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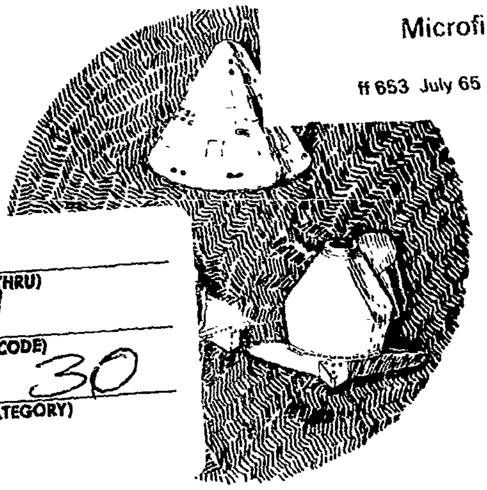

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FINAL REPORT

Volume IV

Resources Requirements Analysis

NORTH AMERICAN AVIATION, INC. SPACE and INFORMATION SYSTEMS DIVISION

NASA CR 92158

CONTRACT NAS9-6445 SID 66-1853-4

STUDY OF A RENOVATED COMMAND MODULE LABORATORY AND RENOVATED COMMAND MODULE

Final Report

VOLUME IV - RESOURCES REQUIREMENTS ANALYSIS

15 DECEMBER 1966

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FOREWORD

This document is submitted by the Space and Information Systems Division of North American Aviation, Inc., to the National Aeronautics and Space Administration Manned Spacecraft Center in partial fulfillment of the final reporting requirements of Contract NAS 9-6445, "Study of a Renovated Command Module Laboratory and Renovated Command Module."

The final report has been prepared in a series of five volumes as listed below.

Volume I	Summary	SID 66-1853-1
Volume II	Mission System Performance and Configuration Analysis	SID 66-1853-2
Volume III	Subsystems Analysis	SID 66-1853-3
Volume IV	Resources Requirements Analysis	SID 66-1853-4
Volume V	Cost Analysis (Limited Access)	SID 66-1853-5

S&ID acknowledges the voluntary technical contributions made to this study by a number of companies. The Avco Corporation contributed ablator data which were used as a basis for determining the feasibility of heat shield renovation. A report covering the data provided by Avco is included as an appendix to Volume III.

A. C. Electronics Division of General Motors Corporation supplied data on technical problems associated with renovating the Apollo G&N system and estimated costs.

The Defense Programs Division of General Electric Company provided characteristic data on G. E.'s active space pointing systems.

Westinghouse Electric Corporation provided data on rendezvous radar and transponder characteristics.

The Aeronautical Division of Honeywell, Inc., provided renovation data on the Apollo Block II stabilization and control system and associated costs.

The Autonetics Division of North American Aviation, Inc., provided data on an alternative guidance and navigation system and estimated costs.

Cost information and general renovation requirements on individual components were also provided by numerous other suppliers.

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INTRODUCTION

NASA, the Air Force, and Industry have over the past several years studied the possibilities of renovation and reuse of expensive relatively undamaged man-rated space hardware, thereby, extending its usefulness and mission performance capability and cost effectiveness. In the interest of developing this line of thinking and to specifically apply the ideas developed to date the NASA entered into study contract NAS9-6445 with NAA/S&ID on 26 August 1966. This study was designed to develop a feasibility/concept together with a budgetary and planning estimate for the renovation of Apollo command modules, which have already completed their primary mission, into either renovated command modules (RCM's) for use on top of the launch stack for low inclination earth orbital missions or as renovated command module laboratories either dependent or independent (RCMC-(D), RCML (I) to be launched into orbit mounted in the Spacecraft instead of the LM adapter (SLA).

The study approach considered the Apollo Block I and Block II vehicles and was specifically focussed on the requirements from "splashdown" to delivery out the door of the contractors facility.

During the course of the study the problems of changes to existing Apollo recovery procedures, disassembly, testing, utilization of existing spare hardware, test and operations, subcontractor support, facilities and cost analysis together with the necessary program planning and scheduling problems were identified. Based upon available data from the existing Apollo program and from the recovery test and analysis data from S/C 009 and 011, renovation and refurbishment approaches were developed. These approaches were traded off in terms of cost of renovation versus the cost of producing a new CM or a new laboratory.

Presented in this volume are the results, conclusions, potential problem areas, and recommendations of those supporting functions which make up the Resources Requirements Analysis (RRA) portion of the study. The elements which make up the scope of the RRA are shown in Figure 1.

Each functional area is presented herein as a separate section and is complete within itself, except for the cost analysis task and cost data, which are presented in detail in Volume V of this report.

Where appropriate, each section contains the specific ground rules relating to that specific functional area. When reference is made to existing

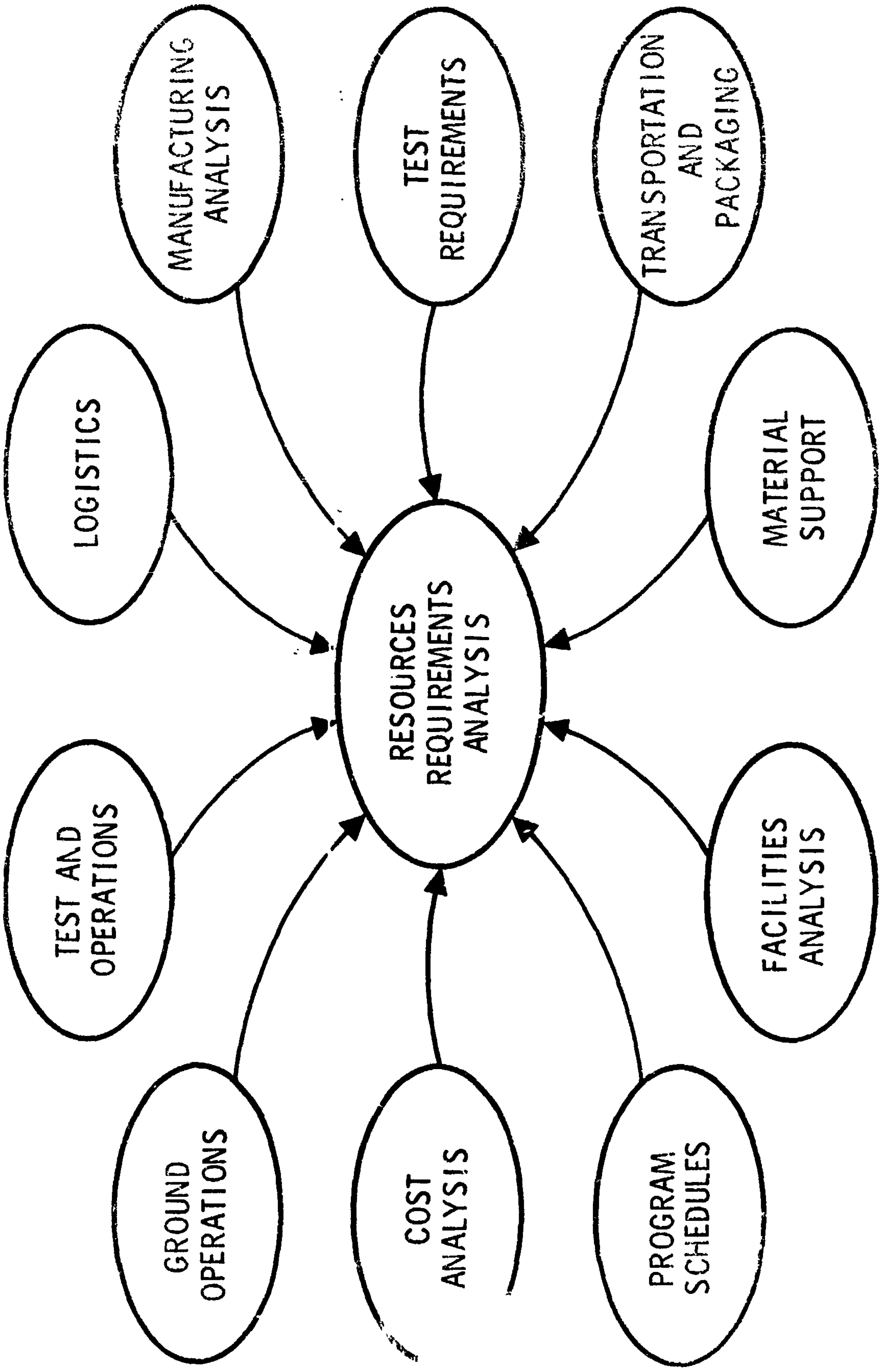


Figure 1. Resources Requirements Analysis

documentation, it is assumed that NASA has access to these data. Otherwise all reference material is contained herein where appropriate.

GROUND RULES AND ASSUMPTIONS

The general ground rules established for the resources requirements analysis portion of the study are presented in the following listing. Some of the ground rules presented may be found elsewhere in this final report and are only repeated here for clarity.

1. The study would include the necessary requirements from CM splashdown to delivery of the renovated vehicle from Building 290, Downey.

2. There would be essentially three types of vehicles analyzed and cost-analyzed during the study:

   Renovated command modules (RCM) using a Block II recovered Apollo vehicle.

   A dependent renovated command module laboratory (RCML (D))

   An independent renovated command module laboratory (RCML (I))

3. The study program would consider used Block I or Block II vehicles for renovation as either dependent or independent laboratories. Only Block II vehicles would be considered for renovation to refly as a complete spacecraft.

4. Delta recovery procedures will be developed and grossly integrated with the existing Apollo procedures. (These procedures are contained in a separate report and will be submitted to the NASA project study manager.)

5. Maximum utilization would be made of existing Apollo program capabilities where applicable on a non-interference basis.

6. Recovered vehicles would be completely disassembled as follows:

   Vehicles designated to become RCM's would be stripped of all hardware except for the secondary structure and wiring harness.

Vehicles designated to become RCMI (I) would be stripped of all hardware except selected portions of the secondary structure.

Vehicles designated to become RCML (D) would be completely disassembled including unnecessary secondary structure and bracketry.

7. Studies were based on a total of 11 vehicles: five RCM's and six RCML's (either dependent or independent).

8. Only first-level analysis would be made of KSC requirements, since no mission configurations have been defined.

CANDIDATE VEHICLES

To provide specific vehicles upon which to base the study analysis, early in the program the NASA/S&ID study management team selected a list of candidate vehicles for schedule planning and cost purposes which are shown in Table 1. These vehicles were chosen to represent a cross-section of available spacecraft. The study results can be applied essentially to other vehicles of similar configuration.

Table 1. RCM/RCML Candidate Vehicles

CM	Flight No.	Available for Renovation	RCML		RCM
012	204	January 1967	(D)		
014	205	February 1967	(D)		
020	502	June 1967	(I)		
101	207	August 1967	(I)	or	S/C
103	504M	March 1968	(I)	or	S/C
105	209A	May 1968	(I)	or	S/C
107	210A	September 1968	(I)	or	S/C
108	212A	January 1969	(I)	or	S/C

D = Dependent
I = Independent
All vehicles are potential candidates for dependent laboratory

COST MODELS

From the list of candidate vehicles, the cost models were selected again only for study purposes, and to provide a standard basis for all elements of the study program. These cost models are:

1. For the laboratory, both dependent and independent: S/C 012
2. For the renovated command module: S/C 101
3. For the new command module: S/C 103 (this model was also used to develop the cost of a new inner structure). This cost analysis of a new vehicle was developed to provide a comparison of new versus renovated vehicles.

VEHICLE TYPES AND CONFIGURATIONS

The information and data presented in Table 2 was extracted from the study data developed by the systems and subsystems engineering functions. These data present the basic vehicle types, gross capabilities, configurations, and new development items (cruciform, airlock, micrometeoroid and thermal shielding and insulation, and the Block I to Block II tunnel modifications).

The RCM dependent laboratory may be made from either Block I or Block II spacecraft and will be considered suitable for 30-day missions. It will consist, primarily, of an inner pressure shell with an airlock, thermal protection, a meteoroid bumper, and a docking arrangement modified to dock with a CSM. These vehicles will be mounted on a cruciform structure in the SLA during launch. They will have no heat shields and will not be able to reenter the earth's atmosphere. This configuration will have no systems other than a postlanding fan circulating air from the basic command module through a 5-inch flexible duct.

The RCM independent laboratory will essentially be the same as the dependent laboratory, except that it will have selected systems added for support of specific programs or missions as desired, and, in its most advanced form, will carry the cryogenics, EPS and ECS radiators, etc., from a Block II service module on the cruciform mounting structure, as well as a full complement of command module systems and equipment, with deletions as required by the specific mission.

Table 2. RCM Vehicle Types

Dependent Laboratory	Independent Laboratory	Spacecraft
Block I or II	Block I or II	Block II
Thirty-day duration	Thirty-day duration	Thirty-day duration
Inner press shell only	Inner press shell only	Complete CM
No reentry heat shields	No reentry heat shields	Reentry heat shield
Airlock added	Airlock added	No airlock
Thermal protection added	Thermal protection added	No thermal protection added
Meteoroid bumper added	Meteoroid bumper added	No meteoroid bumper added
Zero systems	Minimum to full CSM systems	Essentially complete CM
Modified docking arrangement	Modified docking arrangement	Standard docking equipment
Cruciform mount required	Cruciform mount required	No mount required
No SM required	No SM required	New SM required
Low earth orbit synch or lunar	Low earth orbit sync or lunar	Low earth orbit only

The RCM spacecraft will be a Block II command module with all systems refurbished, with certain deletions (such as G&N) which are not needed in the low-altitude, low-inclination, earth orbital missions which these vehicles will be assigned to fly. The RCM will mount on the top of the stack and will utilize a new service module. Basic Apollo specifications, tests, and checkout procedures will be used in designing the RCM.

RCML CONCEPT

Figure 3 shows the progression of a vehicle from recovery through the renovation cycle to the basic dependent laboratory configuration, using a "shopping-list" approach. Whole systems or portions of systems can be added, providing varying degrees of independence and a fully independent configuration, depending on mission requirements. The RCML is assumed to be capable of being used in low and synchronous earth orbits and in lunar orbits.

RCM CONCEPT

The Block II Apollo vehicles to be used as renovated command modules will be recovered as quickly as practicable after splashdown and taken aboard the pickup ship where all necessary purging and safing activities will take place. There, the aft heat shield will be removed for the purpose of eliminating salt-water corrosion. This is accomplished, in part, by flushing desalinated water through the heat shield honeycomb and in rinsing down all exposed structures and systems. The vehicle will then be returned to the manufacturer's plant for complete disassembly (Figure 4), systems refurbishment, necessary modifications such as removing some of the G&N equipment, and rebuilding to the original Apollo specifications for use in the low-inclination, low-altitude, earth orbit-AAP-missions.

Fully Independent RCML

An independent RCM laboratory configuration is shown in Figure 5. The configuration was revised by redesign of the RCS panels to satisfy the RCM laboratory requirements. The RCS components will be utilized, but repacked into a panel or box configuration better suited to the RCM laboratory. The RCS panels will then form sides for a meteoroid/thermal box that will house the fuel cells and tankage below the honeycomb sandwich panel, thus permitting a better installation of the ECS/EPS radiator panels around the laboratory, and mounted on the upper surface of the honeycomb sandwich structure panel.

This concept is based on utilization of the Block II SM components in the same manner as used on the Apollo SM. To provide a flat surface for installation of the fuel cells and tankage, a honeycomb sandwich panel

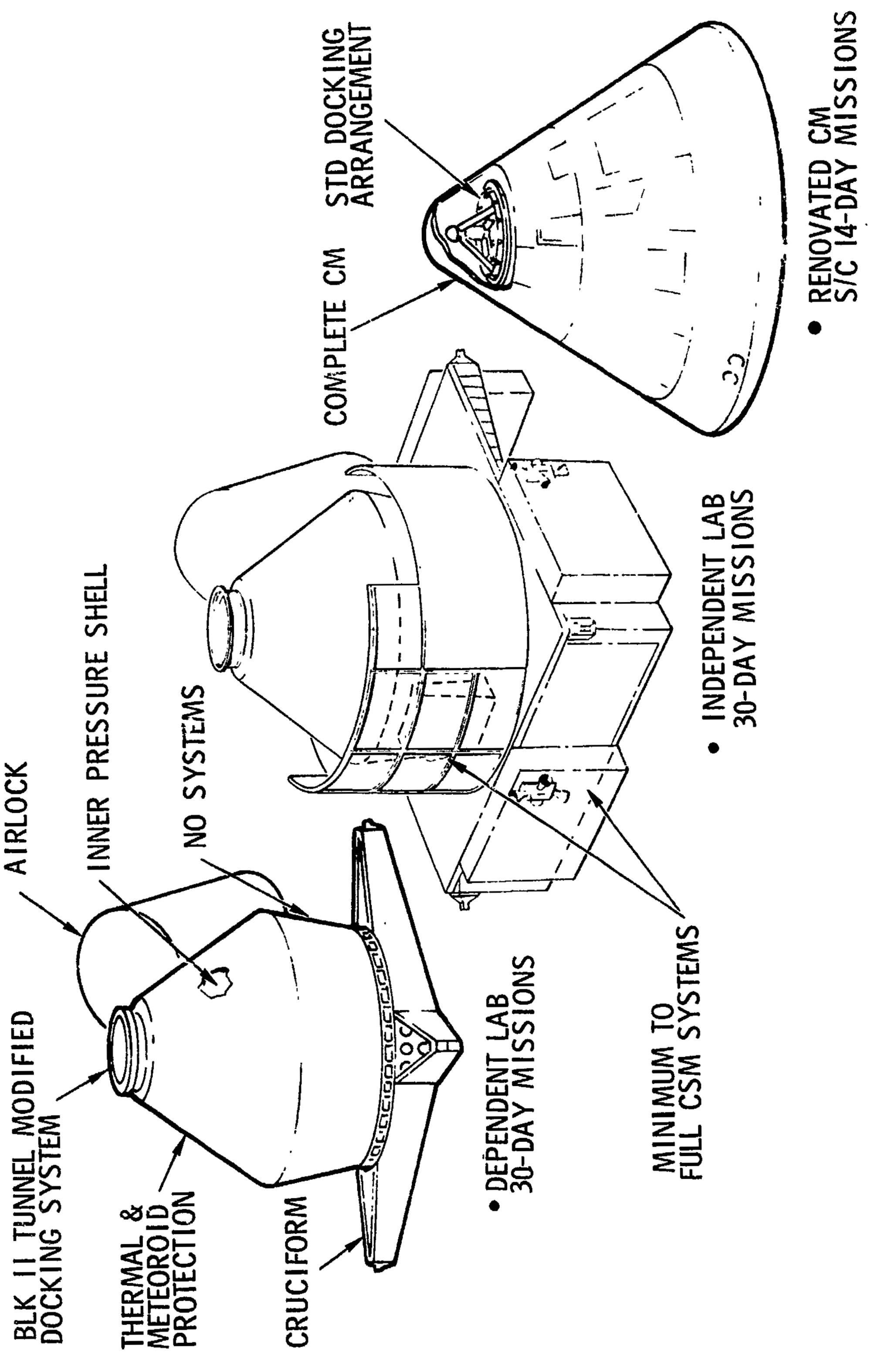


Figure 2. RCM Vehicle Types

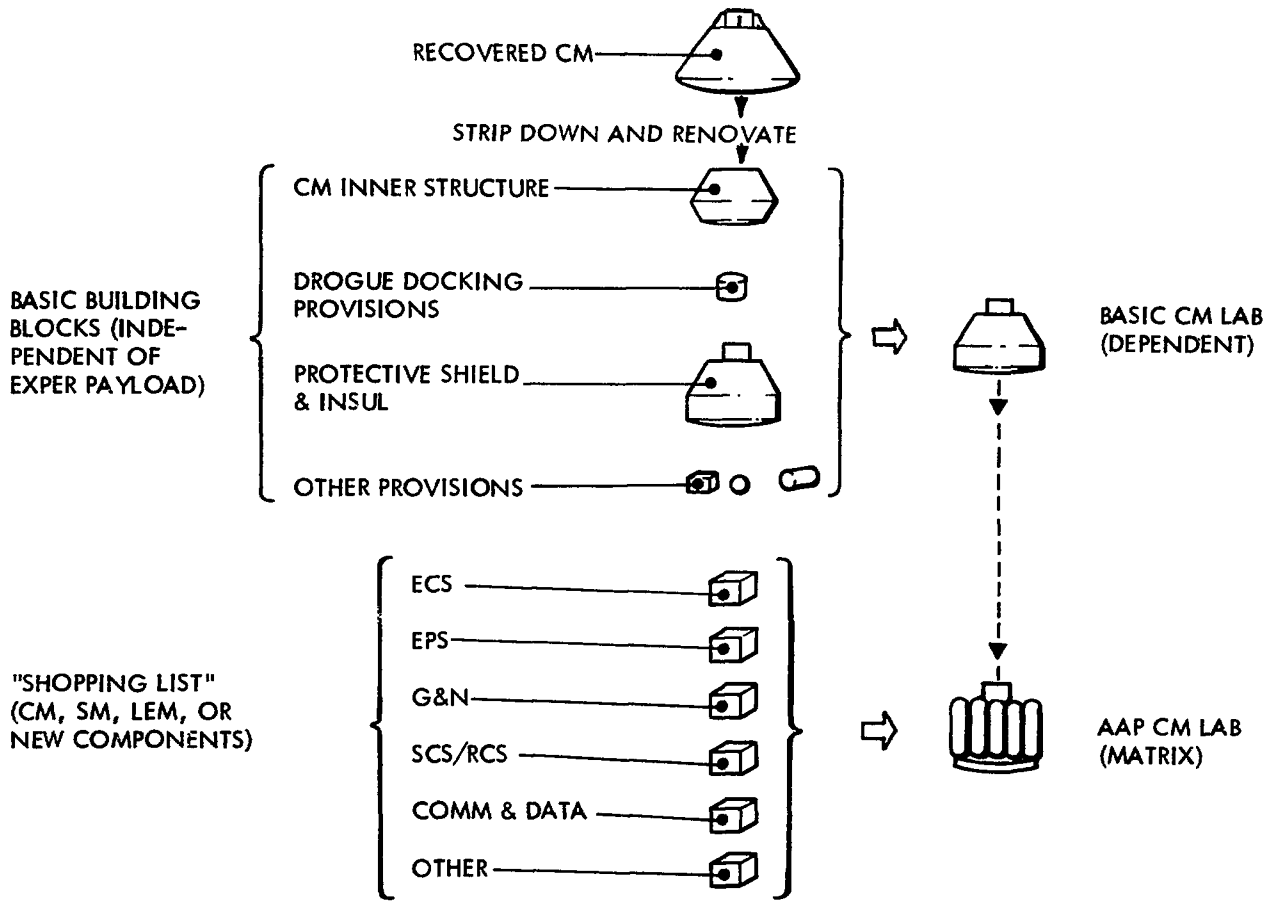


Figure 3. Renovated Command Module Laboratory Concept

is installed on the upper surface of the cruciform structure and the laboratory mounting ring is reduced in height, equivalent to the sandwich thickness, to maintain the same height from SLA attach points to the upper face of the docking adapter. The sandwich panel permits installation of the SM components in the same manner as in the existing Apollo service module.

RCM LABORATORY - DEPENDENT CONFIGURATION

The conceptual development of the RCM laboratory was performed to define and determine the necessary modification and/or additions to convert both the Apollo Block I and Block II command modules into a basic RCM laboratory. By definition in the study ground rules, the basic RCM laboratory is a dependent-type laboratory configuration capable of operating in conjunction with the CSM. Consequently, this dependent RCM laboratory configuration does not require installation of any of the Apollo subsystems, since it derives all of its system functional capabilities from the CSM. It is dependent upon the CSM for active environmental control, electrical power, attitude control, etc., which can be transferred to the lab through the docking tunnel and the existing LM interface connectors.

Figure 6 shows the dependent RCM configuration which consists of the CM primary structure (pressure vessel), environmental protection (i.e., micrometeoroid shield, thermal insulation for passive thermal control, and radiation protection), the LM docking structure, airlock, portions of the CM secondary structure, basic provisions for minimum instrumentation, and the laboratory/experiment mounting support structure.

The dependent RCM laboratory configuration was designed to retain portions of the CM secondary structure necessary to allow reinstallation of renovated CM subsystems and SM components to transform the laboratory functional capabilities, in steps, from the dependent configuration to a fully independent RCM laboratory configuration capable of independent operation and experiment support for a nominal thirty-day mission.

LABORATORY/EXPERIMENT SUPPORT STRUCTURE DESIGN

The structural loads and design criteria used in the design of the laboratory/experiment support structure were based on data obtained from the LM/SLA Loads Report. If the stiffness and the cg location of the combined laboratory-plus-experiments-plus-support structure were the same as for the LM, these loads would be applicable. However, the laboratory may constitute a smaller payload than the LM and a lighter supporting structure would, therefore, be possible. The resulting reduction in the stiffness of this arrangement (i.e., laboratory/experiment support and SLA structure) will cause an increase in the dynamic load factor. In the initial approach to the structural design, the existing load

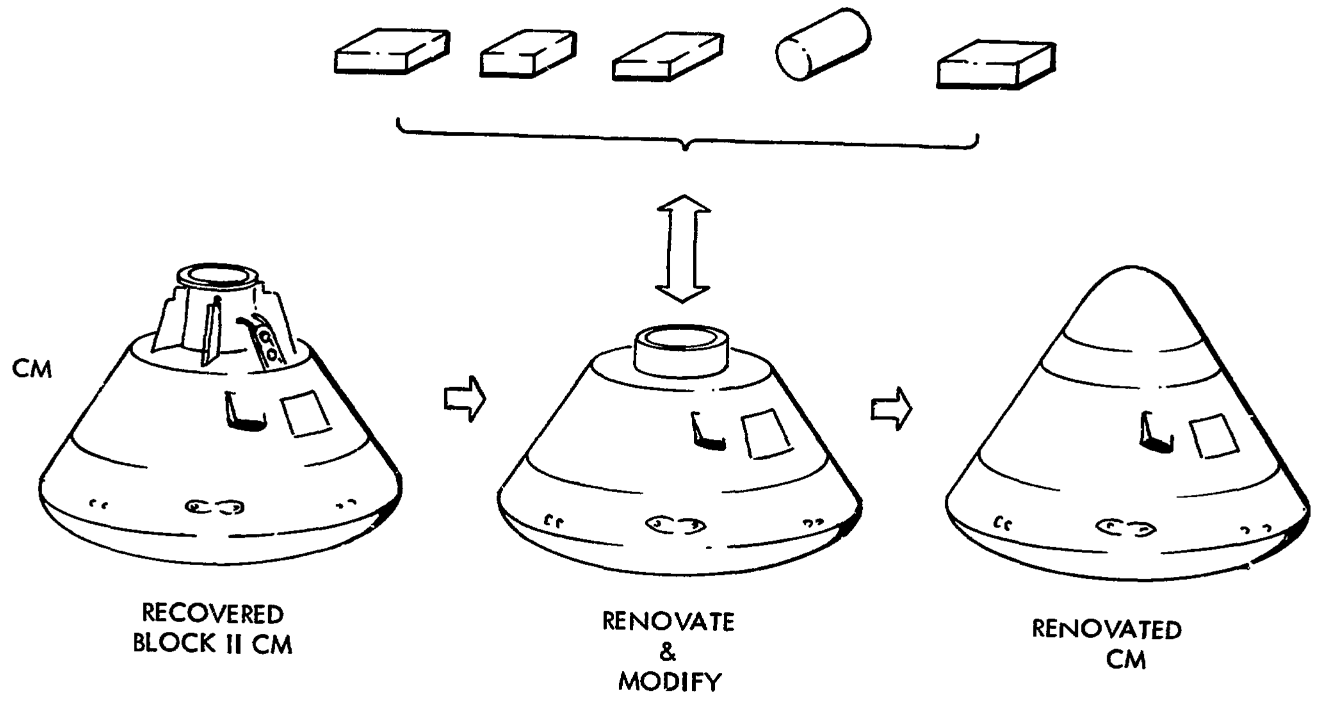
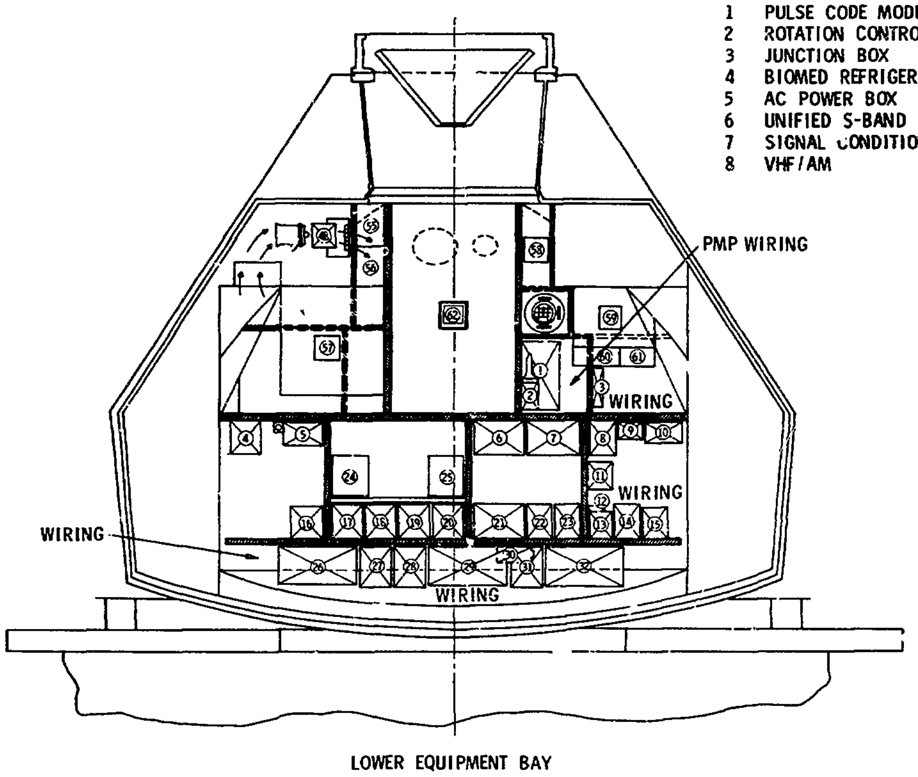
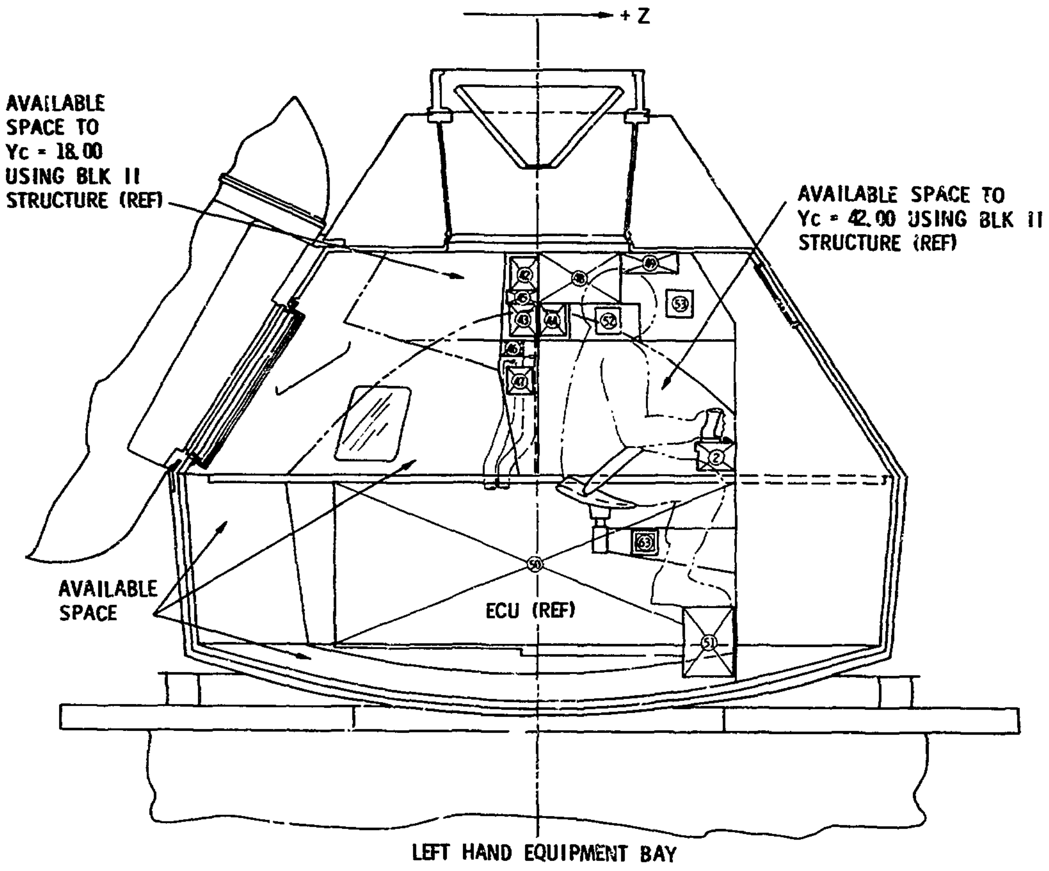


Figure 4. Renovated Command Module Concept



1 PULSE CODE MODULATOR
2 ROTATION CONTROL
3 JUNCTION BOX
4 BIOMED REFRIGERATOR
5 AC POWER BOX
6 UNIFIED S-BAND
7 SIGNAL CONDITIONER
8 VHF/AM
9 TRIPLEXER
10 VHF BEACON
11 MEDICAL SUPPLIES
12 S-BAND RF SWITCH
13 HI FREQ TRANSCEIVER
14 PREMODULATION PROCESSOR
15 AUDIO CENTER
16 CONTROL ELECTRONICS
17 GYRO DISPLAY COUPLER
18 DISPLAY ELECTRONICS
19 REACTION JET DRIVER
20 S-BAND POWER AMPLIFIER
21 DATA STORAGE EQUIPMENT
22 UP DATA LINK
23 CENTRAL TIMING
24 GYRO PACKAGE
25 GYRO PACKAGE
26 INVERTER
27 BATTERY
28 BATTERY
29 INVERTER
30 BATTERY CHARGER
31 BATTERY
32 INVERTER
48 CABIN AIR RECIRCULATION UNIT
55 TIMING CONTROLS AND DISPLAYS
56 LIGHTING CONTROLS AND DISPLAYS
57 COMMUNICATION AND ANTENNA CONTROLS AND DISPLAYS
58 SCS CONTROLS AND DISPLAYS
59 RCS CONTROLS AND DISPLAYS
60 CAUTION/WARNING
61 DOCKING CONTROLS AND DISPLAYS
62 RCM EXPERIMENTS CONTROLS AND DISPLAYS

Figure 5. Block II Fully Independent RCM Laboratory (Sheet 1 of 3)



2	ROTATION CONTROL
42	PRESSURE SUIT RECEPTACLE
43	PRESSURE SUIT RECEPTACLE
44	PRESSURE SUIT RECEPTACLE
45	COMMUNICATIONS CONNECTORS
46	WATER DELIVERY ASSEMBLY
47	WIRING AND ECS DUCTS
48	CABIN AIR RECIRCULATION UNIT
49	ELECTRICAL RECEPTACLES
50	ENVIRONMENTAL CONTROL UNIT (ECU)
51	LiOH CANNISTERS
52	CRYO CONTROLS AND DISPLAYS
53	EPS CONTROLS AND DISPLAYS
63	SEAT RESTRAINT

Figure 5. Block II Fully Independent RCM Laboratory (Sheet 2 of 3)

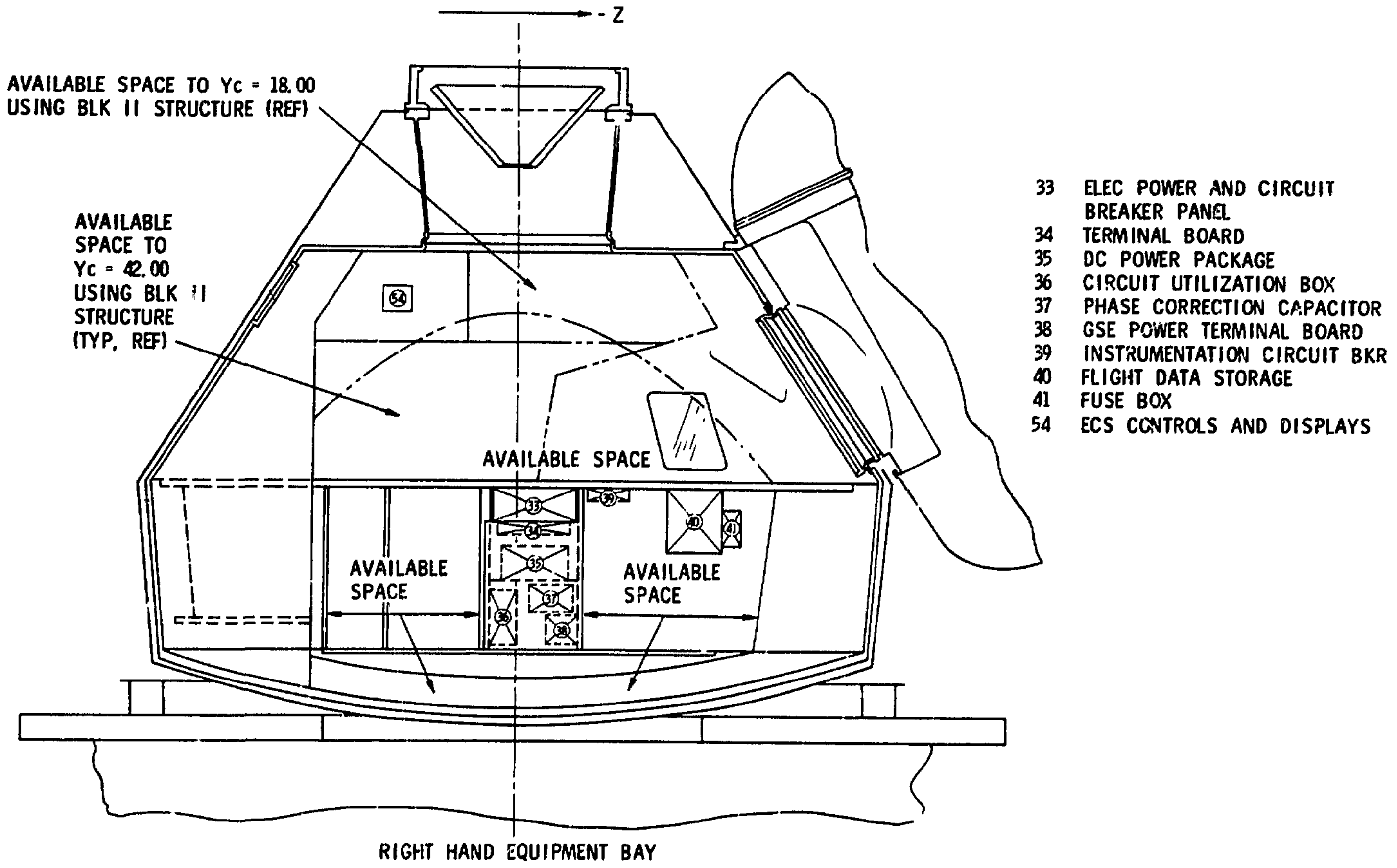


Figure 5. Block II Fully Independent RCM Laboratory (Sheet 3 of 3)

factor has been increased by 0.5 g in the lateral direction and 1.0 g in the axial direction. The load factors used for the critical conditions in the support structure baseline designs are stated in Figure 6 for the S-V configuration.

Three laboratory/experiment mount structures were designed (Figure 7). Design 1 is acceptable for a maximum laboratory/experiment weight of 15, 000 pounds and Designs 2 and 3 are satisfactory for a maximum laboratory/experiment weight of 33, 800 pounds (i.e., SLA structure capability limited). Designs 1 and 3 are of the web-beam construction; Design 2 represents a tubular truss-design approach.

The web-beam structure designs are preferred because they allow for simpler installation and attachment of components for the independent RCM laboratory, as well as integration of experiment packages and assemblies.

INNER STRUCTURE	
FORWARD SECTION	281.0
CENTER SECTION	757.9
AFT SECTION	244.8
SECONDARY STRUCTURE	
R.H. EQUIP. BAY	67.0
L.H. EQUIP. COMP	25.6
LOWER EQUIP. BAY	53.8
FORWARD COMPT AREA	5.6
CENTER SECTION	95.2
DOCKING & DROGUE INSTALL.	
DOCKING LATCH, CABLE ETC.	49.2
DROGUE INSTALL.	53.8
AIRLOCK INSTALL.	172.9
METEOROID & THERMAL PROTECT.	
LABORATORY SHELL	239.0
AIRLOCK PROTECT.	72.4
LABORATORY/EXPERIMENT MOUNT	575.0
ELECTRICAL PROVISIONS	2.8
RCM LABORATORY-DEPENDENT	2,696.0

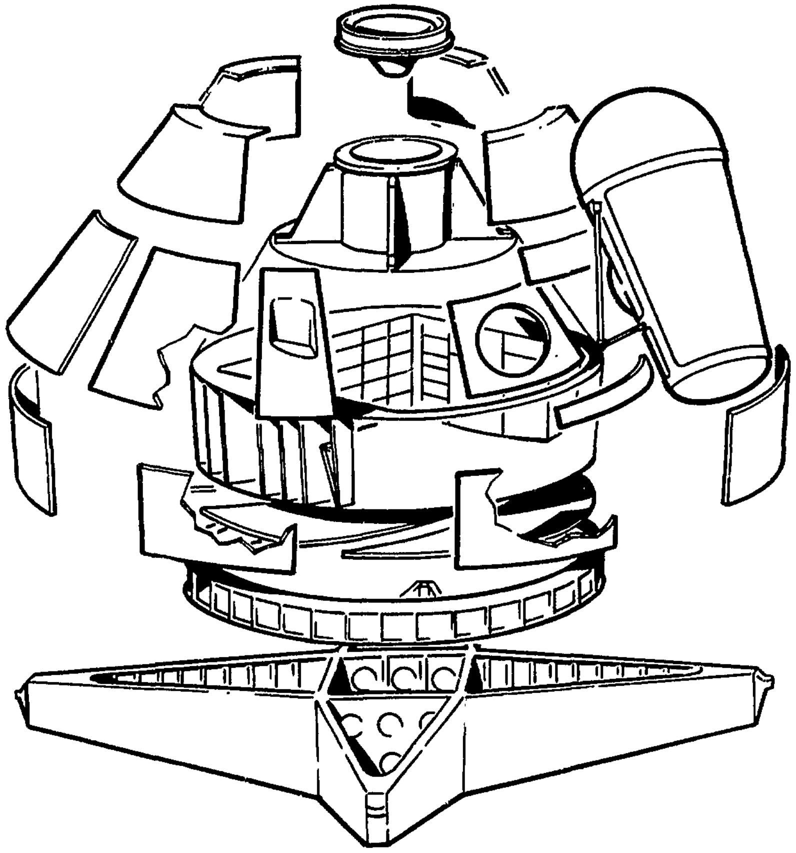
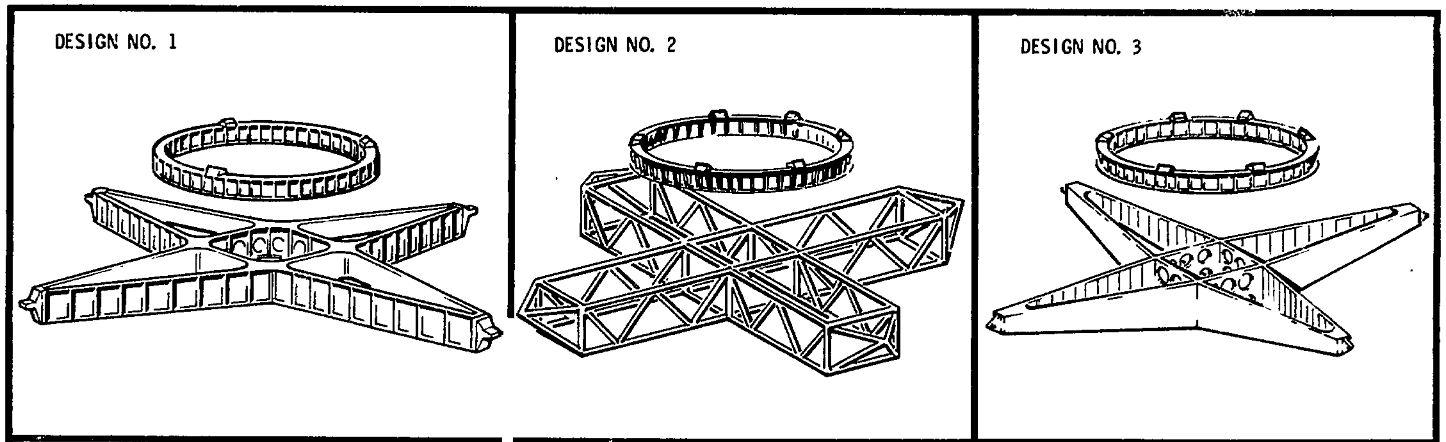


Figure 6. RCM Laboratory - Dependent Configuration



DESIGN NO. 1	DESIGN NO. 2	DESIGN NO. 3
WEB-BEAM DESIGN	TRUSS DESIGN	WEB-BEAM DESIGN
DESIGN LOAD - 10,000 LB MAX LOAD LIMIT - 15,000 LB SAFETY FACTOR - 1.5 TOTAL WEIGHT - 575 LB	DESIGN LOAD - 25,000 LB MAX LOAD LIMIT - 33,800 LB SAFETY FACTOR - 1.5 TOTAL WEIGHT - 638 LB	DESIGN LOAD - 25,000 LB MAX LOAD LIMIT - 33,800 LB SAFETY FACTOR - 1.5 TOTAL WEIGHT - 688 LB

Figure 7. Laboratory/Experiment Support Structure

II. GROUND OPERATION REQUIREMENTS

The ground operations study analysis established requirements leading to renovation and RCM/RCM laboratory delivery and to those prelaunch operations at the KSC industrial area and on the launch pad. These requirements are the basis for GSE identification; facility and site activation requirements; and field operation planning, including scheduling, logistics support, and training. Other ground operational areas of interest are recovery operations and postflight testing. In this study, preliminary flow charts were developed for the recovery operations of a spacecraft scheduled for renovation, for the renovated command module, and the dependent and independent laboratories. The scope of the study was limited to spacecraft recovery and the Downey operations. However, Florida operations are also presented as a means of judging impact and identifying problem areas.

Because ground operation requirements must be approved by NASA before issuance of a control document for GSE procurement and field operations, the following information is provided for early consideration and action: The nominal lead time for ground operation requirements approval by NASA has been established as 15 months before shipment from Downey. This time span has been reduced in recognition of RCM/RCM laboratory program pressures, therefore, prompt NASA approval action is essential. The new approval schedule has the following justifications:

1. The revised recovery operations will not require additional facility activation.
2. The RCM was found to have little impact on the Apollo checkout schedules.
3. The dependent laboratory has few systems to be checked out although it carries three new components (the airlock, cruciform support, and micrometeoroid bumper).
4. The independent laboratory presents a very severe problem and the reduced schedule may present problem areas.

The new schedule was developed on the basis of previous experience with the dependent laboratory and because of the probability that experiments may not be defined even after later operational flows are developed and issued. Should any of the flight articles incorporate new type equipment other than that currently envisioned for renovation, severe scheduling problems may be introduced.

RECOVERY OPERATIONS

Analysis of operations during CM recovery was directed primarily toward improving the condition of the recovered spacecraft. The operations shown in Figure 8 have not been fully developed, and at this time only indicate desirable requirements. It will be noted that recovery operations actually begin while the spacecraft is still descending and it is believed that in-flight operations before splashdown require additional study. For example, crew safety may be involved in continued use of electrical power. Different in-flight procedures may be identified if landing is in sight of the carrier. As such, when on-target landings are imminent, electrical power might be allocated for continuing ECS circulation, thereby deleting the later requirement for ECS decontamination and providing some additional cooling to coldplated items. Conversely, should black box cooling prove to be important for renovation, then every effort should be made to establish early ECS turn-off times to increase ECS cooling before splashdown.

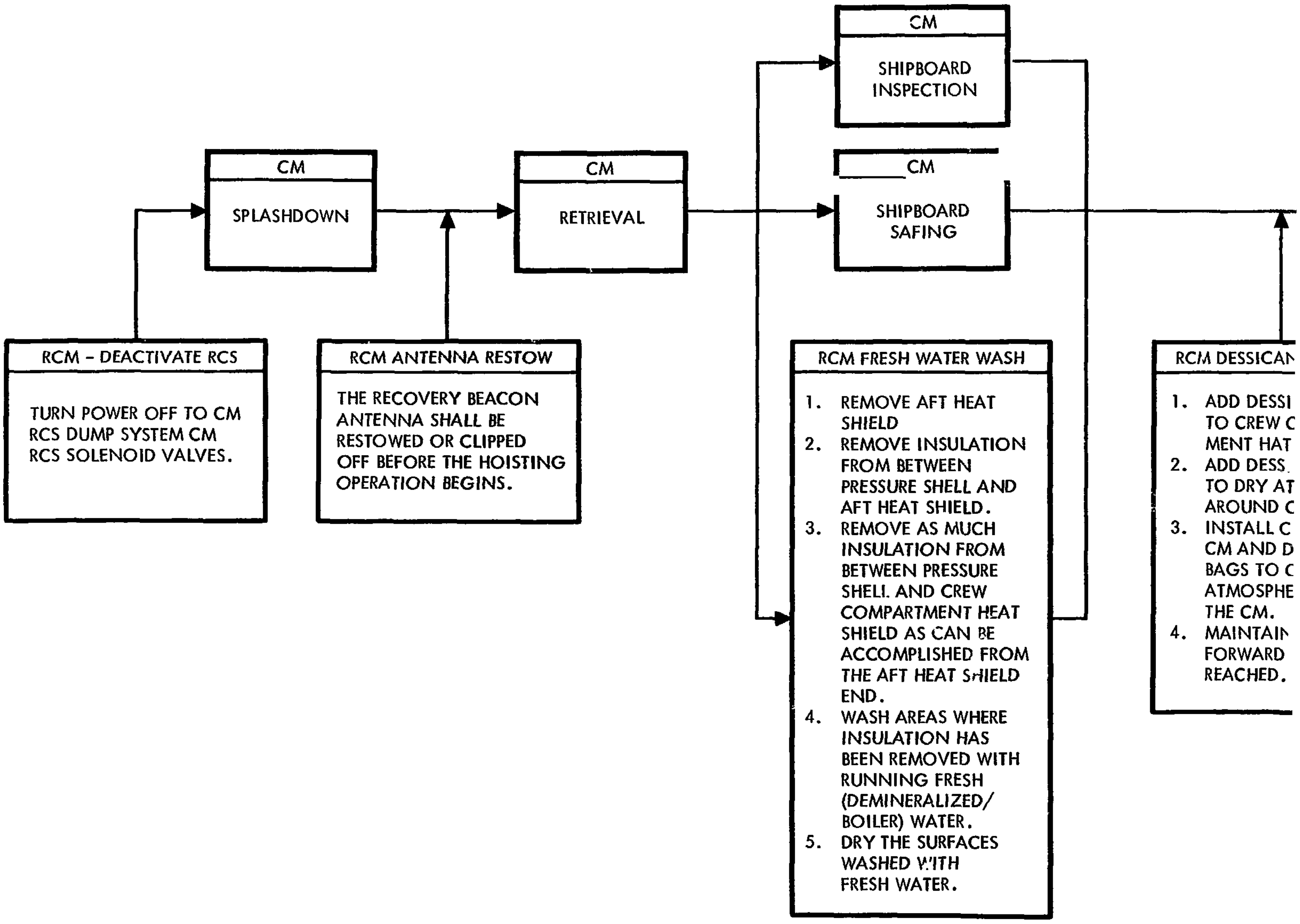
The requirement to restow the HF antenna is based on damage to the antenna structure during recovery of previous spacecraft.

Shipboard pyrotechnic safing and subsequent inspection appear to be obvious requirements.

Other shipboard inspection procedures should include the taking of any samples specified for shipboard collection, and all photographic activities.

Flight crew retrieval is not covered since this may occur at sea or aboard ship, and is accomplished at the discretion of the astronauts. However, the desirability of keeping sea water out of the command module strongly favors shipboard egress of the flight crew.

One major problem is sea water penetration into the space between the heat shield and the inner structure. Comprehensive studies should be taken to devise means of preventing entry of sea water into this area. As a further precaution, all metallic surfaces that may be exposed to a saline environment should be covered with an anti-corrosion, protective coating. The extreme importance of avoiding the corrosive effects of salt water cannot be overemphasized.



RCM - DEACTIVATE RCS

TURN POWER OFF TO CM RCS DUMP SYSTEM CM RCS SOLENOID VALVES.

RCM ANTENNA RESTOW

THE RECOVERY BEACON ANTENNA SHALL BE RESTOWED OR CLIPPED OFF BEFORE THE HOISTING OPERATION BEGINS.

RCM FRESH WATER WASH

1. REMOVE AFT HEAT SHIELD
2. REMOVE INSULATION FROM BETWEEN PRESSURE SHELL AND AFT HEAT SHIELD.
3. REMOVE AS MUCH INSULATION FROM BETWEEN PRESSURE SHELL AND CREW COMPARTMENT HEAT SHIELD AS CAN BE ACCOMPLISHED FROM THE AFT HEAT SHIELD END.
4. WASH AREAS WHERE INSULATION HAS BEEN REMOVED WITH RUNNING FRESH (DEMINERALIZED/BOILER) WATER.
5. DRY THE SURFACES WASHED WITH FRESH WATER.

RCM DESSICAN

1. ADD DESSI TO CREW C MENT HAT
2. ADD DESS TO DRY AT AROUND C
3. INSTALL C CM AND D BAGS TO C ATMOSPHE THE CM.
4. MAINTAIN FORWARD REACHED.

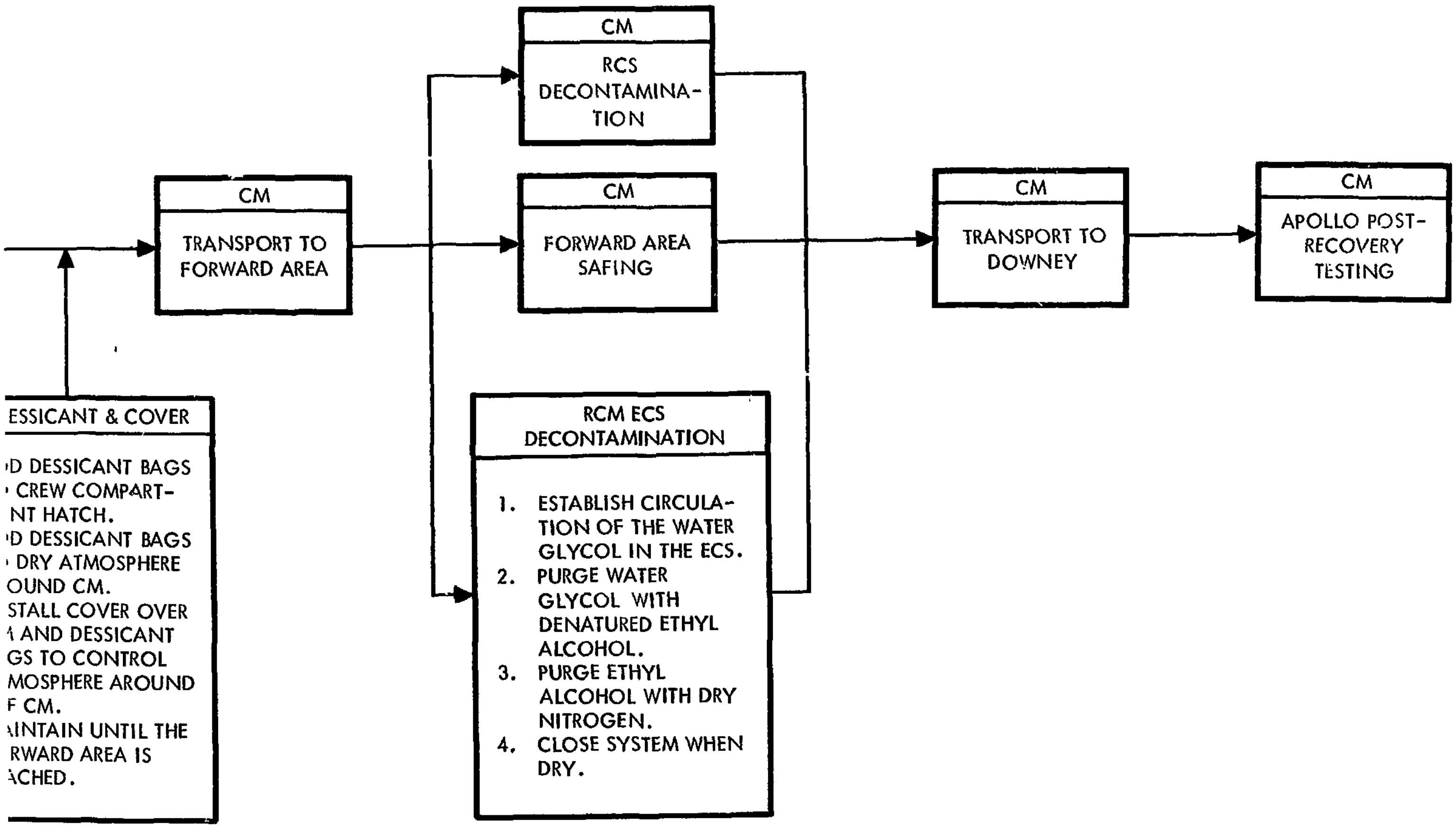


Figure 8. CM/RCM Recovery Flow (Revised per ILAD S/M S/66-219)

Because total prevention of sea water damage cannot be accomplished during fabrication of the spacecraft, it becomes increasingly important to limit salt water damage during shipboard operations. The space in question could either be cleaned by diffusion of the salt into fresh water, with the heat shield in place, or the heat shield could be removed for direct fresh water flushing and cleaning. Unfortunately, both methods have some drawbacks. The diffusion method would require filling and draining the space with clean, fresh water two or three times, followed by filling and draining with water containing passivating on protective material. Drainage would be provided in that the CM tension ties could be removed, thus providing three 1.4-inch diameter holes through the aft heat shield. This flushing operation is quite simple but its effectiveness appears to be relatively low. It also does not solve the problem of the insulation material (in the space between the heat shield and the inner structure), which will stay wet until removed.

Disassembly of the aft heat shield and complete removal of the insulation material will permit more effective desalting operations and drying of the exposed surfaces. The disadvantages to this approach are the number of men, amount of equipment, and time required to perform these operations. It appears possible that the recovery vessel could reach the point of debarkation before the flushing and cleaning operation was completed.

In view of the preceding considerations, the method requiring removal of the heat shield was selected as the best solution because it provides the greatest possible protection for the CM inner structure, the aft compartment equipment installations, and the heat shield.

FORWARD AREA OPERATIONS

RCS decontamination will be accomplished at this point regardless of the future use of the CM. Decontamination of the ECS is specified in event water glycol circulation has not been maintained. Current ECS requirements are that circulation of the water/glycol fluid must be maintained for at least 11 hours out of each 12-hour period and if circulation is stopped, purge and decontamination of the system should occur as soon as possible. NASA believes that the circulation restrictions imposed on the ECS are too stringent. It is possible that intermittent circulation could be permitted and, if so, the requirement to accomplish this operation in the forward area should be reevaluated.

RCM CHECKOUT OPERATIONS

The basic ground rule was that the renovated CM would remain suitbale for earth orbital flights. As such, the heat shield ablator thickness is the sole factor affected by specifying only the earth orbit capability. Therefore, the preliminary checkout operational flow for the RCM (Figures 9, 10, and 11) is identical to any other Block II Apollo space vehicle.

DEPENDENT LABORATORY OPERATIONS

The dependent laboratory has the airlock, the cruciform, and micrometeoroid protection. However, all tests are based on new and different requirements. For example, the proof-pressure test of the dependent laboratory is performed with the airlock attached.

It should be pointed out that the ground operations flow (Figure 1), begin with a proof-pressure test of the inner structure and airlock. This test is not specified for the RCM because approved GSE is not used for this test. Since the restriction to use only approved GSE on the recovery operations and on the laboratories has been lifted, the required proof-pressure test is specified for the laboratories. Disassembly of the recovered CM is considered part of ground operations and, as such, consideration should be given to a recommendation for a proof-pressure test on the recovered CM before renovation begins since renovation of a given spacecraft must be based on a sound inner structure.

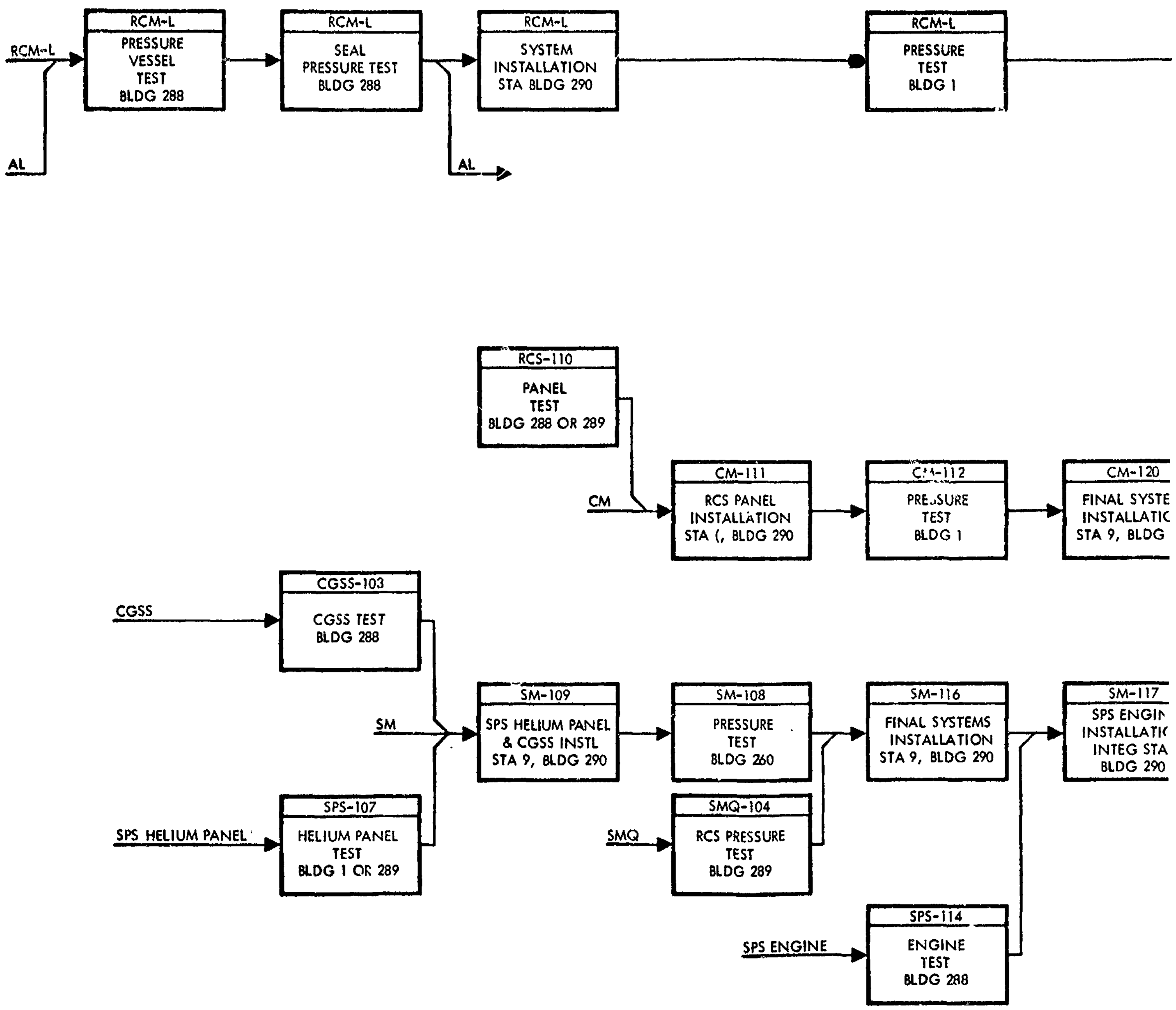
The introduction of the airlock increases the importance of seal-leak testing, which is shown on the operational flow as the second operation. Even though the seals cannot be maintained until launch, early proof that the seals reduce leakage to acceptable values is recommended. In the operational flows shown, the following assumptions have been made:

1. Some systems will be installed in the dependent laboratory (a light in the laboratory, some readout as to the condition of the airlock before opening the hatch, (and some method for exchanging the atmosphere between the CM and laboratory, seem essential).

