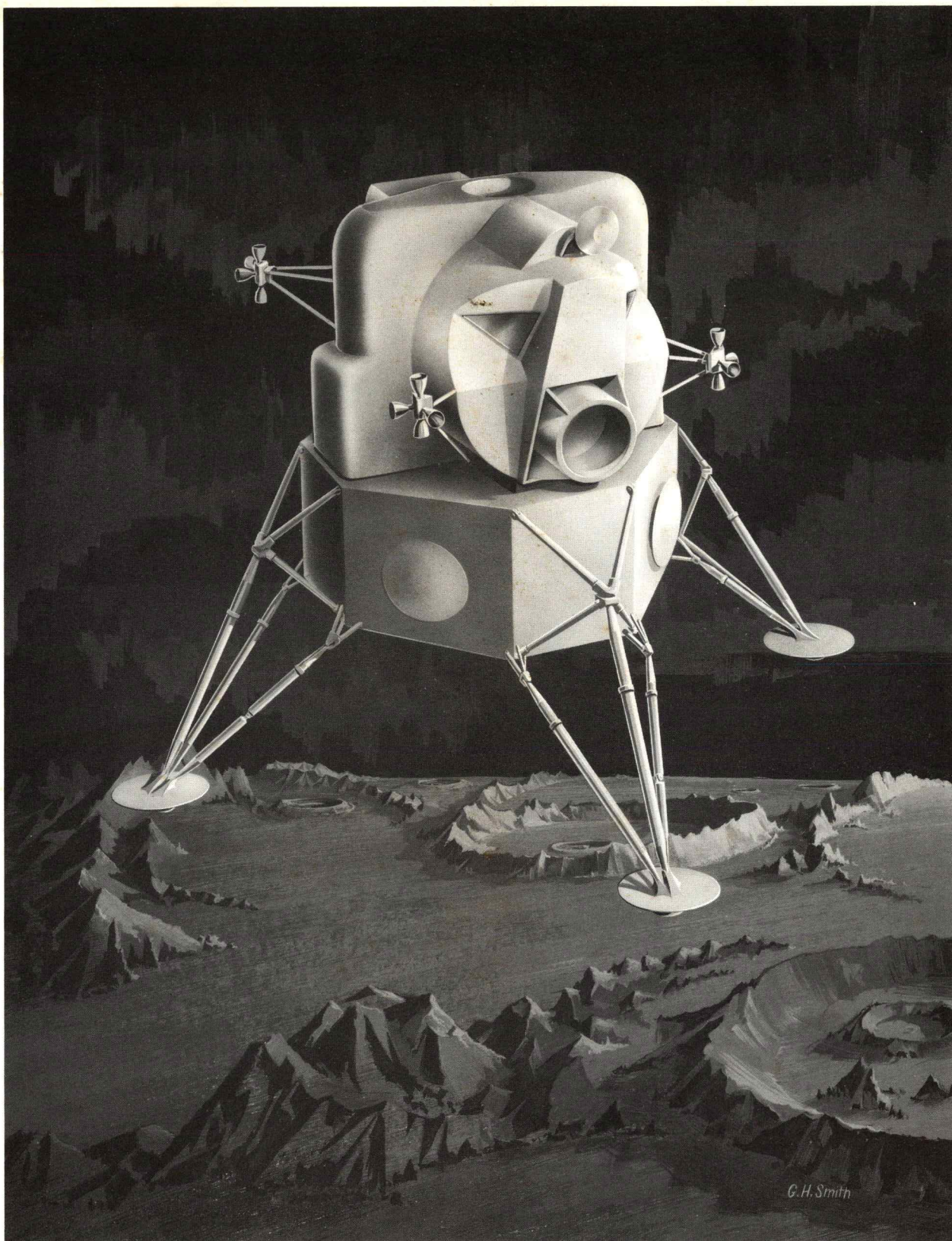


# MANUFACTURING PLAN FOR PROJECT APOLLO— LUNAR EXCURSION MODULE

LPL-850-1



GRUMMAN AIRCRAFT ENGINEERING CORPORATION



# REVISIONS

SECOND SUBMITTAL - 14 OCTOBER 1963

Revised or Added Pages*	Revision Description
General	Plan downgraded from confidential to unclassified.
Introduction	Introduction re-written to define Revision "A" to LPL-850-1.
1-2, 1-3	Expanded write-up with respect to use of advanced engineering information.
1-3	Revised tooling discussion of structural and installation rates.
1-4	Revised Figure 1-2 in accordance with Master Phasing Chart, dated 15 September 1963.
1-5	Added discussion of follow-on manufacturing engineering efforts.
1-6 Thru 1-14	Expanded the management control of LEM activities.
1-9	Added Figure 1-4.
1-13, 1-14	Added discussion of re-training for space manufacturing skills.
1-14 Thru 1-17	Up-dated "make or buy" discussions & figure.
Section 2	Expanded and revised manufacturing facilities plan. Percent utilization of non-exclusive areas noted. All plant layouts up-dated.
3-1 Thru 3-5	Added schedule development and priority data.
3-6	Added discussion of tool movement & tool storage control.
3-6 Thru 3-12	Revised schedule discussion and added TM-2 charts, and summary schedule of TM-2, M-5, & PD units. Deleted Obsolete LTA-4 Schedule.
3-23, 3-24	Added Interchangeability and Replaceability data.
3-27	Added discussion of LEM standards.
3-28	Manufacturing, Assembly and Inspection Record (MAIR) as shown in QC Plan is referenced.
3-29, 3-20	Up-dated review and analysis of subcontractor proposals.
3-36, 3-37	Added discussion of balancing work load.
3-40, 3-41	Revised traceability and configuration control description.
----- *Revised or added pages are dated 14 October 1963.	

REVISIONS

SECOND SUBMITTAL - 14 OCTOBER 1963

Revised or Added Pages*	Revision Description
Section 4	Revised and up-dated all technical discussions to agree with design configuration data available as of 1 October 1963.  Expanded tooling requirements lists. Added fixture sketches.  Revised Subassembly Breakdown & Manufacturing Flow Diagrams in accordance with October 1 configuration.
Section 5	Area for installation of Electrical Power Subsystem changed to clean room.
Section 6	Up-dated the discussion of Manufacturing Test Program.
Section 7	Up-dated the GSE/STE discussions and Planning Flow Diagram.
Section 8	Expanded the Field Site Support data.

# TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
	Introduction . . . . .	xii
	Summary . . . . .	xiii
1	DESCRIPTION AND IMPLEMENTATION - LEM MANUFACTURING PLAN	
1.1	Development Manufacturing Approach . . . . .	1-1
1.2	Implementation of the LEM Manufacturing Plan . . . . .	1-6
1.3	Make or Buy Summary . . . . .	1-14
2	MANUFACTURING FACILITIES	
2.1	Facility Utilization and Manufacturing Flow . . . . .	2-1
2.1.1	Plant 5 - Centralized LEM Assembly, Installation, and Test . . . .	2-5
2.1.2	Plant 3 - Ascent Stage Structural/Mechanical Manufacturing . . . .	2-10
2.1.3	Plant 2 - Descent Stage Structural/Mechanical Assembly and Manufacture of Detail Parts & Minor Subassemblies . . . .	2-18
2.1.4	Plant 12 - Plastic Parts . . . . .	2-18
2.1.5	Plant 4 - Electronic Bench Test and Bench Maintenance . . . . .	2-22
2.1.6	Tool Manufacturing Facilities . . . . .	2-22
2.1.7	GSE/STE Manufacturing Facilities . . . . .	2-27
3	SCHEDULING, PLANNING, METHODS, AND CONTROLS	
3.1	Scheduling . . . . .	3-1
3.1.1	Manufacturing Scheduling . . . . .	3-1
3.1.2	Tool Scheduling . . . . .	3-3
3.1.3	LEM Manufacturing Program Schedules . . . . .	3-6
3.2	Planning . . . . .	3-13
3.2.1	Manufacturing Planning . . . . .	3-13
3.2.2	Tool Planning . . . . .	3-17
3.2.3	Procurement Planning . . . . .	3-22
3.3	Methods and Controls . . . . .	3-23
3.3.1	Mechanical Interface Control . . . . .	3-23
3.3.2	Electrical/Electronic Interface Coordination . . . . .	3-26

TABLE OF CONTENTS (Cont.)

<u>Section</u>	<u>Page</u>
3.3.3     Manufacturing Reliability Control . . . . .	3-27
3.3.4     Control of Subcontractor Tooling and Manufacturing Activities . . .	3-28
3.3.5     Schedule Control . . . . .	3-35
3.3.6     Cost Control . . . . .	3-37
3.3.7     Parts Control (Production Control) . . . . .	3-40
3.3.8     Traceability and Configuration Control . . . . .	3-40
4         STRUCTURAL/MECHANICAL, FLUID, AND ELECTRONIC SUBSYSTEMS	
4.1       Structural/Mechanical and Crew Provisions Subsystems . . . . .	4-1
4.1.1     Structural/Mechanical Subsystems . . . . .	4-2
4.1.2     Crew Provisions Subsystem . . . . .	4-36
4.2       Fluid Subsystems . . . . .	4-36
4.2.1     Propulsion Subsystem - Ascent Stage . . . . .	4-37
4.2.2     Propulsion Subsystem - Descent Stage . . . . .	4-43
4.2.3     Reaction Control and Environment Control Subsystems . . . . .	4-43
4.3       Electrical/Electronic Subsystems . . . . .	4-43
4.3.1     Electrical Power Subsystem . . . . .	4-44
4.3.2     Communications Subsystem . . . . .	4-44
4.3.3     Navigation and Guidance and Stabilization and Control Subsystems .	4-44
5         FINAL ASSEMBLY	
5.1       Final Assembly Description . . . . .	5-1
5.2       Final Assembly and Subsystems Installations - Ascent Stage . . .	5-1
5.3       Final Assembly and Subsystems Installations - Descent Stage . . .	5-5
5.4       Ascent/Descent Joining and Critical Subsystem Alignment. . . . .	5-6
6         MANUFACTURING TEST PROGRAM	
6.1       Description and Implementation . . . . .	6-1
6.2       Manufacturing Tests - Structural/Mechanical, and Crew Provisions Subsystems . . . . .	6-3
6.2.1     Structural/Mechanical Subsystem . . . . .	6-3

TABLE OF CONTENTS (Cont.)

<u>Section</u>	<u>Page</u>
6.2.2 Crew Provisions Subsystem . . . . .	6-4
6.3 Manufacturing Test - Fluid Subsystems . . . . .	6-5
6.3.1 Reaction Control and Propulsion Subsystems . . . . .	6-5
6.3.2 Environmental Control Subsystem . . . . .	6-6
6.4 Manufacturing Test - Electrical/Electronic Subsystems . . . . .	6-7
6.4.1 Electrical Power Subsystem. . . . .	6-7
6.4.2 Communications, Instrumentation, Displays and Controls, Stabilization and Control, and Navigation and Guidance Subsystems . . . . .	6-8
6.5 Ground and Flight Test Programs Support . . . . .	6-10
7 MANUFACTURE OF GSE/STE	
7.1 GSE/STE Manufacturing Plan . . . . .	7-1
7.1.1 Electronic GSE/STE . . . . .	7-4
7.1.2 Fluid Systems GSE/STE . . . . .	7-5
7.1.3 Handling and Transportation GSE . . . . .	7-7
7.1.4 Training Equipment . . . . .	7-8
8 FIELD SITE SUPPORT	
8.1 Test and Launch Site Activities . . . . .	8-1

# LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1-1	Previous Grumman Application of Three Manufacturing Plan Types. . .	1-2
1-2	LTA and LEM Manufacturing Rates . . . . .	1-4
1-3	Organization Chart . . . . .	1-8
1-4	LEM Manufacturing Organization Chart . . . . .	1-9
1-5	Make or Buy Summary - Ascent Stage . . . . .	1-15
1-6	Make or Buy Summary - Descent Stage . . . . .	1-16
2-1	Basic LEM Manufacturing Flow Through Bethpage Facility . . . . .	2-4
2-2	Plant 5 LEM Assembly, Installation, & Test. . . . .	2-6
2-3	Plant 5 - Clean Room for Bench Test, Assembly and Installation of RCS, ECS, and EPS. . . . .	2-7
2-4	Clean Room - RCS, ECS, and EPS Installation & Testing . . . . .	2-8
2-5	Clean Room - Inspection and Cleaning Facilities . . . . .	2-9
2-6	Plant 3 - LEM Ascent Stage Structural/Mechanical Manufacturing . . .	2-11
2-7	Plant 3 - Vertical Lathe Equipment . . . . .	2-12
2-8	Plant 3 - Milling Equipment . . . . .	2-13
2-9	Plant 3 - Forming and Bonding Equipment . . . . .	2-14
2-10	Plant 3 - Resistance and Automatic Fusion Welding Equipment. . . . .	2-15
2-11	Plant 3 - Automatic Welding Equipment . . . . .	2-16
2-12	Plant 3 - Chemical Milling Facility . . . . .	2-17
2-13	Plant 2 - LEM Descent Stage Structural/Mechanical Assembly & Manufacture of Detail Parts & Minor Subassemblies . . . . .	2-19
2-14	Plant 2 - Forming Equipment and Consolidated Detail Parts Facility . .	2-20
2-15	Plant 2 - Forming and Age-Hardening Facilities . . . . .	2-21
2-16	Plant 12 - Fiberglass Manufacturing Facilities . . . . .	2-23
2-17	Jig and Fixture Manufacturing Facilities. . . . .	2-24
2-18	Template and Tooling Mockup Facilities. . . . .	2-25
2-19	GSE/STE Manufacturing Facilities . . . . .	2-28
2-20	Test Equipment Shop . . . . .	2-29
3-1	Manufacturing Scheduling Flow . . . . .	3-12

LIST OF ILLUSTRATIONS (Cont.)

<u>Figure</u>		<u>Page</u>
3-2	Tool Scheduling Flow . . . . .	3-5
3-3	LEM TM-2 Descent Stage Subassembly Breakdown & Manufacturing Flow and LEM TM-2 Descent Stage Manufacturing Schedules . . . . .	3-8
3-4	Manufacturing Schedule Summary - LEM TM-2, M-5, PD-4, PD-1, PD-5, and PD-2 . . . . .	3-12
3-5	Manufacturing Planning Flow . . . . .	3-14
3-6	Sample LEM Shop Work Order and Route Card . . . . .	3-16
3-7	Tool Planning Flow . . . . .	3-18
3-8	ME-269 Record Sheets . . . . .	3-19
3-9	Grumman Tool and Equipment Letter Codes . . . . .	3-21
4-1	LEM General Arrangement Configuration . . . . .	4-3
4-2	LEM Subassembly Breakdown . . . . .	4-4
4-3	Ascent Stage Structural Subassembly Flow . . . . .	4-5
4-4	Descent Stage - Subassembly Breakdown . . . . .	4-6
4-5	Chem-Milling of a Typical LEM Detail . . . . .	4-9
4-6	Face Subassembly Breakdown and Manufacturing Flow . . . . .	4-12
4-7	Cabin Subassembly Breakdown and Manufacturing Flow . . . . .	4-13
4-8	Mid Section Subassembly Breakdown and Manufacturing Flow . . . . .	4-14
4-9	Aft Equipment Bay Subassembly Breakdown and Manufacturing Flow . . . . .	4-15
4-10	Typical Combination Fixture-Welding and Machining of Skin and Cruciform Assemblies . . . . .	4-19
4-11	Combination Fixture-Welding of N&G Dome to Cabin Subassembly . . . . .	4-20
4-12	Weld Fixture-Welding of Face to Cabin Subassembly . . . . .	4-21
4-13	Weld Fixture-Weld Tunnel to Top Deck . . . . .	4-23
4-14	Combination Fixture-Welding of Lower Deck, Side Skin/Cruciform and Upper Deck/Docking Tunnel Subassemblies . . . . .	4-24
4-15	Combination Fixture-Welding of Aft Ring and Forward Bulkhead . . . . .	4-25
4-16	Joining of Face/Cabin and Mid Section Subassemblies . . . . .	4-27
4-17	Final Structural Assembly Fixture-Ascent Stage . . . . .	4-29
4-18	Final Structural Assembly Fixture-Descent Stage . . . . .	4-33

LIST OF ILLUSTRATIONS (Cont.)

<u>Figure</u>		<u>Page</u>
4-19	Manufacturing Flow Diagram-Ascent/Descent Lines and Ascent Tanks . .	4-40
4-20	Automatic Fusion Welding of Aluminum Ascent Tanks . . . . .	4-41
4-21	Induction Brazing of Line Assemblies . . . . .	4-42
5-1	Installation, Joining, and Alignment Flow . . . . .	5-2
5-2	Manufacturing Alignment and Functional Test Fixture . . . . .	5-7
7-1	GSE/STE Planning and Manufacturing Flow . . . . .	7-3
7-2	Preventive Maintenance Procedure Form . . . . .	7-6

LIST OF TABLES

<u>Table</u>		<u>Page</u>
2-1	LEM Area Allocation Summary . . . . .	2-1
2-2	LEM Facility Availability and Usage Schedule . . . . .	2-2
4-1	Ascent Stage - Major Assemblies and Major Tools Required . . . . .	4-10
4-2	Descent Stage - Major Assemblies and Major Tools Required . . . . .	4-31
4-3	Ascent Stage - Flight-Weight Propulsion Tank Fixtures . . . . .	4-38
4-4	Ascent Stage - Boiler Plate Tank Fixtures . . . . .	4-39

## INTRODUCTION

Revision "A" to the "LEM Manufacturing Plan" is submitted in fulfillment of the requirements of paragraph 3.4 - Documentation Requirements List for Type I Documents.

NASA/MSC approval of this document was forwarded in letter SLP-22-63-496, Subject: "Contract NAS 9-1100, Item #22, Manufacturing Plan, Grumman Report LPL-850-1".

This approved plan incorporates the refinements requested by NASA during the draft review held in Houston, Texas on 17 and 18 October 1963. The RASPO has also provided a review prior to release for printing. A third submittal of the LEM Manufacturing Plan is scheduled for publication during April 1964.

In accordance with a NASA/MSC agreement, all data contained in this second submittal is based on LEM Program information which was available as of 1 October 1963.

NASA recipients of this document may refer questions or comments to MSC, Attention: SLP, Mr. Donald B. Sullivan. Grumman comments shall be directed to Chris Hansen, Manufacturing Engineering, Plant 2.

## SUMMARY

The "LEM Manufacturing Plan" emphasizes a unified team effort for the management, implementation, and control of all manufacturing phases. This LEM manufacturing team concept assures closely coordinated technical and managerial programs for effectively performing the following major LEM functions:

- LEM Fabrication, assembly, and subsystem installations.
- Manufacturing test programs for both in-house fabricated units and vendor supplied subsystem components.
- Fabrication of LEM handling and Transportation GSE; fluid systems GSE/STE; electronic GSE/STE; and training equipment.
- Design and manufacture of tooling for LEM fabrication, assembly, and installation operations.
- Selection, utilization, and maintenance of manufacturing equipment and processes.
- Manufacturing team support of field-site activities.

Summarized approaches to these six major LEM manufacturing functions are described in Section 1.1. As stated throughout this plan, the primary goals of highest mission reliability, on-schedule performance, and lowest possible over-all costs have established the criteria for the evaluation and selection of all manufacturing procedures and techniques.

Grumman fully recognizes the responsibility to NASA for the control of both in-house and vendor manufacturing performance. Section 3.3 outlines the methods and controls which are planned for satisfying these requirements.

SECTION 1 - Description and Implementation - LEM  
Manufacturing Plan

SECTION 1  
DESCRIPTION AND IMPLEMENTATION -  
LEM MANUFACTURING PLAN

1.1 DEVELOPMENT MANUFACTURING APPROACH

Grumman has selected a proven Development Manufacturing Plan to satisfy the high reliability requirements, to meet the critical schedule milestones, and to achieve lowest possible over-all program costs.

The effectiveness of this manufacturing approach which is specifically geared for low-volume/low-rate production, has been demonstrated by the on-schedule development of the highly sophisticated Grumman A-6A Intruder and E-2A Hawkeye manned flight systems.

For comparative purposes, Figure 1-1 shows previous Grumman applications of the Experimental, Development, and Production Plans.

Negotiated LEM Program costs reflect the use of the ideally suited development manufacturing approach. The factors which have influenced this selection are summarized as follows:

- Primary consideration has been given to the extreme program flexibility required for rapid response to LEM refinements and changes. Engineering design details will be continuously influenced by further accumulation of scientific manned space flight data and by test program results. Anticipated refinements and allowance for future LEM growth potential must be accommodated by giving advanced consideration to ease of tool and equipment modification and to adjustment of manufacturing and testing techniques. The Development Plan combines the flexible and adaptable features of the Experimental Plan with the reliable and economical characteristics of the Production Plan.

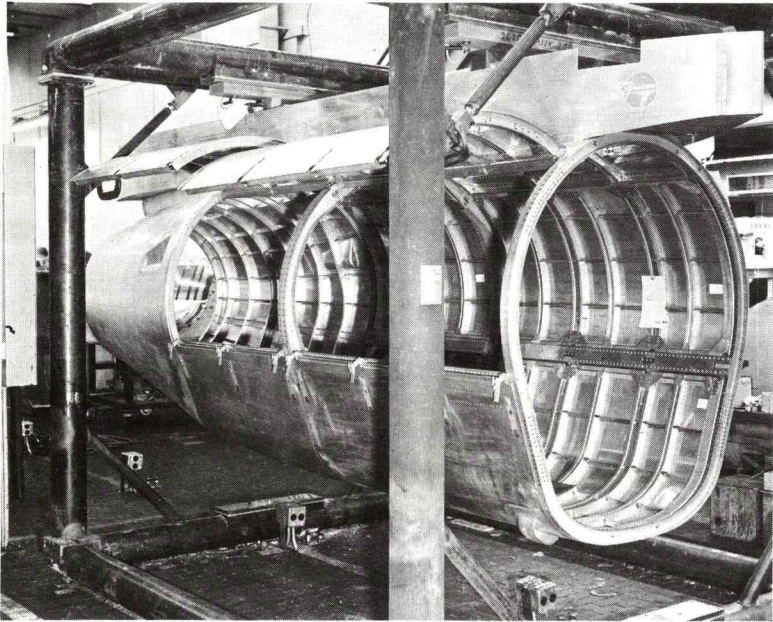
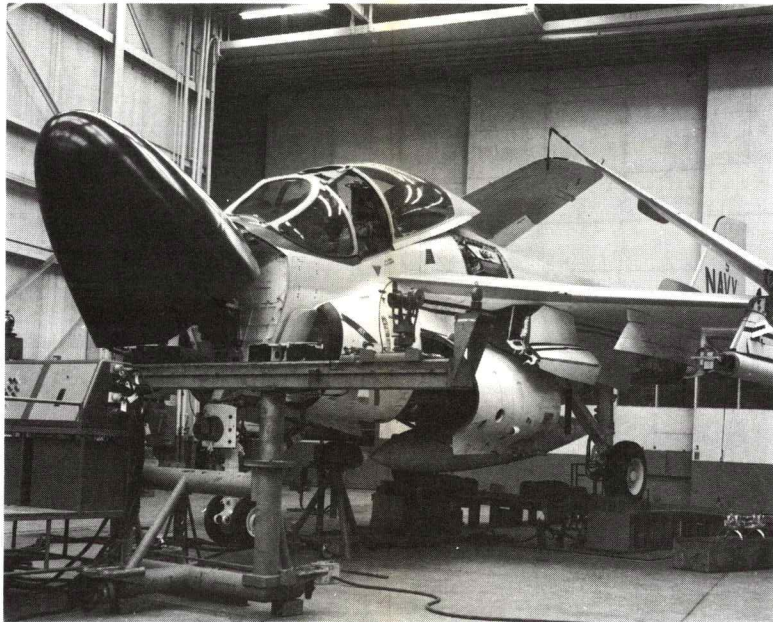

Experimental Manufacturing Plan	Development Manufacturing Plan Also Selected for LEM Program	Production Plan
<p>Grumman Application:</p> <p>The "Experimental Manufacturing Plan" is used when only one or two units are to be produced. Follow on manufacture is not considered.</p> <p>Previous Example:</p> <p>Flying engine test cell for attachment to the B-45 aircraft.</p>  <p>Experimental Fabrication of Engine Test Cell</p> <p>Manufacturing Data:</p> <p>Two units were produced. The first was completed eight months after go-ahead and the second unit three months thereafter.</p>	<p>Grumman Application:</p> <p>The "Development Manufacturing Plan" is used for programs requiring a transition from the design, development, test and evaluation phases to a low quantity follow-on manufacturing phase.</p> <p>Previous Example:</p> <p>A-6A Intruder, the latest jet aircraft for carrier and land based general purpose attack.</p>  <p>Manufacture of A-6A Intruder Aircraft</p> <p>Manufacturing Data:</p> <p>Thirty-six systems have been produced to date. This aircraft is being produced at a rate of two units per month. (Maximum LEM rate will also be two units per month).</p>	<p>Grumman Application:</p> <p>The "Production Plan" is used for programs which warrant highly refined tooling, equipment, process, and handling concepts, commensurate with high production rates.</p> <p>Previous Example:</p> <p>The completed Grumman F9F-6 &amp; 7 series Navy jet aircraft programs.</p>  <p>Production Line for F9F Series Aircraft</p> <p>Manufacturing Data:</p> <p>A total of 816 F9F-6 &amp; 7 aircraft were produced at a maximum rate of 67 units per month.</p>

Figure 1-1. Previous Grumman Application of Three Manufacturing Plan Types

- Overlapping of engineering design, tooling, manufacturing, and equipment program efforts will be necessary, because of the critical LTA and LEM schedules. Advanced engineering design information, such as layouts and jig point locations, will be used to initiate tool designs, as well as to expedite the fabrication of fixture frames and incorporation of major jig point fittings. Therefore, on-schedule availability of major fixtures is made possible by the judicious use of advanced information. The Development Manufacturing Plan is particularly applicable to this method of program acceleration.
- Figure 1-2 shows a peak structural manufacturing rate of two units per month for the 23rd and 30th month, and peak installation rates of two units per month for the 24th and 27th month after go-ahead. Fabrication of LTA-2 through LTA-6 and LEM-1 will be completed during the manufacturing peak period between mid October 1964 and mid February 1965. Completion of these six units during the 4-month period will yield an average structural manufacturing rate equivalent to 1.5 units per month for the peak period. Seven installations (LTA-1 through LTA-6 and LEM-1) will be completed during the 4.5-month installation peak period between December 1, 1964 and mid April 1965 for an average of 1.6 units per month. The Grumman tooling program was planned for the average rates stated above utilizing a double-shift production shop operation for the structural assembly phases.

Previous Grumman aircraft programs of comparable manufacturing rates have proven that high reliability at the lowest cost is most readily achieved by applying the Development Manufacturing Plan.

Since reliability, cost, and schedule objectives are also directly related to manufacturing producibility, the LEM engineering design concepts are being developed with maximum emphasis on use of existing state-of-the-art fabrication and testing techniques. The contribution of the LEM manufacturing team for producibility assurance is discussed in Section 3.3.3.

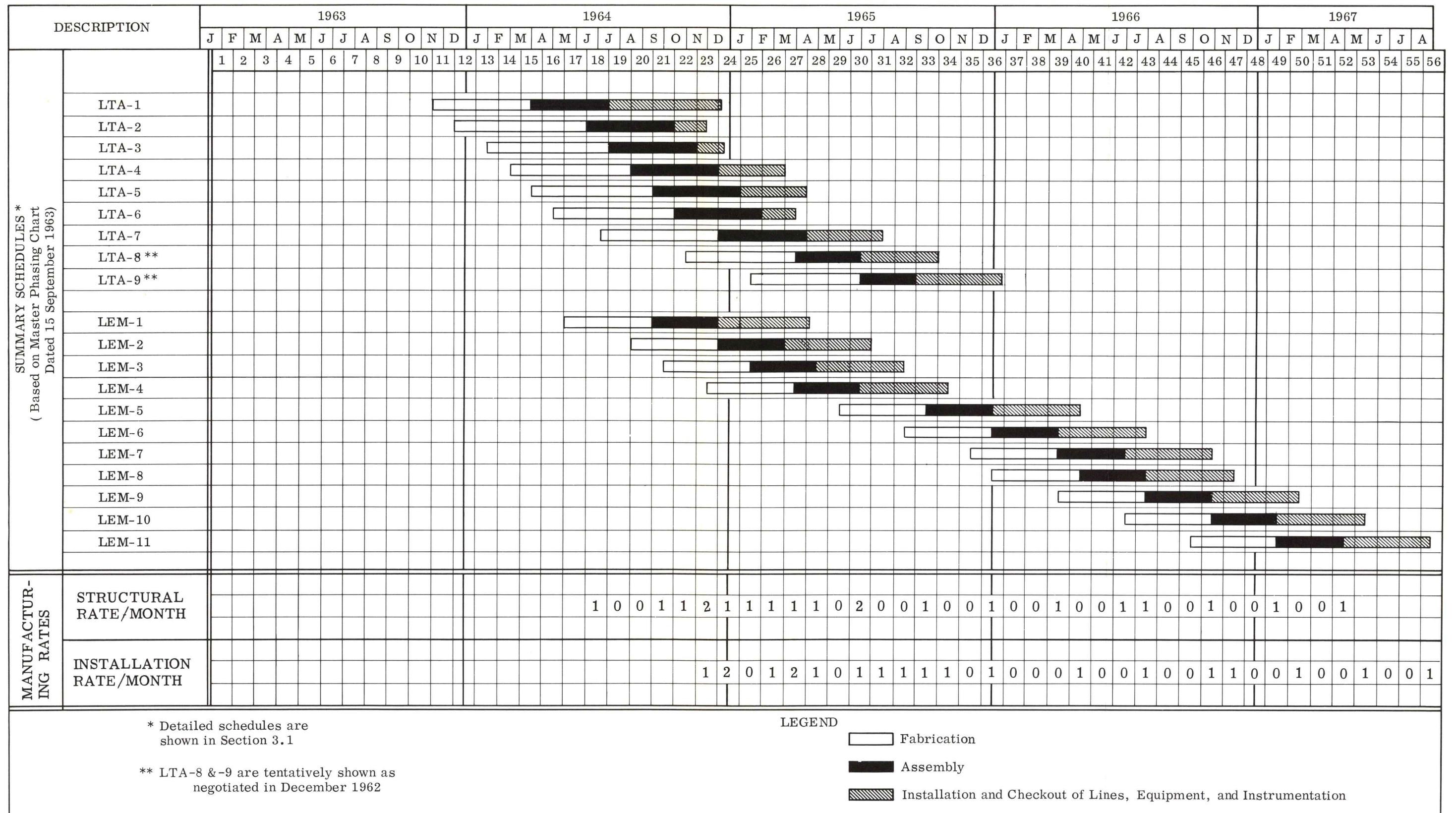


Figure 1-2. LTA and LEM Manufacturing Rates

Highly skilled development shop technicians and minimum tooling of good quality will be utilized for the manufacture of the early LTA test modules. Some detail parts and minor subassemblies for these initial units will be fabricated on an experimental basis with adequate quality control. Subassembly and assembly fixtures for all manufacturing, up to and including the LTA-3 module, will incorporate the major jig point locations. As engineering designs progress, these tools will be improved and refined by the addition of other locating and clamping devices and by provisions for completing interchangeability/replaceability requirements. The subassembly breakdown will be expanded and additional tool families provided to accommodate the manufacturing rate and the concurrent development requirements shown in Figure 1-2 and also for achieving the lowest possible combined tooling and manufacturing costs.

The basic tooling program will be completed during the manufacture of the LTA-4 Environmental Development Module. This tooling progression will result in early tool deliveries to meet initial LTA completion schedules, and will allow for the development of LTA-5 and subsequent modules using finally configured tooling.

The continued tooling program will provide for incorporation of normal engineering changes resulting from LTA and LEM test programs; initial tool prove-out changes; tool maintenance and repair; trouble shooting production problems, and subcontractor liaison. Tooling personnel will also be provided for assistance during periodic inspection of tools, liaison and tooling efforts for maintaining the I&R program requirements, and for maintaining precision optical alignment tool systems.

The sophisticated nature of the LEM Program dictates the use of manufacturing team technicians identified with each LTA and LEM. Each member of this team will be identified with a given subsystem from its acceptance through installation, testing, and field-site support. Upon completion of the mission, this experienced team will revert to a subsequent module within the same booster series. This assures clear lines of task continuity and the benefit of a high experience factor.

The manufacturing test plans also emphasize the aforementioned "subsystem team approach" for assurance of the highest quality and reliability levels. Manufacturing test teams will make maximum use of GSE/STE for bench tests of mechanical, fluid, and electrical/electronic subsystems. Periodic maintenance and calibration of manufacturing test GSE/STE will be dictated by an "IBM alerting system". This periodic servicing will assure the highest level of equipment performance.

A team of subsystem test technicians, under the direction of the Structural/Mechanical Lead Technician, will also install test instrumentation and will participate in the set-up, performance, and documentation of the ground and flight test programs.

LEM GSE/STE requirements are divided into the four general classifications of handling and transportation GSE, electronic GSE/STE, fluid systems GSE/STE, and training equipment. The manufacturing approach has been established to enable efficient fabrication of the four distinctly different equipment types.

Grumman will use existing Avionic, Hydraulic, Tool and Test Equipment Shops which are presently organized with the necessary specialized skills, equipment, and facilities. This plan affords the advantages of optimum flexibility and maximum utilization of existing capabilities. Although many equipment types are required, production line or completely centralized facility concepts are not warranted since the manufacturing rate for each unit is minimal.

Sections 4 through 7 describe specific manufacturing, tooling, process, equipment, and manufacturing test plans for each LEM subsystem.

## 1.2 IMPLEMENTATION OF THE LEM MANUFACTURING PLAN

As stated in the original proposal, Grumman has fully recognized that accomplishing the LEM objectives requires a "single product organization" which is solely concerned with the successful development of the LEM.

Accordingly, the "LEM Manufacturing Team", as shown in Figure 1-3, has been specifically organized to implement and manage all phases of the LEM manufacturing program. Maximum emphasis has been placed on the utilization of the best available managerial and technical talent, coupled with a manufacturing organization which is best suited for the LEM Program objectives. Key personnel assigned to the LEM Program are shown in Figure 1-4.

Mr. William Bruning, the LEM Manufacturing Manager, reports directly to the Program Manager. He is responsible for the coordination and management of all LEM fabrication, assembly, and installation operations; equipment fabrication; manufacturing testing; tooling; processes, and on-site and field support activities. In addition, he is responsible for the control of all applicable interfaces with NASA-MSC, NAA, and Grumman subcontractors.

As a member of the Program Management Team, the LEM Manufacturing Manager implements his responsibilities in the following manner:

- In conjunction with the other managers, Mr. Bruning reports weekly to the Program Manager and provides information such as completed activities for the preceding week and anticipated effort for the succeeding week.
- He consults with the Program Manager on a regular basis with regard to cost/schedule performance of all tooling, test equipment, process, and manufacturing functions for the LEM Program. Further, he informs the Program Manager of manpower and facility planning status and unique technical aspects of the manufacturing program which may require support from the Program Office.
- He attends and participates in the monthly reviews of all contract line items as called by the Program Director and Program Manager. Mr. Bruning is also responsible for maintaining cognizance of all technical, cost, and schedule performance for Line Item 012, Final Assembly and Acceptance Tests.

LEM MANUFACTURING ORGANIZATION CHART  
Showing Relationship to Manufacturing and Equipment and Process Engineering Departments

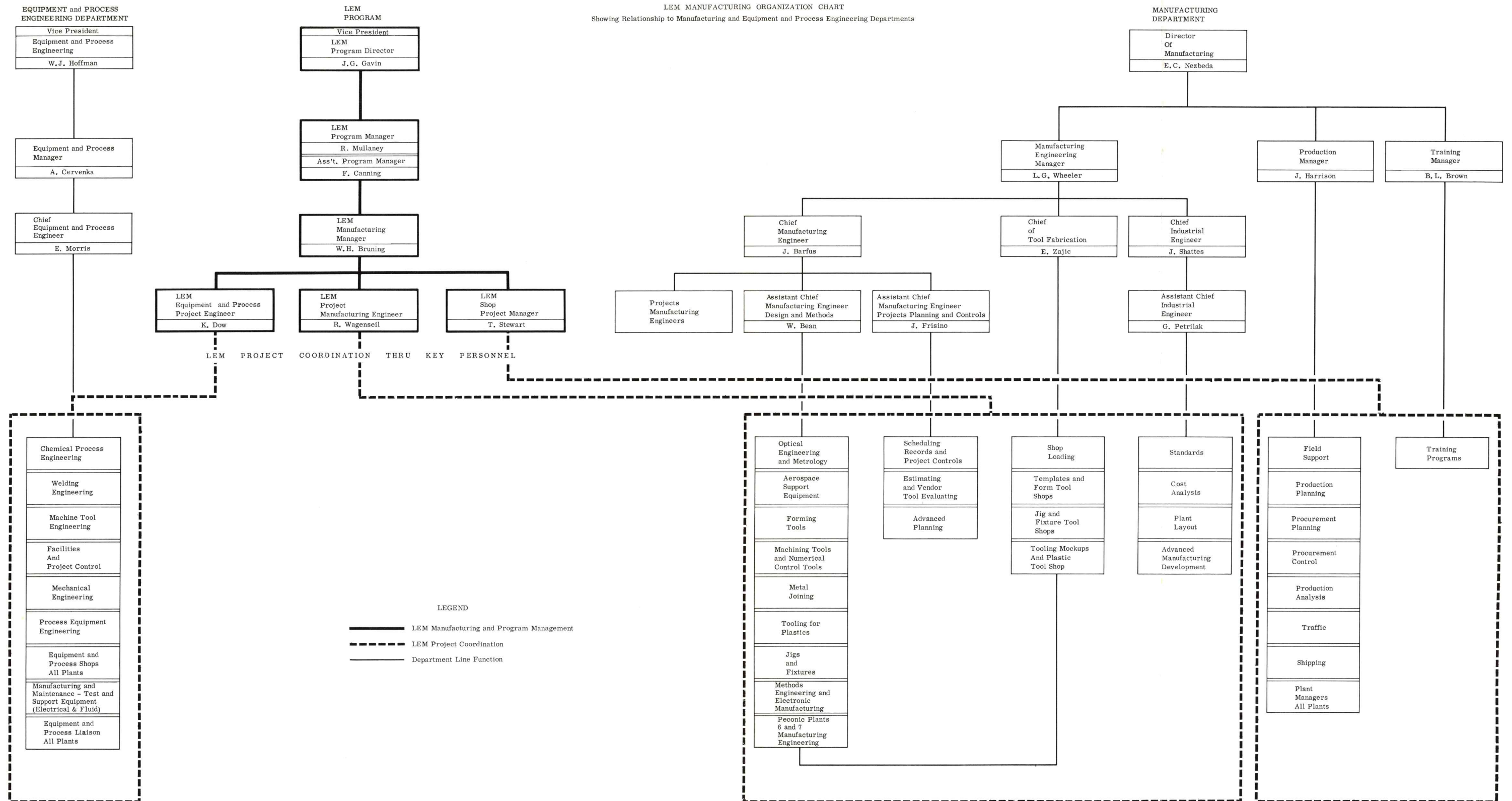


Figure 1-3. Organization Chart

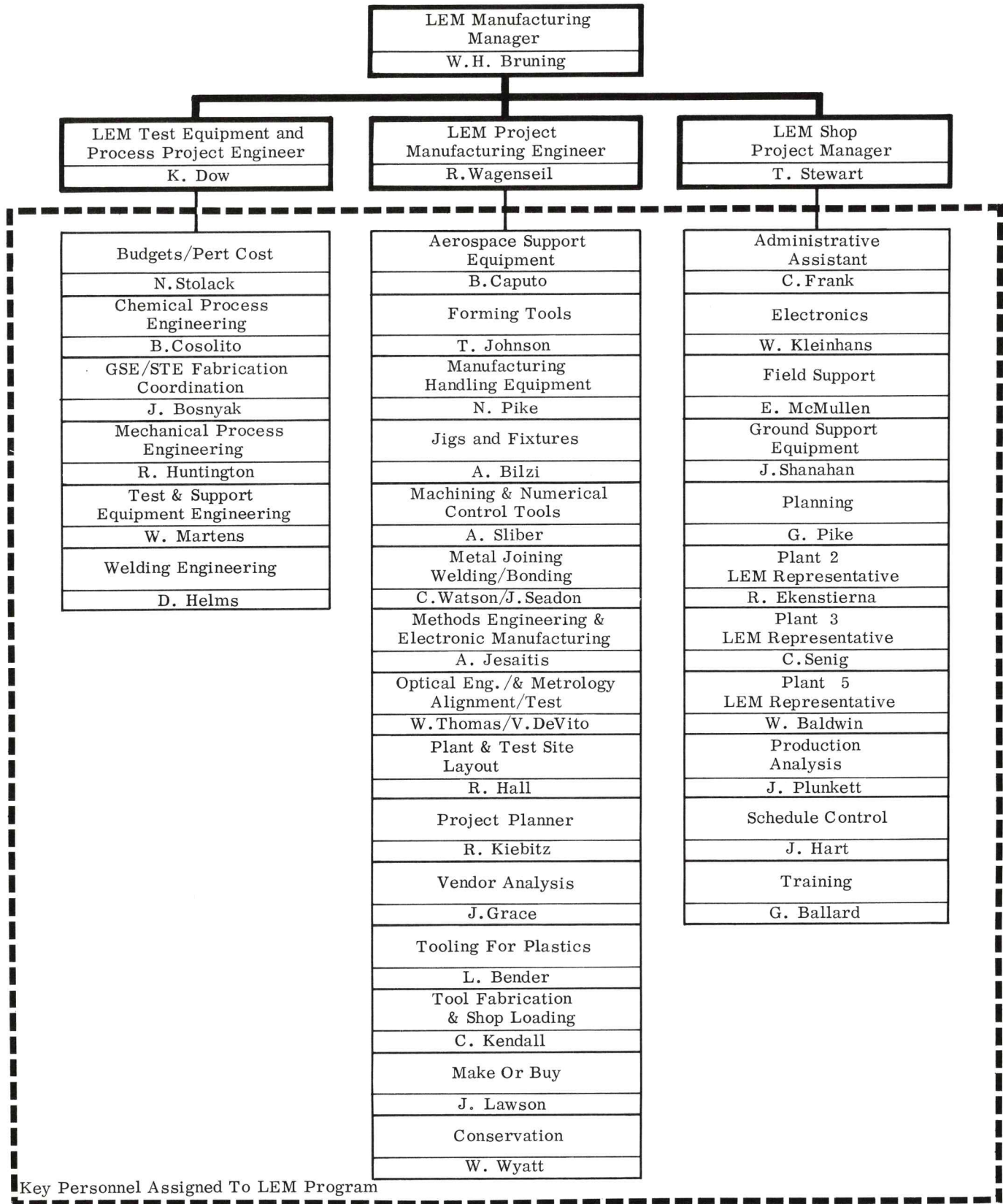


Figure 1-4. LEM Manufacturing Organization Chart

- The release of engineering information for maintaining tooling and fabrication schedules, and concepts for design producibility are frequently reviewed with the Engineering Manager.
- Quality control and reliability requirements, as outlined by NPC-200-2 and augmented by the RASPO Quality Control Representative, are reviewed with the Quality Control Manager to assure unified approaches for maintaining the required degree of manufacturing quality. To further a common understanding, the Manufacturing Manager attends and participates in the biweekly review meetings scheduled by the RASPO Quality Control Representative and the Grumman Quality Control Manager.
- Requirements and plans for field-site test technician support and the training program for test technicians, both for field-site and in-house test, are discussed with the Test and Support Manager.
- Reviews are conducted with the Business Manager for timely delivery of sub-contracted components. Personnel are supplied for evaluation of subcontractor proposals and for assistance with the monitoring of subcontractor cost, schedule, and technical performance. The Manufacturing Manager reviews and supplies data such as estimates, manpower distributions, and justifications for Manufacturing personnel requirements, change proposals, and overtime requests.
- Manufacturing milestones and corresponding time estimates are approved and supplied by the LEM Manufacturing Manager.
- He attends and participates in the Management Reviews scheduled by MSC.

Mr. Bruning is assisted by a LEM Manufacturing Management Staff which directly supervises and controls the performance of all functional manufacturing tasks. The following three team members are directly assigned to the LEM Program Management Staff:

- Robert Wagensiel, the LEM Project Manufacturing Engineer, is responsible for developing, providing, and maintaining all tooling necessary for the manufacture of the LEM, and is responsible for coordinating with LEM engineering to assure that the end items are producible. The responsibility of establishing and maintaining proper tool planning schedules; adequate facility arrangements for manufacturing; fabricating and maintaining handling equipment and providing optical measurement support for tests and alignment of hardware, also belongs to the LEM Project Manufacturing Engineer.
- Kenneth Dow, the LEM Test Equipment and Process Project Engineer, is responsible for the manufacturing, modification, and sustaining efforts required for fluid and electrical/electronic subsystem test equipment which is designed by the test equipment and process engineers. He is also responsible for developing the process systems necessary for the manufacture of the LEM; establishing test equipment fabrication schedules, monitoring the fabrication and maintenance of test equipment, and for translating engineering design information into process requirements for producing hardware.
- Thomas Stewart, the Shop Project Manager, is responsible for converting LEM engineering information into parts, subassemblies, final assembly, and follow-up through acceptance testing and field operations of the LEM. He establishes internal and external lead times in accordance with schedules and budgets, establishes and maintains proper production planning schedules, and coordinates with LEM engineering to assure compatibility of manufacturing plans with engineering progress. He also has the responsibility of providing technicians for field support activities, controlling spares (both in-house and in the field), shipping of hardware and completed LEM assemblies, and the supervision of procurement planning and controls. LEM representatives for each participating Grumman plant have been assigned to assist the Shop Project Manager in the control of LEM manufacturing activities. In addition, each major shop section or group has an assigned representative for direct manufacturing supervision.

The LEM Manufacturing Manager and his staff maintain their offices in the Plant 25 Engineering Center, and are located adjacent to the Program Management, Engineering, Quality Control, Test, and Business Management Sections. Immediate proximity to the over-all LEM Program allows for close observation and review of all program phases by virtue of the shortest possible lines of communication. This arrangement is presently resulting in a thorough knowledge of the latest LEM Program status; close coordination for initial manufacturing and equipment planning and schedule development; rapid investigations for make or buy decisions, and early contacts regarding producibility.

Figures 1-3 and 1-4 show "key personnel" who are responsible for coordinating the design and fabrication activities of the Manufacturing Engineering, Test Equipment and Process Engineering, and corporate manufacturing organizations. They are responsible for the direct supervision of participating sections and groups within the corporate organization.

Some key section personnel assigned for LEM planning and control, tool and equipment design, and process planning are presently located in the Plant 25 LEM offices. Other key section personnel will be assigned to this facility as the manufacturing effort increases.

Management control of LEM priority, with respect to other Grumman programs, is implemented in the following manner:

- The LEM Manufacturing Manager periodically reports the status of the program to the Director of Manufacturing. He requests priority action on items which require the specific attention of the Director. As indicated in Figure 3-1 and described in Section 3.1.1, the Director of Manufacturing approves and signs the manufacturing schedules. This establishes the over-all priority with respect to other programs.
- The Shop Project Manager reports the status of the program to the LEM Manufacturing Manager weekly. He requests action on priority items as required from the corporate Production Manager and meets with him monthly for a complete LEM Program review.

- The LEM Plant Representatives report to the LEM Shop Project Manager at a weekly meeting in Plant 25. All manufacturing program aspects, including priority are reviewed at this meeting.
- The LEM Plant Representatives are responsible for maintaining priority control for the tasks being performed within his plant.

The reputation for producing military and commercial aircraft of consistently high quality is evidence of the manufacturing skills available at Grumman. The effectiveness of re-training flexible and versatile personnel for space manufacturing is illustrated by the workmanship, cleanliness, and accuracy standards being maintained for the current NASA-OAO Spacecraft Program. However, these space skills must be expanded to meet the requirements of the LEM Program, and a training program has been established for this purpose.

All LEM training is directed by Mr. T. Moorman, LEM Support Manager, thus LEM manufacturing training requirements are directed to his office. Present plans are for all LEM system and subsystem instruction to be provided by the Grumman Service School, under the supervision of Mr. D. Wolf. The Service School is a group within the Service and Product Support Department.

All non-system LEM manufacturing training requirements are provided by Manufacturing Training under the direction of Mr. B. L. Brown, Manufacturing Training Manager, and his appointed LEM Coordinator, Mr. G. Ballard. This department is responsible for the development of additional skills and refinements of others. Some of the skill courses currently being presented are:

- Soldering School
- Maintenance and Servicing of High Vacuum Equipment
- Vibration Theory
- Vibration Parameters and Relationships

- Optics Technician Training
- Basic Electronics
- Rocket Engine Technician Training Program, which includes operation and maintenance of engine system components; cleaning and purging of components and engine systems; propellant handling and safety precautions; use of ground service equipment; altitude simulation, and instrumentation.

Specific training will be included at Grumman and at subcontractor sites for subsystems such as Ascent and Descent Propulsion, Reaction Control, Electrical Power, Environmental Control, Communication and other electronic subsystem components.

