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FACILITY FORM 602

MANUFACTURING PLAN FOR PROJECT APOLLO - LUNAR EXCURSION MODULE

(NASA-CR-156224) MANUFACTURING PLAN FOR PROJECT APOLLO: LUNAR EXCURSION MODULE (Grumman Aircraft Engineering Corp.) 148 p

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Grumman LEM

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LPL-850-1

Report #LPL-850-1
14 May, 1963

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Contract Requirements	Contract Item	Model	Contract No.	Date
Exhibit E	3.4	LEM	NAS 9-1100	14 May, 1963

Type I — Preliminary — NASA Approval Pending

Primary Code No. 022

Report #LPL-850-1

Manufacturing Plan for Project Apollo – Lunar Excursion Module

Prepared for
The National Aeronautics and Space Administration
Manned Spacecraft Center

Prepared By:
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Coordinated By:
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Manufacturing Engineering

Approved By:
William H. Bruning
William H. Bruning
LEM Manufacturing Manager

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Grumman LEM

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INTRODUCTION

This Plan is submitted in fulfillment of the requirements of paragraph 3.4-Documentation Requirements List for Type I documents.

The content of the "LEM Manufacturing Plan" complies with the Grumman recommended outline which was approved as the basis for this initial issue. NASA approval was forwarded by Mr. Robert O. Piland, former Deputy Manager, Apollo Spacecraft Project (LEM) in letter SPP/LEM-63-50, dated 4 April, 1963.

Technical discussions and related illustrations contained herein are primarily based on the LEM General Arrangement Configuration #2B. By necessity, manufacturing descriptions for internal structure were based on the early Structural Arrangement Configuration #2 in order to satisfy the plan submittal date of four months after go-ahead, as specified in EXHIBIT E to contract NAS9-1100. The Engineering Department is presently revising Structural Arrangement #2 as a continuation of the LEM design effort.

This document, which has been prepared for NASA management information, will be revised to reflect future LEM progress at intervals to be specified by MSC-ASPO.

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; Electronic GSE; 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 overall 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 overall program costs.

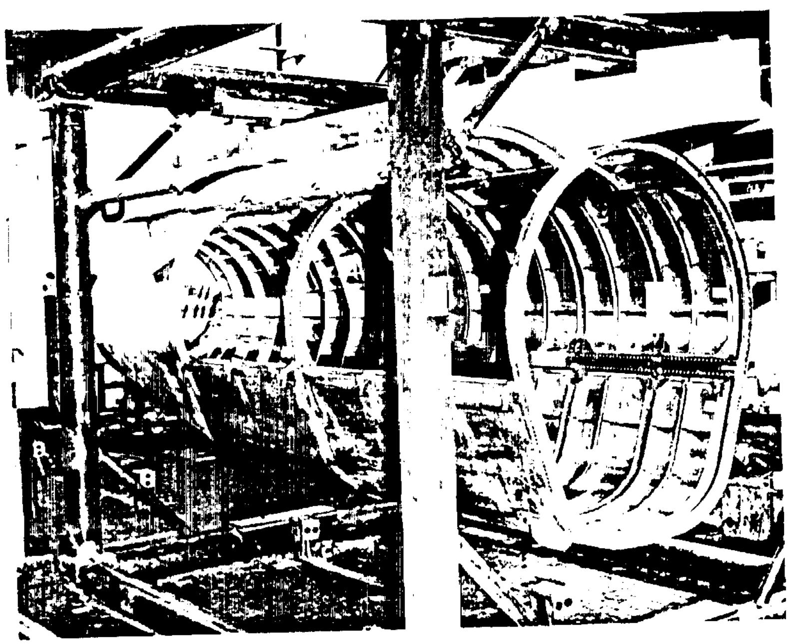
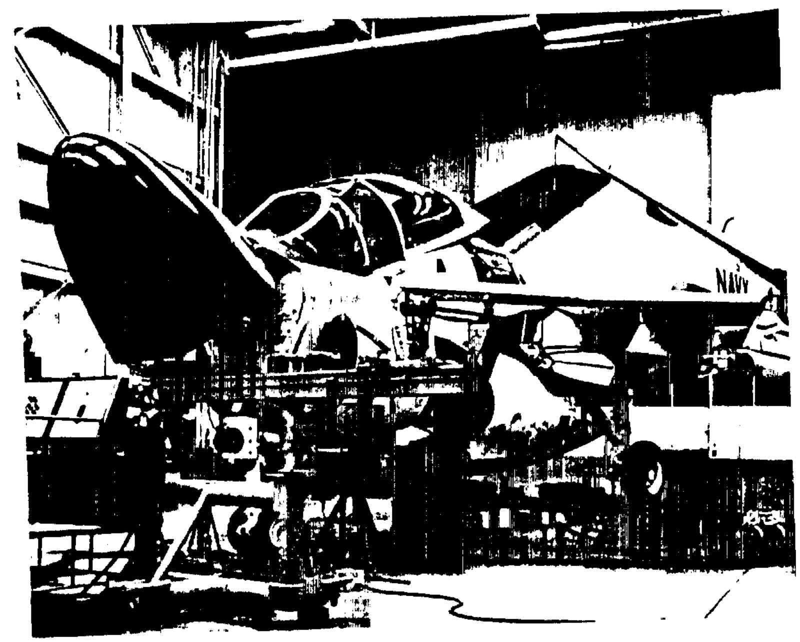
The effectiveness of this manufacturing approach which is specifically geared for low-volume/low-rate production, has been demonstrated by the on-schedule development of the highly sophisticated Grumman A-6A Intruder & E-2A Hawkeye manned flight systems.

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 below.

- 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.

- Because of the critical LTA & LEM schedules, a maximum overlap of engineering design, tooling, manufacturing and equipment program efforts

Experimental Manufacturing Plan	Development Manufacturing Plan Also Selected for LEM Program
Grumman Application: The "Experimental Manufacturing Plan" is used when only one or two units are to be produced. Follow on manufacture is not considered.	Grumman Application: 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.
Previous Example: Flying engine test cell for attachment to the B-45 aircraft.	Previous Example: A-6A Intruder, the latest jet aircraft for carrier and land based general purpose attack.
 Experimental Fabrication of Engine Test Cell	 Manufacture of A-6A Intruder Aircraft
Manufacturing Data:	Manufacturing Data:

will be necessary. Consequently, advanced Engineering Design information will be used to accelerate the start of the fabrication programs, thus allowing the completion of detail Engineering drawings at a later date. The Development Plan is particularly applicable to this method of program acceleration.

- Figure 1-2 shows a maximum structural manufacturing rate of two units per month and a total of twenty* LTA & LEM vehicles. 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 and schedule objectives are also directly related to manufacturing producibility, the LEM Engineering design concepts are being developed with maximum emphasis on 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.

Utilization of highly skilled development shop technicians allows for a minimum subassembly breakdown and accordingly a minimum tooling concept for the early LTA test modules. Thus some detail parts and minor subassemblies for these initial units will be fabricated on an experimental basis, but 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.

Also, the subassembly breakdown will be expanded and additional tools will be provided to accommodate the manufacturing rate and concurrent development requirements as shown in Figure 1-2.

The basic tooling program will be completed during the manufacture of the LTA-4 Environmental Development module. This tooling progression will result in early

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* Pending further study of configuration & utilization, LTA-8 & -9 are tentatively included as originally negotiated in December, 1962.

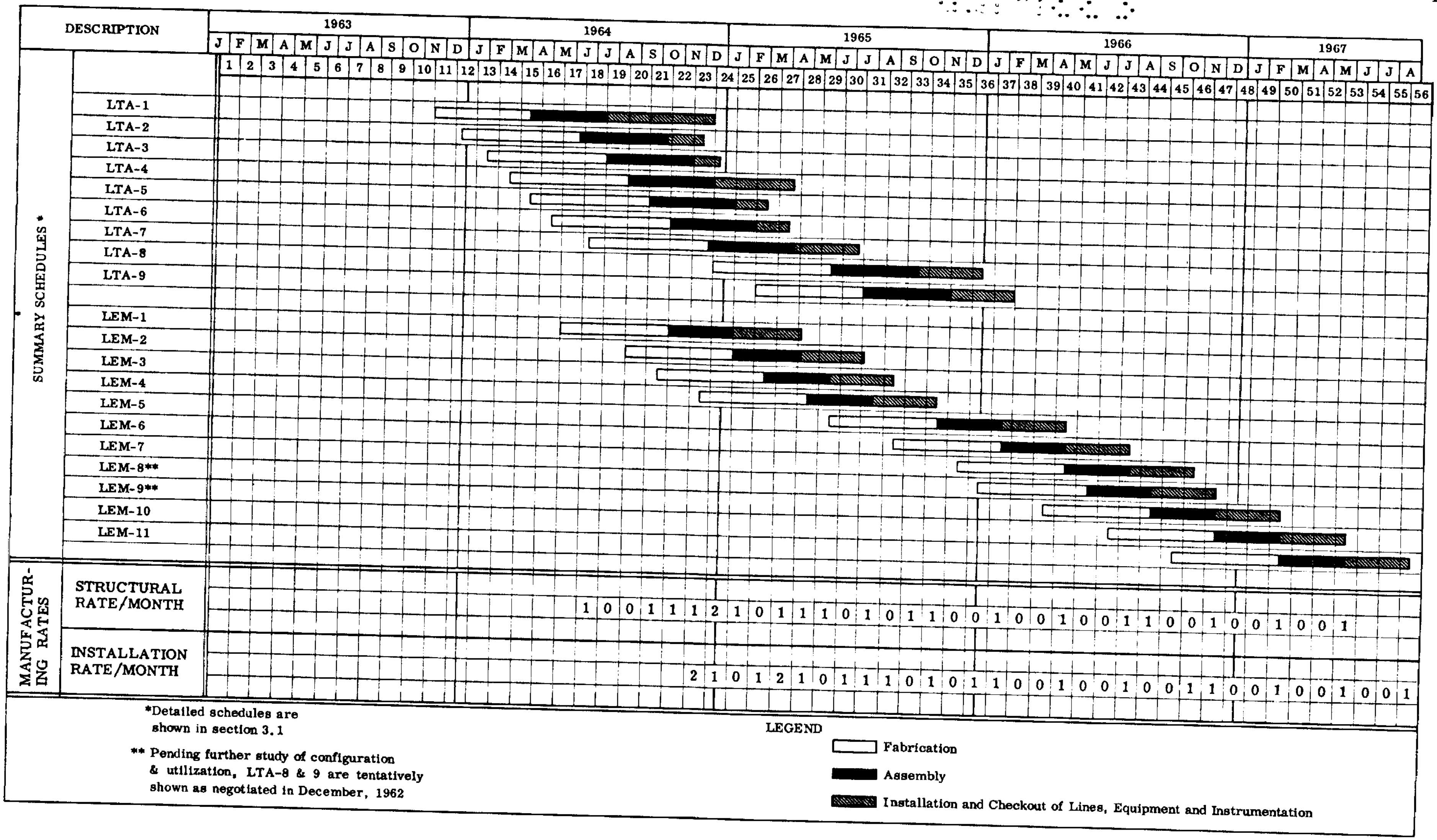

Figure 1-2. LTA and LEM Manufacturing Rates

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 sophisticated nature of the LEM program dictates the use of manufacturing team technicians identified with each LEM module. 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 Production Test plans also emphasize the aforementioned "Subsystem Team" approach for assurance of the highest quality and reliability levels. Production Test teams will make maximum use of GSE equipment for bench tests of mechanical, fluid, and electrical/electronic subsystems. Periodic maintenance and calibration of manufacturing test GSE 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 Ground Support Equipment requirements are divided into the four general classifications of handling and transportation GSE; electronic GSE; fluid subsystem GSE; & 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 Central 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 production 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 module.

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.

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

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

- Robert Wagenseil, 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 Equipment and Process Project Engineer, is responsible for developing, providing and maintaining the manufacturing equipment and the process systems necessary for production of the LEM. He is also responsible for establishing and maintaining proper

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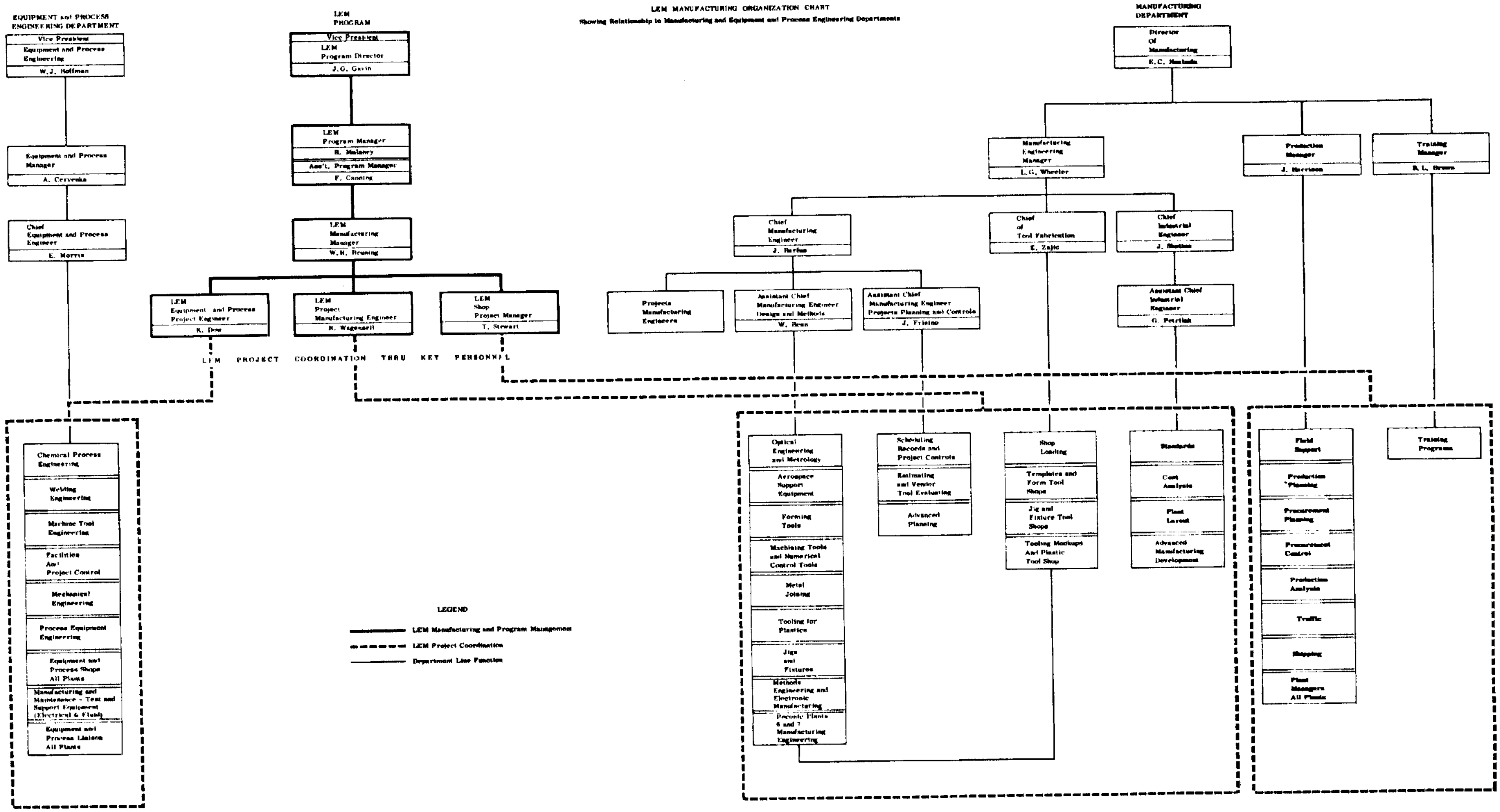


Figure 1-3. Organization Chart

manufacturing and test equipment and process schedules; for fabricating and maintaining the test and support equipment used at Grumman; and for converting engineering information into processes 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, the shipping of hardware and completed LEM assemblies, and the supervision of procurement planning and controls.

This staff reports to Mr. Bruning and operates as a coordinated team for overall program unity. Individually, they are responsible for the activities of Equipment and Process Engineering, Manufacturing Engineering and Manufacturing as described above. This "management team" concept assures a unified manufacturing approach, and also provides effective program control through the arrangement of three readily manageable units.

Further, the Manufacturing Manager and his staff maintain their offices in the plant #25 Engineering Center, and are located adjacent to LEM sections such as Program Management, Engineering, Quality Control, Test, and Business Management. Immediate proximity to the overall 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.

Figure 1-3 shows the utilization of "key personnel" who coordinate the design and fabrication activities of the Manufacturing Engineering, Equipment And Process Engineering and Manufacturing corporate 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 also presently located in the plant #25 LEM offices. Other key section personnel will be assigned to this facility when sufficient information is generated.

Grumman procedures for implementing and managing the LEM Manufacturing program are summarized below.

- 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 1-4 and 1-5. This summary is solely intended as a reference for familiarization with the Grumman subsystem manufacturing tasks which are described in Section 4.

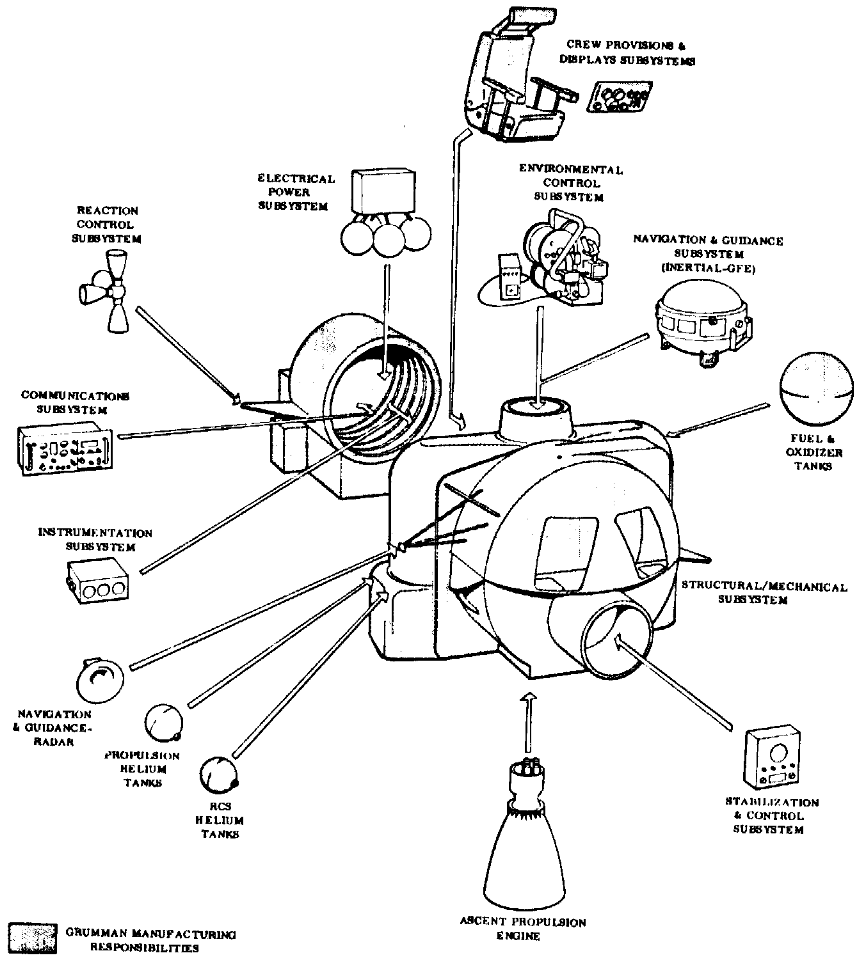
Complete "Make or Buy" plans are described in the individual Subsystem Procurement Plans. The preliminary Ground Support Equipment Planning and Requirements List No. LLI-400-1 shows the items of GSE which are tentatively planned for Grumman use.

Consistent with the Grumman concept of good business management in the areas of manufacturing, planning and long-range programming, 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.

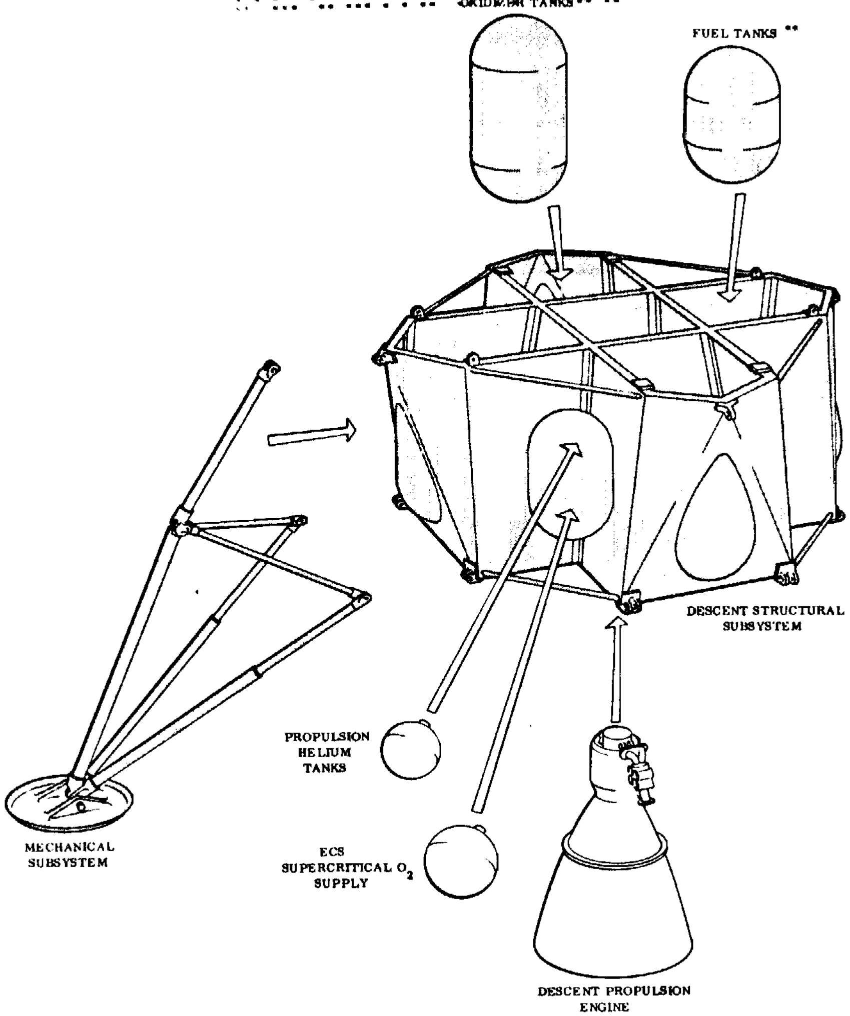
Fully recognizing the responsibility for subcontractor performance, Grumman will monitor and control subcontractor tooling and manufacturing activities using the procedures described in Section 3.3.4.



Subsystem	Primary Source: Grumman	Primary Source: Subcontractor	Grumman Manufacturing Tasks
Structural/Mechanical Subsystems	X		All Fabrication & Assembly
Propulsion Subsystem		Bell Aerosystems	Fabrication & Assembly Of Fuel Tanks, O_2 Tanks & Lines. System Integration & Test.
Reaction Control Subsystem		Marquardt	Fabrication Of He Tanks & Lines. System Integration & Test.
Environmental Control Subsystem		Hamilton-Standard	Fabrication Of Lines. System Integration & Test.
Crew Provisions & Displays Subsystems	X		Fabrication & Assembly Of Seats & Restraints; Lighting; Panels & Consoles. Installation Of Displays
Navigation & Guidance-Inertial		GFE	Subsystem Integration, Installation, Alignment & Systems Test.
N & G - Radar		X*	(Subsystem Integration, Installation, Alignment & Systems Test.)
Stabilization & Control Subsystem		X*	Fabrication, Integration & Test - Network Control Panels For Attitude Reference/Control Coupling Electronics.
Electrical Power Subsystem		X*	Fabrication of Cryogenic Reactant Lines. Integration & Test
Communications Subsystem		X*	VHF - LEM/CM Antenna, Wiring, Installation & Test.
Instrumentation Subsystem		X*	Installation & Test
Final Assembly	X		All Assembly, Installation, Alignment & Test.

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

Figure 1-4. 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		Rocketdyne (Also Parallel Engine Development) *	Fabrication & Assem of Fuel Tanks, O_2 Tanks & Lines. System Integration & Test.
Environmental Control Subsystem (Supercritical O_2 Supply)		Hamilton-Standard	Fabrication of ECS Lines. System Integration & Test.
Final Assembly	X		Assembly, Installations, & Test.

* Subcontractor To Be Announced At A Later Date

** Grumman Manufacturing Responsibility Pending Further "Make Or Buy" Studies

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

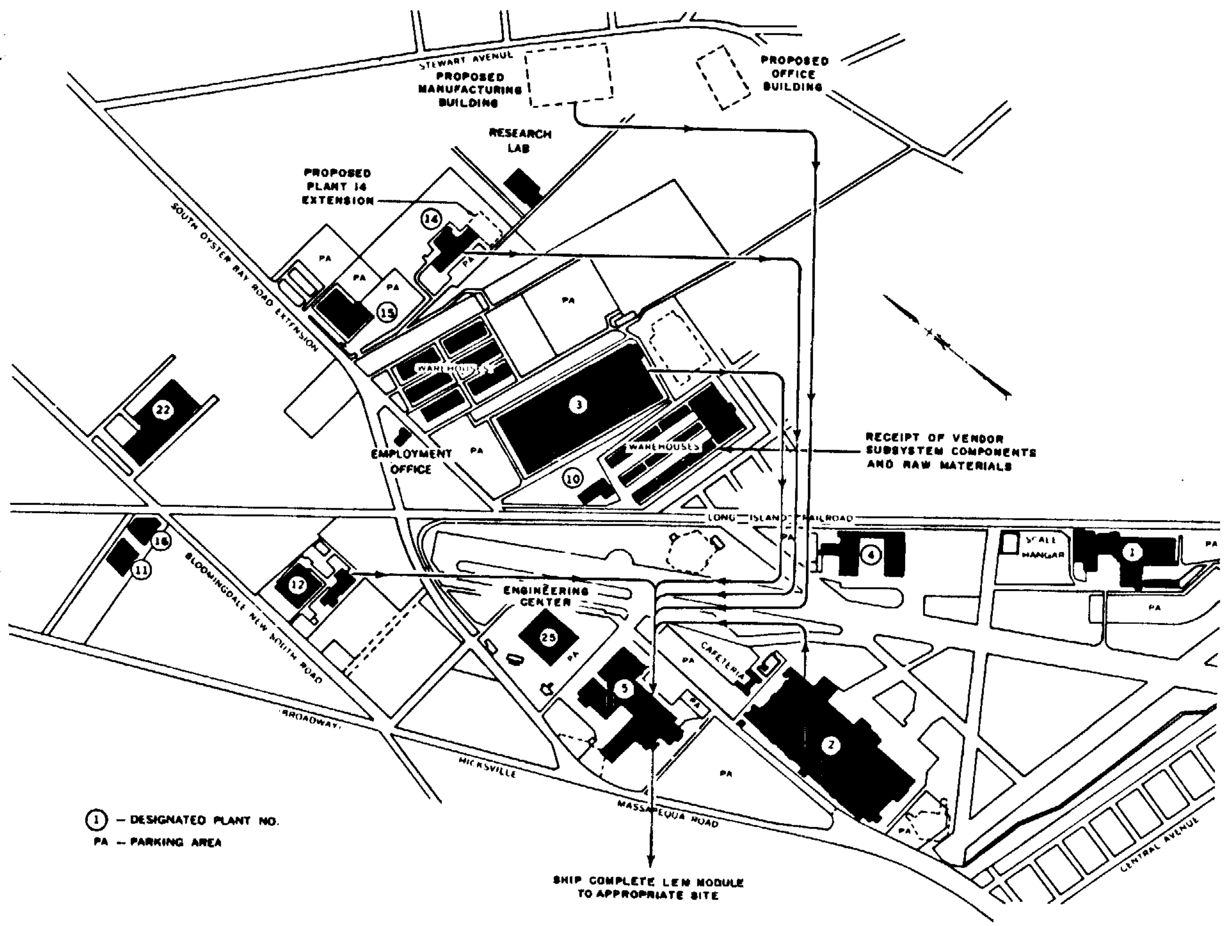
SECTION 2 – Manufacturing Facilities

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 one mile radius thus allowing for an efficient flow of parts, components and subassemblies to the centralized assembly, installation and test facility. As shown in Figure 2-1, plant #5 has been delegated the responsibility for all operations beginning with assembly and continuing through the shipment of the LEM module. This facility, which also houses the Grumman corporate offices and other NASA programs such as 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 and Reaction Control 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 module 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.



Bethpage Facility

LEGEND

PLANT	DESCRIPTION OF LEM ACTIVITIES
5	Centralized LEM Assembly, Installation and Test Assembly and integration of all systems requiring clean room environment. Final assembly, integration and test of all electrical, fluid and structural/mechanical subsystems. Preparation and shipping of complete LEM module to appropriate site. Also fabrication of crew provisions subsystem and some machined parts.
3	Major LEM Structural/Mechanical Manufacturing Machining operations, fabrication of honeycomb and welded assemblies, windshield fabrication, chem-milling, fabrication of tanks, and assembly of LEM ascent and descent structural/mechanical subsystems.
2	LEM Detail Parts and Minor Subassemblies Fabrication of sheet metal detail parts, skins, tubular assemblies, controls and landing gear components.
Proposed Mfg. Building	Electrical Assemblies and Electronic Bench Test Fabrication of electrical assemblies, bench test and repair of subcontractor supplied electronic components.
14	Bench Test and Partial Assembly of Reaction Control Subsystem
12	Plastic Parts Fabrication
Warehouses	Receipt of Vendor Subsystem Components and Raw Materials

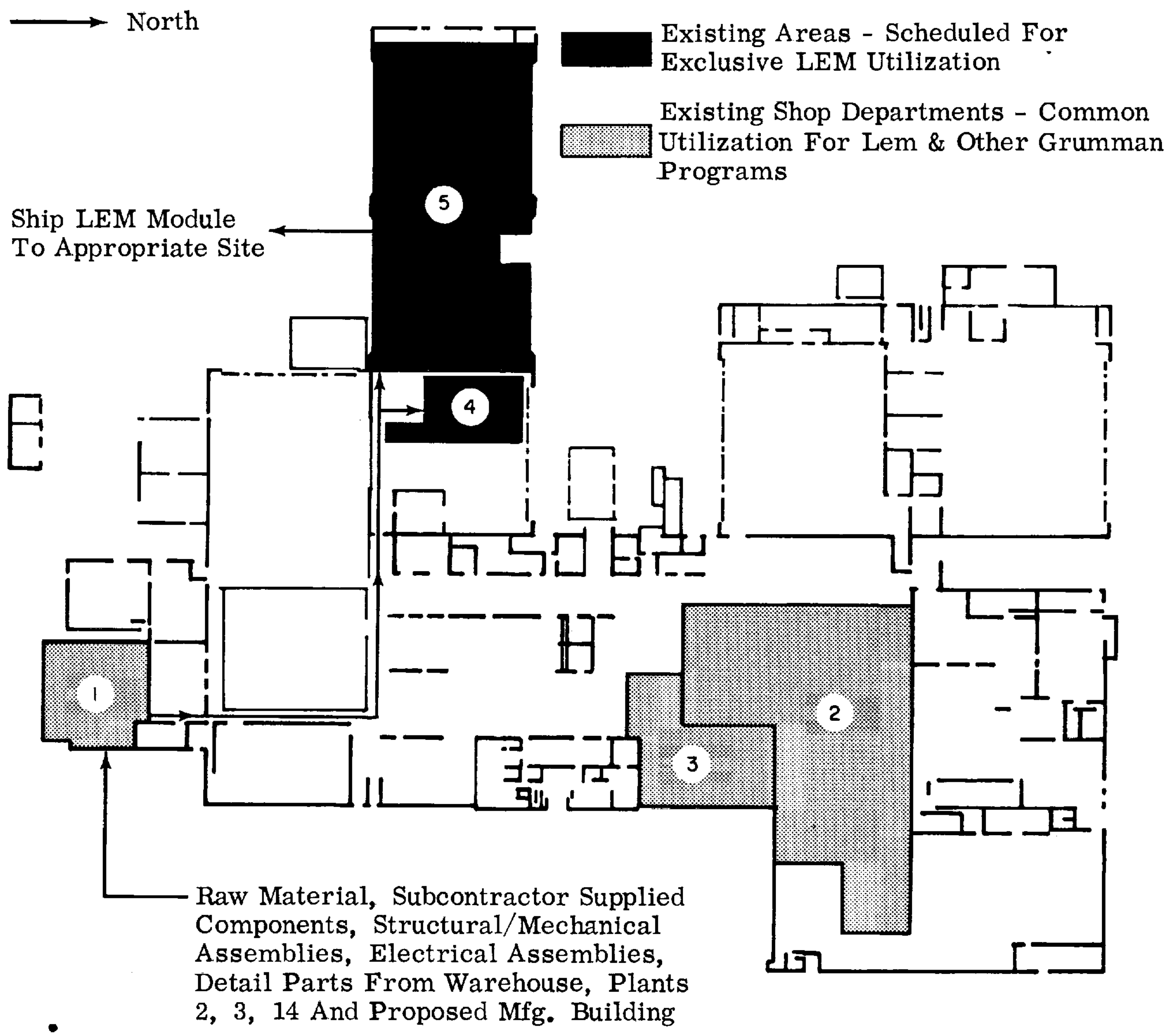
Figure 2-1. Basic LEM Manufacturing Flow Through Bethpage Facility

Other Grumman plants shown in Figure 2-1 will manufacture the Structural/ Mechanical Subsystem and other detail parts and subassemblies; fabricate electrical wiring and live assemblies; and bench test vendor supplied electronic Subsystem components. Sections 2.1.1 through 2.1.6 describe present plans for manufacturing facility utilization. Tool and GSE fabrication facilities are described in Sections 2.1.7 and 2.1.8.