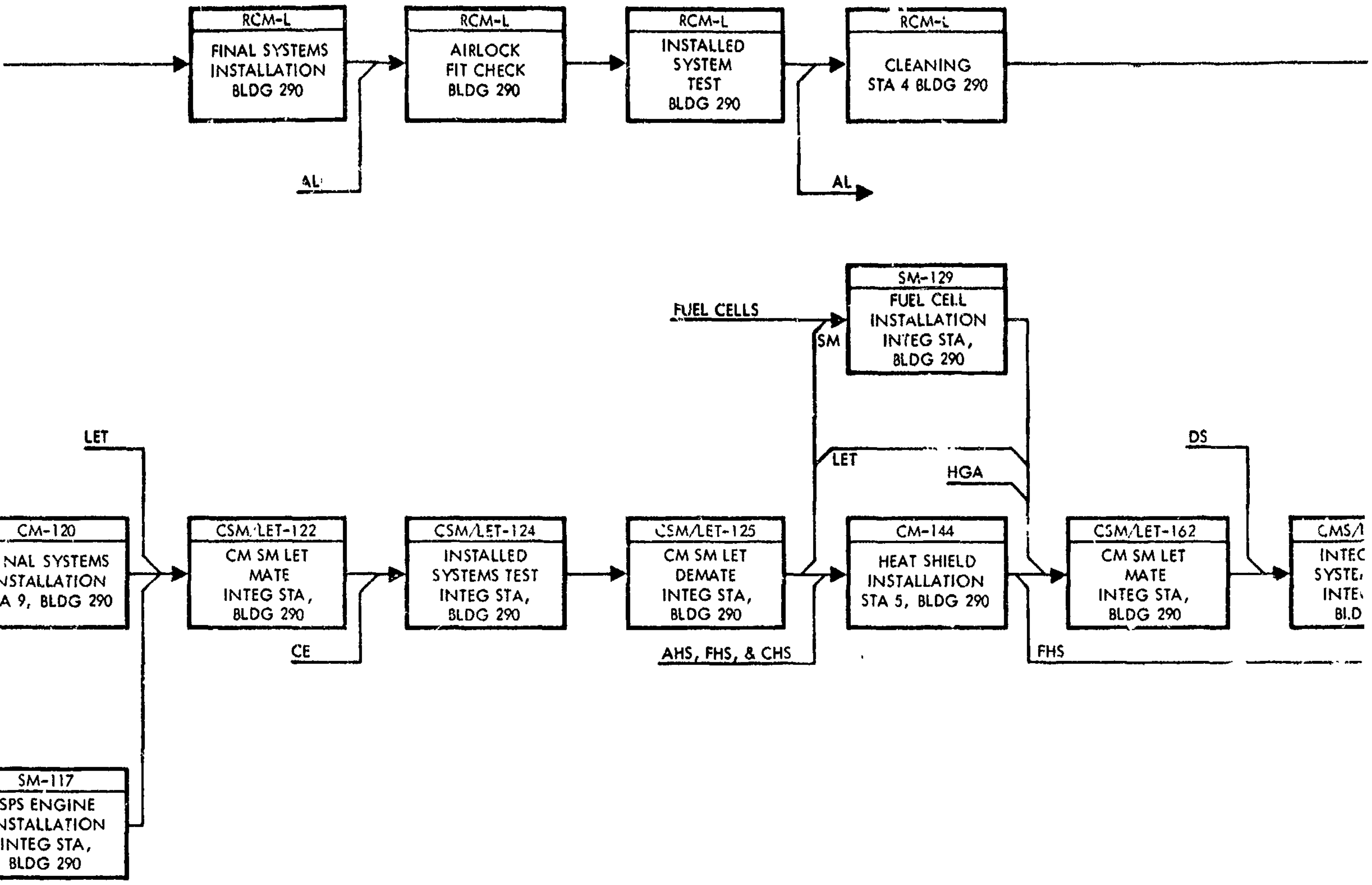
2. It is almost certain that the airlock will need to be demounted for access during subsystem installation and test.

3. Both the airlock and the laboratory will later undergo installation of the micrometeoroid protection and be shipped to Florida.

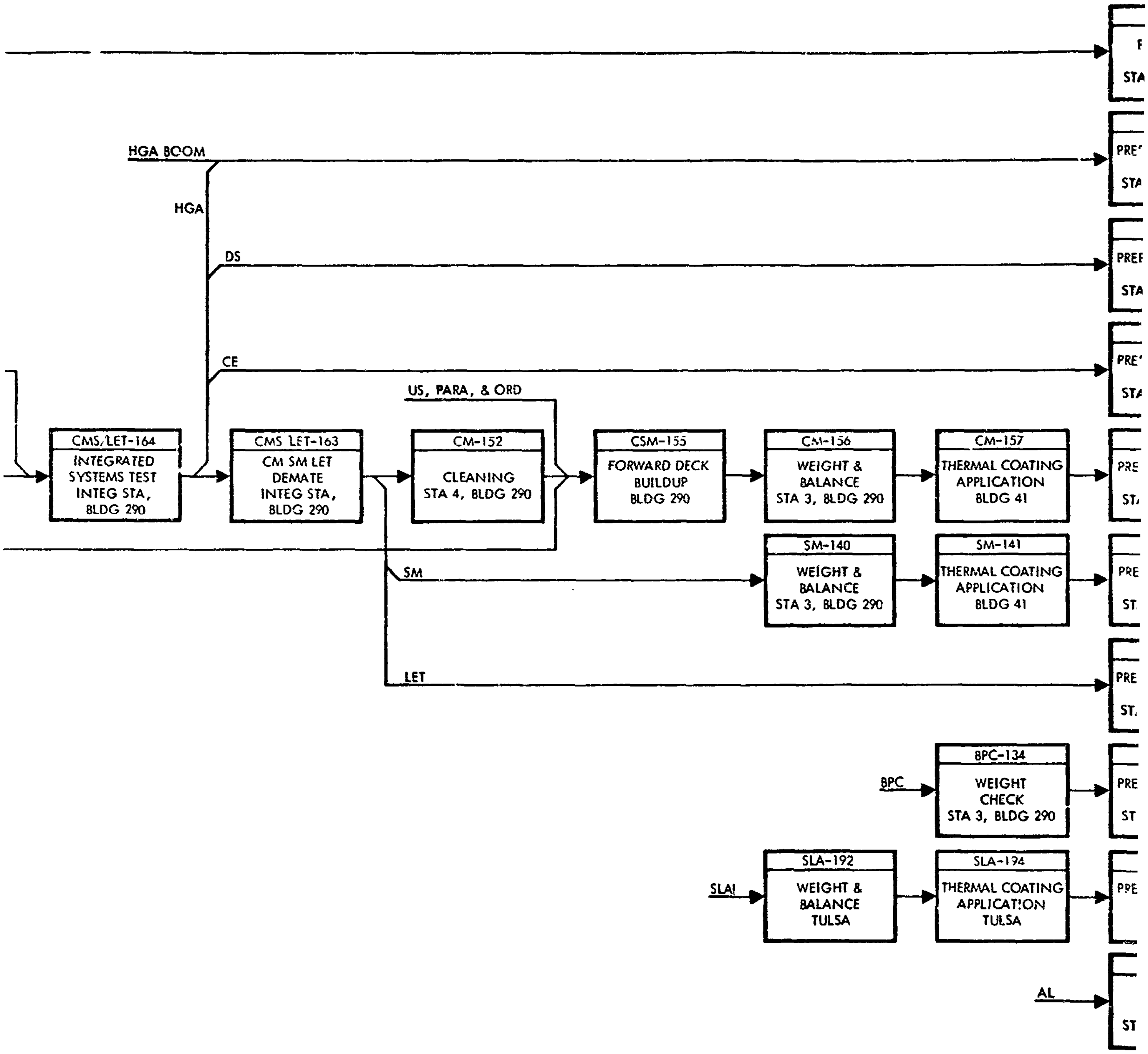
4. Shipment of the dependent laboratory may occur with the airlock mounted in place, or the laboratory and airlock may be shipped separately. The final decision will be based upon the number of subsystems in the dependent laboratory and the tests to be performed in Florida.

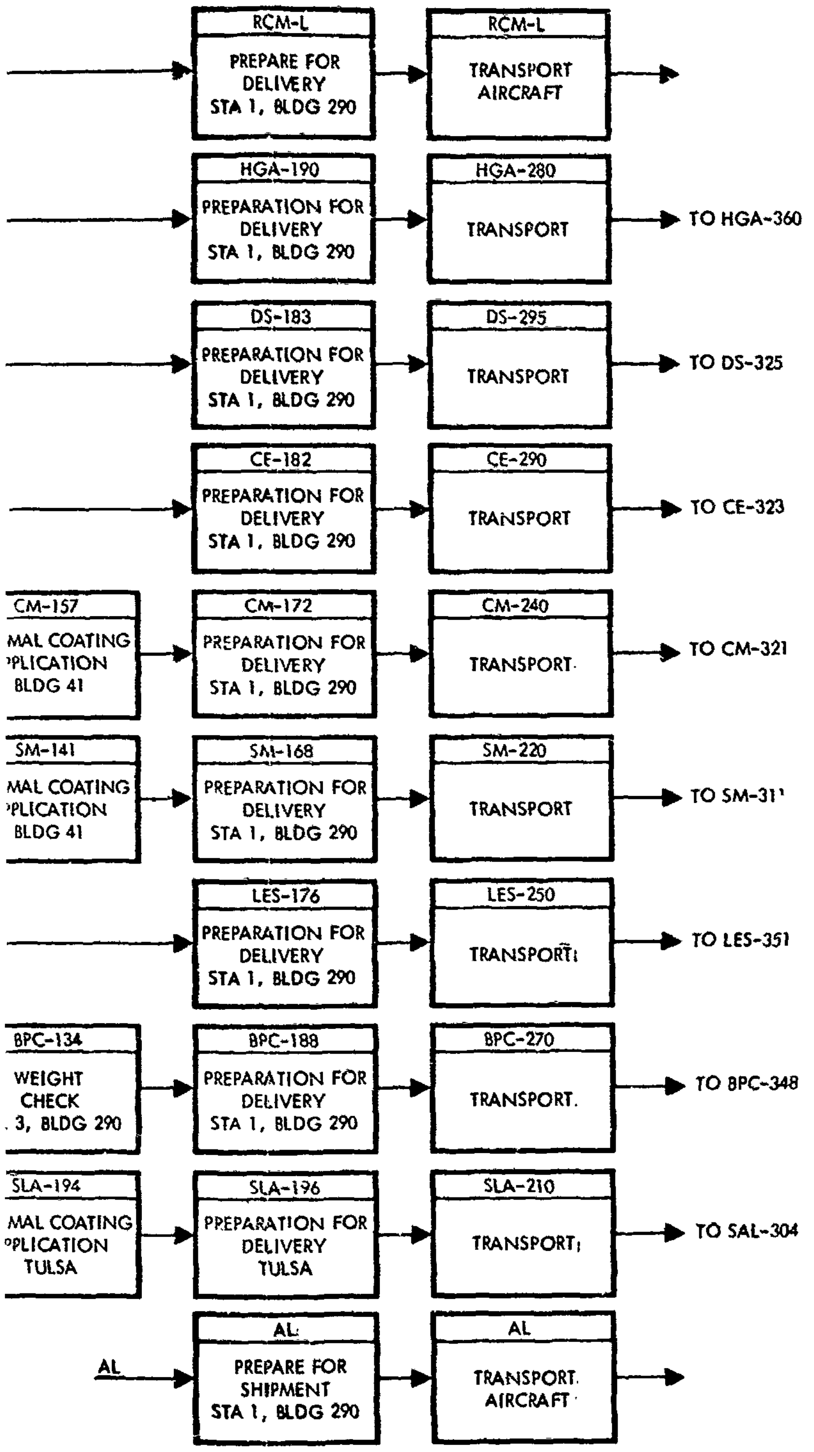

RCM-L
AL
RCM-L
PRESSURE VESSEL TEST BLDG 288
RCM-L
SEAL PRESSURE TEST BLDG 288
AL
RCM-L
SYSTEM INSTALLATION STA BLDG 290
RCM-L
PRESSURE TEST BLDG 1
RCS-110
PANEL TEST BLDG 288 OR 289
CM
CM-111
RCS PANEL INSTALLATION STA (, BLDG 290
CM-112
PRESSURE TEST BLDG 1
CM-120
FINAL SYSTE INSTALLATIC STA 9, BLDG
CGSS
CGSS-103
CGSS TEST BLDG 288
SM
SM-109
SPS HELIUM PANEL & CGSS INSTL STA 9, BLDG 290
SM-108
PRESSURE TEST BLDG 260
SM-116
FINAL SYSTEMS INSTALLATION STA 9, BLDG 290
SM-117
SPS ENGIN INSTALLATIC INTEG STA BLDG 290
SPS HELIUM PANEL
SPS-107
HELIUM PANEL TEST BLDG 1 OR 289
SMQ
SMQ-104
RCS PRESSURE TEST BLDG 289
SPS ENGINE
SPS-114
ENGINE TEST BLDG 288

FOLDOUT FRAME 2



FOLDOUT FRAME 3





BLOCK NUMBER ASSIGNMENTS

100	TO	199	DOWNEY AND TULSA
200	TO	299	TRANSPORT TO KSC
300	TO	399	KSC INDUSTRIAL AREA
400	TO	499	LAUNCH COMPLEX

ABBREVIATIONS

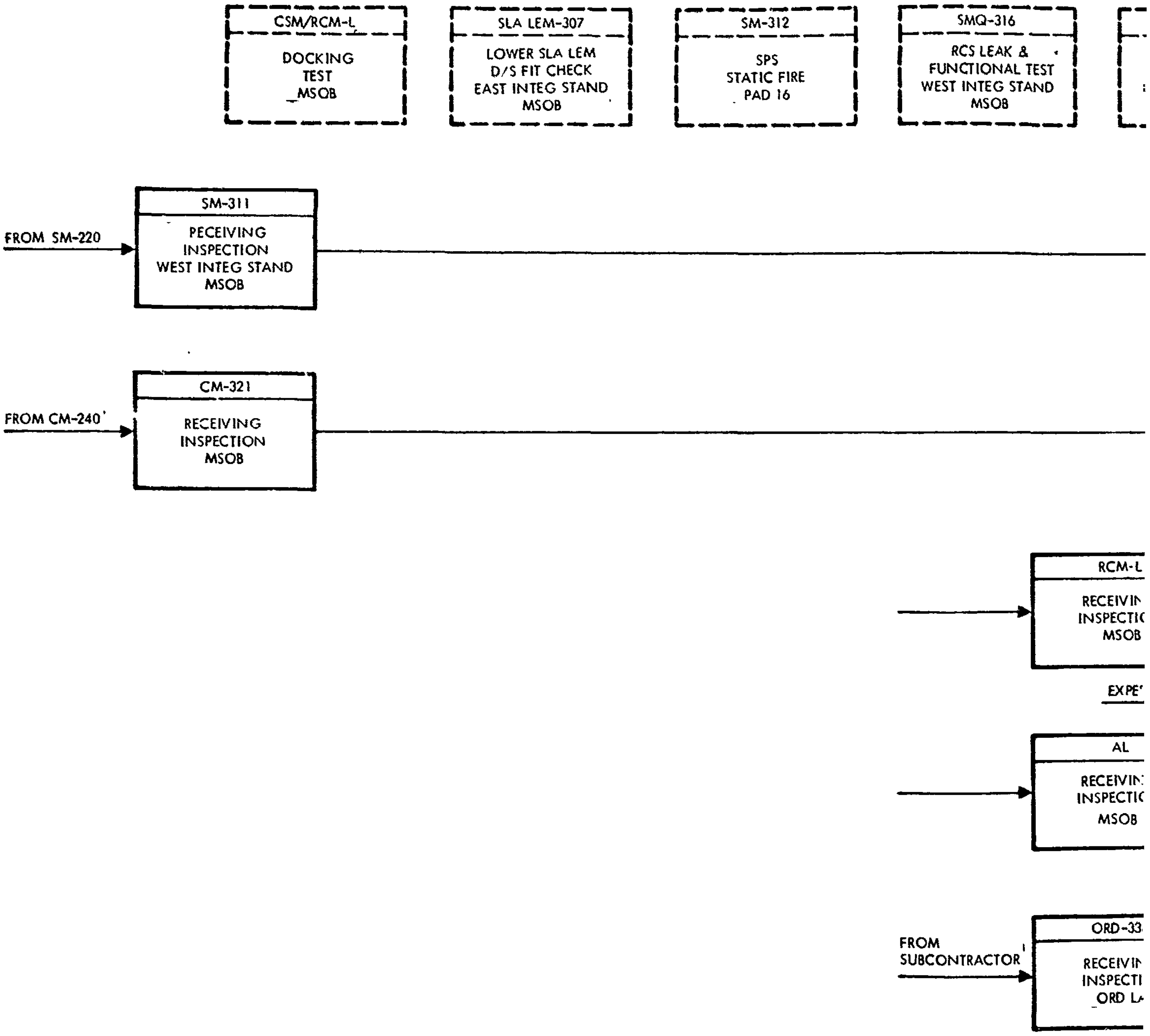
AHS	AFT HEAT SHIELD
BLDG	BUILDING
BPC	BOOST PROTECTIVE COVER
CE	CREW EQUIPMENT
CGSS	CRYOGENIC GAS STORAGE SUBSYSTEM
CHS	CREW COMPARTMENT HEATSHIELD
CM	COMMAND MODULE
CSM	CM SM MATED
DS	DOCKING SUBSYSTEM
FHS	FORWARD HEAT SHIELD
HGA	S-BAND HIGH-GAIN ANTENNA
INSTL	INSTALLATION
INTEG	INTEGRATED
LES	LAUNCH ESCAPE SYSTEM
LET	LAUNCH ESCAPE TOWER
ORD	ORDNANCE
PARA	PARACHUTE
RCS	REACTION CONTROL SUBSYSTEM
SLA	SPACECRAFT/LEM ADAPTER
SM	SERVICE MODULE
SMQ	SERVICE MODULE RCS QUADS
SPS	SERVICE PROPULSION SUBSYSTEM
STA	STATION
US	UPRIGHTING SUBSYSTEM
AL	AIRLOCK
RCM-L	RENOVATED COMMAND MODULE-LABORATORY
RCM	RENOVATED COMMAND MODULE-SPACECRAFT

NOTES:

1. SEQUENCE OF FLOW IS INDICATED BY ARROWHEADS, NOT BY BLOCK NUMBERS.
2. THE FIRST LINE IN EACH BLOCK IS USED FOR BLOCK IDENTIFICATION (e.g., CM-112). THE SECOND AND THIRD LINES DESCRIBE THE FUNCTION PREFORMED (e.g., PRESSURE TEST). THE FOURTH AND FIFTH LINES INDICATE THE TEST STATION (e.g., BLDG 1).
3. READ CM AS RCM

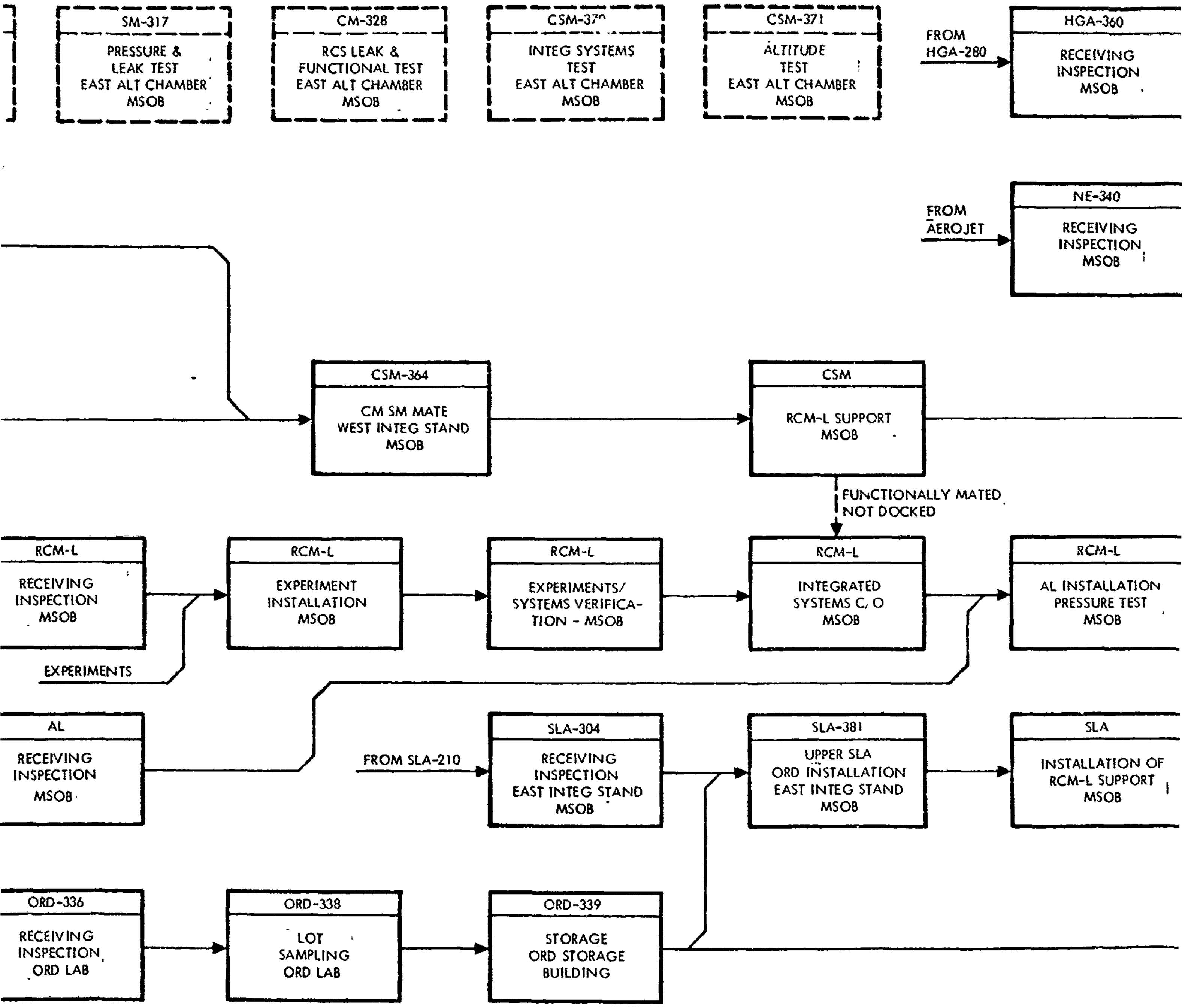
Figure 9. RCML and RCM Spacecraft Flow, Downey

FOLDOUT FRAME 1



FOLDOUT FRAME 2

FOLDO



FOLDOUT FRAME 3

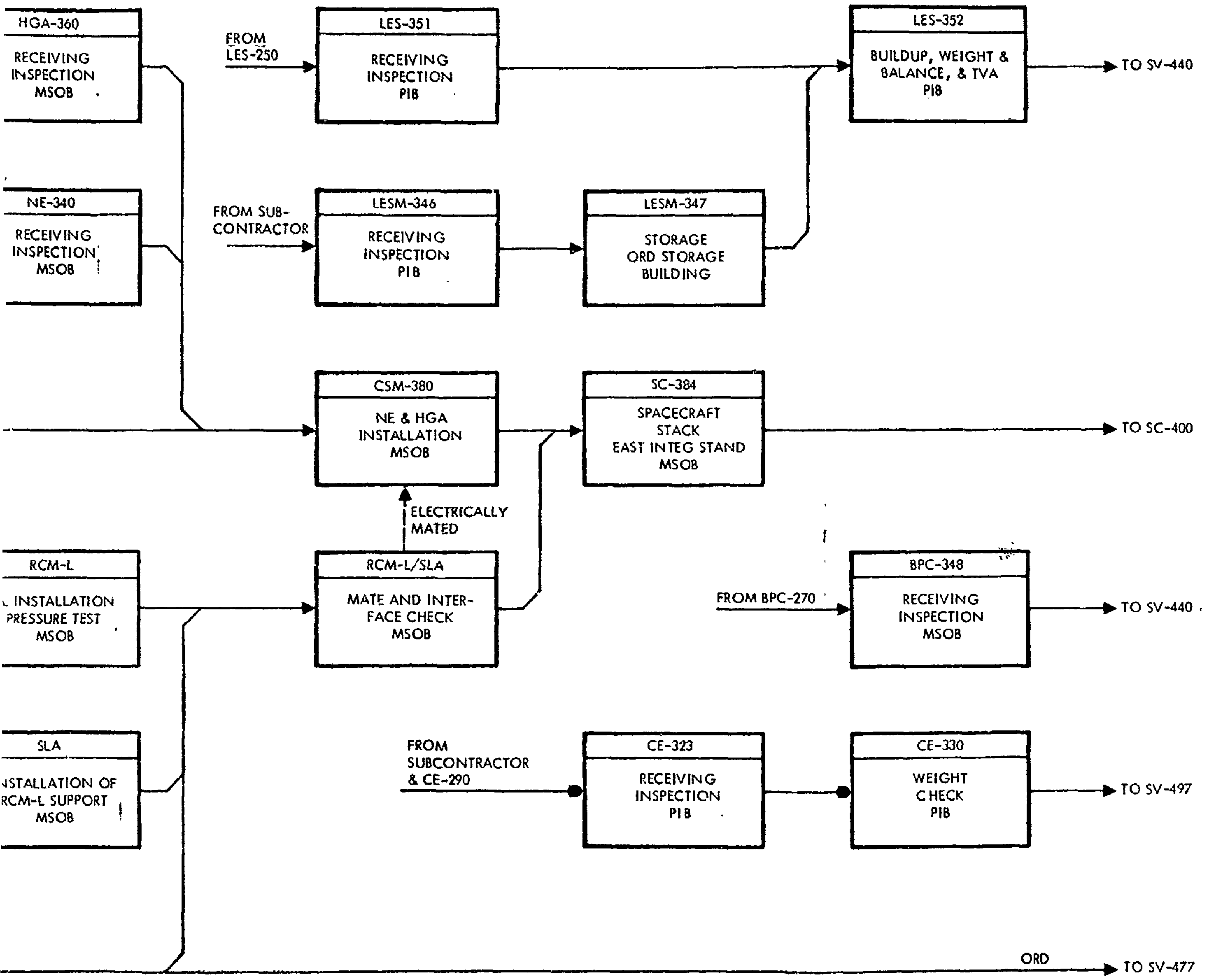
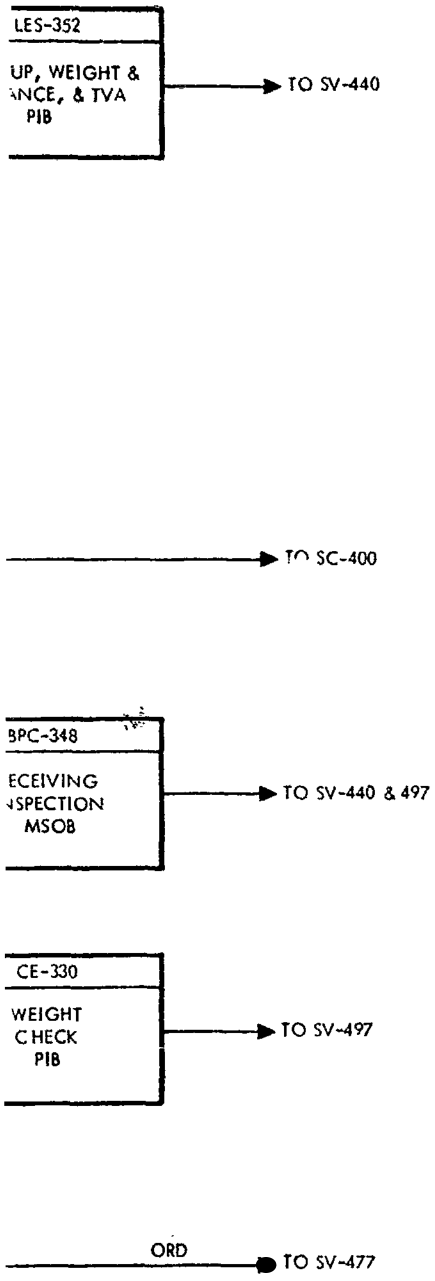


Figure 10. RCML and RC



BLOCK NUMBER ASSIGNMENTS

100 TO 199	DOWNEY AND TULSA
200 TO 299	TRANSPORT TO KSC
300 TO 399	KSC INDUSTRIAL AREA
400 TO 499	LAUNCH COMPLEX

ABBREVIATIONS

RCM-L	RENOVATED COMMAND MODULE LABORATORY
RCM	RENOVATED COMMAND MODULE-SPACECRAFT
ALT	ALTITUDE
A/S	ASCENT STAGE
BPC	BOOST PROTECTIVE COVER
CE	CREW EQUIPMENT
CGSS	CRYOGENIC GAS STORAGE SUBSYSTEM
*CM	COMMAND MODULE
CSM	CM SM MATED
DS	DOCKING SUBSYSTEM
D/S	DESCENT STAGE
ECS	ENVIRONMENTAL CONTROL SUBSYSTEM
FCSTF	FUEL CELL SYSTEM TEST FACILITY
GAEC	GRUMMAN AIRCRAFT ENGINEERING CORPORATION
HGA	S-BAND HIGH-GAIN ANTENNA
INSTL	INSTALLATION
INTEG	INTEGRATED
KSC	KENNEDY SPACE CENTER
LAB	LABORATORY
LEM	LUNAR EXCURSION MODULE
LES	LAUNCH ESCAPE SUBSYSTEM
LESM	LAUNCH ESCAPE SUBSYSTEM MOTORS
MSOB	MANNED SPACECRAFT OPERATIONS BUILDING
NE	NOZZLE EXTENSION (SPS)
ORD	ORDNANCE DEVICES
PIB	PYROTECHNIC INSTALLATION BUILDING
PYRO	PYROTECHNIC DEVICES
RCS	REACTION CONTROL SUBSYSTEM
RF	RADIO FREQUENCY
RRT	RENDEZVOUS RADAR TRANSPONDER
SC	SPACECRAFT
SLA	SPACECRAFT LEM ADAPTER
SM	SERVICE MODULE
SMQ	SERVICE MODULE RCS QUADS
SPS	SERVICE PROPULSION SUBSYSTEM
SV	SPACECRAFT LAUNCH VEHICLE MATED
TVA	THRUST VECTOR ALIGNMENT
AL	AIRLOCK

NOTES:

1. SEQUENCE OF FLOW IS INDICATED BY ARROWHEADS NOT BY BLOCK NUMBERS.
2. THE FIRST LINE IN EACH BLOCK IS USED FOR BLOCK IDENTIFICATION (e.g., CM-321).
   THE SECOND AND THIRD LINES DESCRIBE THE FUNCTION PERFORMED (e.g., RECEIVING INSPECTION).
   THE FOURTH AND FIFTH LINES INDICATE THE TEST STATION (e.g., MSOB).

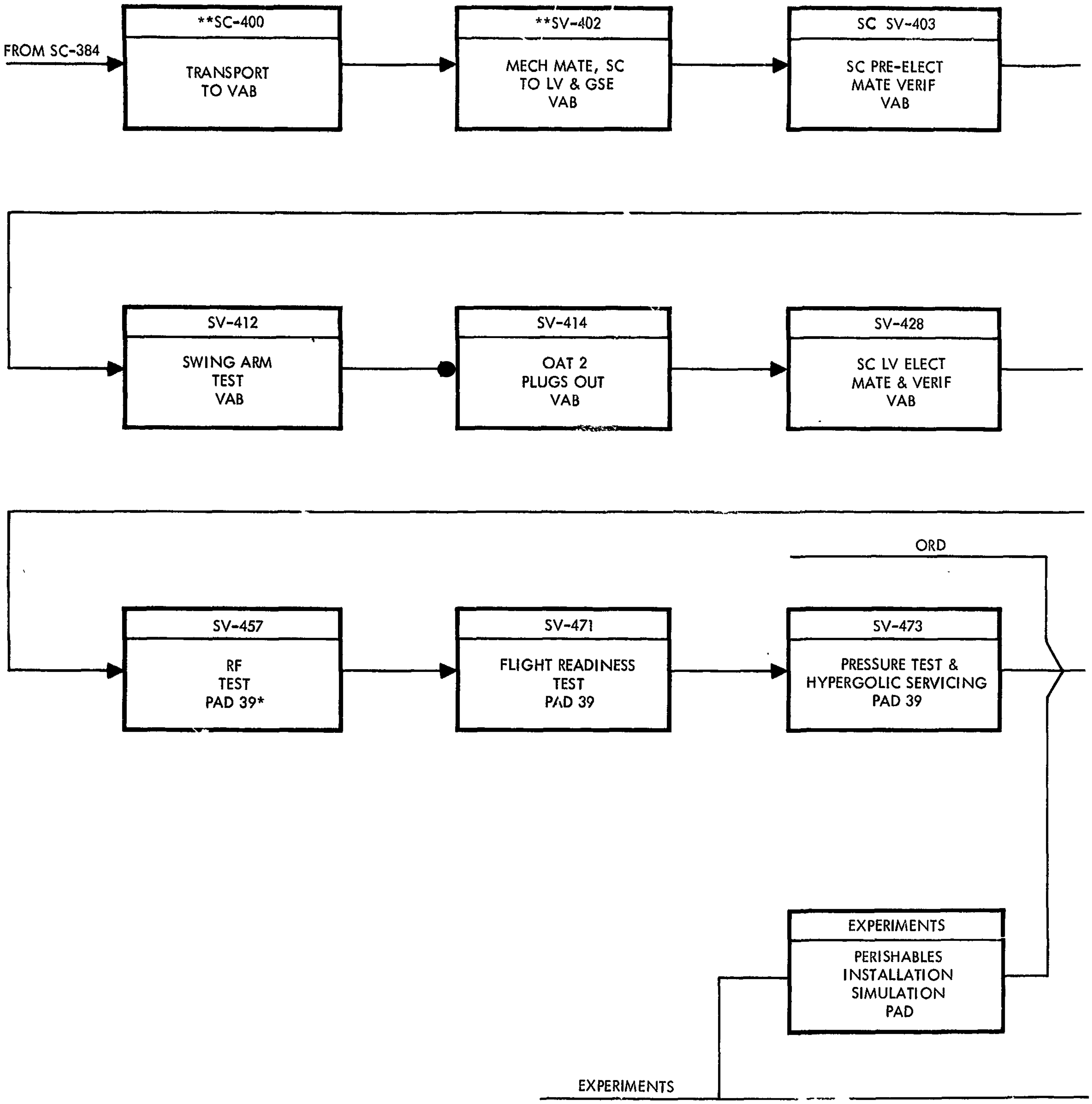
* READ CM AS RCM

SYMBOLS

┆ ┆ ALTERNATIVE OPERATION

Figure 10. RCML and RCM Spacecraft Flow, KSC Industrial Area

FOLDOUT FRAME 1



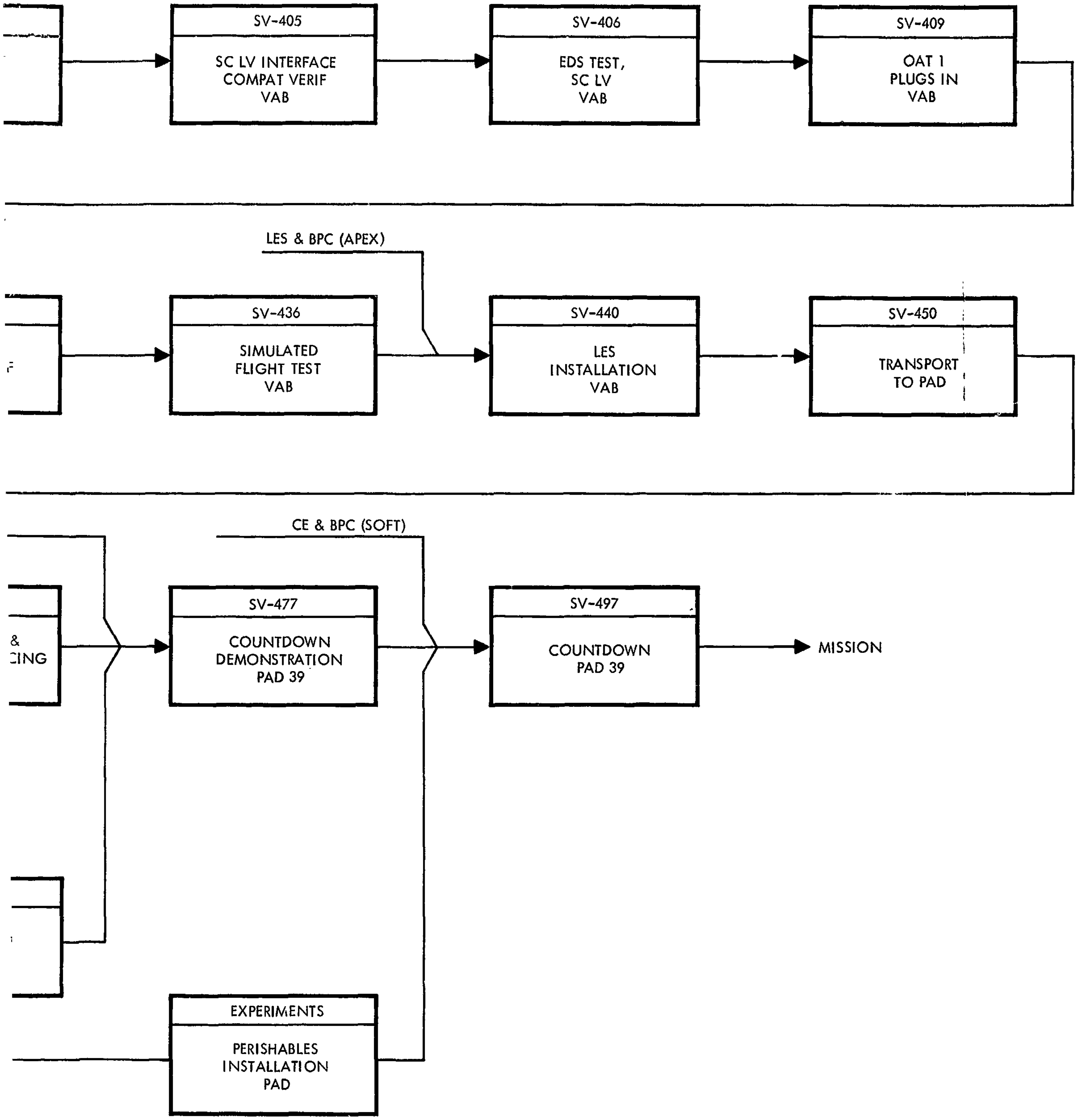
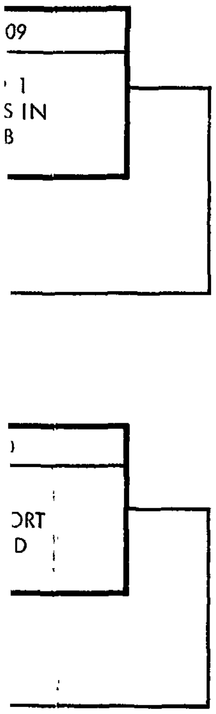


Figure 11. RCMI

FOLDOUT FRAME 3



BLOCK NUMBER ASSIGNMENTS

100 TO 199 DOWNEY AND TULSA
200 TO 299 TRANSPORT TO KSC
300 TO 399 KSC INDUSTRIAL AREA
400 TO 499 LAUNCH COMPLEX

ABBREVIATIONS

BPC	BOOST PROTECTIVE COVER
CE	CREW EQUIPMENT
COMPAT	COMPATIBILITY
EDS	EMERGENCY DETECTION SUBSYSTEM
ELECT	ELECTRICAL
GSE	GROUND SUPPORT EQUIPMENT
KSC	KENNEDY SPACE CENTER
LES	LAUNCH ESCAPE SUBSYSTEM
LV	LAUNCH VEHICLE
MECH	MECHANICAL
OAT	OVERALL TEST
ORD	ORDNANCE DEVICES
RF	RADIO FREQUENCY
SC	SPACECRAFT
SV	SC/LV MATED
VAB	VEHICLE ASSEMBLY BUILDING
VERIF	VERIFICATION

NOTES:

1. SEQUENCE OF FLOW IS INDICATED BY ARROWHEADS, NOT BY BLOCK NUMBERS.
2. THE FIRST LINE IN EACH BLOCK IS USED FOR BLOCK IDENTIFICATION (E.G., SV-414). THE SECOND AND THIRD LINES DESCRIBE THE FUNCTION PERFORMED (E.G., OAT 2). THE FOURTH LINE INDICATES THE TEST STATION (E.G., VAB).

*READ VAB & PAD 39 AS PAD 34 OR PAD 37 IF SATURN IB BOOSTER IS USED.

**SC & SV INDICATES RCM-L IN THE SLA

ure 11. RCML and RCM Spacecraft Flow, Launch Complex 39

5. The laboratory must be inverted for docking test with the spacecraft CSM.

The Florida checkout of the dependent laboratory (Figures 10 and 11) will depend on the amount and type of installed systems. In its minimal configuration, few, if any, problems are anticipated, other than the docking test. Without systems or substantial interface with the CM, the integrated systems test with the command module will be minor. The dependent laboratory is assumed to be completely inoperative during the boost phase.

INDEPENDENT LABORATORY OPERATIONS

The experience gained in working with the dependent laboratory will reduce the problems of the pressure vessel proof test and the seals pressure test. However, installation of spacecraft systems, usually located in the SM, on the cruciform (or SLA, in independent laboratory support) will introduce a new configuration to be tested. If all systems are Apollo Block II systems, the present Apollo GSE should be suitable for RCML (I) checkout. However, connections between the GSE and the independent laboratory will be different unless the Apollo spacecraft interfaces are observed and maintained in the design of the independent laboratory.

There is too much required traffic into and out of the independent laboratory during system intstallation and checkout to permit keeping the airlock assembled on the RCM independent laboratory. The same is also true of later Florida operations.

Some savings in shipping equipment can be made if the airlock and laboratory are shipped assembled. A tradeoff study should be made to determine if these savings are sufficient to warrant installation of the airlock before shipment and its removal again in Florida.

The Downey RCM independent laboratory flow sequence (Figure 12) is quite straightforward. The cruciform is installed early, because it must be available when the subsystems installation occurs. Although the flow indicates that the connections between subsystem components mounted in the RCM independent laboratory and cruciform have not been broken, it is permissible to break these connections if necessary. Conversely, since the independent laboratory is never separated in flight from the systems on the cruciform, it may be that the subsystem will be designed without disconnect capabilities. This would mean that, once connected, system integrity would need to be maintained.

Weight and balance operations are shown before installation of the micrometeoroid bumper because the handling problems with the bumper installed have not been clarified. The bumper and its thermal insulation are quite light; calculation of their affect on the c.g. of the RCM independent laboratory will almost certainly prove to be negligible.

The impact of the independent laboratory on the Florida operations (Figures 13 and 14), is quite severe. Not only must a larger mass be inverted for docking test, but the implication of the need for an independent laboratory suggests support of experiments by laboratory systems and an active module on the launch pad. It must also be remembered that while the independent laboratory is being checked out in Florida, the Apollo checkout facilities are being used for the CSM to be used for the flight.

PROBLEM AREAS

The chief problem areas have been highlighted in consonance with their applicable operational flow in previous paragraphs. It appears that since both programs show the need to ship the CM back to Downey in the best possible condition, the potential conflicts between the existing Apollo and proposed RCM/RCM laboratory programs should be easily resolved. However, a NASA decision is required before more detailed operational requirements can be realistically prepared.

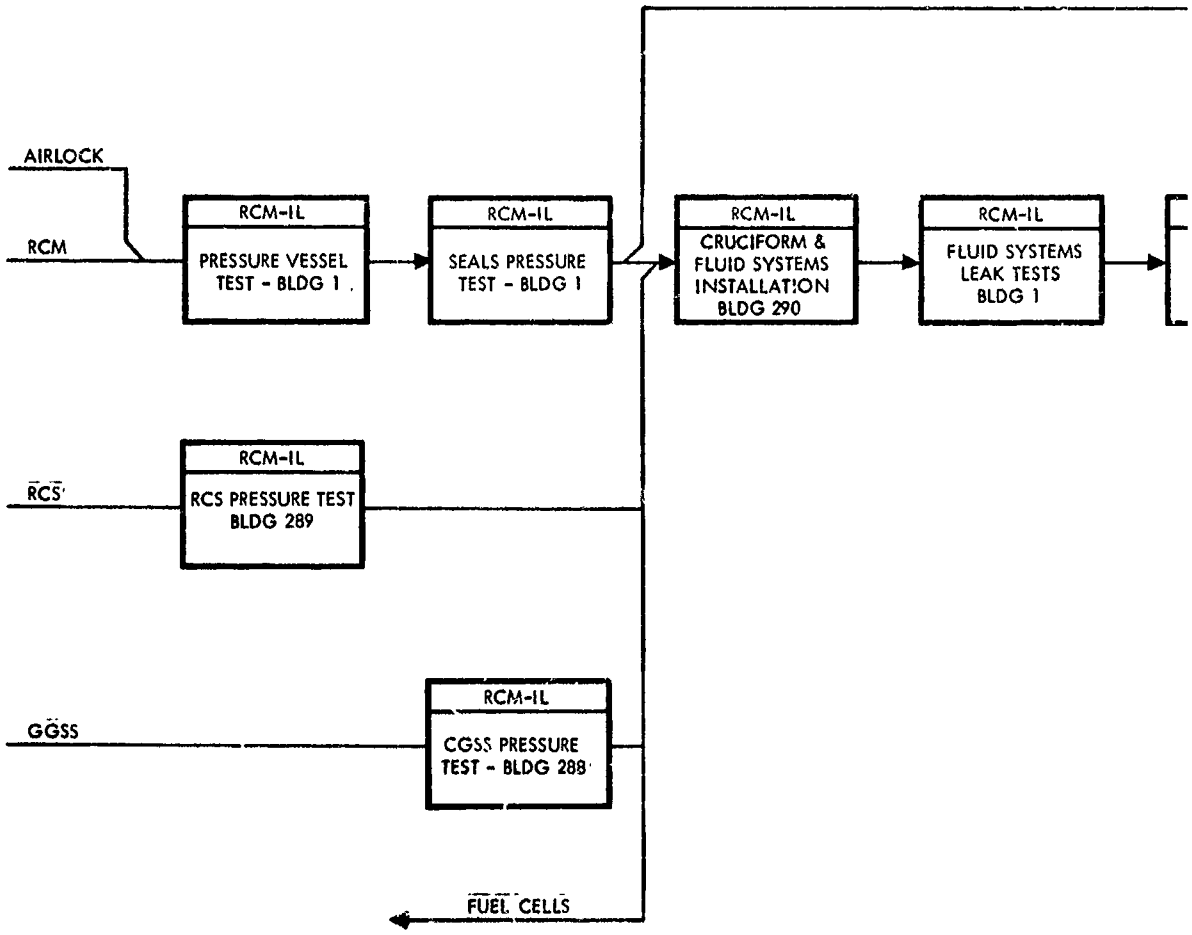
A few problems relating to the Downey effort remain. The tradeoff studies for separate or assembled shipment of the airlock and laboratories have not been made, but it is certain that transport to Florida in either configuration is possible.

The major impact of the renovated CM laboratories will occur when the independent laboratory gets to Florida. A few of the problems that must be resolved are described in subsequent paragraphs.

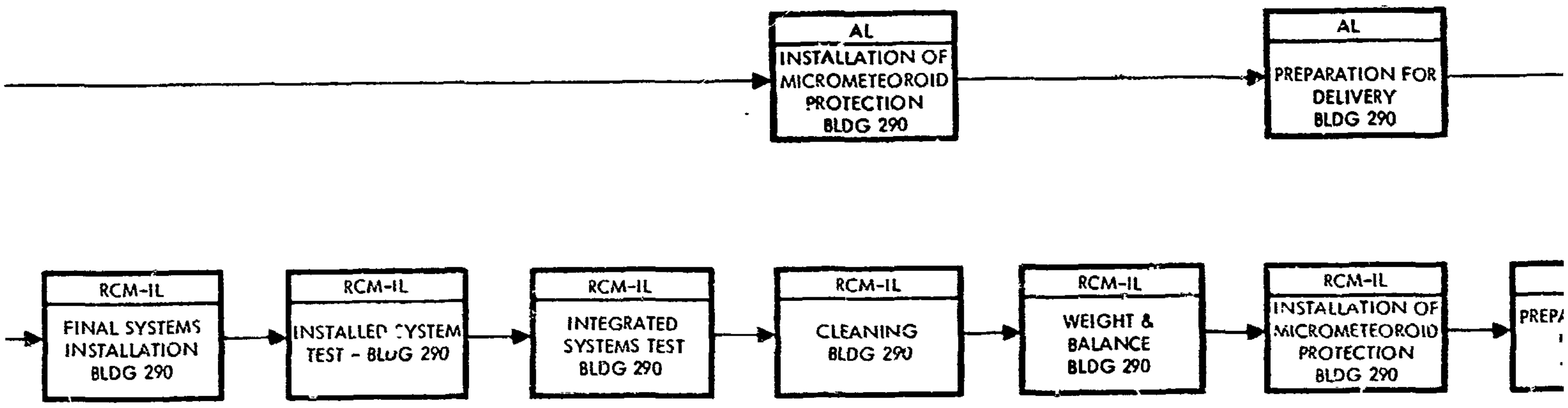
Launch Pad

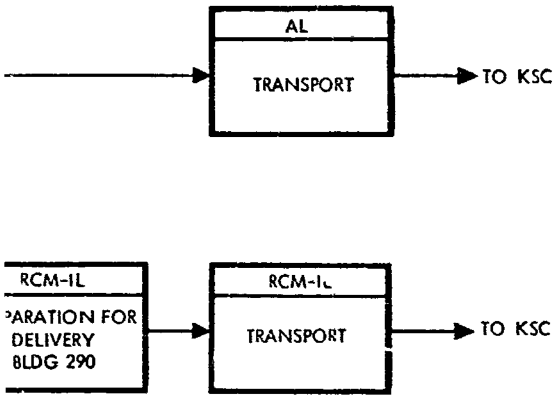
It must be assumed that the independent laboratory will be started up on the ground. The launch pad has some checkout capability in the SLA area for Saturn V flights, but no capability on Pads 34 and 37. Even where a checkout capability exists at the VAB and Pad 39, the equipment supplied is for the LM. However, the LM has no cryogenics and has other system differences. As such, a major modification of the launch complex capabilities will be required if the independent laboratory is to be tested and activated on the pad. The presence of the airlock will also complicate entry to and ventilation of the RCM laboratory in the stacked position.

FOLDOUT FRAME 1



2


AL
INSTALLATION OF MICROMETEOROID PROTECTION BLDG 290
AL
PREPARATION FOR DELIVERY BLDG 290
RCM-IL
FINAL SYSTEMS INSTALLATION BLDG 290
RCM-IL
INSTALLED SYSTEM TEST - BLDG 290
RCM-IL
INTEGRATED SYSTEMS TEST BLDG 290
RCM-IL
CLEANING BLDG 290
RCM-IL
WEIGHT & BALANCE BLDG 290
RCM-IL
INSTALLATION OF MICROMETEOROID PROTECTION BLDG 290
PREPA



BLOCK NUMBER ASSIGNMENTS

100 TO 199 DOWNEY AND TULSA
200 TO 299 TRANSPORT TO KSC
300 TO 399 KSC INDUSTRIAL AREA
400 TO 499 LAUNCH COMPLEX

ABBREVIATIONS

AHS	AFT HEAT SHIELD
BLDG	BUILDING
BPC	BOOST PROTECTIVE COVER
CE	CREW EQUIPMENT
CGSS	CRYOGENIC GAS STORAGE SUBSYSTEM
CHS	CREW COMPARTMENT HEAT SHIELD
CM	COMMAND MODULE
CSM	CM/SM MATED
DS	DOCKING SUBSYSTEM
FHS	FORWARD HEAT SHIELD
HGA	S-BAND HIGH-GAIN ANTENNA
INSTL	INSTALLATION
INTEG	INTEGRATED
LES	LAUNCH ESCAPE SYSTEM
LET	LAUNCH ESCAPE TOWER
ORD	ORDNANCE
PARA	PARACHUTE
RCS	REACTION CONTROL SUBSYSTEM
SLA	SPACECRAFT/LEM ADAPTER
SM	SERVICE MODULE
SMQ	SERVICE MODULE RCS QUADS
SPS	SERVICE PROPULSION SUBSYSTEM
STA	STATION
US	UPRIGHTING SUBSYSTEM
AL	AIRLOCK
RCM-IL	INDEPENDENT LAB

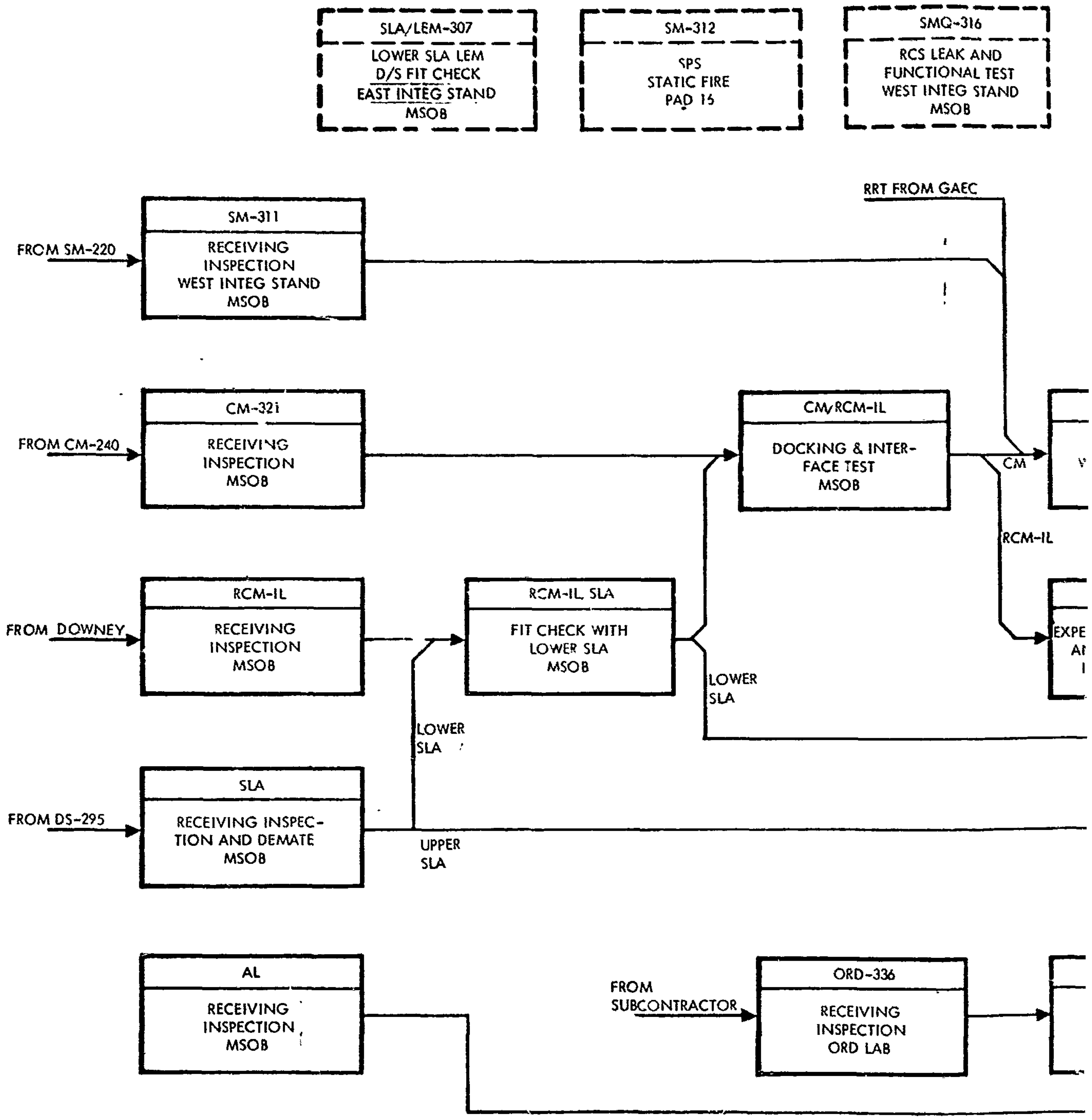
NOTES:

1. SEQUENCE OF FLOW IS INDICATED BY ARROWHEADS, NOT BY BLOCK NUMBERS
2. THE FIRST LINE IN EACH BLOCK IS USED FOR BLOCK IDENTIFICATION (e.g., CM-112). THE SECOND AND THIRD LINES DESCRIBE THE FUNCTION PERFORMED (e.g., PRESSURE TEST). THE FOURTH AND FIFTH LINES INDICATE THE TEST STATION (e.g., BLDG 1).
3. CM NOT SHOWN - NO JOINT TESTS

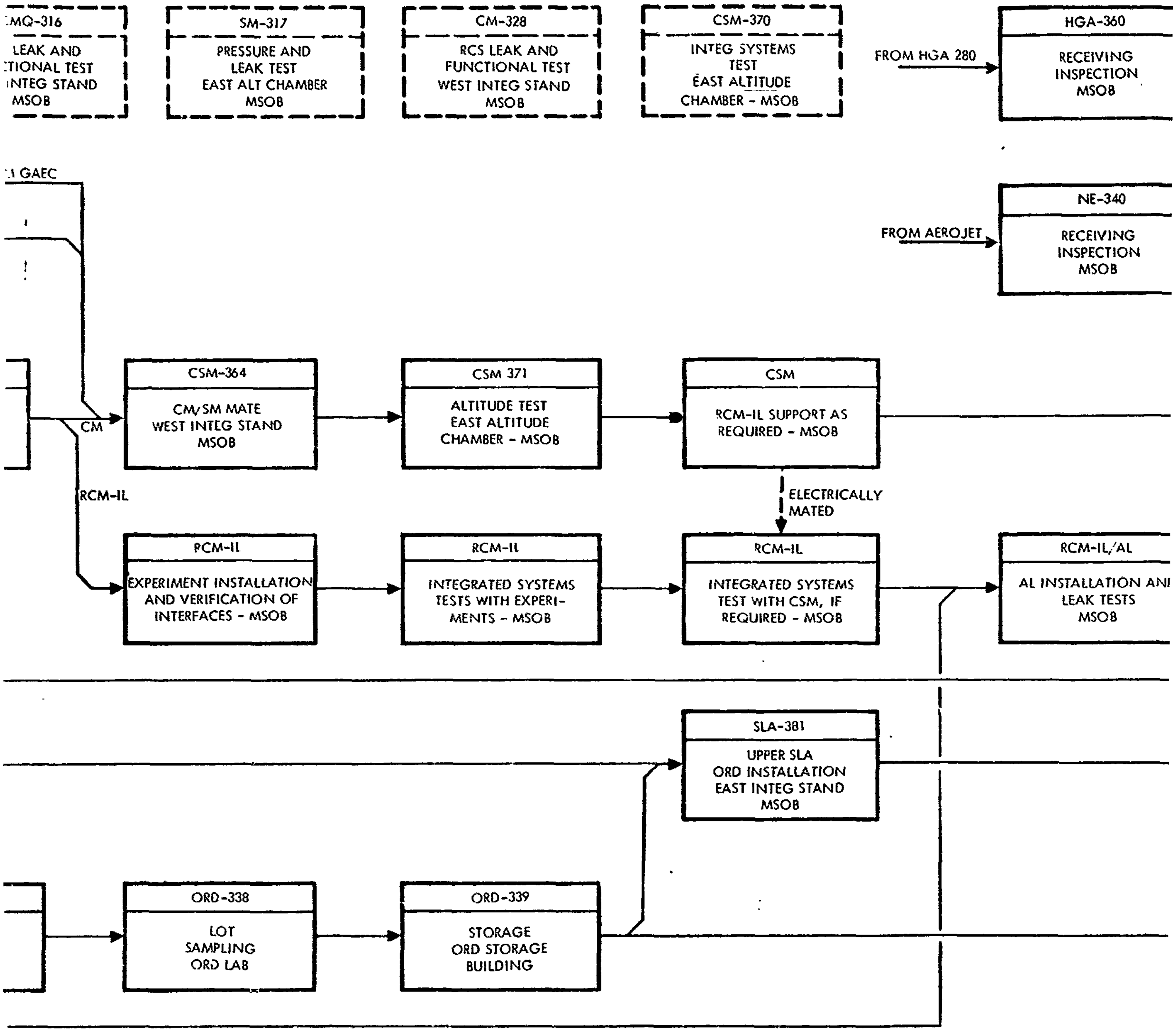
12

Figure 12. RCML (I) Spacecraft Flow, Downey

FOLDOUT FRAME 1



FOLDOUT FRAME 2



FOLDOUT FRAME 3

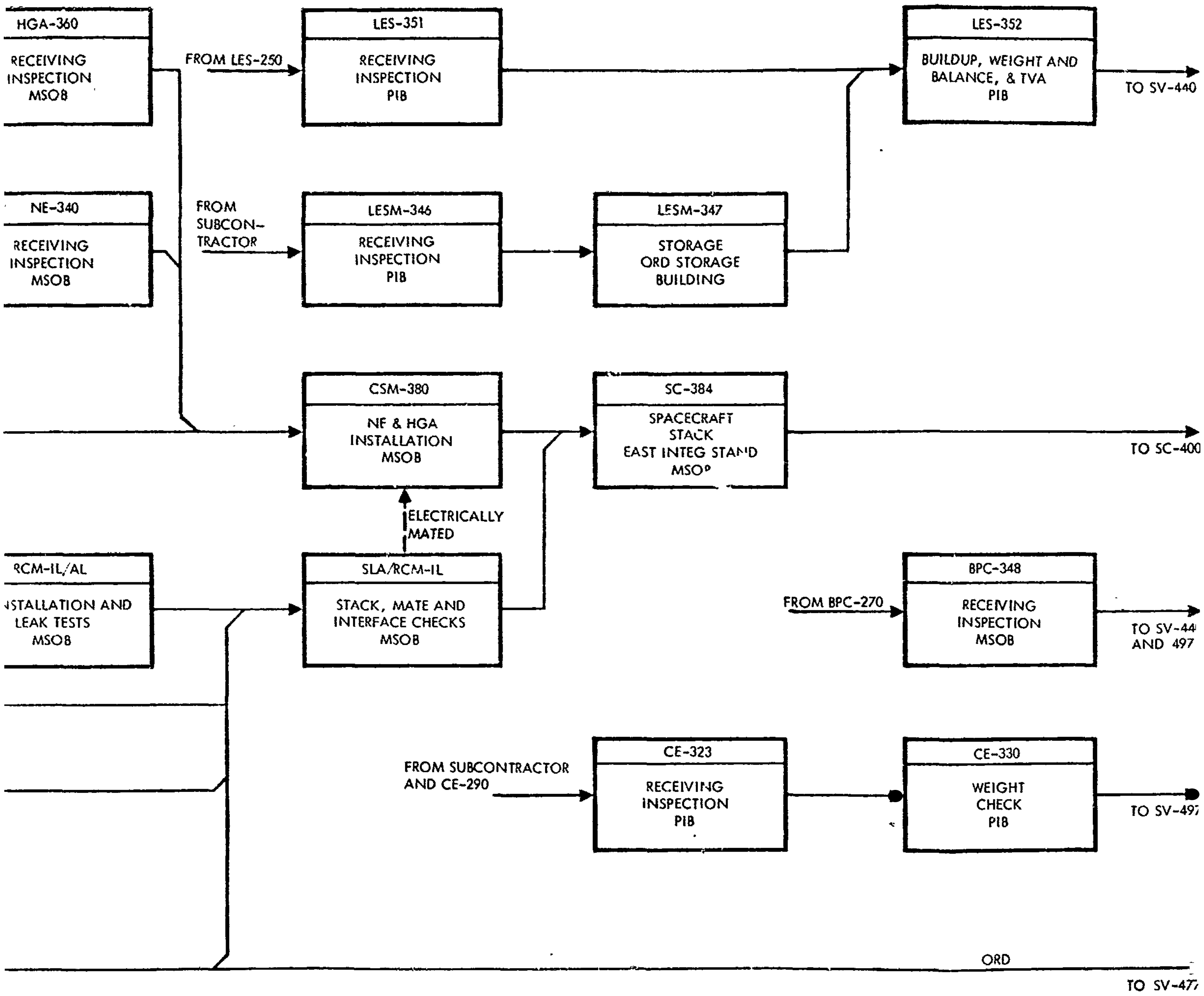
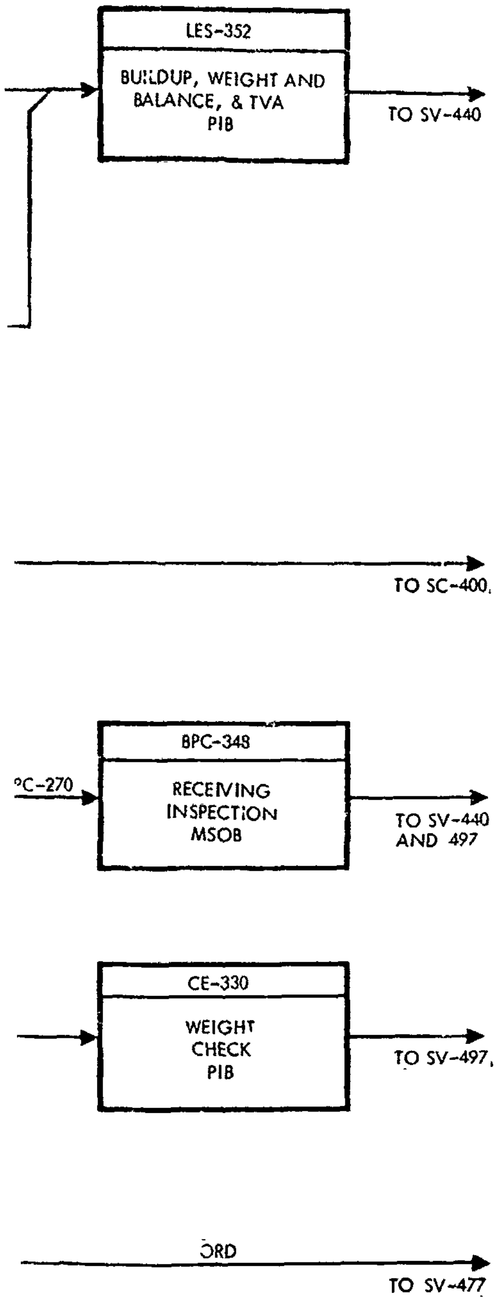


Figure 13.