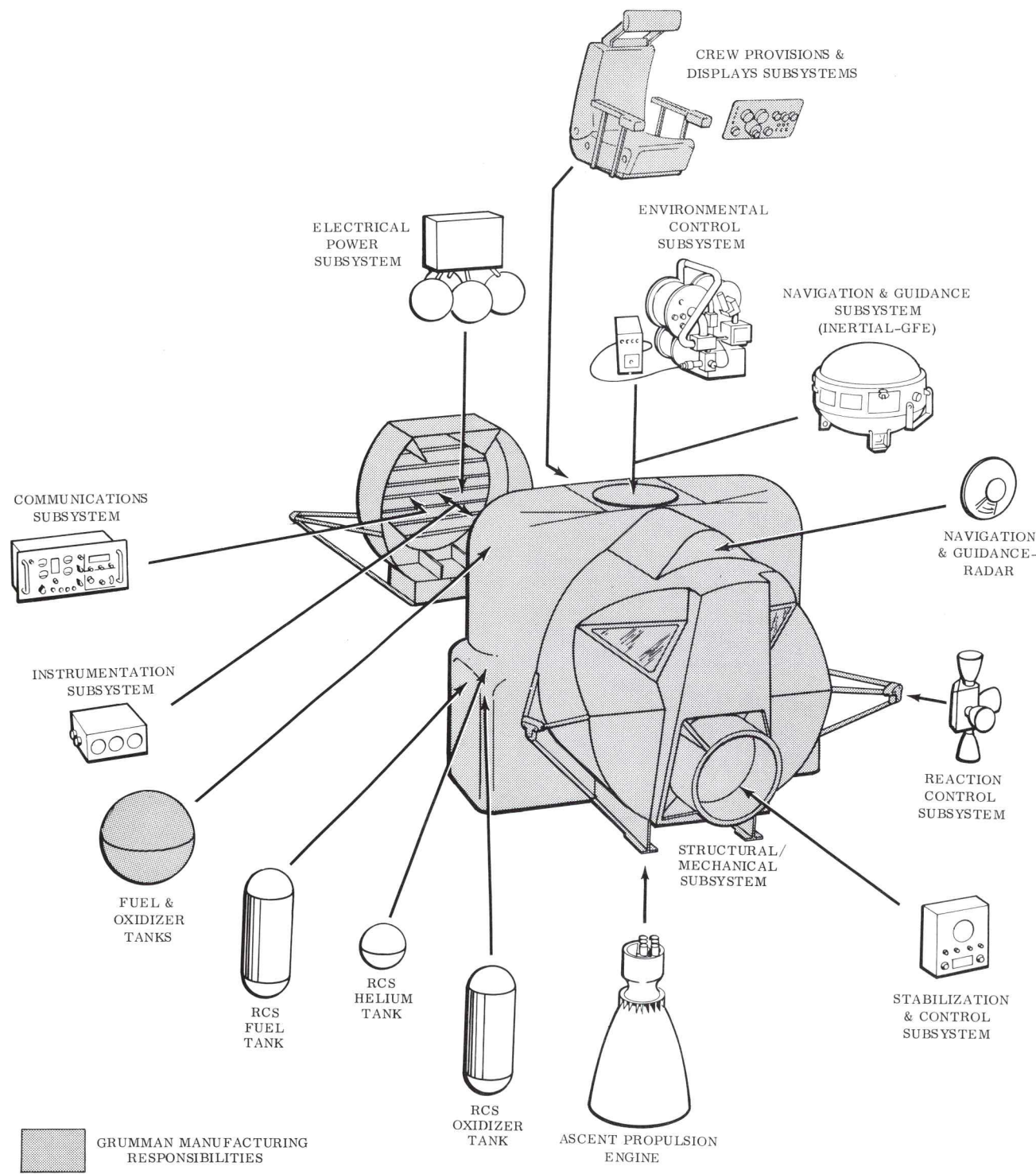
Grumman procedures for implementing and managing the LEM manufacturing program are as follows:

- The Manufacturing Manager and his three staff members form a team which is an integral part of the "single product organization".
- Key section personnel are assigned to supervise and coordinate the design and fabrication activities.
- Skilled engineers and technicians within sections and groups of the corporate organization are responsible for performance of program tasks.

### 1.3 MAKE OR BUY SUMMARY

At Grumman, LEM "make or buy" decisions and source selections are determined by the LEM and corporate management committees.

The present status of the "make or buy" plans for LEM subsystems are shown in Figures 1-5 and 1-6. This summary is solely intended as a reference for familiarization with the Grumman subsystem manufacturing tasks which are described in Section 4.

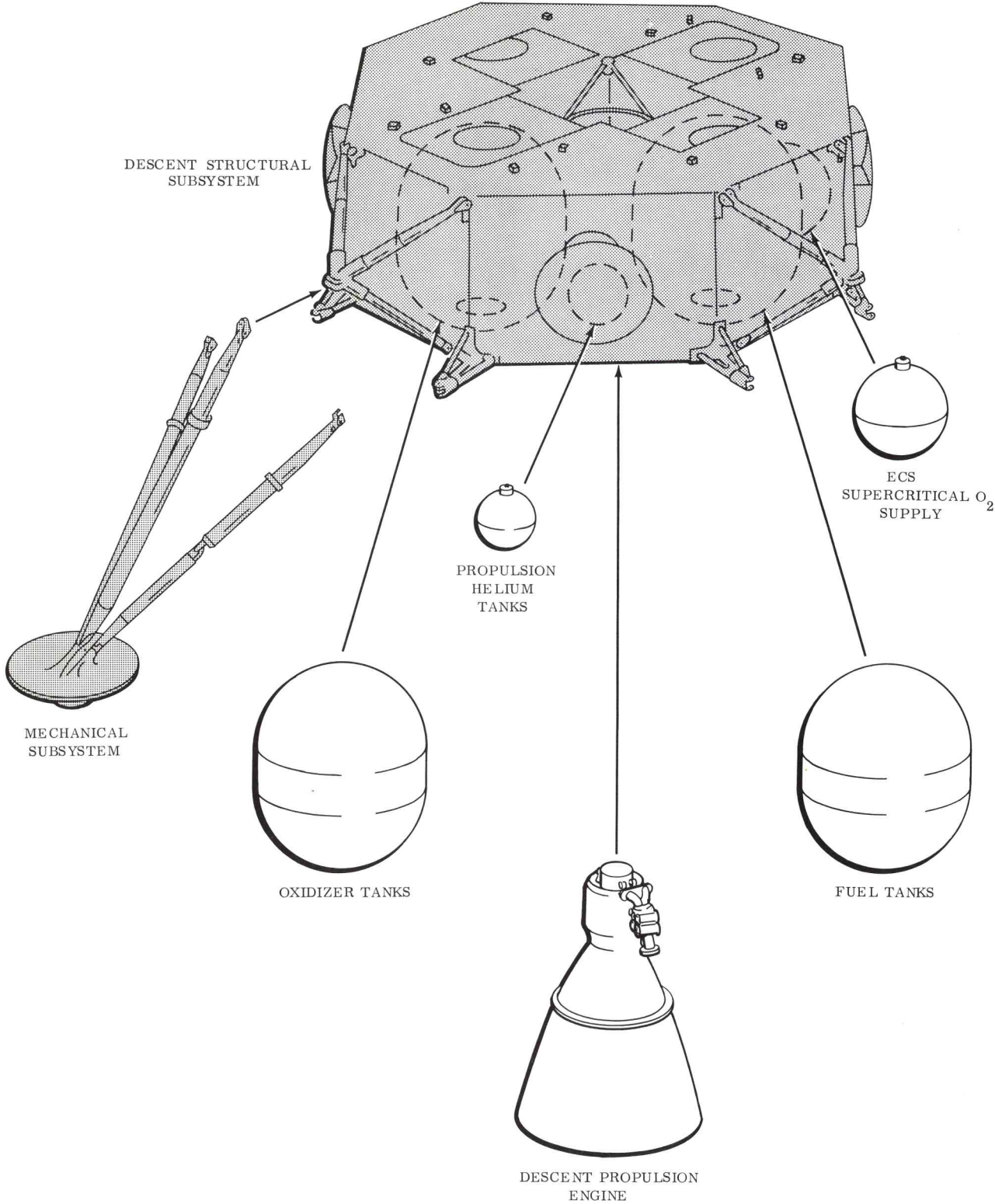


Subsystem	Primary Source		Grumman Manufacturing Tasks
	Grumman	Subcontractor	
Structural/Mechanical Subsystems	X		All Fabrication & Assembly
Propulsion Subsystem		Bell Aero-systems	Fabrication & Assembly of Fuel Tanks, O <sub>2</sub> Tanks & Lines. System Integration & Test.
Reaction Control Subsystem Propulsion & Thrust Chambers Propellant Tanks		Marquardt Bell Aero-systems. Hamilton-Standard.	Fabrication of Lines. System Integration & Test.
Environmental Control Subsystem			Fabrication of Lines. System Integration & Test.
Crew Provisions & Displays Subsystems	X		Fabrication & Assembly of Seats & Restraints; Lighting; Panels & Consoles. Installation of Displays
Navigation & Guidance Subsystem Inertial Measurement Unit Rendezvous & Landing Radar		GFE RCA	Subsystem Integration, Installation, Alignment & Systems Test.
Stabilization & Control Subsystem Attitude & Translation Control Descent Engine Control Guidance Coupler In-Flight Monitor Gimbal Drive Actuator; Rate Gyro; Attitude Reference; Computer		RCA  X*	Fabrication, Integration & Test Network Control Panels For Attitude Reference/Control Coupling Electronics.
Electrical Power Subsystem Fuel Cell		Pratt & Whitney X*	Fabrication of Cryogenic Reactant Lines. Integration & Test
Auxiliary Batteries; Cryogenic Storage & Supply; Battery Charger Communications Subsystem		RCA	VHF-LEM/CM Antenna, Wiring, Installation & Test.
Instrumentation Subsystem Pulse Code Mod.-Timing Equip. Data Storage Equipment In-Flight Test System		Radiation Leach RCA	Installation & Test
Final Assembly	X		All Assembly, Installation, Alignment & Test.

\* Subcontractor(s) To Be Announced At A Later Date.

Figure 1-5. Make or Buy Summary-Ascent Stage.





Subsystem	Primary Source		Grumman Manufacturing Tasks
	Grumman	Subcontractor	
Structural Subsystem	X		All Fabrication, Assembly & Test
Mechanical Subsystem	X		All Fabrication, Assembly & Test
Propulsion Subsystem Descent Engine		Rocketdyne & STL (Parallel Engine Development Program)	Fabrication of Lines. System Integration & Test.
Titanium Propulsion Tanks		X*	
Environmental Control Subsystem (Supercritical O <sub>2</sub> Supply)		Hamilton-Standard	Fabrication of ECS Lines. System Integration & Test.
Final Assembly	X		Assembly, Installations, & Test.
			* Subcontractor To Be Announced At A Later Date

Figure 1-6. Make or Buy Summary-Descent Stage



Complete "make or buy" plans are described in the individual Subsystem Procurement Plans. The preliminary Ground Support Equipment Planning and Requirements List No. LLI-400-1 Revision A shows the GSE items which are tentatively planned for Grumman use.

Consistent with the Grumman concept of good business management in the areas of manufacturing planning and long-range programing, further LEM "make or buy" decisions will be made in accordance with the following basic corporate policy:

- Aerospace structural assemblies are "make" items. Some of these items may be purchased from vendor sources when such action is deemed necessary to normalize the manufacturing workload.
- Grumman does not generally compete in electronic design and manufacture, although integration considerations have occasionally made it necessary for Grumman to fabricate components to its own specifications.
- Mechanical assemblies such as valves and cylinders are "buy" items. On occasion, limited quantities may be produced on-site, but follow-on quantities are purchased.
- Machined parts are generally "buy" items. All requirements in excess of the quantities which can be produced on company-held equipment are purchased from outside sources, most of whom are "small business" concerns.

Fully recognizing the responsibility for subcontractor performance, Grumman will monitor and control subcontractor tooling and manufacturing activities using the procedures described in Section 3.3.4.

SECTION 2 - Manufacturing Facilities

SECTION 2  
MANUFACTURING FACILITIES

2.1 FACILITY UTILIZATION AND MANUFACTURING FLOW

Present facility planning for the LEM Program indicates that virtually all Grumman manufacturing tasks, outlined in Section 1.3, will be performed within the Bethpage, New York, facilities. The plants selected for LEM manufacturing are located within a 1-mile radius; thus allowing for an efficient flow of parts, components, and subassemblies to the centralized assembly, installation and test facility.

Table 2-1 summarizes the total manufacturing areas allocated for exclusive LEM utilization, and also shows the equivalent LEM areas programmed within commonly utilized departments. A facility availability schedule is shown in Table 2-2.

Grumman Plant Number	Exclusive LEM Area Allocations (Square Feet)	LEM Area Assigned Within Commonly Utilized Departments (Square Feet)
5	62,800	9100
3	12,100	19,200
2	8000	13,800
All Plants Total	82,900	42,100

Table 2-1  
LEM Area Allocation Summary

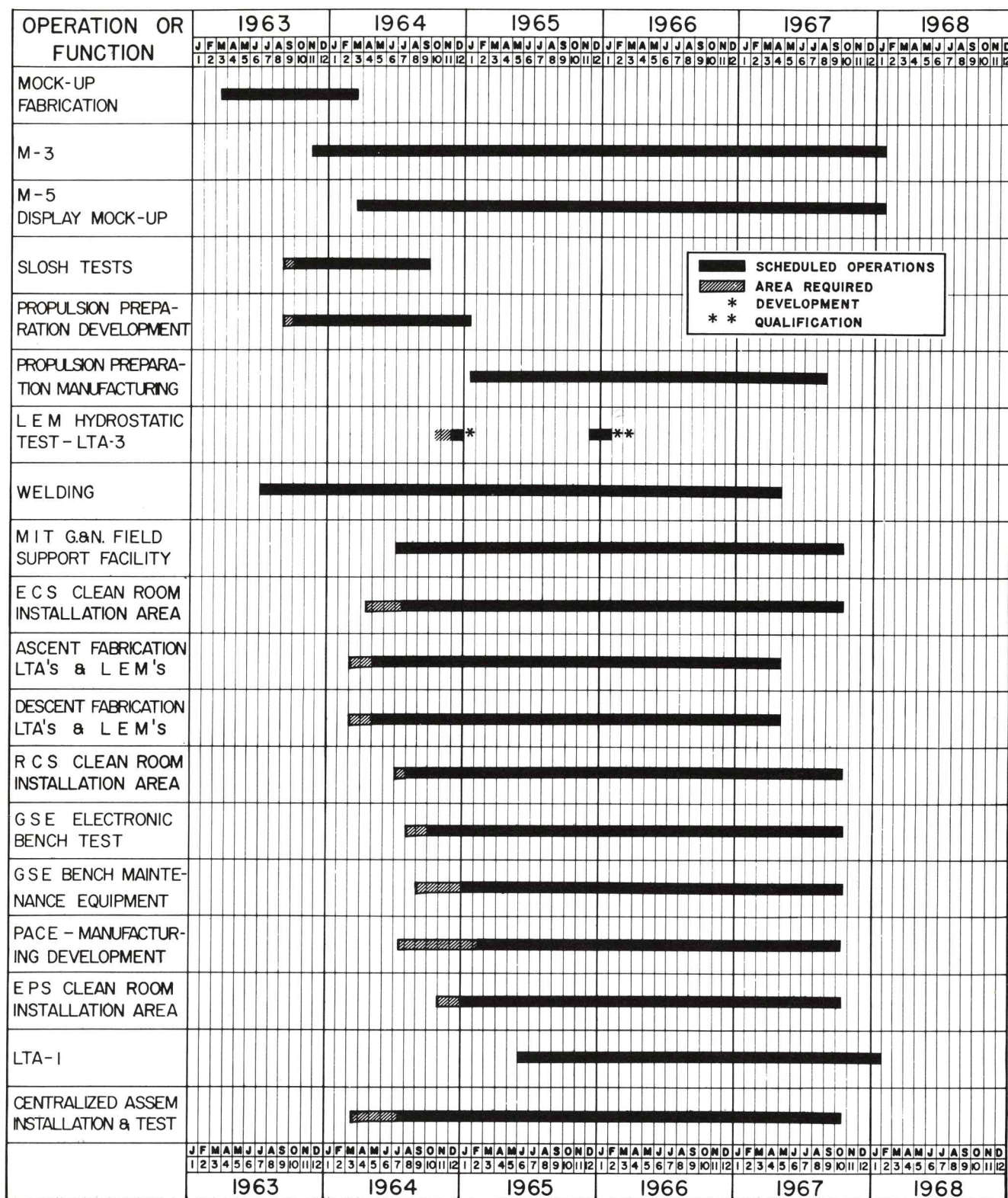

 E. ARALJO  
 29 OCTOBER 63

Table 2-2 LEM Facility Availability and Usage Schedule

Grumman will provide liaison space for LEM Program subcontractors at the Bethpage facility. It is planned that rework on vendor supplied components, other than bench maintenance operations, will be performed at the vendors' manufacturing facility.

As shown in Figure 2-1, Plant 5 has been delegated the responsibility for all operations beginning with assembly and continuing through shipment of the LEM. In addition, the Plant 5 final assembly area will be utilized for manufacturing modification and rework operations. This facility, which also houses the Grumman corporate offices and other NASA programs (e.g. the OAO Spacecraft and the Echo A-12 Satellite Canister Assemblies), was selected for the following reasons:

- The Grumman class II clean room which will be used for installation and test of the Environmental Control, Reaction Control, and Electrical Power Subsystems, is located within Plant 5.
- Adequate area, directly adjacent to the clean room, will be available for modification into a better-than-standard shop environment. This area is required for all other subsystem installations, interwiring, Ascent/Descent Stage mating, final installations, optical alignment of critically positioned subsystem components, and complete LEM test programs.
- Plant 5 houses the laboratories to be used for LEM static, vibration and environmental tests.
- The close proximity of Plant 5 to the Plant 25 Engineering Center, which contains the LEM Engineering and Management offices, will allow for the shortest possible lines-of-communication between engineering, manufacturing, and test personnel. This proximity will result in close coordination for producibility and will contribute to the effective control of all program phases.

Other Grumman plants shown in Figure 2-1 will manufacture the Structural/Mechanical Subsystem, other detail parts and subassemblies, and bench test vendor-supplied electronic

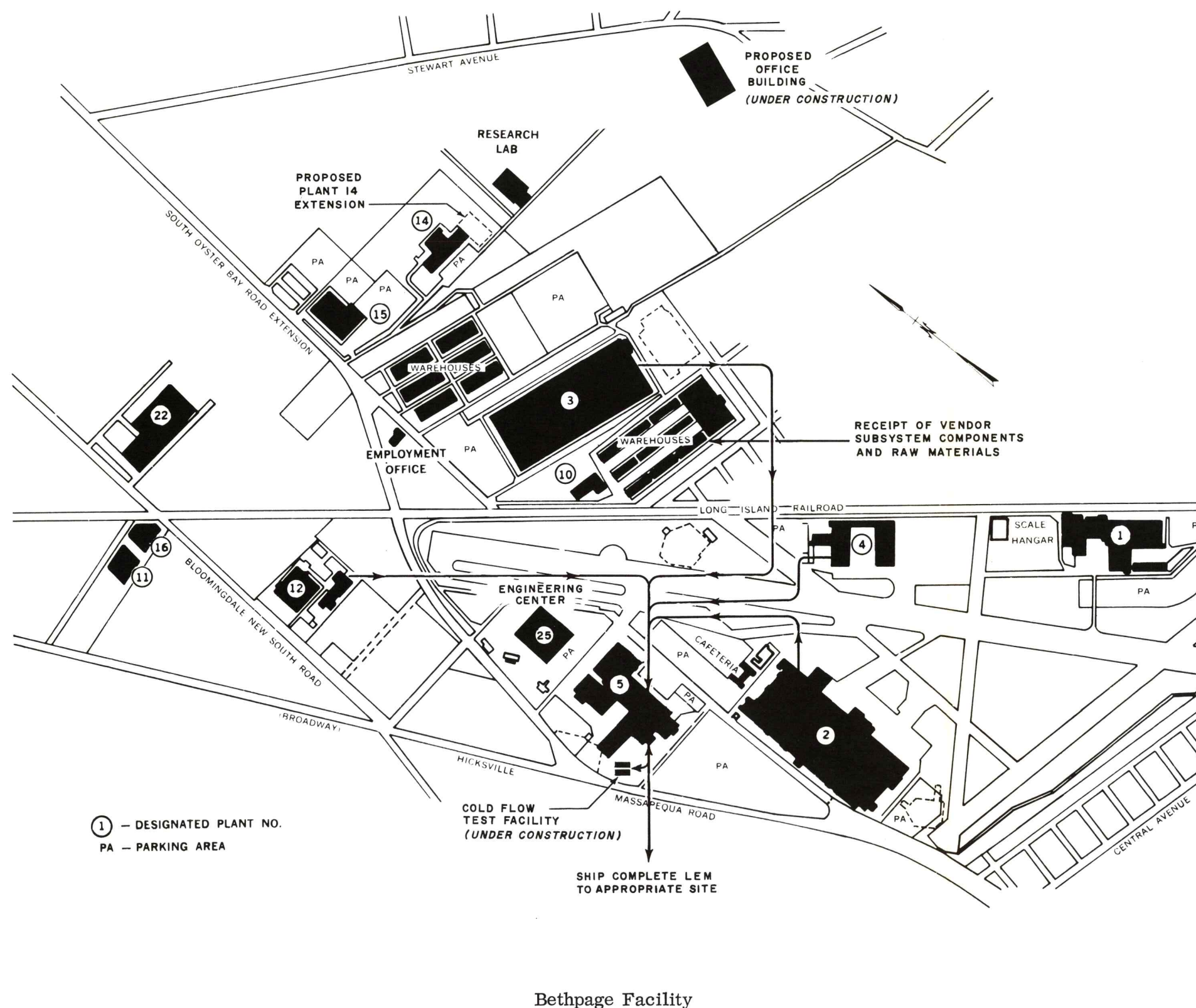


Figure 2-1. Basic LEM Manufacturing Flow Through Bethpage Facility



subsystem components. Sections 2.1.1 through 2.1.5 describe present plans for manufacturing facility utilization. Tool and GSE/STE fabrication facilities are described in Sections 2.1.6 and 2.1.7.

#### 2.1.1 Plant 5 - Centralized LEM Assembly, Installation, and Test

Figure 2-2 shows exclusive LEM utilization of 57,200 square feet of existing Plant 5 area and 5600 square feet for the Cold Flow Test Facility which is under construction. The existing area is subdivided into 5000 square feet of clean room area for the RCS, ECS, and EPS requirements, and 52,200 square feet for other assembly, installation, and test operations. Specific areas within the assembly and test areas are also shown in Figure 2-2.

Preliminary data from floor stability tests conducted by MIT indicates that the 4700 square foot area proposed for MIT test and bench maintenance of LEM Navigation and Guidance Subsystem is acceptable, and a firm decision is expected in December 1963. MIT has verbally stated that floor drift was negligible and that isolation blocks will not be required for their equipment.

Areas within the clean room are shown in Figure 2-3, and photographs of the Grumman clean room are shown in Figures 2-4 and 2-5.

In addition to the exclusive LEM areas, some Plant 5 shop departments which manufacture details and electrical and other subassemblies for all Grumman programs will also be utilized for LEM manufacturing. The machine shop will fabricate some of the machined parts for the Structural/Mechanical Subsystem.

An analysis has been made of the utilization of the final assembly, installation, and acceptance test area to verify its adequacy in the event of a lengthened installation and checkout cycle. In this analysis the cycle was increased from 4 to 10 months resulting in peak facility loadings at the end of 1964 and in the second quarter of 1965. It was concluded that there were sufficient stations available to accommodate the modules during each of these peaks.

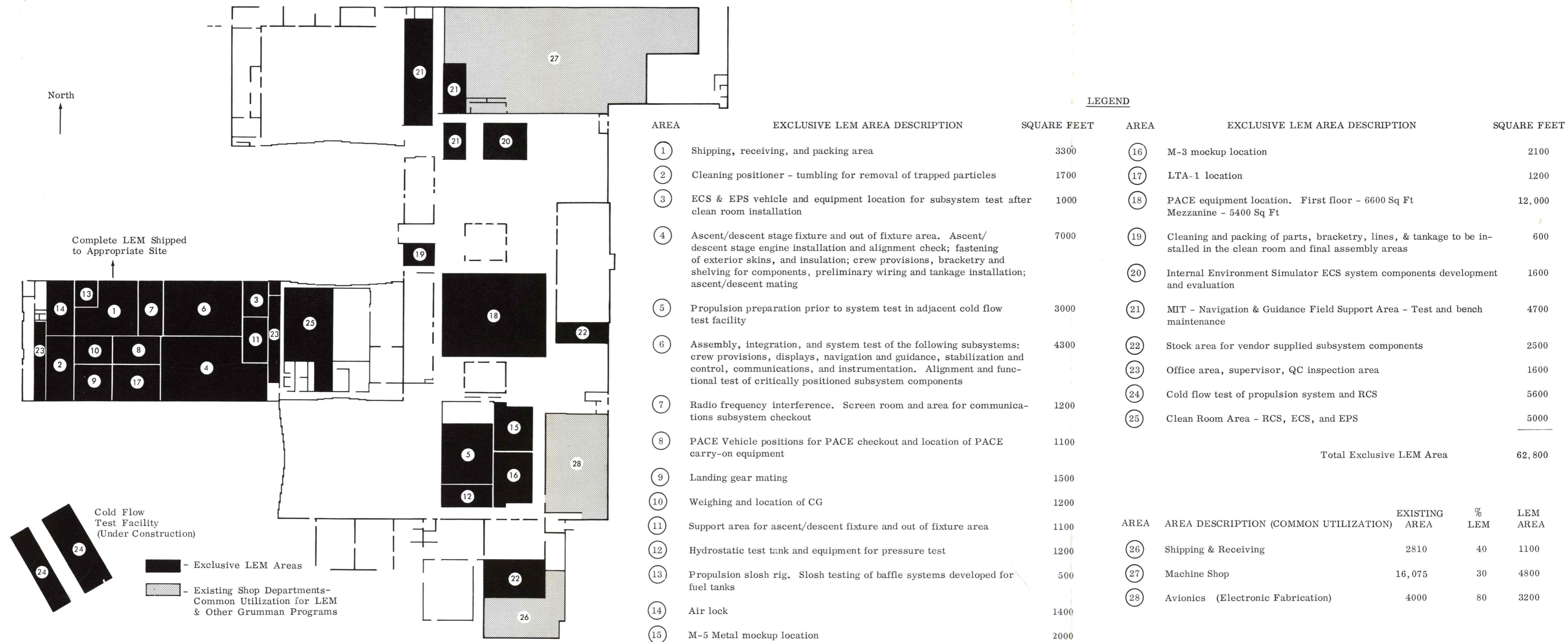
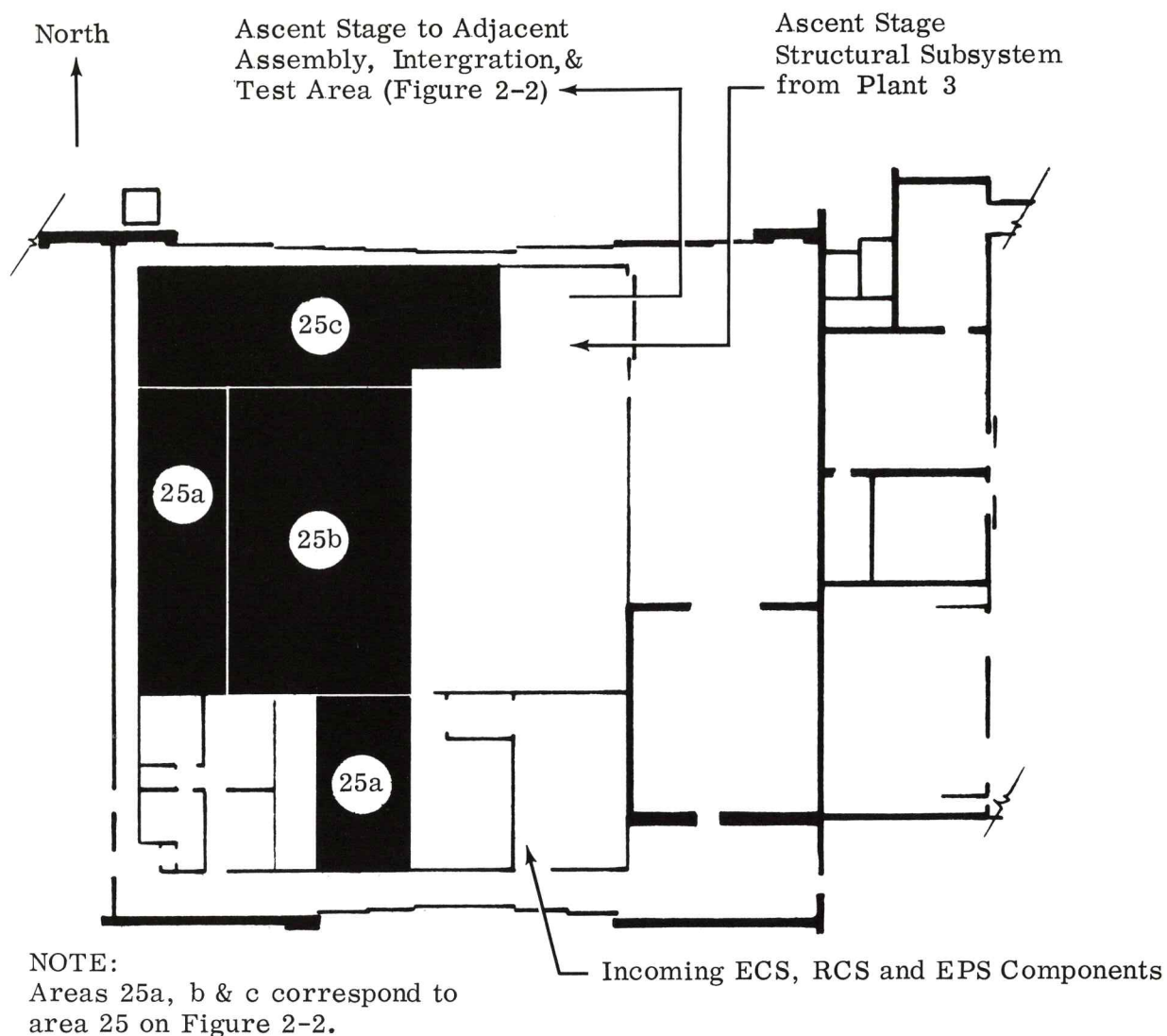


Figure 2-2. Plant 5 LEM Assembly, Installation, & Test



Existing Area Scheduled  
for Exclusive LEM Utilization

LEGEND		
AREA	LEM AREA DESCRIPTION	SQUARE FEET
(25a)	ECS Bench Test Area	1000
(25b)	ECS Assembly & Installation	2500
(25c)	RCS & EPS Bench Test, Assembly, & Installation	1500
		Total 5000

Figure 2-3. Plant 5 Clean Room for Bench Test, Assembly and Installation of RCS, ECS & EPS.

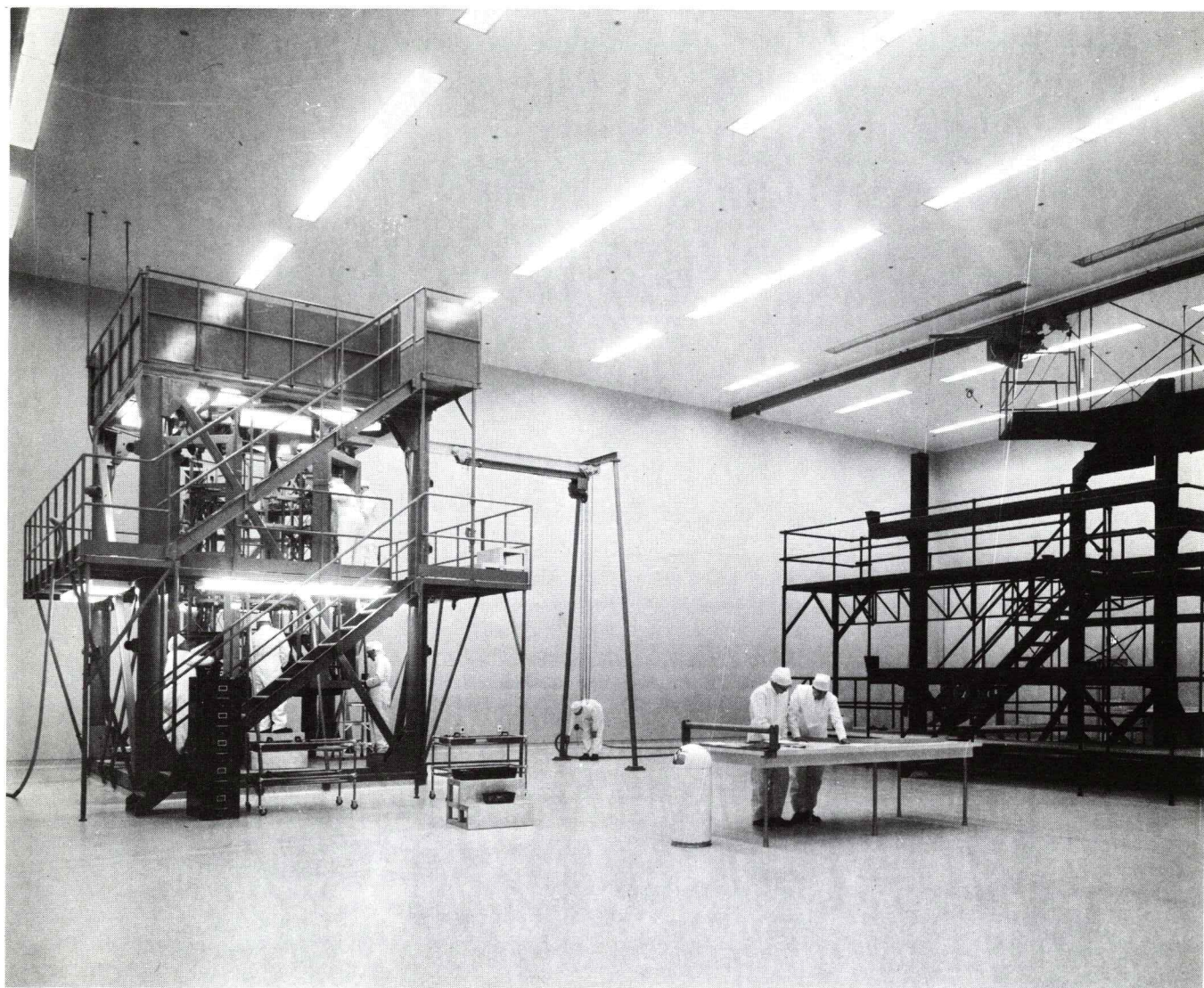
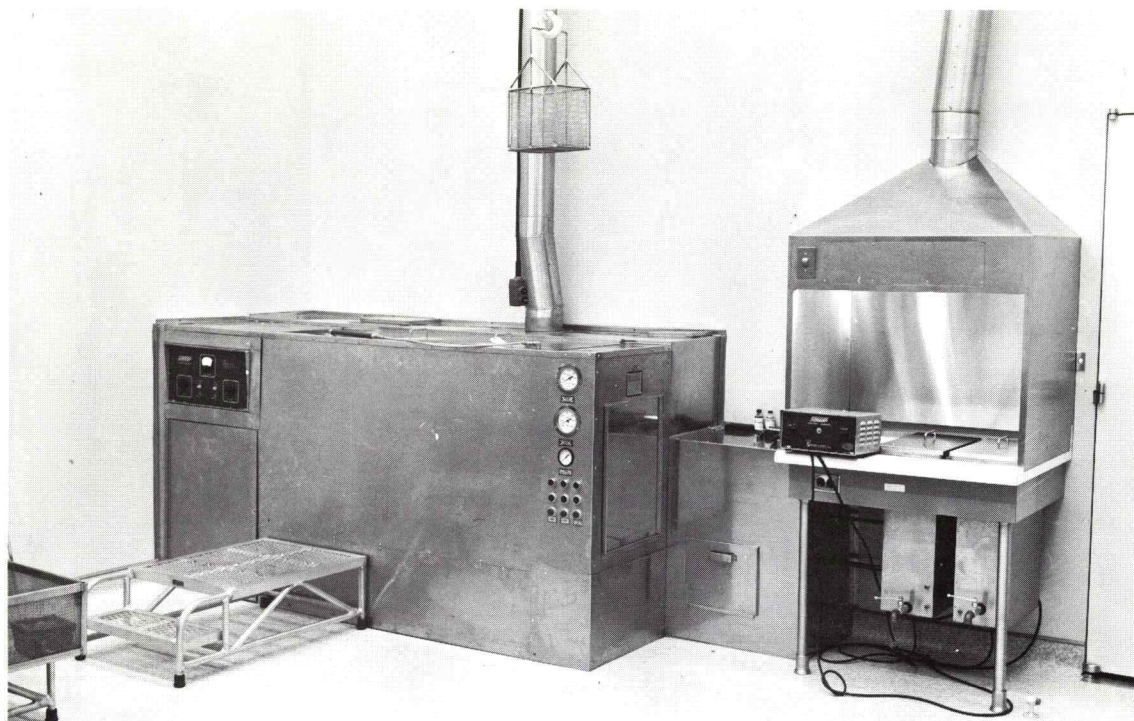
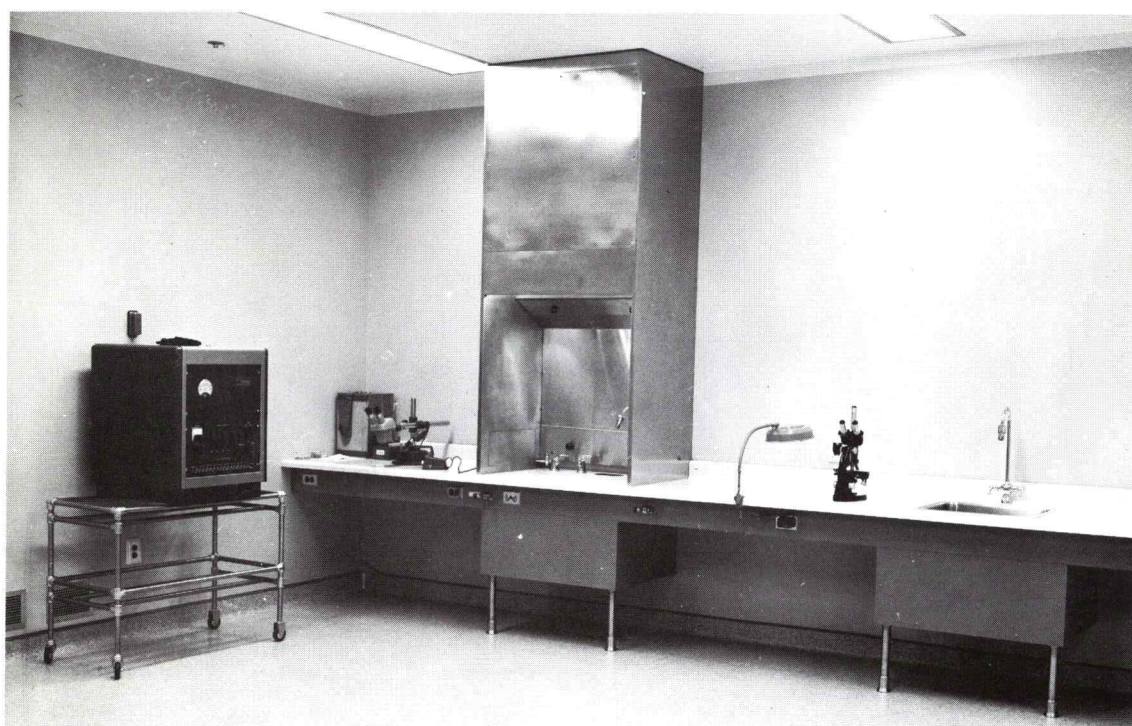


Figure 2-4. Clean Room- RCS, ECS and EPS Installation and Testing



Ultrasonic Cleaning Facility  
for Cleaning Detail Parts



Inspection Area  
for Monitoring Cleanliness of Area  
and Detail Parts Inspection

Figure 2-5. Clean Room - Inspection & Cleaning Facilities

The analysis was made primarily to assure adequate facilities. It is planned, however, to satisfy modifications and contingencies by use of an extended and/or second shift as described in Section 3.1.3.

#### 2.1.2 Plant 3 - Ascent Stage Structural/Mechanical Manufacturing

This facility has been selected for ascent stage structural fabrication since it is specially equipped with a complete range of equipment and facilities for: manual or automatic fusion welding, resistance welding, chemical milling, spin forming, honeycomb, and machining.

As shown in Figure 2-6, approximately 12,100 square feet of assembly area will be allocated for the manufacture of the Ascent Stage Structural/Mechanical Subsystem. All major ascent stage subassembly, assembly, and welding fixtures, described in Section 4, will be located in this area. Note the adjacent location of existing fusion and resistance welding departments. This arrangement was specifically established to assure a smooth manufacturing flow between all subassembly and major assembly operations of mechanical fastening, automatic fusion welding, and resistance welding.

Plant 3 will also produce the fuel and oxidizer tanks required to the Ascent Propulsion Subsystem. Special equipment for flow forming, circumferential fusion welding, tank-half machining, heat treating, and age hardening are available for the tank program.

All chemical milling operations for structural weight reduction will be performed in Plant 3.

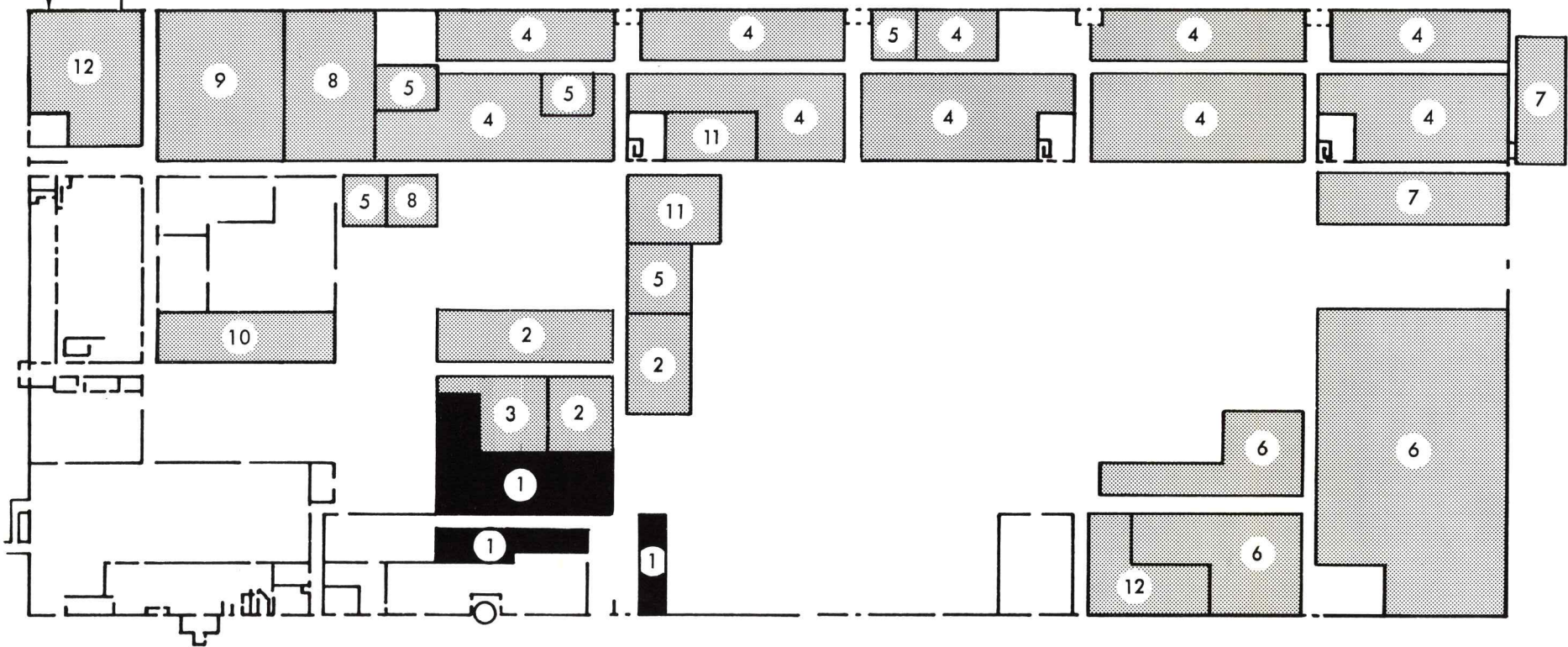
LEM details such as bonded honeycomb shelves will be fabricated in a specialized shop area which is fully equipped for parts preparation and autoclave or platen press bonding techniques.

Plant 3 major manufacturing equipment and facilities scheduled for utilization throughout the LEM Program are shown in Figures 2-7 through 2-12.