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

Figure 2-2 shows exclusive LEM utilization of 24,000 square feet of existing plant #5 area. This area is subdivided into 5,000 square feet of clean room area for the RCS and ECS requirements, and 19,000 square feet for other assembly, installation and test operations. Specific areas within the clean room and the assembly area are shown in Figures 2-3 and 2-6 respectively. Photographs of the Grumman clean room are shown in Figures 2-4 and 2-5.

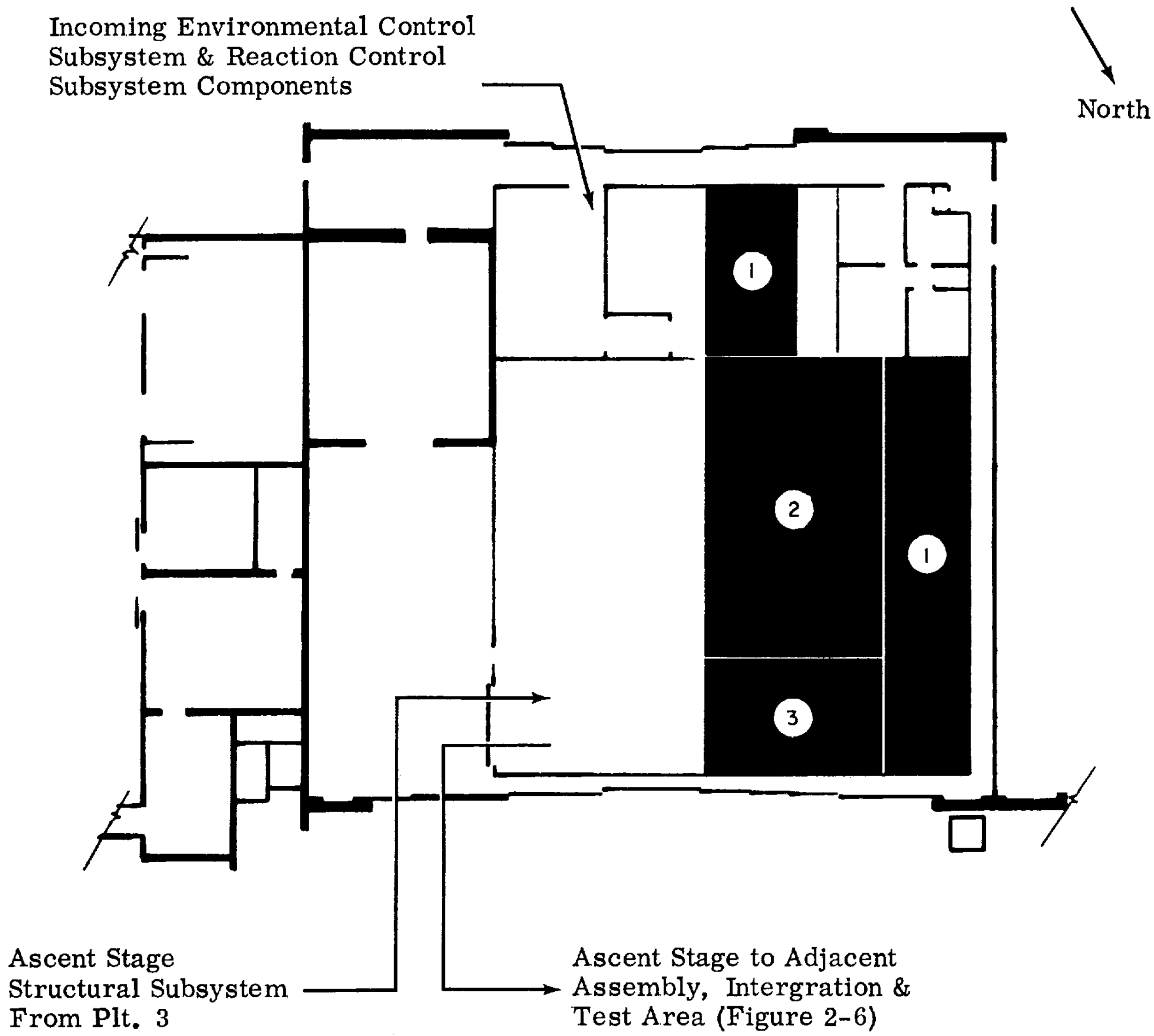
In addition to the exclusive LEM areas, some plant #5 shop departments which produce details and subassemblies for all Grumman programs will also be utilized for LEM manufacturing. The Machine Shop will fabricate some of the machined parts for the Structural/Mechanical Subsystem and the Crew Provisions Subsystem. Crew seats and other provisions will be provided by the Controls Department.



LEGEND

Area No.	Area Description
1	Shipping and Receiving
2	Machine Shop
3	Controls Shop
4	Existing Clean Room - 5,000 Sq. Ft. For Exclusive LEM Use - RCS and ECS
5	Existing Area - LEM Assembly, Installation and Test

Figure 2-2. Centralized LEM Assembly, Installation & Test, Bethpage Plant No. 5



■ Existing Area Scheduled for Exclusive LEM Utilization

LEGEND

Area No.	LEM Area Description	Square Feet
(1)	Environmental Control Subsystem Bench Test Area	1,500
(2)	Environmental Control Subsystem Assembly & Installation	2,750
(3)	Reaction Control Subsystem Assembly & Installation	750
		Total 5,000 Sq. Ft.

Figure 2-3. Plant #5 Clean Room for Bench Test, Assembly and Installation of Reaction Control Subsystem and Environmental Control Subsystem

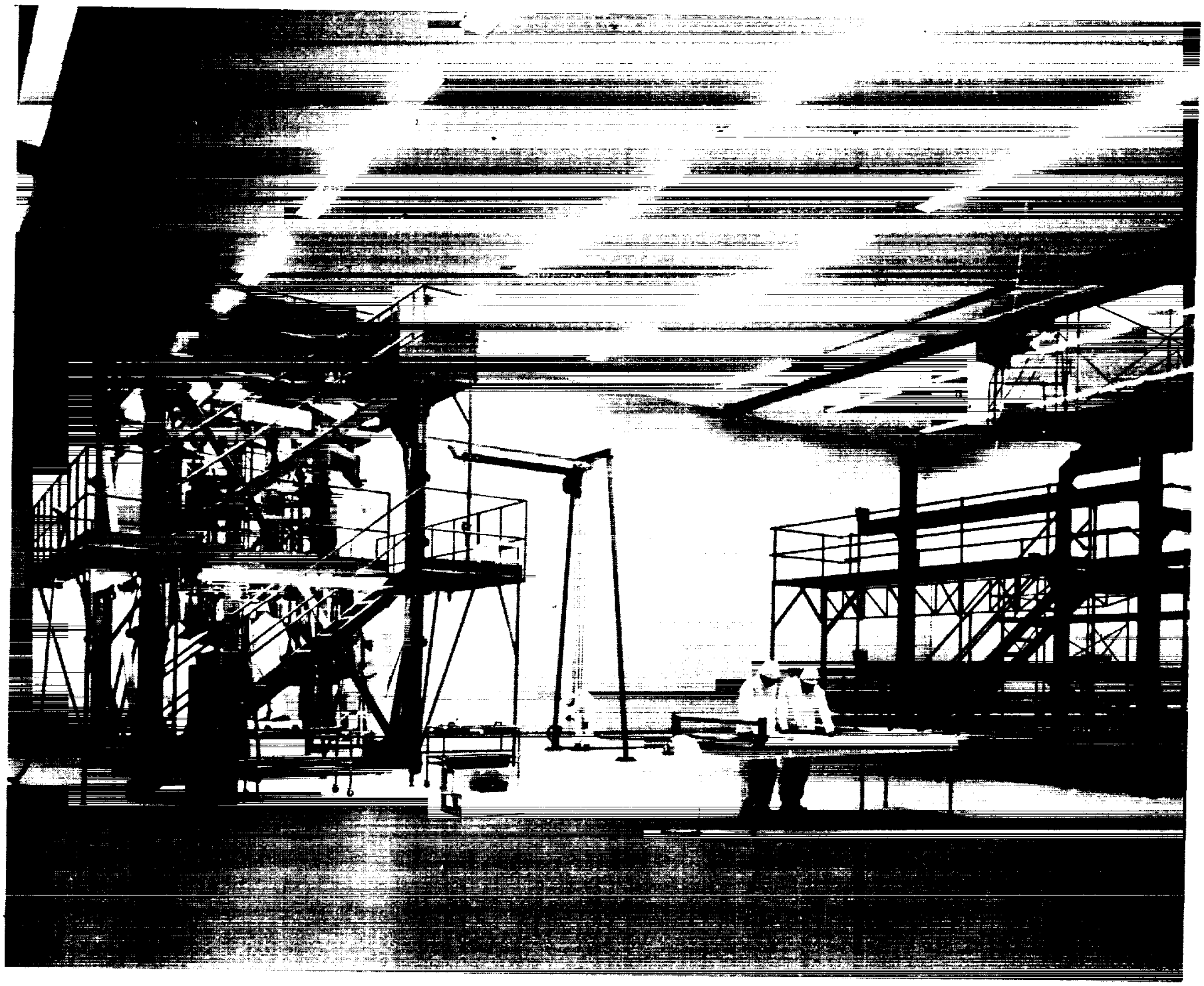
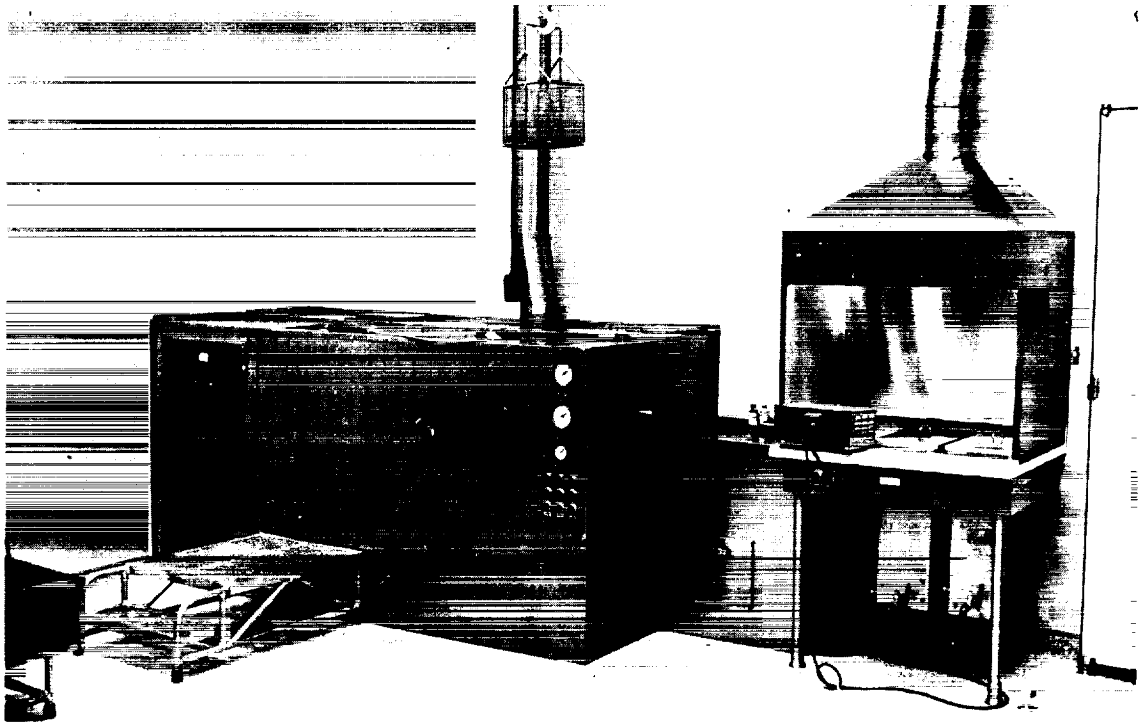


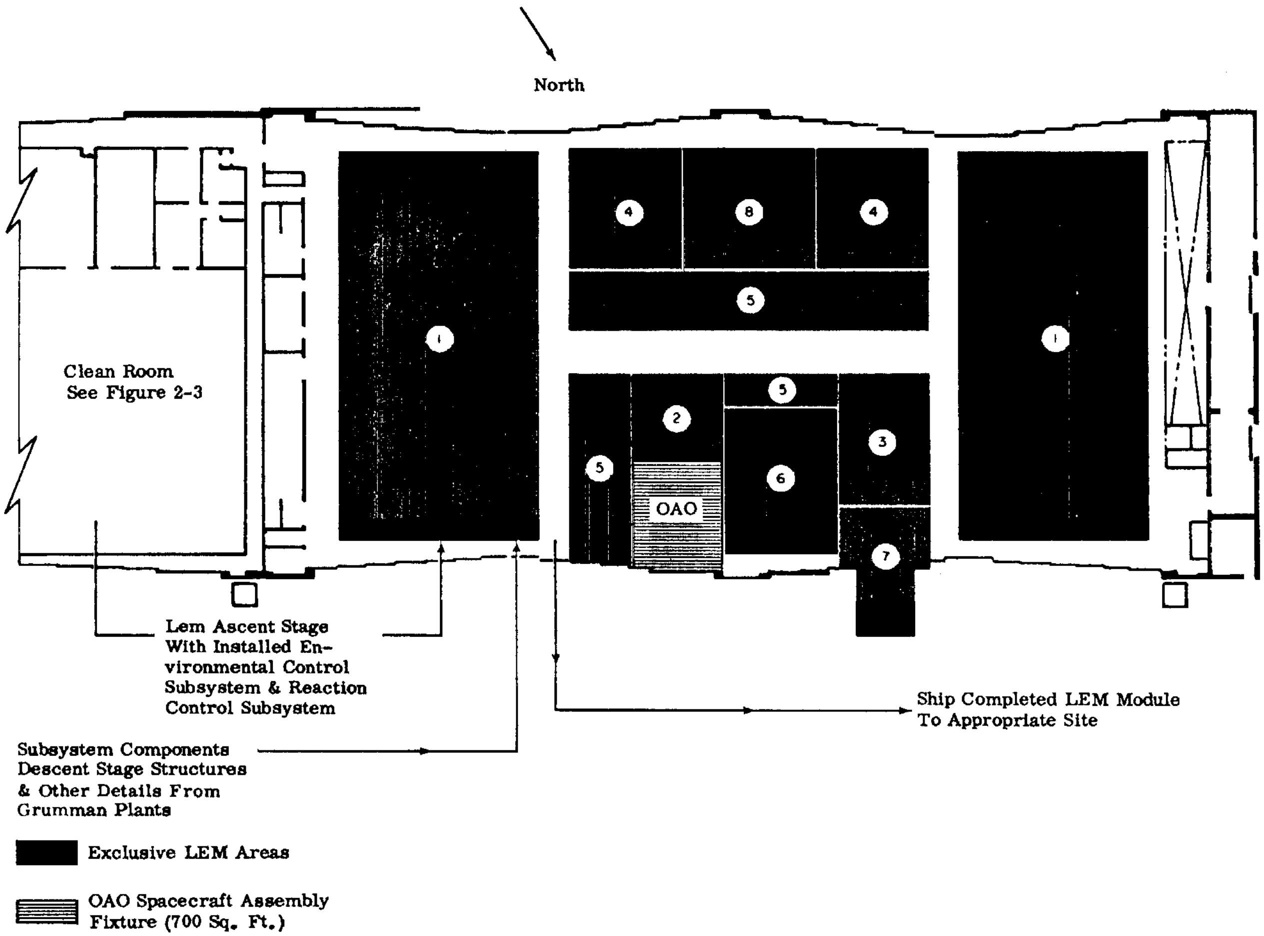
Figure 2-4. Clean Room - LEM-RCS & ECS Installation and Testing



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



LEGEND

Area	LEM Area Description	Square Feet
(1)	Assembly, integration & system test of the following subsystems: crew provisions & displays; navigation & guidance; stabilization & control; electrical power; communications and instrumentation. Alignment & functional test of critically positioned subsystem components.	10,000
(2)	Ascent stage engine installation & alignment check. Fastening of exterior skins & insulation.	500
(3)	Descent stage engine installation & alignment check. Landing gear mating trial. Ascent/descent mating.	875
(4)	Final installation & checkout. Module location for PACE.	2,075
(5)	Flexible aisles - minor installations, weights, inertial balance, CG location & moment of inertia determination.	2,700
(6)	Radio frequency interference screen room. Communications subsystem checkout.	1,200
(7)	Internal environmental simulator area (man rated altitude chamber). ECS testing.	450
(8)	Location of PACE equipment.	1,200
	Total Square Footage	19,000

Figure 2-6. Plant #5 - LEM Assembly, Installation and Test

2.1.2 Plant #3 - Major Structural/Mechanical Manufacturing.

This facility has been selected for major Ascent/Descent 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; plexiglass; and machining.

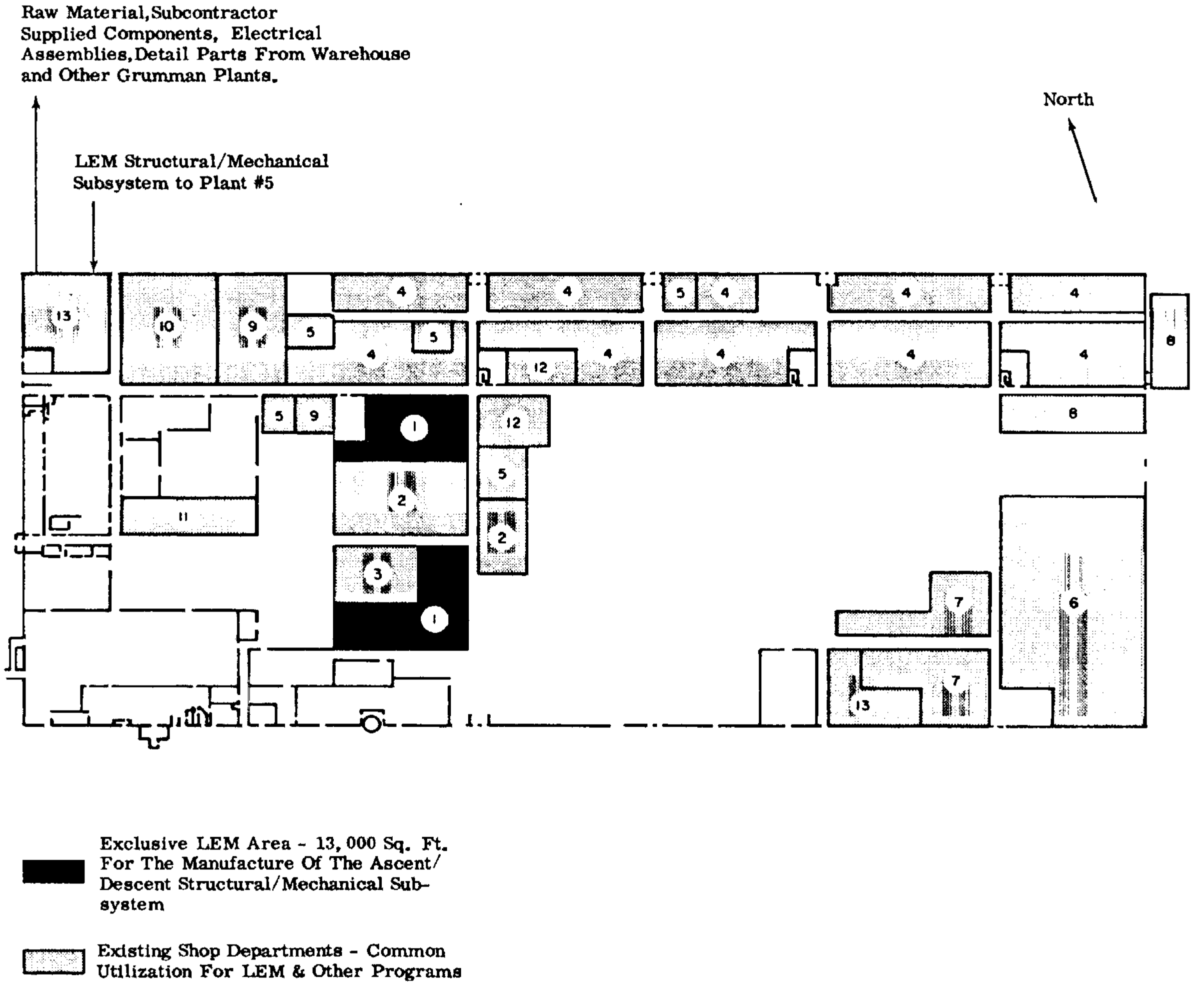
As shown in Figure 2-7, approximately 13,000 square feet of assembly area will al- located for the manufacture of the Ascent and Descent Structural/Mechanical Subsystem. All major subassembly, assembly and welding fixtures described in Section 4 will be located in this area. Note the adjacent location 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 for the Propulsion Subsystem. Special equipment for flow forming, circumferential fusion welding, tank half machining, heat treating and age hardening are available for the tank program.

Chemical milling facilities located within plant #3 are widely recognized as being the most modern and one of the largest in the aerospace industry. All chemical milling operations for structural weight reduction will be performed in this facility.

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.

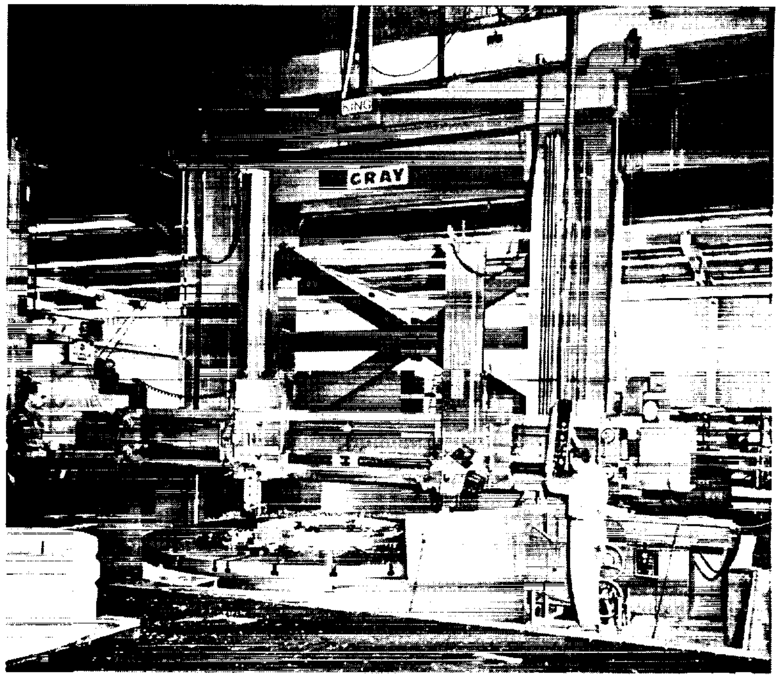
Photographs of plant #3 major manufacturing equipment and facilities scheduled for utilization throughout the LEM program are shown in Figures 2-8 through 2-13.



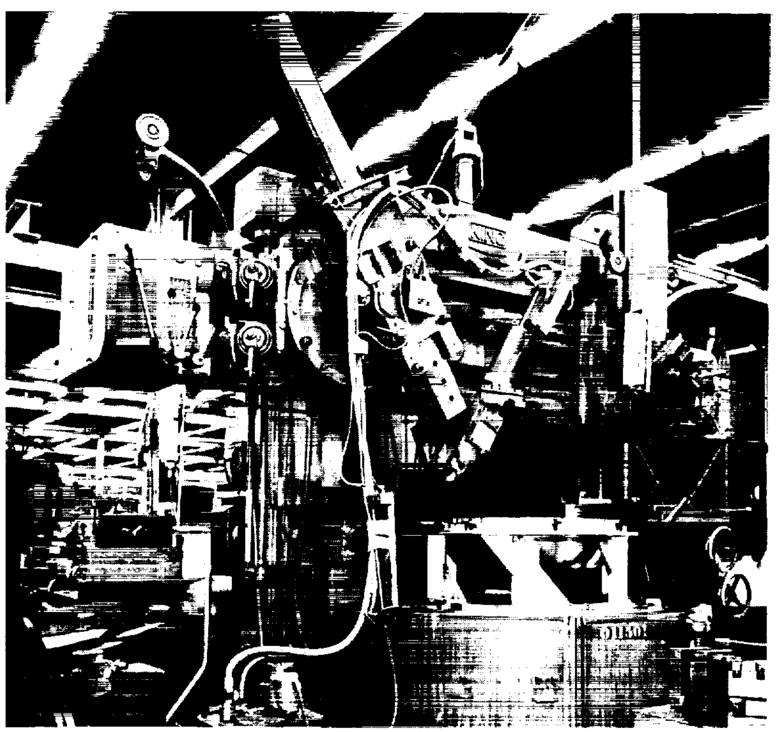
LEGEND

Area No.	Area Description
1	Exclusive LEM Area For Structural/Mechanical Subsystem
2	Fusion Welding
3	Resistance Welding
4	Machining
5	Inspection
6	Honeycomb
7	Plexiglass
8	Chemical Milling
9	Forming
10	Shear and Rout
11	Heat Treat
12	Spin Forming
13	Shipping and Receiving