BLOCK NUMBER ASSIGNMENTS

100 TO 199	DOWNEY AND TULSA
200 TO 299	TRANSPORT TO KSC
300 TO 399	KSC INDUSTRIAL AREA
400 TO 499	LAUNCH COMPLEX

ABBREVIATIONS

AL	AIRLOCK
ALT	ALTITUDE
A/S	ASCENT STAGE
BPC	BOOST PROTECTIVE COVER
CE	CREW EQUIPMENT
CGSS	CRYOGENIC GAS STORAGE SUBSYSTEM
CM	COMMAND MODULE
CSM	CM/SM MATED
DS	DOCKING SUBSYSTEM
D/S	DESCENT STAGE
ECS	ENVIRONMENTAL CONTROL SUBSYSTEM
FCSTF	FUEL CELL SYSTEM TEST FACILITY
GAEC	GRUMMAN AIRCRAFT ENGINEERING CORPORATION
HGA	S-BAND HIGH-GAIN ANTENNA
INSTL	INSTALLATION
INTEG	INTEGRATED
KSC	KENNEDY SPACE CENTER
LAB	LABORATORY
LEM	LUNAR EXCURSION MODULE
LES	LAUNCH ESCAPE SUBSYSTEM
LESM	LAUNCH ESCAPE SUBSYSTEM MOTORS
MSOB	MANNED SPACECRAFT OPERATIONS BUILDING
NE	NOZZLE EXTENSION (SPS)
ORD	ORDNANCE DEVICES
PIB	PYROTECHNIC INSTALLATION BUILDING
PYRO	PYROTECHNIC DEVICES
RCS	REACTION CONTROL SUBSYSTEM
RF	RADIO FREQUENCY
RRT	RENDEZVOUS RADAR TRANSPONDER
SC	SPACECRAFT
SLA	SPACECRAFT/LEM ADAPTER
SM	SERVICE MODULE
SMQ	SERVICE MODULE RCS QUADS
SPS	SERVICE PROPULSION SUBSYSTEM
SV	SPACECRAFT/LAUNCH VEHICLE MATED
TVA	THRUST VECTOR ALIGNMENT
RCM-IL	INDEPENDENT LAB

NOTES:

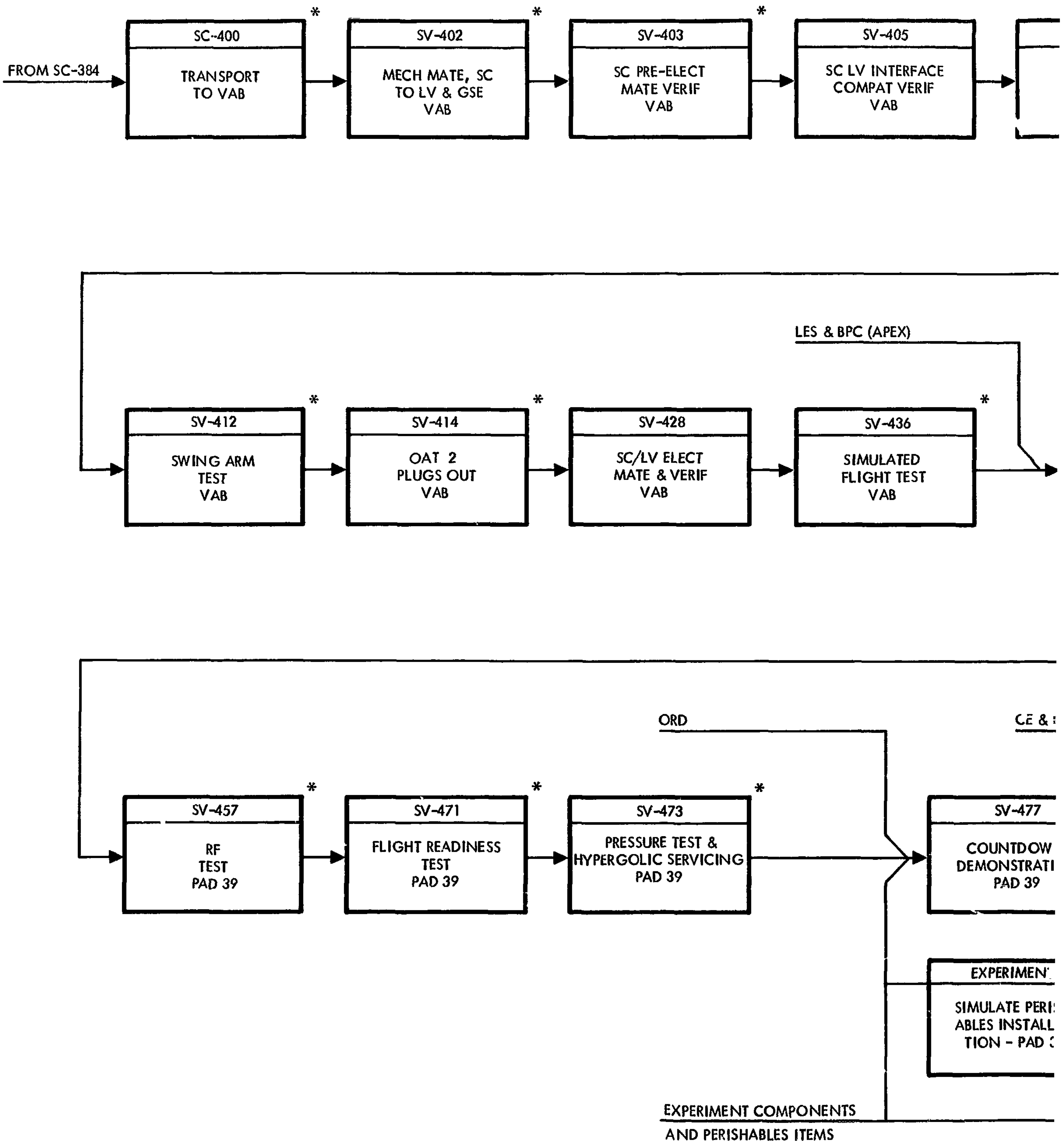
1. SEQUENCE OF FLOWS IS INDICATED BY ARROWHEADS, NOT BY BLOCK NUMBERS.
2. THE FIRST LINE IN EACH BLOCK IS USED FOR BLOCK IDENTIFICATION (e.g., CM-321). THE SECOND AND THIRD LINES DESCRIBE THE FUNCTION PERFORMED (e.g., RECEIVING INSPECTION). THE FOURTH AND FIFTH LINES INDICATE THE TEST STATION (e.g., MSOB).

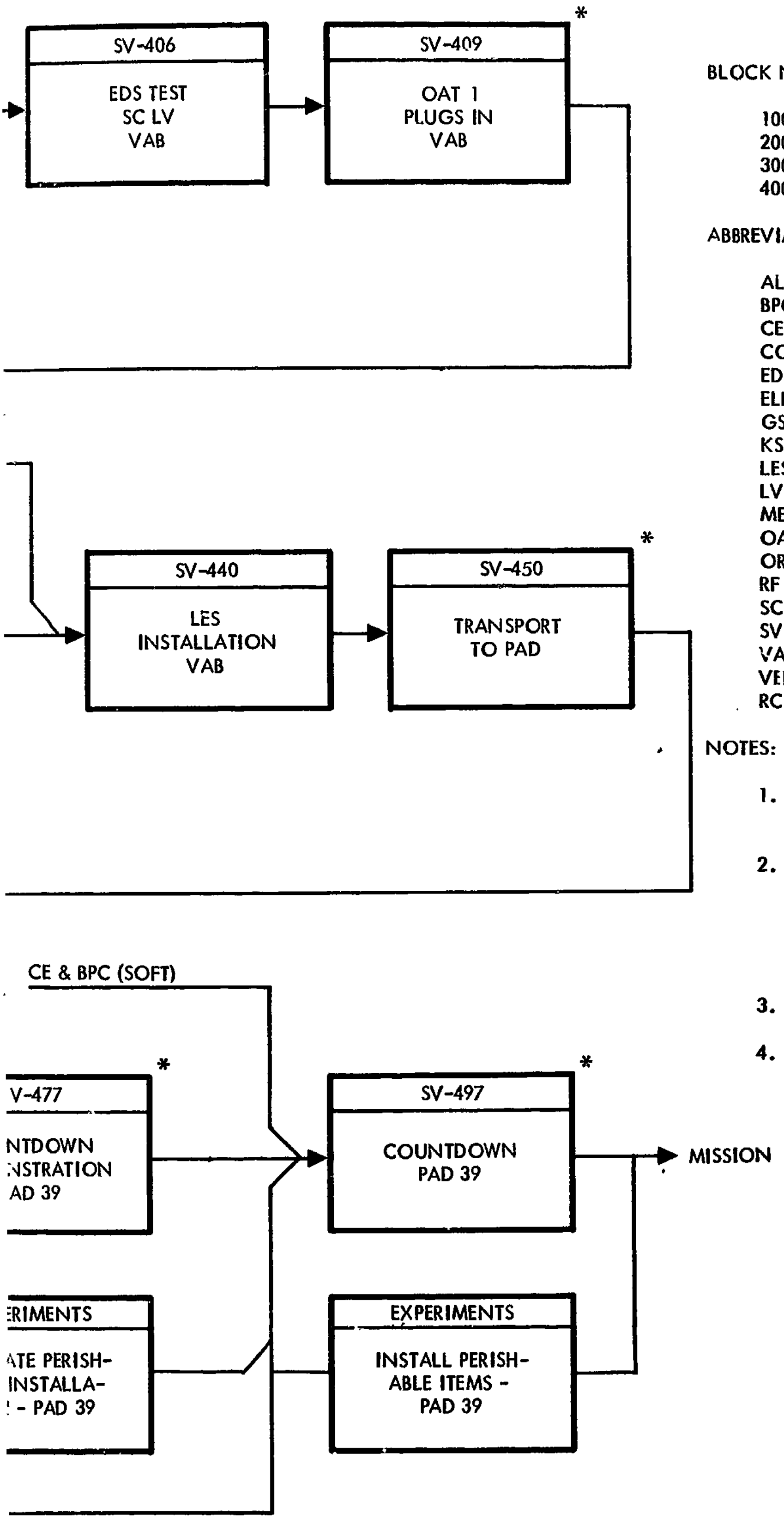
SYMBOLS

[ ] ALTERNATIVE OPERATION

Figure 13. RCML and Block II Spacecraft Flow, KSC Industrial Area

FOLDOUT FRAME 1





BLOCK NUMBER ASSIGNMENTS

100 TO 199 DOWNEY AND TULSA
200 TO 299 TRANSPORT TO KSC
300 TO 399 KSC INDUSTRIAL AREA
400 TO 499 LAUNCH COMPLEX

ABBREVIATIONS

AL	AIRLOCK
BPC	BOOST PROTECTIVE COVER
CE	CREW EQUIPMENT
COMPAT	COMPATIBILITY
EDS	EMERGENCY DETECTION SUBSYSTEM
ELECT	ELECTRICAL
GSE	GROUND SUPPORT EQUIPMENT
KSC	KENNEDY SPACE CENTER
LES	LAUNCH ESCAPE SUBSYSTEM
LV	LAUNCH VEHICLE
MECH	MECHANICAL
OAT	OVERALL TEST
ORD	ORDNANCE DEVICES
RF	RADIO FREQUENCY
SC	SPACECRAFT
SV	SC/LV MATED
VAB	VEHICLE ASSEMBLY BUILDING
VERIF	VERIFICATION
RCM-IL	INDEPENDENT LABORATORY

NOTES:

1. SEQUENCE OF FLOW IS INDICATED BY ARROWHEADS, NOT BY BLOCK NUMBERS
2. THE FIRST LINE IN EACH BLOCK IS USED FOR BLOCK IDENTIFICATION (E.G., SV-414). THE SECOND AND THIRD LINES DESCRIBE THE FUNCTION PERFORMED (E.G., OAT 2). THE FOURTH LINE INDICATES THE TEST STATION (E.G., VAB).
3. * INDICATES TESTS IN WHICH RCM-IL WOULD PARTICIPATE.
4. FOR SIB FLIGHTS READ VAB AND PAD 39 AS PAD 34.

Figure 14. RCML and Block II Spacecraft Flow, Launch Complex 39

The SLA work platforms will require modification, and new launch complex antenna coupling sets will also be required through the SLA that are compatible with the CSM.

Industrial Complex

Checkout in the industrial area presents similar problems. The checkout sequence of the CSM for the flight that will carry the dependent laboratory will be concurrent with the checkout of the laboratory. If the LM/GSE is modified for independent laboratory use at the launch complex, similar modification to the manned systems operations building (MSOB) LM/GSE may permit its use on the independent laboratory in the industrial area. It can be readily ascertained that scheduling checkout of the independent laboratory will be constrained by the availability of required GSE equipment.

GSE Integration

Another factor that must be considered is the design of the independent laboratory so that it can use the available CSM/GSE in Downey. If this design is effected, subsequent utilization of LM equipment will probably be further complicated. Conversely, design of the independent laboratory to fit LM launch pad umbilical and GSE connections will compound the checkout problem at Downey using CSM/GSE. A comprehensive GSE utilization analysis of the tradeoffs involved appears mandatory.

Experiments

Installation and checkout of experiments, which either the dependent or independent laboratory will carry, presents an undefined problem area. The subsequent identification and resolution of these problems depends on experiment design, flight requirements, and identification and application to a given flight configuration. Other problems must be anticipated as the impact on Florida is analyzed rather than being inspected. The operational analysis and problem solution effort will be time consuming, and it is recommended that this analysis be initiated as soon as possible.

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III. TEST AND OPERATIONS

SCOPE

Test and operations studies were performed in support of engineering development of the operations requirements for postrecovery, Downey test prior to delivery of the renovated vehicle, and, to a limited extent, field operations at KSC. The refined operations requirements, described in Section I, were then subjected to implementation planning studies to determine those resources required in addition to presently programmed Apollo resources. Alternate approaches were considered for all phases of operations during the study. Plans and schedules were developed to form a basis for determining operations resources needs and utilization scheduling.

The following assumptions and ground rules were the basis for the study program:

1. Apollo resources would be used to the maximum extent possible.
2. There must be no impact on the Apollo program.
3. Ground operations would be conducted in the same manner as for Apollo with respect to procedural and quality assurance measures.
4. The study assumed a program of six laboratories (RCML) and five renovated command modules (RCM).
5. Postrecovery operations would be sequenced to provide earliest possible initiation of preservation requirements as determined by engineering analysis.
6. Apollo CSM preflight procedural operations and quality assurance measures would be adapted to postrecovery operations as well as RCM and RCML checkout.

Detailed ground rules and assumptions are discussed in the applicable operations portion of this report, and provide a basis for the operations resources required to implement the RCM and RCML program(s). Changes to the existing Apollo capability were determined through assessment of available Apollo resources. These studies were coordinated with NAA Apollo program management. It was concluded that the RCM/RCML program operations were feasible, with some supplemental resources required.

SHIPBOARD RECOVERY OPERATIONS

Shipboard recovery operations include the time from command module splashdown to ship arrival at the forward area and removal of the CM from the ship to a forward area. Operations consist of those procedures specified in SID 66-1493, Apollo S/C Postretrieval Procedures, Supplement SM 2A-08-SC012. Additional RCM and RCML operations include the start of aft heat shield removal and core sampling at the earliest time after splashdown. Salt spray and water contamination may result between the inner and outer volumes of the CM, which will cause structural degradation and severe cost penalties if not decontaminated at the earliest possible time after CM splashdown.

The shipboard operations task times shown as part of the schedule in Figure 15 were estimated based on limited Apollo experience applicable to removing access panels for CM RCS leak checks, inspections, checklist procedures, photographic coverage, and start of aft heat shield removal. Follow-on operational flow times, developed from S/C 012 and subsequent vehicles, may further define these times.

The following ground rules and assumptions were used during this study to determine schedule, personnel, and equipment requirements.

1. Early removal of the aft heat shield is highly desirable.
2. Safety is of prime importance in respect to radiation effects, red tagging unfired pyros/mortars, and the protection of the crew from CM RCS toxis and flammable fumes. It was assumed that NASA/NAA safety requirements would be coordinated with all Department of Defense activities aborad ship.
3. A contractor team would participate in all operations aboard ship.
4. All exterior and interior parts of the CM to be inspected and photographed before and after ship board operations to maintain quality assurance coverage and documentary records.
5. Average ship travel to a forward port assumed to be three days.
6. Recovery ship outfitting two weeks prior to launch for ship mission support preparation.
7. Additional materials and equipment required aboard ship for aft heat shield removal, core sampling, and wash-spray cleaning of the CM between inner and outer volumes.

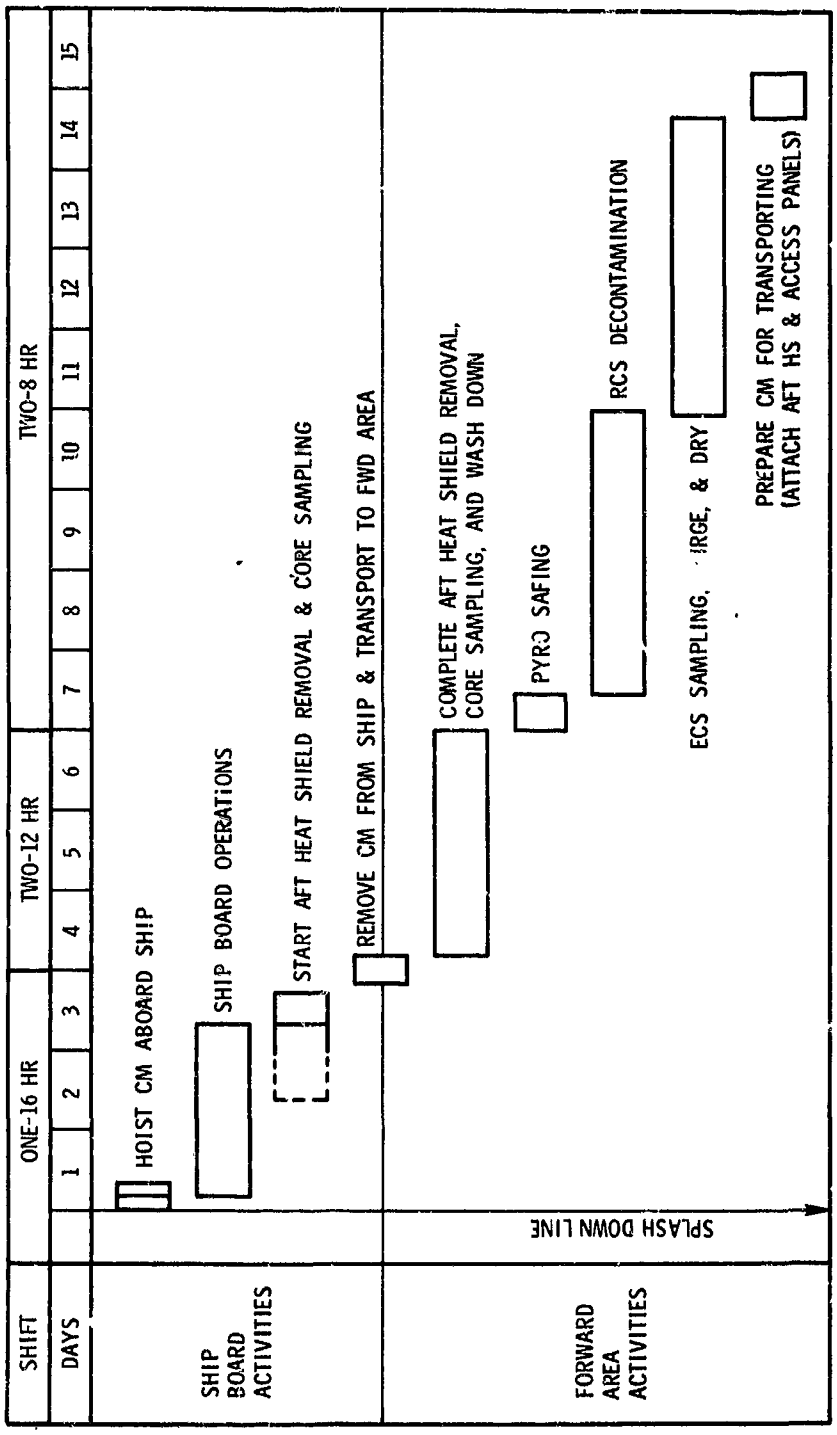

Figure 15. Recovery Operations Schedule

8. Assume a remote forward area but possible ship travel to an American coast. Complete aft heat shield removal and wash down can be accomplished if ship travel exceeds six days.

9. Core samples to be obtained for both NASA-MSC and NAA/AVCO.

This study was limited to a prime landing area considered for CM retrieval. Other possible landing areas that may involve sending personnel and equipment by air to a new location were not considered. Evaluation of shipboard operations indicated that the aft heat shield removal may be accomplished at the hander deck level in an area remote from the aircraft. A sheltered area is required to prevent any additional salt spray from entering the CM interiors.

The schedule for shipboard operations presented in Figure 15 shows the CM being hoisted with the astronauts remaining in the craft until the CM is aboard ship. Two hours additional time are required for early removal of the astronauts by helicopter to the ship. For approximately two and one-half days, procedures are followed as outlined in NASA support manual, Apollo S/C Postretrieval Procedures, Supplement SM 2A-08(SC012) (SID 66-1493).

As the ship approaches the forward area, aft heat shield removal and core sampling begins. Aft heat shield removal and core sampling may begin earlier, depending on the completion of safety inspections and decisions of NASA/NAA team leaders. The CM should be protected from adverse environments upon removal to a forward area.

If the CM reenters at a different location than planned, it is recommended that shipboard C2A Greyhound aircraft transfer the crew and equipment to the new location. Approximately 15,000 pounds can be transported by this aircraft. In addition, if forward area equipment is required at a new landing forward port, it may be possible to provide Logistics support for crew and equipment transport to that area for systems decontaminations support. It is highly desirable to provide portable equipment that may be easily transported.

Analysis of the tasks and schedules of operations to be performed aboard ship indicates a requirement for a NAA test team consisting of a team leader, seven technicians, and one quality control expert. Specialist technicians are required in the areas of pyro technic safing and CM RCS inspections. These two technicians should also be qualified to assist the team leader in performing vehicle status checklists and status inspections. One photographer technician is required to assure documentation coverage for NAA evaluations. Four structural mechanics are required for heat shield core sampling, and removal of access panels and the aft heat shield. The quality control expert is required to maintain quality assurance records.

Delta equipment requirements aboard ship include (1) a support structure to lift the CM for removal of the aft heat shield, (2) drill unit, (3) core drill set, (4) wrench kit, (5) cutting and crimping set, (6) fresh water, (7) isopropyl alcohol, (8) spraying equipment, (9) core canisters, and (1) heat shield vent plugs. A gaseous nitrogen drying unit is required for heat shield drying operations. Also, a cover is required to provide protection for the CM during transport. If safety permits operations to be performed at the hanger deck level, a CM enclosure may not be required. Checks will be performed for radiation levels, unfired mortars and pyros, and CM RCS fumes before removal of the CM from the flight deck to the hangar deck. Equipment required for completion of the aft heat shield wash-spray and drying operations will be removed from the ship to the forward area to complete these operations.

FORWARD AREA OPERATIONS

Forward area operations begin where the CM is received at the dock and continue to CM placement in the air transport for shipment to the contractor facility. Operations pertinent to the RCM and RCML consist of procedures specified in SID 66-1494 Apollo RCS Deactivation Procedures Handbook, plus the procedures developed during this study (e.g., shield removal; core sampling; water/alcohol wash-spray of the outer surface of the inner vessel and inner surface of the outer vessel; ECS flush, purge, and drying; and reinstallation of the aft heat shield).

Task times were estimated based on Apollo experience applicable to aft heat shield removal, core sampling, pyrotechnic safing, CM RCS decontamination, and ECS purging and drying operations. These flow times are subject to updating from subsequent Apollo CM postrecovery operations.

The following ground rules and assumptions used during this portion of the study to determine schedule, personnel, and equipment requirements are:

1. Aft heat shield removal as early as possible.

2. Safety of equipment and personnel of prime importance.

3. Photographic coverage and quality assurance records to provide all pertinent information before, during, and after operations for complete system records and engineering evaluation.

4. Personnel other than the shipboard crew to arrive in the forward area about two days in advance of the retrieval ship entry into the forward port.

5. Equipment necessary to complete aft heat shield removal, wash-spray, and drying operations to be transferred from ship board to the forward area.

6. RCS decontamination and pyrotechnic safing procedures, would be identical to Apollo procedures.

7. ECS sampling, purge, and drying operations to be performed.

8. Aft heat shield and crew compartment access panels to be re-attached to the CM for shipment.

9. Technicians required for aft heat shield removal, coring operations, and wash-spray and drying operations to be returned to the contractor facility after completion of these operations.

10. The deactivation crew and equipment to be returned to the contractor facility.

This study was limited to forward areas associated with primary Atlantic and Pacific recovery areas. Other CM landing areas were not considered except in recommendations of shipment of personnel and equipment by means of government airlift for necessary operations to preserve the CM's at the earliest date after splashdown. Analysis of forward area operations resources indicate a need for removal of the aft heat shield in the open air with the CM protected from adverse environments until after RCS decontamination. Depending on the availability of government-furnished 440 volt ac 3-phase, 115 volt ac 1-phase, and 28 volt dc, portable power supplies, the CM may have to be moved to an enclosed building for completion of ECS purge and drying operations.

The recovery operations schedule for forward area operations, Figure 15, shows that aft heat shield removal and wash-spray and drying operations require approximately three days for completion, and will be performed by an eight-man crew. The eight structural mechanic technicians will be returned to the contractor facility after heat shield removal. The schedule shows ECS purge and drying operations to require a nine-man crew to work four days at 16 hours per day. This crew will consist of two engineers, four technicians, two quality assurance personnel, and one photographer. The total increase of time in the forward area is approximately 10 days. As compared to the normal NAA five-man recovery crew, eight personnel must be transported to the forward area by government-furnished airlift at splashdown plus one day. Changes from Apollo procedures include ECS purge and drying operations, structural support of heat shield removal, and quality assurance. The aft heat shield and access panels are secured to the CM in preparation for shipment to the contractor plant. Equipment and NAA crews will be returned to Long Beach, California, by government-furnished airlift. The CM will be transported on a flat-bed vehicle and delivered to NAA Downey Building 247 for further operations. During shipment, the CM will be protected from adverse environments and damage from movement.

Delta equipment and facility resources will consist of equipment for ECS flush, purge, and drying; equipment transferred from the ship for core sampling, aft heat shield removal, and washing operations; and equipment to provide protection to the CM during transport.

If anomalies which require preservation or decontamination occur in the CM systems during flight, a delay in RCM/RCML associated operations may be anticipated until the source of the anomaly is determined. However, aft heat shield removal and preservation will be accomplished as soon as possible if that structure is not considered a part of the anomaly.

DOWNEY BUILDING 247 POST RECOVERY OPERATIONS

Results of the study indicate that no additional operations need be added to Apollo, Phase I postrecovery operations, as denoted for Apollo Block I in CCA 1020 Contract NAS 9-150. However, there is a four-day reduction in the Phase I operations at Downey, since the aft heat shield removal and core sampling begins aboard ship and is completed in the forward area. This reduction of Phase I work effort consists of partial visual inspections and photographic coverage of all accessible CM internal and external areas, core sampling operations and removal of the aft and crew compartment heat shields; removal of ECS water glycol, waste, and potable water samples for analysis; and removal of access panels for system inspections and operations. Total work days, not including transportation from CM splashdown to completion of Building 247 operations, is approximately 28 work days (not including any Apollo Phase II anomaly tests.)

SYSTEMS PRESSURE TEST

An RCML (I) systems pressure test schedule is presented in Figure 16. In performance of these tests, the RCML (I) will be received in Building 1 for systems pressure tests after systems installations. All systems will be attached with exception of the SM RCS quads and meteoroid shields. The SM RCS quads will be pressure tested in Building 289 Cell 5A or 5B prior to RCML arrival in Building 1. The ECS system will be leak checked and proof-pressure tested, as will the CGSS, the EPS and ECS radiator water glycol systems will be leak checked, and the pressure vessel, docking ring seal, and airlock will be functionally leak checked. The RCS quads will be received from Building 289 Cell 5A or 5B and installed on the cruciform. The connections of the quad to the cruciform will be leak checked at proof pressure. The GSE/SMD will be disconnected and the RCML moved to the

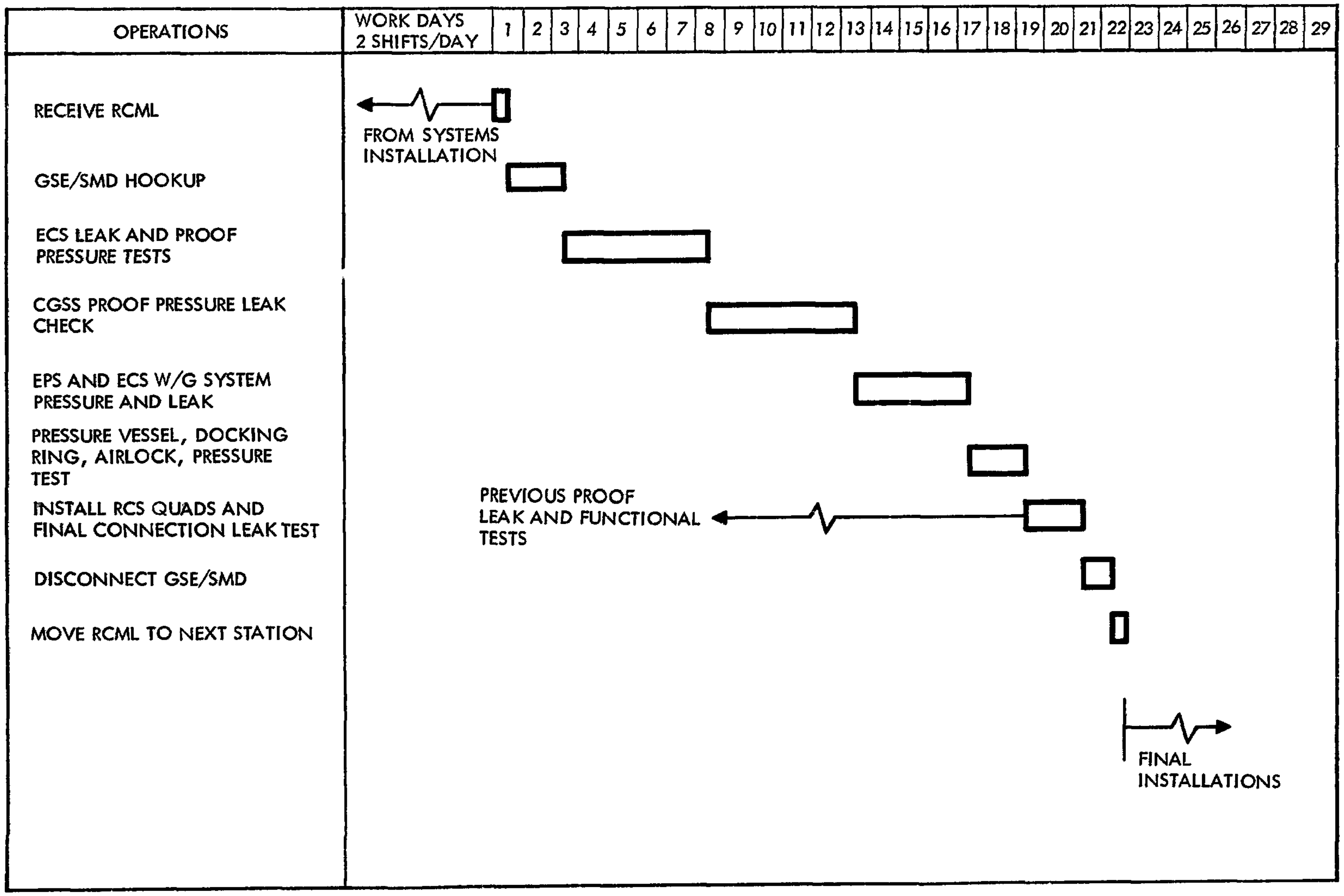

Figure 16. RCML (I), Building 1, System Pressure Tests

next station for final installation. This schedule is based on a two-shift work day.

A pressure test cell utilization study was performed to determine if RCM and/or RCML vehicles will impact Apollo Block II pressure tests. The test cells vehicle loading schedules, (Figure 17) was developed. The upper portion of the schedule shows RCML (I) 020 coincident with S/C 109, indicating that two vehicles require the Building 1 test cell at the same time for systems pressure testing. The equipment and facilities available do not allow for simultaneous testing of two articles. Renovated vehicle schedules can be adjusted to apparent noninterference with Apollo, however, the resulting test cell utilization load allows little or no test cell maintenance time with high probability of Apollo schedule impact. In addition, schedule adjustment to availability of the Building 1 test cell may be adverse to scheduling use of other cells and Building 290 checkout resources. While the RCM and RCML (I) pressure test schedules were developed by applying a 90 percent learning factor to present Apollo test times, indications are that the number of test operations performed on Apollo spacecraft may increase slightly in the future. All factors considered, Building 1 cell loading becomes critical, (high-risk scheduling), at a flow rate of 10 vehicles per year. Therefore, this study revealed a requirement for additional test cell capability to support the RCM and RCML programs. The lower section of Figure 17 reflects the subassembly test cell, Building 289, test cells 5A and 5B requirements developed from analysis of RCM and RCML requirements, and Apollo utilization. The indicated continuous utilization by Apollo Block II includes practical allowance for station maintenance. Detailed analysis was conducted of the RCM/RCML program requirements with respect to determining the extent of overload and impact on Apollo. It was concluded, subject to further study, that it was not feasible to process an additional two to four vehicles per year through these subassembly pressure test facilities.

Solutions to the test cell overload problem are discussed in Section X of this report. Modifications of test cell GSE/SMD equipment may be necessary to support checkout of the SM EPS radiators, CGSS, and airlock. Further study is required to determine time-sharing of equipment, such as recording and pneumatic units, to facilitate this checkout which is normally performed on the SM in Building 260.

DOWNEY BUILDING 290 OPERATIONS RESOURCES ANALYSIS

Operations planning studies and analyses were performed to determine support resources required to implement the RCM and RCML Downey Test Operations in Building 290, evaluate feasibility of using programmed Apollo capability, and provide preliminary identification of required supplements to these resources. This implementation planning was coordinated with and based on the operations requirements analysis presented in Section I of this report.

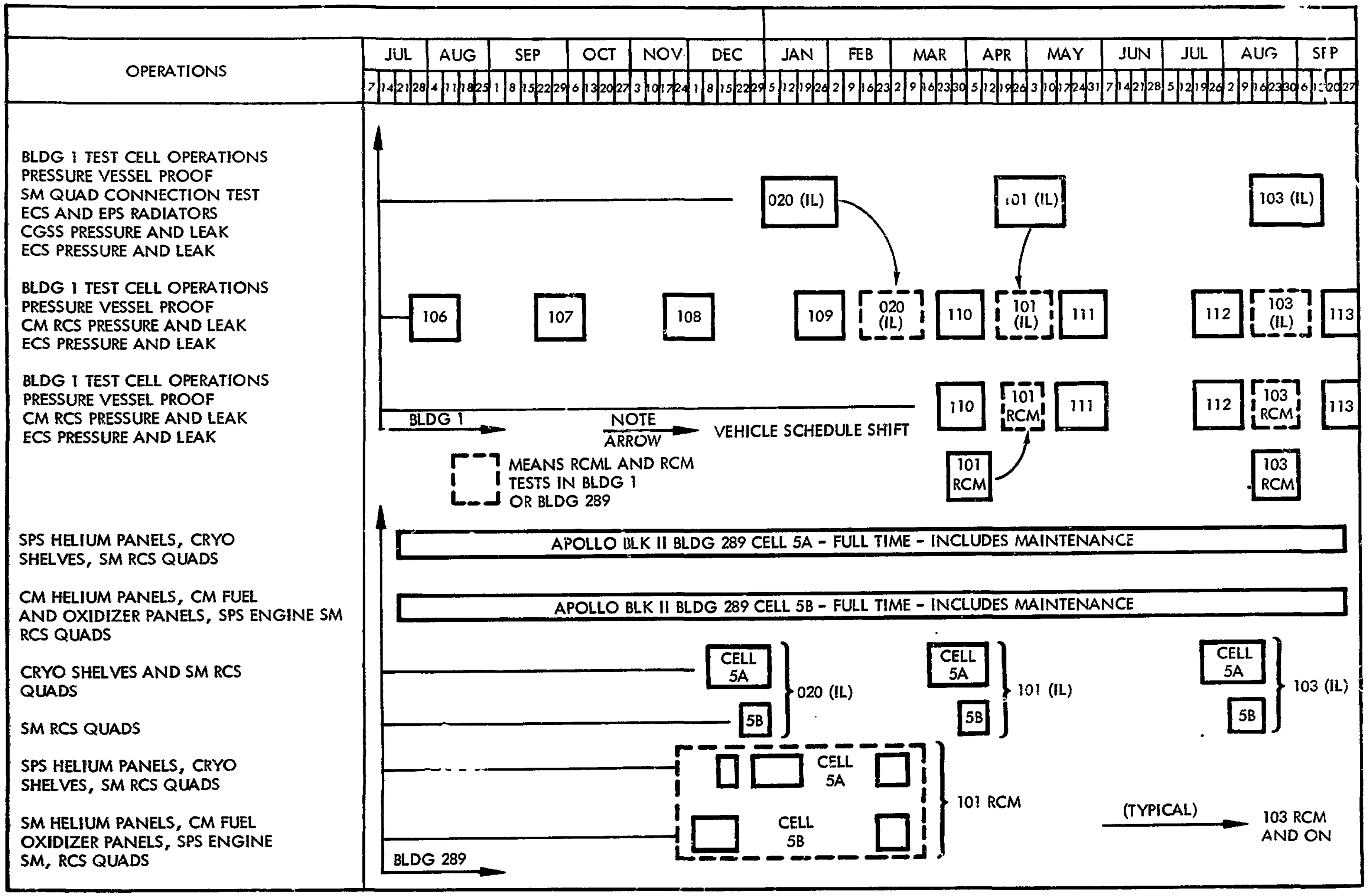

Figure 17. Test Cells Vehicle Loading Schedule, Block II, RCM and RCML

Downey Test and Operations plans and schedules developed during this study for use in the RCML resources utilization analysis are reflected in the operation flow schedules shown in Figures 18 and 19 for the dependent laboratory (RCML (D)) and the independent laboratory (RCML (I)), respectively. RCM studies were based on a typical Apollo Block II Downey Test Operations flow schedule as shown in Figure 20, which assumes a Block II service module, and is subject to change for an AAP designed service module. It can be seen that the RCML (D) laboratory requires little support except for pressure testing, and therefore, was of no significance to the Building 290 analysis.

Early in the study, it became obvious that time was not available for analysis of all possibilities associated with the RCM and RCML (I). A cursary examination revealed factors of cost effectiveness, master scheduling, and impact on Apollo, which were considered in narrowing the analysis. Figure 21 shows Apollo station utilization per MDS 9, Rev. 3. The preceding factors included, but were not limited to, the following:

1. Utilization loading of the Building 290 checkout station becomes critical at eight spacecraft per year, allowing an increase of two over Apollo Block II. Problems on any spacecraft will impact all downstream vehicles processed in that station. AES preliminary definition studies recommended five Building 290 checkout stations for a delivery of eight spacecraft per year to avoid this schedule risk[1].

2. An additional station is mandatory if two RCM or RCML (I) vehicles are to be in the Building 290 checkout area at the same time (any increment of overlap including occupancy), based on the ground rule that there must be no impact to Apollo Block II deliveries.

3. The RCM can be accommodated by the Block II stations at a delivery rate of one per six months by increasing the quantities of certain equipment time-shared between stations. The additional loading would, however, eliminate station slack time and involve potential Apollo schedule risk to Block II spacecraft 110 and subsequent.

4. A new station must be provided or an existing station modified to support the RCML (I) configuration.

5. It was assumed that if the combined RCM and RCML (I) checkout flow loading requires an additional checkout station in Building 290, the new station would be designed for RCML support in consideration of cost effectiveness.

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[1] Ground Support and Logistics. NAA S&ID SID 65-1639

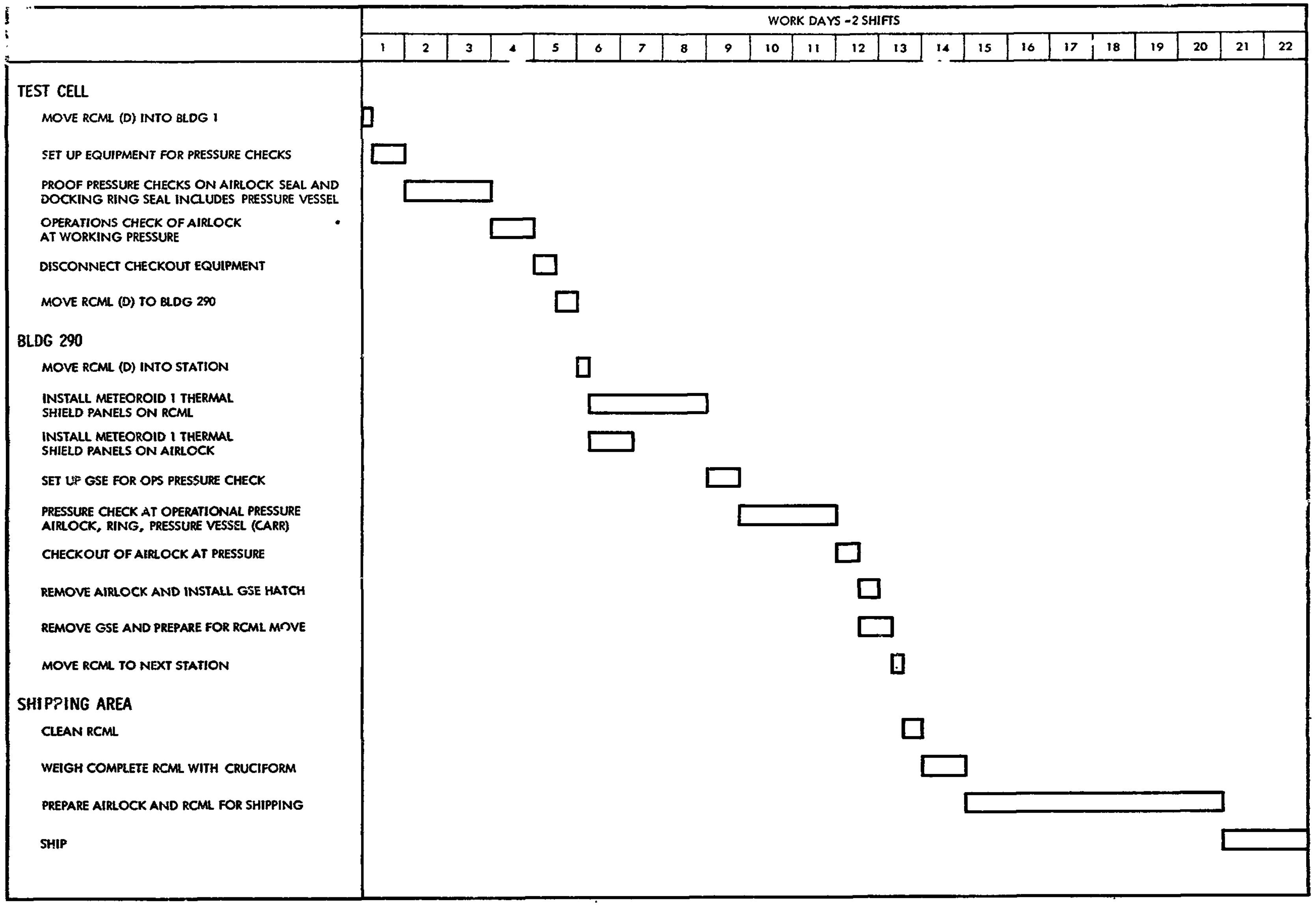
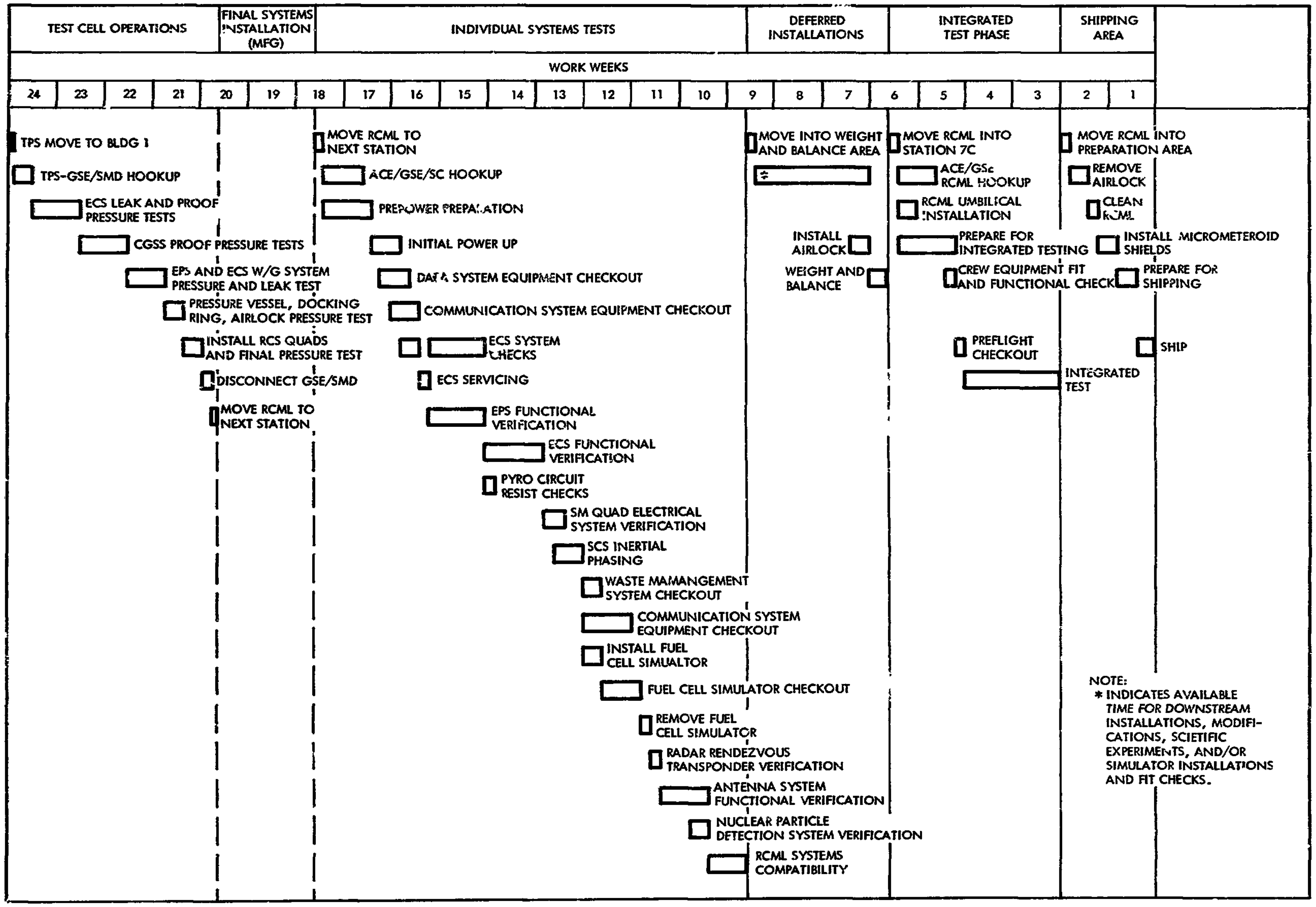


Figure 18. RCML (D) Checkout Requirements, Downey



NOTE:
* INDICATES AVAILABLE TIME FOR DOWNSTREAM INSTALLATIONS, MODIFICATIONS, SCIETIFIC EXPERIMENTS, AND/OR SIMULATOR INSTALLATIONS AND FIT CHECKS.

Figure 19. RCML (I) Downey Checkout Flow

6. Lead time for engineering, equipment provisioning, and site activation dictates S/C 020 as the earliest possible RCML (I). It is noted that for a new station, approximately eight months are required for GSE procurement, plus three months for site activation.

7. The cost of either modification of an existing Apollo station, or implementation of a new station to support the RCML (I) will be significant against the procurement of only one RCML (I).

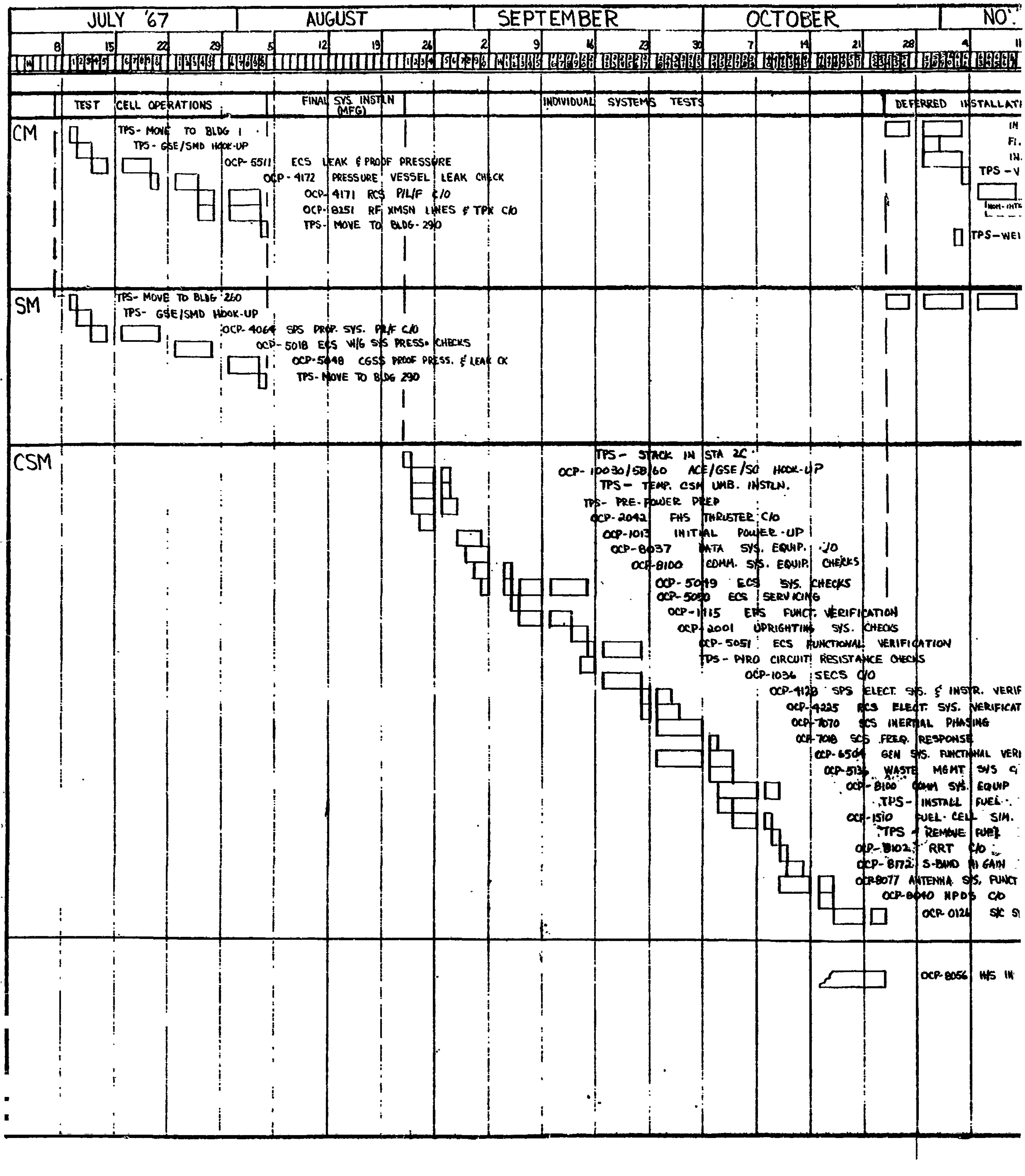
Using the preceding factors, a station utilization plan was evaluated for mixed reuse of all command modules from the candidate spacecraft listed in Table 1. The checkout was scheduled to support delivery of each renovated vehicle as early as possible after the original Apollo launch. S/C 012 and 014 command modules were assigned as dependent laboratories to use the RCML (I) checkout stand as a work station with portable systems test GSE. Since S/C 020 and 101 overlapped, S/C 101 was selected as an RCM. By changing the station assignments for Apollo Block II S/C 110 and subsequent, three RCM (S/C 101, 103, and 107 or 108) would be processed for delivery from September 1968 through 1969. Three RCML (I) could be processed during the same calendar period in a new station.

Station utilization plots were developed for use of the preceding above candidate Block II spacecraft, either all as RCM or all as RCML (I), without addition of a new station. Figure 22 shows that the RCM requirements overload the four Apollo stations, causing loss of mandatory station maintenance periods. Figure 23 shows that an additional station is required for RCML (I) if the desired delivery schedule is to be maintained.

These initial studies indicated the need for evaluating a total program with additional candidate spacecraft to determine requirements and station scheduling for a total of six RCML (S/C 012 and 014 as dependent) and five RCM. Such a program is feasible with one new station for RCML (I). Final delivery of the combined vehicles would be in early 1970, assuming S/C 115 as the last Apollo spacecraft, and mid-1970 if additional Apollo vehicles are programmed beyond S/C 115.

The impact on Apollo Block II checkout station utilization and activation requirements for the RCML (I) and RCM is shown in Figure 24. When compared to Figure 21 it can be seen that S/C 110, 111, and 112 have been reassigned to another checkout station with no preceding slack time. Figure 24 also reflects total loading of equipment, including ACE-S/C requirements.

FOLDOUT FRAME 1



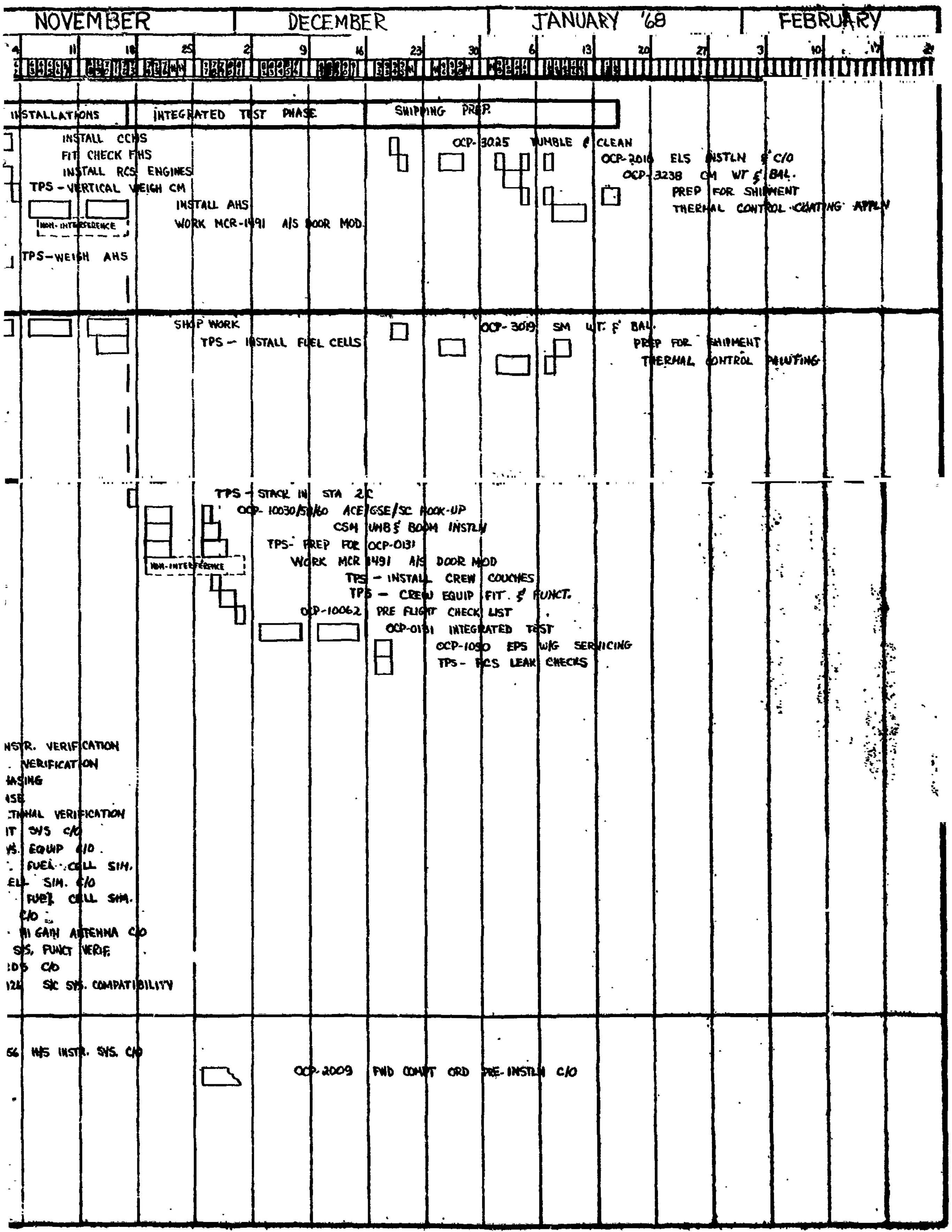


Figure 20. Spacecraft 106, Downey Checkout Flow, MDS 9 Rev 3

FOLDOUT FRAME 1

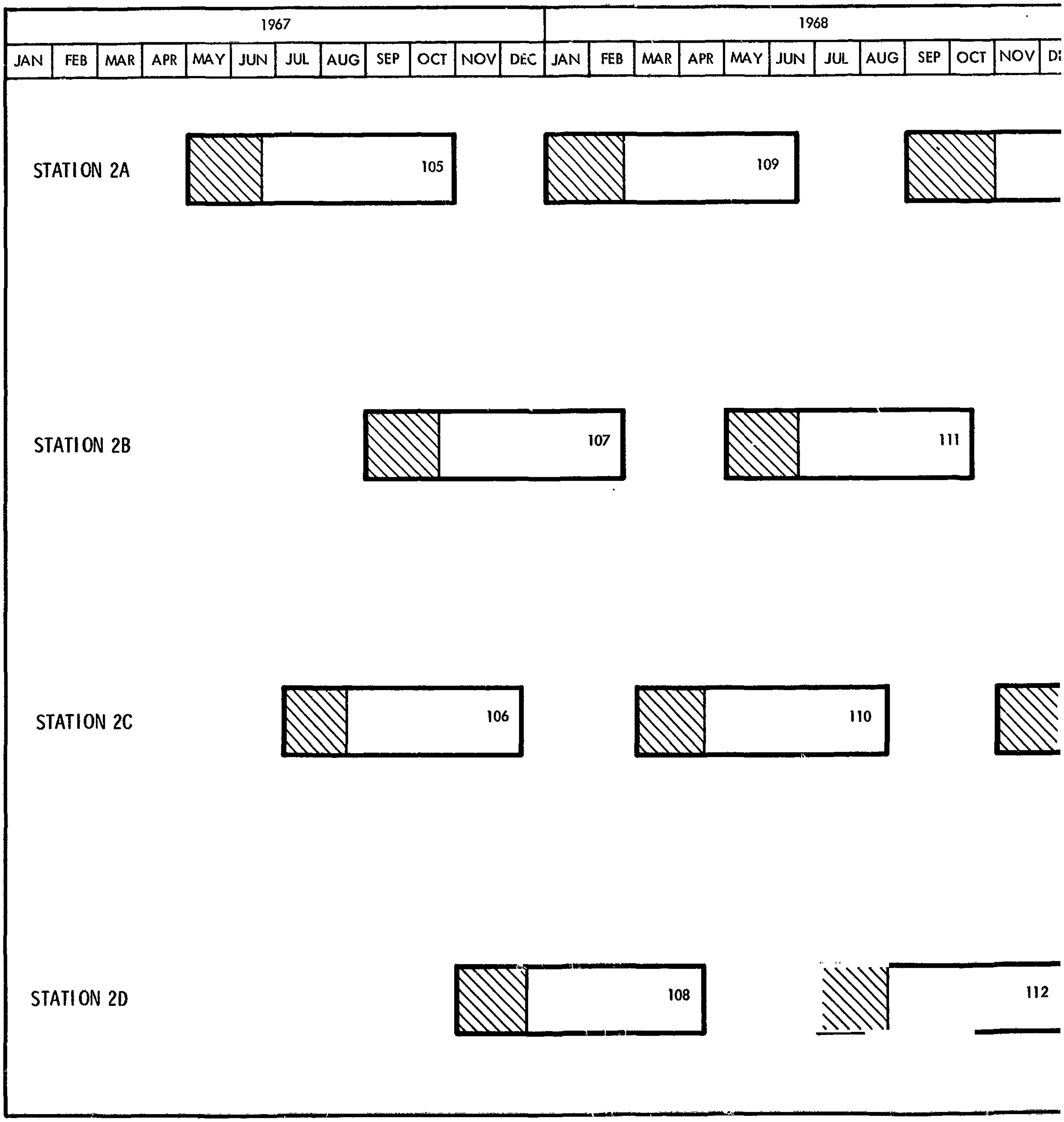
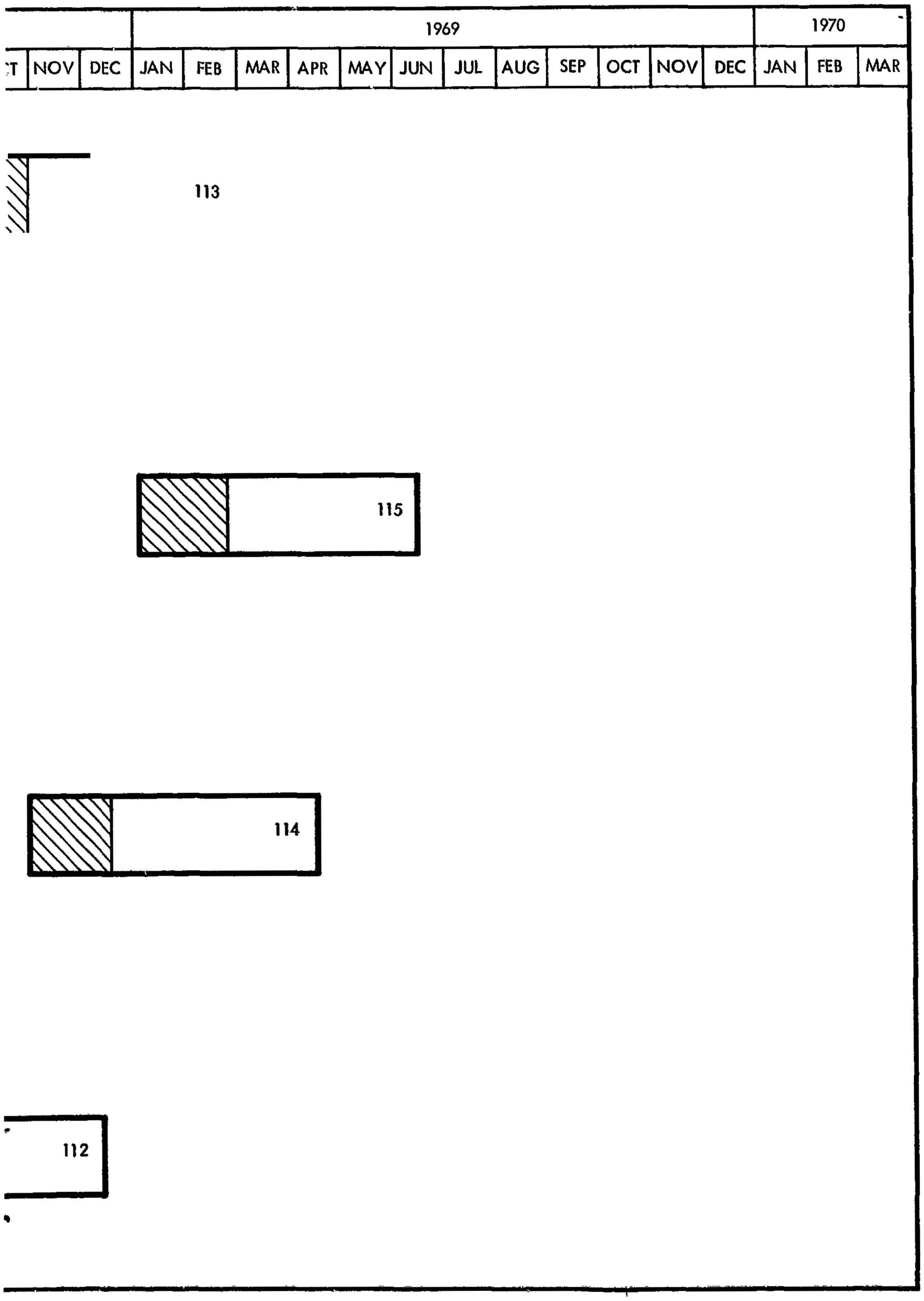


Figure 2.

