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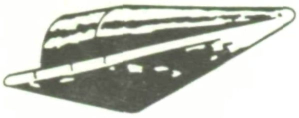
MDC E0308

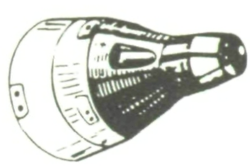
Phase B System Study
FINAL REPORT

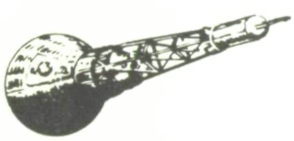


Part III–4

PROGRAM ACQUISITION PLANS

FACILITIES UTILIZATION AND MANUFACTURING





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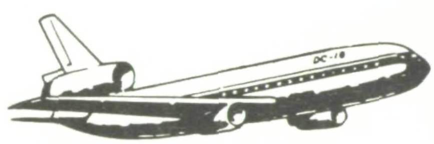

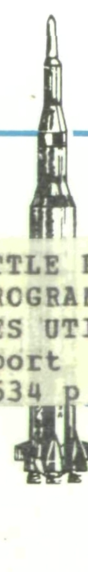

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McDONNELL DOUGLAS CORPORATION

MARTIN MARIETTA DENVER DIVISION

TRW SYSTEMS GROUP

PAN AM

REPORT MDC E0308
30 JUNE 1971

Space Shuttle System

PHASE B STUDY FINAL REPORT

Part III- 4
Program Acquisition Plan

FACILITIES UTILIZATION & MANUFACTURING

SUBMITTED UNDER

NASA CONTRACT NO. NAS 8-26016

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MCDONNELL DOUGLAS CORPORATION

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FOREWORD

The requirements necessary to conduct a Phase C/D program leading to an operational Space Shuttle System, and the McDonnell Douglas Corporation Team approach to implement them are defined in seven Program Acquisition Plans. By report numbers, they are:

MDC E0308 - III -

1 Program Management

2 Engineering and Development

3 Operations

4 Facility Utilization and Manufacturing

5 Test

6 Logistics and Maintenance

7 Cost and Schedule Estimates

The Program Management Plan impacts all of the other plans, by establishing the procedures and management activities for the entire program. Second in order of impact is the Engineering and Development Plan, which defines design and development effort and leads into manufacturing, test, and operation discussions, each in its own volume. The facilities section of the Facilities Utilization and Manufacturing Plan supports the Manufacturing, Operations, and Test Plans by identifying and defining the facilities required. Support requirements, in terms of maintainability, maintenance, logistics engineering, material support and control, supply control, packaging, and handling and transportation are defined in the Logistics and Maintenance Plan. Finally, the Program Cost and Schedule Estimates Plan describes cost/schedule activity and cost analysis methods for the total program.

As applicable, the plans are further categorized into Space Shuttle, Booster, and Orbiter. The following baseline assumptions and ground rules were employed in the Phase B study and are reflected in the plans:

Configuration - To facilitate timely, cost-effective implementation, all plans were developed independent of configuration, wherever practical. Where it was necessary to consider specific configurational aspects, the May 1971 MDC Space Shuttle was used. This configuration is outlined below, along with the other guidelines and assumptions used:

- Delta Orbiter
- Canard Booster
- 550,000 lb thrust main engines
- 1100 nm across-range capability
- Two-stage, fully reusable vehicle/system
- Maximum payload capability of 65,000 lb launched due east
- Airbreathing engines burning JP fuel

Phase C/D Management and Organization

- Two vehicle contractors (Booster and Orbiter) are each contracted and managed by one of two NASA centers. A Vehicle System Integration Activity (VSIA) type organization is responsible for the integration of the Space Shuttle System, and delegates integration tasks to one or the other NASA Center/Vehicle contractor combination.
- Innovative management techniques and new ways of doing business to minimize program cost are stressed.

Operations

- The major horizontal flight testing will be conducted at EAFB.
- Final assembly and operational launches (including vertical launch and horizontal shakedown flight test) are conducted at KSC.

- The operational fleet consists of four Orbiters and three Boosters
- Operational life is 10 years

Schedule

- First horizontal flight - June 1976
- First manned orbital flight - April 1978
- Operational phase initiated - July 1979

The remainder of this foreword provides synoptic overviews to this and the remaining six Program Acquisition Plans. The purpose of the overviews is to offer the reader of this plan an insight into the content of the remaining plans.

PROGRAM MANAGEMENT PLAN
(MDC E0308-III-1)

The Program Management Plan defines management requirements and procedures which will permit the contractors, under NASA guidance and direction, to design, build, test, and develop a Space Shuttle System. The plan identifies and describes management activities essential to the conduct of the program. Key issues facing management and the interrelationship of these issues with cost, schedules, and technical performance lead into the Work Breakdown Structure (WBS), management organization, commonality implementation, and management techniques. The WBS, and a detailed definition of the products and services related to the individual WBS elements, is presented.

Organization of the contractor's corporate structure and the Space Shuttle Program team are discussed, and organization charts presented. Management contacts and interrelationships among MDC, NASA, teammates, and subcontractors are discussed. Such discussion includes approaches for conducting the necessary reviews and meetings, techniques for communication processes, procedures for interface control documentation for hardware-to-hardware interfaces and joint operating agreements for establishing and recording working relationships between contractors.

The commonality implementation section describes such concepts as the use of similar or interchangeable parts, as well as the economies inherent in common design approaches, similar technical depth, shared test and analytical results.

Management techniques, including the MDC Management Information System, which plans, controls, and provides visibility into project and functional cost and schedule performance within the WBS framework, are presented. Configuration management procedures discussed include identification, control, and status accounting for the baseline configuration and changes thereto.

PROGRAM MANAGEMENT PLAN
(MDC E0308-III-1)

The approach to data management, vehicle acceptance, traceability, make or buy, and subcontract management are presented as part of the management techniques section.

The appendix outlines the approach to three alternate MDC-suggested contracting options and compares these options with the baseline.

ENGINEERING AND DEVELOPMENT PLAN
(MDC E0308-III-2)

This plan defines the requirements for the total engineering effort involved in the design of the Space Shuttle System and the approach to implement these requirements. The plan is divided into three sections: Shuttle Systems, Booster, and Orbiter.

Shuttle System - The Space Shuttle section contains only that engineering and integration effort required for the analysis, development and test of the mated configuration. Policy activities, such as critical program categories and commonality control (which would be implemented through a NASA/VSIA-type activity) are also included. Those activities that are involved with the management, engineering, integration, assembly and test of the separate Boosters and Orbiters are included in their respective sections.

Following a discussion of the criticality categories approach and the approach to, and control of, commonality, the management approach for the Space Shuttle is discussed using the VSIA-type organization baseline.

Detail design and development activities include describing the physical and performance characteristics of the Shuttle, critical design analyses (such as boost phase analysis, off-nominal performance evaluation, separation analysis, and abort techniques), and design optimization and effectiveness analyses.

System integration activities include discussions of requirements analysis and allocation, trade study identification for those trade studies to be refined in Phase C, and development of criteria documents to group those criteria for each system and subsystem into a working document.