Figure 2-7. Plant #3 - Major LEM Structural/Mechanical Manufacturing

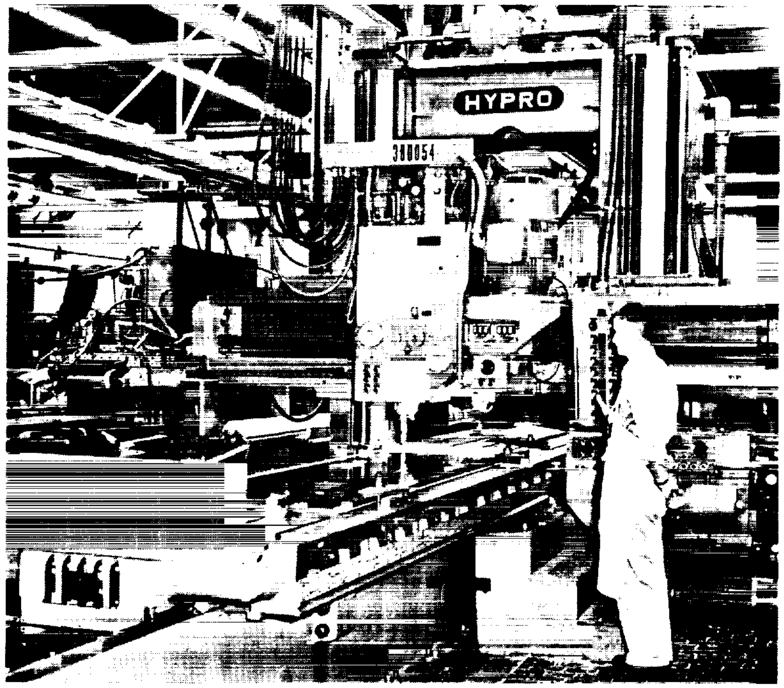


14' Vertical Lathe
For Machining LEM Ring Details
and Subassemblies

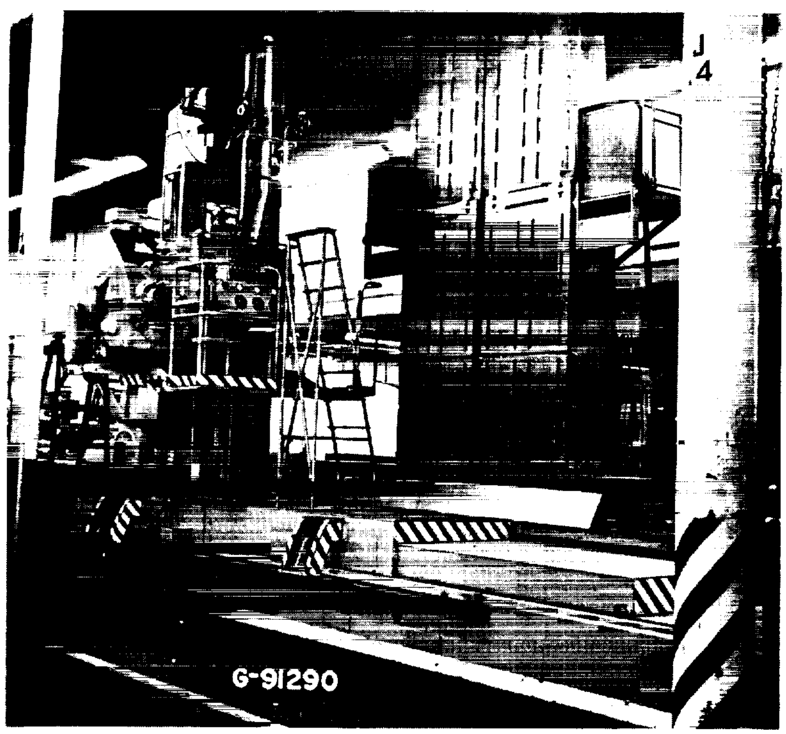


62" Vertical Turret Lathe
For Machining Smaller LEM Rings
and Spherical Parts

Figure 2-8. Plant #3 - Vertical Lathe Equipment

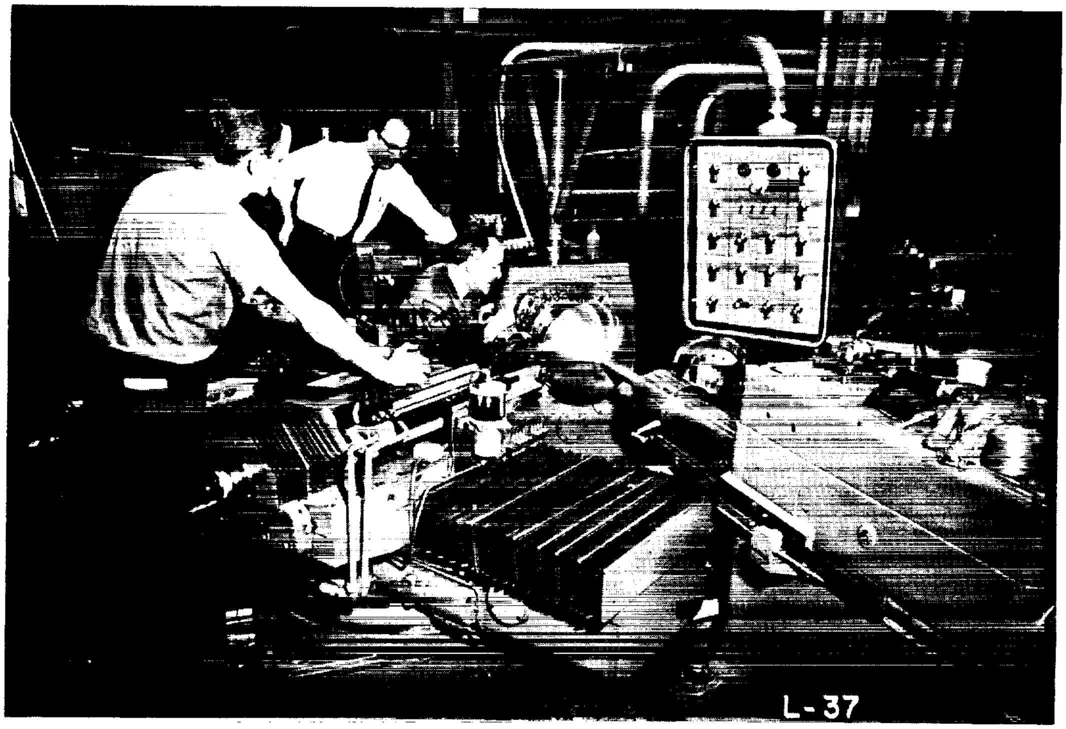


Planer Milling Machine
For Descent Structure Main Beam
Components

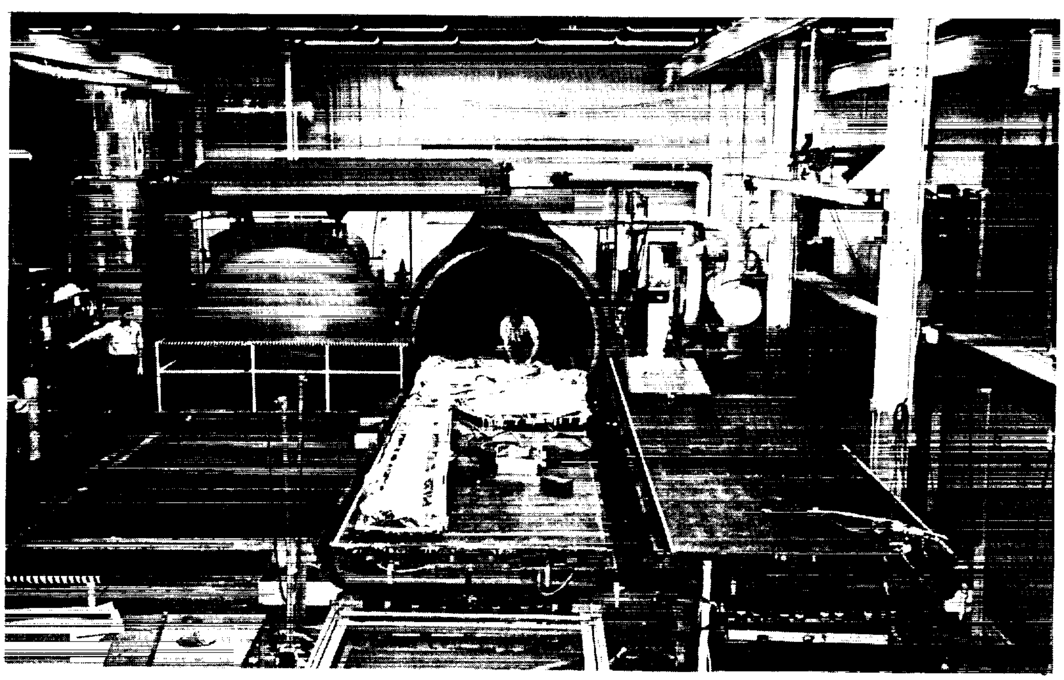


Hydrotel - Tracer Milling Machine for
LEM Contoured & Pocketed Detail Parts

Figure 2-9. Plant #3 - Milling Equipment

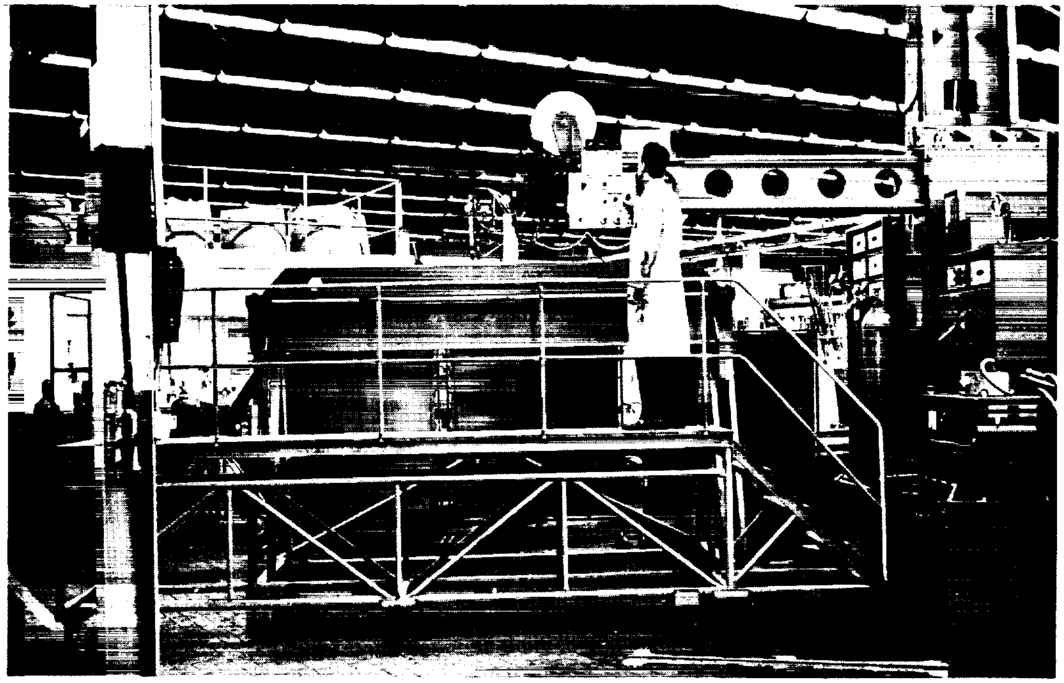


BOKO Flow-Forming Machine for Forming
and Machining of Propulsion Tank Details

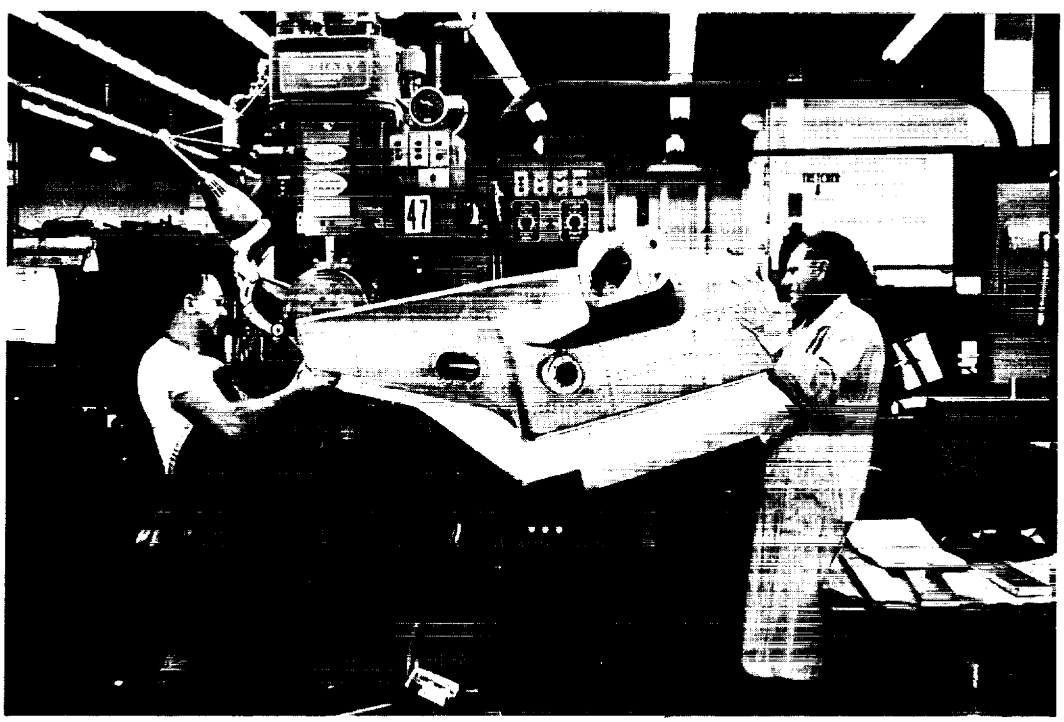


Autoclave for Honeycomb Bonding
of LEM Equipment Shelves

Figure 2-10. Plant #3 - Forming and Bonding Equipment

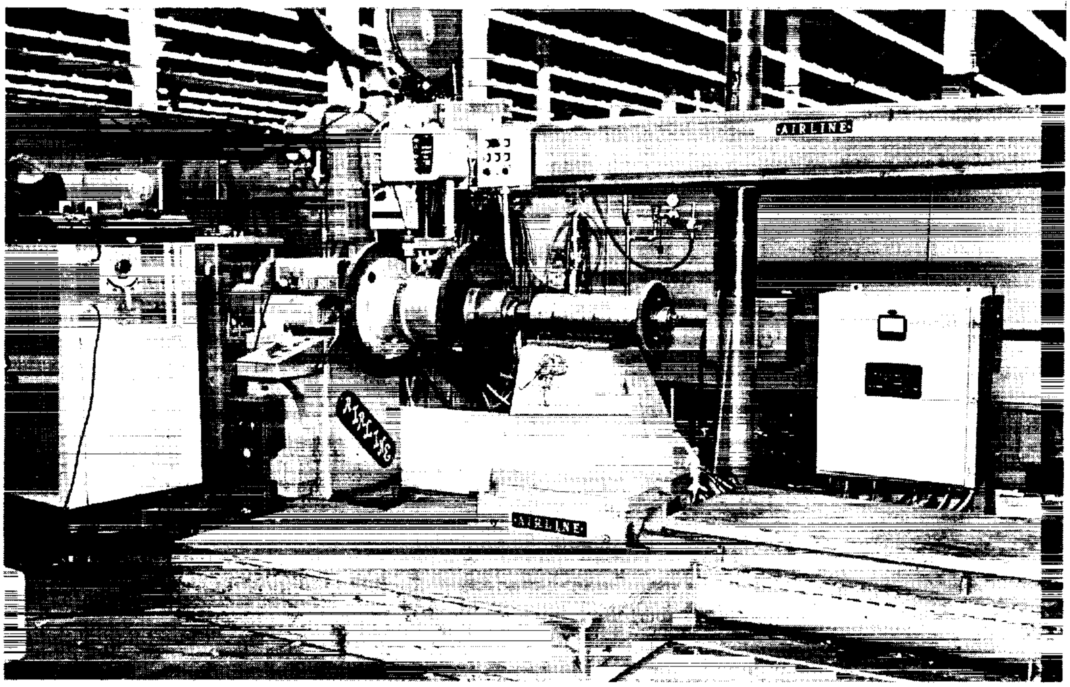


Boom Type Torch Manipulator–
Automatic Fusion Welding for Joining
Major LEM Subassemblies

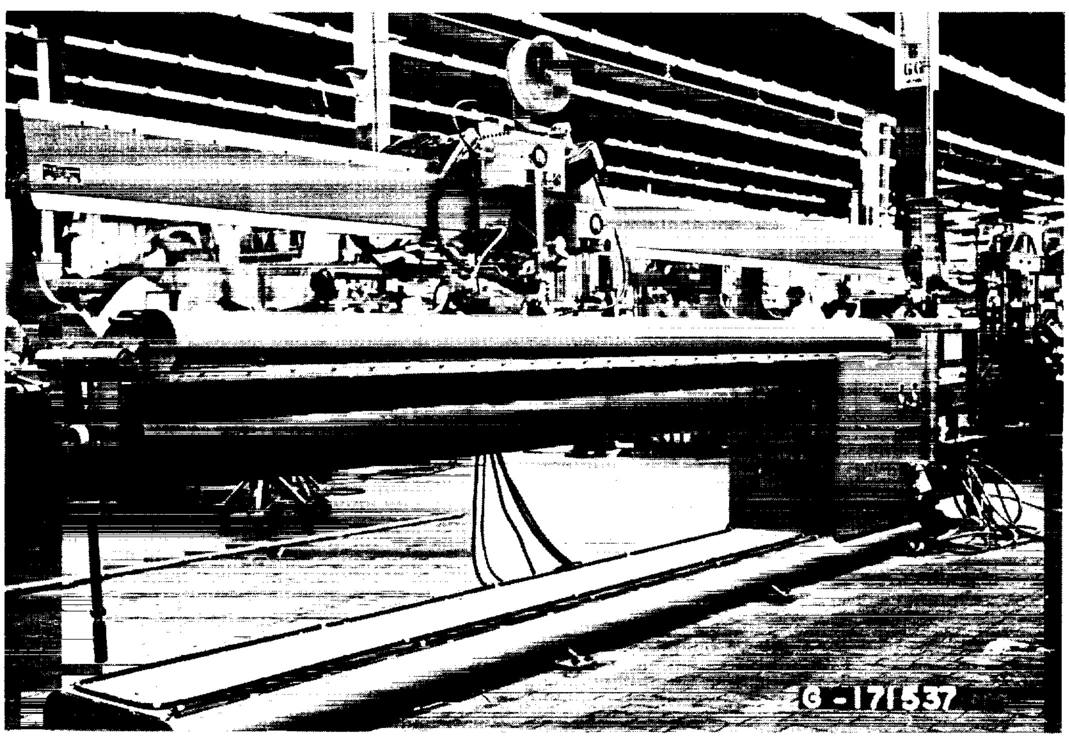


Resistance Seam Welder for Joining Frames
to the Ascent Stage Subassemblies

Figure 2-11. Plant #3 - Resistance and Automatic Fusion Welding Equipment

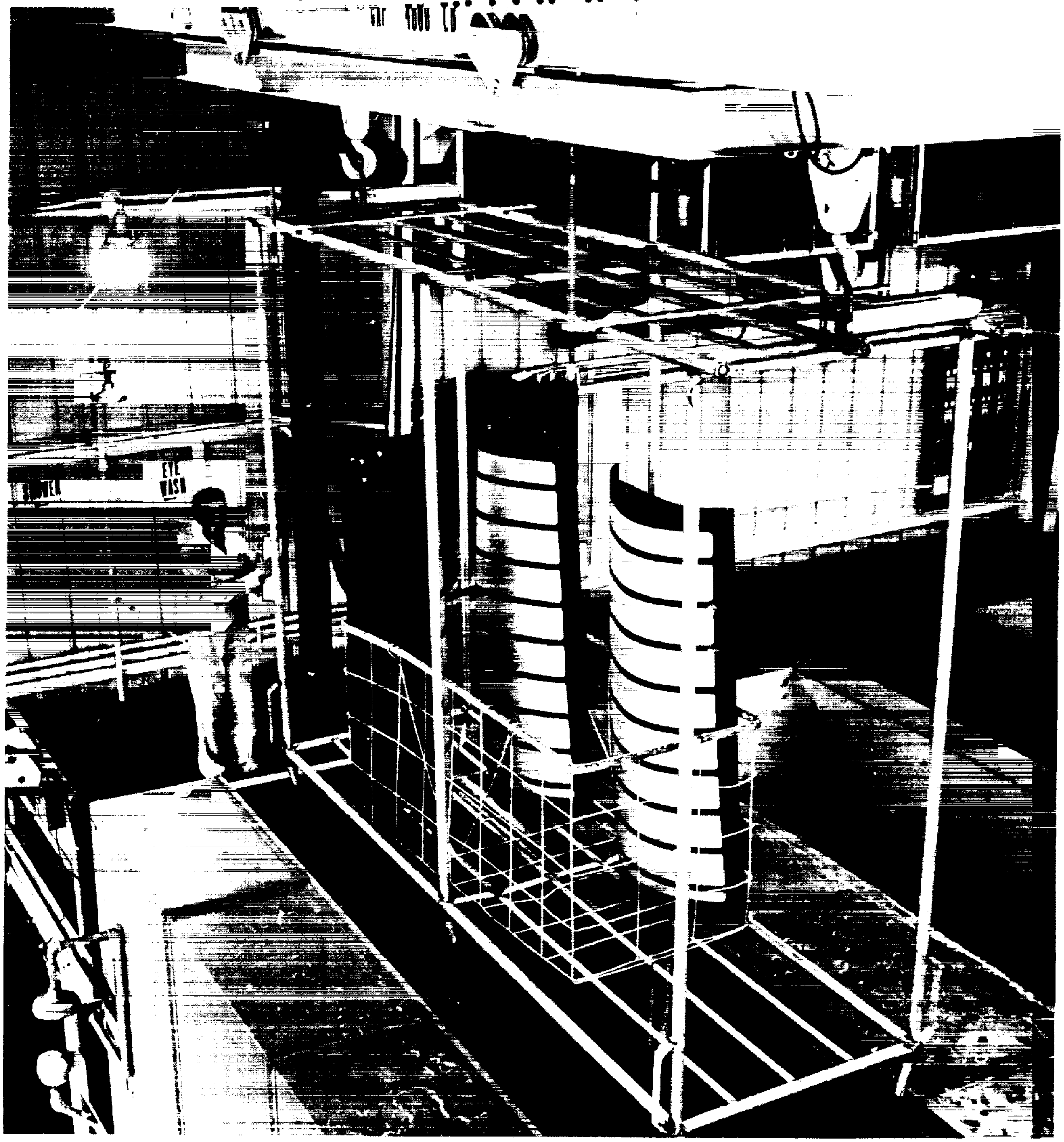


Combination Longitudinal & Circumferential
Welder for Combined Automatic Welding
Operations - LEM Docking Tunnels



Automatic Longitudinal Fusion Welder for
Welding of Large Ascent Stage Cylinders
(Height Modification Planned)

Figure 2-12. Plant #3 - Automatic Welding Equipment



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

Figure 2-13 Plant #3 Chemical Milling Facility

2.1.3 Plant #2 - LEM Detail Parts and Minor Subassemblies.

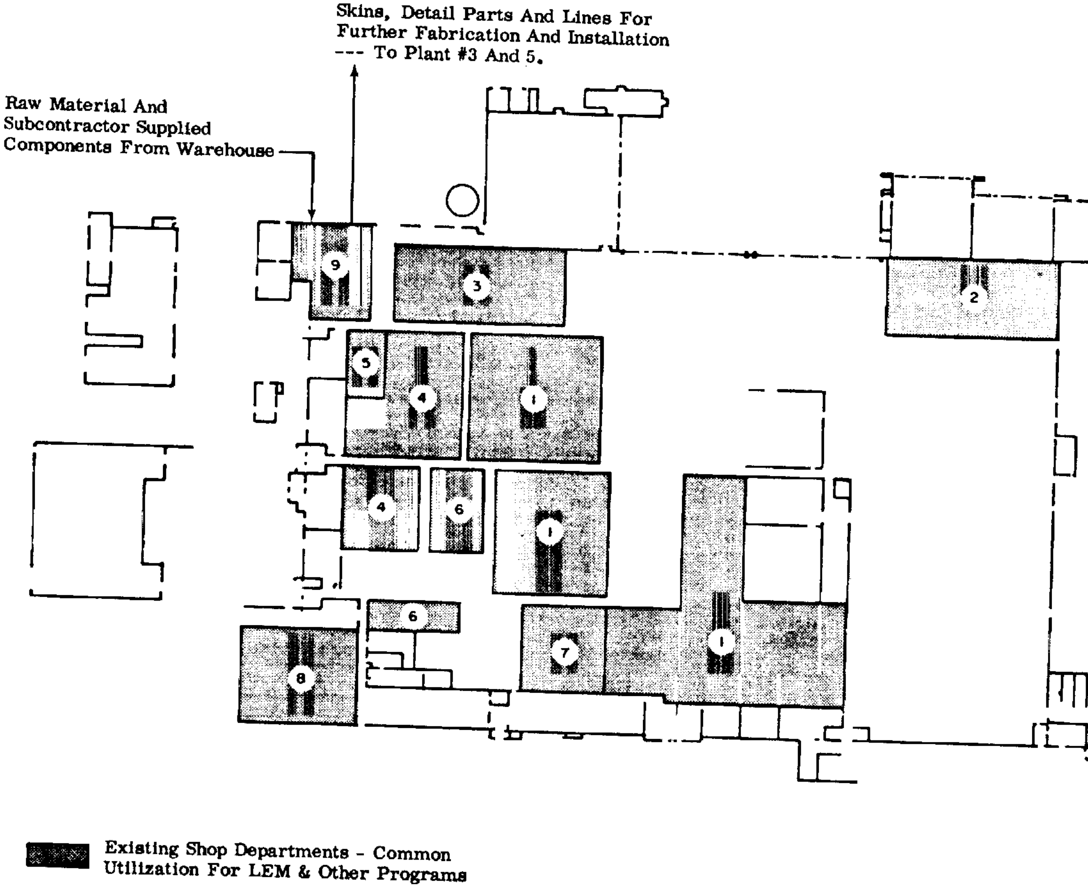
This plant is presently fabricating the majority of the sheet metal detail parts for all Grumman programs. These consolidated facilities are fully equipped with the most modern machinery ranging from unique Hufford stretch wrap forming equipment to conventional drill presses. As shown in Figure 2-14, LEM detail parts will also be fabricated in plant #2 for continued manufacturing efficiency.

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.

Flash 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.

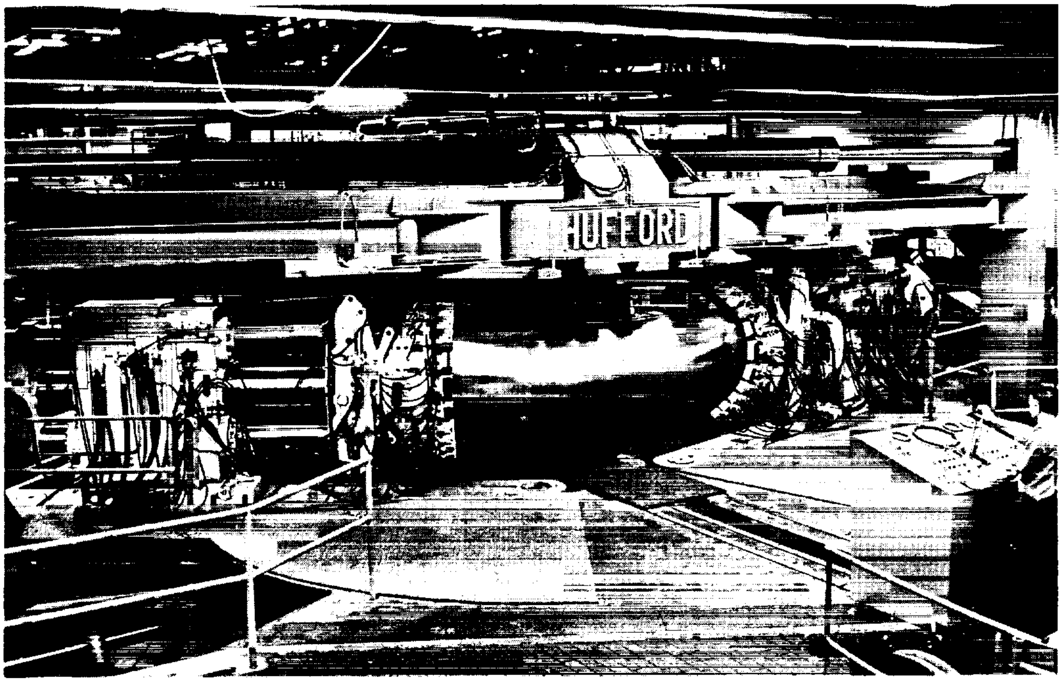
Photographs of major manufacturing equipment located within plant #2 are shown in Figures 2-15 and 2-16 on the following pages.



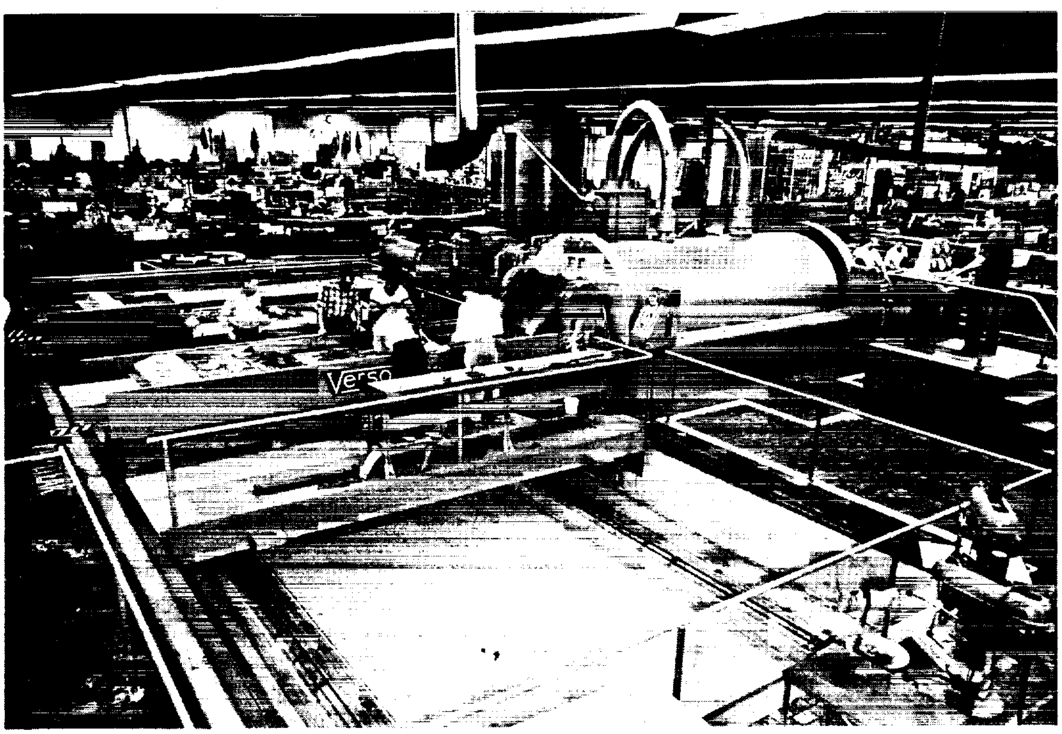
LEGEND

Area	Area Description	Area	Area Description
1	Centralized Detail Parts Manufacturing Facility	5	Anodize
2	Lines Manufacture	6	Inspection
3	Minor Subassemblies	7	Stock and Tool Storage
4	Manual Fusion and Flash Welding	8	Heat Treat
		9	Shipping and Receiving

Figure 2-14. Plant #2 - LEM Detail Parts and Minor Subassembly Fabrication

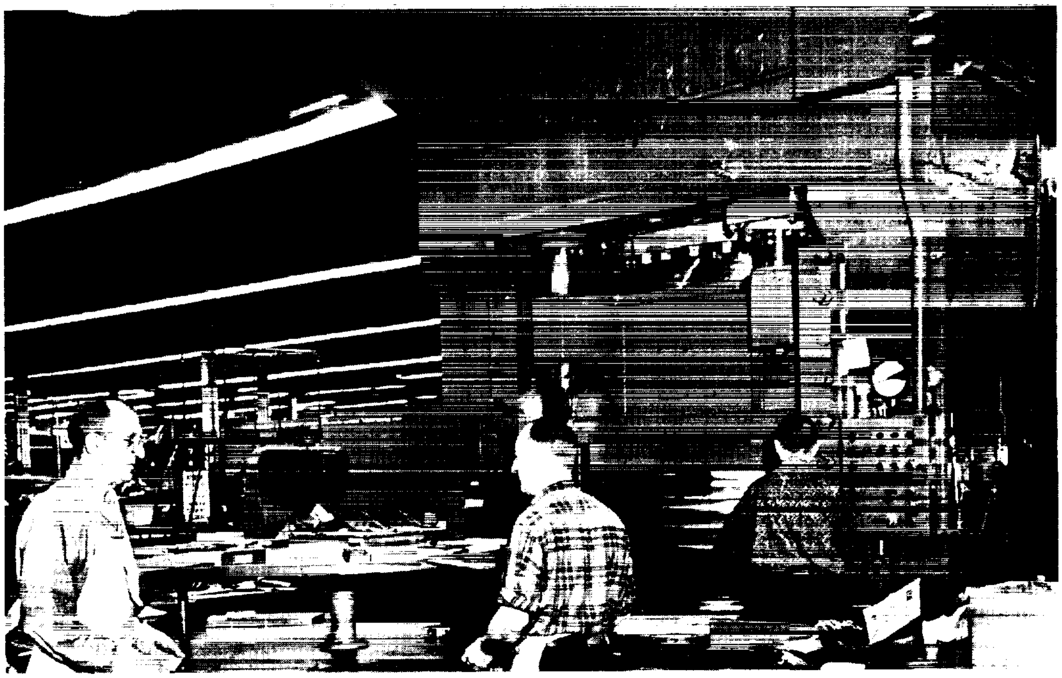


Stretch Wrap Forming Machine -
For Large LEM Ascent Stage Skins

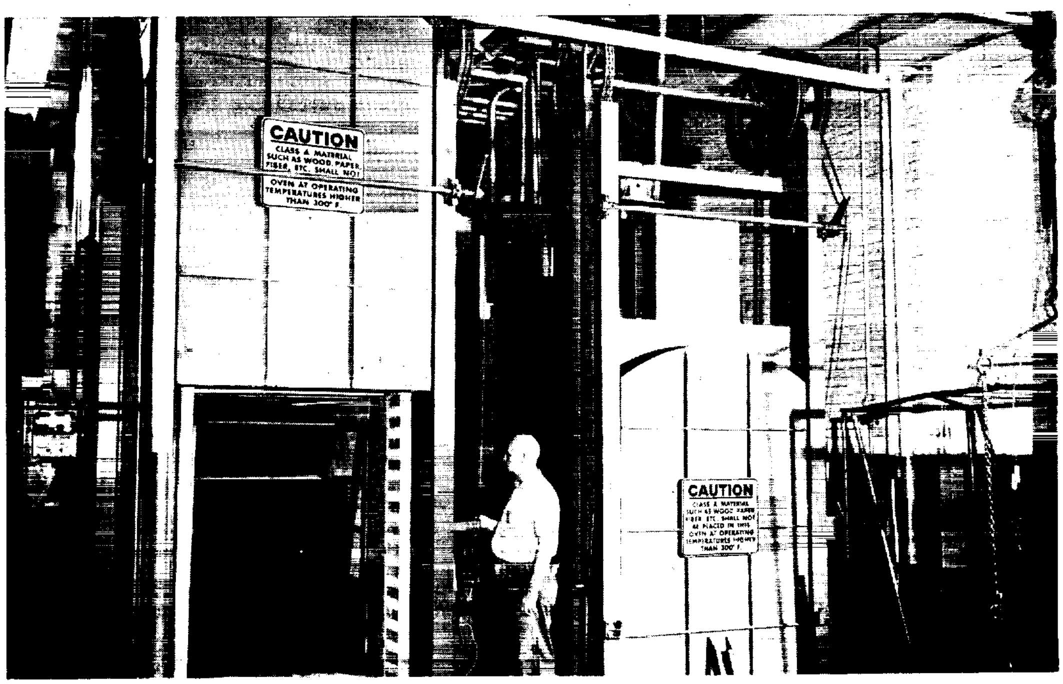


Direct Acting Hydraulic Press.
Also Shows a Partial View of the Consolidated
Detail Parts Manufacturing Facility.

Figure 2-15. Plant #2 - Forming Equipment & Consolidated Detail Parts Facility



Rubber Forming Press for
LEM Detail Parts



AGE Hardening Ovens
for Aluminum LEM Details

Figure 2-16. Plant #2 - Forming and Age-hardening Facilities

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, inspection and test requirements for the development of aerospace plastic components. Photographs of the Grumman plant #12 facility are shown in Figure 2-17.

2.1.5 Proposed Manufacturing Plant.

To increase the corporate manufacturing facilities, Grumman is presently planning a new building which is tentatively scheduled for completion in February, 1964. Grumman plans to utilize, a portion of this plant for bench test and repair of LEM vendor supplied electronic subsystem components. In addition, Grumman fabrication and assembly of electrical subassemblies for the LEM program will be conducted in this new facility.