Incoming Raw Material, Subcontractor  
Supplied Components, Electrical  
Assemblies and Detail Parts from Warehouse  
and Other Grumman Plants

LEM Ascent Structural/Mechanical  
Subsystem to Plant 5

North



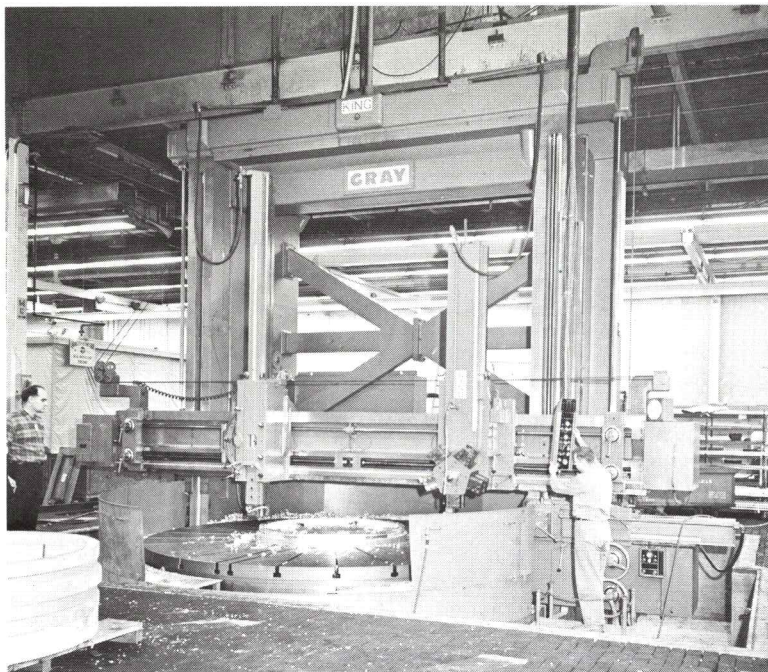
Exclusive LEM Area-12,000 Sq Ft  
for Ascent Structural/Mechanical  
Subsystem Manufacture

Existing Shop Departments - Common  
Utilization For LEM & Other Programs

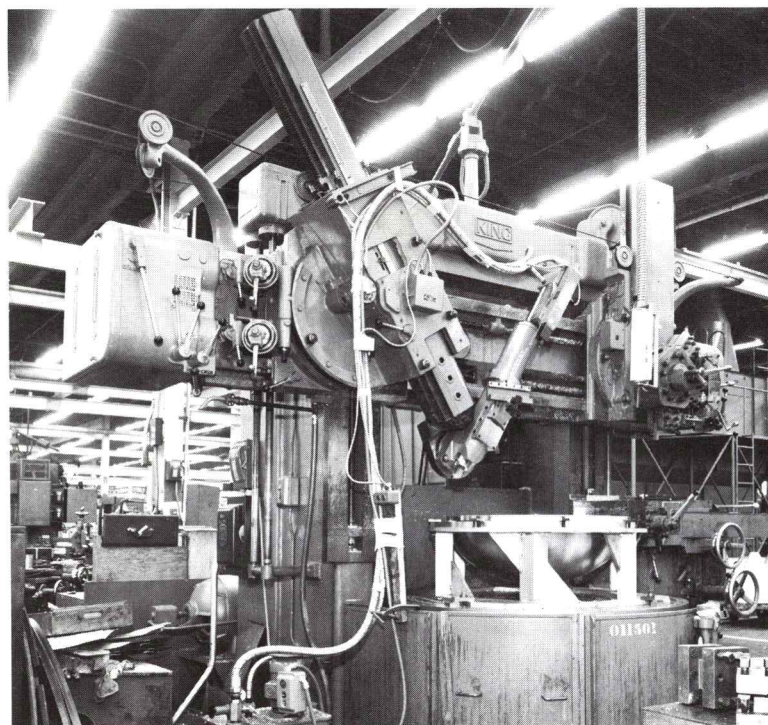
LEGEND

AREA	AREA DESCRIPTION	EXISTING AREA	% LEM	LEM AREA
①	Exclusive LEM Area for Ascent Structural/Mechanical Sub- system	12,100	100	12,100
②	Fusion Welding	12,000	8	1000
③	Resistance Welding	6900	8	600
④	Machining	75,700	3	2300
⑤	Inspection	9100	20	1800
⑥	Honeycomb	49,250	8	4000
⑦	Chemical Milling	9100	6	500
⑧	Forming	21,900	10	2000
⑨	Shear and Rout	11,800	6	700
⑩	Heat Treat	5600	12	700
⑪	Spin Forming	5900	75	4400
⑫	Shipping and Receiving	11,900	10	1200

Figure 2-6. Plant 3-LEM Ascent Stage  
Structural/Mechanical  
Manufacturing

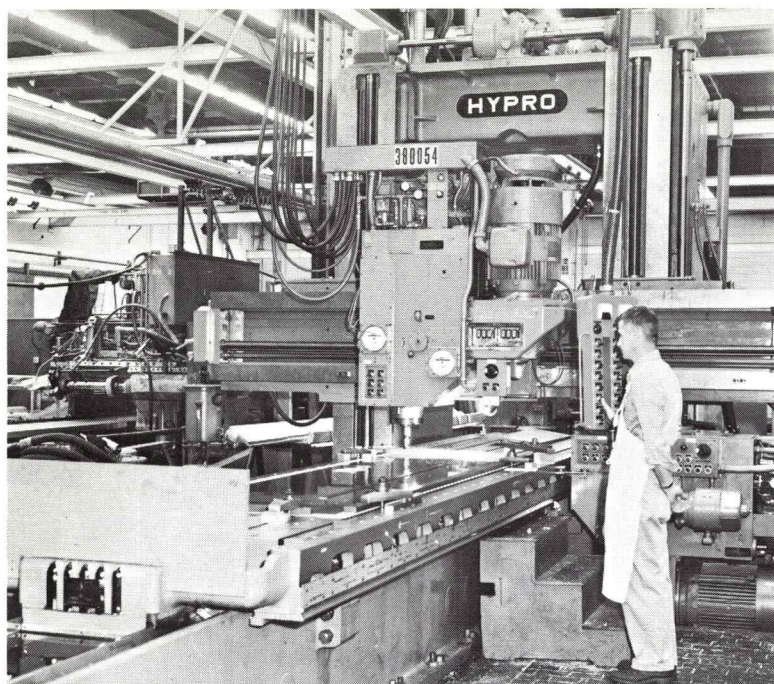


14-Ft Vertical Lathe  
for Machining LEM Ring Details  
and Subassemblies

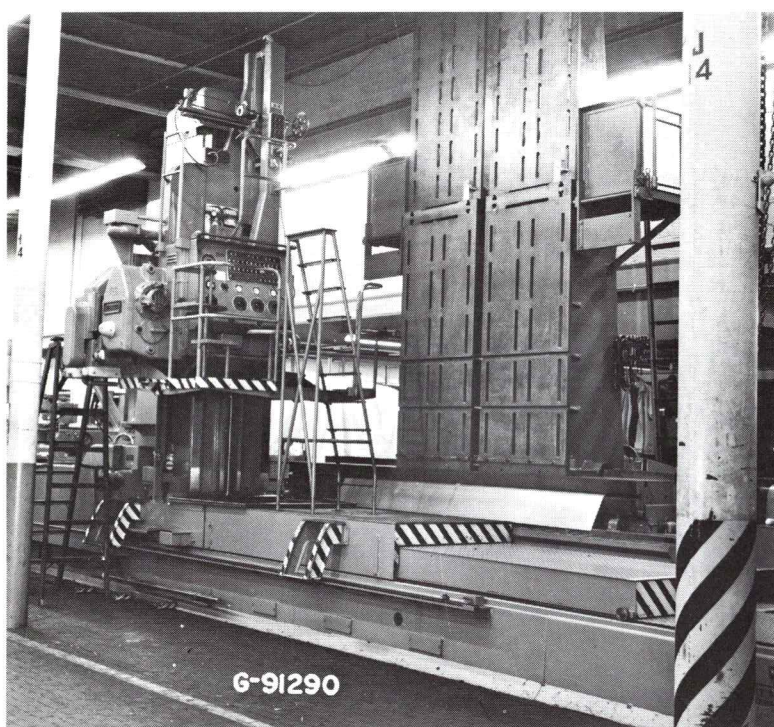


62-In. Vertical Turret Lathe  
for Machining Smaller LEM Rings  
and Spherical Parts

Figure 2-7. Plant 3 - Vertical Lathe Equipment

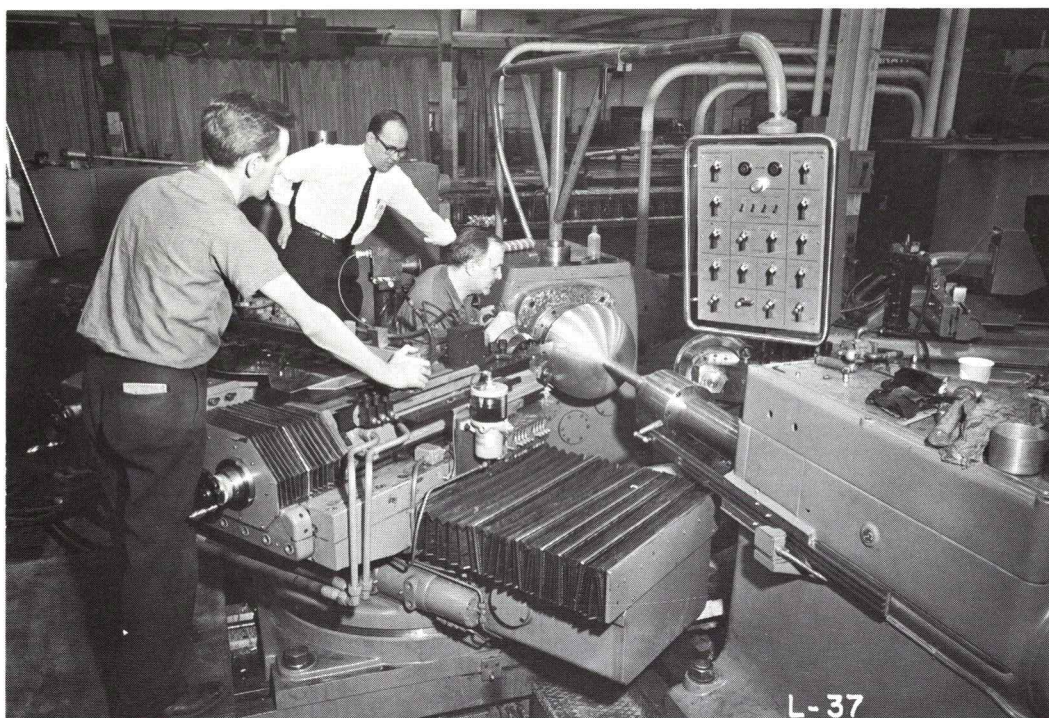


Planer Milling Machine  
for Descent Structure Main Beam  
Components

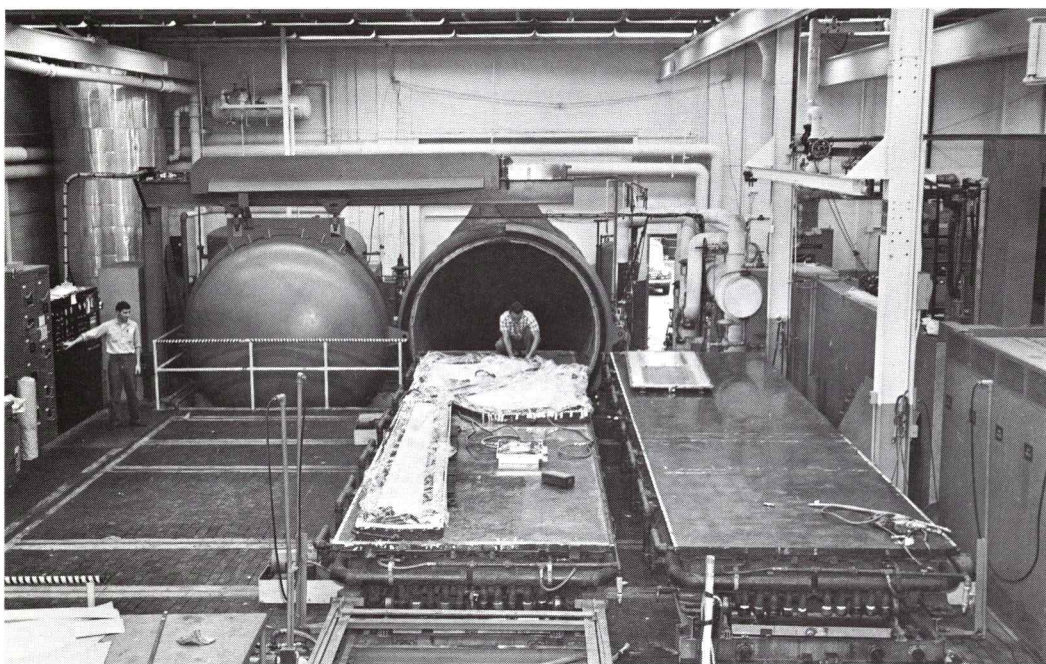


Hydrotel - Tracer Milling Machine for  
LEM Contoured & Pocketed Detail Parts

Figure 2-8. Plant 3- Milling Equipment

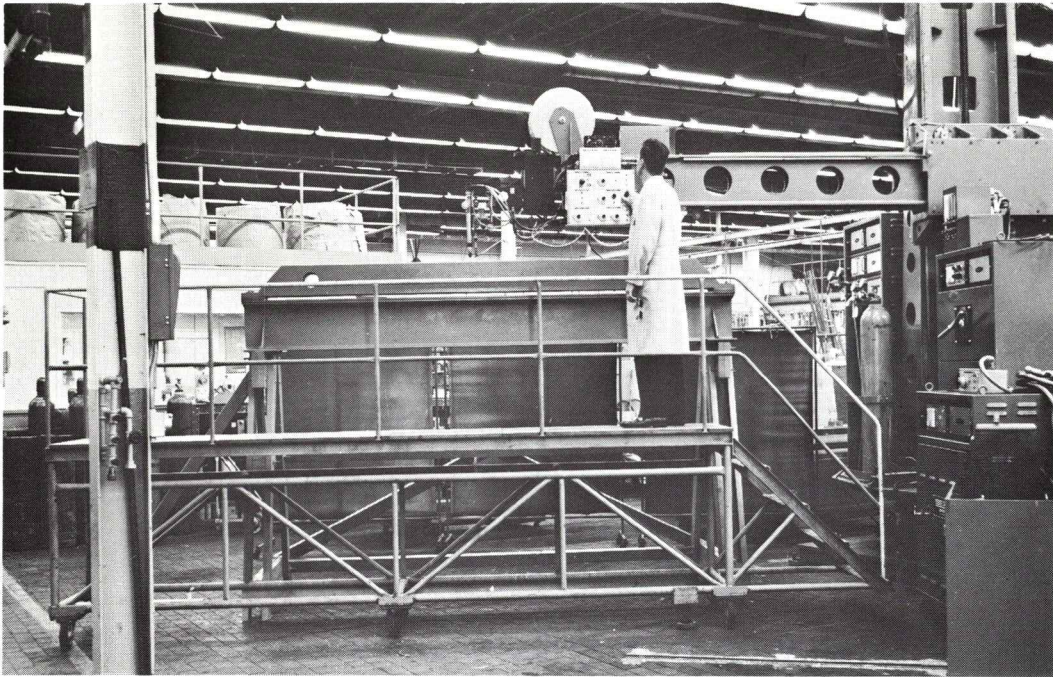


BOKO Flow-Forming Machine for Forming  
and Machining of Propulsion Tank Details

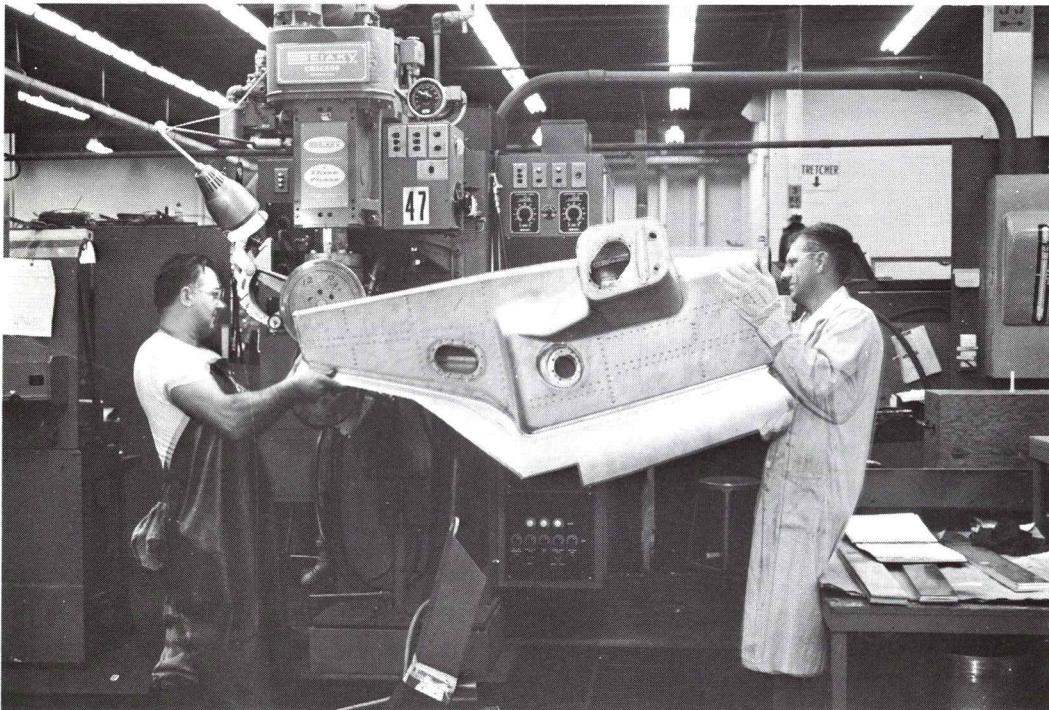


Autoclave for Honeycomb Bonding  
of LEM Equipment Shelves

Figure 2-9. Plant 3 -Forming and Bonding Equipment

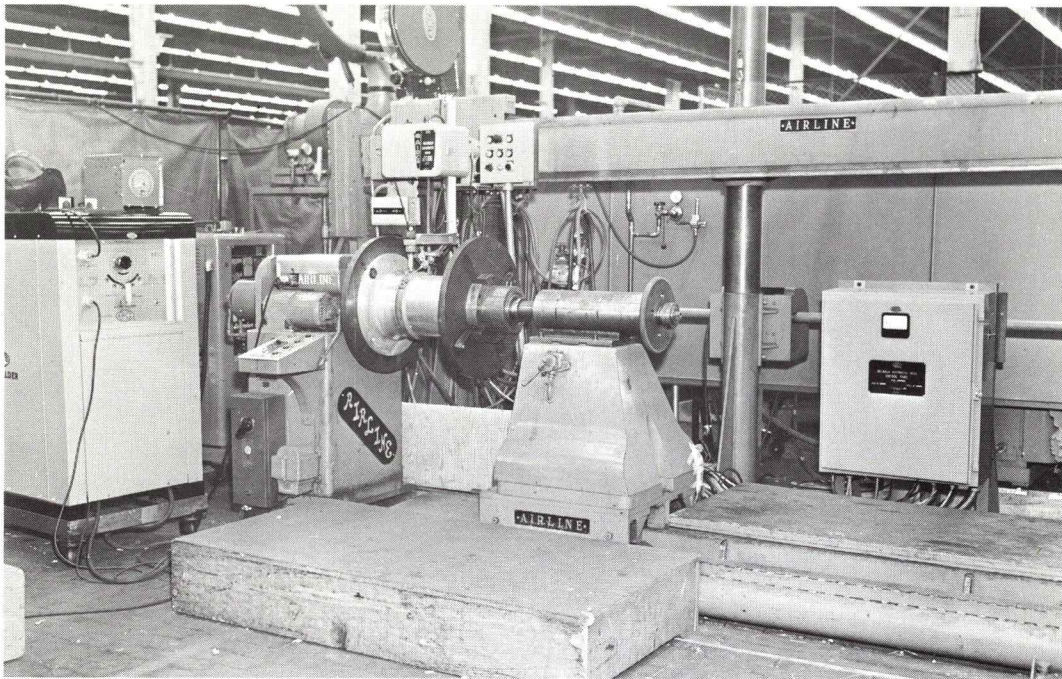


Boom Type Torch Manipulator—  
Automatic Fusion Welding for Joining  
Major LEM Subassemblies

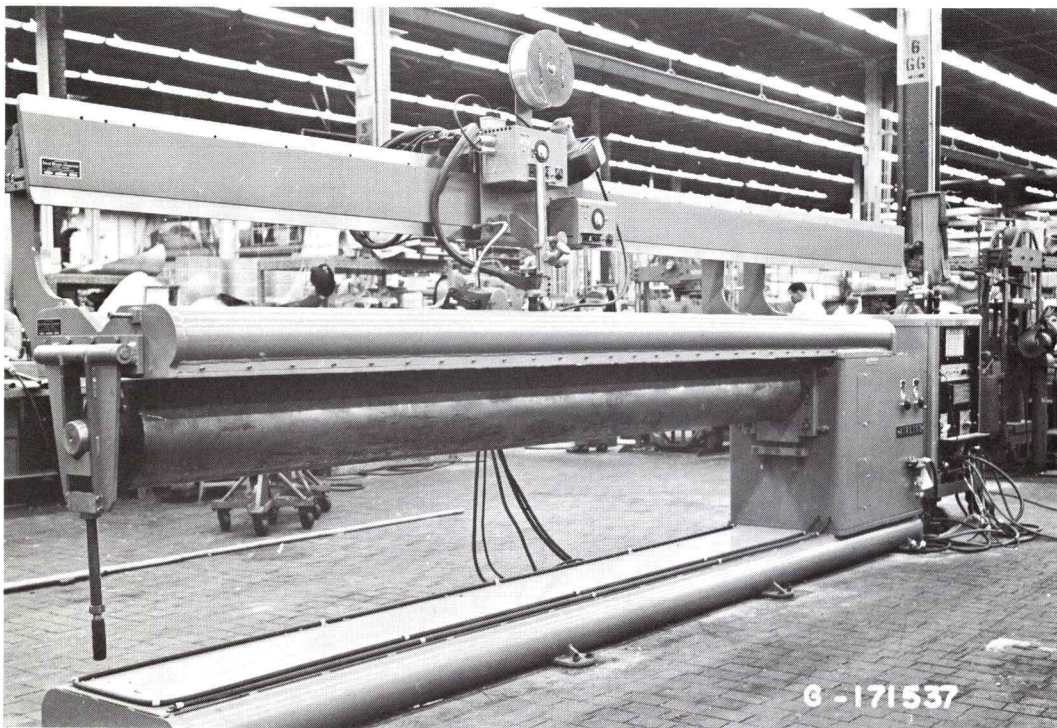


Resistance Seam Welder for Joining  
Secondary Subassemblies

Figure 2-10. Plant 3 - Resistance and Automatic Fusion Welding Equipment

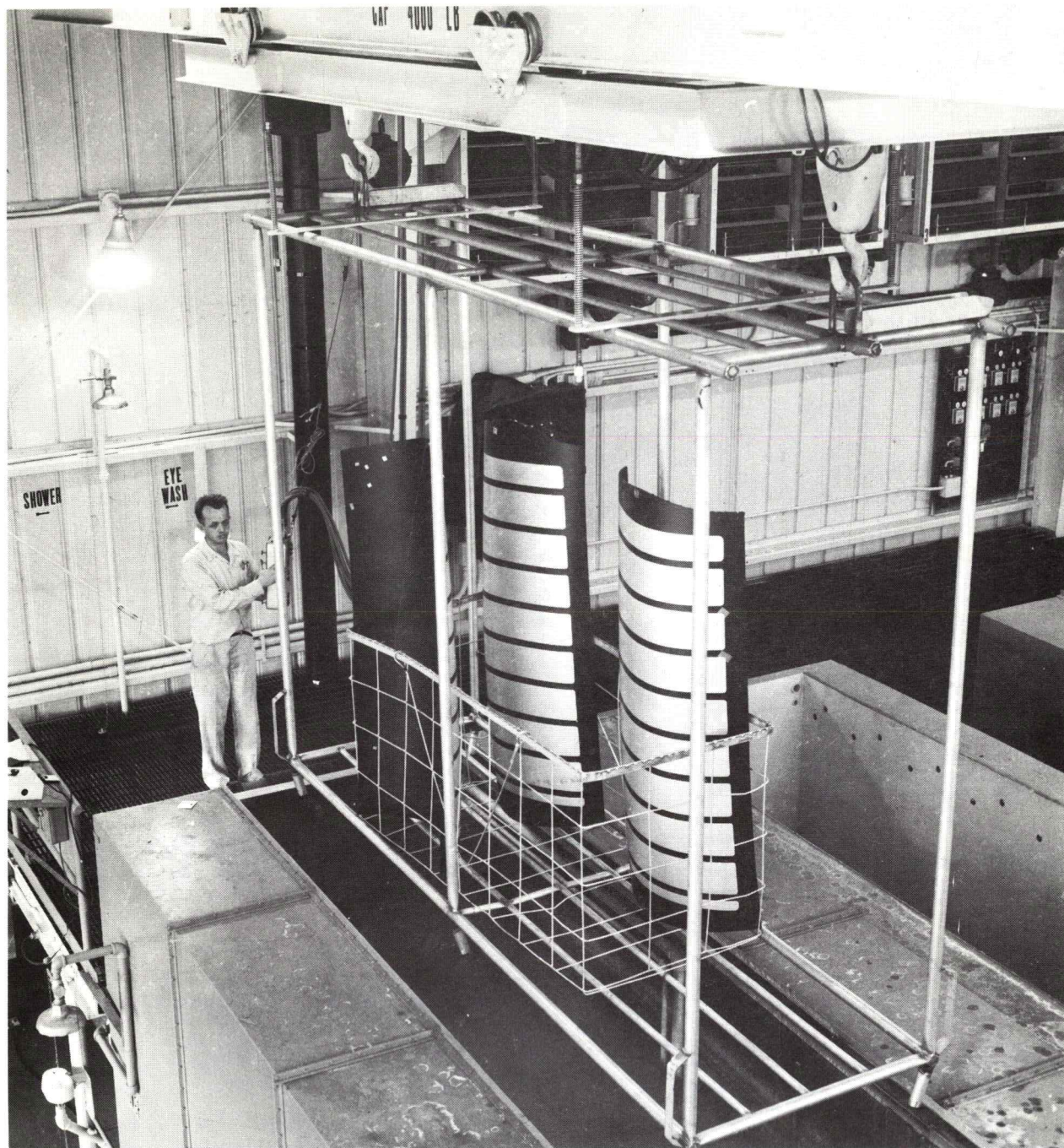


Combination Longitudinal & Circumferential  
Welder for Combined Automatic Welding  
Operations - LEM Docking Tunnels



Automatic Longitudinal Fusion Welder for Welding of  
Large Ascent Stage Subassemblies

Figure 2-11. Plant 3- Automatic Welding Equipment



Planned for Utilization Throughout the LEM Program  
for Reduction of Structural Weight.

Figure 2-12. Plant 3- Chemical Milling Facility

### 2.1.3 Plant 2 - Descent Stage Structural/Mechanical Assembly and Manufacture of Detail Parts and Minor Subassemblies.

As shown in Figure 2-13, Plant 2 has been selected for the manufacture of LEM detail parts and for assembly of the descent stage structure, which consists primarily of basic sheet metal construction. Since this plant is presently producing the majority of the sheet metal parts for all Grumman programs, fabrication of LEM detail parts in this plant will result in continued manufacturing efficiency. These consolidated facilities are fully equipped with the most modern machinery ranging from Hufford stretch wrap forming equipment to conventional drill presses.

The assembly of the descent stage in Plant 2 is also advantageous by virtue of available shop skills and facilities presently being utilized for the fabrication of similar mechanically fastened assemblies.

Tubular line assemblies for the Propulsion, Reaction Control, Environmental Control, and Electrical Power Subsystems will be fabricated using tube bending and induction brazing equipment housed in Plant 2.

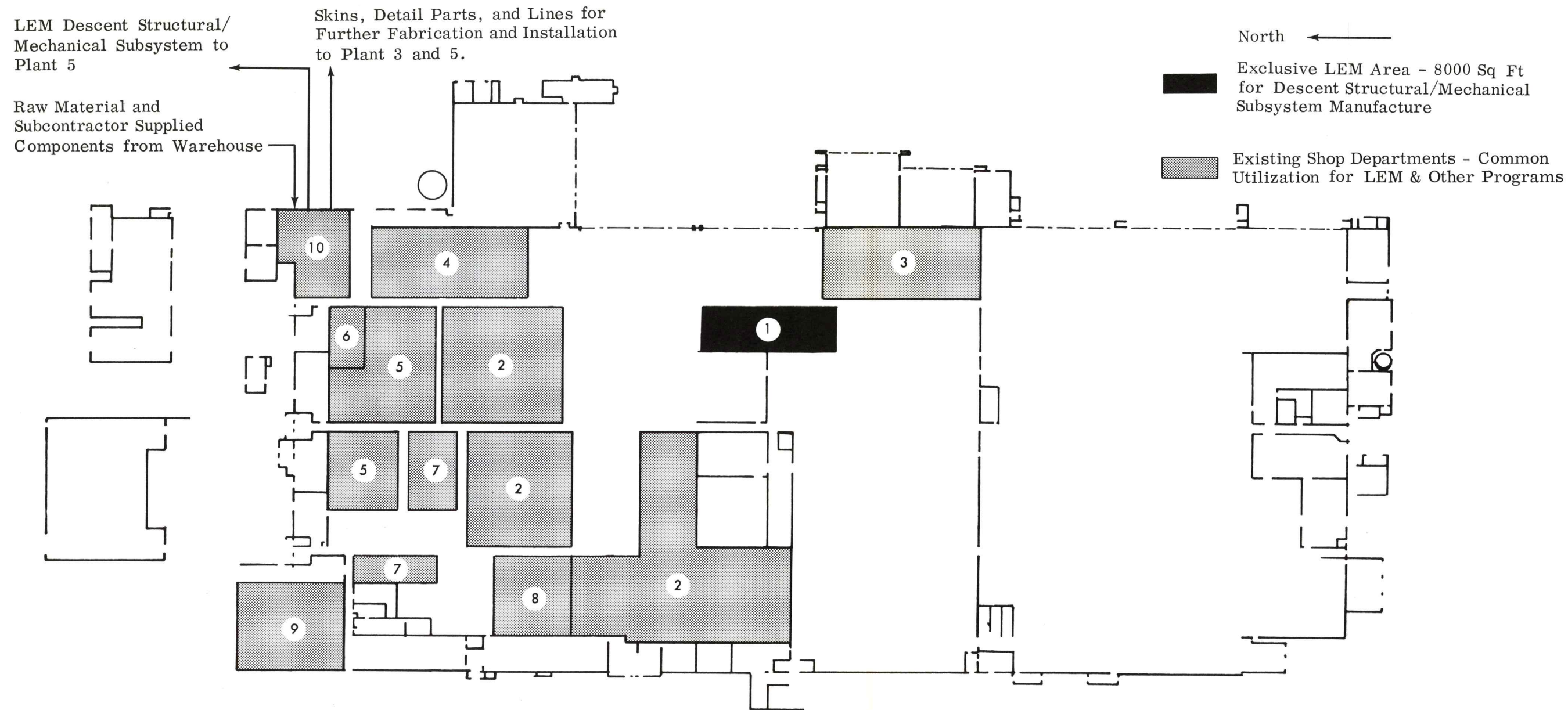
Welding equipment available in various capacity ranges will be used during the manufacture of Lunar Landing Gear subassemblies.

Bench assembly areas will produce the mechanically fastened or welded secondary structural subassemblies for both the ascent and descent stages.

Major equipment located within Plant 2 are shown in Figures 2-14 and 2-15.

### 2.1.4 Plant 12 - Plastic Parts

Plastic parts, such as the LEM/CM VHF antenna components and other details, which will be located within the crew and equipment compartment subassemblies will be fabricated in Plant 12. This facility is fully equipped to satisfy all tooling process, fabrication,

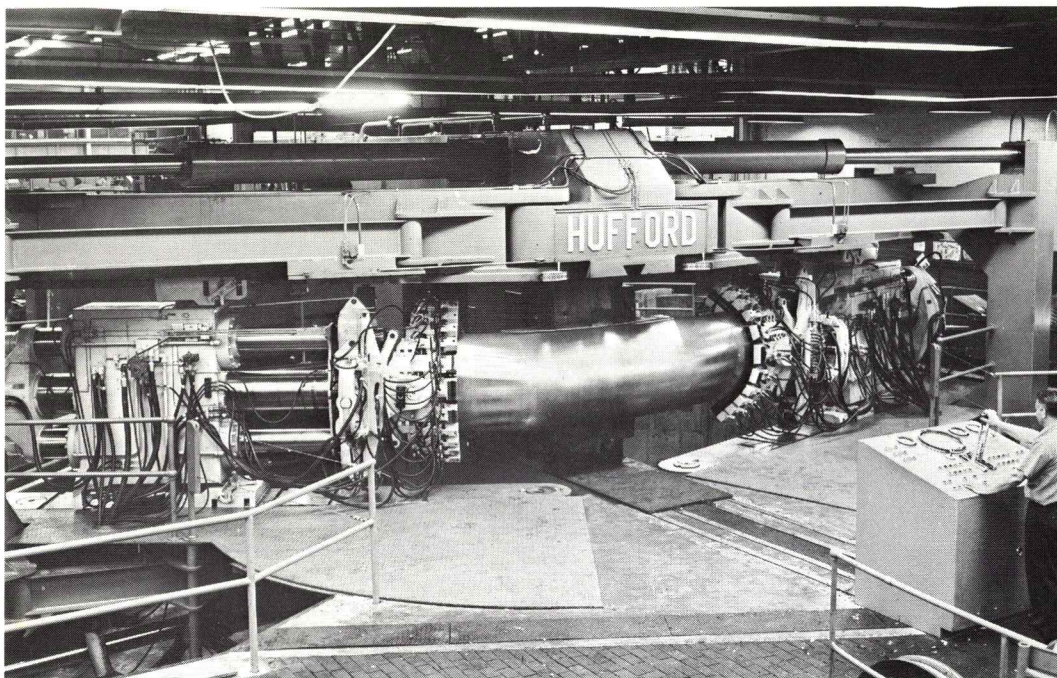


LEGEND

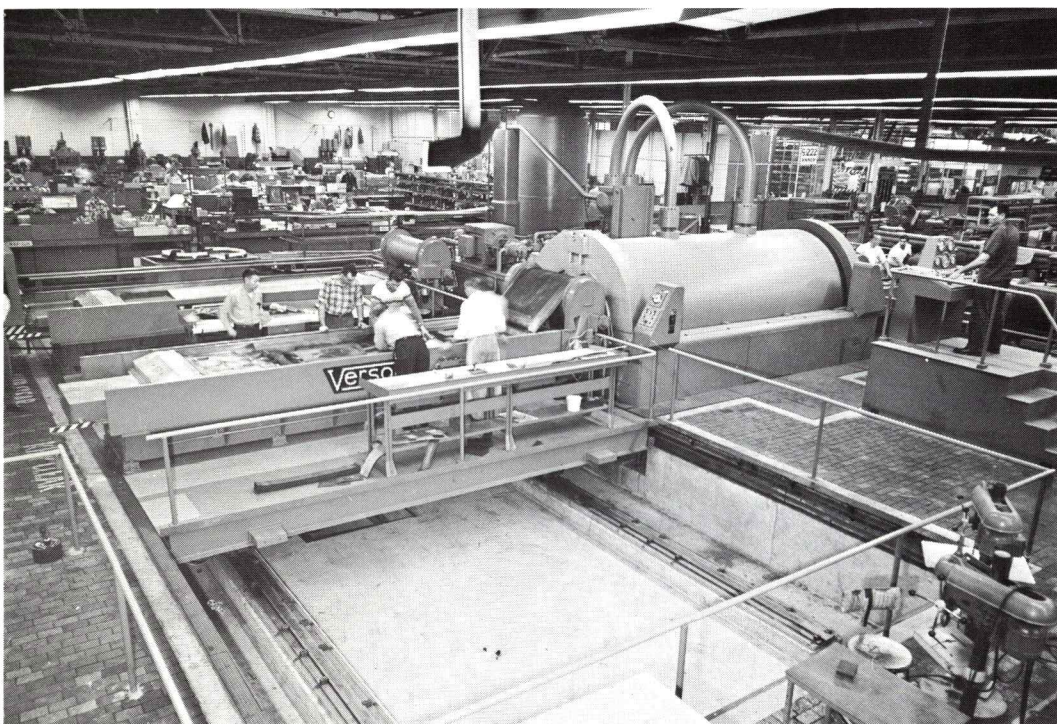
AREA	AREA DESCRIPTION	EXISTING AREA	% LEM	LEM AREA	AREA	AREA DESCRIPTION	EXISTING AREA	% LEM	LEM AREA	AREA	AREA DESCRIPTION	EXISTING AREA	% LEM	LEM AREA
①	Exclusive LEM Area for Descent Structural/Mechanical Subsystem	8000	100	8000	④	Minor Subassemblies	13,300	3	400	⑧	Stock and Tool Storage	7630	13	1000
②	Centralized Detail Parts Manu- facturing Facility	64,300	10	6400	⑤	Manual Fusion and Flash Welding	5500	8	400	⑨	Heat Treat	11,200	12	1300
③	Lines Manufacture	11,300	20	2300	⑥	Anodize	2800	14	400	⑩	Shipping and Receiving	14,000	5	700
					⑦	Inspection	11,500	8	900					

Figure 2-13. Plant 2- LEM Descent Stage  
Structural/ Mechanical Assembly  
& Manufacture of Detail Parts  
and Minor Subassemblies





Stretch Wrap Forming Machine  
for LEM Ascent Stage Skins

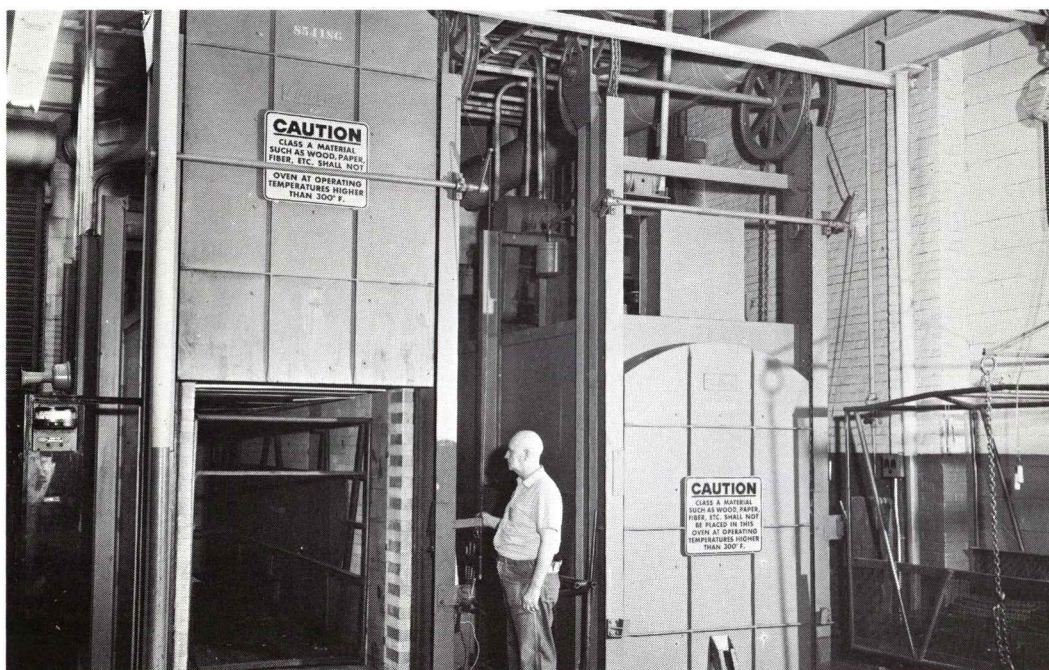


Direct Acting Hydraulic Press.  
Also Shows a Partial View of the Consolidated  
Detail Parts Manufacturing Facility.

Figure 2-14. Plant 2- Forming Equipment & Consolidated Detail Parts Facility



Rubber Forming Press for  
LEM Detail Parts



Age-Hardening Ovens  
for Aluminum LEM Details

Figure 2-15. Plant 2- Forming and Age-Hardening Facilities

inspection, and test requirements for the development of aerospace plastic components. The Plant 12 facility is shown in Figure 2-16.

#### 2.1.5 Plant 4 - Electronic Bench Test and Bench Maintenance

Plant 4 will be utilized for electronic bench test and maintenance of vendor supplied electronic subsystem components. This plant is presently performing electronic testing, repair, modification, and updating of Grumman electronic instrumentation and equipment for other programs.

#### 2.1.6 Tool Manufacturing Facilities

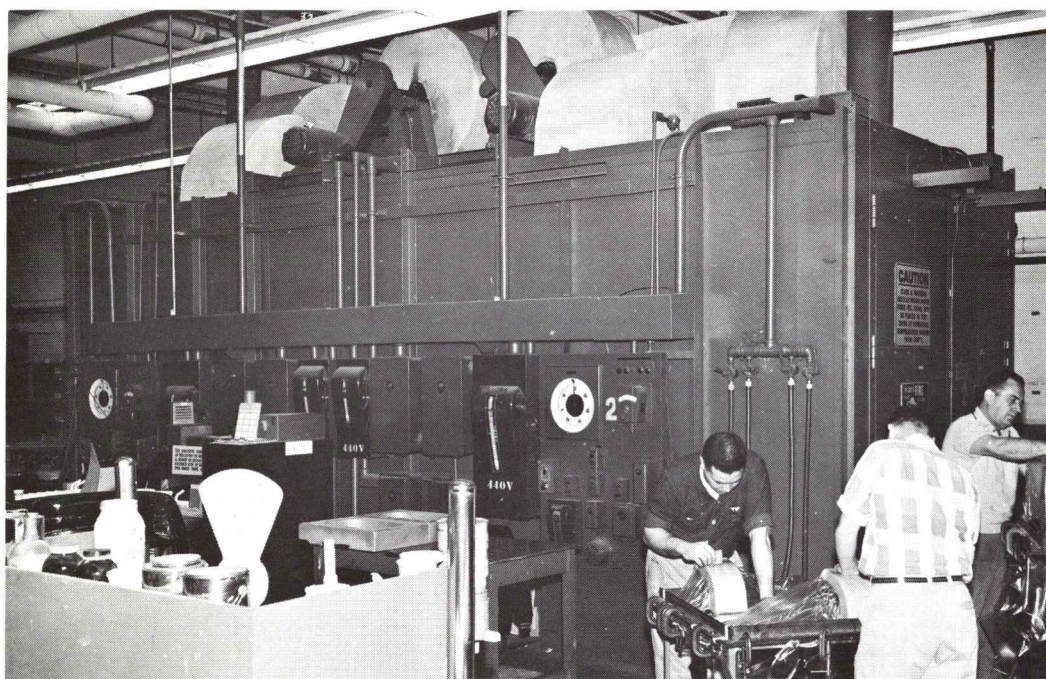
The Grumman tool manufacturing facilities represent approximately 126,000 square feet of plant area. The tool shop areas and all specialized production and maintenance shops will be fully utilized to insure on-time delivery of all tooling requirements for the LEM Program. The facilities are arranged according to either the degree of specialization or the needs of individual plants to provide the necessary close support for the production areas.

The Jig and Fixture Shops, shown in Figure 2-17, constitute the largest of the tool manufacturing facilities. These shops occupy approximately 36 percent of the total area. Tools varying from two-story assembly fixtures to small intricate drill jigs are produced. Set-up and assembly of jigs and fixtures comprise the bulk of the effort. Details such as machined parts and some weldments are supplied by supporting shops. Precision jig boring and grinding facilities and extensive use of optical tooling techniques are utilized to provide the accurate production tooling required for rapid assembly procedures.

The Template Shop, shown in Figure 2-18, produces router, trim, and other similar templates that are developed from loftings. These templates are used to facilitate the fabrication of sheet metal detail parts. The Template Shop work involves highly skilled manual labor, thus minimizing the equipment and facility requirements. Approximately

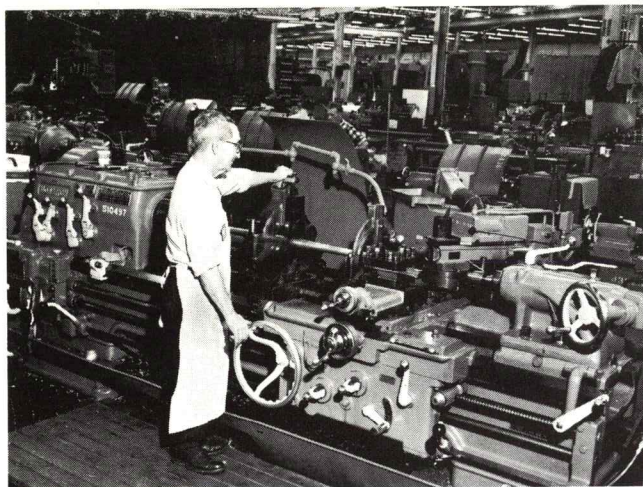


Fiberglass Facility

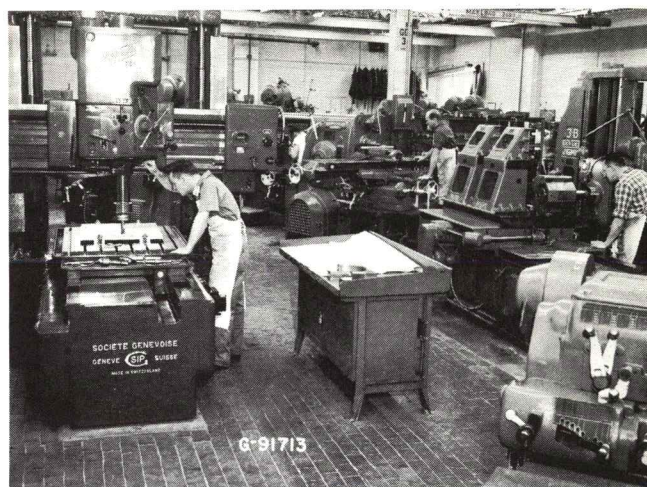


Electric Oven  
for Curing Vacuum Bagged Fiberglass Reinforced Parts

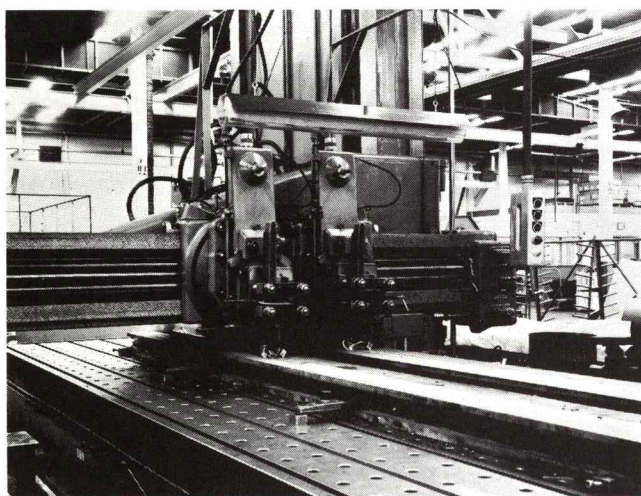
Figure 2-16. Plant 12 - Fiberglass Manufacturing Facilities



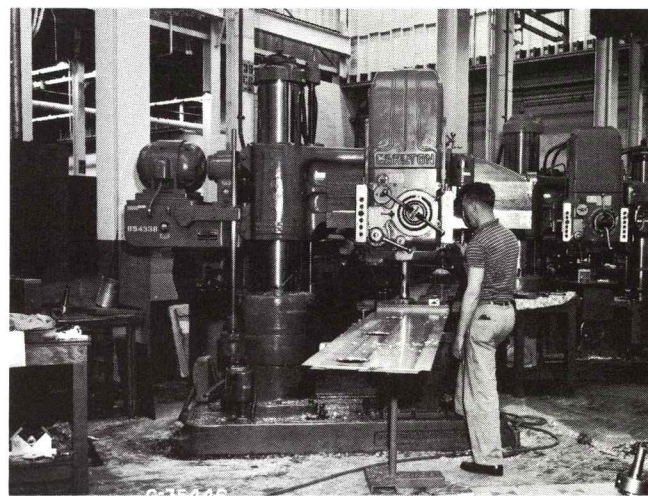
Tooling Machine Shop Lathe Area



Tool Jig Boring Area



Rockford Openside Planer  
for Heavy Machining

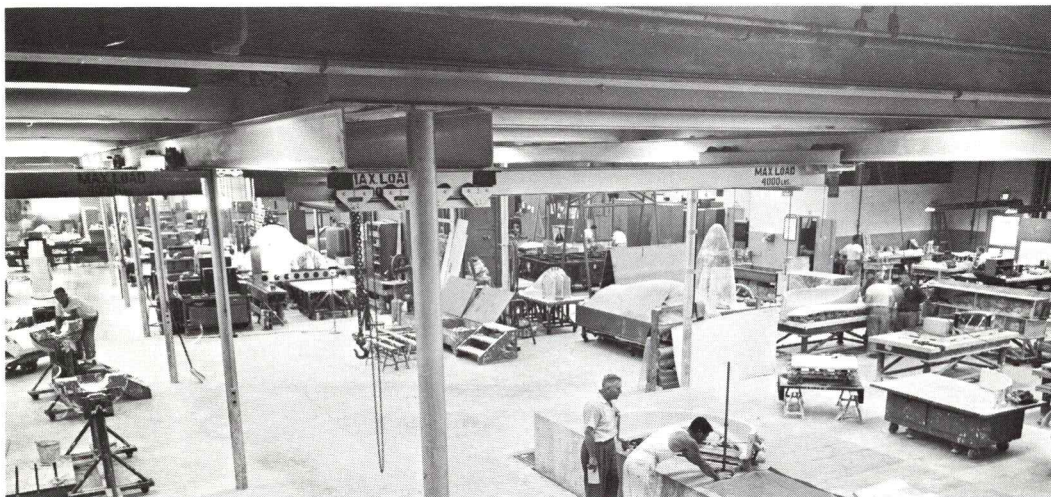


Radial Arm Drill Press Area

Figure 2-17. Jig and Fixture Manufacturing Facilities



Template Shop for  
After-Form Detail Tools



Plaster Shop for  
Plaster Tooling Mock-Ups & Models

Figure 2-18. Template and Tooling Mockup Facilities

16 percent of the total tool manufacturing shop area is allotted to template manufacture. The majority of this area is located in Plant 2 where most sheet metal parts are fabricated.

Patterns and three-dimensional form blocks of wood, masonite, or aluminum are fabricated in the Pattern Shops for use in the manufacture of sheet metal parts. Planers, jointers, circular saws, sanders, and other conventional wood working machinery are used in the manufacture of these tools. Cam-controlled routers for high-speed profiling and other specialized production-type equipment are used to attain a high degree of efficiency. These shops, occupying about 10 percent of the total tool shop area, are also primarily located in Plant 2.

The Plaster Shop, shown in Figure 2-18, provides all plaster tooling mock-ups, models, and a major portion of the compound curvature skin tooling for all plants. These mock-ups are constructed using carefully aligned templates which are filled in and fixed with plaster compounds. Dies and skin tooling are fabricated by taking plaster or plastic casts from these mock-ups. All tooling mock-ups and models for compound curved LEM skins will be produced in this facility. The Plaster Shop is located entirely in Plant 11 and represents approximately 20 percent of the tool manufacturing facilities.

The Die Shop, located in Plant 2, occupies approximately 6 percent of the total Tool Shop area. Close tolerance steel dies for production blanking, forming, and rolling operations are fabricated in this shop utilizing precision grinding equipment and support from the Tooling Machine Shops.

The Tooling Machine Shops provide support for all of the Tool Shops. Machine Shop equipment including milling machines, lathes, shapers, and grinders are available for any metal cutting operations required. Approximately 12 percent of the Tool Shop area is utilized for these shops.

In addition to the tooling facilities, the complete manufacturing capability of the company is available for tool fabrication on an "as required" basis. This includes heat treat, paint and

other finishing operations, and specialized production equipment which could not be justified for full time Tool Shop usage.

Complete coordination of all cognizant personnel and constant monitoring of shop loading and control procedures is the key to efficient use of the Tool Shop capabilities described herein.

#### 2.1.7 GSE/STE Manufacturing Facilities

LEM Ground Support Equipment, including Handling and Transportation GSE, Electronic GSE/STE, Fluid Systems Support GSE/STE, and Training Equipment will be manufactured in existing shop facilities currently producing similar components for other aerospace programs. The manufacturing tasks will be routed to the Tool, Test Equipment, or Avionic Shops based on the specialized skills, equipment, or facilities required for fabrication.

The GSE manufacturing facility, within the Tool Shop organization will fabricate the Handling and Transportation Equipment, and also some cabinets, chassis, and work benches for other equipment. This shop, shown in Figure 2-19, is equipped for all heavy fabrication utilizing standard metal cutting, forming, and welding equipment.

The Test Equipment Shops and Avionic Shop Departments are responsible for Electrical/Electronic GSE/STE used during manufacturing and off-site tests. In addition, the Test Equipment Shops have the primary responsibility for all Fluid Systems Support GSE/STE. These shops, shown in Figures 2-19 and 2-20, are equipped to handle the fabrication and functional test of hydraulic, pneumatic, and environmental ground support equipment, in addition to fabrication, calibrating, and maintaining all types of test equipment for electronic or fluid subsystems.

A section of the Avionic Production Shop also participates in electronic GSE/STE manufacture. This area is equipped to manufacture circuit boards, harnesses, and other electronic subassemblies, and to integrate these components into panels, consoles, and chassis manufactured by supporting shops. This shop is also responsible for calibration and functional checkout of test units.

