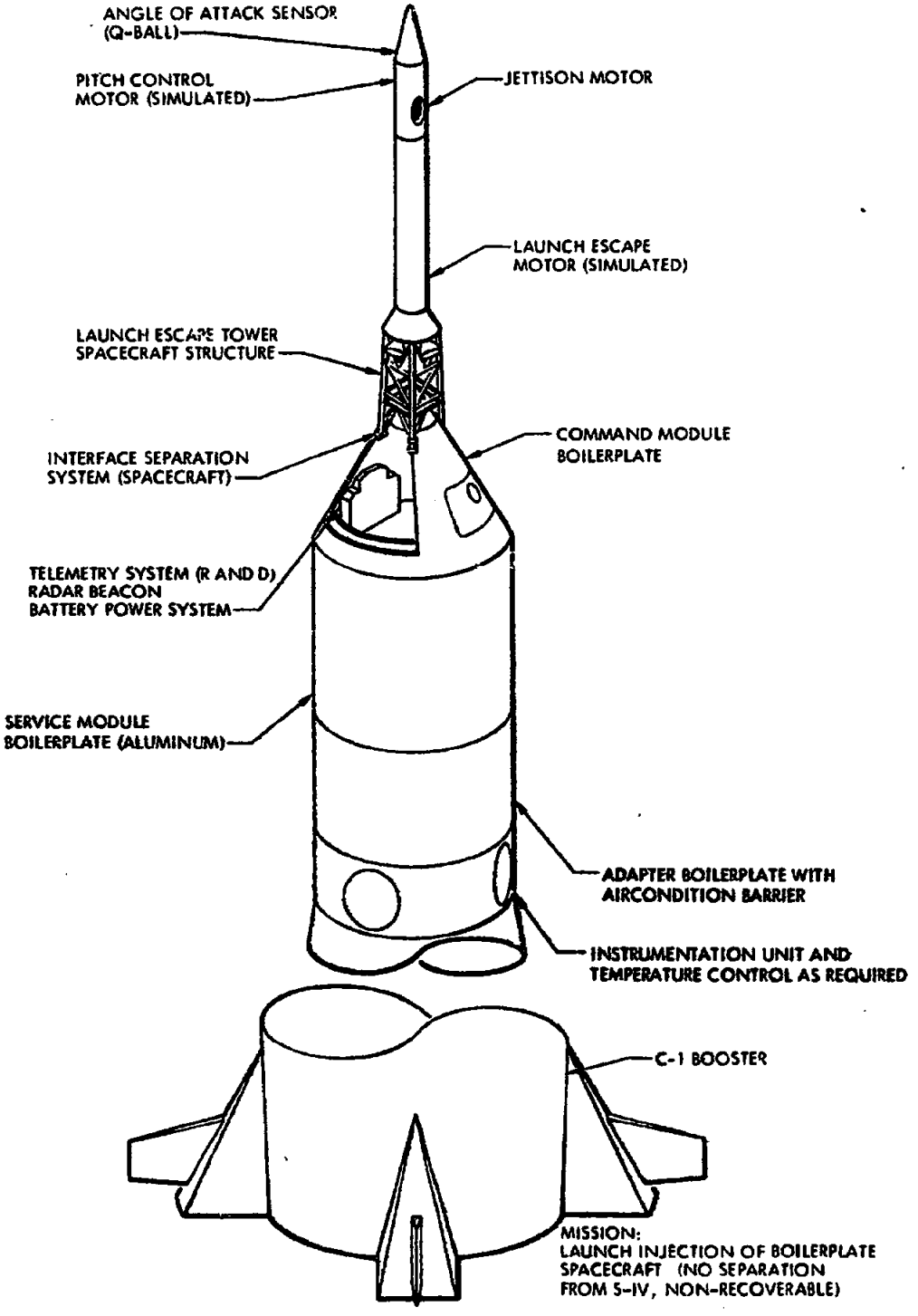


Figure 91. B-15 Third Spacecraft for Booster Compatibility

[redacted]

[redacted]

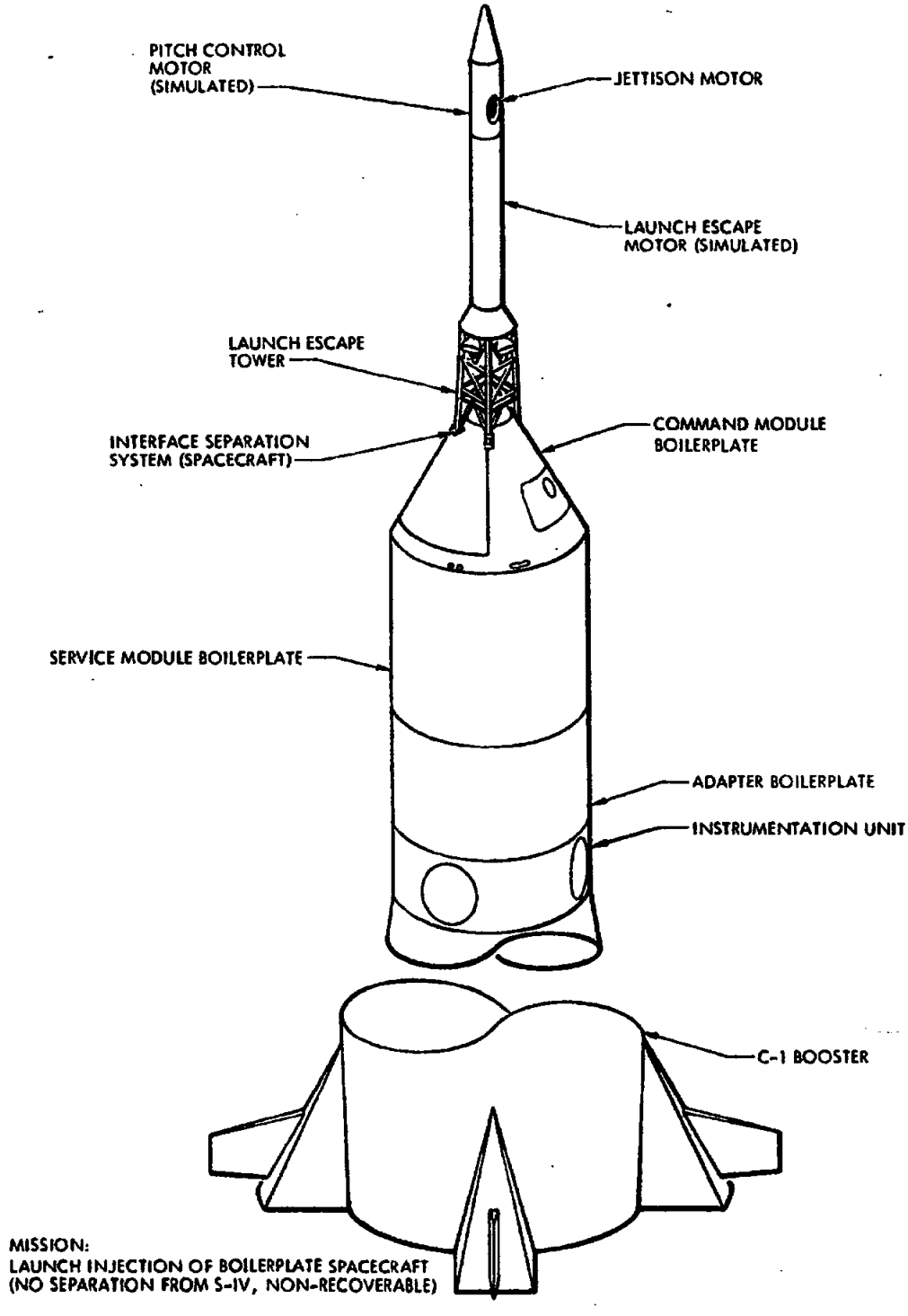


Figure 92. B-16, B-18 Spacecraft for Booster Compatibility Verification

[redacted]

[redacted]

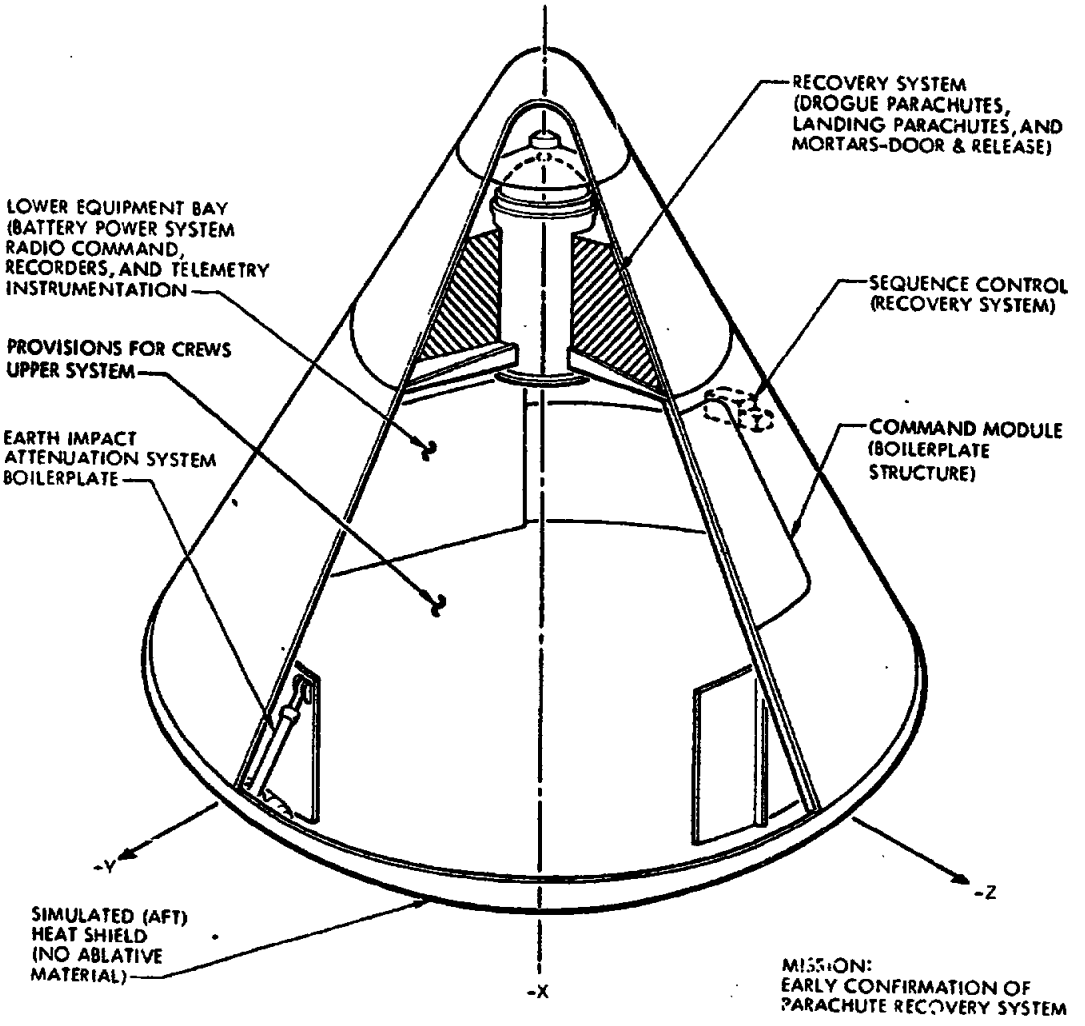


Figure 93. B-19 Command Module for Parachute Recovery

[redacted]

[redacted]

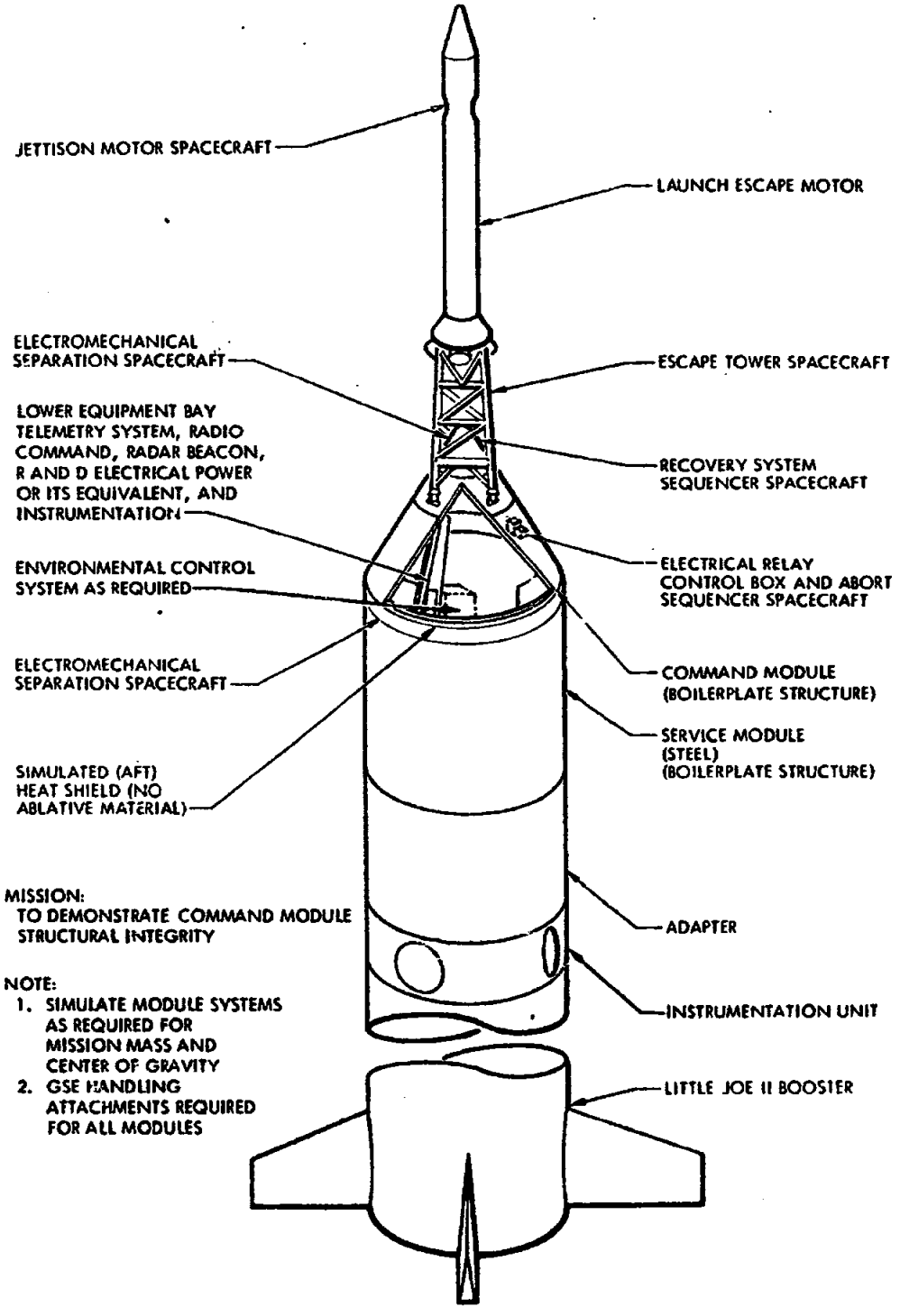


Figure 94. B-22 Command Module for High Altitude LES Verification

[redacted]

[redacted]

abort just prior to tower jettison, and to demonstrate the capability of the launch escape system to propel the command module a safe distance from the launch vehicle during the abort. Secondary test objectives will be to determine the command module stability characteristics during a simulated reaction control system failure, and to demonstrate the parachute recovery system.

This boilerplate will consist of a command module, service module, Little Joe II adapter and a launch escape system. Command module equipment will include a partial stabilization and control system, reaction control system, battery power system, telemetry and instrumentation, and sequencers.

Tests will be conducted at the White Sands Missile Range, New Mexico.

B-23—Back-up Boilerplate for B-6 and B-12

B-23 will be used as a backup for B-6 or B-12 in the event B-6 or B-12 does not attain the desired test objectives. If B-6 and B-12 are both successful, another test mission will be assigned to B-23.

B-25—Command Module for Water Recovery Procedures and Handling Equipment Development

The mission of B-25 (Figure 95) will be to demonstrate the capability of handling and recovery equipment. The boilerplate configuration will be the external shell of the command module complete with hoisting and handling provisions.

B-25 has been shipped to MSC, Houston, Texas, for NASA test and evaluation.

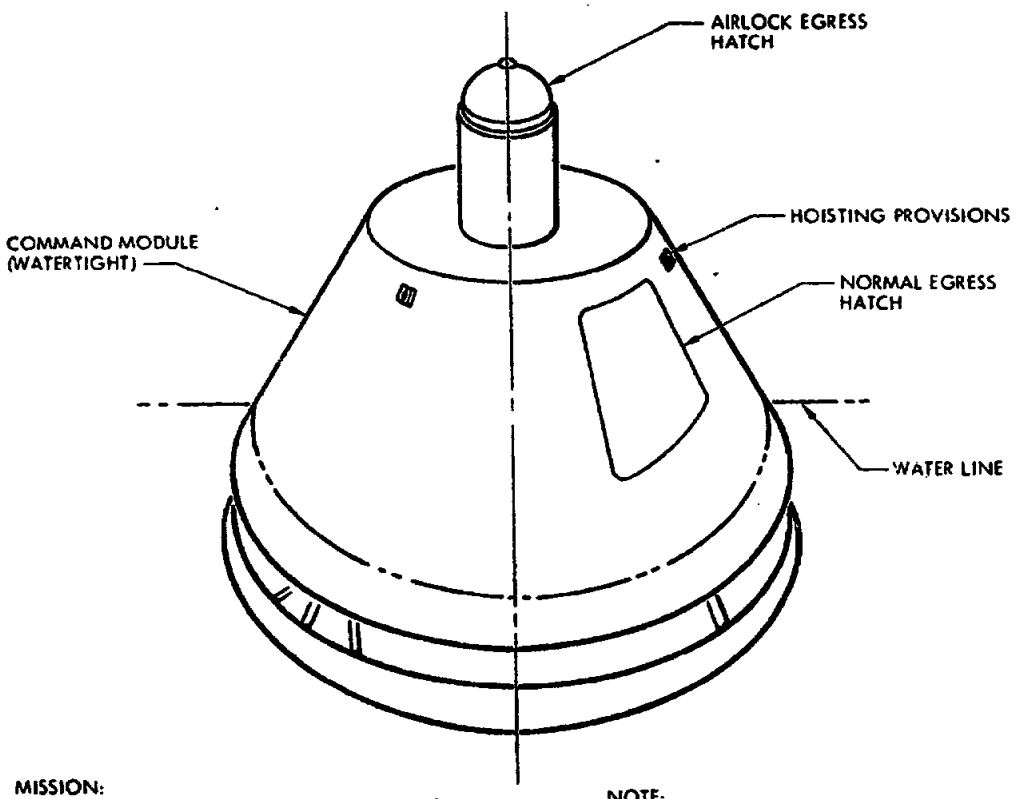
SPACECRAFT

Airframe 001—Spacecraft for Propulsion System Qualification

Airframe 001 (Figure 96) spacecraft configuration will consist of a command module, a spacecraft adapter, and a ground adapter with a separation system from spacecraft to command module. It will be equipped with all the systems and instrumentation required to conduct the propulsion tests. This spacecraft will be used to verify propulsion systems under normal and emergency flight environments.

The test objectives are to evaluate propulsion systems performance under low-altitude conditions; to obtain environmental data on vibration, acoustic and base heating; and to verify reaction controls system performance and compatibility. The spacecraft will be used at the development test site,

[redacted]



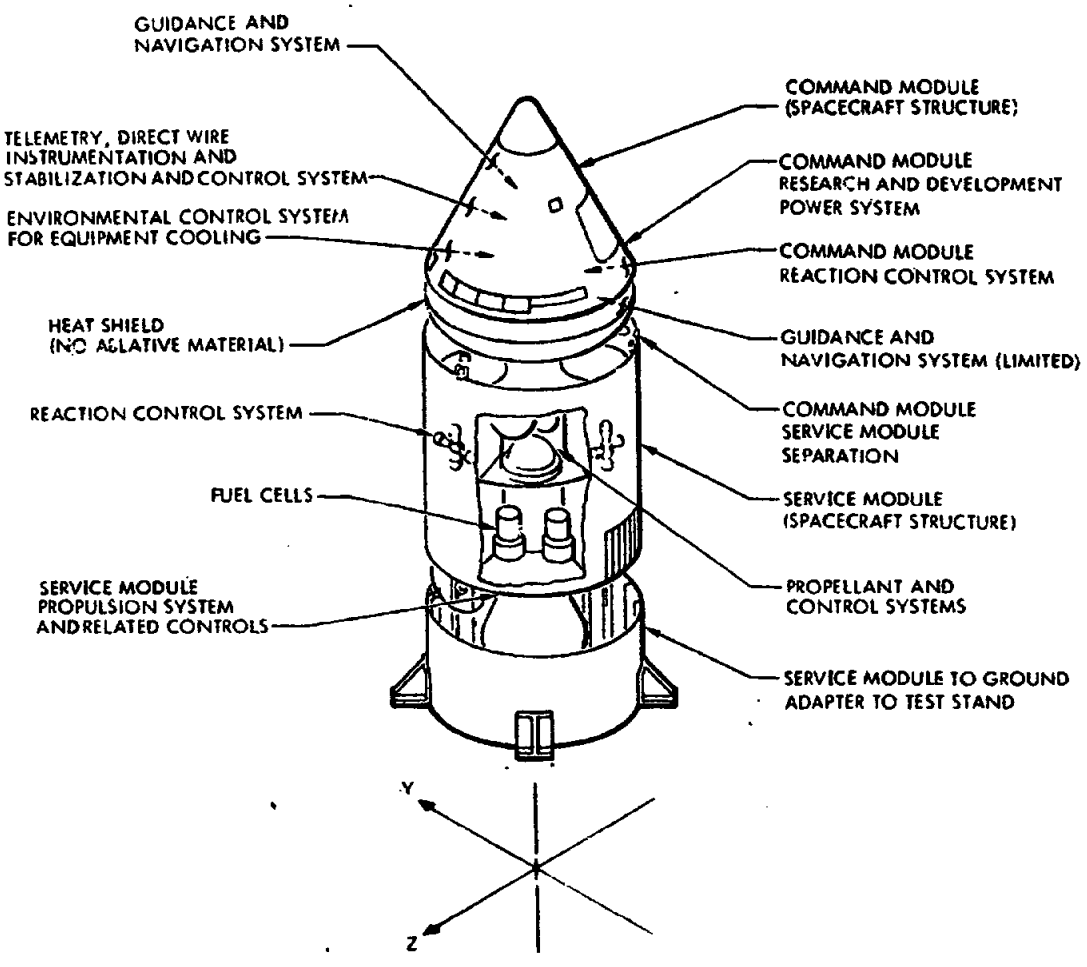
MISSION:
DEMONSTRATION OF EQUIPMENT HANDLING CAPABILITY FOR THE COMMAND MODULE AT A SIMULATED RECOVERY SITE (LAND AND WATER) AS A DESIGN FOR PICKUP EQUIPMENT. DEMONSTRATION OF HANDLING AND TRANSPORTING EQUIPMENT AND TECHNIQUES.

NOTE:
1. SIMULATE COMMAND MODULE AND SYSTEMS AS REQUIRED TO OBTAIN PROTYPE FLOTATION CHARACTERISTICS
2. GSE HANDLING ATTACHMENTS REQUIRED

Figure 95. B-25 Command Module for Recovery Procedures and Handling Equipment Development

[redacted]

[redacted]



MISSION:
VERIFY PROPULSION SYSTEMS OPERATIONS FOR NORMAL AND EMERGENCY FLIGHT CONDITIONS THROUGH STATIC HOT FIRING GROUND TESTS.

Figure 96. AFRM 001 Spacecraft for Propulsion System Qualification

[redacted]

[redacted]

White Sands Missile Range, New Mexico, and will be capable of firing with a crew in the command module on a separate pad.

Airframe 002—Command Module and LES for Max q LES Verification

Airframe 002 (Figure 97) will consist of command module, boilerplate service module, boilerplate adapter, and a launch escape tower spacecraft system. This spacecraft will be used for qualification of the launch escape system at maximum q, and for demonstration of the structural integrity of the command module. Evaluation of the recovery complex and separation dynamics will also be objectives of this flight. The systems used will be limited to those which are required to perform tasks necessary for conducting the tests. Therefore, the parachute recovery system with sequence control system will be included. Little Joe II will be used as a booster. The test will be conducted at White Sands Missile Range, New Mexico.

Airframe 004—Spacecraft for Static Test No. 1

The first static test article (Figure 98) is composed of a spacecraft command module, service module, adapter, and a launch escape tower. It will be programmed for static tests to verify structural integrity under launch pad static loads and structural integrity under all simulated boost conditions. No systems will be required. Direct wire instrumentation will be used with these tests which will be performed locally.

Airframe 005—Command Module for Static Test No. 2

Airframe 005 (Figure 99) consists of a spacecraft command module that will be used for verification of structural stiffness and integrity during reentry and recovery phases under simulated thermal environment and shock loads. No systems will be involved; however, direct wire instrumentation will be required. These tests will be performed locally.

Airframe 006—House Spacecraft No. 2

Airframe 006 (Figure 100) will be used for vibration and acoustic testing in support of the environmental test objectives of airframe 008. After the first manned Apollo flight, airframe 006 will be used as House Spacecraft No. 2. This spacecraft will be used to check system performance and compatibility and to confirm design changes prior to inclusion in actual flight vehicles. Malfunction analysis and development of operational procedures for vehicle and mission will be additional objectives of this spacecraft.

The spacecraft configuration will include a command module, a service module, an adapter, and a launch escape system of spacecraft design and

[redacted]

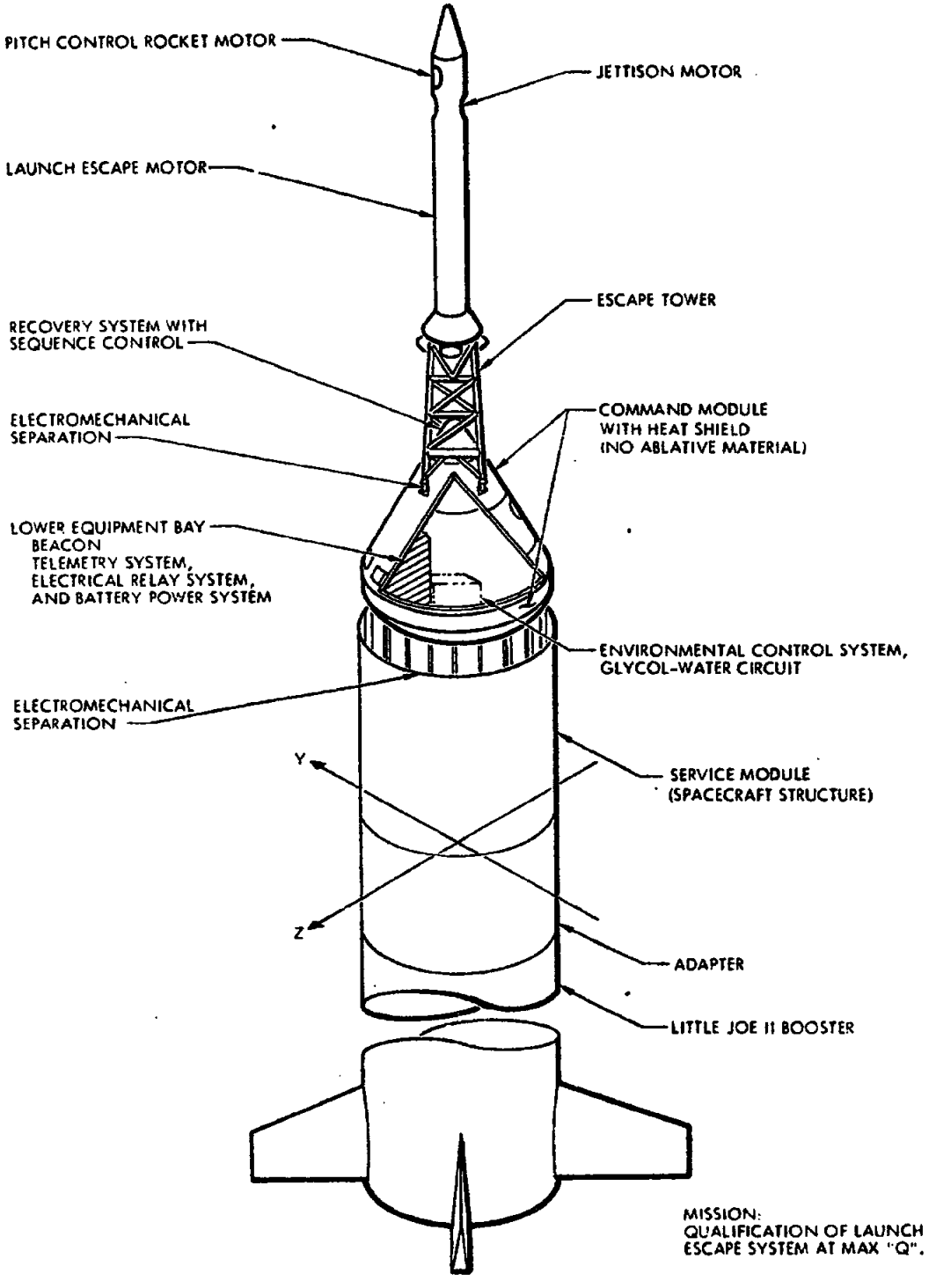


Figure 97. AFRM 002 Command Module and Launch Escape System for Max q LES Verification

[redacted]

[redacted]

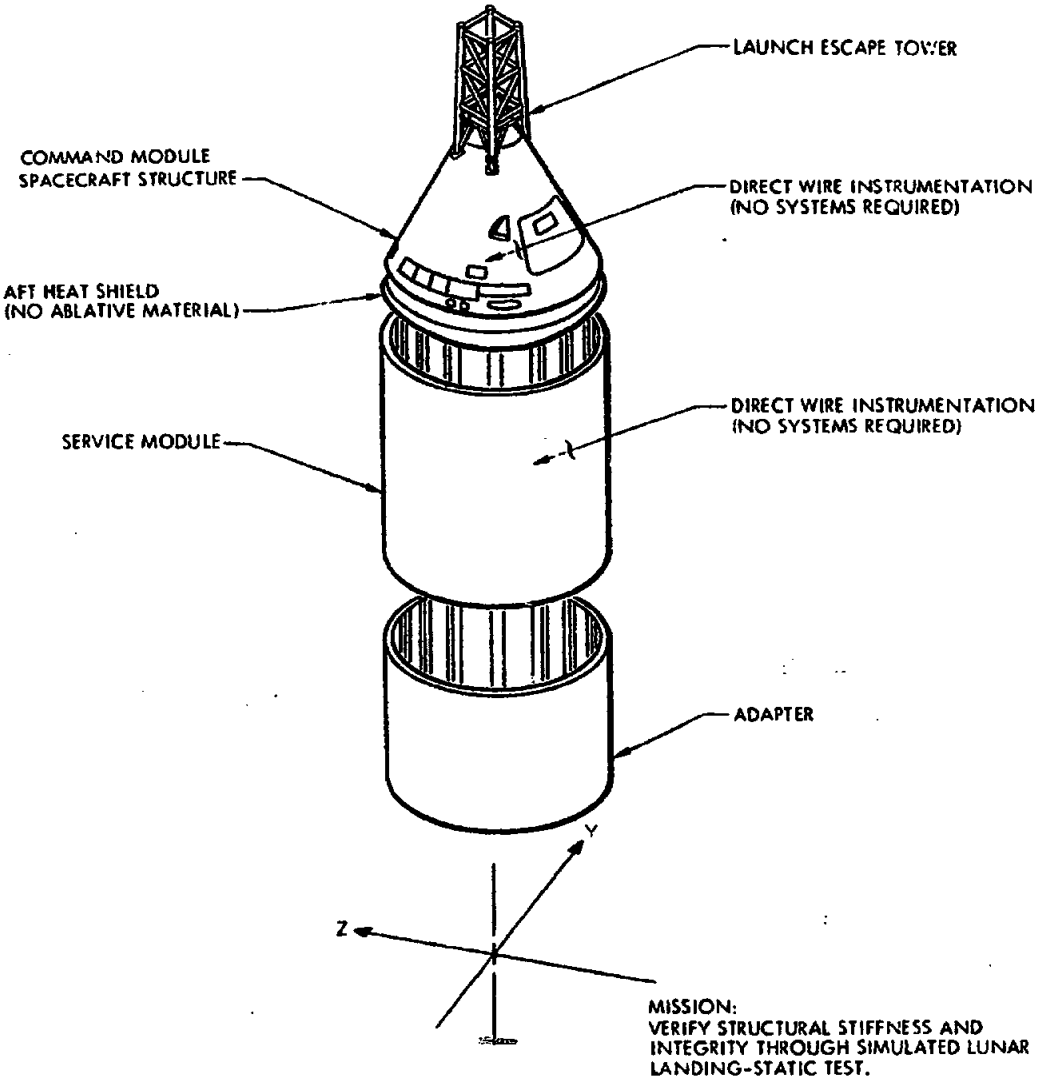
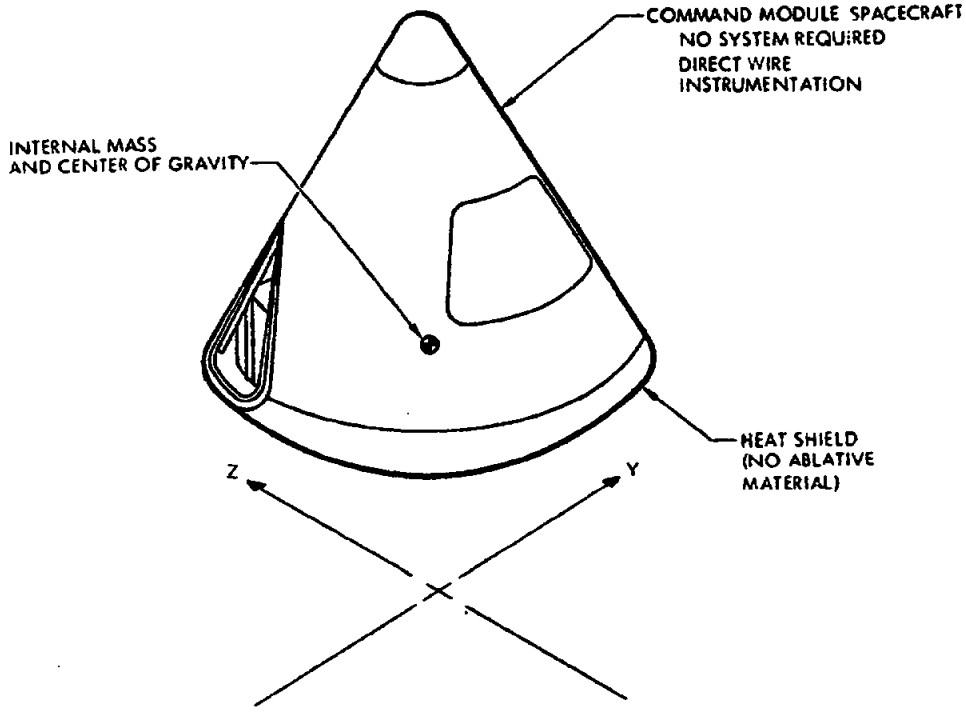


Figure 98. AFRM 004 Spacecraft for Static Test No. 1

[redacted]

[redacted]



MISSION:
VERIFY STRUCTURAL STIFFNESS &
INTEGRITY DURING REENTRY & RECOVERY-
STATIC TEST.

Figure 99. AFRM 005 Command Module for Static Test No. 2

[redacted]

[redacted]

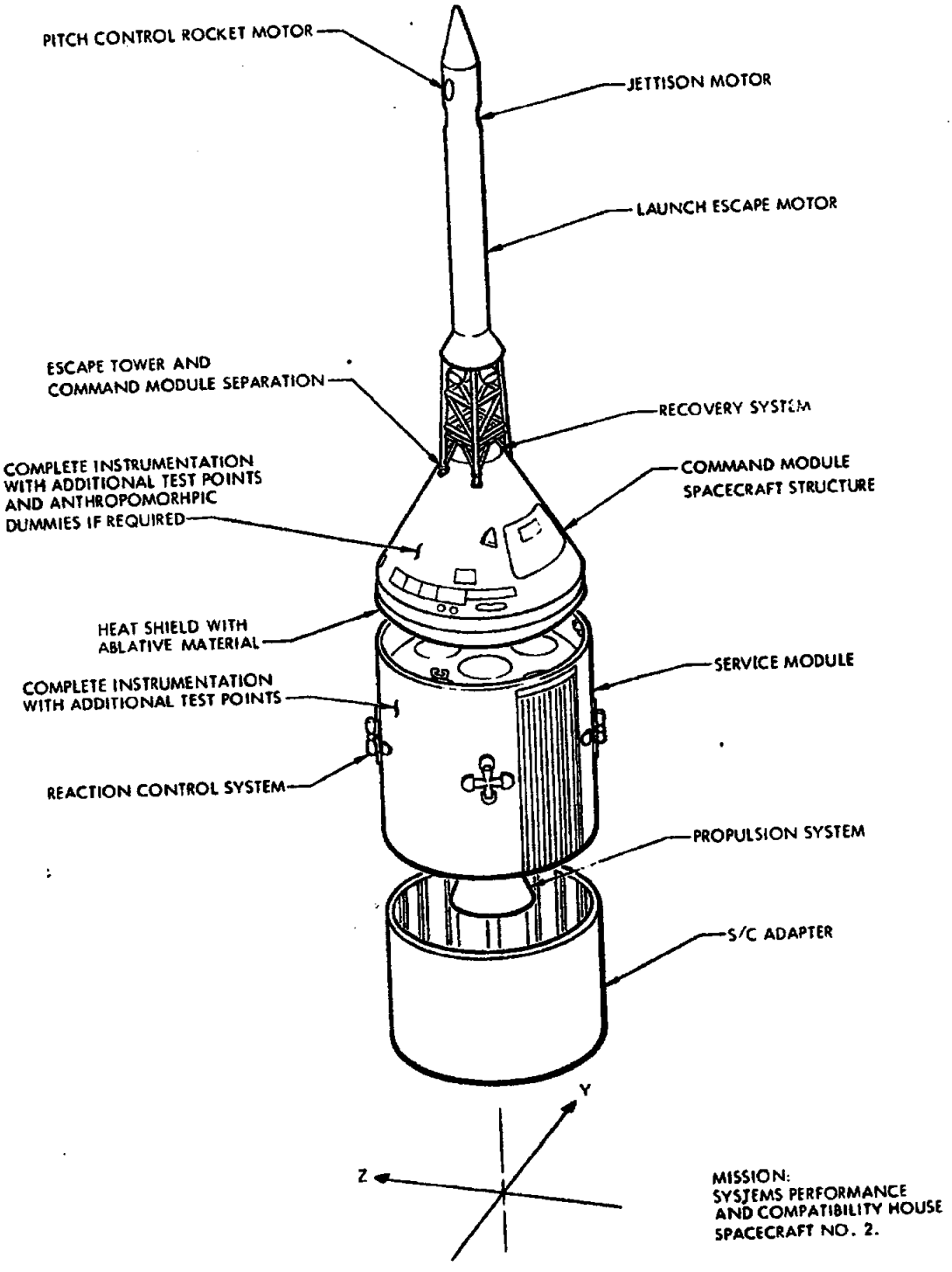


Figure 100. AFRM 006 House Spacecraft No. 2

[redacted]

[redacted]

structure. Complete spacecraft systems will be required except that the LES motors will be inert.

Airframe 008—Spacecraft for Environment Proof

The environmental proof spacecraft (Figure 101) consists of a spacecraft command module, spacecraft service module, and a spacecraft adapter. All systems to be used in verifying design adequacy of the complete spacecraft under simulated mission environments will be included. Confidence in equipment will be verified by qualification studies of spacecraft ability to withstand environmental conditions that are present during prelaunch, launch, boost, separation, earth orbit, lunar and cislunar environment, reentry, earth landing, and recovery.

Airframe 009—Spacecraft for Launch and Recovery Qualification Flight

Airframe 009 is the first manned spacecraft. This spacecraft (Figure 102) consists of the spacecraft command module, spacecraft service module, spacecraft adapter, spacecraft launch escape system, and all essential spacecraft systems required for a manned flight. This vehicle will be used for qualification of the C-1 launch vehicle, command and service modules, and essential spacecraft systems for manned orbital flight. It will verify recovery operations, entry, and readiness of the recovery complex. The secondary test objectives are to demonstrate separation capability for orbital flight and to evaluate the following: abort capability, crew shock absorption system, stability, control, reaction control, and the fuel cell module under zero g.

Airframe 010—C/M and LES for Pad Abort

The pad abort spacecraft (Figure 103) consists of a spacecraft command module, a pad adapter, and a spacecraft escape tower. The primary mission of this spacecraft will be to qualify the launch escape system. The test objectives will be to evaluate the stability margins and launch escape tower jettison dynamics, control system operation, and structural integrity. This spacecraft will also be used to demonstrate the recovery system from pad abort. These tests will be conducted at the White Sands Missile Range, New Mexico.

Airframe 011—Spacecraft for Second Manned Flight

This spacecraft (Figure 104) will be used for the second manned flight. It will be composed of a complete spacecraft, fully equipped, to verify (1) the capability of a multimanned spacecraft to complete an orbital mission, (2) the operation of GOSS with manned spacecraft, and (3) the capability of the manned spacecraft recovery complex. The inflight crew

[redacted]

[redacted]

reaction will also be evaluated. A series of manned orbital flights will follow to provide data regarding long-term space operations, bio-medical effects, and crew spacecraft compatibility and performance needed to proceed into the lunar missions.

[redacted]

[redacted]

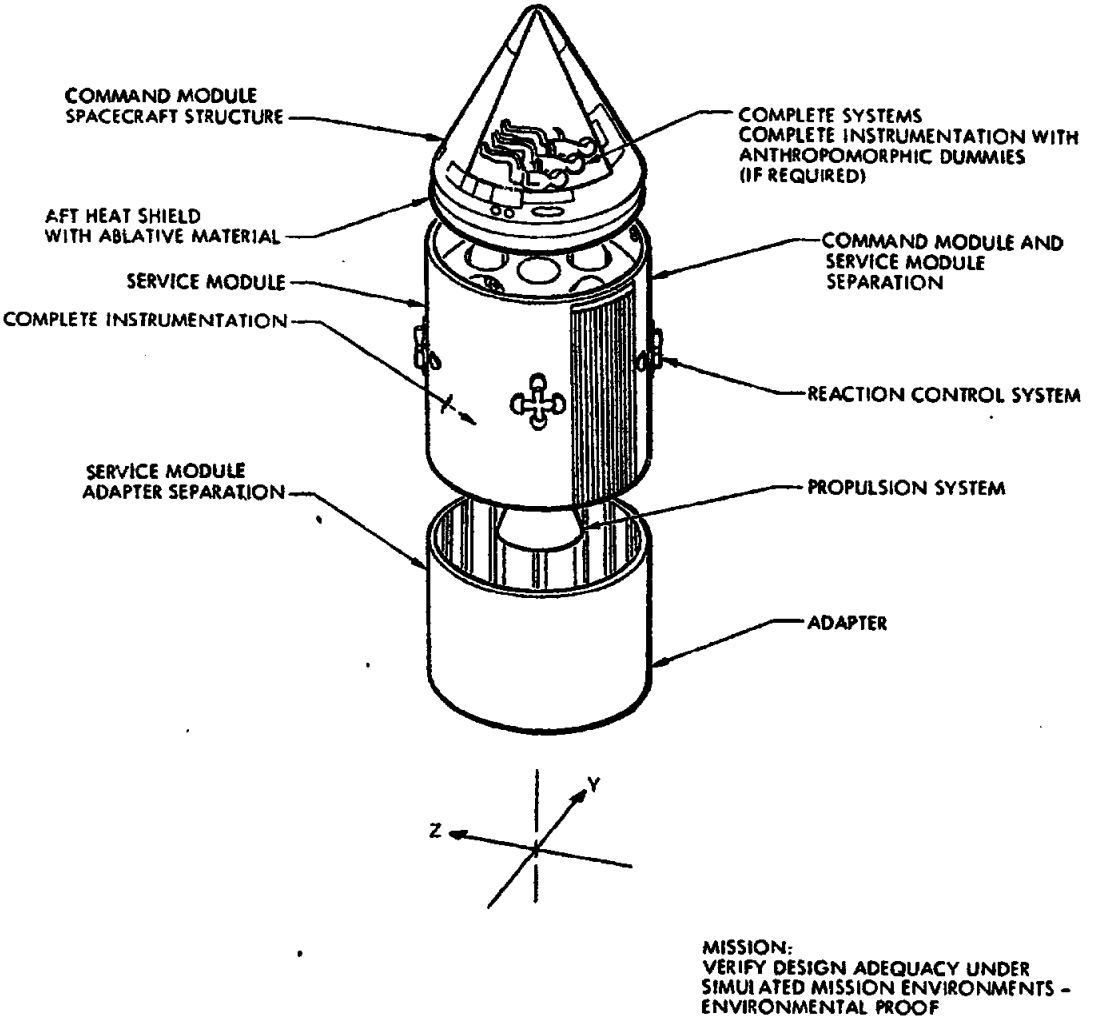


Figure 101. AFRM 008 Spacecraft for Environmental Proof

[redacted]

[redacted]

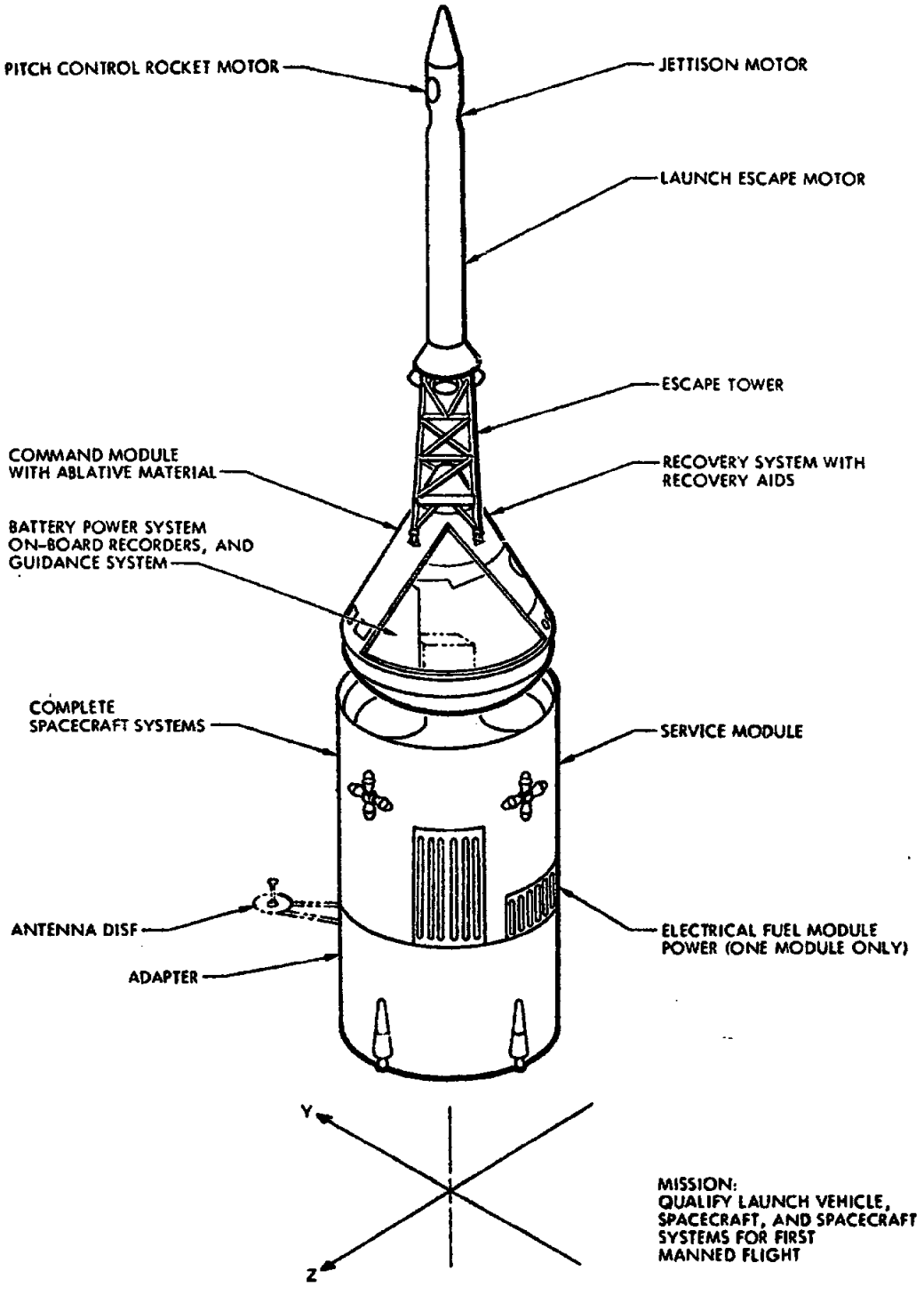


Figure 102. AFRM 009 Spacecraft for First Manned Flight and Service Module Propulsion Verification

[redacted]

[redacted]