2.1.6 Plant 14 - Bench Test and Partial Assembly of Reaction Control Subsystem.

The plant #14 Systems Test Center will be used to bench test and partially assemble the Reaction Control Subsystem. A clean room with test facilities is available to satisfy the environmental standards of the RCS. After completion of the test program, the RCS is packaged, sealed and forwarded to the plant #5 clean room for installation into the Ascent Structural/Mechanical Subsystem as described in Section 2.1.

2.1.7 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 the degree of specialization, or the needs of individual plants in order to provide the necessary close support for the production areas.

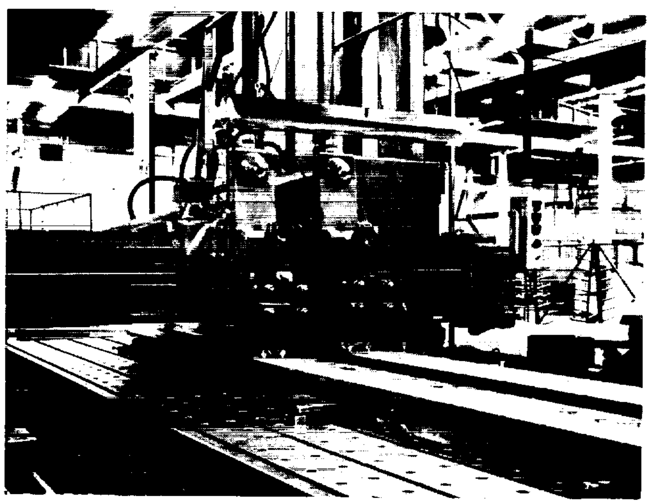
Fiberglass Facility

Electric Oven
for Curing Vacuum Bagged, Fiberglass Reinforced Parts

Figure 2-17. Plant #2 - Fiberglass Manufacturing Facilities

Tooling Machine Shop Lathe Area

Tool Jig Boring Area

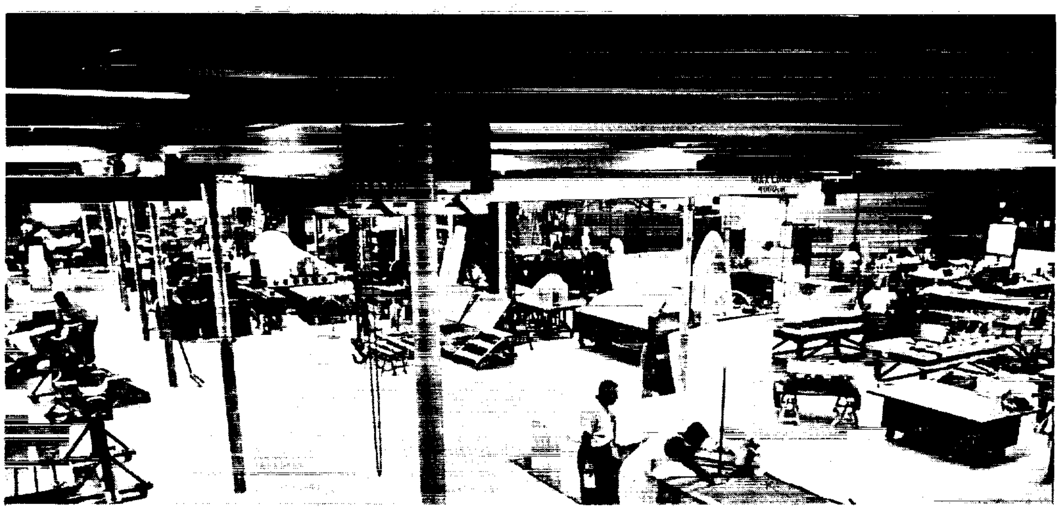


Rockford Openside Planer
for Heavy Machining

Radial Arm Drill Press Area

Figure 2-18. Jig and Fixture Manufacturing Facilities

Template Shop - for
After-Form Detail Tools



Plaster Shop - for
Plaster Tooling Mock-Ups & Models

Figure 2-19. Template and Tooling Mockup Facilities

The Jig and Fixture Shops, shown in Figure 2-18, constitute the largest of the tool manufacturing facilities. These shops occupy approximately 36% 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 2-19, 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 16% 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, occypying about 10% of the total tool shop area, are also primarily located in Plant #2.

The Plaster Shop, shown in Figure 2-19, 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 compounts. Dies and skin tooling are fabricated by taking plaster or plastic casts from these mock-ups. All tooling mock-ups and models for the curved LEM crew compartment skins will be produced in this facility. The Plaster Shop is located entirely in Plant #11 and represents approximately 20% of the tool manufacturing facilities.

The Die Shop, located in plant #2, occupies approximately 6% 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% 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.

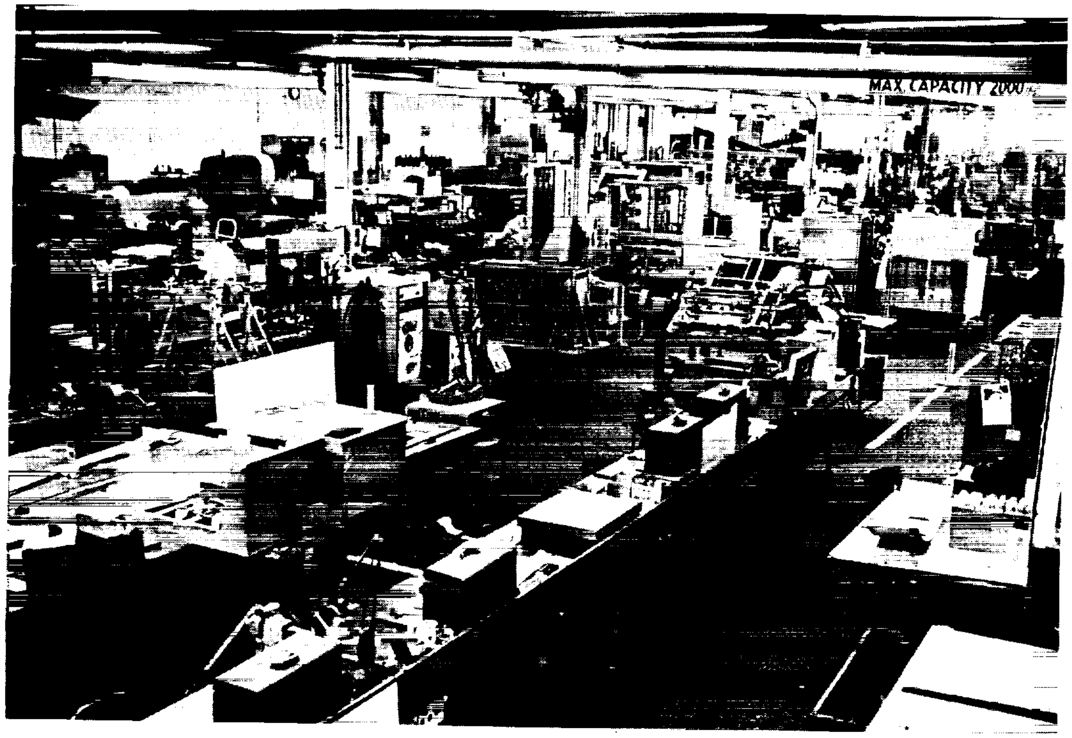
2.1.8 GSE Manufacturing Facilities

LEM Ground Support Equipment, including Handling and Transportation GSE, Electronic GSE, Fluid GSE 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, Central 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 2-20, is equipped for all heavy fabrication utilizing standard metal cutting, forming and welding equipment.

The Central Equipment Shop and Avionic Shop departments are responsible for Electrical/Electronic GSE used during manufacturing tests and off-site tests. In addition, the Central Equipment Shop has the primary responsibility for all Fluid Systems GSE. This shop, shown in Figures 2-20 and 2-21, is 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 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.

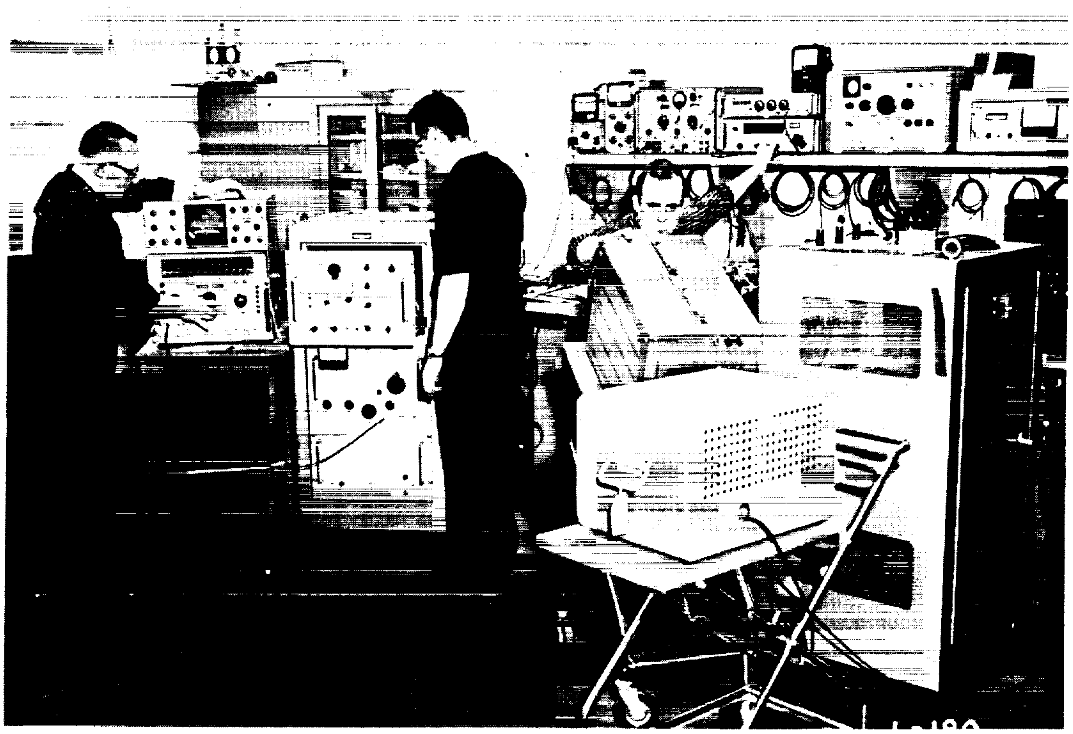


Fabrication Shop for Handling &
Transportation GSE

Central Equipment Shop for
Fluid Systems GSE & Electronic GSE

Figure 2-20. GSE Manufacturing Facilities

Central Equipment Shop -
Mechanical Instrument Calibration Area



Central Equipment Shop -
Electronic GSE Calibration Area

Figure 2-21. Central 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 & 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 & 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 & Tool scheduling systems are described in sections 3.1.1 & 3.1.2. LEM Manufacturing program 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 development of manufacturing lead-times, the LEM Shop Project Manager uses manufacturing flow & tool/equipment lead-time data provided by the LEM Project

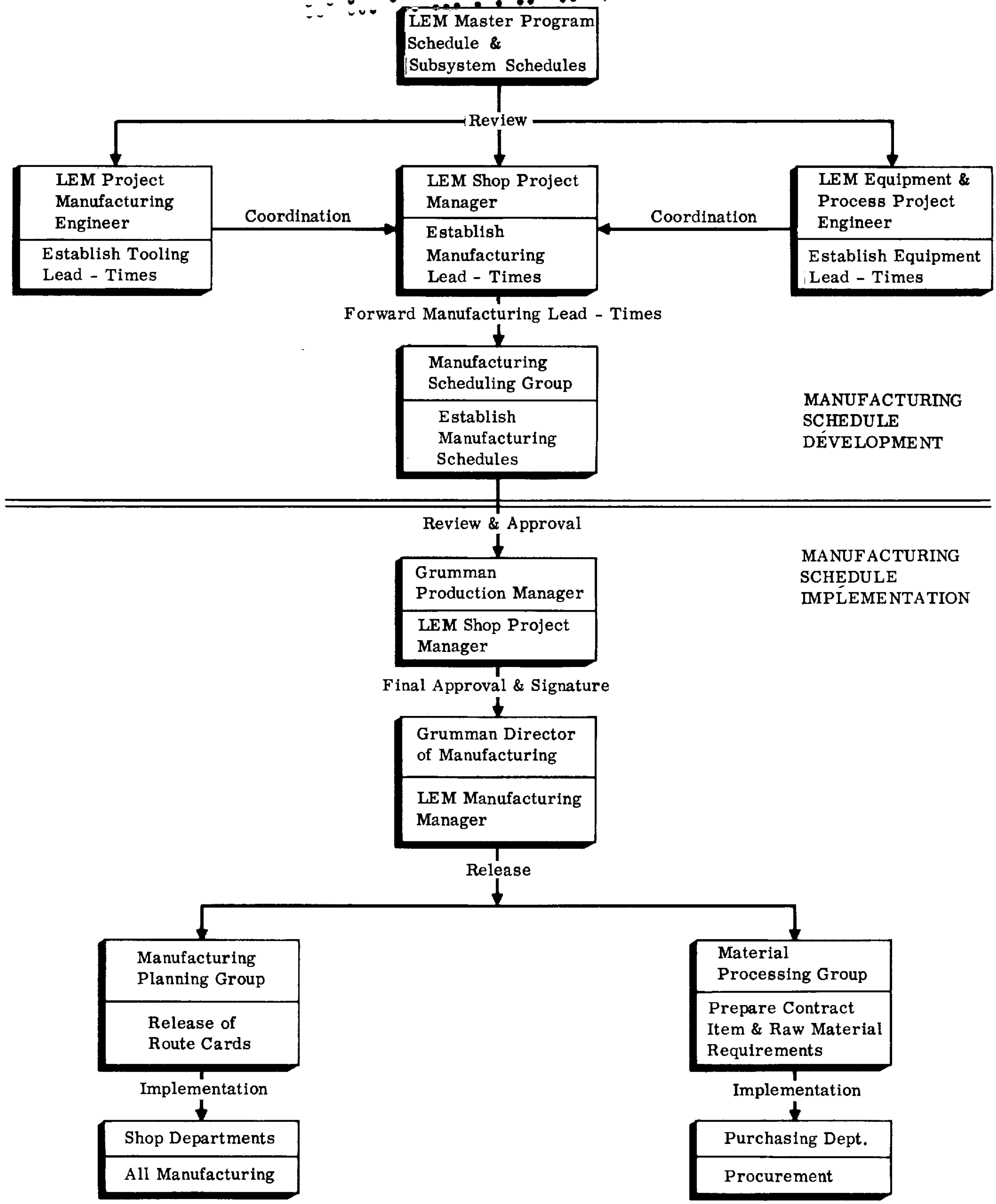


Figure 3-1. Manufacturing Scheduling Flow

Manufacturing Engineer and the 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 corporate Manufacturing Scheduling group where subsystem and component manufacturing schedules are generated. Work sheets or charts are used to generate these schedules. Included are priority information for purchased parts, details, subassemblies, major components, final assembly, testing and acceptance.

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 signature of the Grumman Director of Manufacturing constitutes 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

The major tooling schedules have been developed in accordance with the LEM Master Program Schedule, Subsystem Component Schedules, manufacturing lead-time requirements, and the selected subassembly breakdown arrangements. The initial development and periodic up-dating of these basic schedules 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.

Detailed tool due date schedules and charts are generated within the structure of the LEM Master Schedule and basic Tool Schedules. The Scheduling Group develops these tool due dates by closely considering the following factors:

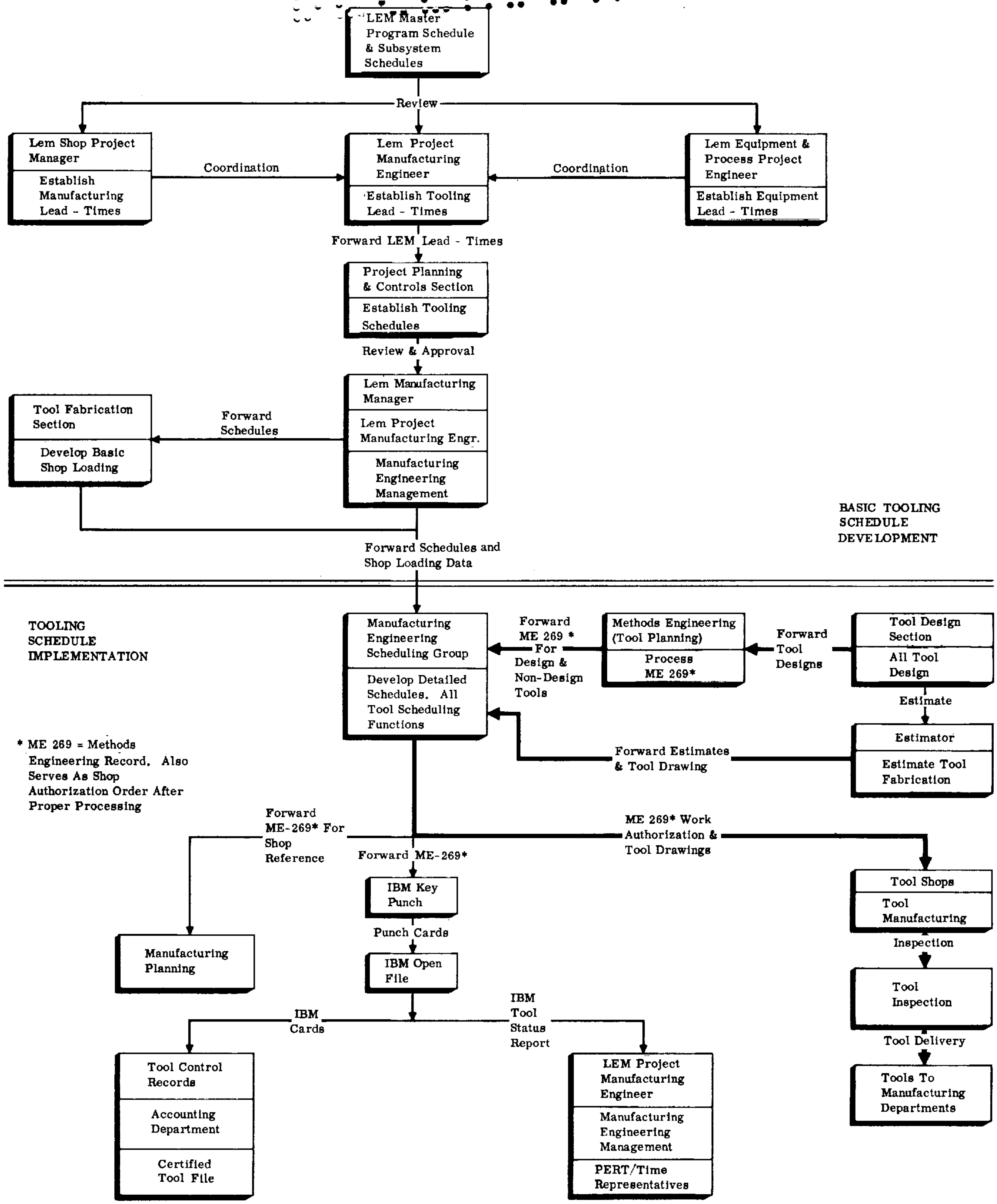


Figure 3-2. Tool Scheduling Flow

- 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 for dual use of master gauges.

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 are established, the ME-269 Record Sheet is processed and becomes the sole authorization order for initiation of Tool Shop effort. Completed tools are inspected and are subsequently delivered to the manufacturing departments.

Recording of the tool program and status reporting are accomplished using an IBM key punched 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.

Figure 3-3 shows a detailed Tooling and Manufacturing Schedule for the LTA-4 Environmental Development Module. This module has been selected for schedule development since it represents the first complete module with all subsystems operational. In addition, the major tooling program is planned for completion during the development of LTA-4. Thus, basic tooling schedules are best defined by selecting LTA-4 since tooling is primarily a non-recurring type of effort. The recurring manufacturing activities for other LTA and LEM modules are not shown. However, all module completions are shown in the Figure 1-2 Manufacturing Rate Diagram.

In accordance with the LEM Master Schedules which are included in the Master Program Plan #LPL-13-1, Figure 3-3 shows completion of subsystem installations for LTA-4 during April, 1965. This date, and the schedules for the availability of vendor supplied system components, have formed the basis for the development of the LTA-4 Tooling and Manufacturing Schedule.

Lead-times for all activities and the necessary sequence of events have been closely coordinated and reviewed by the LEM Manufacturing Manager and his staff. The subassemblies, major tools, and manufacturing operations shown in the schedule are described and illustrated in Sections 4 and 5.

Some major manufacturing milestones for the LTA-4 are:

- Completion of Ascent major subassembly fixtures-May, 1964
- Completion of Ascent final assembly fixture-September, 1964
- Completion of Ascent subassembly manufacturing-October, 1964
- Completion of Ascent structural assembly-December, 1964
- Completion of all tooling-Descent-September, 1964
- Completion of Descent structural assembly-October, 1964
- Completion of tooling for Ascent/Descent installations-February, 1965
- Completion of all subsystem installations-April, 1965

Figure 3-4 shows only basic schedules for Handling and Transportation GSE, Fluid Systems GSE and Electronic GSE. Manufacturing scheduling of specific equipment and

[redacted]

	TASK	DESCRIPTION
ASCENT STRUCTURE	Tooling	Master Gages & Tooling Mockups
	Tooling	Detail Parts & Minor Subassembly Tools
	Manufacture . .	Skins, Machine And Other Detail Parts
	Manufacture . .	Minor Subassemblies
	Tooling	Windshield Bulkhead Assembly Fixture
	Manufacture . .	Windshield Bulkhead Assembly
	Tooling	Crew Compartment Assembly Fixture
	Manufacture . .	Crew Compartment Assembly
	Tooling	Pressurized Equipment Compartment(Fwd.) Assembly Fixture
	Manufacture . .	Pressurized Equipment Compartment (Fwd.) Assembly
	Tooling	Final Weld Fixture
	Manufacture . .	Joining of the 3 Major Assemblies
	Tooling	Aft Pressurized Equipment Compartment Assembly Fixture
	Manufacture . .	Aft Pressurized Equipment Compartment Assembly
	Tooling	Unpressurized Equipment Bay Assembly Fixt.
	Manufacture . .	Unpressurized Equipment Bay Assembly
	Tooling	Final Assembly Fixture
	Manufacture . .	Final Structural Assembly & Establish Interchangeable Hole Patterns, Mounts and Master Controlled Interfaces
	Tooling	Inspection Checking Fixtures
	Manufacture . .	Inspection of Ascent/Descent Separation Plane, Engine & RCS Mount Hole Patterns
	Manufacture . .	Tumbling, Vacuum & Other Cleaning
ASCENT INSTALLATIONS	Tooling	Clean Room Dolly (GSE Design)
	Manufacture . .	Installation of ECS & RCS Equipment in Clean Room
	Tooling	Engine Mating Fixture (GSE Design)
	Manufacture . .	Installation of Propulsion Subsystem. Engine Alignment Check. Other Subsequent Installations
	Tooling	Handling Dolly (GSE Design)
	Manufacture . .	Continued Subsystem Installations. Fastening of Insulation & Exterior Skins
DESCENT STRUCTURE	Tooling	Master Gages & Local Tooling Mockups
	Tooling	Detail Parts & Minor Subassembly Tools
	Manufacture . .	Skins, Machine and Other Detail Parts
	Manufacture . .	Minor Subassemblies
	Tooling	Assembly Drill & Ream Jigs - Main Beams
	Manufacture . .	Main Beams
	Tooling	Assembly Drill & Ream Jigs - Intermediate Beams
	Manufacture . .	Intermediate Beams
	Tooling	Final Assembly Fixture
	Manufacture . .	Final Structural Assembly & Establish Interchangeable Hole Patterns and Master Controlled Interfaces
	Tooling	Inspection Checking Fixtures
	Manufacture . .	Inspection of Ascent/Descent Separation Plane, Engine Mount Hole Pattern
	Tooling	Flash Welding Fixtures
	Manufacture . .	Landing Gear Struts
	Tooling	Keller Drill Jigs
	Manufacture . .	Drilling Landing Gear Strut Connections
	Tooling	Inspection Checking Fixtures
	Manufacture . .	Dimensional Check of Assembled Landing Gear
	Manufacture . .	Tumbling, Vacuum & Other Cleaning
DESCENT INSTALLATIONS	Tooling	Engine Mating Fixture (GSE Design)
	Manufacture . .	Installation of Propulsion Subsystem. Engine Alignment Check. Trial Mating of Landing Gear. Installation of Other Components, Insulation & Exterior Skins
ASCENT/DESCENT INSTALLATIONS	Tooling	Joining Dolly (GSE Design)
	Manufacture . .	Ascent/Descent Joining & Final Interwiring
	Tooling	Manufacturing Alignment & Functional Test Fixture
	Manufacture . .	Installation & Alignment of Nav. & Guidance Subsystem. Location Check of RCS Engines. Check Descent Engine & Relationship to Ascent Stage

LEGEND
▬ ▬ ▬ TOOL DESIGN & FABRICATION
▬▬▬ LTA-4 FABRICATION, ASSEMBLY & INSTALLATIONS

Figure 3-3. Tooling and Manufacturing Schedule for LTA-4 Environmental Development Module

[redacted]

Grumman LEM

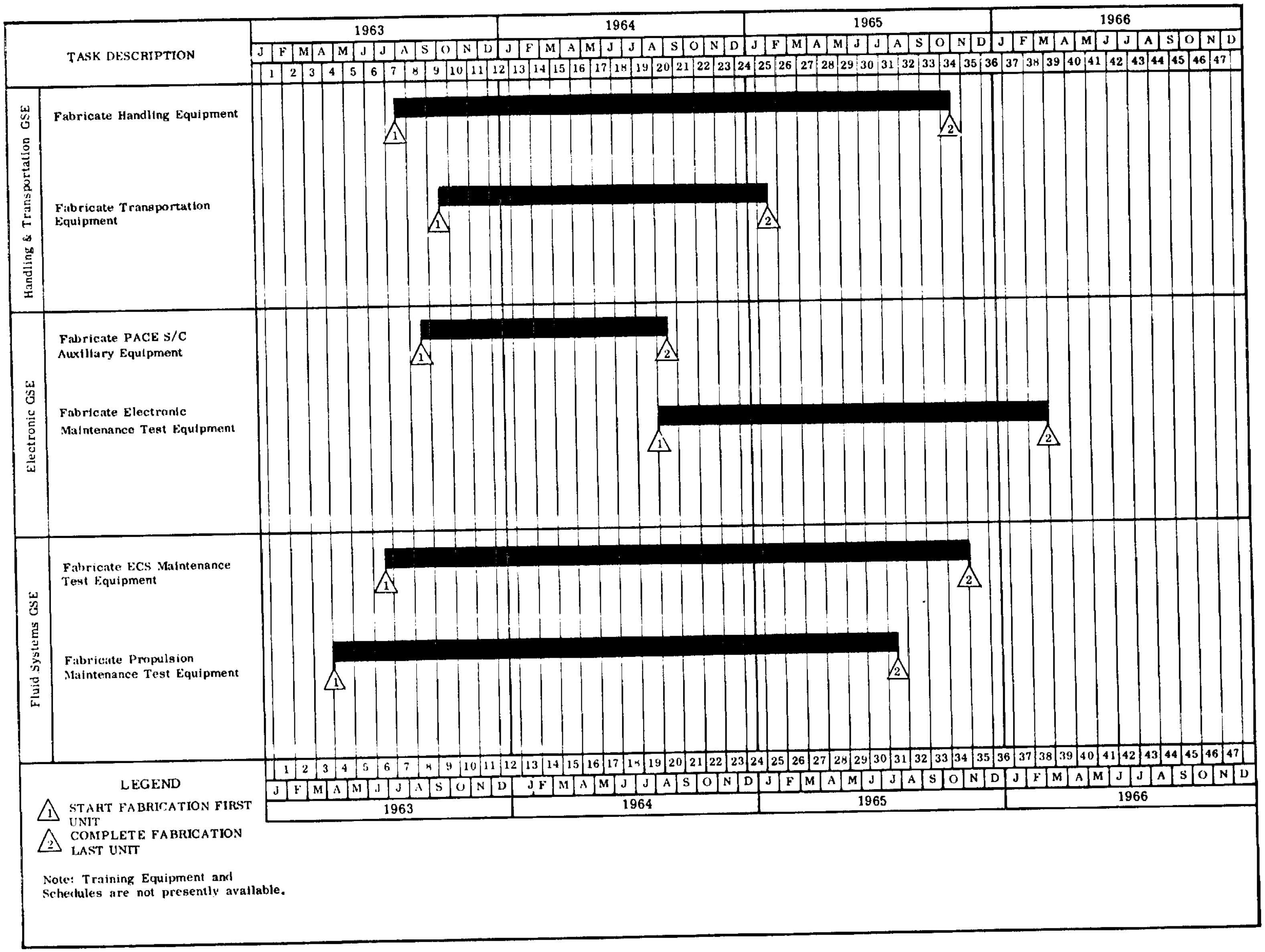


Figure 3-4. Basic Manufacturing Schedule-LEM Ground Support Equipment

quantities of GSE was not attempted for this initial Plan submittal since these schedules could not be prepared with realism and confidence.

Detailed fabrication schedules for GSE will be established when quantities and "Make or Buy" plans are futher developed. A subsequent submission of the GSE Planning and Requirements List # LLI-400-1 is presently being prepared by LEM Engineering. This revision will contain detailed schedules which will include the following information:

- 30% and 80% design completions.
- Shop release dates.
- Manufacturing completion dates.
- Test completion dates.
- First GSE, utilization dates for applicable modules.
- Site destinations.
- Disposition of equipment.

3.2 Planning

Conversion of Engineering design information into LEM hardware and associated GSE 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 planning, tool planning 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, "Manufacture of GSE".

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 of 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 below.

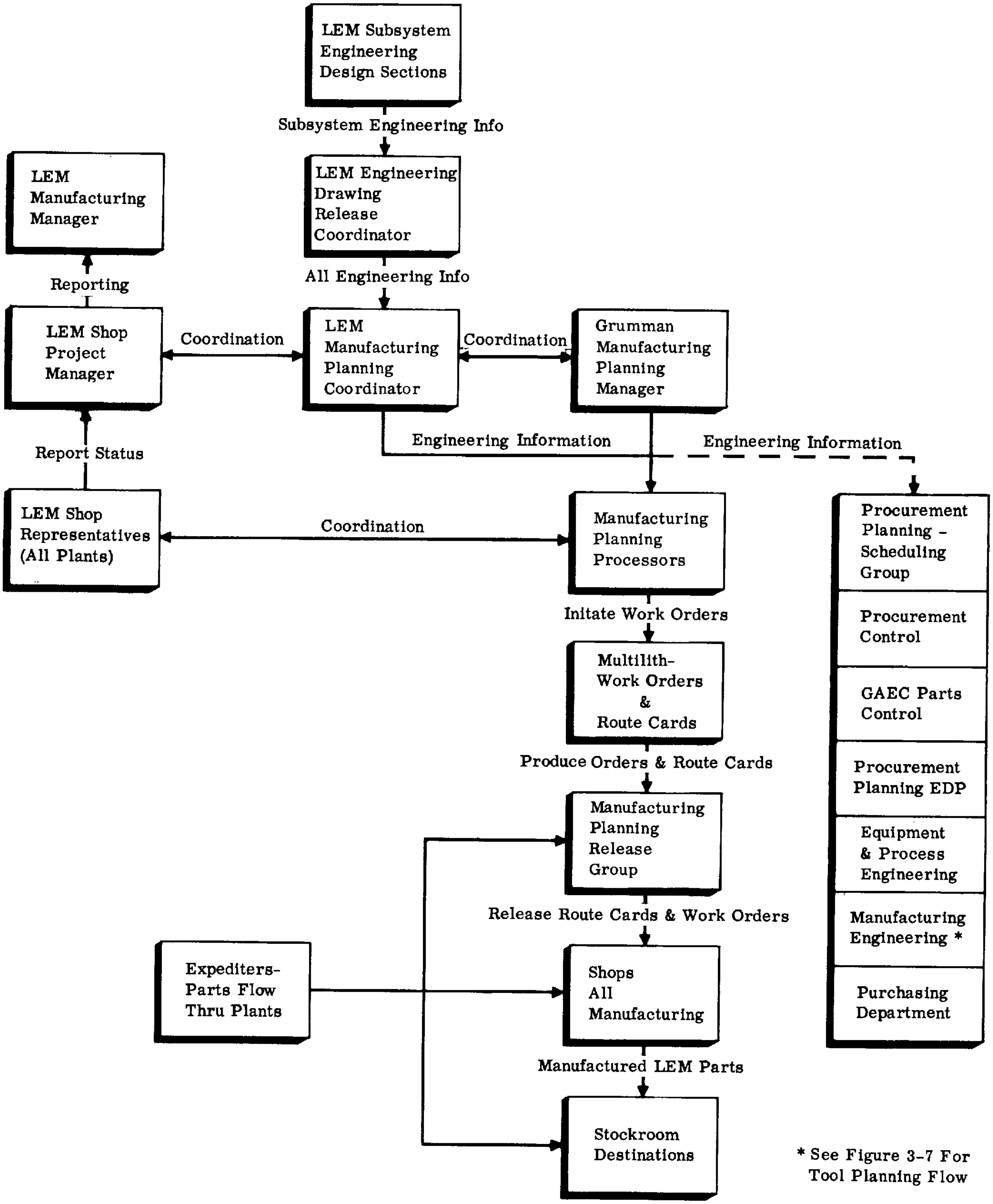


Figure 3-5. Manufacturing Planning Flow

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 cogizant 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.