Test requirements are discussed for the various categories of ground and flight tests to which the Space Shuttle will be subjected. These include tests of the separation system, EMC tests, wind tunnel and dynamic tests of the mated

ENGINEERING AND DEVELOPMENT PLAN
(MDC E0308-III-2)

configuration, and vertical flight tests.

Finally, ground support equipment (GSE) critical areas and development problems are discussed and a development schedule presented.

Booster and Orbiter Systems - The Booster and Orbiter sections define the engineering and development requirements, and the approach to implementing these requirements, in the design and development of the Booster and Orbiter and their associated support equipment.

Management procedures, including organization; planning and control; schedules; key engineering activities that affect the timely completion of the design and development; and logic networks are discussed. The section on manpower describes the procedure for making engineering manpower forecasts by work breakdown structure for each engineering discipline and department.

The approach to configuration management, consisting of configuration identification, control and accounting is detailed. A discussion of data management addresses planning for interface control, document control, and program and design review. The role of the Interface Control Working Group (ICWG) and the application of interface control logic are outlined.

In the contingency planning and analysis section, the approach to making allowances for off-nominal task results and resource expenditures is discussed. System engineering and integration is concerned with design studies and analyses for system sizing and design refinement, and with trade studies to refine subsystem development and performance, resolve key issues, and explore growth potential. Major interfaces are defined, and the interface control plan discussed.

Sections 2.3.2.4 (Booster) and 2.3.3.4 (Orbiter) encompass a detailed discussion of subsystems development, including airframe, propulsion, avionics, crew station, and power supply groups.

ENGINEERING AND DEVELOPMENT PLAN
(MDC E0308-III-2)

These sections describe each subsystem, potential problems in its development, the approach to design, development, and test, and a development schedule for each subsystem.

The GSE development section discusses the engineering and design approach and acceptance test requirements. Major test articles, simulators and mockups required for Orbiter and Booster development, are described and the purpose of each test defined.

Design and development support requirements from safety, reliability, maintainability, human factors, materials and processes, and design services are discussed, and support activity scheduled.

OPERATIONS PLAN
(MDC E0308-III-3)

This plan defines the requirements for Space Shuttle, ground and flight operation and the MDC approach to implementing those requirements.

The requirements section of this plan is subdivided into Space Shuttle System, Booster, and Orbiter, and contains both ground and flight requirements. The paragraph (or paragraphs) of the approach section pertaining to these requirements is noted. Such notation provides traceability between the requirements and approach sections.

The approach section of the plan is divided into ground and flight operations. Ground operations include the activities from landing rollout through launch. The flight operations section includes activities from liftoff through landing.

The ground operations section discusses the activities from acceptance testing through the launch phase. Turnaround cycle activities are described in detail. This cycle consists of postlanding, maintenance, prelaunch, and launch activities. In addition, detailed timelines of these activities are included. Other activities pertinent to ground operations, such as operational facilities and activation, rescue capability, hold/recycle capability, alternate landing sites (and others) are also addressed in this section. Also included are the activities associated with the development flight test program, both horizontal and vertical.

The flight operations section discusses the anticipated missions and includes timelines and sequence-of-events charts. The mission operations systems, as well as mission control functions, are described, as are such activities as landing operations, aborts, and crew training. Such other operational interfaces as tracking and data relay satellite, experiments, and the scientific community are addressed in this plan.

FACILITY UTILIZATION AND MANUFACTURING PLAN
(MDC E0308-III-4)

The Facility Utilization and Manufacturing Plan:

(a) provides clear definition of the Government owned and Contractor facilities required to support the Space Shuttle Phase C/D program; and

(b) describes the manpower, material, and facilities needed to plan, manufacture, and functionally test flight hardware and (GSE).

The summary section includes a discussion of the rationale for facility site selection based on two factors:

(1) the chosen operational site for the Shuttle and

(2) the transportation problem posed by the size of the Booster and Orbiter vehicles.

Considered in the plan are evaluations of candidate launch sites, and sites for final assembly, propulsion tank fabrication and subassembly, fuselage manufacturing and assembly, and horizontal flight test.

The remainder of the facility section is devoted to discussing and defining the operations support characteristics of the KSC facility, which based on the selection rationale, was chosen as the operational site.

The appendix summarizes management and control procedures, including planning, scheduling, tooling, and control. The tooling philosophy and approach for manufacture of the Space Shuttle is, basically, to minimize construction of major fixturing, thus, minimizing costs. The assembly of the Orbiter main fuselage, which utilizes the main propulsion tank as a tooling base on which to build the main fuselage, provides a good example of the MDC philosophy. The Booster manufacturing approach employs existing major tooling and fixtures by adaptation and usage of Saturn tooling and G.S.E. The modular approach to the manufacture of vehicle major assemblies is emphasized.

FACILITY UTILIZATION AND MANUFACTURING PLAN
(MDC E0308-III-4)

Major manufacturing problems, and their proposed solutions, are presented and discussed. These problems are categorized, as applicable, by Booster and/or Orbiter.

The long lead requirements are listed and in the discussion of the respective assemblies the description of the manufacturing sequence tests, tooling and facilities requirements, schedules and cost estimates therefore as well as the rationale for each of the selections and decisions made.

TEST PLAN
(MDC E0308-III-5)

The Test Plan is presented in three major sections - Space Shuttle, Booster, and Orbiter. The plan, based on the use of state-of-the-art technology and existing facilities wherever possible, addresses the definition of requirements and test approach to all levels of testing from design development, verification of requirements, predelivery acceptance, and mission demonstration. Overall testing philosophy is to minimize the extent and cost of testing, commensurate with attaining mission success and crew safety. In addition, the test plan has been carefully phased into the other related plans-management, facilities, engineering and development, operations, logistics and maintenance, and cost and schedules.

Shuttle System - This section discusses the total program summary, and reveals MDC test philosophy, including the explanation of test phases and definitions. The formal equipment qualification plan and the methods by which qualified hardware is attained along with test equipment requirements and facilities, the failure analysis routine, documentation, and safety requirements are also discussed.

Ground tests include mated and proximity wind tunnel tests, scaled model dynamic tests, and separation system tests. Wind tunnel test requirements are defined and candidate facilities and model scales identified. Test requirements are categorized as aerodynamic, thermodynamic, loads, structural dynamics, and propulsion.

The section on mated and vertical flight vehicle tests includes discussions of:

(1) electromagnetic compatibility tests, which will be conducted on the launch pad prior to the first vertical takeoff of the mated configuration

(2) low-level dynamic response tests

(3) launch site tests, which include those tests that prepare and ready vehicles and ground systems for static fire tests and the readiness tests of systems being prepared for vertical flight

TEST PLAN
(MDC E0308-III-5)

(4) vertical flight tests to evaluate and verify mission phase characteristics and subsystem operation during prelaunch, launch, and Booster ascent.

The philosophy of nonrepetitive testing is carried over from the factory acceptance test program to the launch site tests.

Participating roles of reliability, quality assurance, and safety in the test program, and the MDC approach to test management conclude the Shuttle System Section.

Booster and Orbiter - The Booster and Orbiter sections define the detailed requirements for test and the associated approach for test implementation. Flight characteristics of the vehicles are supported by wind tunnel testing, flight simulation studies, and in-flight verification.