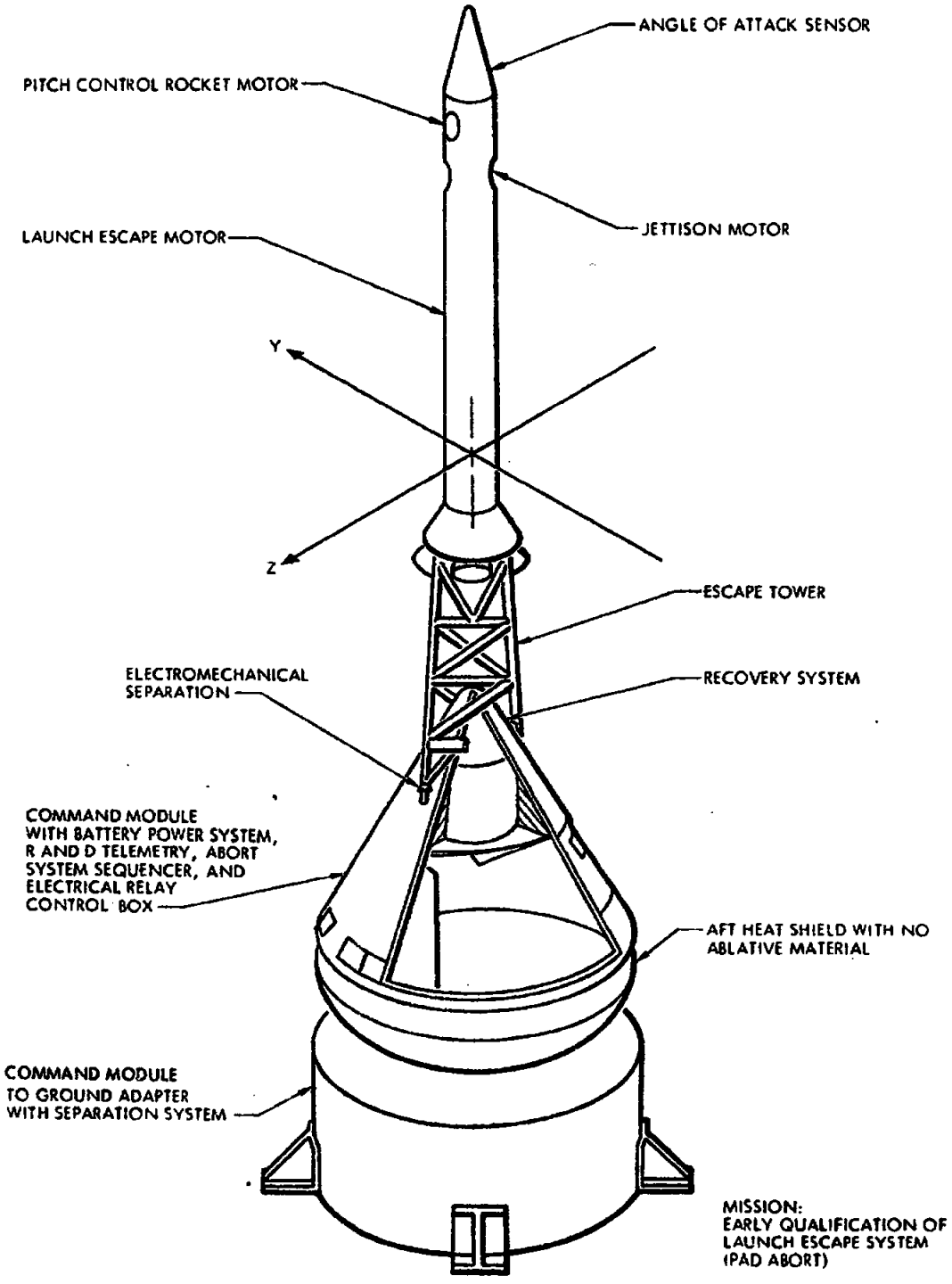


Figure 103. AFRM 010 Command Module and Launch Escape System for Pad Abort

[redacted]

[redacted]

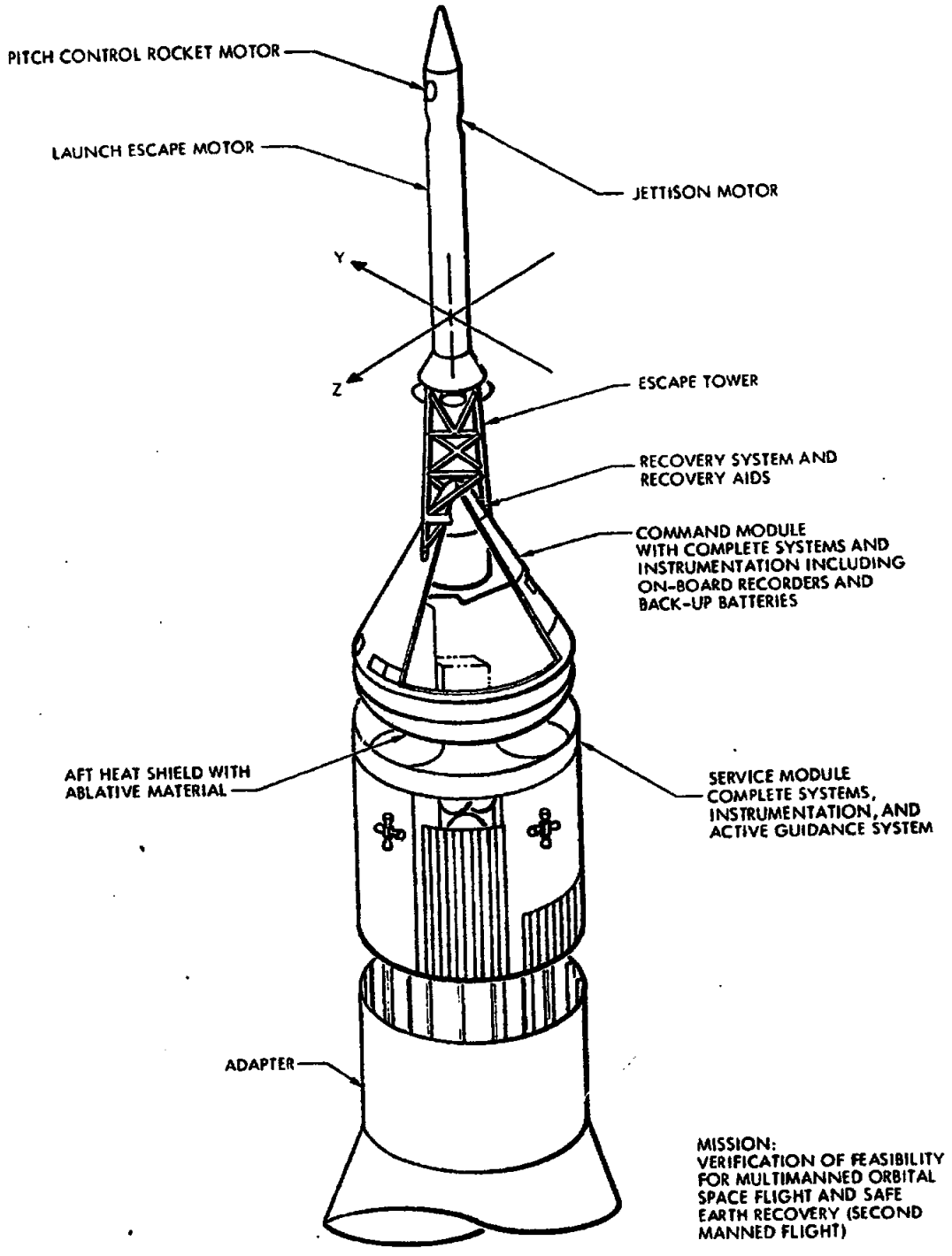


Figure 104. AFRM 011 Spacecraft for Second Manned Flight—Earth Orbital Qualification

[redacted]

[redacted]

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.

SERVICE PROPULSION SYSTEM

The service propulsion system (SPS) will provide 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; however, 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 preliminary flight rating test qualification tests, evaluate basic design parameters and performance, certify safe usage, and evaluate the propellant system at sea level. Test fixture F-3 will be used for the subcontractor qualification tests at simulated altitudes and space environments. Test fixture F-2 will be used at the White Sands Missile Range to determine engine and propellant system interaction effects and overall compatibility; it also will permit continuance of service propulsion system tests when airframe 001 is undergoing 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. Off-the-shelf components will be used in this test initially, while qualified components will be used in the final phases.

Testing of the service propulsion system 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. Prototype hardware also will be used in house spacecraft 2 (airframe 006) to confirm development design changes and systems compatibility. The

PRECEDING PAGE BLANK-NOT FILMED

[redacted]

[redacted]

propulsion spacecraft (airframe 001) test at the White Sands Missile Range will evaluate service propulsion system performance, heat transfer, and fuel handling and storage problems under conditions at near sea level. Further testing requirements of the service propulsion system for its ultimate mission will be determined by tests on airframe 008.

REACTION CONTROL SYSTEM

The reaction control system will control attitude and stabilization of the Apollo spacecraft. (The command module and service module have similar reaction control systems.) The reaction control system is pulse-modulated, and uses storable hypergolic propellants which are pressure-fed. It consists of a helium pressurized storage and distribution subsystem, oxidizer storage and distribution subsystem, fuel storage and distribution subsystem, propellant control valves, and 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. Prototype hardware will be used as it becomes available. In general, all system components will be tested to 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 development tests that include experimental, prototype development, preliminary flight rating, and qualification-reliability 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 reaction control system test on the breadboard level. Purpose of the test will be to determine the compatibility of the subsystems and to obtain essential development data.

Initial testing of the reaction control system for preliminary operational procedures will be conducted in house spacecraft 1 (boilerplate 14) and simulated propellants will be used. The reaction control system performance will be evaluated in the propulsion spacecraft airframe 001, and actual propellants will be used for this test. House spacecraft 2 (airframe 006) tests will confirm development design changes, evaluate systems compatibility, and evaluate and develop operational procedures. The reaction control system will be tested further on airframe 008 to determine its readiness for the final mission.

LAUNCH ESCAPE SYSTEM

The launch escape system (LES) consists essentially of the pitch control motor, tower jettison motor, launch escape motor, tower structure, and the

[redacted]

tower release device. Two operational functions of the system include 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.

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 17, 29, and 17 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 will be required for each motor to verify the design prior to flight tests.

Pad abort test of boilerplate 6 and airframe 010 will evaluate the flight dynamic characteristics of the launch escape system. 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 launch escape system tests on boilerplates 12 and 23, and airframe 002 will evaluate system performance at maximum q conditions. During abort tests, additional data will be obtained from escape tower structural verification and operation of the parachute system. Further structural integrity tests (including related launch escape system tests) of the tower will be conducted on boilerplates 9, 13, and 15.

High altitude LES tests including recovery systems 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. Due to limitations of the test configuration, partial launch escape system tests (tower or motors) will be performed on airframes 004, 006 and 008. Tests of the tower structure and release mechanism are included on boilerplates 6, 9, 12, 13, 14, 15, 16, 18, 22, and 23, and on airframes 002, 004, 006, 008, and 010.

EARTH LANDING SYSTEM

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 tested initially by the subcontractor or the contractor and will progress through complete system hardware testing. Tests emphasizing interface areas will explore complete system problems. 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 B-3 and B-19 for reuse of the articles only.

The earth landing system will be installed on the environmental proof spacecraft (airframe 008) to verify the system's capability to withstand the environmental conditions of the Apollo missions.

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

Pad abort escape test for boilerplate 6

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

High altitude abort for boilerplate 22

Further results on the operating capabilities of the earth landing system will be gained from the recovery of boilerplate 23 and airframe 010.

ENVIRONMENTAL CONTROL SYSTEM

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, CO_2, toxic gases, and other contaminant removal.

Materials will be examined by the subcontractor for integrity and reliability under Apollo environments. Components for the environmental control system will be tested by the subcontractor for performance requirements and design modifications in simulated environmental and/or dynamic conditions to verify flow rates, pressure drops, electrical and thermal characteristics, functional performance, and response times. The subcontractor also 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 environmental control system and will employ 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. S&ID also will analyze subsystem interaction and compatibility, preflight and inflight testing and monitoring, and GSE interaction and compatibility.

[redacted]

[redacted]

ECS qualification tests will be performed on B-14. Major tests on the environmental control system will be performed on house spacecraft, airframe 006, and the environmental proof spacecraft, airframe 008. Initial flight performance of the environmental control system will be tested on airframes 002, 009 and 010. Flight performance will be verified on instrumented and manned orbital spacecraft airframe 011.

ELECTRICAL POWER SYSTEM

The electrical power system consists of major components and subsystems which include fuel cells, mechanical accessories, pyrotechnics, solid-state inverters, sequencers, secondary-type zinc 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 their conformance to procurement specifications. S&ID also will conduct system and integrated system level tests on breadboards, boilerplates, and spacecraft.

Operational characteristics of the sequence subsystem and electro-explosive devices will be evaluated in the pad abort tests (boilerplate 6 and airframe 010) and abort tests (boilerplates 12 and 23, and airframe 002). Compatibility of the electrical power system on the subsystem, system, and integrated system level will be determined by the house spacecraft tests (boilerplate 14, and airframe 006). Effects of heat and vibration on the electrical power system will be determined by the propulsion spacecraft test (airframe 001). The environmental test will determine operational characteristics of the electrical power system in simulated mission environments (airframe 008).

GUIDANCE AND NAVIGATION SYSTEM

The guidance and navigation system is comprised of the inertial measurement unit, the sextant, guidance computer, display and controls, final approach equipment, sun finder assembly, and the power and servo assembly.

Design and development testing will be accomplished by the associate contractor and his subcontractors. This phase of the test program will be continued to system completion. S&ID testing will cover interface requirements, systems and operational compatibility, and computer simulation in order to verify system design and performance. Initial testing will be conducted on house spacecraft (boilerplate 14) and environmental proof spacecraft (airframe 008).

[redacted]

[redacted]

Flight operations will determine subsystem operation ability in spacecraft environment and to demonstrate controlled entry into the earth's atmosphere. Subsystem interface operation ability is an objective for Apollo-Saturn flight of airframe 009. Demonstration of most functions with relationship to manned control will be carried out on airframe 011.

STABILIZATION AND CONTROL SYSTEM

The stabilization and control system (SCS) consists of sensing elements, electronic circuitry, and control elements which stabilize and control the vehicle through all flight phases. Major components are the inertial elements, mission programmer (unmanned only), control panels, electronic computer assemblies, command module reaction controls, service module reaction controls, and propulsion system gimbaling controls.

Components and subassemblies will be tested initially at the subcontractor's facility. They will undergo complete system hardware tests accomplished by reaction control motors and analog simulation. Additional tests emphasizing interface areas will be conducted by S&ID to explore complete system problems.

Initial testing with other systems will begin in the house spacecraft (boilerplate 14) where they will be operated in various combinations to assure systems 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 system and reaction control motor systems will be conducted in the propulsion spacecraft (airframe 001).

The ability of the stabilization and control system to produce the controllability needed to maintain proper entry conditions will be verified on spacecraft airframes 009 and 011, which will be tested from a Saturn launch vehicle.

COMMUNICATIONS AND INSTRUMENTATION SYSTEM

The communications and instrumentation system comprises the radio frequency and data handling equipment, antenna subsystem, and instrumentation procured by S&ID from subcontractors and the research and development instrumentation supplied by NASA-MSC. Much of the procured equipment is being manufactured or procured by a major subcontractor (Collins Radio Company). The NASA-supplied items include equipment to

[redacted]

[redacted]

be used only on research and development missions and also equipment to be used on operational missions.

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

S&ID tests will consist mainly of procured equipment evaluation tests, receiving inspection, system integration tests, and acceptance tests of both procured and NASA-supplied equipment.

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 subsystem tests will be performed on airframe 001. Partial antenna equipment group flight evaluation tests will be conducted on airframes 002 and 010.

LIFE SYSTEMS

The success of each Apollo flight is contingent upon the safety of the astronaut and upon his ability to perform his functions and duties. A life systems test program will provide a positive evaluation of all factors affecting crew reliability and safety and will demonstrate that the crew can perform required tasks at the required level of proficiency under anticipated mission conditions.

The life systems test program will evaluate crew performance as an integral function of Apollo system design. Primary emphasis will be placed on required reliability and safety goals achieved by integrating human capabilities and limitations with systems design.

The program will follow logical progression of systems evaluation, beginning with individual systems tests and continuing through multiple systems test and flight test. Tests will be conducted 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-mission simulations.

Evaluation of individual systems operation will 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 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

[redacted]

[redacted]

requirements, and precedures are established, tests will follow progression of typical design-development to first-run and prototype hardware installed in boilerplates 1 and 2, and in airframes 001, 006, and 008. During this latter phase the major emphasis will be placed on crew performance validation during partial- and full-mission simulation studies.

GROUND SUPPORT EQUIPMENT

Ground support equipment is defined as all equipment required to inspect, test, adjust, calibrate, appraise, gauge, 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 hoists, slings, adapters, dollies, winches, electromechanical subassemblies, bench maintenance equipment, covers, computers, and complete checkout consoles. Due to 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 of the same configuration as the GSE to be utilized for flight operations, except for functions unique for the particular test.

Components and subassemblies will be developed and tested at S&ID and at several subcontractors' facilities where they will progress to complete subsystem test development. In addition, S&ID will conduct in-house GSE breadboard tests to emphasize interface areas for resolving complete system problems.

GSE employment will begin with boilerplate 1 and continue through to boilerplate 23. The category and quantity of GSE will be determined during tests. For example, servicing equipment will start, significantly, with boilerplate 6 and continue through boilerplate 23. 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 evaluations tests conducted on airframes 001, 002, 004, 005, and 010. Complete sets of GSE prototypes will be used and tested on airframes 006, 008, 009 and 011.

STRUCTURAL TESTS

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

[redacted]

The test program will begin with laboratory tests to gather design and development information under combined flight environments and loads for prototype structural components. Criteria of static and aerodynamic loads, hard vacuum, heat, meteoroid impact, vibration, and acoustics will be applied. Included are 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, prototype structure, and bracketry. Boilerplate 9 will be shipped to Marshall Space Flight Center, Huntsville, Alabama, where it will be subjected to simulated dynamic flight stresses under the direction of the 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 configuration.

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

MECHANICAL DEVICES

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

Components of each device (viz., latches, cable-cutting release units, shock struts, adjustments, and pivot points) will be development tested for conformance to mission environments and 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. In this manner, 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 hyper-environments 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 improvement of design.

Further verification and qualification of the devices will result from ground and flight testing of the boilerplates and spacecraft which use these mechanical devices. For example, the recoverable command modules will provide operational data when the forward compartment cover and heat shield release mechanisms are subjected to flight loads. Separation devices for the launch escape tower and modular interfaces will be evaluated during test flight missions.

[redacted]

[redacted]

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. In the event that studies are inconclusive, laboratory tests will be conducted to obtain conclusive evidence and to reach an objective engineering decision. Of primary interest is the selection of materials and processes that offer superior strength-to-weight properties. These include reliability, weldability or bondability, and high resistance to critical mission environment, such as radiation, hard vacuum, meteoroid impact, and reentry.

The major criteria for design and material selection for early spacecraft will be airworthiness and spaceworthiness as demonstrated in other programs. The final selection will be made from 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.

WIND TUNNEL TEST PROGRAM

Wind tunnel test program data will provide an evaluation basis for the design and performance of the space vehicle, for the spacecraft with launch escape system, and for the command module during flight from reentry through recovery. These configuration will be examined for aerodynamic stability, pressure distributions and air loads, heat transfer, and structural dynamics.

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

1. Preliminary design data using idealized aerodynamic configurations for models

2. Design confirmation with updated models to include effects of small asymmetries and surface irregularities included in vehicle design

3. Production configuration evaluation with updated models to include final production vehicle design

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

[redacted]

[redacted]

Wind tunnel tests with the drogue parachute also will provide stability, drag, and parachute-module dynamics data.

THERMAL PROTECTION SYSTEM

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, tests of this system will simulate the anticipated flight environment of the spacecraft during boost, abort, earth orbit, translunar and lunar orbit, earth return, and earth atmosphere reentry.

Developmental tests 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, small-scale tests will be made on the individual materials for thermal and mechanical properties. Subsequent tests will be performed on composite panels 2 by 3 feet in size. S&ID will conduct performance evaluation tests (design data and analysis verification tests) to assure conformance to the procurement specifications.

Included in 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, and thermal expansion coefficient and thermal conductivity properties of the ablative materials will be determined by these tests. Acoustical and vibrational environments will be simulated. Mechanical fasteners, adhesive bond, and large composite panel thermal exposure tests for structural integrity of the heat shield ablative material and substructure will form an integral part of the development program. Thermodynamic tests in plasma-arc tunnels will determine the performance of the ablative material when exposed to thermal environments applicable to the Apollo program. Space environment tests will be performed according to capabilities of the test facilities.

The spacecraft flight and static test program relevant to the thermal protection system includes airframes 006, 005, and 008. Design information will be obtained for verification of flight environments, 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 for thermal analysis for the Apollo spacecraft and systems.

[redacted]

[redacted]

RELIABILITY

RELIABILITY PROGRAM

The ambitious nature of the Apollo mission dictates that Reliability Engineering activities be designed to emphasize preventative rather than curative measures to achieve the extreme reliability and safety objectives. To this end, the preventative elements of the program concentrate on high-integrity design; stringent control measures; comprehensive ground testing; and personnel selection, assignment, training, and motivation.

The following curative measures will supplement the foregoing preventative measures:

1. Corrective actions resulting from analyses and reviews of designs, processes, and controls

2. A rapid-response failure and problem reporting system that emphasizes recurrence control and evaluation of the effectiveness of such action

3. Continuous program reviews and reorientation as necessary to establish new priorities and to expeditiously resolve current problems

ORGANIZATION

The Apollo Reliability Engineering Department comprises the following functional units:

1. Criteria and Evaluation

2. Electronic Systems Analysis

3. Mechanical Systems Analysis

4. Qualification Test

The foregoing are under the technical and administrative direction of the Apollo Reliability Engineering Manager. Additional support will be provided by a S&ID Central Reliability Unit in the areas of data and programming, component technology, safety, training, and research.

PRECEDING PAGE BLANK-NOT FILMED

[redacted]

[redacted]

REQUIREMENTS

Mission reliability and crew survival apportionments contained herein are predicated upon the assumption of a direct lunar landing. Lunar orbit rendezvous (LOR) missions necessitate a new apportionment of the program objectives. The revised apportionments will be incorporated in a revision of this document.

In accordance with Part 3, Technical Approach, of the Apollo Spacecraft Statement of Work, the probability of accomplishing the mission objectives will be 0.90. Mission objectives, as employed herein, are predicated upon a lunar landing and earth return mission and include successful recovery of the crew upon landing. In addition, the probability that the crew will not have been subjected to conditions greater than the nominal limits will be 0.90, and the probability that the crew will not have been subjected to conditions greater than the emergency limits will be 0.999.

APPORTIONMENT

The probability-of-success objective for the Apollo mission includes the effects of ground complex; launch vehicle; navigation and guidance system; and the Apollo command, service and lunar landing module reliabilities. In order to define initial requirements for the command and service modules, this reliability objective (0.90) will be apportioned to each of the major elements. These apportioned reliabilities are as follows:

GOSS complex	0.999
Boost vehicle (as defined by NASA)	0.950
Command and service modules	0.960
Lunar landing module	0.988

The reliability apportioned to the command and service modules provides the basis for preliminary apportionments for each mission phase, subsystem, and subassembly. Summaries of the preliminary apportionments are contained in Tables 4 through 7.

Reliability apportionments in the form of numerical reliability objectives will be transmitted to the subcontractors in the statements of work and/or the equipment procurement specifications. A reliable operating life (based on single-mission capability plus checkout time as applicable) and a total operating life requirement will be specified.

[redacted]

Table 4. Preliminary Major Element Reliability Apportionment (Lunar Landing Mission)

Item	Apportioned Reliability	Crew Safety Probability
GSE	0.9999	0.99999
GOSS complex	0.999	0.99999
Boost phase	0.950	0.99994
Command and service modules	0.960	0.9992
Lunar landing module	0.988	0.9999
Total mission reliability*	0.900	
Total crew safety probability*		0.999
*Values per Statement of Work		

[redacted]

[redacted]

Table 5. Preliminary Command and Service Module Reliability Apportionment to Mission Phase

Mission Phase	Apportioned Reliability	Crew Safety Probability
Ground	0.99966	0.99999
Lift-off to translunar	0.99995	0.99999
Translunar	0.9825	0.99965
Lunar approach and landing	0.9988	0.99997
Lunar operations	0.99687	0.99993
Lunar launch to transearth	0.99994	0.99999
Transearth	0.9824	0.99965
Earth approach and entry	0.99992	0.99999
Earth landing	0.99995	0.99999
Mission reliability	0.960	
Mission crew safety probability		0.9992

Table 6. Preliminary Command and Service Module Reliability Apportionment to Subsystem Level

Subsystem	Apportioned Reliability	Crew Safety Probability
Guidance and control	0.989	0.99982
Navigation and guidance	(0.994)	(0.9999)
Stabilization and control	(0.995)	(0.99992)
*Communications	0.9925	
Mission propulsion	0.99977	0.99997
Reaction control (command module)	0.99996	0.99996
Reaction control (service module)	0.996	0.99997
Earth landing system	0.99994	0.99994
Mechanical	0.993	0.99997
Structural and heat protection (including spacecraft adapter)	0.997	0.99995
Environmental control	0.9935	0.9997
Electrical power	0.9955	0.99997
Instrumentation	0.9955	
*Launch escape	0.9978	0.99995
Module mission reliability	0.960	
Total crew safety probability		0.9992

*System reliability not included in calculation of mission reliability

[redacted]

[redacted]

Table 7. Preliminary Subsystem Reliability Apportionment to Subassembly Level

Subassembly	Mission Reliability
NAVIGATION AND GUIDANCE SUBSYSTEM	
Digital computers (2)	0.99661
Inertial measurement units (2)	0.99997
Space sextant	0.99967
Radar antenna transmitters and crystals (2)	0.99983
Radar power supply and processing electronics	0.99867
Dc-ac inverters (2)	0.99960
Periscope	0.99974
Velocity meter	0.99990
Total mission reliability	0.994
STABILIZATION AND CONTROL SUBSYSTEM	
Attitude gyros (3)	0.99930
Rate gyros (3)	0.99999
Stabilization and control electronics (3)	0.99720
Inverters (3)	0.99998
Optical sensors (2)	0.99970
Pilot and copilot controls (2)	0.99999
Video cameras (2) and periscope	0.99999
A-N printers (3)	0.99989
FDI panel controls (2) and three-axis indicator	0.99986
NAV path indicator and controls (2)	0.99997
Propulsion and display panels (2)	0.99955
Reentry planning displays (2)	0.99994
Status displays (2)	0.99995
Reentry pressure instruments (2)	0.99998
Reaction control (command module)	0.99996
Reaction control (service module)	0.99624
Total mission reliability	0.995
REACTION CONTROL SUBSYSTEM (COMMAND MODULE)	
Jets and controls	0.99999
Propellant feed	0.99997
Total mission reliability	0.99996
REACTION CONTROL SUBSYSTEM (SERVICE MODULE)	
Jets and controls	0.99994
Propellant feed	0.99630
Total mission reliability	0.99624
MECHANICAL SUBSYSTEM	
Air lock and docking lock mechanism	0.9985
Umbilical separation	0.9975
Separation (command and service modules)	0.9985
Parachute cover ejection	0.9985
Total mission reliability	0.993
ELECTRICAL POWER SUBSYSTEM	
Fuel cells	0.9973
Reactant pressurization	0.9987
Static inverters	0.9997
Regulators	0.9998
Total mission reliability	0.9955
LAUNCH ESCAPE SUBSYSTEM	
Yaw control motors	0.9994
Launch escape motor	0.998
Launch escape tower	0.9997
Rocket motor ignition (2)	0.99999
Total mission reliability	0.9971

[redacted]

[redacted]

Preliminary reliability apportionment has been determined for each mission phase. The apportionment for a subsystem operating during a particular mission phase is based upon the complexity of the subsystem, its sensitivity to the environment existing during the phase, and the effect a subsystem failure would have on crew safety. The total reliability probability for each subsystem is determined by taking the products of the individual subsystem mission phase reliabilities. The total crew safety probability for each subsystem is determined in a similar manner. This apportionment is shown in Table 8. It should be noted that this approach assumes no redundancy between systems nor does it account for the influence of men's actions and override capabilities to enhance the accomplishment of the mission.

The system apportionment establishes objectives required to meet the defined mission reliability and crew survival probability goals. The apportionment also specifies the allowable probability of failure (one minus the reliability probability) for a given number of mission hours. The allowable failure rates will be computed and will be allocated to the components in each system by the same techniques used for the mission phase and system apportionments.

When environmental conditions, operating times, and generic failure rates have been defined for each component, reliability predictions will be made and the results will be compared with the apportioned values. This comparison will provide a basis for necessary trade-offs between components so that over-all objectives can be met.

Reliability apportionment for the ground support complex will employ methods similar to that used for spacecraft systems. However, consideration will be given to the equipment types according to mission essential equipment, operating ground equipment, and support ground equipment. Each of the three groups will be further subclassified into ranking gradients of reliability-apportioned values.

DESIGN RELIABILITY

Early in the Apollo design stage, an investigation will be made to determine the mechanization of each subsystem that will be used to meet the program objectives. To arrive at optimum mechanization, extensive trade-off studies will be made between requirements in performance, weight, volume, reliability, and cost. The mechanization decisions that will be made for Apollo will be presented in the Apollo Spacecraft Requirements Specification (SID 62-700-2).

[redacted]

Table 8. Preliminary Subsystem Reliability Apportionment to Mission Phase

System / Mission Phase		Prelaunch	1st-2nd Stage Boost	Parking Orbit	Inject to Trans-lunar	Trans-lunar	Lunar Orbit and Landing	Lunar Explo-ration	Lunar Launch	Lunar Orbit	Inject to Trans-earth	Trans-earth	Reentry	Earth Landing	Recovery	Total
Time (Minutes)		260.0	8.4	58.0	6.0	3900.0	180.0	1268.0	5.9	66.0	2.0	3690.0	25.0	12.0	4320.0	13,761.3
Navigation and guidance	R	0.999969	0.999991	0.999978	0.999996	0.997478	0.999837	0.999193	0.999995	0.999983	0.999999+	0.997613	0.999974	0.999994		R 0.994
	P_e	0.999999+	0.999999+	0.999999+	0.999999+	0.999966	0.999998	0.999989	0.999999+	0.999999+	0.999999+	0.999968	0.999999+	0.999999+		P_e 0.99992
Stability and Control	R	0.999974	0.999993	0.999981	0.999997	0.997898	0.999864	0.999327	0.999996	0.999986	0.999999+	0.998311	0.999978	0.999995		R 0.995
	P_e	0.999999+	0.999999	0.999999+	0.999999+	0.999996	0.999999+	0.999998+	0.999999+	0.999999+	0.999999+	0.999996	0.999999	0.999999+		P_e 0.9999
Command module reaction control	R													0.999960		R 0.99996
	P_e													0.999960		P_e 0.99996
Environmental control	R	0.999972	0.999992	0.999979	0.999996	0.997696	0.999851	0.999263	0.999996	0.999984	0.999999	0.997820	0.999976	0.999994	0.998979	R 0.9935
	P_e	0.999998+	0.999999+	0.999999	0.999999+	0.999894	0.999993	0.999966	0.999999+	0.999999	0.999999+	0.999899	0.999999	0.999999+	0.999953	P_e 0.9997
Electrical power	R	0.999961	0.999994	0.999986	0.999998	0.998405	0.999897	0.999689	0.999997	0.999911	0.999999+	0.998491	0.999984	0.999996	0.999293	R 0.9955
	P_e	0.999999+	0.999999+	0.999999	0.999999+	0.999989	0.999999	0.999997	0.999999+	0.999999+	0.999999+	0.999999+	0.999999+	0.999999+	0.999995	P_e 0.99997
Structural and heat protection	R	0.999987	0.999996	0.999990	0.999998	0.998937	0.999931	0.999660	0.999998	0.999993	0.999999+	0.998994	0.999989	0.999997	0.999529	R 0.997
	P_e	0.999999+	0.999999+	0.999999+	0.999999+	0.999972	0.999998	0.999991	0.999999+	0.999999+	0.999999+	0.999973	0.999999+	0.999999+	0.999987	P_e 0.99995
Mechanical	R		0.9959167											0.997083		R 0.993
	P_e		0.999983											0.999987		P_e 0.99997
*Communications	R	0.999967	0.999991	0.999976	0.999996	0.997362	0.999828	0.999149	0.999995	0.999982	0.999999+	0.997485	0.999973	0.999993	0.998822	R 0.9925*
	P_e															P_e —
Instrumentation	R	0.999981	0.999995	0.999986	0.999997	0.998476	0.999902	0.999512	0.999997	0.999989	0.999999+	0.998558	0.999984	0.999996	0.999325	R 0.9957
	P_e															P_e —
Service propulsion	R								0.999999+	0.999998	0.999999+	0.999775	0.999997			R 0.99977
	P_e								0.999999+	0.999998	0.999999+	0.999775	0.999997			P_e 0.99977
Service module reaction control	R			0.999983	0.999997	0.998019	0.999873		0.999996	0.999987	0.999999	0.998145	0.999979			R 0.9960
	P_e			0.999999+	0.999999+	0.999985	0.999999+		0.999999+	0.999999+	0.999999+	0.999986	0.999999+			P_e 0.99997
*Launch escape	R		0.997100													R 0.9971*
	P_e		0.999950													P_e 0.99995
Earth landing	R													0.999940		R 0.99994
	P_e													0.999940		P_e 0.99994
Total	R	0.999844	0.995878	0.999883	0.999979	0.987001	0.999155	0.996449	0.999974	0.999811	0.999991	0.987475	0.999861	0.996955	0.997129	R 0.9600
	P_e	0.999994	0.999978	0.999994	0.999994	0.999802	0.999986	0.999941	0.999993	0.999992	0.999993	0.999596	0.999991	0.999882	0.999935	P_e 0.9992

Note: This analysis is for the lunar landing mission including earth landing and does not include aborts

R = Mission reliability.
P_e = Probability of crew survival

*Not included in total apportionment

[redacted]

An approved parts list will be established for Apollo systems and will include applicable Minuteman parts in addition to parts that have sufficient substantiating data to verify application suitability and the required reliability level. Additions or deletions will be a combined decision of Apollo Design and Reliability Engineering. The ground support equipment will utilize parts from the Apollo standard parts list wherever possible. In addition, a qualified parts list will be established to include those parts from the Apollo approved parts list that have been formally qualified.

Equipment reliability is a function of the environmental and operational conditions to which the equipment is subjected. A preliminary estimate of these conditions will be made by design and reliability engineers using classical techniques. Failure rates will then be determined and compared with failure rates that were apportioned from mission objectives. If this comparison indicates that mission objectives cannot be met, various analytical techniques will be employed to arrive at alternative designs which will be compatible with mission reliability objectives. The principal analytical approaches to be used are environmental conditions, derating, redundancy, design simplification, and parameter drift analysis.

During preliminary design of electronic circuitry, the method of adding part failure rates to determine component failure rates will be employed. Other analyses will be required to investigate failure modes caused by cumulative tolerance build-ups due to part parameter drift rather than by sudden part failures. There are five reliability tolerance methods which are specifically aimed at determining the soundness of the design. These methods are adaptable to large computers (IBM 7090) or small general purpose computers. Listed in order of sophistication, these methods are as follows:

Mandex worst-case analysis

Vinil worst-case analysis

Parameter variation method

Moment method

Monte Carlo method

By representing the circuit as a mathematical equation, the functional relationship between random parameter variation and circuit output variation is determined. These analyses, performed in minutes by a computer, closely simulate thousands of hours of breadboard investigation. Any mechanical or electromechanical component function that can be described by an analogous circuit function can be analyzed by any or all of the five methods listed.

[redacted]

[redacted]

RELIABILITY, CREW SAFETY, AND DESIGN REVIEWS

The Apollo reliability program includes a procedure for assessment and review of the reliability concept, effort, and achievements throughout all phases of contract performance. At these reviews, primary consideration will be given to (1) safety and integrity of systems, subsystems, and components; (2) conservative designs reflecting the maximum reliability attainable, consistent with performance, weight, and cost considerations; (3) early detection of actual or potential deficiencies, system incompatibility, and trends or conditions that could jeopardize flight or crew safety; and (4) elimination of unsatisfactory conditions through a system of rapid corrective action.

The Apollo Reliability Manager is responsible for establishing and chairing a Reliability and Crew Safety Review Board consisting of the following permanent and on-call membership from the following organizations:

Apollo Reliability Engineering

Design Engineering

Project Integration

Quality Engineering

Life Sciences (Human Factors)

Material, Components, and Processing

Standards

Logistics Engineering

Systems Test

This reviewing function will be implemented within the first six months of program initiation and will be conducted at milestones commensurate with design reviews. The results of the review and recommendations will be documented and transmitted to the Design Review Board for consideration.

[redacted]

A Design Review Board will be established consisting of the following membership:

Apollo Chief Engineer (chairman)

Apollo Assistant Chief Engineer (as designated)

Quality Assurance Director

Manufacturing Manager

Systems Design Manager and Supervisor

Project Integration Manager

Apollo Reliability Engineering Manager

Formal design reviews will be conducted in three sequential stages: early development review, design phase review (prior to 100-percent drawing release), and flight test phase. The Design Review Board will prepare a report at the conclusion of each review, and final disposition for each item in the report will be made with recommended corrective action where applicable.

RELIABILITY MONITORING AND DOCUMENTATION

The Apollo Reliability Manager will be responsible for monitoring the progress of all reliability activities including preparing and submitting to higher management all reliability documents and reports. A data center will be established to act as the sole agency for accumulation, storage, collation, and processing of all reliability data. Data and reports generated by this data center will provide a basis for the Reliability Manager to determine that reliability/crew-safety objectives are being attained, and that all work affecting reliability is being performed in accordance with the program plan.

The documentation and reporting system will provide periodic reports to S&ID and NASA to permit a continuous accounting of reliability progress and problems throughout the program. Reliability documentation and reporting will be done in accordance with the Apollo statement of work. Documentation and reporting requirements will be met by including the desired information in reports required by the statement of work.

[redacted]

[redacted]

SUBCONTRACTOR RELATIONSHIPS

Major subcontractors will be required to establish a reliability program in consonance with the Apollo Statement of Work and military specification MIL-R-27542, and to prepare reliability program and qualification test plans. Plans will be reviewed by S&ID and NASA-MSC.

Reliability engineers with specialized experience in the various subsystems will be assigned to monitor reliability program progress at each subcontractor location. The reliability engineer will provide liaison between the subcontractor and S&ID, assist the subcontractor in the solution of reliability and test problems, and furnish the subcontractor with failure feedback information for corrective action.

Before a major subcontractor will be authorized to proceed with production, the following prerequisites will be met:

The design will be approved by S&ID for reliability, function, and manufacturing and quality feasibility.

The subcontractor's quality control and inspection plans will be approved by S&ID.

The test plans and facilities will be approved by S&ID.

Commensurate requirements and controls will be transmitted to subtier suppliers.

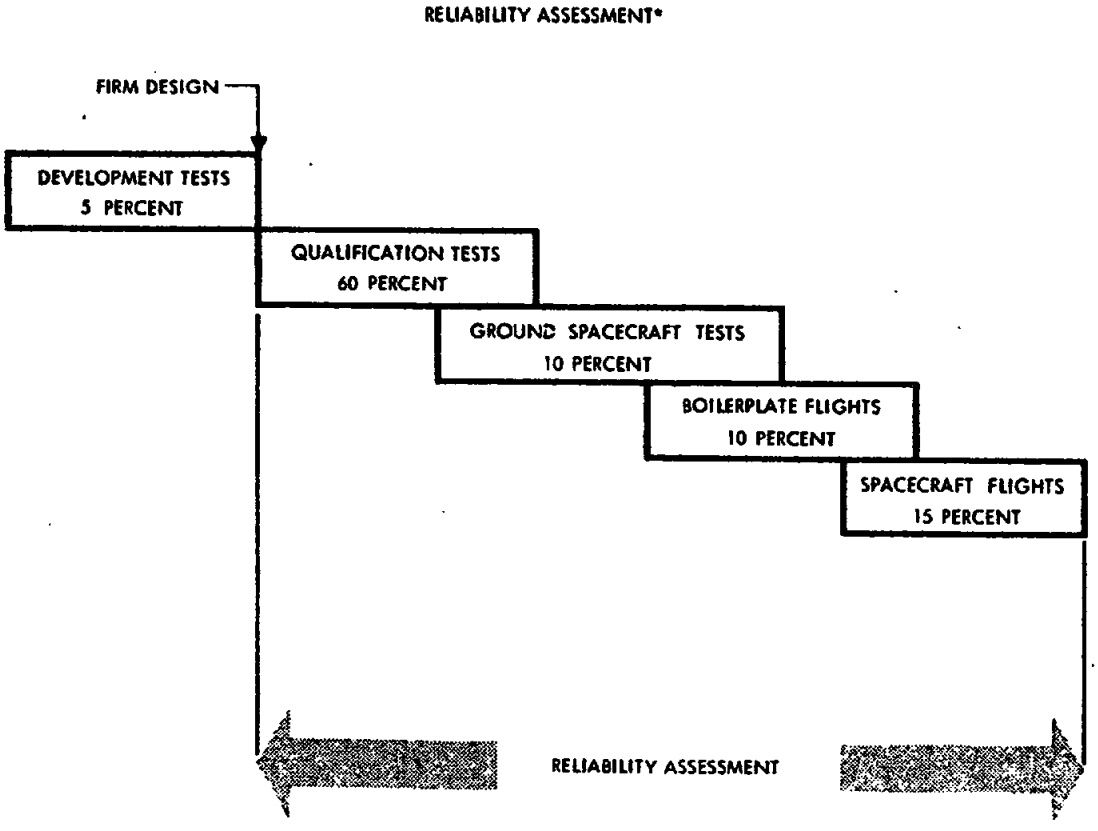
The subcontractor will have provided indoctrination and training in reliability and quality for all employees.

RELIABILITY MEASUREMENT AND ASSESSMENTS

S&ID intends that all testing at the part, component, subsystem, and system level will be used to provide mission reliability and crew safety data. The qualification test plan for Apollo is a consolidation of a sequence of tests starting with certain material evaluations and proceeding through actual flight and recovery of the spacecraft. Figure 105 illustrates the integration of all testing into an over-all test plan. Qualification testing of materials, parts, components, subsystems, and systems under functional and environmental stresses will, in general, follow development tests but will include certain development tests results. Qualification tests will be conducted to assure that the design will be capable of meeting anticipated Apollo mission requirements. Other tests on nonflight hardware will demonstrate the capabilities of integrated systems and the complete spacecraft and their reliable operation under the performance and environmental conditions expected during actual flight.

[redacted]

[redacted]



*ASSESSMENT—A BY-PRODUCT OF ENGINEERING TESTS

Figure 105. Apollo Test Plan

[redacted]

[redacted]

Qualification tests will be conducted on all equipment designed for use in the spacecraft command module, service module, adapter assembly, and associated ground support equipment. The statistically designed test plan will provide for the maximum utilization of data from all ground and flight tests conducted throughout the Apollo program.

Although tests conducted during the development of hardware may be considered preliminary qualification, formal qualification will not be initiated until reasonable assurance exists that the equipment will pass qualification requirements. The qualification test program will establish the flightworthiness of the equipment.

Qualification tests will consist of the application of specification environmental and functional stress levels, performance variability tests, performance and environmental design margin verification on the hardware. Confidence in equipment reliability will be developed from these tests and data obtained from the environmental-proof and house spacecraft, from equipment acceptance tests, and from tests conducted during the prelaunch and launch operations. Each portion of the overall test program will contribute some percentage (Table 4) of the total data used to assess reliability.

Quantitative and qualitative reliability analyses (logic networks, criticality ranking and failure mode analyses) will be used to assign testing priority to equipment that is condisered essential to crew survival and mission success.

The principal test effort will begin at the part or component level. Part evaluation tests will be performed as necessary when data are lacking and when economically or technically more advantageous than tests at the component level. However, such tests are expected to be minimized by the use of resistors, diodes, and other parts of known high reliability in all possible applications. Parts and components will be divided into the following three categories for qualification test planning purposes:

Category I - This will include newly designed parts or components for which no valid test or experience data exist. A rigorous program of testing is planned for these parts.

Category II - This will include existing hardware for which partially satisfactory prior test and expreience data can be provided or Category III hardware that is to be modified for the Apollo application. These items will be subjected to additional qualification testing, the scope of which will depend upon the nature and sufficiency of prior data.

[redacted]

Category III - This will include existing hardware for which satisfactory qualification test data already exist. Except in a few cases, Category III parts and components will, by definition, require no further testing. All existing test and experience data, however, will be carefully reviewed for substantiation of the complete suitability of the part or component for the specific application.

Subsystem and system qualification tests will be statistically planned to provide reliability evaluation data, performance variance, off-limit performance, wearout data, and exploration of the effect of such performance on system functional parameters. Interaction and interface problems between components and subsystems will also be explored.

Ground support equipment items will be qualified by a plan similar to that for spacecraft systems and subsystems. The amount of testing to be performed on each item will be based upon the criticality of the item and characteristics of the equipment such as complexity, use history, previous testing, apportioned reliability, predicted reliability, and frequency and duration of operation.

Flight hardware test data will be processed and analyzed for quick reaction to malfunction data and for rapid assimilation of trend data. Malfunctions that occur or are discovered during the tests will receive top priority for corrective action. On-the-spot failure analysis will be extensively employed in these tests. Performance limits will be determined by design studies of system requirements and by tolerability and integration measurements. Operating parameters, measured as a function of time, will be used to define the traditional go, no-go acceptance criteria.

FAILURE AND PROBLEM REPORTING, ANALYSIS, AND FEEDBACK

Analysis and recording of failures will establish the mode, probable cause, and effect of failures, and will differentiate between failures due to the equipment itself and those due to human errors in handling, transporting, storing, maintaining, and operating the equipment. On-the-spot failure diagnoses will be accomplished by a team of engineering specialists, reliability engineers, and quality control engineers; and reasonable facilities will be available so that the program can continue without interruption while analysis is being accomplished on an urgent basis. The method of analysis and reporting will be compatible with the NASA reporting system.

[redacted]

[redacted]

The failure reporting system will be established as early as possible in the design phase and will encompass spaceborne equipment, ground operational support systems (GOSS), and ground support equipment. The objectives of this system are the collection, recording, analysis, and feedback of all failures or problems occurring at the following locations:

Major subcontractors

Suppliers

In-plant design evaluation, fabrication, installation test, and checkout

Customer-controlled tests and checkout

Off-site installation test and checkout

Customer use on the mission

Analyses will identify failures by type and classification as defined in the following listing:

<u>Type</u>

Primary	Self-induced failure of the equipment
Secondary	Failure induced by human error or by failure in other equipment

<u>Classification</u>

Critical	Reliability degrading failure with ramifications in crew safety
Major	Reliability degrading failure that will influence accomplishment of the mission or mission objectives
Minor	Failure with no ramification in mission success or crew safety but which influences the basic integrity of the equipment and constitutes a nuisance value or maintenance incident

Failures experienced during test and ground operations will be interpreted in terms of their influence on mission success or crew safety had they occurred in flight.

[redacted]

Problem and failure reporting for Apollo will be accomplished by using the procedure and forms that have been proved on the GAM-77 Hound Dog program. Among the advantages of using this procedure are that problem and failure reporting disciplines are already established, the system has been successful on the GAM-77 program, and no retraining is required. Any new features that Apollo reliability may require as the program develops can be easily incorporated.

MANUFACTURING RELIABILITY

Failure of equipment in service due to errors in purchasing, packaging, handling, workmanship, and inspection are as important as failure due to design. The Apollo reliability/crew-safety requirements necessitate a stringent manufacturing control program. To accomplish this, a quality assurance program integrating Reliability Engineering, Quality Engineering, and Quality Control has been designed to assure that the quality requirements are determined and satisfied throughout all phases of contract performance. The manufacturing reliability program will provide for monitoring, control, and improvement of manufacturing processes to assure that reliability requirements are satisfied.

This manufacturing program relies on assessment of design, manufacturing, and inspection capabilities; documented control of procurement, manufacturing, and inspection; reporting and analysis of discrepancies and malfunctions; and a method for prevention of recurrences.

RELIABILITY INDOCTRINATION AND TRAINING

All Apollo personnel will be selected and assigned tasks on the basis of past experience, education, cooperation, attitude, and awareness of the importance to their tasks. Indoctrination, training, and continued evaluation will be an integral part of the Apollo program. The S&ID Training Department, in coordination with the Apollo Reliability Manager and the various functional departments, will be responsible for in-house and subcontractor reliability indoctrination, motivation, and training.

New employees who will be associated with the Apollo program will receive at least two hours of orientation on concepts as applied to Apollo. Supervisory personnel will receive courses in the reliability program plan, the Apollo test plan, job instruction training techniques, familiarization with engineering methods in applicable fields, reliability data analysis and interpretation, quality control methods, and methods of constructing yield charts.

[redacted]

All engineers on the Apollo program will receive reliability training and will be indoctrinated in the influence of their decisions on reliability and crew safety. Formal courses will be offered covering the various technical aspects of reliability, statistical reliability theory, systems and components analysis, failure allocations, qualification test planning and analysis, data requirements, and methods of data analysis.