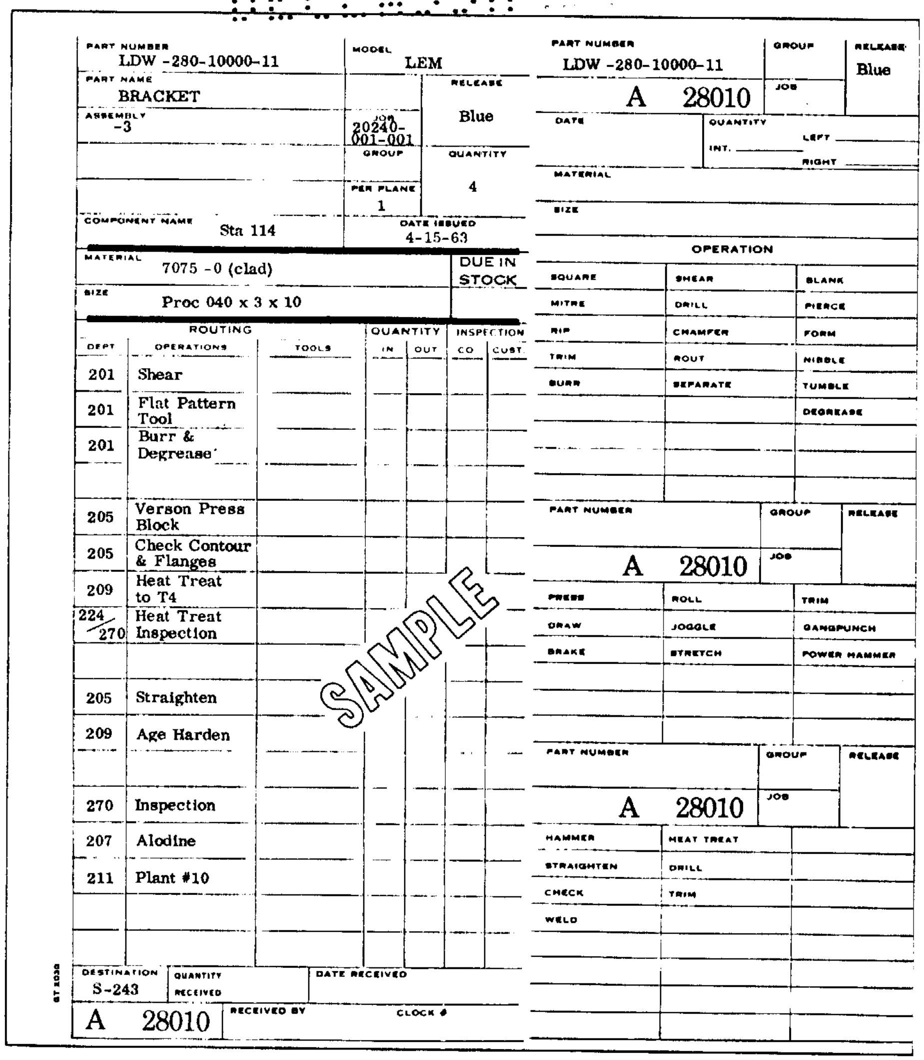
Multilith personnel produce the shop work orders and route cards which were initiated by the processors. This group also issues the work orders to the delegated shop departments. Route Cards are forwarded to the Manufacturing Planning Release group, and master files are kept of all work orders. Sample work order and route cards are shown in Figure 3-6.

Manufacturing Planning Release personnel evaluate all work orders for detail parts 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 quantitiy 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 returned to the Release Group for filing.

Expediting personnel maintain close coordination with the shop and parts control groups to provide constant monitoring of part availability requirements.

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.



PART NUMBER LDW -280-10000-11 | MODEL LEM | PART NUMBER LDW -280-10000-11 | GROUP | RELEASE Blue

PART NAME BRACKET | RELEASE Blue | A 28010 | JOB

ASSEMBLY -3 | JOB 20240-001-001 | GROUP | QUANTITY 4 | 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

DEPT	OPERATIONS	TOOLS	QUANTITY IN	QUANTITY OUT	INSPECTION CO	INSPECTION 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					

OPERATION: SQUARE, SHEAR, BLANK, MITRE, DRILL, PIERCE, RIP, CHAMFER, FORM, TRIM, ROUT, NIBBLE, BURR, SEPARATE, TUMBLE, DEGREASE

PART NUMBER | GROUP | RELEASE | A 28010 | JOB

PRESS, ROLL, TRIM, DRAW, JOGGLE, GANGPUNCH, BRAKE, STRETCH, POWER HAMMER

PART NUMBER | GROUP | RELEASE | A 28010 | JOB

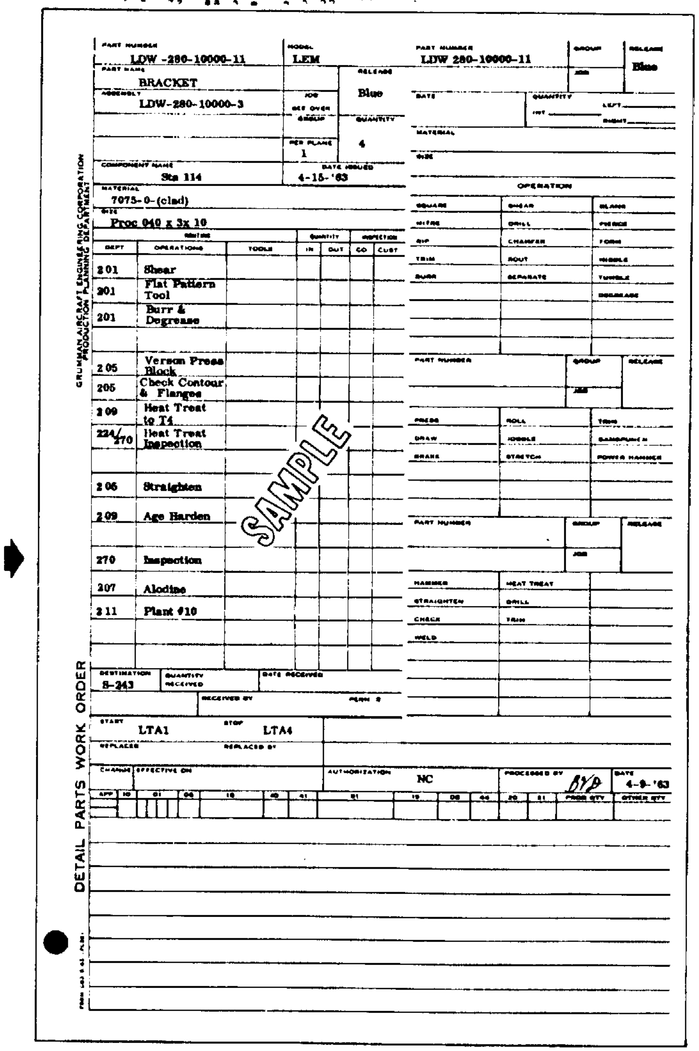
HAMMER, HEAT TREAT, STRAIGHTEN, DRILL, CHECK, TRIM, WELD

DESTINATION S-243 | QUANTITY RECEIVED | DATE RECEIVED | A 28010 | RECEIVED BY | CLOCK #

SAMPLE

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

WORK ORDER
Authorizing Shop
Effort



GRUMMAN AIRCRAFT ENGINEERING CORPORATION PRODUCTION PLANNING DEPARTMENT

PART NUMBER LDW -280-10000-11 | MODEL LEM | PART NUMBER LDW 280-10000-11 | GROUP | RELEASE Blue

PART NAME BRACKET | RELEASE Blue

ASSEMBLY LDW-280-10000-3 | QUANTITY 4 | PER PLANE 1

COMPONENT NAME Sta 114 | DATE ISSUED 4-15-'63

MATERIAL 7075-0-(clad) | SIZE Proc 040 x 3x 10

DEPT	OPERATIONS
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
206	Straighten
209	Age Harden
270	Inspection
207	Alodine
211	Plant #10

DESTINATION S-243 | START LTA1 | STOP LTA4 | AUTHORIZATION NC | PROCESSED BY [illegible] | DATE 4-9-'63

SAMPLE

DETAIL PARTS WORK ORDER

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

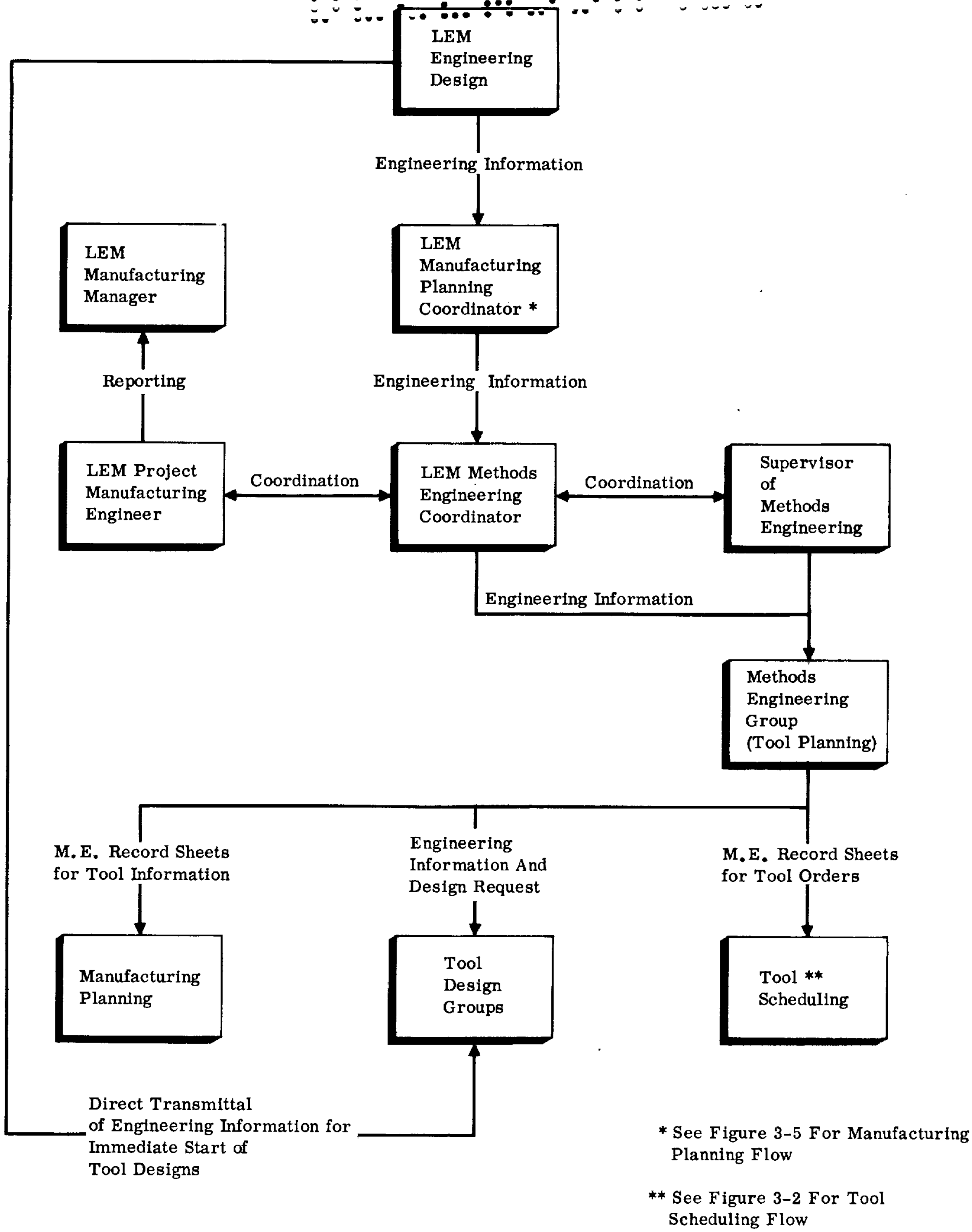


Figure 3-7. Tool Planning Flow

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. . This form is the sole authorization for the manufacture of LEM tools. 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 "Rework 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 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. .

DECLASSIFIED

DECLASSIFIED

GRUMMAN AIRCRAFT ENGINEERING CORP.
MANUFACTURING ENGINEERING
METHODS ENGINEERING TOOL REWORK RECORD

SHT. 1 OF 1

DWG NO LSS 210-10210 | MODEL LEM | DWG. NAME SUPPORT ASSY. STA 241. CONSOLE | LOFTED NO

JOB NO 74240 001-001

DASH NO	TOOL CODE	TYP ORD	EST HRS	ORD BY	DUE DATE	DATE WNT	WORKMAN	INST	ENG'G CHANGE	TO RC	PT INFO	SCHED	TOOLING INFORMATION
				AJ		5/1/3			ADV				TOOLED -11 THRU - 16
-11-12	TTP	PR	1.0	AJ	J-3	6/4/3	02 206	02 003	2 nd ADV		✓		ADD 1/8 TO FLAT PATTERN IN AREA OF JOGGLE.
-11-12	PBT	TR	0.6	"	"	"	"	5-02 2-06	"		✓		MOVE JOGGLE LINE.
-11	HPB	PR	2.5	"	"	"	02 207	02 003	"		✓		REVISE JOGGLE LOCATION & SLOPE
-12	HPB	PR	2.5	"	"	"	"	"	"		✓		PER PBT & VIEW A-A, 2ND ADV REL. DWG.

SAMPLE

ME 269 A

ME - 269A Revision Record And Tool Shop Revision Order

PART NO LSS 210-10210-11-12 | PART NAME BRACKET | NEXT ASSEM. -1-2 | LOFTED YES NO ✓ | MO AFFECTED PART YES NO X | MO NO.

GRUMMAN AIRCRAFT ENGINEERING CORP.
MANUFACTURING ENGINEERING
METHODS ENG'G RECORD

SHT I OF I

MODEL LEM | SHIP EFFECTIVITY LTA #1 | 1 JOB NO 74240-001-001 | REMARKS

MATERIAL 2024-0 AL AL

SIZE PROC. 040x4x8 1/4

DEPT	ROUTING: OPERATION & PRODUCTION TOOLS	TOOL CODE	TYP. ORD.	EST. HRS	ORD. BY	DUE DATE	DATE WENT	WORKMAN	DESTI-NATION	SCHED.	✓	TOOLING INSTRUCTIONS
		TTP	PO	2.3	AJ	G-3	5/1/3	02 206	02 001			PER ADV. REL DWG.
												(FOR CARTER BOX)
												#30 ALL HOLES
												(REF: SD 132)
	FORM IN "O" COND.											
		PBT	TO	2.1	AJ	G-3	5/1/3	02 208	5-02 206			PER ADV REL DWG & TTP
												USE PRODUCTION HOLES
												FOR W HOLES
												(REF: SD 126)
	-11	HPB	PO	4.0	AJ	G-3	5/1/3	02 207	02 003			PER PBT & ADV. REL. DWG.
	-12	HPB	PO	4.0	AJ	G-3	5/1/3	02 207	02 003			FOR "O" MAT'L
												MINIMUM HT.
												NOTE: SEE VIEW A-A FOR
												JOGGLE SLOPE IN 5/8 FLG.
												(REF: SD110

SAMPLE

FOR TOOLING AND/OR METHODS CHANGES TO PARTS FABRICATION ONLY

REV	DATE	BY	REV	DATE	BY	REV	DATE	BY	REV	DATE	BY

ME 269

ME - 269 Record Sheet And Tool Shop Authorization Order

Figure 3-8. ME - 269 Record Sheets

TOOL & EQUIPMENT CODES

ADJ	Assembly Drill Jig
AF	Assembly Fixture
ANT	Arvey Drill Template
APT	Air Punch Template
ARB	Arbor
BB	Bending Block
BD	Blanking Die
BDD	Beading Die
BDT	Blanking Die Template
BED	Bending Die
BET	Bending Die Template
BF	Boring Fixture
BFD	Blank and Form Die
BFT	Blank and Form Die Template
BFW	Wharton Boring Fixture
BKB	Bucking Bar
BMD	Blank and Mark Die
BMF	Boring Mill Fixture
BMT	Blank and Mark Die Template
BOB	Boring Bar
BOF	Bonding Fixture
BPD	Blank and Pierce Die
BPT	Blank and Pierce Die Template
BRF	Broaching Fixture
BSP	Special Adapter
BT	Brake Template
BUD	Burnishing Die
BXD	Blank, Pierce and Form Die
BXT	Blank, Pierce and Form Die Template
✓BZF	Brazing Fixture
CBR	Counterbore
CBT	Pneumatic Router Box Template
CC	Contour Cam
CD	Curling Die
CDC	Drill and Counterbore Comb.
CF	Checking Fixture
CND	Coining Die
COF	Combination Fixture
CP	Plug
CR	Contour Rollers
CRC	Reamer & Counterbore Comb.
CRD	Corner Radius Die
CRF	Chamfer Routing Fixture
CSF	Cincinnati Swivel Mill Fixture
CSK	Countersink
CT	Contour Template
DA	Die Accessories
DD	Draw Die
DDR	Draw Die Rubber
DDT	Draw Die Template
DHD	Drop Hammer Die
DHR	Drop Hammer Male Die
DID	Diameter Die
DJ	Drill Jig
DJW	Wharton Drill Jig
DKD	Dinking Die
DKT	Dinking Die Template
DMD	Dimpling Die
DP	Drill Plate
DRB	Drill and Router Board
DRJ	Drill and Ream Jig
DRL	Drill
DRP	Drill and Ream Plate
DRT	Drill and Router Template
DST	Drill and Scribe Template (Formed)
DSU	Drill and Scribe Template (Flat)
DT	Drill Template (Formed)
DU	Drill Template (Flat)
DTJ	Drill and Trim Jig
ED	Expanding Die
EMD	Embossing Die
ERD	End Radius Die
ERF	Erco Riveting Fixture
EXD	Extrusion Die
EXT	Expendable Tools
FAD	Flattening Die
FD	Form Die
FDT	Forming Die Template
FLD	Flanging Die
FMC	Form Milling Cutter
FOD	Forging Die
FPC	Formed Piece
FPD	Form and Pinch-Off Die
FST	Speedy Drill Template
FT	Form Tool
FTD	Form and Trim Die
FWF	Flashwelding Fixture
FWM	Flex White Master
FWS	Flashwelding Set-Up Card
GA	Grinding Accessories
GCT	Grind Check Template
GF	Grinding Fixture
GHE	General Handling Equipment
GHT	General Hand Tools
GMC	General Miscellaneous Cutter
GMX	Miscellaneous Gage
GP	Plug Gage
GPT	Gang Punch Template
GR	Ring Gage
GS	Snap Gage
GTP	Thread Plug Gage
GTR	Thread Ring Gage
GTS	Thread Snap Gage
GTX	Taper Plug Gage
GTY	Taper Ring Gage
HAT	Hose Assembly Tool
HB	Hammer Block
HBR	Hand Brake Radius Bar
HBT	Hammer Block Template
HD	Hufford Die
HDT	Hufford Die Template
HE	Handling Equipment
HF	Holding Fixture
HFD	Hydroform Die
HFT	Hydroform Die Template
✓HPB	High Pressure Block
HRJ	Hand Router Jig
HTA	Heat Treat Accessories
HTF	Hydrotel Fixture
IBF	Induction Brazing Fixture
ICF	Inspection Checking Fixture
ICT	Inspection Checking Template
IF	Installation Fixture
IJ	Installation Jig
JD	Joggle Die
JDT	Joggle Die Contour Template
JI	Jaw Inserts
JLT	Joggle Location Template
JST	Joggle Set-Up Template
LCT	Lines Contour Template
LEF	Lettering Accessories
LF	Lathe Fixture
LFW	Wharton Lathe Fixture
LT	Locating Template
LTE	Lab Test Equipment
MA	Milling Accessories
MAT	Masking Template
MCA	Machine Accessories
MCT	Master Contour Template
MDP	Master Drill Plate
MF	Milling Fixture
MFB	Male and Female Block
MFT	Male and Female Block Temp.
MFW	Wharton Milling Fixture
MOD	Model
MOF	Molding Form
MOT	Molding Template
MP	Master Part
MPC	Permanent and Semi-Permanent Mold
MPX	Machine Program
MUF	Mockup Fixture
ND	Notching Die
NF	Nesting Fixture
NLD	Notch and Lettering Die
✓OAF	Optical Alignment Fixture
OE	Office Equipment
OTA	Optical Tooling Accessories
PA	Profiling Accessories
PB	Press Block
PBD	Press Brake Die
PBH	Combination Press and Hammer Block
PBT	Press Block Template
PCD	Pierce and Cut-Off Die
PCT	Part Check Template
PD	Piercing Die
PDT	Pierce Die Template
PE	Plating Equipment
PF	Profiling Fixture
PFD	Pierce and Form Die
PFT	Pierce and Form Die Template
PLF	Proof Loading Fixture
PMF	Portable Mill Fixture
PNT	Punch and Nibble Template
POT	Pierce & Cut-Off Die Template
PRF	Portable Router Fixture
PRJ	Pedestal Router Jig
PRT	Press Brake Die Template
PST	Punch and Scribe Template
PT	Punch Template
PTD	Pierce and Trim Die
PTN	Pattern
PTT	Pierce and Trim Die Template
PXD	Pierce, Trim and Form Die
RAF	Radial Arm Router Fixture
RCT	Roll Contour Template
RD	Roll Die
RDT	Radial Arm Drill and Router Template
RF	Riveting Fixture
RJ	Reaming Jig
RMR	Reamer
ROJ	Router Jig
RVS	Rivet Set
SAF	Safety Equipment
SC	Spinning Chuck
SCA	Spinning Chuck Template
SCF	Scribe Fixture
SCL	Special Clamp
SCT	Scribe Template
SD	Stretch Die
✓SDM	Stretch Die, Maust
SDR	Schematic Drawings
SDT	Shear and Drill Template
SF	Saw Fixture
SHD	Shaving Die
SKD	Staking Die
SKF	Skin Mill Fixture
SMC	Spar Mill Cutter
SMF	Spar Mill Fixture
SPF	Spotfacer
SPM	Special Purpose Machine
SPR	Spring Forming Tools
SPT	Strippit Punch Template
✓SRJ	Setback Router Jig
SRT	Shear Template
ST	Saw Template
STE	Silk Screen Stencil
STT	Scribe and Trim Templates
SUG	Set-Up Gage
SWA	Spotweld Accessories
SWD	Swaging Die
SWF	Spotweld Fixture
SWT	Spotweld Template
TBA	Tube Bending Accessories
TBD	Tube Bending Die
TBS	Special Tool Bit
TD	Trim Die
TEQ	Testing Equipment
TF	Twisting Fixture
TFT	Tube Forming Tools
THT	Threading Tools
TJ	Tapping Jig
TP	Test Plug
TR	Trimming Rollers
TTA	Arvey Die Master
TTB	Jig Master
TTC	Jig Template
TTD	Control Master
TTE	Master Tool Template
TTF	Facility Gage
TTG	General Tooling Tool
TTH	Master Flat Pattern Template
TTP	Flat Pattern Production Template
TTR	Record Template
TTW	Wiping Template
UPT	Upholstery Template
URT	Universal Router Template
VEH	Vehicles and Accessories
WA	Welding Accessories
WD	Washer Die
WDJ	Watts Drill Jig
WF	Welding Fixture
WM	White Master
WPB	Verson Press Block
WPD	Wiping Die
WRS	Special Wrench
XFD	Pierce, Cut-Off and Form Die
XFT	Pierce, Cut-Off and Form Die Template
XSD	Blank, Pierce and Shave Die
YOK	Squeezer Yokes

✓ Codes added this revision

Figure 3-9. Tool and Equipment Code Lists

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.

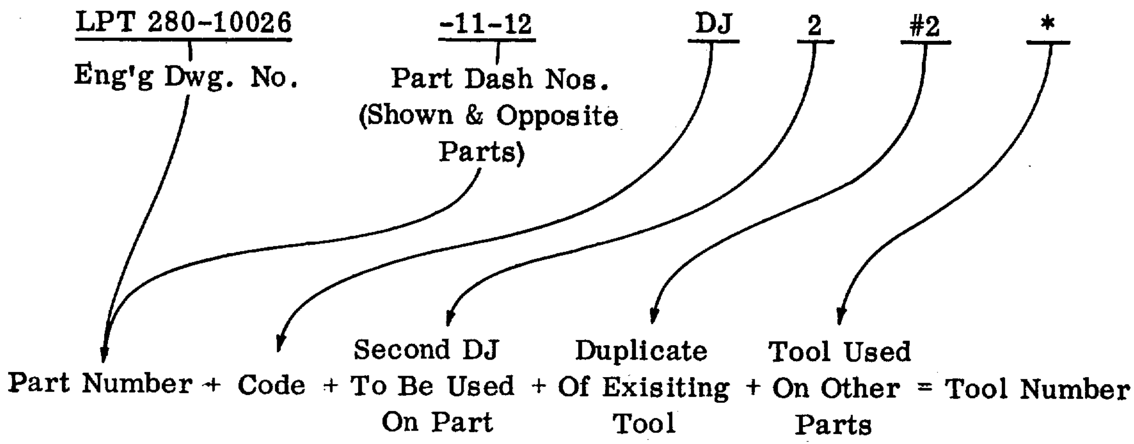
There are many intricate parts that require several tools to complete a basic operation, i.e., one part might require three separate drilling operations and therefore three separate jigs. The Designer assigns the basic tool number to the drill jig performing the first of these operations; the basic tool 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.

The 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

This 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 28-10026 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.

The Designer may add as many symbols to the basic tool number as are needed to make a completely descriptive tool number. A very elaborate example follows:



3.2.3 Procurement Planning

The Procurement Planning Department is responsible for Manufacturing Scheduling (previously described in Section 3.1.1), material processing, and Engineering drawing distribution.

LEM Engineering information is analyzed to determine the specific contractual requirements for materials and vendor services. The resulting information is processed and transmitted to the Electronic Data Processing Department (EDP), for incorporation with the "Where Used Requirements Procurement Inventory Tape". The following three basic documents are developed for the Purchasing Department by EDP:

- Raw Material Procurement Lists.
- Material Requirements and Status Reports.
- Min/Max Requirements and Status Reports.

Identical procedures are used for satisfying the requirements of Spare Parts and Support Material Lists; Requests for Diversion of Material; Field Changes; and Discrepant Material Tags.

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

The LEM interchangeability/replaceability program for mechanical interfaces will be pursued in accordance with established and proven aerospace practices. An I & R List will be generated by Grumman when further configuration details become available.

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

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 subassembly 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 descent 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 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 convenience of assembly and handling.

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

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.

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 below and is discussed in Sections 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 has assigned representatives to the "Effort Analysis Team" for review of proposed subcontractor approaches to tooling, equipment processes and manufacturing. This review and analysis of manufacturing programs is presently being completed with the four major subcontractors listed below:

- Rocketdyne- Descent Propulsion
- Bell Aerosystems- Ascent Propulsion
- Marquardt- Reaction Control Subsystem
- Hamilton Standard- Environmental Control Subsystem

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 the

LVR-270-4 are listed below 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 section 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."

Tooling ---" all dimensional tooling, (such as dies, jigs, fixtures, etc.) required to fabricate the engine and rocket engine components, ------------------. The vendor shall specify that the proposed tooling is adequate for fabrications of ____ quantities of parts (specified by components referenced in 1.1) at the rate of _______ parts per month. Item 1.1 referenced above 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."

"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."

"Vendor shall identify all tools using Grumman Tool & Equipment codes." 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 one 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 one-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 one 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 can not 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 orgainization, has the prime responsiblility 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.
- 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 overall 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 will be used to control the receipt of materials; vendor activities; information releases; and management of manufacturing manpower.

A partial PERT network for the LEM Propulsion Subsystem "Heavyweight Rig A, B & C Tank" program is shown in figure 3-10. This network is typical of the manufacturing participation planned for the entire PERT/time program.

3.3.6 Cost Control

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

Expenditures will be monitored using a PERT Companion Cost System, pending future NASA and Grumman agreements regarding a suitable and effective plan. Present

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This partial network, extracted from the LEM Propulsion PERT Network dated 1 March, 1963 Shows the manufacturing, tooling & equipment activities & events for the "Heavyweight Rig A, B & C Tank" program. This sample is typical of the manufacturing contributions planned for the overall PERT program.

Legend
- Manufacturing Tooling & Equipment
- Other Activites & Events

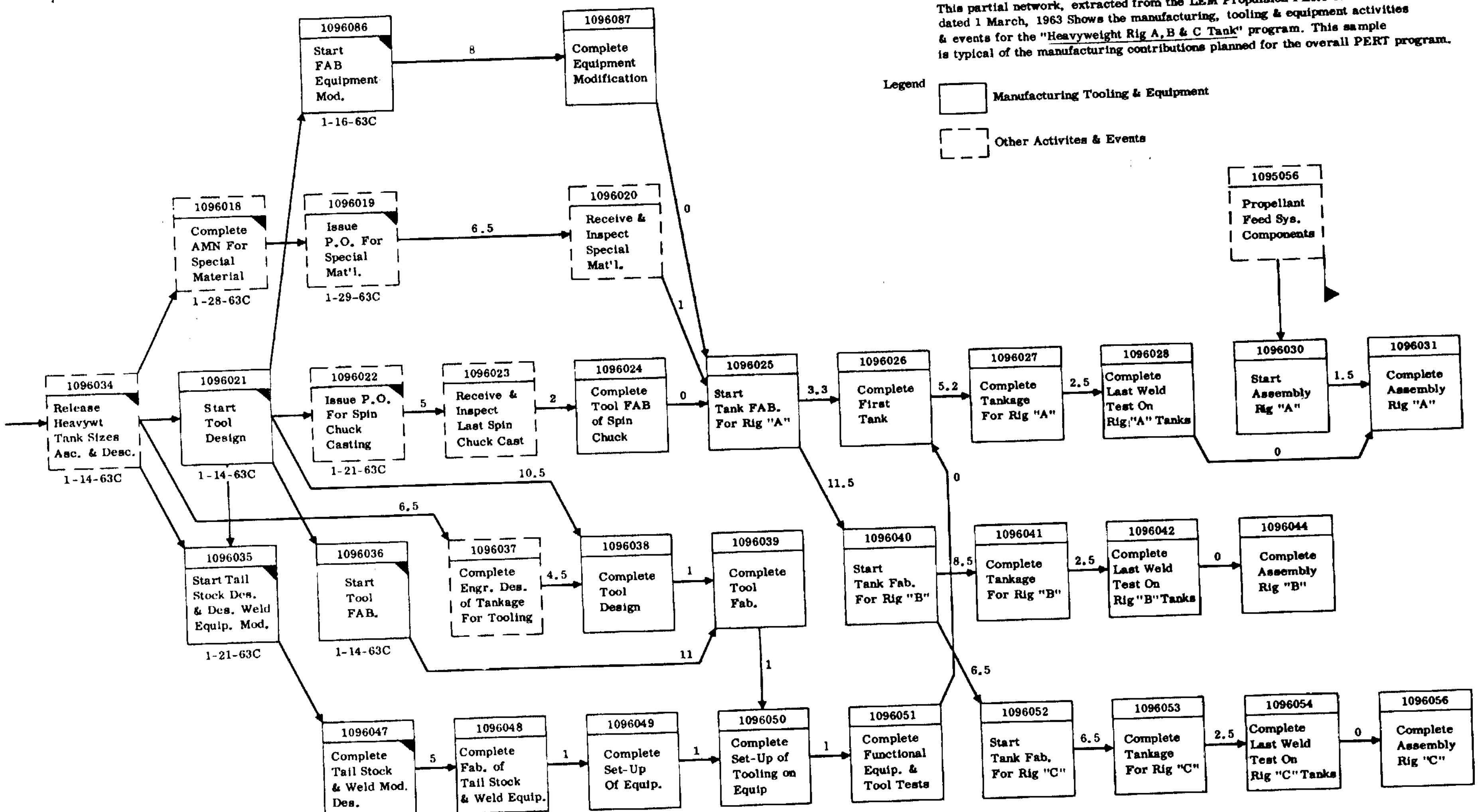


Figure 3-10. Partial PERT Network – LEM Propulsion Subsystem

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 E.D.P. 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 E.D.P. 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, changes in scope and has the additional advantages of ready comprehension throughout the organization.