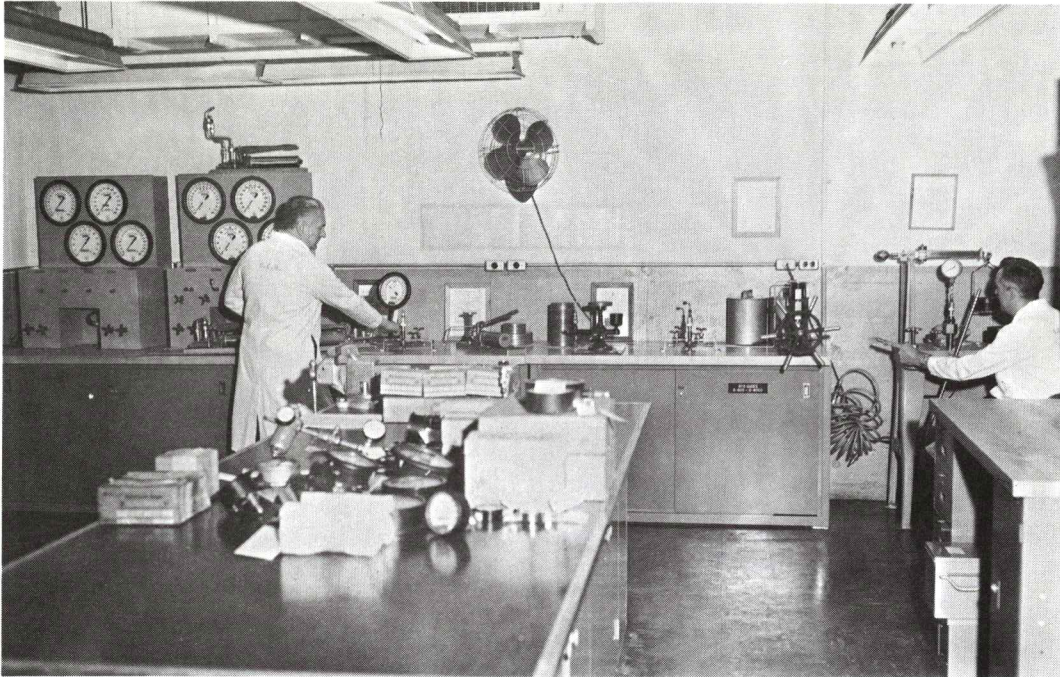


Fabrication Shop for Handling &  
Transportation GSE

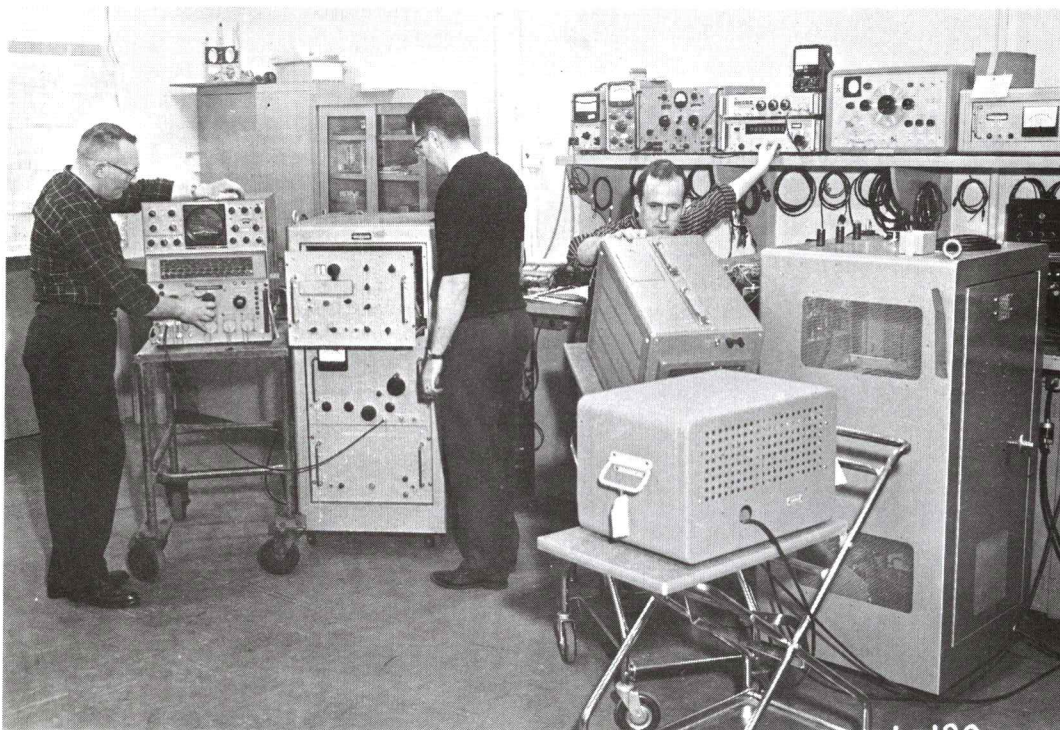


Test Equipment Shop for  
Fluid Systems & Electronic GSE/STE

Figure 2-19. GSE/STE Manufacturing Facilities



Test Equipment Shop-  
Mechanical Instrument Calibration Area



Test Equipment Shop-  
Electronic GSE/STE Calibration Area

Figure 2-20. Test Equipment Shop

SECTION 3 - Scheduling, Planning, Methods, and Controls

### SECTION 3

## SCHEDULING, PLANNING, METHODS, AND CONTROLS

### 3.1 SCHEDULING

On-schedule performance is a major consideration for the LEM Program, and our past record is a matter of particular significance. A detailed accounting of Grumman schedule performance is shown in the original LEM Proposal. All major milestones regarding development, customer evaluation, and manufacturing for the current A-6A and E-2A aircraft programs have been, and continue to be met.

At Grumman, scheduling and planning operations are closely interrelated since coordination is mandatory - from the initial planning stage through completion of the manufacturing task. However, for clarity of presentation, planning and scheduling for the LEM Program are described in separate report sections.

The LEM Master Program Schedule and individual subsystem schedules form the basis for development of detailed schedules for tooling, GSE, equipment, and manufacturing. Past contributions for manufacturing and installation lead-time requirements are presently reflected in the Master Schedule.

Manufacturing and tool scheduling systems are described in Sections 3.1.1 and 3.1.2. LEM Program manufacturing schedules are shown in Section 3.1.3.

#### 3.1.1 Manufacturing Scheduling

As shown in Figure 3-1, the lead-time requirements for tooling, equipment, and manufacturing are established by the LEM Manufacturing Management Staff. During the

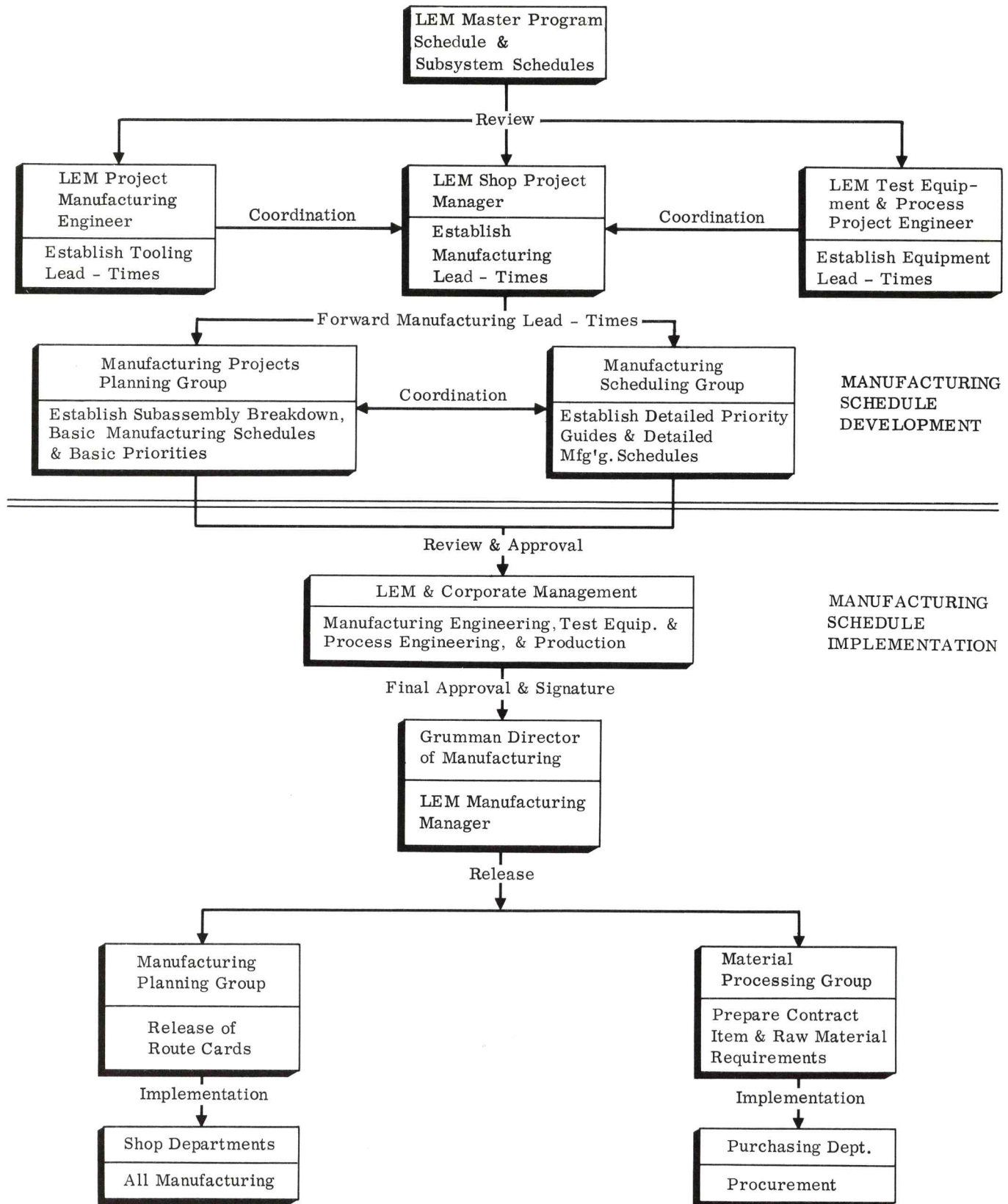


Figure 3-1. Manufacturing Scheduling Flow

development of manufacturing lead-times, the LEM Shop Project Manager uses manufacturing flow and tool/equipment lead-time data provided by the LEM Project Manufacturing Engineer and the Test Equipment and Process Project Engineer. This coordination results in agreement and assurance of compatible program sequences and approaches.

Lead time information is forwarded to the Manufacturing Projects Planning Section where the basic manufacturing schedules are developed. These schedules, as shown in Section 3.1.3, include major engineering drawing release requirements, due-dates for all primary tooling and manufacturing activities necessary to satisfy the master program charts, receipt of subcontractor supplied components, and final assembly installation and test operations.

These schedules are forwarded to the Manufacturing Scheduling Section where detailed "family tree" priority groups are established for engineering drawing releases, shop work orders, and procured items. Basic manufacturing schedules are used by this group to develop the detailed schedule requirements for component manufacturing. These procedures are repeated for each different configuration module. Identical units will be scheduled completely within the Manufacturing Scheduling Section.

Recognizing the importance of effective manufacturing schedules, review and approval by the LEM Manufacturing Manager, LEM Shop Project Manager, and the Grumman Production Manager is mandatory. The signatures of the Grumman Director of Manufacturing and the LEM Manufacturing Manager constitute final approval of all schedules. Copies of all schedules are forwarded to the Manufacturing Planning Group for release of route cards to the shop departments. The Material Processing Group also receives copies of the schedules for preparation of contract item and raw material requirements which are forwarded to the Purchasing Department.

### 3.1.2 Tool Scheduling

Major tooling schedules are integrated within the aforementioned basic manufacturing schedules, and are programmed to satisfy the fabrication lead time requirements in

accordance with the selected subassembly breakdown. The initial development and periodic up-dating of these basic manufacturing schedules (including tooling) are the responsibility of the LEM Project Manufacturing Engineer. As shown in Figure 3-2, he is assisted by a LEM planner who represents the Project Planning and Controls Section. These schedules are forwarded to the Tool Fabrication Section where basic shop-loading data is developed. The shop-loading data and schedules are forwarded to the Manufacturing Engineering Scheduling Group where detailed tool due-date schedules are generated within the structure of the LEM Master Schedule and basic manufacturing schedules. The Scheduling Group develops these tool due-dates by closely considering the following factors:

- Conformance with PERT/Time Networks.
- Availability of engineering information.
- Allowance for manufacturing lead-times for determining individual tool completion dates.
- For design-type tools, allowance for tool fabrication lead-times for determining individual tool design completion dates.
- Tool design progress reports.
- Status of Tool Shop loading for balancing and adjustment of work effort.
- Schedule compatibility to facilitate use of masters during tool fabrication.

The procedures for schedule implementation, recording, and status reporting are also shown in Figure 3-2. The Methods Engineering Section (Tool Planning) determines the tooling requirements and prepares "Methods Engineering Record Sheets, ME-269" for both design and non-design type tools. This procedure is described in Section 3.2.2. The Record Sheets, together with tool fabrication estimates, tool drawings, and destinations are forwarded to the scheduling groups for review of due-dates and status of shop loading. When acceptable due-dates and priorities have been established, the ME-269 Record Sheet

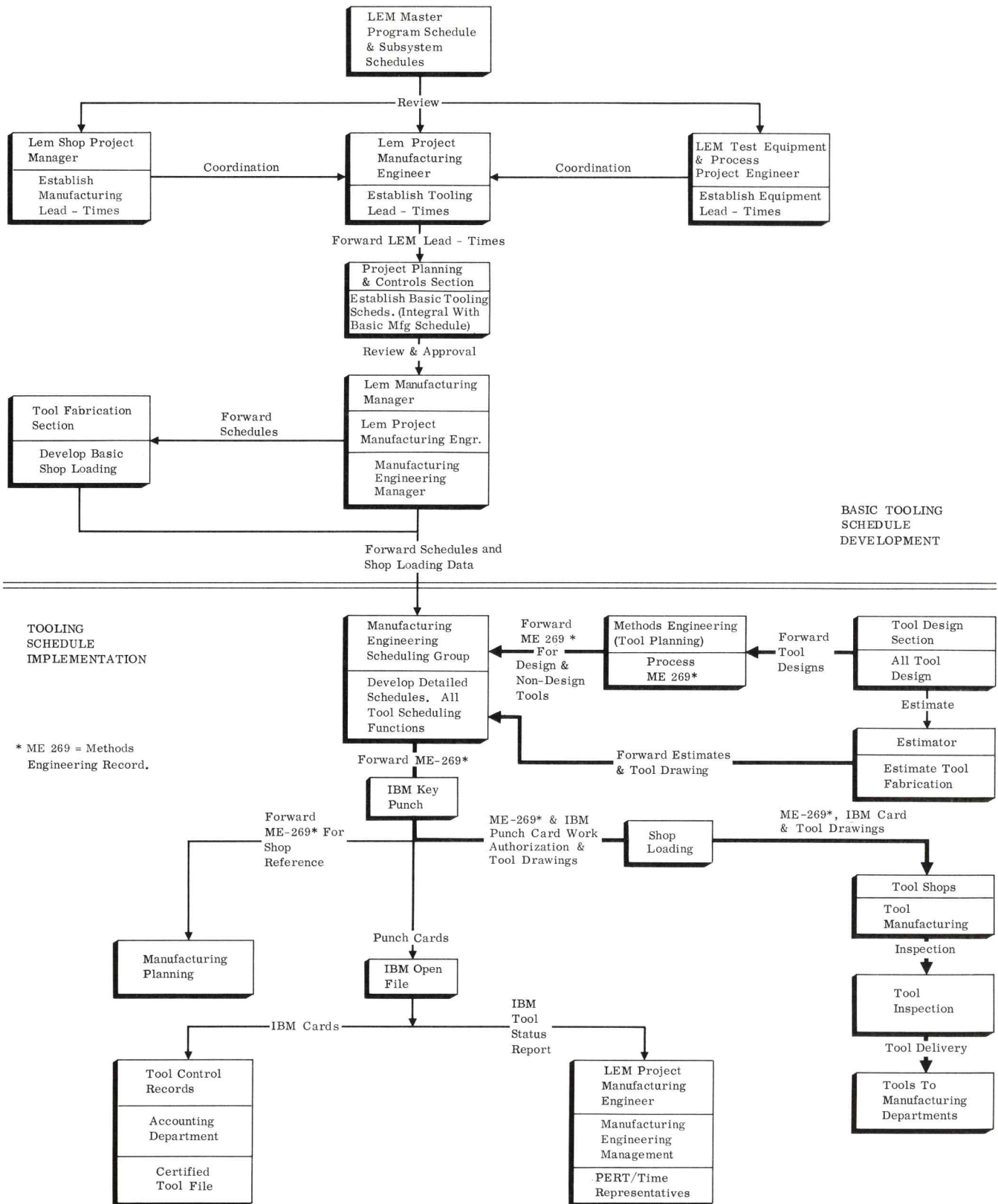


Figure 3-2. Tool Scheduling Flow

is processed and forwarded to the IBM Key Punch Section where IBM cards are made. The cards are forwarded to the IBM Open File and to the Shop Loading Section where they become the sole authorization order for initiation of tool shop effort. Completed tools are inspected and subsequently delivered to the manufacturing departments. Manufacturing Engineering retains the responsibility for tool improvements, rework, maintenance, repair, and replacement, but may not perform these functions until the tool is released by the Production Department. This insures the completion of all required parts which are fabricated in the tool before rework is initiated. This requirement is necessary since the revision may be for a particular or subsequent module and not applicable to the one presently being assembled.

The Manufacturing Engineering Scheduling Group is responsible for the monitoring of/and initiating authorization for all tool movements into and out of Grumman in coordination with Purchasing, Production, Tool Control, and Subcontracts. All tool movement and storage within Grumman is controlled by the Tool Control Section. This section is under the jurisdiction of the Production Department.

Recording of the tool program and status reporting is accomplished using an IBM key punch card system. This system is used for maintaining cognizance of "completed and incomplete tools". Thus, tool program status can readily be reported to the LEM Project Manufacturing Engineer, Manufacturing Engineering Management, and PERT/Time representatives. Further, the IBM system satisfies the requirements of Tool Control Records, Accounting Department Records, and the Certified Tool File.

### 3.1.3 LEM Manufacturing Program Schedules

Detailed tooling and manufacturing schedules are being developed using the LEM Phasing Charts, dated 15 September 1963, as shown in the Master Program Plan LPL-13-1.

Concentrated scheduling efforts are presently being applied to the early modules such as the TM-2 Thermal Model of the Descent Stage, M-5 Master Metal Mockup, the PD units, and LTA-1 through LTA-4.

The NASA Mock-up Review, held at Grumman on 16 through 18 September 1963, has resulted in design changes to the ascent stage face assembly. In addition, very recent design changes, based on the continuation of the design phase through 1 October 1963, have also affected the aft pressure dome, unpressurized equipment bay, and the mid-section tunnel area. Consequently, manufacturing tasks and operational sequences, which have already been defined, must be reviewed and revised in accordance with the latest configuration as shown in the Section 4 flow diagrams.

The manufacturing schedule for TM-2 (Thermal Model of Descent Stage without Landing Gear) is shown in Figure 3-3. This pictorial arrangement has been adopted as a standard format for all LEM manufacturing schedules (and is also being used for all other Grumman programs). The inclusion of the LEM subassembly breakdown sequences as a visual aid is a factor which has made this type of chart a universally accepted working tool by the Manufacturing Departments. These initial schedules establish the requirements for receipt of engineering design information, and are also used as the basis for detailed manufacturing planning and scheduling. As such, they are reviewed by the Director of Manufacturing and the LEM Manufacturing Manager, and are revised to indicate progress at 2 week intervals.

Figure 3-4 shows a summary schedule for TM-2, M-5, PD-1, PD-2, PD-4, and PD-5 descent stages. A similar summary of the ascent stages will be developed in accordance with the aforementioned review of the ascent changes.

A single-shift shop operation is planned for subsystem installations, as well as functional and factory checkout. An extended shift and a second shift will be added when necessary for modifications and contingencies. Experience in development programs indicates that the above concept is best suited for these tasks.

GSE usage and availability requirements will be used to develop manufacturing schedules for Handling and Transportation GSE, Fluid Systems and Electronic GSE/STE. All items shown on the approved "GSE Planning and Requirements List, LLI-400" will be subject to a detailed analysis for "make or buy" decisions, and schedules will be developed for items to

## LEM TM-2

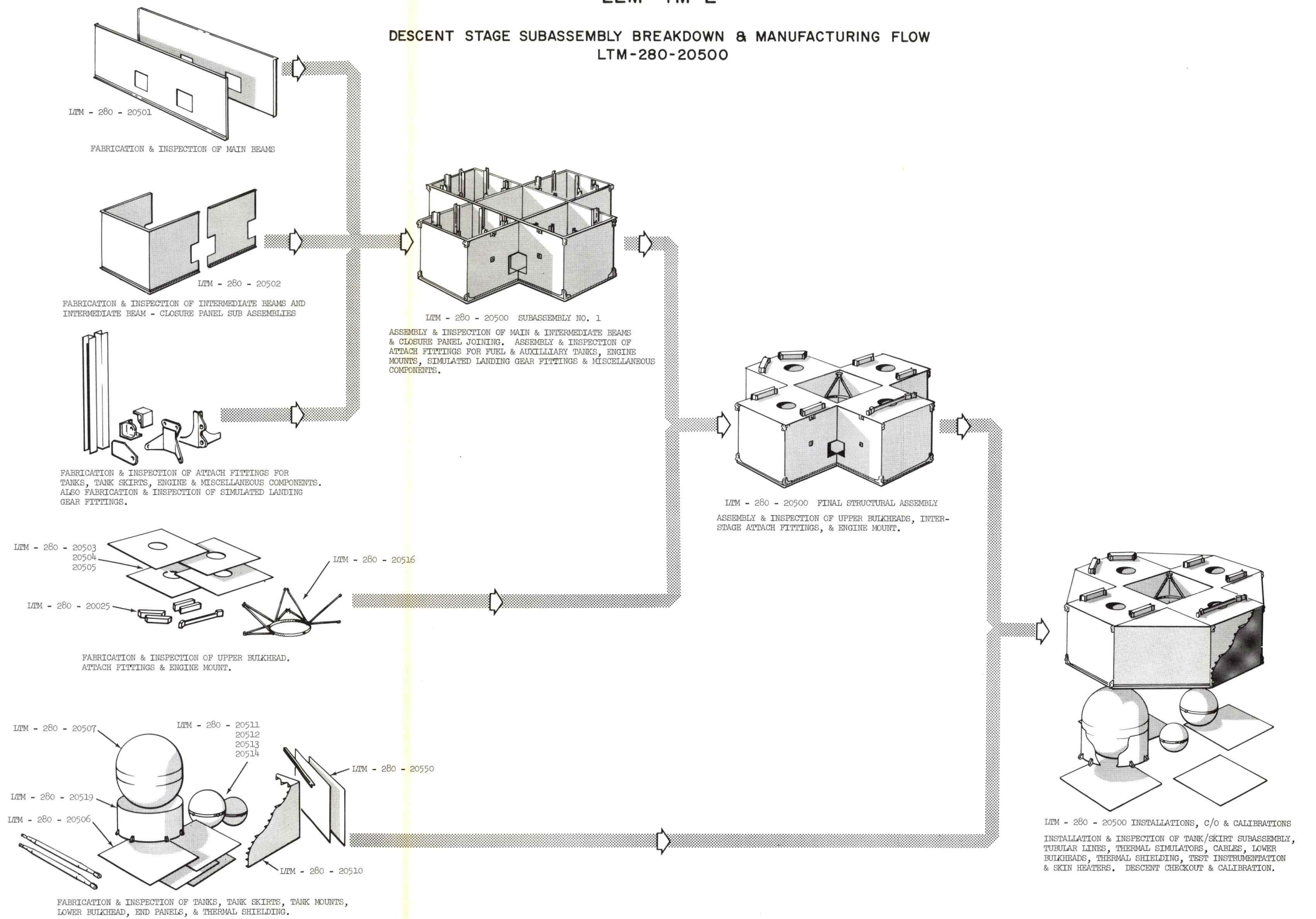
DESCENT STAGE SUBASSEMBLY BREAKDOWN & MANUFACTURING FLOW  
LTM-280-20500

Figure 3-3. LEM TM-2 Descent Stage Sub-assembly Breakdown & Manufacturing Flow. Sheet 1 of 4

MANUFACTURING SCHEDULE  
LEM TM-2 DESCENT STAGE  
(SEE SUBASSEMBLY BREAKDOWN ON SHEET 1 OF 4)

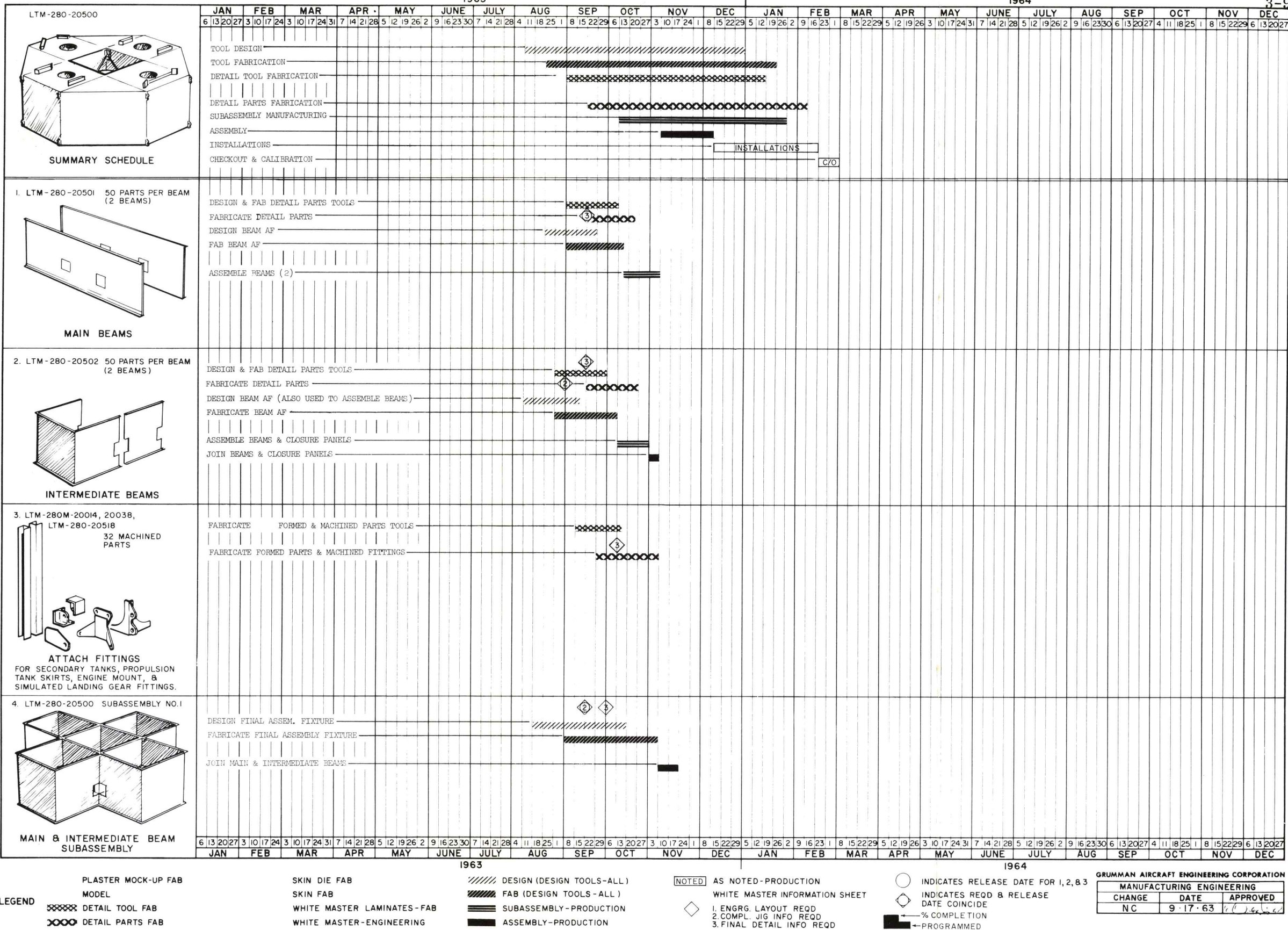
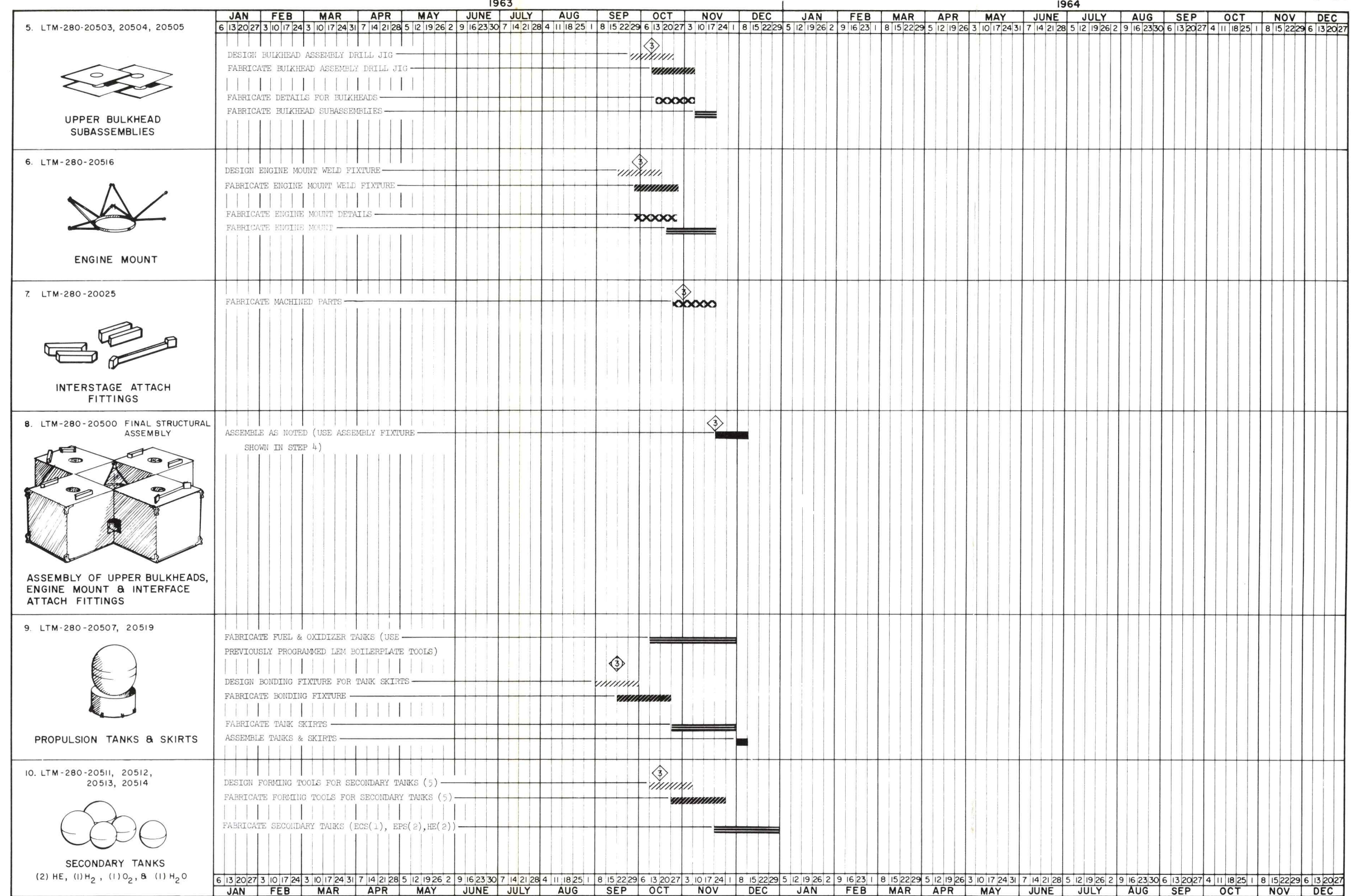


Figure 3-3. LEM TM-2 Descent Stage Manufacturing Schedule Sheet 2 of 4



# MANUFACTURING SCHEDULE LEM TM-2 DESCENT STAGE (CONTINUED)

3-10



LEGEND  
 PLASTER MOCK-UP FAB MODEL  
 XXXX DETAIL TOOL FAB  
 OXXX DETAIL PARTS FAB

SKIN DIE FAB  
 SKIN FAB  
 WHITE MASTER LAMINATES-FAB  
 WHITE MASTER-ENGINEERING

////// DESIGN (DESIGN TOOLS-ALL)  
 //// FAB (DESIGN TOOLS-ALL)  
 ===== SUBASSEMBLY-PRODUCTION  
 ===== ASSEMBLY-PRODUCTION

NOTED AS NOTED-PRODUCTION WHITE MASTER INFORMATION SHEET  
 1. ENGRG. LAYOUT REQD  
 2. COMPL. JIG INFO REQD  
 3. FINAL DETAIL INFO REQD

INDICATES RELEASE DATE FOR 1,2,8,3  
 INDICATES REQD & RELEASE DATE COINCIDE  
 % COMPLETION  
 PROGRAMMED

GRUMMAN AIRCRAFT ENGINEERING CORPORATION  
 MANUFACTURING ENGINEERING  
 CHANGE DATE APPROVED  
 NC 9-17-63

Figure 3-3. LEM TM-2 Descent Stage Manufacturing Schedule Sheet 3 of 4



# MANUFACTURING SCHEDULE LEM TM-2 DESCENT STAGE (CONTINUED)

3-11

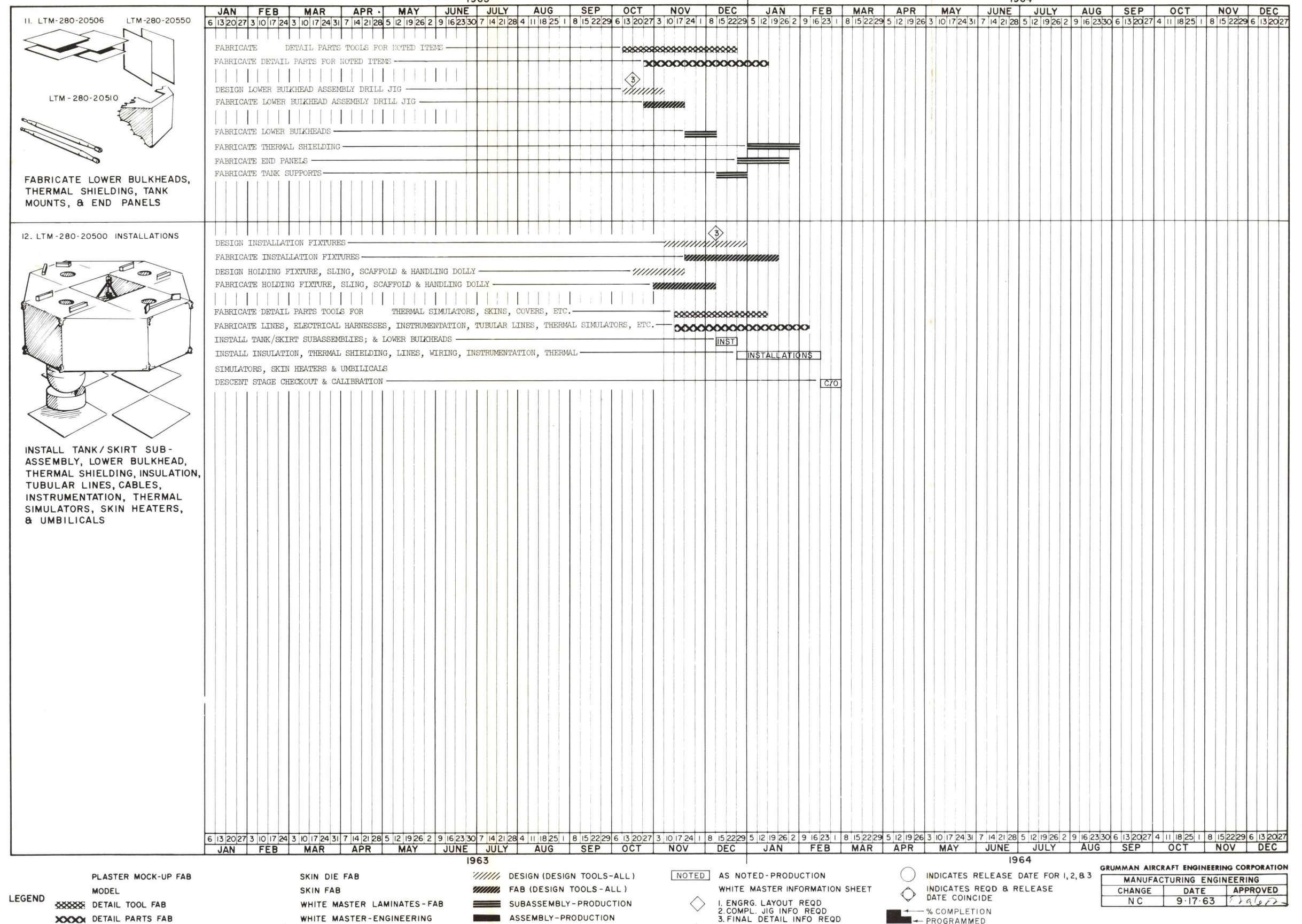


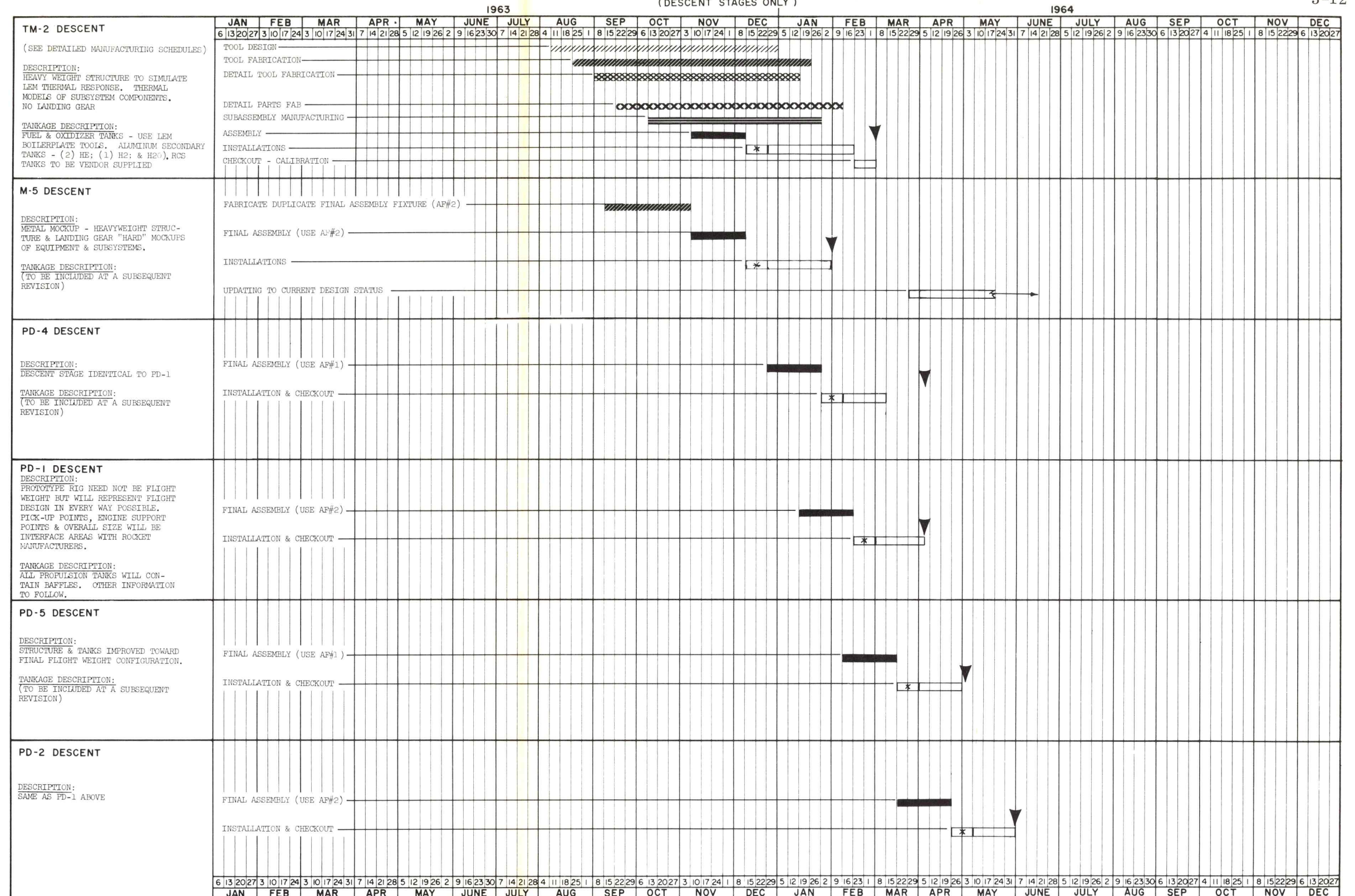
Figure 3-3. LEM TM-2 Descent Stage Manufacturing Schedule Sheet 4 of 4

# MANUFACTURING SCHEDULE SUMMARY

LEM TM-2; M-5; PD-4; PD-1; PD-5; & PD-2

(DESCENT STAGES ONLY)

3-12



**LEGEND**

PLASTER MOCK-UP FAB  
MODEL

DETAIL TOOL FAB  
DETAIL PARTS FAB

SKIN DIE FAB  
SKIN FAB  
WHITE MASTER LAMINATES - FAB  
WHITE MASTER - ENGINEERING

DESIGN (DESIGN TOOLS - ALL)  
FAB (DESIGN TOOLS - ALL)  
SUBASSEMBLY - PRODUCTION  
ASSEMBLY - PRODUCTION

\* INITIAL INSTALLATION - PROPULSION TANKS & LOWER BULKHEADS

AS NOTED - PRODUCTION  
WHITE MASTER INFORMATION SHEET

1. ENGRG. LAYOUT REQ  
2. COMPL. JIG INFO REQ  
3. FINAL DETAIL INFO REQ

INDICATES SCHEDULED DATE PER LEM PROGRAM PLAN SCHEDULE DATED 13 September 1963

○ INDICATES RELEASE DATE FOR 1, 2, & 3  
◇ INDICATES REQD & RELEASE DATE COINCIDE

GRUMMAN AIRCRAFT ENGINEERING CORPORATION		
MANUFACTURING ENGINEERING		
CHANGE	DATE	APPROVED
1, 2	9-24-63	

Figure 3-4. Manufacturing Schedule Summary  
LEM TM-2, M-5, PD-4, PD-1, PD-5, & PD-2



be fabricated in-house. PERT networks being developed for all items of GSE will be used as a guide for generating GSE/STE manufacturing schedules.

### 3.2 PLANNING

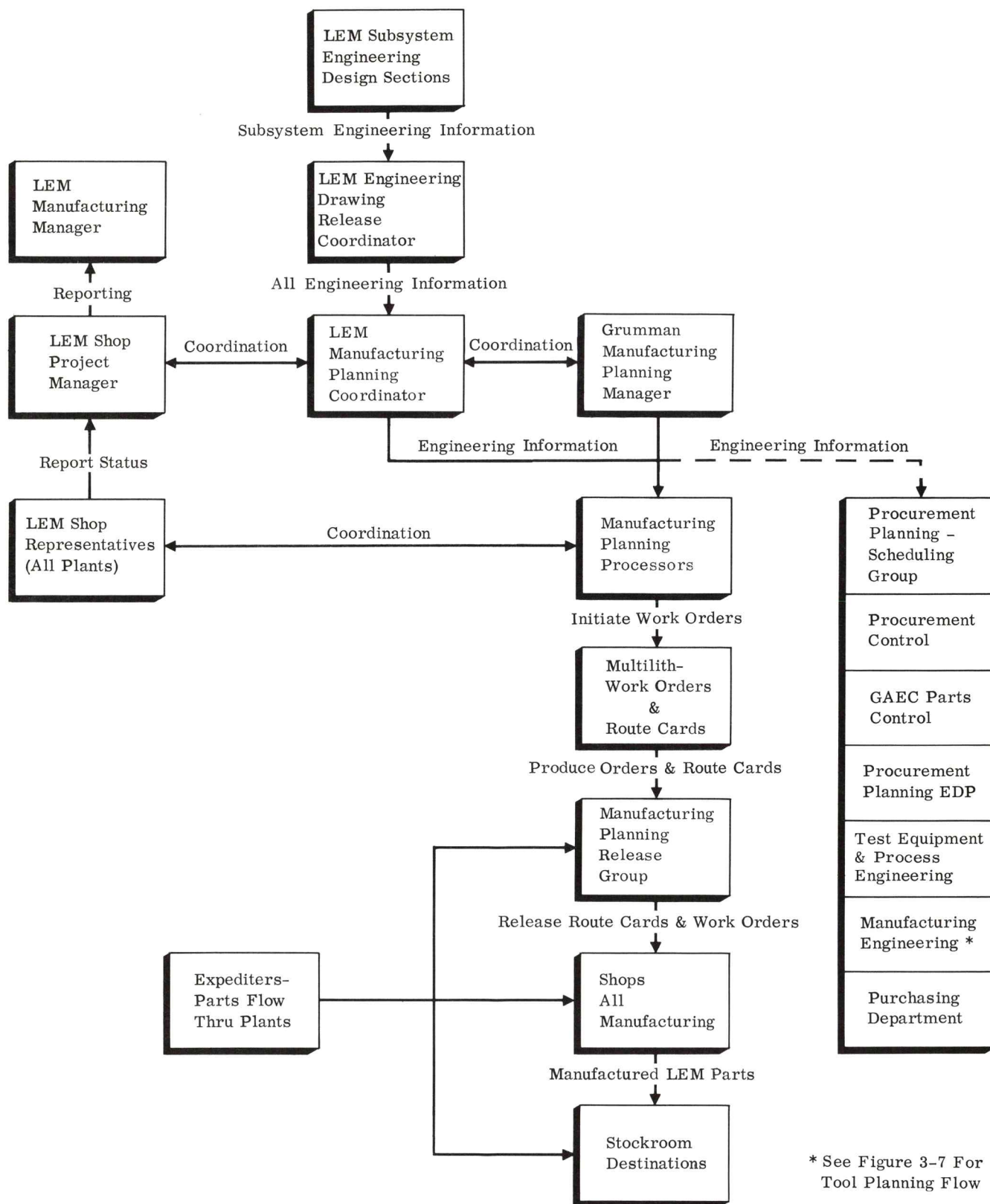
Conversion of engineering design information into LEM hardware and associated GSE/STE will be accomplished in accordance with the established planning procedures presently being applied to other Grumman aerospace manufacturing programs.

Planning operations for LEM, which include Manufacturing, tool and procurement planning are described in Sections 3.2.1 through 3.2.3. For clarity and convenience, GSE planning procedures are outlined in Section 7.

#### 3.2.1 Manufacturing Planning

A Manufacturing Planning Coordinator has been assigned to the LEM Program for implementation and control of the corporate manufacturing planning functions. He reports to the Grumman Production Planning Manager, and provides the LEM Shop Project Manager with program status information. He also serves as the central agent for distribution of engineering design data to all cognizant Grumman departments.

Effective manufacturing planning is accomplished through the utilization of the four primary functions: processing engineering information, multilith preparation of work orders and route cards, manufacturing planning releases, and expediting through shop departments. These functions are shown in Figure 3-5 and are described as follows:



\* See Figure 3-7 For Tool Planning Flow

Figure 3-5. Manufacturing Planning Flow

- LEM Processing personnel translate and convert engineering information into types of detail parts, assemblies, and installations required during the manufacturing program. This group also initiates shop authorization orders for all advanced, released, and changed design data. Constant liaison is maintained with all cognizant Grumman departments for a unified planning activity. As described in Section 3.3.8, key punched cards for configuration control, serialization, and traceability originate in this group. Thus, the processors, under the supervision of the LEM Manufacturing Planning Coordinator, are responsible for determining necessary action and for distribution of information through the manufacturing organization.
- Multilith personnel produce the shop work orders and route cards which were initiated by the processors. This group also issues the work orders to the delegated shop departments. Route cards are forwarded to the Manufacturing Planning Release Group, and master files are kept of all work orders. Sample work order and route cards are shown in Figure 3-6.
- Manufacturing Planning Release personnel evaluate all work orders and process these orders by establishing Kardex records which contain information such as part numbers, groupings, originating departments, and final part destination. Route cards issued to the shop departments state the applicable job charge number and indicate a given number of parts required. Part quantity releases are determined by periodic review of manufacturing program schedules. Kardex records are used to record part quantities ordered, date of issue, and total cumulative quantity. Original route cards are retained by Quality Control for filing.
- Expediting personnel maintain close coordination with the shop and parts control groups to provide constant monitoring of part availability requirements.