Vehicle subsystem testing encompasses the development of the airframe structure and the thermal protection system; the propulsion group, including the main engines and fuel system, the attitude control propulsion system, the airbreathing engines and fuel system, and the auxiliary power unit; the avionics group, including the associated software validation; the auxiliary power group; and the ground support equipment.

Combined systems tests will utilize functioning setups of actual hardware components. The main integration activities include the entire avionics array, the hydraulics and avionic flight control system, and the propulsion integration test program.

The completed vehicle test program describes the utilization plan for horizontal flight testing, structural and dynamic response assurance, and installed subsystems integration. The philosophy of ground acceptance testing, and predelivery flight acceptance, completes the Booster and Orbiter test plans as individual vehicle units.

LOGISTICS AND MAINTENANCE PLAN
(MDC E0308-III-6)

This plan presents the MDC logistics and maintenance approach, which will provide an integrated support program from the design phase through the operational phase. The plan consolidates all individual logistics support elements into an interrelated, interfaced, and program-phased activity. Included in the plan is a milestone chart which provides for timely and adequate identification, development, and scheduling of the logistics support requirements.

As nearly as possible, reusable Space Shuttle logistics and maintenance functions have been related to present airline practices which have been developed through extensive operating experience.

The plan is organized (in format) by functional activity. Each function, i.e., maintenance, technical publications, etc., is presented as an identifiable entity within the Logistics and Maintenance Plan.

PROGRAM COST AND SCHEDULE ESTIMATE PLAN
(MDC E0308-III-7)

This plan provides cost and schedule planning data which can be used for making decisions vis-a-vis the development and operation of a two-stage fully reusable Space Shuttle. The required data consist both of the costs for each part of the system, and of time phasing of these costs to establish funding requirements.

This report covers the development activities starting with Phase C of Phased Project Planning (PPP) through completion of a ten-year operational cycle. The traffic model assumed for the operational cycle was specified by NASA for this project. The costs to be used for GFE items (main engines) were provided by NASA.

These data are organized as required by DRD MF003M, which defines the specific data to be included. Four data forms are required which provide a complete breakdown of cost, schedule, and technical characteristics data, organized to the work breakdown structure and reported at Level 5.

The first section provides cost information on Cost Estimate Data Form A. This data form includes cost estimates, the time phasing recommended to spread the cost estimates for funding purposes, and the data necessary to derive unit costs for recurring items. Separate cost estimates are presented for nonrecurring (RDT&E) activities, recurring production activities, and recurring operations activities; non-recurring costs through first Manned Orbital Flight (MOF) are also presented.

The next section presents Data Form B, with detailed cost estimates divided across specific subdivisions of work for each WBS item. The subdivisions of work encompass design, test, tooling, production, and materials and subcontracts.

The technical characteristics data presented in Data Form C are a concise summary of the performance, sizing, and complexity parameters used in estimating the cost of each item of the WBS. Some other vehicle parameters have also been included to provide a more comprehensive description of those Shuttle technical, physical, and mission characteristics which are important in understanding the costs.

Data Form D presents the fiscal funding requirements for RDT&E, production, and operations activities.

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4.1 INTRODUCTION

This document is responsive to DRD number TM001M (Facility Utilization and Manufacturing Plan). Its purpose is to form a common base for use by NASA and contractor management for the acquisition, utilization, and development of major facilities required to implement and conduct the program.

This plan is the MDAC approach to the Space Shuttle Booster and Orbiter facilities and manufacturing tasks for C/D program phases.

The Facility Utilization and Manufacturing Plan is one of seven plans and ties in closely with three of these: 5.0 Test Plan, 6.0 Logistics and Maintenance Plan, and 3.0 Operations Plan. These plans should be referred to for further detail in related areas.

The plans described in this report are interrelated and this interrelationship figured in the overall requirements for manufacturing, test, and operational sites.

It is important that this plan be interrelated and coordinated closely with all Program Acquisition Plans to ensure that the total program approach is optimumly achievable. Each of the Program Acquisition Plans is intended to promote in-depth visibility of a particular program requirement, however it is mandatory that "over-lapping" functions be integrated into each plan. Figure 4.1-1 shows the relationships of this plan with the other Program Acquisition Plans.