Tool and equipment budget breakdowns will also conform to the requirements of the PERT Companion Cost System. However, 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 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 forword the comparative data to the Project Engineers. Thus, immediate action can be initiated to assure lowest overall 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 is being investigated and will be effected through a set of procedures by which the configuration of deliverable end items is identified, controlled, and documented. Implementation of Configuration Management shall assure 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 following paragraphs summarize the basic concepts which Grumman is studying for further refinement of a Configuration Management system.

The LEM Engineering Department will direct the Manufacturing efforts associated with Configuration Control by establishing the "Controlled Items List". The Manufacturing Planning Department will use this list to identify the shop work orders which are applicable to the controlled items selected by Engineering. Each work order will be accompanied by a key punched card which is retained by the Quality Control Department until the work has been accomplished. The card will be forwarded to a data retention center following task completion.

Key punched cards will contain the information necessary for producing a complete configuration list at any time during the life of a specific module.

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 & Crew Provisions Subsystem.

As shown in Section 1.3 "Make Or Buy Summary", Grumman is responsible for the manufacture, and assembly of the Structural/Mechanical and Crew Provisions Subsystems. The following Sections 4.1.1 through 4.1.1.5 describe the manufacturing plans for the Structural/Mechanical Subsystem. The basic manufacturing approaches for the Crew Provisions Subsystem are shown in Section 4.1.2.

The "Development Manufacturing Plan" for these subsystems requires a logical progression from initial LTA fabrication to follow-on manufacturing of subsequent LTA & LEM Modules. Three basic steps are planned for assurance of on-schedule performance; maximum manufacturing reliability; and lowest overall program costs:

- For all manufacturing up to and including the LTA-3 module, 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 the LTA-4 module 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, the LTA-5 and subsequent LTA and LEM modules will be developed using finally configured structural assembly tooling.

- The structural manufacturing technicians who participate in the development of the initial LTA modules 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 Subsystem

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

The Ascent and Descent Stage Subassembly Breakdown Diagrams are shown in Figures 4-2 and 4-3 respectively. Since Engineering design concepts for internal structure are not firm, these diagrams and related discussions are based on the Structural Arrangement Configuration #2, which is presently being modified. The 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 mating structure will minimize the structural work during the

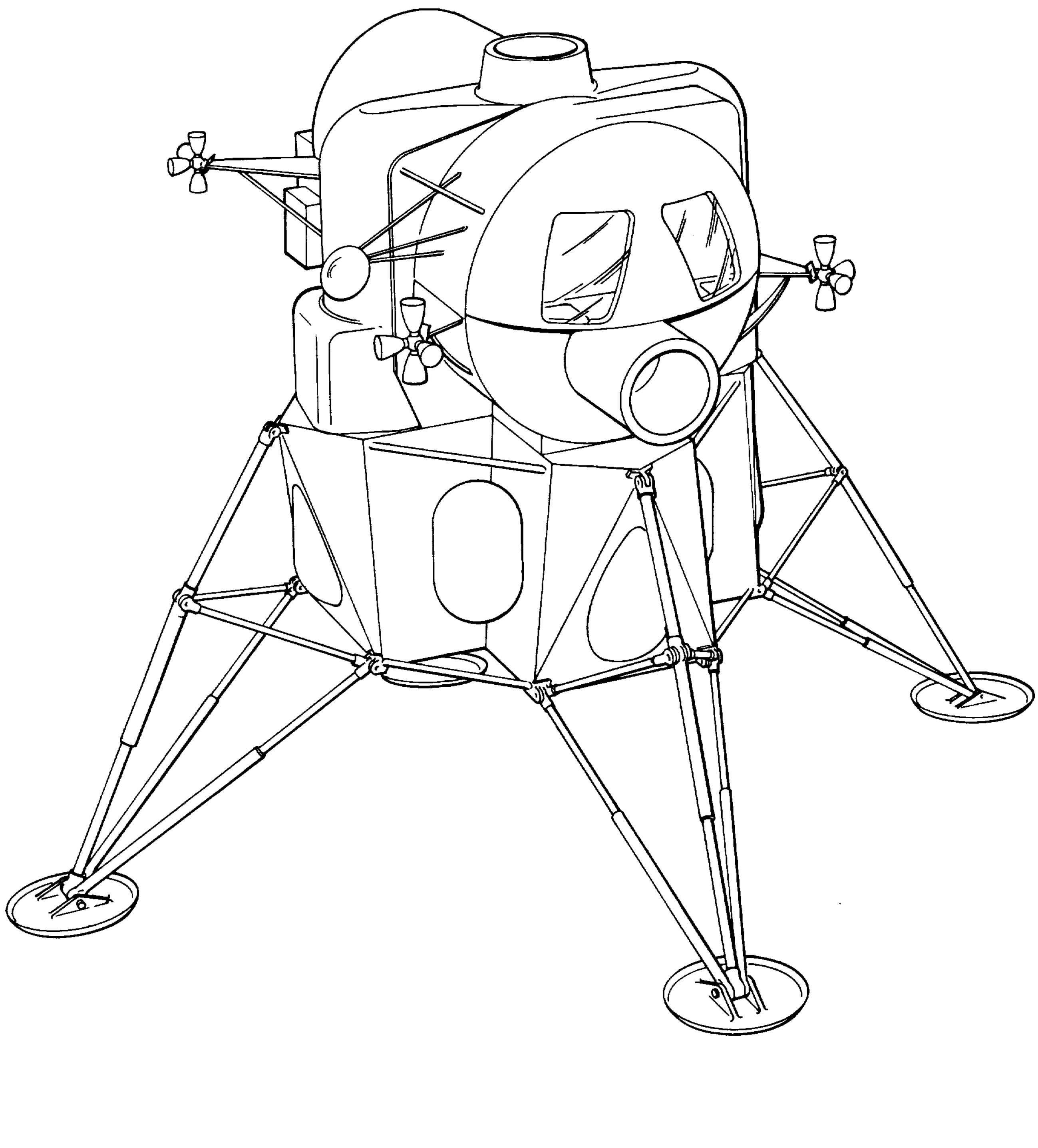
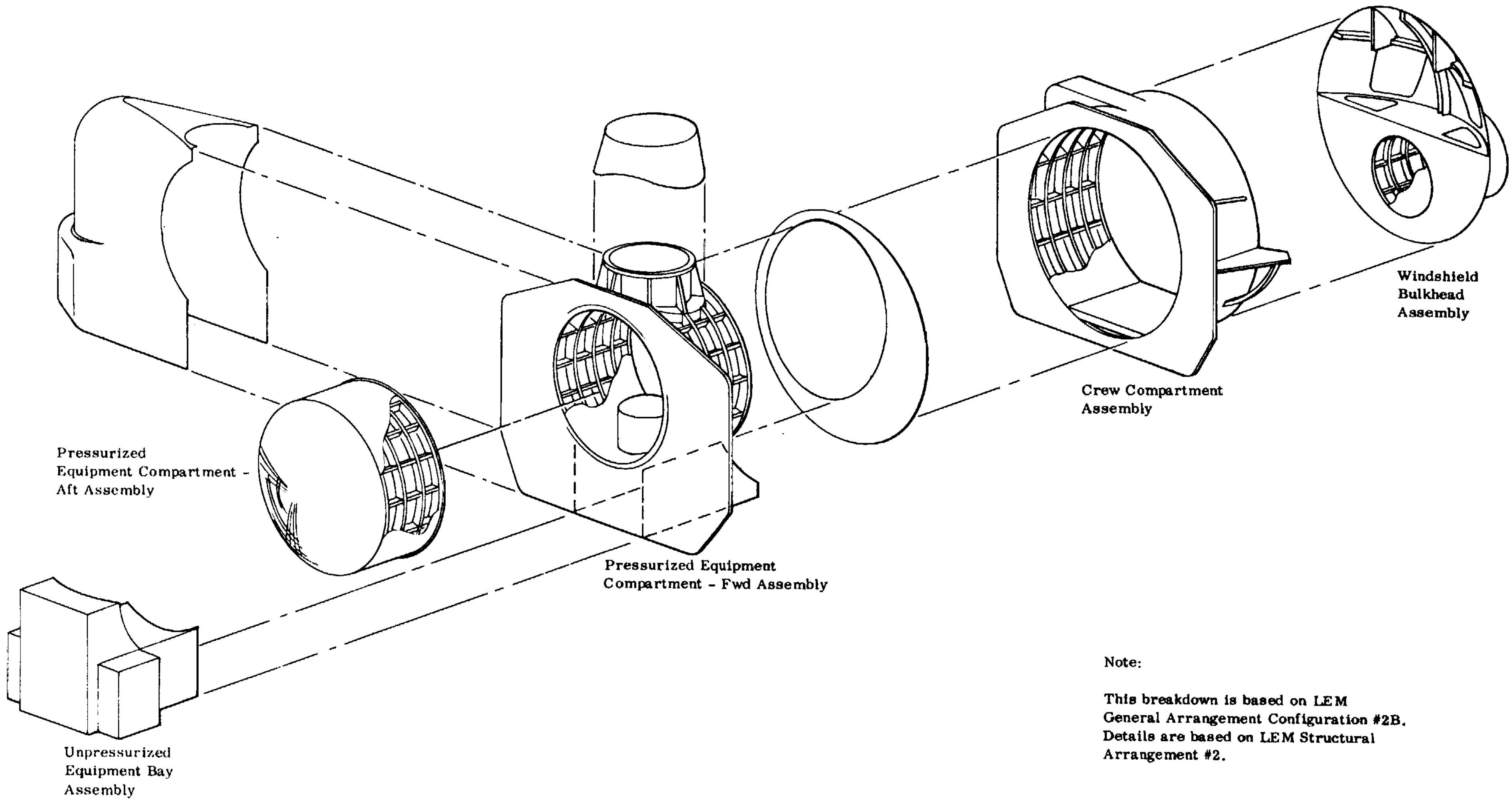


Figure 4-1. LEM General Arrangement Configuration #2B



Note:

This breakdown is based on LEM General Arrangement Configuration #2B. Details are based on LEM Structural Arrangement #2.

Figure 4-2. Ascent Stage - Subassembly Breakdown

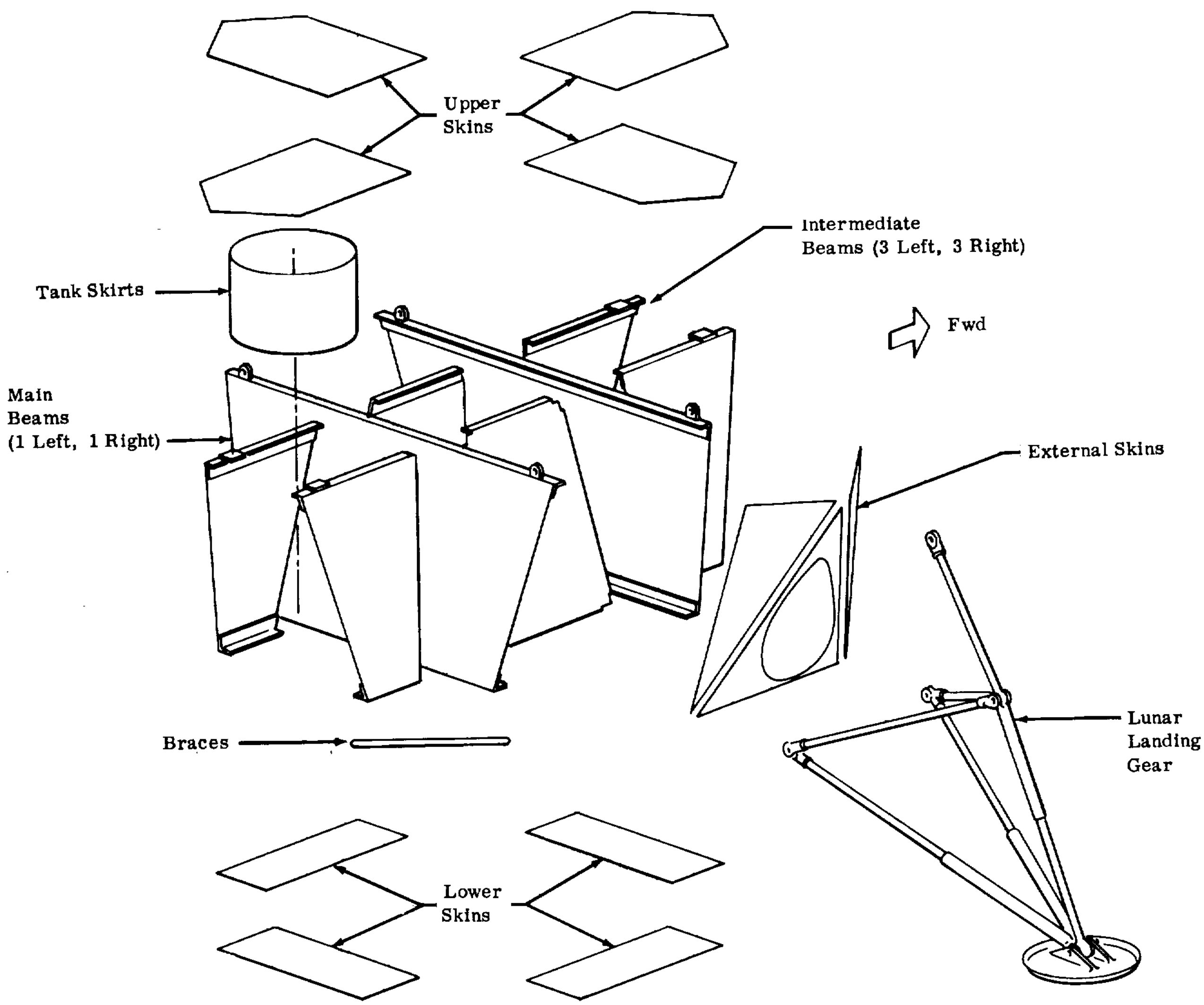


Figure 4-3. Descent Stage - Subassembly Breakdown

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 shown in Figure 4-3 indicates one major assembly stage and various component subassembly operations. This minimum breakdown is considered adequate for the maximum manufacturing rate of two 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, and 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 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. Grumman facilities and techniques in this area of fabrication are widely recognized as being one of the largest and most modern in the aerospace industry. Since this capability is somewhat unique, typical manufacturing procedures for a chem-milled LEM crew compartment frame detail are shown in Figure 4-4. All operations from part forming 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 crew compartment and some equipment compartments, 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. Figure 4-5 shows the manufacturing flow and includes the major assembly tools, some subassembly tools, GSE and manufacturing handling equipment.

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 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.

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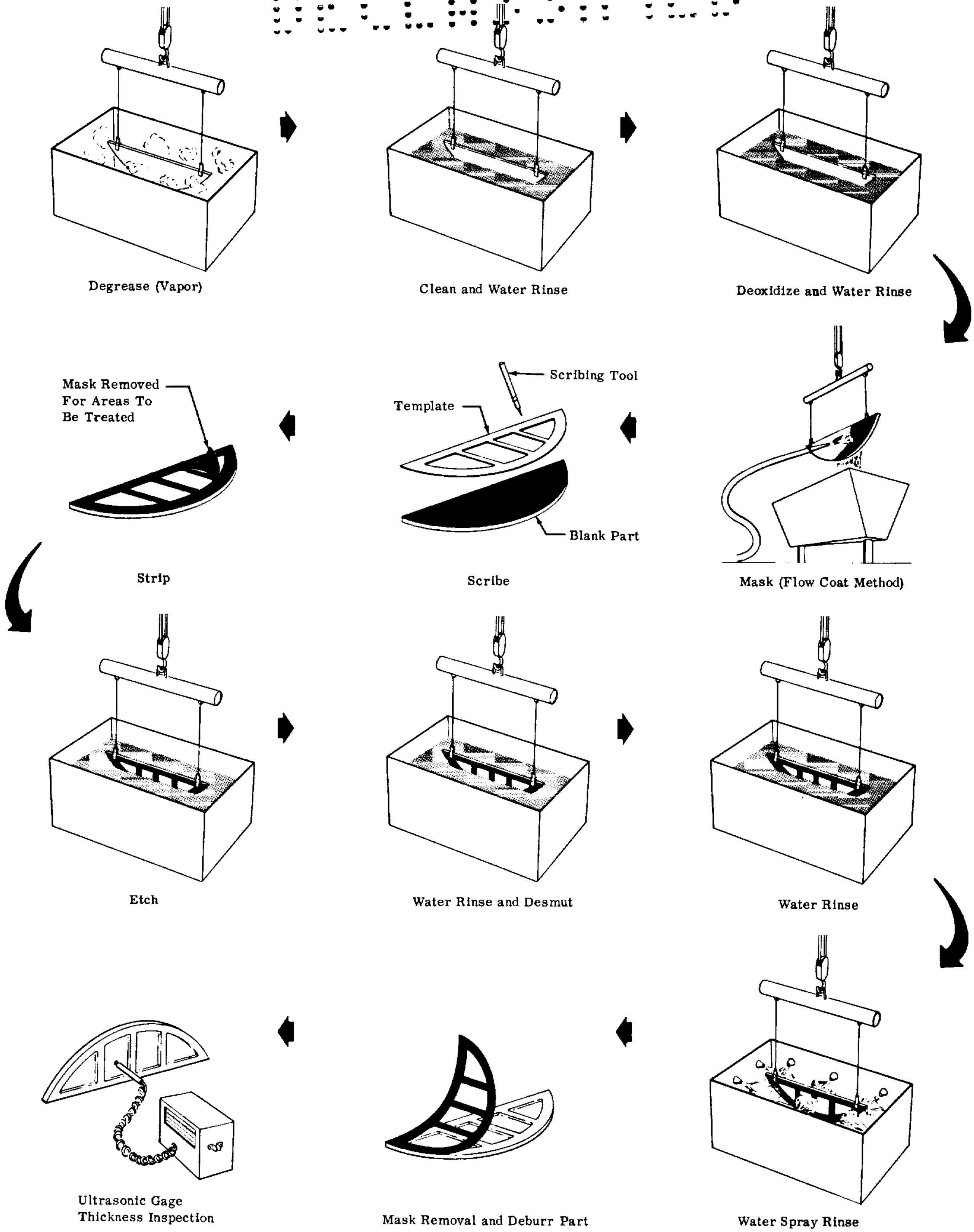
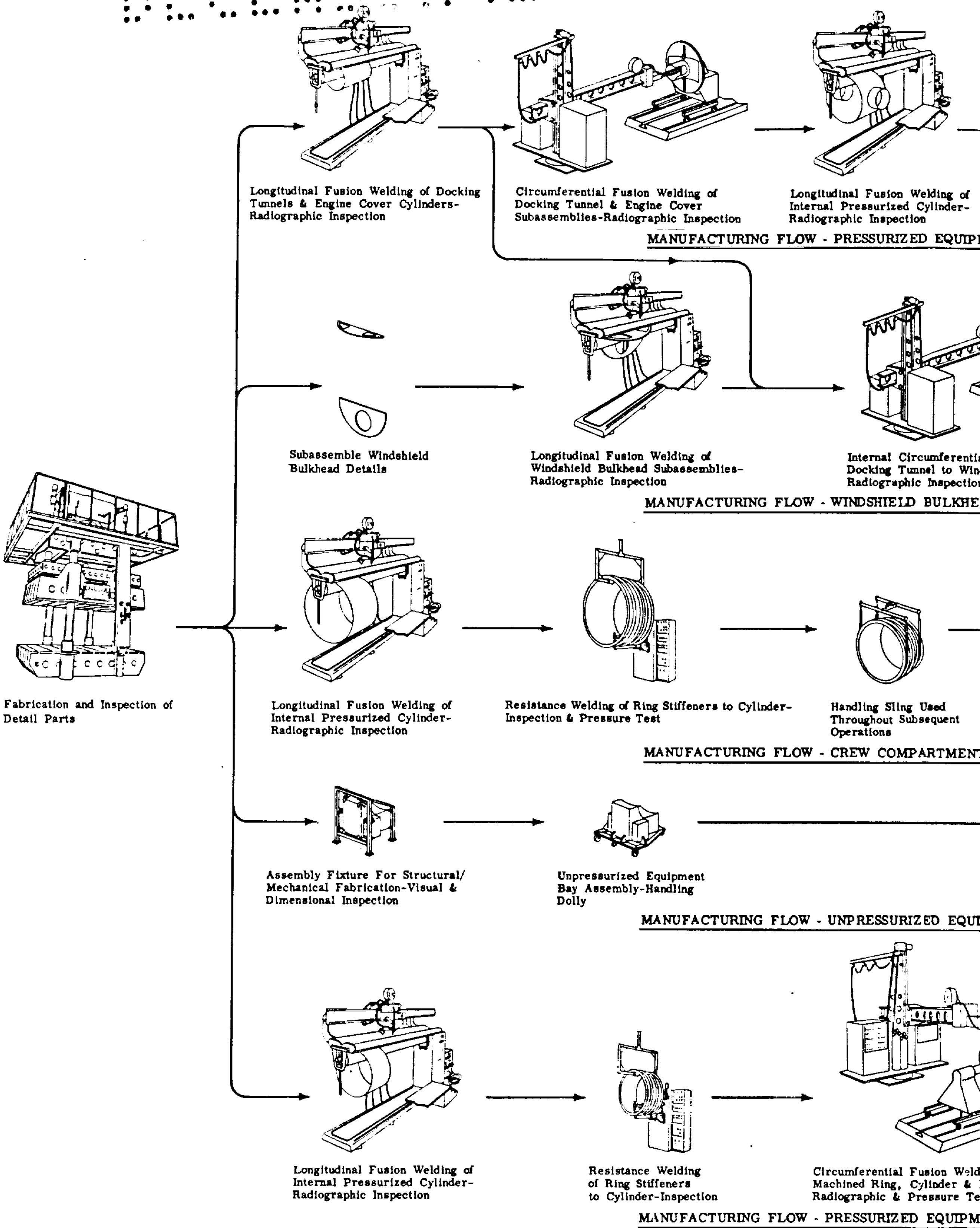


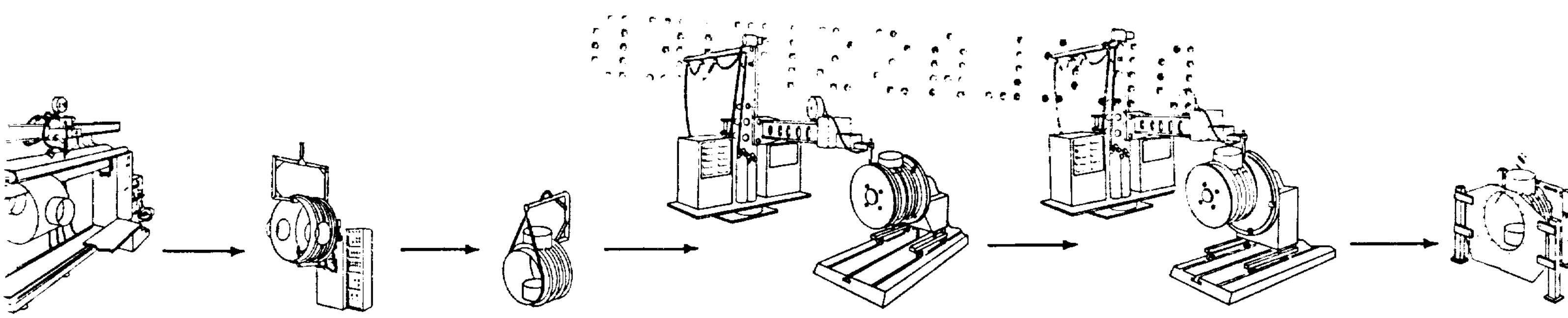
Figure 4-4. Chemical Milling of a Typical LEM Detail

ASCENT STAGE			
Major Operation And Fixture Number	Type Of Major Tool	Number Of Duplicate Tools Required	Assembly Name Or Operation Description
#1	Assembly Fixture	None	Windshield Bulkhead Assembly
#2	Assembly Fixture	1	Crew Compartment Assembly
#3	Assembly Fixture	1	Pressurized Equipment Compartment-Forward Assembly
#4	Assembly Fixture	1	Pressurized Equipment Compartment-Aft Assembly
#5	Assembly Fixture	1	Unpressurized Equipment Bay Assembly
#6	Welding Tool/Equipment System	None	Joining of Assembly #1, #2, and #3
#7	Assembly Fixture	1	Joining of Previous Assembly and Assemblies #4 and #5.
#8	Inspection Checking Fixtures	None	Inspection of Separation Plane; Engine Mount and RCS Mount Hole Patterns.

TABLE 4-1 - Ascent Stage Major Assemblies and Major Tools Required *

*See Figure 4-2 for Ascent Subassembly Breakdown.
See Figure 4-5 for Ascent Stage Manufacturing Flow.


Longitudinal Fusion Welding of Docking Tunnels & Engine Cover Cylinders-Radiographic Inspection
Circumferential Fusion Welding of Docking Tunnel & Engine Cover Subassemblies-Radiographic Inspection
Longitudinal Fusion Welding of Internal Pressurized Cylinder-Radiographic Inspection
MANUFACTURING FLOW - PRESSURIZED EQUIP
Subassemble Windshield Bulkhead Details
Longitudinal Fusion Welding of Windshield Bulkhead Subassemblies-Radiographic Inspection
Internal Circumferenti Docking Tunnel to Win Radiographic Inspectio
MANUFACTURING FLOW - WINDSHIELD BULKHE
Fabrication and Inspection of Detail Parts
Longitudinal Fusion Welding of Internal Pressurized Cylinder-Radiographic Inspection
Resistance Welding of Ring Stiffeners to Cylinder-Inspection & Pressure Test
Handling Sling Used Throughout Subsequent Operations
MANUFACTURING FLOW - CREW COMPARTMEN
Assembly Fixture For Structural/ Mechanical Fabrication-Visual & Dimensional Inspection
Unpressurized Equipment Bay Assembly-Handling Dolly
MANUFACTURING FLOW - UNPRESSURIZED EQU
Longitudinal Fusion Welding of Internal Pressurized Cylinder-Radiographic Inspection
Resistance Welding of Ring Stiffeners to Cylinder-Inspection
Circumferential Fusion Weld Machined Ring, Cylinder & Radiographic & Pressure Te
MANUFACTURING FLOW - PRESSURIZED EQUIPM



linal Fusion Welding of Pressurized Cylinder- ıphic Inspection

Resistance Welding of Ring Stiffeners to Cylinder-Inspection

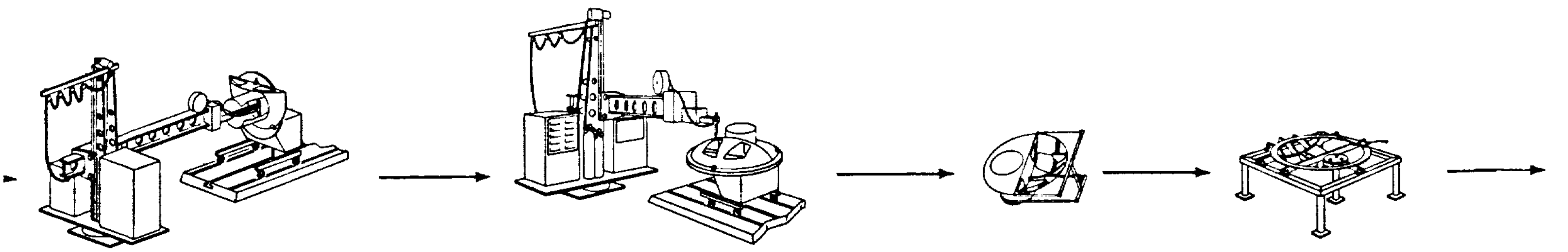
Handling Sling Used Throughout Subsequent Operations

Circumferential Fusion Welding of Machined Ring to Cylinder-Radiographic Inspection

Fabricate Transition Detail, Circumferential Welding of Transition to Cylinder-Radiographic Inspection & Pressure Test

Assembly Fixture For Structural/Mechanical Visual & Dimensional

PRESSURIZED EQUIPMENT COMPARTMENT - FWD ASSEMBLY



Internal Circumferential Fusion Welding of Docking Tunnel to Windshield Bulkhead-Radiographic Inspection

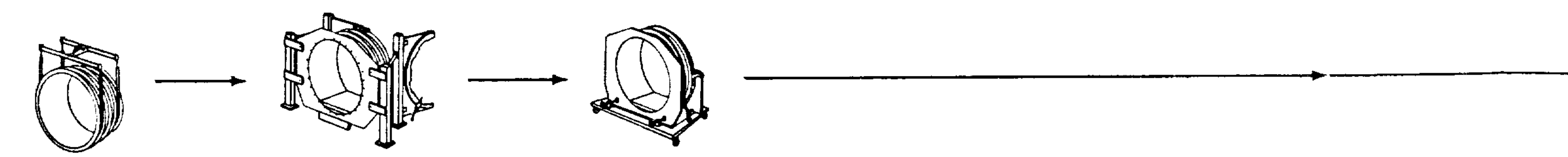
Programmed Automatic Fusion Welding of Upper Windshield Area-Radiographic Inspection & Pressure Test

Handling Sling Used Throughout Subsequent Operations

Assembly Fixture For Further Structural/Mechanical Fabrication-Visual & Dimensional Inspection

Winds Handl

VINDSHIELD BULKHEAD ASSEMBLY



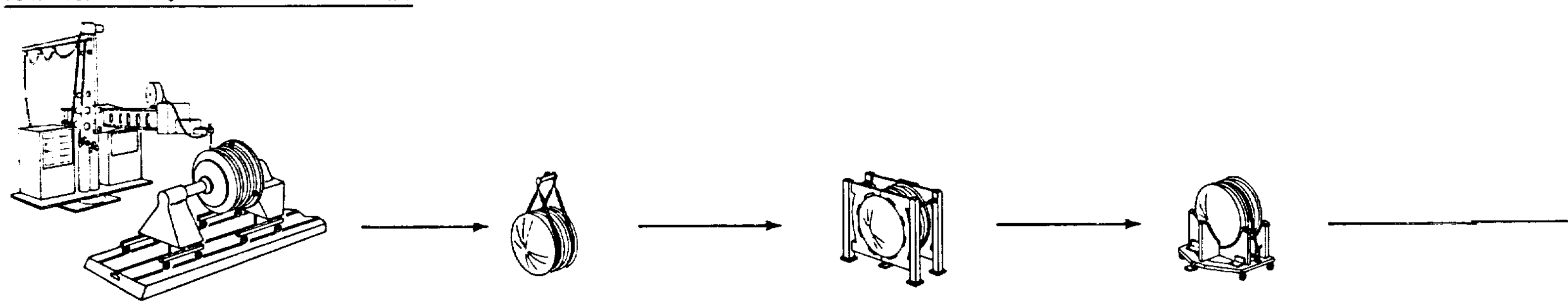
Handling Sling Used Throughout Subsequent Operations

Assembly Fixture For Further Structural/Mechanical Fabrication-Visual & Dimensional Inspection

Crew Compartment Assembly-Handling Dolly

REW COMPARTMENT ASSEMBLY

NPRESSURIZED EQUIPMENT BAY ASSEMBLY



umferential Fusion Welding of Fwd hined Ring, Cylinder & Pressure Dome, iographic & Pressure Test

Handling Sling Used Throughout Subsequent Operations

Assembly Fixture For Further Structural/Mechanical Fabrication-Visual & Dimensional Inspection

Pressurized Equipment Compartment- Aft Assembly Handling Dolly

RESSURIZED EQUIPMENT COMPARTMENT - AFT ASSEMBLY

FOLDOUT FRAME 2

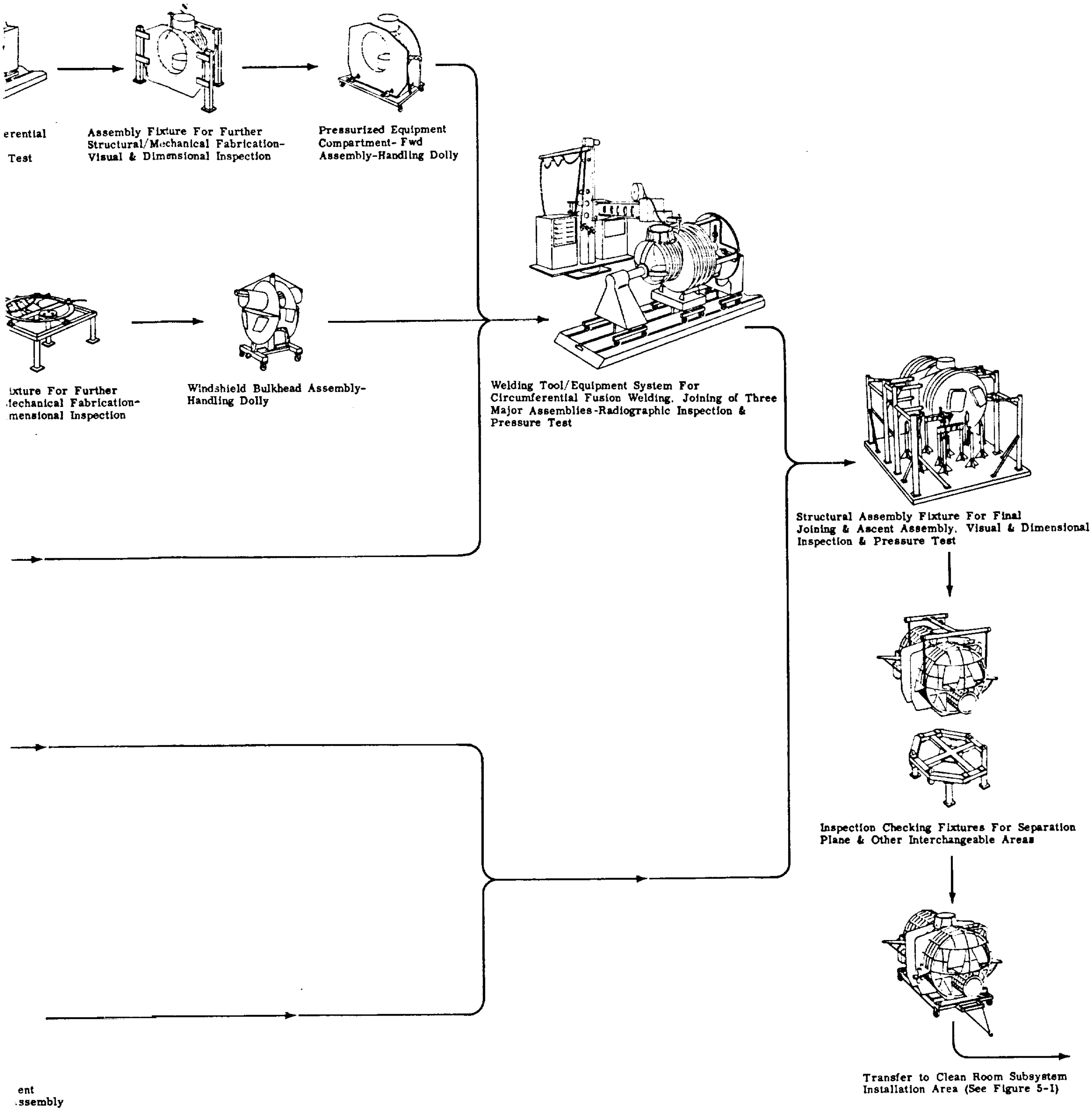


Figure 4-5. Manufacturing Flow Diagram - Ascent Stage

Grumman LEM

stations will be 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.
- An Inert gas environment will shield all "under-the-torch" welding operations. Shielding may also be provided on the underside of the weld area, depending on the alloy being joined.
- Tooling for holding, aligning, clamping and chilling will be integrated with the welding equipment. Some equipment will be programmed for contour welding.
- All equipment such as presently available longitudinal welders, combination longitudinal/circumferential welder, and boom welder 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.