Apollo production personnel will receive specialized training in their respective fields. In special skill, equipment, and process categories, certification will be employed in accordance with the provisions specified in the Apollo Quality Control Plan (SID 62-154). Certification of inspection and of special processes and fabrication (such as welding, soldering, wiring, radiography, magnetic particle, dye penetrant, and bonding) may be reviewed by NASA to verify proficiency in such operations.

Each supplier or subcontractor will be required by contract or purchase order to establish and maintain a reliability training program similar to that outlined for S&ID.

HUMAN ENGINEERING

A detailed analysis of typical Apollo missions and a description of all tasks in which the Apollo crew members might participate will be fundamental to a definition of the contributions of the crew-to-system reliability. The performance characteristics and limitations of the crew members will be considered during reliability apportionment as an element in system reliability to the extent that primary or backup responsibility is assigned to them.

Human engineering analyses will be conducted to provide assurance that potential sources of human error are minimized in the spacecraft, ground support equipment, and associated ground operations through appropriate task assignments. Life Systems personnel will assist in man-machine trade-offs to ensure that optimum use is made of the crew members as power sources, controllers, pattern recognizers, and error detectors. This will permit simplification of certain vehicle systems whenever reliability can thereby be increased.

Human engineering personnel will participate in all reliability/crew-safety reviews and in appropriate design reviews. Conformity to SID 62-167, Human Engineering Criteria for Space Systems, is a requirement for all Apollo designs, and continuous analysis and close coordination with design and reliability personnel will assure this conformance.

[redacted]

[redacted]

III. SUMMARIES OF PLANS

TEST OPERATIONS

REQUIREMENTS

The test plan for the Apollo Spacecraft Development Program must necessarily encompass all effort required to evaluate and qualify components and parts, major subassemblies, subsystems, equipment in the spacecraft, and supporting equipment. Separate test programs have been or will be established for each major system. In general, these programs will commence at the subcontractor's test facility at the component and subsystem level. NAA-S&ID will monitor major subcontractor test programs and will do performance evaluation and integrated systems tests of its own at the subsystem and system level to ensure conformance to established specifications. Detailed plans for testing are delineated in two NAA-S&ID documents: "Qualification-Reliability Test Plan" (SID 62-204) and "General Test Plan" (3 volumes: SID 62-109).

The general test plan is a joint effort of Apollo Engineering Test Integration and Apollo Test and Operations with Test Integration providing appropriate engineering requirements for all major ground and flight tests to be conducted under the cognizance of Apollo Test and Operations.

Portions of the "General Test Plan" relating to the major hardware ground and flight test programs have been included in the program plan because of the significance of these tests. Figure 106 indicates the major hardware proposed for the test program, as well as schedules and missions of the various ground and flight tests. Figure 107 illustrates that the major hardware items can be grouped as follows:

1. Ground tests include dynamic test boilerplate, propulsion spacecraft, static test spacecraft, house spacecraft, environmental spacecraft, and impact test boilerplates.

2. Air drops include two boilerplates used for confirmation of parachute recovery subsystems operation.

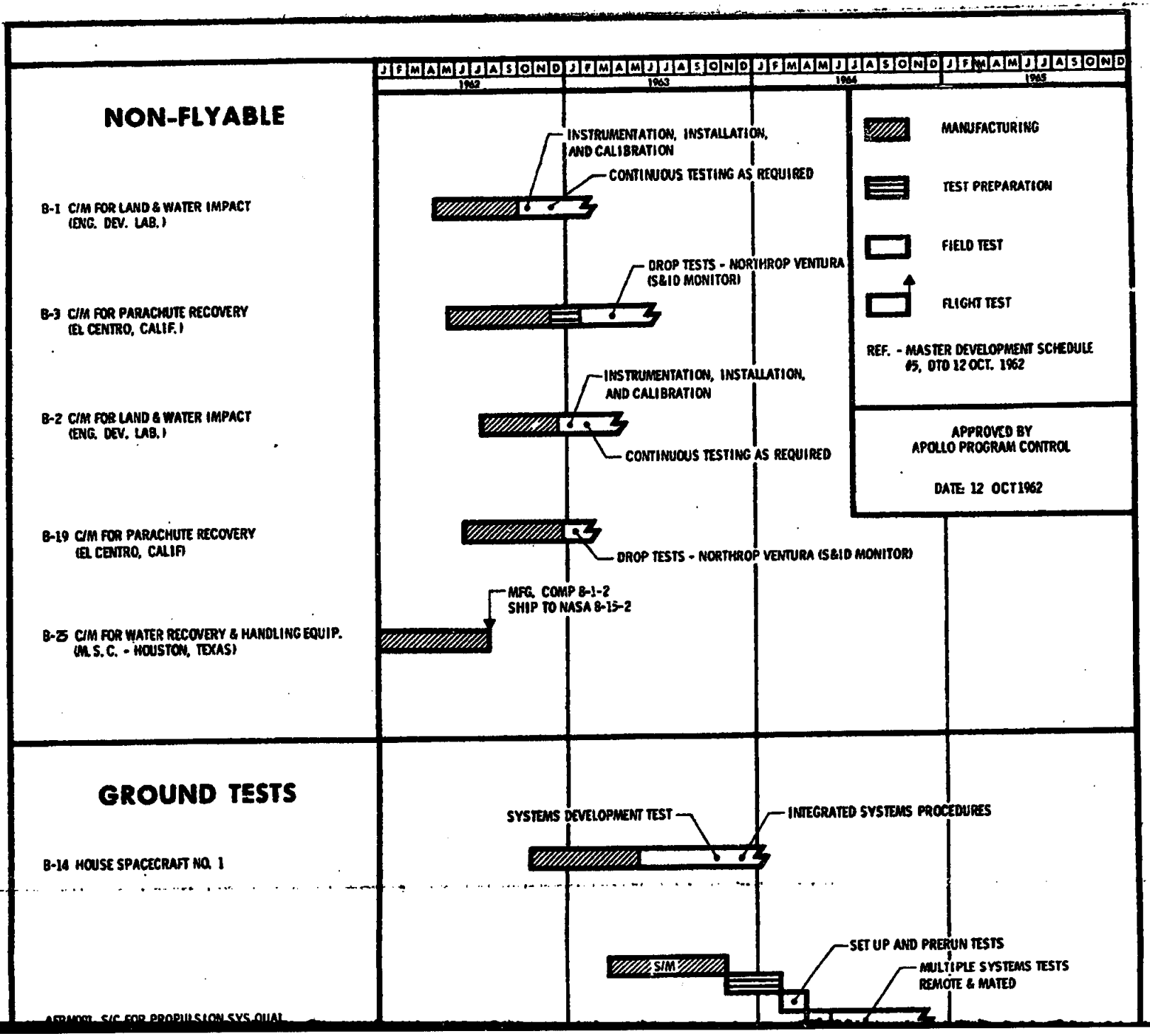
3. Pad abort tests will demonstrate, evaluate, and qualify the launch escape system.

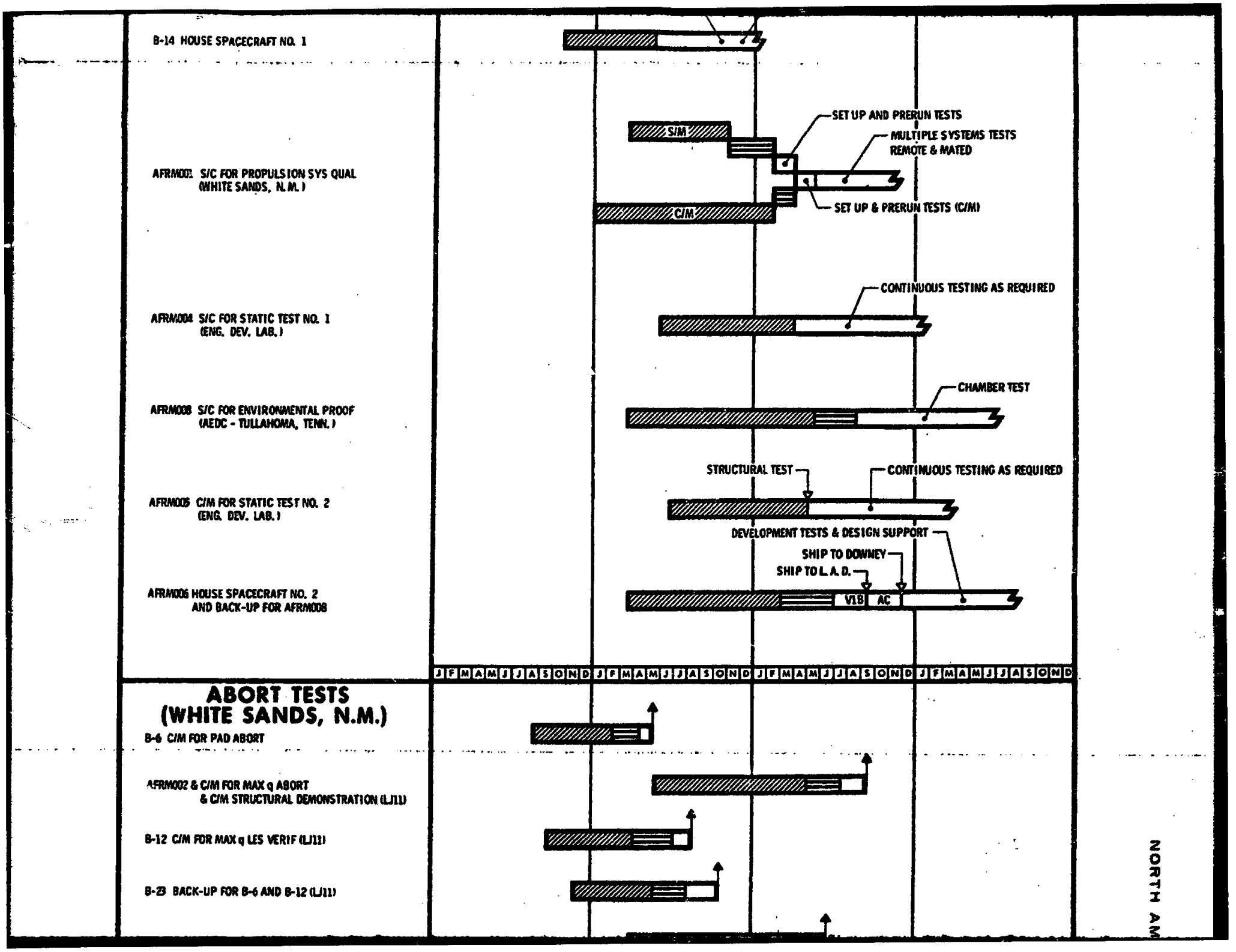
4. Little Joe II launches include boilerplates and spacecraft launches for demonstration and evaluation of abort capabilities at high altitude and maximum q, and also verification of command module structure.

PRECEDING PAGE BLANK-NOT FILMED

[redacted]

PRECEDING PAGE BLANK-NOT FILMED




B-14 HOUSE SPACECRAFT NO. 1
AFRM001 S/C FOR PROPULSION SYS QUAL (WHITE SANDS, N.M.)
S/M
C/M
SET UP AND PRERUN TESTS
MULTIPLE SYSTEMS TESTS REMOTE & MATED
SET UP & PRERUN TESTS (C/M)
AFRM004 S/C FOR STATIC TEST NO. 1 (ENG. DEV. LAB.)
CONTINUOUS TESTING AS REQUIRED
AFRM008 S/C FOR ENVIRONMENTAL PROOF (AEDC - TULLAHOMA, TENN.)
CHAMBER TEST
AFRM005 C/M FOR STATIC TEST NO. 2 (ENG. DEV. LAB.)
STRUCTURAL TEST
CONTINUOUS TESTING AS REQUIRED
AFRM006 HOUSE SPACECRAFT NO. 2 AND BACK-UP FOR AFRM008
DEVELOPMENT TESTS & DESIGN SUPPORT
SHIP TO DOWNEY
SHIP TO L.A.D.
V18
AC
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
ABORT TESTS (WHITE SANDS, N.M.)
B-6 C/M FOR PAD ABORT
AFRM002 & C/M FOR MAX q ABORT & C/M STRUCTURAL DEMONSTRATION (LJ11)
B-12 C/M FOR MAX q LES VERIF (LJ11)
B-23 BACK-UP FOR B-6 AND B-12 (LJ11)
NORTH AM

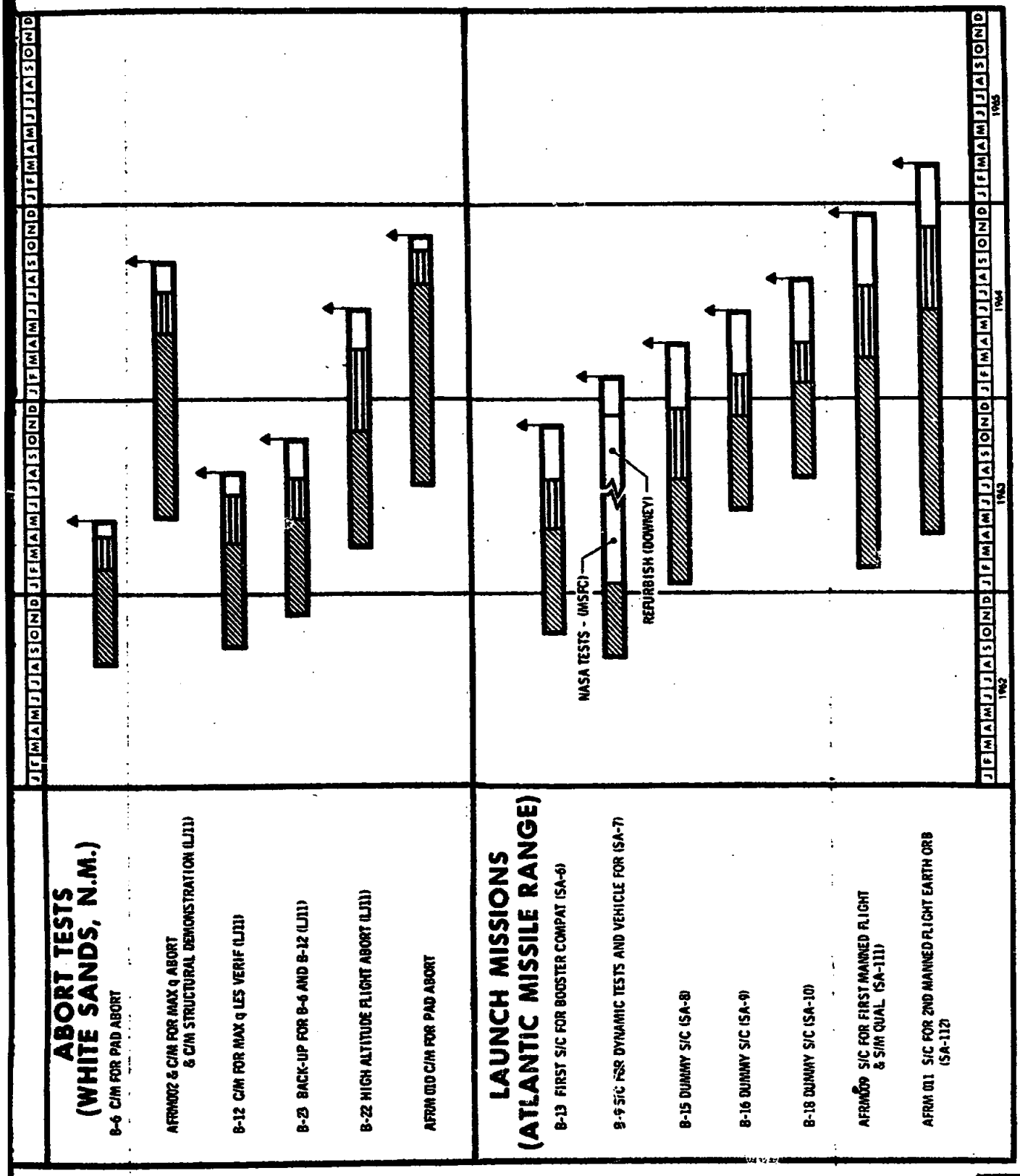


Figure 106. Flyable and Nonflyable Test Hardware

[redacted]

C/M	25	QUALIFICATION OF S/C DESIGN FOR WATER STABILITY AND FLOTATION
C/M + S/M + LES	14	HOUSE SPACECRAFT 1 TESTS
C/M + S/M + LES	9	DYNAMIC STRUCTURAL COMPATIBILITY WITH LAUNCH VEHICLE
C/M	2	EARTH IMPACT AND CREW ATTENUATION SYSTEMS CONFIRMATION (LAND, WATER)
C/M	1	EARTH IMPACT AND CREW ATTENUATION SYSTEMS CONFIRMATION (LAND, WATER)
CONFIGURATION	NUMBER	OBJECTIVE

BOILERPLATES

GROUND TESTS

C/M	19	CONFIRMATIO RECOV
C/M	3	CONFI PARACHUTE
CONFIGURATION	NUMBER	O

BOILERPLATES

AIR DROPS

SPACECRAFTS

CONFIGURATION	TYPE	OBJECTIVE
C/M + S/M + LES	PROPULSION S/C AFRM 001	VERIFICATION OF PROPULSION SYSTEM OPERATION
C/M + S/M + LES	STATIC TEST NO. 1 AFRM 004	VERIFICATION OF STRUCTURE STIFFNESS (SIMULATED PRE-LAUNCH THROUGH LUNAR LANDING)
C/M + S/M + LES	HOUSE S/C NO. 2 AFRM 006	VIBRATION & ACOUSTIC EVALUATION VERIFICATION OF SYSTEMS PERFORMANCE AND COMPATIBILITY BETWEEN MODULES AND GSE
C/M	STATIC TEST NO. 2 AFRM 005	VERIFICATION OF STRUCTURE STIFFNESS AND INTEGRITY DURING REENTRY AND RECOVERY PHASES
C/M + S/M + LES	ENVIRON PROOF S/C AFRM 008	VERIFICATION OF COMPLETE SPACECRAFT DESIGN UNDER SIMULATED MISSION ENVIRONMENTS

NOF

	CONFIRMATION OF PARACHUTE RECOVERY SYSTEM
	CONFIRMATION OF PARACHUTE RECOVERY SYSTEM
ER	OBJECTIVE
LATES	

OPS

C/M	AFRM 010	LES QUALIFICATION FOR PAD ABORT (RECOVERABLE)
AIRFRAME		
C/M	6	LAUNCH ESCAPE PROPULSION SYSTEM EVALUATION (RECOVERABLE)
CONFIGURATION	NUMBER	OBJECTIVE
BOILERPLATES		

PAD ABORTS

E/M + LES	22
C/M + LES	23
C/M + LES	12
CONFIGURATION	NUMBE

LITTLE JO
LAUNCH FL

SPACECR	
CONFIGURATION	TYPE
C/M + LES	MAX-
ABORT
APRM 0

CONFIGURATION	NUMBER	OBJECTIVE
C/M + LES	22	DEMONSTRATE STRUCTURAL INTEGRITY OF C/M (RECOVERABLE)
C/M + LES	23	BACK UP FOR B-12, B-6 (RECOVERABLE)
C/M + LES	12	LES QUALIFICATION AT MAX q ABORT (RECOVERABLE)

LITTLE JOE II LAUNCH FLIGHTS

SPACECRAFTS

CONFIGURATION	TYPE	OBJECTIVE
C/M + LES	MAX-q ABORT APRM 002	DEMONSTRATION OF C/M STRUCTURAL INTEGRITY (RECOVERABLE)

BOILERPLATES

CONFIGURATION	NUMBER	OBJECTIVE
C/M + S/M + LES	18	S/C FOR BOOSTER COMPATIBILITY (NON-RECOVERABLE)
C/M + S/M + LES	16	S/C FOR BOOSTER COMPATIBILITY (NON-RECOVERABLE)
C/M + S/M + LES	15	S/C FOR BOOSTER COMPATIBILITY (NON-RECOVERABLE)
C/M + S/M + LES	9	DETERMINATION OF DYNAMIC STRUCTURAL COMPATIBILITY WITH CI LAUNCH VEHICLE
C/M + S/M + LES	13	S/C FOR BOOSTER COMPATIBILITY (NON-RECOVERABLE)

C-1 LAUNCH FLIGHTS

SPACECRAFTS

CONFIGURATION	TYPE	OBJECTIVE
C/M + S/M + LES	AFRM 009	MANNED FLIGHT & S/M QUALIFICATION
C/M + S/M + LES	AFRM 011	MANNED ORBITAL SPACE FLIGHT AND SAFE EARTH RECOVERY

Figure 107. Spacecraft Test Missions

[redacted]

5. Saturn C-1 launches include boilerplates and spacecraft launches for system compatibility verification and qualification of spacecraft and systems for manned earth orbital flight.

The major hardware test plans are described in the following paragraphs.

SPACECRAFT TEST PREPARATION PROGRAM

Scope

The spacecraft test preparation program consists of planning, scheduling, implementing, performing, reporting, and evaluating engineering tests on the Apollo spacecraft at the Downey facility. The program is designed to verify satisfactory operation of the individual and integrated systems, as specified by the NAA-S&ID and the NAA-MSC. The major goal is to have the vehicle flight ready and to achieve an extremely high degree of reliability in all components and systems.

Objectives

The following breakdown lists the major objectives of the spacecraft test preparation program.

First Order Test Objectives

1. Perform tests for evaluation and qualification 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 test site

3. Demonstrate and evaluate spacecraft operational GSE compatibility

4. Determine and evaluate necessary procedures and data to assure that the NASA-MSC and the NAA-S&ID test requirements and objectives have satisfactorily been accomplished prior to shipment to test site

5. Determine and evaluate man-machine interface criteria

Second Order Test Objectives

1. Demonstrate a logical development of techniques, procedures, and facilities

2. Demonstrate crew in-flight test capabilities associated with mission simulation tests

[redacted]

3. Demonstrate and evaluate boilerplate interim GSE compatibility

4. Determine and evaluate operation of research and development instrumentation and communication equipment to be used in all boilerplates and airframes

Test Requirements

Test requirements for individual and combined systems tests and integrated systems tests of the various boilerplates and airframes will be included in the detailed test plans. The test requirements will reflect the test objectives, which will be tailored for each spacecraft configuration and mission.

Test Description

The spacecraft flight readiness sequence 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 the test site.

In the test preparation area, a complete examination of the spacecraft systems and subsystems will be performed to insure conformance with the latest configuration, specifications, and engineering orders and to insure the readiness of the hardware for test operations.

Individual tests will be conducted on each system in the spacecraft to insure the functional operation of the systems and to verify individual system performance within engineering specifications. Combined and integrated systems tests will be conducted to insure satisfactory operation of all spacecraft systems. Integrated systems tests will include mission abort sequence simulation to demonstrate the functional capability of the entire spacecraft before shipment to the test site.

After adequate examination and cleaning of the spacecraft, individual modules will be weighed and the center of gravity determined. The escape tower and command module will be aligned and the combined center of gravity will be determined. The gross center of gravity for the spacecraft will be computed.

Modifications on the spacecraft will be made, depending on the NASA-MSC and the NAA-S&ID test requirements. Additional testing will be performed with the system or systems affected by the modifications to verify and substantiate satisfactory individual and integrated system performance.

The spacecraft will be demated, tumbled, cleaned, and necessary preparation made for shipment to the test site.

Facilities

The present test preparation program planning is based on the use of an area in building 1 at the Downey USAF Plant 16 facility, and subsequently, in an interim area at the Downey facility. Completion of Downey facility building 6A will enable using the operational GSE and test facility to accomplish spacecraft test preparation operations, with the exception of actually firing the propulsion and reaction control systems, of space condition operation of the environmental control system, and of usage of the supercritical gases used in the spacecraft for the operation of the fuel cell. However, the fuel cell will be operated by using nontoxic gases.

Reliability

The primary objectives of Apollo Reliability Engineering, in providing support for the spacecraft test preparation, will be to monitor all functional and integrated tests, accumulating system performance data, system operating times, and times to failure on the spacecraft and GSE. This information will be collected in sufficient quantity to establish parameter drift trends, failure areas, and satisfactory confidence levels, when analyzed statistically with previous qualification test results.

PREQUALIFICATION FLIGHT DROP TEST PROGRAM (BOILERPLATES 3 AND 19)

Scope

The prequalification flight drop program will prequalify the parachute subsystem, from parachute cover ejection through touchdown. Parachute performance and riser force data, along with command module dynamics, will be obtained from these tests. A C-133A airplane will be used as the drop aircraft. Drops will be made on land and water, using boilerplate command modules.

Test Objectives

The objectives of the drop test program are to be accomplished within the performance capabilities and flight environments of the C-133A aircraft. The objectives are as follows:

1. To evaluate and prequalify the parachute subsystem performance in the air

2. To evaluate the operation of the various release, ejection, and deployment mechanisms

[redacted]

3. To evaluate the sequential operations of the subsystems

4. To obtain test data to evaluate the command module dynamic characteristics and loads during parachute operation.

Test Description

Command Module Configuration

The configuration for boilerplates 3 and 19, furnished by NAA-S&ID to Northrop-Ventura, will include the following:

1. Command module boilerplate structure

2. Flotation and stability characteristics similar to spacecraft

3. Maintenance and servicing hatches

4. Simulated heat shield

5. Provisions for addition of crew seats and crew support system

6. Parachute compartment cover with lock and release mechanism

7. Hoisting and handling attachments for test use

Northrop-Ventura will supply and install the following:

1. Battery electric power subsystem

2. On-board instrumentation and recorders

3. Radio command and telemetry subsystems

4. Parachute and sequence controller subsystems

5. Special deceleration and stabilization test parachutes

6. Mechanical location aids

Tests

System Verification Tests. Four drops will be performed to verify proper operation of the subsystems and the satisfactory integration of the C-133A, command module, and test range operations and instrumentation.

[redacted]

[redacted]

Prequalification and Evaluation Tests. To satisfy the test objectives, fifty-eight flight drops of the command module from the C-133A aircraft will be performed over a dynamic pressure range q. The range of dynamic pressures of the drops will be limited by the C-133A aircraft. Evaluation of the parachute subsystem over the flight recovery phase of the mission will be accomplished.

GSE Configuration

GSE will be provided for handling, transportation, checkout, servicing, and maintenance operations.

Instrumentation and Data

On-board sensors will provide data for the telemetry system and for the backup of on-board recorders. On-board cameras will record parachute sequencing and operation. The test range phototheodolites will be used to obtain trajectory data. Support aircraft will provide photographic coverage during the in-flight operations. The data will be sufficient to prequalify the parachute subsystem. Data reduction will be performed by both the government test facility and the NAA-S&ID Data Reduction Center at Downey, California.

Facilities

The present planning is based on the use of the government test facility of the 6511th Air Force Group (parachute) at the Naval Air Facility at El Centro, California. The Salton Sea (water drop) facility may be required also. The El Centro test facility can provide all the aircraft test support and other test support required for the program, except for the drop aircraft (C-133A).

Special Requirements

The flight drop program will be conducted by the Northrop-Ventura Division at the El Centro test range. A C-133A aircraft and the associated GSE is required by the Northrop-Ventura Division to conduct the program. Modifications must be made to the C-133A, so that it can be used as a drop aircraft. The modifications will not require any change to the basic aircraft structure. It will consist of removal of the aft landing ramp door and the addition of a floor-mounted carrying and release rack for the command module. Hoisting and release mechanisms will be added to the carrying and release rack. The NAA-S&ID has subcontracted the design and modification of the C-133A to the Douglas Aircraft Company, Inc., Aircraft Division, Long Beach, California. After the completion of the flight drop program, the C-133A will be remodified to a service condition by the Douglas Company and returned to the Air Force.

[redacted]

[redacted]

MISSION ABORT TESTS

Scope

The objectives of the mission abort tests are as follows:

1. To evaluate flight dynamics of the launch escape system
2. To evaluate the ability of the launch escape system to perform as designed
3. To evaluate recovery system
4. To evaluate the structural integrity of the launch escape system and the command module

These evaluations will be made at a series of critical points in the mission profile. The critical points are: prelaunch, maximum dynamic pressure (max. q), and high altitude.

Test Description

The test vehicle configuration will vary with the critical point being evaluated.

For the pad abort tests (prelaunch point), the test vehicle will consist of the command module, the launch escape tower, the escape, pitch, and jettison rocket motors, and the ground adapter. The ground adapter is anchored to the launch pad, and the command module with the launch escape system is mounted vertically upon the adapter. The test is initiated with a simulated abort signal, the escape motor is ignited, and the command module separates from the adapter and proceeds on its flight path. At a timed interval near apogee, the jettison motor will be started, and the escape tower will separate from the command module.

The flight path of the command module is governed by the resultant thrust vector of the launch escape motor and the pitch motor. The recovery of the command module will be accomplished with the parachute system.

For the maximum q and high altitude abort tests, the test vehicle will consist of the command module, the launch escape system, a boilerplate service module, and the Little Joe II booster. The tests are initiated with the launch of the Little Joe II booster. For the maximum q abort, the abort is initiated at a predetermined dynamic pressure. The high altitude abort is initiated by a time delay device. The actual abort sequences are the same for all three abort tests.

[redacted]

[redacted]

The pad abort tests will utilize one boilerplate command module (boilerplate 6) and one airframe command module (airframe 010). The maximum q tests will also utilize one boilerplate command module (boilerplate 12) and one airframe command module (airframe 002).

The high altitude test will use one boilerplate command module (boilerplate 22).

An additional boilerplate command module will be used as a backup vehicle for boilerplate 6 or boilerplate 12. This will be boilerplate 23.

Facilities

The mission abort test program will be conducted at the White Sands Missile Range, New Mexico. The facilities will consist of a blockhouse, a transfer room, a gantry, a hazardous assembly area, and a test support area. The existing facilities at White Sands Missile Range will be modified to meet the requirements of the mission abort tests. Optical and radar tracking will be furnished by the White Sands Missile Range equipment and personnel.

Test Dates

The abort test will be conducted at White Sands Missile Range during the period between the first quarter of 1963 through the last quarter of 1964.

SPACECRAFT ENVIRONMENTAL PROOF TEST PROGRAM

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 with two spacecrafts (airframe 006 and airframe 008). 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, including vibration excitation) and vibration and acoustic tests. Environmental conditions associated with propulsion operation are included as a portion of the hot propulsion system test on airframe 001. Compound stresses will be imposed whenever possible to provide maximum attainable reliability confidence.

[redacted]

Objectives

Space Simulation (Thermal-Vacuum Chamber)

This category is directed toward the following objectives:

1. To verify the operational suitability of a prototype spacecraft under simulated space environmental conditions of lif.-off, boost, orbit, and reentry

2. To verify the reliability of a prototype spacecraft under simulated space environmental conditions and to gain increased confidence in the suitability of the vehicle for manned flight operations

3. To determine the heat balance and equilibrium temperature distributions for earth and inertial orientation at maximum and minimum energy conditions

4. To evaluate the effects of outgassing during systems operation

5. To evaluate the effects of cyclic heating and cooling on the structure and systems operation

6. To verify the proper operation, susceptibility to failure, and interaction of all systems, including wiring, gas line, and fluid line connections during simulated low-pressure vibration conditions

7. To determine the vibration transmissibility of the spacecraft structure, with the absence of aerodynamic damping

8. To evaluate operation and suitability of spacecraft operation under various conditions of depressurization

9. To evaluate operation of the in-flight radiation instrumentation, dosimetry equipment, and shielding for secondary radiation buildup within the capsule

Vibration and Acoustic

The following objectives are sought in these tests:

1. To determine susceptibility to failure of the structure, operating systems, and equipment of the spacecraft when it is subjected to simulated service vibration environment

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

[redacted]

[redacted]

3. To determine nonstressed noise and vibration levels in spacecraft

4. To determine the susceptibility to failure of structure and equipment supports of the spacecraft when it is subjected to ground handling and transportation vibration

5. To determine acoustic transmissibility of the command module and service module structures and to determine vibration response of primary and secondary structures in the 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 entry)

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.

Test Description

Space Simulation (Thermal-Vacuum Chamber)

The spacecraft will be mounted in the space-simulating chamber within a vehicular mount capable of rotating the spacecraft to provide simulated solar, earth albedo, and earth radiation inputs at varying spacecraft orientations. The mounting should also include a suitable method for isolation of the vehicle from the mount during vibration testing. The command module will be manned during certain portions of the tests for operating the manual controls during changeover, to test the backup redundant systems.

With spacecraft equipment operating and with subsystems set to simulate anticipated mission duty cycles, the spacecraft will be tested during simulated earth orbital missions of varying durations. Missions will be segmented into several phases.

The lift-off and boost phase will simulate the pressure versus time relationship, with particular emphasis on pressure regulation within the spacecraft.

The conditions of the simulated orbital phase are included in Table 9. Table 9.

[redacted]

[redacted]

Table 9. Simulated Orbital Phase Test Conditions

Test Condition	Duration	No. of Runs	Pressure (mm Hg)
Earth orbit - maximum energy (Earth and inertial orientation)	10 hr	3	1×10^{-6}
Earth orbit - minimum energy (Earth and inertial orientation)	10 hr	3	1×10^{-6}
Earth orbit mission	24-72 hr	3	1×10^{-6}
Command module leak (Earth orbit)	90 min	2	1×10^{-6}

During the operations listed above the spacecraft will be rotated with respect to the radiation sources to simulate the cyclic heating and cooling that will be encountered during earth orbits. These tests are the minimum requirements to accomplish the test objectives and to demonstrate the performance, durability, and repeatability used in establishing the desired level of reliability for satisfactory accomplishment of the first manned flight.

The entry phase will place particular emphasis on pressure regulation and proper sequencing of recovery systems.

Additional space simulation tests will include the following:

Test Condition	Duration
Earth orbit	14 days
Transit (solar orientation)	10 hours
Lunar mission	14 days
Command module leak	4 days

Space Simulation (Vibration)

The spacecraft will be elastically supported in a simulated space environment equal to 1×10^{-3} mm Hg and vibration-excited in the longitudinal direction through the adapter structure. Excitation level will be up to 5 g and will cover the frequency range from 5 to 2000 cycles per second.

[redacted]

[redacted]

Excitation level at each input point and the bidirectional response of primary and secondary structure throughout the spacecraft must be obtained. Systems operation will also be monitored. A minimum of three tests will be conducted for demonstration of reliability.

Vibration and Acoustic

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 axes. The operations will be monitored for system malfunctions and structure and equipment failures. Internal and external acoustic levels and panel vibration will be measured for use in space-flight noise rating analysis. The individual modules and the entire spacecraft (with systems not operating) will be subjected to ground handling and transportation vibration spectrum to determine susceptibility to failure of the structure, equipment, and equipment supports.

Acoustic Tests of Modules. The modules will be mounted in holding jigs for orienting the modules in the acoustic field and for isolating the modules from vibration greater than 5 cycles per second. 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 broad-band and narrow-band excitation.

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 vibrations test data, will be used to evaluate the space-flight nonstressed acoustic and vibration levels.

Facilities

Space Simulation

The space simulation tests are to be conducted at the AEDC Mark I facility. Airframe 008, the environmental proof spacecraft with applicable prototype systems, will be utilized. Subsequent phases may be conducted in the space simulation facility planned for the Manned Space Flight Simulator in Houston, Texas.

Vibration and Acoustic

The vibration and acoustic tests are to be conducted with airframe 006, the house spacecraft No. 2, which will employ applicable prototype systems. The NAA-S&ID Engineering Development Laboratory and the Los Angeles Division, Acoustic Test Facility will be utilized.

[redacted]

[redacted]

SERVICE PROPULSION PROGRAM

Scope

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

The principal test vehicle will be a spacecraft, service module, and command module with the necessary in-flight systems. However, the service module main propulsion system will initially be evaluated with a service propulsion test fixture, F-2. This fixture will provide early assessment of the pressurization, propellant, and rocket engine subsystem interfaces and certify the system design. The F-2 fixture will be of battleship construction, simulating the service propulsion flight configuration. The F-2 fixture program will continue for problem analysis and accumulation of reliability statistics in support of the Apollo program.

The first operational tests of the electrical power system, i.e., the fuel cells and their associated cryogenic systems, will be accomplished on airframe 001.

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 simulate, those to be used in the test preparation and prelaunch operations for the flight spacecraft.

Objectives

Afrm 001 Test Objectives

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

1. To evaluate and demonstrate the service module service propulsion integrated pressurization, propellant and rocket engine system performance under normal and off-limit propellant inlet conditions

2. To evaluate and demonstrate the command module and service module reaction control systems' performance for normal and off-limit propellant inlet conditions

[redacted]

[redacted]

3. To evaluate Apollo propellant handling, thermal conditioning, and transfer equipment and procedures

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

5. To evaluate techniques and procedures for flight vehicle service propulsion and reaction control system (command module and service module) acceptance

6. To evaluate interactions between the propulsion systems and all associated control and monitor systems during operation of the service propulsion system

7. To evaluate servicing and maintenance of the electrical power fuel cell and cryogenic systems installed in the service module

8. To evaluate operation and performance of the complete electrical power system (fuel cell) when operating in a spacecraft under the influence of other spacecraft systems

F-2 Test Fixture Objectives

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

1. To evaluate the operational procedures and performance of the service module service propulsion under normal and off-limit conditions

2. To determine facility and GSE compatibility with the service module main propulsion system

3. To evaluate and improve propellant servicing, leak detection, purge, and checkout procedures

4. To investigate problems and malfunctions evidenced on airframe 001 and flight operations

Test Description

Service Propulsion F-2 Test Fixture

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

[redacted]

[redacted]

propulsion systems. Plumbing and components will be replaced with spacecraft hardware as it becomes available.

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 calibrations will be accomplished.

Following system 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. As one test of malfunction, firing will be conducted with a failed injector valve and with both high- and low-pressure propellant delivery pressures, followed by operations with oxidizer-fuel ratios above and below the normal two-to-one ratio.

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

It is intended that the F-2 fixture be used continuously for malfunction and problem analysis, as a result of difficulties encountered during propulsion systems tests (airframe 001) and during spacecraft flight missions. The test fixture will be used to develop and prove-out modifications to the spacecraft throughout the program.

Propulsion Test Spacecraft Airframe 001

Airframe 001 will be a prototype spacecraft containing systems of flight status, except that the main service module engine flight nozzle will not be employed and sea level nozzles will be used on some reaction control systems tests.

The primary systems to be tested on the spacecraft are as follows:

1. Service propulsion
2. Service module reaction control system
3. Command module reaction control system

[redacted]

[redacted]

4. Propulsion control and display

5. Electrical power systems

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

1. Stabilization and control system: To be available full time for propulsion control investigation under actual firings

2. Guidance and navigation system: To be installed as required for integrated systems demonstrations during propulsion firings

3. Telemetry: To be installed as required for integrated systems demonstrations during propulsion firings

4. In-flight test: To be installed as required for integrated systems demonstrations during firing of the propulsion system

5. Controls and displays: To be installed to support operations of the above systems and determine interactions with other systems

The supporting systems required during the propulsion test program are:

1. Service module environmental control: To support the mated closed command module operation and supporting cryogenic subsystem, as required.

2. Command module environmental control: To support equipment operation and human occupancy when a closed command module is required during service module firings

The service module airframe 001 firing tests will be preceded by a thorough test preparation and a cold test period for the vehicle and associated ground support systems. The service module will be instrumented and checked out in the preparation area at Downey, prior to shipment to the test site. After its arrival at the test site, the service module will be inspected, and then it will be installed on the stand for final test preparation, compatibility test, and instrumentation calibration with the facility. Leak, purge, and propellant servicing techniques and procedures will be investigated. Simulated firings will be conducted for procedure and test control verification. Control of the service module propulsion system will be accomplished from the blockhouse for the initial operations.

[redacted]

[redacted]

The command module will be prepared for test prior to delivery to the test site and will be processed as specified above for the service module. Initial tests will consist of reaction control system firing tests, using manual remote control from the blockhouse. The stabilization control system will then be activated and an evaluation of the integrated systems performed. Programming equipment will be used, either to drive a rate table, or to simulate inertial elements signals, so that flight modes can be investigated.

Spacecraft multiple systems testing will be sequenced to demonstrate progressively the development of the systems and the man-machine compatibility. Present plans are to use the command module as a remote (hard-wire) control station and then progress to a mated spacecraft operations. Ultimate demonstration of the man-machine compatibility may require manning of the mated spacecraft during firing operations.

Scheduling requires the propulsion test program to be phased to specific flight program requirements. The first series of tests will be aimed at providing verification of the propulsion systems and control modes to ground-qualify the spacecraft systems in support of airframe 009, the first manned flight mission. The second series of tests will provide the confidence level necessary to qualify the system for airframe 011, the second manned earth orbital mission. The third series of tests will further demonstrate the systems operation and reliability in support of airframe 011. Thereafter, testing will be extended to demonstrate systems operation and reliability for extended earth-orbit and lunar-mission profiles.

Facility

The propulsion test program will be conducted at the propulsion test facility being provided by NASA-MSC at the White Sands Missile Range, New Mexico.

HOUSE SPACECRAFT TESTS

Scope

House spacecraft testing will be a continuous effort that will have three main phases: system 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 properly the systems concerned and for the ability of the GSE to detect and isolate system failures. System testing with the house spacecraft will be done with major emphasis on integrated systems testing.

[redacted]

[redacted]

Data obtained from the continual testing of the house spacecraft systems will be used in determining the suitability and reliability of design specifications. The information from the tests will also be used to evaluate safety factors in systems design and the reliability of 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 carried out with the second house spacecraft (airframe 006).

Objectives

Systems and GSE Evaluation

The following objectives will be sought:

1. To assure proper performance of components and subsystems
2. To verify individual major systems performance under ambient and certain vibration and acoustic environments
3. To verify system conformance to design specifications
4. To assess GSE compatibility with systems
5. To evaluate requested design modifications
6. To evaluate compatibility of GSE with spacecraft systems
7. To evaluate life systems crew equipment and crew station design for compatibility with human engineering criteria

Operations Development

The following objectives will be sought:

1. To verify systems integration in, and between, major modules
2. To evaluate the adequacy of GSE to detect and isolate system failure
3. To establish reliability and confidence levels during simulated flight missions

[redacted]

[redacted]

4. To evaluate in-flight maintenance capability

5. To determine electromagnetic susceptibility levels

6. To confirm development design modification, as developed during Phase I (systems and GSE evaluation)

7. To determine suitability of design specifications

8. To verify human performance criteria (handling, checkout, and maintenance operations)

9. To determine system performance as a function of operating time and specific functional inputs and environmental conditions

10. To develop handling and integrated systems checkout procedures

11. To develop operational procedures for vehicle and mission (ground and flight crews)

12. To verify that all items of equipment and all procedures and environments are designed for optimum crew safety

Design Support

The following objectives will be sought:

1. To evaluate design development changes prior to inclusion in flight systems

2. To determine malfunction mode limits and trends

3. To evaluate growth potential of GSE for eventual automatic checkout capability

4. To analyze system malfunctions occurring during test preparation

5. To evaluate human factors inherent in systems design for ground and flight crew performance

Test Description

House spacecraft testing will begin with boilerplate 14 (designated house spacecraft 1), scheduled for delivery in May 1963. This spacecraft will be a skeletal structure with removable skin. It will permit mounting spacecraft systems in their proper geometric relationship to each other, so

[redacted]

[redacted]

that actual operating characteristics may be determined. This testing will permit modification assessment on sites within working systems, so that developmental systems may be properly assessed prior to time of prototype manufacturing. Much of the system installation will be of a temporary nature (packaged breadboard) until prototype systems are firmly established. The systems will be updated to full prototype as soon as system availability will permit.

The second house spacecraft (airframe 006) will be a full-prototype structure and systems to develop integrated systems checkout and procedures. It will be delivered in March 1964. This vehicle will be used to execute the vibration and acoustic portions of the environmental proof test program, to resolve interface problems, to verify intersystem compatibility, to develop and evaluate operational procedures, and to perform malfunction mode analysis as the over-all test program proceeds. The first house spacecraft will be integrated into this phase of testing as the prototype systems are installed. It will be somewhat limited in that the removable skin will not permit cabin pressurization testing in the command module.

During all phases of the testing program, the prototype systems will be updated by modification or actual replacement with production hardware to ensure that test result data will be valid for the current flight hardware reliability criteria.

Facilities

The house spacecraft testing program will be instituted at the Downey facility building 6 annex, the Engineering Development Laboratory vibration facility at Downey, and the acoustic facility at the Los Angeles Division. A complete set of GSE will be used to handle the test operations of all systems, with the exception of actual firing of mission propulsion and reaction control motors. These systems will be tested with nontoxic liquids or gases to assess control of the system without violating local safety ordinances.

APOLLO-SATURN TEST PROGRAMS

Scope

The Apollo-Saturn testing will be executed, utilizing both boilerplate and production spacecraft, with the initial objective of development and qualification of the spacecraft and systems for manned earth orbital flight. Five boilerplates are programmed for flight operations with Saturn launch vehicles prior to manned Apollo flight operations. Early flights are programmed for launch vehicle-spacecraft compatibility and environmental investigations. Subsequent flights are programmed for systems development, to culminate in qualification of the spacecraft for manned earth orbital missions.

[redacted]

[redacted]

Test Description

Testing of those Apollo spacecraft schedules for flight operations with Saturn launch vehicles will be initiated at the completion of manufacturing final assembly and will continue throughout flight operations. Test operations will be divided into the following general areas: prelaunch operations testing, launch operations testing, flight operations testing, and recovery operations testing.

Prelaunch Operations

Downey testing will consist primarily of the installation and calibration of instrumentation, complete functional checks of individual systems, calibration of test and checkout instrumentation, configuration updating, and partial integrated systems checks. The second part of the flight test preparation will be completed at the Atlantic Missile Range. It will consist of individual and integrated systems checks, static firings of reaction control systems and the mission propulsion system wherever applicable, and altitude chamber checks. The flight acceptance test operations will culminate in the final launch-pad integrated checkout of the launch vehicle, spacecraft, control centers, and support activities, prior to initiation of the launch countdown.

Launch and Flight Operations

Launch operations will be initiated with the start of the launch countdown, after all functional checks of the spacecraft, the launch vehicle, and launch complex GSE are completed. The countdown will consist of two phases: the prelaunch countdown and the final launch countdown. The prelaunch countdown will include such items as spacecraft systems functional checks, checks of abort circuits, spacecraft servicing, electrical hook-up of certain ordnance items, and final instrumentation checks. Activities which do not lend themselves readily to a time-critical operation will be accomplished in the interim period between completion of the prelaunch countdown and initiation of the final countdown.

Recovery Operations

The recovery operations begin with the first deployment of any equipment or personnel associated with a recovery force. The entire operation encompasses the support of the recovery crew, under the technical direction of the Recovery Control Center (RCC), the Integrated Mission Control Center (IMCC), Air Rescue Service, direction finding (DF) stations, and DOD naval forces.

Upon receipt of impact prediction data from the IMCC, the RCC will direct the recovery crew, composed of NASA and contractor personnel, to

[redacted]

[redacted]

the best-known touchdown point. Air Rescue Service and DF stations will monitor recovery and rescue-aid signals prior to, and after, landing. Airborne rescue personnel will be air-dropped to assist the spacecraft if necessary.

Arriving at the impact site, the recovery crew will, with the necessary GSE, inspect the command module and deactivate systems or make them safe. The crew will make necessary repairs and prepare the command module for airlift to a designated area. The spacecraft crew will be transported to the designated debriefing area by the fastest available means.

For water recovery the nearest RCC will furnish the impact prediction data to DOD naval forces. Retrieval of the spacecraft and crew will be accomplished by using ship cargo booms or modified ships service booms.

In the absence of the regular recovery crew, a retrieval crew will inspect the command module, deactivate systems or make them safe, and transport the command module to the nearest suitable airfield for airlift to a designated area. There the recovery crew will undertake completion of the recovery operations.

Facilities

The Apollo-Saturn tests will be conducted at the Atlantic Missile Range. Pending completion of presently planned Apollo spacecraft checkout facilities, interim facilities will be required for early test articles. Pads 34 and 37 will be utilized for conducting launch operations.

[redacted]

[redacted]

QUALITY CONTROL

The objective of the S&ID Quality Control organization is to assure a quality product at an economical cost in accordance with NASA Quality Program Provisions for Space System Contractors, NCP 200-2. This objective is accomplished through management, documentation, and organization and fulfills the requirements of NCP 200-2.

MANAGEMENT

Quality Assurance is a functional division responsible for all quality assurance programs and is organized under a single director. To assure functional independence, the director reports directly to the Division president and is a member of the Management Council.

The Division Director of Quality Assurance is responsible for Quality Control, Administration and Planning, Space and Missile Systems Test, and Reliability.

The Director of Quality Control is responsible to the Division Director of Quality Assurance. He is responsible for technical guidance by Quality Engineering and the Quality Control Laboratory and for product quality by the Procurement and Fabrication Quality Control and The Space and Missile Systems Inspection Groups.

The Apollo Quality Control Manager reports to the Director of Quality Control in a line capacity and to the Apollo Program Manager in a staff Capacity. He is responsible for the proper execution of the over-all Apollo Quality Control Program. His office monitors the program, apprises both Management and NASA of program progress, and prepares or approves all quality control reports to the customer.

DOCUMENTATION

Basic quality control concepts are established on the corporation level by the Quality Control Policy Manual and on the division level by the Policies and Procedures Manual.