RELATIONSHIP TO OTHER PROGRAM ACQUISITION PLANS

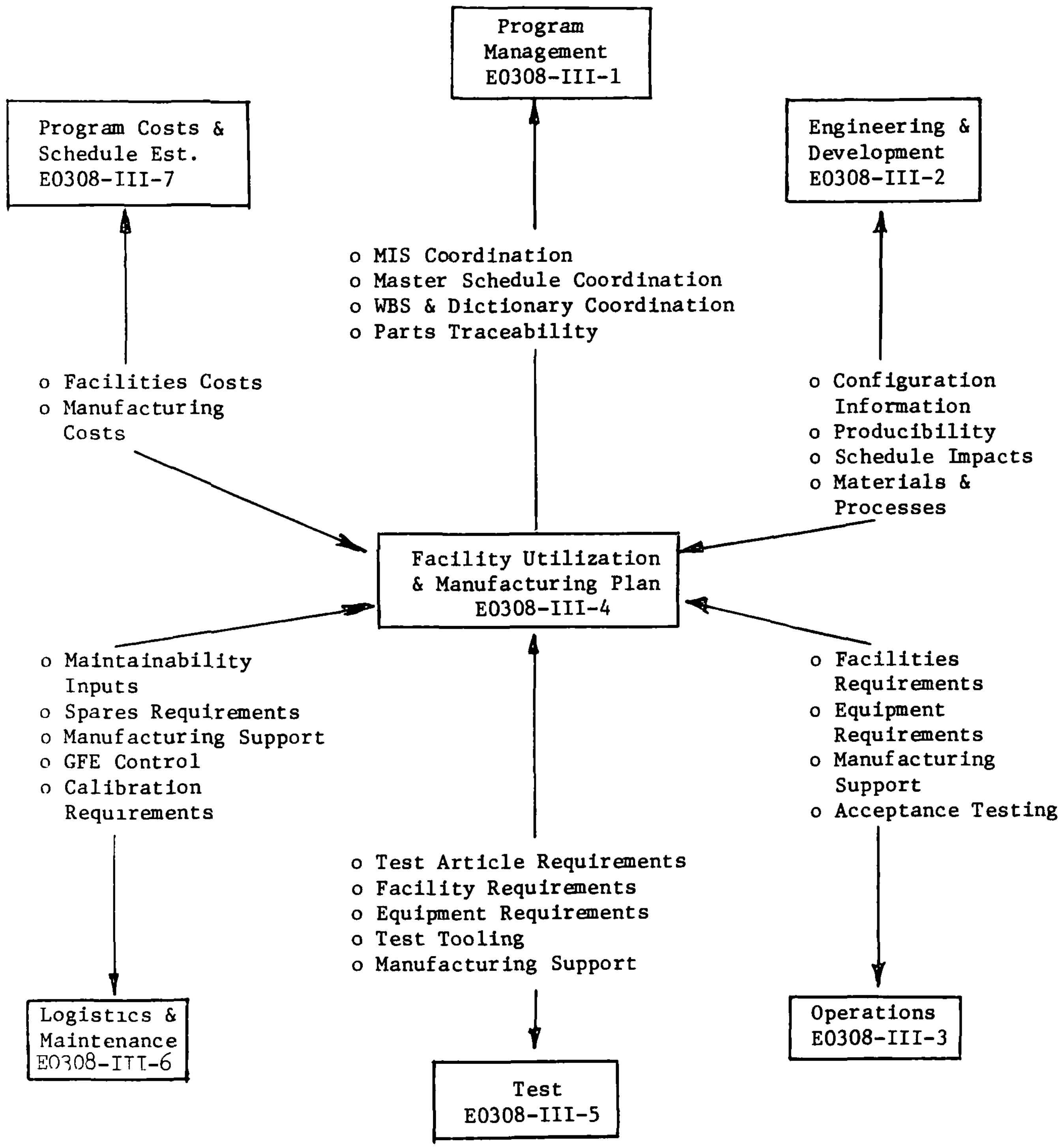


FIGURE 4 1-1

The plan describes or identifies all of the known major facilities required to conduct the program. The facilities listed include those required for the development, test and manufacturing disciplines of the program. Each facility identified, including Government furnished equipment and machine tools, is described, its program requirement, use and relocation are defined and explained. Schedules and estimated costs indicating dates for facility and equipment requirements as well as long lead items being identified and rationale therefore are also presented.

Government facilities have been examined and are planned to be used to the greatest economic advantage to the program.

Where joint contractors, tenancy or common use of facilities and equipment is advantageous, coordinated work around schedules will be prepared and implemented to meet the master schedule requirements.

The plan also identifies and presents proposed solutions to the major manufacturing problems presumed to develop and be involved in the successful conclusion of the Space Shuttle Program. Recommended action for solutions to the manufacturing problems is included where solutions have not yet been resolved.

Existing manufacturing technology and processes related to the respective functions as well as "state of the art" techniques and new technology being pressed into service are discussed.

4.2 SUMMARY

The facilities and manufacturing plans described in this report are interrelated and this interrelationship figured in the overall requirements for manufacturing, test and operational sites.

The main Shuttle vehicles are illustrated in Figures 4.2-1 and 4.2-2 for the booster and orbiter, respectively, and production consists three primary operations: main propulsion tank fabrication, fuselage subassembly, and final assembly. Transportation of these major subassemblies from operation to operation is also a major consideration, and the net result of all considerations is the following major site selections:

- o Propulsion tank fabrication and assembly for both booster and orbiter--- Michoud
- o Assembly of booster and orbiter fuselages--------------------Michoud
  (MDC St. Louis Facility is an alternate for orbiter)
- o Final assembly of booster and orbiter ---------------------- KSC
  (MDC St. Louis Facility is an alternate site for the orbiter)
- o Horizontal Flight Tests ----------------------------KSC & Edwards AFB
- o Operational Shuttle Site ------------------------------------ KSC

Details of the rationale for site selection are given in Section 4.2.2, and transportation evaluations are in the Appendix. (Section 4.8.5).

A summary of the current allocation of component manufacturing and test functions among government and contractor sites follows:

Several options exist for each component indicated for manufacture at Contractor sites.