The internal pressure skin sections and the stiffening rings and frames will be joined by resistance welding methods. The following procedures will be utilized for these operations.

- Cleaning, operator and equipment qualification, equipment maintenance, and inspection procedures will be the same as previously described for automatic fusion welding.
- Frame and ring locations on the internal skin sections will be established by jigs, fixtures or templates. After fusion tack welding, these subassemblies will be removed from the tools and transferred to the resistance welding areas. Although pilot holes for locating frames to skins are frequently used in lieu of tooling, and fusion welding methods are commonly used to close pilot holes, these techniques will not be permitted for the LEM program because of possible reliability degradation.

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.

Fixtures #1 through #5 (Table 4-1) incorporate provisions for establishing index references in the individual subassemblies. Thus, positioning these subassemblies during subsequent joining operations can be readily and accurately accomplished.

Figure 4-5 (Manufacturing Flow Diagram) shows the basic plans for subassembly fabrication and final structural assembly of the Ascent Stage.. The seven major manufacturing sequences are outlined below.

Fabrication of the Windshield Bulkhead Assembly is accomplished in the following manner:

- Automatic fusion welding of the forward docking tunnel and other bulkhead weldments.
- Clean and locate all skins, subassemblies, rings and frames in Major Fixture #1. Manually fusion tack weld all details and remove from the tool.

- Complete all resistance welding operations and forward to the subassembly area.

- Replace the bulkhead assembly in Fixture #1. Locate and install all secondary structure, hatch provisions, windshield attachments and sealing members, and equipment mounts. Establish index references for subsequent assembly. Machine mating skin edge using portable milling attachment or transfer to machine shop for turning on a vertical boring mill.

The Crew Compartment Assembly is fabricated in the following manner:

- Roll and automatic fusion weld the internal cylindrical skin section using available longitudinal welding equipment.

- Clean and locate formed ring stiffeners around the cylindrical skin section using templates. Tack fusion weld, remove templates, and transfer to the resistance welding area.

- Resistance weld rings, stiffeners and floor attachment points. Circumferential rings are split for ease of installation. Ring joints are mechanically spliced after completion of welding operations.

- Locate and clamp the cylindrical subassembly in Major Fixture #2 (Table 4-1). Install aft bulkhead, floor, seat tracks, secondary structure, equipment mounts. Establish index references for subsequent assembly. Machine mating skin edges using a guided portable machining attachment.

The Pressurized Equipment Compartment - Forward Assembly requires the following major operations:

- Produce a fusion and resistance welded cylindrical assembly using the same procedures as outlined for the Crew Compartment Assembly.

- Fabricate the upper docking tunnel assembly and the engine cover assembly using resistance and automatic fusion welding methods.

- Join a machined ring to the aft face of the cylindrical assembly using the automatic boom welding equipment and welding tooling.
- Join the upper docking tunnel to the cylindrical assembly using resistance roll seam or automatic fusion welding methods.
- A transition section accommodates the diameter change between the Crew Compartment and the Forward Equipment Compartment. This transition is also automatically fusion welded to the forward face of the Equipment Compartment. Since the boom welding equipment is designed to cover a 360^{o} floor area, numerous welding stations can be placed radially to achieve maximum equipment utilization and flexibility.
- The completed weldment is placed in Major Fixture #3 (Table 4-1) where the aft bulkhead, engine cover, hatch mechanisms, secondary structure and equipment mounts are joined. Hold patterns are produced in the aft mechanical sealing face.
- The forward face of the transition section is also trimmed in this fixture. Index references are established for subsequent assembly.

The Pressurized Equipment Compartment - Aft Assembly is produced as follows:

- Fabricate a fusion and resistance welded cylindrical assembly using the same techniques as outlined for the Crew Compartment.
- Locate the cylindrical assembly in Major Fixture #4 (Table 4-1) where both cylinder edges are trimmed using guided portable machining equipment. Remove from fixture.
- Locate and clamp the previously trimmed cylinder; a formed and trimmed dome; and a machined ring in an automatic fusion welding fixture.
- Transfer to the machine shop and trim the forward mechanical sealing face using a vertical boring mill.
- Return the subassembly to Major Fixture #4 for drill and reaming of hole patterns through the mechanical sealing flange. Secondary structure and equipment mounting provisions are also installed in this fixture.

The Unpressurized Equipment Bay Assembly, as previously mentioned, is fabricated using mechanical fastening techniques. Procedures are as follows:

- Manufacture formed frames, stiffeners and skins.
- Progressively join these details in Major Fixture #5 (Table #4-1). This fixture contains tooling locators and clamps for maintaining position of details and contour.

Structural Joining of the Windshield Bulkhead Assembly; Crew Compartment; and the Pressurized Equipment Compartment - Forward Assembly is accomplished utilizing automatic fusion welding as follows:

- Automatic welding equipment, standard accessories, and special welding fixtures are integrated to produce the two circumferential weld joints. This tool/equipment system is designated as Station #6 (Table 4-1).
- Hoisting bars, slings, and overhead hoisting equipment assure proper and safe loading operations.
- 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.

Final Structural Ascent Stage Assembly is accomplished by joining the previous major welded structure to the Pressurized Equipment Compartment (Aft Assembly) and the Unpressurized Equipment Bay. These three major assemblies are located in the Final Assembly Fixture (Figure 4-6) and the following final structural operations are accomplished:

- In addition to the joining of the three major assemblies, mounts and interchangeable hole patterns are incorporated for the Ascent Propulsion engine and Reaction Control engines.

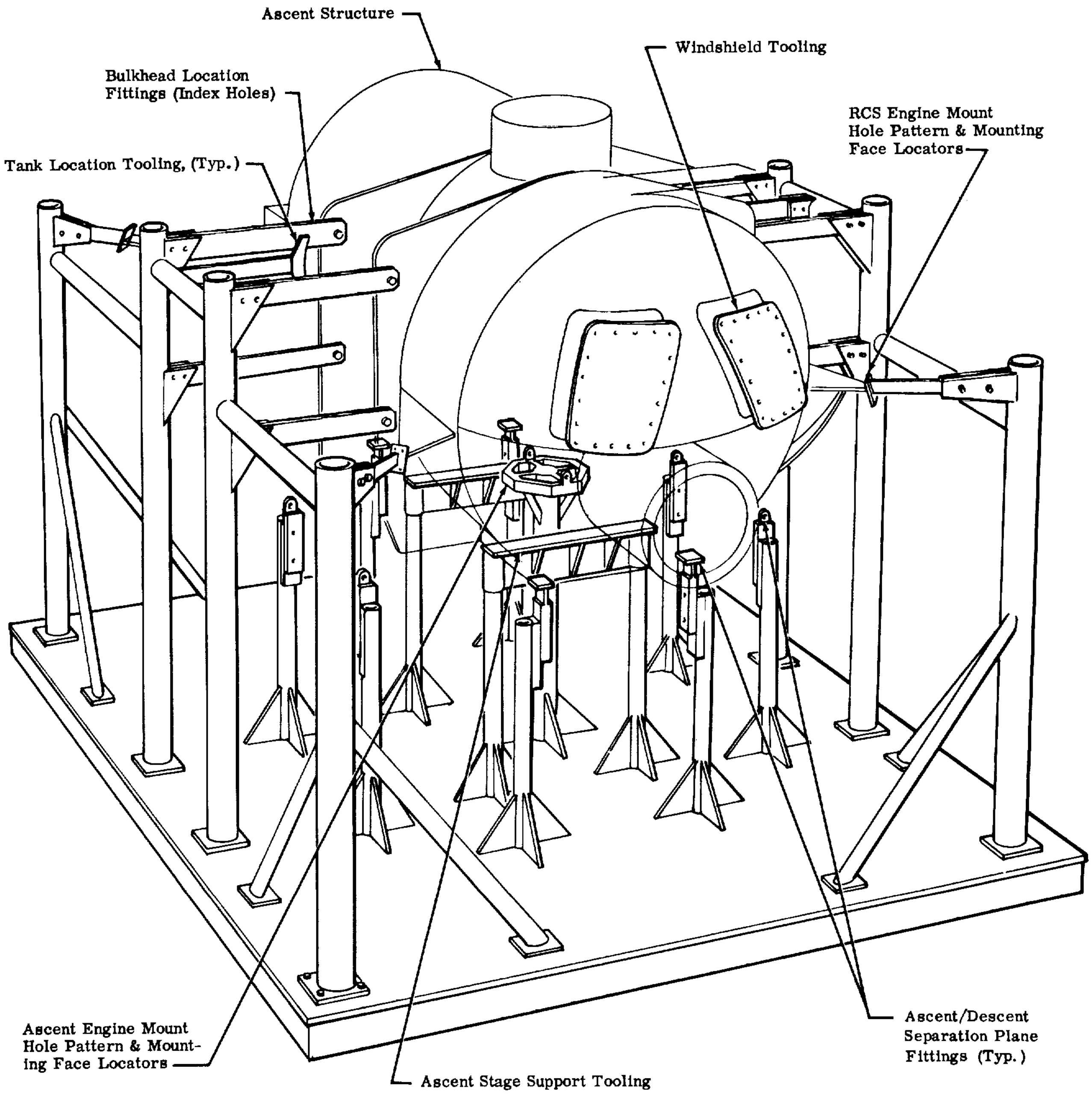


Figure 4-6. Final Structural Assembly Fixture - Ascent Stage

- The Ascent/Descent separation plane and interchangeable mating hole patterns or devices are established.
- Structural provisions for accepting the fuel, oxidizer and helium tanks are incorporated.
- Windshields are fitted, installed and sealed.
- The remainder of the equipment mounting provisions and secondary structure are installed.
- Methods for achieving interchangeability between Grumman structure and vendor supplied components are discussed in Section 3.3.1. Ascent stage separation, RCS, and Propulsion engine mounting hole patterns are checked using inspection checking fixtures. (Operation #8, Table 4-1).

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. Consequently, subassembly and assembly tools will be similar in design to those previously 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 4-7 shows the manufacturing flow, major

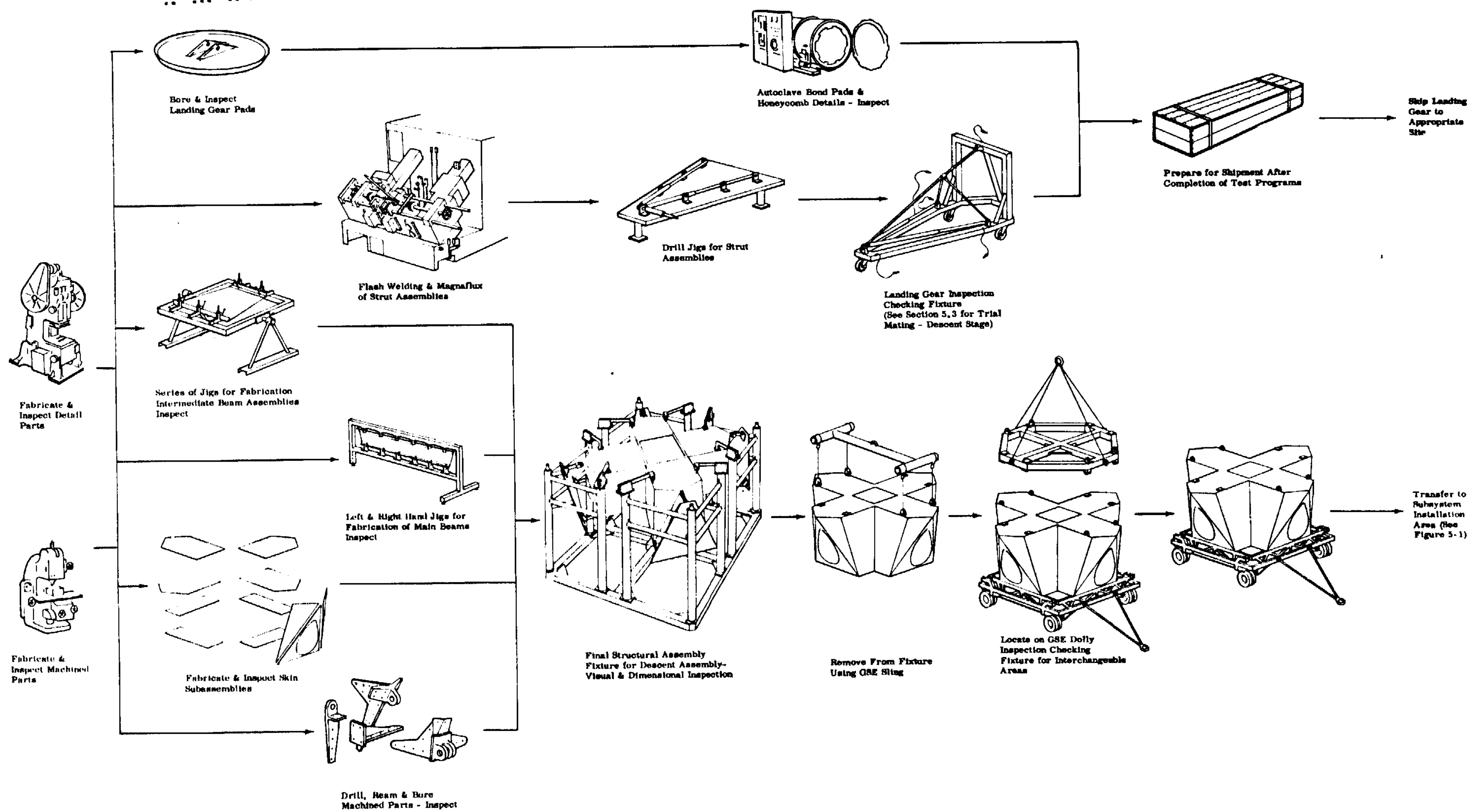


Figure 4-7. Manufacturing Flow Diagram-Descent Stage

subassembly and assembly tools, inspection checking fixtures, and GSE handling equipment. The major manufacturing sequences for the Descent Structural Subsystem are outlined below:

- Left and right hand assembly drill and ream jigs (#1 Table 4-2), are provided to locate, clamp, drill and ream the main structural beams.
- A family of similar tools are used to produce the three left and three right hand intermediate beam assemblies (Operation #2 - Table 4-2).
- Final structural assembly is accomplished using the Figure 4-8 Assembly Fixture. This tool is loaded for initial joining of main and intermediate beam subassemblies. Installation of skins and secondary structure follows. Master controlled interfaces are established. These include the landing gear attachment points; engine gimbal and actuating pick-ups; Ascent/ Descent separation plane; and all tank attachment points.
- Inspection checking fixtures (Operation #4, Table 4-2), 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.

The lunar landing gear is an assembly consisting of a series of welded strut subassemblies which couple the Descent Structure with the landing pads. Although a maximum of eight gears 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.

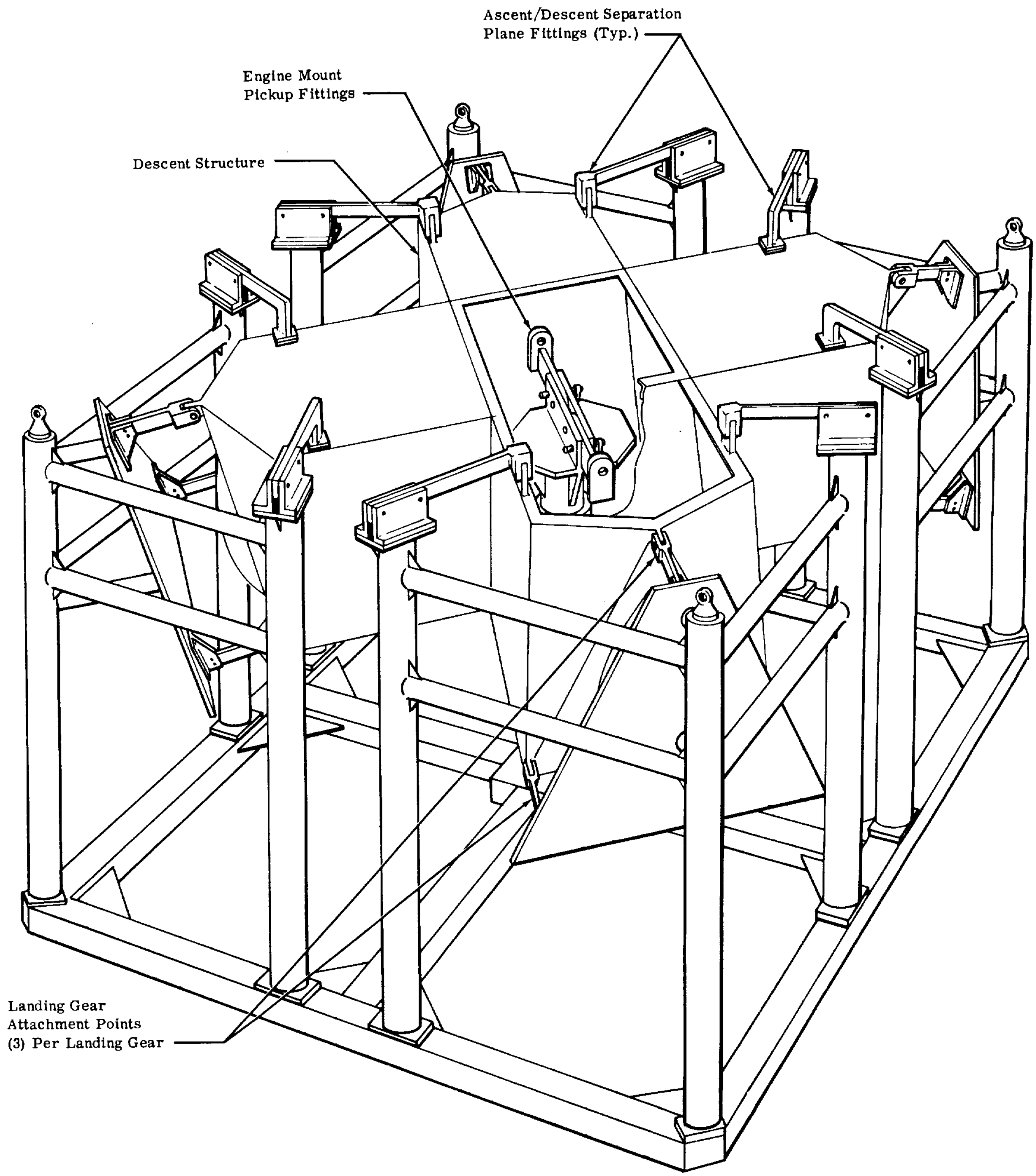


Figure 4-8. Final Structural Assembly Fixture - Descent Stage

DESCENT STAGE			
Major Operation And Fixture. Number	Type Of Major Tools	Number Of Duplicate Tools Required	Assembly Name Or Operation Description
#1	Assembly Drill and Ream Jig - (1 Left and 1 Right)	None	Descent Structure - Main Beams (L & R)
#2	Assembly Drill and Ream Jigs (Family of Tools)	None	Descent Structure - Intermediate Beams (3L & 3R)
#3	Assembly Fixture	None	Final Assembly - Descent Structure
#4	Inspection Checking Fixtures	None	Inspection of Ascent/Descent Separation Plane; Engine Mount Hole Pattern.
#5	Flash Welding Fixtures (Family of Tools)	None	Flash Welding of Landing Gear Struts
#6	Keller Drill Jigs (Family of Tools)	None	Drilling of Landing Gear Strut Connections.
#7	Inspection Checking Fixture	None	Dimensional Inspection of Assembled Landing Gear.

Table 4-2 - Descent Stage - Major Assemblies and Major tools Required. *

* See Figure 4-3 For Descent Stage Subassembly Breakdown.
See Figure 4-7 For Descent Stage Manufacturing Flow.

The basic manufacturing plans for the Lunar Landing Gear are outlined below:

- Machine end fittings and prepare tubular sections.
- These details are joined using flash welding equipment and locating and clamping tooling. A series of these tools (#5 Table 4-2) are required because of the different strut configurations for each gear assembly. All equipment settings are certified for the particular application.
- All flash welded struts are magnafluxed and proof load tested.
- Welded struts are located in drill jigs (#6, Table 4-2) 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 strut subassemblies are joined in an inspection checking fixture (#7 TABLE 4-2) to check overall length and to assure compatibility with the mating Descent pick-up points.
- The landing gear assembly, including the pad, are trial mated with the Descent Structure to assure proper fit. This procedure occurs during the installation phase as described in Section 5.
- Since the Landing Gear are not shipped as an integral part of the LEM module, 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 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 Subsystem

Grumman manufacturing plans for fabrication and integration of line assemblies; helium pressurization, and fuel and oxidizer tanks into the Propulsion, Reaction Control and Environmental Control Subsystems are described in Sections 4.2.1 through 4.2.3. Production testing of these components is described in Section 6.

Refer to the "Make or Buy" Summary, Section 1.3, for the present status of Fluid Subsystem "Make or Buy" plans.

4.2.1 Propulsion Subsystem - Ascent Stage

The aluminum Ascent Stage 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. Figure 4-9 shows the manufacturing flow for both Ascent and Descent Stage tanks and lines. The Descent tank program is described in Section 4.2.2.

The Ascent tanks are manufactured in two halves from aluminum sheet stock formed on a Boko Flow-Forming Machine; trimmed to size; and welded together. The tank halves are formed in two operations, the first being power spinning of the sheet stock to an initial shape. After an annealing cycle, the final forming operation is performed

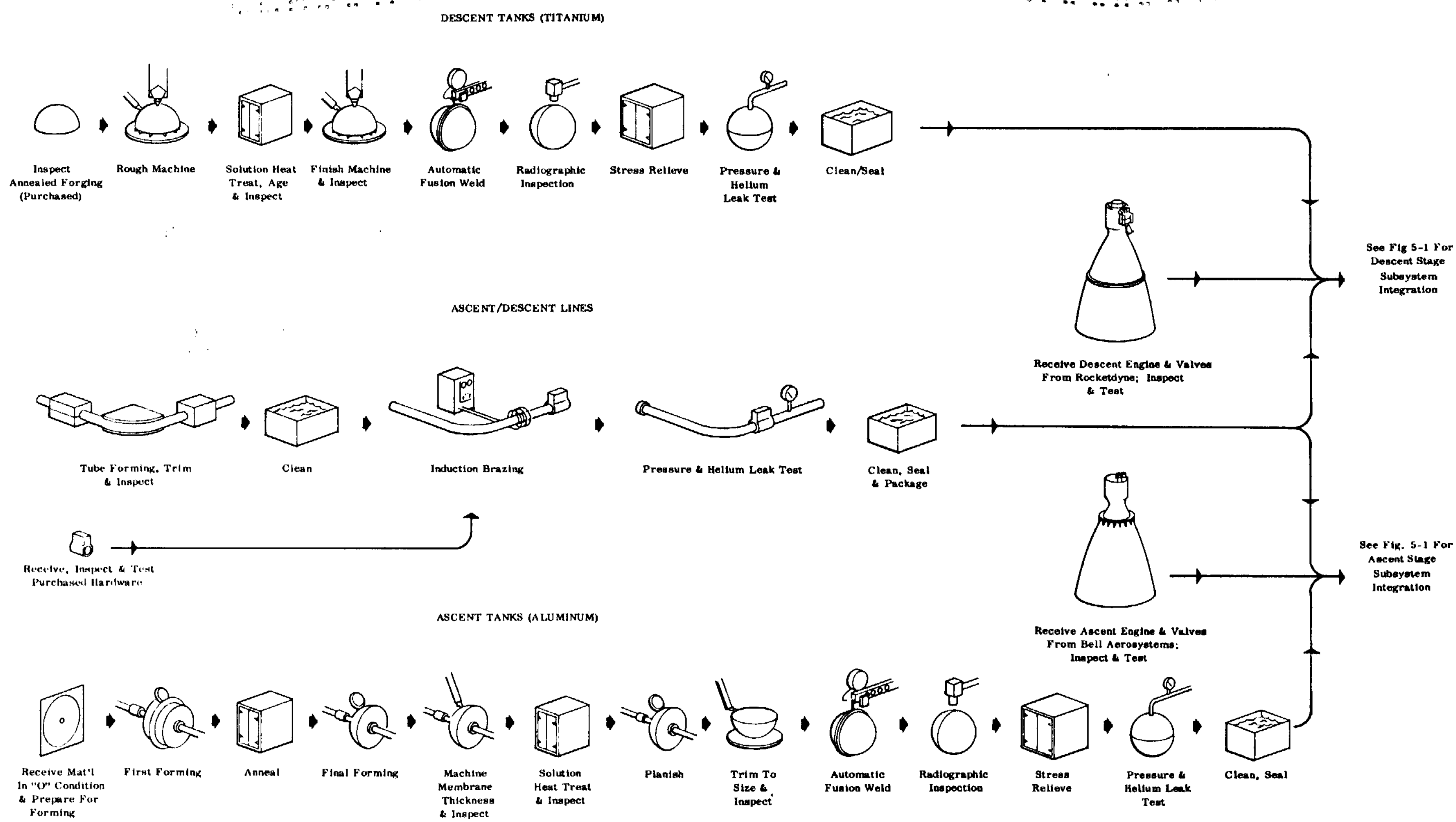


Figure 4-9. Manufacturing Flow Diagram-
Ascent/Descent Tanks and Lines

over a mandrel. Without removing the part from the mandrel, the membrane thickness is machined to size. This detail is removed from the mandrel and solution heat treated. The tank halves are placed back on the mandrel and a planishing operation is performed to remove any distortions incurred during the heat treat process. Each half is trimmed to size and cleaned. Welding is accomplished using the gas tungsten arc welding process with localized inert gas shielding as shown in Figure 4-10. A radiographic inspection is performed to insure a quality weld. The tanks are stress relieved and 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 4-11. 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.

4.2.2 Propulsion Subsystem - Descent Stage

A "make or buy" decision has not been finalized for the Descent Stage titanium tanks. However, if these fuel and oxidizer tanks are to be "make" items, Grumman will utilize the approaches described in this report section. Figure 4-9 shows the manufacturing flow for the Descent Stage tankage.