The Quality Assurance Operating Procedures Manual establishes the practices for the functional division and defines this organization's internal operational methods. Quality Engineering bulletins, Quality Control Laboratory bulletins, and Inspection instructions are employed to provide direction in specific applications.

[redacted]

[redacted]

ORGANIZATION

The Quality Control organization provides the technical direction and inspection services for assuring the delivery of a quality product to the Customer. Quality Control acts as the "buyer" of the Material Division's procurements, the manufactured article, and the products conformance testing. After assuring that the product meets the established requirements, this organization acts as the "seller" to the customer.

The responsibilities of the Quality Control department include the planning and implementation of all operational activities associated with the control of supplier and in-house product quality. In general, this effort includes the direct inspection of products in all stages of completion as well as all technical support activities. The program has been designed, developed, and implemented to prevent variance from the design parameters. However, when discrepancies occur the program provides the means for their detection, a comprehensive evaluation of the cause, and a rapid means for instituting corrective action and assuring the prevention of the same discrepancy in the future.

QUALITY ENGINEERING

The Quality Engineering Section is staffed with engineers and analysts who are specialists in all areas of quality control program design, development, and implementation. They provide technical support to Engineering, the Material Division, Manufacturing, the inspection areas, and other Quality Assurance Departments in all matters affecting the quality of company products.

Design and Specification Review

The Apollo Design Review Board, with the Reliability Manager as chairman, provides the method for assuring that the Apollo spacecraft and associated equipment meet the contract requirements, the program plan, the NASA Statement of Work, and the design configuration reflected on the layout. These reviews also include the facilities, operations, and processes utilized in the program regardless of design origin.

The design phase review is conducted prior to or concurrent with release of engineering documents based on detail design, drawings, and specifications to assure that the product can be produced and inspected.

A team of Quality Engineering personnel is assigned to aid the design review effort and are responsible for assuring that requirements for determining and controlling quality are included in the design.

 [redacted]

[redacted]

Quality Engineering is responsible for and acts as the group chairman for determining the individual part, component, or assembly identification and traceability requirements on NASA Contracts. The group is composed of representatives from Reliability, Project Integration, and Design Engineering.

Procurement Specification, Process Specification, Equipment Specification, Quality Control Specification, Supplier Control Documents, and all major subcontractor documents are reviewed by Quality Engineering to assure inclusion of quality control provisions and requirements. These may include the control of a material's chemical and physical properties, processes, fabrication and inspection methods, personnel training and certification, and other related parameters effecting quality of product.

Training and Certification of Personnel

S&ID training and certification is administered and conducted by the Training Department. Quality Control is responsible for initiating training programs for Quality Control personnel. The course outline and content are developed by the Training Department working in conjunction with Quality Control Management. In addition, Quality Control provides input to other training programs where quality provisions and considerations are pertinent.

Inspection and Test Inspection Sheets

Inspection and test instruction sheets (ITI's) are developed for the purpose of providing specific instructions establishing the methods and objectives of inspection and testing, the listing of equipment to be used, and the inspection acceptance criteria. The quality engineers and analysts review and approve production orders for accurate interpretation of the design requirements to provide uniform inspection and test operations and assurance of compliance with design criteria.

Quality Audits

The Quality Audit Group is responsible for assuring adequacy of procedural coverage and compliance to the procedures. Specifically, the audit program purposes are to review and evaluate Quality Control Systems, Procedures, and personnel; to recommend corrective action; and to provide follow-up to assess results of corrective action. Four types of audits are conducted, administrative, product, procedural (conformance to documents), and personnel. Quality audit summary reports will be prepared as required.

[redacted]

Materials Review and Component Quality Analysis

The S&ID corrective action system assures effective review, disposition, and control of nonconforming material. The quality of parts are continuously monitored in all stages of procurement, manufacturing, and test as reflected by failure reports, discrepancy data analysis, and customer reports. Each deviation from a specification occurring at any of these stages is evaluated for cause and need for corrective action. A single nonconforming material reporting document is used to report and record all action taken including problem description, circumstances, probable cause, on-the-spot corrective action, tests, analysis, disposition of material or parts, and corrective action follow-up.

QUALITY CONTROL LABORATORY

The Quality Control Laboratory, which is staffed with engineers and analysts who are specialists in all areas of testing and control, provides technical support to Quality Control, Manufacturing, and Engineering in matters affecting the quality of S&ID products.

Materials and Processes

The Quality Control Laboratory provides the testing, consultation, and analysis support necessary for identifying, qualifying, accepting, and using raw materials investigates and resolves material problems. This group is staffed with personnel who are skilled in metallurgy, chemistry, and plastics.

The Process Control Group establishes and maintains control of all processes that affect the quality of a product. This includes such functions as preparation of control procedures, certification of personnel and equipment, support to the quality audit efforts under Quality Engineering, analysis of processing materials, and evaluation of processed parts.

Metrology and Standards

The Metrology and Standards Group maintains and operates the S&ID Measurement Standards Laboratory, which assures that all measurements can be traced to the National Bureau of Standards. This group maintains and calibrates all company working standards and provides calibration procedures for using these standards in calibrating measuring instruments. A rigid recall system assures recalibration at the specified intervals.

Laboratory Services

The Laboratory Services supports the Quality Control Laboratory in preparing test specimens, special test jigs and fixtures, and other items requiring machine shop work.

[redacted]

[redacted]

Measuring and Calibration

A primary effort of the Quality Control Laboratory is to provide the customer with assurance in the test equipment or measuring device used by the company in the Quality Assurance function. Documentation will be maintained as a part of the company's contractual obligation to provide the customer with documented evidence of validity of the evaluation and certification for the program.

Certification is the written and approved attestment that an acceptable item of test or measuring equipment will perform the required test or measurement to the specified degree of accuracy.

Test or measuring equipment is notorized as acceptable by placement of a decal or other marking on the equipment or the equipment document as evidence of certification.

Procurement and fabrication control is staffed with engineers, analysts, and technicians who are specialized to provide technical support to receiving inspection, source inspection, resident Quality Control representatives to assure quality of procured products.

PROCUREMENT QUALITY CONTROL

Source Selection and Monitoring

Procurement sources are evaluated on the basis of quality history records and/or quality surveys. If other selection methods are not feasible, procured items are thoroughly inspected to qualify the sources of commercial items. Documented qualitative and quantitative evidence is made available to indicate that a particular supplier has a record of supplying high-quality articles of the type procured or has the facilities and quality control system capable of supplying articles which meet the quality requirements. In all cases, a quality history record of suppliers is maintained, and performance is reviewed continuously.

This department conducts purchase order reviews to assure selection of qualified sources and verifies incorporation of design, reliability, applicable codes, and quality assuring requirements. This is in addition to procurement specification review, which is accomplished by Quality Engineering.

Source Inspection

Source inspection is applied where requirements for special, duplicate, or peculiar environmental equipment would be necessary to forego extensive disassembly may be required to accomplish the testing at S&ID. Specific

[redacted]

[redacted]

in-process functions or special circumstances may dictate source inspection to assure S&ID and contractural requirements.

Resident Quality Control Representation

A resident quality control representative is stationed in each major subcontractor facility. The duties and responsibilities of assigned personnel will parallel those of a source inspector for assurance of product quality. However, in addition to assistance to the supplier in fulfilling his contractual obligations related to product quality, surveillance over the subcontractor's quality control system will be maintained to assure conformance to NCP 200-2.

Receiving Inspection

The mechanical and electronic excellence of procured items is ensured by 100-percent receiving inspection prior to acceptance for Apollo program usage. This inspection normally is performed upon receipt at S&ID. However, when it is expeditious or necessary, the inspection is performed at the supplier's plant by S&ID source inspectors. This inspection and testing is performed in accordance with approved instructions that provide detailed step-by-step information which includes all criteria required for acceptance.

The materials and components are inspected for identification and damage, physical, dimensional, hardness tests, and functional requirements. Both nondestructive (fluorescent penetrant, ultrasonic, etc.) and destructive type inspections are employed as required.

Components and subassemblies are tested under environmental conditions for temperature, vibration, acceleration, etc., as required to assure product quality.

Upon receipt of raw materials, hardware, and components, copies of the supplier's reports regarding test results, certification, and physical and chemical properties are evaluated and compared with applicable specification requirements for completeness and accuracy. Inspection warranties and markings are checked. Random checks of raw materials, and chemical and physical properties are made by the Quality Control Laboratory to assure that the supplier's documentation correlate with the material furnished.

Receiving inspection records and analyzes all inspection data and maintains a complete record of their activities. The data is evaluated for quality and reliability assessment and for corrective action. Rejected material and components are appropriately marked and segregated for processing by Quality Engineering material review action.

FABRICATION QUALITY CONTROL

Product quality is assured by performing in-process inspection of all work done in the detail manufacturing areas including sheet metal, machine processing, electrical and electronic subassemblies, and tubing.

[redacted]

Process Control

Process control is the regulation of processing, fabrication, and assembling functions at the source to prevent quality degradation. Quality Engineering is responsible for defining this control and for coordinating the control effort; the Quality Control personnel in the manufacturing area are responsible for enforcing controls. The Quality Control Laboratory aids in defining problems and recommends or establishes preventive measures.

Soldering and Welding

Individual operators and inspectors are certified by the Quality Control Laboratory. The in-line control of soldering is facilitated by constantly surveying the methods, equipment, and techniques of the operators.

Nondestructive Testing

Nondestructive testing, such as radiographic examination, florescent penetrant, ultrasonic, magnetic partical, etc., will be certified by the Quality Control Laboratory. All certified nondestructive inspectors are periodically recertified to assure their proficiency.

Dimensional Tooling

Engineering drawings, master dimensions, loft lines, and tool design drawings will be reviewed to determine tooling requirements, dimensions, tolerances, and construction parameters. Progressive tooling inspection records and their application to the tool under construction will be pre-planned. Records of all tooling inspection will be maintained.

Systems Measurement Devices and GSE

Fabrication Quality Control will inspect each item of ground support equipment to assure that it conforms physically and functionally to applicable documentation and to prove compatibility with other systems. Functional testing of each GSE component and assembly will be conducted with a comprehensive ground equipment test set and with approved documentation and test procedures.

SPACE AND MISSILE SYSTEMS INSPECTION

Space and missile systems inspections are conducted by engineers, analysts, and inspectors who are instructed and trained in the areas of inspection, control, and testing.

[redacted]

[redacted]

The product inspection is responsible for all inspection and testing activities during assembly and checkout of the Apollo vehicle and through final acceptance by the customer. Each inspection or test operation will be performed in accordance with a preplanned inspection instruction sheet as prepared by Quality Engineering. Applicable variable inspection or test data and operating times are recorded and will become part of the permanent record of each vehicle.

Fabrication

The inspection effort will consist of inspecting the fabrication of details, welding, cleaning, processing, and dimensional accuracy using jigs, fixtures, and templates.

Assemblies

Inspection will verify that all subassemblies and assemblies are fabricated in accordance with applicable drawings, process specifications, inspection test instructions, planning tickets, engineering orders, and standard inspection procedures. Inspection will verify that all parts and components have been 100-percent inspected prior to assembly and/or installation. Identification and traceability records will be verified and maintained as applicable.

Installation and Checkout

Inspectors will assure that subassemblies and assemblies are installed and connected in accordance with approved procedures and functionally tested to process specifications. Tests will be witnessed and verified by inspectors.

Inspection Sign-off Records

Inspection will accumulate the operating times, part removal and replacement records, configuration records, discrepancy data, and on-the-spot corrective action for sequenced inspection operations. The completed sign-off records will be retained by Inspection Technical Services as required by contract.

Transportation and Handling

Inspection will assure that dollies and handling fixtures are maintained and that parts, components, and assemblies are located or tied down in such a manner as to prevent possible damage of parts.

[redacted]

[redacted]

Change Verification

A complete record of applicable engineering changes for the subassembly or assembly item under inspection will be maintained in that inspection area. Items will not be moved from assembly areas without verification that applicable engineering orders have been accomplished.

Inspection Technical Services

Inspection Technical Services will maintain record system for acquiring inspection data, assign and control serialization identities, monitor engineering changes to assure documentation of article and configuration, assemble deliverable end-item data packages, and negotiate customer acceptance of deliverable articles.

OFF-SITE TESTING - AMR

The Quality Control requirements and responsibilities are maintained to provide assurance that physical and functional characteristics of materials, assemblies, and complete end items conform to company and contractual requirements for off-site testing. Assigned tasks and responsibilities to satisfy NASA requirements for quality control of Apollo projects are established.

Systems Test Inspection

Quality Control will perform a complete receiving inspection of the spacecraft modules and associated equipment upon arrival at the off-site location and will document all in-transit instrumentation.

During the spacecraft modules stage final acceptance checkout, Quality Control will ascertain accuracy of the test preparations, tests, and other acceptance requirements to assure compliance with applicable S&ID work standards and stage final checkout specifications.

Quality Control has authority to remove and update the configuration record for discrepant components or subsystems and will recertify compliance of supplementary required tests with applicable S&ID spacecraft modules final acceptance checkout specifications.

Quality Control documentation of the spacecraft modules final acceptance checkout will be in compliance with all contractual requirements and will include the applicable data.

When spacecraft modules final acceptance checkout documentation has been reviewed by cognizant S&ID supervision, Quality Control will submit

[redacted]

[redacted]

each spacecraft module and associated documentation to NASA for final acceptance and will represent S&ID whenever inspection functions involve the customer's inspection representatives.

Technical Services

Off-site testing will be performed in a similar operation to that of inspection technical services at Downey. In accordance with MIL-Q-9858, NCP 200-2, and other applicable criteria proper preservation, packaging, packing, marking, identification, and handling of all articles throughout all phases of receival, storage, and shipment will also be assured.

Effective procedures, instructions, and records will be maintained to assure that any article offered for acceptance to the customer is preserved, packaged, and packed in conformance with the contract.

Quality Control requirements for the maintenance of trainers, GSE, and spacecraft components for the Apollo program will parallel the Quality Control requirements imposed on the manufacture of Apollo components. All phases of overhaul, repair, preventive maintenance, and modification will be accomplished in accordance with applicable S&ID and Government specifications and will be so performed that the resultant component will have been restored to its original serviceability and reliability.

Quality Control Engineering and Laboratory

Quality Control Engineering and laboratory personnel will analyze contract specification and control requirements to assure adequate procedural implementation of the inspection operation. Additional functions will include GSE and test equipment calibration and control sampling of propellant, fluid, and atmosphere for contamination control and analyses. Other functions of these groups are the initiation and follow-up of corrective action; Government-furnished property surveillance and control; the monitoring and inspection of the historical data requirements; maintenance of a precision inspection tool crib; maintenance of test equipment and a meter room; and support to Engineering of such services as alignment, hardness testing, dye penetrant inspection, etc.

The Material Review Section of Quality Control Engineering will provide material review support for dispositioning and controlling discrepant and failed articles. This action will consist of, but will not be limited to, on-the-spot analysis, retest as required, and dispositions in consonance with requirements.

Random quality control audits of the same nature as those conducted at Downey to assure continuous, compatible quality operations will be conducted.

[redacted]

Monthly quality reports and quarterly audit summaries will be prepared and transmitted to Downey for inclusion in reports to NASA. Quality Control management status reports will be prepared and submitted.

OTHER OFF-SITE TESTING

The quality control requirements and responsibilities necessary to assure that physical and functional characteristics of materials, assemblies, and completed end items conform to NASA requirements for quality control of Apollo projects as established by contractual requirements for off-site testing.

Quality Control will perform a complete receiving inspection of the spacecraft modules and associated equipment upon arrival at the off-site location and will document all in-transit instrumentation.

During the final spacecraft modules acceptance checkout, Quality Control will ascertain accuracy of the test preparations, tests, and other acceptance requirements to assure compliance with applicable S&ID work standards and final spacecraft module checkout specifications.

Quality Control has authority to remove and up-date the configuration record for the removal and replacement of any discrepant component or subsystem, and will certify compliance of supplementary required tests with applicable S&ID final spacecraft modules acceptance checkout specifications.

Quality Control documentation of the final spacecraft modules acceptance checkout will be in compliance with all contractual requirements and will include the applicable data.

When the final acceptance checkout is completed, Quality Control will submit each spacecraft module and associated documentation to NASA for final acceptance and will represent S&ID whenever inspection functions involve NASA's inspection representatives.

Technical Services

Effective procedures, instructions, and records will be maintained to assure that any article offered for acceptance to the customer is preserved, packaged, and packed in conformance with the contract.

Quality control requirements for the maintenance of trainers, GSE and spacecraft components for the Apollo program will parallel the quality control requirements imposed on the manufacture of Apollo components. All phases of overhaul, repair, preventive maintenance, and modification

[redacted]

[redacted]

will be accomplished in accordance with applicable S&ID and Government specifications and be so performed that the resultant component will have been restored to its original serviceability and reliability.

Quality Control Engineering and Laboratory

Quality Engineering and laboratory personnel will analyze contract specification and control requirements to assure adequate procedural implementation of the inspection operation. Additional functions will include GSE and test equipment calibration and control sampling of propellant, fluid, and atmosphere for contamination control and analysis; initiation and follow-up of corrective action; Government-furnished property surveillance and control; monitoring and inspection of the historical data requirements; maintenance of a precision inspection tool crib; maintenance of a test equipment and meter room; and support to Engineering of such services as alignment, hardness testing, dye penetrant inspection, etc.

The Material Review Section of Quality Control Engineering will provide material review support for dispositioning and controlling discrepant and failed articles. This action will consist of, but will not be limited to, on the spot analysis, retest as required, and dispositions in consonance with requirements.

Random quality control audits of the same nature as those conducted at Downey to assure continuous, compatible quality operations will be conducted.

Monthly quality reports and quarterly audit summaries will be prepared and transmitted to Downey for inclusion in reports to the customer. Quality Control management status reports will be prepared and submitted.

[redacted]

[redacted]

MANUFACTURING

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

TOOLING

The design and fabrication of spacecraft tooling are predicated upon the high reliability factors of this program. Close alliance with engineering has been established to ensure flexibility in adapting to expected design and technical change. The most complex tooling will be those fixtures used in forming, bonding, and brazing of the outer command module heat shields. Automatic skate welding and trimming equipment for joining the segments of each assembly will be used extensively.

Tool Aspects

Tooling for production of the Apollo spacecraft will encompass the areas of welding, bonding, forming, and brazing as required to produce components, structures, assemblies, and modules of Apollo-specified quality. Insofar as practical, tooling will be designed and fabricated to high-quality/low-volume production standards. Tools will be designed and fabricated to critical tolerances to minimize bonding, welding, forming, and brazing problems during construction.

Special Tooling

Five areas will constitute the major tool complexities of the command and service modules. Circumferential welding, cylindrical-section longitudinal welding, adhesive aluminum bonding, high-energy sizing, and assembly operations form the areas where multiple functions of each tool will be required.

[redacted]

[redacted]

SPACECRAFT FABRICATION AND ASSEMBLY PROCEDURES

Command Module

The command module consists of a crew compartment of adhesive-bonded aluminum sandwich structure enclosed in a brazed stainless steel heat-shield assembly. The crew compartment consists of two major assemblies: the aft sidewall and the aft bulkhead structure complete assembly, as shown in Figure 108. These assemblies are joined by automatic butt-fusion-weld joining the inside skins and lap-bonding the outside facing sheets.

Aft Sidewall and Aft Bulkhead Structure Complete Assembly

The aft sidewall and aft bulkhead structure assembly is constructed of bonded aluminum honeycomb sandwich, which consists of the inner-shell skin assembly, aft bulkhead skin assembly, the inner-shell aft bulkhead skin assembly complete, and the bond assembly. The sandwich construction consists of an inner skin assembly, and honeycomb core segments and outer facing sheet segments adhesive-bonded in accordance with specification to complete the structural assembly.

Panel, Bulkhead, and Tunnel Cylinder Complete Assembly

The panel, bulkhead, and tunnel cylinder assembly is constructed of bonded aluminum honeycomb sandwich, which consists of the tunnel cylinder inner skin assembly, the one-sixth inner skin subassembly (six required), the panel-bulkhead inner skin assembly, the inner skin complete assembly, and the bond assembly.

Heat Shield Assembly

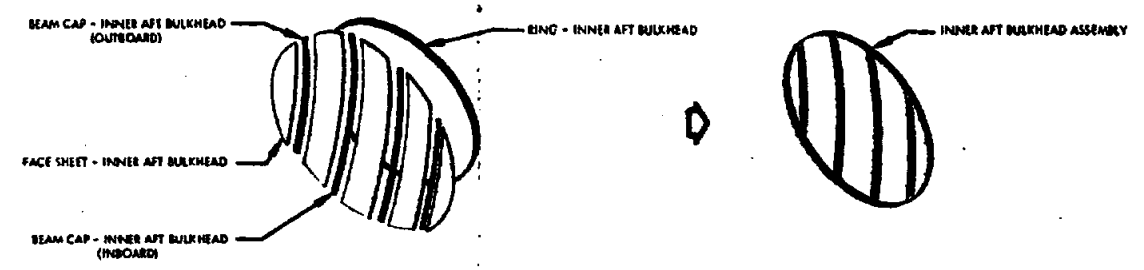
The heat-shield assembly is constructed of brazed steel honeycomb sandwich, which consists of the quarter fairing assembly (four required), aft heat-shield assembly, and the sidewall heat-shield assembly. All steel brazing will be fabricated by a vendor and delivered to the Space and Information Systems Division prior to final trim, weld joining, and installation. (See Figure 109.)

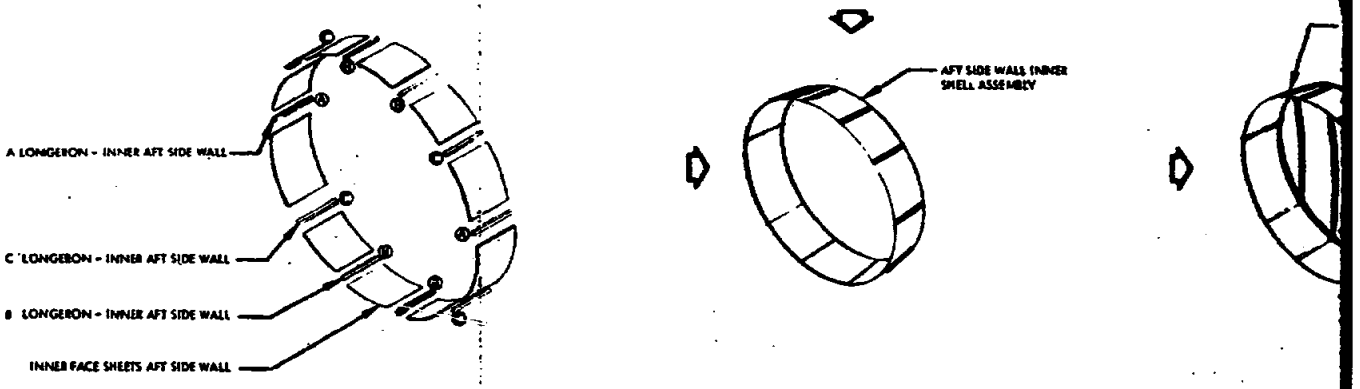
Command Module Final Assembly

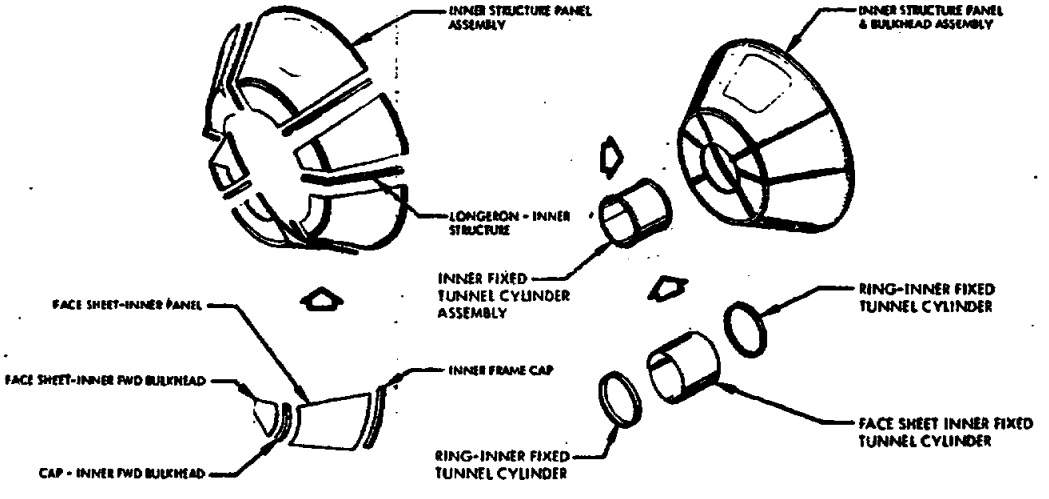
The command module final assembly consists of the forward heat shield compartment, sidewall heat shield assembly, aft heat shield bulkhead assembly, crew compartment assembly, internal equipment portions, and all external components.

[redacted]

[redacted]

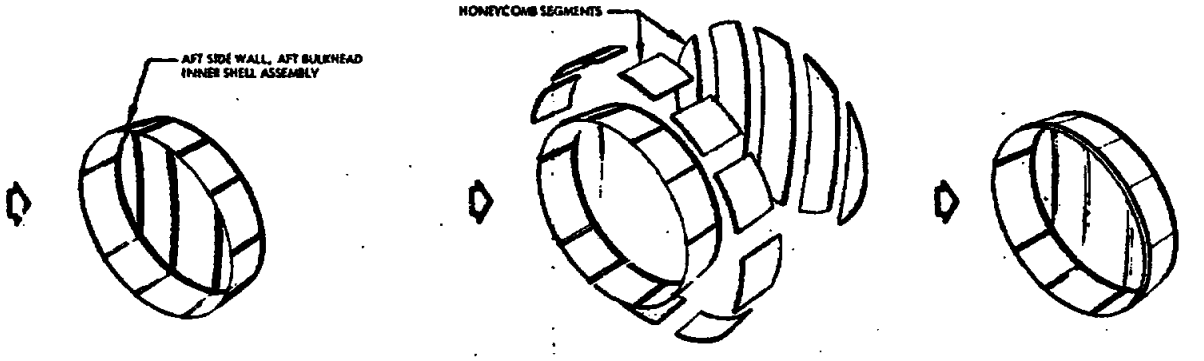

BEAM CAP - INNER AFT BULKHEAD (OUTBOARD)
RING - INNER AFT BULKHEAD
INNER AFT BULKHEAD ASSEMBLY
FACE SHEET - INNER AFT BULKHEAD
BEAM CAP - INNER AFT BULKHEAD (INBOARD)


AFT SIDE WALL INNER SHELL ASSEMBLY
A LONGERON - INNER AFT SIDE WALL
C LONGERON - INNER AFT SIDE WALL
B LONGERON - INNER AFT SIDE WALL
INNER FACE SHEETS AFT SIDE WALL

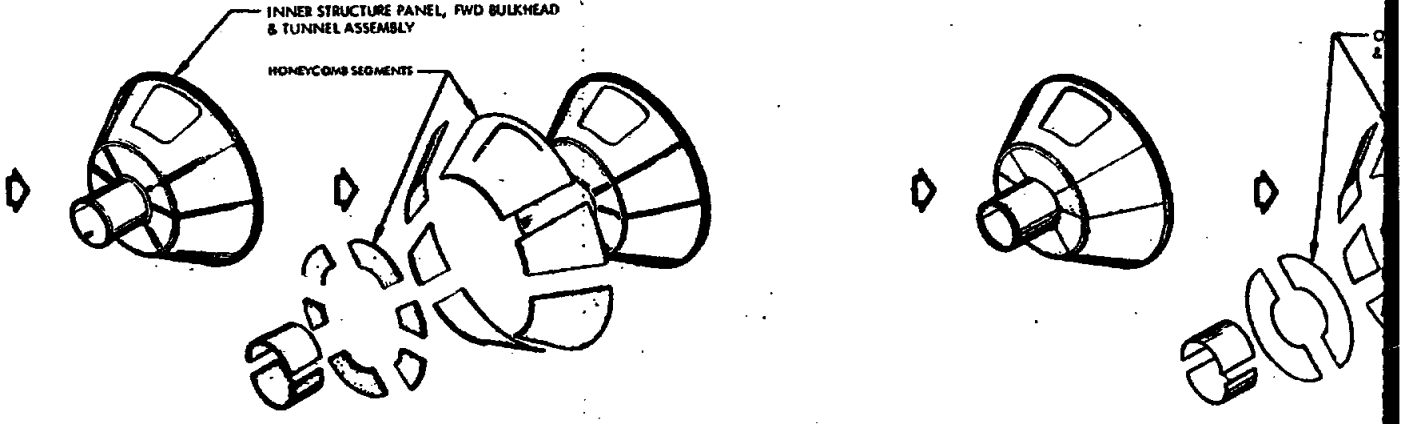

INNER STRUCTURE PANEL ASSEMBLY
INNER STRUCTURE PANEL & BULKHEAD ASSEMBLY
LONGERON - INNER STRUCTURE
INNER FIXED TUNNEL CYLINDER ASSEMBLY
RING-INNER FIXED TUNNEL CYLINDER
FACE SHEET-INNER PANEL
FACE SHEET-INNER FWD BULKHEAD
INNER FRAME CAP
FACE SHEET INNER FIXED TUNNEL CYLINDER
RING-INNER FIXED TUNNEL CYLINDER
CAP - INNER FWD BULKHEAD

FT BULKHEAD ASSEMBLY

E WALL INNER
SSEMBLY



STRUCTURE PANEL
HEAD ASSEMBLY



-INNER FIXED
NEL CYLINDER

SHEET INNER FIXED
NEL CYLINDER

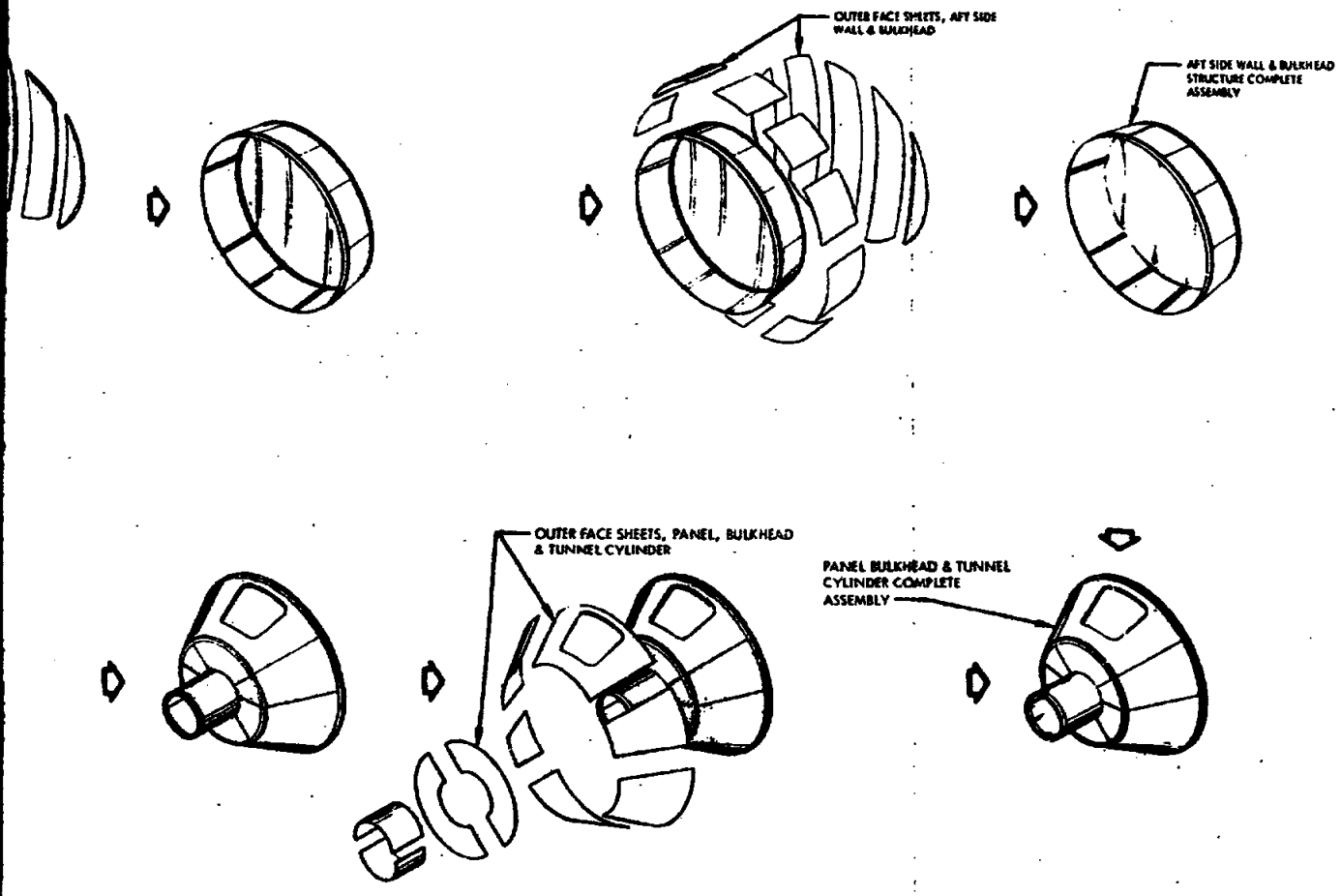


Figure 108. Inner

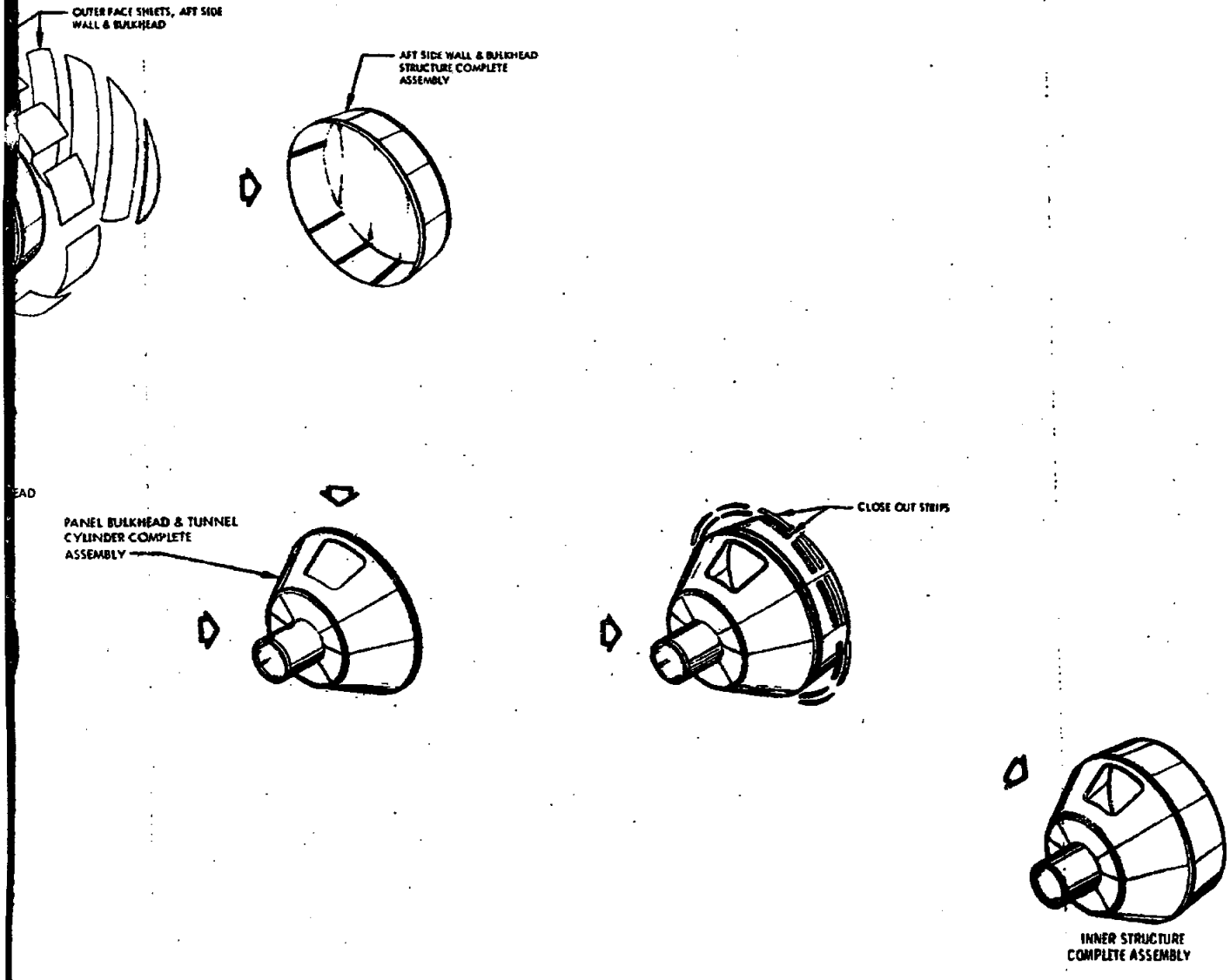
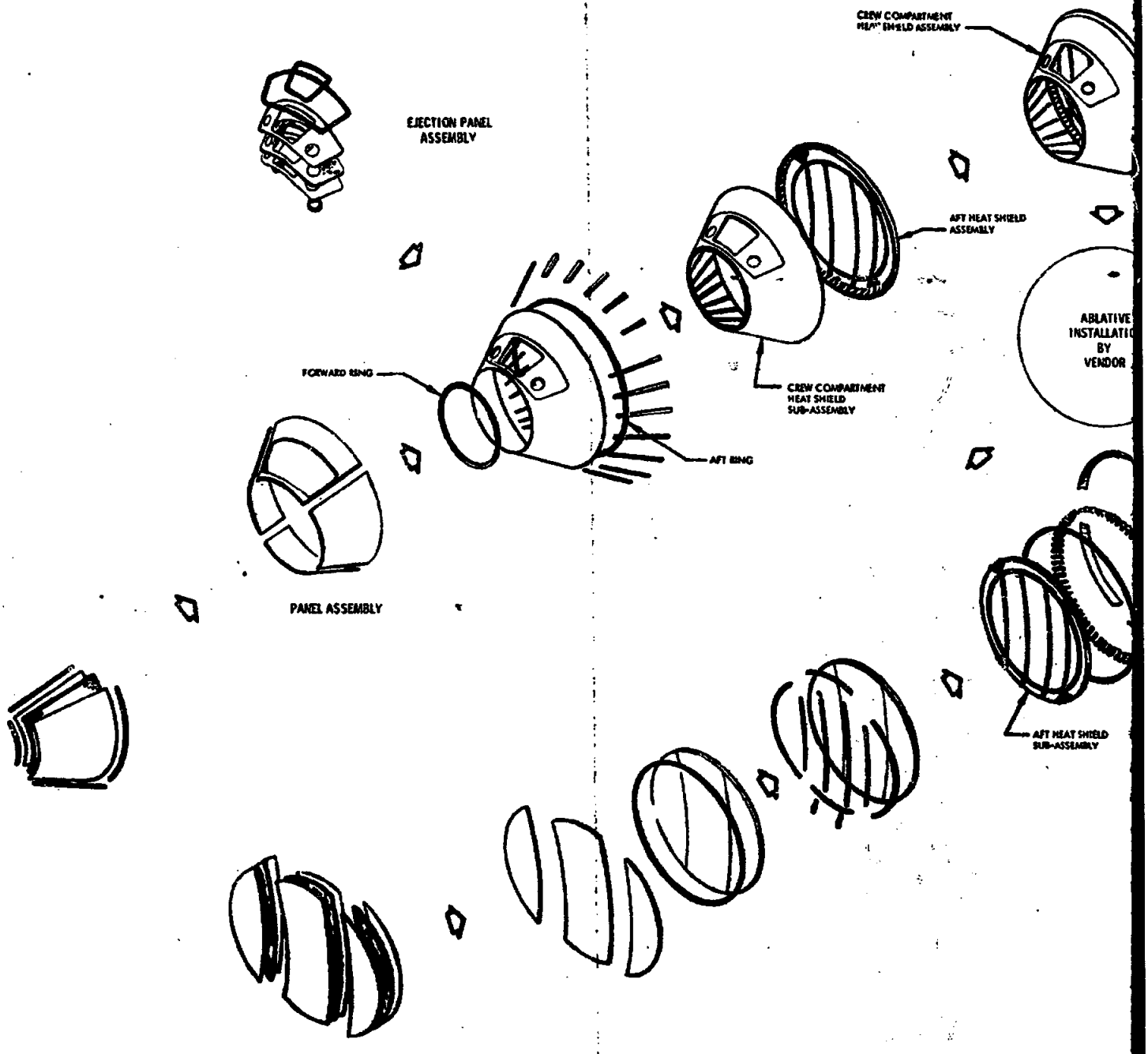
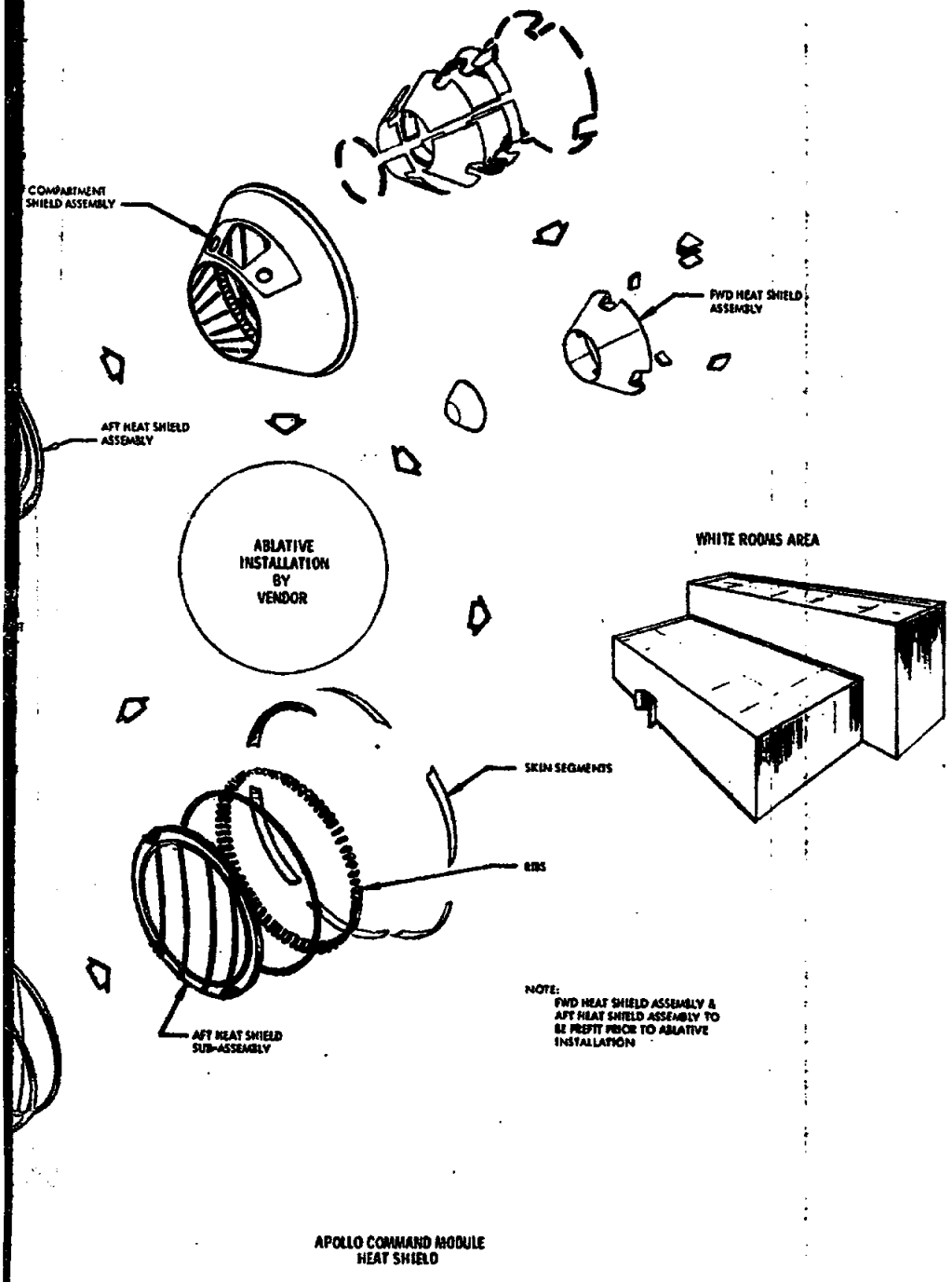


Figure 108. Inner Structure Assembly Sequence

NORTH


EJECTION PANEL ASSEMBLY
CREW COMPARTMENT HEAT SHIELD ASSEMBLY
AFT HEAT SHIELD ASSEMBLY
ABLATIVE INSTALLATI BY VENDOR
FORWARD RING
CREW COMPARTMENT HEAT SHIELD SUB-ASSEMBLY
AFT RING
PANEL ASSEMBLY
AFT HEAT SHIELD SUB-ASSEMBLY



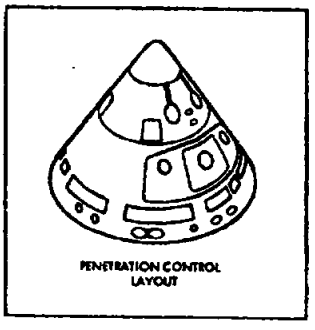


Figure 109. Heat Shield Assembly Sequence

[redacted]

At the conclusion of structure build-up, each assembly joining component installation will be inspected for quality. Control master gauges are used to mate interface coordination to the launch escape tower and the service module.

The assemblies will be disassembled, cleaned in accordance with specifications, and delivered to the "white room" final assembly area.

LAUNCH ESCAPE TOWER

The launch escape tower assembly is a fusion-welded, titanium tubing structure with fittings at each end for attachment to the launch escape motor skirt and the command module release mechanism. The completed assembly will conform to net length with all attach holes made full size and coordinated to mating assemblies. (See Figure 110.)

Launch Escape Tower Nose Cone

The nose cone is of steel sheet-metal fabrication. The upper segment of the cone will be spin-formed. The lower conical segment will be rolled in two half-sections and fusion-welded to form one truncated cone segment. The upper and lower segments will be fusion-welded circumferentially and spin-formed to size. The bolt pattern for attachment to the tower jettison motor fitting will be coordinated by a control master gauge.

Launch Escape Structure Skirt

The launch escape skirt is a welded and riveted construction consisting of four longerons, four aft circular rings, and four skin segments. The longerons and rings will be fusion-welded, and the skin segments will be riveted to the longerons. A bolt pattern and circumferential location of skin segments and longerons for mating to the launch escape motor will be coordinated by a control master gauge. The aft bolt pattern for mating to the launch escape tower will be controlled by a master gauge.

SPACECRAFT SERVICE MODULE

The major structure assembly will be performed in a vertical assembly station, into which the bonded aft bulkhead, engine frames, radial panels, truss structures, heat shields, and radiator panels will be routed for complete structure assembly. Each assembly, beginning with the lower sections, will be positioned progressively in the tool and joined by bolts or rivets to complete the structure. (See Figure 111.)