BOOSTER CONFIGURATION

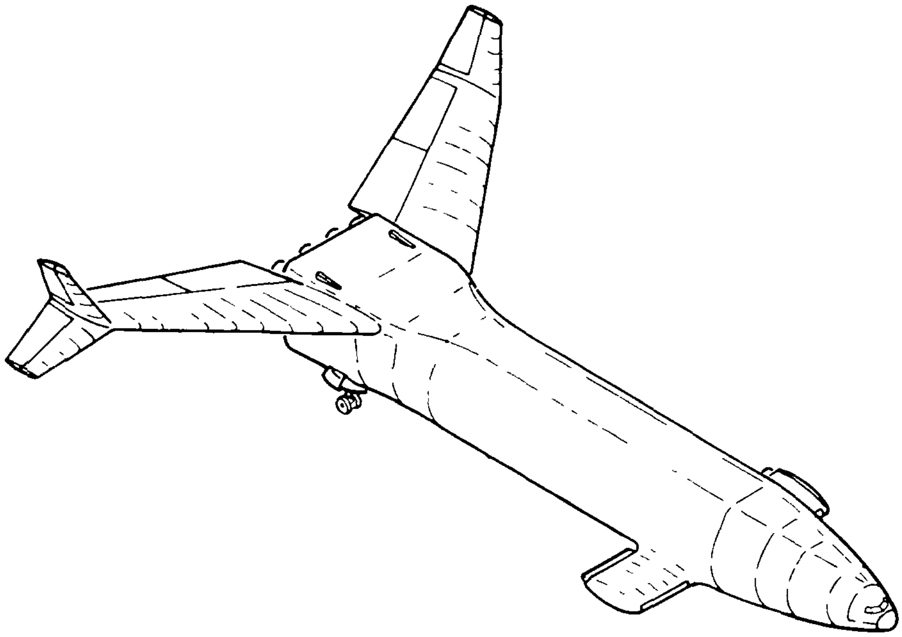


FIGURE 4.2–1

ORBITER CONFIGURATION

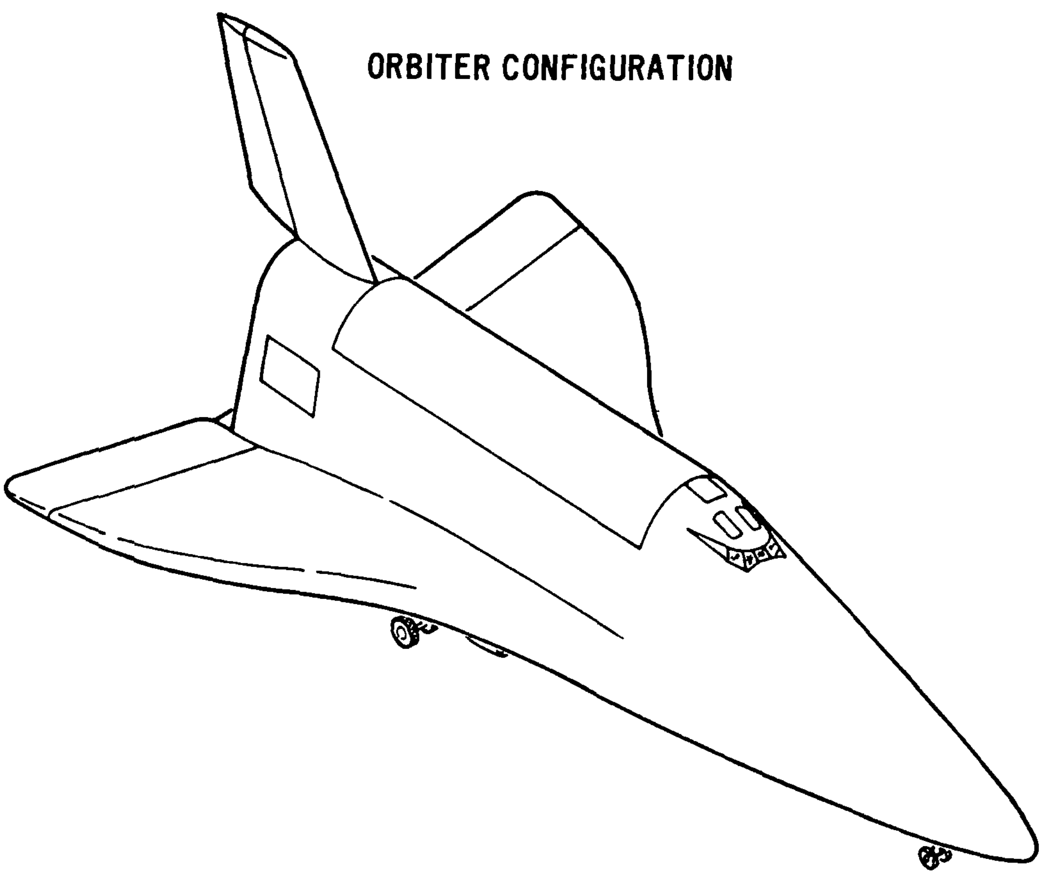


FIGURE 4.2–2

SUMMARY OF RECOMMENDATIONS FOR MAJOR FACILITY LOCATIONS

Function	Location
Final Assembly (Booster, Orbiter)	Kennedy Space Center, Florida
Assembly (Installation of Wings, Vertical Fins, Control Surfaces, and Final Checkout)	
Booster	
Main LH2 Propulsion Tank Assembly	Michoud, La.
Main Fuselage Assembly	Michoud, La.
LO2 Tank (Propulsion)	Michoud, La.
Wing Assembly & Control Surfaces	Contractor
Forward Fuselage	Contractor
Aft Thrust Structure	Michoud, La.
Intertank Structure	Michoud, La.
Canards	Contractor
Thermal Protection System (TPS)	Contractor
Orbiter	
Main Propulsion Tank Assembly	Michoud, La.
Main Fuselage Assembly	Michoud, La.
Wing Assembly	Contractor
Crew Station/Airlock Module	Contractor
Secondary Propulsion Tanks	Contractor
Nose Cap	Contractor
Control Surfaces	Contractor
Fin	Contractor
Thermal Protection System (TPS)	Contractor

Testing	
Wind Tunnel	NASA-Contractor-Other
Airframe	MSC-MSFC-Contractor-NASA-Lewis
Propulsion	Contractor-KSC
Avionics	Contractor
Crew Station	MSC-Contractor
Power Supply	Contractor
Integrated Vehicle	Kennedy Space Center
Flight Simulators & Mockups	NASA-Contractor
Mated Vehicle	NASA-Contractor
Horizontal Flight Test (Airplane Mode)	
High Risk Testing	Edwards AFB, California
Low Risk Testing	Kennedy Space Center
Operations	
Launch Operations	Kennedy Space Center
Maintenance Operations	Kennedy Space Center

Joint Facility Use - This plan is submitted with the premise that MDC would have responsibility for both booster and orbiter. It is unlikely, however, that any single contractor would have such responsibility and it would be split under two or more contractors. No difficulty is foreseen with joint contractor use of any of the facilities, KSC or Michoud. Work-around schedules will be written to permit joint tenancy and common use of expensive fabrication and test equipment.

Alternate Location of Orbiter Construction - The orbiter vehicle fuselage construction is now slated for Michoud. The wings and fins are then added at KSC final assembly. An alternate plan is presented in Section 4.8.6 of the Appendix wherein the orbiter propulsion tanks would still be constructed at Michoud, La. They would then be barged to the MDC, St. Louis, plant where all subsequent manufacturing and assembly would be done. This option has the advantage of lower costs for liaison and engineering coordination.

4.2.1 MDC Facilities Utilization and Manufacturing Plan - Key Features

The MDC Facilities Utilization and Manufacturing Plan will provide the customer with the most cost effective method of producing the shuttle vehicles. This is accomplished by making maximum utilization of existing government and contractor facilities, transporters, other ground support equipment (GSE), tooling and manufacturing equipment. The plan eliminates duplication of facilities, selects those requiring modest or no modification and maximizes dual usage of the facilities. Unique application of existing S1B and S1C transporters and accessories and innovative assembly techniques result in lower program costs. An additional benefit of the combination of Michoud and KSC as selected sites is it provides for maximum geographic flexibility in selection of the shuttle system fabrication and assembly locations. The proposed fabrication and assembly work percentages are as follows:

LOCATION	OPERATION	% OF TOTAL MANUFACTURING PROGRAM
KSC	Final attachment of wings, control surfaces, installation of some TPS and final check-out.	9%
Michoud	Booster and Orbiter main propulsion tank assembly, final fuselage assembly, installation of system components and assembly checkout.	20%

The remaining 71% of the shuttle manufacturing effort is available for assignment to other areas of the country.

The key features of the plan which result in a cost effective program are as follows:

- Selection of KSC as final assembly and operations site.
- The addition to the VAB @ KSC will be utilized for final assembly of the Booster and Orbiter vehicles and then will become the program operations and maintenance building. This approach eliminates the need for a newly constructed final assembly building at some other location which would have a very short program useful life.
- Modification of launch complex No. 39 is considerably more cost effective than construction of a totally new launch facility.
- Selection of KSC as final assembly site permits:
    - Utilization of existing water transportation facilities.
    - Dual utilization of a new landing site.
- Selection of Michoud as the tank assembly and final fuselage assembly site.
- No modification to the basic building structure of building 103 for assembly of Orbiter and Booster fuselages.
- Dual usage of High Bay Building 110.
- Dual usage of modified hydrostatic/cleaning station Building 110.
- Dual usage of new pnemostatic test facility.
- Dual usage of new insulation/installation facility.
- Dual usage of the precision weld and machining area Building 103.
- Dual usage of Orbiter and Booster fuselage checkout bay, using common computers.
- Dual usage of missile grade air compressor facility.
- Dual usage of storage area.
- Dual usage of personnel during schedule gaps.
- Dual usage of component high pressure test facility.
- Dual usage of existing manufacturing systems and procedures.

- Innovative use of existing S-IC/S-IB transporters as transporters (modified).
  - Use existing training manual.
  - Use existing maintenance manuals.
  - Use existing maintenance tooling.
  - Use existing drawing.
  - Use existing spares parts inventory.
  - Use existing operator training facilities.
  - Use existing transportation plan.
  - Use existing ramps and roadway.
  - Use existing prime movers and installed systems.
  - Use existing spiders (modified).
- Innovative use of existing S-IC transporter as an assembly fixture.
  - Eliminates the requirement for Booster fuselage final assembly tooling dock by employing a CG shift assembly technique.
  - Has the capability of precision alignment required for section joining.
  - Provides mobility during the final assembly operations.
  - Eliminates the requirement for overhead cranes.
  - Eliminates the requirement for slings and fixtures.
  - Provides flexibility for support of contingencies away from final fuselage assembly plant.
- Innovative use of existing S-IB transporter as an assembly fixture
  - Eliminate the requirement for an Orbiter fuselage final assembly tooling dock.
  - Provides rotational capability during insulation and final assembly operations.
  - Maximum use of existing Saturn tooling for booster LH_2 and LOX tank fabrication.

4.2.2 Facility Site Selections and Rationale

It quickly became apparent in the Phase B study that the selection of shuttle facility sites hinged on two factors: the chosen operational site for the shuttle, and the component transportation problem posed by the magnitude of both the booster and orbiter components.