The vendor supplied annealed titanium forgings for the tank halves are solution heat treated and aged after being rough machined to size on a Vertical Boring and Turning Machine as shown in Figure 4-12. The finish machining operation will also be accomplished on the same machine. After a preweld cleaning operation, the titanium

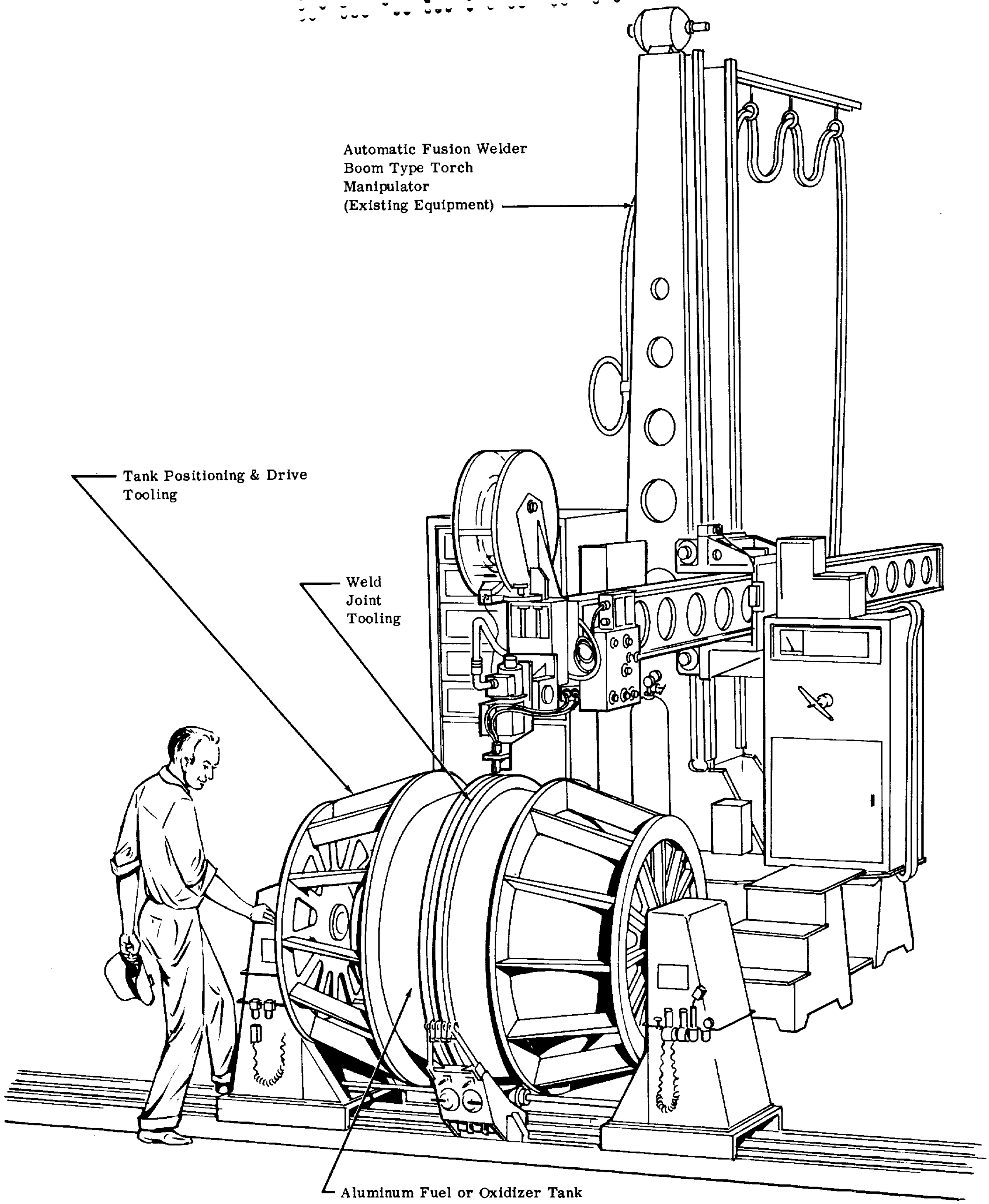


Figure 4-10. Automatic Fusion Welding of Aluminum Ascent Tanks

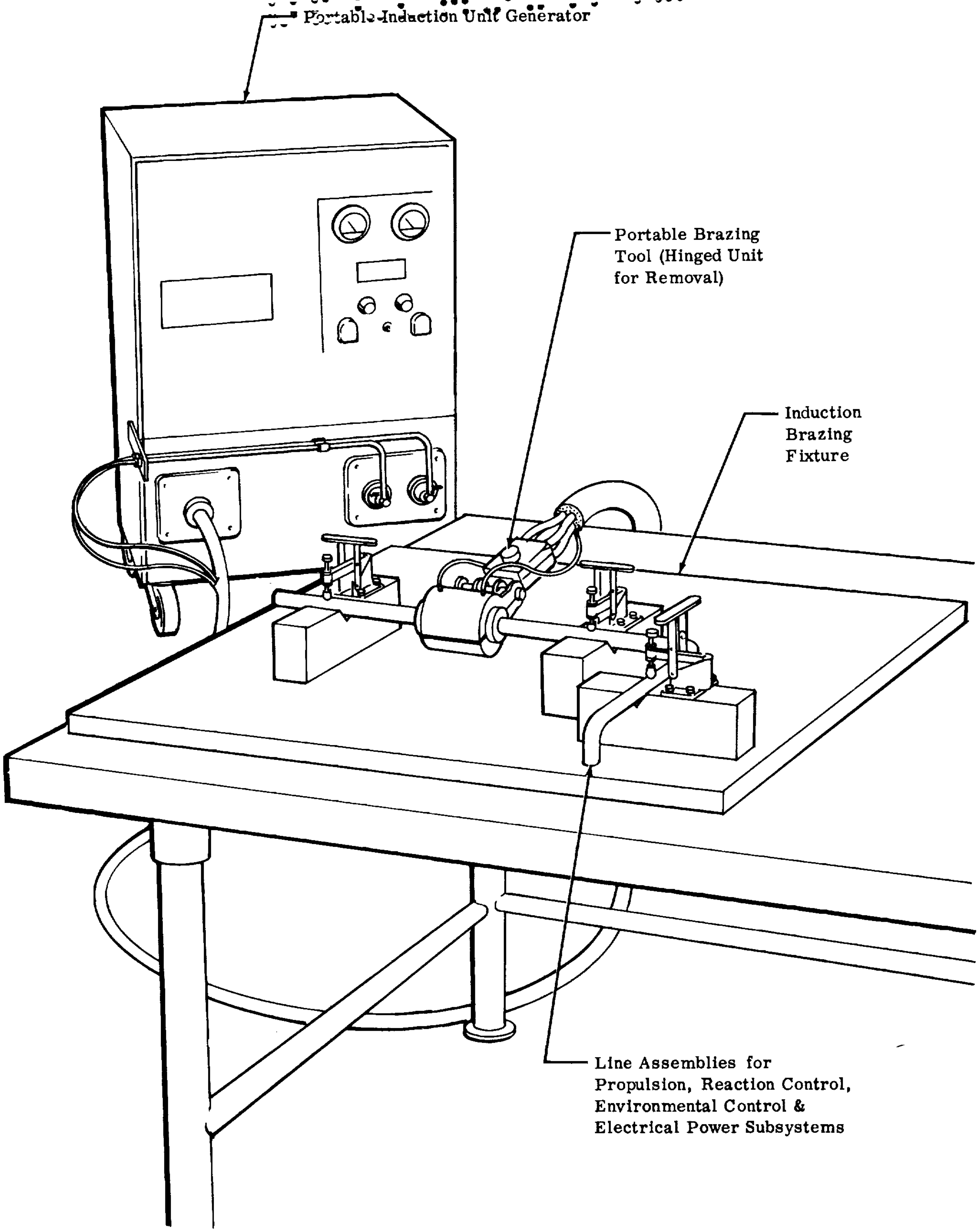


Figure 4-11. Induction Brazing of Line Assemblies

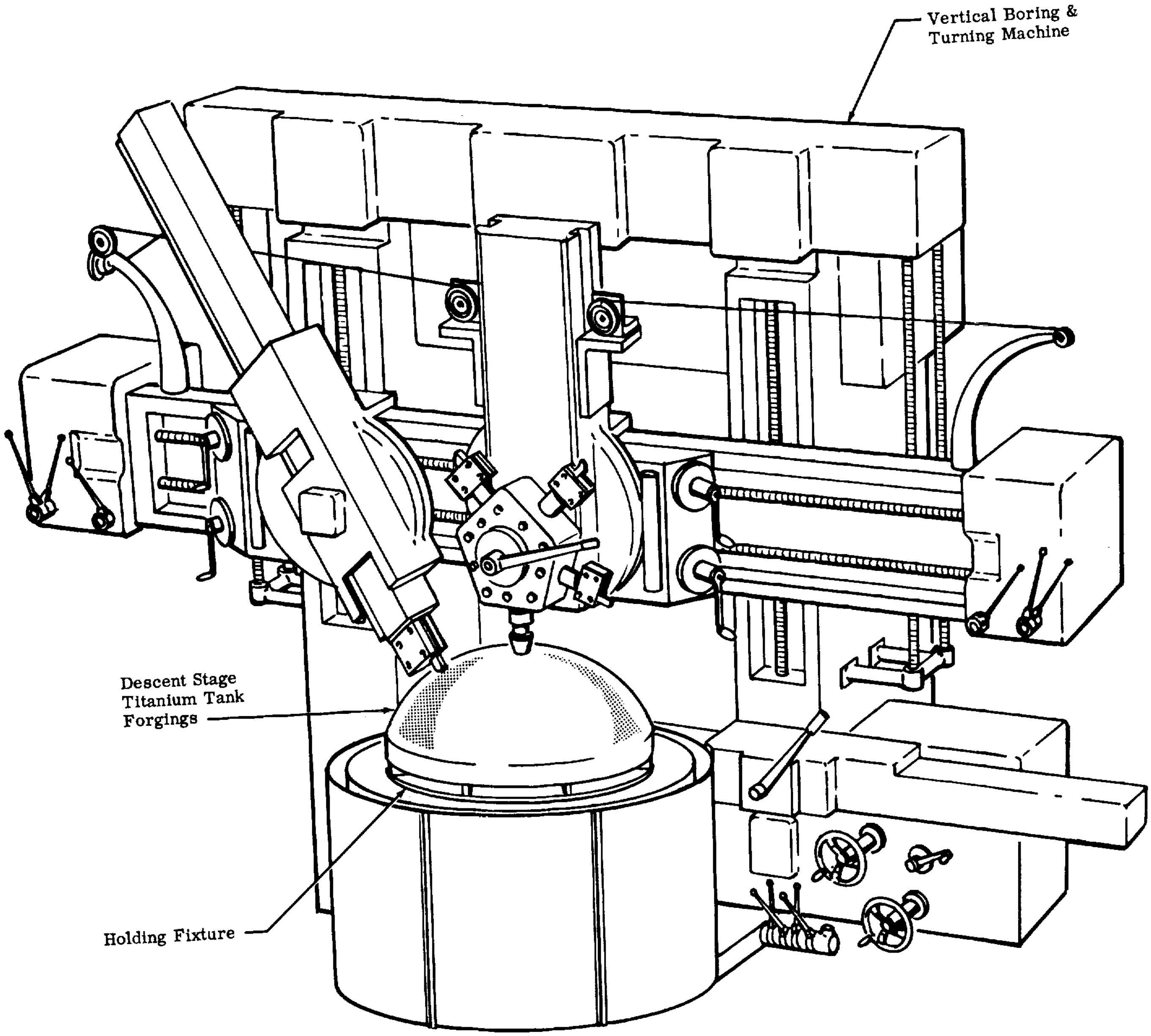


Figure 4-12. Machining of Descent Propulsion Tank Forging

tank halves are welded using an inert gas chamber unless equally effective shielding methods can be devised, or if the tank design allows for welding from the inside utilizing the tank itself as an inert gas chamber. After a radiographic inspection is performed to insure a quality weld, the tanks are stress relieved and pressure and helium leak tested. Following inspection, the tanks are ready for cleaning and sealing prior to entrance into the assembly area.

The fabrication of line assemblies and the subsequent integration of engines, 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 line assemblies and titanium helium pressurization tanks required for the Reaction Control Subsystem and line assemblies for the Environmental Control Subsystem are Grumman "make" items. Production methods similar to those described for the Ascent Stage lines in Section 4.2.1 and Descent Stage titanium tanks in Section 4.2.2 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. See 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

Line assemblies for 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 Navigation and Guidance subsystem and the functional testing of the Stabilization and Control subsystem components.

The alignment and functional testing of the critically positioned N & G and S & C 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 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 are integrated throughout these operations as described in Section 6. Maximum utilization of GSE is made during the final assembly phases since a capability for performing the majority of these tasks is also 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 is cleaned using tumbling, vacuum, and possibly exterior washing methods. Tumbling for removal of trapped particles is accomplished using a cleaning fixture which will be a duplicate of the NAA/CM apparatus or a modification thereof. After cleaning, the Ascent Structure is secured to a GSE handling dolly for entrance into the clean room.

All test and installations for the Environmental Control and Reaction Control Subsystems must be performed under controlled environmental conditions. A 5,000 square foot area within the 8,900 square foot Plant #5 clean room manufacturing and test facility is presently planned for these LEM requirements. However, some RCS components will be tested and assembled in a clean area within the Plant #14 Systems Test Center. Adequate Plant #5 clean room area is available for both the

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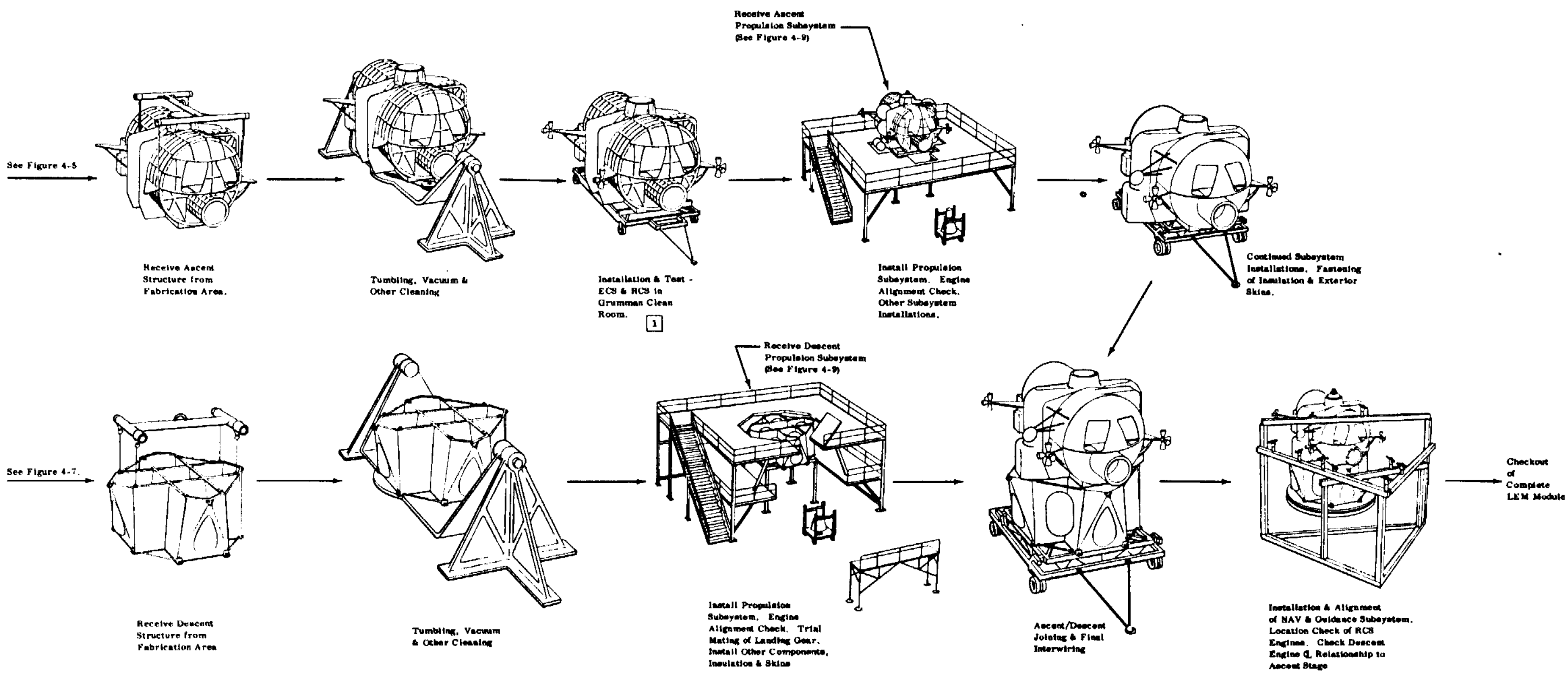

1 Noted operation performed in the Grumman Clean Room. All other operations are performed in an adjacent area which will be a better than standard shop environment and maintained as a clean installation & test facility.

Figure 5-1. Installation, Joining and Alignment Flow

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, and optimum manufacturing, installation, inspection and testing techniques.

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

All Environmental Control 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 are 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 is the installation of the ascent engine; fuel, oxidizer and helium tanks; and associated line assemblies. This station consists 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 were 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 is required. A boresight reference gage is 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 are used to set the mirror reference.

Upon completion of Ascent engine installation, an optical check is 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 is oriented to the thrust center line and fixed to the top of the Ascent Stage. The indexing cube and electronic leveling device 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 are 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 is also accomplished in the handling station. After final inspection and test, the Ascent Stage is 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 is cleaned after receipt from the subassembly manufacturing area. Vacuum and manual washing methods are 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;

and associated line and valve subassemblies. All connections will probably be induction brazed. A minimum of structural fabrication is 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 are used. The center line of thrust established is 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 is 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 are installed in the engine mating and a subsequent handling station. Final operations include the fastening of insulation and some skin panels. To assure proper fit, Lunar Landing Gear are trial mated to the Descent Stage in the engine mating station.

5.4 Ascent/Descent Joining and Critical Subsystem Alignment

The Ascent and Descent Stages, less Landing Gear, are mated in a GSE handling dolly. Compatibility of the separation plane between the two stages is checked, and final interwiring is performed.

The LEM module is 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 module is installed on the precision air-bearing indexing table of the alignment fixture. Jig points are provided to obtain an

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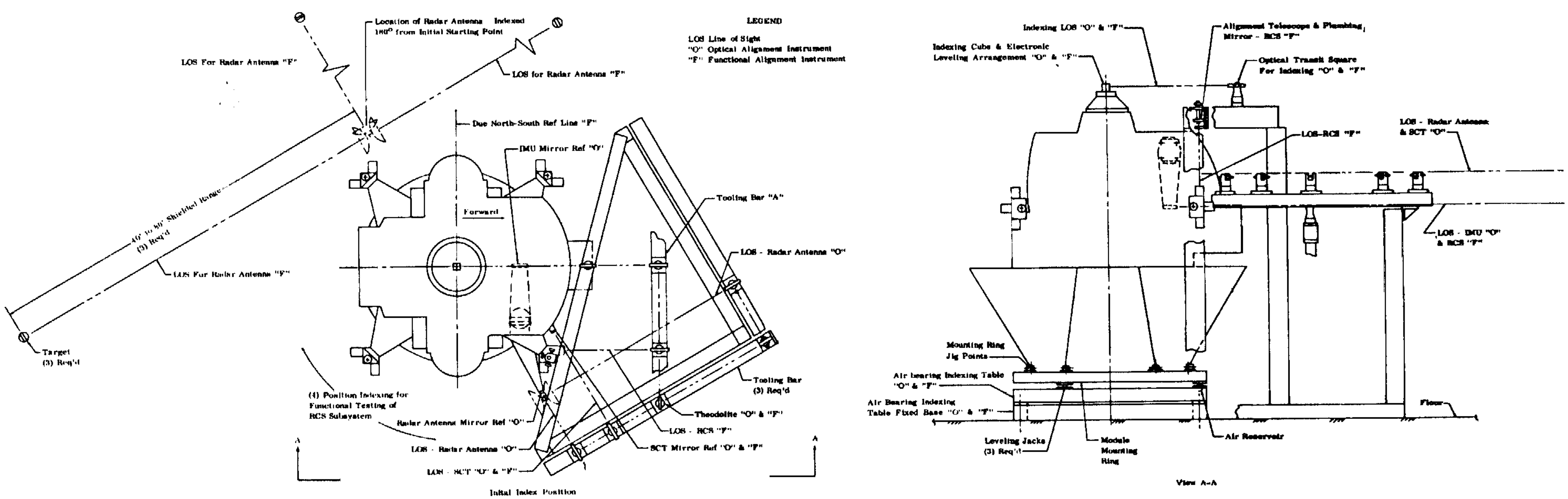

Figure 5-2. Manufacturing Alignment and Functional Test Fixture

approximate location. The module is 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 are now parallel to the axis of table rotation and "gravity vector".

The optical transit square provided for indexing is collimated to the indexing cube. The optical transit square is 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 is installed on the antenna mounting surface. This Radar Antenna mount is adjusted until the optical transit squares are collimated to the mirror references and locked in position.

An IMU (Inertial Measurement Unit) mirror reference gage is installed on the IMU isolation mount with stainless steel inserts attached. This isolated mount serves as as common mount for the IMU and the SCT (Scanning Telescope). The weight and C.G. 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 is adjusted until it is leveled out and the optical transit square is collimated to the mirror reference. A plastic shim is then poured around the stainless steel inserts to maintain their proper orientation.

Connections between the Ascent and Descent Stage are now released. Collimation of the optical transit squares to the mirrors on the IMU, Radar Antenna, and Descent Engine mirror reference gages are 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 are now removed and the two units installed per specifications. The SCT is placed on its mount and the SCT mirror reference gage installed. The SCT mount is 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 are accomplished in four table indexing positions as described below:

The initial indexing position, used for the aligning operations, is also 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 is 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 is inserted into the nozzle of two of the engines. Collimation of the optical transit square to the mirror on the gage is checked. The vertical line of sight to the boresight reference mirror on the engine cluster is established with a plumbing mirror, collimation of the alignment telescope to the boresight reference mirror on the gage is checked to altermine the amount of error. If engine assembly is out of tolerance, corrections must be made and location rechecked at this time. This procedure is to 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 is rotated 90^{o} 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 now be checked. Note that instrument alignments have not been changed from the initial index position to accomplish this measurement.

For the third index position, the table is rotated 90^{o} clockwise, controlling the table position as noted above. The location of the third TCA cluster of Reaction Control Subsystem engines may now be checked. Procedures and instrumentation alignments remain the same as those of the preceeding index position.

The functional testing of the Radar Antenna on the range is also accomplished in the third index position. It may be performed now or after the fourth TCA cluster of Reaction Control System engines have been checked.

For the fourth index position, the table is rotated 90° clockwise, and the location of the fourth TCA cluster of Reaction Control Subsystem engines are checked. Procedures and instrumentation alignments remain the same as those for the preceding index position.

Functional testing of the complete Navigation and Guidance Subsystem is also accomplished in the fixture. Once the module equipment has been aligned, functional testing of the subsystem is performed. This is 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 is 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 are 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 are described in Section 6.5.

SECTION 6 – Manufacturing Test Program

SECTION 6
PRODUCTION LIST 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 GSE used for manufacturing test; and the utilization of highly trained teams of test technicians.

The amount of testing will be held to a practical minimum, in accordance with the test specifications and the reliability requirements. All test data will be logged for maintaining complete records of the individual component and supplier.

As described in Section 7.1.1, the GSE 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 module. 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. Test technicians will perform manufacturing testing of components and subsystems and will support the 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 participate in the development, reliability, qualification and acceptance test programs and will assure the orderly flow of subsystems and components to maintain test schedules. 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 Department 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 fixtures will be constructed and maintained by Production Test and Instrumentation Technicians for this program.

Fittings and major components will be tested in order 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 Landing Gear Subsystem Technician.

6.2.2 Crew Provisions Subsystem

Production 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, 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. Production 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 Subsystem

Manufacturing test requirements of the Reaction Control and Propulsion Subsystems are primarily the same. These test programs will be conducted at three levels:

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

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

Component - 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.

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.

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 such as component test stands, propellant storage and temperature conditioning units, stage structures for hot firing, purge and flush units, 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 the clean room area.

This subsystem will be inspected when received from the vendor to assure compliance with the applicable Specification Control Drawing. In most cases, the "as received" items will be subsystem components.

Functional tests of these components at Grumman will be performed to determine pressure drops at working flows, internal and external leakage, and operating efficiency.

These components will be assembled to the section level and performance tests initiated. Stimuli not present will be simulated. Criteria for monitoring include heat removal efficiency, temperature control, pressure control, and time response to change.

Upon completion of section testing, the sections will be assembled in a holding fixture and the complete system will be activated to assure proper functioning. The subsystem will be disassembled to the required level for installation into the LEM structure. After installation, the tests for a completed Environmental Control Subsystem will be repeated.

6.4 Manufacturing Test - Electrical/Electronic Subsystems

This report section describes the manufacturing test approaches for the Electrical Power, Communications, Instrumentation, 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 suppply.
- 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 reactant gas, and sealed after the completion of test phases.

Component - Fluid storage and supply will require leakage and functional tests on supercritical reactant gas flow benches. The fluid storage tanks will require a supply of liquid reactants for loading and heating tests.

Section - Fluid storage and supply will include leakage and functional tests using a supply of liquid reactants, external or module controls, leak detectors, instrumentation and vapor disposal or dispersal equipment.

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

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

6.4.2 Communications, Instrumentation, Stabilization and Control, and Navigation and Guidance Subsystems

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

- Verification of incoming components and subsystems.
- Assembly and integration testing during manufacturing build-up.
- Acceptance testing of the completed module.

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 have sufficient facilities to fault isolate to a replaceable element and be able to check the subsystem after a repair or modification.

The Bench Test Station will be capable of operation to check the entire subsystem simulating any interface with other subsystems. This station will evaluate 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 functioning.

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.

The Assembly and Integration 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 Assembly and Integration test station will be capable of checking all operational parameters as 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.

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 vehicle 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 Subsystems at WSMR.
- Structural test teams will participate in the static, drop, environmental, and vibration tests at Grumman.
- Assembly and instrumentation technicians will erect test equipment, install instrumentation, conduct,. witness and document the tests required by the Engineering Test Plan.
- Follow LTA and LEM modules 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; both at Grumman and at field-site locations. Personnel will also repair and modify the GSE as required.

SECTION 7 – Manufacture of GSE

SECTION 7
MANUFACTURE OF GSE

7.1 GSE Manufacturing Plan

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

The plans described herein are 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" decisions will also be influenced by critical GSE 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 orignated by Grumman. Maintenance and Calibration procedures will be developed upon completion of the GSE,and the equipment will be tested at the vendor location in accordance with the test specification. Equipment will be retested upon receipt at Grumman. After NASA approval, the equipment will be delivered to the appropriate site.

The GSE Manufacturing Plan emphasizes the use of existing Avionic, Hydraulic, Tool and Central Equipment shops which are presently organized with the specialized skills, equipment, and facilities. Grumman facilities for GSE 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 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 is shown in Figure 7-1. For continuity and maximum efficiency, GSE 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 manufacturing. Although the Central Equipment Shop is primarily concerned with only GSE manufacturing, closely related concepts are applied.

In general, the following procedures summarize the implementation plan for all in-house GSE 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 manufacturing lead-times. These groups also maintain detailed manufacturing schedules and charts for measuring GSE progress, shop workload, and manpower forecasts.

- Purchased GSE component requirements are determined by the LEM Subsystem GSE Engineers and procurement requests are forwarded to the Purchasing Department.

- 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.

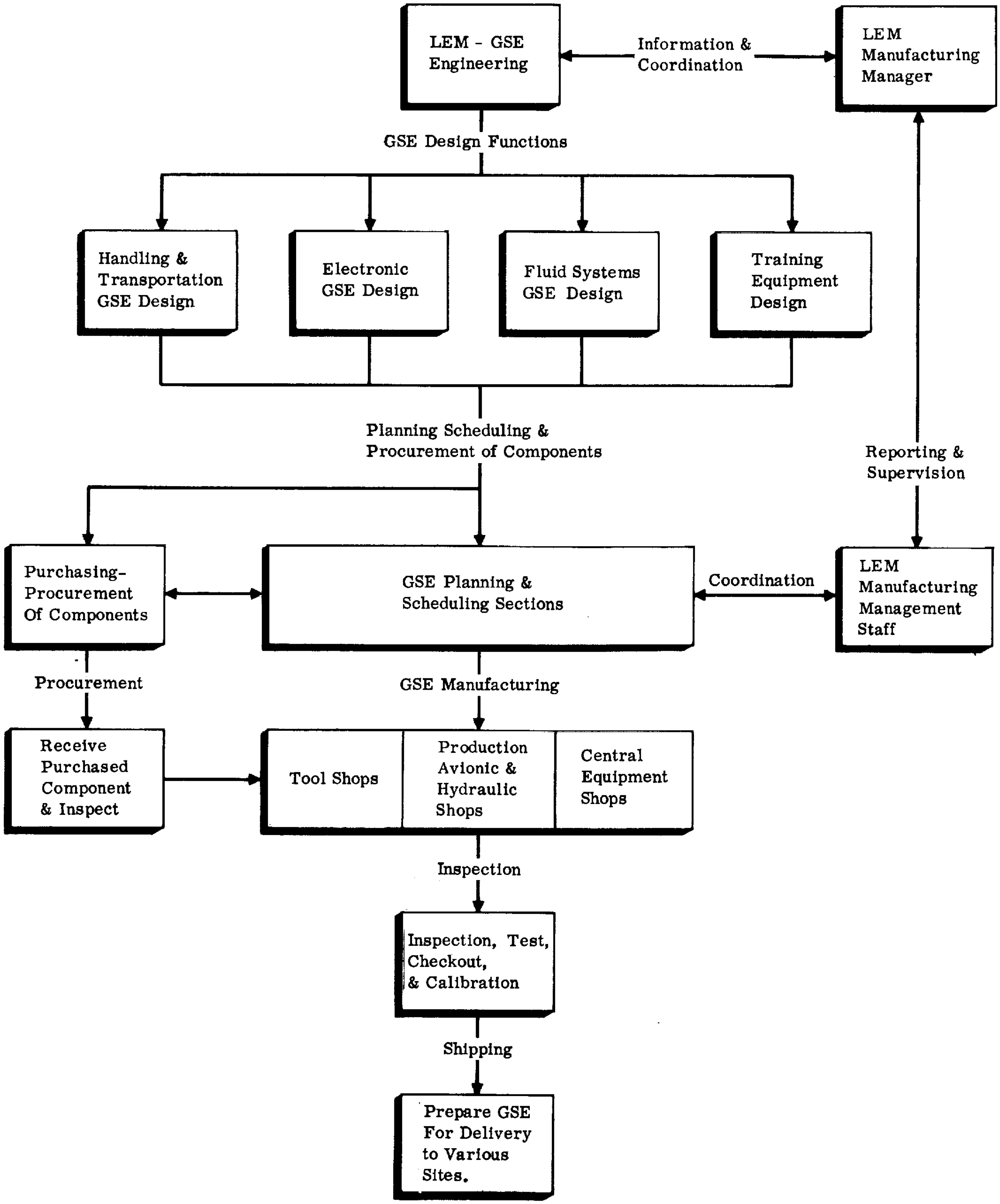

Figure 7-1. GSE Planning & Manufacturing Flow

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

Electrical/Electronic GSE for manufacturing tests or for site delivery is fabricated in the Grumman Central Equipment Shop 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 Central Equipment Shop 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 Grumman equipment cycle which automatically tells 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".

Grumman

PREVENTIVE MAINTENANCE PROCEDURE

No. 20167

EQUIPMENT DESCRIPTION

Name Vacuum System **Model** L-DW410-100	**Issue Date** 4-10-63
	Revision No. Date
Manufacturer GAEC	**Page** 1 of 1

FREQ. CODE	INSTRUCTIONS
	1.0 Scope
	1.1 This procedure covers electrical, electronic, and mechanical inspection of the high vacuum chamber in plant 23.
	2.0 Special Equipment Req'd.
	2.1 None
	3.0 Instructions
04	3.1 Check all relays, coils, contacts and mechanical parts. Repair or replace defective components.
	3.2 Check all electrical connections for tightness.
12	3.3 Clean, lubricate and calibrate electronic temperature recorder as per calibration procedure 256000-03.
	3.4 Check ionization amplifier. 600P tubes should be returned to original tube sockets.
	ETC.

SAMPLE

Prepared: CJF Checked: ADE Approved: RLL	Dept. E&P ENG.	Date 4-10-63	Approved WBM	Dept. E&P ENG.	Date 4-10-63

E&P 82 SHT. 1

Figure 7-2. Form: Preventive Maintenance Procedure

7.1.2 Fluid Systems GSE

The Development of Fluid Systems GSE begins with the receipt of detailed test parameters from the appropriate subsystem. These test parameters are then collated and used to generate a series of specifications for the required G S E. These specifications thus generated will include interface documentation. Upon approval of the specifications by NASA, the G S.E. 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 effect and the concurrent development of a detailed manufacturing schedule. During the design phase, there will be continuous review to insure compliance with the specification, including a reliability check. Toward the latter phase of the design effect, GSE fabrication will be initiated.

Primary Manufacturing responsibility for all Fluid Systems GSE has been assigned to the Central Equipment Shop. This department is supported by other shops for heavy structural fabrication of frames and trailer components.

Maintenance, calibration and checkout procedures are developed concurrently with the design and fabrication phases. Functional checkouts will be performed after completion of fabrication. Contingent upon NASA approval, the GSE will be delivered to the appropriate site.

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 such as 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 require 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 serves as a model for the follow-on units. Minimum tooling for reduced overall GSE costs is 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 visualaid 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.