[redacted]

[redacted]

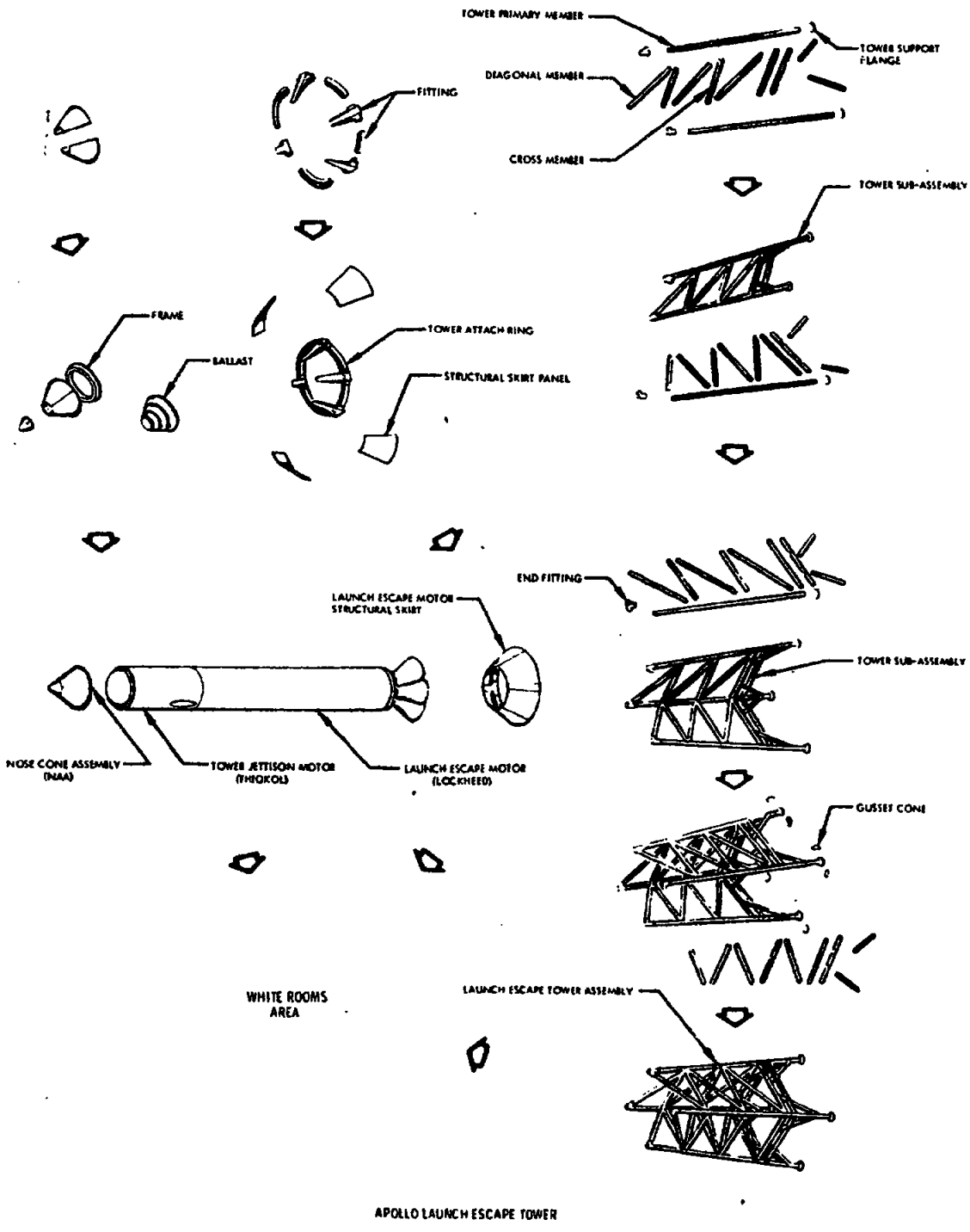
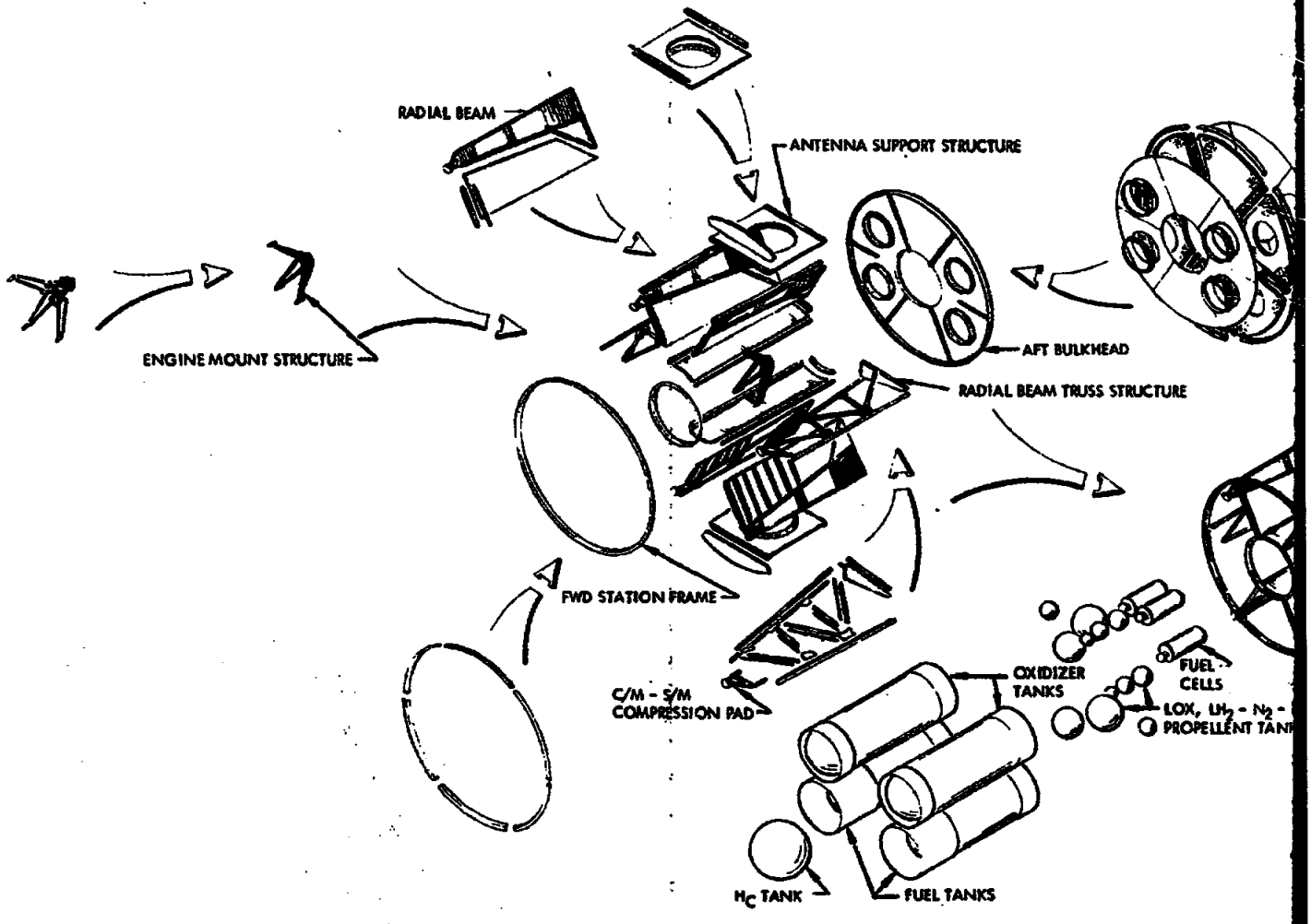


Figure 110. Launch Escape Tower Assembly Sequence

[redacted]

[redacted]


RADIAL BEAM
ANTENNA SUPPORT STRUCTURE
ENGINE MOUNT STRUCTURE
AFT BULKHEAD
RADIAL BEAM TRUSS STRUCTURE
FWD STATION FRAME
C/M - S/M
COMPRESSION PAD
OXIDIZER
TANKS
FUEL
CELLS
LOX, LH2 - N2 -
PROPELLENT TANK
HC TANK
FUEL TANKS

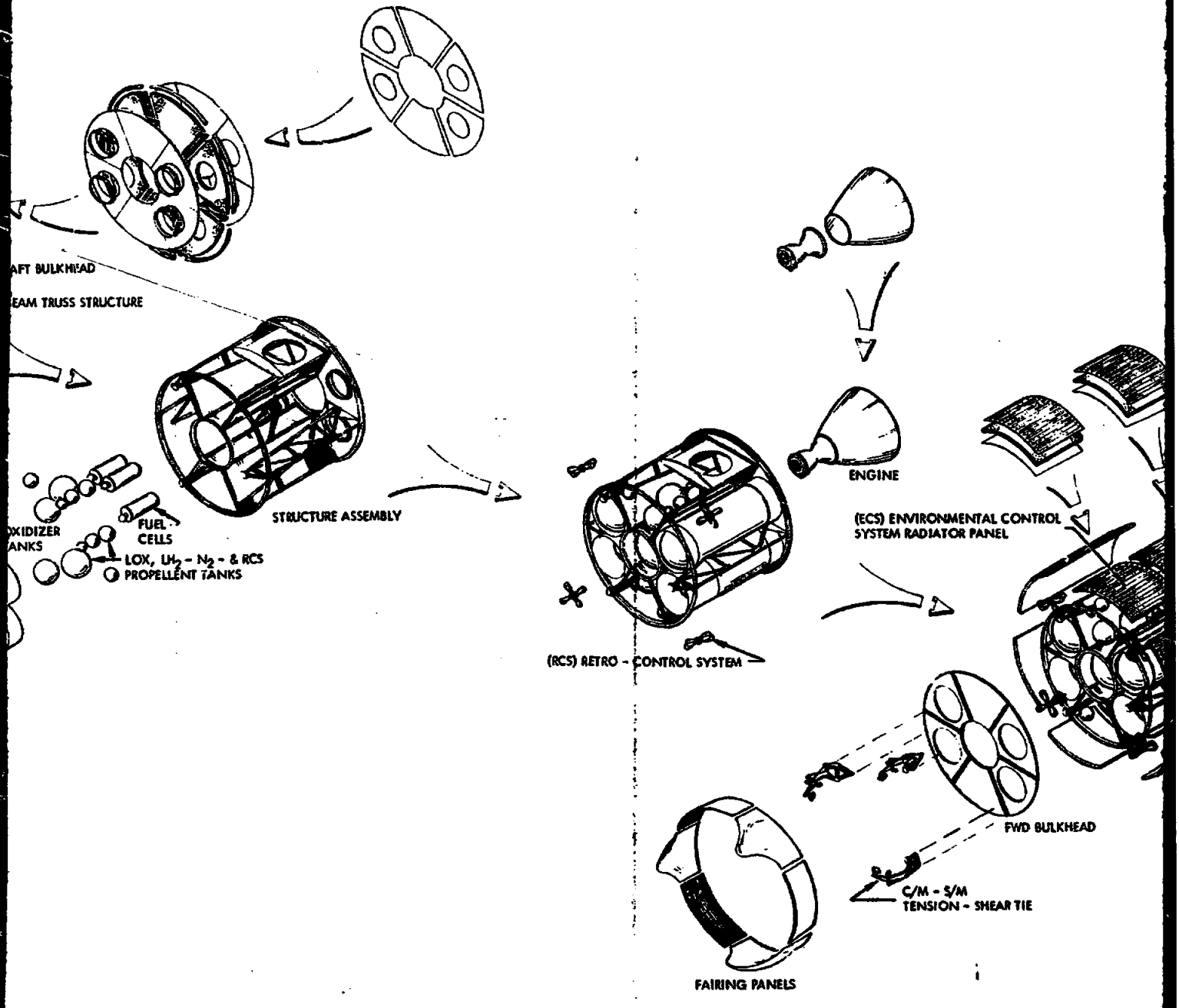

AFT BULKHEAD
EAM TRUSS STRUCTURE
OXIDIZER
ANKS
FUEL
CELLS
LOX, LH_2 - N_2 - & RCS
PROPELLENT TANKS
STRUCTURE ASSEMBLY
ENGINE
(ECS) ENVIRONMENTAL CONTROL
SYSTEM RADIATOR PANEL
(RCS) RETRO - CONTROL SYSTEM
FWD BULKHEAD
C/M - S/M
TENSION - SHEAR TIE
FAIRING PANELS

Figure 111.

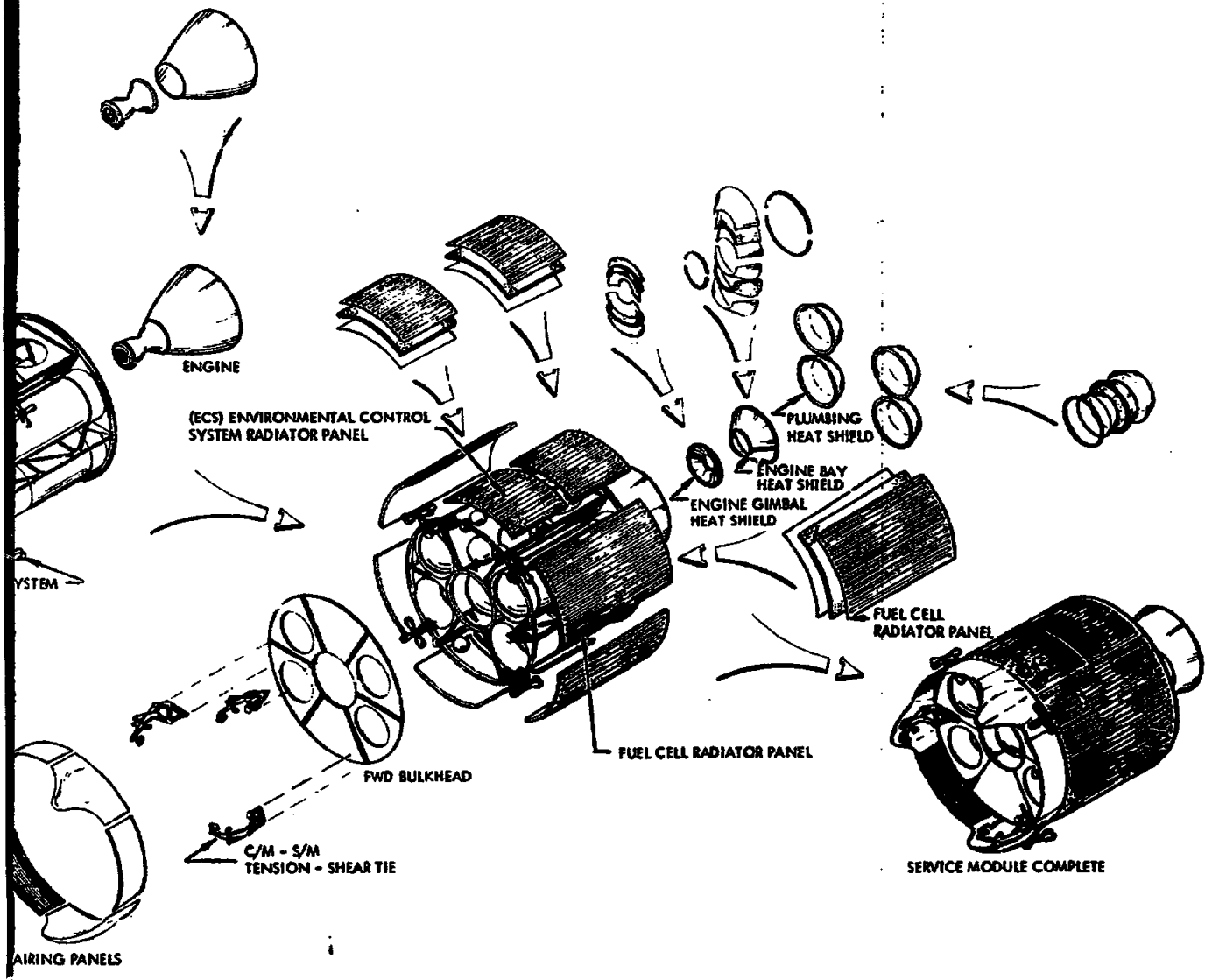


Figure 111. Service Module Assembly Sequence

[redacted]

SPACECRAFT ADAPTER

The spacecraft adapter will be assembled in a vertical position, and panel assemblies, torque boxes, blow-out panels, and access doors positioned in the tool and joined mechanically. (See Figure 112.)

ASSEMBLY MATING

Structural Fit-Check

At the completion of the structural assemblies (one for each of the four modules comprising the Apollo concept), they are delivered to the mating area for fit-check and alignment procedures. A support fixture, similar to that utilized for final assembly in the white room, is used for assembly mating in a vertical position.

Optical Alignment

During the structural fit-check procedures, alignment operations will be conducted simultaneously to ensure conformance to design data. Theodolites, with levels or auto-collimators, will be used to check spacecraft alignment and station-plane values.

After assembly mating and alignment procedures have been completed satisfactorily, the spacecraft will be disassembled and the modules returned to their respective assembly areas. There they will be disassembled further as required for cleaning prior to transfer to the white room for final assembly.

TEST AND CHECKOUT

System Components

Following final assembly of subsystem components, acceptance tests will be conducted in the subsystem checkout area. Environment-sensitive assemblies will undergo functional tests in the critical systems and will be subjected to simulated environmental conditions. Critical subcontracted equipment also will be routed to this area for functional checkout prior to module installation. These tests will be held to tighter tolerances than required for a complete system checkout test. Major subcontractor technicians and engineering personnel will be present in an advisory capacity during checkout and malfunction analysis and repair.

System components showing malfunction after module installation will be subject to reconditioning and acceptance in the bench maintenance area. Components which do not meet the stringent requirements of test evaluation

[redacted]

[redacted]

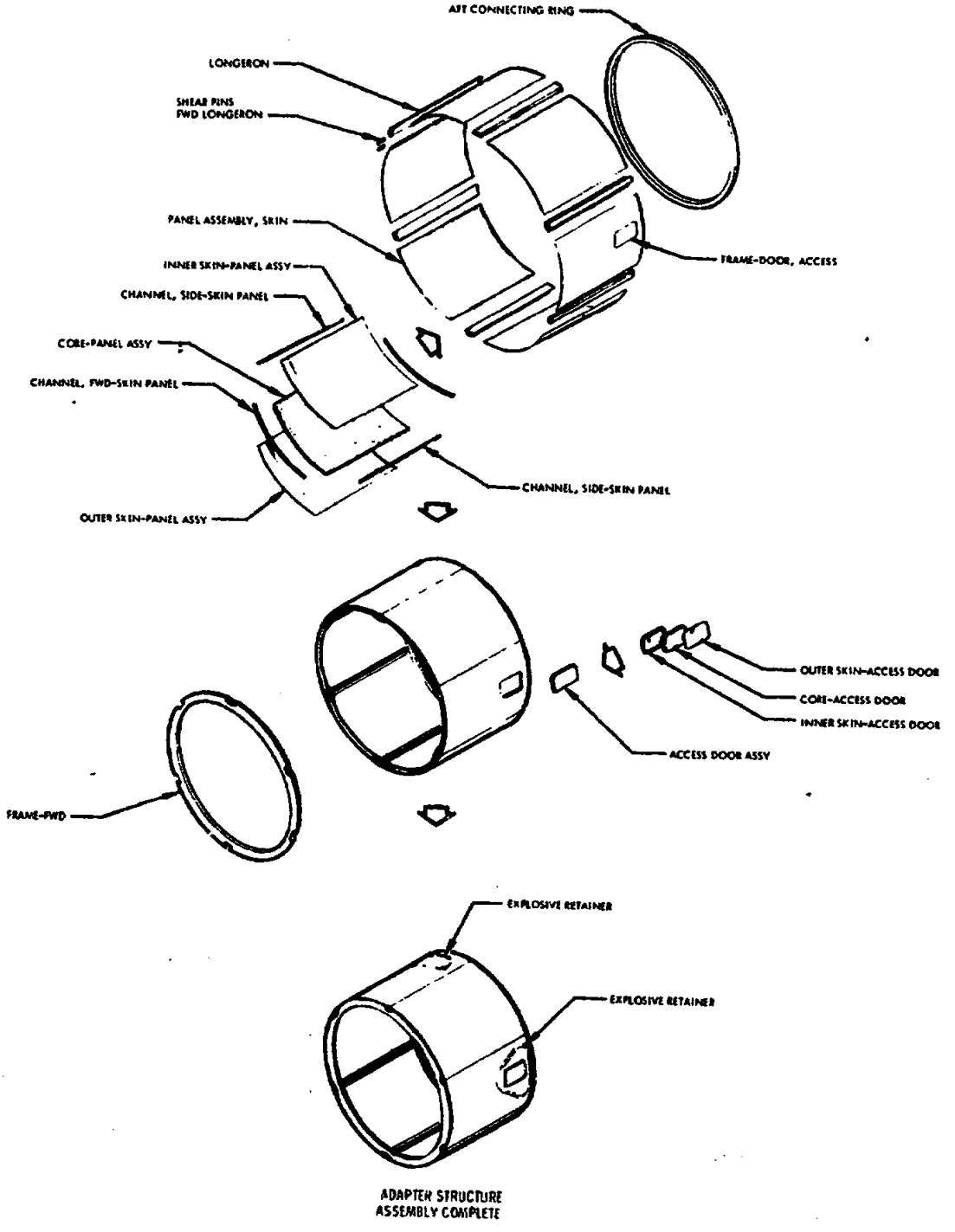


Figure 112. Prototype Spacecraft Adapter Assembly Sequence

[redacted]

[redacted]

will be rejected and returned for analysis and repair. Some test equipment used in the bench maintenance testing area will be capable of performing more extensive analysis than GSE for combined systems, acceptance, or launch operations.

Systems Tests

Manufacturing tests of each system will be conducted while the spacecraft is in the vertical position in the manufacturing test area. This has a distinct advantage in that systems will be tested in the same orientation plane as the prelaunch tests on the launching pad.

Factory checkout for separate systems and combined systems will be identical to, and interchangeable with, GSE used in the assembly area at Atlantic Missile Range.

Spacecraft Modules

Following module systems installation, the command, service and adapter module systems will be checked individually in order to be consistent with module system completeness. (See Figure 113.) Module simulators will be used to verify interface compatibility. Factory checkout equipment at this station will be identical to the GSE used in acceptance and preflight test operations. All pressurized systems will be tested with approved leak-detection methods. The command module will undergo a 7.5 psig pressure test following installation of the proper systems, and will be leak-checked with a G. E. Haliade Leak Detector or equivalent. Leak and obstruction tests will be performed on all tube installations, and flow checks performed on all pneumatic and engine systems. An automatic megger testing operation will be conducted on all wiring.

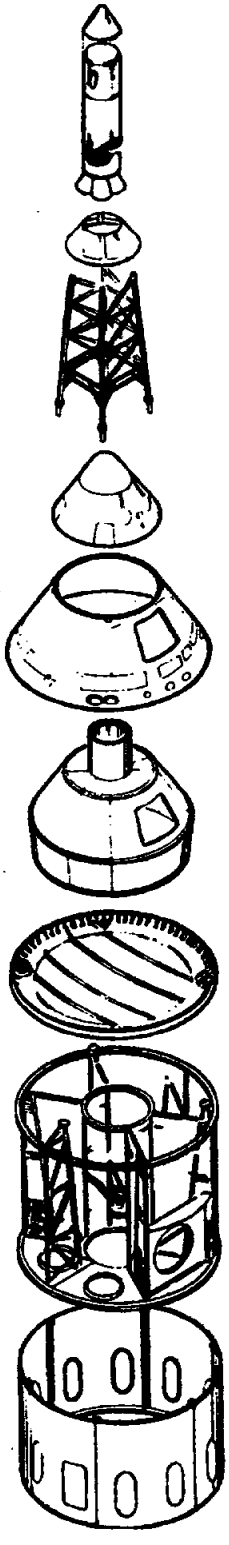
SYSTEMS INTEGRATION ASSURANCE TEST

After individual systems have passed independent functional tests, an integrated systems checkout will assure integration of the units into an operational spacecraft. To ensure compatibility, the integrated systems must be operated under simulated prelaunch and launch conditions.

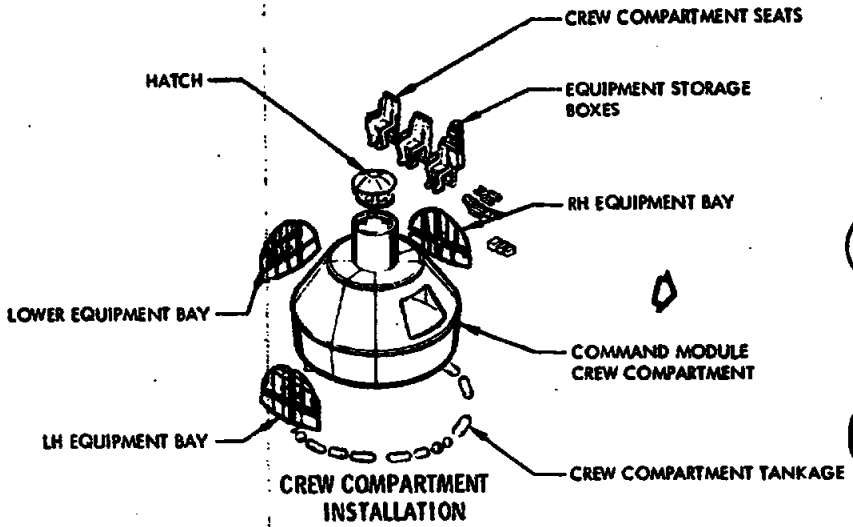
For integrated systems operations, verification of telemeter information will be transmitted by air link to S&ID's multichannel ground station located at Downey, California. The station, comparable to a launch facility, is capable of handling incoming signals from three telemeters simultaneously. Manufacturing integrated systems operations will be performed with flight test personnel phased into the operation during the first part of the program.

[redacted]

[redacted]

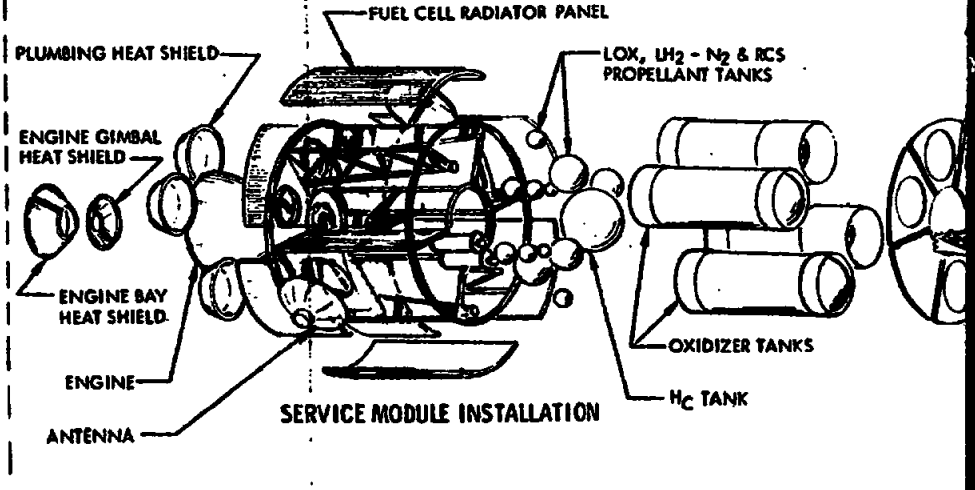


ASSEMBLIES DELIVERED TO WHITE ROOMS AREA



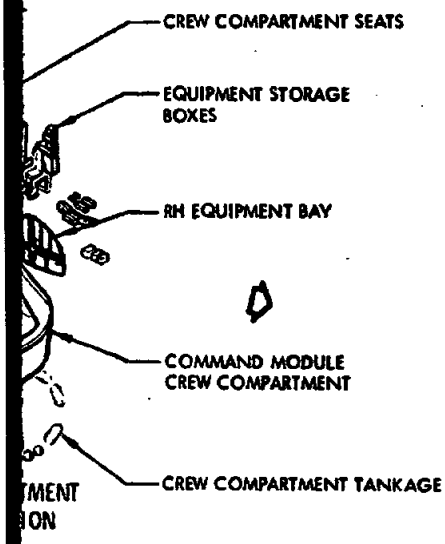
CREW COMPARTMENT INSTALLATION

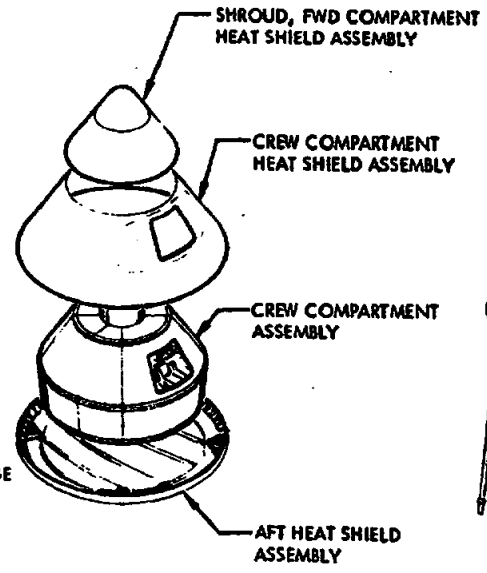
HEAT SHIELD INSTALLATION

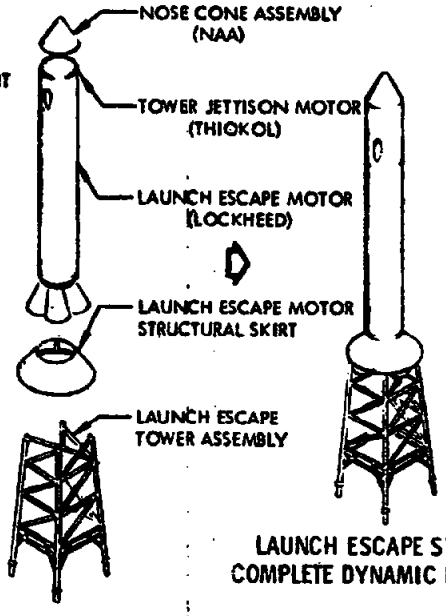


SERVICE MODULE INSTALLATION

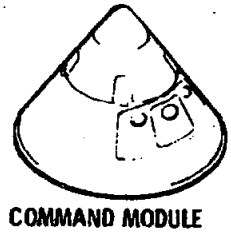
PRECEDING PAGE BLANK-NOT FILMED



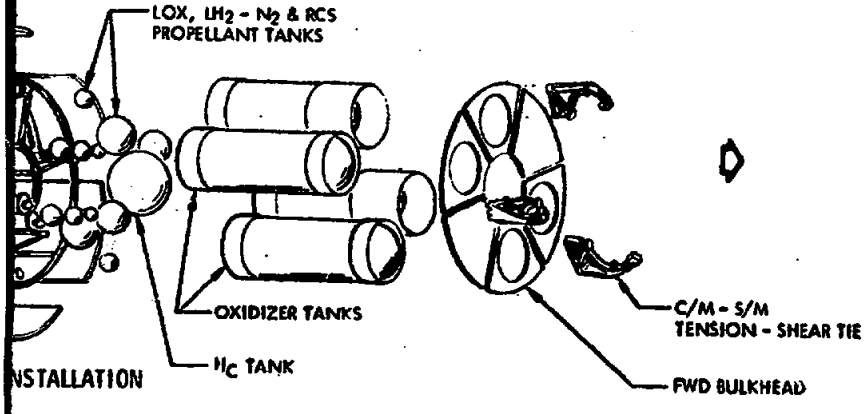


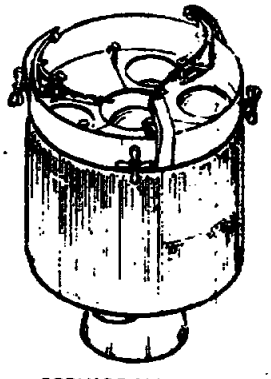


LAUNCH ESCAPE SYSTEM
COMPLETE DYNAMIC BALANCE

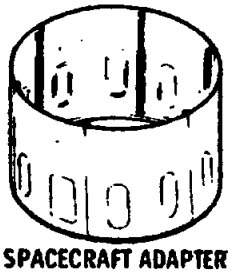


COMMAND MODULE
COMPLETE ASSEMBLY
DYNAMIC BALANCE

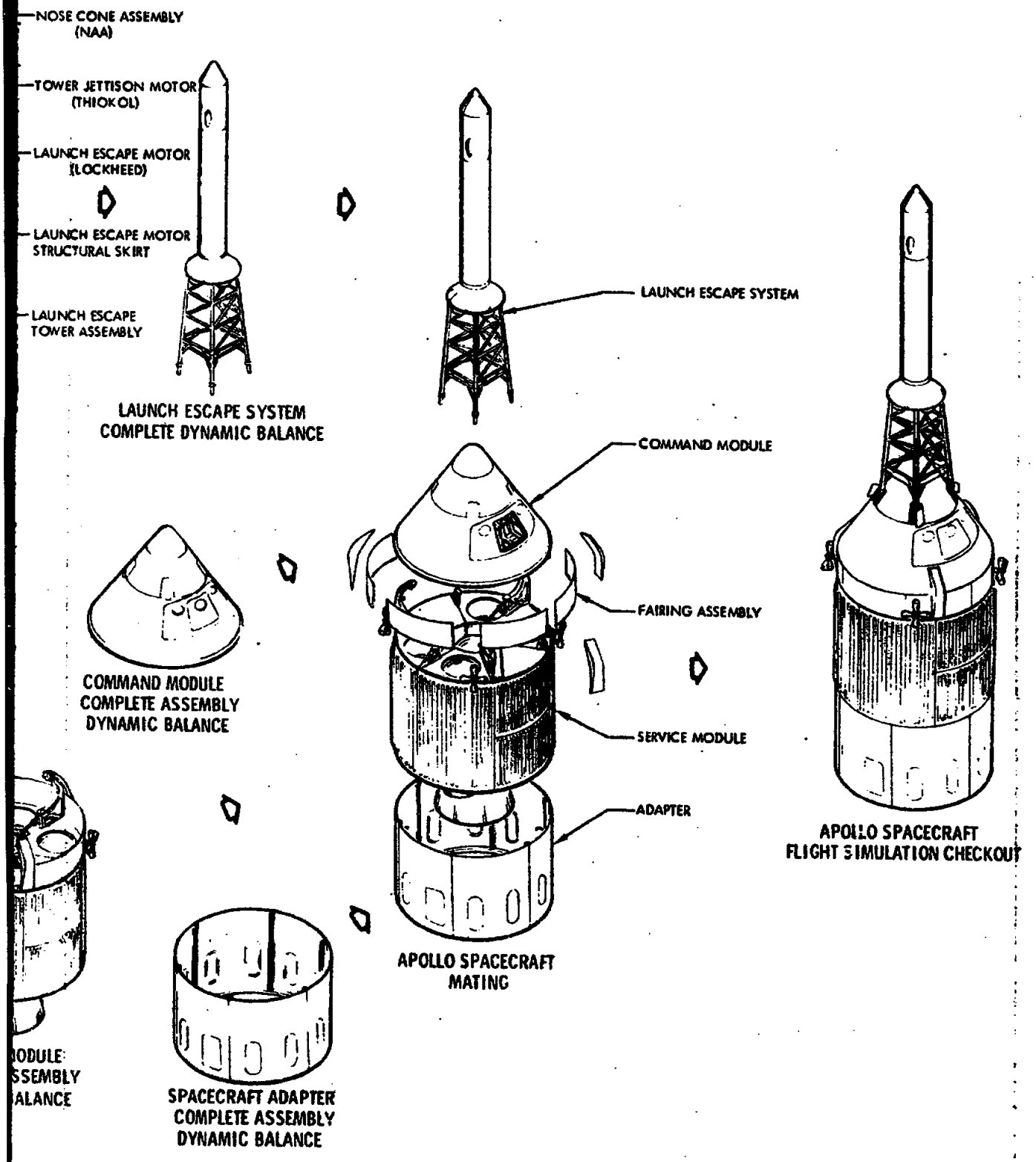




SERVICE MODULE
COMPLETE ASSEMBLY
DYNAMIC BALANCE



SPACECRAFT ADAPTER
COMPLETE ASSEMBLY
DYNAMIC BALANCE


NOSE CONE ASSEMBLY (NAA)
TOWER JETTISON MOTOR (THIOKOL)
LAUNCH ESCAPE MOTOR (LOCKHEED)
LAUNCH ESCAPE MOTOR STRUCTURAL SKIRT
LAUNCH ESCAPE TOWER ASSEMBLY
LAUNCH ESCAPE SYSTEM COMPLETE DYNAMIC BALANCE
LAUNCH ESCAPE SYSTEM
COMMAND MODULE
FAIRING ASSEMBLY
SERVICE MODULE
ADAPTER
APOLLO SPACECRAFT MATING
APOLLO SPACECRAFT FLIGHT SIMULATION CHECKOUT
COMMAND MODULE COMPLETE ASSEMBLY DYNAMIC BALANCE
SPACECRAFT ADAPTER COMPLETE ASSEMBLY DYNAMIC BALANCE

Fig

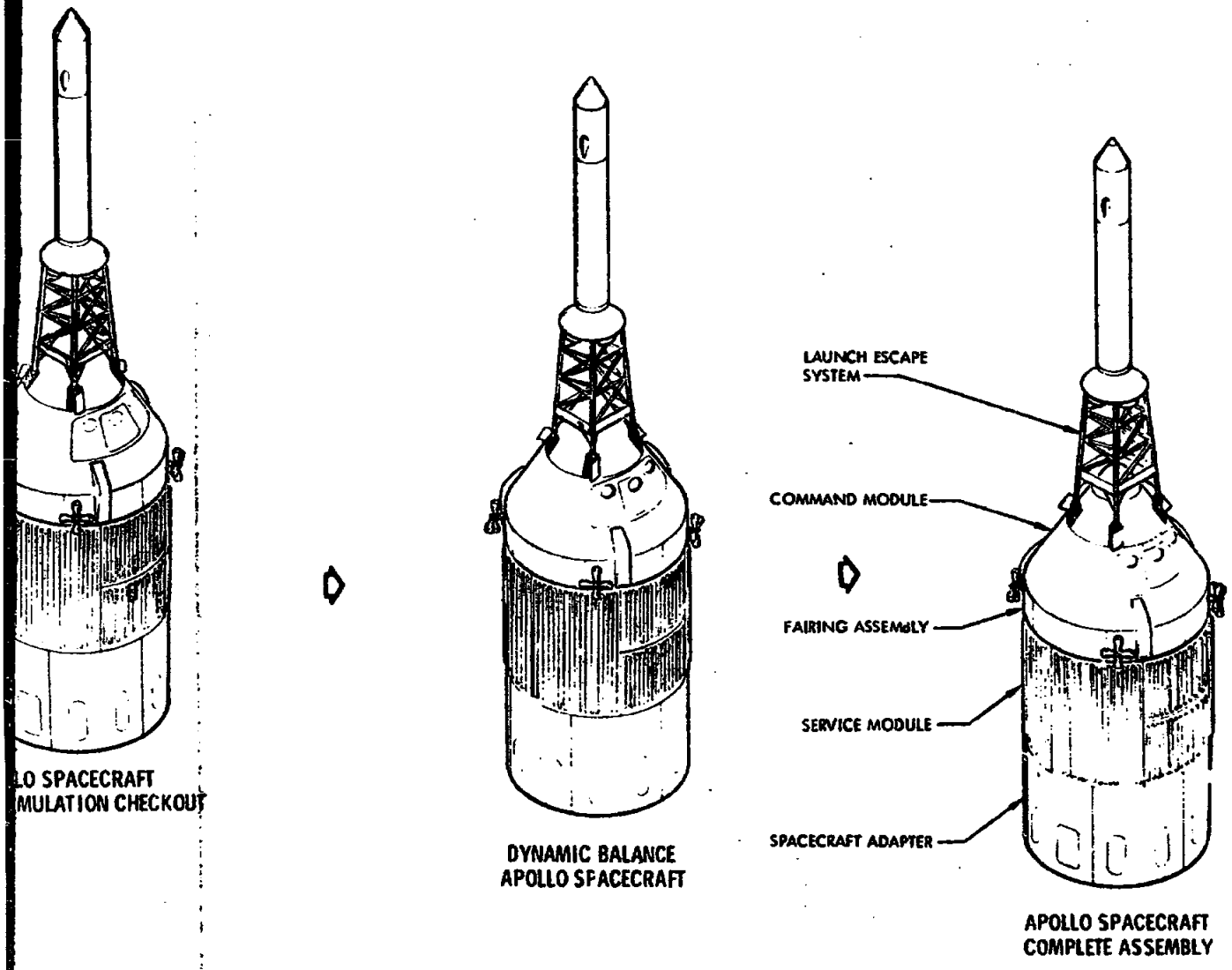


Figure 113. Spacecraft White Room Assembly Sequence

[redacted]

Laboratory equipment will meet National Bureau of Standards calibration standards and the functional standards established by quality control and engineering specifications.

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

GROUND SUPPORT EQUIPMENT

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

Functional Testing

Every item of GSE will be tested functionally to verify compatibility with specific system designs. Functional test operations will be accomplished by simulating signals normally received from, or sent to the Apollo spacecraft. Signals then will be observed on the console by means of gauges, meters, lights, or electronic indicators.

Calibration

Electronic and pneumatic measuring devices will be calibrated and serviced prior to installation in the consoles. Each device will be calibrated and serviced in a complete laboratory and verified by quality control.

Manufacturing schedules are listed in Figures 114 through 123.

Manufacturing plans for the Apollo spacecraft are explained in greater detail in the Apollo Manufacturing Plan, SID 62-102.

[redacted]

[redacted]

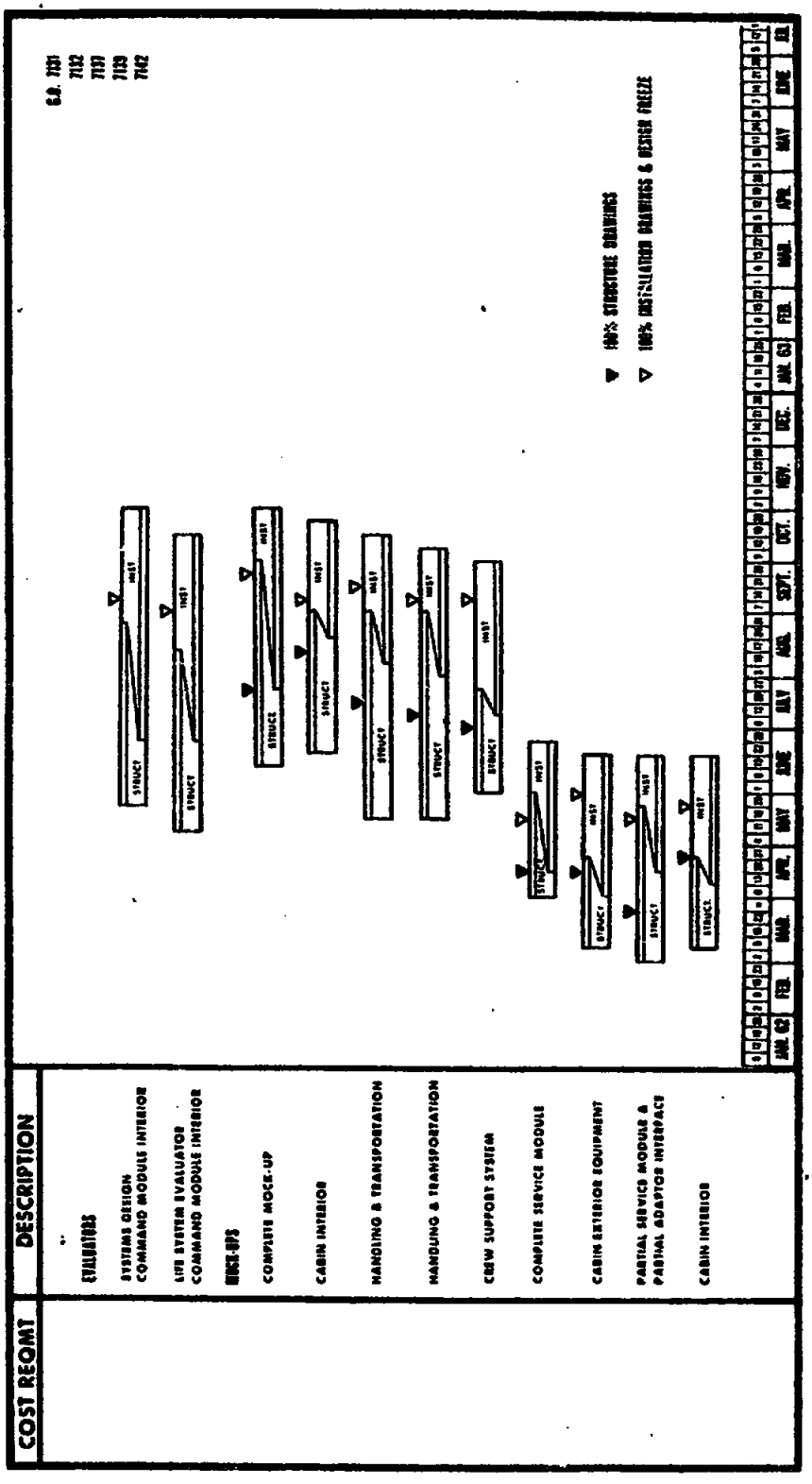


Figure 114. Apollo Mock-Up and Evaluator Schedule

[redacted]

[redacted]

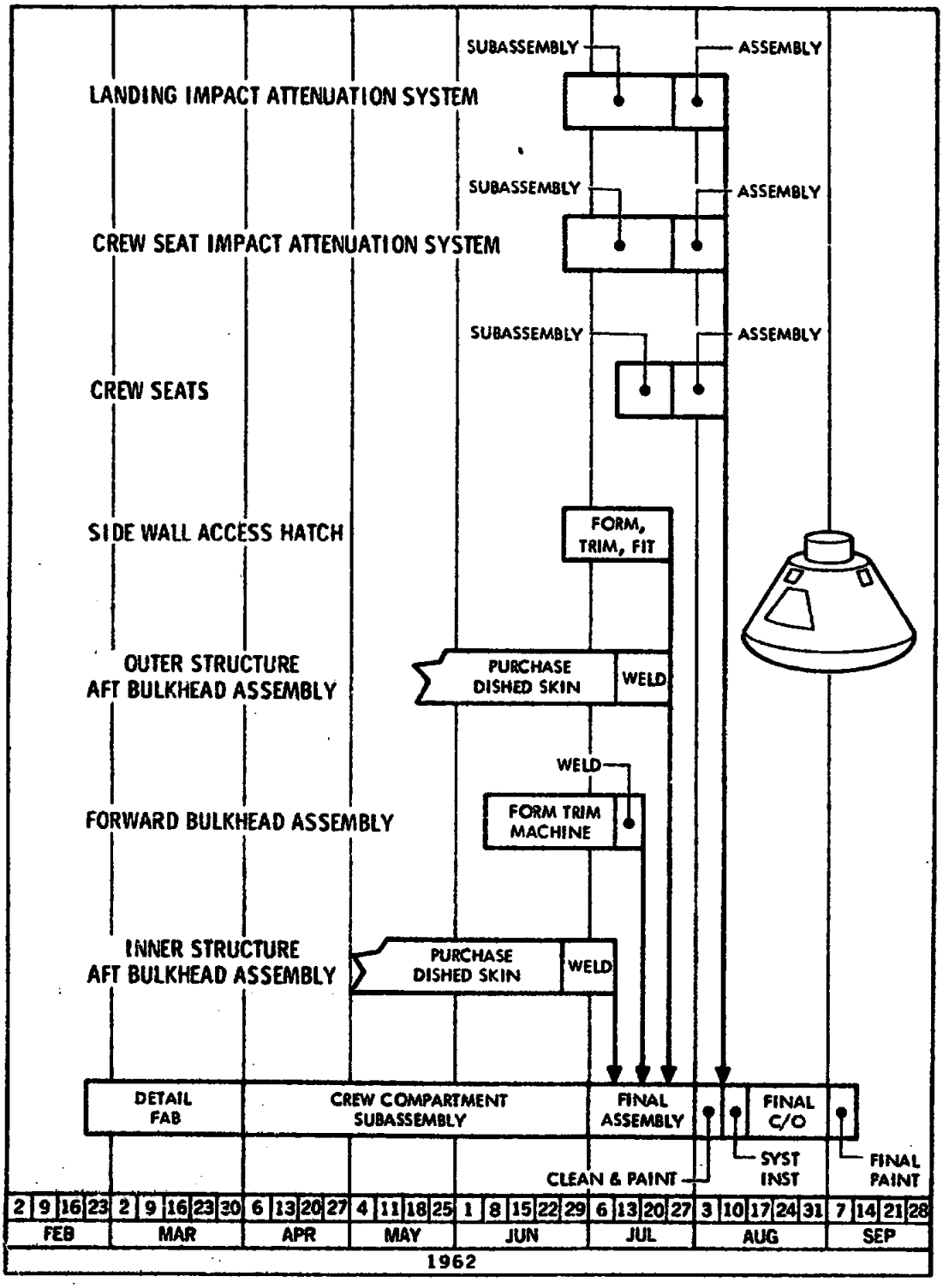


Figure 115. Apollo Boilerplate Command Module No. 1 Master Schedule

[redacted]

[redacted]

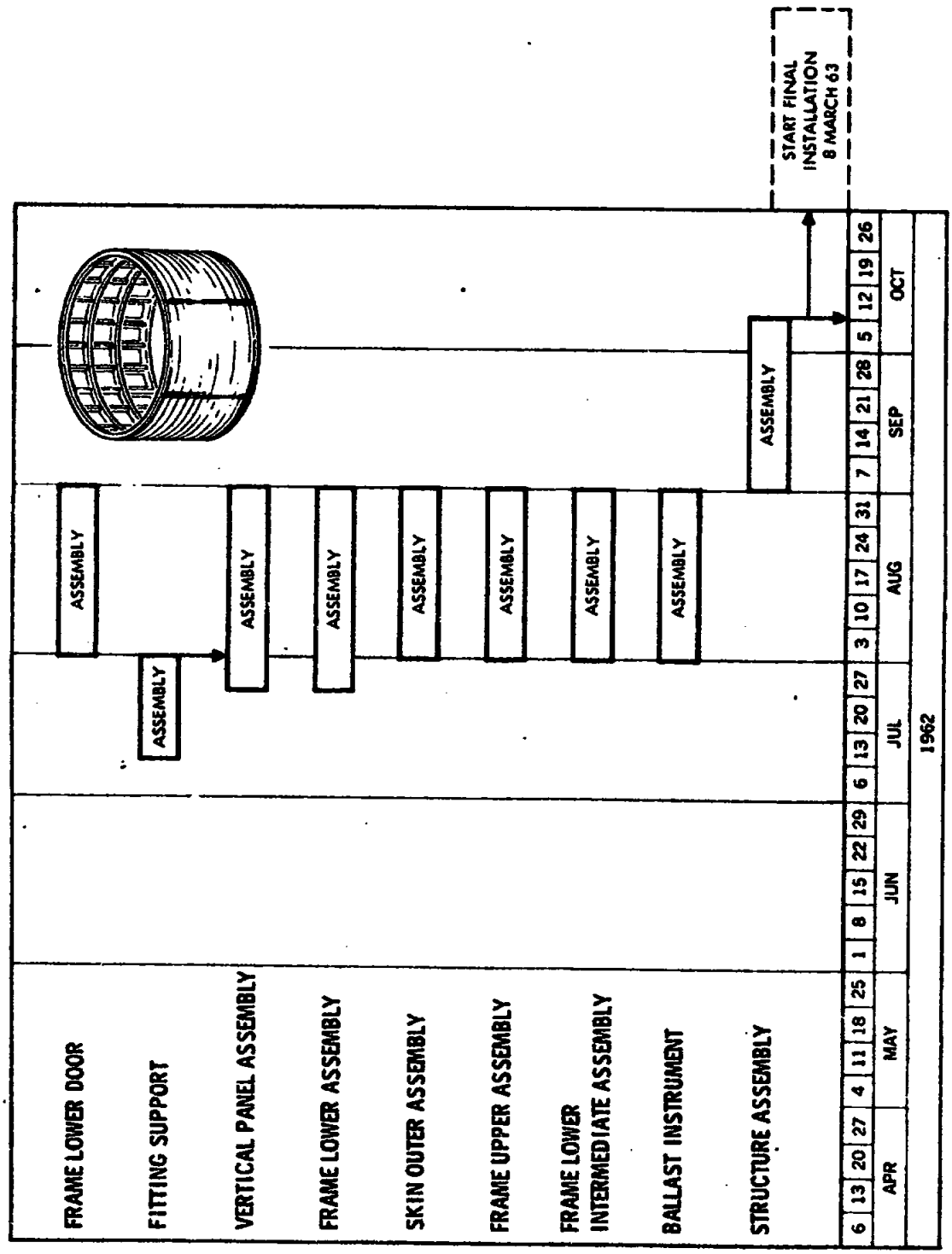


Figure 116. Apollo Boilerplate Service Module No. 1 Master Schedule

[redacted]