PART NUMBER LDW -280-10000-11		MODEL LEM		PART NUMBER LDW -280-10000-11		GROUP		RELEASE Blue			
PART NAME BRACKET				A 28010		JOB					
ASSEMBLY -3		JOB 20240-001-001 GROUP		DATE		QUANTITY INT. _____ LEFT _____ RIGHT _____					
		PER PLANE 1		MATERIAL		SIZE					
COMPONENT NAME Sta 114		DATE ISSUED 4-15-63									
MATERIAL 7075 -0 (clad)		DUE IN STOCK									
SIZE Proc 040 x 3 x 10											
ROUTING		QUANTITY		INSPECTION							
DEPT.	OPERATIONS	TOOLS	IN	OUT	CO.	CUST.					
201	Shear										
201	Flat Pattern Tool										
201	Burr & Degrease										
205	Verson Press Block										
205	Check Contour & Flanges										
209	Heat Treat to T4										
224/270	Heat Treat Inspection										
205	Straighten										
209	Age Harden										
270	Inspection										
207	Alodine										
211	Plant #10										
DESTINATION S-243		QUANTITY RECEIVED		DATE RECEIVED							
A 28010		RECEIVED BY		CLOCK #							

PART NUMBER LDW -280-10000-11		GROUP		RELEASE Blue	
A 28010		JOB			
DATE		QUANTITY INT. _____ LEFT _____ RIGHT _____			
MATERIAL		SIZE			
OPERATION					
SQUARE	SHEAR	BLANK			
MITRE	DRILL	PIERCE			
RIP	CHAMFER	FORM			
TRIM	ROUT	NIBBLE			
BURR	SEPARATE	TUMBLE			
		DEGREASE			
PART NUMBER LDW -280-10000-11		GROUP		RELEASE Blue	
A 28010		JOB			
PRESS		ROLL		TRIM	
DRAW		JOGGLE		GANGPUNCH	
BRAKE		STRETCH		POWER HAMMER	
PART NUMBER LDW -280-10000-11		GROUP		RELEASE Blue	
A 28010		JOB			
HAMMER		HEAT TREAT			
STRAIGHTEN		DRILL			
CHECK		TRIM			
WELD					

ROUTE CARD  
Accompanies Work  
Order And Shows  
Job No., Quantity  
And Release

WORK ORDER  
Authorizing Shop  
Effort

PART NUMBER LDW -280-10000-11		MODEL LEM		PART NUMBER LDW 280-10000-11		GROUP		RELEASE Blue			
BRACKET				A 28010		JOB					
ASSEMBLY LDW-280-10000-3		JOB 20240-001-001 GROUP		DATE		QUANTITY INT. _____ LEFT _____ RIGHT _____					
		PER PLANE 1		MATERIAL		SIZE					
COMPONENT NAME Sta 114		DATE ISSUED 4-15-'63									
MATERIAL 7075-0-(clad)		DUE IN STOCK									
SIZE Proc 040 x 3x 10											
ROUTING		QUANTITY		INSPECTION							
DEPT.	OPERATIONS	TOOLS	IN	OUT	CO.	CUST.					
201	Shear										
201	Flat Pattern Tool										
201	Burr & Degrease										
205	Verson Press Block										
205	Check Contour & Flanges										
209	Heat Treat to T4										
224/270	Heat Treat Inspection										
205	Straighten										
209	Age Harden										
270	Inspection										
207	Alodine										
211	Plant #10										
DESTINATION S-243		QUANTITY RECEIVED		DATE RECEIVED							
A 28010		RECEIVED BY		CLOCK #							

PART NUMBER LDW -280-10000-11		GROUP		RELEASE Blue	
A 28010		JOB			
DATE		QUANTITY INT. _____ LEFT _____ RIGHT _____			
MATERIAL		SIZE			
OPERATION					
SQUARE	SHEAR	BLANK			
MITRE	DRILL	PIERCE			
RIP	CHAMFER	FORM			
TRIM	ROUT	NIBBLE			
BURR	SEPARATE	TUMBLE			
		DEGREASE			
PART NUMBER LDW -280-10000-11		GROUP		RELEASE Blue	
A 28010		JOB			
PRESS		ROLL		TRIM	
DRAW		JOGGLE		GANGPUNCH	
BRAKE		STRETCH		POWER HAMMER	
PART NUMBER LDW -280-10000-11		GROUP		RELEASE Blue	
A 28010		JOB			
HAMMER		HEAT TREAT			
STRAIGHTEN		DRILL			
CHECK		TRIM			
WELD					

Figure 3-6. Sample LEM Shop Work Order  
And Route Card



### 3.2.2 Tool Planning

In accordance with the manufacturing planning approach, a LEM Methods Engineering Coordinator has been assigned to supervise the corporate tool planning functions. He reports directly to the Supervisor of Grumman Methods Engineering and provides program status information to the LEM Project Manufacturing Engineer. Tool planning procedures are shown in Figure 3-7.

The Methods Engineering Group receives all advanced, released and changed LEM engineering information from Manufacturing Planning. Information receipt dates and change status are entered on Grumman Form GT-2009-R1 for a continuous record of drawing disposition.

Planning and ordering of LEM tools is accomplished using the "Methods Engineering Record Sheet, ME 269", which is shown in Figure 3-8. Copies are forwarded to Manufacturing Planning for tooling information and also to Tool Scheduling for issuance of tool fabrication orders.

All LEM tooling revisions are initiated by the Methods Engineering Group using the "Re-work Sheet, ME-269A", which is also shown in Figure 3-8. The procedures for distribution and ordering are basically the same as described for original tools.

Tool Shops manufacture non-designed LEM detail tools using the engineering information and the instructions stated in the ME 269 Form. Where applicable, tool shops follow the standards outlined in the Grumman "Detail Tool Manual".

Designed tools and equipment for the LEM Program are manufactured and identified in accordance with the individual drawings. All tooling, both detail and assembly, is inspected by the Tool Inspection Group of the Quality Control Department.

Grumman is using an existing tool and equipment identification system for the LEM Program. A number for a piece of equipment or a tool is formed by adding a letter code to a LEM part number. If the part number is LPT 280-10026-11, three typical tools to make

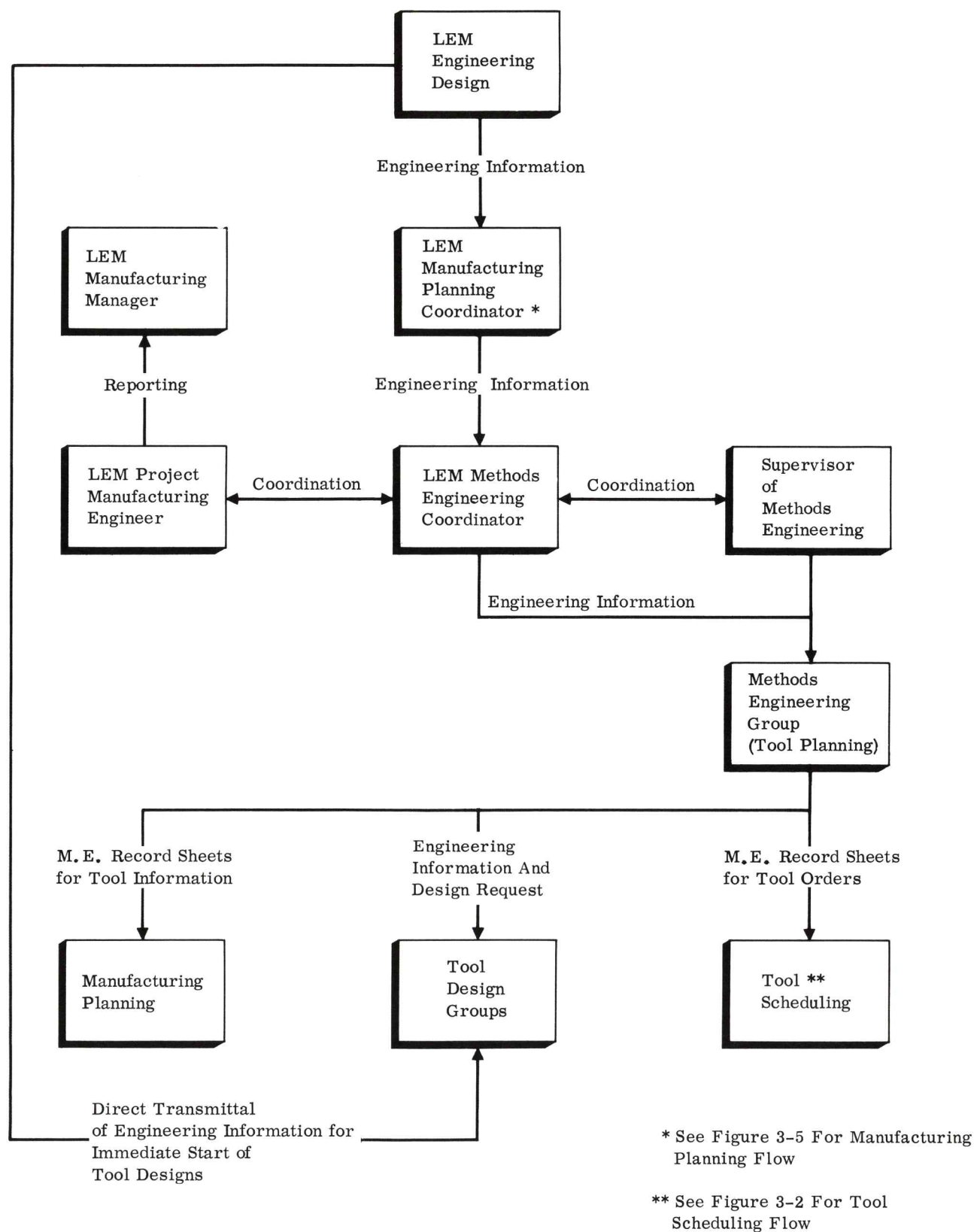


Figure 3-7. Tool Planning Flow

[illegible][illegible]

ME - 269A Methods Engineering Tool Rework Record

ME - 269 Methods Engineering Record Sheet

Figure 3-8. ME - 269 Record Sheets

this part would be LPT 280-10026-11 ADJ, LPT 280-10026-11 DRJ, and LPT 280-10026-11 ICF. A single part number plus a code thus represents a basic number for a tool or piece of equipment. There is only one exception to this rule; when a tool can make a part and its opposite, the odd and even dash numbers become part of the tool number, i.e., LPT 280-10026-11-12 DJ. Grumman Tool and Equipment Codes are shown in Figure 3-9.

Occasionally, more than one work station will be used to meet LEM manufacturing schedules. This will require that a duplicate of an existing tool be made. By simply adding #2 to the original tool number, the new tool number is derived, i.e., LPT 280-10026-17 DJ#2. Note that the number symbol (#) must be included.

There are many parts that require several tools to complete a basic operation (i.e., one part might require three separate drilling operations and therefore three separate jigs). The Designer assigns the basic tool number to the drill jig performing the first of these operations; the basic tool number, followed by the number 2 and 3, etc., for subsequent operations, but which may or may not be the actual second or third operation on the part.

- First drill jig ordered - LPT 280-10026-7 DJ
- Second drill jig ordered - LPT 280-10026-7 DJ2
- Third drill jig ordered - LPT 280-10026-7 DJ3

Note, the last number is for identification only, not to determine sequence of manufacturing operations.

If a tool or piece of equipment can be used to perform the same operation on more than one part, the Designer adds a star (\*) to the basic number (i.e., LPT 280-10026-DJ#). The Methods Engineer lists all other parts made with this basic tool. Although the star (\*) must be stamped on the physical tool, all other part numbers must not appear on the tool. By convention, the basic tool number is that one bearing the lowest part number of a group of parts, for which multiple usage tools are applicable.

ADJ	Assembly Drill Jig	GHE	General Handling Equipment	PMF	Portable Mill Fixture
AF	Assembly Fixture	GHT	General Hand Tools	PNT	Punch and Nibble Template
APT	Air Punch Template	GMC	General Miscellaneous Cutter	PRF	Portable Router Fixture
ARB	Arbor	GMX	Miscellaneous Gage	PRJ	Pedestal Router Jig
BB	Bending Block	GPT	Gang Punch Template	PRT	Press Brake Die Template
BD	Blanking Die	HB	Hammer Block	PST	Punch and Scribe Template
BDT	Blanking Die Template	HBT	Hammer Block Template	PT	Punch Template
BKB	Bucking Bar	HD	Hufford Die	PTD	Pierce and Trim Die
BMF	Boring Mill Fixture	HDT	Hufford Die Template	PTN	Pattern
BOF	Bonding Fixture	HE	Handling Equipment	RAF	Radial Arm Router Fixture
BPD	Blank and Pierce Die	HF	Holding Fixture	RCT	Roll Contour Template
BPT	Blank and Pierce Die Template	HFD	Hydroform Die	RD	Roll Die
BRF	Broaching Fixture	HFT	Hydroform Die Template	RDT	Radial Arm Drill and Router Template
BSP	Special Adapter	HPB	High Pressure Block	RF	Riveting Fixture
BT	Brake Template	HRJ	Hand Router Jig	RJ	Reaming Jig
BXD	Blank, Pierce and Form Die	HTA	Heat Treat Accessories	ROJ	Router Jig
BXT	Blank, Pierce and Form Die Template	HTF	Hydrotel Fixture	RVS	Rivet Set
BZF	Brazing Fixture	IBF	Induction Brazing Fixture	SAF	Safety Equipment
CBT	Pneumatic Router Box Template	ICF	Inspection Checking Fixture	SC	Spinning Chuck
CC	Contour Cam	ICT	Inspection Checking Template	SCA	Spinning Chuck Accessories
CF	Checking Fixture	IF	Installation Fixture	SCF	Scribe Fixture
COF	Combination Fixture	IJ	Installation Jig	SCL	Special Clamp
CP	Plug	JD	Joggle Die	SCT	Scribe Template
CR	Contour Rollers	JDT	Joggle Die Contour Template	SD	Stretch Die
CRD	Corner Radius Die	JI	Jaw Inserts	SDM	Maust Stretch Die
CRF	Chamfer Routing Fixture	JLT	Joggle Location Template	SDR	Schematic Drawings
CT	Contour Template	JST	Joggle Set-Up Template	SDT	Shear and Drill Template
DA	Die Accessories	LF	Lathe Fixture	SF	Saw Fixture
DD	Draw Die	LT	Locating Template	SKF	Skin Mill Fixture
DDR	Draw Die Rubber	LTE	Lab Test Equipment	SMF	Spar Mill Fixture
DDT	Draw Die Template	MA	Milling Accessories	SPT	Strippit Punch Template
DHD	Drop Hammer Die	MAT	Masking Template	SRJ	Setback Router Jig
DHR	Drop Hammer Male Die	MCA	Machine Accessories	SRT	Shear Template
DID	Diameter Die	MCT	Master Contour Template	ST	Saw Template
DJ	Drill Jig	MCX	Numerical Control Media Continuous Path	STE	Silk Screen Stencil
DKD	Dinking Die	MDP	Master Drill Plate	STT	Scribe and Trim Template
DKT	Dinking Die Template	MEX	Numerical Control Media Engineering	SUG	Set-Up Gage
DMD	Dimpling Die	MF	Milling Fixture	SWA	Spotweld Accessories
DP	Drill Plate	MFB	Male and Female Block	SWD	Swaging Die
DRB	Drill and Router Board	MFT	Male and Female Block Temp.	SWF	Spotweld Fixture
DRJ	Drill and Ream Jig	MOD	Model	SWT	Spotweld Template
DRP	Drill and Ream Plate	MOF	Molding Form	TBA	Tube Bending Accessories
DRT	Drill and Router Template	MOT	Molding Template	TBD	Tube Bending Die
DST	Drill and Scribe Template (Formed)	MP	Master Part	TD	Trim Die
DSU	Drill and Scribe Template (Flat)	MPD	Miscellaneous Press Die	TEQ	Testing Equipment
DT	Drill Template (Formed)	MPT	Miscellaneous Press Die Template	TFT	Tube Forming Tools
DU	Drill Template (Flat)	MPX	Numerical Control Media Point To Point	TP	Test Plug
DTJ	Drill and Trim Jig	MTX	Numerical Control Media Tooling	TTA	Arvey Die Master
ED	Expanding Die	MUF	Mockup Fixture	TTB	Jig Master
EHB	Electrical Wiring Harness Board	OAF	Optical Alignment Fixture	TTC	Jig Template
ERD	End Radius Die	OE	Office Equipment	TTD	Control Master
ERF	Erco Riveting Fixture	OTA	Optical Tooling Accessories	TTE	Master Tool Template
EXT	Expendable Tools	PB	Press Block	TTF	Facility Gage
FAD	Flattening Die	PBD	Press Brake Die	TTG	General Tooling Tool
FD	Form Die	PBH	Combination Press and Hammer Block	TTH	Master Flat Pattern Template
FDT	Forming Die Template	PBT	Press Block Template	TTP	Flat Pattern Production Template
FLD	Flanging Die	PCD	Pierce and Cut-Off Die	TTR	Record Template
FPC	Formed Piece	PCT	Part Check Template	TTW	Wiping Template
FPD	Form and Pinch-Off Die	PD	Piercing Die	UPT	Upholstery Template
FT	Form Tool	PDT	Pierce Die Template	URT	Universal Router Template
FTD	Form and Trim Die	PE	Plating Equipment	WA	Welding Accessories
FWF	Flashwelding Fixture	PF	Profiling Fixture	WD	Washer Die
FWM	Flex White Master	PLF	Proof Loading Fixture	WF	Welding Fixture
GCT	Grind Check Template			WM	White Master
GF	Grinding Fixture			WPB	Verson Press Block
				WPD	Wiping Die
				YOK	Squeezer Yokes

Tool Category Prefix (Example: XADJ, YAF, ZSRJ):

X - Acceptance Gages  
Y - Acceptance Gages to be saved from routine scrap  
Z - To be saved from routine scrap

Figure 3-9 Grumman Tool and Equipment Letter Codes.



Departmental Spare Requirements Lists are prepared for Grumman fabricated parts and subassemblies.

Further, the Procurement Planning Department is the central agency for issuance, control, and recording of engineering information for the manufacturing departments. These releases are distributed in accordance with Manufacturing Planning instructions.

### 3.3 METHODS AND CONTROLS

Satisfying the LEM Program objectives requires formal and proven techniques for control of schedules, costs, manufacturing reliability, subcontractor activities, mechanical/electronic interfaces, and for traceability and configuration control. Methods for maintaining these controls are described in Sections 3.3.1 through 3.3.8.

#### 3.3.1 Mechanical Interface Control

Planning and managing the LEM interchangeability/replaceability program for mechanical interfaces will begin by establishing requirements for interface design, tolerance ranges, master gage control, matched tooling, manufacturing/inspection procedures, and an I&R List.

Although the I&R List is primarily an Engineering responsibility, Manufacturing Engineering will generate a preliminary list in conjunction with Engineering. Primary considerations in establishing this list include NASA I&R Requirements, part design, reliability, and producibility. To attain the required producibility features necessary for I&R, Manufacturing Engineering reviews and influences part design concepts. As basic Engineering designs progress, Manufacturing Engineering will revise and up-date the preliminary list and negotiate with Engineering to establish the final I&R List. This list will be submitted by Engineering for NASA approval.

Successful accomplishment of interchangeability/replaceability requirements for any given component is directly related to the degree of tooling and the method of fabrication. Hard

masters will be utilized to achieve full interchangeability at structural interface points such as engine mounts, landing gear and adapter connect fittings, and separation plane fittings. Doors and access panels will be master controlled at attach points only, thus minimizing costly trim and contour mastering.

Basic tooling information which is utilized for fabrication of masters, is represented by master contour templates, tooling mockups, and white masters. Additional information is obtained from basic engineering geometry and incorporated in the master gages.

The four primary areas which require mechanical interface control are described below:

- Docking interfaces between LEM and the Command Module and integration of the LEM with the Apollo System will require Grumman coordination and agreements with NASA and NAA. Since NAA is responsible for docking arrangements and interfaces, it is expected that master control tooling, if necessary, will also be provided to Grumman by NAA. Integration of LEM with the Apollo System will be accomplished using structural provisions located within the NAA Service Module Adapter. Although these structures are an NAA responsibility, the assignment of the contractor responsible for the LEM/SM Adapter interface design details has not been established.

Thus, Grumman will use or will provide master control and inspection tooling in accordance with future NASA decisions.

- Mechanical interfaces between fluid, electrical/electronic and structural LEM subsystems and components will require Grumman coordination with NASA and subcontractors. Some non-critically located subsystem components will be coordinated to the Structural Subsystem by manufacturing to specified engineering drawing tolerances, without master gage tooling. However, subcontractor supplied components such as ascent/descent rocket engines, reaction control engines, and all other critically positioned subsystem components will require master gage coordination. A proven tooling policy will be applied to satisfy the interchangeability requirements for structure/subsystem mating.

Grumman will manufacture a master gage to coordinate jig and fixture fabrication for the Structural Subsystem. An inspection checking fixture will be provided for assurance of product quality. A master and inspection checking fixture will also be supplied to the subcontractor. Thus, Quality Control acceptance, as dictated by the use of the inspection checking fixtures at both Grumman and at subcontractor locations, will assure the interchangeability of corresponding interfaces. This plan and documented vendor requirements are further detailed in Section 3.3.4.

- Mechanical interfaces between the major subassemblies within the Landing Gear and Structural Subsystems are controlled by the in-house tooling, manufacturing, and quality control programs. Prime examples of these interfaces are the mating of ingress/egress hatches to the crew compartment tunnels, seats to the support structures, ascent/descent separation plane, and landing gear to the descent stage structure. Grumman assembly tools used to complete these interchangeability requirements will be coordinated using master gage control.

In addition, some fixtures used to establish the ascent/descent major sub-assembly jig point locations must also be coordinated with master gages. This concept assures the necessary tolerance control during the structural assembly sequence which is shown in Section 4, and also provides an efficient means for duplication of major tools.

Compound curved areas of the Structural Subsystem configuration will be controlled by the plaster tooling mockup program. These mockups serve as masters for the development and coordination of all sheet metal tools. Tooling mockups will not be required for the descent stage prime structure since the geometry consists of straight line elements. Local mockups and models will be provided for secondary structure such as indented skin details.

- Whenever possible, coordination between the mechanical interfaces of LEM subsystems and associated Handling and Transportation GSE will be achieved without need for master gage tooling. On occasion, the GSE may be required to support the LEM subsystems in interchangeable areas. This coordination of subsystems and in-house manufactured GSE can be readily accomplished since Grumman will retain a complete set of all LEM master gages.

### 3.3.2 Electrical/Electronic Interface Coordination

During the early stages of LEM development, Design Control Specifications will be written and will include requirements for coordination of electrical/electronic interfaces. With this information, a cable and harness checker can be programmed to make the necessary checks concerning signal flow paths.

Once the subsystem design has been formally released, interfaces cannot be revised, either by Grumman or the vendor, without prior approval of the LEM Business Office. Since Grumman subsystem and GSE engineers are in constant contact with the vendors,

proposed changes can be reviewed and documentation can be monitored. Subsequent to approval, GSE/STE changes can be incorporated to accommodate revised interface requirements.

### 3.3.3 Manufacturing Reliability Control

Because of the direct relationship between ultimate LEM reliability and producibility, constant liaison is presently being maintained with Design Engineering to provide information regarding the latest manufacturing and testing techniques, processes, and equipment. Whenever necessary, producibility surveys will include the manufacture of sample structural elements to investigate manufacturing feasibility of the structural design. These surveys will assist in establishing the trade-offs between design concepts and producibility.

Grumman will make maximum use of proven fabrication techniques and available manufacturing equipment. This approach, rather than attempting to exceed the present state-of-the-art, will assure optimum reliability and on-schedule performance.

If new cost or performance improvement concepts in manufacturing techniques are indicated during the course of the LEM Program, the Grumman Manufacturing Development Organization will immediately institute programs for method or process development. However, the new technique will be thoroughly proven and tested while LEM fabrication is maintained using an interim proven technique.

The LEM Structural Subsystem manufacturing breakdowns shown in Section 4 were influenced toward producibility by giving full consideration to manloading, lead times, tolerance requirements, and assembly and handling convenience.

Copies of applicable specifications are maintained in the office of the shop foreman. It is his responsibility to supply parts and assemblies which conform to these manufacturing standards. Specifications are also maintained by the Quality Control Department and are used during inspections to verify product conformance.

Control of product quality and tool/equipment accuracy is assured by virtue of the procedures outlined in the "Grumman Quality Control Program Plan", Report LPL-81-1, Volume I.

The LEM Quality Control Plan sets forth the Grumman procedures for implementing the requirements of NASA Quality Publication NPC-200-2 and Contract NAS 9-1100. The ultimate objective of this plan is to provide optimum quality assurance that the LEM meets design criteria, contract reliability and performance levels, and maintainability and serviceability requirements.

The Manufacturing, Assembly, and Inspection Record (MAIR) is shown in the Quality Control Plan and will be used as documentary evidence of all manufacturing and inspection operations completed for LEM assemblies.

Inspection and test plans are described for detail parts, assembly, installations, checkout, and for witnessing and verifying the acceptance test programs. In addition, plans are described for tool inspection, process control, monitoring of clean room operations, and calibration of precision measuring and test equipment.

Consequently, the manufacturing concepts for "building producibility into the system", and the quality control measures integrated throughout all LEM development phases are a vital contribution for achieving optimum LEM reliability.

#### 3.3.4 Control of Subcontractor Tooling and Manufacturing Activities

Grumman has established a four phase program for control of LEM subcontractor manufacturing performance. The objectives are to monitor technical approaches, and to assist the LEM Program Management and Business Offices in the control of subcontractor schedule and financial performance. This program is outlined as follows and is discussed in Paragraphs 3.3.4.1 through 3.3.4.4:

- Review and analysis of all subcontractor cost and technical proposals, with regard to tooling, equipment, processes, and manufacturing approaches.
- Contribution to the "Vendor Requirements" documents for inclusion of associated manufacturing program requirements.
- Monitoring and review of subcontractor manufacturing programs.
- Procurement control to notify the LEM Purchasing Office of subcontractor delivery performance.

#### 3.3.4.1 Review and Analysis of Subcontractor Proposals

Grumman assigned representatives to the "Effort Analysis Team" are engaged in a continuing review of proposed subcontractor approaches to tooling, equipment, processes, and manufacturing. The review and analysis of proposals and subsequent selection of a subcontractor has been completed as follows:

- Rocketdyne                      - Descent Propulsion Subsystem - Engine
- STL                                - Descent Propulsion Subsystem - Engine  
(Parallel Engine Development Program)
- Hamilton-Standard        - Environmental Control Subsystem
- Bell Aerosystems        - Ascent Propulsion Subsystem - Engine Reaction Control Subsystem - Propellant Tanks
- Marquardt                    - Reaction Control Subsystem - Propulsion and Thrust Chambers

- RCA
  - Navigation and Guidance Subsystem - Rendezvous and Landing Radar
  - Stabilization and Control Subsystem - Attitude and Translation Control, Descent Engine Control, Guidance Coupler, and the In-Flight Monitor Components
  - Communications Subsystem
  - Instrumentation Subsystem - In-Flight Test System
- Pratt & Whitney
  - Electrical Power Subsystem - Fuel Cell
- Radiation
  - Instrumentation Subsystem - Pulse Code Modulation and Timing Equipment
- Leach
  - Instrumentation Subsystem - Data Storage Equipment

As a prerequisite to formal contract acceptance, the manufacturing representatives of the "Effort Analysis Team" have performed the following functions and will continue their activities for future vendor negotiations:

- Evaluate technical approaches and cost estimates for tooling, equipment, process, and manufacturing tasks.
- Determine application and use of special test equipment.
- Review the basis for the cost estimates and evaluate changes due to original task omissions, reestimates of original tasks, and new tasks resulting from schedule and vendor work statement changes.
- Preliminary review of manufacturing approaches for compatibility between the mechanical and electrical/electronic interfaces of corresponding subsystems or components.

### 3.3.4.2 "Vendor Requirements" Documentation

Statements regarding the procedures and concepts required for satisfactory vendor manufacturing performance are included in the "Vendor Requirements" documentation. These documents being completed for applicable LEM subsystems show vendor manufacturing guidelines, program controls which Grumman will exercise, and services and/or items, which will be supplied to facilitate vendor manufacturing programs.

"Vendor Requirement" Document LVR-270-4, dated 12 March 1963, for the LEM Descent Propulsion Subsystem contains the manufacturing conditions developed by Grumman for assurance of satisfactory vendor performance. Excerpts from LVR-270-4 are as follows and are generally typical for all documentation of this type:

- Processes - The vendor shall submit a list of process specifications to be used in the manufacture of the rocket engine. Where a process is controlled by an internal document, rather than a government specification, the entire document shall be submitted for approval.
- Grumman Supplied Tooling - It is the intent of Grumman to supply any tooling necessary for mechanical interface coordination. Each deliverable item will be considered acceptable for physical dimensions of mechanical interfaces by Grumman only when it has been certified by Grumman Quality Control Personnel as having been checked using a Grumman supplied inspection checking fixture. Grumman will make available master gauges if required by the Vendor.

- Dimensional tooling is to be provided by the vendor in order to adequately meet all of the hardware requirements as specified herein. The Vendor shall indicate what limitations and/or assumptions have been made in providing the tooling program. For a LEM component that is used commonly on the Apollo Command Module or Service Module, the same acceptance procedure is required as specified above. However, due to the common usage, it may be necessary for the master gages and/or checking fixtures to originate with a source other than Grumman. The vendor shall specify that the proposed tooling is adequate for fabrications of \_\_\_\_\_ quantities of parts (specified by components referenced in LVR-270-4, Item 1.1) at the rate of \_\_\_\_\_ parts per month. (Item 1.1 includes the list of hardware components to be included in the vendors task description.)
- Special Tooling Report - After delivery of the first unit(s) of supplies called for in this purchase order, Vendor shall submit to Grumman in accordance with Table I, a list of tools per Manufacturing Engineering Form 224 and completed as of the delivery of the first unit, detailing the quantity, the description, tool number and the individual cost (reasonably estimated if necessary) of each tool together with the part number for which it is used. (Table I is the Documentation Type and Delivery Schedule included in the Vendor Requirements document.)
- Quarterly Special Tooling Report - Vendor shall submit in accordance with Table I, a similar list of tools which have been completed since the submission of the previous list. If there are no additional completed tools to report at the date of quarterly submission, a statement to that effect will be submitted. The completion invoice shall be accompanied by a list of any tools completed and not previously reported.

- Tool List - Each special or quarterly special tooling list shall be certified as follows: "We certify that we, as custodian, are accountable to Grumman for the above tools, that they are the property of the U.S. Government, that they have been so identified and that they are available for inspection by Government Representatives".
- Tool and Equipment Codes - Vendor shall identify all tools using Grumman Tool and Equipment Codes. In addition, the vendor may use his own existing identification system.
- Manufacturing Plan - The Vendor shall prepare a manufacturing plan that includes such items as plans, schedules, methods and controls. This is to be submitted 1 month after purchase order go-ahead.

#### 3.3.4.3 Monitoring and Review of Subcontractor Manufacturing Programs

The Grumman manufacturing team will participate in the Monitoring and Review Plan as outlined in the "Vendor Requirements" documents. This plan is described below:

- Quarterly Program Review Meetings. - This is a 1-day review devoted to program progress and will include a review of manpower, facilities, organizational problems, cost, and schedules. This will be held at the vendor's facilities.
- Bi-Monthly Meetings. - The bi-monthly meetings between the Vendor and Grumman constitute the primary personal contact for review and monitoring of the detail development program at the working level. On specific occasions it might be desirable to have second tier subcontract personnel in attendance at these meetings. Minutes will be published by Grumman and the appropriate content thereof, as approved by the LEM Purchasing Manager, will constitute technical direction to the vendor. Meeting agendas will be jointly determined between the Grumman and vendor project personnel at least 1 week prior to each meeting. These meetings will normally convene at Grumman on a scheduled basis. They may, on occasion, be convened at the vendor's plant.

- Other Meetings. - From time to time as the program develops, there will be a need for less formal meetings primarily for the exchange of technical information. It is desired that there be sufficient mutual confidence between Grumman and the vendor that these meetings can take place with minimum disruption of useful work. The object is the exchange of technical information. Technical direction can originate only from the designated subsystem engineer. Technical direction resulting in cost changes cannot be acted upon until authorized by purchase order amendments.

In addition to the Monitoring and Review Plan, Grumman will closely control the mechanical and electrical/electronic interface programs (as defined in Sections 3.3.1 and 3.3.2) by maintaining personal liaison with NASA, NAA, and cognizant subcontractors.

Support will also be provided to the LEM Business Office when necessary for evaluation of cost and schedule performance pertaining to the vendor manufacturing, tooling, and equipment programs.

#### 3.3.4.4 Procurement Control

The Procurement Control Department, operating as an integral part of the Manufacturing organization has the prime responsibility of notifying the LEM Purchasing Office of contract items and materials in limited supply. This effort, and the subsequent follow-up for Grumman use of received components, is accomplished in the following manner:

- Expedite the procured items to the Grumman departments to meet LEM manufacturing schedules.
- Control and monitor Grumman repair of defective LEM purchased items if such items are considered repairable and if they are critically needed to support the manufacturing program.

- Monitoring of purchased parts which are borrowed or permanently diverted from the manufacturing cycle.
- Allocation and control of serialized subsystems.
- Coordinate procured items needed for spares, field changes, and GSE/STE.
- Publish critical shortage documents for purchased parts.
- Coordinate the efforts of receiving and inspection on critical purchased items by priority.

### 3.3.5 Schedule Control

Grumman will utilize PERT/Time reports for analyzing current manufacturing progress and for projecting future performance. PERT specialists have been assigned to assist the LEM Manufacturing Management Staff for providing the tooling, equipment, and manufacturing contributions to the over-all PERT program.

The primary responsibilities of these specialists are as follows:

- Coordinate and assure the comprehensive development of all manufacturing milestones.
- Contribute to the preparation and up-dating of the diagrams.
- Collect initial and revised time estimates for manufacturing activities.
- Analyze computer output data for up-dating requirements.
- Distribution of PERT information to the Manufacturing Management Staff.

In addition to monitoring of Grumman schedules, PERT/Time reports will be used as a means of evaluating and adjusting schedules for the receipt of materials, vendor activities, information releases, and management of manufacturing manpower.

Normalizing the shop workload for maintaining tool fabrication and LEM manufacturing schedules will be accomplished through an analysis of the specific condition and the application of one or more of the following procedures:

- The flexibility of the Grumman organization allows for the immediate transfer of personnel from one department or section to another for optimum skill utilization. Consequently, a stable level of skilled personnel is maintained, and efficient resolution of critical priority items in tooling and product manufacture is assured. This same flexibility is inherent in the tool and equipment design sections.
- Other Grumman shop departments or plants which maintain the required manufacturing specialty are frequently contacted for "open-time", thus allowing for temporary transfer of the manufacturing task.
- The subassembly breakdown sequence is thoroughly analyzed to determine whether the priority of the component can be temporarily altered to permit installation at a later assembly stage.
- In selected instances, the authorization of overtime, multiple-shift shop operations, and/or maximum manloading of assembly stations is an effective means for solution.

- Occasionally, maximum manloading is hampered by the relatively small size or the confining configuration of the component. Based on an analysis of over-load duration and economics, duplicate tools or a refined subassembly tooling breakdown may be provided to improve manloading for maintaining schedule performance.
- Some detail parts are re-processed and in some cases are re-designed by engineering for utilization of less critical equipment and facilities.
- A stable machined parts workload is maintained by producing initial quantities at Grumman and subcontracting the balance. If schedules allow, the complete release of machined parts may be subcontracted.

### 3.3.6 Cost Control

Performance within the established budgets for the manufacturing functions, tooling equipment, and processes is a major goal of the LEM manufacturing program.

Expenditures will be monitored using a PERT Companion Cost System as outlined in the Program Master Plan. Present methods and procedures for controlling the manufacturing functions can be adapted to generate and monitor a PERT Companion Cost System.

Electronically processed expenditure reports, prepared and distributed by the Accounting Department, form the basis for the accumulation of all cost monitoring data.

Because of the recurring nature of the manufacturing operation and the primarily non-recurring nature of tool and equipment functions, the allocation of the budgets for implementing the two efforts must be somewhat different. The manufacturing budget is distributed to the various shop departments who are assigned work tasks in the LEM Program. To make this distribution more meaningful and functional in control, the budget is further subdivided

into contractual line items, subsystems, and major systems. This breakdown will be developed in accordance with the future requirements of the PERT Companion Cost System.

The established accounting codes of the company will be assigned as usual to indicate the type of labor (manufacturing as distinct from engineering, etc.) and item identification. The introduction of cost coding into the work orders authorizing the Manufacturing Department to proceed with its tasks, provides the proper account to which labor is charged. The EDP equipment summarizes the actual labor charges in a manner which allows for periodic summaries of:

- Planned vs actual man-hour expenditures.
- Planned vs actual manpower utilization.
- Percent cost expended vs percent hardware accomplishment.

The tabulations supplied by EDP make it possible to distribute control data to all levels of management at frequent intervals. An important element in this program of planned expenditures is planned cost reduction on selected learning curves which tend to demand improvement in techniques, methods, and programming.

The system is flexible enough to readily encompass changes in budget allotments, planned expenditures, as well as changes in scope, and has the additional advantages of ready comprehension throughout the organization.

Tool and equipment budget breakdowns will also be developed in accordance with the requirements of the PERT Companion Cost System. Approval to proceed with any given task is being, and will continue to be, managed in the following manner:

- As engineering information is generated, cognizant LEM key personnel who represent the tooling and equipment design functions, prepare Work Authorization Statements. These statements contain itemized estimates of anticipated group effort.
- The LEM Project Manufacturing Engineer or the Test Equipment and Process Project Engineer review the Work Statements to determine conformance with the Manufacturing Plan and the validity of the estimates. The Project Engineers are assisted in these reviews by the LEM Project Planning and Control Specialists.
- Approval of the Work Statements by the cognizant Project Engineer constitutes authorization to proceed with the work tasks.
- Work Authorization Statements are revised as dictated by further engineering information. Again, each revision requires approval of the Project Engineer.
- Tool and equipment fabrication is initiated by Shop Work Orders which contain the estimated cost for each task. This Work Order constitutes the authorization for a particular shop department to proceed with a specific task.
- Electronically processed feedback of actual expenditures are compared to the Work Statement Budget. The Project Planning and Control Specialists forward the comparative data to the Project Engineers. Thus, immediate action can be initiated to assure lowest over-all program costs.

### 3.3.7 Parts Control (Production Control)

Parts Control, as an adjunct of the Plant Superintendents Office, assists the individual plants by monitoring the LEM manufacturing process, with special emphasis on the expeditious flow of parts and materials. A Parts Control Representative is assigned to each assembly department for the following production control functions:

- Develop Shortage Reports and expedite departmental requirements to meet the schedule of the affected subassemblies.
- Record and expedite shortage items for incorporation of parts into those assemblies which have progressed to a subsequent assembly station.
- Monitor detail parts stock inventories to maintain schedules for the subassemblies and assemblies.

### 3.3.8 Traceability and Configuration Control

Configuration management on LEM will be effected through a set of procedures by which the configuration of deliverable modules is identified, controlled, and documented. The LEM Engineering Department will provide a "Controlled Items List", which serves as a basis of manufacturing efforts in configuration control. Manufacturing will account for these traceable items by indicating on the Work Order and Route Cards that these items are traceable. As the part is manufactured, it is accompanied by a punched card containing the serial number and all pertinent information related to that particular part. The punched card remains with the part until it is issued by the stockroom. At that time, the module number on which it will be used is recorded.

Upon receipt of an Engineering Change Notice, the Manufacturing Planning Department processes the change and establishes module effectivity. Each Work Order will be accompanied by a punched card which is retained by the Quality Control Department until the

change has been accomplished in the pre-established module. The completed punched card is forwarded to the data retention center to become incorporated in the records for that particular module. The punched card contains the information necessary for producing a complete configuration list at any time during the life of a specific module. Implementation of configuration management procedures assures that:

- All delivered end items are configured in accordance with the applicable released information required to fabricate, test, accept, operate, maintain, and support the end item.
- Appropriate procedures, systems, and organizations are initiated in the design and development phase to facilitate transition into formal configuration control after the "configuration freeze".
- All delivered end items are accurately and completely described by readily available documentation.
- For approved changes in an end item configuration, corresponding changes are made in all related support elements (i.e., test equipment, support equipment, spares, manuals, tooling, training equipment, documentation, etc.).
- There exists a configuration status list documenting the configuration and all approved changes.
- The specific location and status of each "controlled item" of equipment, by part number and serial number, is known at all times.
- All proposed changes to end items will be controlled by a Change Control Board.

The Quality Control Department will be responsible for assurance of module conformance with the change information specified on the key punched card.

SECTION 4 - Structural/Mechanical, Fluid, and Electronic  
Subsystems

## SECTION 4

### STRUCTURAL/MECHANICAL, FLUID, AND ELECTRONIC SUBSYSTEMS

#### 4.1 STRUCTURAL/MECHANICAL AND CREW PROVISIONS SUBSYSTEM.

Grumman is responsible for the manufacture and assembly of the Structural/Mechanical and Crew Provisions Subsystems, as described in Section 1.3, "Make or Buy" Summary. The following Sections 4.1.1 through 4.1.1.3 describe the manufacturing plans for the Structural/Mechanical Subsystem. The basic manufacturing approaches for the Crew Provisions Subsystem are described in Section 4.1.2.

The Development Manufacturing Plan for these subsystems requires a logical progression from initial LTA fabrication to subsequent LTA and LEM follow-on manufacture. The following three basic steps are planned for assurance of on-schedule performance, maximum manufacturing reliability, and lowest over-all program costs:

- For all manufacturing up to and including the LTA-3 Grumman plans to use a minimum subassembly breakdown and a minimum tooling concept. Specially skilled shop technicians, who are completely adaptable to this procedure, will manufacture the early LTA units. Only the major assembly and subassembly type tools will be provided. These tools will incorporate the major jig-point locations. Detail tools used for after-form manufacturing operations will be minimized.
- As Engineering designs progress and after some designs have been modified to incorporate the initial manufacturing and test program results, the subassembly breakdown will be expanded and the tooling program will be refined. This expansion is planned to accommodate the manufacturing rate and concurrent

development requirements as shown in Figure 1-2. During LTA-4 fabrication, the initial major assembly tools will be refined by the addition of other locating and clamping devices, additional detail and subassembly tools will be provided, and a few major tools will be duplicated. This tooling phase is planned for completion during the assembly of the LTA-4 Environmental Development Module. Thus, LTA-5 and subsequent LTA's and LEM's will be developed using finally configured structural assembly tooling.

- The structural manufacturing technicians who participate in the initial LTA development will also form the nucleus of an expanded manufacturing team. These key technicians will provide the experience factor which is necessary for planned "learning-curve" cost reductions.

#### 4.1.1 Structural/Mechanical Subsystems

All tooling and manufacturing procedures described herein for the ascent structure, descent structure, and lunar landing gear are based on the October 1, 1963 LEM General Arrangement Configuration which is shown in Figure 4-1. Figure 4-2 shows the LEM subassembly breakdown.

The Ascent and Descent Stage subassembly breakdown and manufacturing flows are shown in Figures 4-3 and 4-4, respectively. All breakdowns were established by closely reviewing the manufacturing lead times and manloading capabilities for maximum reduction of elapsed manufacturing time, commensurate with the critical assembly schedules. In addition, full consideration has been given to satisfying the tolerance and anticipated interchangeability requirements, utilization of available equipment ranges and facilities, and convenient handling throughout the manufacturing phases.