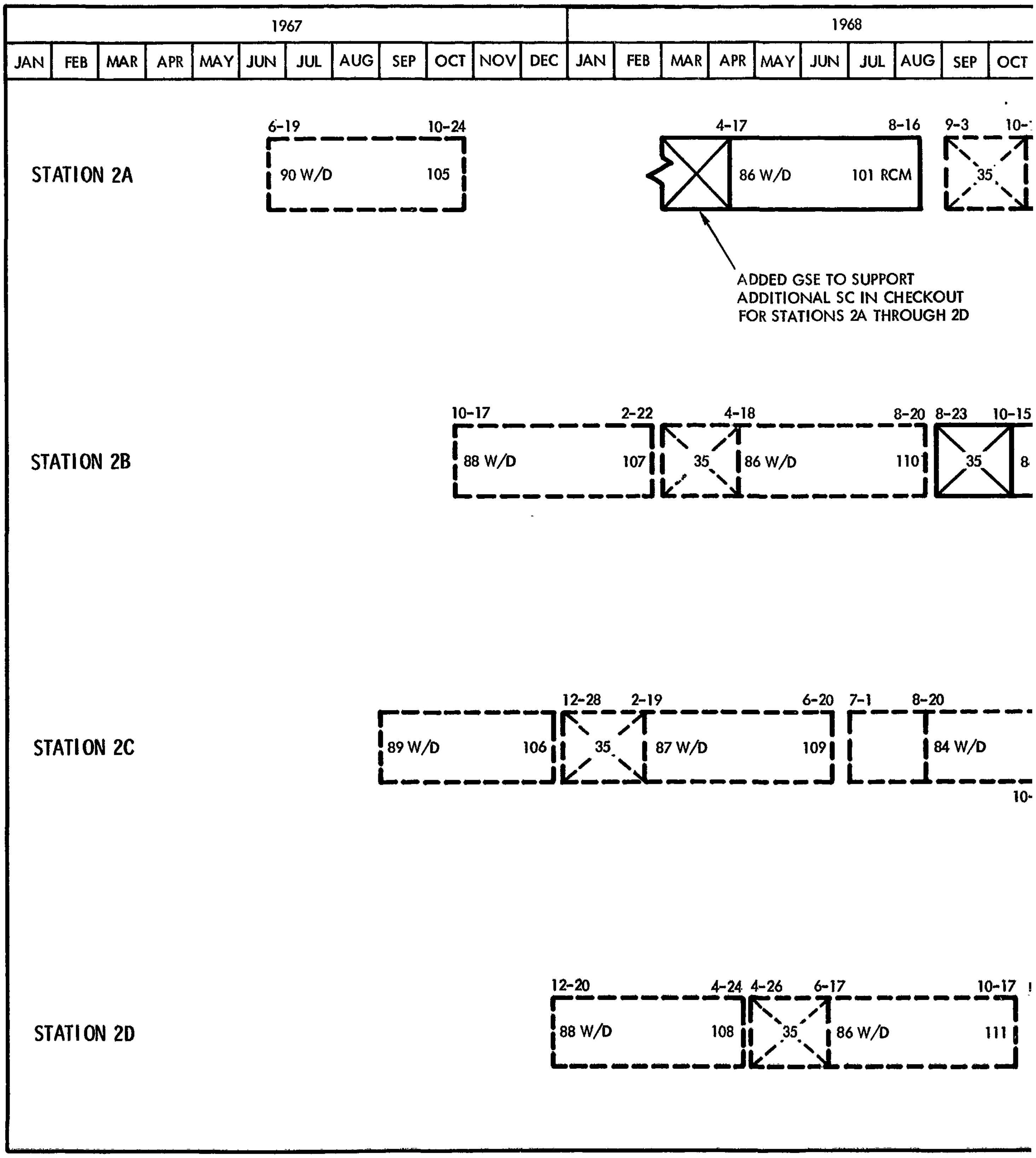
FOLDOUT FRAME 2



igure 21. Checkout Station Utilization, Block II, per MDS 9 Rev 3

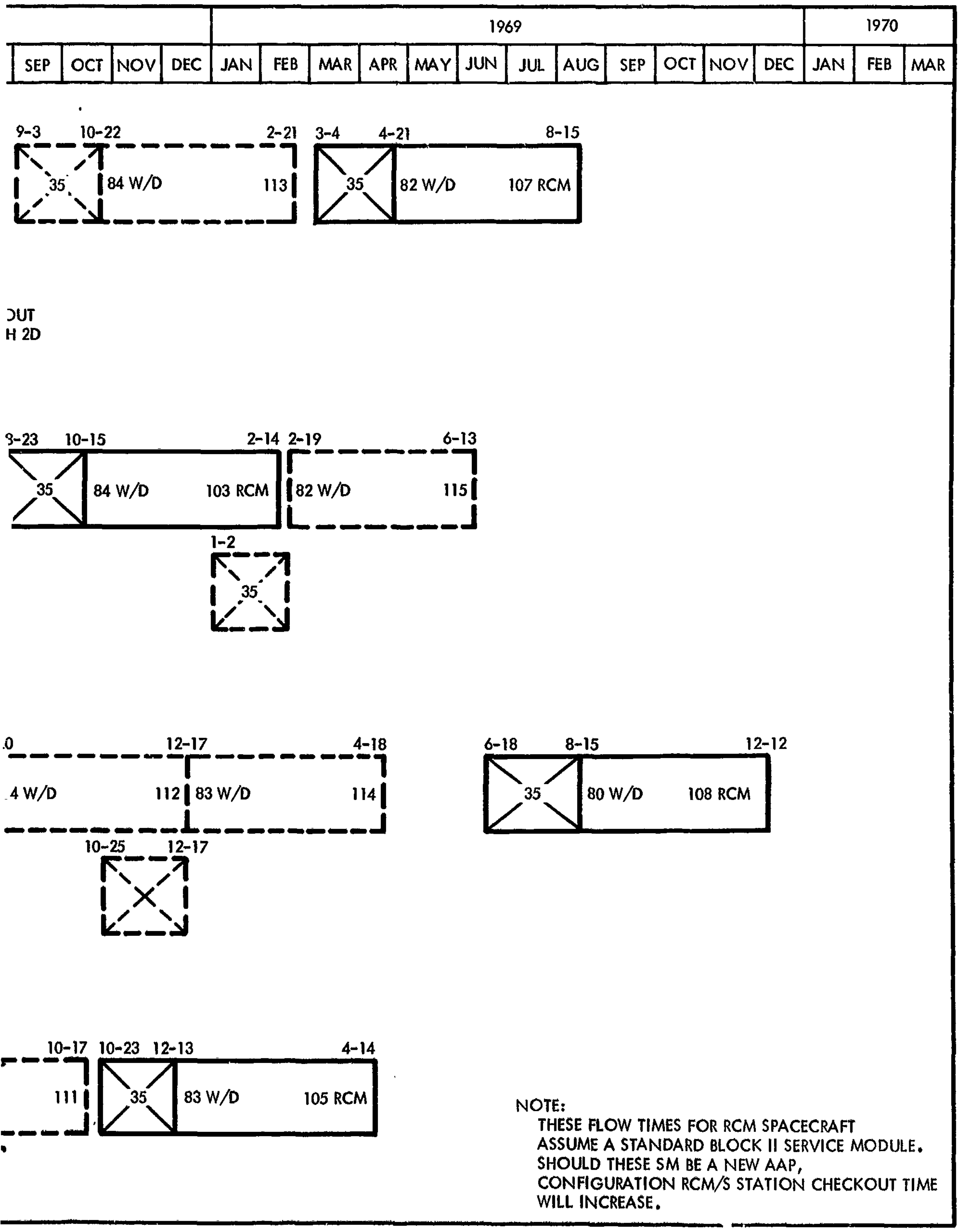
FOLDOUT FRAME 1

NORT



ADDED GSE TO SUPPORT
ADDITIONAL SC IN CHECKOUT
FOR STATIONS 2A THROUGH 2D

FOLDOUT FRAME 2

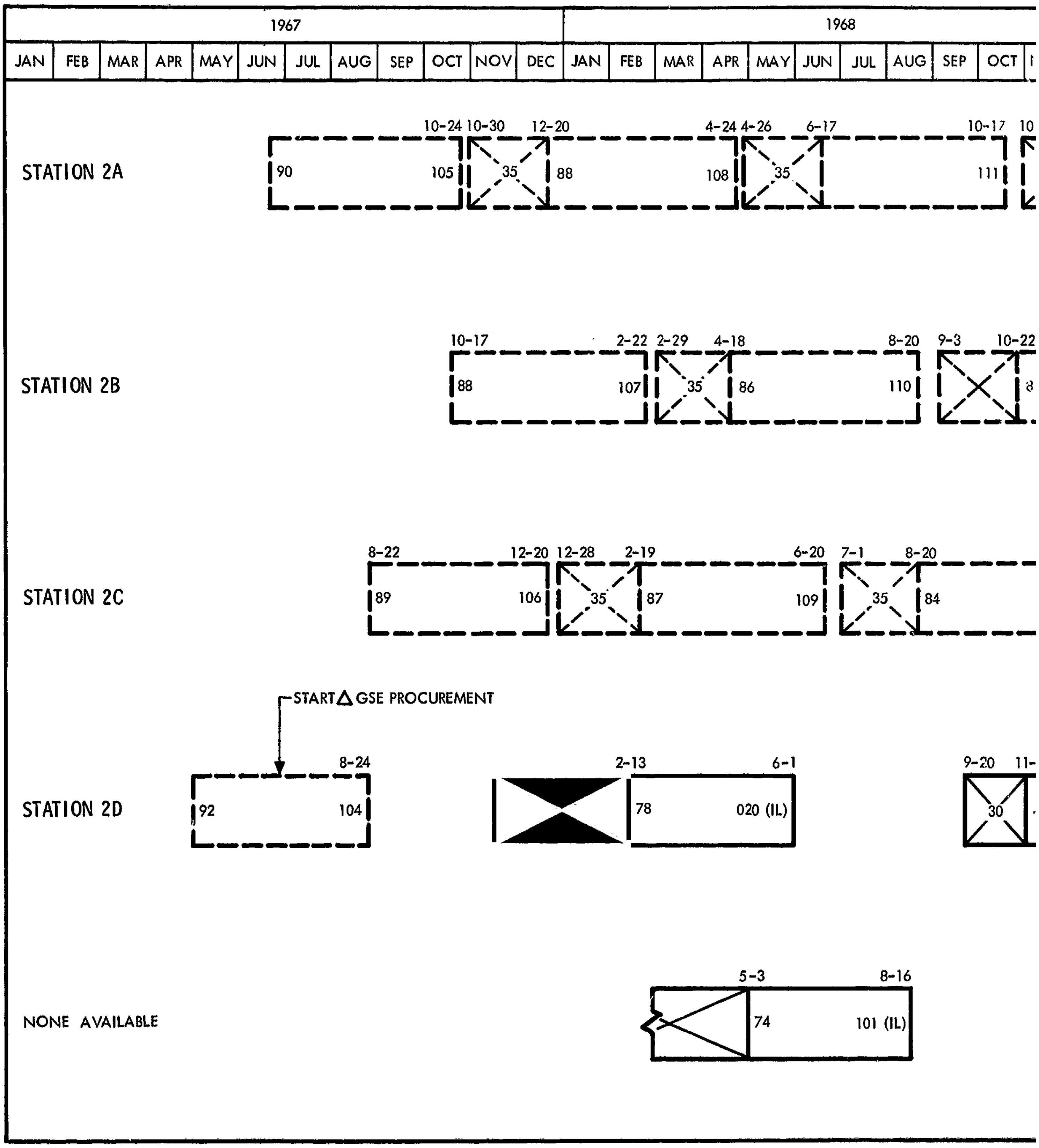


NOTE:
THESE FLOW TIMES FOR RCM SPACECRAFT ASSUME A STANDARD BLOCK II SERVICE MODULE. SHOULD THESE SM BE A NEW AAP, CONFIGURATION RCM/S STATION CHECKOUT TIME WILL INCREASE.

Figure 22. RCM Spacecraft, Building 290, Station Utilization

FOLDOUT FRAME 1

NORTH



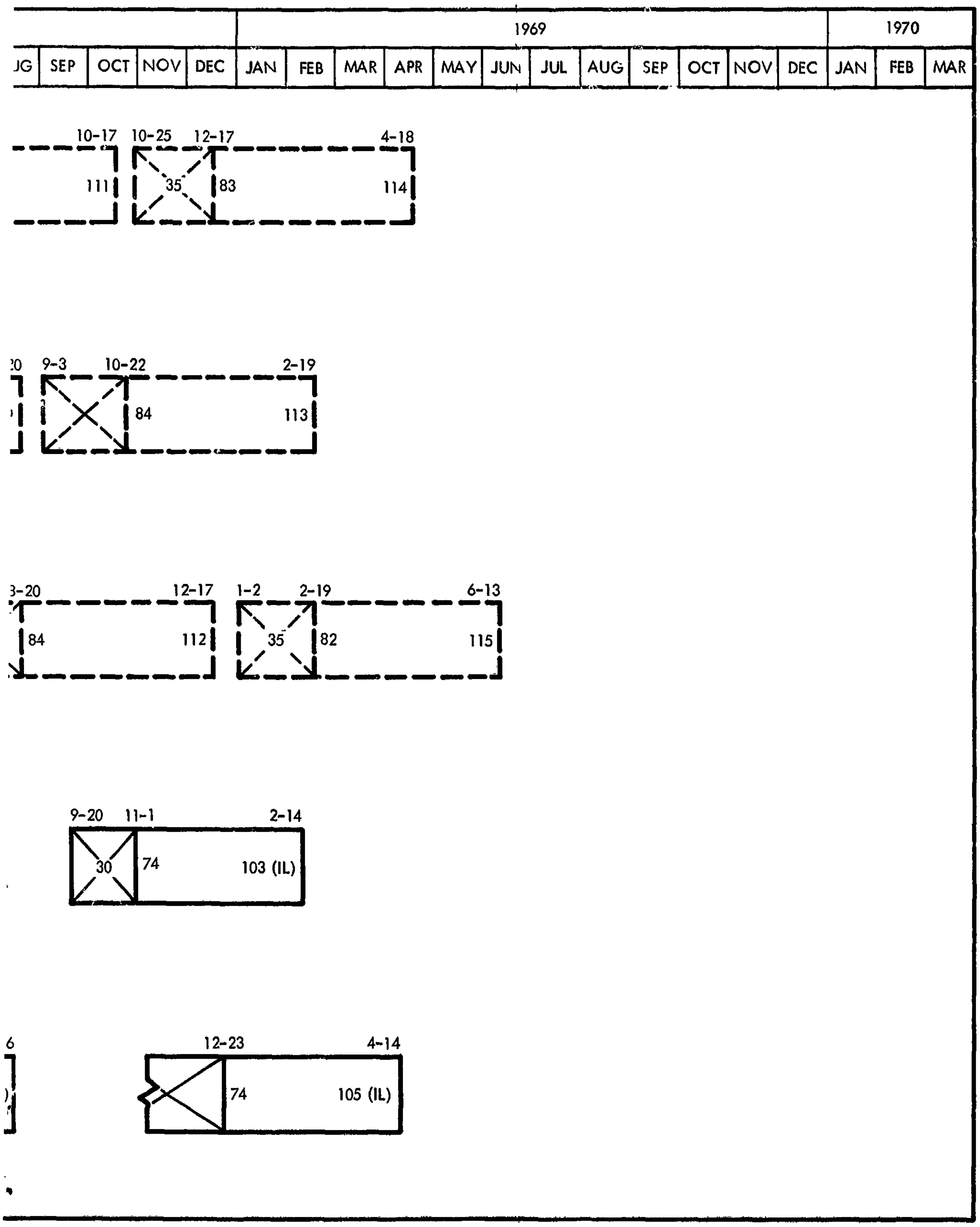


Figure 23. RCM Building 290 Station Utilization

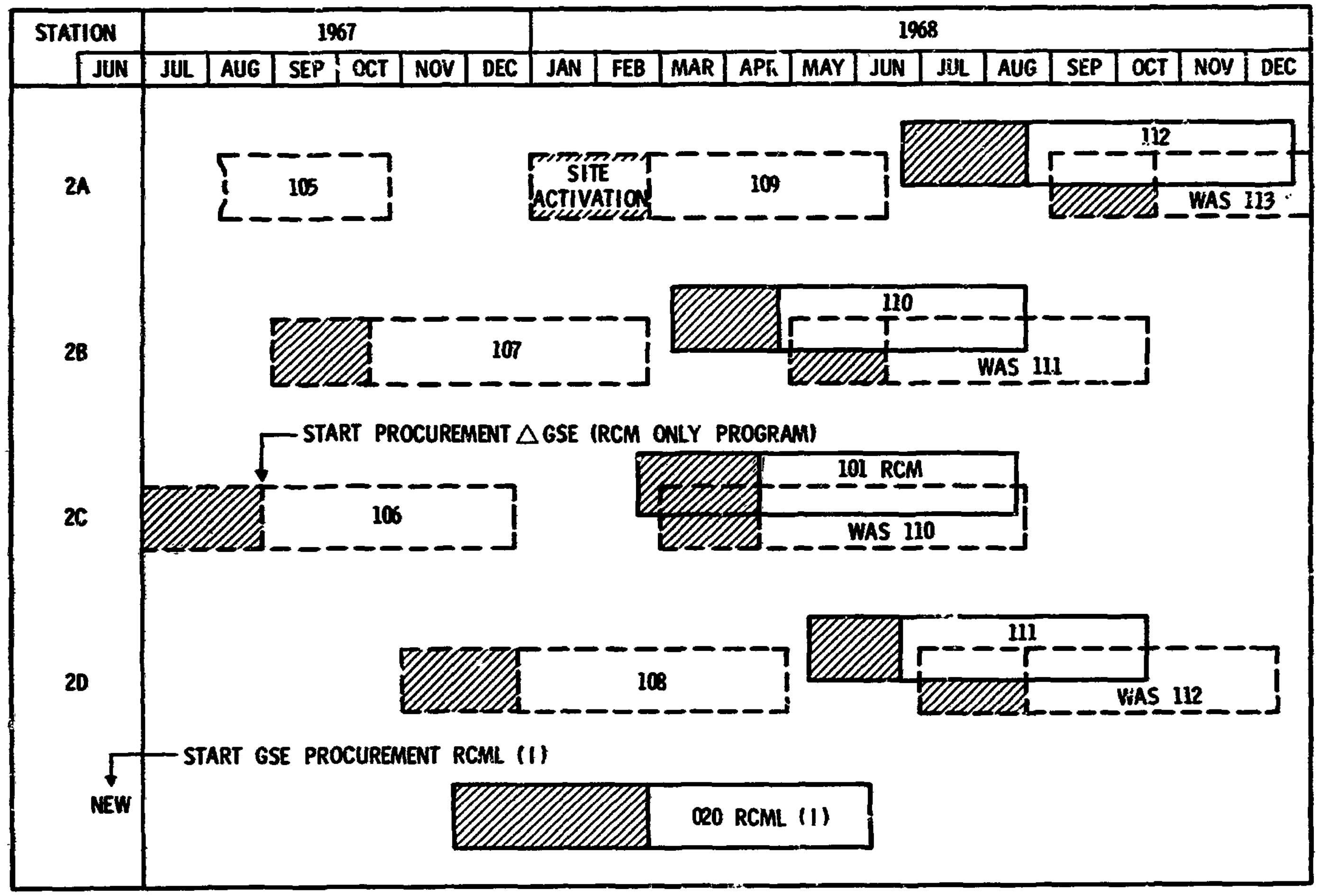


Figure 24. Building 290 Station Utilization (RCM and RCML Added to Block II)

Support equipment requirements listed in Table 3, for the RCML (D), RCML (I), and RCM reflect deltas to Apollo inventory. These lists assume multiple RCML (I) and/or RCM with respect to time-sharing GSE. The lists were developed, in coordination with Apollo program management, by analysis of Apollo GSE utilization. Columns 1 and 2 of the Table identify the GSE item model and nomenclature, respectively. New models are denoted by no assigned model number, (e. g., A34-XXX). The next three columns show the GSE requirements for the dependent laboratory, independent laboratory, and RCM, respectively. The RCM column includes new requirements only where Apollo time-shared items are not capable of supporting more than six vehicles per year. The RCML (D) and RCML (I) columns identify total laboratory support, including Apollo time-shared items. A numeral in more than one column indicates requirement for an added Apollo model or new item to support the respective program. Columns 6 and 7 show the total new or added Apollo model requirements for both RCM and RCML. It should be noted that the changes to Apollo equipment are not an accumulation of Columns 3 through 5. These equipment are time-shared and, in most cases, one additional unit will satisfy the combined requirements. Where the Apollo unit must be changed to support the RCML, a percentage of modification is shown. A summary of the changes to Apollo equipment for each configuration is as follows:

Item	New	Added	Apollo Time-Shared
RCM (Dependent)	5 (Mfg)	2	21
RCM (Independent)	9 (Mfg) 5 (GSE)	24	92
RCM	0	13	151

Study limitations did not permit an evaluation of RCML (I) support through modification of an existing station in event no RCM's were prograr med. However, the equipment requirements include the work stand and th GSE shown for the RCM, plus modification required for cabling, patching,

Table 3 . List of Equipment Requirements for Building 290 Downey Operations to Support RCML and RCM

1 Model No.	2 Nomenclature	3 Dependent Laboratory	Needs S/A	4 Independent Laboratory	Needs S/A	5 RCM	Needs S/A	6 New Requirements	7 Additional Requirements	8 Modification Required (Percent)	Remarks
A14-011-0001	Ground cooling cart	X	*	X	*						
A14-014	Cleaning positioner	Mfg	*	Mfg	*			?			ATO vacuum clean
A14-033-0001	ECS stimuli generator, suit			1	*	1	*		1		
A14-034-0001	ECS pressure distribution test stand			1	*	1	*		1		
A14-037-101	Adapter and duct set	X	*	X	*						Future facility air
A14-046	Auxiliary crane control	X	*	X	*						
A14-052	Heater power supply			X	*						
A14-053-0001	Fuel cell protect cover			X	*						independent laboratory 3 fuel cells
A14-054-0001	LO_2 cryogenic tank protect cover			X	*						
A14-055-0001	LH_2 cryogenic tank protect cover			X	*						
A14-036	Ground air circulating unit	X	*	X	*						
A14-035-0002	Vacuum cleaner	X	*	X	*						
A14-074	Load bank, electric			X	*						
A14-084	Fuel cell substitute unit										
A14-087 } or SK-9106 }	Inverter substitute unit			1	*	1	*		1		Prefer SK-9106
A34-XXX	RCML radiator protect cover set			Mfg	*						
A14-132	Crew hatch outer handle assembly	X	*	X	*						
A14-133-XXX	Crew hatch protective seal	1	*	1	*			1		50	50 percent of Apollo design A14-133-201
A14-134	Ten-ton hydro set	X	*	X	*						

Table 3 . List of Equipment Requirements for Building 290 Downey Operations to Support RCML and RCM (Cont)

1 Model No.	2 Nomenclature	3 Dependent Laboratory	Needs S/A	4 Independent Laboratory	Needs S/A	5 RCM	Needs S/A	6 New Requirements	7 Additional Requirements	8 Modification Required (Percent)	Remarks
A14-139	Pyro initiator substitute unit			1	*				1		RCML separation 1 box (6 squibs) 16 nozzles
A14-146-201	SM RCS fluid disposal adapter set			X	*						
A14-152	C&D coaxial test assembly					Delete					No C band required
A14-154-0001	DC digital indicator			Mfg	*						
A34-XXX	RCML protective cover	Mfg	*	Mfg	*						Mfg required (2)
A34-XXX	RCML airlock protective cover	Mfg	*	Mfg	*						Mfg required (2)
4-185	Vacuum cleaner, portable	1	*	1	*				1		In place of using A14-014
A14-187-0001	Auxiliary air purification unit, small	X	*	X	*						
A14-191-101	Light set			Delete							Use work around
A14-236	Degasser, water glycol			X	*						
A34-XXX	Disconnect set, umbilical fluid/electrical			1	*			1			Price same as A34-243-101
C14-009	Crew systems checkout group			X	*						
C14-021	Telemetry ground station			X	*	Apollo problem					
C14-032-101	Antenna checkout group			X	*						
C14-051	Pyrotechnics BME			X	*						Modify to -101
C14-075-301	Propulsion system fluid checkout unit			X	*						FDS change
C14-089	Mobile data recorder			X	*						} either 1
C14-089-101	Mobile data recorder			X	*						

Table 3 . List of Equipment Requirements for Building 290 Downey Operations to Support RCML and RCM (Cont)

1 Model No.	2 Nomenclature	3 Dependent Laboratory	Needs S/A	4 Independent Laboratory	Needs S/A	5 RCM	Needs S/A	6 New Require- ments	7 Additional Require- ments	8 Modification Required (Percent)	Remarks
C14-200-101	Carry-on receiver and baseplate					Delete					Use C14-264
C14-201-101	Carry-on baseplate unit					Delete					Use C14-265
C34-XXX	Cable set	Partial Required Lighting, Cooling		X	*						Use old C14-178 C14-309 Modified
C34-XXX	Electrical J box set (2)	Partial Required Lighting, Cooling		X	*						Use old C14-557 C14-562 C14-558 C14-561 and modify to Station 7C Configuration
C14-207	DTCS rack			1	*	1	*		1		
C14-208	DTMS rack			1	*	1	*		1		
C14-210-101	Carry-on PCM			1	*	1	*		1		
C14-211-301	Digital signal conditioner and multiplex unit			1	*	1	*		1		
C14-212-301	Analog signal conditioner and sampling unit			1	*	1	*		1		
C14-264	Carry-on receiver and baseplate - ACE			1	*	1	*		1		
C14-265	Carry-on dual baseplate - ACE			1	*	1	*		1		
C14-266	Carry-on stimuli generator - ACE			1	*	1	*		1		Delete C14-220
C14-213-301	ACE G&N Signal conditioner switching					1	*		1		
C14-232	Data interleaving			1	*				1		
C14-220-101	Carry-on command stimuli unit							Delete			Use C14-266

Table 3 . List of Equipment Requirements for Building 290 Downey Operations to Support RCML and RCM (Cont)

1 Model No.	2 Nomenclature	3 Dependent Laboratory	Needs S/A	4 Independent Laboratory	Needs S/A	5 RCM	Needs S/A	6 New Require-ments	7 Additional Require-ments	8 Modification Required (Percent)	Remarks
C14-240-601	Servicing equipment ACE-SC adapters			1	*				1		
C14-262-101	DC power supply, ACE			1	*				1		
C14-268-101	Service equipment DTCS			1	*				1		
C14-316	SC ground power filter			1	*				1		
C14-348-0001	PRN ranging test set			X	*						Can time-share
C14-376	UDL buffer and relay verification unit			X	*						
C14-418	SC ground power supply			X	*						Basic availability
C14-420	Up-data link equipment			X	*						
C14-442	RF system checkout unit			X	*						
C14-458	Static EMI checkout device			X	*						
C14-471-101	Flow sensor set - SM RCS nozzle			X	*						
C14-480	Initiators stimuli unit			X	*						
C14-484	External signal conditioner set			1	*				1		
C14-596	RF antenna set			X	*						
C14-597	RF transmission line set			X	*					?	Tie into Station 7C
C14-599	RF switch console			X	*						
C14-640	SMRCS injector flow sensor			X	*						
C34-317	Nuclear particle detection system percent			X	*						
C34-391-201	ACE carry-on cable set			1	*	1	*		1		May be modified for laboratory
C34-XXX	RCML electrical separation simulator			1	*			1			Similar to C34-397

Table 3 . List of Equipment Requirements for Building 290 Downey Operations to Support RCML and RCM (Cont)

1 Model No.	2 Nomenclature	3 Dependent Laboratory	Needs S/A	4 Independent Laboratory	Needs S/A	5 RCM	Needs S/A	6 New Require-ments	7 Additional Require-ments	8 Modification Required (Percent)	Remarks
C34-XXX	RCML/CM docking checkout unit			1	*			1			Similar to C34-396
9EH-XXXX	RCM (D) support base	1	*					Mfg			RCM 10, 000 lbs
9EH-XXXX	RCM (IL) support base			1	*			Mfg			RCM 25, 000 lbs
9EH-XXXX	Weight and balance fixture			1	*			Mfg			
9FS-XXXX	Docking ring pressure leak test fixture			1	*			Mfg			Pressure cell
9EH-XXXX	RCML integrated stand			1	*			Mfg			
H14-021	GSE handling cart	X	*	X	*						
H14-052	Positioning trailer (NB)	X	*	X	*						Provide adapter ring
H14-073	SC sling without LES	X	*	X	*						
H14-080	Fuel cell ship container			X	*						
H14-101	Access platform	X	*	X	*						
H14-091	Access stand CM hatch	X	*	X	*						
H14-098	Handling and install set - RCS			X	*						
H14-1158	Equipment install fixture			X	*						
H14-118-0001	LO_2 storage tank container			X	*						
H14-119-0001	LH_2 storage tank container			X	*						
H14-127	Cable/fitting set weight and balance			X	*						Possible use with mod
H14-178	Weight and balance load relieving device			X	*						
9EH-XXXX	RCML weight and balance set horizontal			1	*			Mfg			

Table 3. List of Equipment Requirements for Building 290 Downey Operations to Support RCML and RCM (Cont)

1 Model No.	2 Nomenclature	3 Dependent Laboratory	Needs S/A	4 Independent Laboratory	Needs S/A	5 RCM	Needs S/A	6 New Requirements	7 Additional Requirements	8 Modification Required (Percent)	Remarks
H34-238	HGA install fixture			X	*						
H14-9015	Weight and balance jack set			X	*						
S34-XXX	Fluid distribution system	Partial air and pressure		1	*					X	Modify S14-014
S14-019-0002	ECS water glycol service set			X	*						
S14-053-0001	ECS water glycol trim control			1	*				1		
S14-067	Mobile pressure test unit	X	*	X	*						
S14-079	Portable module leak unit	X	*	X	*						
S14-084-0001	Halogin leak detector	X	*	X	*						
S14-098	Portable hydrogen leak detector			X	*						
S14-113-0001	Servicing vacuum unit EPS H_2			1	*				1		Or equivalent (2)
S14-113-0002	Servicing vacuum unit EPS O_2			1	*				1		Stoke - Pumps HE-283
S14-121	Water glycol refrigeration unit			X	*						
S14-140-101	ECS W/G servicing cart			X	*						
S14-140-201	ECS W/G servicing cart			X	*						
GFP-H-052	Trailer, rail type	X	*	X	*						
GFP-H-100	Maintenance platform	X	*	X	*						
GFP-H-101	Access platform	X	*	X	*						

Table 3 . List of Equipment Requirements for Building 290 Downey Operations to Support RCML and RCM (Cont)

1 Model No.	2 Nomenclature	3 Dependent Laboratory	Needs S/A	4 Independent Laboratory	Needs S/A	5 RCM	Needs S/A	6 New Requirements	7 Additional Requirements	8 Modification Required (Percent)	Remarks
GFP-H-203	Positioning trailer	X	*	X	*						
GFP-S-003	Mass spectrometer	X	*	X	*						

LEGEND:

X - Requirement exists and is time-shared with Apollo.

* - Equipment requires a site activation task.

1 - A new item is required identified by an unknown model number (e.g., A34-XXX Disconnect Set, Umbilical Fluid/Elect) or an added Apollo requirement is needed identified by a model number (e.g., A14-033-0001).

Mfg - Manufacturing and/or Facilities Handling should provide this item.

and fluid distribution systems. Minimum requirements are indicated and assumptions concerning the availability of excess Apollo equipment, such as one ACE carry-on for RCM support, may be optimistic. Two Apollo stations are supported by a common service equipment room which could pose problems with parallel checkout of two spacecraft in the station pair. Time-shared GSE must, in most cases, be revalidated after moving. A complete analysis was beyond the scope of this study, particularly since Apollo operations programs have not yet been stabilized.

An investigation of ACE-S/C control and monitor complex (control room, computer room, and distribution room) indicated the need for an additional station, four versus three for Apollo. Although the ground rule for ACE planning (50 percent availability/spacecraft station is a minimum) implies that up to six stations could be supported by the three ACE-S/C stations at NAA Downey, experience dictates that an ACE must be available on the order of 75 percent of the time. While Apollo program conditions should improve, attempting to support several renovated vehicles with the excess capability of Apollo ACE stations would jeopardize Apollo schedules. The requirement for the fourth ACE is, however, subject to a complete engineering study of the total checkout systems in Building 290 to determine the minimum cost approach. Involvements include the GSE and ACE peripheral equipment, interface with the control rooms, and problems related to time-sharing of the equipment that affect the capability of ACE time-sharing.

Further study of the Downey test operations support resources required in Building 290 should include, but not be limited to, the following:

1. Detailed study of station requirements as a function of specific vehicle program schedule.

2. A detailed study of the relationship of ACE-S/C time-sharing versus Building 290 checkout complex design and GSE time-sharing.

3. Updating of the GSE lists provided herein to reflect Apollo operations and support studies now in progress that may affect station use times, configurations, and GSE quantities.

4. If only RCML vehicles are considered, perform a study of modification of an existing station versus activation of a new station in respect to a major cost savings versus potential impact on Apollo due to station modification down time (may include adjacent station-sharing same-service equipment room).

5. Tradeoff studies to establish an optimum master program considering manufacturing, pressure testing, and Building 290 requirements as a whole.

KSC OPERATIONS

Limited planning studies and analyses were performed to determine resources capabilities for the RCM and RCML programs at KSC. Reports from previous studies were reviewed, such as SID 65-1539, Ground Support and Logistics, (10 Dec 1965) developed during the AES Preliminary Definition Phase, and Contract NAS 10-2947, Checkout and Launch Systems Engineering Study for Apollo Applications Program (AAP), Volumes I through IV, (May 1966). These documents were developed around experiment missions requirements similar to those the RCML program may require. Implementation planning was based on the requirements and flows developed for ground operations given in Section I of this report.

A cursory evaluation of the RCM support requirements indicates no major problem areas. The Manned Spacecraft Operations Building (MSOB) altitude chamber appears to be the pacing item, assuming GSE quantities are supplemented where necessary. In the RCM time period, equivalent to about Block II S/C 110, the chamber will be utilized about one month per CSM. Allowing two weeks between CSM for station maintenance operations, eight spacecraft can be processed per year or a total of two RCM in addition to Apollo Block II. This is compatible with delivery capability discussed in the Downey Test Operations. This assumes interface testing with a laboratory would take on the order of only one week as shown on the preliminary RCM and RCML field schedule, Figure 25. It further assumes all CSM are processed in accordance with shipping availability rather than an irregular launch schedule with any resulting spacecraft stay time being after MSOB checkout. Associated GSE was assumed to remain fixed (i. e.), not time-shared with the launch complexes. It should be noted that requirements relating to redesigning the RCM associated SM for extended mission capability will probably impact field scheduling, therefore, altitude chamber scheduling and use times.

Study of the KSC facility and equipment support for RCML operations was directed toward identification of potential problem areas for future studies. Assumptions included the following:

1. RCML will carry experiments that will be installed at KSC.
2. Potential requirements for laboratory, with experiments, interface test with mission associated CSM.
3. Cable connection adequate for CSM/RCML electrical interface testing rather than physical docking. This will not satisfy thorough RF or electromagnetic compatibility evaluation.

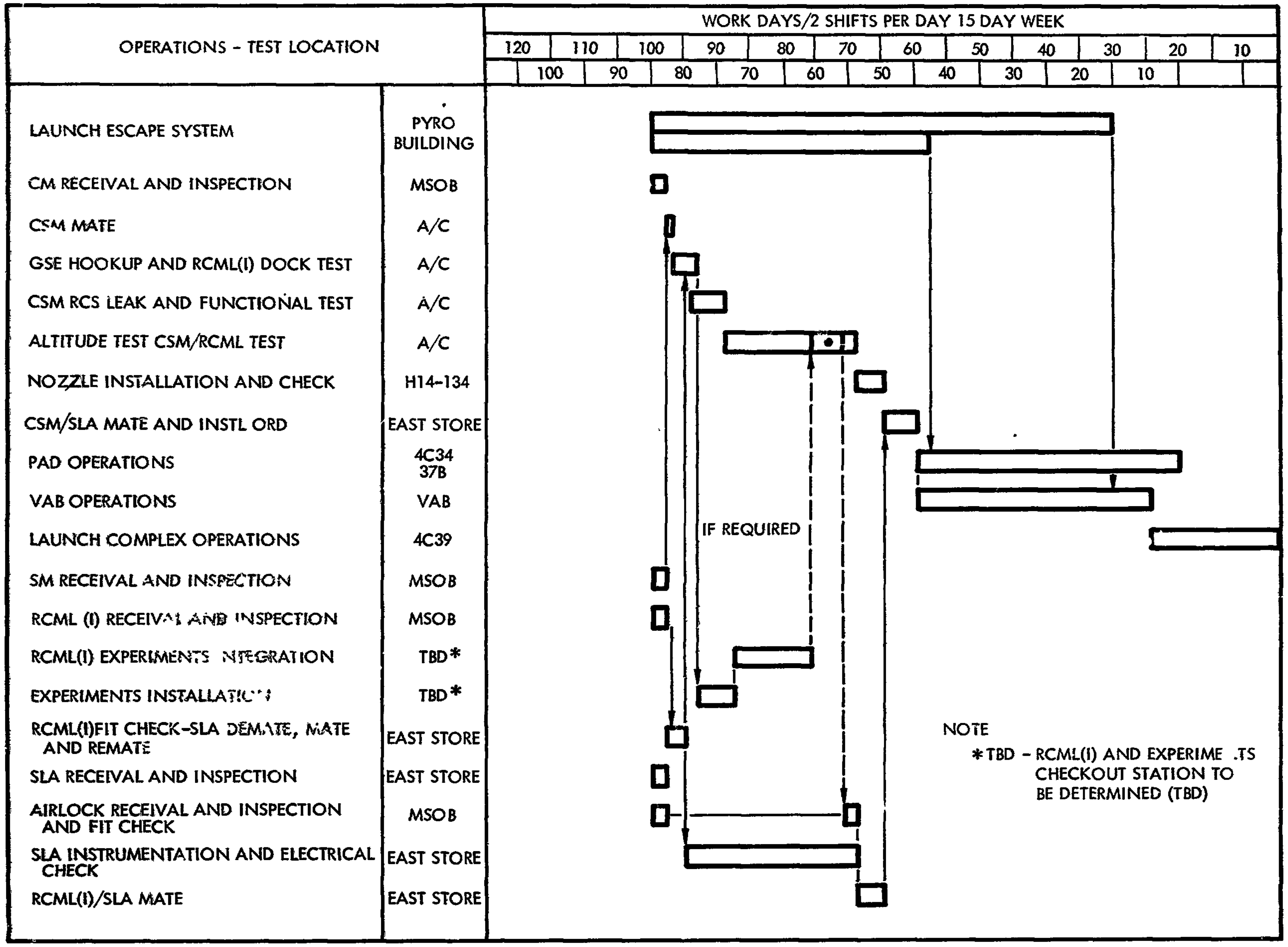


Figure 25. RCM (I) Preliminary KSC Schedule-Mission RCML 020

4. RCML to be tested in a similar manner as the Apollo CSM.

5. Delivery rate of independent laboratories at about six months intervals.

6. Total Apollo CSM, RCM and RCML flow rate to peak at ten per year.

Dependent and independent laboratories were not studied separately. The significant difference between the dependent and independent laboratory resources are believed to probably be in the area of GSE support. CSM/RCML interface testing would vary, however, this was beyond the scope of this study. A station or work area will be required for experiment installation. The advisability of checkout capability in this station will largely depend on the nature of the experiments.

Interface testing with the CSM, electrically connected by GSE cables, can best be performed in the MSOB. This suggests activating a laboratory checkout station in the proximity of the CSM altitude chamber. Depending upon related scheduling, the LM altitude chamber, including LM GSE adaptation, could possibly be used to minimize total delta resources for RCML. As an alternative, the West Stokes stand could be modified and activated for RCML integrated systems test capability. The latter would require a complete GSE complement similar to that required for NAA Building 290 RCML checkout station. A third alternative should be considered wherein all RCML checkout is performed stacked on the launch vehicle (LV) at the Vehicle Assembly Building (VAB) (Saturn V mission) or launch pad (Saturn 1B missions), inclusive of RCML/CSM electrical interface tests. This would tend to reduce the delta GSE required at KSC, but would dictate a longer lead time for the respective LV.

Facility support and GSE will be required at the launch complexes for RCML support. Where possible, existing LM support should be used or modified to be compatible with RCML to minimize delta resources.

In conclusion, gross evaluation revealed the following probable KSC support deficiencies as problem areas for future study consideration:

1. Work station(s) for experiment installation in RCML

2. RCML systems/experiment checkout site

3. Implementation of CSM/RCML interface tests, including RF and EMI requirements

4. RCM operations and support resources if field modification is required of related SM for extended mission

5. Possible use of LM facilities and equipment for RCML

6. Total Apollo, RCM, and RCML GSE requirements.

The preceding studies must be based on a known total launch program for Apollo and AAP programs to include interrelated mission support scheduling of vehicle operations and resources utilization.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The operations planning studies concluded that the required RCM and RCML ground operations can be implemented by supplementing Apollo facilities, equipment, and manpower. Delta resources requirements related to each major ground operations are summarized in subsequent paragraphs.

Postrecovery

Shipboard and forward area operations requirements can be implemented by adding personnel to the NAA recovery team and providing equipment necessary for heat shield removal, vehicle wash down, and ECS deactivation and preservation. The additional forward area operations would of course extend the time before the CM returns to NAA Downey and requires additional personnel.

Downey Test Operations

The major resources problem areas disclosed in the Downey test operations analysis was that of the pressure test cells, the NAA, Downey Building 290 checkout station support to the independent laboratory, and quantities of time-shared GSE available Apollo CSM Downey checkout. The pressure test cell capability must be supplemented for a program of several renovated vehicles. A new checkout station in Building 290 to support independent laboratories is required if the combined RCM and RCML programs exceed delivery of two vehicles per year. Modification of an existing CSM station to support RCML would be feasible and potentially considerably less expensive for a program of less than two renovated vehicles per year. The capability of Apollo time-shared GSE is, in many cases, saturated by Apollo utilization, therefore, additional GSE is required even for a program of only one renovated vehicle if Apollo vehicle delivery schedules are not to be impacted. About 24 added items of time-shared GSE are required for a combined program of RCML (assumes new station) and RCM as compared to

13 for RCM only with no additional checkout stations. A total of four per year, two each RCML and RCM, can be processed with addition of the RCML station.

Only a gross assessment of KSC resources requirements could be achieved without a defined total Apollo and AAP program. The significant KSC resources deficiency appears to be the need for a RCML checkout station in the MSOB. LM support resources should be considered, but compatibility analysis was beyond the scope of this study. GSE quantities must be supplemented and RCML associated modifications are required at the launch complexes.

A summary of problem and/or future study areas is presented as follows:

1. Safety involvements and constraints during shipboard and forward area postrecovery operations. This study must coordinate the combined safety requirements of DOD, NASA, and NAA.

2. NAA, Downey pressure test cell utilization, based on refined RCM and/or RCML operations planning and a specific master program plan and vehicle schedule.

3. NAA, Downey Building 290 checkout station utilization based on refined RCM and/or RCML operations planning and a specific master program plan and vehicle schedule.

4. Time-sharing factors related to utilization programming of the Building 290 checkout support resources. The relative constraints between GSE time-sharing and ACE time-sharing must be evaluated with respect to total complex design, limit of available Apollo equipment, and increased vehicle quantity flow rate.

5. KSC operations and resources support requirements based on detailed operations requirements and a specific total Apollo and AAP program.

6. RCML schedule and cost reduction with respect to relaxing procedural and quality assurance measures comensurate with reduced crew safety implications.

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IV. LOGISTICS ANALYSIS

SCOPE

This Logistics analysis is based on those support activities associated with (1) equipment utilization during the CM postrecovery operations, (2) material/ component accountability and handling during the CM renovation program, and (3) RCM/RCML Building 290 test and checkout support. For this study, only material support, training, site activation, and technical documentation were evaluated for the RCM/RCML Logistics program. A Logistics Concept for support of the CM renovation program was defined that formulates the planned support requirements of the renovated spacecraft during operations from recovery through final checkout in Building 290, Downey. All renovation support requirements are delta requirements to the Apollo program. KSC support requirements were not a part of this study.

Logistics data were developed as part of the total cost analysis for the operational phase of the renovation program. These data were prepared for test support, site activation, and technical documentation for three configurations of renovated vehicles: the RCM, RCML (D), and the RCML (I). Training and spares costs were not required for this study.

RENOVATION CONCEPT

The philosophy and approach, based on study results, regarding development of a RCM/RCML support operation and service plan are contained in this analysis. The principles upon which the renovation program support activities are based as well as the support functions having major impact on parallel Apollo program operations are discussed.

Background

The analysis is based on the utilization of existing Apollo site activation and Logistics policies, procedures, and functions from spacecraft recovery to checkout is completed in Building 290. Existing support operations provide and control support services associated with Apollo spacecraft, ground support equipment, and spares (end items and material) provided by the contractor. These support services include all functions necessary for sustaining maintenance and operations to support test and mission objectives. required to meet RCM/RCML milestones.

The concept is a result of analyses of RCM/RCML system and subsystem evaluation, manufacturing, test and operational data, Apollo program plans, schedules, and documentation, and NASA and Gemini hardware reuse documentation. Also, the pertinent support activities are reflected from recovery through test and checkout in Building 290 prior to shipment to KSC.

Objectives

Although the study support activities are based on the current Apollo program operations, support function requirements resulted from analyses of Apollo flight hardware reuse programs. Delta objectives, those determined for the Apollo program include:

1. The necessity to define a support system which would provide accountability and control of all renovation support functions in support of the Test and Operations and Manufacturing disciplines from postrecovery through final checkout in Building 290
2. The requirement to define a hardware reuse accountability system for hardware control during removal, test, renovation, certification, storage, and installation phases of renovated subsystems and components at NASA, contractor or subcontractor facilities
3. The site activation requirements for integration of a modified or new checkout station in Building 290 with the capability to support the independent laboratory configuration
4. The definition of technical documentation and support manuals necessary for RCM/RCML program support
5. The delta training and training equipment requirements necessary to train flight personnel for RCML (I) operations, and tasks.

Material Support System

The RCM/RCML material support system will be required to provide contractor central management and control of all renovation support functions for CSM postrecovery operations through final RCM/RCML checkout in Building 290 (Figure 26). The system will revolve around a support center from which the renovation program contractor/subcontractor support operations, involving modification, repair, liaison, coordination, and warehousing, will be scheduled and maintained.

Upon recovery of a CM and delivery to NAA, Downey, every component removed from the spacecraft will be recorded with respect to nomenclature, part number, visual condition, and disposition, e. g. test laboratory,

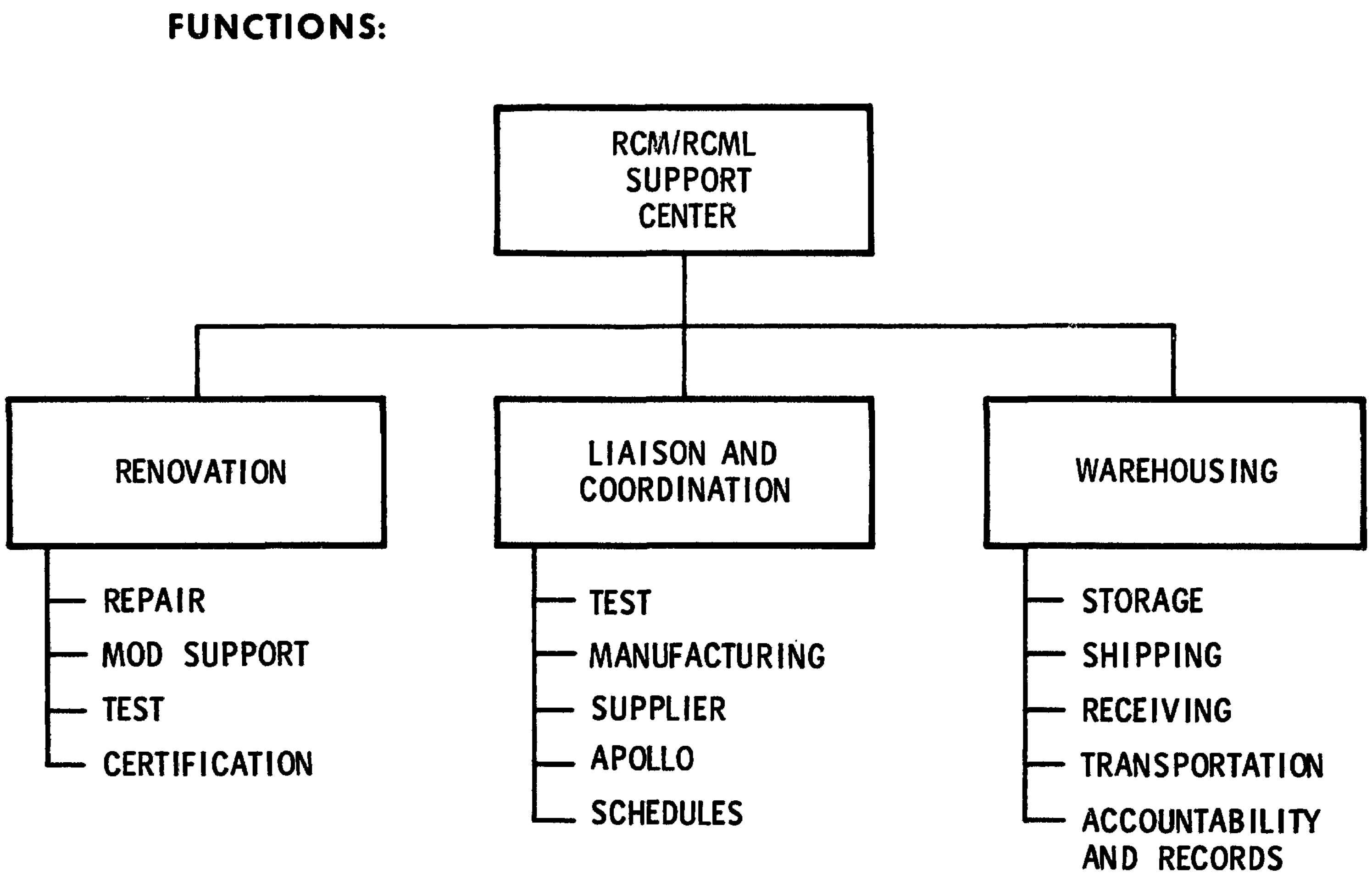


Figure 26. Material Support Plan

storage, subcontractor, etc. The items will be expedited to the location specified, renovated as required, and returned for appropriate reuse. The support system will utilize available Apollo residual spares to the fullest extent to reduce program costs. The RCM/RCML program will replenish the critical Apollo spares stock on a "use-as-needed" basis. Apollo program GFE/GSE will be shared or transferred to the RCM/RCML program as required but only on a non-interference basis with the Apollo operations.

Support Center

A RCM/RCML support center will be organized to provide central management, direction, and control of all Logistic renovation support functions required and accomplished in support of the RCM/RCML program operations. Personnel assigned to this organization will be physically located adjacent to and/or in the immediate proximity of the present Apollo CSM maintenance requirements and test support (MR&TS) activity so as to attain maximum utilization of Apollo CSM MR&TS records, facilities, communication equipment, personnel and capabilities.

The support center will be manned by personnel performing tasks that will provide adequate and economical Logistics support to assure successful fulfillment of RCM/RCML program requirements and will be organized as shown in Figure 26. The major functions of the support center will be to:

1. Provide a communications and expedite system that will support the RCM/RCML program with required hardware, spares, GSE, and test equipments on a timely basis
2. Establish and operate a repair system to support RCM/RCML Downey operations
3. Store, issue, and distribute RCM/RCML repairable and serviceable assets, such as GSE, spares, and subsystems
4. Provide inventory management and a cycling inventory of RCM/RCML assets
5. Stage and distribute GSE and supporting parts for the postrecovery period as determined necessary
6. Maintain configuration control and applicable records
7. Document and maintain master repair schedules
8. Provide GSE and related equipment for Downey RCM/RCML station activation.

The RCM/RCML support center will utilize applicable, existing Apollo procedures, data, and facilities and will have a minimum impact on Apollo activities that are paralleled by RCM/RCML program requirements. This approach will eliminate redundant efforts, expedite support requirement implementation, and reduce RCM/RCML program costs.

Hardware Accounting Procedure

The initial phase of implementing the RCM/RCML accountability system will include processing of hardware removed from recovered spacecraft for postrecovery testing, with the majority of the effort conducted at NAA, Downey. The system will include utilization of inventory records specialists, who will process necessary paperwork. Also, handling expeditors will be utilized to accomplish rapid distribution of component parts removed for testing, renovation, replacement, storage and/or disposal disposition. Detailed coordination with NAA Apollo, RCM/RCML program functions, and with NASA will be accomplished during further application of the overall postrecovery test, reuse and renovation disposition accounting system. Processing of subsystems and components removed from recovered flight vehicles, regardless of recovery location, is shown in Figures 27 and 28.

Accountability procedures are being established and are currently being implemented to maintain control over present Apollo flight and residual hardware reuse and excess disposition. This will affect NASA Apollo hardware that has been delivered and accepted via DD-250. The procedures require segregation of returned hardware from that hardware used for work in progress, and will provide accountability through a definitive and auditable accounting system. Apollo program contract end items meeting the preceding specifications will be included in the existing provisioned hardware inventory control system for property accounting purposes. Distribution and location of property removed from returned Apollo spacecraft for the RCM/RCML program will be recorded for accounting purposes, and the residual property identified and controlled.

Spares Support

Initial spares identification for support of the RCM/RCML program will be based on an anlysis of program objectives and definition of the .nctional and operational criteria. Existing reliability data on "off-the-shelf" items will be evaluated in determination of specific sparing requirements. Pertinent spares data compiled from the Apollo program will be utilized in arriving at a mean demand equation that will verify spares prediction within minimum but adequate program support. Long-lead-time spares and repair parts will be released for procurement, or fabrication, as necessary to support the program schedules. Preliminary GFE "off-the-shelf" spares will have been identified. The primary objectives of the RCM/RCML spares support program

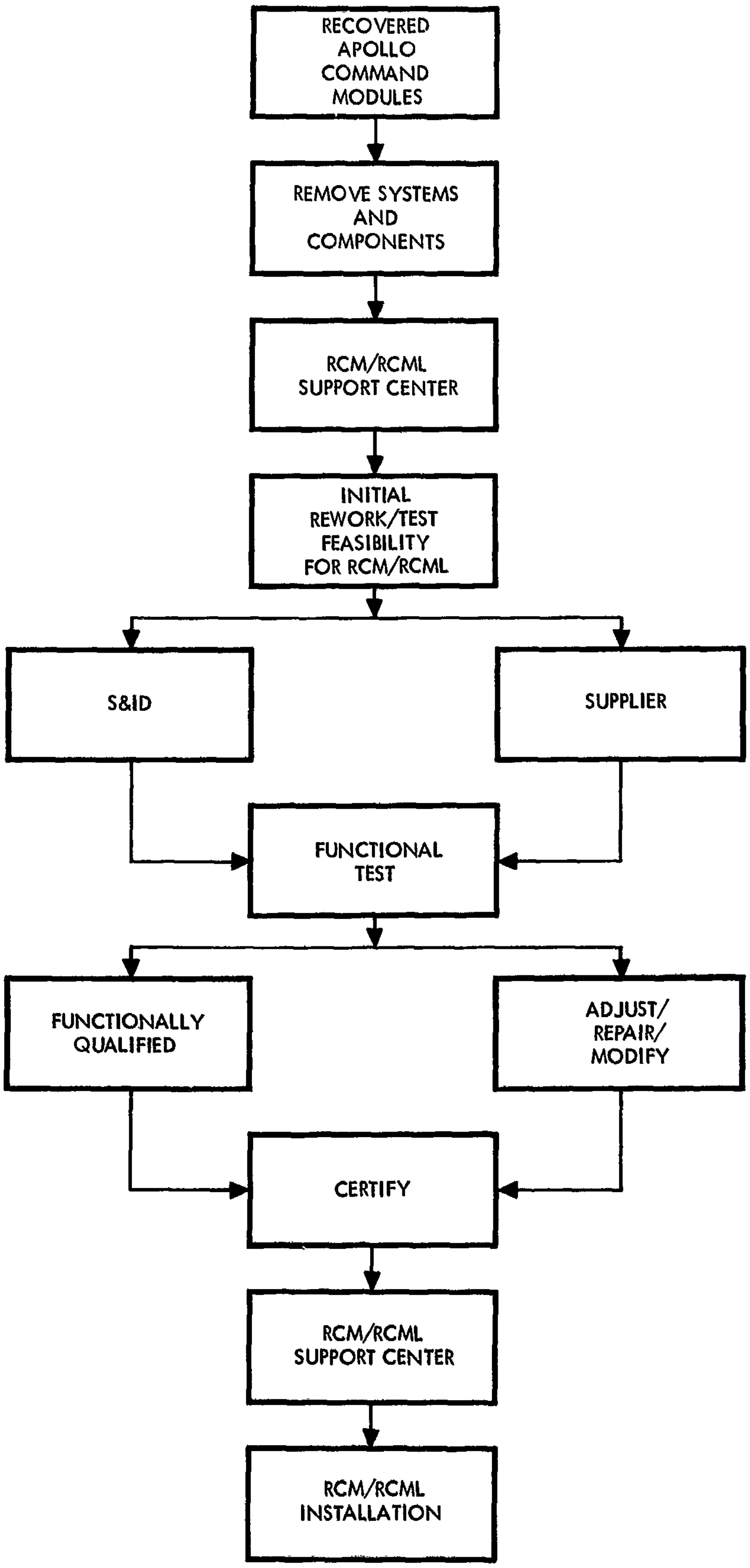


Figure 27. Recovered Spacecraft, Subsystem and Component Renovation Flow Cycle

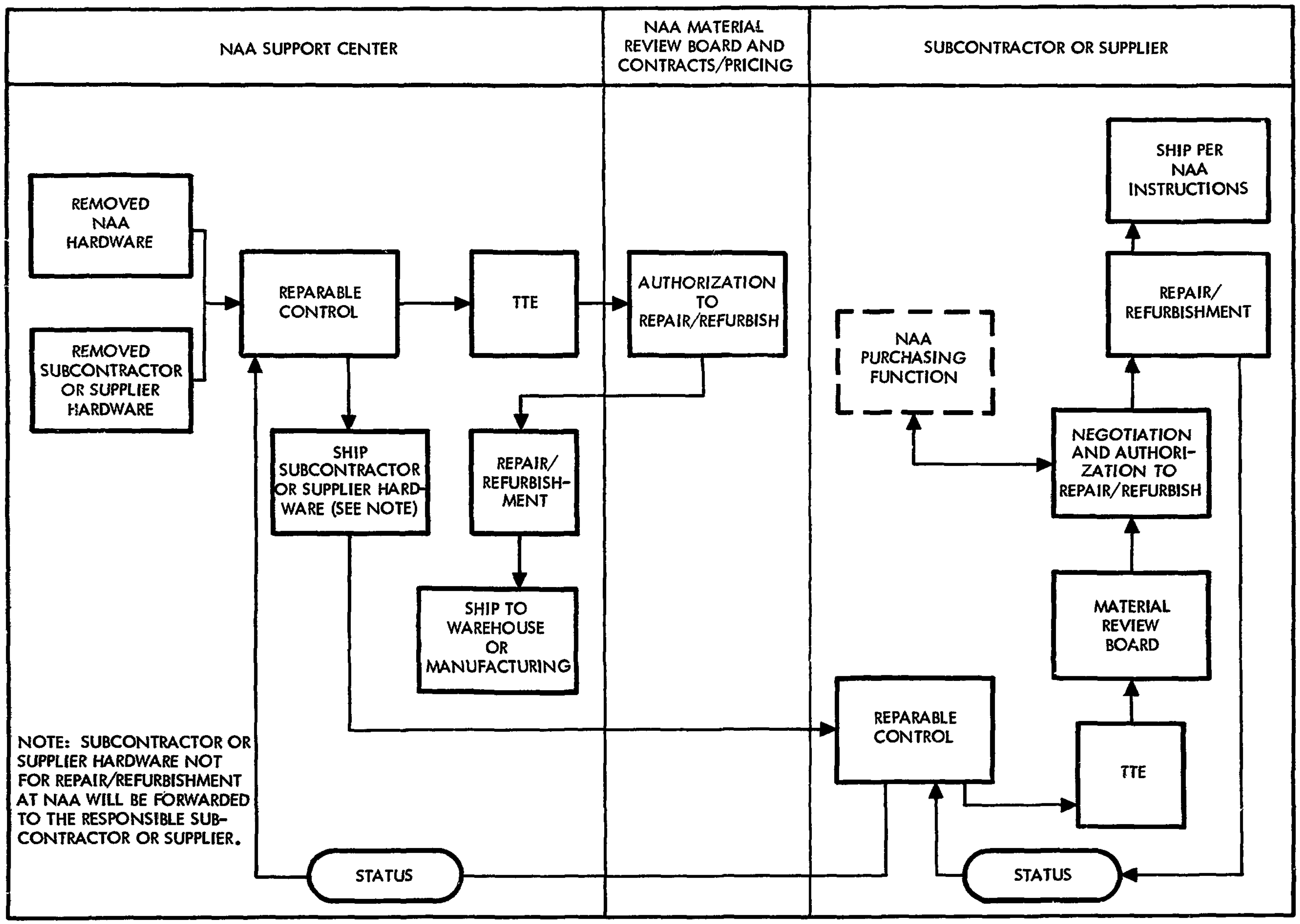


Figure 28. Renovation Control Cycle

will be to assure adequate quantity of spares to support all phases of the RCM/RCML program and to make maximum use of Apollo CSM residual spares and certified renovated items as declared available. Firm spares requirements will be established early in the program through utilization of recommended lists of spares obtained from applicable equipment sources and analysis of S&ID manufactured items.

Government-Furnished Property (GFP) Utilization

Equipment end-items currently retained at NAA under the NAS9-150 contract, which are available and qualified for use in the RCM/RCML program will be transferred from the Apollo inventory and classified as GFE. Certain GFP/ACE if available will be furnished to NAA S&ID by the U. S. Government at designated times to support the RCM/RCML program and as approved by the Contracting Officer. NAA will assist in obtaining items determined to satisfy GFP/ACE RCM/RCML support requirements at no cost or at minimum cost. These requirements will include items such as handling dollies and workstands. NAA will utilize, to the maximum extent possible, Block I vehicle residual GFP/ACE spare items modified for Block II use. The Contracting Officer will provide NAA with disposition instructions concerning GFE following RCM/RCML program utilization. Some residual Apollo end-items (ACE) currently at NAA will be acquired by transfer to the contract (RCM/RCML) and will be identified as government property and delivered as such. Other residual Apollo equipment required for RCM/RCML will fall under the general GFP clause of the contract. Facility end-items under Contract NAS7-300 and some items required from various other government agencies will be requisitioned under normal contractual requisitioning procedures.

Training

The magnitude and scope of training effort required will be directly proportional to: (1) RCM and RCML mission requirements; (2) airborne vehicle configuration design and changes; and (3) ground support equipment configuration changes and new requirements. Current Apollo CSM training course material and other documentation will be revised and/or adapted to accommodate significant RCM/RCML changes. In instances where a major program difference makes it technically or economically infeasible to use existing Apollo training material, new documentation, visual training aids and/or simulation equipment will be developed and produced as required.

The Apollo Block I/II Training Plan, SID 65-1408, will be supplemented to reflect the delta flight crew training required for integration of RCM/RCML training courses, resources, and management controls. RCM (I) Laboratory mission simulation will be required to assure flight crew orientation and familiarization with the major changes in system/subsystem configuration and utilization. Existing Block I Apollo mission simulators may not be able to satisfy this new requirement. Renovated command module mission simulation requirements appear to be within the capability of the new Block II Apollo mission simulator (AMS). (It should be noted that a contract has been let or is currently being negotiated for this AMS.) AMS availability dates and RCM training schedule integration with Block II Apollo CSM training may develop into major problem areas.

A mission simulator requirement is identified to provide specific and detailed simulation of the various mission experiments which the RCM (I) laboratory flight crew must perform. Extensive use of the present Block I AMS is considered and several additional and specific conditions having a definite bearing on effort and cost involved in this new requirement must be evaluated, including:

1. Hardware configuration differences between the Block I spacecraft and the independent renovated command module laboratory
2. RCML training schedule integration with AMS schedules that are already established and are being utilized
3. Probability of adapting AMS software programs to satisfy certain requirements identified for RCML mission simulation (this could range from 100 percent use to not more than 40 percent revision of current programs for adaptation)
4. RCML missions, though generally similar to scheduled Apollo missions, will differ with respect to definitive flight crew operational requirements.
5. Magnitude and complexity of visuals requirements will be contingent upon the degree of independent operations designed into the renovated command module laboratory (e. g., CSM providing all guidance and navigation services would eliminate the requirement for these stellar navigational aids and visuals).
6. Adaptation and utilization of Apollo training equipment previously produced for CSM flight crew training. For example, the Apollo Part Task trainer hardware, currently located at NASA MSC and currently being considered by McDonnell Aircraft Corp. for use on the Orbital Workshop Mission Modification program.
7. New Block II AMS's for which contractual negotiations are underway for at least one and possible two units.

The milestone chart (Figure 29) identifies major planning and/or scheduling events in the development cycle as anticipated for fabrication of a new RCML (I) simulator. Key dates upon which the schedule is based are (1) 1st RCML launch date; (2) training start date, and (3) definition of RCML system performance details. All other activities are geared to assure availability of the completed hardware and software in place, checkout, and ready to commence crew mission training not later than 8 months prior to the first RCML launch.

Software modification and/or development requires the longest lead time of any portion of the simulator system and, as a result, could have the greatest impact on attainment of the desired operational date. Since software development can be instigated as soon as the general RCML performance parameters have been defined, it is desirable to have these parameters established and published at the earliest possible date but no later than 22 months prior to the first scheduled independent RCML launch.

Site Activation

Site activation effort will be required during the NASA postrecovery and NAA, Downey phases of the RCML/RCM program. Postrecovery requirements will pertain to supporting the activity with the specified renovation GSE wherever needed. Downey site activation requirements will involve installation and checkout of a new station in Building 290.

Recovery Requirements. The initial requirements to be accomplished during the postrecovery phase will require a multiple support effort. Certain ground support equipment (e. g., command module handling slings, aft heat shield packing and shipping container, CM holding jig, etc.), and bulk material (consumables) will have to be procured, allocated, distributed and placed on the command recovery ship in the primary recovery zone and also on the major recovery ship in the alternate recovery zones. Ground support and handling equipment required at each location must be adequate to enable the postrecovery RCM team to remove the aft heat shield, flush the insulated area with demineralized water, drain, and accomplish all tasks required to prevent corrosion resulting from exposure to the salt water environment. Conceivably, this requirement can be satisfied primarily and most economically through allocation and distribution of equivalent contractor manufacturing and handling STE, GSE, and GFP to the respective recovery ships as opposed to establishing and satisfying new GSE requirements.