[redacted]

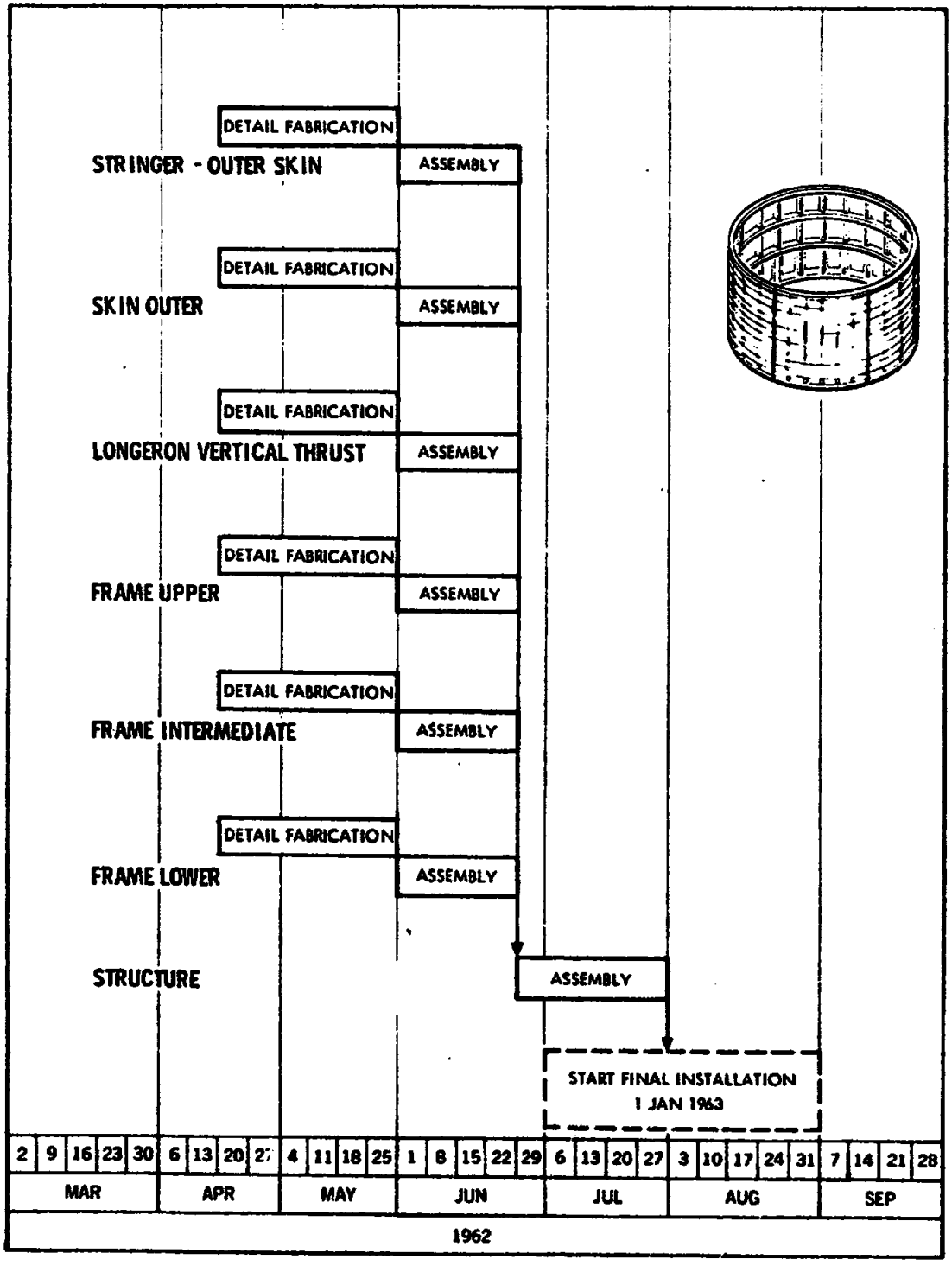


Figure 117. Apollo Boilerplate Adapter No. 1, Boilerplate No. 9

[redacted]

[redacted]

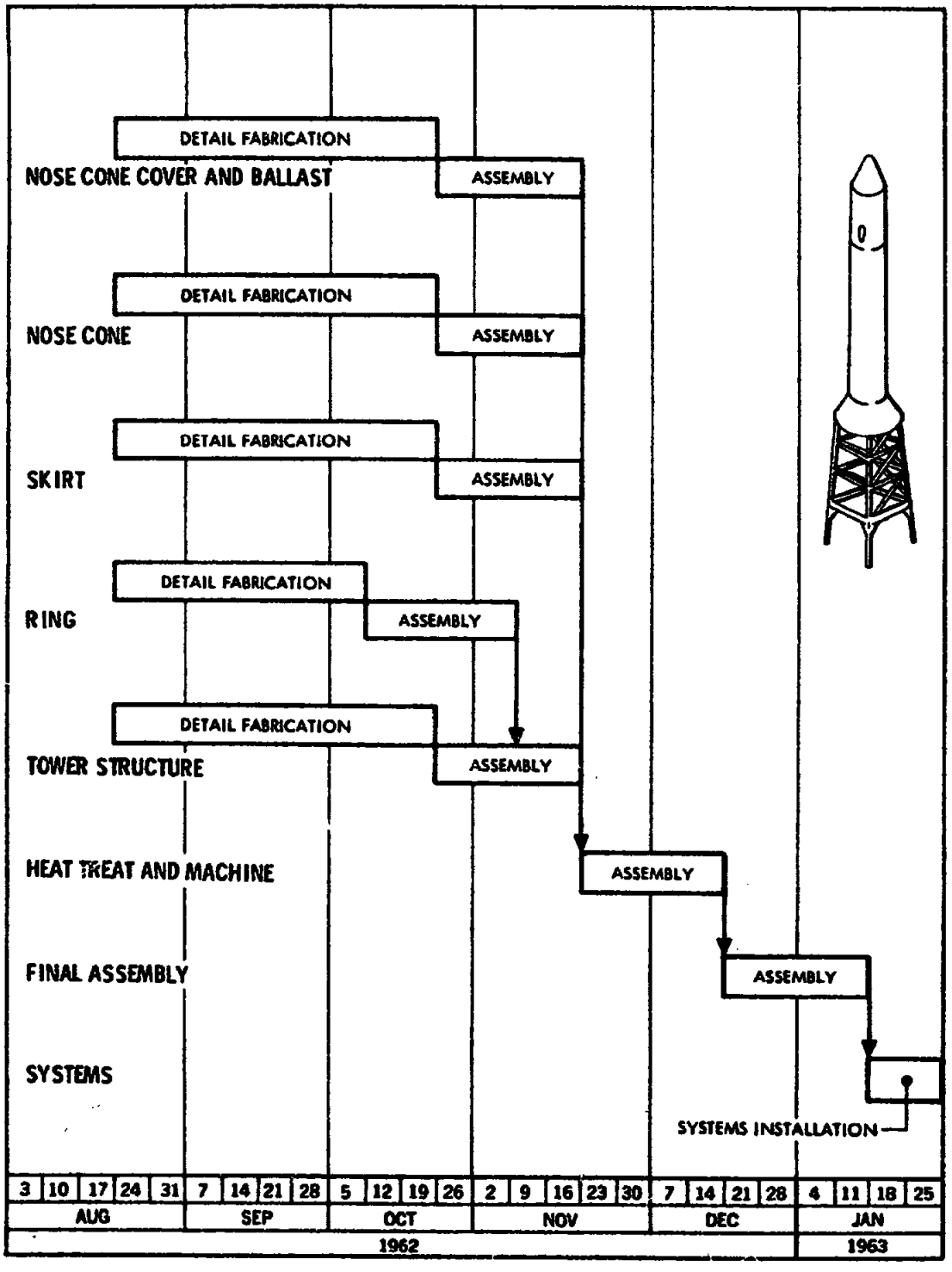
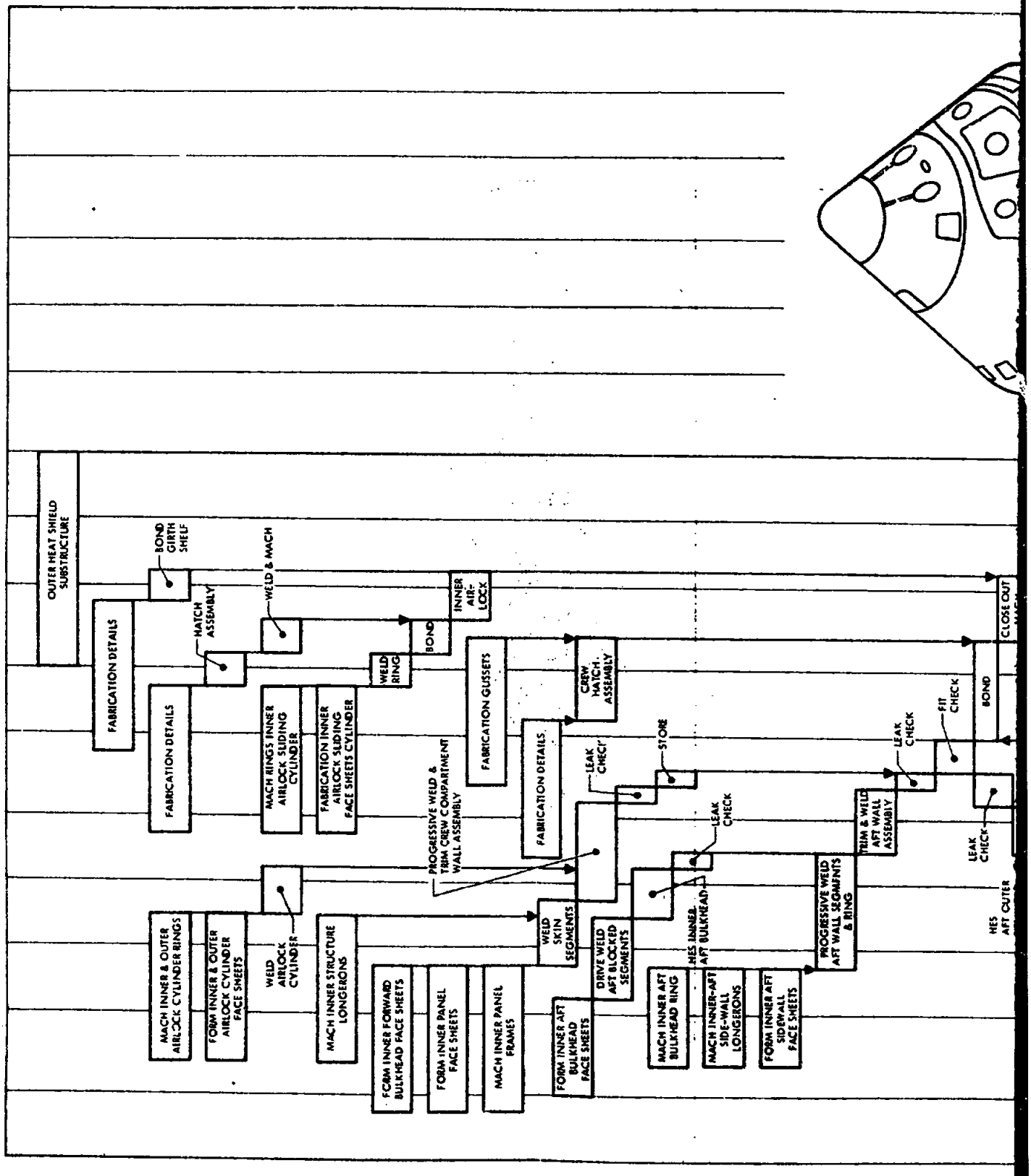


Figure 118. Apollo Boilerplate Launch Escape Tower (Static No. 1) Master Schedule

[redacted]

[redacted]


OUTER HEAT SHIELD SUBSTRUCTURE
FABRICATION DETAILS
BOND GIRTH SHELF
HATCH ASSEMBLY
FABRICATION DETAILS
WELD & MACH
MACH RINGS INNER AIRLOCK SLIDING CYLINDER
FABRICATION INNER AIRLOCK SLIDING FACE SHEETS CYLINDER
WELD RING
BOND
INNER AIR-LOCK
FABRICATION GUSSETS
CREW HATCH ASSEMBLY
FABRICATION DETAILS
LEAK CHECK
STORE
PROGRESSIVE WELD & TRIM CREW COMPARTMENT WALL ASSEMBLY
LEAK CHECK
TRIM & WELD AFT WALL ASSEMBLY
LEAK CHECK
FIT CHECK
BOND
CLOSE OUT
LEAK CHECK
HES AFT OUTER
MACH INNER & OUTER AIRLOCK CYLINDER RINGS
FORM INNER & OUTER AIRLOCK CYLINDER FACE SHEETS
WELD AIRLOCK CYLINDER
MACH INNER STRUCTURE LONGERONS
FORM INNER FORWARD BULKHEAD FACE SHEETS
FORM INNER PANEL FACE SHEETS
MACH INNER PANEL FRAMES
WELD SKIN SEGMENTS
FORM INNER AFT BULKHEAD FACE SHEETS
DRIVE WELD AFT BLOCKED SEGMENTS
HES INNER AFT BULKHEAD
MACH INNER AFT BULKHEAD RING
MACH INNER-AFT SIDE-WALL LONGERONS
FORM INNER AFT SIDEWALL FACE SHEETS
PROGRESSIVE WELD AFT WALL SEGMENTS & RING

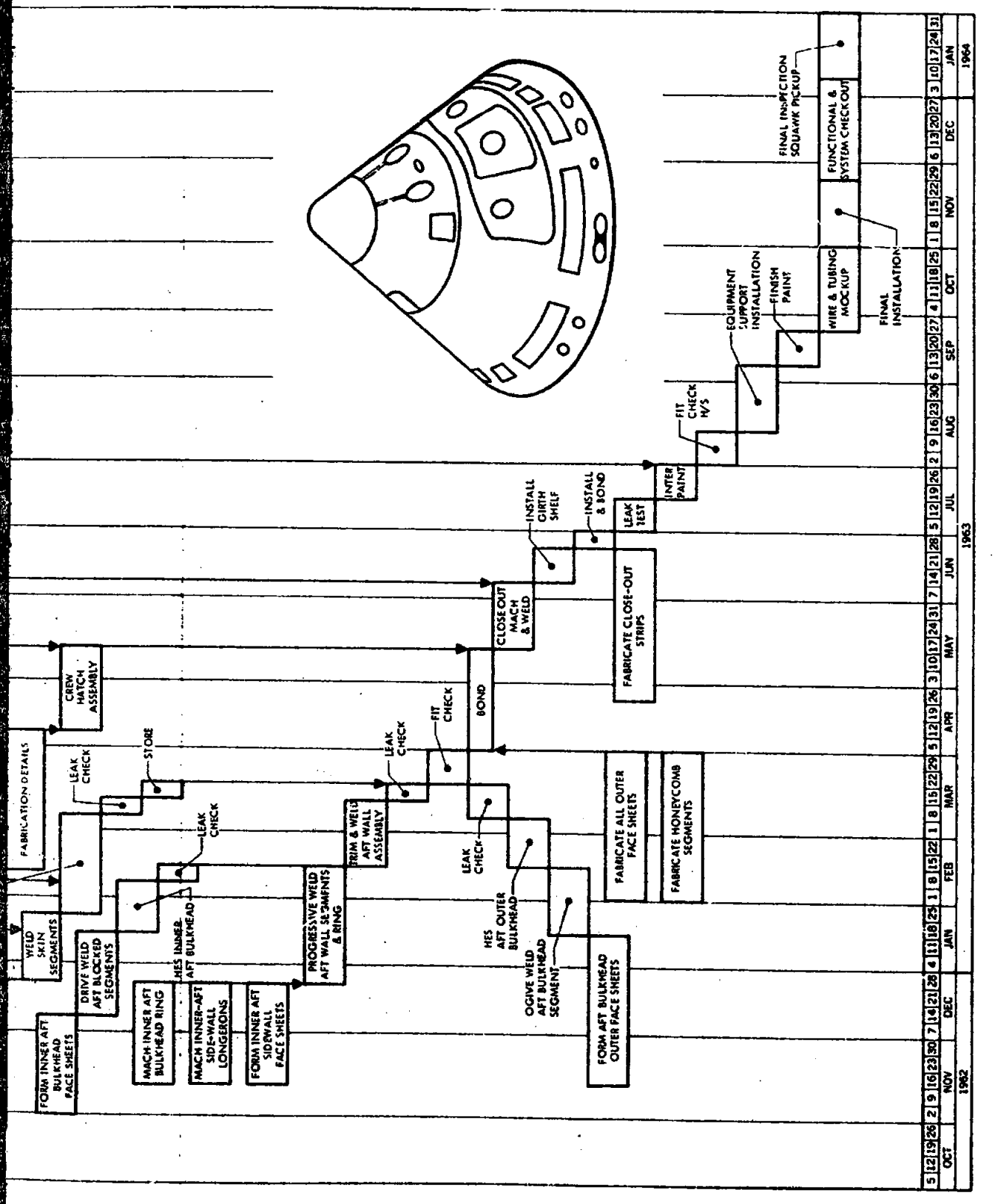
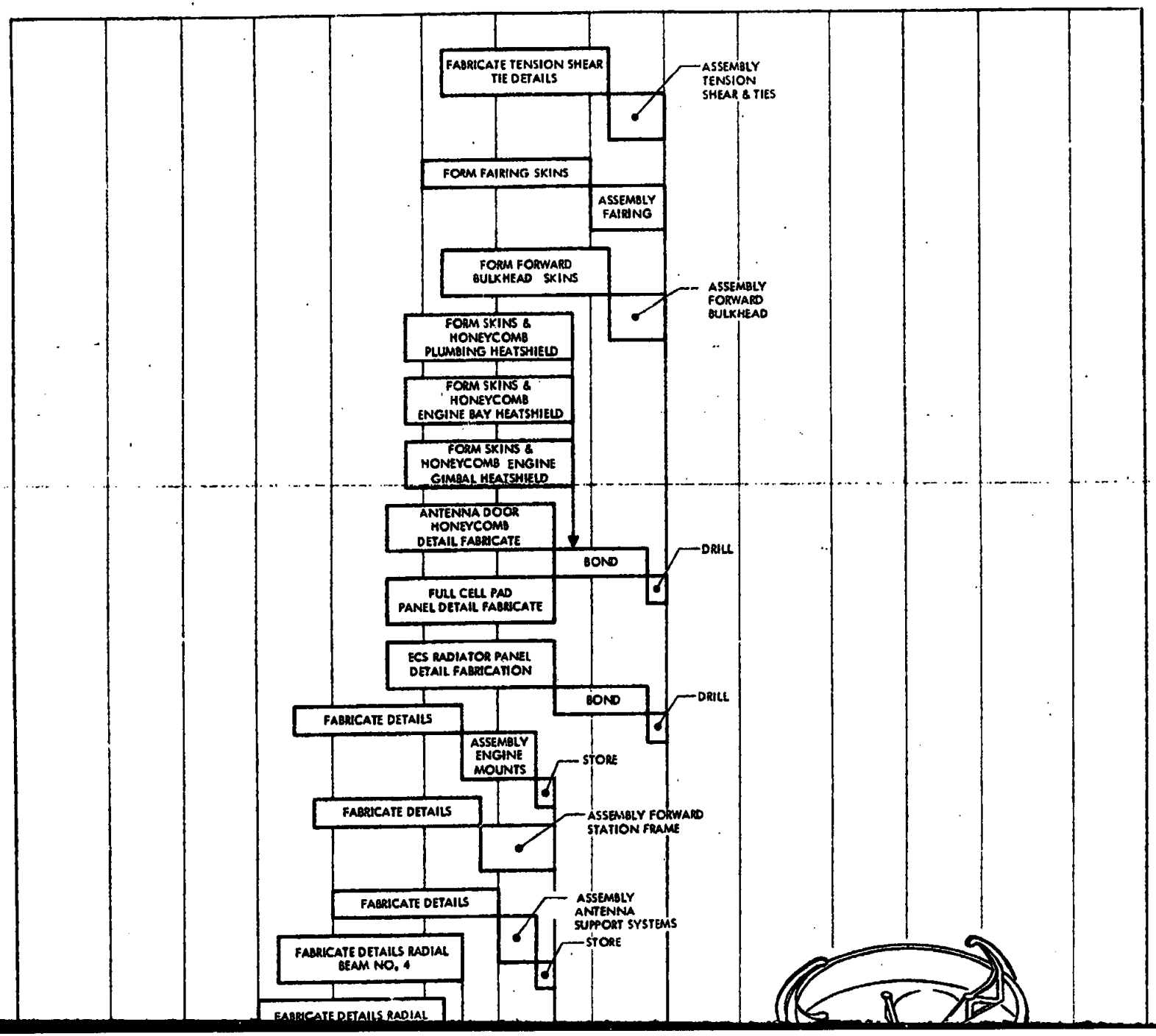
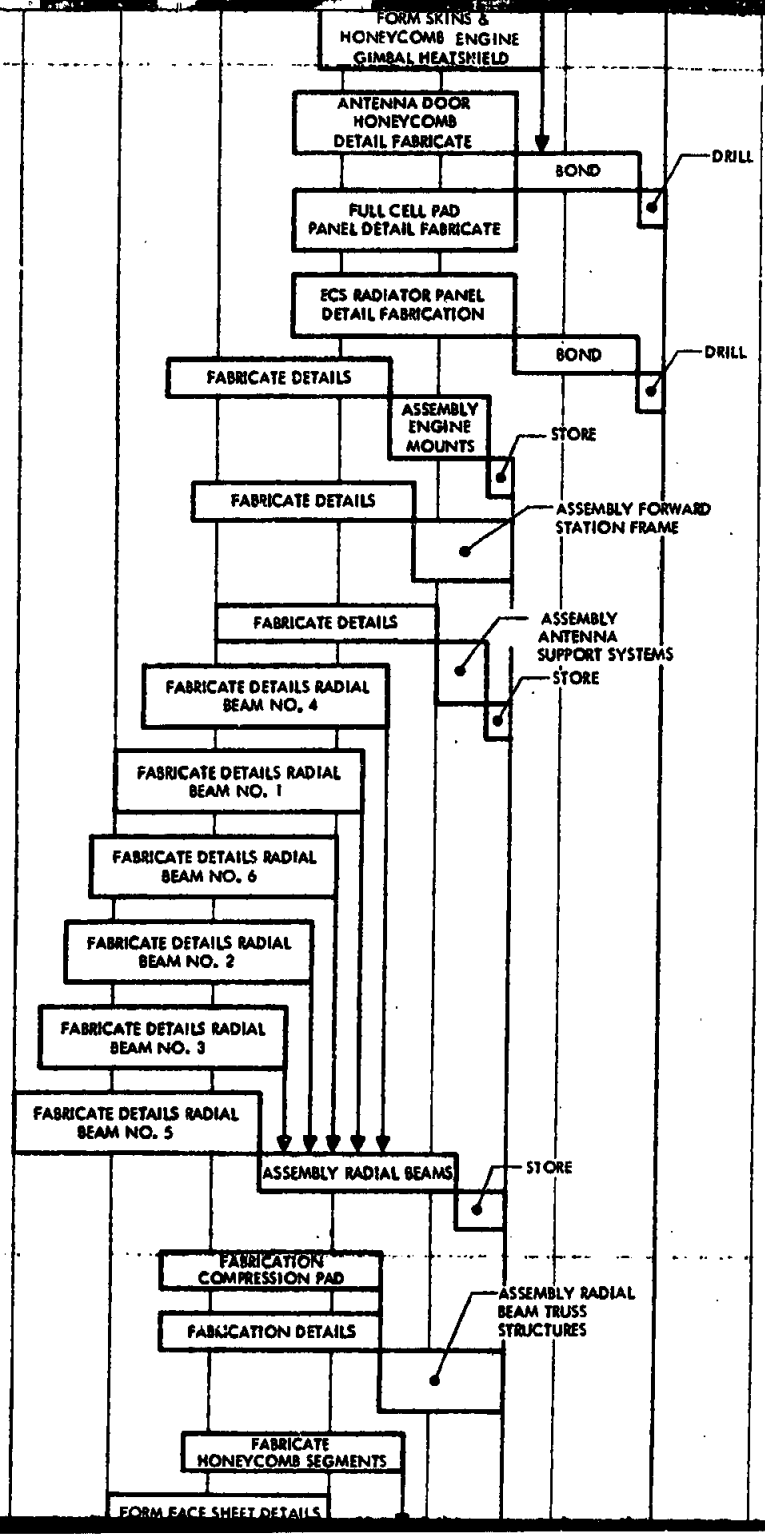
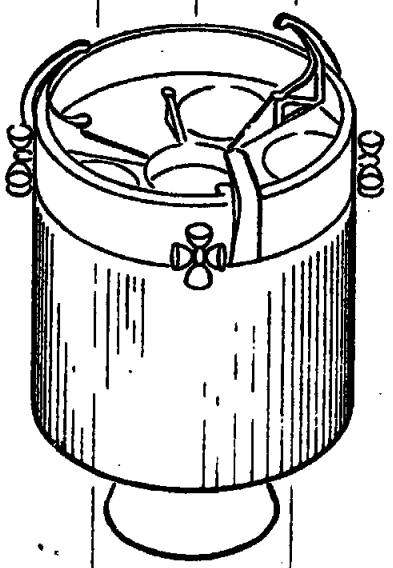


Figure 119. Apollo Spacecraft Command Module AFRM 001 Master Schedule


FABRICATE TENSION SHEAR TIE DETAILS
ASSEMBLY TENSION SHEAR & TIES
FORM FAIRING SKINS
ASSEMBLY FAIRING
FORM FORWARD BULKHEAD SKINS
ASSEMBLY FORWARD BULKHEAD
FORM SKINS & HONEYCOMB PLUMBING HEATSHIELD
FORM SKINS & HONEYCOMB ENGINE BAY HEATSHIELD
FORM SKINS & HONEYCOMB ENGINE GIMBAL HEATSHIELD
ANTENNA DOOR HONEYCOMB DETAIL FABRICATE
BOND
DRILL
FULL CELL PAD PANEL DETAIL FABRICATE
ECS RADIATOR PANEL DETAIL FABRICATION
BOND
DRILL
FABRICATE DETAILS
ASSEMBLY ENGINE MOUNTS
STORE
FABRICATE DETAILS
ASSEMBLY FORWARD STATION FRAME
FABRICATE DETAILS
ASSEMBLY ANTENNA SUPPORT SYSTEMS
STORE
FABRICATE DETAILS RADIAL BEAM NO. 4
FABRICATE DETAILS RADIAL





NORTH AMERICAN AVIATION

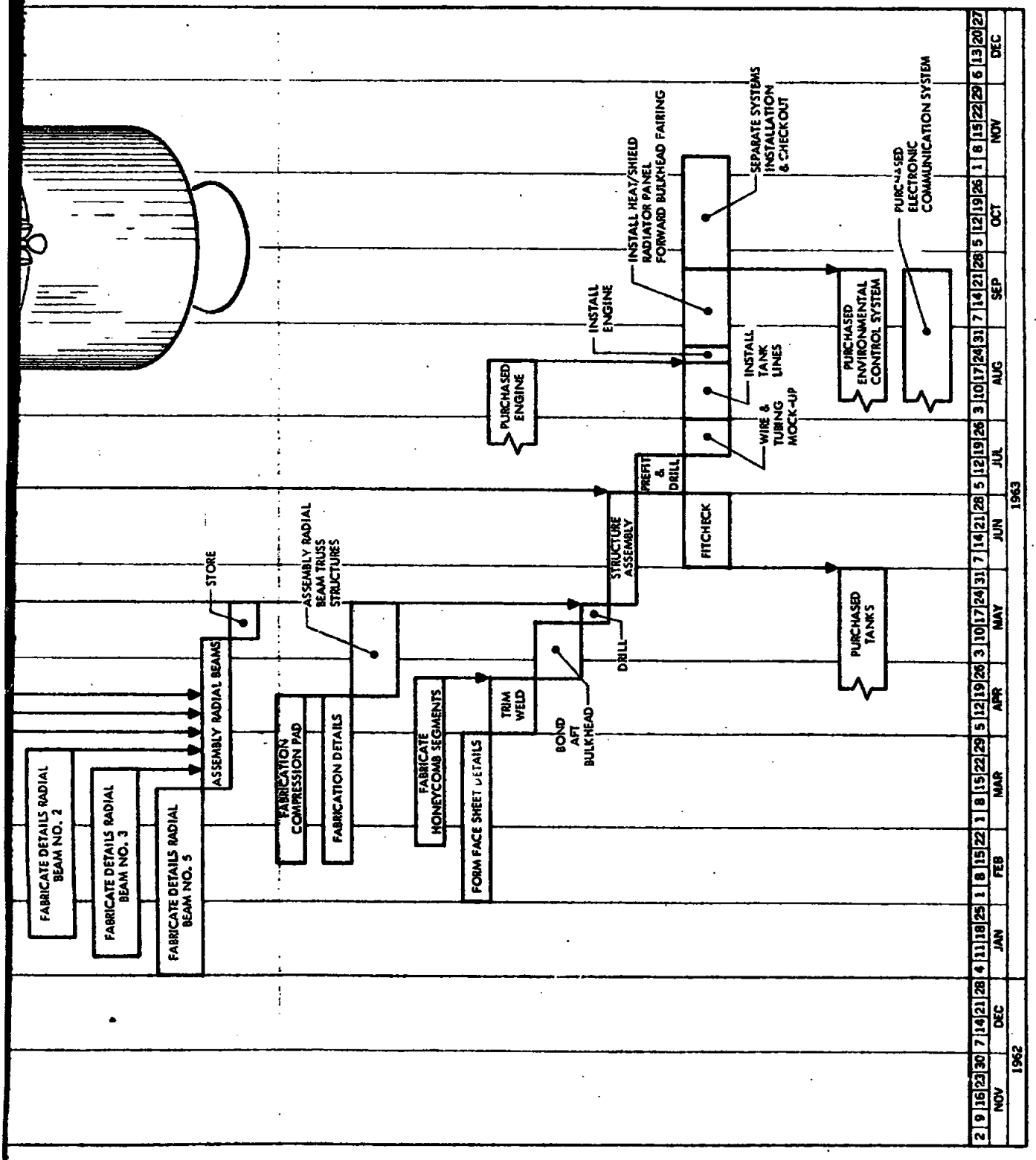


Figure 120. Apollo Spacecraft Service Module Master Curve

[redacted]

[redacted]

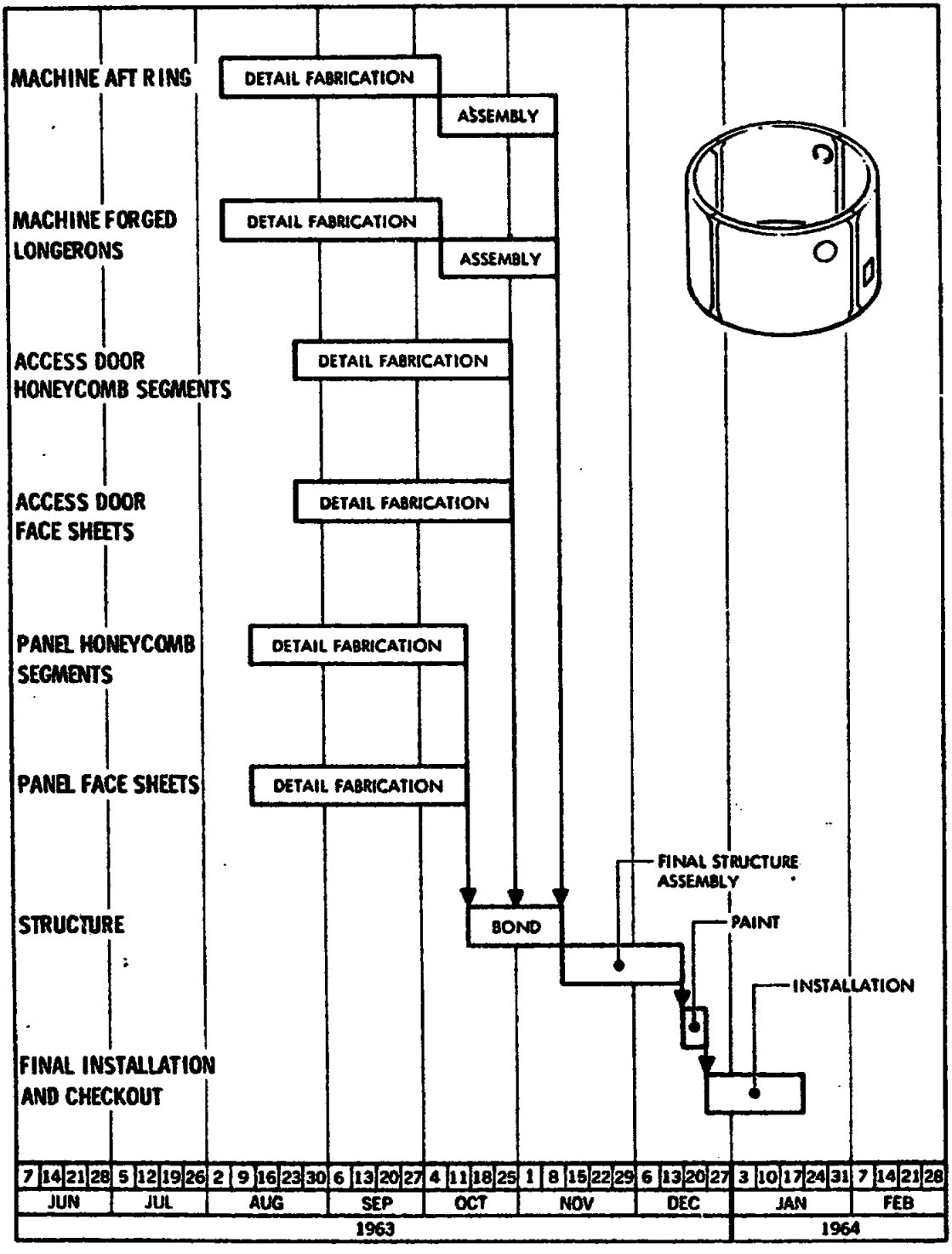


Figure 121. Apollo Spacecraft Adapter Master Schedule AFRM 009

[redacted]

[redacted]

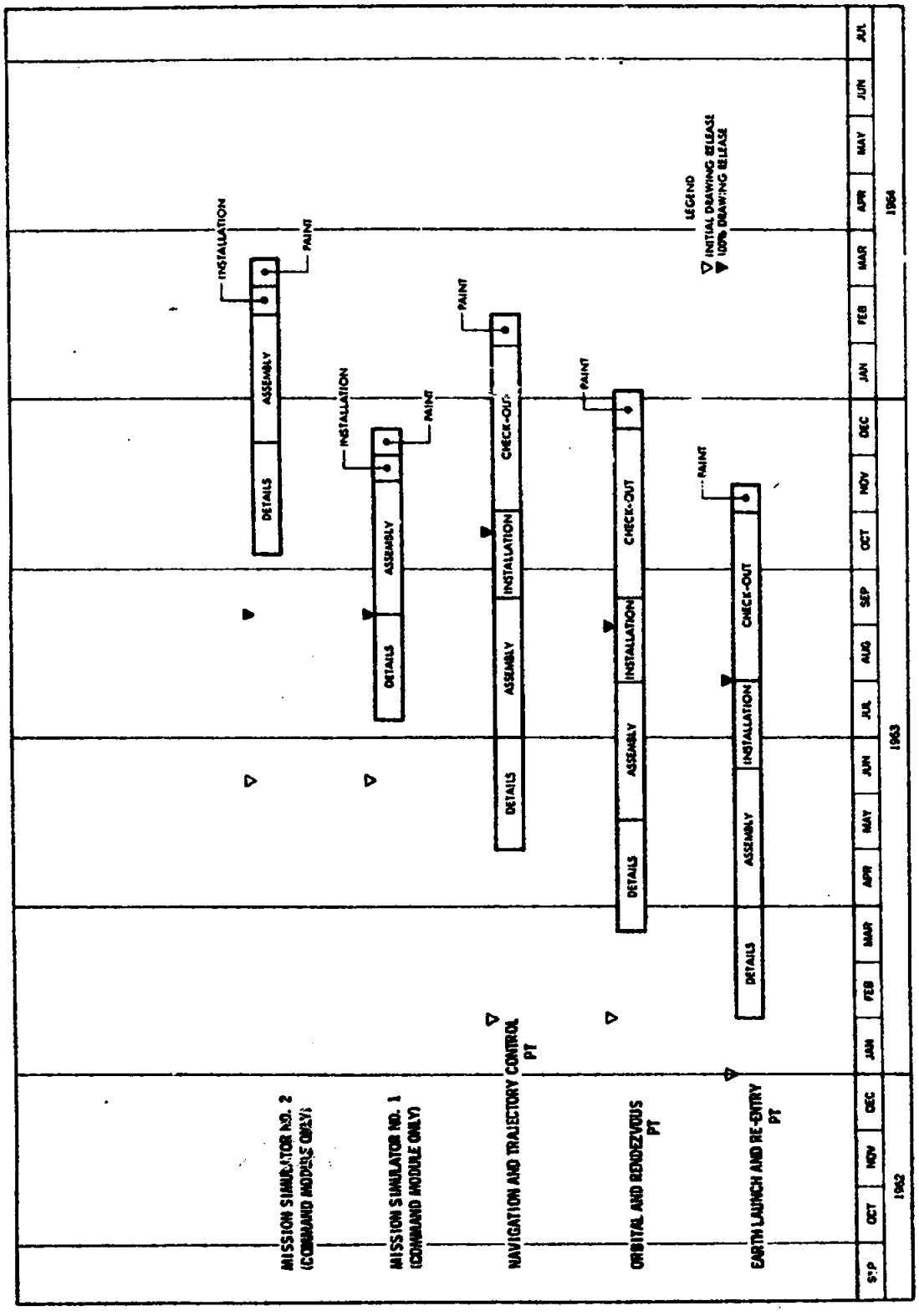


Figure 122. Apollo Training Equipment

[redacted]

[redacted]

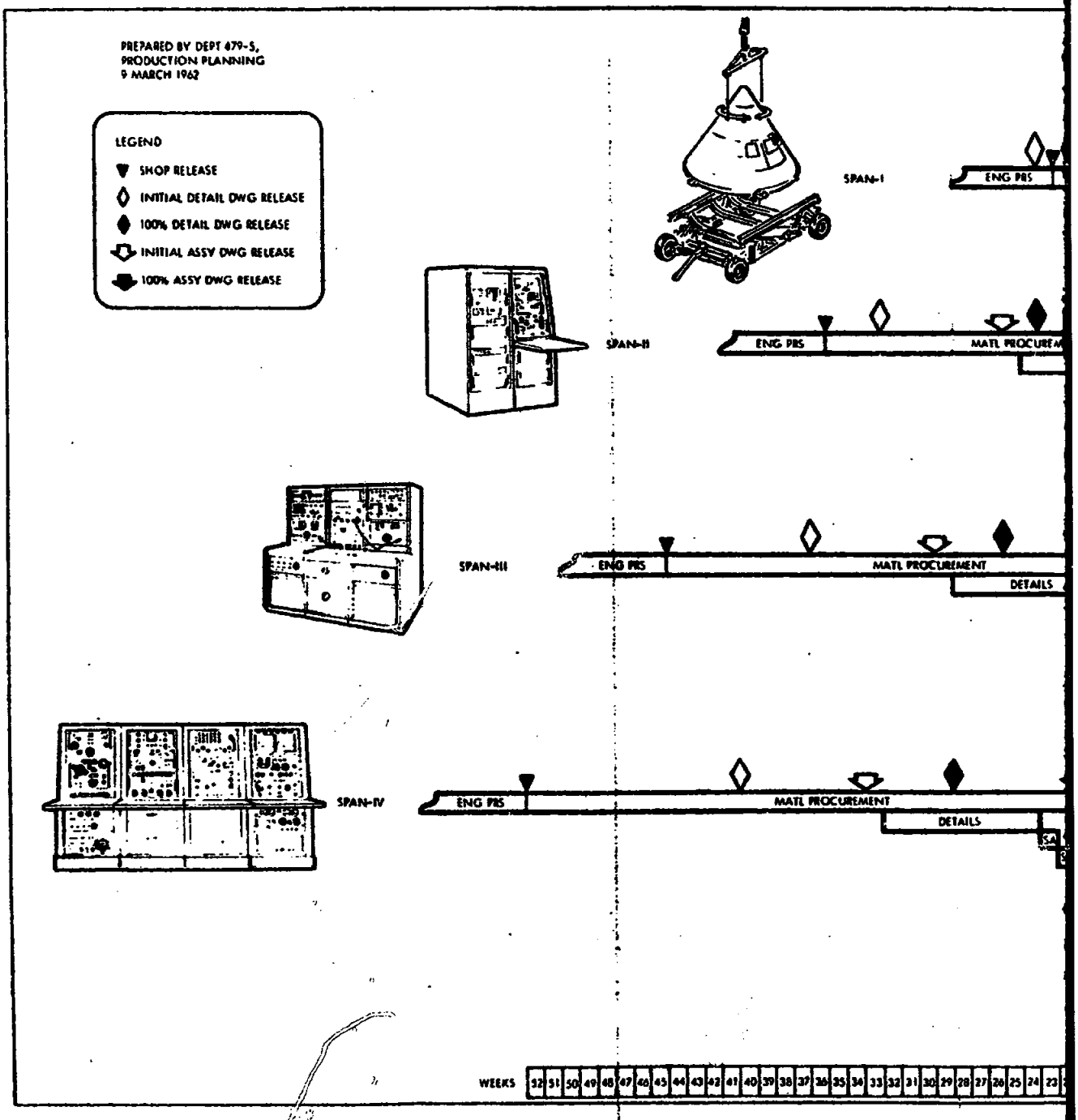


Figure 123. Apollo GSE

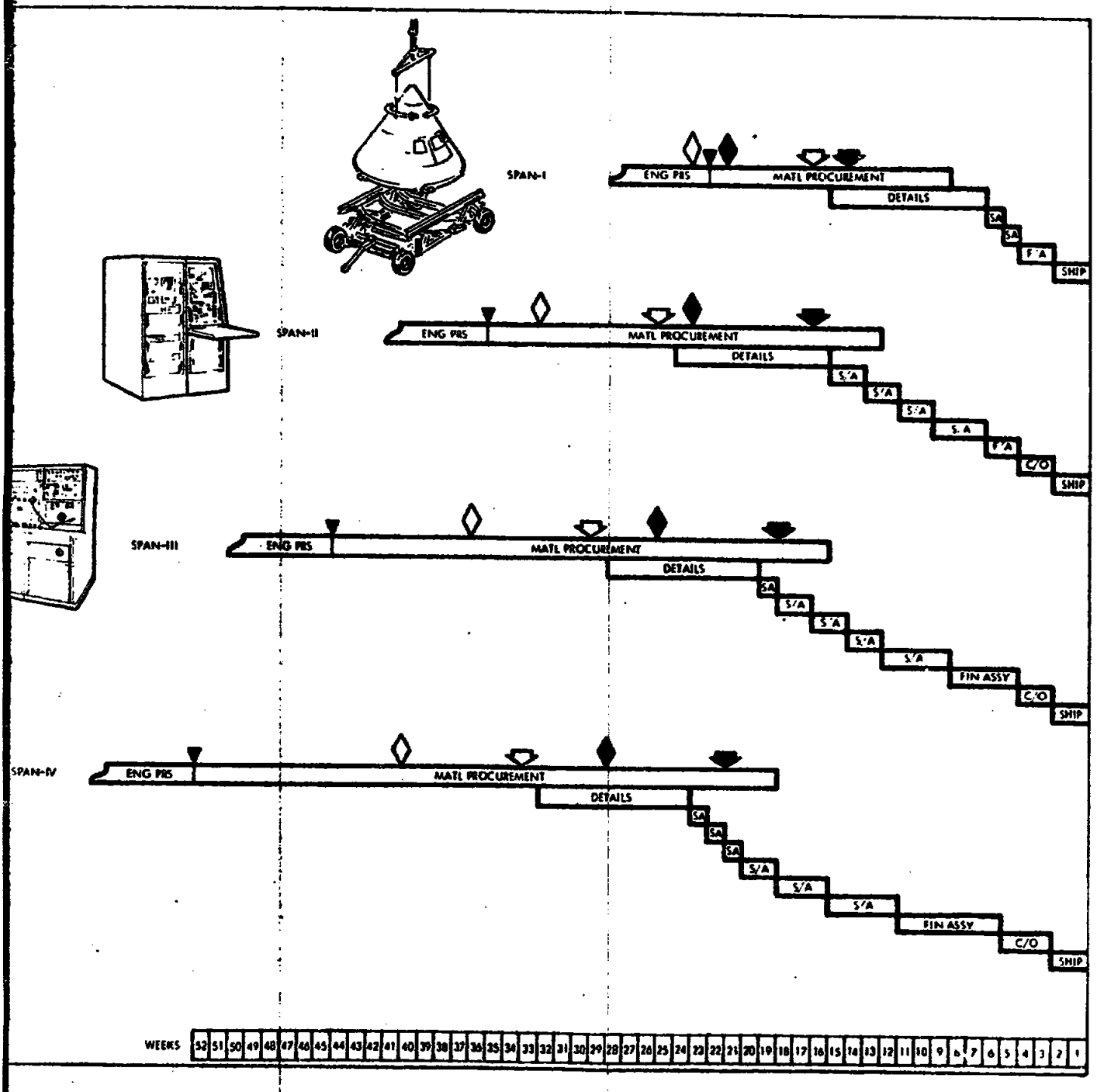


Figure 123. Apollo GSE Tim , Spans

[redacted]

[redacted]

FACILITIES

The Apollo spacecraft will be developed, designed, and manufactured by S&ID at Air Force Plant No 16 in Downey, California. The development, fabrication, assembly, test, and checkout of the Apollo spacecraft and support equipment will involve the North American Aviation plant facilities described in the following pages, as well as certain Government, subcontractor, and vendor laboratory facilities. The facilities and capabilities of the subcontractors and associate contractors will be utilized to the maximum extent possible where they suit the requirements of the program. The Downey facility is shown in Figure 124.

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

DIVISION LABORATORIES

S&ID's applied science laboratories, including engineering development, life sciences, space sciences, and information systems, will expand to support the Apollo program requirements.