The Ascent Stage breakdown will permit optimum manloading for installation of secondary equipment mounting structure in the individual major subassemblies. This feature, and the concept for providing interchangeability between the subsystem components and the

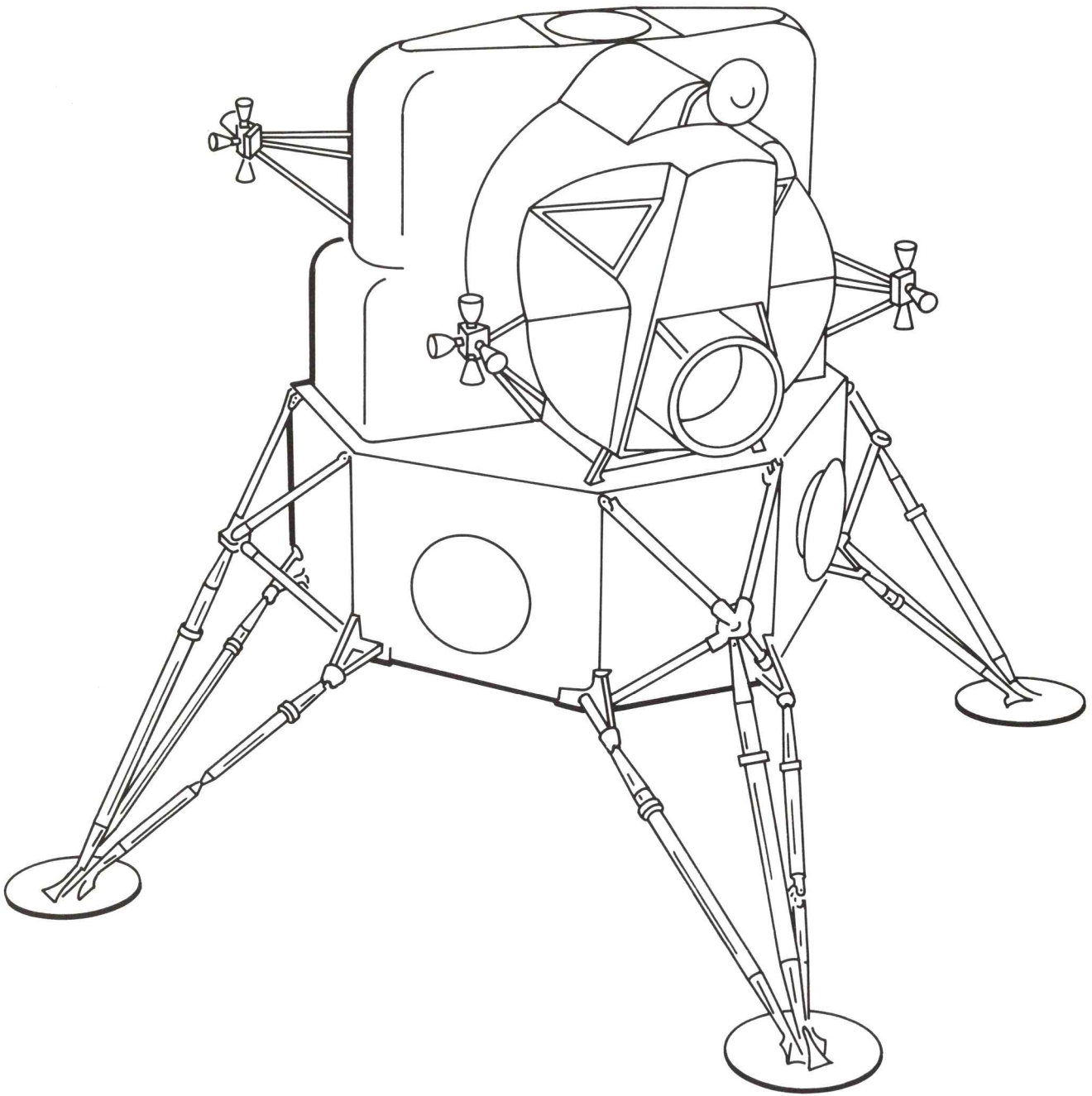


Figure 4-1 LEM General Arrangement Configuration

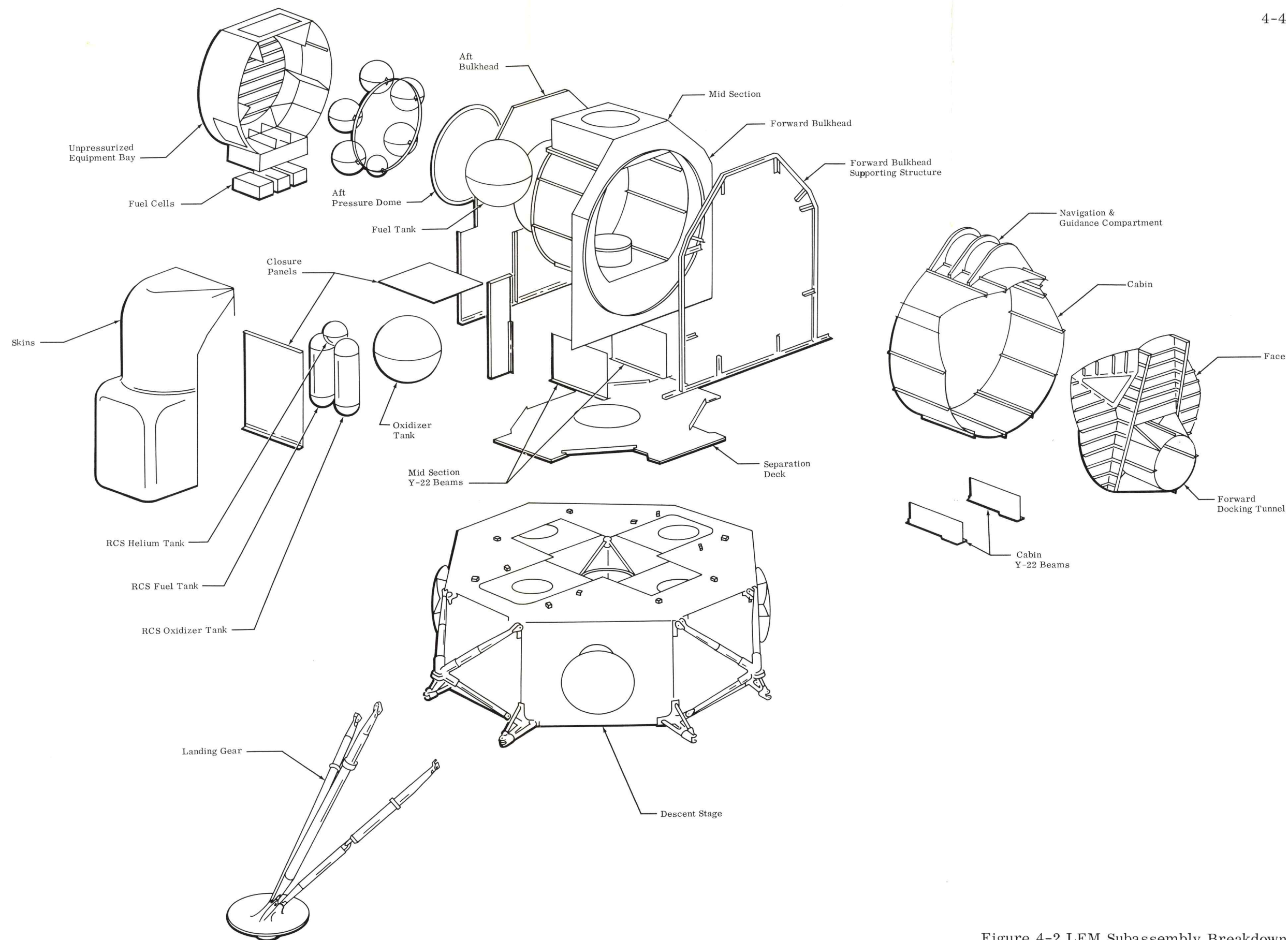


Figure 4-2 LEM Subassembly Breakdown

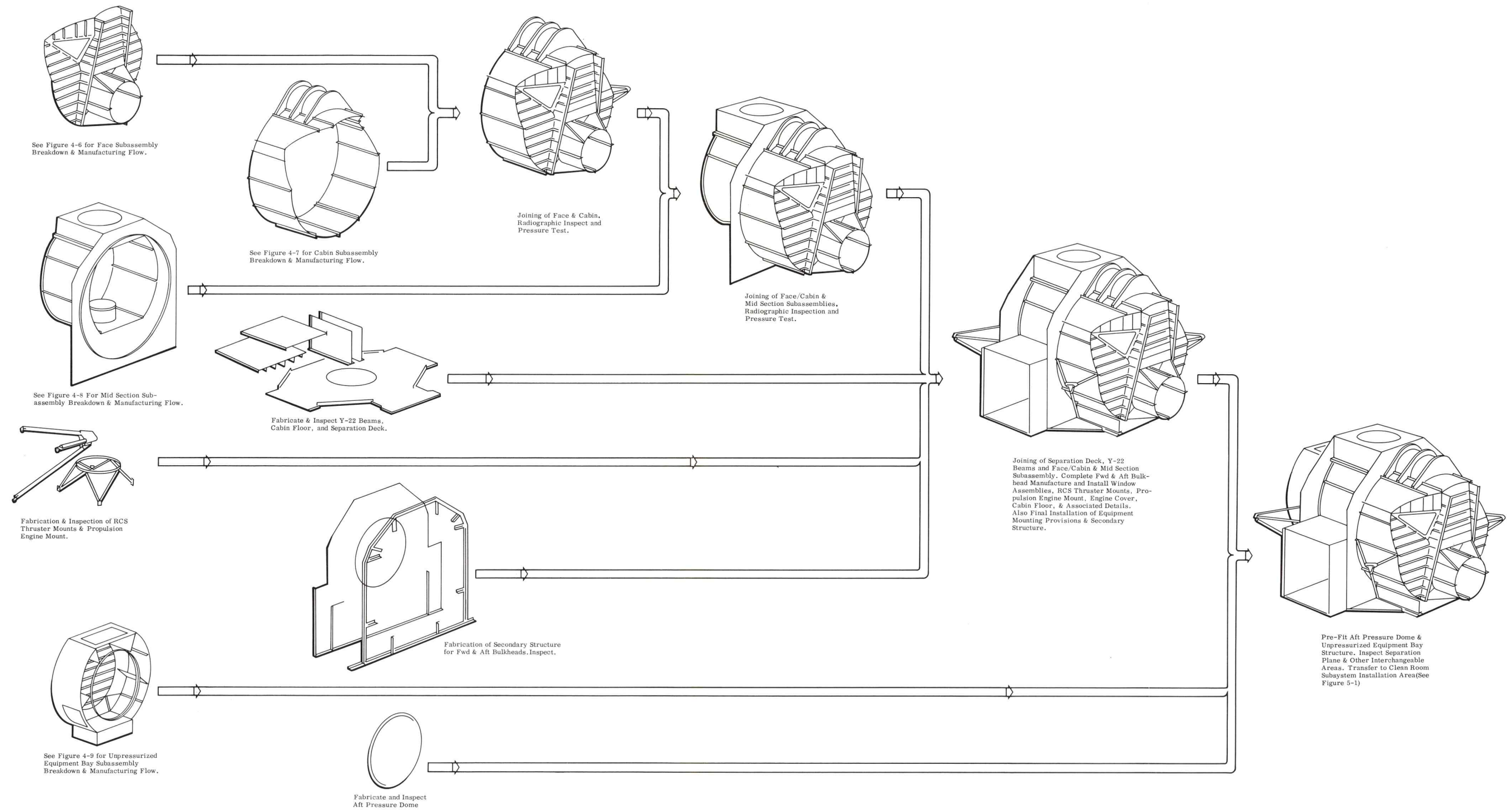


Figure 4-3 Ascent Stage Structural Subassembly Flow

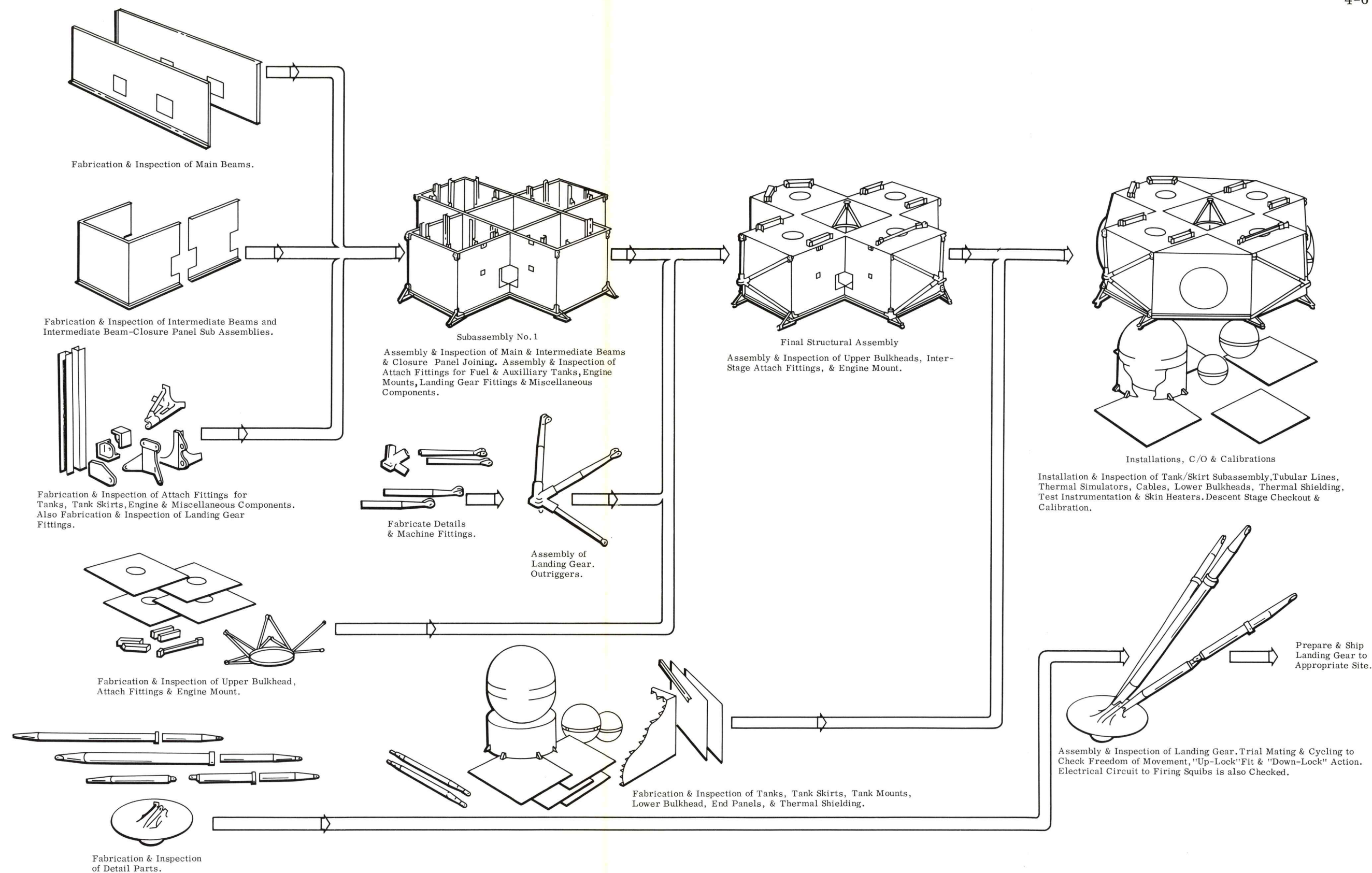


Figure 4-4. Descent Stage-Subassembly Breakdown

minating structure will minimize the structural work during the ascent subsystem installation phase. These factors are extremely important for meeting the compressed subsystem installation schedules, because of the manloading limitations within a completed Ascent Stage structure.

The Descent Stage subassembly breakdown and manufacturing flow shown in Figure 4-3 indicates one major assembly stage and various component subassembly operations. This minimum breakdown is considered adequate for the average manufacturing rate of 1.5 units per month.

All structural subassembly and assembly operations for the Ascent and Descent Structural/Mechanical Subsystem will be performed by maintaining clean assembly practices in standard shop environments.

#### 4.1.1.1 Manufacture of Detail Parts

Detail parts for the LEM Program will be manufactured in the various specialized shop departments which are located throughout the Bethpage Facility.

The centralized sheet metal parts fabrication facility shown in Section 2 will produce the majority of the formed skin and frame details. Forming tools will be provided for compound curved skins, as well as details with curved heel-lines, deep joggles, and changing flange angles. After-form drill and trim tools will be held to a practical minimum. Tooling will be more extensive for some sheet metal parts, depending on configuration, tolerances, or coordination requirements.

Honeycomb equipment shelves will be produced in a specialized shop which is fully equipped for parts preparation and platen press or autoclave bonding.

In accordance with the Grumman procurement policy, initial quantities of machined parts will be manufactured in-house, and some follow-on quantities will be competitively subcontracted. In-house manufacture of initial machined parts will be accomplished by fully

utilizing standard set-up and clamping tools, overlay templates, part layout methods, numerical control, and jig boring techniques in lieu of formal tooling. For those parts which remain a Grumman manufacturing responsibility, some drill jigs, drill plates, and machining tools will be provided to replace hand layout and shop set-up. In addition, some numerical control applications will be expanded.

Chemical-milling will have wide application for minimizing the weight of the Structural/Mechanical Subsystem. Typical manufacturing procedures for a chem-milled LEM crew compartment frame detail are shown in Figure 4-5. All operations from vapor degreasing through ultrasonic inspection of detail thickness are shown.

#### 4.1.1.2 Manufacture of Subassemblies and Final Structural Assembly - Ascent Stage

The Ascent Stage is primarily a double walled pressurized structure fabricated of formed skin and frame members. Internal aluminum skins are designed for pressurization of the Cabin & Mid Section, while external skins serve as meteoroid shielding. The unpressurized Aft Equipment Bay is a subassembly which is fabricated using conventional mechanical fastening methods.

Structural subassembly and final structural assembly operations for the Ascent Stage will require the utilization of manufacturing techniques such as automatic fusion welding, resistance welding, and mechanical fastening.

Table 4-1 lists the major Ascent Stage subassemblies and also shows the major tooling requirements. Figures 4-6 through 4-9 show the manufacturing breakdown and flow for the major Ascent Stage subassemblies.

The highest degree of manufacturing reliability is required to satisfy the specifications for Ascent Stage pressurization. Consequently, automatic fusion welding techniques, very similar to those employed for the welding of man-rated booster structures, will also be extensively applied for the LEM Program. All automatic fusion welding stations will be

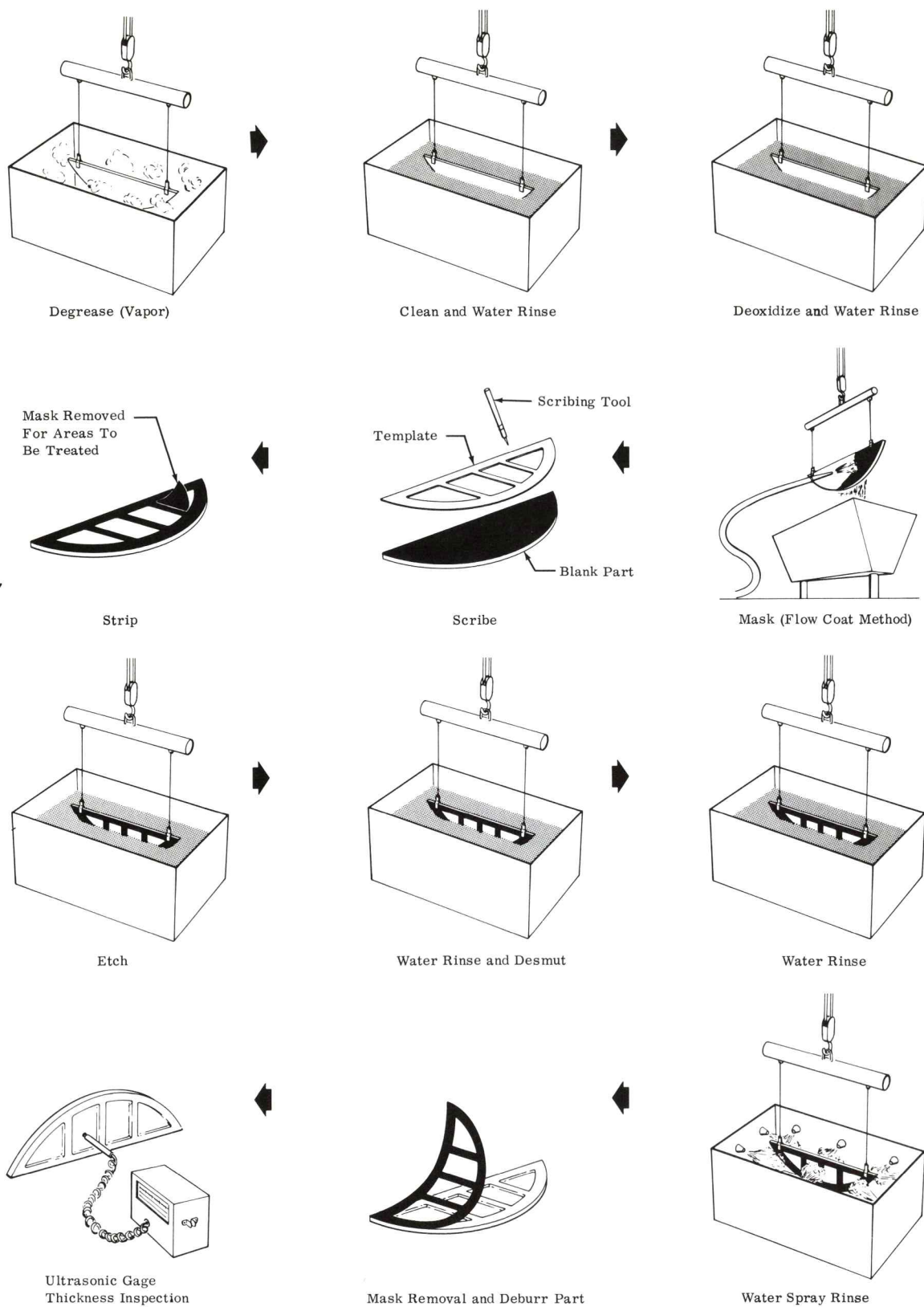


Figure 4-5. Chemical Milling of a Typical LEM Detail

ASCENT STAGE*		
Major Assembly Operation And Fixture Number	Major Tool Type	Assembly Name Or Operation Description
1	Weld Fixture	Joining of Face Center Panel Machined parts
2	Weld Fixture	Joining of L/R Face Outboard Panel Machined parts
3	Weld Fixture	Joining of Assemblies 1 and 2
4	Weld Fixture	Forward Docking Tunnel
5	Combination Fixture	Weld Assemblies 3 and 4. Install glass attach points, and sealing members.
6	Combination Fixture	Navigation & Guidance Dome. Final machine cruciform edges.
7	Combination Fixture	Cabin Skin Subassembly. Machine trim cruciforms in fixture prior to each weld.
8	Combination Fixture	Weld Assemblies 6 and 7. Machine Cabin Subassembly to accommodate Face.
9	Weld Fixture	Join Assemblies 5 and 8 (Face/Cabin Subassembly)
10	Combination Fixture	Mid-Section Skin Subassembly. Machine trim cruci- forms in fixture prior to each weld.
11	Weld Fixture	Upper Docking Tunnel
12	Weld Fixture	Upper Docking Tunnel to Upper Deck
13	Combination Fixture	Join Assemblies 10, 12, and Lower Deck. Machine trim forward and aft faces.
14	Combination Fixture	Join Fwd Bulkhead and Aft Ring to make Mid Section Subassembly. Machine trim Forward Bulkhead flange.
15	Assembly Fixture	Unpressurized Equipment Bay
16	Weld Fixture	Join Assemblies 9 and 14
17	Assembly Fixture	Separation Deck
*See Figure 4-3 for Ascent Stage Subassembly Breakdown, and Figures 4-6 through 4-9 for Ascent Stage Manufacturing Flow.		

Table 4-1. Ascent Stage - Major Assemblies and Major Tools Required (Cont.)

ASCENT STAGE* (Cont)		
Major Assembly Operation And Fixture Number	Major Tool Type	Assembly Name Or Operation Description
18	Assembly Fixture	Cabin Y-22 Beams
19	Assembly Fixture	Mid Section Y-22 Beams
20	Assembly Fixture	Ascent Stage Final Structural Assembly
21	Assembly Fixture	Forward Bulkhead Secondary Structure
22	Assembly Fixture	Aft Bulkhead
23	Installation Fixtures	All installations of external structure, tank and engine mounts, Separation Plane, and equipment mounting provisions requiring an Installation Fixture
24	Inspection Checking Fixture	Inspection of Separation Plane, Engine Mount, and RCS Mount Hole Patterns
*See Figure 4-3 for Ascent Stage Subassembly Breakdown, and Figures 4-6 through 4-9 for Ascent Stage Manufacturing Flow.		

Table 4-1 Ascent Stage - Major Assemblies and Major Tools Required

developed to include the following practices which are presently used at Grumman for assurance of highest quality:

- Close tolerance fit-up for preparation of mating weld joint edges on details or subassemblies will be accomplished by trimming after all previous manufacturing operations have been completed.
- Tooling will be provided to assure a close tolerance relationship between corresponding diameters of welded parts or subassemblies.
- Only a minimum of elapsed time will be permitted between cleaning and welding operations. Clean handling and assembly practices will be exercised during all phases of welding.

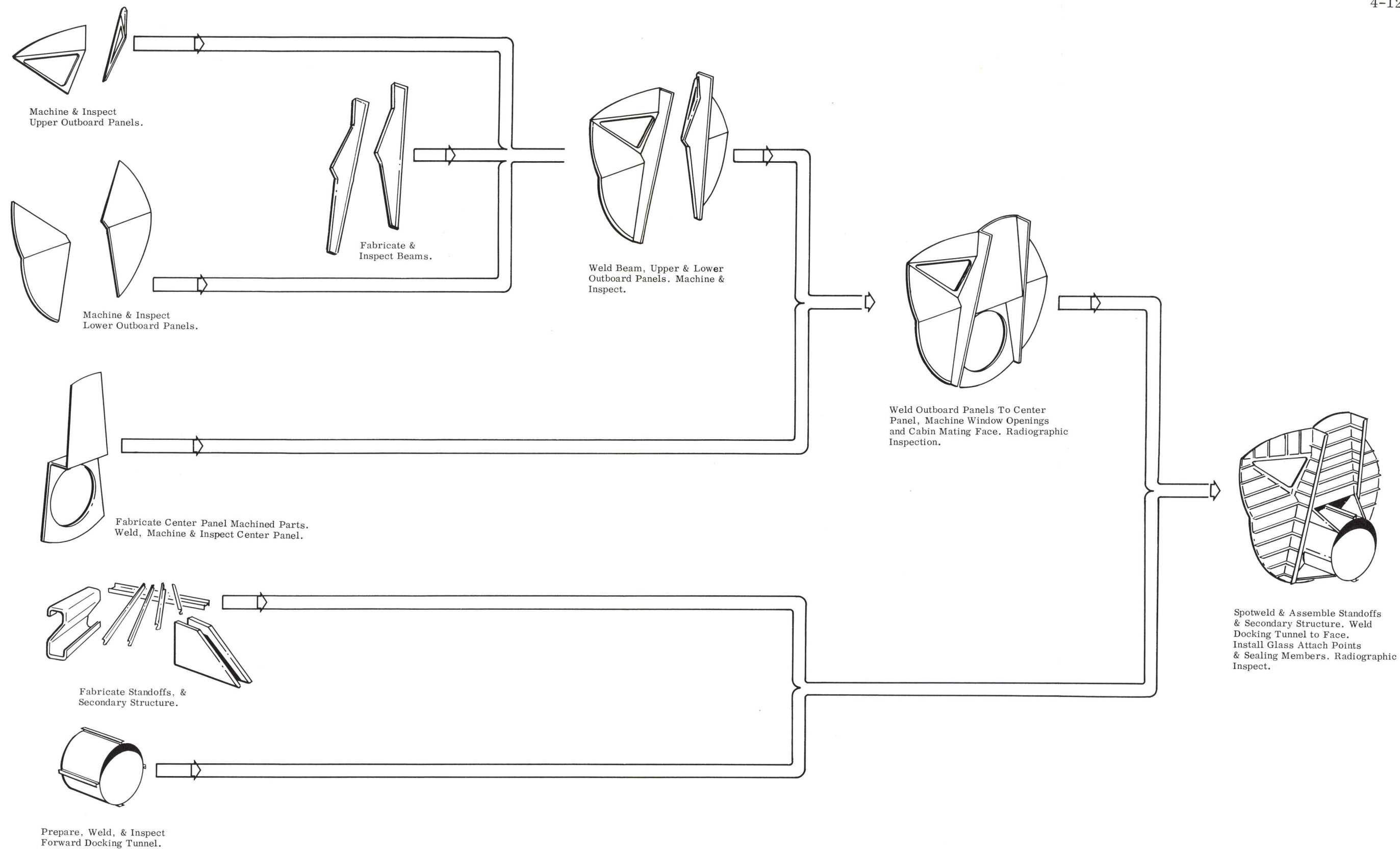


Figure 4-6 Face Subassembly Breakdown & Manufacturing Flow

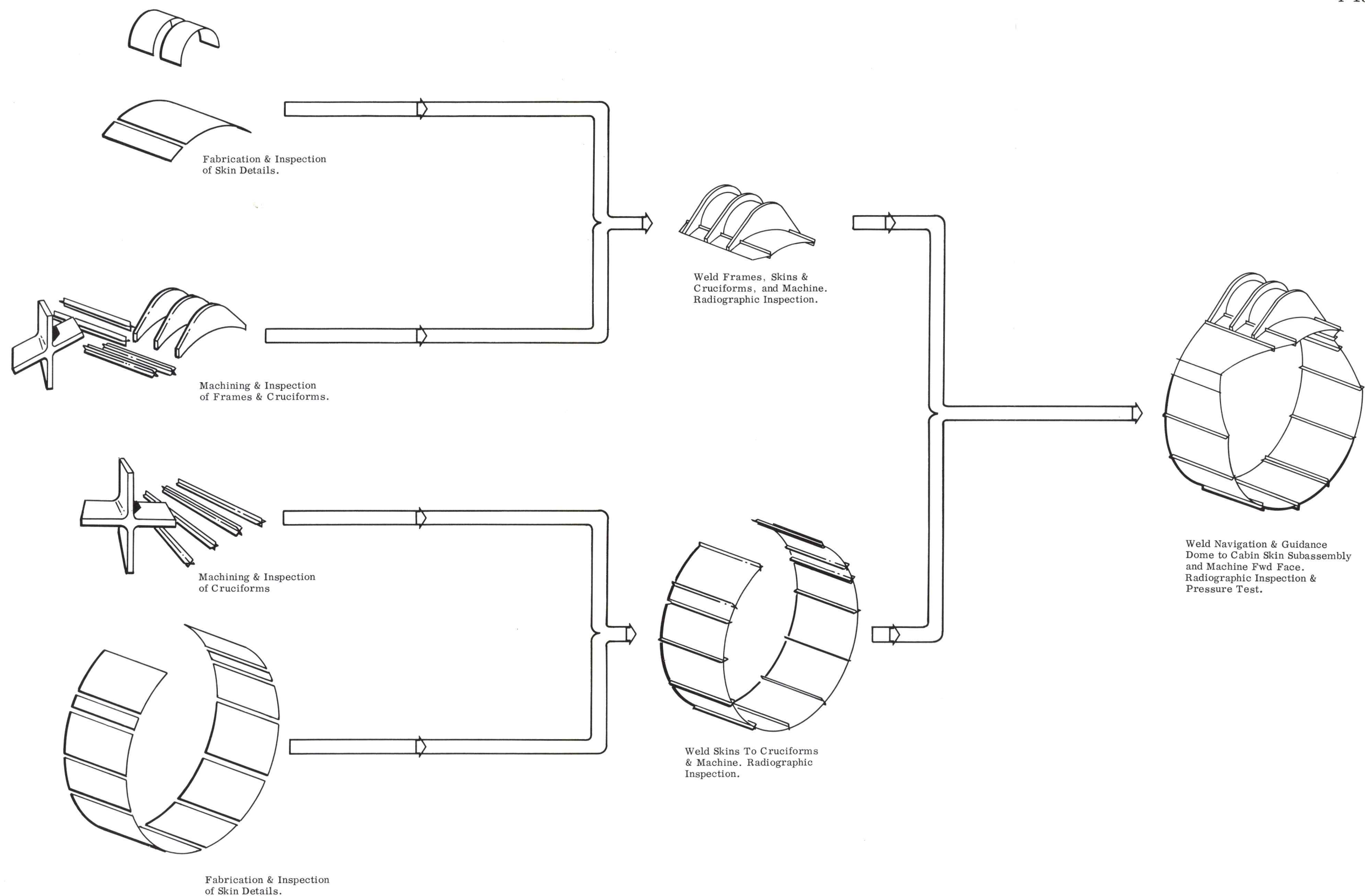


Figure 4-7 Cabin Subassembly Breakdown  
& Manufacturing Flow

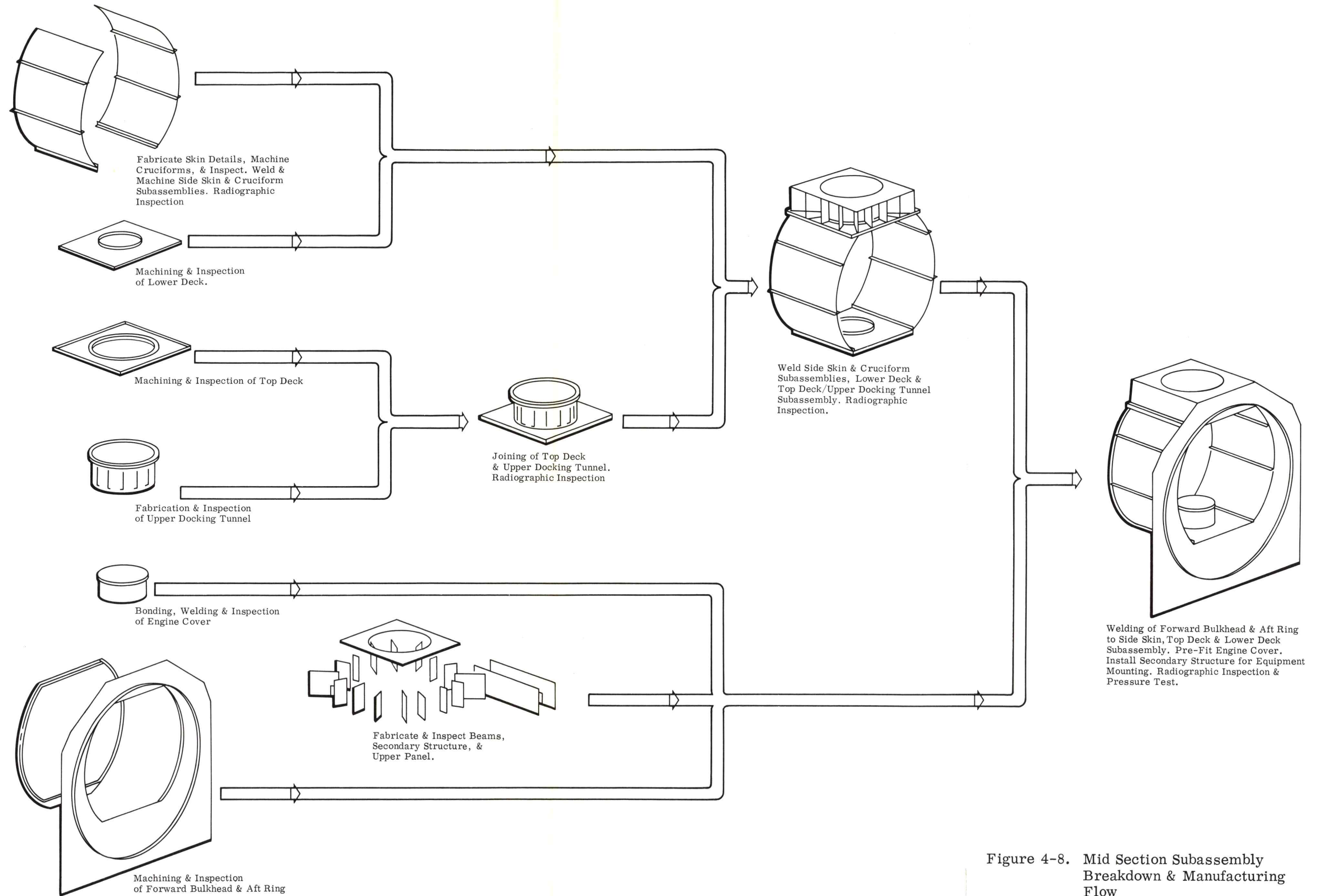


Figure 4-8. Mid Section Subassembly Breakdown & Manufacturing Flow

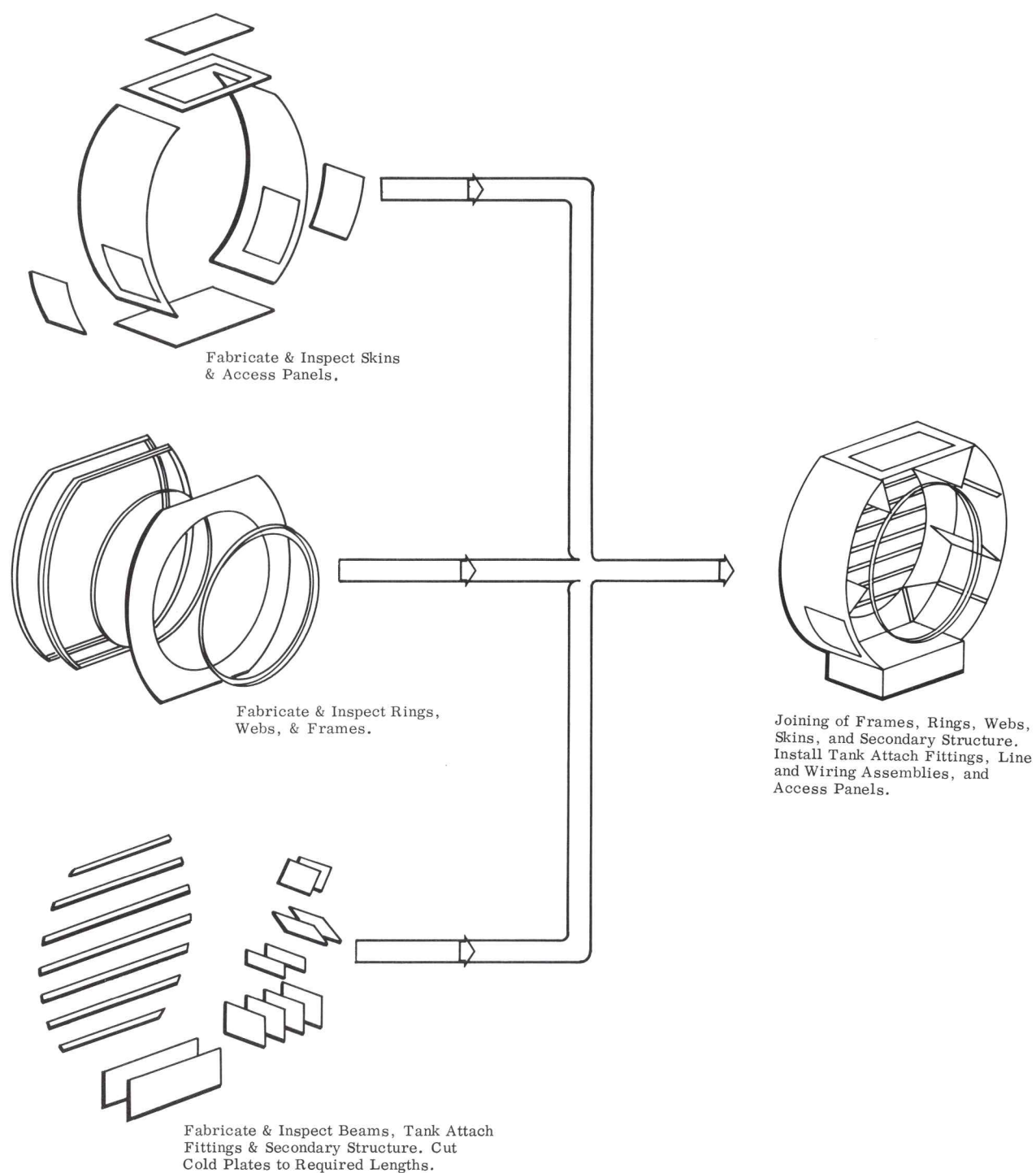


Figure 4-9 Aft Equipment Bay Subassembly Breakdown &amp; Manufacturing Flow

- An inert gas environment will shield all "under-the-torch" welding operations. Shielding will also be provided on the underside of the weld area.
- Tooling for holding, aligning, clamping, and chilling will be integrated with the welding equipment. Some equipment may be programmed for contour welding.
- All equipment such as presently available longitudinal welders, combination longitudinal/circumferential welder, and boom welders will be serviced at periodically scheduled intervals.
- All welding operations will be performed by certified equipment operators. Periodic re-certification is mandatory.
- Sample weldments will be produced and tested prior to all LEM welding phases to qualify the equipment settings. All settings are documented for future reference and control.
- Pressure tests and radiographic, visual, and dimensional inspections will be integrated into the manufacturing cycle. These tests will be planned in a sequence to allow for assurance of quality at the earliest practical stages of subassembly.

All of the welded subassemblies will require secondary mechanical fastening-type assembly operations, and the non-pressurized Aft Equipment Bay will be completely fabricated using these conventional aircraft techniques.

The fixtures listed in Table 4-1 contain provisions for establishing index references in the individual subassemblies. Thus, positioning these subassemblies during subsequent joining operations can be readily and accurately accomplished. The major manufacturing sequences are outlined in the following paragraphs.

4.1.1.2.1 Face Subassembly Fabrication - Fabrication of the Face Subassembly (Figure 4-6) is accomplished in the following manner:

- Fabricate Center Panel machined parts. Weld, machine, and radiographic inspect Face Center Panel Subassembly (Table 4-1, Operation 1).
- Finish machine Face Center Panel
- Fabricate Outboard Panel machined parts. Weld beam and upper and lower panels to complete L/R Face Outboard Panel Subassemblies. Radiographic inspect (Table 4-1, Operation 2).
- Finish machine L/R Face Outboard Panel Subassemblies.
- Prepare and weld L/R Outboard Panels to Face Center Panel. Radiographic inspection (Table 4-1, Operation 3).
- Machine window openings and Cabin mating face using a portable milling attachment.
- Fabrication of standoffs and secondary structure.
- Weld and assemble standoffs and secondary structure.
- Fabricate skin details and machine cruciforms for Forward Docking Tunnel.
- Prepare, weld, and radiographic inspect the Forward Docking Tunnel (Table 4-1, Operation 4).
- Prepare and weld Forward Docking Tunnel to Face. Install glass attach points and sealing members. Radiographic Inspect (Table 4-1, Operation 5).

4.1.1.2.2 Cabin Subassembly Fabrication - The Cabin Subassembly (Figure 4-7) is fabricated in the following manner:

- Fabricate Navigation and Guidance (N&G) Dome skin details.
- Machine N & G Dome frames and cruciforms.

- Prepare and weld skins, frames, and cruciforms to complete N & G Dome Sub-assembly. Final machine cruciform edges and radiographic inspect. (Table 4-1, Operation 6).
- Fabricate Cabin skin details and machine cruciforms.
- Prepare skins and cruciforms and weld Cabin Skin Subassembly using the combination fixture shown in Figure 4-10. Machine trim cruciforms in fixture prior to each weld (Table 4-1, Operation 7).
- Radiographic inspection of weld joints.
- Prepare and weld N & G Dome to Cabin Skin Subassembly using the combination fixture shown in Figure 4-11. Radiographic inspect and pressure test local weld joints (Table 4-1, Operation 8).
- Trim Cabin Subassembly in fixture to accommodate Face, utilizing a guided portable machining attachment. Install some secondary structure required for equipment provisions. Establish index references for subsequent assembly.

4.1.1.2.3 Face and Cabin Subassemblies Joining - The Face and Cabin Subassemblies are joined as follows:

- Prepare and weld Face and Cabin Subassemblies in the weld fixture shown in Figure 4-12 utilizing a "track" guide (Table 4-1, Operation 9).
- Radiographic inspection and pressure test.

4.1.1.2.4 Mid Section Subassembly Fabrication - The Mid Section Subassembly (Figure 4-8) requires the following major operations:

- Fabricate skin details and machine cruciforms.

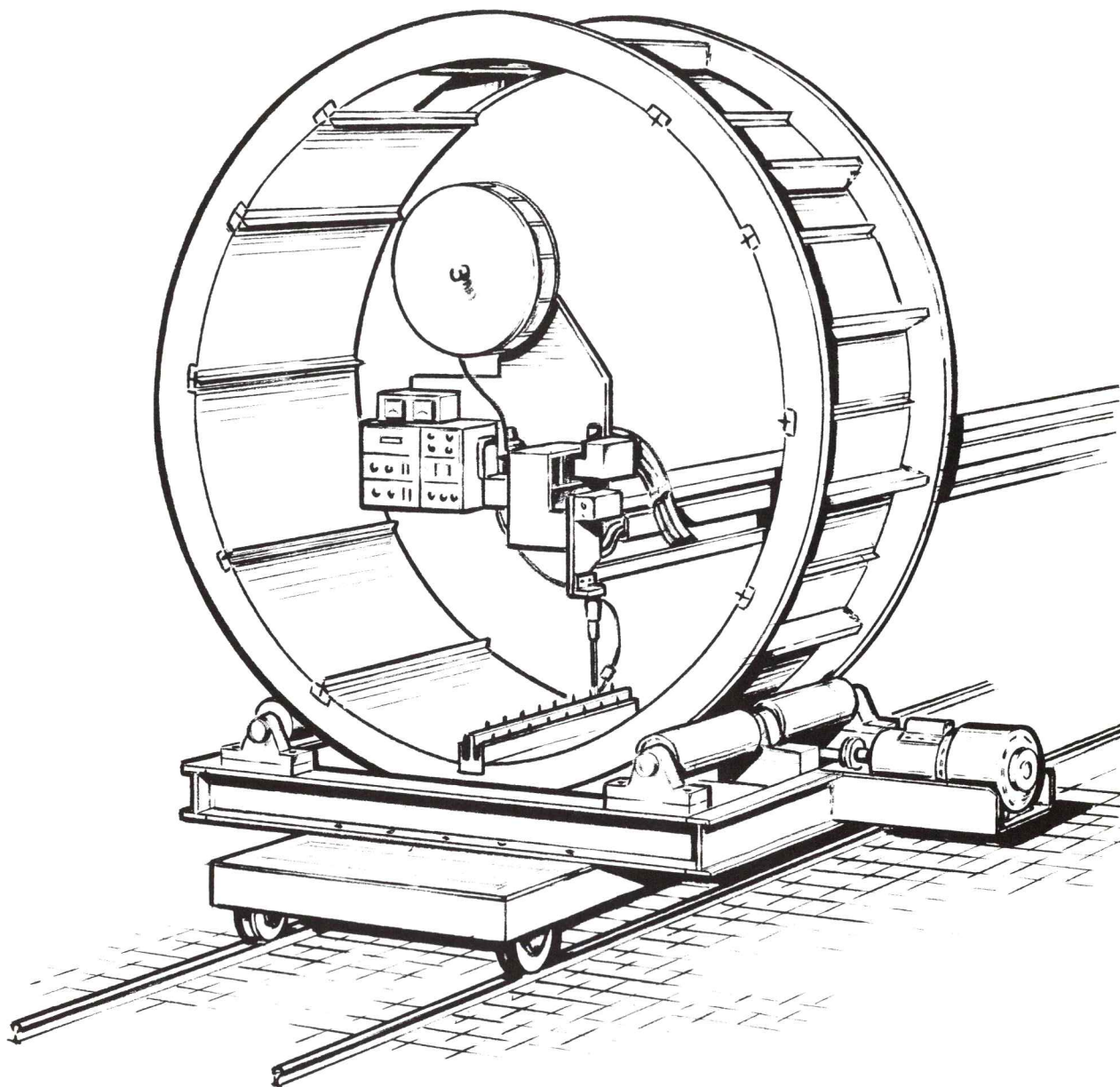


Figure 4-10 Typical Combination Fixture-Welding & Machining  
of Skin & Cruciform Assemblies

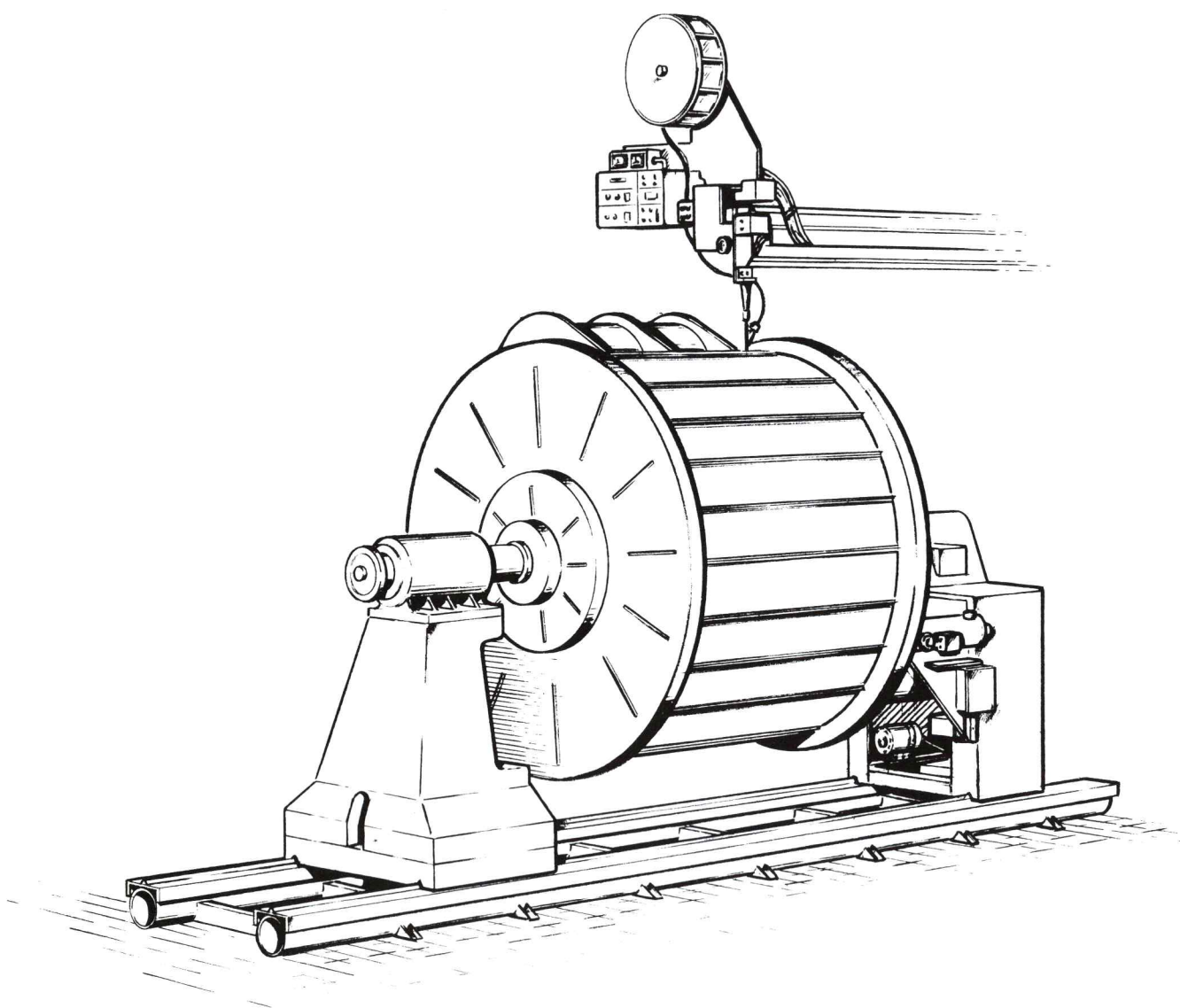


Figure 4-11 Combination Fixture-Welding of N&G Dome to Cabin Subassembly

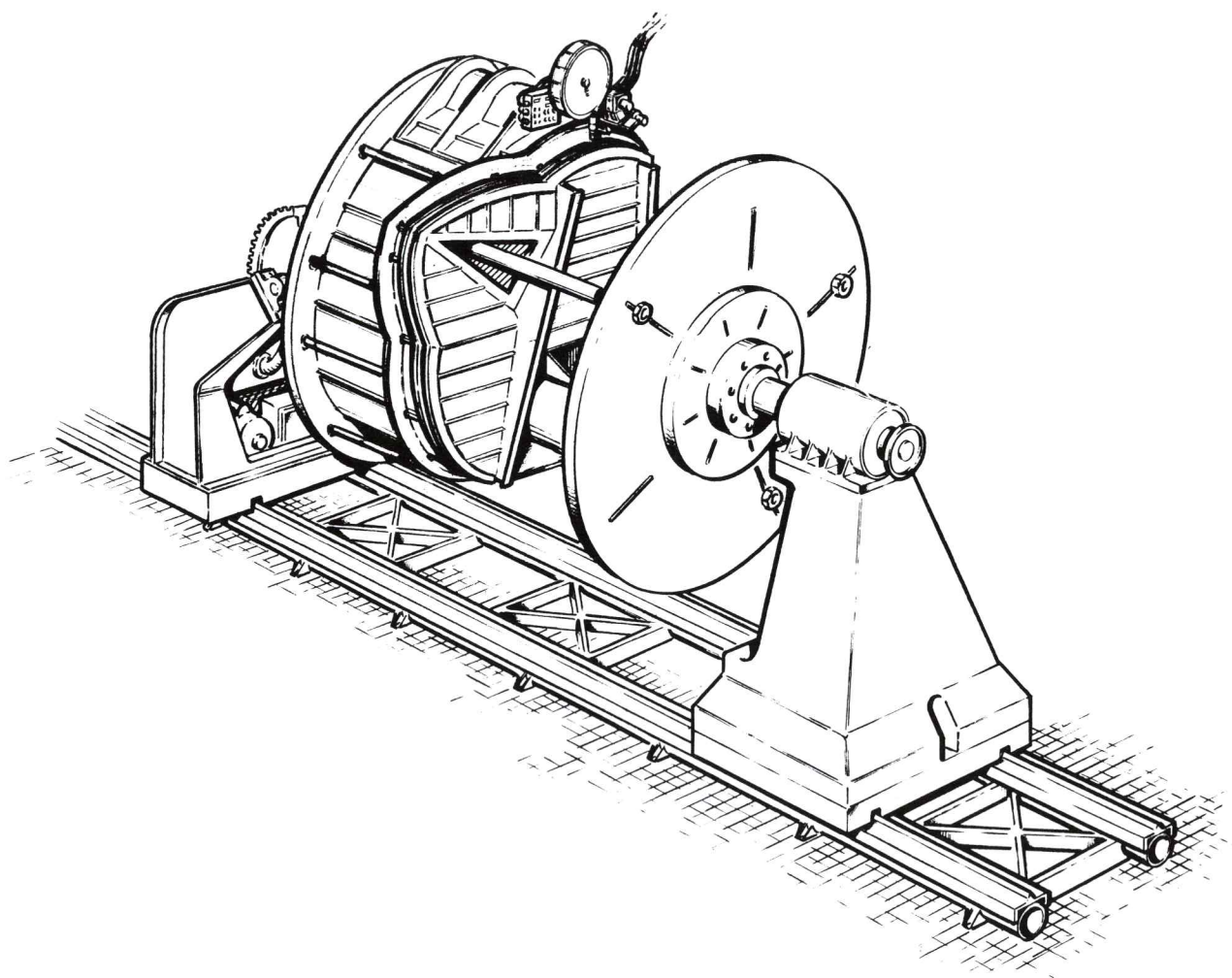


Figure 4-12 Weld Fixture-Welding of Face to Cabin Subassembly

- Prepare, weld, and machine L/R side skin and cruciform subassemblies in a combination fixture similar to the fixture shown in Figure 4-10. Radiographic inspect all welds (Table 4-1, Operation 10).
- Machine top and lower decks.
- Machine Upper Deck, and fabricate secondary details and assemble.
- Machine ring details, and fabricate cylindrical and supporting structure. Prepare, weld, radiographic inspect, and pressure test Tunnel Subassembly (Table 4-1, Operation 11).
- Prepare and weld Tunnel to Top Deck using the weld fixture shown in Figure 4-13. Attach supporting structure and radiographic inspection of weld (Table 4-1, Operation 12).
- Prepare and weld side skin and cruciform subassemblies, Lower Deck and Upper Deck/Upper Docking Tunnel Subassembly utilizing the combination fixture shown in Figure 4-14. Trim forward and aft faces. Radiographic inspection and pressure test (Table 4-1, Operation 13).
- Machine Aft Ring and Forward Bulkhead utilizing numerical control techniques.
- Machine rings and fabricate honeycomb core, skins, and sheet metal cylinder. Assemble Engine Cover Subassembly.
- Preparation and welding of Aft Ring and Forward Bulkhead to Upper Deck, L/R Side Skin and Lower Deck Subassembly utilizing the Figure 4-15 combination fixture. Machine trim Forward Bulkhead flange in the fixture. Radiographic inspection of all welds (Table 4-1, Operation 14).
- Pre-fit Engine Cover Subassembly and pressure test.
- Fabricate and install beams and secondary structure for equipment mounting.