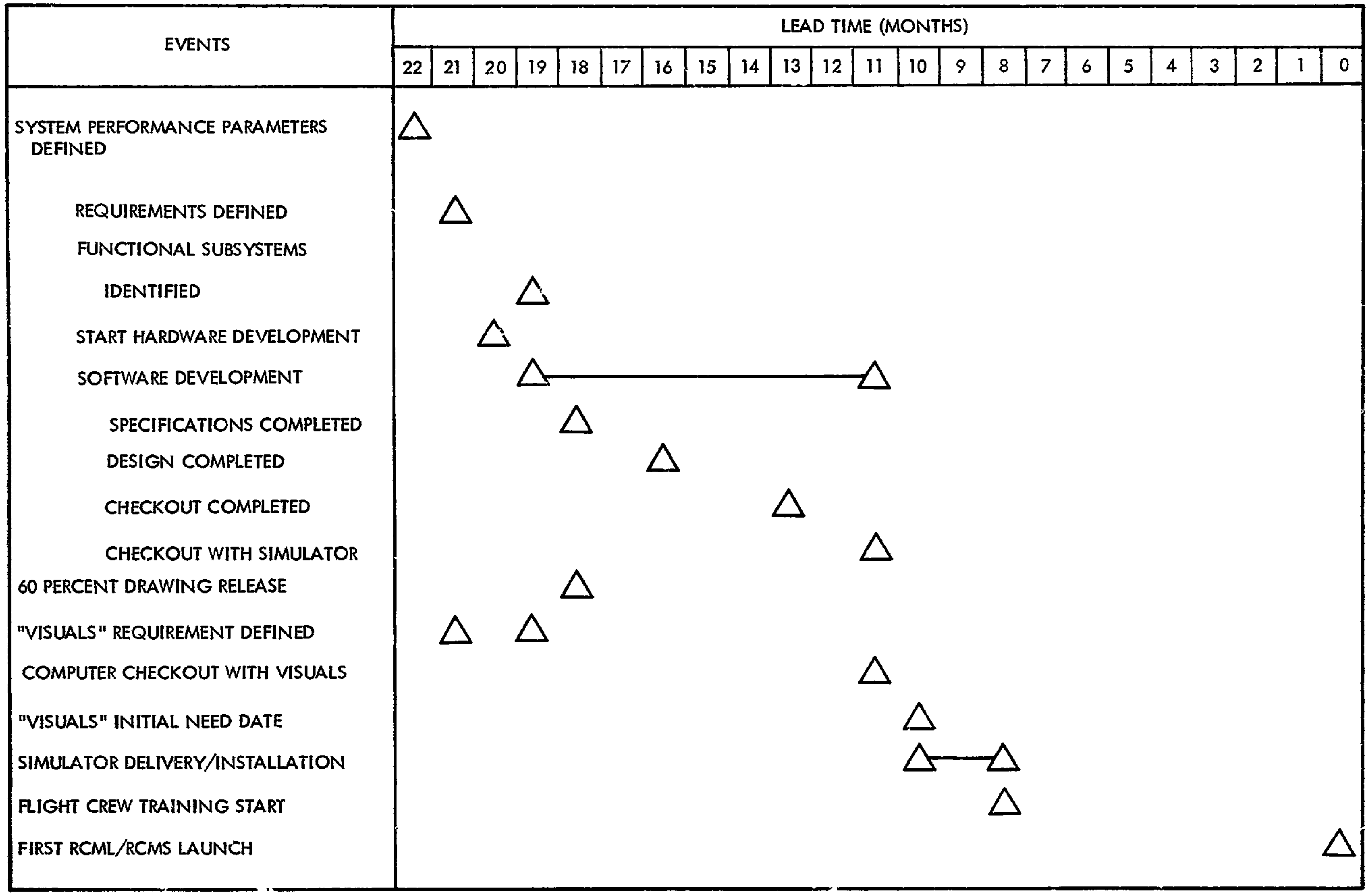


Figure 29. Renovated Command Module Laboratory (Independent) Simulator Milestones

Additional ground support equipment (e. g. water glycol service unit, vacuum system EPS service, lightweight water transfer unit) will be required for ECS deactivation at the postrecovery forward area.

Initiation of the shipping process; assuring arrival of the equipment in an undamaged condition at the various locations on schedule; providing spares support; and assembly, disassembly, and subsequent return of the support equipment to the Downey facility constitute new responsibilities for the contractor. Contractual requirements supplemental to Contract NAS9-150 do not currently exist for shipboard postrecovery or forward area activity support.

Downey Operations. The second requirement, of considerably greater magnitude, is the activation of a new checkout and test station in Downey Building 290 to process the independent renovated command module laboratory and renovated command module. The location tentatively considered for the station is area 7C which is presently available and is immediately adjacent to equipment support rooms. New operational checkout procedures will have to be prepared in conformance with the RCML configuration. Additional ground support equipment will be required beyond that equipment available for sharing since use of much existing GSE items is precluded because of scheduling incompatibility with the Apollo CSM scheduled flow through existing stations in Building 290. Major equipment items required include a modified CSM workstand (similar to H14-124), modified automatic checkout equipment (ACE), interconnecting cabling, and related support equipment. Lead time items having major impact on the new station will be the modified CSM workstand equivalent, which may require approximately six months to fabricate and deliver. Modified ACE, if required, will also require six months to fabricate. All GSE must be available for installation within 30 days after installation of the CSM workstand is begun to assure availability of the test station for operations at a target date approximately eight months after renovation program go-ahead. Spares and bulk consumable support of RCML/ RCM during test and checkout in Building 290 will be provided by the RCML/ RCM support center in the same manner as currently utilized to support existing test stations at that location.

Technical Support Documentation

A need was revealed for new checkout, maintenance, renovation, launch, and recovery documentation. Preliminary investigation indicated this new documentation will be prepared as proposed revisions or supplements to existing Apollo logistics documents or documented separately, as applicable. Minimum revision and reissue of existing documents is anticipated. Since

Apollo launch and support operations procedures are being prepared during the same time period as RCM/RCML program definition, these procedures may be prepared as drafts of material recommended for inclusion in the overall Apollo documentation. Depending on the nature and extent of the differences, they will be produced as addendums to existing Apollo documents and will contain independent procedures or they will consist of shorter sections to be inserted in the basic Apollo documents.

Appropriate Apollo support manuals will be revised in detail and compared to (1) the analyses of logistics operations for RCM/RCML; (2) the additional subsystems and GSE required for support of RCM/RCML, and (3) any estimated additions or modifications to existing Apollo facilities and personnel requirements. A similar process of refinement for the basic Apollo documentation will produce definitive maintenance and operations procedures for specific RCM/RCML equipments.

Renovated RCML technical support documentation will consist essentially of the current Apollo CSM manuals and/or documents revised or modified to accommodate the RCML peculiar systems, equipment, and NASA-designated experiments information. The RCML (dependent) documentation requirements will be minimal since limited portions of subsystems are required with the pressure shell for experiment operations. The RCML (independent) documentation requirements will be comparably extensive since this vehicle is of a new type spacecraft, and will utilize the Apollo Block II data to a maximum extent. Probable documentation requirements will include:

1. Renovated Command Module Laboratory Familiarization Manual
2. Renovated Command Module Laboratory Flight Crew Procedures
3. RCML Mission Simulator Instructor's Handbook
4. RCML Mission Simulator Operating and Maintenance Instructions Handbook
5. Apollo CM Postrecovery and Retrieval Procedures
6. Site Support Lists (SSL)
7. Checklists

The RCM (I) laboratory is initially intended to be assembled from a Block I spacecraft pressure shell and subsystems for which basic documentation already exists. Should it not be possible to refurbish a Block I subsystem, a Block II subsystem will be utilized. However, the overall RCML configuration is a perturbation of a Block I CSM with the basic shell and structural members essentially undisturbed, whereas the majority of subsystems will have been removed and replaced with refurbished subsystems remounted both internally and externally to the basic structure and shell. Therefore, major changes will be made to existing Block I/II subsystem support documentation and will necessarily reflect changes in application as well as method of operation, in some cases. All current Block II Apollo CSM and GSE data will be applicable to RCM's since these spacecraft conform to Block II configuration.

RCM/RCML material support documentation will use basic Apollo documents for baseline RCM/RCML documentation direction; i.e., the GSE Planning and Requirements List (SID 62-417); GSE Utilization Chart (SID 63-1524); Basic Site Support Lists (SID 62-94-1 and 3); and the Master Repair Planning Document.

Documentation pertaining to material support at applicable RCM/RCML sites, with the differences between Apollo and RCM/RCML requirements clearly identified, will provide a basis for determining delta material support and manpower requirements.

Control of documentation will be the same as that described in applicable Apollo documents. Some documents will be common to both Apollo and the RCM/RCML programs; others will be in the form of supplements to Apollo documents; and a third category will be unique to one system or the other. A system of identification will be designed so that the effectivity of documents will be readily apparent.

STUDY ANALYSIS

Evaluation and comparison of the engineering analyses, preliminary design drawings, and specifications, to the Apollo program provided a basis for establishment of support requirements for the RCM/RCML program. Apollo data used as a baseline for the study analysis included the Apollo Support Plan (SID 62-702-1), the Apollo Maintenance Plan (SID 62-702-2) and the Apollo Training Plan Block I/II (SID 65-1408). The following criteria were used in analyzing flight hardware renovation requirements:

1. Apollo flight hardware, previously used in flight, will not be reused in manned flight (per NASA Procedural Standards Bulletin PS-33, Code No. 28.4, dated 30 June 1966) unless the material review board determines that minimum conditions have been met.

2. Other constraints on reuse of hardware for such programs as Apollo and the RCM/RCML programs are denoted in MSC Management Instruction MSCI 5310.1 dated 7 July 1966, which states that crew safety and mission success must not be compromised for the sake of cost reduction.

Subject to prior commitments and hardware constraints listed herein, applicable S/C 011 and 012 hardware may be utilized for the RCM/RCML program. In response to an action item generated at the Apollo Program Management Review, August 3, 1966, NAA provided NASA with a list of Apollo S/C 011 and 012 hardware items having a potential for reuse on subsequent vehicles or as spares. Selection of parts was based on the MSC Management Instruction MSC 5310.1 and NASA Bulletin PS-33, Code No. 28.4, with minor differences. NAA Apollo has requested permission from NASA to retain specific Block I flight hardware items for reuse to supplement spares where a contingency exists; i.e., consumption has been higher than anticipated, and the items involved could be refurbished more quickly and less expensively than by reprovisioning the required spares.

A RCM/RCML-Apollo spares availability analysis was performed to define the probable Apollo spares utilization requirements during the renovation program. In projecting availability of spares residual to the Apollo CSM program for use in supporting the RCM/RCML program, the following premises were considered to be valid:

1. The RCM would conform to Apollo CSM Block II configuration, thereby resulting in applicability of Block II spares
2. The first RCML (I) and two RCML (D) would be fabricated from Apollo CSM Block I systems/subsystems, which would permit limited use of residual Block I spares.
3. NASA/MSC would authorize release/reallocation of spares, as might be required by the RCM/RCML program, from Apollo Contract NAS9-150.

In all cases where a "recovered" system/subsystem is intended for reuse on any of the RCM/RCML flight vehicles, it will be mandatory that the repair/refurbish/renovation process include:

1. A thorough bench check with replacement of all damaged or unserviceable parts
2. The new serviceable parts used as well as all original parts reused, will have acceptance tested in accordance with appropriate specifications
3. Service life "zeroed"

4. The reassembled system/subsystem calibrated within design tolerances

5. Appropriate corrosion prevention treatment

6. The replaced item modified to a Block II configuration if necessary.

The system/subsystem items removed from recovered flight vehicles will be processed through disassembly/renovation/reassembly, which is similar to the current NAA Apollo modification and repair system.

A possible constraint exists, involving utilization of selected Block II high-cost ($5000 and over) Apollo hardware as spares for the RCM/RCML program. The Apollo program is currently using a Spares Support Through Utilization of Production Hardware System or "Piggyback System," to preclude a requirement for additional spares. Production hardware is procured ahead of need dates and is used, as required, as a replacement item to support Apollo test requirements. The failed item is repaired and/or modified in time to support a later need date. A spare is procured only if the failed item is nor repairable or will not support the schedule. Therefore, RCM/RCML spares requirements for Apollo items falling into the above system will have to be procured as individual spares, unless the RCM/RCML program is authorized by Apollo NAA management and NASA to use the Apollo "Piggyback System." The RCM/RCML program will procure any "borrowed" Apollo spares utilized, if an additional Apollo requirement exists.

Apollo spares consumption, according to existing data, has been less than anticipated for some of the CSM subsystems, however, several contingency factors must be considered relative to the withdrawal of spares from the Apollo CSM stock to support the RCM/RCML program. Apollo (NASA) management must give approval of RCM/RCML program utilization of residual Apollo spares. The Apollo CSM program must be given first priority if a schedule conflict occurs where both programs might have a need for an item of which only a quantity of one is available. Also, it will be mandatory that the RCM/RCML program replenish the Apollo CSM stock for any items used as long as the two programs are being pursued concurrently.

Table 4 lists the Apollo systems and subsystems, with an estimate of their potential application to the RCML (D), RCML (I), and RCM respectively. The percentage of major system spares procured for the Apollo program is shown in Table 5. RCM/RCML utilization of Apollo subsystem items available will minimize end-item costs and provide RCM/RCML replacements that will meet the specification and schedule requirements. Table 6 presents a list of end-items that NAA Apollo Engineering requires to be replaced after an operational mission. This table also indicates the results of an availability study of Apollo released spares that were identified as released spares by Apollo spares analysts and also taken from the computerized Site Support List, By System (SID 63-94-5) dated September 1966. Due to study limitations for the spares availability analysis, Table 6 does not reflect spares that may have been procured at a higher assembly level. On items noted as NSL (no spares listed), the preceding statement, could, in some instances, also apply.

Renovated hardware items that could be utilized are not reflected. However, it should be important noted that various subsystem/system hardware spares will be required as replacement parts on refurbished items (e.g., displays and controls, such as toggle switches, indicators, connectors, and wiring harnesses).

CONCLUSIONS

Analyses of the RCM/RCML tasks revealed that delta requirements of the Apollo program to provide minimum but adequate support exist in the following areas:

Material Support System

A material support system, including a support center, will be required to provide a control system to support the renovation of CM's designated to become RCM's or RCML's. The support center will have control of functions necessary for CM hardware removal and followup action relative to Apollo flight hardware reuse. The support center will also provide controls for hardware during test, certification, storage, and installation phases of the renovated subsystems and components at all prescribed NASA, NAA, subcontractor or supplier/facilities for the RCM/RCML program. The RCM/RCML program will utilize, as applicable, the Apollo hardware reuse system accountability procedures for postrecovery hardware and, in addition, will implement RCM/RCML delta functions necessary to assure inventory control, necessary paperwork processing, rapid distribution of parts removed for testing, refurbishment, replacement, and/or storage. Certification of and authorization to use Apollo residual and renovated components will also be a function of the accountability cycle.

Table 4. RCML and RCM System and Subsystem Requirements

Subsystem	RCML (Dependent)	RCML (Fully Independent)	RCMS
Telecommunications		X	X
Intercommunications	Minor		X
C/M RCS			X
S/M RCS		X	
S/M EPS		X	
C/M EPS		X	X
S/M ECS		X	
C/M ECS		X	X
S/M cryogenics		X	
Instrumentation		X	X
Electronics		X	X
Displays and controls	Minor	X	X
SCS		X	X
G&N			X
Entry monitor			X
Crew system			X
ELS			X
Sequential events controller			X
Electrical (wiring harness and control boxes)	Minor	X	
Support structure	X	X	
Airlock	X	X	
Heat shield			X
Micrometeoroid shielding	X	X	
Insulation	X	X	X
Tunnel	X	X	
Adapter	X	X	
Probe and ring	X	X	X
LSS (food)		X	X
EPS radiators - SM		X	
ECS radiators - SM		X	

LEGEND

X - Utilization of full subsystem

Minor - Utilization of something less than full subsystem

Table 5. Apollo CSM Spares (Major Systems) Procured/Released

System/Subsystem	Percent Total Apollo CSM Program Spares Released (By Part Number)
SPS	3.48
EPS	11.9
ELS	1.2
ECS	8.1
Communication system	35.0
SCS	22.0
Instrumentation	2.8
Electronics and displays	2.7
Others	12.82
Total	100.00

Source: Apollo Site Support List by System, SSL Report SID 63-94-5 (17 September 1966).

Table 6. RCM/RCML Replacement Parts for Apollo Spares Availability Analysis

Replacement Item	Part No.	Apollo Spares Available
Instrumentation Block II		
Engine inject head temperature	V36-757533	NSL
	V36-757523	NSL
CM SM separation monitor	F01-750009	NSL
Docking probe temperature	V36-751521	NSL
Docking System		
Probe mechanism	V36-575-101	NSL
Docking ring	V36-316-050	NSL
	V36-551-300	NSL
Recovery System		
Main parachute	ME901-0695-001	1
Retention assembly	ME901-0693-0001	NSL
	ME901-0693-0002	NSL
Main parachute riser	ME901-0694-001	1
Drogue parachute riser	ME453-00051-0091	1
RCS Block II		
Test point disconnect couplings	NPP	NSL
Propellant disconnect couplings	ME273-0011	9
Propellant disconnect couplings	ME273-0019	9
Propellant disconnect couplings	ME273-0021	9
Propellant disconnect couplings	ME273-0024	9
Helium explosive valve	ME284-0019	3
Propellant explosive valve	ME284-0130	4
Helium pressure regulator unit	ME284-0022	2
Check valve assembly	ME284-0024	4
Helium pressure relief valve	ME284-0062	2
Burst diaphragm isolation	ME251-0005	NSL
valve	ME284-0346-0009	2
Propellant latching solenoid valve	ME284-0276	6
Flexible hose	ME271-0019	NSL
Dynatube fitting	ME273-0046	15
Rocket engine	ME901-0067	2
Nozzle extension	ME901-0189	3

Table 6. RCM/RCML Replacement Parts for Apollo Spares Availability Analysis (Cont)

Replacement Item	Part No.	Apollo Spares Available
Communications & Data		
HF recovery antenna	NPP	NSL
VHF recovery antenna	NPP	NSL
SCIN antenna	NPP	NSL
Waste Management System		
Blower	ME901-0030-0005	2
Battery vent valve	ME901-0068-0004	1
Fecal canister assembly	V16-601418-501	NSL
Urine disposal lock	ME901-0029-0004	NSL
Flex hose	ME271-0015-0003	NSL
LSS/ECS		
Steam duct heater	ME-363-0013-0001	NSL
Urine nozzle heater	ME-363-0012-0002	1
Suit circuit cooling unit	813000-10-1	3
	813000-1	NSL
	813000-11-1	3
	813000-5-1	1
Suit evaporator	NPP	NSL
Water evaporator	NPP	NSL
Glycol-to-suit air heat exchanger	NPP	NSL
Water separator	NPP	NSL
Water separator pump assembly	NPP	NSL
Glycol evaporator	812000-2	NSL
Glycol evaporator (secondary loop)	812000-2	NSL
Cabin pressure relief valve	810400-1	NSL
Pressure relief valve with manual override	NPP	NSL
Pressure relief valve with manual override	NPP	NSL
CO_2 and odor absorber removable container (26 replacements)	811450-1	NSL
Waste water tank	812200-1	NSL

Table 6. RCM/RCML Replacement Parts for Apollo Spares Availability Analysis (Cont)

Replacement Item	Part No.		Apollo Spares Available
PLV blower	826070-3		NSL
PLV outlet valve	816032-1		NSL
Temperature sensor, steam duct	836060-1		NSL
Waste water tank quantity measurement pressure transducer	836010		NSL
Structure			
Forward heat shield	V16-326410		NSL
LET & launch cover	NPP		NSL
EPS	Block II	Block I	
Battery reentry & postlanding	ME461-0012	ME461-0012	15
Battery, pyrotechnic	ME461-0007	ME461-0007	14
LH electrical feedthrough	V36-597008		NSL
RH electrical feedthrough	V36-597014		NSL
SECS (Block II)			
Master events sequencer controller	ME901-0567-0014		NSL
Lunar docking event controller	ME476-0036-0001		NSL
Earth landing sequencer controller	ME901-0001-0019		2
Pyrotechnic continuity verification box	V16-541130-101		NSL
CM RCS controller	NPP		NSL
Flashing light	ME443-0038-0001		NSL
Flashing light power supply	ME464-0095-0002		NSL

LEGEND
NSL - No spares listed
NPO - No part No. provided

Site Activation

Site activation requirement deltas will include modified and/or a new checkout station in Building 290 to support the respective RCML (D) and/or RCML (I) configurations. The magnitude of this requirement will depend on further definition of the RCM and RCML checkout requirements.

Technical Documentation

Technical documentation and manuals will be required for RCM/RCML support and will be prepared as revisions and/or supplements to existing Apollo publications or documented separately as required. Specific documentation, containing information relative to the RCML and RCM configuration requirements, may include: a Renovated Command Module Laboratory Operations Handbook, Flight Crew Procedures, Mission Simulator Instructor's Handbook, Mission Simulator Operating and Maintenance Instructions Handbook, Postretrieval Procedures, Site Support Lists, Checklists, and Operational Checkout Procedures. All current Block II Apollo CSM and GSE documentation will be applicable to the RCM configuration since these items will conform to the Block II configuration. Any modifications, revisions or changes to existing technical support documentation dictated by the RCM/RCML configurations will be kept as simple as possible; i.e., individual page changes, rather than complete revisions.

Training

Current Apollo CSM training course material and other documentation will have to be adapted to accommodate the RCM/RCML changes. The magnitude and scope of the delta training requirements will be determined by the RCM/RCML mission tasks, airborne vehicle configuration design and changes, and ground support equipment configuration changes. New training documentation, visual training aids and/or simulation equipment must be developed and produced only if existing Apollo training material is not technically adequate or economically feasible. The RCML (I) operations will require training mission simulation of expected critical experiment and housekeeping tasks. Existing Apollo Block I mission simulators may not be able to satisfy this new requirement. Since various mission experiment tasks are not yet identified, for the RCML (I) flight crew, a new RCML training simulator may be required. Considerations involving the utilization of the Apollo mission simulator include:

1. Hardware configuration differences between the Apollo spacecraft and RCML (I)

2. Integration of the RCML mission simulator training requirement with existing Apollo mission simulator schedules

3. RCML mission simulator software requirements will not be fully adaptable to the Apollo mission simulator requirements

4. RCML flight crew operational requirements, although similar to Apollo, will differ in some areas; e.g., experiment operation.

5. Adaptation and utilization of existing Apollo CSM flight crew training equipment; e.g., the Apollo Part Task trainer hardware.

The RCM mission simulation requirements appear to be within the capability of the Block II Apollo mission simulator. However, AMS availability dates may not be compatible for RCM training schedule integration with Apollo Block II CSM training, and may present a major training integration problem. The Apollo Block I/II Training Plan (SID 65-1408) will have to be supplemented to reflect the RCM/RCML training courses, resources, and management control deltas.

Utilization of GFP

Analyses of the possible utilization of Apollo government-furnished property currently in possession of NAA revealed many GFP end-items, such as handling dollies and workstands, may be made available for use on the RCM/RCML program. This equipment listed in Contract NAS9-150 can be accepted by NASA and transferred in support of the contract and deemed GFE. The necessary GFP/ACE, if available, will be furnished to NAA by the U.S. Government at designated times to support the RCM/RCML program as approved by the Contracting Officer. Facility end-items and certain items required from various other Government agencies will be requisitioned under normal contractual requisitioning procedures. The RCM/RCML program will benefit economically if these procedures are permitted.

Ground support and handling equipment must be available to support the RCM/RCML postrecovery and test sites. Conceivably, this requirement can be satisfied most economically through allocation and distribution of equivalent NAA Apollo Manufacturing and handling STE, GSE, and GFP. Additional GSE will be required in some areas; e.g., water glycol service unit, vacuum system EPS service, lightweight water transfer unit. GSE spares support will be required. Modified ACE may also be a requirement. Completion of a new test station in Building 290, Downey is required approximately eight months after the renovation program go ahead. To assure that this date is met, all required GSE must be available for installation within thirty days after placement of the RCML (I) workstand is begun.

Spares Analysis

The following conclusions were reached during the Apollo spares availability analysis, following discussions with NAA Apollo Supply Support personnel responsible for spares identification, selection, provisioning and control:

1. Adequate Block I spares will be available for support of the dependent RCML.

2. Adequate residual Block I spares will be available unless sparing demands are unusually heavy and unforeseen demands occur prior to launch of S/C 020.

3. The three sets of airborne systems/subsystems removed from S/C 012, S/C 014, and S/C 020 will be available as backup spares stock for RCML (I).

Apollo Block II spares availability for selected items costing over $5, 000 may be a constraint on the RCM/RCML program because of the current Apollo incorporation of a Spares Support through Utilization of Production Hardware System, or "Piggyback System". Production items purchased ahead of scheduled installation dates are used, as required. to replace failed hardware during Apollo test operations, thereby precluding spares purchasing, unless the failed item is not repairable.

A major problem area was identified during the Logistics analysis that could have a considerable impact on the RCM/RCML program subsystem/ components spares requirements. Action was taken in July, 1966 by Apollo CSM program management to establish firm "critical decision" dates for responsible major subcontractors and suppliers after which further spare orders would not be placed. The Apollo subcontractors, their respective system/subsystem, critical decision dates, and associated lead times are as shown in Table 7.

Spares were not considered for Aeronca Honeycomb panels or Avco heat shields. It shall be noted that heat shield lead time is approximately 92 weeks. Within 2 years these subcontractors will have received orders for the final Apollo material/spares hardware requirements, unless spares procurement dates are extended. If procurement deadline dates are not extended, it is possible that all subcontractor tooling involved with respective hardware item manufacturing would not be available when required. Considerably increased lead times, schedules, learning/manufacturing curves, and costs will result if startup is necessary to reactivate the subcontractors for production of the RCM/RCML hardware requirements.

Table 7. Apollo Subcontractor Critical Decision Dates

Subcontractor	System/Subsystem	Critical Decision Date	Lead Time
Beech Aircraft Co.	Cryogenics	3 Feb 67	15 months
DeHavilland Aircraft	Recovery antenna	5 Feb 67	5 months
Westinghouse	Static inverters	3 May 67	12 months
Minneapolis Honeywell, Inc.	Stabilization & control system	5 June 67	12 months
Collins Radio Corp.	Telecommunications	5 July 67	12 months
Philco	Nuclear particle detection system	26 July 67	12 months
Dalmo Victor Co.	Hi-gain antenna	16 Aug 67	12 months
Bell Aerosystems	Positive expulsion tanks (CM&SM)	26 Sept 67	6 months
Aerojet General Corp.	Service propulsion engine	1 Oct 67	9 months
General Time Corp.	Central timing system	5 Oct 67	9 months
Parker Aircraft Co.	Valve modules	3 Nov 67	6 months
Gibbs	Event timer	8 Nov 67	4 months
Motorola, Inc.	Up-data link	1 Dec 67	7 months
Northrop-Ventura	Earth-landing system-sequencers	1 Dec 67	6 months
Simonds Precision Prod.	S/M fuel gauging system	10 Dec 67	6 months

Table 7. Apollo Subcontractor Critical Decision Dates (Cont)

Subcontractor	System/Subsystem	Critical Decision Date	Lead Time
Amecom Div.	Antennas	5 April 68	6 months
Northrop-Ventura	Earth landing system	18 June 68	6 months
Pratt & Whitney	Fuel cells	15 Nov 68	13 months

This critical decision date problem on Apollo major subcontractor spares requirements is currently under review by the Apollo program. Redefinition and extension of these dates by Apollo would relieve the RCM/RCML problem considerably. Further study of spacecraft system reuse requirements will be required to specifically define those subsystem and components that are most critical for reuse or replacement, and to ascertain the effect on the renovation program of the proposed Apollo subcontractor procurement critical decision deadline dates.

V. TRANSPORTATION AND PACKAGING

An analysis was performed on the RCML to establish the transportation requirements and to prepare a preliminary transportation plan distinguishing the delta vehicle shipping requirements from those of the current Apollo program. In accordance with the plan for the renovated command module spacecraft, equipment, procedures, and operations currently being used for Apollo spacecraft shipments will be utilized. The primary transport carrier will be a C-133B, B-377PG, or B-377SG aircraft. The transportation plan for the fully independent RCML will require development of new transport equipment and procedures (approximately eight). The primary transportation mode will be performed with either a B-377PG or B-377SG aircraft. The transportation plan for the fully dependent RCML will also require development of new transport equipment and procedures (approximately six), utilizing either a B-377PG or B-377SG aircraft. The alternate transport mode for renovated command module spacecraft and laboratories is by sea.

The size, weight, and configuration of the renovated command module spacecraft and laboratories were analyzed to determine requirements for loading and tie-down into transport aircraft. The characteristics of the spacecraft and laboratories also were examined to determine the requirements for protection of equipment from the environments expected in transportation, handling, and storage. The transport equipment and procedures currently in use in Apollo spacecraft shipment were reviewed to evaluate their utilization for renovated command modules. Transportation equipment requirements for use on the renovated command module spacecraft, dependent laboratory, and independent laboratory were identified. The items of equipment were designated as Apollo time-sharing or new equipment. Preliminary transportation plans also were developed for spacecraft and laboratories. Packaging and transport equipment requirements are shown in Table 8.

TRANSPORTATION PLAN

The plan for accomplishing transportation of the RCM spacecraft and RCM laboratory from Downey to KSC is based on full utilization of equipment and procedures already in use for the Apollo program. The plan identifies the support equipment for handling, transportation, and storage; describes the procedures for preparation for delivery, loading, tie-down, and unloading; and identifies the transport modes which will be utilized to meet delivery schedules.

Table 8 . Packaging and Transport Equipment Requirements

Part or Model No.	Nomenclature	Dep Lab	Ind Lab	RCM	Apollo Time Share	New Req
A14-026	Cap and Plug Set, CM			X	X	
A14-133	CM Main Crew Hatch Cover			X	X	
A14-134	Auxiliary Crane Control	X	X	X	X	
H14-008	CM Support Base			X	X	
H14-073	CM Sling	X	X	X	X	
S14-125	CM Water Glycol Recirculating Unit		X	X	X	
DX-24008	Bridle Sling CM			X	X	
FA-0020	Umbilical Support			X	X	
GFP-H-203	CM Transportation and Positioning Dolly			X	X	
MK392-10067	Container-Heavy Tiedown Chains	X	X	X	X	
10068	Container-Tiedown Devices	X	X	X	X	
10071	Container-CM Bridle Sling			X	X	
10209	Container-Boost Protective Cover, CM			X	X	
10230	Container-CM Boost Cover, Fwd X_C = 81.00			X	X	
10232	Container-CM Hard Cover			X	X	
10235	Container-CM Crew Hatch			X	X	
10257	Container-CM Thermal Blanket			X	X	
10274	Container-CM Filter Breather			X	X	
10325	Container-Thermo-Humidigraph		X	X	X	
MK393-10001	Container-CM Oxygen Subsystem ECS Filter		X	X	X	
MK394-10058	Skid Assembly-CM Tiedown Ring			X	X	
10067	CM Filter Breather Protective Cover			X	X	
MK395-10028	CM Thermal Blanket			X	X	
MK396-10062	CM Loading-C-133B Aircraft			X	X	
10065	CM Local Movement-Semi-trailer			X	X	
10066	CM Transport-C-133B Aircraft			X	X	
10074	CM Transport-B-377SG			X	X	
10103	CM Upper Tiedown Ring Lug Assembly			X	X	
10109	CM Tiedown Eyenut			X	X	
10110	CM Transport-B-377PG			X	X	
10116	CM Local Movement Semi-trailer-B-377PG			X	X	
10118	CM Pedestal			X	X	
10120	CM Hoist Sling Bolt			X	X	
10166	Power Supply-IMU Transport, CM			X	X	
MK399-10065	CM Protective Cover			X	X	
10067	CM Desiccant Bag, Nylon		X	X	X	
10069	CM Preservation and Packaging			X	X	
10073	CM Air Transport Filter			X	X	
10082	CM Accelerometer Mounting and Installation			X	X	
10084	CM ECS Oxygen Subsystem Filter			X	X	
10088	CM Accelerometer Container		X	X	X	
10094	CM Eyenut Container			X	X	
10102	Thermo-Humidigraph Bracket		X	X	X	
MK399-	RCML Environmental Cover	1	1			1
MK399-	RCML Rigid Transport Cover	1	1			1
MK399-	RCML-Thermal Blanket		1			1
MK392-	Container-RCML Environmental Cover	1	1			1
MK392-	Container-RCML Rigid Transportation Cover	1	1			1
MK392-	Container-RCML-Thermal Blanket		1			1
MK396-	RCML Local Movement, Semi-Trailer B-377PG	1	1			1
MK396-	RCML (Dep Lab) Transport, B-377PG	1				1
MK396-	RCML (Indep Lab) Transport, B-377PG		1			1

Note: Although some items may be listed as GSE also, they are repeated here for clarification.

RCM SPACECRAFT

Methods for packaging and transport of the renovated command module spacecraft are identical with those used for the Block II Apollo Spacecraft (Reference SID 62-1083, Apollo Spacecraft Packaging and Transport Plan). This plan includes mounting of the spacecraft vertically on the CM support base (H14-008). The innter and outer crew hatches are removed and shipped separately. The CM interior is desiccated for humidity control, and termal blanket (MK395-10028) is provided for temperature control of the RCS. An auxiliary trailer is provided to furnish electrical power for the G&N IMU heater.

To prevent accidental detonation of installed ordnance devices, an electrostatic shield (MK395-10037) is provided to serve as a conductor for dissipating static charge buildup. A flexible environmental cover (A14-180) is installed for protection against sand, dust, rain, etc., and a rigid transport cover (MK399-10065) is installed over the environmental cover for protection against low-velocity impacts.

Transport of the spacecraft is accomplished by truck from the S&ID facilities at Downey, California, to the Long Beach airport. At the airport the spacecraft is transloaded into a B-377PG aircraft or a C-133B aircraft. To utilize the "Pregnant Guppy," the following support equipment is required: loading adapter (ASL-9021), B-377PG pallet, special semi-trailer (Model 151-40718), and CLT-45 trailer, in addition to handling slings and crane control. In utilizing the C-133B aircraft, the spacecraft is installed on the transportation pallet with the positioning trailer (GFP-H-203), winched to the aircraft, and shored for proper load distribution with tie-down chains which prevent lateral, longitudinal, and vertical movements.

Process specifications delineating detailed packaging and transportation procedures will be prepared for each spacecraft. The only problem anticipated is that of availability of the transportation equipment; only one set is available, and its use may conflict with shipping schedules of basic Apollo spacecraft.

RCM LABORATORY (FULLY INDEPENDENT)

The recommended transport mode for the laboratory is by B-377PG or B-377SG aircraft. Transport by these aircraft precludes any major disassembly. The RCS quads are removed and shipped separately in a special temperature-controlled container (MK392-10229). Preparation for shipment required installation of radiator cover set (A14-063). A new environmental cover and a new rigid transport cover are required to protect the meteorite shield, air lock, and radiators. The CM interior must be desiccated for humidity control A new thermal blanket is required to provide heating of the communications equipment.

Transport of the laboratory is accomplished by hoisting the laboratory and mount onto the B-377PG loading adapter (ASL 9021) and pallet (ASL 9020), which are positioned on a special semi-trailer (Model 151-40718).

Additional shoring is required between the loading adapter and mount to achieve adequate clearances within the aircraft. The RCML is transported to Long Beach Airport where transloading into the aircraft is accomplished with the high-lift loader (CLT-45). Figure 30 shows the recommended shipping sequence and equipment.

Process specifications will be prepared for each RCML delineating detailed packaging and transport procedures for accomplishing and controlling the necessary operations.

RCM LABORATORY (DEPENDENT)

The transport plan for the RCML is identical with that of the 100-percent-independent laboratory except for the deletion of (1) separate shipment of RCS quads, (2) radiator covers, (3) desiccation of interior, and (4) thermal blanket.

ALTERNATE TRANSPORT MODES

The alternate transport modes for the RCM spacecraft and laboratory are by sea transport from the Port of Long Beach. Previous studies performed for the basic Apollo spacecraft (SID65-708, Apollo Spacecraft Alternate Transport Plan) revealed that freighters from the States Marine-Isthmian Agency (Types VC-2, VC-3, C-2 and C-3) can handle spacecraft and space hardware. Because of the sizes of the spacecraft and laboratory, they must be secured on deck and behind the ship's superstructure to prevent "green-water" hazards. It is necessary to provide NAA technical support on board the vessel during the journey to monitor humidity, temperature, and tie-down and to take corrective measures as necessary.

Truck transportation has been studied; however, because of the long travel distances, highway obstructions, and new equipment requirements as discussed in the referenced report, overland transport is not recommended.

RECOVERY OPERATIONS SUPPORT

Packaging is to provided for equipment used aboard the recovery carrier for removal of the aft heat shield. The work stand is disassembled for stowage; and the tools are packaged in reusable, moisture-vapor proof, desiccated containers. The decontamination unit (S14-053) is packed for immediate use, since it is air lifted by C-130 to the forward area to await arrival of the recovered spacecraft.

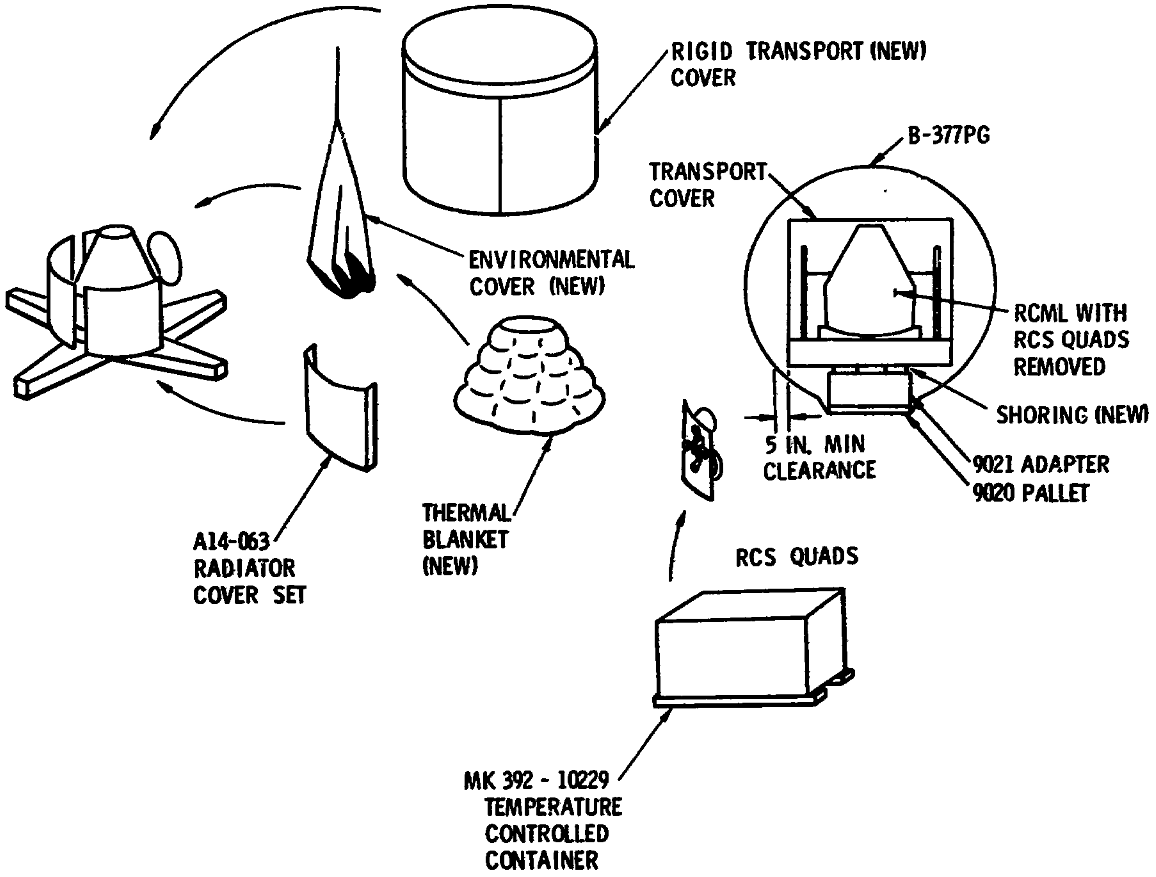


Figure 30. Packaging and Transportation

SUBSYSTEMS RENOVATION SUPPORT

Subsystems removed from the recovered spacecraft for return to suppliers for renovation are packaged in accordance with supplier's packaging data or in accordance with S&ID packaging standards.

VI. MANUFACTURING ANALYSIS

The manufacturing approach is the end result of analysis and comparative evaluation of spacecraft disassembly and renovation techniques. The RCML and RCMS considered in the study are identified by spacecraft model and flight number in the Introduction to this volume. Spacecraft 012 was selected as a cost model baseline for the independent laboratory, RCML (I), and S/C 101 was selected as a cost model for the RCMS. The dependent laboratory, RCML (D), is discussed briefly for comparison of the differences in systems and structures required for the independent laboratory.

The manufacturing analysis was based on the criteria delineated in the contractual statement of work and comparison of the previous concept feasibility study, Apollo manufacturing plan, and Apollo Block I and II systems installation plans.

SCOPE AND OBJECTIVE

Manufacturing Analysis encompasses the following effort: Manufacturing support to vehicle recovery, heat shield removal, spacecraft disassembly, structural modification and repair, fabrication of new parts, renovation and refurbishment of subsystems and components, structural assembly, new and renovated subsystem installation and component checkout, new tooling requirements, and use of existing Apollo production tooling and special test equipment on a time-shared basis. Available spare parts and components provisioned in support of the Apollo program will be used in lieu of fabrication or procurement of replacement parts. Spare parts utilization is discussed in Section IV of this report.

Renovated Command Module Independent Laboratory

Development of the techniques and operational sequences are based on renovation of a recovered Apollo Block I CM for reuse as an RCML (I). The G&N, earth recovery, and earth landing systems are not required for the independent laboratory configuration and will not be renovated or installed. The independent version may be designed using an Apollo Block I or II vehicle.

Renovated Command Module Dependent Laboratory

The RCML (D) is structurally similar to the independent version except that systems mounted on the laboratory support structure and in the interior of the laboratory necessary to sustain an independent mission are omitted. Some new items, such as an instrument panel and mounting provisions, will be required. The dependent laboratory is identified for cost and trade-off studies and will not be discussed further because of similarity to the RCML (I).

Renovated Command Module Spacecraft

The sequence of operations discussed for renovation of a recovered Block II CM for use as an RCM consists of the complete restoration of the spacecraft to ready it for reuse in manned space flight and to assure structural and operational integrity of renovated subsystems and components in accordance with the contractor's quality control plan developed for specific items applicable to certain sections of NPC-200-2.

APOLLO MANUFACTURING POLICIES AND PROCEDURES

Policies and procedures documented by SID 65-324, Apollo Manufacturing Plan, will be used for guidelines during the performance of this program. Apollo Manufacturing will provide support to S&ID Logistics beginning with the initial teardown, test, and evaluation operations reflected by the prime inspection modification and repair order (IMRO) and all subordinate IMRO's. Modification and repair effort on NAA hardware returned from test sites and monitor and control procedures for placing a repairable item into the manufacturing cycle is the responsibility of S&ID Logistics.

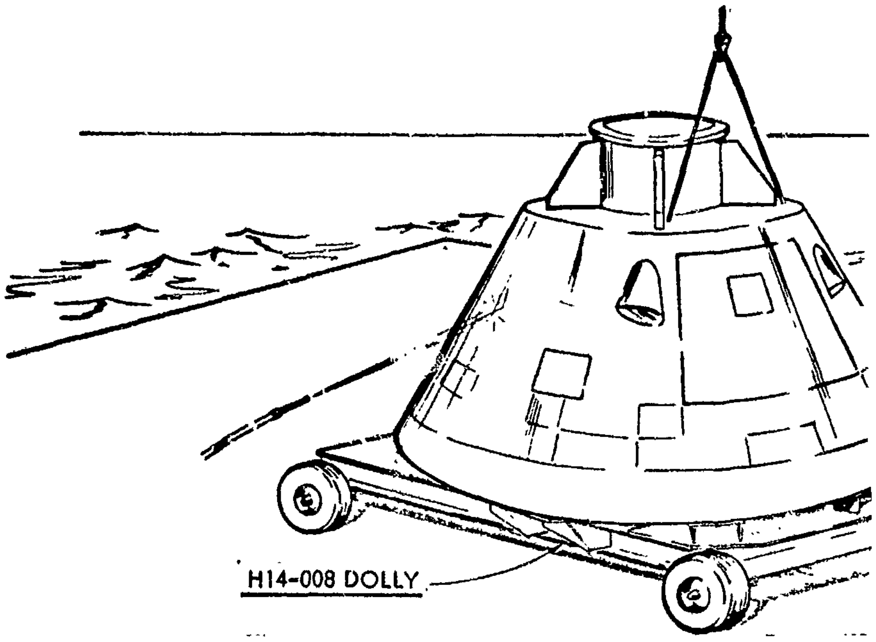
MANUFACTURING SUPPORT TO RECOVERY OPERATIONS

Recovery operations for the Apollo CM are the joint responsibility of NASA and NAA ATO recovery teams. Spacecraft recovery is described in Section III of this report. Manufacturing support will be provided during recovery operations for assistance in removal of the heat shields, access doors, and related equipment and spacecraft cleaning as illustrated in Figures 31 and 32. Technical assistance will be provided to Apollo Test Operations.

RCML INDEPENDENT

Figure 33 shows the Manufacturing flow proposed for the RCML (I) configuration.

FOLDOUT FRAME 1

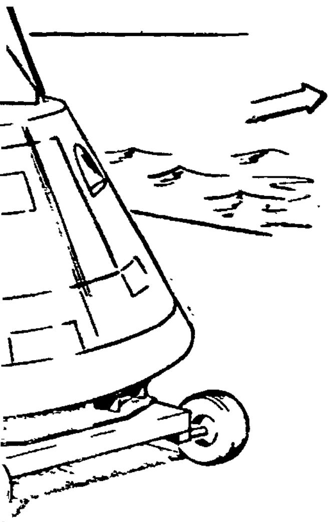


A. FLUSH EXTERIOR SURFACES WITH SHIP'S FRESH
AS SOON AS SPACECRAFT IS HOISTED ABOARD
PLACED ON DOLLY.

B. PERFORM FIRST STAGE SHIPBOARD POST RECOV
OPERATIONS. REF. DOCUMENT NO. SID 66-14
SUPPORT MANUAL REV. 20A.

NOTE: REMOVE HEAT SHIELDS AS SOON AS POSSIB
SUITABLE SELECTED AREA IN THE FOLLOWING
POSED MANNER AND CLEAN STRUCTURE THOR
TO PREVENT SALT WATER CONTAMINATION.

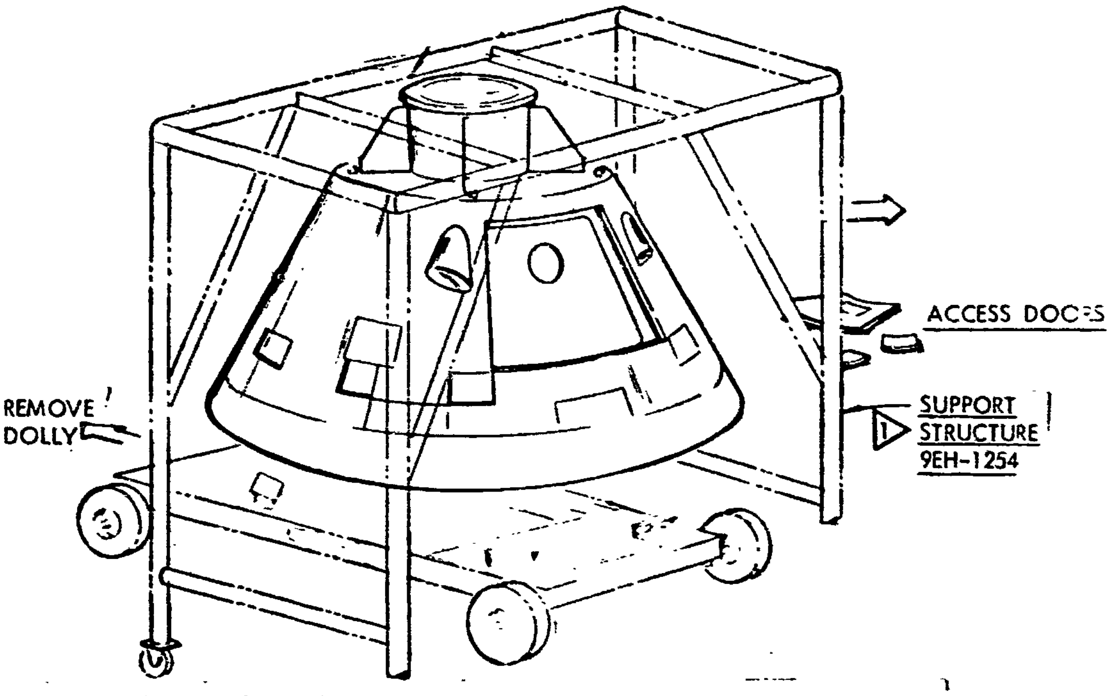
FOLDOUT FRAME 2



IP'S FRESH WATER
ED ABOARD AND

OST RECOVERY
. SID 66-1493 NASA

AS POSSIBLE IN A
OLLOWING PRO-
CTURE THOROUGHLY
INATION.



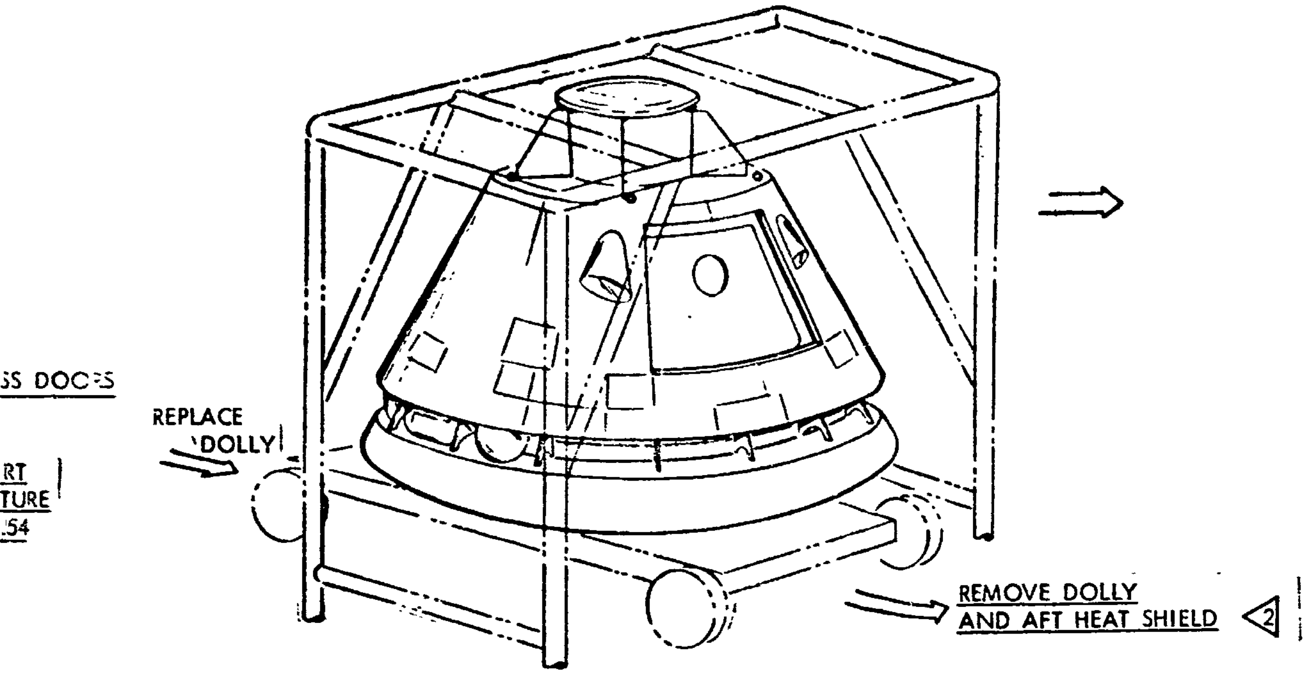
A. INSTALL SPECIAL STRUCTURE UTILIZING TOWER ATTACH POINTS.

B. LIFT COMMAND MODULE AND REMOVE SPECIAL DOLLY H14-008.

C. CORE DRILL THROUGH AFT HEAT SHIELD ABLATOR SURFACE AT 59 ATTACH POINTS AND THREE TENSION TIE POINTS TO EXPOSE ATTACH BOLTS, REMOVE BOLTS. (USE SPECIAL EQUIPMENT LISTED)

KIT ▷1
1. SUPPORT STRUCTURE
2. DRILL UNIT
3. CORE DRILLS
4. WRENCHES
5. HOT AIR BLOWER

D. CORE DRILL CREW COMPARTMENT HEAT SHIELD ABLATOR SURFACE AND REMOVE ACCESS DOOR BETWEEN FRAMES 3 & 4. DISCONNECT TWO OXIDIZER DUMP LINES FROM OXIDIZER PANEL.



A. LIFT COMMAND MODULE APPROX. SIX INCHES AND DISCONNECT COAX CABLES FROM C&S BAND ANTENNAS. REMOVE BRACKETRY, CLAMPS AND ELECTRICAL GROUNDING STRAPS AS REQUIRED.

B. DISCONNECT APPROX. SIX PLUGS FROM WIRE LEADS BETWEEN AFT HEAT SHIELD AND BOTTOM SIDE OF PORK CHOP FRAMES.

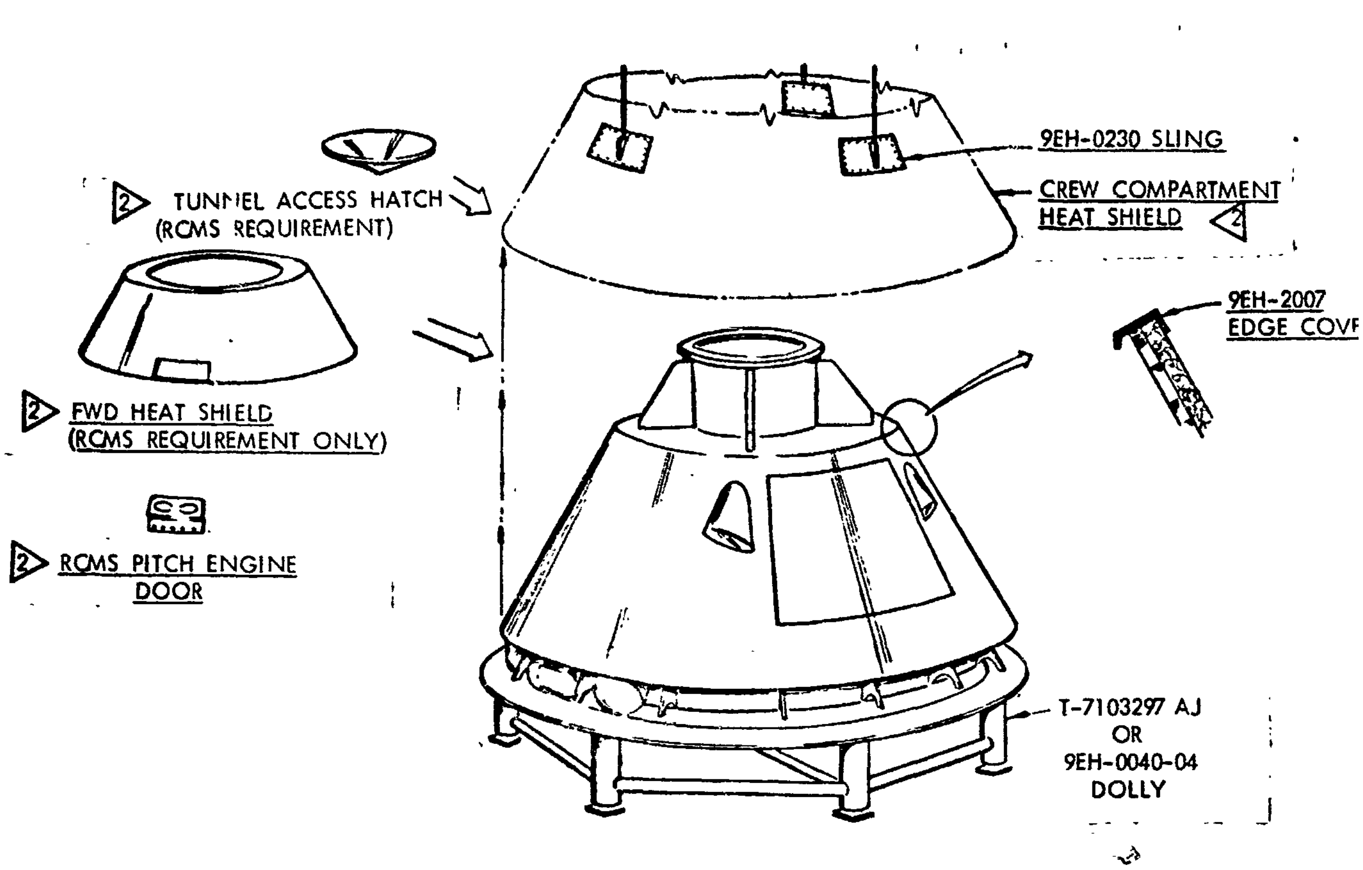
C. LIFT COMMAND MODULE FREE OF AFT HEAT SHIELD.

D. CLEANING OPERATIONS:
1. REMOVE INSULATION (PG 150)
2. FLUSH AND CLEAN ALL COMMAND MODULE & AFT HEAT SHIELD EXPOSED SURFACES WITH FRESH WATER.
3. HOT AIR DRY (USE KIT ITEM NO. 5).
4. PLACE BAGS OF DESICCANT IN CAPSULE AS REQUIRED.

***E.** IF COMMAND MODULE IS SHIPBOARD AND/OR AT FORWARD AREA, RE-INSTALL AFT HEAT SHIELD UTILIZING THREE TENSION TIE BOLTS, REPLACE ACCESS DOORS AND HEAT SHIELD CREW HATCH.

*DISREGARD ITEM "E" IF ALL DISASSEMBLY AND CLEANIN OPERATIONS ARE TO BE PERFORMED IN-HOUSE AT S&ID

1 SHIPBOARD AND/OR FORWARD AREA DISASSEMBLY WILL REQUIRE ORDERING OF SPECIAL GSE ITEMS TO REPLACE IN-HOUSE FACILITY & TOOLING ITEMS.



ANING
S&ID.

WILL
PLACE

A. LOWER AND PLACE COMMAND MODULE (MINUS AFT HEAT SHIELD) ON T-7103297 ASSEMBLY JIG OR DOLLY 9EH-0040-04.

B. REMOVE ELECTRICAL GROUNDING STRAPS BETWEEN FORWARD BULKHEAD AND CREW COMPARTMENT HEAT SHIELD. REMOVE LOCKING BOLTS ON STRINGERS, CORE DRILL AND REMOVE SCIMITAR ANTENNA AND DISCONNECT COAX CABLE.

C. REMOVE RCS ENGINES (APPROX. 44 BOLTS AND 24 LINES). REMOVE PG 150 INSULATION, HEAT SHIELD BOLTS FROM PORK CHOP FRAMES AND GIRTH RING (APPROX. 900 BOLTS).

D. DISCONNECT INSTRUMENTATION WIRE PLUG FROM SIGNAL CONDITIONERS AFT COMPARTMENT.

E. CORE DRILL AND REMOVE UMBILICAL COVER, DISCONNECT WIRE PLUGS AND COAX CABLES, DISCONNECT HARD LINES AND REMOVE UMBILICAL ASSEMBLY.

F. DISCONNECT STEAM DUCT AT BO

G. PRE-FIT NEW FORWARD HEAT SHIE RCM SPACECRAFT PRIOR TO CREW HEAT SHIELD REMOVAL.

H. REMOVE "I BEAM" STRINGERS.

I. INSTALL SLING NO. 9EH-0230 AN COMPARTMENT HEAT SHIELD.

2 J. RCMS HEAT SHIELD ASSEMBLIES W SHIPMENT TO AVCO FOR REFURBI

ø DISREGARD ITEM "G" FOR RCML

Figure 31. RCML and RCMS C/M Shipboard, In-House Disassembly Requirements

MENT
△2

9EH-2007
EDGE COVER

UCT AT BOTH ENDS.

HEAT SHIELD ASSEMBLY ON
TO CREW COMPARTMENT

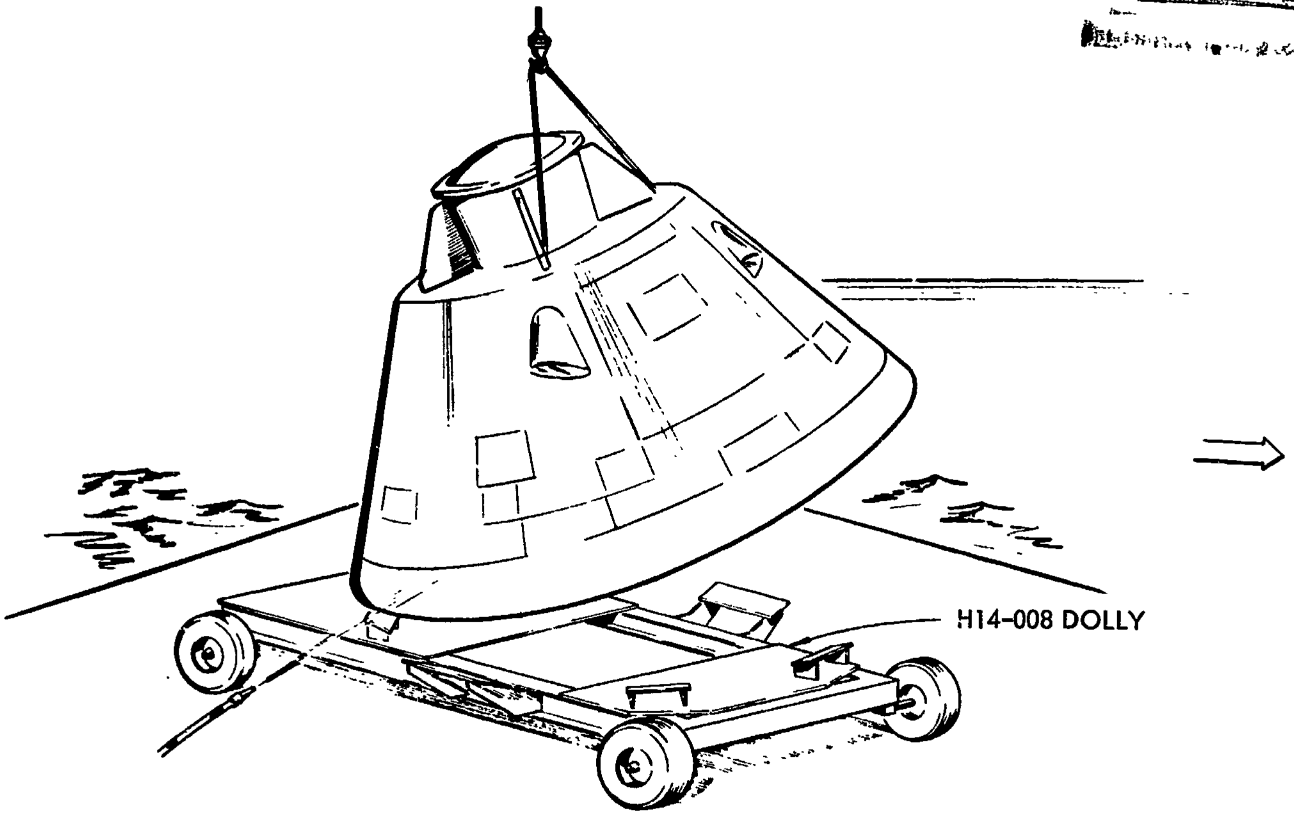
NGERS.

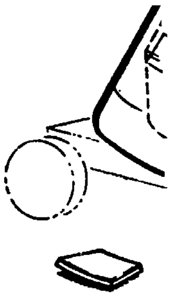
H-0230 AND REMOVE CREW
HIELD.

EMBLIES WILL REQUIRE
OR REFURBISHMENT.