Engineering Development Laboratories

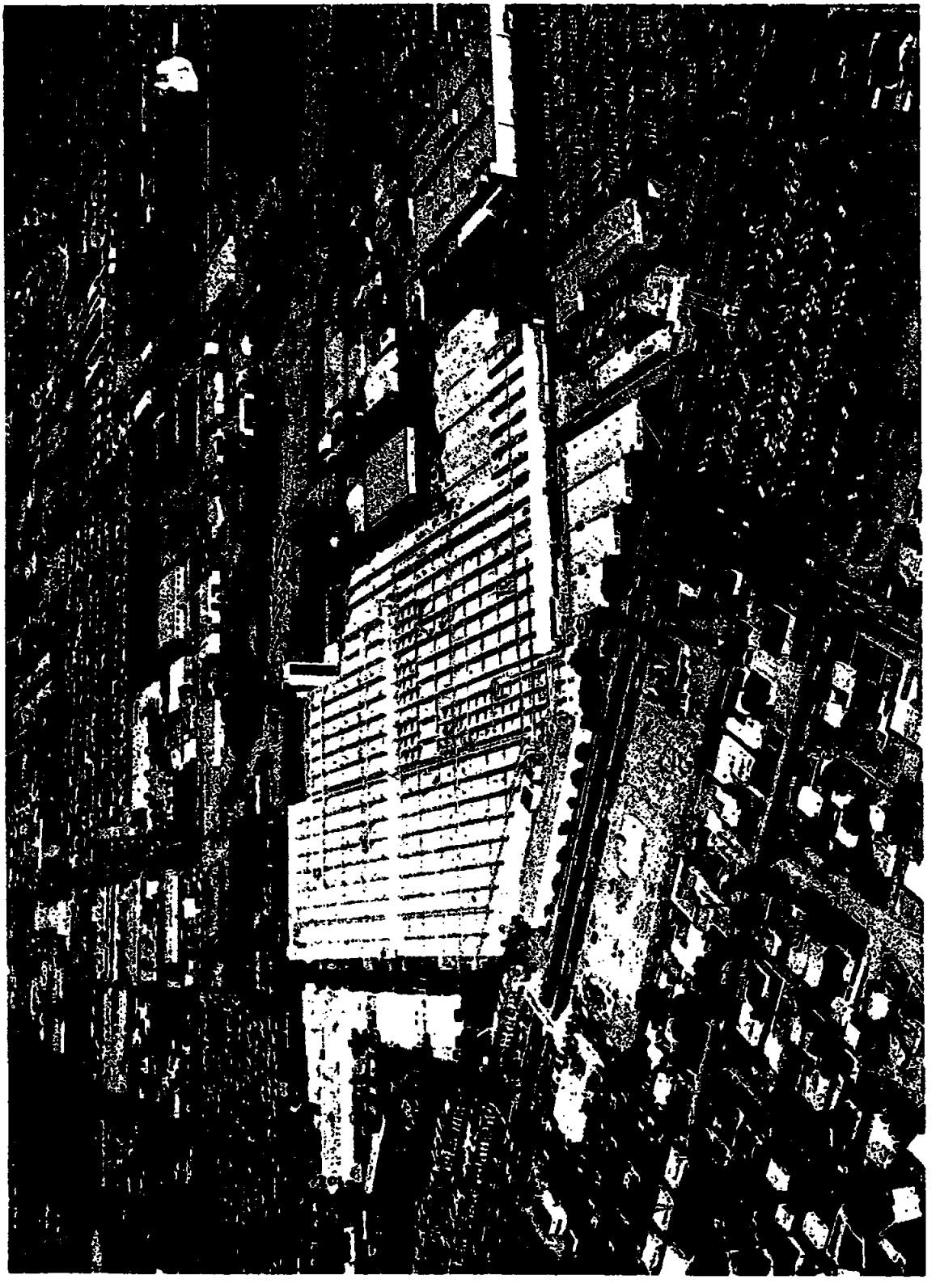
Existing, relocated, or new laboratory facilities to be operated by S&ID's Engineering Development Laboratory personnel will be located, either at Air Force Plant 16, or S&ID's adjoining facilities, in Downey, California. Development tests performed off-site will be witnessed and monitored by S&ID personnel.

The Downey division laboratories will provide testing services to develop and advance the state-of-the-art in prototype, design proof, qualification, reliability, and quality verification. Equipment and spacecraft systems will be subjected to simulated service environments, including static and dynamic loads, transient temperatures, acoustics, acceleration, shock, salt spray, humidity, fungus, sand and dust, solar radiation, cold sink of space, and altitude.

An impact test facility will be required early in the program for the purpose of simulating land and water impact and testing recovery aids, water

[redacted]

[redacted]



[redacted]

[redacted]

egress, flotation, and logistics recovery. This facility will be constructed at the Downey site. The steel structure will be demountable construction to facilitate relocation.

A general purpose environmental laboratory for high-temperature processing, material properties testing, and general environmental testing will be established by relocating existing equipment into the former Autonetics Division Laboratory, building No 18, located at the Downey site. Funds will be requested from NASA for special environmental equipment to be installed in this S&ID building.

A Space Systems Development Facility laboratory will be established for the Apollo program. This NASA-financed building will house special vibration and shock equipment, an acoustic facility, a general purpose dynamics test area, a space simulation test area, an electrical power system and environmental control systems test area and a breadboard development and electrical checkout area. The environmental control system test cell will contain a bell-shaped vacuum chamber 18 feet in diameter. This chamber will accommodate the command module and space radiators. It will provide for the simulation of flight profiles and for the removal of water vapor emitted from the command module during certain tests. The acoustic facility will include an existing acoustic chamber plus a new progressive wave chamber capable of producing white noise with sound intensities of 170 db and a large and a small quiet-room. These latter items will be required to support the Apollo program and are to be provided by NASA. Existing shakers will be relocated in the dynamics test area, as well as new shock testers, electrodynamic and hydraulic shakers, and other equipment.

An annex to the Space Systems Development Facility will be separately constructed to provide for development and verification testing of the spacecraft reaction control systems, including live firing of the reaction control motors in reinforced concrete test cells.

Laboratory facilities for navigation and guidance to be used by Massachusetts Institute of Technology will be installed in an existing building on the Downey site. A guidance and control systems laboratory to synthesize breadboard tests, to examine modulation schemes, to analyze tests, and to evaluate switch logic will also be installed in an existing building at the Downey site. An anechoic chamber and necessary screen rooms will be constructed into the expanding electrical and electronic laboratories. Several laboratory functions will be relocated to other buildings on the Downey site to permit expansion of adjacent laboratory areas.

[redacted]

Life Science Laboratories

Division laboratories for conducting analytical and experimental studies on physiological processes, behavioral processes, and bioastronautics, and for developing specialized hardware and techniques for life support, space systems, and flight sciences will be provided. Laboratories for conducting applied research and development in the fields of sensors and pattern recognition and laboratories for developing displays and components for detection, tracking, and data processing will also be provided. Initially, the Life Science Laboratories were established in a leased facility in Torrance, California. These laboratories will be relocated to Building 5 at the Downey site when they become available.

Maximum use will be made of existing laboratory facilities of North American. The highly specialized laboratory facilities of other NAA divisions will be utilized as required. For example, radiation tests will be performed by Atomics International. North American's Aerospace Laboratories in El Segundo, California, will be used to support the Apollo program, including the nonmetallics laboratory, the chemical laboratory, the thermodynamics laboratory and the sonic testing facility. The sonic testing facility will be modified by NAA to produce narrow-band discrete frequencies to pressure levels up to 170 db for Apollo testing. This acoustic chamber, housing the world's largest catenary horn, will provide simultaneously acoustical and mechanical vibration at elevated temperatures for Apollo development tests.

The construction of a Company-financed, hard-vacuum space chamber at the Aerospace Laboratory is nearly complete. The facility will be used to support the Apollo spacecraft program. The stainless steel chamber will be 15 feet in diameter and 26 feet long, and it will be housed in a 50- by 60-foot building. Its ultimate vacuum pressure capability will be 1×10^{-8} mm of mercury.

AEROTHERMODYNAMIC TESTING

A highly concentrated, aerothermodynamic test program is proposed for the Apollo spacecraft design and development. A list of recommended wind tunnel test facilities is presented in Table 1.

COMPUTER AND SIMULATION FACILITY

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

[redacted]

[redacted]

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

PROPULSION SYSTEMS DEVELOPMENT FACILITY

This facility will be located on the White Sands Missile Range near Las Cruces, New Mexico. Major facility developments are described in the following paragraphs.

Test Stands

Two test stands will be constructed to support the Apollo spacecraft during testing operations. One test stand will support the service module propulsion system during the hot firing development testing program, and the second stand will support the assembled command and service modules during combined systems operations hot firing conditions. An umbilical tower and boom will be installed to service the umbilical connections on the spacecraft, and a gantry crane will be provided to position the spacecraft. Terminal rooms will be provided at each stand for short run cables connecting the long run cables from the control center to the stands. An adapter will be installed over the flame bucket to support the spacecraft and a thrust measuring system will be added to indicate engine reaction and thrust. The stands will be constructed to permit full-engine gimbaling. A ground control station will be constructed to house the propellant transfer units that will be used to tank the spacecraft prior to static firing tests. A Firex system will be installed to protect the spacecraft and structure against damage from fire and explosions resulting from spillage.

Test and Range Facilities

The site of the proposed Propulsion Systems Development Facility is in a remote area of the White Sands Missile Range. Therefore, requirements such as ambulance service, fire protection, cafeteria, shop facilities, reproduction, etc., must be provided.

[redacted]

Control and Instrumentation Center

A new building will be constructed to provide an area for the equipment and activities needed to conduct tests and acquire data on firing operations. Room will be provided for twenty two-bay consoles. A closed-circuit television system for observation of the test stand during actual firing will be installed. Provisions will be made for recording equipment to register approximately 400 measurements on the spacecraft during the test runs. This building will be air-conditioned to provide for proper operation of equipment and comfort of personnel.

Service Building

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

Liquid and Gas Storage and Transfer

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

Additional Service Facilities

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

DATA GROUND STATION

A new pulse coded modulation and pulse amplitude modulation data acquisition and processing system will be installed in building No. 6 on the Downey site. This area will be located adjacent to the final assembly and systems integration and checkout facility. The data reduction station and computer-plotter area will be noise-controlled and will have a raised floor for cable distribution and for installation of air-conditioning plenum chambers. The data reduction station will house approximately forty different electronic systems of various sizes. This room will have complete copper-screen shielding against radio frequency interference. Adjacent to this area will be the data review and information center, the projection and viewing room, a dark room, and a maintenance and storage area. The location of the data ground station in building No. 6 is shown in Figure 125.

[redacted]

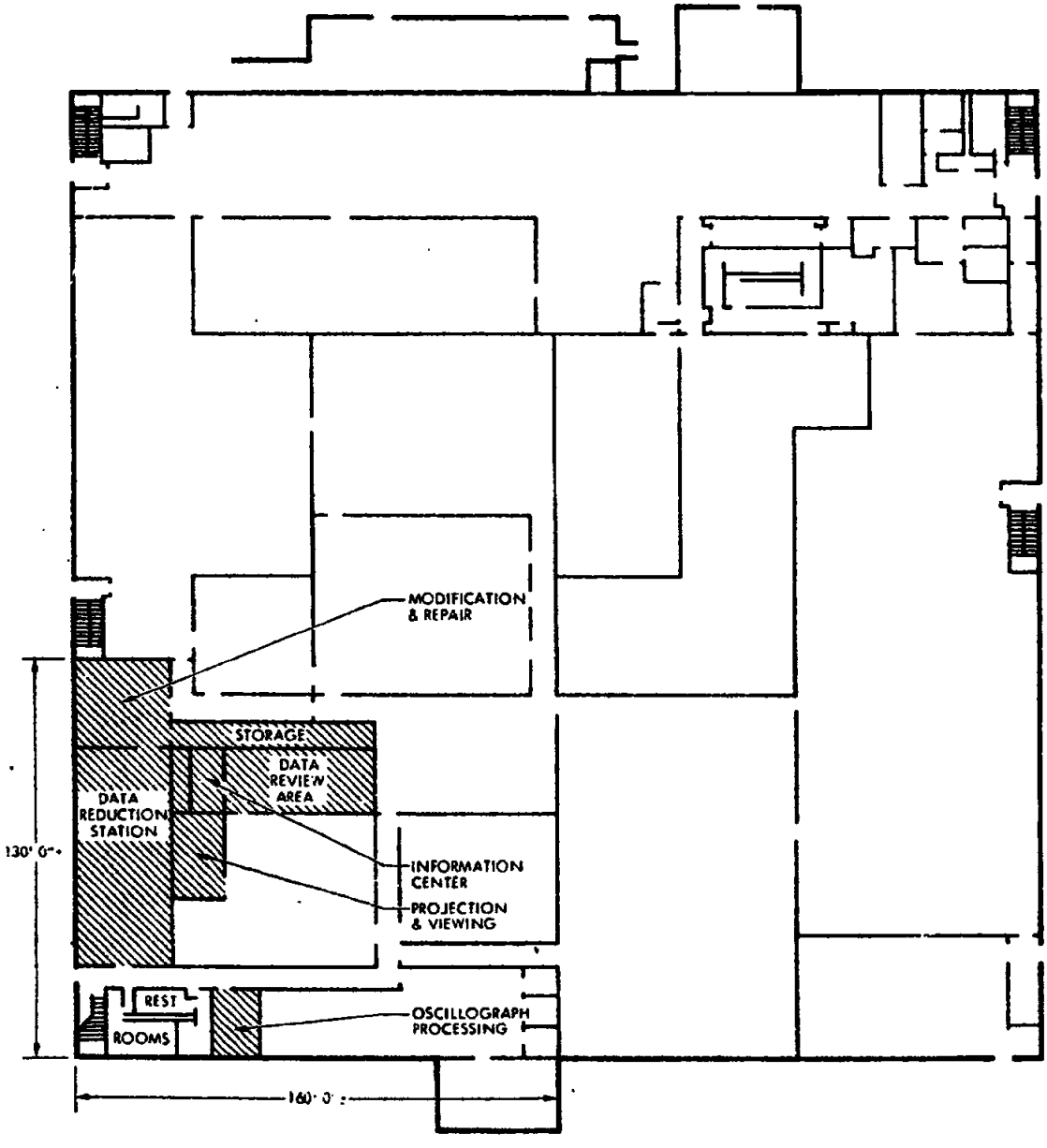


Figure 125. Data Ground Station Location in Building No. 6

[redacted]

[redacted]

The building modification for the new ground station will include the installation of the raised floor, air-conditioning for clean, temperature- and humidity-controlled air, acoustic walls and ceilings for noise control, and regulated and unregulated power.

BONDING AND TEST FACILITY

A new building will be constructed at Air Force Plant No. 16 in Downey to house the bonding and testing facility, which is comprised of storage, core fabrication, cleaning and processing, adhesive preparation, prebond assembly, autoclave bonding, and inspection operations. The new building will be approximately 130 feet by 180 feet by 30 feet high, separated into two 50-foot spans and one 30-foot span, with partial mezzanine coverage over the 30-foot span for offices and rest rooms.

Bridge crane service will be provided throughout the facility by four separate bridge crane systems, three two-ton 48-foot spans and one five-ton 40-foot span, all with 24-foot hook heights.

Two autoclaves will be utilized for the bonding operations because of the irregular size and shape of the articles to be bonded. One autoclave will be a 12-foot-diameter, 20-foot long, end-loading cylindrical type; whereas, the other will be a specially designed 15-foot-diameter, 18-foot-deep pit mounted top-loading type.

The cleaning and processing area of the facility will house a vapor degreaser, etch tank, and rinse tank, all of which will be pit-mounted and have a usable area of 7 feet by 18 feet by 12 feet deep, as well as a 15- by 20-foot gas-fired curing oven and a paint spray booth.

Refrigeration and air-conditioning equipment will be required for the storage, preparation, and use of adhesive materials in the bonding process.

Partial occupancy is expected in April for the major equipment items, with building completion scheduled for 1 May 1963.

TRAINING EQUIPMENT FABRICATION

An area of approximately 32,000 square feet has been allocated to training equipment fabrication in Building No. 43 of the Compton facility. This area supports the following operations: raw stock storage, detail parts fabrication, structural assembly, precision mechanical assembly, electrical wire build-up, electrical and electronic subassembly, functional testing, equipment installation, systems checkout, and necessary offices to support the operation.

[redacted]

[redacted]

Major facility items to be installed in this area include a potting room 19 by 30 feet, a 4-ton self-supported, top-rider, bridge crane of 25-foot span and 120-foot run and 16-foot hook height, a 6-foot by 1/4-inch capacity gap shear, an 8-foot by 1/4-inch capacity press brake, a 2-inch-diameter capacity tube bender, an NAA-designed tube welder, electronic test equipment, motor generators to supply required test voltages, and environmental air generators to supply cool air to training equipment computer bays.

It is anticipated that skeleton operations will begin in April 1963. The area will become fully operational by June 1963.

SUBASSEMBLY, ASSEMBLY, AND MOCK-UP

Subassembly, assembly, and mock-up, which consist of the fabrication of mock-ups, boilerplates, and spacecraft, will be accomplished in building No. 1 at Downey.

Approximately 90,000 square feet of manufacturing area will be used as follows:

Mock-up fabrication	-	18,000 square feet
Boilerplate fabrication	-	30,000 square feet
Spacecraft fabrication	-	42,000 square feet

Existing facilities will be used as much as possible. Relocation of secondary utilities and equipment will be required to prepare the area for occupancy. Existing bridge cranes will be fully utilized. However, additional cranes will be added in both high- and low-bay areas to support requirements.

RADIOGRAPHIC FACILITY

An extension to the existing X-ray building is required to provide a facility for radiological inspection of welded structures and components used in the fabrication of the service and command modules.

The building (24 feet by 80 feet by 16 feet high) will be erected adjacent to the north wall of building 134, Downey. The new addition will contain an X-ray room (1100 square feet) and a storage and handling room (900 square feet). A metal sliding door (16 feet by 14 feet) will be located at each end of the building, and the X-ray room door and the pedestrian door will be lead lined.

Protection from primary and secondary radiation will be in compliance with applicable local and federal codes. Reinforced, 12-inch-thick concrete

[redacted]

[redacted]

block, filled with concrete, will be used for exterior walls where X-ray protection is required. An internal partition dividing the X-ray room and preparation areas will consist of metal studs, lined with 1/4-inch-thick sheet lead to a height of 10 feet.

PLASTER MASTER FACILITY

A facility is required for modification and maintenance of master models of the command and service modules. They will be constructed of thermally stable plaster. The models will be transported on heavy-duty carts.

The plaster master facility will consist of a conventional 100- by 60-foot, 20-foot-high, prefabricated steel, rigid frame building with metal siding. The building will be located adjacent to existing Building 699 and 700 in the preflight area. The building structure will contain a 16- by 16-foot metal sliding door at each end, pedestrian doors, flashing, and a rain gutter where the addition adjoins the existing structure. A 6-inch reinforced concrete slab and foundations will support live and dead structure loadings and plaster master wheel loads.

GROUND SUPPORT EQUIPMENT FABRICATION

GSE equipment will be fabricated in the 131,000-square-foot Slauson facility leased by NAA. Fabrication of GSE workstands, adapters, covers, slings, alignment and weighing fixtures, supports, transfer units, and other associated equipment will be achieved in a 257,000-square-foot area of Air Force Plant No. 3, Tulsa, Oklahoma.

Fabrication work at Slauson will consist of building pneumatic consoles, hydraulic consoles, electrical consoles and panels test sets, wire harness assemblies, vacuum systems, and other associated equipment.

Wire harness assemblies will be fabricated in existing manufacturing areas equipped with the latest up-to-date equipment. Recently developed materials of all kinds are available for drawer, console, and structure fabrication.

The Slauson facility is equipped with 10,000-pound bridge crane, which will operate over 37,000 square feet of floor area. Lighting in assembly areas is a minimum of 125 foot-candles at the working surface level. Low- and high-pressure tubing fabrication to a maximum of three inches in diameter can be accomplished with existing equipment. In the final installation and checkout area, either a line-flow or a station-build-up type of operation can be effected, because of the flexibility of the existing layout. Temperature- and humidity-controlled functional test areas are available for checkout of GSE.

[redacted]

[redacted]

It will be necessary to rearrange present areas, utilities, and facilities to integrate Apollo GSE fabrication into existing layouts.

SYSTEMS INTEGRATION AND CHECKOUT FACILITY

A new facility will be constructed for systems integration and checkout. The existing 320-foot-wide building No. 6, Downey, will be extended 261 feet to the west. This new building will be of rigid frame construction with exterior walls of reinforced concrete and protected metal. This addition will include a white room area 113 feet by 320 feet. The white room area will consist of a 70-foot high bay, 63 feet by 350 feet, and a 45-foot low bay, 50 feet by 320 feet. The high-bay area will have a 15-ton bridge crane, with a 55-foot hook height. The low-bay area will have a 10-ton bridge crane, with a 35-foot hook height. An air lock at each end of the low-bay area will provide ingress and egress to the white room area. These air locks will have 10-ton fixed position crane coverages, with 35-foot hook heights.

The white room area will be flanked on the east and west sides by two-story support areas. The west support area will be approximately 50 feet by 350 feet by 36 feet high. Eight control rooms will be located in the upstairs portion. Each control room will have a corresponding equipment servicing room on the first floor. The second floor will also house a data recording room.

The east support area will be approximately 94 feet by 320 feet by 37 feet high. The first floor will house subcontractor operations, bench maintenance, systems support, GSE maintenance, a general foreman's office, a lunch room, a locker room, restrooms, and building equipment rooms. The second floor will house a white room area for subassembly operations, calibration crib, subcontractor offices, house spacecraft and flight test engineering offices, building equipment rooms, and restrooms.

This addition to building No. 6 should be complete and operational by 1 October 1963. As an interim measure an area of approximately 10,000 square feet in building No. 1, at Downey, is being set up for boilerplate systems integration and checkout. Of this area, 7700 square feet are high bay and will be used for systems installation and systems checkout. The remaining 2300 square feet are for bench maintenance and systems subassembly. This area should be fully operational by July 1962.

The integration of modules and escape towers, the checkout of the various systems, and the checkout of instrumentation will be accomplished in the existing hydrostatic test tower. This 110-foot tower is equipped with a bridge crane capable of handling Apollo modules. Power and equipment will be required to checkout subsystems and instrumentation for this operation.

[redacted]

[redacted]

First- and second-floor layouts of the building 6 addition are shown in Figures 126 and 127.

PROGRAM MANAGEMENT

The Apollo Program Manager's office and the program management supporting functions will be located in adjacent areas in building No. 1, at Downey. The supporting functions include:

Contracts

Material

Facilities

Associate Contractor Relations

Quality Control Management

Program Control

Office area for the NASA Apollo representatives is being provided near the program management offices. Offices for the associate contractors' and subcontractors' representatives will also be provided in this same area, or in building No. 6, near the engineering group.

ENGINEERING

Apollo engineering operations offices and design areas will be consolidated primarily in building No. 6, at Downey, immediately adjacent to the systems integration and checkout facility. Approximately 180,000 square feet of this building will be utilized by the Apollo engineering group. Additional area for the expected growth of the engineering group will be provided in building No. 1.

To provide adequate office space for Apollo program engineering personnel, building 6 will be modified as necessary to up-grade existing shop and laboratory areas to office standards. An existing white room area will be retained for clean-room, laboratory-type operations. Specific modifications required include installation of suspended acoustical ceiling, tile floor, permanent partitions, air-conditioning, fire sprinklers, and light fixtures in substandard areas. An area on the first floor of this building will house the data ground station.

TRAINING AREA AND CLASSROOMS

An area of between 15,000 and 20,000 square feet will be assigned for training area and classrooms. This area will be divided into formal and practical classrooms. The formal classrooms will be used for briefings, indoctrination, and lectures related to crew missions and systems training.

[redacted]

[redacted]

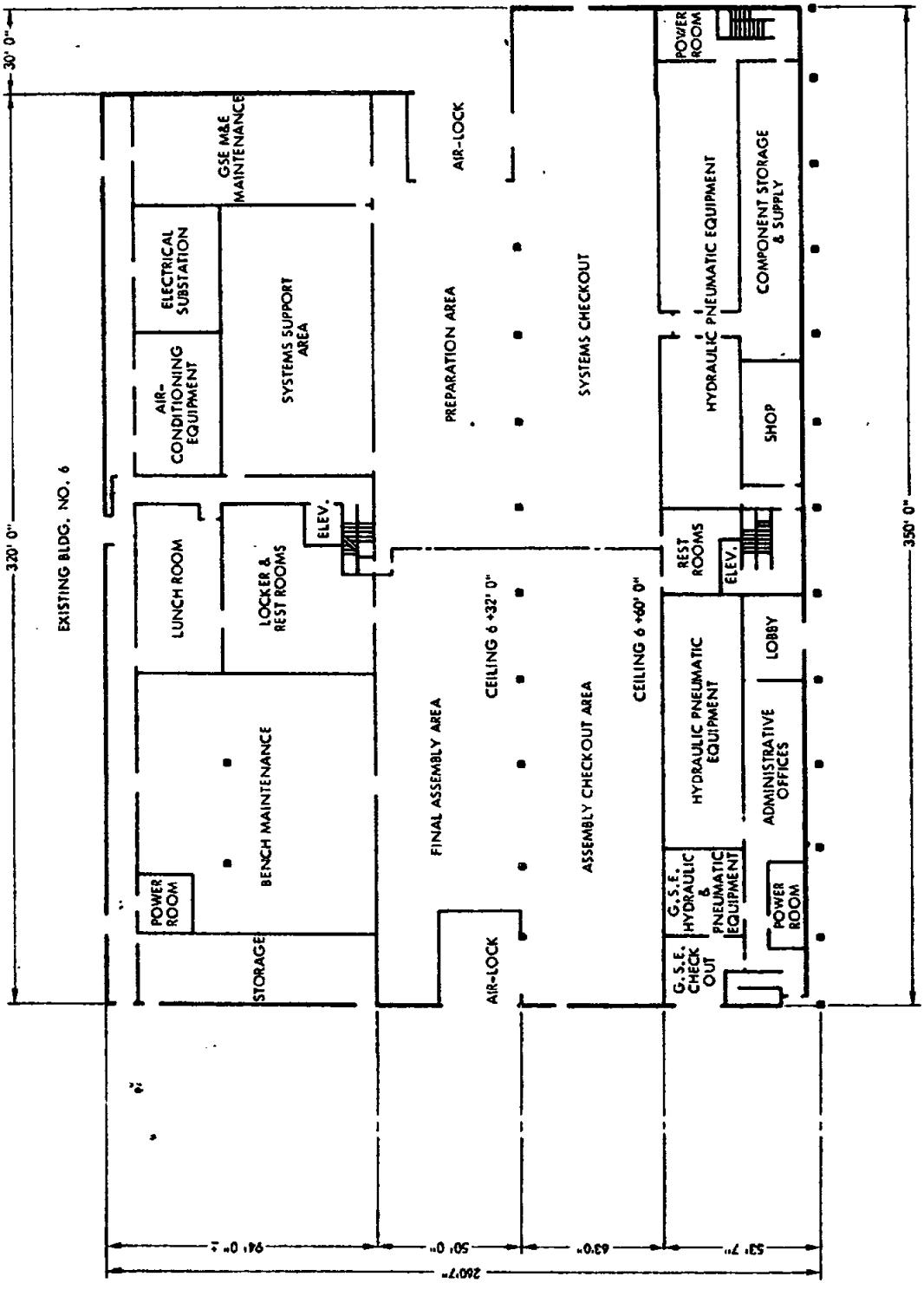


Figure 126. First-Floor Layout of Building No. 6 Addition

[redacted]

[redacted]

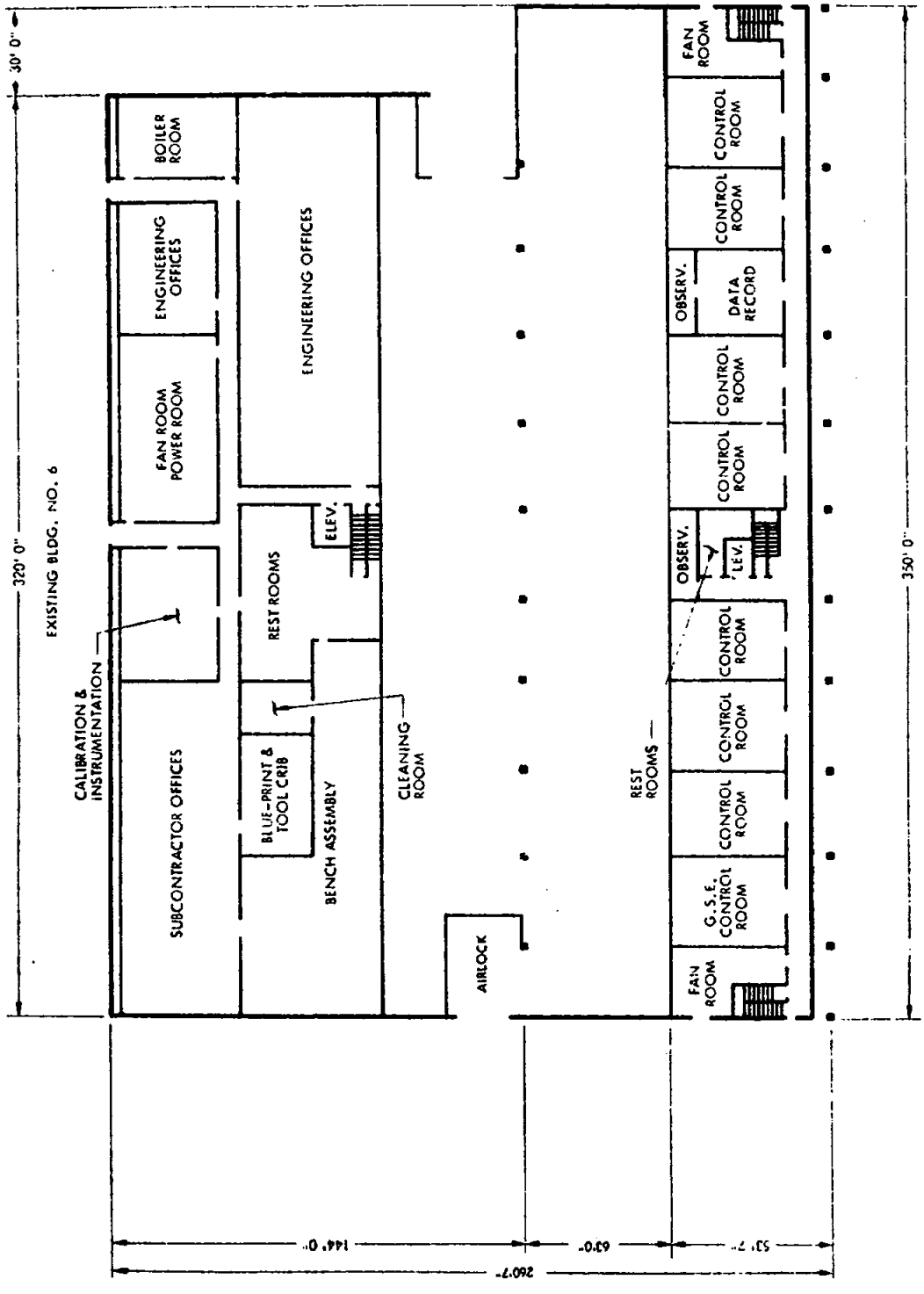


Figure 127. Second-Floor Layout of Building No. 6 Addition

[redacted]

[redacted]

The practical classrooms will house maintenance and simulation trainers, large training-aid devices, and supporting GSE.

MOCK-UP DISPLAY AREA

It is planned to have a permanent mock-up display and modification area. The purpose is to provide a place to retain, modify, and display all of the non-deliverable mock-ups.

ATLANTIC MISSILE RANGE

Facilities will be required at the Atlantic Missile Range for inspection, checkout, test, and mating of the spacecraft with the booster.

Upon arrival at the range, the modules will enter a receiving area for inspection and preparation for checkout. The receiving inspection will include a configuration review down to the subsystem module level. A clear white room is essential for this operation. Functional checkout operations will require electrical interconnecting of the spacecraft modules and ground support equipment necessary for the service and command modules. Approximately 10,000 square feet of clear white room area will be needed for functional checkout operations. After the initial inspection and checkout, the horizontal and vertical weight and center of gravity will be determined for the modules. Then the modules will be removed to a remote area where the launch escape motors will be assembled.

Next, the spacecraft will undergo a series of tests in another remote facility, during which the reaction control system will undergo functional hot firing tests and leakage tests. The environmental control system will also undergo functional tests and fuel cell leakage checks.

The hermetic property of the command module will be verified by a series of checks in altitude chambers before and after a static-firing test. Two altitude chambers with control and checkout areas will be required.

A test stand will be needed for the vertical-mated module firing. Storage will be required for propellants, cryogenics, gas, etc. A control room will also be required. Static-firing tests will be conducted, either from this control room or the command module itself.

Following static-firing and altitude chamber tests, the spacecraft will be moved to the vertical checkout facility. The test configuration will consist of an S-1 stage and S-2 stage simulator, adapter, service module, and command module. A simulated countdown will be performed and will be followed by a simulated flight. Currently, it is planned to do vibration checks, as well as weight, balance, and center-of-gravity checks at this facility.

[redacted]

[redacted]

The spacecraft will then be moved to a vertical assembly building for physical mating with the actual multistage Saturn booster. Following vertical assembly, the spacecraft will undergo high-pressure leak tests of cryogenic, pressurant, and propellant systems.

Following the fluid systems checkout, the spacecraft will be moved to the arming tower for the installation of the recovery subsystem, the ordnance items, the escape tower, and the loading and alignment of solid rocket motors.

Contractor requirements at the launch site include space in the control center for ground support equipment peculiar to the operation of the spacecraft and provisions on the gantry and umbilical towers for the handling and servicing functions. Facilities will be required for storable propellants.

GROUND OPERATION SUPPORT SYSTEMS

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

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

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

[redacted]

LOGISTICS

This section summarizes four Apollo logistics documents: Maintenance Concept, Maintenance Plan, Support Plan, and Training Plan. The Apollo Maintenance Concept delineates the general requirements and considerations for the accurate formulation of support planning. The Apollo Maintenance Plan provides specific information relative to the types, phases, levels, and locations of maintenance required to implement the Maintenance Concept. The Apollo Support Plan similarly specifies in detail the system and methods necessary to provide timely and adequate support of Apollo test and operational functions. The Apollo Training Plan encompasses training requirements for the flight crew and the ground operations and maintenance personnel.

MAINTENANCE CONCEPT

In conformity with the Test Plan and the Operational Plan, the Maintenance Concept outlines the S&ID policies pertaining to the maintenance of the Apollo spacecraft and related ground support and training equipment. It provides the feasible methods of a system of maintenance to ensure the accomplishment of test objectives and the achievement of reliability goals.

MAINTENANCE PLAN

In accordance with the Maintenance Concept, the Maintenance Plan will include maintenance objectives, levels of maintenance, and maintenance analysis.

Maintenance Objectives

The principle objective of the Maintenance Plan is to establish a level of maintenance in keeping with economical, timely, and reliable support of the test objectives and to identify the areas and levels of maintenance to all concerned.

Levels of Maintenance

To establish and maintain the highest degree of reliability, three levels of maintenance have been established: systems maintenance,

[redacted]

[redacted]

replaceable package maintenance, and contractor factory repair and overhaul. These levels of maintenance were established based on the programmed GSE at each maintenance location and in keeping with the feasibility of repair.

Systems maintenance is that maintenance performed at a test site and includes servicing, adjusting, and repair by removal and replacement of replaceable packages. This maintenance is performed with the available GSE to certify the system.

Replaceable package maintenance is maintenance performed on major subassemblies. This maintenance will normally be accomplished at the bench maintenance area of a test site and will be limited to minor repair and certification.

Contractor factory repair and overhaul is maintenance of replaceable package components and subassemblies using the factory resources of the contractor, the subcontractor, and the supplier. This is an unlimited capability.

Maintenance Analysis

S&ID, with the support of the subcontractors, will develop and maintain a maintenance analysis that will generate the basic information necessary for a logistic support program. This program will include operations and maintenance data, supply support data, support manuals, and training plans.

SUPPORT PLAN

Material (Spares) Support

S&ID will identify and provide the material and services to support the Apollo test program as specified in the NASA statement of work. The objective is to ensure that complete material and spares support is available to the level determined by the maintenance and test plans. Policies and procedures developed for in-house control of the effort will be similar to those required at off-site facilities.

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

[redacted]

The scope of S&ID responsibilities at off-site facilities will comply with existing company policies and procedures. The greatest level of support will be required for the operations at the Atlantic Missile Range. Time will be a critical factor, and the nature of the test operation will demand immediate response to requirements for maintenance, parts replacement, and emergency test support material. The Apollo test program at AMR and other test sites will require an adequate number of qualified supply support personnel. A complete stock of spares and material based on maintenance concepts and test parameters will be provided at each site.

Direct air transport service will provide minimum turn-around time for hardware items. An immediate-response communication system for in-house and supplier support will be established. This system will be designed to fulfill all requests for replacement parts and emergency test support.

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

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

Packaging, Handling, and Transportation

S&ID will provide for packaging, handling, and transportation that will effect safe and timely delivery of all hardware developed under the Apollo program. To achieve this goal, the following policies will be complied with:

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

2. Equipment will be protected as economically and efficiently as is consistent with anticipated hazards of shipment and storage.

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

[redacted]

[redacted]

4. Packaging, handling, and transportation manuals will control the procedures for preservation, packaging, marking, handling, loading, transporting, unloading, and storing.

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

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

Modification, Repair, and Overhaul

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

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

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

[redacted]

[redacted]

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

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

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

Support Manuals

S&ID will provide manuals to support flight-rated hardware commencing with the launch escape system installed in boilerplate 6.

Manuals will be written to the level of skilled technicians and engineering personnel and will include the following categories:

Manual	Purpose
Spacecraft Familiarization and Description Manual	This manual will provide, in sufficient detail, a functional understanding of the installed spacecraft systems. The manuals will be a series of documents, and each document will be based upon a specific spacecraft configuration.
Spacecraft Operations Manual	This manual will include sequential procedures for the launch, flight support, and recovery teams.

[redacted]

[redacted]

Manual	Purpose
Flight Operations Manual	This manual will include operational instructions and sequential procedures for the spacecraft crew during all phases of flight.
Transportation and Handling Manual	The manual will include procedures and special requirements for transportation, handling, and storage of the spacecraft and major items of GSE.
Systems Checkout Manuals	These manuals will include sequential procedures required to accomplish separate systems checkout, and will be maintained current by updating processes to support spacecraft system configurations.
Combined Systems Checkout Manual	This manual will contain the sequential procedures required to conduct a complete integrated systems checkout and will support each spacecraft configuration as required.
Integrated Spacecraft/Little Joe II Operations Manual	The instructions will cover mating procedures, compatibility testing, propellant loading and monitoring, countdown, recovery and other instructions related to the functions.
Ground Support Equipment Maintenance Manuals	These manuals will include procedural instructions directly associated with and required for the operation, checkout, maintenance, repair, and calibration of the GSE.
Spacecraft Equipment Repair Manuals	These manuals will include maintenance and repair instructions for the components of the command and service modules, and spacecraft adapter.
Trainer Maintenance Manuals	These manuals will include the maintenance and procedural instructions for the checkout, maintenance, repair, and calibration for the trainer equipment.

[redacted]

[redacted]

Quality Assurance provisions for support manuals will include engineering review to ensure technical accuracy and verification of technical information and procedures utilizing operational configurations of systems or equipments.

S&ID will provide a fast-reaction change program to include personnel at test sites to document procedural or instruction changes and to incorporate contractors' facility-generated changes in support manuals used during test operations. These changes and revisions will require S&ID and NASA approval prior to implementation.

TRAINING PLAN

The Apollo training plan outlines the training requirements derived from analyses of available systems, mission, and personnel information. The training and associated support activities are described for flight crew, flight operations, and preflight operations personnel without specifying responsibility for implementation. The plan will be revised as additional data become available to detail all Apollo training activities. When they are defined, the areas of responsibility for conducting all types of training will also be included. In its later revisions, the plan will be both a compendium of Apollo training and a scheduling document to assure program continuity and integration.

Program Scope

The activities essential to accomplish Apollo program objectives require a well-organized training program to ensure total reliability of performance. Training and training support for both flight and ground personnel will be required.

Flight Crew Training

The three members of the flight crew will require training in individual functions, in crew procedures for the mission, and in combined mission exercises with the ground personnel.

Ground Personnel Training

Two major groups of personnel will require training: flight operations personnel (control center, flight controller, and ground operation support systems (GOSS) personnel) will require training for individual proficiency,

[redacted]

[redacted]

interface training between flight controllers and remote site personnel, and integrated training of all three groups with the flight crews. Preflight spacecraft maintenance and checkout personnel will be trained for each specific spacecraft.

Training Support

Training equipment, devices, and aids; training planning information and the training plan; training manuals and exercises; personnel; and facilities will be required to support the Apollo training program.

Program Approach

Successful mission accomplishment will require effective individual and group training in varied specialities, and combined training practice for each mission. A detailed training program has been planned to meet these requirements. Figure 128 illustrates an analysis sequence to process input information to produce programmed data, and Figure 129 shows analysis of programmed data to determine specific training requirements. With the total learning process defined for all functions and tasks, course syllabi will be definitized. Instructor manuals and training exercises will be keyed to the course syllabi.

Flight Crew Training

The astronaut training for Apollo requires careful programming and maximum flexibility for the most effective use of training time available for each crew member, each crew, and the complex of flight and ground personnel required for mission exercises.

Requirements

The program will provide the following training objectives:

1. Develop crew proficiency in all normal and emergency functions
2. Provide all possible experience in relevant environmental conditions
3. Develop efficient crew procedures and interactions
4. Develop coordination with ground personnel supporting the mission

[redacted]

[redacted]

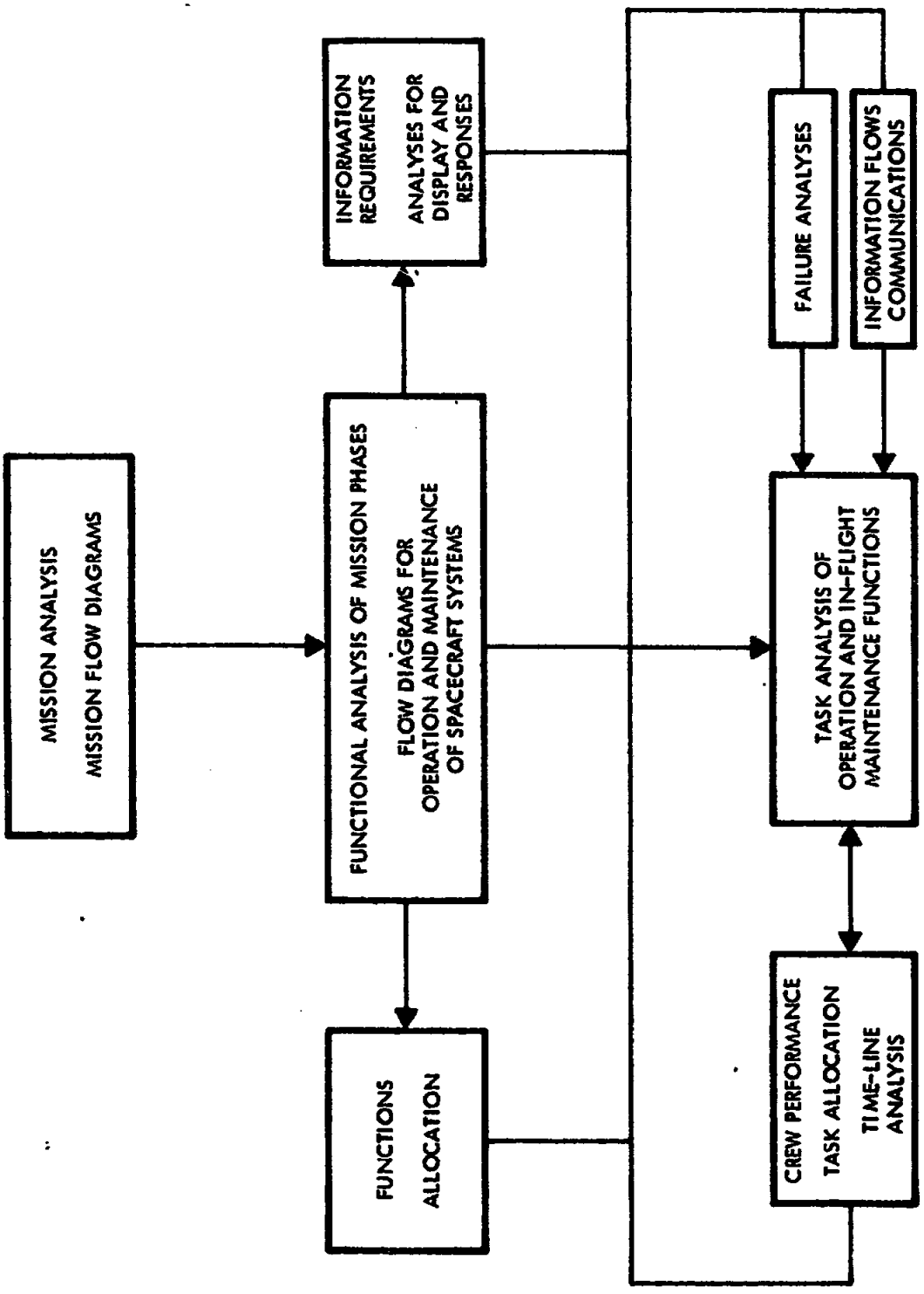


Figure 128. Sequence of Programmed Data for Flight Crew and Systems Monitoring Personnel

[redacted]

[redacted]

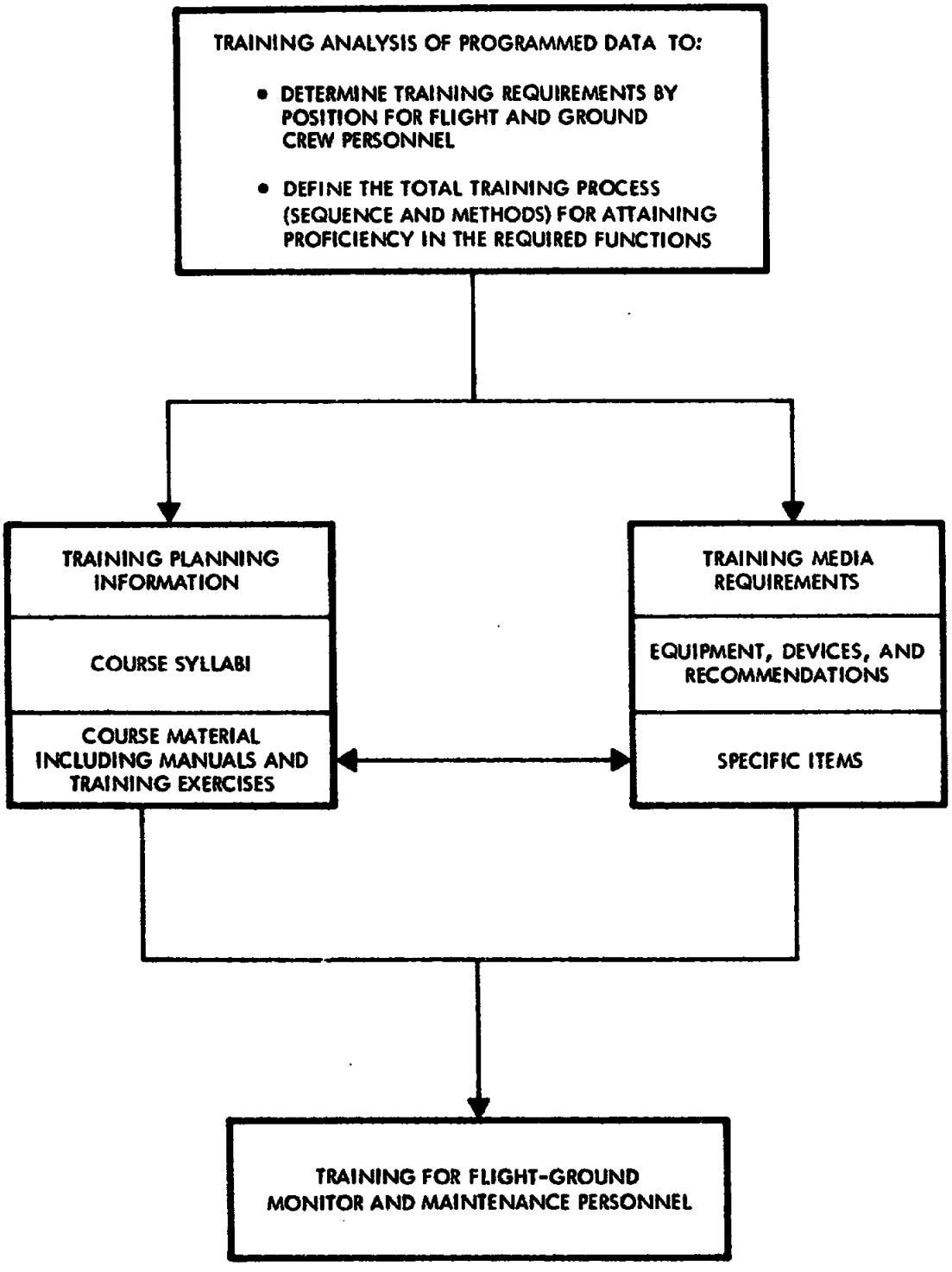


Figure 129. Training Analysis of Programmed Data

[redacted]

[redacted]

The types of training recommended are as follows:

1. Scientific and technical preparation to reinforce each individual's experience and knowledge

2. Environmental training and conditioning for stress environments

3. Physical conditioning

4. Familiarization with Apollo mission objectives, spacecraft, and crew performance requirements

5. Recovery and survival training for normal and emergency situations

6. Spacecraft systems training

7. Crew training in the performance of all mission tasks

8. Preflight procedural training

Program Planning and Coordination

It is recommended that requirements for training the flight crew members be divided into logical units of training. Each unit should be planned as an entity with any prerequisites for learning the unit indicated. The logic of learning a system is shown in Figure 130 with nonsequential units of training designated. Breaks in training between units can be made as necessary for other activities. Unit training will facilitate program planning for training with maximum flexibility for individual requirements. Other advantages include effective use of time through individual scheduling, elimination of over-training and lack of training (individual need for more or less training times on a unit can be arranged), and maximum utilization of trainers will be programmed to avoid delays in training.

Ground Personnel Training

To facilitate training for various personnel, ground personnel training has been divided in two categories: (1) flight operations training and (2) preflight operations or spacecraft maintenance and checkout training.