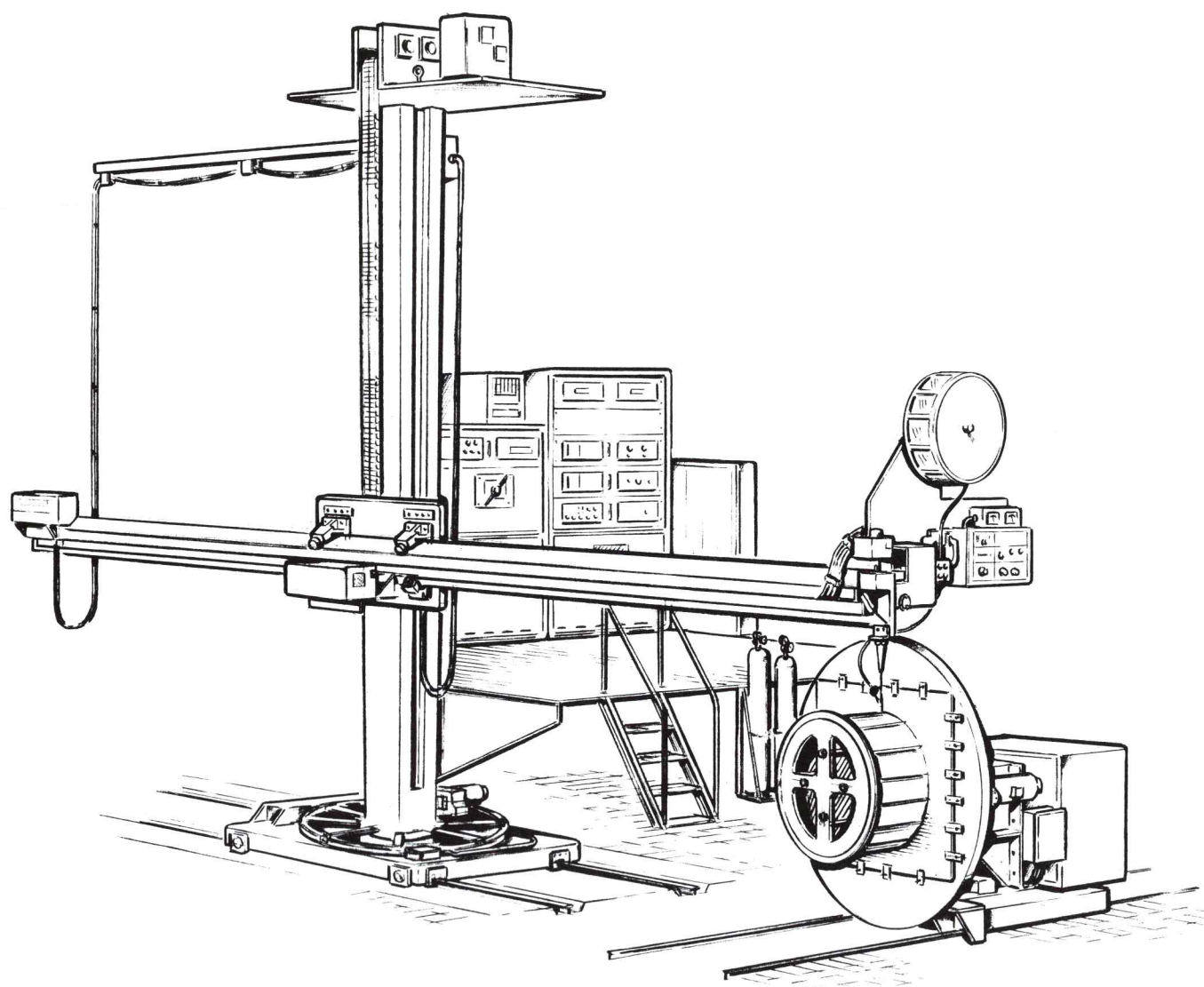


Figure 4-13 Weld Fixture - Weld Tunnel to Top Deck

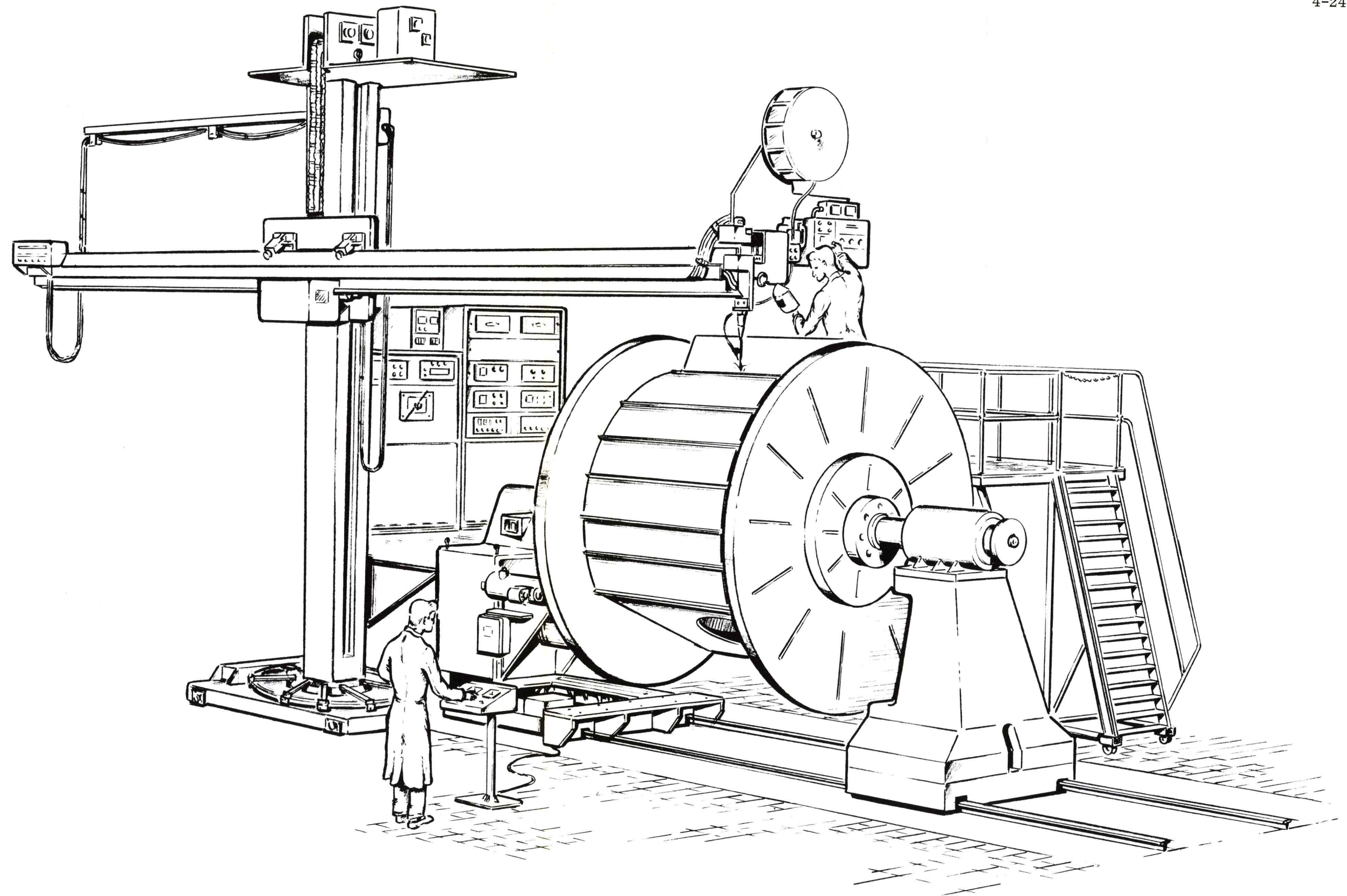


Figure 4-14 Combination Fixture-Welding  
of Lower Deck, Side Skin/  
Cruciform and Upper Deck/  
Docking Tunnel Subassemblies

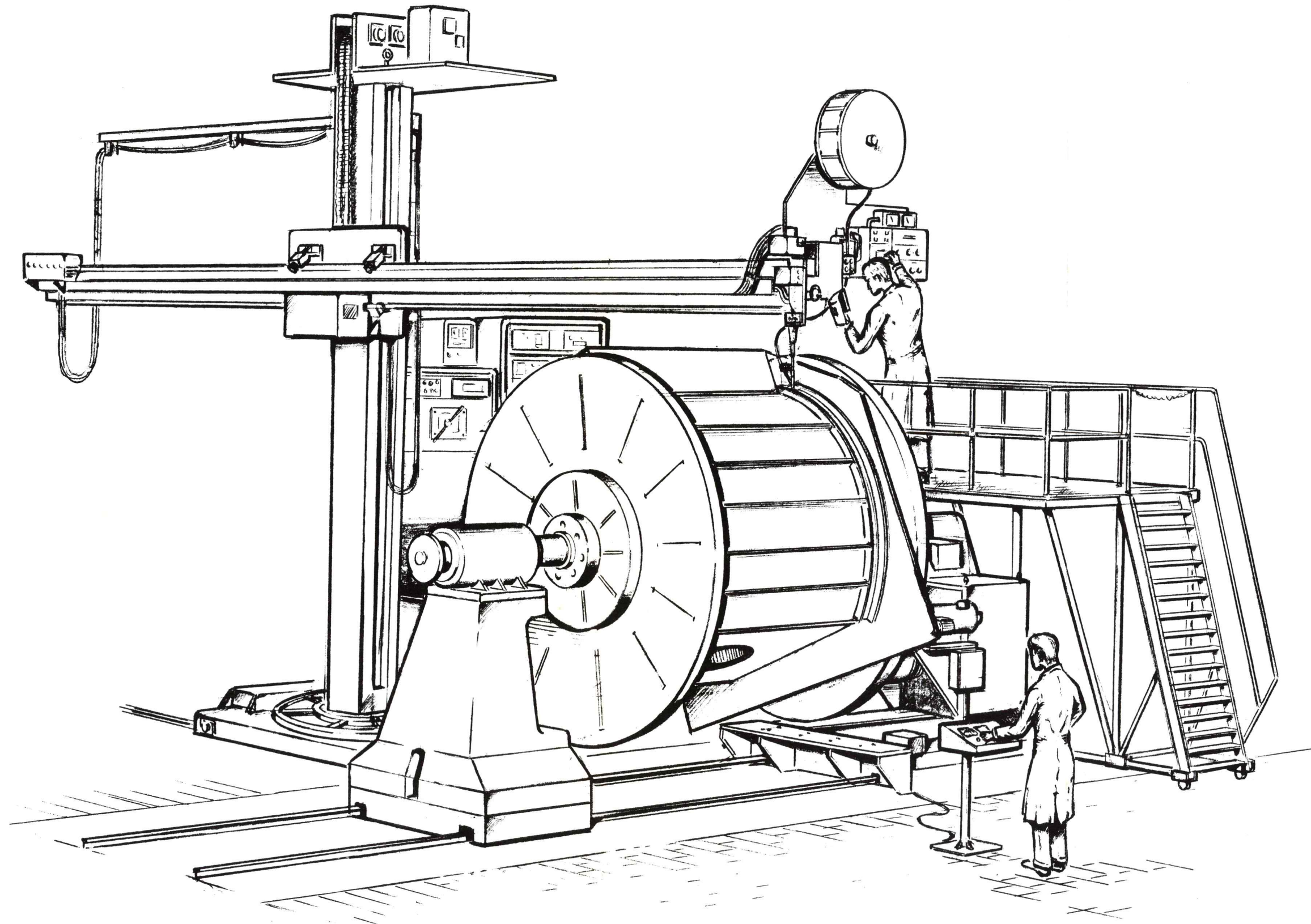


Figure 4-15 Combination Fixture-Welding of  
Aft Ring & Forward Bulkhead

4.1.1.2.5 Aft Pressure Dome Fabrication - The Aft Pressure Dome is produced as follows:

- Prepare material for spinning.
- Spin to required shape and chem-mill to reduce weight.
- Drill attach hole pattern.

4.1.1.2.6 Aft Equipment Bay Subassembly Fabrication - The Aft Equipment Bay (unpressurized) Subassembly (Figure 4-9) is fabricated using mechanical fastening techniques as previously mentioned. Procedures are as follows:

- Manufacture rings, webs, frames, skins, and access panels. Cut cold plate extrusions to length.
- Fabricate tank attach fittings and secondary structure.
- Progressively join these details in major fixture 15 (Table 4-1). This fixture contains tooling locators and clamps for maintaining position of details.

4.1.1.2.7 Face/Cabin and Mid Section Subassemblies Joining - Structural joining of the Face/Cabin and Mid Section Subassemblies (Figure 4-16) is accomplished utilizing automatic fusion welding as follows:

- Automatic welding equipment incorporating standard accessories and a welding fixture is used to produce the circumferential weld joint (Table 4-1, Operation 16).
- Hoisting bars, slings, and overhead hoisting equipment assure proper and safe loading operations.

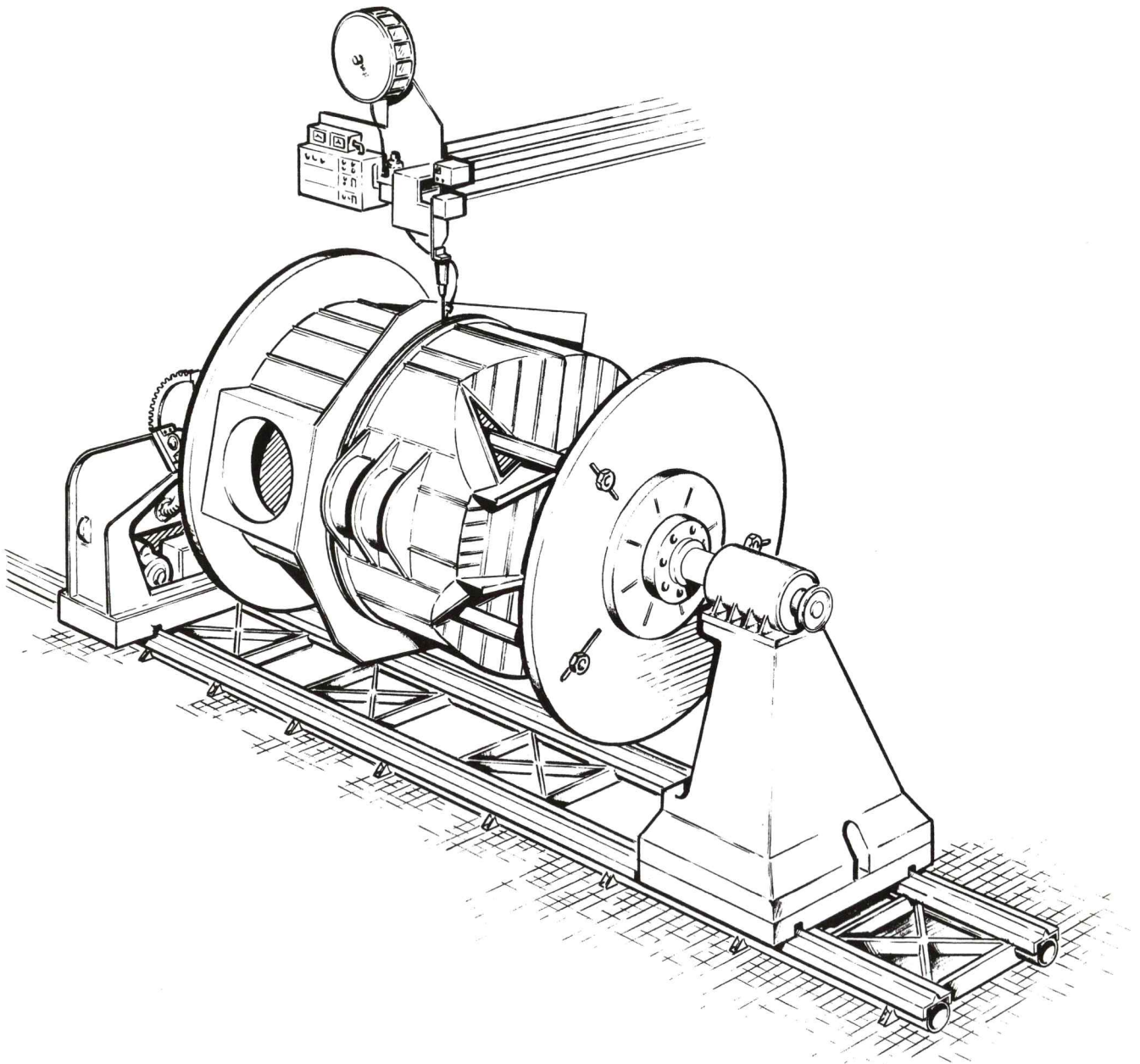


Figure 4-16 Joining of Face/Cabin and Mid Section Subassemblies

- Since index references were established during the final stages of subassembly manufacturing, the three assembly sections can be accurately coordinated in this welding station.
- All previously described welding and inspection practices for achieving optimum weld integrity will be applied during this major assembly operation.

4.1.1.2.8 Ascent Stage Assembly - Final structural Ascent Stage assembly is completed by joining the previous major welded structure to the unpressurized Equipment Bay. Prior to joining, the following structural operations are accomplished:

- Fabricate sheet metal details and machined parts for Separation Deck and assemble (Table 4-1, Operation 17).
- Fabricate sheet metal details and machined parts and assemble Cabin and Mid Section Y-22 Beams (Table 4-1, Operations 18 and 19).
- Locate Separation Deck and Cabin and Mid Section Y-22 Beams in the final assembly fixture shown in Figure 4-17. (Table 4-1, Operation 20).
- Locate and join Face/Cabin and Mid Section Subassembly to the Separation Deck and Y-22 Beams.
- Manufacture necessary secondary structure and complete fabrication of Forward and Aft Bulkheads (Table 4-1, Operations 21 and 22).
- Fabrication and installation of Cabin Floor and internal secondary structure required for equipment mounting provisions.
- Fabricate and attach external structure and some closure panels.
- Fabricate and install RCS Thruster Mounts and Propulsion Engine Mount.

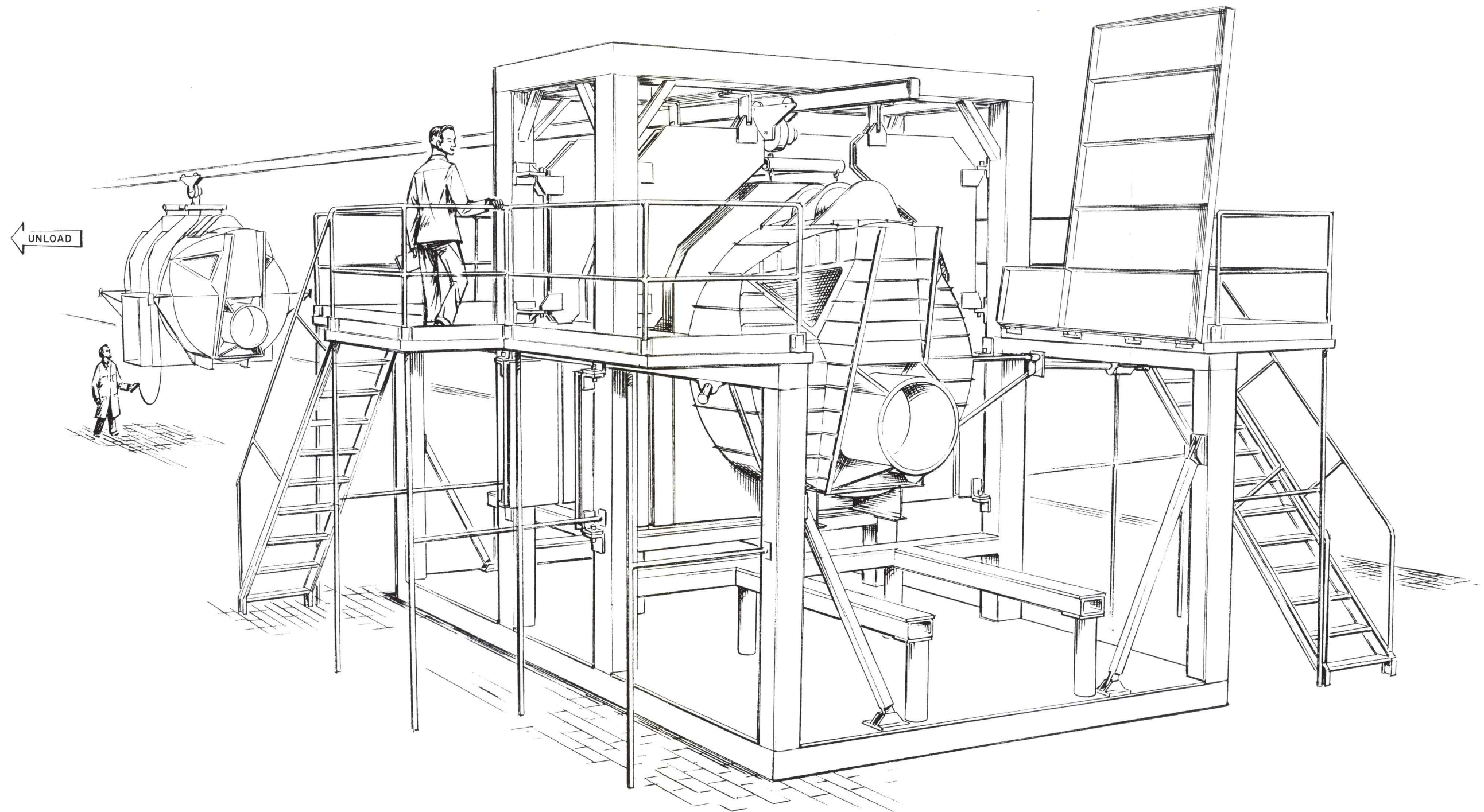


Figure 4-17 Final Structural Assembly  
Fixture-Ascent Stage

- Incorporate structural provisions for accepting the fuel, oxidizer, and helium tanks.
- Fit, install, and seal windshield subassemblies.
- Installation of remaining equipment mounting provisions and secondary structure.
- Pre-fit Aft Pressure Dome and unpressurized Equipment Bay.
- Check Ascent Stage separation, RCS, and Propulsion Engine Mount interfaces using inspection checking fixtures (Table 4-1, Operation 24). (Methods for achieving interchangeability between Grumman structure and vendor supplied components are discussed in Section 3.3.1.)

After completion of final structural assembly, the Ascent Stage is removed from the fixture using a GSE hoisting sling. Transfer to the cleaning area is accomplished using a GSE handling dolly. The beginning of subsystem installation in the Grumman clean room is described in Section 5. The external meteoroid shielding skins which are installed after subsystem installations are also described in Section 5.

#### 4.1.1.3 Manufacture of Subassemblies and Final Structural Assembly - Descent Stage.

The Descent Stage is an assembled aluminum beam and skin structure which contains pick-up provisions for the Descent Engine, Landing Gear, fuel and oxidizer tanks, critical oxygen supply, and other Descent equipment. The manufacture of the Lunar Landing Gear is also discussed in this section.

This Structural/Mechanical Subsystem is generally representative of typical aircraft construction. Subassembly and assembly tools are similar in design to those presently used at Grumman for aircraft beam and skin structures.

Table 4-2 lists the subassembly tool families and the major tooling requirement for the Descent Stage and Landing Gear. Figure 4-4 shows the Lunar Landing Gear and Descent Stage Subassembly breakdown and manufacturing flow.

* DESCENT STAGE		
Major Assembly Operation And Fixture Number	Major Tool Type	Assembly Name or Operation Description
1	Assembly Fixture	Descent Structure- Main Beams
2	Assembly Fixture	Descent Structure - Intermediate Beams & Intermediate Beam/Closure Panel Subassembly.
3	Assembly Drill Jig	Upper Bulkhead
4	Assembly Drill Jig	Lower Bulkhead
5	Bonding Fixture	Tank Skirts
6	Assembly Fixture (2 Req'd.)	Descent Stage Final Structural Assembly
7	Installation Fixtures	Installation of Tanks, Tank Skirts and Separation Plane Fittings.
8	Holding Fixture	Final Structure
9	Inspection Checking Fixtures	Inspection of Ascent/Descent Separation Plane and Engine Mount Hole Pattern.
10	Welding Fixtures (Family of Tools)	Welding of Landing Gear and Outrigger Struts
11	Keller Drill Jigs(Family of Tools)	Drilling of Landing Gear and Outrigger Strut Connections.
12	Inspection Checking Fixtures	Dimensional Inspection of Assembled Landing Gear and Outrigger Subassembly.
*See Figure 4-4 for Descent Stage Subassembly Breakdown and Manufacturing Flow		

Table 4-2- Descent Stage- Major Assemblies and Major Tools Required.

4.1.1.3.1 Descent Structural Subsystem Assembly - The major manufacturing sequences for the Descent Structural Subsystem are outlined below:

- An assembly fixture is provided for the fabrication of the main beams (Table 4-2, Operation 1).
- An assembly fixture is used to produce the intermediate beams. The same fixture is utilized for the manufacture of the Intermediate Beam - Closure Panel Subassembly (Table 4-2, Operation 2).
- Assembly drill jigs are used for the manufacture of the upper and lower bulkheads (Table 4-2, Operation 3 and 4).
- Fabrication and inspection of attach fittings for tanks, tank skirts, engine, and miscellaneous components. Also, fabrication and inspection of landing gear fittings.
- Fabrication of Upper Bulkhead attach fittings and inspect.
- Fabricate details and machine fittings and assemble landing gear outriggers.
- Fabricate and inspect tank skirts (Table 4-2, Operation 5).
- Fabrication and inspection of tank mounts.
- Fabricate and inspect end panels and thermal shielding.
- Final structural assembly is accomplished using the assembly fixture shown on Figure 4-18. This tool provides for initial joining of main beams, intermediate beams, and the Intermediate Beam-Closure Panel Subassembly, and for the secondary structure installation. Master controlled surfaces are established. These include the Landing Gear attachment points and supporting structure. gimbal and actuating pick-ups, Ascent/Descent Separation Plane, fuel and auxiliary tank and tank skirt fittings, and RCS mounting provisions (Table 4-2, Operation 6, 7, and 8). A unique feature incorporated in this fixture is the integral track and dolly arrangement. This arrangement is provided to unload

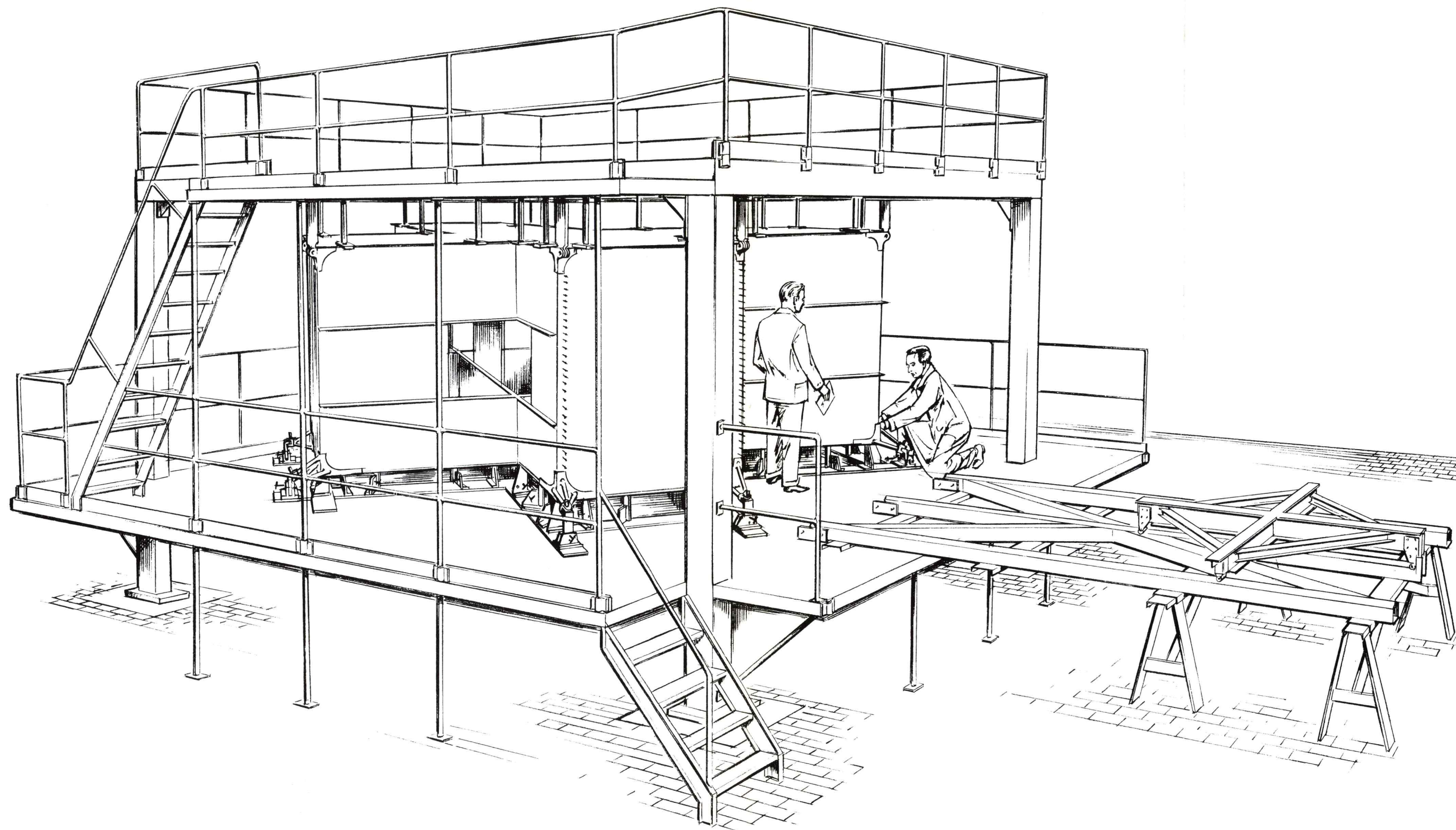


Figure 4-18 Final Structural Assembly  
Fixture-Descent Stage

the fully assembled Ascent Stage from the fixture and make it accessible to in-plant overhead hoisting equipment. This feature facilitates unloading and minimizes the possibility of damage during unloading by confining the movement of the assembly.

- Inspection checking fixtures (Table 4-2, Operation 9), are used to check the interchangeable areas, such as separation plane, and engine mount provisions.
- The completed Descent Structural Subsystem is transferred to the cleaning area using a GSE hoisting sling and a handling dolly. Subsequent installations are discussed in Section 5.

4.1.1.3.2 Lunar Landing Gear Fabrication - The Lunar Landing Gear Assembly consists of a series of welded strut subassemblies which couple the Descent Structure with the landing pads. Although a maximum of two sets are required per month, duplicate tools will not be required since the subassembly breakdown allows for fabrication using a single family of tools.

It is expected that landing gear design modifications will be essential throughout the development program. Thus, all tools will be designed with maximum consideration for removing and relocating tool components to rapidly and economically respond to these engineering changes.

4.1.1.3.3 Landing Gear Outrigger Fabrication - The Landing Gear Outriggers are similar to the Landing Gear in design. They are also constructed of machined parts and welded strut assemblies. The Outrigger Subassembly contains the adapter interface in addition to the Landing Gear attach points.

The basic manufacturing plans for both the Lunar Landing Gear and Outriggers are outlined as follows:

- Machine end fittings and prepare tubular sections.
- These details are joined using welding equipment and locating and clamping tooling. A series of these tools (Table 4-2, Fixture 10) are required because of the different strut configurations for each gear assembly. All equipment settings are certified for the particular application.
- All ferrous welded struts are magnafluxed and proof-load tested.
- Welded struts are located in drill jigs (Table 4-2, Fixture 11) for establishing finished hole sizes and accurate distances between the end fitting holes of each strut subassembly. Semi-portable, automatic feed pneumatic drilling equipment is used to assure consistency of quality.
- Landing Gear pad details are machined and drilled using conventional equipment and standard clamping tools. Honeycomb details are prepared and bonded to the gear pads. Bonding tools and an autoclave are used for this operation. Completed Landing Gear and Outrigger Strut Subassemblies are joined in inspection checking fixtures (Table 4-2, Fixture 12) to check over-all length and to assure compatibility with the mating Descent pick-up points. The Landing Gear assemblies, including the pad, are trial mated with the Descent Structure to assure proper fit. To test functional operation, the Landing Gear is cycled from fold to open several times and the "up-lock" fit and "down-lock" action checked. The electrical circuit to firing squibs is also checked. These procedures occur during the installation phase as described in Section 5.

- Since the Landing Gear are not shipped as an integral part of the LEM, these assemblies are packaged in the transportation GSE, and are forwarded to the appropriate site after the completion of Grumman test programs.

#### 4.1.2 Crew Provisions Subsystem

Grumman is responsible for fabrication and installation of panels, consoles, seats, and restraints, and for the installation of lighting, displays, and control components.

The seats, containing a number of units for achieving the adjustment requirements, consist primarily of welded tubular type subassemblies. Master gages, containing only common jig points, are used to fabricate both floor and seat tools to insure interchangeability of seat assemblies. Combination type fixtures, for welding and drill and ream operations, are provided for producing seat subassemblies. This method of manufacture, proven during previous aircraft welded seat fabrication, is the most economical procedure based on the manufacturing rate. This concept also allows for convenient replacement of seat components.

Panels and consoles are fabricated utilizing standard sheet metal construction methods. Lighting, displays, and control components are mainly purchased items. They are integrated with in-house manufactured items to complete the Crew Provisions Subsystem.

#### 4.2 FLUID SUBSYSTEMS

Grumman plans for the fabrication and installation of the Ascent Stage propulsion tanks and lines are described in Section 4.2.1. Manufacture of lines for Descent Propulsion, Environmental Control, and Reaction Control Subsystems are described in Sections 4.2.2 and 4.2.3. Production testing of these components is described in Section 6. Refer to Section 1.3 for the present summary of Fluid Subsystem "make or buy" plans.

#### 4.2.1 Propulsion Subsystem - Ascent Stage

The aluminum Ascent Stage flight-weight and boiler-plate fuel and oxidizer tanks and associated line assemblies will be produced at Grumman. Accurate tooling for independent detail fabrication and assembly methods will be used to maintain high reliability and to minimize hand-fitting on assembly. The fixture requirements for the flight-weight and boiler-plate tanks are listed in Table 4-3 and 4-4, respectively. Figure 4-19 shows the detailed manufacturing flow for Ascent Stage flight-weight tanks and Ascent/Descent lines.

Tank welding operations are accomplished using the gas tungsten welding process with localized shielding as shown in Figure 4-20. A radiographic inspection is performed to insure a quality weld. The tanks are pressure and helium leak tested. Following inspection, the tanks are ready for cleaning and sealing prior to final assembly.

The line assemblies will be produced from steel tubing formed on a tube-bending machine and trimmed to size. The required valves, fittings, and other purchased hardware are cleaned, positioned in a fixture, and brazed in an inert atmosphere, without flux, using an induction brazing unit as shown in Figure 4-21. The detail line assemblies are inspected, and pressure and helium leak tested prior to cleaning. The above operations will not be performed under clean room conditions since the parts are cleaned, sealed, and packaged prior to entering the assembly area.

Installation of engines and tanks to the structural subsystem and the integration of line assemblies will be performed in a better-than-standard environment, maintaining clean assembly practices. Section 5 contains a more complete description of these operations.

* List of Fixtures		
Part	Fixture Type	Assembly Name or Operation Description
Hemisphere	Spin Chuck Spin Chuck Spin Chuck Spin Chuck Spin Chuck Expanding Die Lathe Fixture	First Forming Second Forming Third Forming Upper } Final Forming and Trim Lower } 1/8" Full Size I.D. at Girth Machine Trim and Cone Area
Boss	Lathe Fixture Lathe Fixture	Machine Inside of Boss Machine Outside of Boss
Mounting Cones	Lathe Fixture Lathe Fixture	Machine Inside of Mounting Cones Machine Outside of Mounting Cones
Hemisphere & Boss Sub-Assy	Weld Fixture Assy Drill Jig	Weld Hemisphere to Boss Cone Attachment
Tank Assembly	Weld Fixture	Final Joining - Girth Weld
Tank Assembly	Boring Mill Fixtures Boring Mill Fixtures Drill Jig	Face Cones  Bore Cones  Cover Attach Holes
Cap Assembly	Lathe Fixture Drill Jig Drill Jig Weld Fixture	Machine Cap Attach Holes Weep Holes Standpipe
Handling Equipment	Dollies  Hoist Rig	For Transporting, Spin Chucks, Raw Material, Preforms, Hemispheres, and Spheres. In-Plant Handling.
*See Figure 4-19 For Flight-Weight Propulsion Tank Manufacturing Flow		

Table 4-3 Ascent Stage LEM Flight-Weight Propulsion Tank Fixtures

List of Fixtures		
Part	Fixture Type	Assembly Name or Operation Description
Hemisphere	Spin Chuck Spin Chuck Lathe Fixture	First Forming First Forming Trim
Boss	Lathe Fixture	Machine Boss
Hemisphere & Boss Sub- assembly	Weld Fixture	Weld Hemisphere to Boss
Tank Assembly	Weld Fixture	Final Joining- Weld at Girth
Tank Assembly	Lathe Fixture Drill Plate	Final Machining Cover Attach Holes
Cover	Lathe Fixture Drill Plate	Machine Cover Cover Attach Holes
Handling Equipment	Dollies  Hoist Rig	For Transporting Spin Chucks, Raw Material, Preforms, Hemispheres, and Spheres. In-Plant Handling

Table 4-4 Ascent Stage - Boiler Plate Tank Fixtures

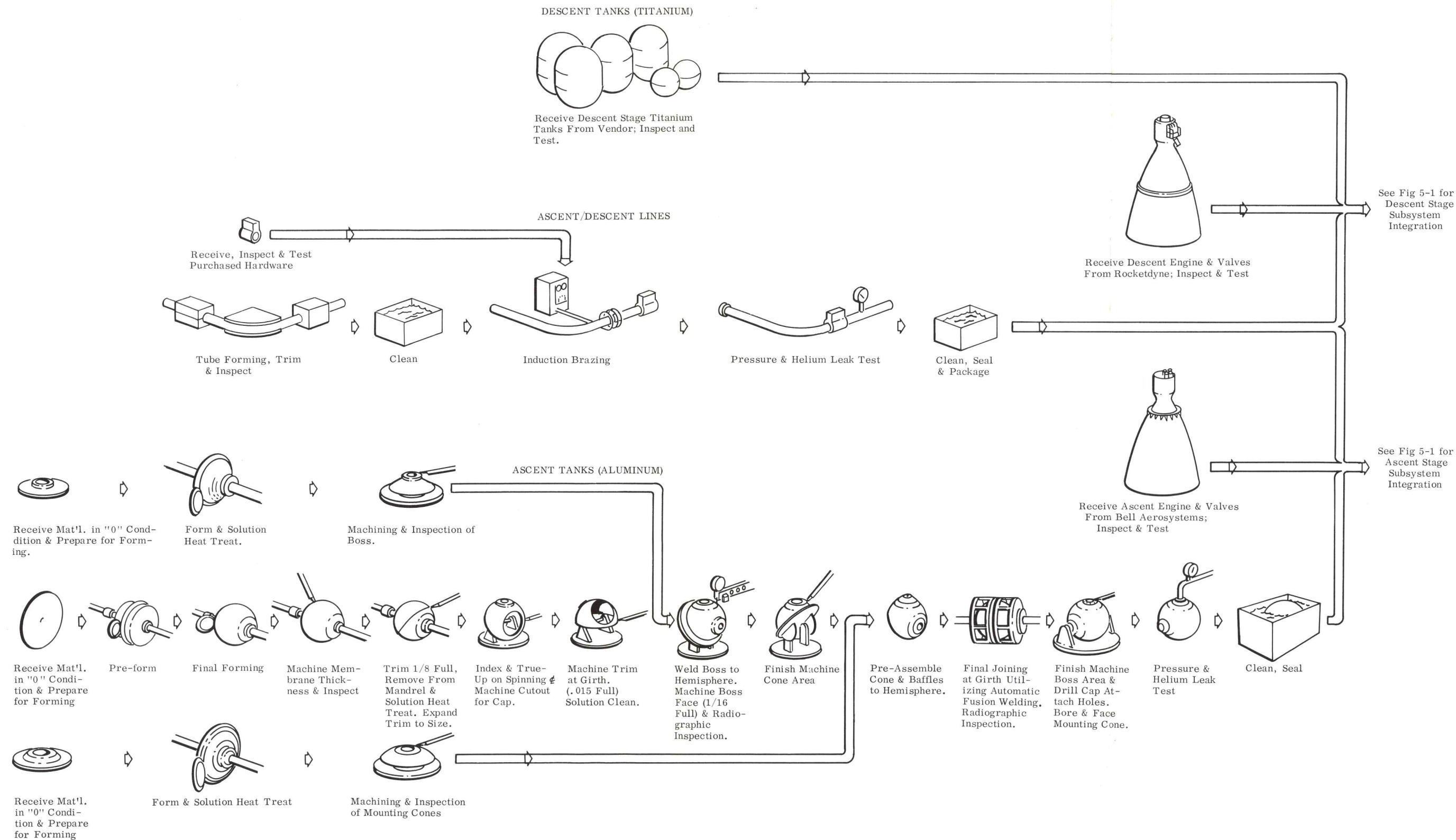


Figure 4-19 Manufacturing Flow Diagram-  
Ascent/Descent Lines &  
Ascent Tanks

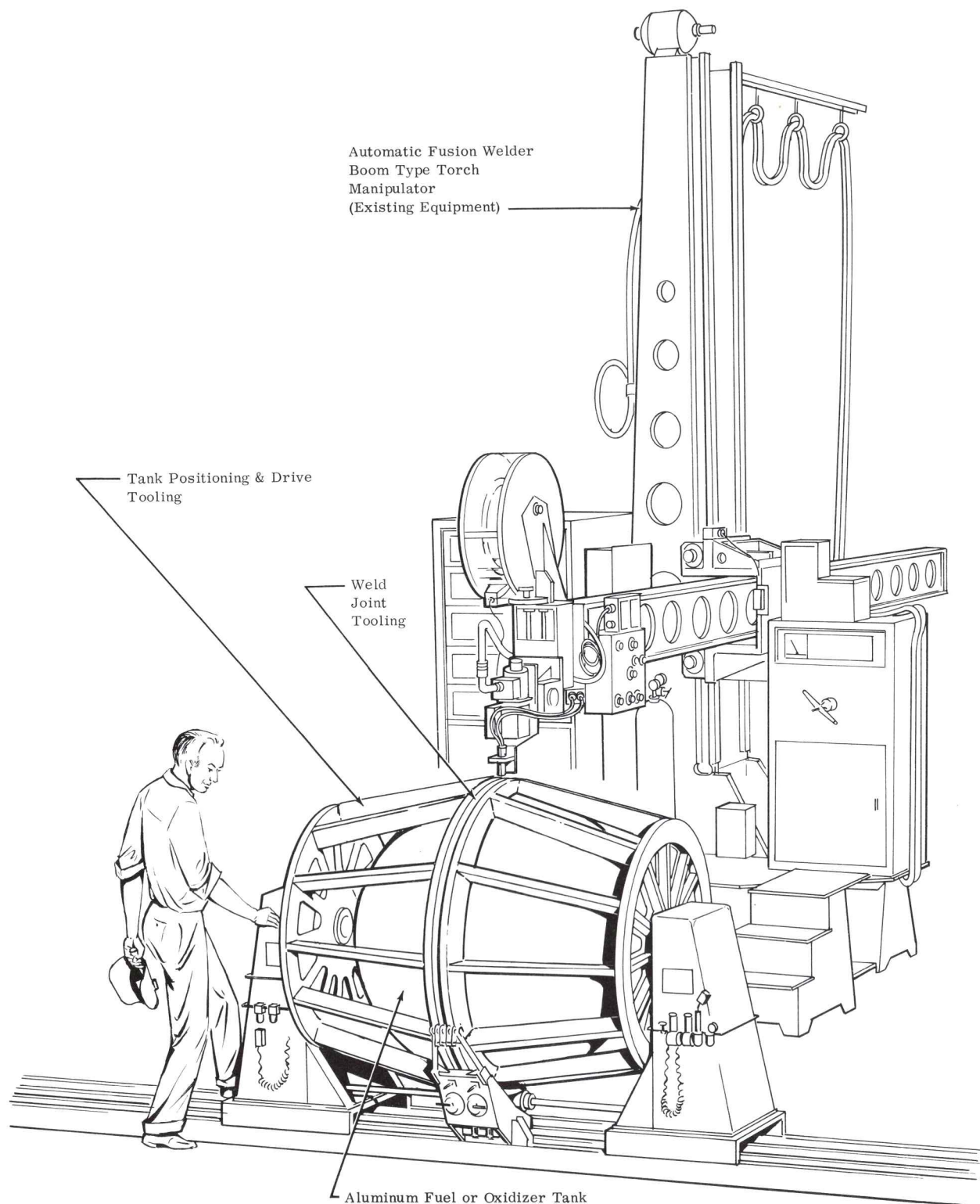


Figure 4-20 Automatic Fusion Welding of Aluminum Ascent Tanks

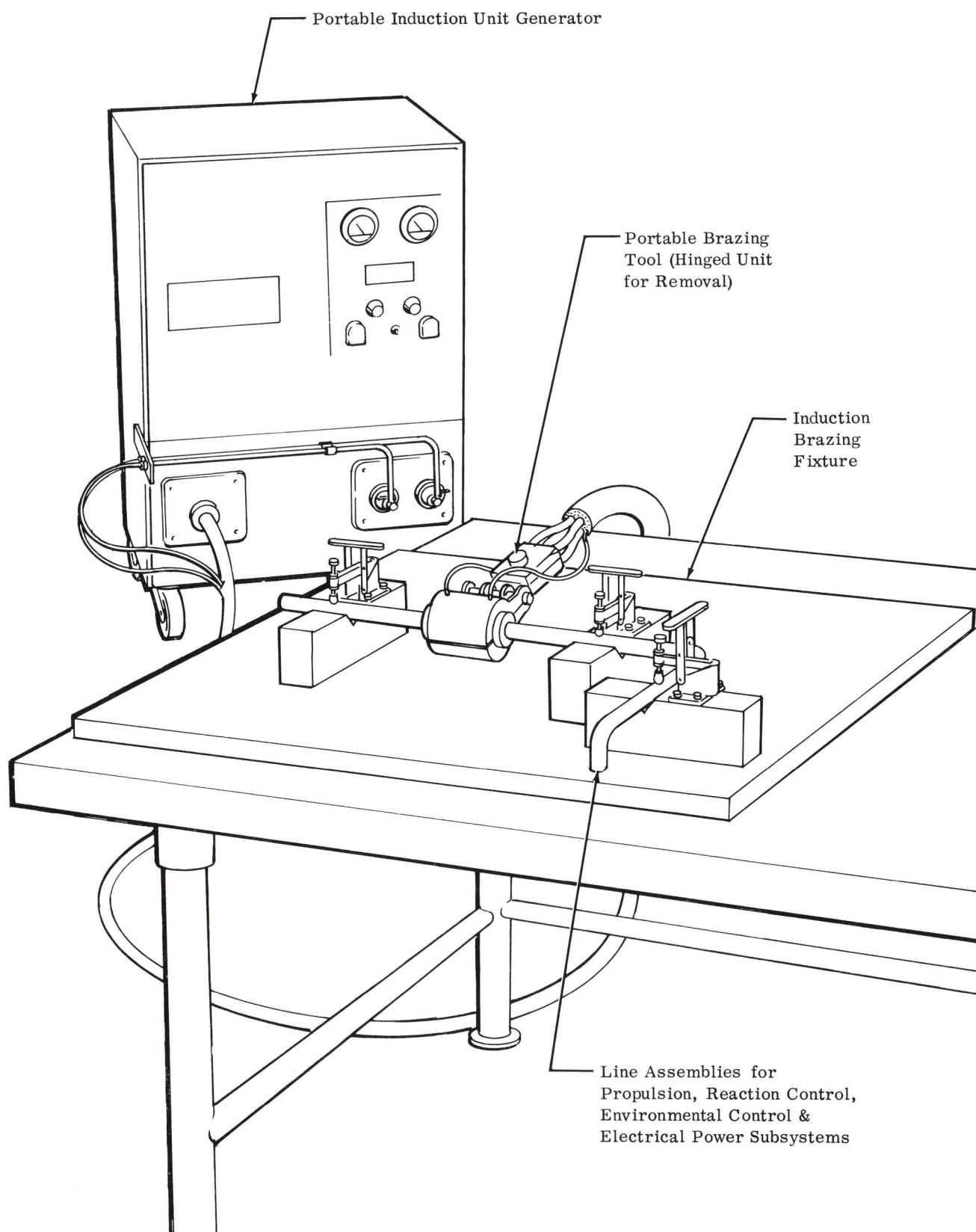


Figure 4-21. Induction Brazing of Line Assemblies

#### 4.2.2 Propulsion Subsystem - Descent Stage

As shown in Figure 4-19, the Descent Stage titanium tanks will be "vended" items. The fabrication of line assemblies and the subsequent integration of engine, tanks, and line assemblies into the structural subsystem is similar to that described for the Ascent Stage in Section 4.2.1.