OR RCML

pboard, Forward Area, and/or
rements for Cleaning





A. FLUSH EXTERIOR SURFACES WITH SHIPS FRESH WATER AS SOON AS SPACECRAFT IS HOISTED ABOARD AND PLACED ON DOLLY.

B. PERFORM FIRST STAGE SHIPBOARD POST RECOVERY OPERATIONS. REF: DOCUMENT NO. SID 66-1493 (NASA SUPPORT MANUAL AS-204)

C. SECURE INNER CREW COMPARTMENT HATCH.

D. INSTALL SPECIAL SLING NO. 9EH-0224.

EQUIPMENT REQUIRED

1. DOLLY
2. SLING
3. HOT AIR BLOWER

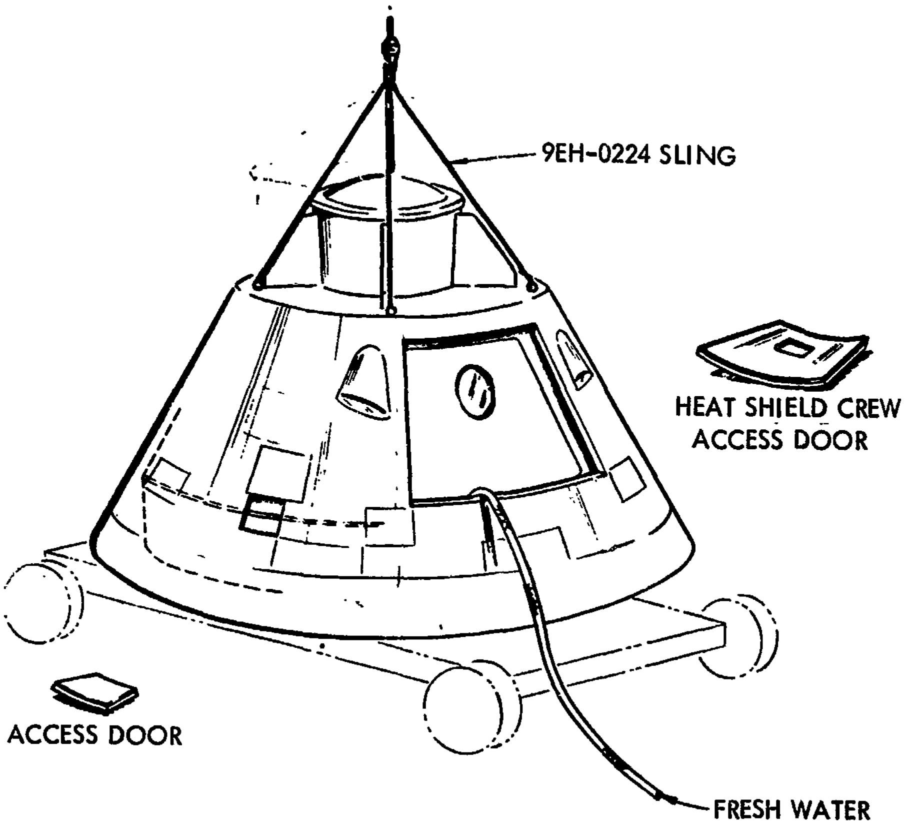
A. F
A
C
C
A

*B. L
B

C. F
A

D. H

Figure 32. RCML C/M



A. FILL AREA BETWEEN OUTER HEAT SHIELD AND INNER CREW COMPARTMENT TO LEVEL OF GIRTH RING WITH FRESH WATER (VISUALLY CHECK WATER LEVEL THROUGH HEAT SHIELD ACCESS DOOR).

*B. LIFT COMMAND MODULE, SLOSH AND DRAIN. (DRILL DRAIN HOLE IN AFT HEAT SHIELD ON BLOCK I VEHICLE ONLY)

C. REFILL, USE FLUSHING ADDITIVE IF APPLICABLE, SLOSH AND DRAIN.

D. HOT AIR DRY (USE KIT ITEM NO. 3)

*PROVIDE SPECIAL TILT DRAIN TYPE GSE FIXTURE FOR FUTURE COMMAND MODULES.

CML C/M Shipboard Cleaning Operations (Alternate Method)

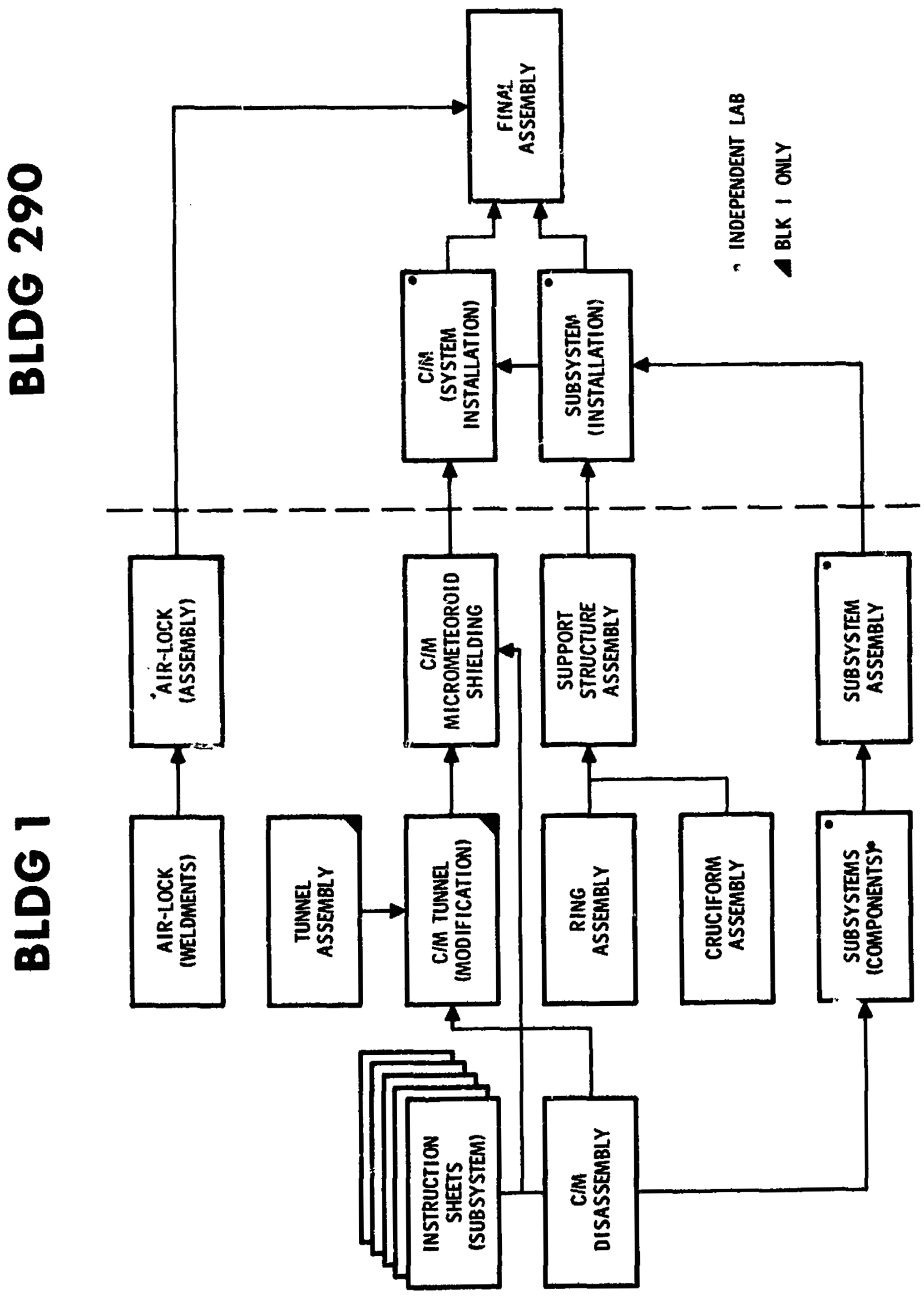


Figure 33. RCML (I) Block I Manufacturing Flow

Vehicle Disassembly - Pressure Shell Exterior and Interior Surfaces

Vehicle disassembly will begin as soon as practical after Apollo recovery testing. All subsystems must be removed from the Block I spacecraft to permit modification of the forward bulkhead to accept a Block II tunnel assembly, which will be bonded to the bulkhead by elevated temperature autoclave process. Components, wiring, plumbing, and partial secondary structures will be removed in accordance with Apollo modification and repair procedures. The pressure shell must be pressure leak-tested after CM disassembly to assure hull integrity.

The stripping of exterior and interior surfaces of the pressure shell after heat shield removal consists of removal of the following:

1. Exterior

   Earth landing system—Crushable cores for shock attenuation, air compressors, drogue chute canisters, parachute covers and riser-bar, flotation bag, canisters and lines, thrusters, recovery beacon light, antenna, and dye marker canister

   Reaction control system—Fuel and oxidizer tanks, oxidizer panel, fuel panel, helium panels and bottles, pitch engines, and plumbing

   Environmental control system—Potable water and waste water tanks

   Electrical—Aft compartment wire harness-girth ring to forward compartment and Band-Aid type wire straps

   Electronic equipment—RCS engine sequencer boxes

   Instrumentation—Signal conditioner instrument panels

   Secondary structure—Frames and bracketry

2. Interior

   Crew systems—Crew couches

   Controls and displays—Main control and display panels

   Environmental control system—Water glycol control panel, oxygen surge tank, ECU package, oxygen control panel, water control panel, oxygen control valves, glycol and miscellaneous plumbing and suit ducts above girth shelf, cabin air heat exchanger, blower, water reservoir and heater, fecal canisters, lower equipment bay cold plates, waste management system, and cabin pressure regulator

Guidance and navigation system—G&N black boxes, panels, and base

Stabilization and control system--Attitude and rate gyros

Electronic equipment—Right-hand forward and right-hand lower equipment bay black boxes

Electrical—Wire connectors from structural mounts, wire matrix, main wire harness, and terminal boards

Plumbing—Desolder, debraze, cut or disconnect mechanical fittings as applicable; all loose and remnant parts of brazed tubing will not be renovated

Secondary structures—All structures except lower right-hand, left-hand, and lower equipment bays and girth shelf

Fabrication of New Parts

New parts fabrication will be in accordance with standard airframe sheet metal and conventional machine shop practices with tooling requirements kept to a minimum cost.

Apollo Block II Access Tunnel and Adapter Fitting

A Block II tunnel will be fabricated including all detail bracketry required for subsequent bonding to the tunnel and forward bulkhead. The tunnel also incorporates a bolt circle on the upper flange to be used for mounting an LM docking drogue adapter ring as shown in Figure 34. A new adapter fitting for use between the tunnel and forward bulkhead also is required, and will be machined from aluminum alloy. The fitting will be bonded to the tunnel before joining the tunnel to the forward bulkhead, and will provide a mating surface for the pressure hatch. Apollo tooling developed for the S/C 007A tunnel modification will be used, and additional tooling required will consist of simple jigs and fixtures.

Apollo Block II Pressure Hatch Assembly - Block II Tunnel

An Apollo Block II circular flat pressure hatch of bonded aluminum honeycomb core construction will be fabricated using existing Apollo production tooling.

LM Docking Drogue Adapter Ring

This ring is machined from aluminum alloy and will be mounted on the access tunnel to provide interface with the drogue and the RCMS docking ring. Tooling requirements will consist of small jigs and fixtures.

Laboratory Support Structure Assembly

The structure assembly is composed of two subassemblies: the lower support structure assembly, and the support ring assembly (Figure 35).

Lower Support Structure Assembly

This assembly consists of stiffened sheet-metal beams 30 inches high fabricated of aluminum alloy standard extrusion and sheet. The beams provide interfaces to the SLA with machined fittings fabricated of aluminum alloy bar at the four LM attach points. Four splice fittings are required to join the beams. The laboratory support ring assembly attaches to the upper surface. The fittings will require fabrication of small jigs and fixtures and each of the 12 beams will be constructed as a separate subassembly requiring left- and right-hand assembly jigs.

Laboratory Support Ring Assembly

The ring assembly is a stiffened sheet-metal box structure 125 inches in diameter fabricated of aluminum alloy standard extrusion and sheet stock which supports the laboratory on the lower support structure assembly. A cross-section of the box is 8-1/2 inches wide by 10 inches high, and includes 24 machined, 3 tension tie, and 3 compression pad fittings fabricated from aluminum alloy bar. Fabrication of tooling, such as jigs and fixtures for machined parts and an assembly jig for the ring assembly, which also will provide for alignment when mounting the tension tie and compression pad fittings, is required.

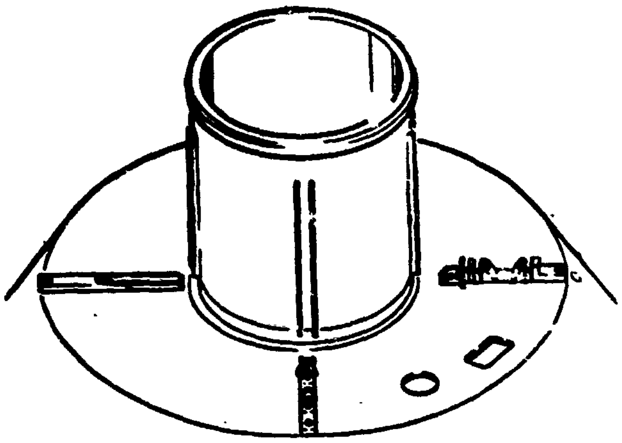
Laboratory Support Structure Final Assembly

The laboratory support structure final assembly will be completed by use of mechanical fasteners after joining the beams with splice fittings and positioning the ring assembly on the lower support structure assembly. An assembly jig will be required to perform the final operation.

Apollo LM Docking Drogue Assembly

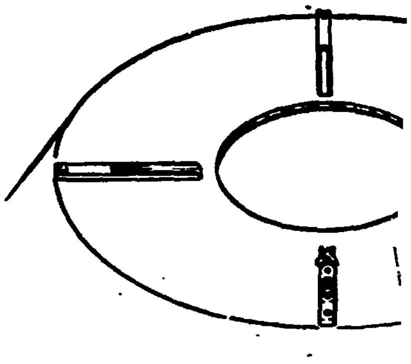
A docking drogue assembly updated to the latest configuration will be fabricated to satisfy the requirements of this program. The drogue is of conical shape and constructed of brazed and bonded aluminum honeycomb

FOLDOUT FRAME 1



SPACECRAFT BLOCK I CONFIGURATION

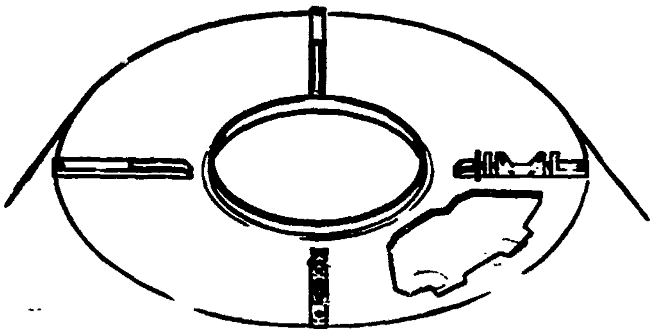
REMOVE ALL EXTERIOR BLOCK I DETAILS FROM FORWARD COMPARTMENT PLUS INTERIOR DETAILS ON -Z QUADRANTS



MAKE INITIAL ROUGH CUT ON FORV
V16-316006 RING

T-7116371 USED FOR FINAL CUT IN
RING

REMOVE CORE AND FILL WITH EPOX
INSTALLATION OF TUNNEL



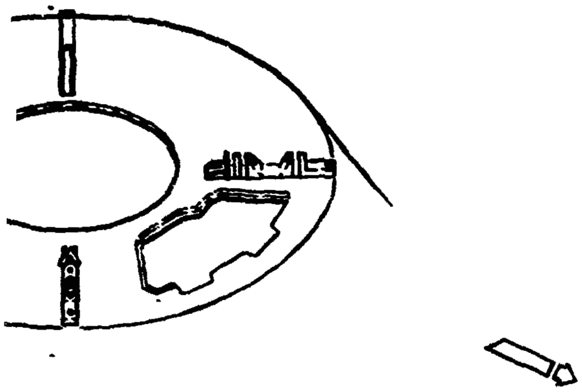
REMOVE ESCAPE TUBE FORWARD OF V16-316006 RING BY USE OF SABRE SAW OR OTHER COMPATIBLE MEANS. THIS WILL PROVIDE ACCESS FOR INITIAL CUT IN AREA OF TUNNEL RING.

T-7116369 USED FOR INITIAL CUT IN -Z QUADRANT FOR FORWARD BULKHEAD FITTING.

T-7116370 USED FOR FINAL MACHINE CUT IN -Z QUADRANT FOR FORWARD BULKHEAD

BLOCK II TL
XC 8L50 TO

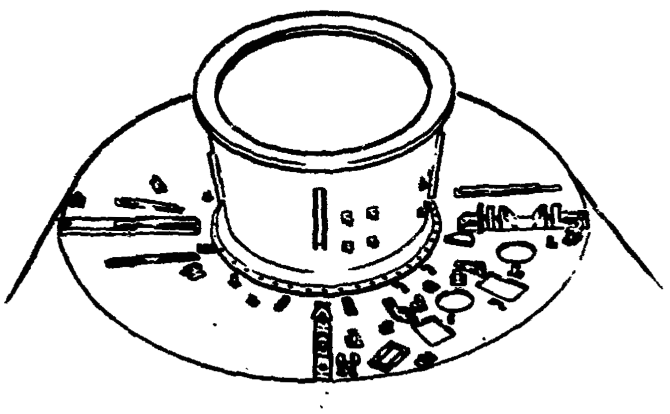
FOLDOUT FRAME 2



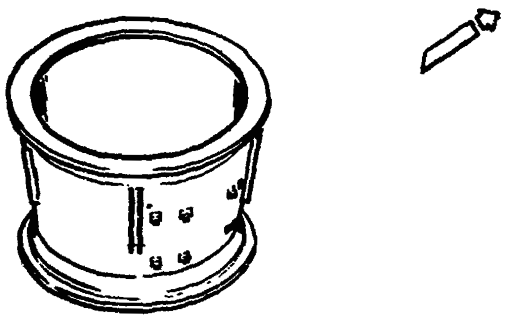
N FORWARD BULKHEAD IN AREA OF

L CUT IN REMOVING V16-316006

H EPOXY TO PROVIDE EDGE FOR



BOND ALL BLOCK II DETAILS IN ALL QUADRANTS, BOND AND
BOLT BLOCK II TUNNEL IN PLACE



CK II TUNNEL CONFIGURATION
8L50 TO 104.50 (NEW)

Figure 34. Tunnel

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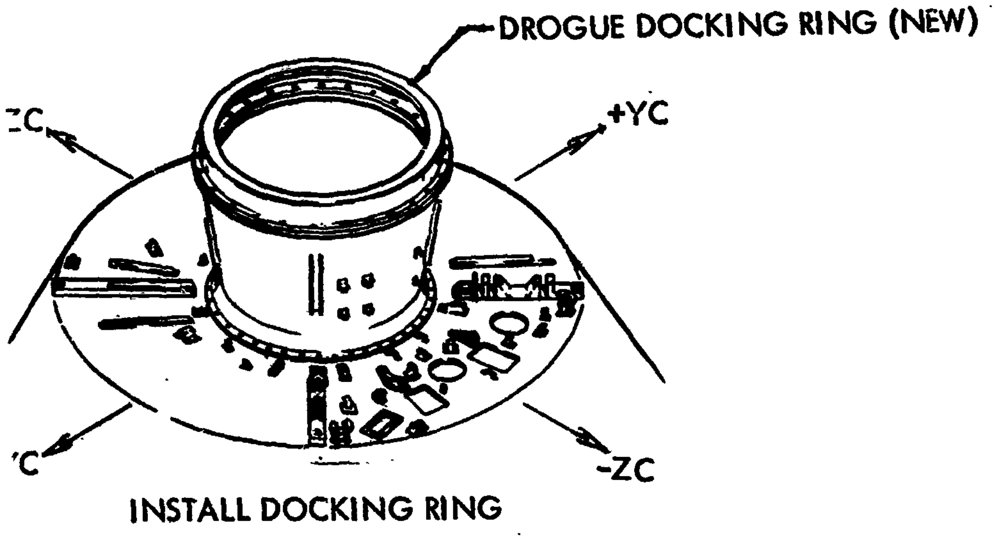

Tunnel Modification and Assembly Command Module RCML
Block I

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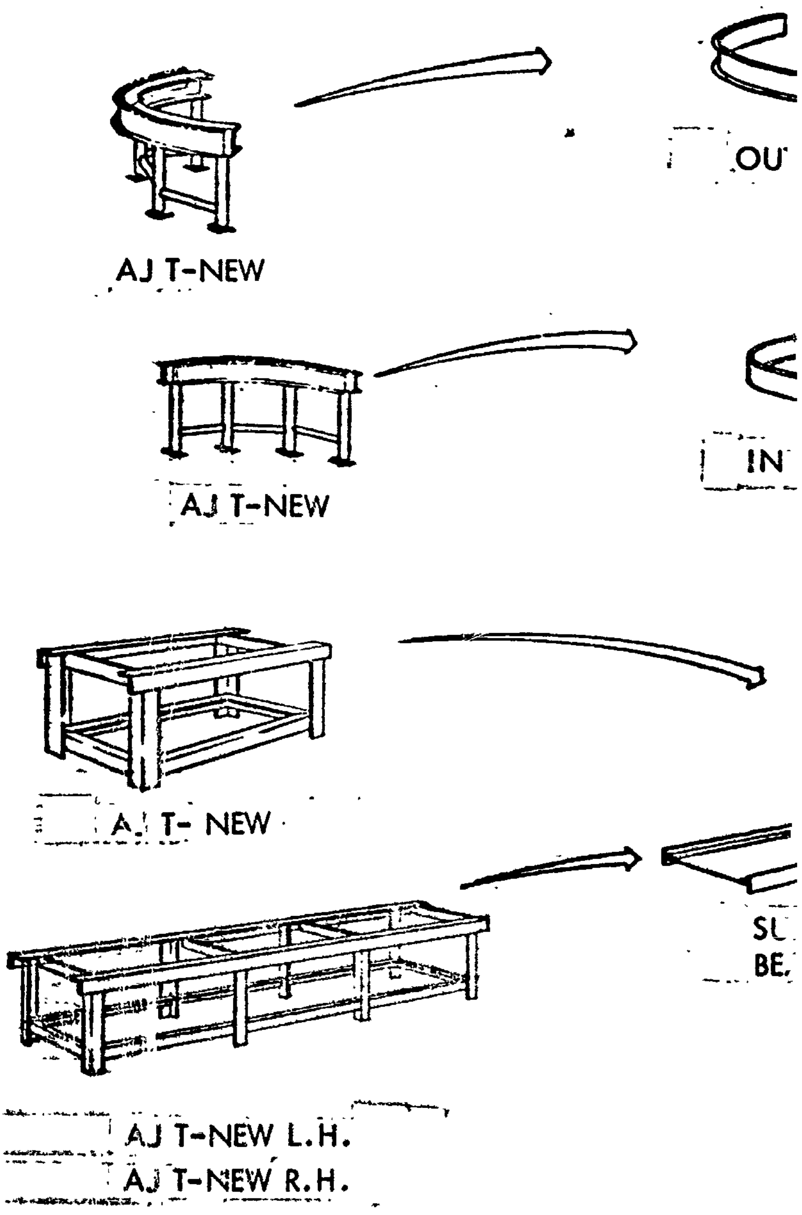

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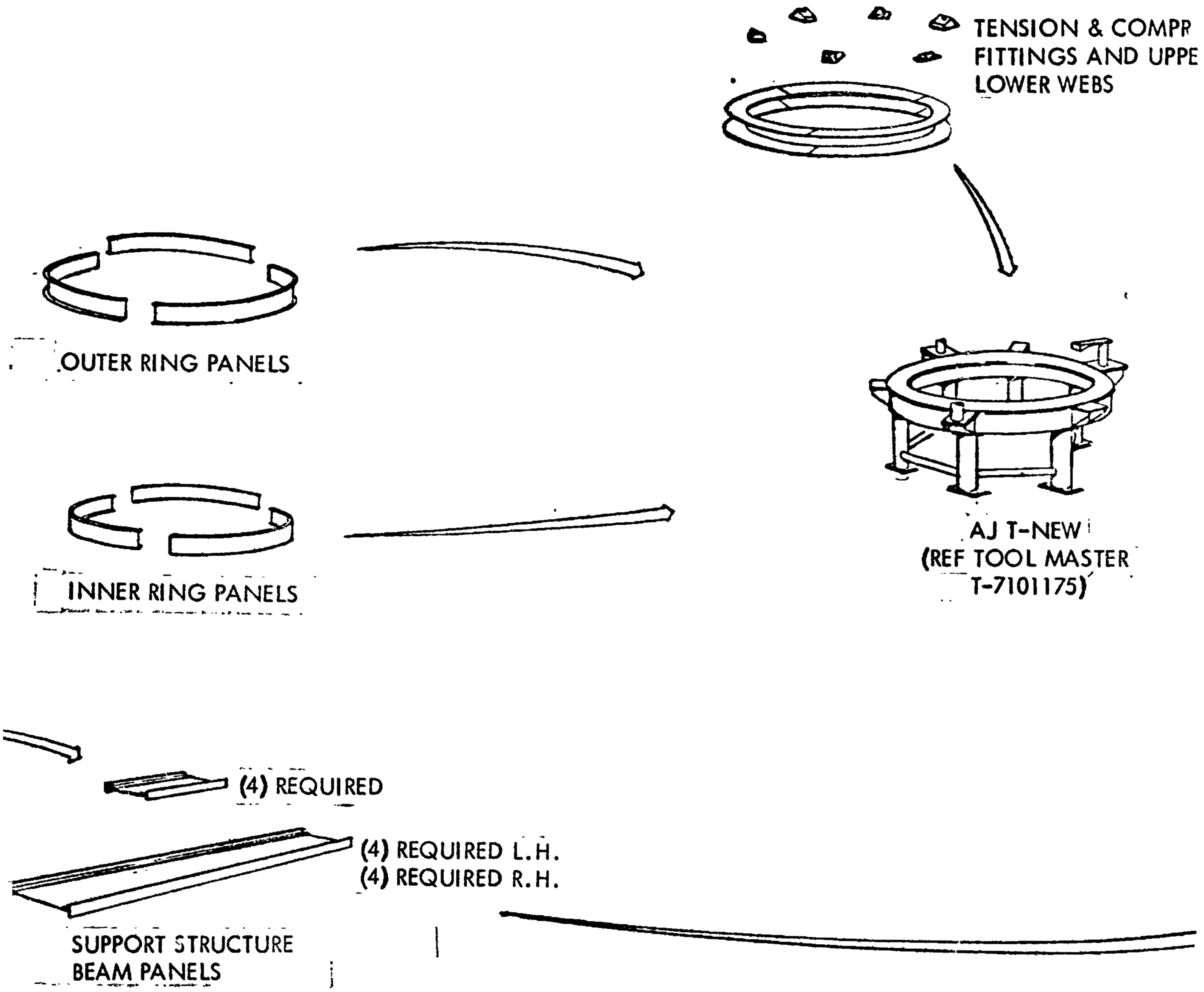

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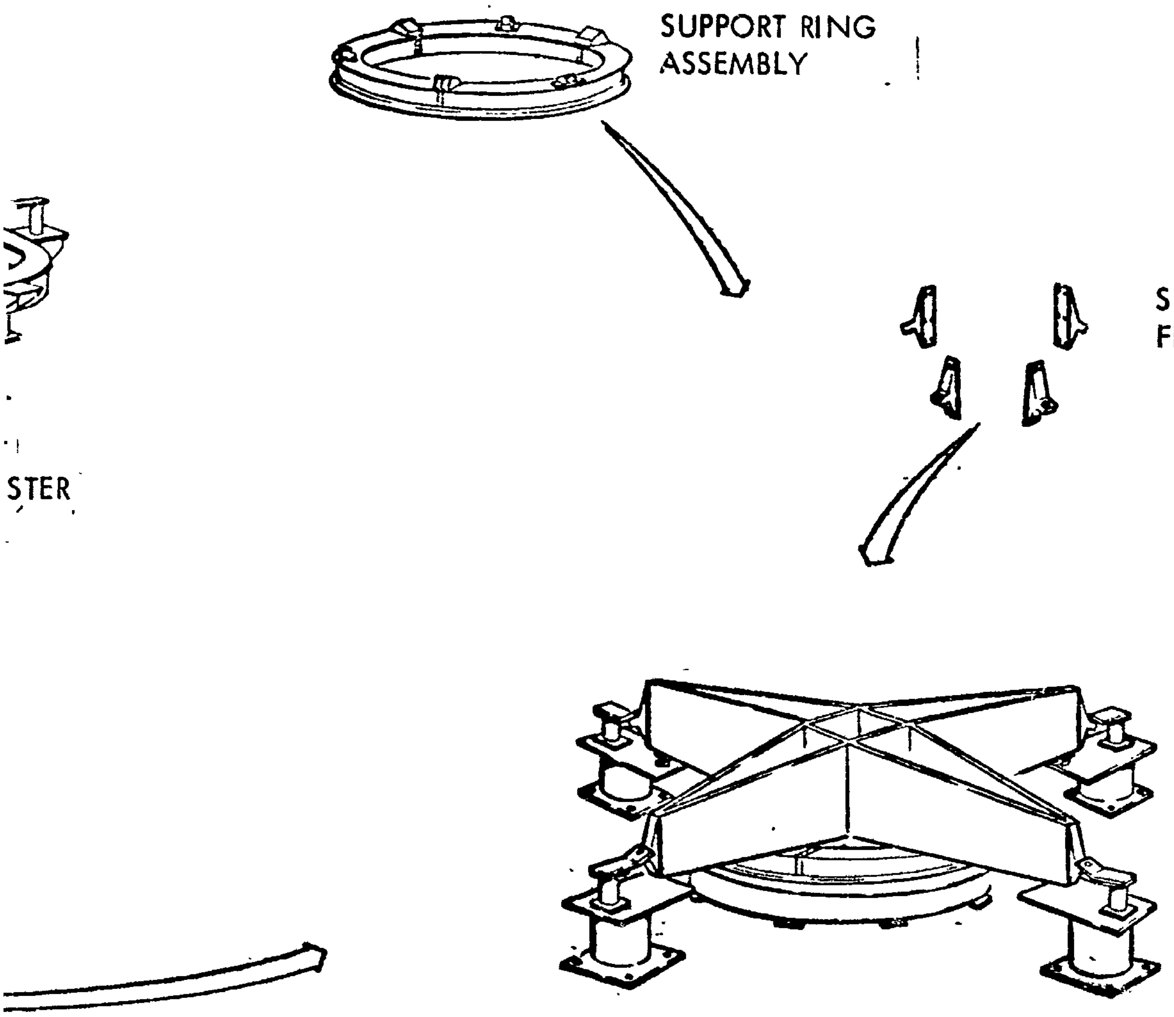

AJ T- NEW

(REF TOOL MASTER T-

NOTE:

SUPPORT RING AND SUPPORT STRUCT
HAVE BEEN INVERTED FOR FINAL
ASSEMBLY

Figure 35. Support Structure Assembl

FOLDOUT FRAME 4

MASTER T-7101175)

RT STRUCTURE
FINAL

Assembly Tooling

core panels stiffened by machined aluminum alloy stringers attached to the forward and aft rings. Apollo production tooling is available.

Airlock Assembly

The airlock assembly consists of a composite welded airlock inner pressure vessel, airlock hatch assembly, and a support structure for joining the airlock to the pressure shell (Figure 36).

Airlock Inner Pressure Vessel

The pressure vessel is approximately 80 inches high and tapers from a 46-inch diameter spherical dome to a spherical section 34 inches in diameter at the bottom. Interface with the pressure shell is accomplished by means of a metal corrugated bellows, a clamping device, and a machined attach ring welded to the conical section of the airlock.

The domes and conical sections are fabricated from aluminum alloy sheet and are chem-milled to a constant thickness to provide land surfaces for weldment. These sections are structurally stiffened at the forward end by circular support rings machined from aluminum alloy to serve as seal mounting rings.

Conventional sheet-metal and machined parts tooling, such as spinning blocks, templates, form rolls, jigs, and fixtures, will be required. Tooling required for weldment will consist of weld fixtures, weld positioners, and a Sciaky head and tailstock positioner. NAA standard spacecraft welding techniques and related tooling will be required for weldment of the airlock assembly.

Airlock Support Structure

The support structure consists of two aluminum alloy formed sheet-metal sheer webs located at the forward and aft ends of the airlock inner pressure vessel and two single-strut members fabricated from aluminum tubing. The strut members are joined to aluminum alloy machined fittings with one fitting located at each end of the strut. The structure is secured to the airlock assembly and provides interface with the pressure shell. Tooling consists of two hydropress form dies, one left- and one right-hand torch weld jig, simple jigs and fixtures for machined fittings, and sheet-metal templates.

Airlock Inner Hatch Assembly

A new circular pressure hatch of aluminum honeycomb core panel will be fabricated similar to that for the Apollo Block II forward pressure hatch. The hatch serves to preserve airtight integrity between the airlock and crew compartment. A combination bonding fixture and assembly jig will be required.

Crew Compartment Hatch - Airlock Attach Fitting

The crew compartment hatch fitting attaches to the existing crew compartment hatch frame and provides a seat for the Apollo Block II circular pressure hatch and also provides the outer interface surfaces for joining the airlock assembly.

This part, complex in nature, will be machined from an aluminum alloy hand forging with the outer mold lines coordinated with the crew compartment hatch frame. Fabrication of this fitting will be accomplished by a combination of conventional machining and numerical control techniques to assure maintaining the compound contours of the mold line surfaces. Apollo tooling is available and will be utilized; additional fixtures will be fabricated as required.

Insulated Micrometeoroid Shields - Pressure Shell

Panels are required for thermal and micrometeoroid protection and will be fabricated in sections to encapsulate the external contours of the pressure shell. Each panel consists of an aluminum alloy skin with a thermal insulation blanket secured to the inner surfaces by means of retaining pins located on 12-inch centerlines. The panels are secured by means of mechanical fasteners to fiberglass support rings attached to the pressure shell in the forward and aft bulkhead and girth shelf areas, including closeout rings surrounding window and hatch openings. Conventional sheet-metal tooling required will consist of flat patterns, simple hand-form blocks, and insulation locating fixtures (Figure 37). Fiberglass moldings will be completed by vacuum bag layup and cure processes. Templates and layup dies are necessary to support this operation.

Insulated Micrometeoroid Shields - Airlock Assembly

In general, the shielding discussed for the pressure shell is applicable to the airlock assembly, but becuase of external contours, tooling such as spinning blocks and contour templates will be required.

Insulated Micrometeoroid Shielding - Systems Components Exposed to Space Environment

Box-type shielding will be fabricated to enclose environmental control and electrical power system radiator panels and for functional components and related plumbing mounted on the laboratory support structure assembly which will be exposed to space environment.

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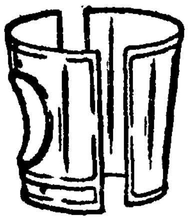
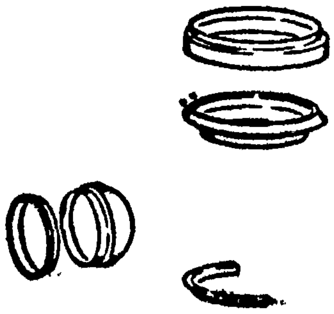


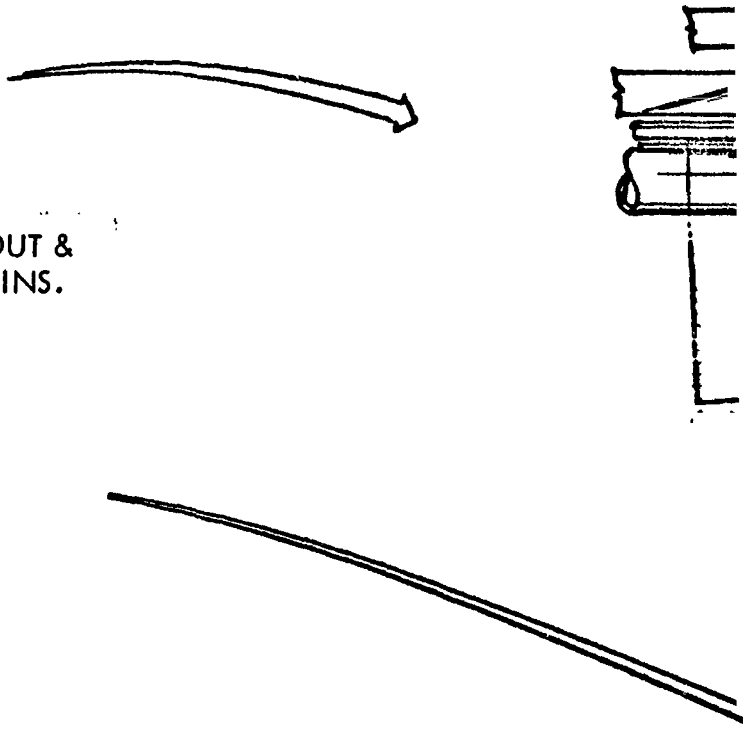
ROLL FORM, MAKE CUTOUT & CHEM-MILL CONICAL SKINS.

FORWARD DOME
T-NEW
SPIN BLOCK

AFT DOME
T-NEW
SPIN BLOCK



DETAIL & MACHINED PARTS



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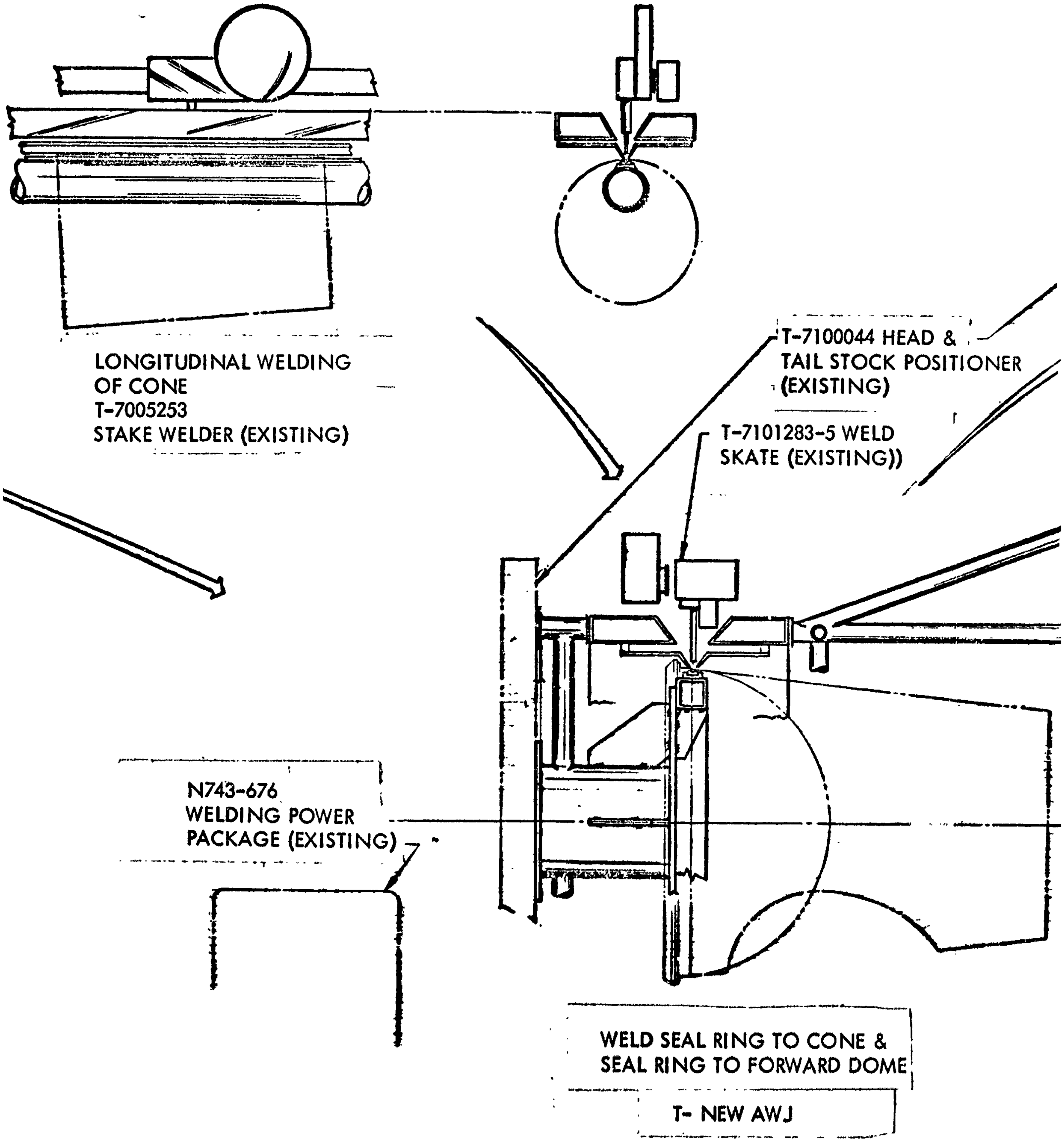

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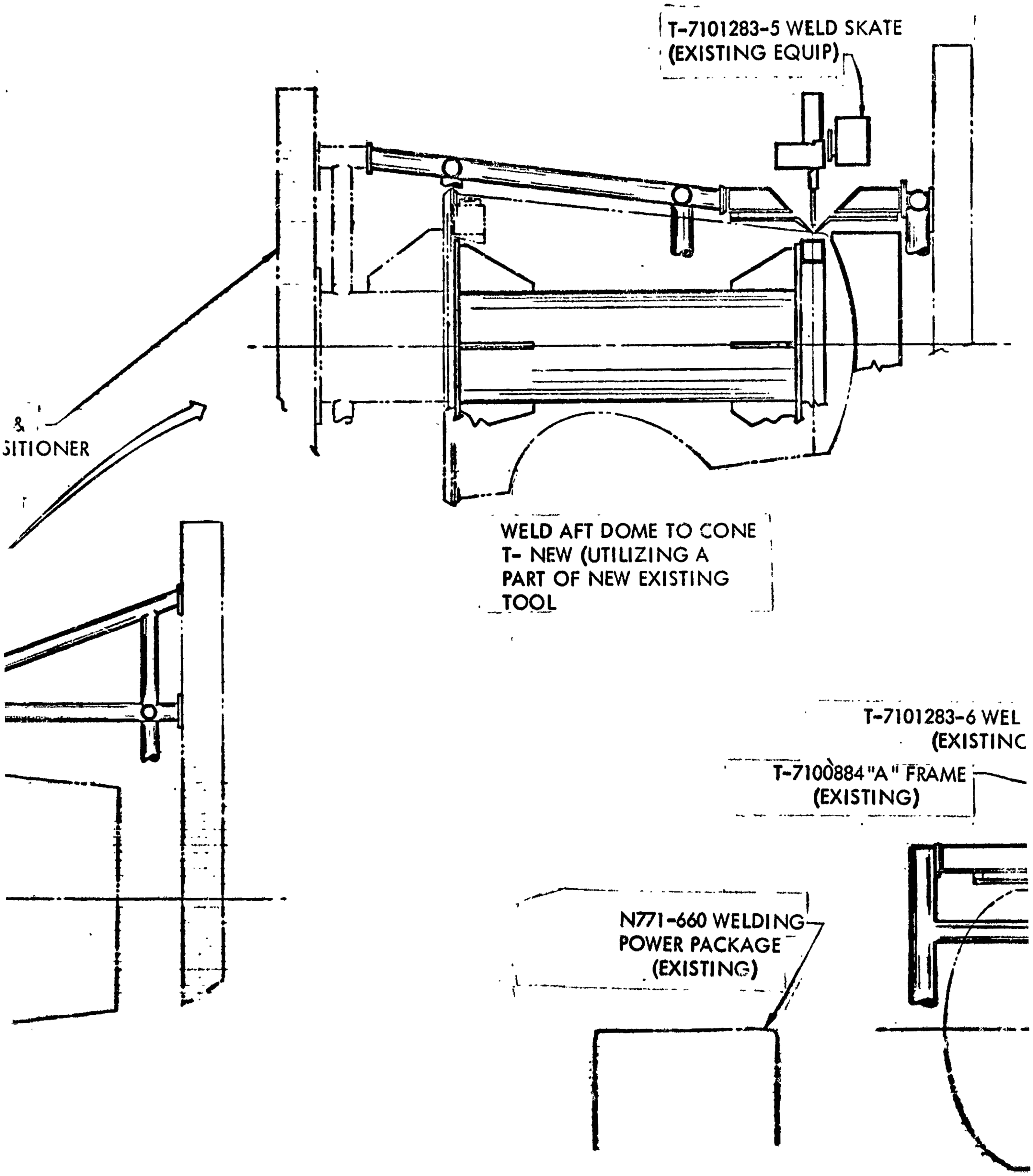

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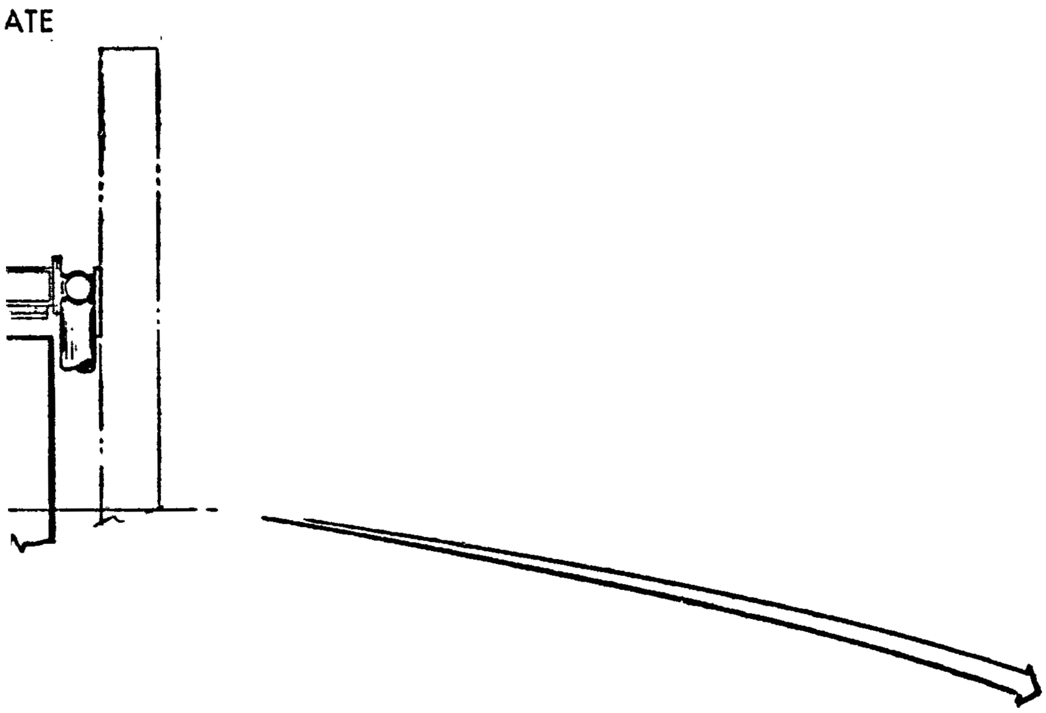
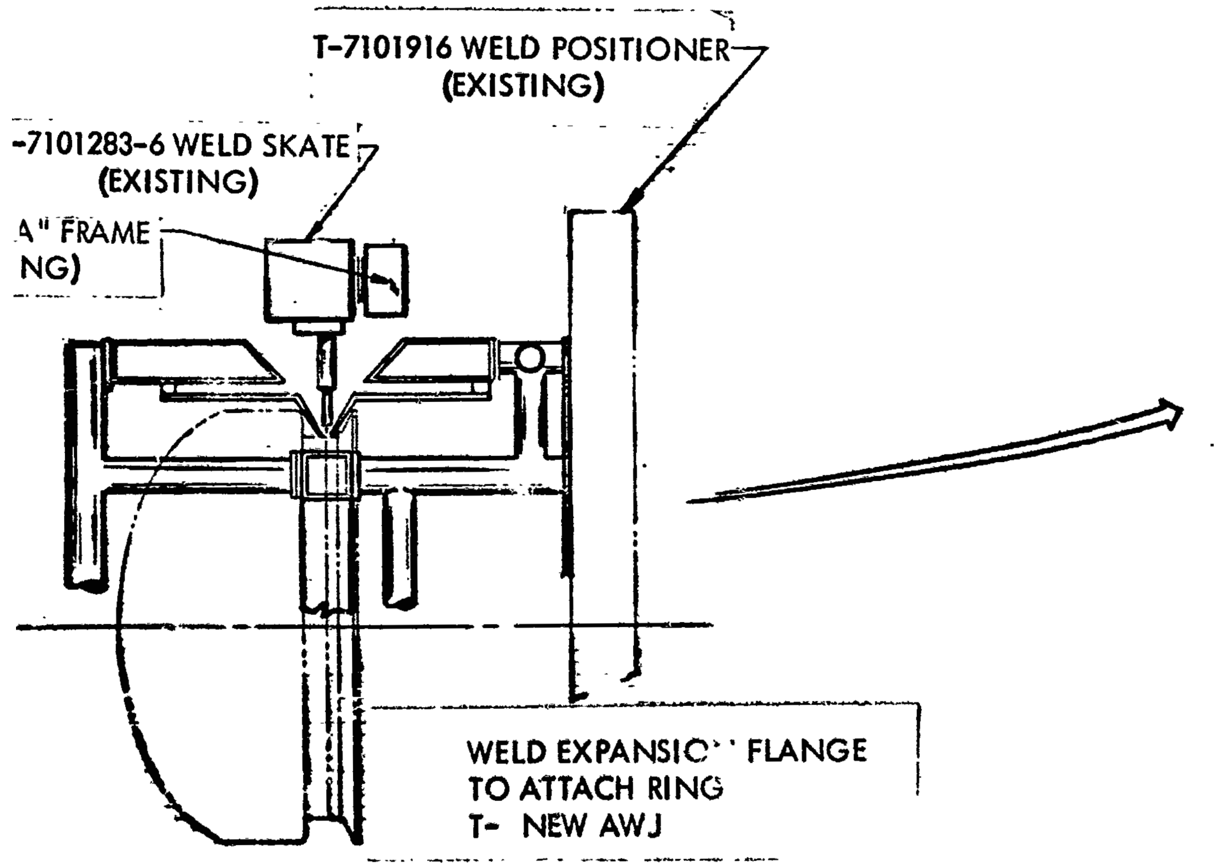




Fig

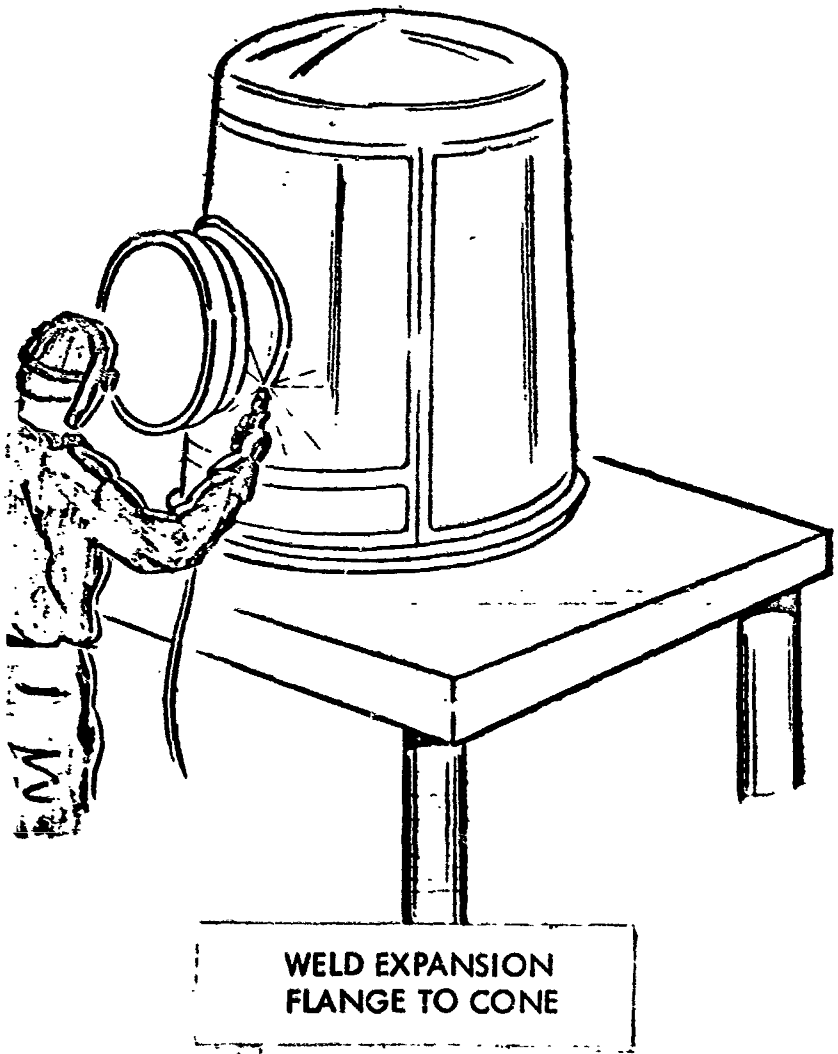
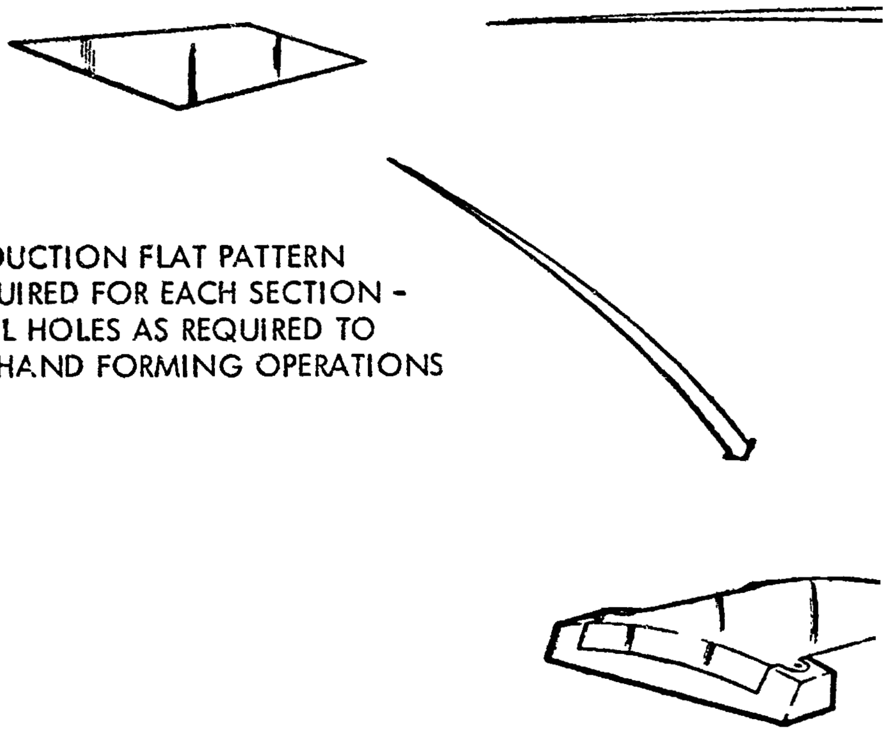


Figure 36. Airlock Assembly Weld Tooling

36

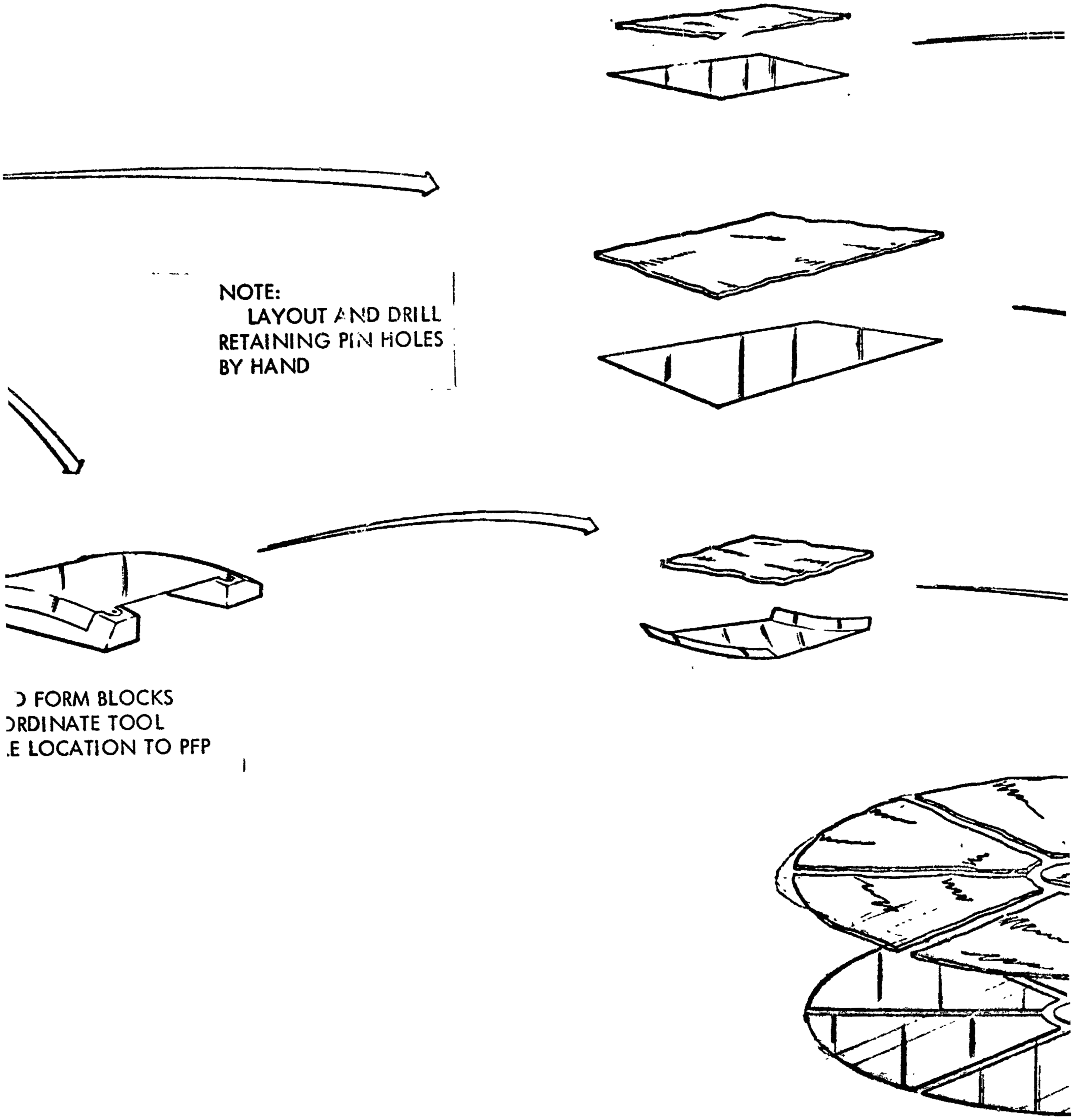
FOLDOUT FRAME 1



PFP (PRODUCTION FLAT PATTERN
ONE REQUIRED FOR EACH SECTION -
ADD TOOL HOLES AS REQUIRED TO
SUPPORT HAND FORMING OPERATIONS

HAND FORM BLOCK
COORDINATE TOOL
HOLE LOCATION TC

FOLDOUT FRAME 2



NOTE:
LAYOUT AND DRILL
RETAINING PIN HOLES
BY HAND

D FORM BLOCKS
ORDINATE TOOL
E LOCATION TO PFP

FOLDOUT FRAME 3

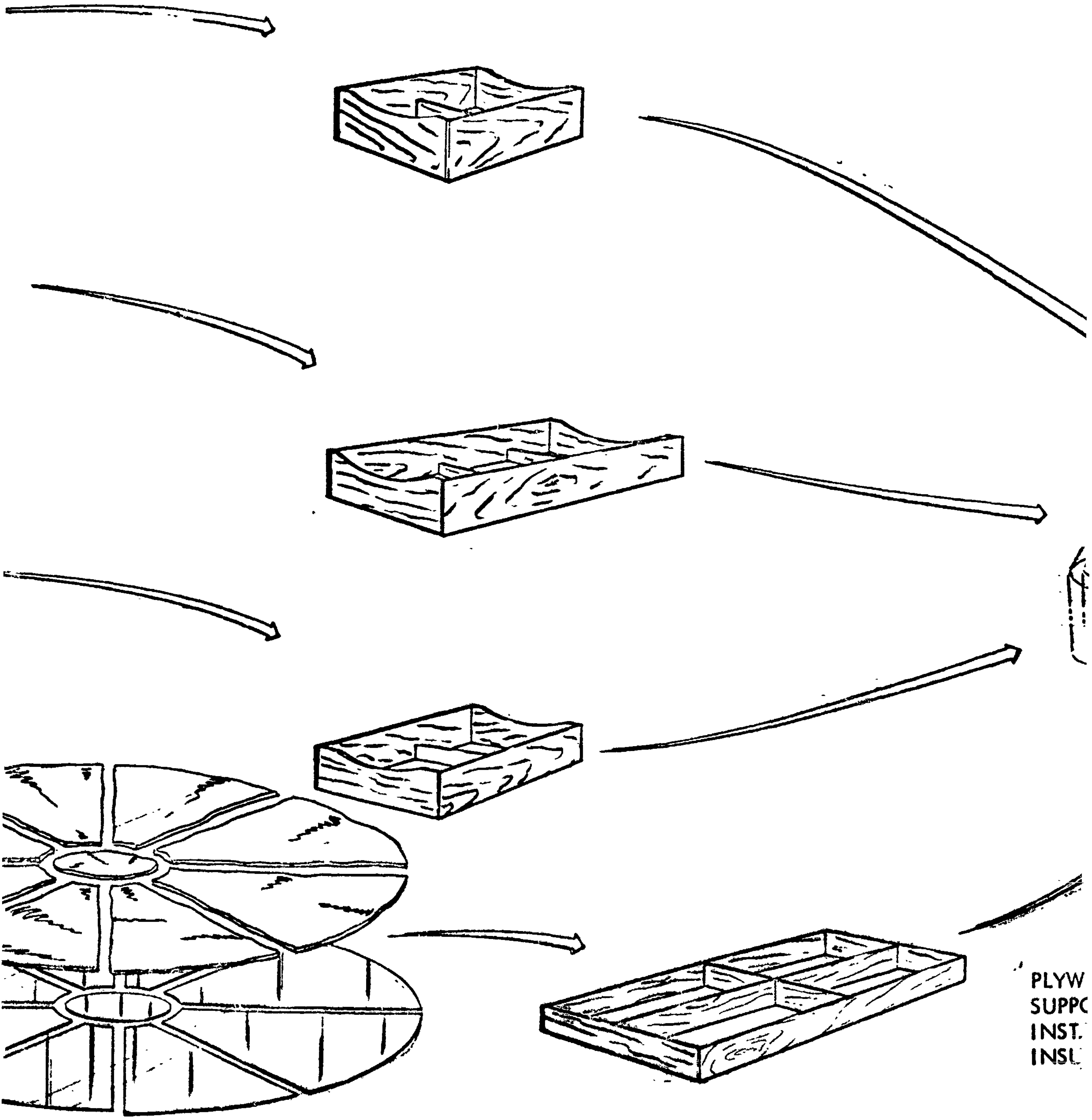


Figure 37. Micromet

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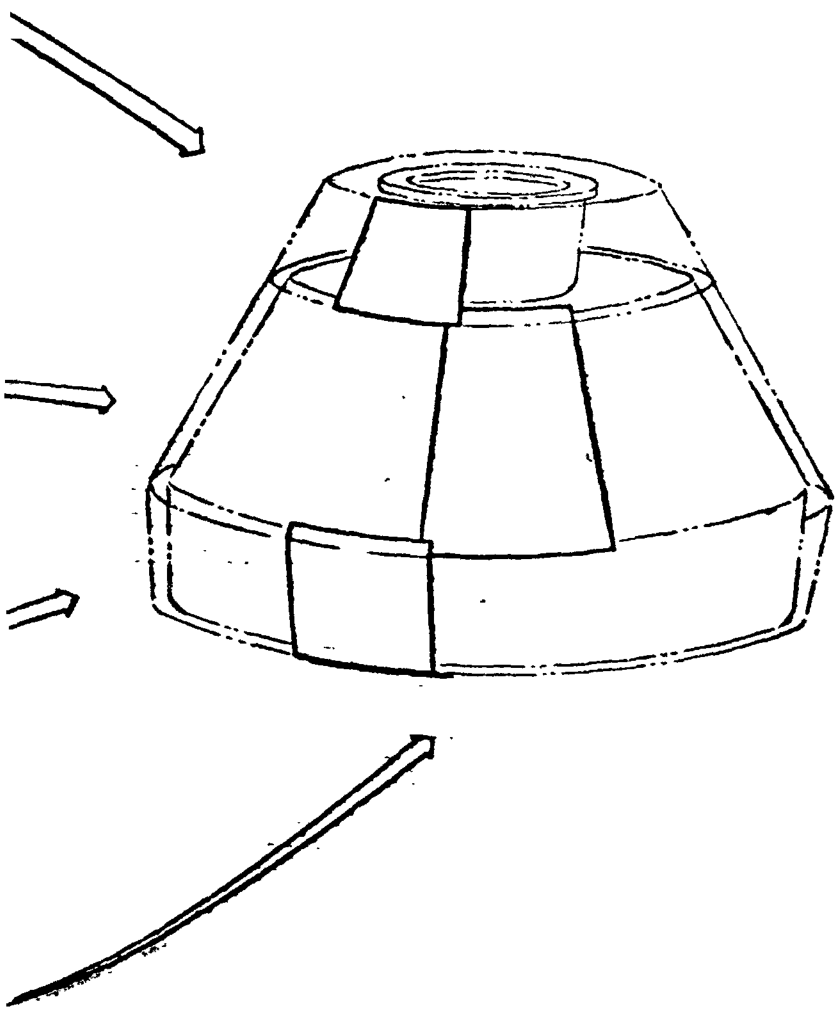

PLYWOOD CRADLES TO SUPPORT SKINS DURING INSTALLATION OF INSULATION MATERIAL

Micrometeoroid Tooling and Assembly

Modification and Repair - Structural

Modification of the pressure shell consists of replacing the existing Apollo Block I access cylinder assembly with a modified Apollo Block II access tunnel and a docking ring. (Figure 34).

The sequence of operations is as follows: remove exterior and interior bonded detail parts located between quadrants, truncate the access cylinder assembly by cutting off above the doubler ring, saw through the forward bulkhead, remove ring, finish machine the cut out, and fill the open core area with epoxy to provide mounting surfaces for the new tunnel and pressure hatch adapter fitting. Apollo tooling developed for Spacecraft 007A modification will be utilized.