[redacted]

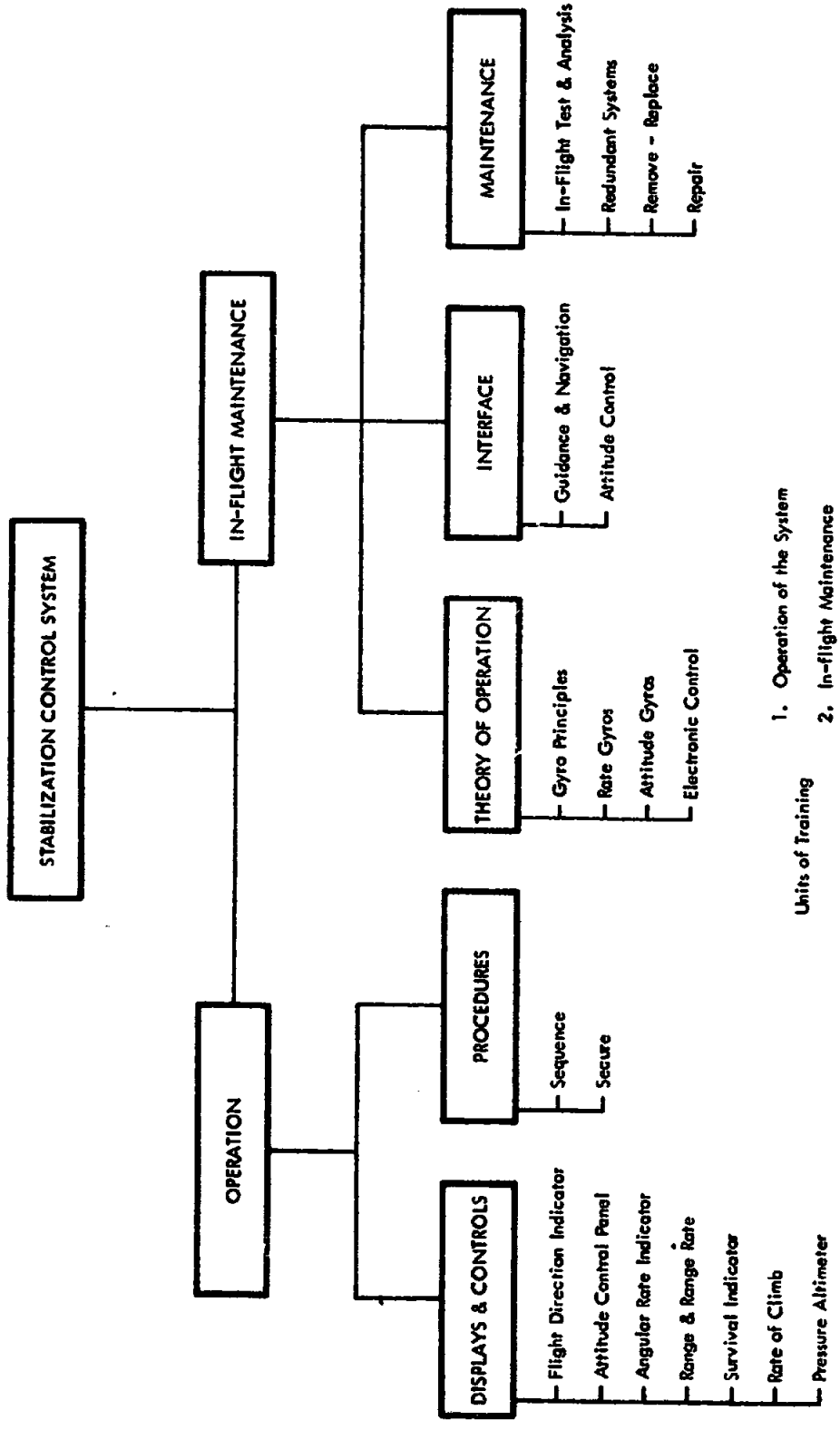


Figure 130. Examples of Apollo Flight Crew Training Units

[redacted]

[redacted]

Flight Operations Training

This training involves three groups of personnel whose activities must be closely integrated.

1. The mission control center directors, flight controllers, and monitors at the launch site

2. The flight controllers at the remote sites

3. The GOSS network facility supervisors, operators, and maintenance personnel

This training involves individual systems and procedures training, interface training between the flight controllers and GOSS network personnel, and integrated training of all three groups with the Apollo flight crews.

Preflight Operations Training

The maintenance and checkout of the spacecraft will require training related to all systems and GSE. Training will be required for contractor, the subcontractor, and the NASA engineering and technical personnel assigned to perform preflight operations tasks. The training will include maintenance and checkout of the spacecraft systems, the maintenance and operation of the control and monitor consoles, and the use of the spacecraft handling equipment. Where system interfaces exist, personnel will be cross-trained as necessary.

Training Equipment

A complete package of training equipment will be required to support the training program. This package will include simulators, and training devices, aids, attachments, accessories, GSE, and parts adjudged most appropriate and effective. Training equipment requirements are based upon mission-related analyses of flight crew, flight operations, and preflight crew personnel performance requirements.

Identification of Apollo Training Equipment

The detailed design for major items of training equipment reflects mission, system, and human performance analyses. This equipment will be supplemented by other training media as task performance and training analysis data are refined.

[redacted]

[redacted]

Major items of training equipment identified at the present time may be classified into three categories: (1) systems trainers, (2) part-task trainers, and (3) the Apollo flight trainer.

The Apollo trainers will be designed to facilitate the transfer of knowledge and attainment of proficiency required for understanding the major systems and to perform in-flight and preflight tasks and procedures relative to operation, maintenance, checkout, and systems management of the Apollo spacecraft and its integral systems.

Trainer Scheduling

The schedule for use of trainer items is based upon the first manned orbital flight. Systems trainers will be used first for NAA and NASA training, part-task trainers will be used for flight crew training, and finally the flight trainer will be used for astronaut and flight operations personnel training.

Trainer Maintenance

Flight trainer and part-task trainer maintenance will be accomplished on a routine basis during stand-down of the equipment from operational status. This maintenance will normally be accomplished at night to permit maximum trainer utilization during daylight hours. Maintenance of systems trainers will be limited to routine servicing requirements and normal upkeep. These trainers will be operated until a failure occurs and repair is necessary. Since systems trainers will be composed primarily of hardware identical to that contained in spacecraft and GSE systems, checkout and repair will follow those procedures established for spacecraft operations.

Supply Support for Trainers

A detailed specification is being prepared to delineate the methods for provisioning trainer support parts specifically for trainer use. The extent to which simulation is incorporated in the flight trainer and part-task trainer design will determine the special consideration that must be given to support parts procurement of peculiar items designed into the simulation systems. Spacecraft and GSE systems components designed for operational use will also be incorporated in the trainers, and support parts will be functionally reliable and comparable to operational hardware.

[redacted]

NASA Facility Support

Trainer maintenance will require considerable base support from NASA facilities. Metrology support will be especially critical; all primary and secondary standards for calibration within the trainers will be obtained from NASA on-site laboratories. NASA base shops will also be utilized for hydromechanical, hydropneumatic, and structural repairs. There will be no requirement for S&ID maintenance and repair areas outside the training complex.

Trainer Modification

Trainer modification and updating will be accomplished whenever necessary. Trainer modification will be timed to coincide with the specialized training required for spacecraft in which personnel are scheduled to be launched. Modification will normally be accomplished with factory-furnished kits.

Training Documentation

Training Plan

To achieve an integrated training effort for all personnel participating in a mission and for the development of coordinated training equipment, aids, and media, the Apollo training plan will describe the training requirements for the entire Apollo program. Individual, crew, and combined training will be defined for the flight crew operations, flight operations, and preflight operations personnel. Phasing of training, training equipment, aids materials, manuals, and training support functions will be shown for each effort and for the combined training for the missions.

Instructor Manuals

To assure consistent and complete use of the Apollo training equipment, an instructor's manual will be prepared for the trainers. Each manual will include operating instructions for both the instructor and the trainee. The complete capability of the trainer will be explained; and a recommended syllabus of exercises, either available or capable of being programmed by the instructor, will be included.

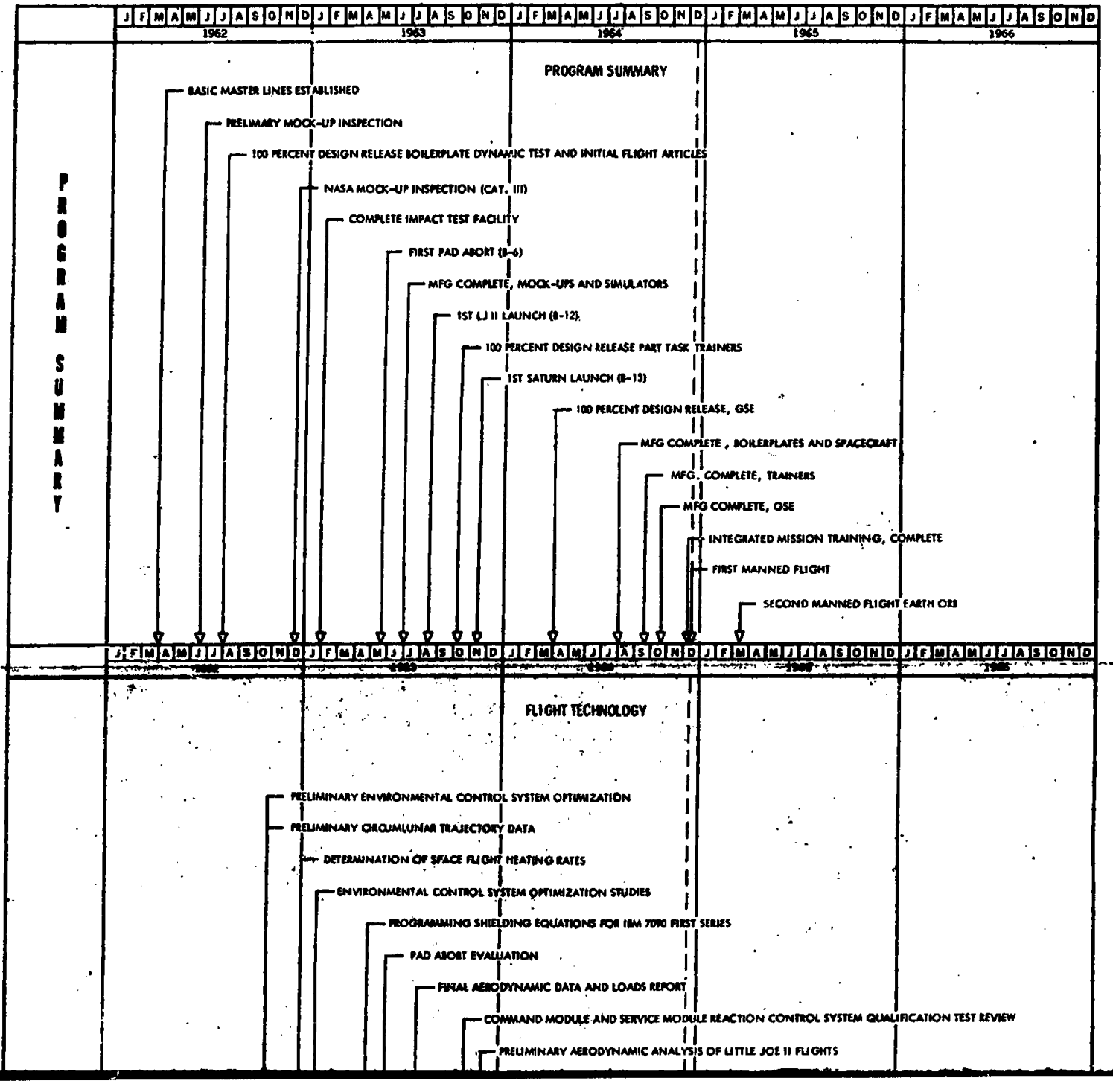
[redacted]

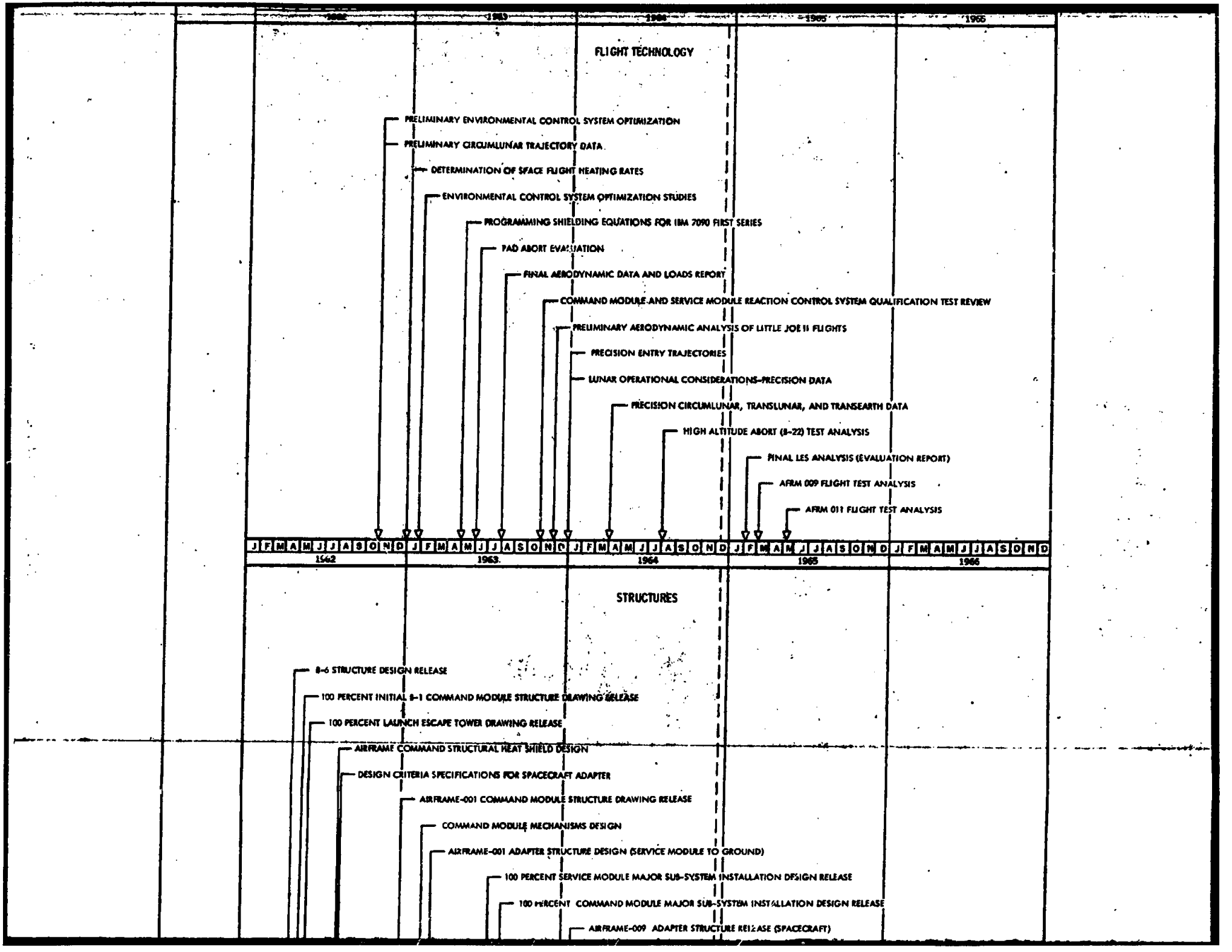
[redacted]

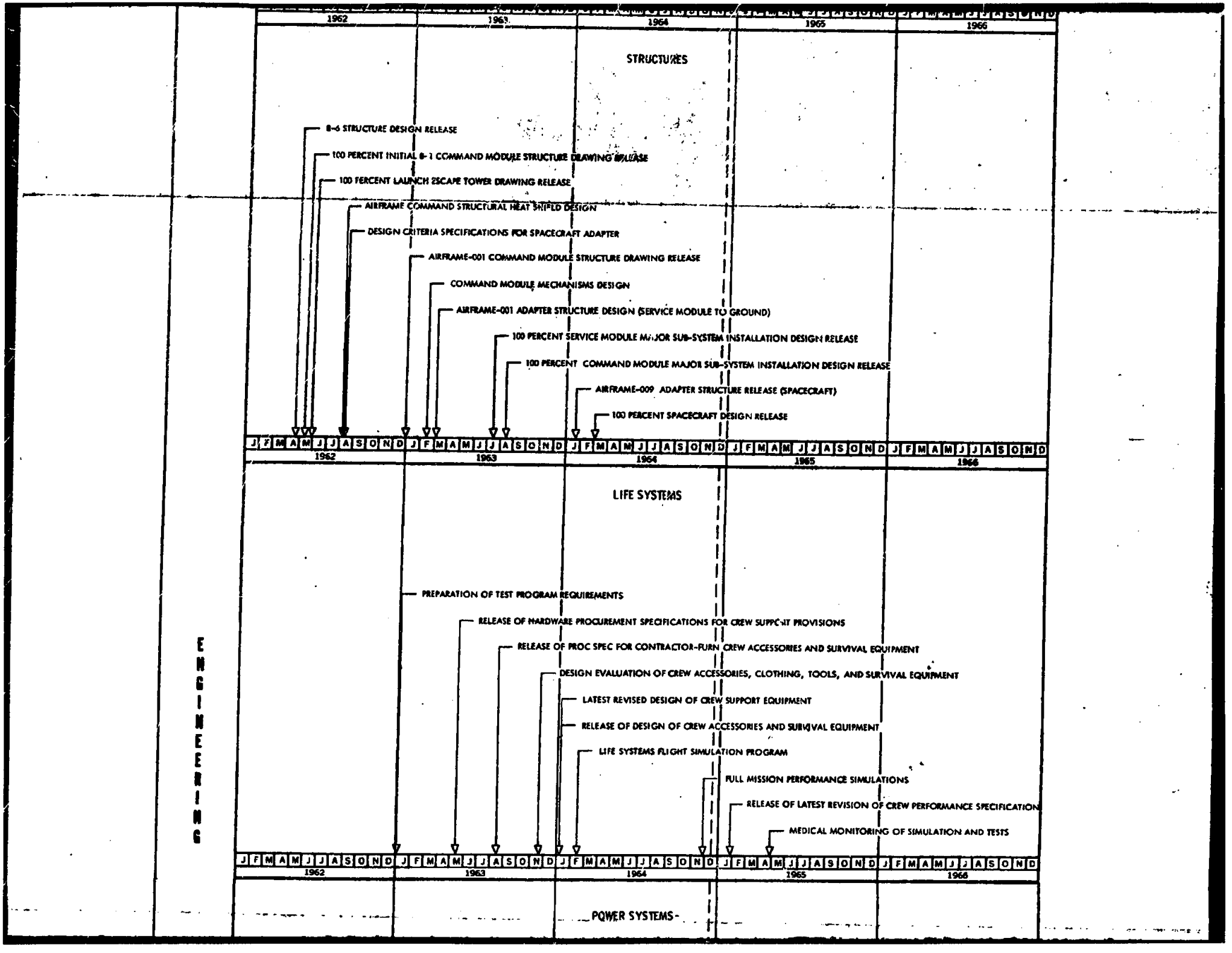
Facilities

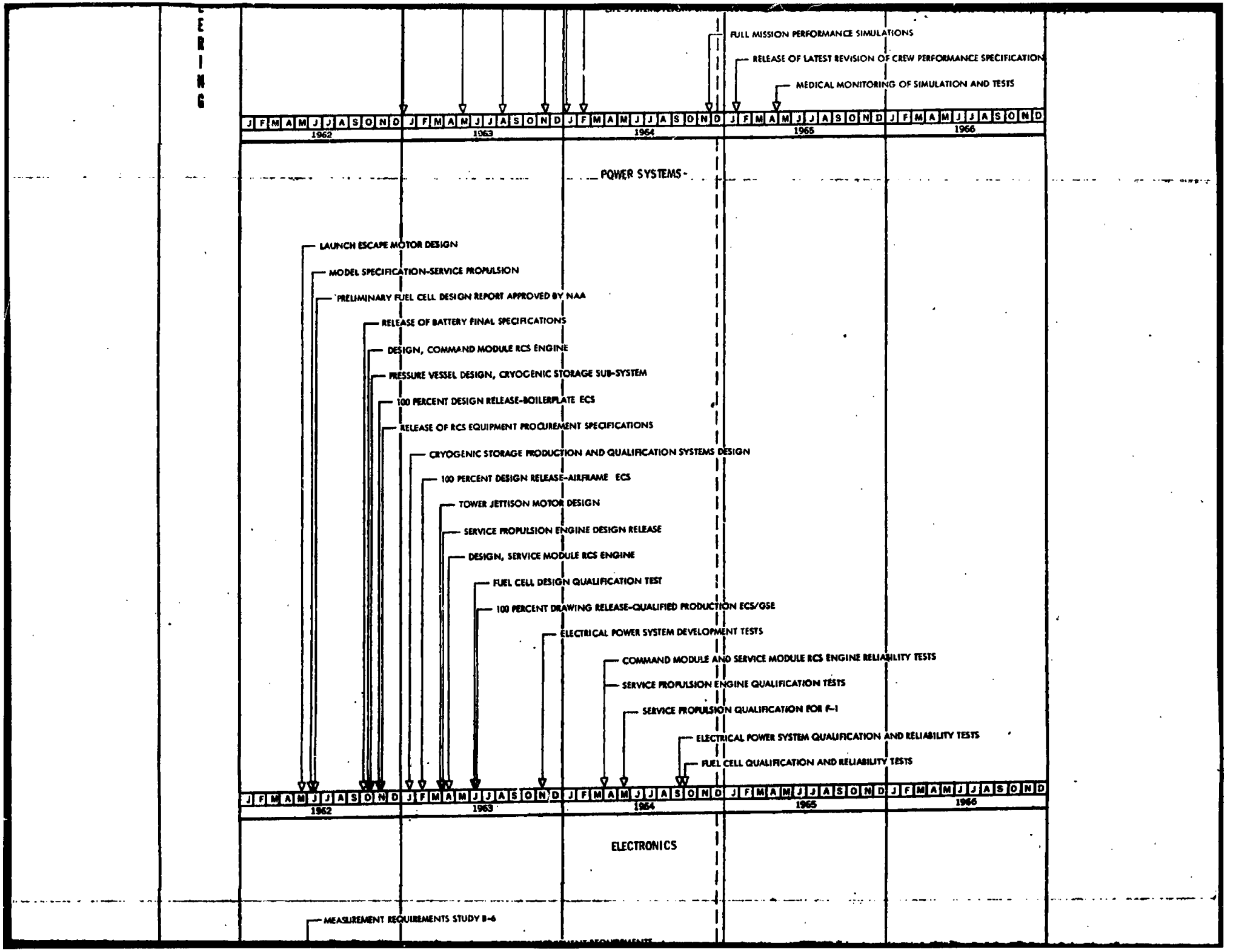
Facility requirements at S&ID, Downey, California, have been planned to conform with existing information. The total area required to support the training program is 16,200 square feet and became available for occupancy 1 October 1962. The training area is sufficient to house 75 students, 50 training personnel, and programmed training equipment. S&ID training facilities will also be available to NASA, subcontractor, and associate contractor personnel as needed. As additional information becomes available and training requirements are reevaluated, specific data (e.g., classroom configuration, lighting, acoustics, air conditioning, and power requirements) will be specified.

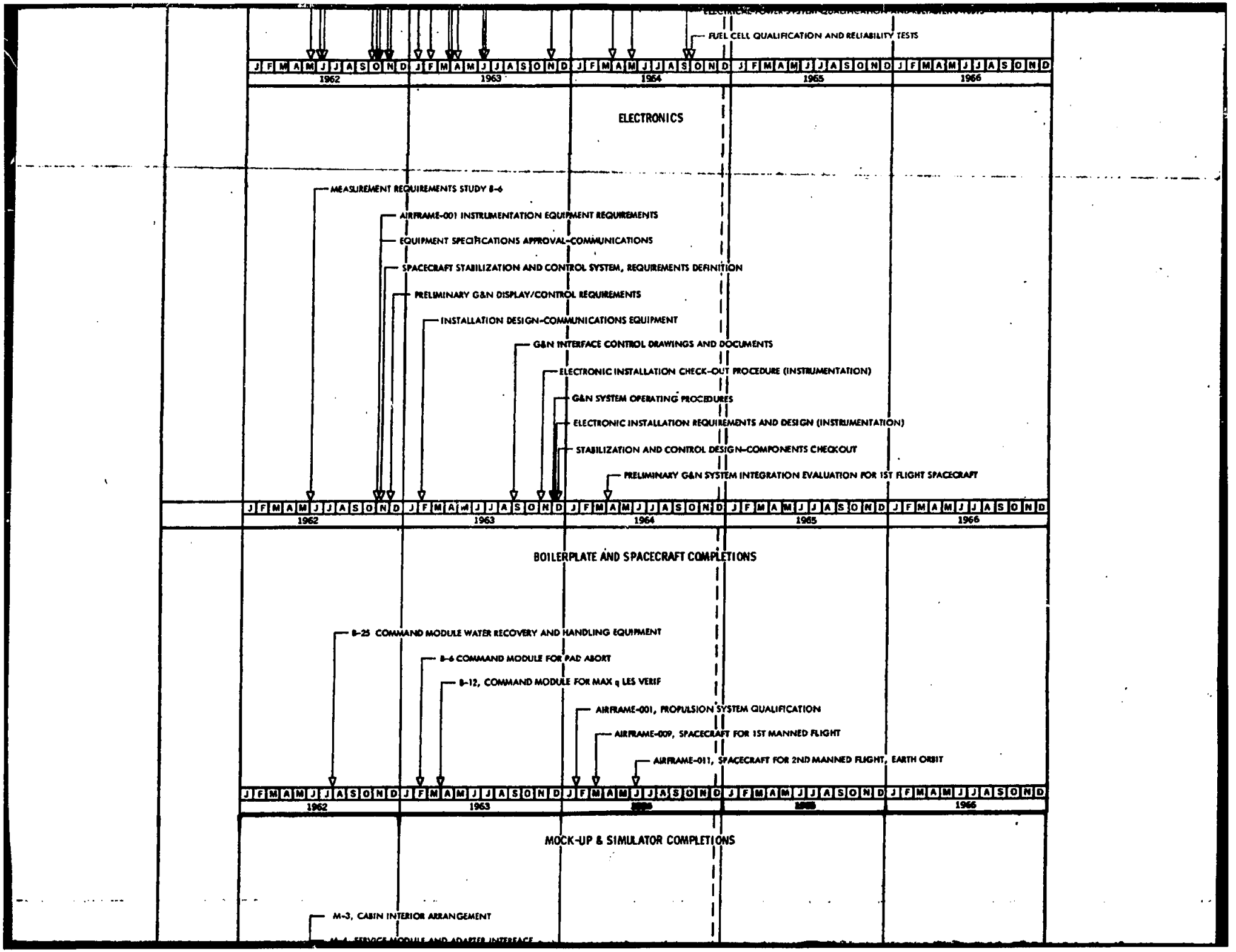
[redacted]

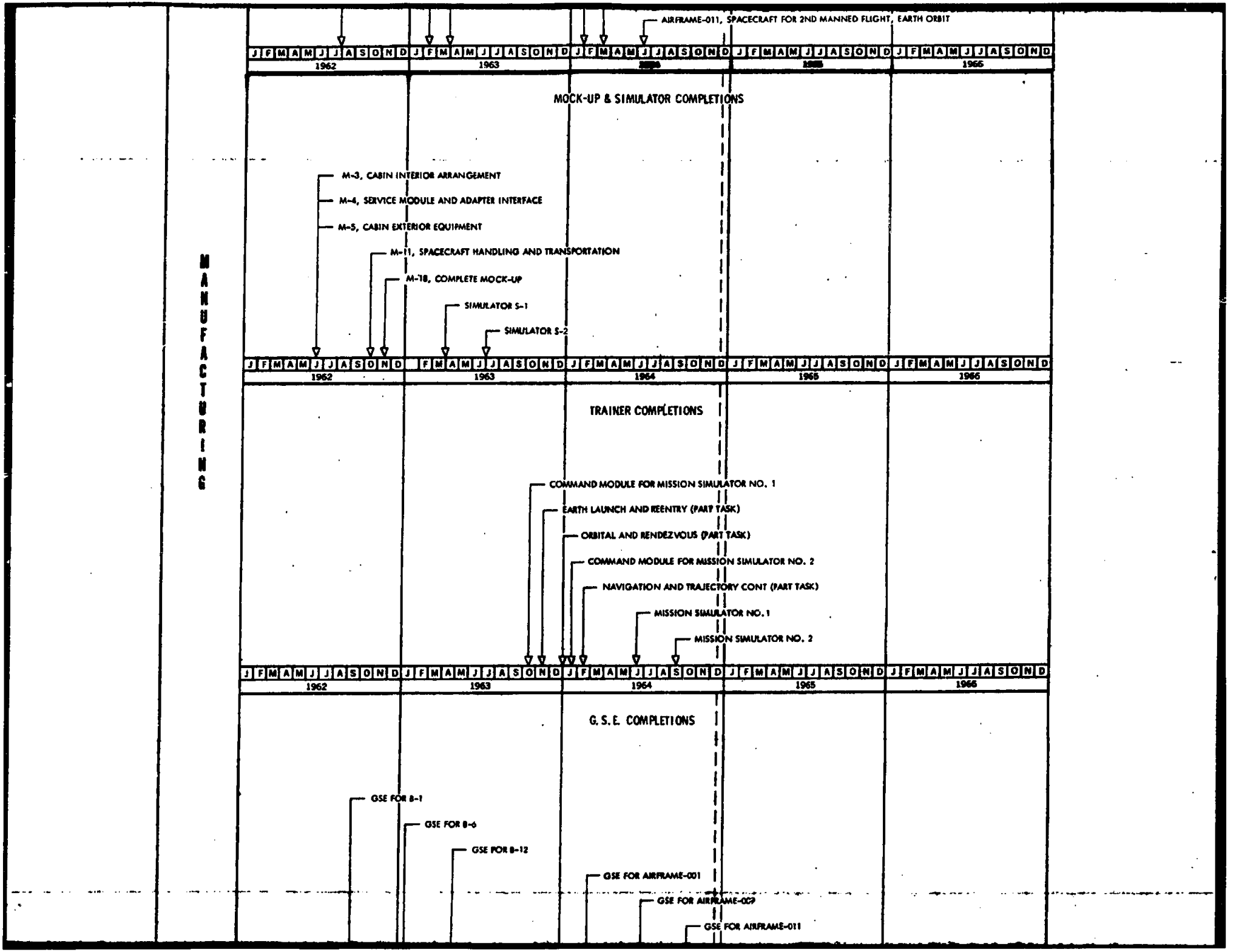

J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
1966
PROGRAM SUMMARY
PROGRAM SUMMARY
BASIC MASTER LINES ESTABLISHED
PRELIMARY MOCK-UP INSPECTION
100 PERCENT DESIGN RELEASE BOILERPLATE DYNAMIC TEST AND INITIAL FLIGHT ARTICLES
NASA MOCK-UP INSPECTION (CAT. III)
COMPLETE IMPACT TEST FACILITY
FIRST PAD ABORT (B-6)
MFG COMPLETE, MOCK-UPS AND SIMULATORS
1ST LJ II LAUNCH (B-12)
100 PERCENT DESIGN RELEASE PART TASK TRAINERS
1ST SATURN LAUNCH (B-13)
100 PERCENT DESIGN RELEASE, GSE
MFG COMPLETE , BOILERPLATES AND SPACECRAFT
MFG. COMPLETE, TRAINERS
MFG COMPLETE, GSE
INTEGRATED MISSION TRAINING, COMPLETE
FIRST MANNED FLIGHT
SECOND MANNED FLIGHT EARTH ORB
FLIGHT TECHNOLOGY
PRELIMINARY ENVIRONMENTAL CONTROL SYSTEM OPTIMIZATION
PRELIMINARY CIRCUMLUNAR TRAJECTORY DATA
DETERMINATION OF SPACE FLIGHT HEATING RATES
ENVIRONMENTAL CONTROL SYSTEM OPTIMIZATION STUDIES
PROGRAMMING SHIELDING EQUATIONS FOR IBM 7090 FIRST SERIES
PAD ABORT EVALUATION
FINAL AERODYNAMIC DATA AND LOADS REPORT
COMMAND MODULE AND SERVICE MODULE REACTION CONTROL SYSTEM QUALIFICATION TEST REVIEW
PRELIMINARY AERODYNAMIC ANALYSIS OF LITTLE JOE II FLIGHTS

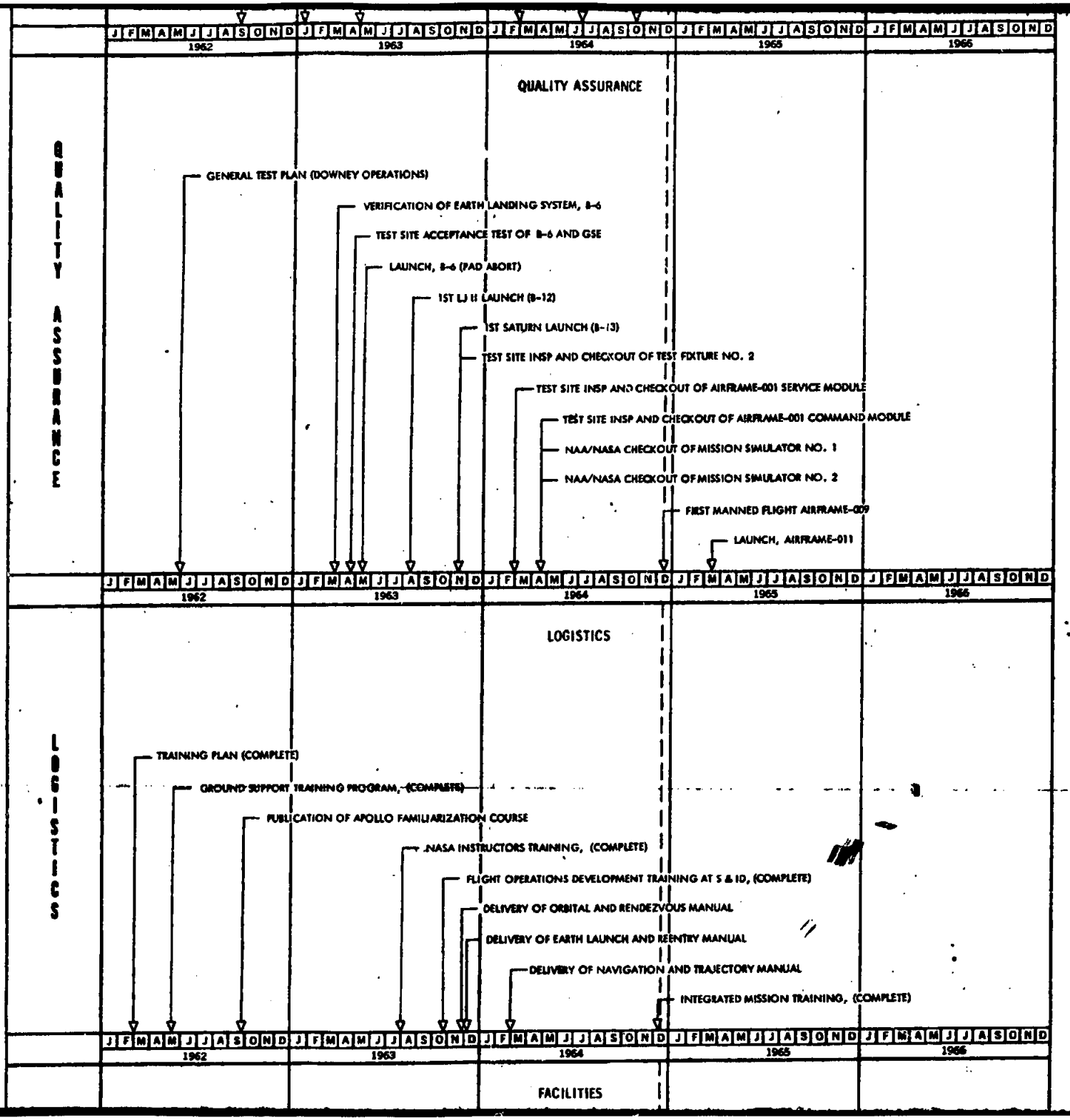

1962
1963
1964
1965
1966
FLIGHT TECHNOLOGY
PRELIMINARY ENVIRONMENTAL CONTROL SYSTEM OPTIMIZATION
PRELIMINARY CIRCUMLUNAR TRAJECTORY DATA
DETERMINATION OF SPACE FLIGHT HEATING RATES
ENVIRONMENTAL CONTROL SYSTEM OPTIMIZATION STUDIES
PROGRAMMING SHIELDING EQUATIONS FOR IBM 7090 FIRST SERIES
PAD ABORT EVALUATION
FINAL AERODYNAMIC DATA AND LOADS REPORT
COMMAND MODULE AND SERVICE MODULE REACTION CONTROL SYSTEM QUALIFICATION TEST REVIEW
PRELIMINARY AERODYNAMIC ANALYSIS OF LITTLE JOE II FLIGHTS
PRECISION ENTRY TRAJECTORIES
LUNAR OPERATIONAL CONSIDERATIONS-PRECISION DATA
PRECISION CIRCUMLUNAR, TRANSLUNAR, AND TRANSEARTH DATA
HIGH ALTITUDE ABORT (B-22) TEST ANALYSIS
FINAL LES ANALYSIS (EVALUATION REPORT)
AFRM 009 FLIGHT TEST ANALYSIS
AFRM 011 FLIGHT TEST ANALYSIS
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
STRUCTURES
B-6 STRUCTURE DESIGN RELEASE
100 PERCENT INITIAL B-1 COMMAND MODULE STRUCTURE DRAWING RELEASE
100 PERCENT LAUNCH ESCAPE TOWER DRAWING RELEASE
AIRFRAME COMMAND STRUCTURAL HEAT SHIELD DESIGN
DESIGN CRITERIA SPECIFICATIONS FOR SPACECRAFT ADAPTER
AIRFRAME-001 COMMAND MODULE STRUCTURE DRAWING RELEASE
COMMAND MODULE MECHANISMS DESIGN
AIRFRAME-001 ADAPTER STRUCTURE DESIGN (SERVICE MODULE TO GROUND)
100 PERCENT SERVICE MODULE MAJOR SUB-SYSTEM INSTALLATION DESIGN RELEASE
100 PERCENT COMMAND MODULE MAJOR SUB-SYSTEM INSTALLATION DESIGN RELEASE
AIRFRAME-009 ADAPTER STRUCTURE RELEASE (SPACECRAFT)


1962
1963
1964
1965
1966
STRUCTURES
B-6 STRUCTURE DESIGN RELEASE
100 PERCENT INITIAL B-1 COMMAND MODULE STRUCTURE DRAWING RELEASE
100 PERCENT LAUNCH ESCAPE TOWER DRAWING RELEASE
AIRFRAME COMMAND STRUCTURAL HEAT SHIELD DESIGN
DESIGN CRITERIA SPECIFICATIONS FOR SPACECRAFT ADAPTER
AIRFRAME-001 COMMAND MODULE STRUCTURE DRAWING RELEASE
COMMAND MODULE MECHANISMS DESIGN
AIRFRAME-001 ADAPTER STRUCTURE DESIGN (SERVICE MODULE TO GROUND)
100 PERCENT SERVICE MODULE MAJOR SUB-SYSTEM INSTALLATION DESIGN RELEASE
100 PERCENT COMMAND MODULE MAJOR SUB-SYSTEM INSTALLATION DESIGN RELEASE
AIRFRAME-009 ADAPTER STRUCTURE RELEASE (SPACECRAFT)
100 PERCENT SPACECRAFT DESIGN RELEASE
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
1966
LIFE SYSTEMS
PREPARATION OF TEST PROGRAM REQUIREMENTS
RELEASE OF HARDWARE PROCUREMENT SPECIFICATIONS FOR CREW SUPPORT PROVISIONS
RELEASE OF PROC SPEC FOR CONTRACTOR-FURN CREW ACCESSORIES AND SURVIVAL EQUIPMENT
DESIGN EVALUATION OF CREW ACCESSORIES, CLOTHING, TOOLS, AND SURVIVAL EQUIPMENT
LATEST REVISED DESIGN OF CREW SUPPORT EQUIPMENT
RELEASE OF DESIGN OF CREW ACCESSORIES AND SURVIVAL EQUIPMENT
LIFE SYSTEMS FLIGHT SIMULATION PROGRAM
FULL MISSION PERFORMANCE SIMULATIONS
RELEASE OF LATEST REVISION OF CREW PERFORMANCE SPECIFICATION
MEDICAL MONITORING OF SIMULATION AND TESTS
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
1966
POWER SYSTEMS
ENGINEERING

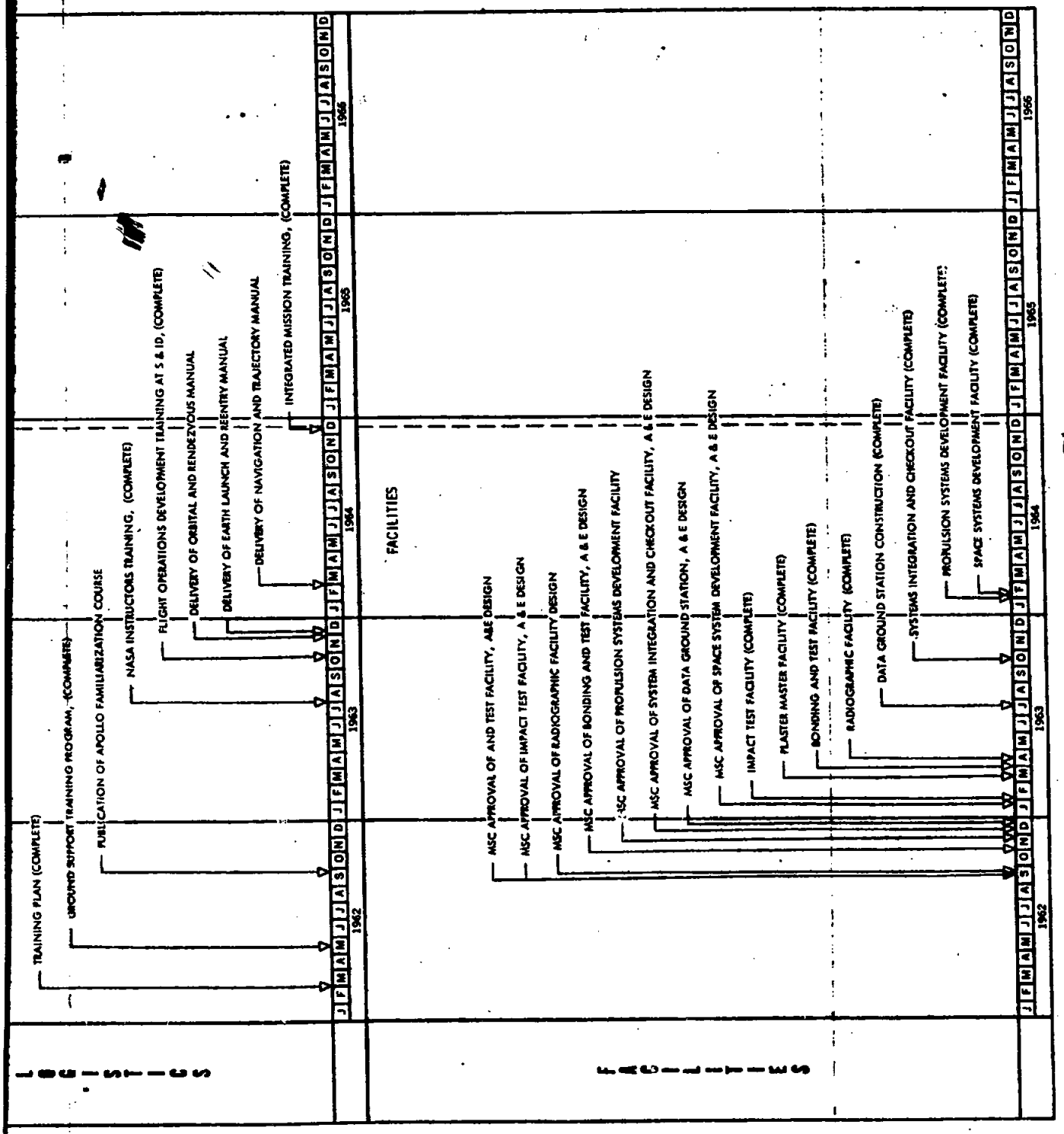

FULL MISSION PERFORMANCE SIMULATIONS
RELEASE OF LATEST REVISION OF CREW PERFORMANCE SPECIFICATION
MEDICAL MONITORING OF SIMULATION AND TESTS
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
1966
POWER SYSTEMS
LAUNCH ESCAPE MOTOR DESIGN
MODEL SPECIFICATION-SERVICE PROPULSION
PRELIMINARY FUEL CELL DESIGN REPORT APPROVED BY NAA
RELEASE OF BATTERY FINAL SPECIFICATIONS
DESIGN, COMMAND MODULE RCS ENGINE
PRESSURE VESSEL DESIGN, CRYOGENIC STORAGE SUB-SYSTEM
100 PERCENT DESIGN RELEASE-BOILERPLATE ECS
RELEASE OF RCS EQUIPMENT PROCUREMENT SPECIFICATIONS
CRYOGENIC STORAGE PRODUCTION AND QUALIFICATION SYSTEMS DESIGN
100 PERCENT DESIGN RELEASE-AIRFRAME ECS
TOWER JETTISON MOTOR DESIGN
SERVICE PROPULSION ENGINE DESIGN RELEASE
DESIGN, SERVICE MODULE RCS ENGINE
FUEL CELL DESIGN QUALIFICATION TEST
100 PERCENT DRAWING RELEASE-QUALIFIED PRODUCTION ECS/GSE
ELECTRICAL POWER SYSTEM DEVELOPMENT TESTS
COMMAND MODULE AND SERVICE MODULE RCS ENGINE RELIABILITY TESTS
SERVICE PROPULSION ENGINE QUALIFICATION TESTS
SERVICE PROPULSION QUALIFICATION FOR F-1
ELECTRICAL POWER SYSTEM QUALIFICATION AND RELIABILITY TESTS
FUEL CELL QUALIFICATION AND RELIABILITY TESTS
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
1966
ELECTRONICS
MEASUREMENT REQUIREMENTS STUDY B-6


FUEL CELL QUALIFICATION AND RELIABILITY TESTS
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
1966
ELECTRONICS
MEASUREMENT REQUIREMENTS STUDY B-6
AIRFRAME-001 INSTRUMENTATION EQUIPMENT REQUIREMENTS
EQUIPMENT SPECIFICATIONS APPROVAL-COMMUNICATIONS
SPACECRAFT STABILIZATION AND CONTROL SYSTEM, REQUIREMENTS DEFINITION
PRELIMINARY G&N DISPLAY/CONTROL REQUIREMENTS
INSTALLATION DESIGN-COMMUNICATIONS EQUIPMENT
G&N INTERFACE CONTROL DRAWINGS AND DOCUMENTS
ELECTRONIC INSTALLATION CHECK-OUT PROCEDURE (INSTRUMENTATION)
G&N SYSTEM OPERATING PROCEDURES
ELECTRONIC INSTALLATION REQUIREMENTS AND DESIGN (INSTRUMENTATION)
STABILIZATION AND CONTROL DESIGN-COMPONENTS CHECKOUT
PRELIMINARY G&N SYSTEM INTEGRATION EVALUATION FOR 1ST FLIGHT SPACECRAFT
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
1966
BOILERPLATE AND SPACECRAFT COMPLETIONS
B-25 COMMAND MODULE WATER RECOVERY AND HANDLING EQUIPMENT
B-6 COMMAND MODULE FOR PAD ABORT
B-12, COMMAND MODULE FOR MAX q LES VERIF
AIRFRAME-001, PROPULSION SYSTEM QUALIFICATION
AIRFRAME-009, SPACECRAFT FOR 1ST MANNED FLIGHT
AIRFRAME-011, SPACECRAFT FOR 2ND MANNED FLIGHT, EARTH ORBIT
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1966
MOCK-UP & SIMULATOR COMPLETIONS
M-3, CABIN INTERIOR ARRANGEMENT


MANUFACTURING
AIRFRAME-011, SPACECRAFT FOR 2ND MANNED FLIGHT, EARTH ORBIT
J F M A M J J A S O N D
1962
1963
1964
1965
1966
MOCK-UP & SIMULATOR COMPLETIONS
M-3, CABIN INTERIOR ARRANGEMENT
M-4, SERVICE MODULE AND ADAPTER INTERFACE
M-5, CABIN EXTERIOR EQUIPMENT
M-11, SPACECRAFT HANDLING AND TRANSPORTATION
M-18, COMPLETE MOCK-UP
SIMULATOR S-1
SIMULATOR S-2
TRAINER COMPLETIONS
COMMAND MODULE FOR MISSION SIMULATOR NO. 1
EARTH LAUNCH AND REENTRY (PART TASK)
ORBITAL AND RENDEZVOUS (PART TASK)
COMMAND MODULE FOR MISSION SIMULATOR NO. 2
NAVIGATION AND TRAJECTORY CONT (PART TASK)
MISSION SIMULATOR NO. 1
MISSION SIMULATOR NO. 2
G. S. E. COMPLETIONS
GSE FOR B-1
GSE FOR B-6
GSE FOR B-12
GSE FOR AIRFRAME-001
GSE FOR AIRFRAME-009
GSE FOR AIRFRAME-011



NORTH AMERICAN



Master Development Plan