#### 4.2.3 Reaction Control and Environmental Control Subsystems

The titanium-helium pressurization tanks required for the Reaction Control Subsystem will be "vended" items. Line assemblies for the Reaction Control and Environmental Control Subsystems are Grumman "make" items. Production methods similar to those described for the Ascent Stage lines in Section 4.2.1 will be used. Integration of the line assemblies, tanks, and vendor supplied Reaction Control and Environmental Control components into the Structural Subsystem will be performed under controlled clean room conditions. A product conforming to the required degree of reliability and cleanliness will thus be assured. Refer to Section 5 for a complete description.

### 4.3 ELECTRICAL/ELECTRONIC SUBSYSTEMS

Manufacturing plans for in-house fabrication and integration of Electrical Power Subsystem line assemblies, and for fabrication of antennas and subsequent installation of these antennas and vendor supplied Communications Subsystem components into the Structural Subsystem are described in Section 4.3.1 and 4.3.2. Grumman will also fabricate the network control panels for attitude reference/control coupling electronics, and will integrate the critically positioned Navigation and Guidance and Stabilization and Control

Subsystems into the module as described in Section 4.3.3. Production testing of Electrical/Electronic Subsystem components is discussed in Section 6.

Refer to Section 1.3 for a summary of "make or buy" plans.

#### 4.3.1 Electrical Power Subsystem

The Electrical Power Subsystem fuel cell will be supplied by Pratt & Whitney. The line and valve subassemblies required to join the cryogenic tanks to the fuel cells will be manufactured at Grumman. Production methods and subsequent integration of these line assemblies into the Structural Subsystem will be similar to that described in Section 4.2.1.

#### 4.3.2 Communications Subsystem

Grumman is responsible for the manufacture and subsequent installation of two types of VHF-LEM/CM antennas. The helical-type antennas are produced by wire winding methods, very similar to the techniques used in the fabrication of tension or compression springs. The conical-type antenna consists of a wire winding on the exterior of a fiberglass cone. The cone detail is manufactured by laying-up fiberglass over a male molding form. This cone is drilled and trimmed to size after a vacuum bag and oven curing operation. A wire-winding applied to the exterior of the cone completes the antenna assembly.

These antenna assemblies, and the vendor supplied communications subsystem components are installed into the Structural Subsystem. An interwiring operation completes the Communications Subsystem installation.

#### 4.3.3 Navigation and Guidance and Stabilization and Control Subsystems

Grumman will fabricate the network control panels for attitude reference/control coupling electronics, using standard sheet metal construction methods, and will integrate the N & G and S & C Subsystems into the module. Grumman will also be responsible

for alignment and functional testing of the critically positioned Inertial Measurement Unit, Scanning Telescope, and Radar Antenna components of the N & G Subsystem, and the functional testing of the S & C Subsystem components.

The alignment and functional testing of the critically positioned N & G and S & C Subsystems components will be performed in one common fixture utilizing a precision air bearing indexing table. The accuracies required may be achieved only through the use of optical tooling techniques. The precision indexing system requires fewer pieces of optical equipment, a smaller structure, and a more compact design which alone suggests lower initial costs. Simplicity of operation and the use of the precision indexing table as a positioning stand for the Radar Antenna Test Range will definitely contribute to lower operating costs in performing the module alignment and functional testing operations. Alignment and functional test procedures are described in Section 5.4.

SECTION 5 - Final Assembly

## SECTION 5

### FINAL ASSEMBLY

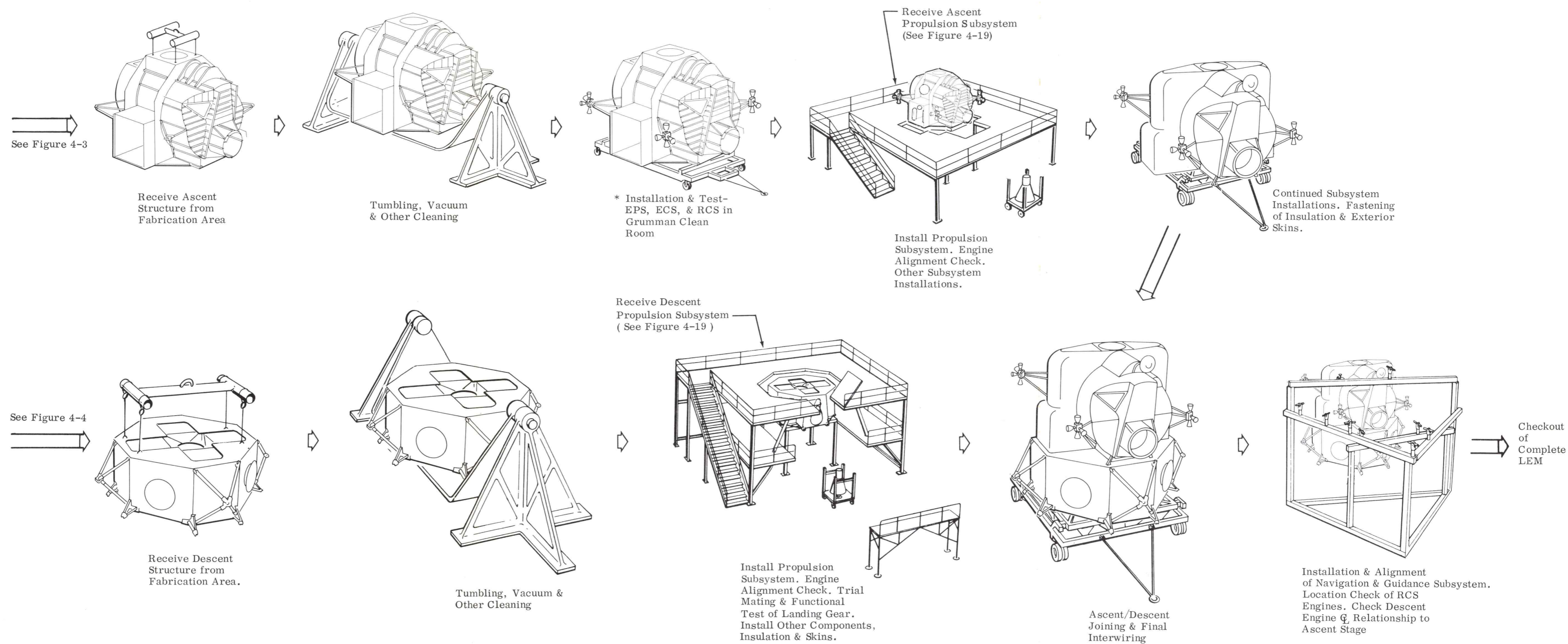
#### 5.1 FINAL ASSEMBLY DESCRIPTION

Final assembly operations will begin with the cleaning of the Ascent and Descent Structural/Mechanical Subsystems and continue through all subsystem installations, interwiring, external ascent skin panel installations, ascent/descent mating, final installations, and optical alignment of critically positioned subsystem components. Production tests will be integrated throughout these operations as described in Section 6. Maximum utilization of GSE will be made during the final assembly phases since a capability for performing the majority of these tasks will also be required at various field-site locations. For economy, all handling GSE fabricated specifically for the in-house manufacturing cycle will not necessarily conform to military specifications for outdoor environmental conditions, transportability, special hardware and fittings, etc.

Figure 5-1 shows the basic installation, joining, and alignment flow up to the beginning of the test program for the complete module.

#### 5.2 FINAL ASSEMBLY AND SUBSYSTEMS INSTALLATIONS - ASCENT STAGE

Prior to partial installations in the existing Grumman "clean room", the Ascent Structural/Mechanical Subsystem received from the subassembly manufacturing area will be cleaned using tumbling, vacuum, and possibly exterior washing methods. Tumbling for removal of trapped particles will be accomplished using a cleaning fixture which will be a duplicate of the NAA/CM apparatus or a modification thereof. After cleaning, the Ascent Structure will be secured to a GSE handling dolly for entrance into the clean room.



\* Noted operation performed in the Grumman Clean Room. All other operations are performed in an adjacent area which will be a better than standard shop environment and maintained as a clean installation & test facility.

Figure 5-1. Installation, Joining and Alignment Flow

All tests and installations for the Environmental Control, Electrical Power, and Reaction Control Subsystems must be performed under controlled environmental conditions. A 5000-square-foot area within the 8900-square-foot Plant 5 clean room manufacturing and test facility is presently planned for these LEM requirements. Adequate Plant 5 clean room area will be available for both the LEM Program and the NASA/OAO Spacecraft installations, alignment, and tests which will continue in this facility.

As a continuation of the OAO policy, the Class II clean room, which is temperature, humidity, and particle size controlled, will be staffed with technically competent manufacturing personnel who also possess demonstrated orderliness and cleanliness work habits. Personnel who participated in establishing the OAO clean room manufacturing program will be utilized to a maximum extent in the LEM Program so that the benefits of experience will be derived in the areas of tool and handling equipment design concepts, cleaning and packaging process applications, efficient clean room area arrangement, as well as optimum manufacturing, installation, inspection, and testing techniques.

Constant monitoring and surveillance of work area cleanliness levels, housekeeping standards, incoming parts and tools, cleaning methods and media, and personnel work habits will maintain and assure performance within established cleanliness standards.

All Environmental Control, Electrical Power, and Reaction Control Subsystem components will be completely integrated and sealed prior to removal of the Ascent Stage from the clean room. Induction brazing techniques will probably be used for the installation of all line assemblies.

The Propulsion Subsystem and other subsequent installations do not presently require the degree of clean room control as described for the two previous subsystems. However, Grumman plans to allocate a LEM area directly adjacent to the clean room, which will be a better-than-standard shop environment and maintained as a clean installation and test facility.

One of the initial operations in this facility will be the installation of the ascent engine; fuel, oxidizer, and helium tanks; and associated line assemblies. This station will consist of a GSE holding fixture and workstand, GSE engine mating fixture, hoisting provisions, and an induction brazing unit. All integration of the tanks, valves, engine and line subassemblies will probably be accomplished using induction brazing methods for maximum reliability and cleanliness.

Since the Structural Subsystem engine pick-up points will be master controlled and jig located during the final structural assembly phase, only an optical alignment check of engine position relative to the ascent separation plane will be required. A boresight reference gage will be inserted in the engine nozzle and set to the center line of thrust established from engine mounting faces and pickup holes. Portable tooling bars and optical transit squares will be used to set the mirror reference.

Upon completion of the ascent engine installation, an optical check will be made between the engine boresight reference gage and the Ascent/Descent Stage interface hard points. If misalignment is indicated, the engine position must be corrected in this station. An indexing cube and electronic leveling device will be oriented to the thrust center line and fixed to the top of the Ascent Stage. The indexing cube and electronic leveling device will serve as the optical reference for all future alignment and functional testing of the Navigation and Guidance, and Stabilization and Control Subsystem components as described in Section 5.4.

Other subsystems such as Crew Provisions and Displays, Stabilization and Control, Electrical Power, Communications and Instrumentation will be installed and interwired in the engine mating and a subsequent handling station. A sequence flow for these subsystems has not been established. The installation of the Navigation and Guidance Subsystem is shown in Section 5.4.

Fastening of Ascent Stage exterior skin panels and insulation will also be accomplished in the handling station. After final inspection and test, the Ascent Stage will be joined to the Descent Stage as described in Section 5.4

### 5.3 FINAL ASSEMBLY AND SUBSYSTEM INSTALLATIONS - DESCENT STAGE

All final operations for the Descent Stage can be performed in the LEM installation and test facility which will be located directly adjacent to the clean room. As previously mentioned, this area will be a better-than-standard shop environment. Clean assembly practices will also be maintained for the Descent Stage.

The completed Structural Subsystem will be cleaned after receipt from the subassembly manufacturing area. Vacuum and manual washing methods will be used. The tumbler method may also be used, pending further study of cleaning requirements. For this report, tumbler cleaning has been included in the Figure 5-1 flow diagram.

A Descent Propulsion Subsystem installation fixture, similar in design to the ascent station, is provided for joining the structure, engine, fuel, oxidizer, and helium tanks; as well as associated line and valve subassemblies. All connections will probably be induction brazed. A minimum of structural fabrication will be required since the Descent Stage, tanks, and engines are planned as interchangeable units. The positional relationship of the engine and descent separation plane is checked using optical methods. As described for the ascent engine, a boresight reference gage will be inserted in the nozzle of the descent engine and set to the center line of thrust established from engine mounting faces and pick up holes. Portable tooling bars and optical transit squares will be used. The center line of thrust established will be for a cold engine and may change due to engine firing and corrosion of the nozzles. An attempt to determine the extent of deviation will be made during future test firings of the engines, and corrections made if necessary.

An optical check will be made between the engine boresight reference gage and the Descent Stage interface hard points after engine installation. If misalignment is indicated, engine position must be corrected in this station. The mirror reference will also be used in the Manufacturing Alignment and Functional Test Fixture, described in Section 5.5, to check the orientation of the descent engine to the indexing cube fixed to the top of the Ascent Stage.

Other components such as the supercritical oxygen and scientific equipment will be installed in the engine mating and a subsequent handling station. Final operations will include the fastening of insulation and some skin panels. To assure proper fit and operation, the Lunar Landing Gear will be trial mated to the Descent Stage and cycled in the engine mating station.

#### 5.4 ASCENT/DESCENT JOINING AND CRITICAL SUBSYSTEM ALIGNMENT

The Ascent and Descent Stages, less Landing Gear, will be mated in a GSE handling dolly. Compatibility of the separation plane between the two stages will be checked and final inter-wiring will be performed.

The LEM will be transferred to a Manufacturing Alignment and Functional Test Fixture (Figure 5-2) for installation and alignment of critically positioned Navigation and Guidance Subsystem components such as the inertial measurement unit, radar antenna, and scanning telescope.

As shown in Figure 5-2, the LEM will be installed on the precision air-bearing indexing table of the alignment fixture. Jig points will be provided to obtain an approximate location. The module will be leveled using the three jacks provided under the module mounting ring and the electronic leveling unit fixed to the top of the Ascent Stage. The ascent engine center line of thrust and the faces of the indexing cube will be parallel to the axis of table rotation and "gravity vector".

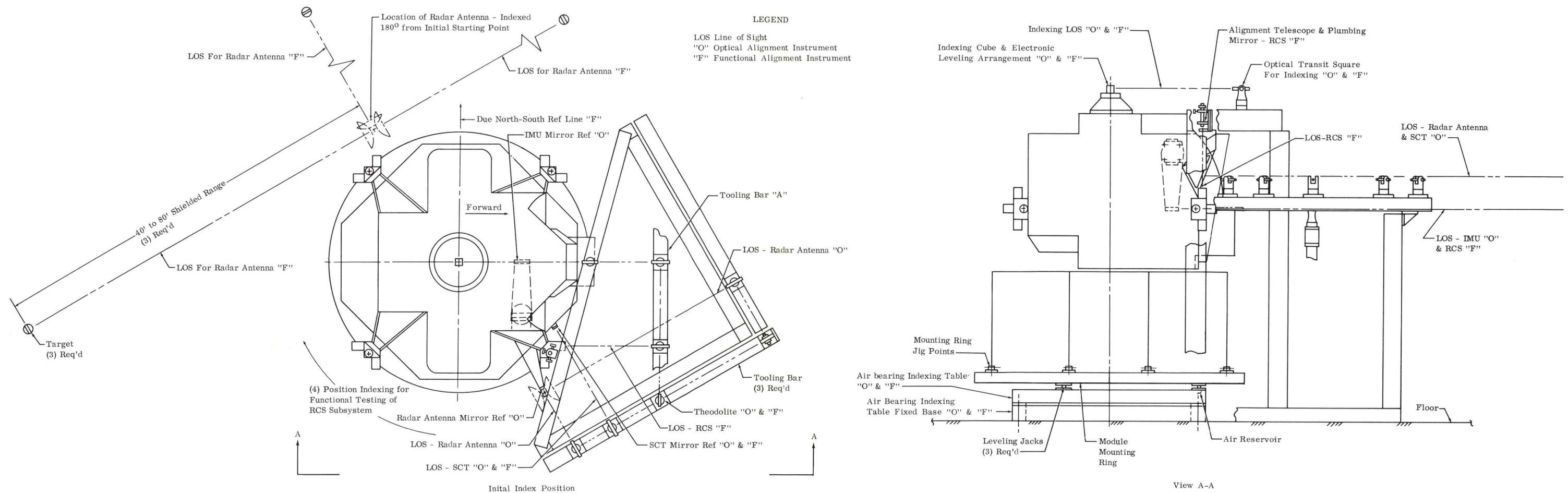


Figure 5-2. Manufacturing Alignment and Functional Test Fixture

The optical transit square provided for indexing will be collimated to the indexing cube. The optical transit square will be dumped and collimated to another optical transit square located on tooling bar "A". Through the use of a theodolite and additional optical and telescopic transit squares, all control lines of sight may be established.

The Radar Antenna mirror reference gage will be installed on the antenna mounting surface. This Radar Antenna mount will be adjusted until the optical transit squares are collimated to the mirror references and locked in position.

An Inertial Measurement Unit (IMU) mirror reference gage will be installed on the IMU isolation mount with stainless steel inserts attached. This isolated mount will serve as a common mount for the IMU and the Scanning Telescope (SCT). The weight and cg location of the mirror reference gage should correspond with that of the actual IMU and SCT components. This requirement must be met to eliminate possible "slumping" of the isolated mount and to achieve the required accuracies. The mirror reference gage will be adjusted until it is leveled out and the optical transit square will be collimated to the mirror reference. A plastic shim will then be poured around the stainless steel inserts to maintain their proper orientation.

Connections between the Ascent and Descent Stage will then be released. Collimation of the optical transit squares to the mirrors on the IMU, Radar Antenna, and Descent Engine mirror reference gages will be checked. If excessive deviations are noted, shims may have to be used to minimize the "racking" of the structure during the mating operation. If shims are required, the alignment procedure must be repeated.

The IMU and Radar Antenna mirror reference gages will be removed and the two units installed per specifications. The SCT will be placed on its mount and the SCT mirror reference gage will be installed. The SCT mount will be adjusted until the optical transit squares are collimated to the mirror references and locked in position.

In addition to functional testing of the Navigation and Guidance Subsystem, the close tolerance positions of the Reaction Control Engines required for stabilization and control, must also be checked in the fixture. These functional tests will be accomplished in four table indexing positions as described below:

- The initial indexing position, used for the aligning operations, will also be used to functionally check the gimbal axis of the Radar Antenna, and the shaft and trunnion axes of the SCT. These axes must be coincident with the Radar Antenna gimbal axis, as the SCT will be used to slave the Radar Antenna for acquisition. The location of one TCA cluster of Reaction Control Subsystem engines may also be checked in the initial indexing position. A gage containing a boresight reference mirror will be inserted into the nozzle of two of the engines. Collimation of the optical transit square to the mirror on the gage will be checked. The vertical line of sight to the boresight reference mirror on the engine cluster will be established with a plumbing mirror. Collimation of the alignment telescope to the boresight reference mirror on the gage will be checked to determine the amount of error. If engine assembly is out of tolerance, corrections must be made and location rechecked at this time. This procedure will be followed for all Reaction Control System engine assemblies. The location of the Descent Engine may also be checked to the indexing cube at this position using the mirror reference gage and an optical transit square.
- For the second index position, the table will be rotated 90 degrees clockwise, controlling the table position with the indexing cube and electronic leveling device and the optical transit square provided for indexing. The location of the second TCA cluster of Reaction Control Subsystem engines may then be checked. Note that instrument alignments will not be changed from the initial index position to accomplish this measurement.

- For the third index position, the table will be rotated 90 degrees clockwise, controlling the table position as noted above. The location of the third TCA cluster of Reaction Control Subsystem engines may then be checked. Procedures and instrumentation alignments will remain the same as those of the preceding index position. The functional testing of the Radar Antenna on the range will also be accomplished in the third index position. It may be performed then or after the fourth TCA cluster of Reaction Control System engines have been checked.
- For the fourth index position, the table will be rotated 90 degrees clockwise, and the location of the fourth TCA cluster of Reaction Control Subsystem engines checked. Procedures and instrumentation alignments remain the same as those for the preceding index position.

Functional testing of the complete Navigation and Guidance Subsystem will also be accomplished in the fixture. Once the module equipment has been aligned, functional testing of the subsystem will be performed. This will be accomplished by rotating the precision indexing table until the IMU is aligned on a due North-South line. This point will be coincident with one of the four indexing positions. Utilizing optical instrumentation on the tooling bars, the IMU can be displaced to any angular position with a high degree of accuracy, permitting calibration of its outputs.

To repeat this procedure at other sites, the IMU mirror reference gage will be used to locate the module to the orthogonal axis of a fixture oriented to a due North-South line by jacking and rotating a positioning table. An optical transit square and a level on the IMU mirror reference gage will be used to control table position.

The manufacturing alignment and functional test operations discussed herein represent the completion of the LEM manufacturing phase. LEM Manufacturing Team support during the Ground and Flight Test Programs is described in Section 6.5.

SECTION 6 - Manufacturing Test Program

## SECTION 6

### MANUFACTURING TEST PROGRAM

#### 6.1 DESCRIPTION AND IMPLEMENTATION

Satisfying the LEM mission reliability objectives requires strict conformance with the detailed test plans and specifications, constant surveillance of the test equipment used for manufacturing test, and the utilization of highly trained teams of test technicians.

All testing will meet maximum reliability requirements and Grumman test specifications. Test data will be logged for maintaining complete records of an individual component and supplier.

As described in Section 7.1.1, the test equipment must be continuously monitored for assurance of optimum equipment performance. Thus, periodic calibration and maintenance operations are scheduled using an "IBM alerting system".

Consistent with the manufacturing approach, test program plans emphasize the use of manufacturing test technician teams identified with each LEM. Each team member is also responsible for a given subsystem. This procedure allows for achieving a high experience level, which is vital to the LEM manufacturing test program. Manufacturing test technicians will perform testing of components and subsystems, and will support all Ground and Flight Test Programs. Specimens, models, and components will be produced for development testing, and assistance will be provided to the Engineering Department for conducting these tests.

Manufacturing test technicians will also participate in the development, reliability, qualification, and acceptance test programs, as well as assure the orderly flow of subsystems and components to maintain test schedules and checkout requirements. Planning and scheduling procedures will be flexible to absorb changes which will be generated by development test programs.

Ground and Flight Test Programs established by the Engineering Flight Test Departments will be supported by manufacturing test technicians. This effort will be coordinated and supervised by the LEM Structural/Mechanical Test Leader who will work with Manufacturing Planning, Quality Control, and Engineering. His tasks will include witnessing, monitoring, and assisting in the documentation of tests performed on his assigned module. In addition, the Structural/Mechanical Test Leader and his team of technicians will assist in implementing the failure analysis corrective cycle and will support the off-site test program operations.

Prior to the beginning of any manufacturing test program, the Quality Control Department will assure conformance with the following requirements:

- Materials and processes used in all previous fabrication operations are in accord with the applicable specifications.
- Fabrication and inspection operations performed previously have been performed by properly trained and certified personnel and equipment.
- Test facilities and equipment have been evaluated for adequacy.
- Visual and operational inspection and checkout of a unit to be tested has been satisfactorily accomplished to applicable specifications and procedures.
- Test equipment and instrumentation to be used has been properly and currently calibrated.

- Parts and materials have been inspected and personnel have complied with the proper cleanliness procedures.
- Detailed Test Plan to be used has been reviewed and approved.

During all test programs, Quality Control will provide the following assurances:

- Tests are conducted in accordance with the specified test procedures.
- Adequate and accurate documentation including data sheets and test logs, is maintained throughout the test program.
- Tests are halted when any deviation from the test procedure is noted. In the event of a failure, an analysis is conducted, corrective and preventive action incorporated, and proper documentation and notification instituted.

## 6.2 MANUFACTURING TEST - STRUCTURAL/MECHANICAL, AND CREW PROVISIONS SUBSYSTEMS

This report section describes the manufacturing test approaches for the Structural/Mechanical Subsystem and the Crew Provisions Subsystem.

### 6.2.1 Structural/Mechanical Subsystem

The testing of the Structural Subsystem starts with the manufacture and testing of specimens and sections of the Structure and continues through the assembly period.

A structural/mechanical technician will work full time during the assembly of a module to assure the timely and smooth flow of structural elements through acceptance testing into the assembly sequence, to assure the integrity of the subsystem, and to provide quick reaction to incorporation of design changes at the proper time in the assembly sequence. The structural/mechanical technician will become the LEM Team Leader when subsystems integration begins. As previously mentioned, he is also responsible for the supervision of the Manufacturing Team throughout the Ground and Flight Test Program for a specific module.

The testing of the Lunar Landing Gear will start with the construction of a 1/6-scale Landing Stability Model and Transitional Drop Test Rig. Various arrangements of Landing Gear and honeycomb shock absorber combinations will be set up and tested.

A honeycomb development test program will be conducted. The necessary test fixture will be constructed and maintained by manufacturing test and instrumentation technicians for this program.

Fittings and major components will be tested to qualify the design reliability. A prototype tripod will be made and tested prior to the testing of the complete subsystem. Subsequent vacuum and drop testing will continue through the LTA Program. This test program will be coordinated by the manufacturing test technician who is responsible for the Landing Gear Subsystem.

#### 6.2.2 Crew Provisions Subsystem

Manufacturing test and instrumentation technicians will assist Engineering set up and conduct tests in support of the Crew Provisions Subsystems Test Plan; seat testing and occupant restraint, as well as seat support and lighting will be included. Additional test support will be maintained while other provisions are being tested by demonstration in mock-ups.

Crew provisions testing will be conducted in the Structural and Lighting Test Laboratories and in the Environmental Test Center, Manufacturing technicians working with Engineering, Planning, and Quality Control will conduct, witness, and assist in the documentation of tests to qualify all components of the Crew Provisions Subsystem.

### 6.3 MANUFACTURING TEST - FLUID SUBSYSTEMS

This report section describes the manufacturing test approaches for the Reaction Control, Propulsion, and Environmental Control Subsystems.

#### 6.3.1 Reaction Control and Propulsion Subsystems

Manufacturing test requirements of the Reaction Control and Propulsion Subsystems are primarily the same, and will be comprised of non-firing or "cold flow" tests to permit the exercise of the systems electrical or continuity checks, as well as pressure and leakage checks. These test programs will be conducted at three levels:

- Component - Propellants and helium.
- Section - Propellant feed and helium pressurization.
- Subsystem - Integratrated helium pressurization and propellant feed.

##### 6.3.1.1 Component

Propellant tests will include a visual inspection for conformance to the Specification Control Drawings and leakage and functional tests on referee propellant flow benches. Hydrostatic proof pressure checks will be performed for all propellant tanks.

Helium tests will also include visual inspection and hydrostatic proof pressure tests of each helium tank. Leakage and functional tests or helium flow benches will be performed

using helium leak detectors. If the helium pressurization section requires grouping of specific components into isolated modules, the module will be tested as a whole.

#### 6.3.1.2 Section

Propellant feed (also helium pressurization) will require visual inspection for conformance with Configuration Design Drawings. Leakage and functional tests will be performed where possible through ground test connections using high pressure gas, leak detectors, instrumentation, and external or module controls.

#### 6.3.1.3 Subsystem

Integrated propellant feed and helium pressurization testing will be accomplished using procedures identical to those previously described for Section testing. After completion of the test program, the subsystems will be purged, pressurized, and sealed.

The test programs for the Reaction Control and Propulsion Subsystems will utilize GSE/STE such as component test stands, propellant storage and temperature conditioning units, stage structures for hot firing, purge and flush units, as well as instrumentation and control consoles. This test equipment will be maintained and calibrated periodically to insure accuracy and cleanliness. Quality Control will monitor all test phases for assurance of test reliability.

#### 6.3.2 Environmental Control Subsystem

Because of the extreme cleanliness requirements associated with the Environmental Control Subsystem, all Grumman tasks for this subsystem, including manufacturing testing, will be performed in a Class II clean room area.

The subsystem will be inspected when received from Hamilton-Standard to insure dimensionally correct components. The subsystem will also be functionally tested. Parameters

to be monitored include, but are not limited to, pressure drop at rated flows, proof pressure, leakage, response to stimuli, and power.

The subsystem will be installed in the LEM and a performance verification test performed. This test will insure that the installed subsystem is performing within its proper design envelope.

#### 6.4 MANUFACTURING TEST - ELECTRICAL/ELECTRONIC SUBSYSTEMS

This report section describes the manufacturing test approaches for the Electrical Power, Communications, Instrumentation, Displays and Controls, Stabilization and Control, and Navigation and Guidance Subsystems.

##### 6.4.1 Electrical Power Subsystem

The Electrical Power Subsystem requires both electrical and fluid manufacturing test programs. Since the electrical test procedures are primarily the same as those described in Section 6.4.2, only the fluid test plans are described herein.

The fluid manufacturing testing will be conducted on the following three levels:

- Component - Fluid storage and supply.
- Section - Fluid storage and supply and energy conversion package.
- Subsystem - Integrated fluid storage and supply and energy conversion package.

All test phases will require a visual inspection for conformance to the Specification Control Drawings and the Configuration Design Drawings. All components will be purged and prepared for shipment to subsequent areas. Sections and Subsystems will be purged, pressurized with inert gas, and sealed after the completion of test phases.

#### 6.4.1.1 Component

Fluid storage and supply will require leakage and functional tests on cryogenic reactant flow benches. The fluid storage tanks will require a supply of liquid reactants for loading and thermodynamic tests.

#### 6.4.1.2 Section

Fluid storage and supply will include leakage and functional tests using a supply of liquid reactants, gaseous reactants, external or module controls, leak detectors, and instrumentation.

Energy conversion package will be tested for leakage and functional operation using a gas supply system, electrical loading equipment, leak detectors, instrumentation, and controls.

#### 6.4.1.3 Subsystem

Integrated fluid storage and supply and energy conversion package will be functionally and leak tested using a liquid reactants supply, a gaseous reactants supply, leak detectors, instrumentation, module or external controls, and loading equipment.

### 6.4.2 Communications, Instrumentation, Displays and Controls, Stabilization and Control, and Navigation and Guidance Subsystems

The basic manufacturing test plans for all LEM Electrical/Electronics Subsystems are similar. Therefore, all test approaches will be discussed as a whole. This basic test plan is discussed in the following three phases:

- Receiving tests of incoming components and subsystems.
- Assembly and integration testing during manufacturing build-up.
- Acceptance testing of the complete module.

#### 6.4.2.1 Receiving Tests

The bench test station is a receiving test facility where subsystems, assemblies, and units shipped by the vendor as qualified units are verified upon receipt at Grumman. It will be designed for semi-automatic operation with manual control and will be capable of fault isolating to a replaceable element and rechecking a subsystem after repair or modification.

The bench test station will be capable of testing subsystems and simulating any interface with other subsystems. This station will verify all the subsystems operational parameters. It will check out the PACE test functions and the ability of PACE data to check out the subsystem. Simulated failures will be made in this manner. Where redundant paths exist, sufficient tests will be performed to assure their operating conditions.

An understanding of operation between the several test stations will develop by using standard electronics test equipment and test techniques. The test equipment complexity will be minimized, consistent with the type of test required, and the designs will permit maximum expansion capabilities to include new tests using the same equipment where possible.

#### 6.4.2.2 Assembly and Integration Tests

The assembly and integration (A&I) test stations' function will be to test the subsystems during manufacturing build-up of the LEM. The approach to testing will be in building block fashion to enable a unit to be installed and checked out for operational parameters, a second unit installed and checked out, and the two units mated for an operational check on the integrated package. This technique will be used up to the complete integration of all subsystems.

The A & I test station will be capable of checking all operational parameters of each unit, assembly or subsystem, as it is installed. It will check out those PACE functions included in the unit, assembly, or subsystem, with or without the mating interfaces. It will accomplish checkouts via the PACE data. The A & I test stations will do end-to-end testing, and will verify redundant signal paths and interface signal paths.

To keep the complexity of testing and training to a minimum, and to allow for maximum expansion of testing and utilization of personnel, standard electronic test equipment and techniques will be used where possible. Self-checking features will be designed into the equipment where possible.

#### 6.4.2.3 Acceptance Tests

The final acceptance test phase will begin when the subsystems have been integrated and tested for proper interface and performance.

The PACE test equipment will be connected to the complete module and acceptance testing initiated. The function of PACE will be the checkout of the operational parameters of the LEM via the PACE data lines.

The PACE equipment will stimulate the several subsystems, measure the response, and compare it with the required answer. In the event of a failure, the PACE will be programmed to trace the source to a section (a group of components). The faulty component will be replaced and the tests affected will be repeated.

The documented test results and histories are sent to Reliability where the various factors can be determined for reliability analysis concerning mission safety and success.

### 6.5 GROUND AND FLIGHT TEST PROGRAM SUPPORT

The manufacturing team will support the LTA Ground Test and LEM Flight Test Programs during all phases of test and launch activities. The following functions will be performed:

- Rocket engine and fuel handling personnel will be engaged in the performance of flow tests and hot firings for the Propulsion and Reaction Control Sub-systems at WSMR.
- Manufacturing test teams will participate in the static, drop, environmental, and vibration tests at Grumman.
- Manufacturing and instrumentation technicians will erect test equipment, install instrumentation, conduct, witness, and document the tests required by the Engineering Test Plan.
- Follow the LTA's and LEM's through checkout and acceptance phases and proceed to off-site facilities as described in Section 8.
- Provide the proper planning and scheduling functions to maintain the continuity of tests.
- Assure orderly replacement of parts and components during the test programs.
- Operate, maintain, and calibrate all GSE/STE both at Grumman and at field-site locations. Personnel will also repair and modify the GSE/STE as required.

SECTION 7 - Manufacture of GSE/STE

## SECTION 7

### MANUFACTURE OF GSE/STE

#### 7.1 GSE/STE MANUFACTURING PLAN

LEM Ground Support Equipment and Special Test Equipment requirements are divided into the four general classifications: Handling and Transportation Support Equipment, Fluid Systems Support Equipment, Electronic Support Equipment, and Training Equipment. This report section describes the present manufacturing plans for GSE/STE. The GSE designs and utilization are not included since these descriptions are shown in the GSE Planning and Requirements List.

The plan described herein is for items which will be manufactured at Grumman.

"Make" items are based on a logical extension of the company's existing capabilities and experience. Further "make or buy" decisions will also be influenced by critical GSE/STE schedule requirements which dictate in-house manufacture to maintain these schedules.

A "buy" decision will result in the provision of a specification which will accompany the requests for competitive vendor quotations. The resulting proposals will be evaluated and a subcontractor selected.

Close monitoring of the selected subcontractor, as described in Section 3.3.4, shall be maintained throughout the program. Concurrent with the subcontractor effort, test specifications will be originated by Grumman. Maintenance and calibration procedures will be developed upon completion of the GSE/STE, and the equipment will be tested at the vendor location in accordance with the test specification. Equipment will be inspected upon receipt at Grumman.

The GSE/STE Manufacturing Plan emphasizes the use of existing Avionic, Hydraulic, Tool, and Test Equipment shops which are presently organized with the specialized skills, equipment, and facilities. Grumman facilities for GSE/STE fabrication are described in Section 2.1.8.

Although many equipment types are required, production line or completely centralized facility concepts are not warranted since the manufacturing rate for each unit is minimal. Consequently, the GSE/STE plan affords the advantages of optimum flexibility for low-rate manufacturing through the use of existing skills and facilities.

The planning, scheduling, and manufacturing flow for all LEM GSE/STE is shown in Figure 7-1. For continuity and maximum efficiency, GSE/STE manufacturing planning, scheduling, and program control will closely parallel the procedures described for the LEM Manufacturing Program (Sections 3.1, 3.2, and 3.3). Familiarity with one system is especially desirable since some common shop departments are used for both LEM and GSE/STE manufacturing. Although the Test Equipment Shop is primarily concerned with only GSE/STE manufacturing, closely related concepts are applied.

In general, the following procedures summarize the implementation plan for all in-house GSE/STE manufacturing:

- LEM Subsystem GSE Engineers for the Fluid, Electronic, and Handling/Transportation equipment develop and are responsible for the completion due dates of all equipment.
- Corporate LEM scheduling or planning representatives provide assistance for determining the GSE/STE manufacturing lead-times. These groups also maintain detailed manufacturing schedules and charts for measuring GSE/STE progress, shop workload, and manpower forecasts.
- Purchased GSE/STE component requirements are determined by the LEM Subsystem GSE Engineers and procurement requests are forwarded to the Purchasing Department.

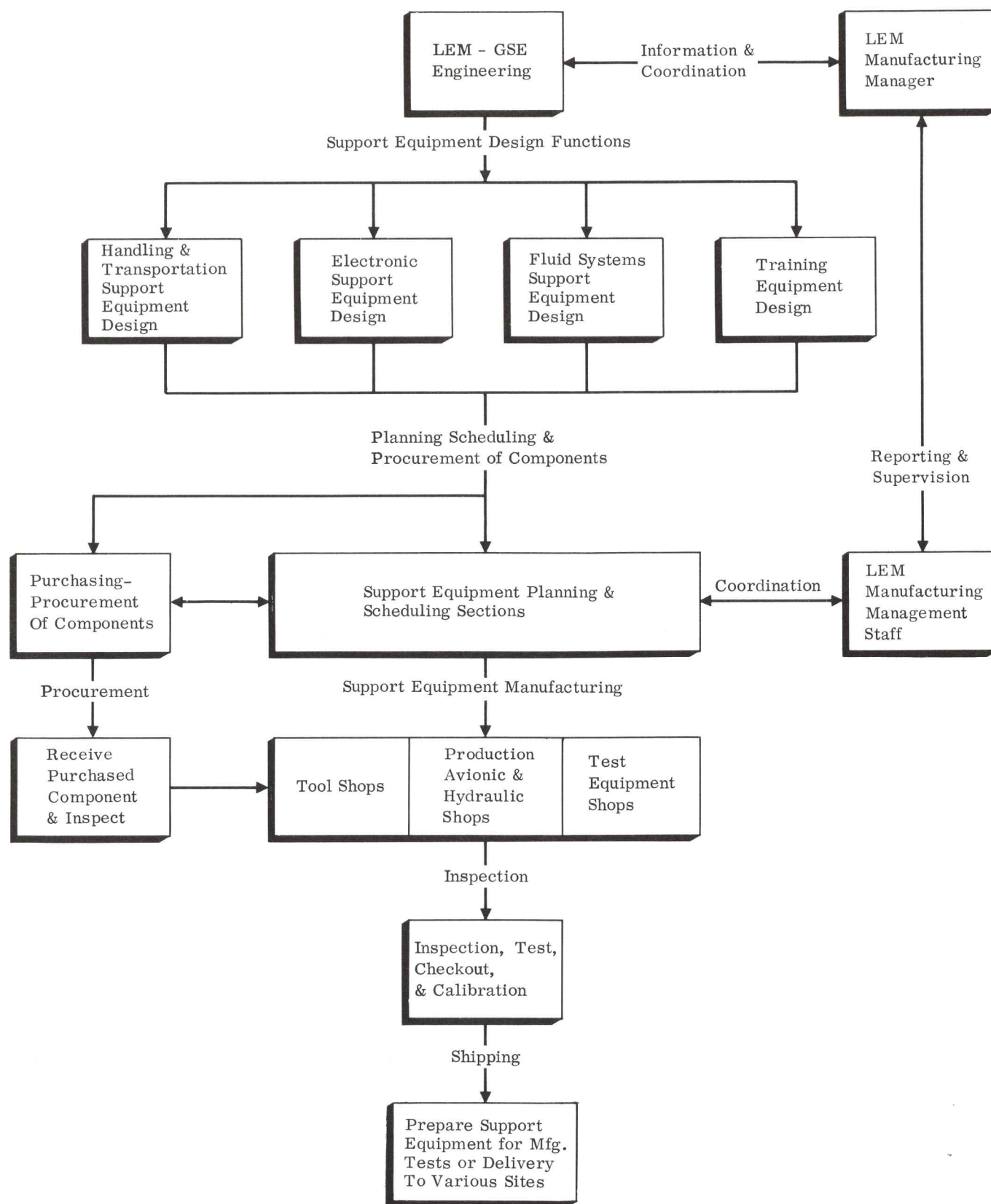


Figure 7-1 GSE/STE Planning &amp; Manufacturing Flow

- Work Authorization Statements are required for all tasks and must be approved by the cognizant corporate supervisor and/or LEM representative.
- Electronically processed expenditure reports, prepared and distributed by the Accounting Department, are used for the accumulation of all cost monitoring data. Cost control will be accomplished in accordance with the future requirements of the PERT Companion Cost System.

Items and quantities of items which will be used as GSE are listed in the "Ground Support Equipment Planning and Requirements List", LLI-400-1, dated 18 March 1963. This listing is not repeated herein.

#### 7.1.1 Electronic GSE/STE

Electrical/Electronic GSE/STE for manufacturing tests or for site delivery is fabricated in the Grumman Test Equipment Shops and the Avionic Shop Departments. In-house fabrication generally implies the manufacture of wiring harnesses, panels, cabinets, and chassis. In addition, Grumman performs the subassembly, assembly, installation, functional testing, calibration, and maintenance operations. Electronic components are usually "buy" items.

The Test Equipment Shops and the Avionic Shop Departments have produced reliable test equipment ranging from resistance measurement units to sophisticated equipment used for testing highly complex computer systems. These shops utilize the latest tools and techniques, and are able to draw support from development groups when new techniques must be applied.

The engineer responsible for the design of a piece of test equipment also prepares an acceptance test, maintenance, and calibration manual. This manual will enable criteria to be established for quality control acceptance prior to release for the production test phase.

The maintenance and calibration portion will establish the servicing intervals and supply information for the performance of calibration operations. Once the interval of maintenance

is established, an IBM card is cut and fed into the Grumman equipment cycle which automatically notifies the calibration and maintenance personnel when it is time to service the equipment. In this way Grumman is able to maintain high confidence in its production test equipment.

The sample "Preventive Maintenance Procedure Sheet" shown in Figure 7-2 provides detailed instructions for all equipment maintenance operations. This sheet is also used to initiate the IBM "service interval alerting system".

### 7.1.2 Fluid Systems GSE/STE

The development of Fluid Systems GSE/STE begins with the receipt of detailed test parameters from the appropriate subsystem engineer. These test parameters are then collated and used to generate a series of specifications for the required test equipment. These specifications thus generated will include interface documentation. Upon approval of the specifications by NASA, when required, the test equipment will be submitted for a "make or buy" decision. "Make or buy" determinations are discussed in Section 7.1.

A "make" decision will initiate an in-house design effort and the concurrent development of a detailed manufacturing schedule in conjunction with the LEM Test Equipment and Process Engineering Fabrication Coordinator. During the design phase, there will be continuous review to insure compliance with applicable specifications, including a reliability check. Toward the latter phase of the design effort, test equipment fabrication will be initiated.

Primary manufacturing responsibility for all Fluid Systems Support test equipment has been assigned to the Test Equipment and Process Project Engineer. The Test Equipment Shop, which is the primary shop for Fluid System test equipment, is supported by other shops for heavy structural fabrication of frames and trailer components. The LEM GSE/STE Fabrication Coordinator maintains constant liaison between support shops, Fluid Systems Support Engineering, and the Purchasing Department to provide the Test Equipment Shop with all information necessary for satisfactory and timely fabrication completion.



# PREVENTIVE MAINTENANCE PROCEDURE

No. 20167

<b>EQUIPMENT DESCRIPTION</b>		<b>Issue Date</b> 4-10-63
<b>Name</b> <u>Vacuum System</u>	<b>Model</b> <u>L-DW410-100</u>	<b>Revision No.</b> <u>        </u> <b>Date</b> <u>        </u>
<b>Manufacturer</b> <u>GAEC</u>		<b>Page</b> <u>1</u> <b>of</b> <u>1</u>
<b>FREQ. CODE</b>	<b>INSTRUCTIONS</b>	
	<p>1.0 Scope</p> <p>1.1 This procedure covers electrical, electronic, and mechanical inspection of the high vacuum chamber in plant 23.</p> <p>2.0 Special Equipment Req'd.</p> <p>2.1 None</p> <p>3.0 Instructions</p> <p>04 3.1 Check all relays, coils, contacts and mechanical parts. Repair or replace defective components.</p> <p>3.2 Check all electrical connections for tightness.</p> <p>12 3.3 Clean, lubricate and calibrate electronic temperature recorder as per calibration procedure 256000-03.</p> <p>3.4 Check ionization amplifier, 600P tubes should be returned to original tube sockets.</p> <p>ETC.</p>	
<b>Prepared:</b> CJF <b>Dept.</b> <b>Date</b> <b>Checked:</b> ADE <b>Approved:</b> RLL <b>TE &amp; P ENG.</b> 4-10-63		<b>Approved</b> <b>Dept.</b> <b>Date</b> WBM <b>TE &amp; P ENG.</b> 4-10-63

E & P 82 SHT. I

Figure 7-2. Preventative Maintenance Procedure Form



Maintenance, calibration, and checkout procedures are developed concurrently with the design and fabrication phases. Functional checkouts will be performed after completion of fabrication.

### 7.1.3 Handling and Transportation GSE

This category of GSE includes all of the equipment required to handle and transport the LEM and its stages plus associated equipment (e.g. work stands, mating fixtures, and special tools).

Since the prime purpose of this GSE is to protect the LEM from excessive loads and other damage during all handling operations, the majority of this equipment is ruggedly constructed of fabricated sheet and structural members. The GSE manufacturing facility within the tool shop organization is particularly well suited for this type of GSE because of heavy equipment availability. In addition, specially skilled tool shop personnel are completely familiar with heavy structural fabrication. The Tool Shop GSE facility is described in Section 2.

LEM Program schedules require the concurrent fabrication of GSE and the LTA Ground Test Modules. This factor, and the low rate of GSE manufacture requires a manufacturing approach which is adjusted for "experimental shop" methods. The tool shop personnel are particularly adaptable to prototype concepts since they are accustomed to "one-of-a-kind" tool manufacture.

Past Grumman experience indicates that this method provides the earliest possible GSE availability, and enables the incorporation of design refinements in sufficient time to reflect usage data into the first off-site deliveries.

The prototype equipment will serve as a model for the follow-on units. Minimum tooling for reduced over-all GSE costs will be provided after the prototype units have been proven.

The final operations for the Handling and Transportation GSE are qualification, test, and acceptance. These operations are performed within the structural test, instrumentation, and environmental test laboratories. All tests and inspections are performed in accordance with the applicable specifications.

#### 7.1.4 Training Equipment

The LEM Training Equipment Program has not been sufficiently defined to permit a manufacturing analysis. Therefore, the approaches developed for previous aerospace "maintenance trainer panel or test bench" programs are described herein.

Training equipment which serves as a visual aid of operating systems, usually simulates or in most cases duplicates the operational systems. Therefore, this type of GSE is assembled in the same shop departments which integrate the systems in the aerospace product. Thus, full advantage is taken of the manufacturing experience factor. These procedures are also planned for LEM training equipment which is scheduled for in-house manufacture.

The benches and equipment chassis or mounts are fabricated in shops which are equipped for sheet metal fabrication. These items are routed to the Avionics or Hydraulics Shop Departments for equipment installation and assembly. Calibration and qualification or acceptance tests are performed in the equipment shops or specialized laboratories.

SECTION 8 - Field Site Support

SECTION 8  
FIELD SITE SUPPORT

8.1 TEST AND LAUNCH SITE ACTIVITIES

The Grumman concept for providing a "Team of Manufacturing and Manufacturing Test Technicians identified with each LTA and LEM" will begin during subsystem acceptance, and will continue through the launch of the Apollo System. Field-site operations support, which is considered a continuation of on-site activity, will be provided during all phases of the test and launch activities required for the LTA Ground Test and LEM Flight Test Programs.

Grumman "Team" personnel will perform the following primary field-site functions:

- Major LEM assembly, test and checkout, as well as repair, replacement, and modification.
- Operation and maintenance of test stands and electronics, fluid, and handling/transportation GSE.
- Manufacturing support to Design Engineering and Flight Test Departments during the performance of special and pre-launch tests.
- Liaison with the Facilities Design Group to insure consideration of Manufacturing needs in the design or alteration of facilities.

A thorough review of all plant personnel is presently being conducted to assure the selection of only top-level, highly-skilled, competent personnel for the LEM Field-site Support Program. Mr. Edward Mc Mullen has been appointed as Coordinator of the LEM Field-