Repair of the pressure shell and touch-up of bare surfaces caused by disassembly or rework will be in accordance with discrepancies noted during teardown, test, and evaluation and will be in conformance with the Standard Repair Manual for Apollo and Saturn II, PUB 543-G-18.

Apollo Block II Tunnel to Inner Structure

Modified Block II tunnel assembly and detail bracketry will be positioned on the pressure shell forward bulkhead and bonded by autoclave process. After bonding, the tunnel will be secured by use of mechanical fasteners.

Renovation/Replacement - Removed Components

All functional components containing elastomer elements originally procured from subcontractors or sources other than NAA will be returned for renovation or replacement as deemed necessary. Renovated items will be restored to original operational and performance specifications.

Components removed for which life expectancy or reliability factors have been established, such as circuit breakers, switches, batteries, and line equipment items such as, valves and regulators will be evaluated and replaced as required. Electronic equipment will be renovated by replacement of crystals, repair of damaged circuitry and general restoration as necessary.

Removed NAA-, subcontractor-, or supplier-fabricated parts which are damaged and are so noted during teardown, test and evaluation will, after disposition by Material Review, be renovated in accordance to the original specifications or replaced by the cognizant source.

Structural Assembly

Micrometeoroid Shield - Pressure Shell

The shields will be positioned on the pressure shell and holes will be transfer-drilled through the shield attach holes into the fibreglass support rings mounted in the forward and aft bulkhead and girth shelf areas including the close-out rings surrounding hatch and window openings to provide location for nutplate installation. After initial fit operations, those shields required to provide accessibility for subsequent systems installations will be removed (Figure 37).

Laboratory Support Structure Assembly

The support ring assembly is positioned on the assembly jig and the beam subassemblies will be assembled into a complete laboratory lower support assembly. Alignment of the support ring with the support structure base completes the assembly shown in (Figure 35).

Subsystems Assembly and Installation

Subsystems installation is discussed in two parts: (1) subsystems mounted in the interior of the laboratory, and (2) subsystems mounted on the laboratory support structure.

Subsystems Mounted in the Interior of the Laboratory

The comparison of installation and assembly techniques is predicated on typical Apollo Block I assembly and systems installation plans, incorporating to secondary structure and systems changes peculiar to the laboratory design. Block I tooling will be used as applicable.

Subsystems consist of environmental control, stabilization and control, controls and displays, communications, electronic data equipment, and electrical power. These installations must provide interface with systems and components mounted on the support structure assembly. Mating of the pressure shell to the laboratory support structure assembly will be accomplished by means of tension tie fittings.

Subsystems Mounted on the Laboratory Support Structure Assembly

Plumbing, tankage, and wiring exposed to space environment will require thermal insulation and shielding protection against micrometeoroid bombardment. Access panels will be provided in the box-type shielding to accommodate plumbing and wiring interfaces for close-out connections. Electrical checkout may be completed by means of feed through plates for test equipment.

Apollo service module partial subsystems are used on the laboratory support structure and include electrical power, cryogenic tankage, environmental control, reaction control, and communications equipment.

Environmental Control System and Electrical Power System Radiator Panels

ECS and EPS radiator panels will be installed.

Electrical Power System

The electrical power system consists of three fuel cells, control valves, and water glycol coolant loop provided by eight EPS radiators, glycol reservoir, pump, and control valves. One coldplate is also required for the power distribution box and water control plumbing lines that interface with the renovated command module potable water management system. A new wire harness will be fabricated for transmission of electrical current between components mounted on the support structure and those of the laboratory interior.

Cryogenic Storage

The cryogenics supply supporting the EPS consists of two hydrogen and two oxygen tanks, related control valves, pressure transducers, heaters and sensors. Life support oxygen is also supplied to the laboratory environmental control unit by the oxygen tanks through inner structure penetration lines.

Environmental Control System

This system is composed of two Apollo Block II service module ECS radiators, control valves, pressure flow transducers, and required plumbing to effect interface with the water glycol system by means of existing inner structure penetrations. A portion of the renovated command module water management system, composed of a potable water and a waste water tank, pressure flow transducers, and related plumbing will also be mounted on the structure.

Reaction Control System

The propulsion system is composed of four Apollo Block II service module RCS panels consisting of fuel, oxidizer, and helium tankage, helium pressure control panel and an RCS engine sequencer box mounted adjacent to the support structure.

Communications Equipment

A high-gain boom antenna and four S-band omni antennas are required.

Final Assembly

The airlock assembly, less those micrometeoroid shields required for subsequent final assembly, will be mated to the pressure shell, and the airlock support structure and shielding will be installed. Pressure leak test will be performed with systems installed.

Micrometeoroid shielding will be installed to cover systems mounted on the support structure assembly, and will also be installed on the pressure shell and airlock assembly as illustrated in Figure 38. A new crew compartment hatch fitting and hatch will be installed.

Tooling Requirements

New tooling requirements are identified and discussed under the appropriate sections of this report. Design and fabrication of new tooling necessary to support the manufacturing objectives of this program will be performed in accordance with Apollo tooling policy, program directives, and division procedures as established for the Apollo Block I and II phases. Typical categories of tooling will include hard and soft tooling for detail, assembly, and installation; simulated components; manufacturing aids; and jig boards as necessary.

Downey material handling equipment provided by Apollo Facilities will be used in lieu of GSE where possible. Existing Apollo tooling, such as jigs, fixtures, and small tools will be used in support of this program as applicable and on a time-shared and noninterference basis with firm Apollo spacecraft schedules.

Factory Checkout

All systems and components to be reinstalled will be certified as operational after renovation by NAA, subcontractors, or suppliers.

Since systems are functionally compatible with present Apollo systems configurations, present functional test, pressure test, and checkout procedures will apply. Existing Apollo checkout equipment, such as special test equipment and ground support equipment will be utilized, but may require minor modification for interface compatibility. The installation operational sequence will be as follows:

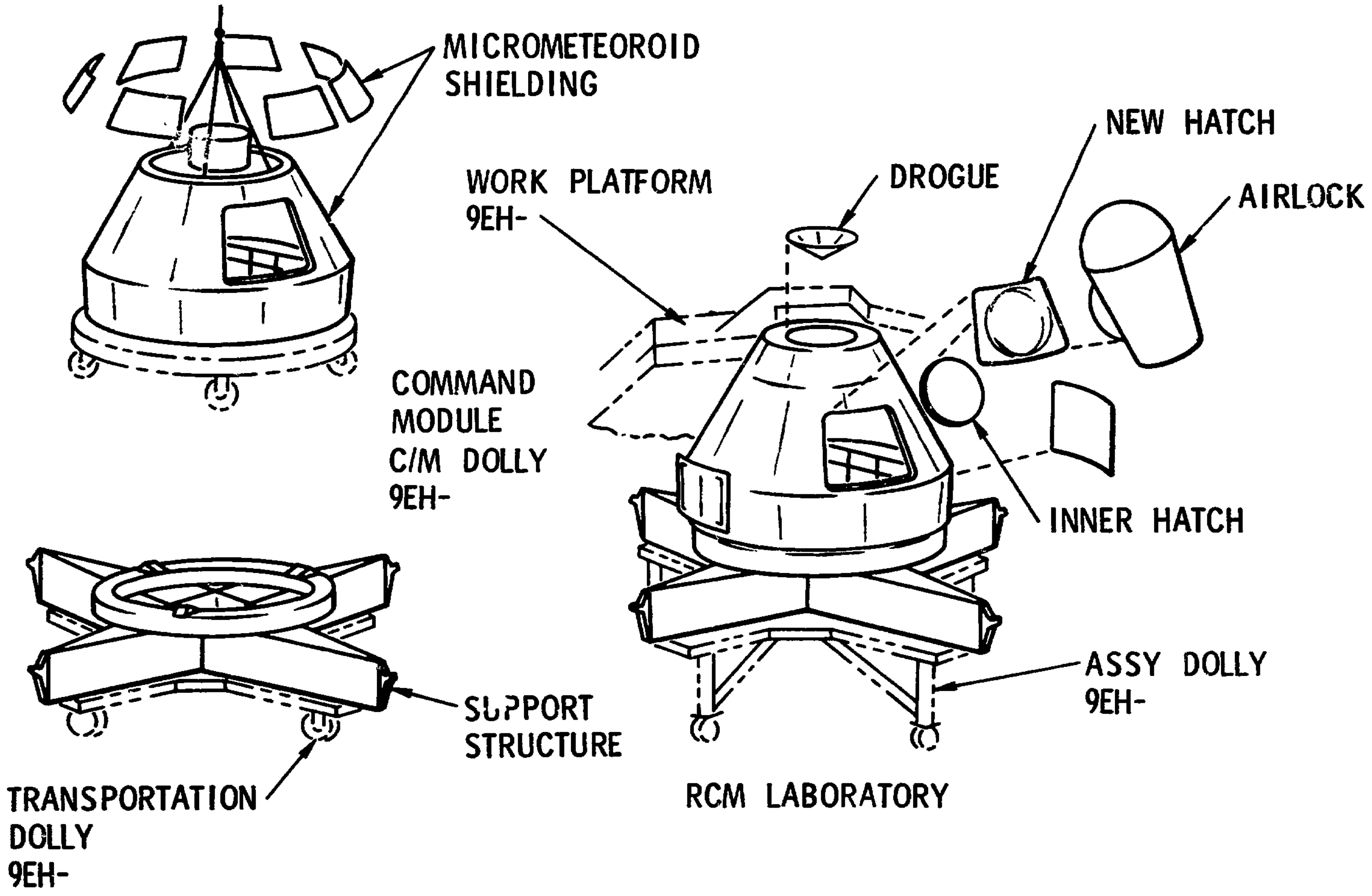

Figure 38. RCML Final Assembly

1. Proof pressure leak test the pressure shell prior to delivery to the installation area.
2. Deliver laboratory and laboratory support structure assemblies on individual material handling dollies to the installation area.
3. Install component simulator tooling on laboratory and support structure.
4. Install penetration plumbing lines.
5. Install subsystem plumbing lines.
6. Purge, braze, flush, and leak test lines as required.
7. Install and connect subsystems components.
8. Install wire harness.
9. Conduct continuity checks.
10. Install system electronic boxes
11. Secure laboratory to the support structure assembly.
12. Close out subsystem connections.
13. Conduct system pressure leak test.
14. Conduct post pressure test final system installations.

The following new tooling will be required to support the preceding operations (available Apollo component simulators may be used for fuel cells):

1. Simulated support structure and secondary structure for use in systems mockup
2. Interface tools for flushing and pressure testing EPS
3. Modular assembly jigs to provide interface with cryogenics
4. Structure interface tools for flush and pressure test
5. Valve simulators for cryogenic, potable water, and waste water tanks

6. Manufacturing aids for plumbing and wiring jig boards

7. Detail and assembly tube tools for plumbing

Techniques and Processes

Manufacturing techniques and processes currently used for the Apollo Block II program will apply to this program. These techniques have attained high capability levels through intensive development, test, and stringent procedural controls by NAA Manufacturing. Many innovations in structural fabrication and assembly procedures that improve product quality and reliability have been resulted from these efforts. Development of new manufacturing techniques or special processes are not anticipated beyond the present state of the art for Apollo spacecraft fabrication.

The tooling principles of air-pressure-actuated chill fingers and copper backup bar assemblies developed for weldment of the Apollo inner structure will be utilized in conjunction with existing automatic welding equipment for the Sciaky head and tailstock positioner.

Manufacturing Schedules

Firm schedules are contingent on receiving a go-ahead for designated spacecraft. Specific milestones, such as engineering drawing releases and long-lead-time items and components requiring the services of subcontractors or suppliers, must be determined sufficiently far in advance to accomplish a firm schedule blend with Apollo program spacecraft delivery schedules to preclude downstream constraints to either program.

The renovation schedules illustrated in Figures 39 through 41 are presented to denote typical flow cycles for preselected spacecraft under optimum Manufacturing conditions. Figure 39 shows a typical Manufacturing schedule for a dependent laboratory concept using an Apollo Block I command module. Figure 40 shows a typical Manufacturing renovation cycle for an independent laboratory using an Apollo Block I command module. Figure 41 shows an independent laboratory utilizing an Apollo Block II command Module.

RCM SPACECRAFT

Figure 42 shows the Manufacturing flow proposed for the renovated command module. Structural assembly, subsystems assembly and installation, tooling requirements, factory checkout, and techniques and processes previously discussed in the RCML Independent section will be identical to those used for Apollo Block II production spacecraft. These topics will not be discussed in this section. Apollo production tooling, material handling, and checkout equipment will be made available on a proportionate maintenance

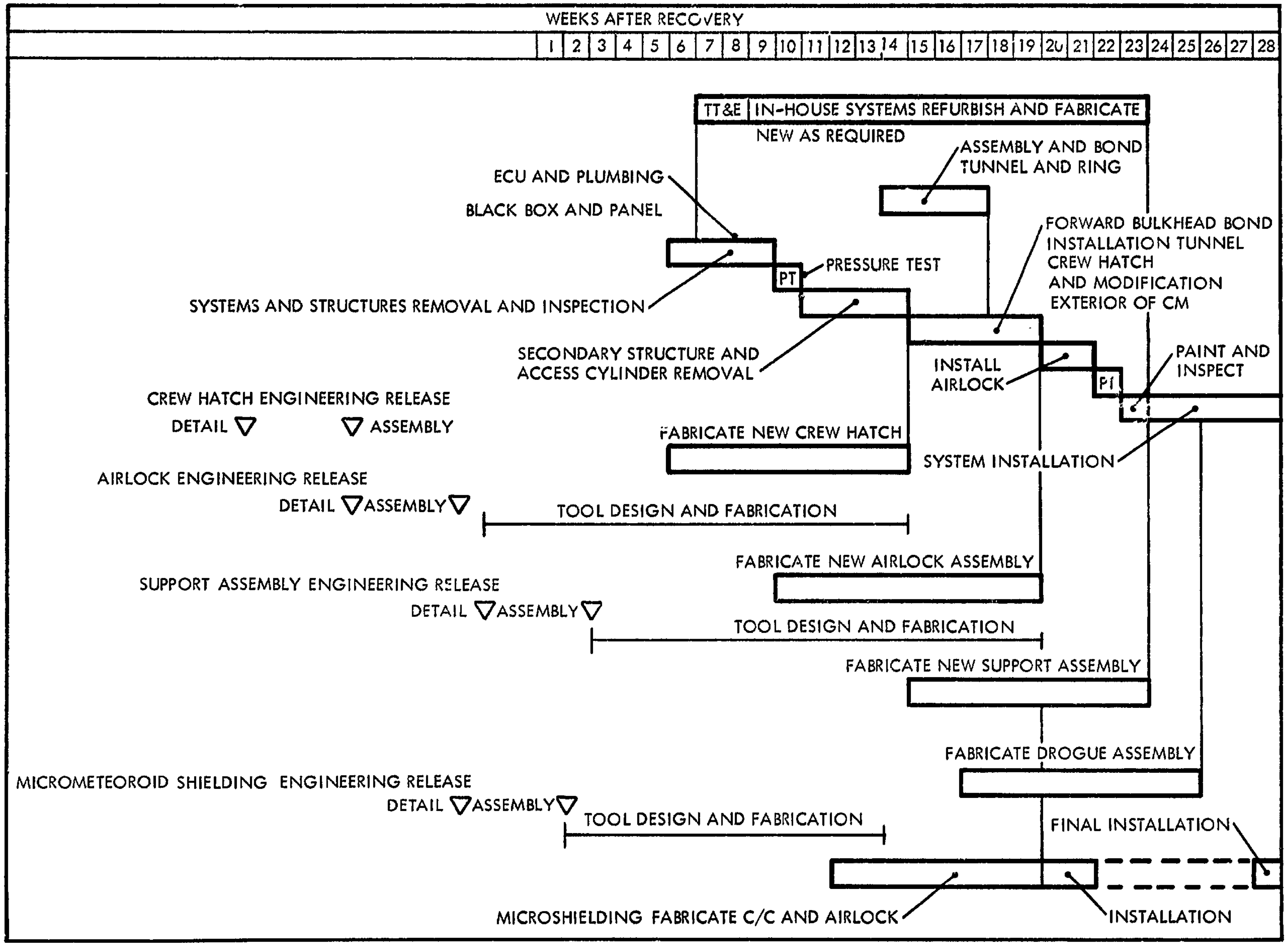

Figure 39. Manufacturing Renovation Schedule, Dependent Laboratory, Block I Vehicle

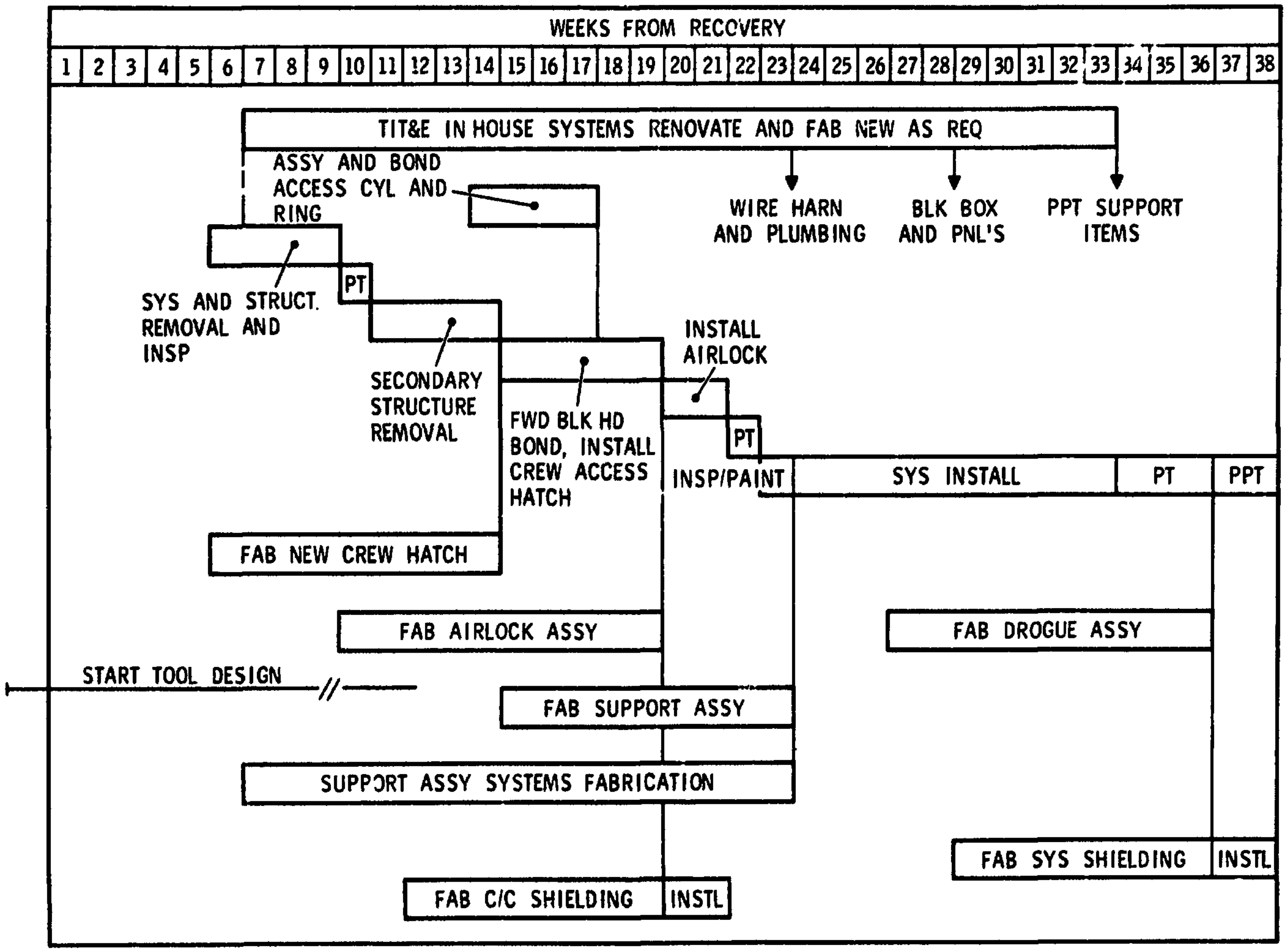

Figure 40. RCML (I) Fabrication Schedule

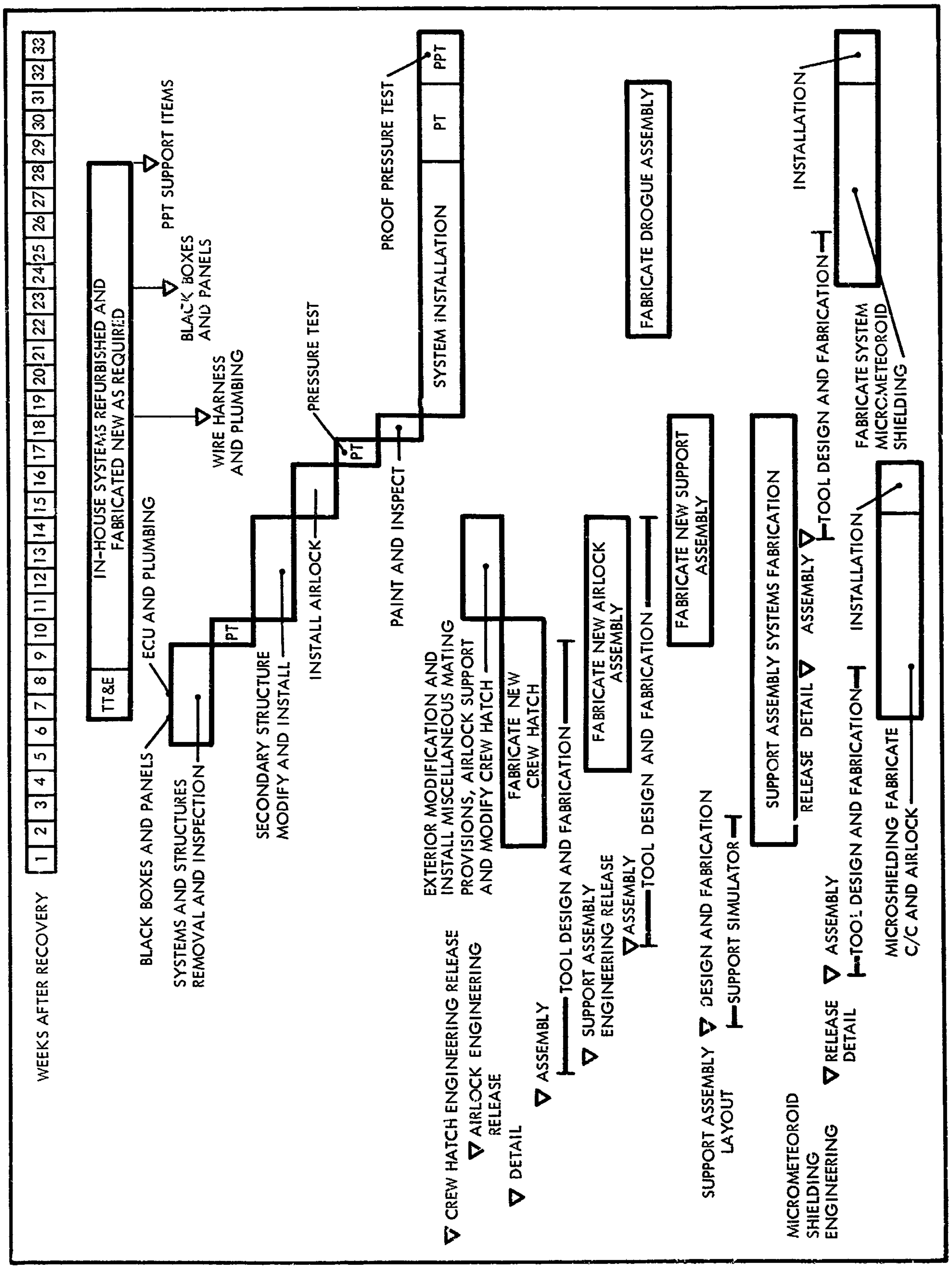

Figure 41. Manufacturing Renovation Schedule, Independent Laboratory, Block II Vehicle

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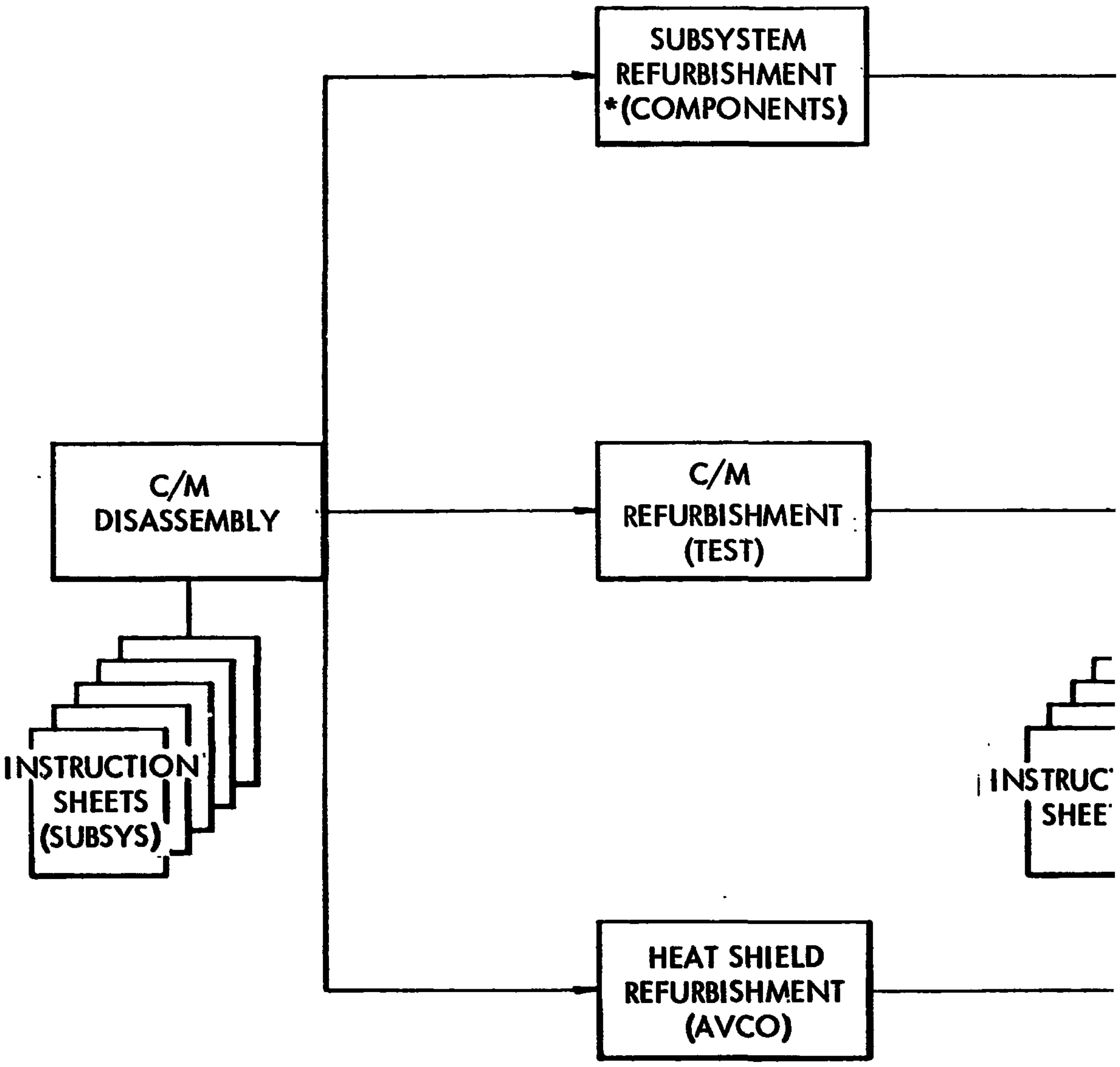

*SUBCONTRACT

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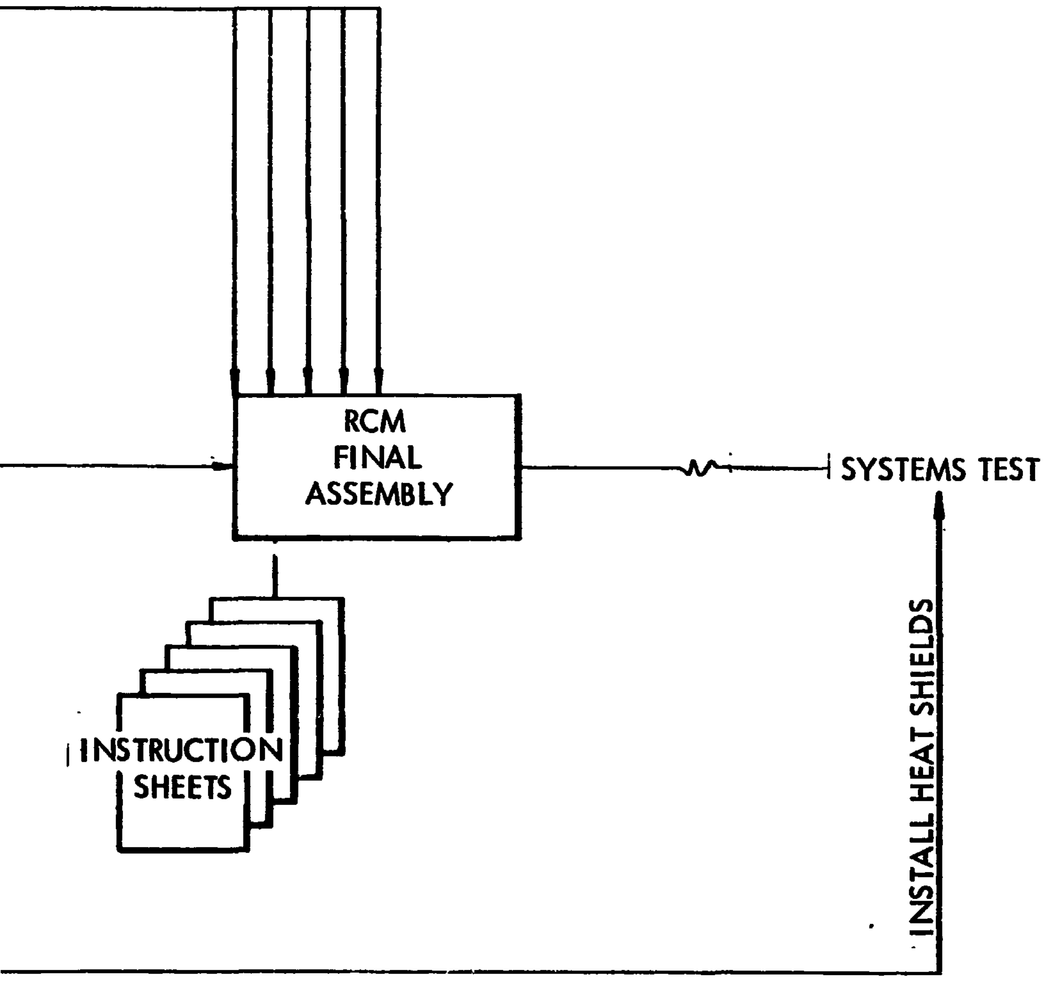

Figure 42. Renovated Command Module Spacecraft (RCMS) Manufacturing Flow Chart

and time-shared basis with Apollo production requirements to support this program, and with minor exceptions, are adequate to provide for these requirements.

The renovated command module systems configuration will differ depending on the mission objectives. The specific hardware requirements for each spacecraft are listed in the Apollo Hardware Utilization List, 63-TO-695-322-2, 30 March 1966.

For purposes of this report, the following systems are required for manned missions and will be reinstalled in accordance with the Apollo Manufacturing Block II Systems Installation Plan, dated 12 October 1966: communications and instrumentation, crew systems, earth landing, electrical power, environmental control, guidance and navigation, reaction control, and stabilization and control.

Vehicle Disassembly - Pressure Shell Exterior and Interior Surfaces

Vehicle disassembly will begin as soon as practical after Apollo recovery testing. Subsystems, components, wiring, plumbing, and partial secondary structures will be removed as prescribed by the instructions sheets shown in Figure 42, and IMRO's. The pressure shell must be pressure leak-tested after disassembly to assure hull integrity.

Stripping of the pressure shell exterior and interior surfaces after heat shield removal is similar to that described under Manufacturing Support to Recovery Operations and shown in Figures 31 and 32.

Exterior Stripping Procedure

Remove the following:

1. Earth Landing System - Crushable cores for shock attenuation, air compressors, drogue chute canisters, parachute covers and riser bar, flotation bag canisters and lines, thrustors, recovery beacon light, antenna and dye marker canister
2. Reaction Control System - Fuel and oxidizer tanks, oxidizer panel, fuel panels, helium panels and bottles, pitch engines and plumbing
3. Environmental Control System - Potable water and waste water tanks
4. Electrical - Girth ring to forward compartment and Band-Aid type wire straps of the aft compartment wire harness

5. Electronic Equipment - RCS sequencer boxes

6. Instrumentation - Signal conditioner instrument panels

Interior Stripping Procedure

Remove the following:

1. Crew Systems - Crew couches

2. Controls and Displays - Main control and display panels

3. Environmental Control System - Water glycol control panel, oxygen surge tank, ECU package, oxygen control panel, water control panel, oxygen and glycol control valves, miscellaneous plumbing and suit ducts above and below the girth shelf as necessary to remove components for refurbishment, cabin air heat, blower, water reservoir and heater, fecal canisters, waste management system and cabin pressure regulator

4. The lower equipment bay coldplates will be removed only if the results of teardown test and evaluation reveal leakage or damage.

5. Guidance and Navigation System - G&N black boxes, panels and base

6. Stabilization and Control System - Attitude and rate gyros

7. Electronic Equipment - Right-hand forward, right-hand lower, and lower equipment bay electronic boxes

8. Electrical - The main crew compartment wire harness will not be removed if the result of Teardown Test and Evaluation satisfies continuity checkout requirements.

Fabrication of New Parts

As a result of hardware expended during the mission, the following items require replacement: Earth landing system flotation bags, drogue, pilot and main parachute equipment, forward heat shield assembly, CSM umbilical, electrical feedthrough plates-forward and aft sidewalls, pitch, roll, and yaw engine nozzle extensions, and machined ablator blocks-umbilical.

Modification and Repair - Structural

Pressure shell repair and touch up of bare surfaces caused by disassembly or rework will be in accordance with discrepancies noted during teardown test and evaluation, and will be in conformance with document 543-G-18, Standard Repair Manual for Apollo and Saturn II.

Renovation/Replacement of Removed Components

The general ground rules established for renovation of all functional components described under Renovation/Replacement of Removed Components in the RCML Independent section.

The new forward heat shield will be prefitted to the command module prior to removal of the crew compartment heat shield assembly during Manufacturing support to recovery operations. See Figure 31.

The forward heat shield, crew compartment heat shield assembly, aft heat shield, and access tunnel hatch will be shipped to the subcontractor for renovation or new ablative coating.

Manufacturing Schedules

Manufacturing schedules are discussed under Manufacturing Schedules in the RCML Independent section.

The renovation schedule shown in Figure 43 for a renovated Apollo Block II command module denotes typical flow cycles for a preselected spacecraft under optimum Manufacturing conditions.

CONCLUSION

This Manufacturing analysis is the result of an in-depth study of the Manufacturing requirements necessary to sustain a spacecraft renovation program of this order and to assure that Apollo command modules can be renovated at a relatively low cost and in time to meet the NASA requirements for operational experimental flight laboratories and spacecraft. In addition to the Manufacturing effort discussed, the following elements were evaluated and used to establish a common baseline to facilitate ease of manufacture at a minimum cost to NASA: Manufacturing producibility of new requirements and the related tooling costs, utilization of existing Apollo production tooling and equipment, subsystem trade-off cost studies, and development of master phasing and detail schedules compatible with the Apollo Master Development Schedule for production spacecraft delivery.

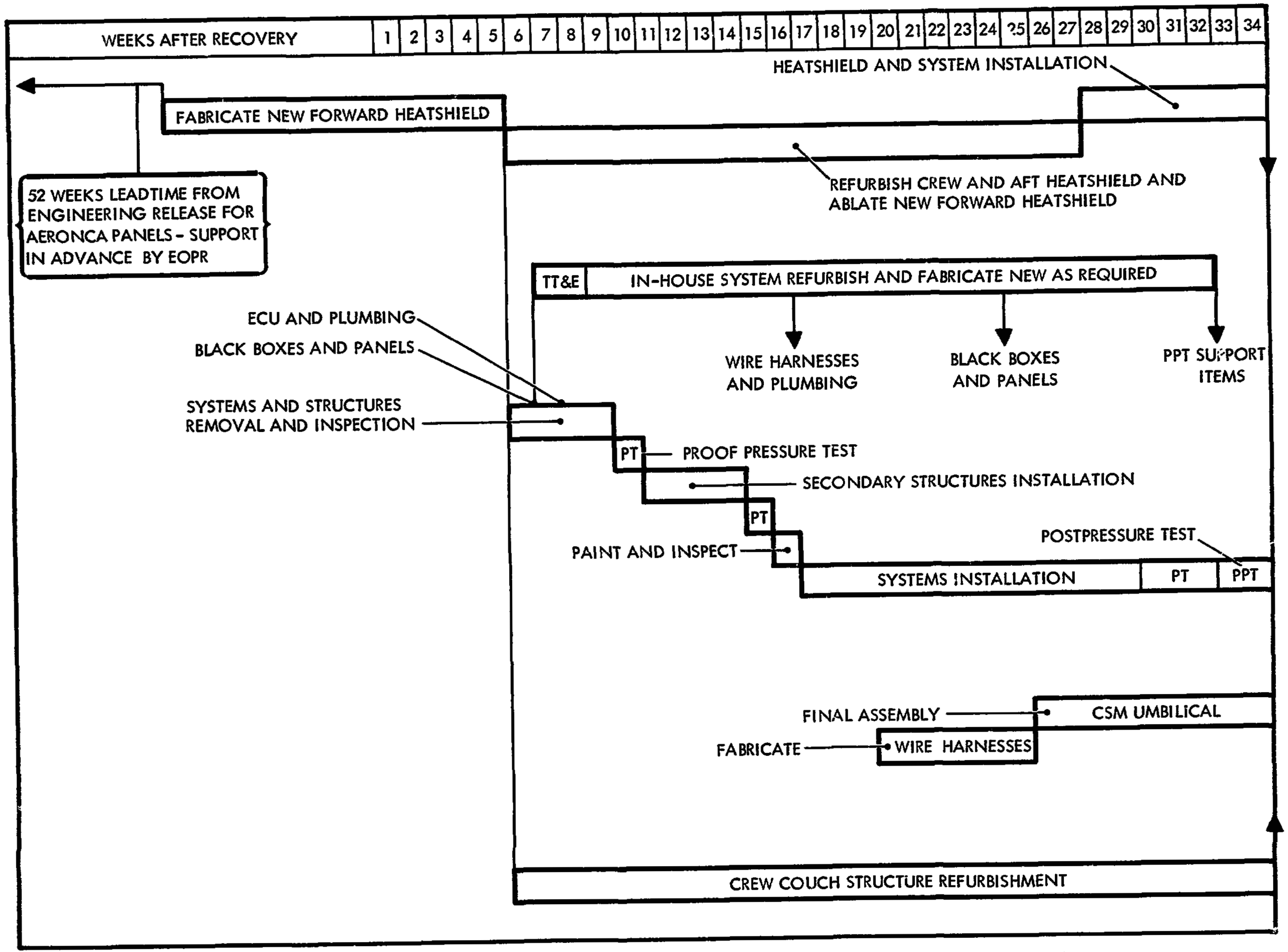

Figure 43. Manufacturing Refurbishment Schedule, Command Module Spacecraft, Block II Vehicle

The degree of success in satisfying the requirements of this program is predicated on utilization of NAA current capabilities and resources. Facilities, manpower, and special skills derived from the Apollo program provide the "know-how" to accomplish the renovation tasks effectively on a time-shared and noninterference level with the current Apollo program.

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VII. TEST REQUIREMENTS

STUDY AREAS

Analysis of the test requirements to support the renovation of a recovered Apollo flight vehicle to the proposed RCM/RCML configurations indicated that the following categories of testing will be involved to varying degrees:

1. Postrecovery testing is designed primarily to evaluate flight failures and anomalies, to ascertain the occurrence of visually detectable physical damage, and to uncover additional failures or anomalies not previously detected.
2. Apollo hardware testing is devised to demonstrate the applicable specific life of the hardware relative to the established Apollo missions.
3. Qualification testing is established to ensure that equipment meets the designated criteria and accomplishes its prescribed functions.
4. Acceptance testing demonstrates that systems, subsystems, and/or components are ready for use.
5. Development testing is performed to verify the compatibility of the designed item with its intended utilization.
6. Exploratory testing is patterned to evaluate the effects of mission environment and operations and to determine the degree of equipment degradation.

APPROACH

The approach to the testing of returned program hardware is, of necessity, very broad in nature since the ultimate reuse requirements have not been specifically delineated. See Figure 44. Therefore, the following ground rules were established as the basis for further analysis.

1. RCM mission requirements not to exceed those established for S/C 101
2. RCM to be renovated to the S/C 101 configuration

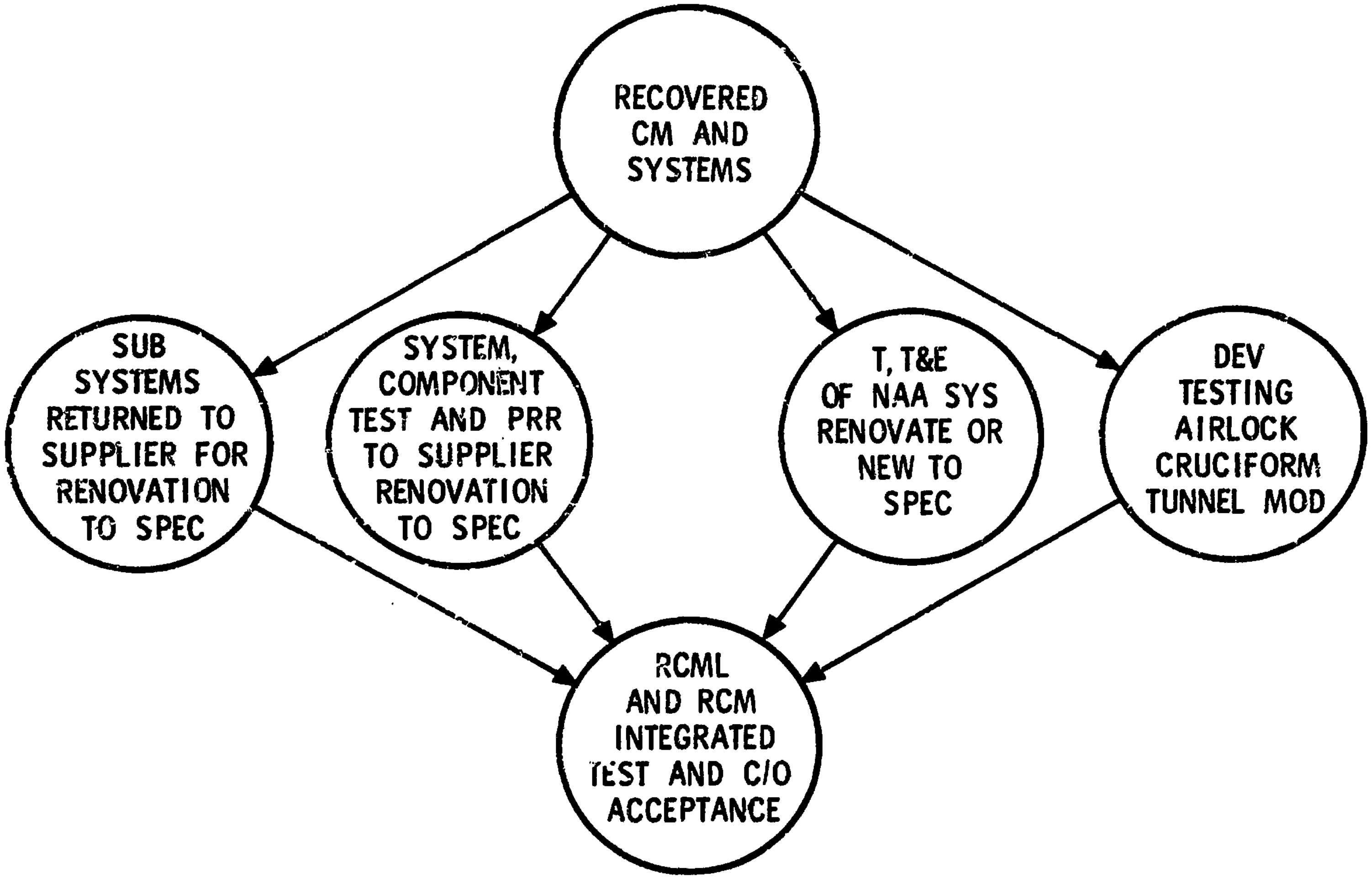

Figure 44. Test Philosophy

3. Postrecovery testing to be completed prior to initiation of CM renovating operations

4. Testing of returned program equipment to be held to the minimum required to assure secondary mission success

5. All Criticality I items (crew safety) must either be new or, if used, capable of passing full qualification testing requirements

The data secured from S/C 009 and S/C 011 postrecovery testing will be the basis for RCM/RCML test planning. Individual flight anomalies will be reviewed to access their applicability to, or impact on, the renovation process.

All RCM program equipment, subject to repair, refurbishment, or renovation will be returned to a "like-new" condition and concurrent with updated configuration requirements.

ANALYSES

Post Recovery Testing

The resulting postrecovery test data provides useful support to ascertaining subsystem status, particularly with respect to marginal or partial performance degradations within specific equipments. However, even expansion of postrecovery test procedures to include measurement of all critical performance parameters may not provide sufficient valid data upon which a judgment concerning the future performance of the components tested can be based. As such, any revision to the postrecovery test procedures, relative to the renovation process, would be oriented to closer control over corrosion prevention actions, timely systems decontamination, handling damage, and removal of components for subsequent anomaly isolation. Implementation of the preceding procedures would then serve to preclude further hardware degradation prior to initiation into the renovation process.

Apollo Hardware Testing

Data developed during limited life testing of some system components does not adequately define the wearout distributions for these items within a system, and expansion of additional life testing to establish second or repeated mission capability is considered to be economically prohibitive. However, an extrapolation of existing empirical data on similar components can be utilized as the basis for identifying potential wearout capability. This "qualification by similarity" concept will be utilized in lieu of further life testing for specific items not nominally subject to significant or critical wearout failure modes (e. g., connectors, static electronic devices, etc.).

Qualification Testing

All potentially reusable equipment secured from the test vehicles and subjected to renovation refurbishment will be fully qualified flight hardware. All replacement components and subsystems currently envisioned for utilization on the RCM/RCML are also qualified to the same extent. No further qualification testing is currently anticipated, and unless future laboratory mission requirements dictate redesign of existing systems, all program equipment can be considered as qualified.

Acceptance Testing

Established equipment acceptance requirements, identified in applicable specifications, will be the basis for reacceptance of repaired, renovated, or refurbished vehicles, systems, subsystems, and components. Items identified for reuse and those qualified by similarity are also subject to the regular acceptance test specified for each item. Verification of acceptance will be required prior to reinstallation or reassembly into the RCM/RCML. Deviations to acceptance criteria will be processed in accordance with existing procedures. Confirmation of acceptance-type tests will be the means for requalifying all equipment.

Development Testing

Additional hardware requirements (i. e., airlock, cruciform, etc.) and changes to existing configurations (e. g., tunnel modification, RCML aft compartment protective cover, etc.) will require varying levels of design development and/or design verification testing. Further identification of the absolute test levels required will be generated as part of the individual development program initiated to meet the identified requirements.

Exploratory Testing

Essentially, the following two categories of exploratory testing have been established:

1. Nonrecurring - A test substantiates the applicability of the results for all subsequent program applications. (e. g., plumbing contamination, internal tubing degradation, etc.)

2. Recurring - Iterative tests must be accomplished to assure adequacy for the next subsequent application. (e. g., radiator coatings, lubricated surfaces, cold plate flushing, etc.)

The majority of the exploratory effort will be accomplished as an intrinsic part of the equipment disassembly and evaluation process rather than predicated on results of postflight inspections and identification of anomalies. Items subject to recurring investigation will be recommended as candidates for inclusion in subsequent postrecovery test procedures.

Subsystem functional tests and integrated vehicle tests for the RCM will be identical to existing Apollo requirements. Revisions will be made, as required, to applicable procedures for subsequent RCML tests.

CONCLUSIONS

System and subsystem renovation may be accomplished as indicated in the following discussion.

> For those systems/subsystems where NAA S&ID has suitable checkout facilities and equipment available, the major elements will be subjected to specific, identified exploratory tests, TT&E, and/or bench checks to define any subsequent renovation requirements necessary for return of the system and/or its elements to its nominal operating stature, as specified.
>
> Systems and subsystems beyond the checkout or renovation capability of NAA S&ID will be returned to their source. The original source will be responsible to conduct TT&E, identified exploratory tests, and repair, renovate, or refurbish the equipment to meet existing specification requirements.

Systems and subsystems that may be subject to deletion due to the nature of the ECM/RCML missions will be subject to required exploratory tests and specific bench checks to identify system status. No further renovation will be accomplished and the system elements will be placed in segregated storage pending customer disposition.

Components will be processed as follows:

1. Components, identified as noneconomical to repair, renovate, or refurbish, will be scrapped.

2. Components, dependent on S&ID checkout and renovation capability, will be subjected to exploratory tests, as required, and bench checks to determine their status relative to reuse, renovation, or replacement.

    a. Items identified as "OK to reuse, as-is" will still be subject to an acceptance test whereby the functional parameters will be checked for original tolerances.

b. Items identified as beyond tolerances and unsuitable for renovation will be subject to replacement. Available Apollo program spares will be used for this purpose. In event the item is not available from the spares inventory, it will be reordered from its original, or approved alternate, source.

c. Items identified as candidates for renovation will be returned to their supplier for TT&E, exploratory testing as required, and repair, renovation, or refurbishment.

3. Reordered, replacement components and those returned from renovation will be subject to acceptance tests, as identified in their respective specifications, prior to storage and/or reinstallation.

4. Spares, utilized as component replacements, will be made directly available and are not subject to redundant acceptance testing other than that which may be required to fulfill established PIA requirements.

System and subsystem tests conducted subsequent to reinstallation will be considered as the acceptance test for that system or subsystem. The testing interface with the RCM/RCML process is shown in Figure 45.

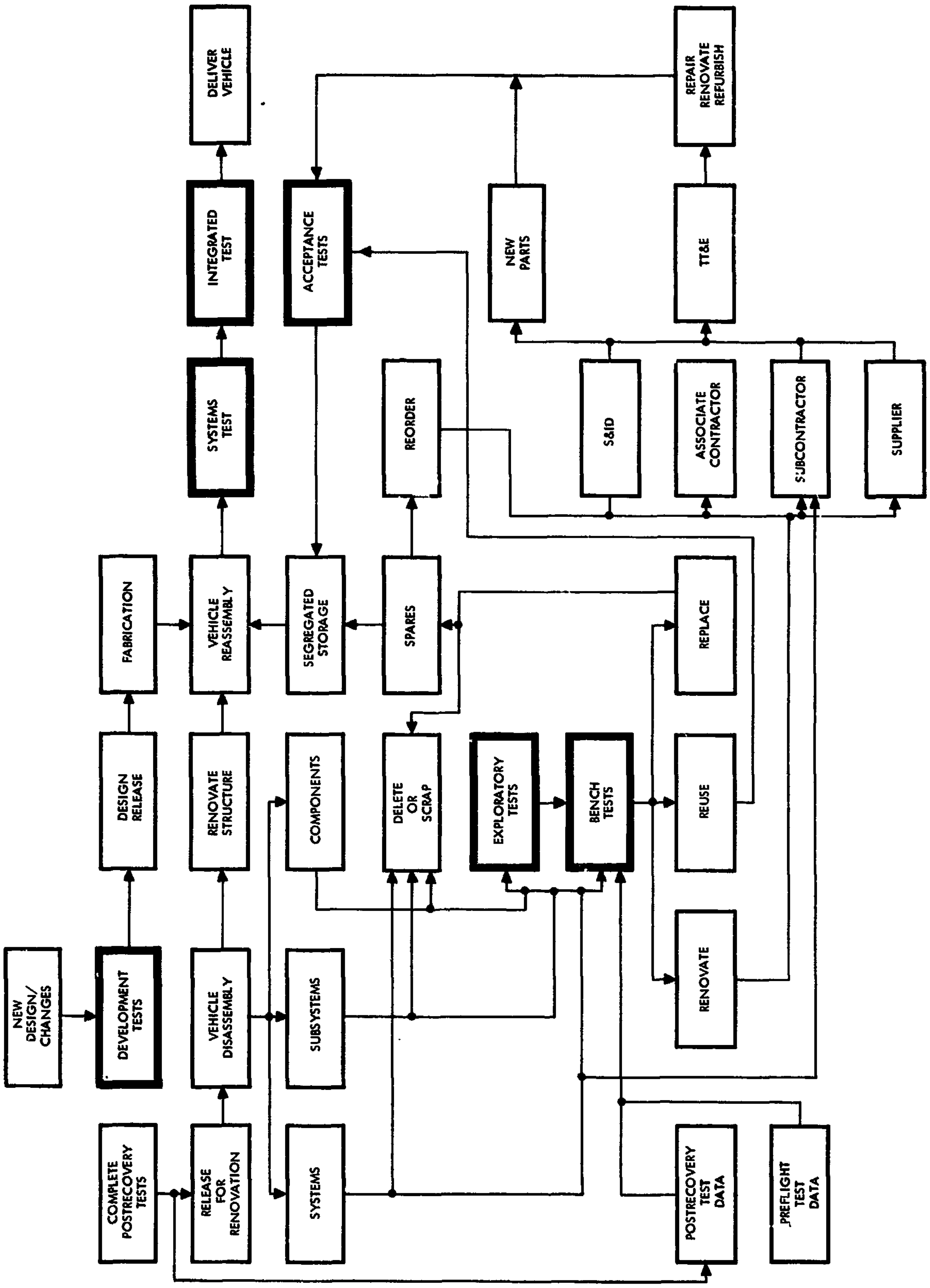

Figure 45. RCM/RCML Test Program Flow

VIII. PROGRAM SCHEDULING

SCOPE

The program planning and scheduling analyses performed during this study have utilized program planning and scheduling data from the Apollo program and other recent related programs. These data were used to provide basic planning factors and to prepare preliminary planning schedules that could be used as schedule guidelines. The basic schedules were then updated at timely intervals based on the actual data generated by the individual study tasks (e.g., engineering, manufacturing, test and operations, etc.). All planning data are based on the NASA M(P)-2A booster schedule and the Apollo Master Development Schedule (MDS-9) Rev. 3, dated 19 August 1966.

A list of the candidate vehicles for the RCM/RCML study program will be found in the introduction to this volume.

CONFIGURATIONS

The study ground rules stated that Block I spacecraft would be used only as RCML's, either dependent or independent, while Block II spacecraft could be used for either RCM or RCML use. For study purposes, therefore, Spacecraft 012 was used as the laboratory cost model and Spacecraft 101 as the RCM cost model. A description of these spacecraft appears elsewhere in this report.

Planning data and schedule requirements associated with the development of renovation criteria and program phasing were established by analyzing all functional areas to ascertain program impact.

As shown in Figure 46, the development/operations phase must begin six months before the splashdown of a candidate spacecraft in order to provide necessary lead time for design activity to support the release of layouts, complete the design review, and release assembly drawings.

The baseline for retrieval and postrecovery test of the candidate spacecraft has been established as a maximum of 30 days. Additional postrecovery time would result in a proportional impact to delivery of the CM to the launch site.

System removal and structural refurbishment periods established by Manufacturing also are indicated in Figure 46. The refurbishment periods

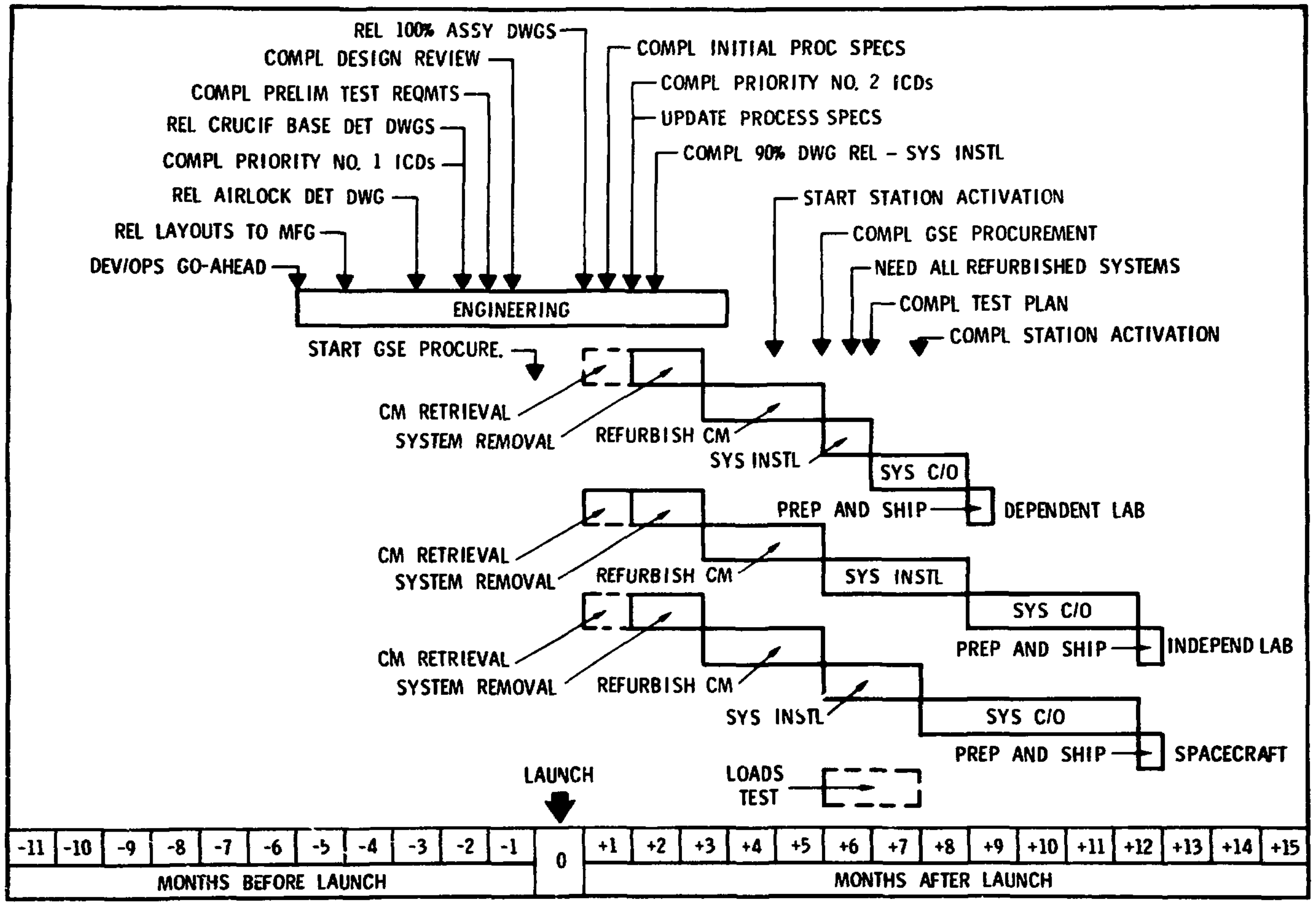

Figure 46. RCM Spacecraft/RCM Laboratory, Program Phasing Schedule

are greater for the laboratory configurations since they provide for new structure design, which includes the cruciform, airlock, micrometeoroid shielding, tunnel modifications, and provisions for external system and equipment mounting. The system installation period is based on current Apollo Block II capability.

RCM ground operations will be implemented by supplementing Apollo facilities, equipment, and manpower. RCM test operations would be the same as basic Apollo, requiring no significant resources. The RCML (D) would require a simple pressure test using portable GSE, while the RCML (I) would use existing Apollo plans and procedures and Apollo ACE and GSE models, but would require a new station configuration. KSC operations for RCM and RCML would be similar to existing plans and procedures, with changes in facilities and equipment required for the latter.

Logistics analysis assumes that NASA would approve the RCMS/RCML use and time-sharing of existing Apollo equipment and materials. A material support system has been identified and will provide central management and control of all renovation support functions for which NAA would be responsible.

Further analysis is needed to develop renovation tasks, schedule requirements, and performance and test specifications on a subsystem basis.

The recovered Apollo command modules will have the systems, subsystems, and components removed for either renovation or replacement. As the components are released for renovation (including repair or modification), the concerned contractor or subcontractor will proceed to refurbish, test, functionally accept, and/or certify the item for reuse.

One of the more important areas of consideration was the review, analysis, and projection of component renovation by the responsible subcontractor. Extensive review was accomplished to prepare a logical system refurbishment schedule in matrix format (Figures 47, 48, 49).

These figures have been prepared for systems that would be returned to the subcontractors for renovation and identify subcontractor lead time, availability of the system for the subcontractor, and NAA need for installation. The forward heat shield would need to be rescheduled from another vehicle in order to be available for installation on the RCM. Systems and subsystems such as EPS, D&C, tunnels, and adapters are not shown in the figures because NAA has sole responsibility for their fabrication and assembly and they do not affect the schedule significantly.