There is also a definite interplay between operations, maintenance and final assembly. For example, shuttle operational activity requires a high bay maintenance building and final assembly of both the orbiter and booster also requires a high bay building. Therefore, co-locating maintenance and final assembly removes the requirement for high bay (over 40 ft.) assembly areas at all other locations (except for specialized tank building operations). Similarly, the operational site and the final assembly site both require a runway suitable for shuttle ferry and recovery. Therefore, co-location of the final assembly and the operational sites eliminates the requirement for a runway at the prime manufacturing assembly site.

4.2.2.1 Launch Operations Site Selection - Selection of the launch site facility is critical not only because this is a key facility in the shuttle program, but because it impacts the selection of other manufacturing and test sites.

The candidate launch sites were evaluated in some considerable depth in the supplement to Trade Study No. 14, dated 10 May 1971. (New vs. existing site) These candidate sites were:

- o K.S.C.
- o White Sands
- o Michael (AAF) Army Air Field
- o Western Test Range

KSC is the site selected in Trade Study No. 14. Details may be found in this study, but in brief:

KSC has numerous advantages relative to the other sites:

a. Most of the required facilities already exist at KSC so nonrecurring costs are 465 million vs 1,100-1,200 million for the other locations. These facilities include the range and range instrumentation, the VAB and associated GSE, and the transporter, LUT and launch pad complex; all of which are available and will serve nicely with minimum modification.

b. Barge water transportation is available. This is an advantage unique with KSC. All other sites lack water transportation and, therefore, the subassembly and assembly must be accomplished at another location with the completed booster and orbiter spacecraft flown to the launch site. Subassembly and final assembly could be accomplished at WTR, White Sands or Michoud, but without water transportation, the fuselage and wings of both the booster and orbiter would also have to be fabricated at the launch site since they are too large to be moved by air or rail transport.

Subassembly and final assembly at KSC also offers commonality between the assembly task and subsequent operational maintenance.

c. Operational considerations are good. All missions (except polar) can be accomplished along established corridors without land overfly. Weather conditions are adequate and terrain does not constitute the hazard it does at other launch sites.

White Sands

a. White Sands has the disadvantage of lacking water barge transport access. This requires all models of both the booster and orbiter to be flown in.

b. Operation from White Sands also poses problems associated with land flyover during launch with associated population/safety problems.

c. Operation from White Sands has a very important disadvantage in that it lacks adequate launch support and range instrumentation facilities.

Michael (AAF) Army Air Field (Dugway P/G)

Great Salt Lake Desert, Utah

a. Michael AAF. Utah, has certain advantages as an Operational Launch Site for Space Shuttle vehicles. They are: higher site altitude (4349 ft.) for potential payload increase, low population density for polar orbit launch.

b. The disadvantages of using this site are: The weather conditions fluctuate between hot and cold depending upon the season; winter p;roduces snow storms and heavy cloud cover.

Barge facilities do not exist. Vehicles would have to be assembled at another location and flown to Michael. Nearest rail line is 30 miles, present highways are not adequate, no space launch facilities, present runway (13,100 x 200) would have to be widened to 300' and

ILS and lights added. Shuttle operations could conflict with operations of the Army Dugway Proving Grounds.

These constraints preclude the possibility that this site can be recommended for Operational Launch.

Western Test Range

The Western Test Range (WTR) is an alternate launch site by reason of its existing launch complex and range instrumentation. WTR suffers from the following critical deficiencies (as compared with KSC):

a. Barge facilities do not exist at WTR. This means that assembly of the booster and orbiter must be accomplished at some other site and flown in to WTR.

b. WTR is not a good operational site:
   - Weather is often poor because of cloud cover
   - The mountains to the east present a hazard to the shuttle because of its limited climb and cruise capability
   - Most Shuttle missions would overfly populated areas if launched from WTR

c. Erection and launch facilities must be added. Only a small percentage of existing facilities can be utilized as compared with KSC.

These disadvantages, and others listed in Trade Study 14, were major criteria used in our recommendation of KSC as the operations site for Shuttle.

4.2.2.2 Final Assembly Site Location - The final assembly site is the location where the following tasks are performed.

- o Mate wings to the booster and orbiter
- o Install vertical fin on orbiter
- o Install booster and orbiter airbreathing engines on horizontal flight test model
- o Conduct initial test and horizontal flight tests on booster and orbiter.
- o Preflight vertical rocket engine test for both booster and orbiter, (separately).

All of the above tasks must be done at a site which has a 10,000 ft. runway adjacent to the assembly area so that the completed spacecraft may be taxied to the runway. It should be noted that if the final assembly location has water access, as little as 9 percent of the total manufacturing and test efforts need be concentrated there. Without water access, approximately 58 percent of the total manufacturing and testing effort would have to be concentrated at the final assembly site. The preferred location for accomplishing the tasks listed above is at KSC, the operational site, since a 10,000 ft. recovery runway, the VAB, and other maintenance/mating/testing facilities will be available. Other final assembly locations which have both adequate runway and barge facilities include: Eglin, St. Louis, Tulsa or Baltimore.

KSC is selected for final assembly since it is also the operational base and facility commonality exists between final assembly, operations and maintenance.

4.2.2.3 Main Propulsion Tank Fabrication and Assembly Sites - Booster and Orbiter

The main propulsion tanks for both the booster and orbiter are constructed of aluminum barrel or conic sections and bulkheads machined in an isogrid or waffle pattern (booster bulkheads do not utilize isogrid). The machining is highly specialized, requiring unique equipment and techniques.

Physical sizes of the completed tanks are as follows:

Booster LOX Tank	55 Ft. Long x 33 Ft. Diameter
Booster LH2 Tank	135 ft. Long x 33 Ft. Diameter
Orbiter Main Tank	117 ft. Long x 23 ft. Wide x 14 ft. High

The requirements of the tank fabrication facility are:

Access to water transportation as the completed tanks cannot be moved by any other mode because of their physical size.

High Bay welding structures, the highest of which will be 140 ft.

A vertical tank cleaning facility able to accommodate the booster LH2 tank.

One hydrostatic test facility for the booster LOX tank and the orbiter LOX tank.

A tank insulation facility in which insulation will be applied to the booster LH2 tank and the LH2 portion of the orbiter main propulsion tank.

The orbiter main tank and the booster LH2 tank require pneumostatic tests. These tests must be conducted at a remote facility because of the high stored energy levels generated during testing.

A survey of all existing government and contractor facilities determined that only two locations, Michoud, Louisiana (See Figure 4.2-3) and Seal Beach, California (See Figure 4.2-4) provide the facilities required for economical tank manufacture. A brief description of each of these facilities follows:

Seal Beach

The special facilities at Seal Beach were constructed specifically for the Saturn II stage and are equipped to manufacture 33 ft. diameter tanks. However, the present facilities are limited to approximately 100 ft. in tank length. The length of the Shuttle main propulsion tanks generates the requirment for two vertical weld stations with a 135' working height. To meet this requirement new facilities would have to be constructed as the present facilities are at their structural limit and adding additional height is not feasible.

Adequate pneumostatic test facilities exist and would not require modification.