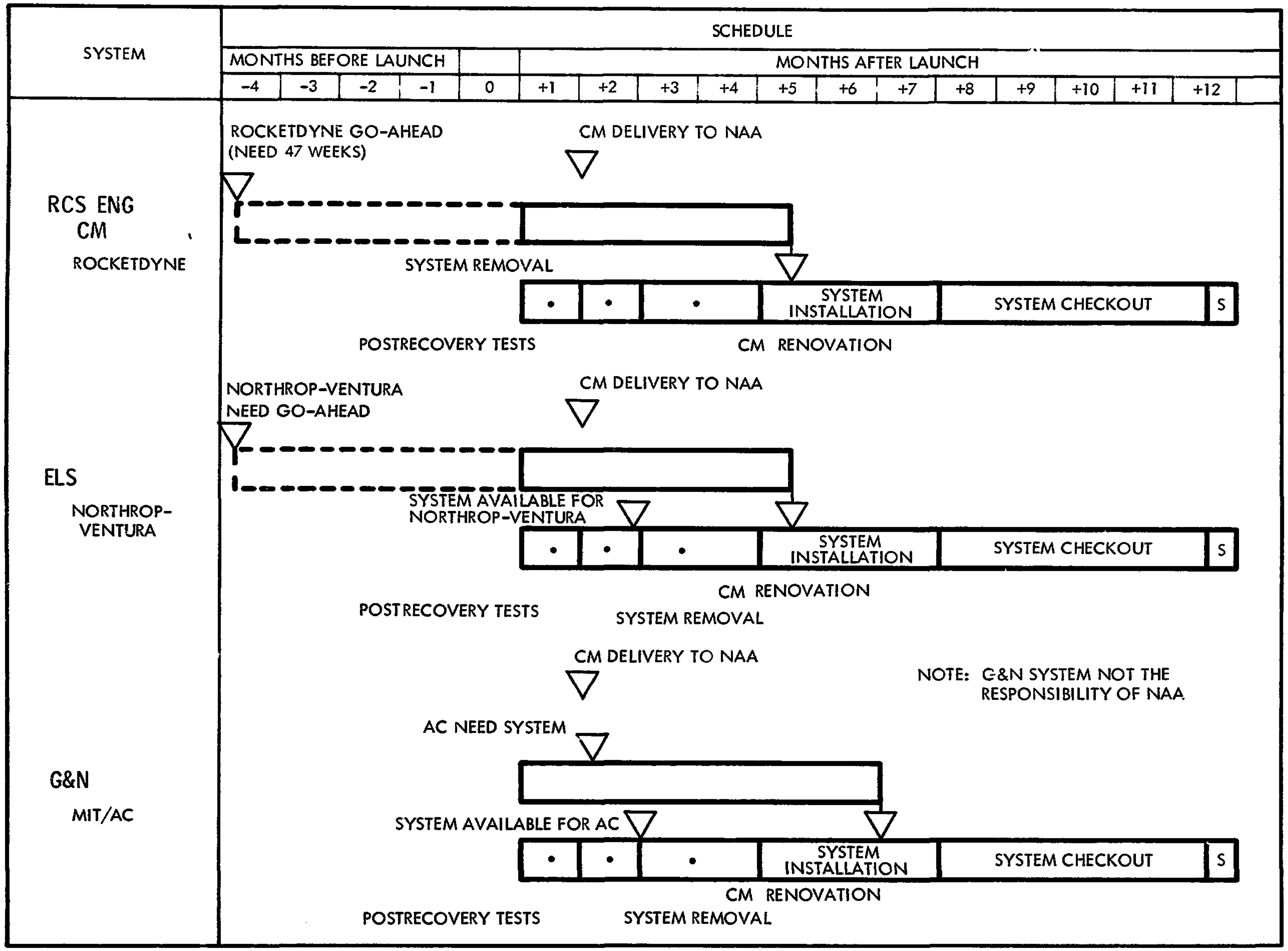

Figure 47. RCM Spacecraft System Renovation

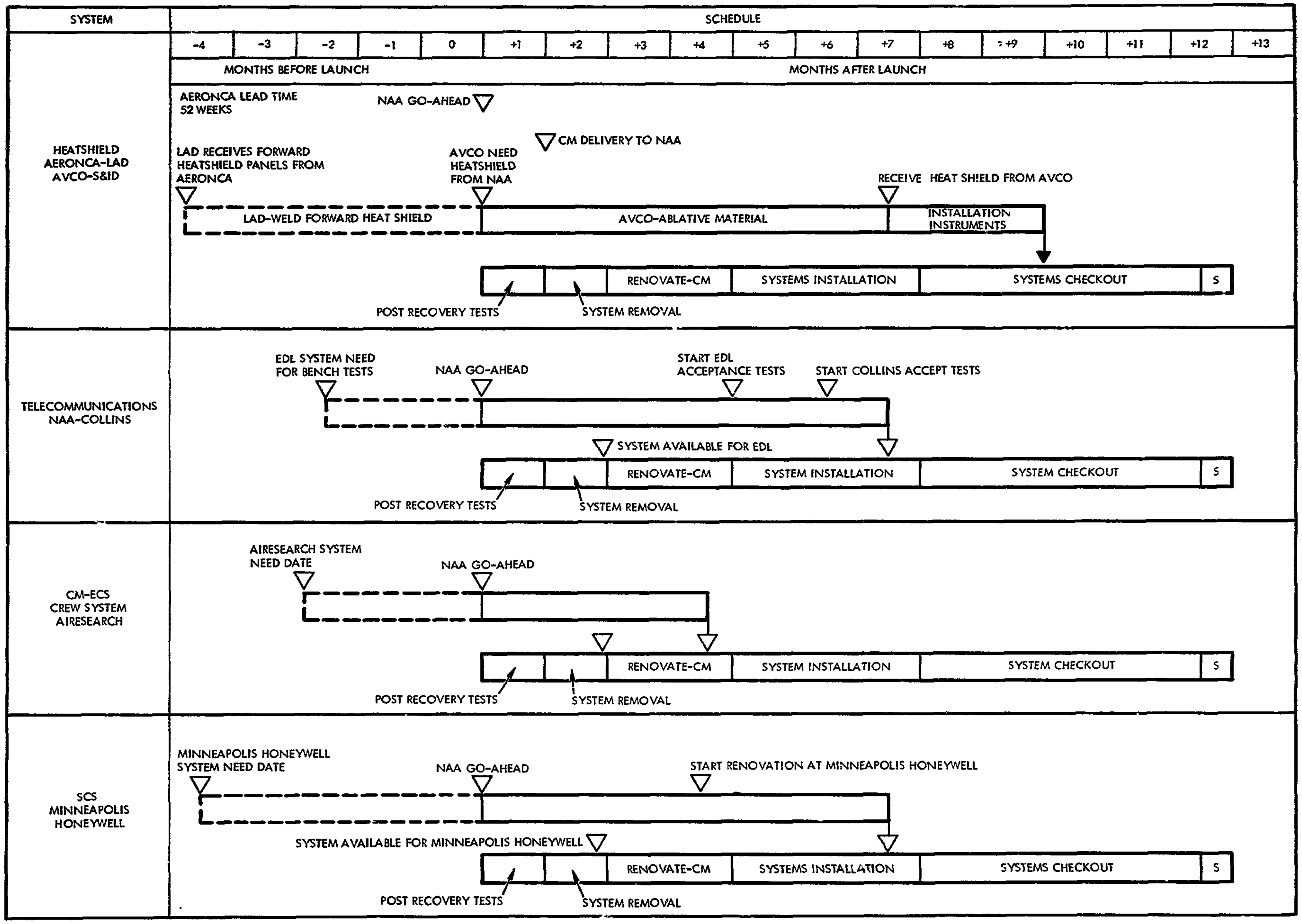

Figure 48. RCM Spacecraft System Renovation

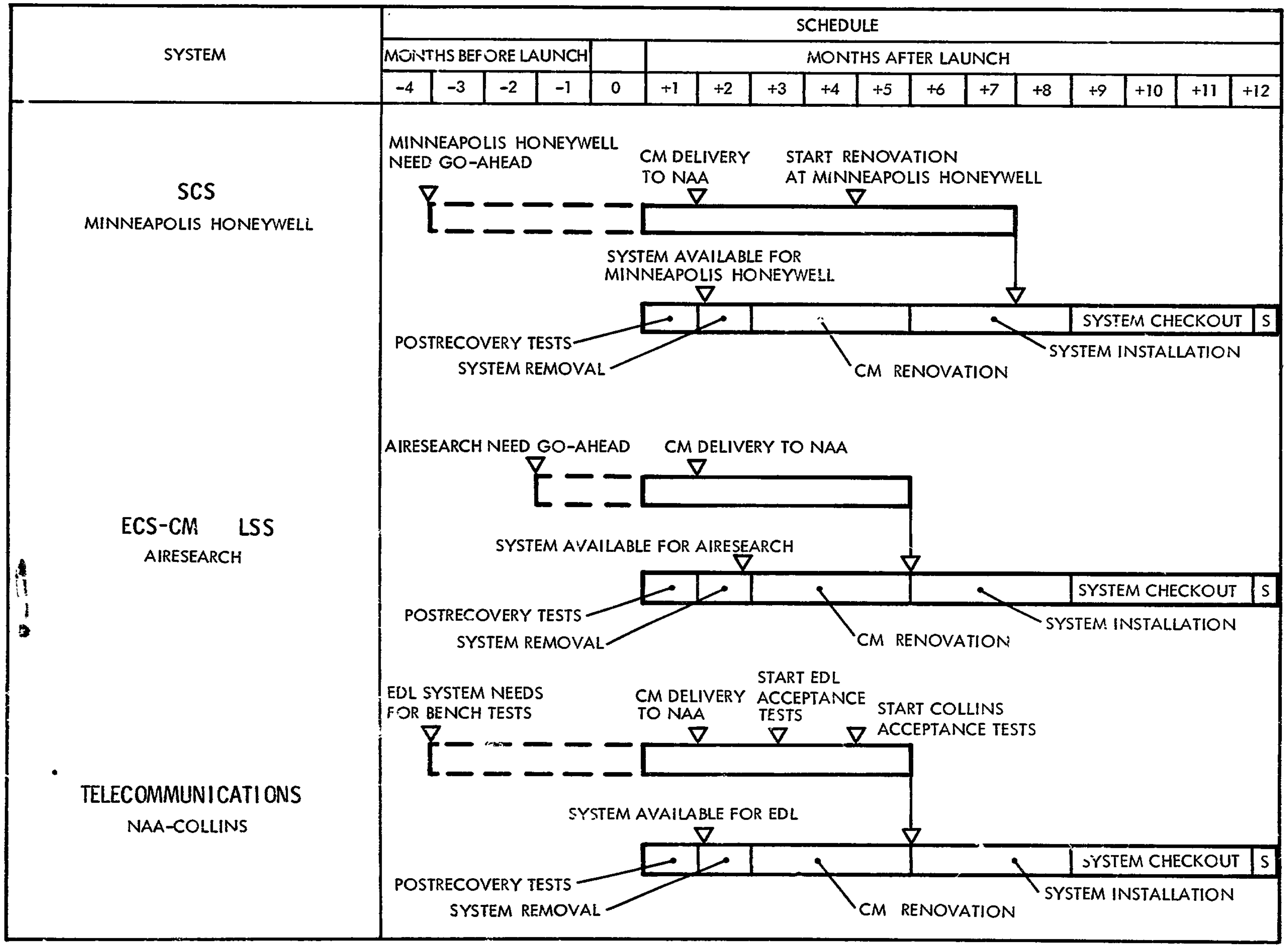

Figure 49. RCML (I) System Renovation

The results of this study strongly indicate that renovation and reuse is feasible and highly desirable from an economic standpoint. The renovated vehicles can be turned around in a relatively short time by making maximum use of existing Apollo facilities and highly skilled and trained personnel and these vehicles will be quite adaptable for use with the AAP-type experiments.

Investigation has indicated that the modifications necessary to existing GSE, automatic checkout equipment, and the manned spaceflight network would be quite small and that, through the use of the building-block concept, an almost infinitely variable group of experiments could be handled.

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IX. COST ANALYSIS

The cost analysis was performed essentially as requested in the contract statement of work, for those minor changes agreed to by NASA and NAA. The costs are related to the specific cost models selected as stated in Section I of this report. No costs were developed for test hardware, off-site activities (except for recovery operations), spares, training and training equipment, mission associated costs, mockup, startup, or maintenance costs.

The cost analysis results are presented in Volume V. A complete and detailed list of cost ground rules is included in addition to specific ground rules pertaining to each vehicle type and other related cost data. Figure 50 shows the cost models and the associated representative spacecraft model number for each vehicle type.

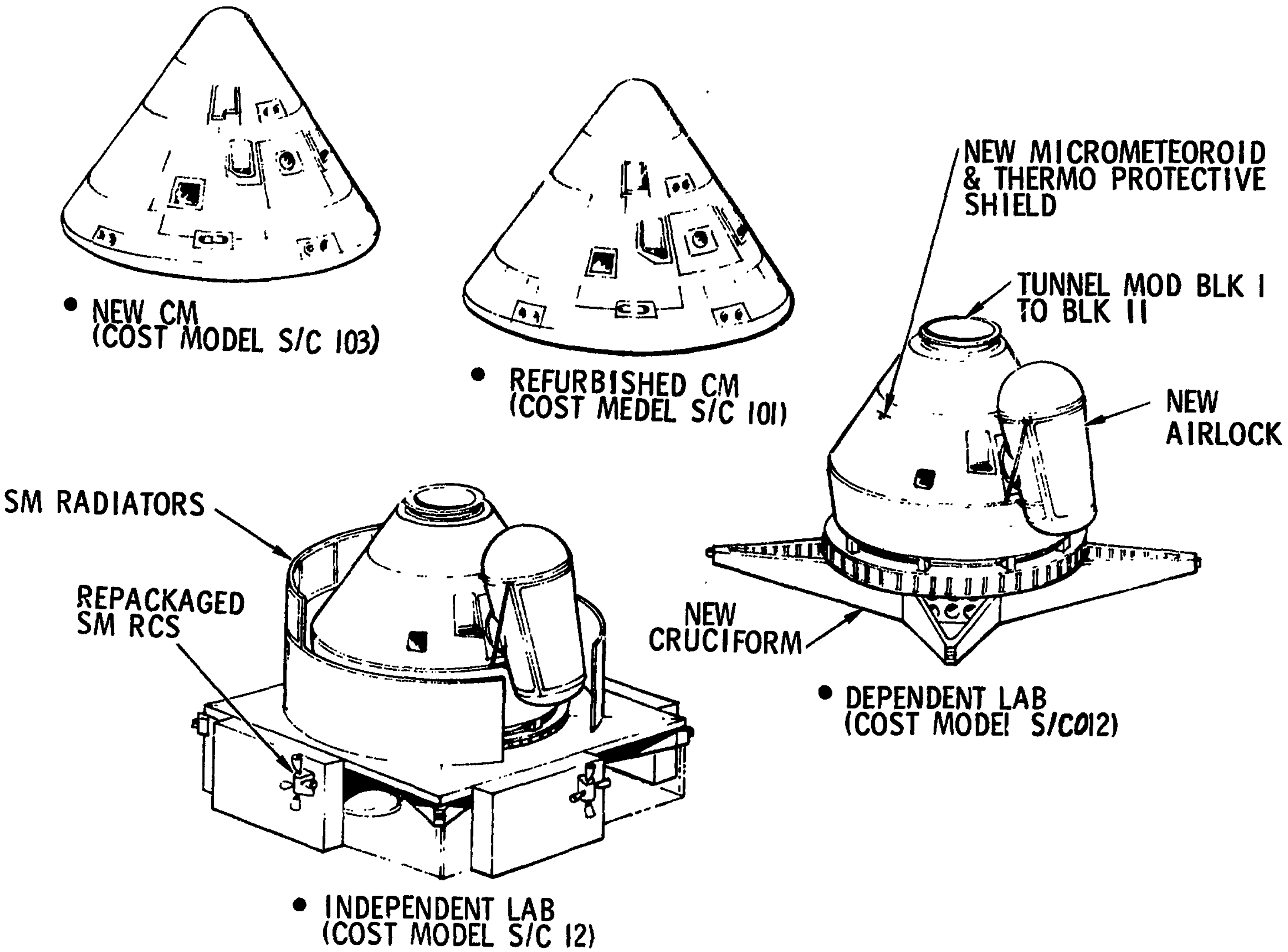


Figure 50. RCM/RCML Cost Relationship

X. FACILITIES ANALYSIS

The facilities analysis for the RCM/RCML study included recovery, system removal, fabrication, final assembly, system installation/checkout, and pressure test requirements. Apollo facilities, present and planned, were reviewed for utilization in support of the RCM/RCML program requirements. Requirements for plant area and other ground space at NAA, Downey, present no problem as they are presently available.

GROUND RULES AND ASSUMPTIONS

1. All RCM facilities requirements are based on non-interference with Apollo Block II production and testing schedules.
2. Off-site facility requirements were not included except for recovery operations. Material handling equipment will be identified for the removal of the aft heat shield during recovery operations.
3. No ground operations test vehicles will be considered.
4. No mockups will be fabricated.
5. It is assumed that the flow time from splashdown to delivery of the vehicle to the launch site is 12 months for the RCM and RCML (I) and 8-1/2 months for the RCML (D).
6. The vehicles selected for the RCM-RCML study are the candidate vehicles previously described in the Introduction.
7. Certain vehicles were selected for use as cost models, and only one vehicle of each configuration will be priced, using a block average of five RCM's or six RCML's. The cost model selected for the RCM configuration is S/C 101; the cost model selected for the RCML (D) configuration is S/C 012; the cost model selected for the RCML (I) configuration is S/C 012.
8. All facilities studies were based on a five-day work week with one eight-hour shift per day for engineering and related support functions. Two eight-hour shifts per day, five days per week, are projected for all manufacturing and test and operations functions.

9. Building 290 GSE installation costs and the facilities site activation support are a part of the logistic cost input data.

10. It is assumed that existing and planned facilities, test equipment, machinery and equipment, and GFP required to support the Apollo program will be available for the RCM program.

11. It is assumed that all material handling equipment, manufacturing aids, and parts protection equipment used on Block II will be available for RCM use.

12. Additional area will be made available as required within existing buildings to accommodate RCM requirements for systems removal, structural modifications, and final assembly (Figure 51, 52, and 53).

13. It is assumed that for the RCM, teardown will be complete, except for wiring harness and inner structure; that for RCML(I), teardown will be complete except for the inner structure; that for RCML(D), teardown will be complete except for portions of the secondary inner structure.

14. It is assumed that systems removal will be accomplished in a bonded area in Building 1 (Figure 54). Also, further disassembly of subsystems, associated with test teardown and evaluation (TT&E), will be performed in existing bench maintenance areas, Downey, or returned to the subcontractor's facility.

15. Material handling equipment will be utilized wherever feasible in Building 290, in place of GSE.

16. RCM requirements for environmental control in the assembly and checkout areas of Building 290 will remain at the class 340,000 dust control level, existing and planned for Apollo Block II (Figure 55).

17. Preinstallation acceptance (PIA) on the RCM program will be performed in the same manner as the Block II "black box" checkout concept.

18. A review and appraisal of existing L&T STE indicated no new STE will be required for the RCM program unless preliminary requirements change. Additions and replacements of existing materials and components is anticipated but cannot be delineated until final program requirements are defined.

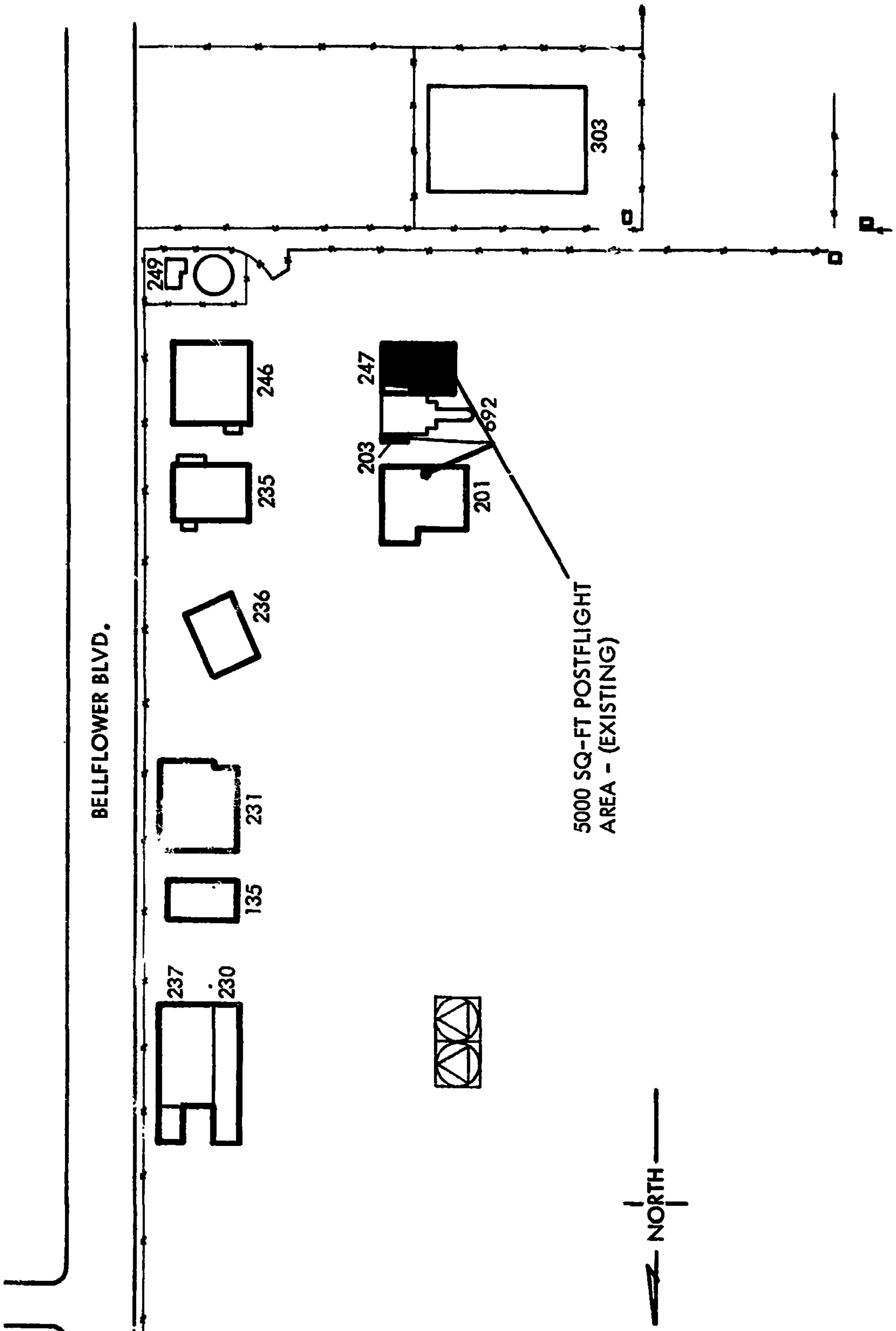


Figure 51. Flight Lines Buildings

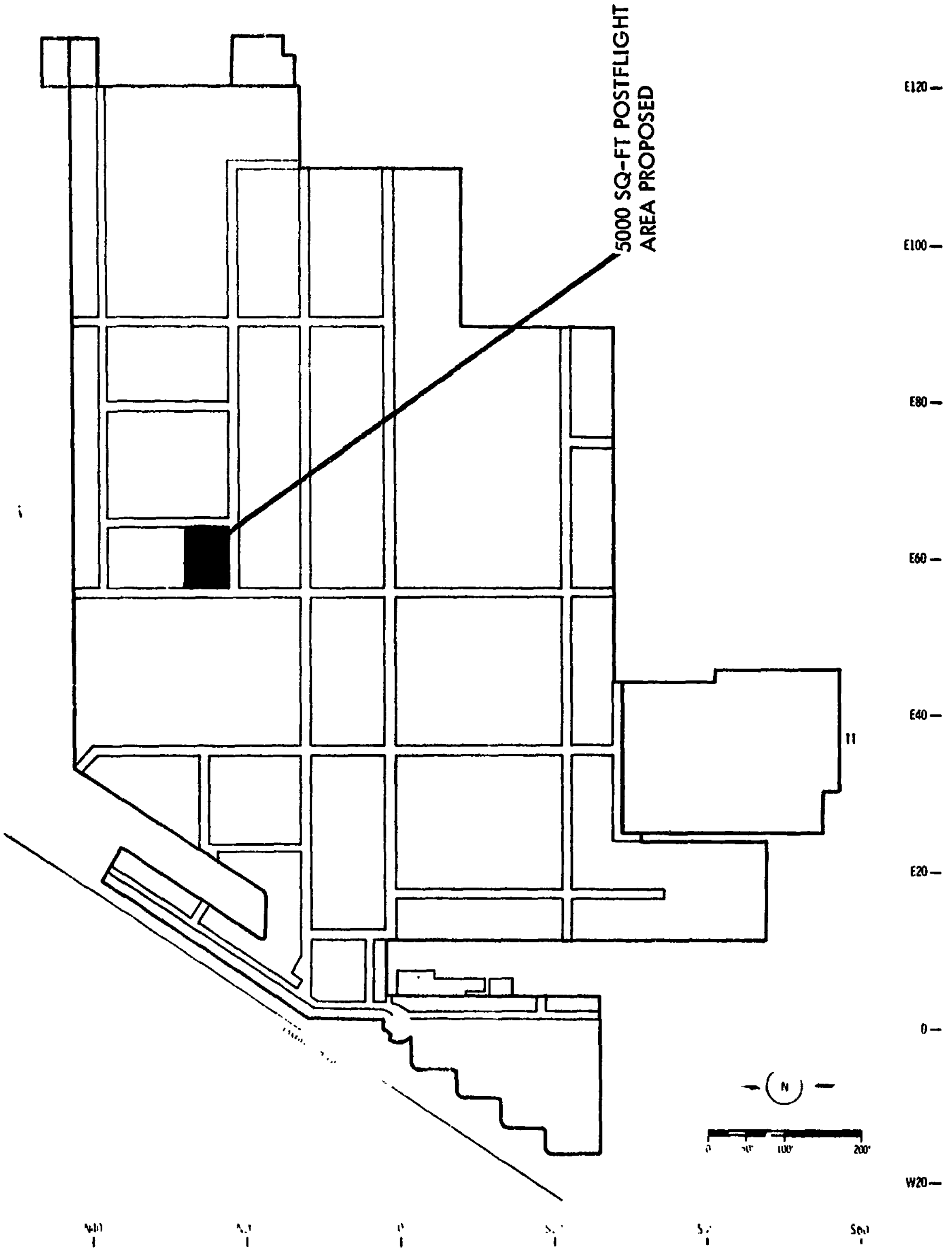


Figure 52. NASA Industrial Plant, Downey, Building 1, Proposed Flight Area

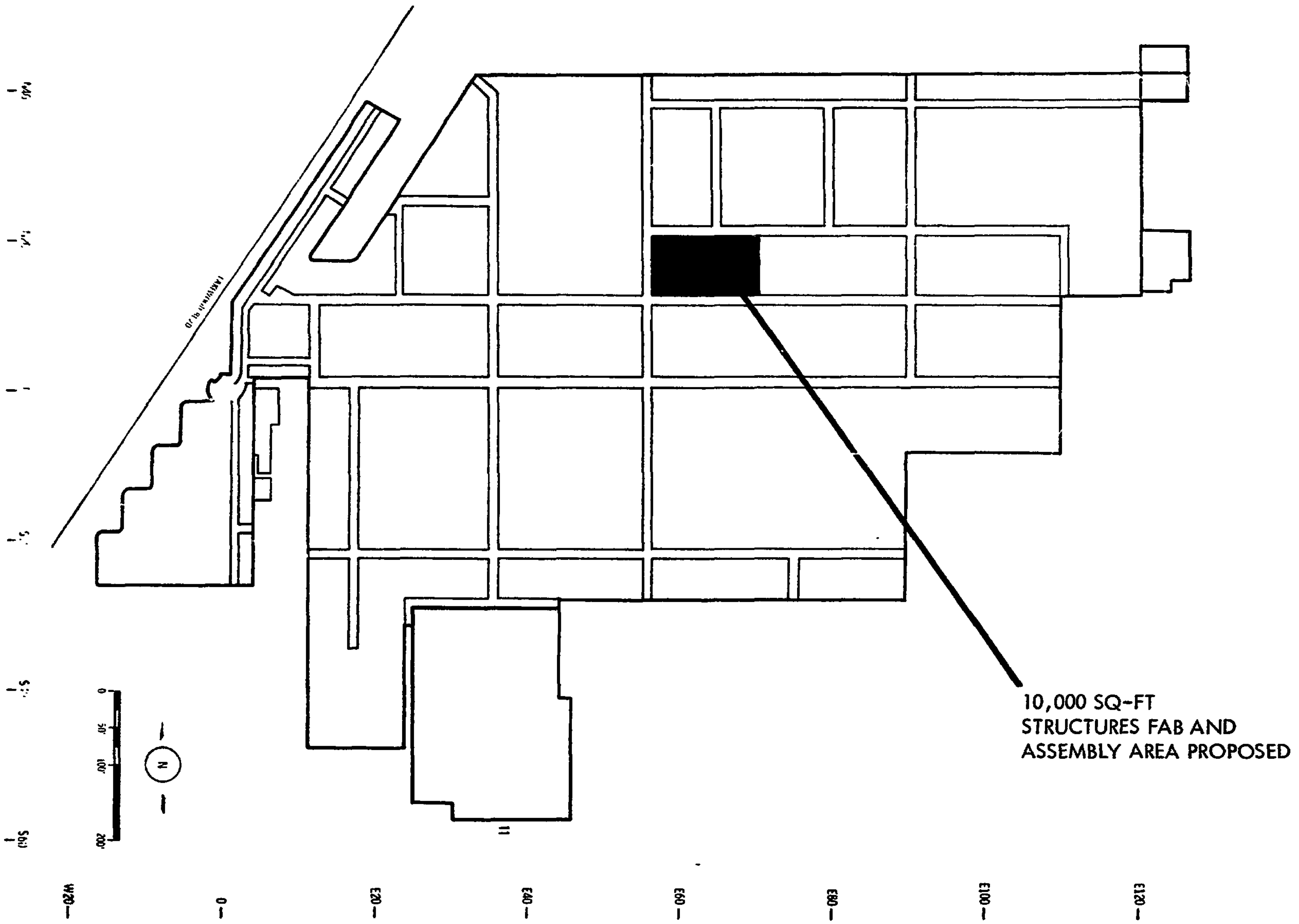


Figure 53. NASA Industrial Plant, Downey, Building 1

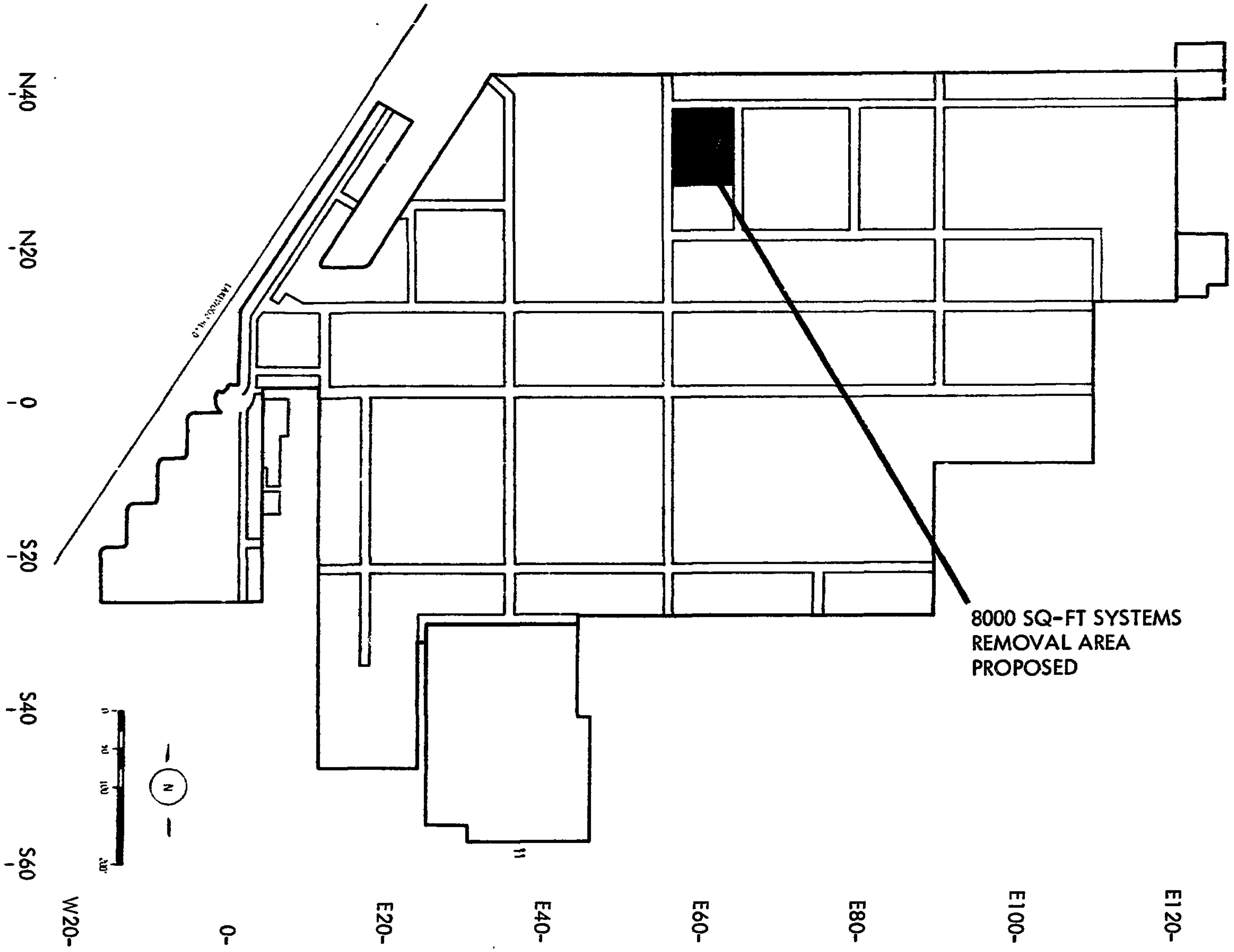


Figure 54. NASA Industrial Plant, Downey, Building 1, Proposed Removal Area

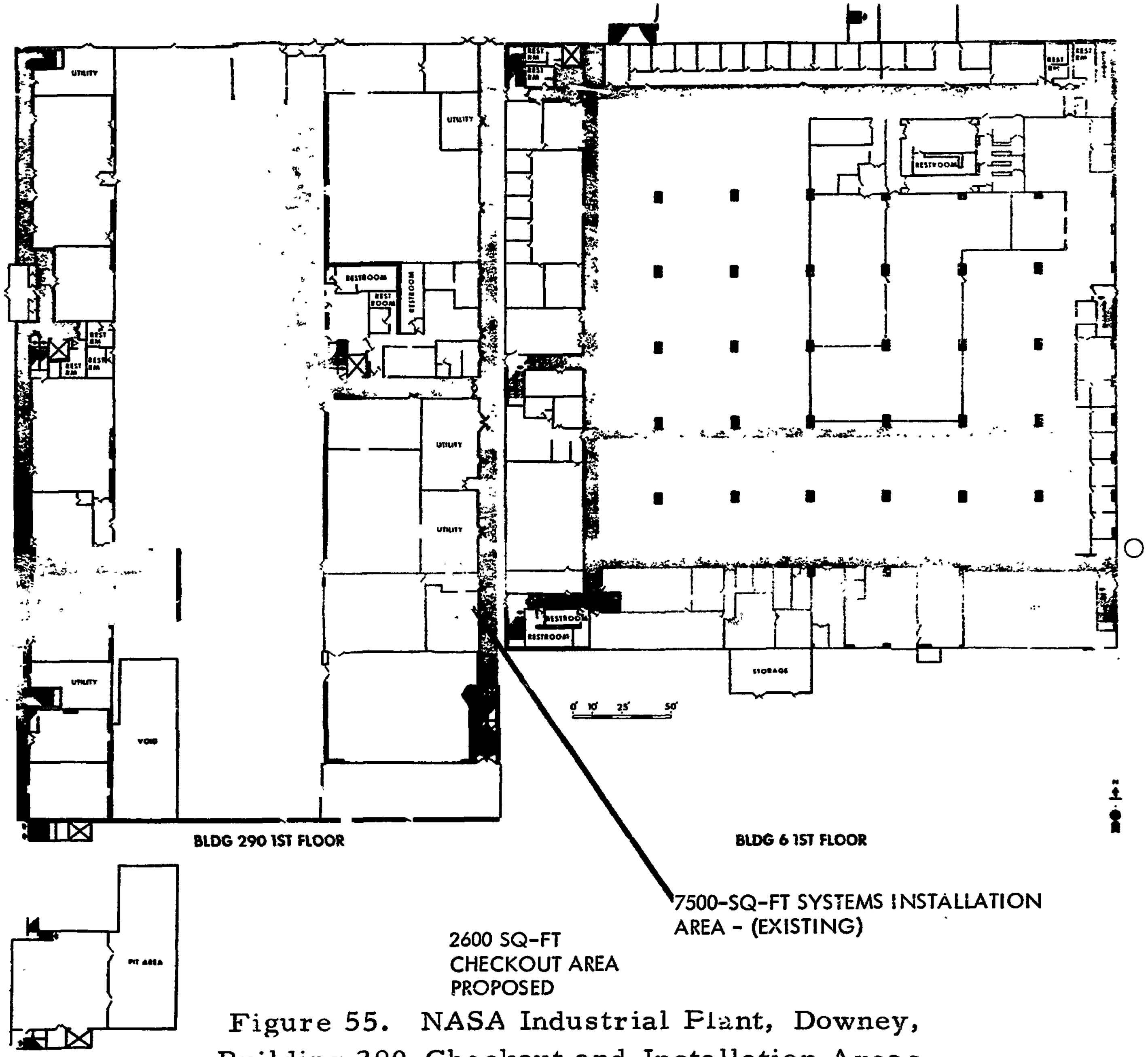


Figure 55. NASA Industrial Plant, Downey, Building 290, Checkout and Installation Areas

RECOVERY OPERATIONS

Two sets of material handling equipment are required aboard ship for removal of the aft heat shield; one set for use in the Pacific and one for use in the Atlantic recovery areas. The CM dolly, H14-008, will be provided as GSE. GSE and packaging and transport systems will provide the necessary container and protection items required for delivery of the CM from the recovery ship to a forward area and/or to Downey.

POSTFLIGHT TESTING - DOWNEY

The postflight testing of the RCM's and heat shield removal will be accomplished in Building 247, Downey. This 3000-square-foot area is capable of accommodating the RCM postflight operations. Electrical power, both 110- and 440-volt, and a compressed air distribution system are available.

Existing machinery and equipment provided for the Apollo Block I and II programs will be utilized. Existing command module handling fixtures and dollies will also be utilized for the RCM requirements when feasible. Additional material handling and parts protection equipment will be required for this operation.

SYSTEMS REMOVAL AND DISASSEMBLY

Removal of systems and secondary structures from the RCM's will be accomplished in Building 1, Downey. Approximately 8000 square feet of bonded area will be required, with 6000 square feet for disassembly and 2000 square feet for interim storage of removed systems. An additional brazing generator will be required to support tubing disassembly. Other machinery and equipment requirements will be provided by utilization of existing shop equipment procured for the Apollo program. Complete electrical and compressed air coverage is available in this area with an existing two-ton bridge crane system.

After systems removal, subsequent teardown, test, and evaluation will be accomplished either at the Downey or subcontractor facilities with no additional facility requirements anticipated (Figure 56, 57, and 58).

Material handling and parts protection devices from the Apollo program will be used wherever feasible as partial fulfillment of RCM requirements. Additional material handling and parts protection devices will be required for removal and disassembly operations.

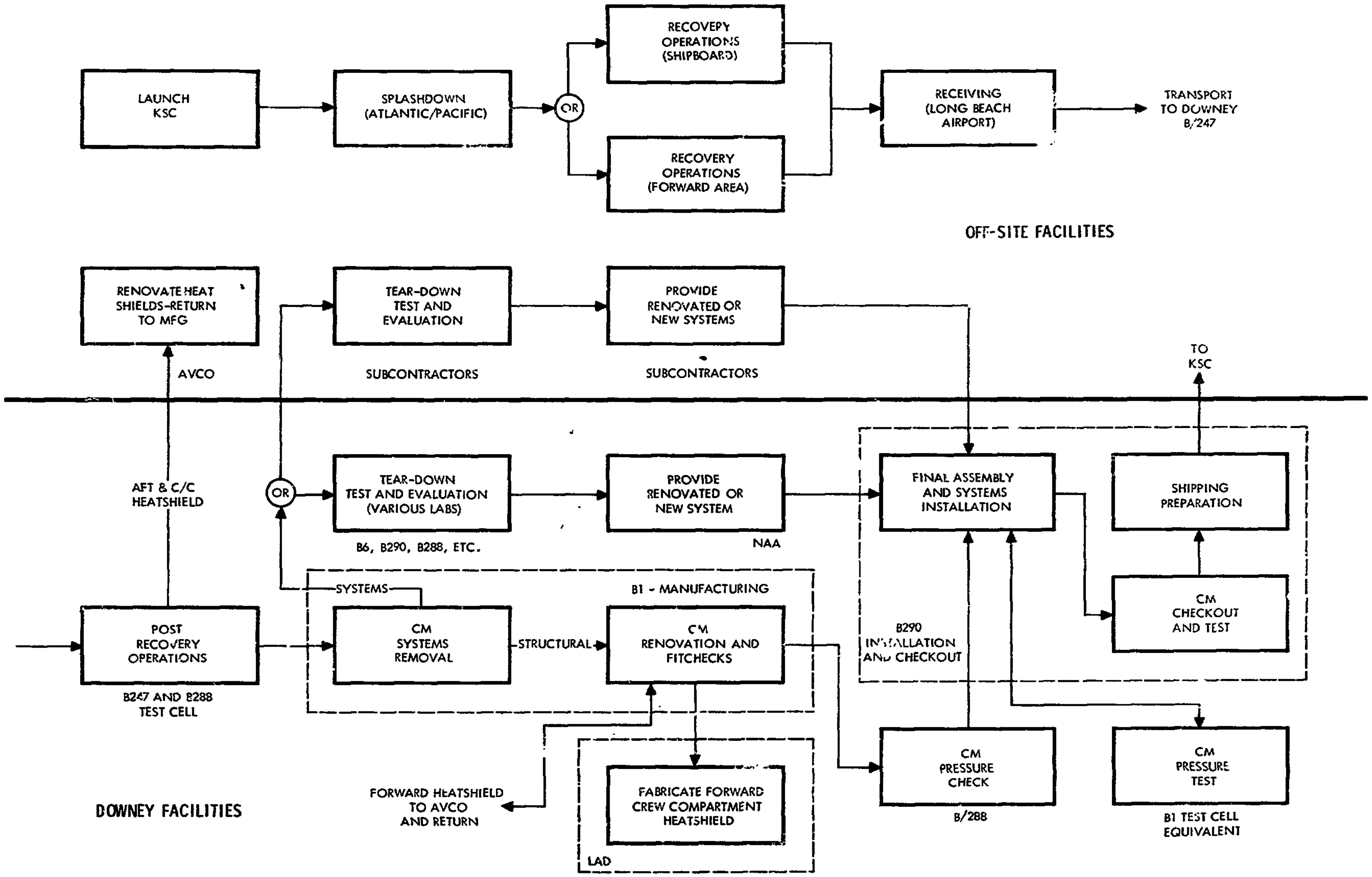


Figure 56. Flow Chart, Facilities/RCM Spacecraft

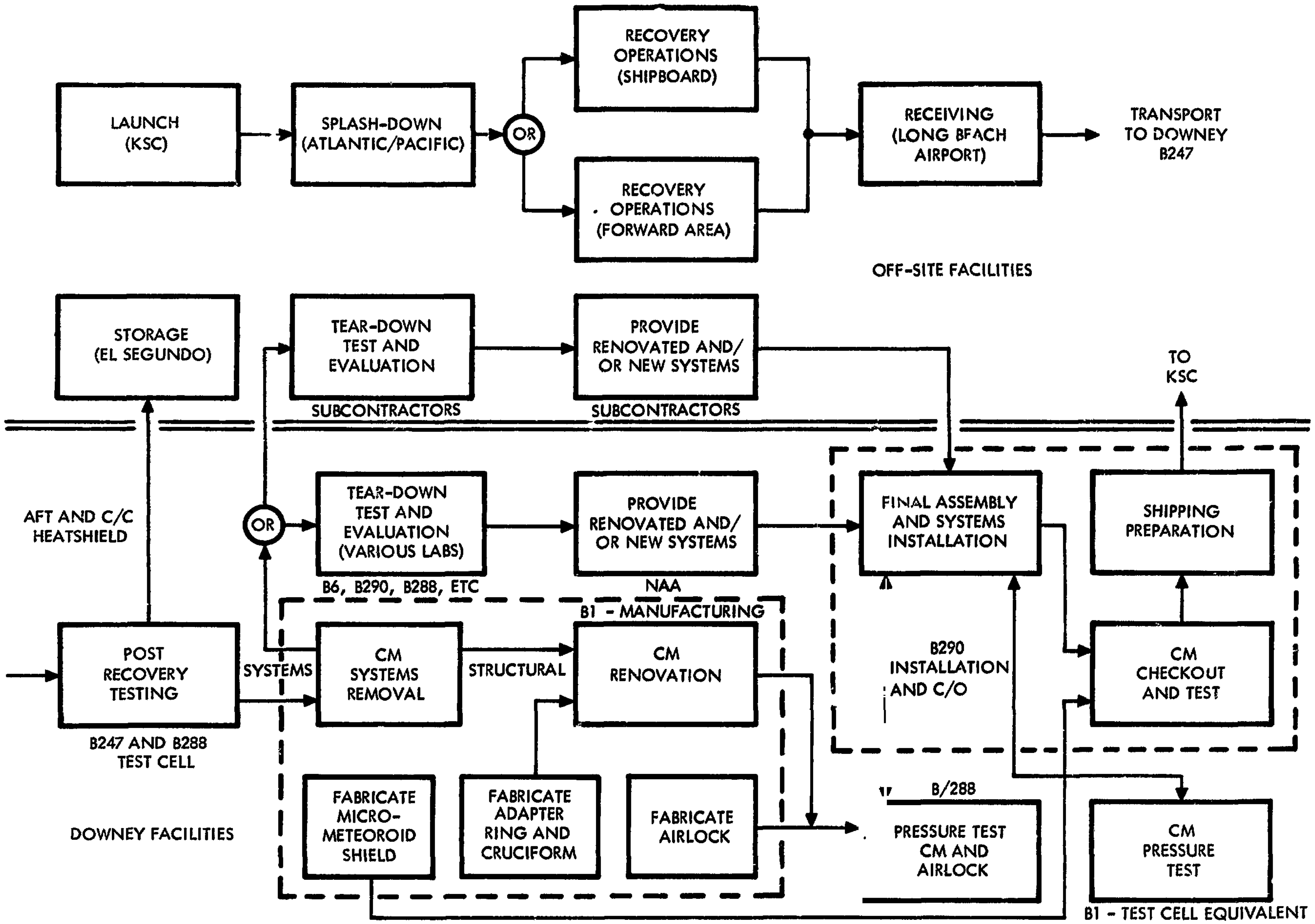


Figure 57. Flow Chart, Facilities/RCM, Independent Laboratory

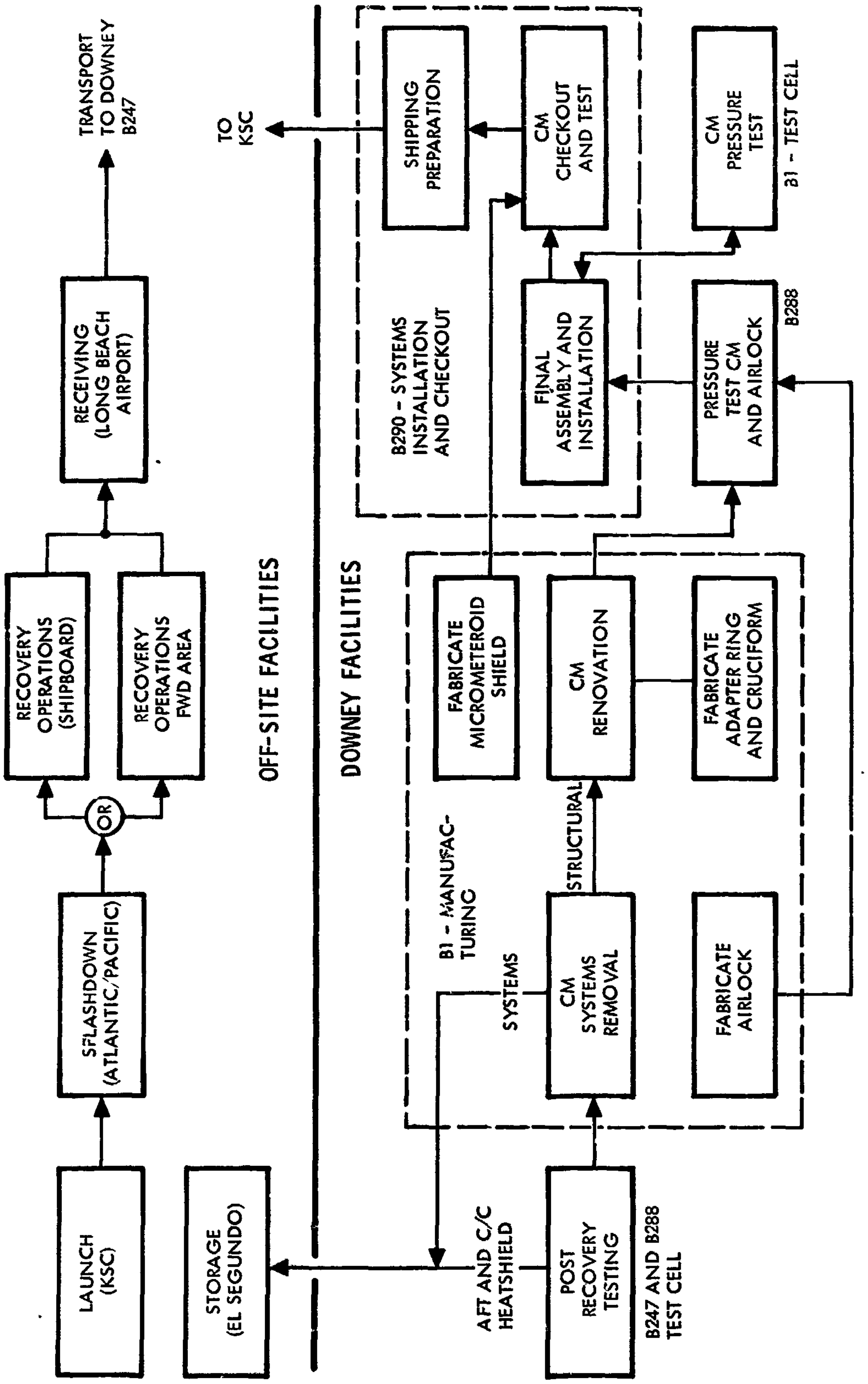


Figure 58. Flow Chart, Facilities/RCM, Dependent Laboratory

FABRICATION AND FINAL ASSEMBLY

Fabrication and final structural assembly requirements for the renovated command modules will be accomplished in the high-bay manufacturing area of Building 1, Downey. Approximately 10, 000 square feet of manufacturing area will be required for these operations (Figure 52). This area will be provided by rearrangement, relocation and/or consolidation of existing manufacturing operations in Building 1.

Each RCM laboratory will be provided with a new support structure (cruciform), adapter ring assembly, air lock, and micrometeoroid shielding. Where required, modification of the command module air lock from Block I to the Block II configuration will be accomplished using existing bonding facilities. Each RCM spacecraft will require fabrication of a new forward crew compartment heat shield and refurbishment of the aft and crew compartment heat shields.

Machinery and equipment required for the Apollo program will be utilized for RCM fabrication. Fabrication of the RCM laboratories will require an additional automatic riveting machine and two additional radial arm drill presses. Industrial Engineering techniques will be utilized to provide for efficient manufacturing flows with minimum interference to the present Apollo production. Existing Apollo material handling and parts protection devices will be used wherever feasible to support RCM fabrication. Additional and/or new material handling and parts protection devices will be required for the new configurations.

BUILDING 290 OPERATIONS

Final assembly and checkout operations of the Apollo spacecraft command modules will be performed in Building 290, which has a low-bay area for installing components in the spacecraft and a high-bay area for conducting checkout operations of the command module. In conformance with engineering specifications, the high- and low-bay areas have environmental dust control up to class level 340, 000. Checkout operations and testing consist of purging and high-pressure testing tubing and tanks; electrical/electronic testing; checking individual equipment; combined systems and integrated systems final checkout utilizing acceptance checkout equipment (ACE) and telemetry stations. Checkout equipment rooms containing ACE and telemetry equipment, power rooms, etc. are strategically located along the high- and low-bay areas. The equipment rooms are also environmentally controlled, and much of the equipment requires continuous cooling. High-pressure gases for purging and testing are piped through the high- and low-bay areas from tank farms located outside the building. Supporting facilities, such as tool rooms, stock rooms, and office areas, are also located in this building.

The RCM manufacturing requirements in Building 290, the existing area, and appurtenances will accommodate, without interference to the existing Apollo program, the RCM vehicles. However, within this area, a new manufacturing station (final assembly) will be required for the RCM independent laboratories. Existing Apollo material handling and parts protection devices will be utilized wherever feasible; however, additional devices will be required to support RCM final assembly and installation operations.

The test and operations area will accommodate the RCM spacecraft requirements, which are similar to Apollo requirements. For the RCM dependent and independent laboratories, an additional checkout station with related fluid and electrical appurtenances will be required. This additional station can be accommodated within existing area. Additional material handling and parts protection devices will also be required to support the test and checkout operations due to increased volumes.

PRESSURE TEST FACILITIES

An analysis of full system testing requirements for the RCM and Apollo vehicles, to be performed in the Building 1 test cell, was completed. The analysis indicated an overlapping of requirements for pressure testing. A completely revised testing schedule was prepared which allowed but less than one week between vehicles tests. Due to the nature of both the existing program and the new work covered by this study, the revised schedule resulted in insufficient production flexibility since problems during test with any one vehicle would impact schedules of following vehicles. Also, delays in launch dates of vehicles planned for refurbishment would result in scheduling interference.

Based on this preliminary analysis, a new pressure test facility is required for either the RCM spacecraft or independent laboratory configurations (Figure 59). Pressure testing requirements for the dependent laboratory can be accommodated with existing facilities.

Subassembly testing is scheduled to be performed in Building 289 (test cells 5A and 5B) and in Building 288 (test cells 2 and 3). See Figure 60. Analysis of current test schedules for pneumatic subassemblies indicated that test cell time is available to perform the known test requirements of this study. This will require minor rescheduling of subassembly testing to fully utilize the facility and test gear. With the RCM pressure test requirements, existing facilities will be fully loaded and any additions to test requirements (such as CCA that would cause a return of the CM for retesting after integrated checkout) could result in the need for additional test facilities. Impact of any new

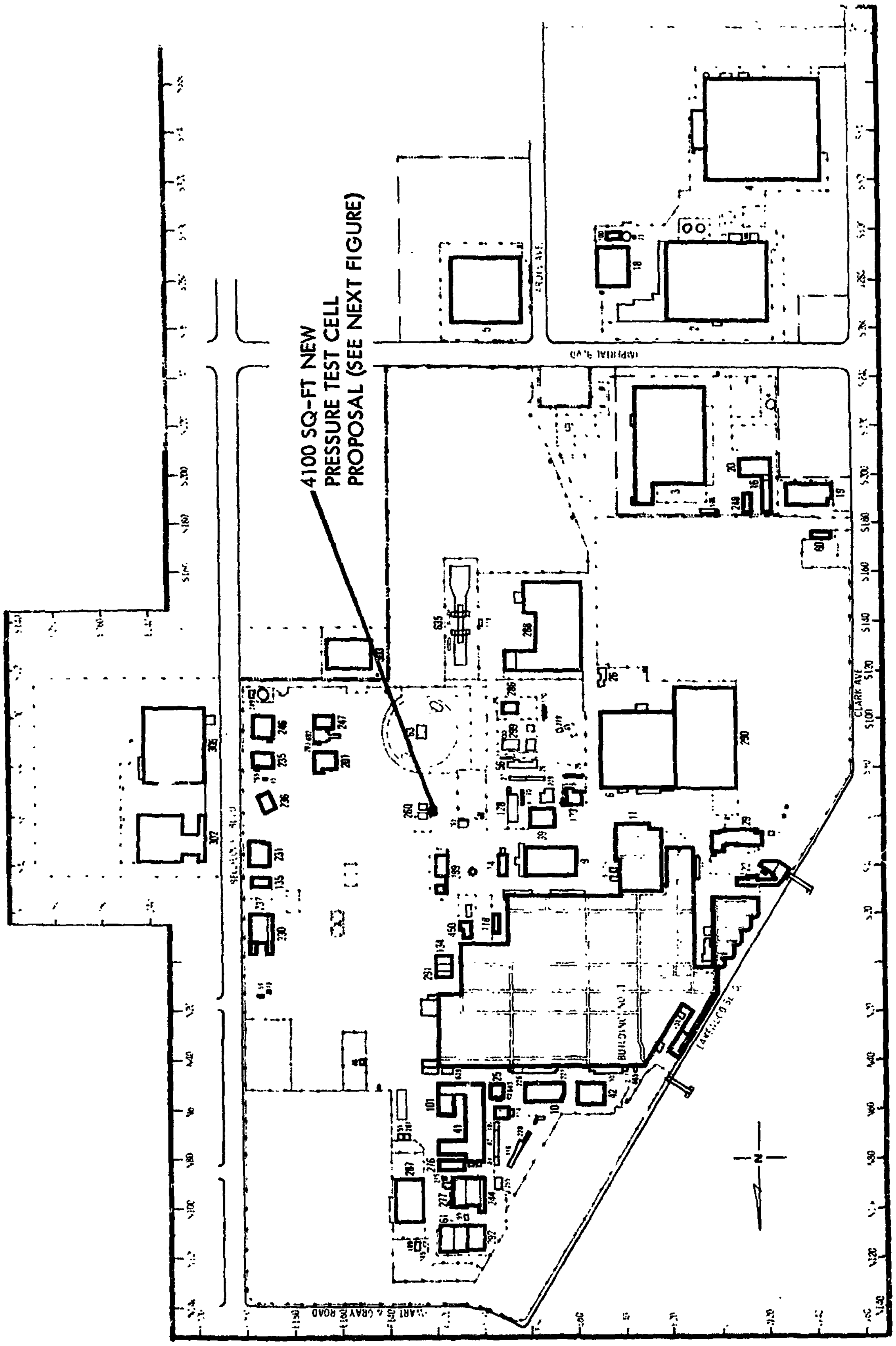
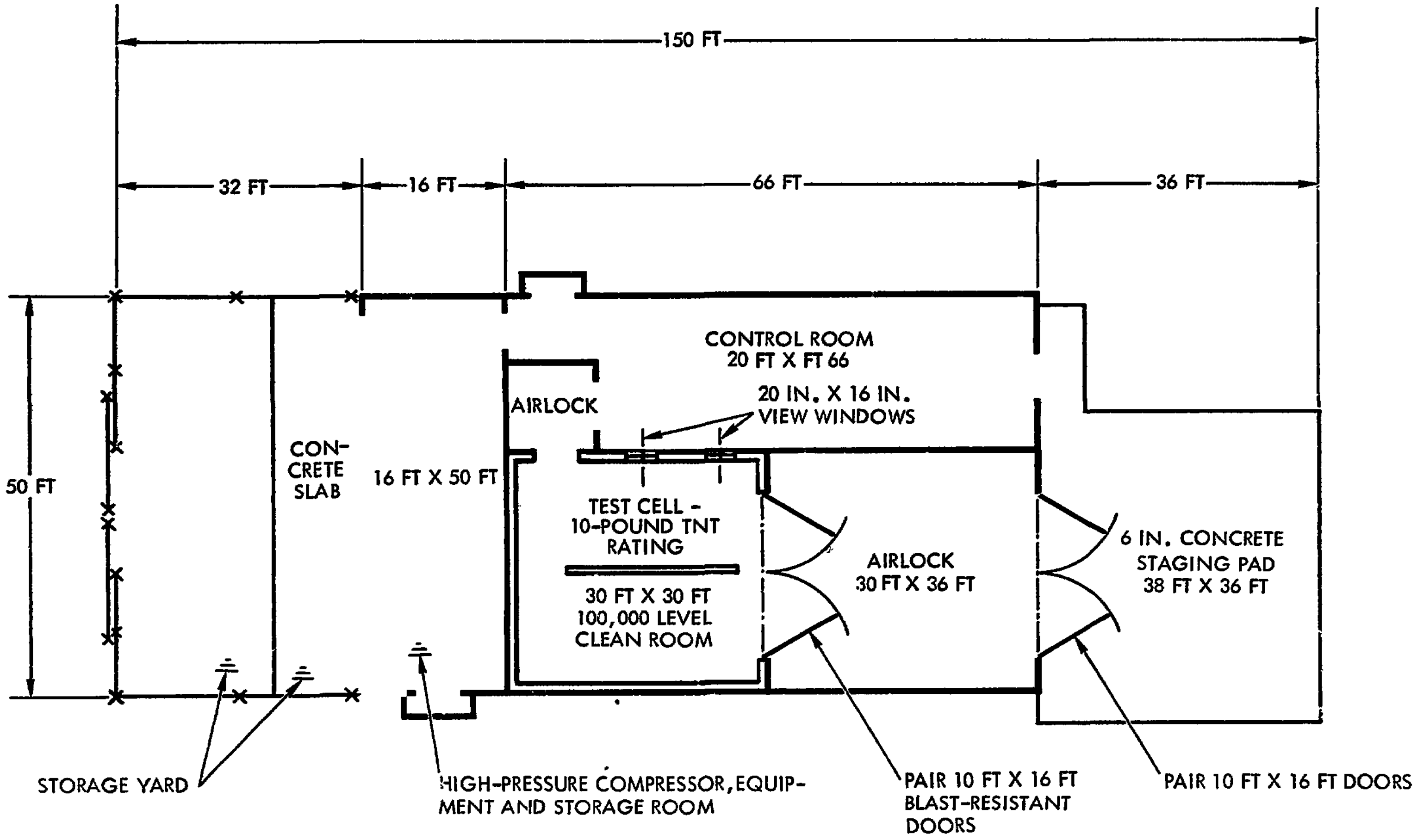


Figure 59. Downey Complex, Proposed New Pressure Test Cell Area



NOTE: 4100-SQUARE FOOT INSIDE AREA

Figure 60. RCM P· ,sure Test Facility

CM will depend on specific schedules for vehicles and subassemblies. It is assumed that Building 288 (test cells 2 and 3) will continue to be available for pneumatic testing of subassemblies and structures.

Existing Apollo material handling and parts protection devices will be utilized wherever feasible, however, additional devices will be required to support the pressure-testing operations.

PROGRAM TECHNICAL SUPPORT

To support RCM program requirements in all areas of responsibility, information and data concerning program requirements must be constantly gathered and monitored by F&IE. (See Figures 56, 57 and 58 for typical facilities flow data. This information includes schedule constraints, interface problems, identification of long lead-time procurement items and pre-acquisition evaluation of selected material handling, special test equipment, and government-furnished equipment installations. Schedules will be developed to provide timely information for design, fabrication/procurement of material handling, manufacturing aids, parts protection, and associate contractor support.

Facilities and Industrial Engineering will review manufacturing plans and vehicle test plans for the operations phase of the RCM program and determine material handling, parts protection, and manufacturing aids requirements for all manufacturing areas and test functions from detail manufacturing through final assembly and checkout. Vehicle changes and process flow changes will be analyzed for new equipment and/or equipment modification requirements. Compatibility verification of existing equipment and additional requirements will be determined. Design criteria and final design will be prepared and procurement initiated for additional new or modified equipment.

Technical support will be provided by F&IE for the initial occupancy and rearrangement of plant areas required for RCM fabrication, assembly, and checkout. This support includes, but is not limited to, preparation of design criteria; design coordination and review of specifications and drawings; preparation of general and detail layouts; initiate, schedule coordination; job order initiation and coordination; and providing technical cost evaluation of materials and/or subcontractor bid packages for all phases, from design to complete installation of facilities projects.

Industrial engineers will provide product/process improvement by analyzing process changes, new processes, materials, operating models, and spacecraft configurations. In addition, industrial engineers will identify areas conducive to improvement by changes in processes, detail manufacturing, materials, and/or assembly methods using latest state-of-the-art techniques in manufacturing, engineering, and operations research, including automation, value analysis, and development of new techniques to provide an improved product at lower costs and reduced flow times. All techniques researched and proved acceptable will be initiated and implemented.

Associate and subcontractor facility requirements will be analyzed and coordinated by F&IE. Design, installation, and relocation services will be provided in addition to area, utilities, equipment, communications, and maintenance of clean room in accordance with associate and subcontractor control standards.

XI. MATERIAL SUPPORT

Costs of new and renovated command modules were supplied by the Material Division for comparison and cost-effectiveness trade-offs. New CM costs were based on cost formats established under contract NAS9-5017. These provided for major, minor, and other material costs to be determined in accordance with quantities and schedules established by Program Control, using Spacecraft 103 as the baseline configuration. Collection of CM costs in this manner would provide valid cost comparisons between new subsystems and renovated subsystems obtained as GFE items from recovered spacecraft designated for use in the RCM program.

Renovation costs were developed as an outgrowth of activity conducted by Subsystems Engineering. Renovation approaches were developed and costed in accordance with the final renovation approach for each subsystem. It is significant that final program approaches were not altered except for end items within a subsystem area in which the value of replacement was equal to or less than the cost of renovation.

Several areas require further investigation. The following subsystem discussions indicate the activity required to assure meeting program objectives within program cost and schedule.

SUBCONTRACTORS

Avco - Heat Shield Ablator

The Avco Corporation report (included as an appendix to Volume III) confirms the feasibility of the renovation approaches developed. Considered purely on a cost basis, the renovation of the aft heat shields with total replacement of ablator material is at best a marginal saving.

Several conclusions presented in the Avco report will require resolution before a renovation program can be undertaken. From a schedule standpoint, the total replacement of any portion of the heat shield assembly (forward, crew, and aft sections) entails the longest lead time presently experienced on the Apollo program. This will necessitate close attention in subsequent phases to assure availability of the heat shield.

Collins - Communications and Data System

The basic renovation approach is to strip equipment from the CM and subject it to bench checks and a simplified acceptance test procedure. Communications equipment failures would be corrected by overhaul and repair (O&R). A complete system would then be subjected to a system acceptance test procedure.

This approach creates a variable situation in identifying hardware items requiring overhaul and repair. Failures could be determined either during bench check, simplified end-item acceptance testing, or the functional system acceptance test operation. The failed item would be subjected to FMEA action. If major failures occur during system acceptance test operations, schedule support to the renovation program is likely to be a function of replacement time and cost.

Based on this approach, further assessment of renovation requirements are needed to assure performance within projected schedules and cost.

Honeywell - Stabilization and Control System

The renovation of this subsystem must be coordinated with Apollo Block II requirements to assure minimum cost. O&R activity initiated and controlled by Apollo Block II is scheduled for completion in the third quarter of 1967. Honeywell agrees that schedules can be supported according to the baseline renovation approach supplied by Subsystems Engineering. Further effort is required to determine minimum cost of an O&R program after the conclusion of Block II requirements.

Honeywell recommends the establishment of a provisional spare parts list for the renovation activity contemplated. It is believed that this proposal should be investigated further to determine cost and schedule advantages.

Northrop-Ventura - Recovery System

Little cost saving is available in the renovation of this subsystem except in the end item identified as the sequence controller. Renovation requirements of the sequence controller should be determined and renovation operations integrated into the Block II production requirements to offset and possibly to reduce the cost of the recovery subsystem.

GFE ASSOCIATE CONTRACTORS

A-C Electronics - Guidance and Navigation Subsystem

Required subsystem performance, cost, and schedule information has been obtained and incorporated into this study after much administrative delay. It is recommended that further participation be on a fully funded basis or controlled by NASA level for subsequent phases.

CONCLUSIONS

General schedule assessments have been made which demonstrate the feasibility of the renovation program within the general time constraints for anticipated re-launch dates.

Activities have been identified that require initiation before establishment of the Renovation Program in order to attain projected launch dates. Schedule conclusions are summarized in Section IX (Figures 47, 48, 49). These findings must be subjected to further detailed investigation, requiring funded subcontractor support, to verify schedule attainability and confidence in attendant cost studies.

Engineering studies to establish renovated laboratory and spacecraft configuration must be conducted and findings approved by NASA. This definition must be detailed enough to permit the generation of specifications and ICD requirements. Engineering studies of approved baseline configurations must be carried to the point that detailed subcontractor statements of work can be established for hardware requirements.

The magnitude of the program to convert recovered command modules into the desired laboratory or spacecraft configurations must be supported by funded subcontractor participation on a command module subsystem and possibly equipment level. This activity must detail the refurbishment task requirements for subsystems for each renovated command module approved configuration.

Modifications of CM subsystems for laboratory use must be defined. Rework and/or design of new structural components must be determined. These activities will provide authoritative cost and schedule conclusions.

Subsystem refurbishment requirements for the preparation of the CM for a second operational flight also must be defined. Operational requirements for individual subsystems and techniques to accomplish the renovation must be established, specified, and concurred with by subcontractors. Conclusion of these activities will provide authoritative cost and schedule conclusions.

Preliminary process specifications, to the subsystem level, must be developed to:

1. Determine status of flight hardware

2. Determine test procedures to identify sources of out-of-tolerance performance

3. Determine scope of repair to refurbish out-of-tolerance equipment.

These specifications must take into account both renovated CM configurations.

Plans to re-accept or requalify the Apollo Block II CM subsystems and equipment planned for the laboratory and spacecraft configurations must be defined and approved. Test plans will be generated to specify necessary testing, determine facility requirements and availability, and provide a basis for firm cost and schedule commitments.