Seal Beach lacks a hydrostatic test facility therefore one would have to be constructed.

A new tank insulation facility would be required.

Seal Beach has access to water transportation.

Seal Beach is located in a skilled aerospace labor surplus area, so personnel relocation costs would be minimal.

SITE PLAN – MICHOUD ASSEMBLY FACILITY

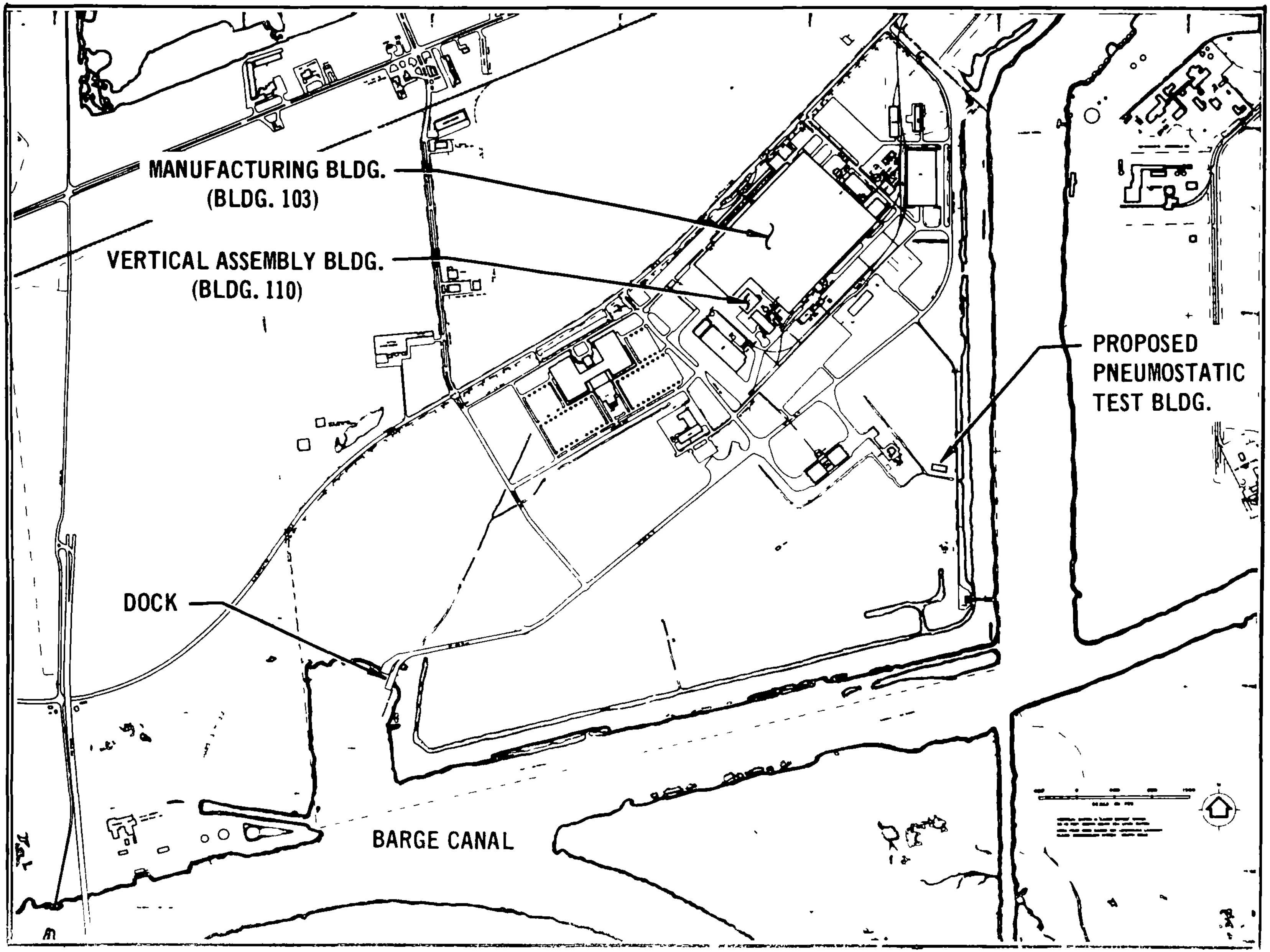


FIGURE 4.2-3

SEAL BEACH COMPLEX

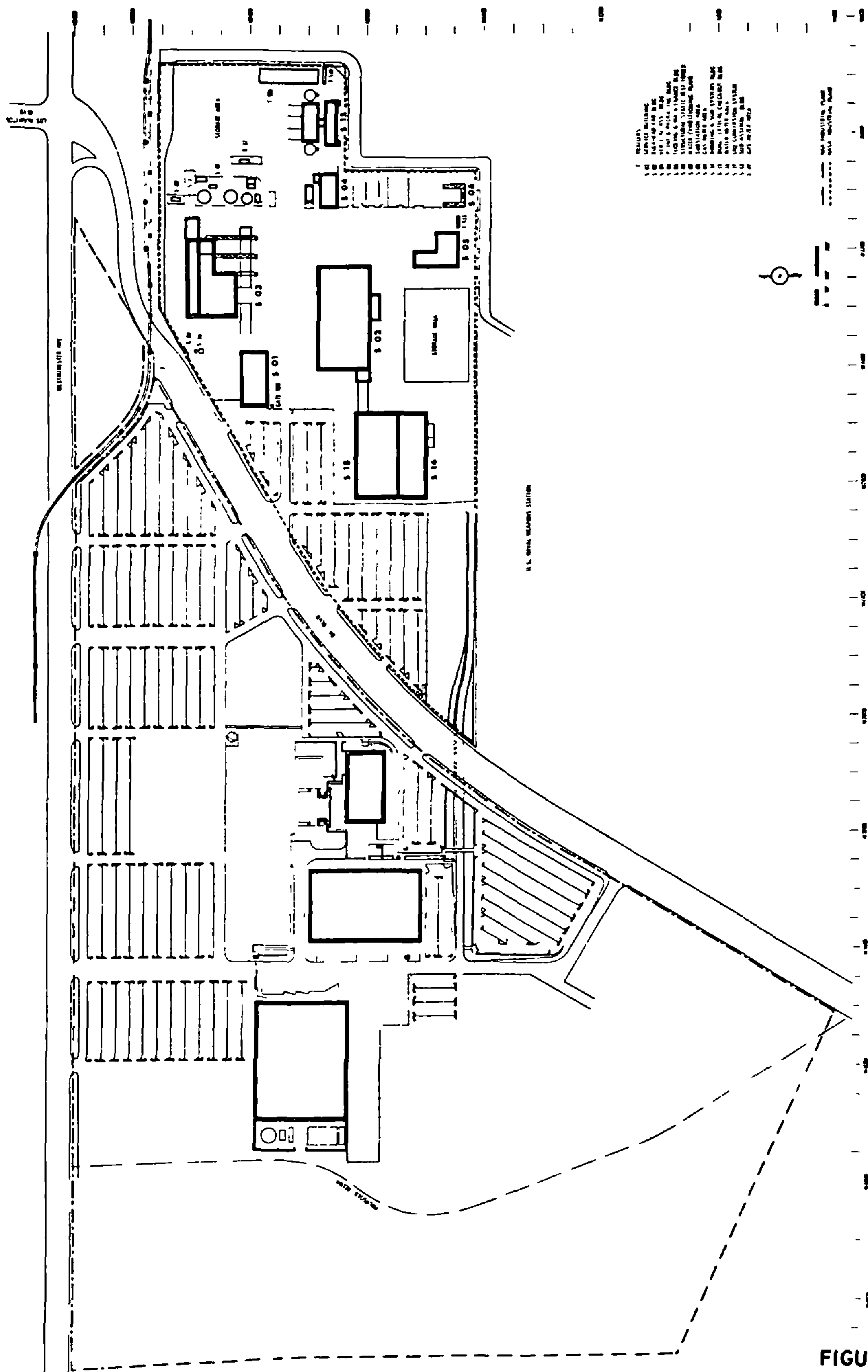


FIGURE 4.2–4

Seal Beach has relatively little manufacturing capability beyond that for tank assembly.

Seal Beach is presently decommissioned and would have to be reactivated in 1973 (with current schedules).

Michoud

The facilities at Michoud are oriented to the production of Saturn S-I-B and S-I-C stages. However, the present vertical assembly stations are limited to a maximum tank length of 85 ft. To meet the requirements generated by the Shuttle Main Propulsion Tanks, one existing vertical weld station would have to be increased in height and one new station constructed within the existing Vertical Assembly Building (Bldg. No. 110).

The existing pneumostatic test facilities (are designed for low level pneumostatic leak checks and it would not be economically feasible to modify these structures for the stored energy levels encountered during Shuttle main LH2 tank proof tests.

A small component high pressure test facility exists but again it is not large enough and is not economically feasible to modify for the Shuttle tanks, therefore, a new pneumostatic test facility would be required.

Michoud has a hydrostatic test facility which with modification would be adequate.

Michoud has excellent access to water transportation and is considerably closer to the launch site than Seal Beach.

A new tank insulation facility would be required.

Michoud is now in operation and will be in operation in 1973 on Skylab (but at a lower activity level) so that no site activation costs will be incurred.

Final selection and cost analysis between these two sites is given in Section 4.2.2.4 Fuselage Manufacturing and Assembly Sites.

4.2.2.4 Fuselage Manufacturing and Assembly Sites - Fuselage assembly is the operation where the fuselage of the orbiter and booster are completed by combining the tanks, the fuselage bulkheads, formers, and skins, and all the subsystems such as propulsion, hydraulic and electrical.

The previous section established two candidates for tank fabrication, Michoud, Louisiana, and Seal Beach, California. Also, Section 4.2.2.2 established KSC as the location for booster and orbiter final assembly. There are two logical choices as to where fuselage assembly manufacturing could be done; at the propulsion tank fabricating facility (Michoud or Seal Beach) or at the other end of the necessary water connecting link, KSC. (A third alternative - Orbiter only - is the Contractor's facility and this alternate approach is covered in the Appendix, Section 4.8.6).

KSC is not set up to support a manufacturing operation, and adequate supporting shops, personnel and equipment are not now available. Moreover, performing fuselage assembly manufacturing at KSC along with other tasks would unduly concentrate activity in one location. For these reasons the fuselage assembly manufacturing will also be at the tank assembly facility.

As stated previously, the two tank fabrication facilities under consideration are Seal Beach and Michoud. In order to consider these sties for fuselage assembly manufacturing the following requirements must be satisfied:

Site must have access to water transportation.

Site must have 1,200,000 sq. ft. of manufacturing floor space, 210,000 sq. ft. of which must be a minimum of 40 ft. clear in height.

A brief description of the two sites as related to fuselage assembly follows:

Seal Beach

This location has adequate access to water transportation although it is a considerable distance from the selected final assembly and launch site.

Seal Beach is the smaller site (450,000 sq. ft. vs 3,500,000 sq. ft. at Michoud). Additional space for offices, labs, etc. would be made available at the Contractor facilities nearby but not adjacent to the NASA facility.

The site does not have a manufacturing building large enough to manufacture and assemble both the booster and orbiter fuselages, therefore a new facility would have to be constructed.

During 1967 (a peak year) the following annual operating costs were compiled:

FACILITY OPERATING COSTS
SPACE DIVISION - SEAL BEACH
FY-67 (Peak Year)

Total Square Footage — 450,000 NASA; 670,000 NAR

Personnel — 4,700 (H.C.)

Operating Costs by Function:

Utilities	573,000
Communications	895,000
Plant Maintenance	799,000
Custodial	569,000
Security & Fire Protection	665,000
Reproduction & Photography	1,100,000
Transportation	375,000
Medical	75,000
Supplies	2,800,000
Total	7,851,000

Cost per Sq. Ft. - $7.00

Cost per H/C - $1,670.00

Michoud

The site has excellent access to water transportation and is considerably closer to the final assembly and launch site than Seal Beach.

Michoud has a 1,977,900 sq. ft. manufacturing building with a nominal 40 ft. clear height which is adequate for the booster and orbiter fuselage assembly.

During 1967 (a peak year) the following annual costs were compiled:

FACILITY OPERATING COSTS
MICHOUD ASSEMBLY FACILITY
FY-67 (Peak Year)

Total Square Footage	3.6 million
Office Space	740,000 sq. ft.
Lab Space	552,000 sq. ft.
Manufacturing Checkout and Support	2.4 million sq. ft.

Personnel 12,000 (H.C.)

Operating Costs by Function:

Utilities	$2,400,000
Communications	300,000
Plant Maintenance	7,000,000
Custodial	650,000
Security	450,000
Reproduction	2,500,000
Transportation	800,000
Fire Protection	206,000
Photography	350,000
Medical	250,000
Supplies	2,000,000
Total	$16,906,000

Cost per sq. ft. - $4.70

Cost per H/C - $1,408.00

During Phase B a cost comparison of the two sites was made, the results of which are as follows:

Overall Cost Analysis, Michoud vs. Seal Beach

		Michoud	Seal Beach
Vertical Assembly LH2 Tank			
Mod. Michoud		265,000	
New Seal Beach			2,000,000
Vertical Assembly Orbiter Tank			
Mod. Michoud		530,000	
New Seal Beach			2,000,000
Hydrostatic Test & Cleaning Facility			
Mod. Michoud		275,600	
New Seal Beach			2,400,000
Anodize Facility			
New Michoud		1,920,000	
New Seal Beach			1,920,000
Pneumostatic Test			
New Michoud		339,200	
Existing Seal Beach			0
Insulation Installation Orbiter & Booster LH2 Tanks			
New Michoud		636,000	
New Seal Beach			636,000
Final Assembly Fuselage (Orbiter & Booster)			
Mod. Michoud		60,000	
New Seal Beach			8,250,000
Site Activation		0	37,000,000
Transportation (1 Year)		250,000	2,190,000
	Totals	4,275,800	56,396,000

Based on the close proximity to the final assembly and launch site and the foregoing cost analysis, Michoud is selected as the main propulsion tank and fuselage assembly site for both booster and orbiter. See Figure 4.2-5 for a preliminary layout of the Michoud Manufacturing Building No. 103.

MICHOUD OPERATIONS MANUFACTURING BUILDING LAYOUT

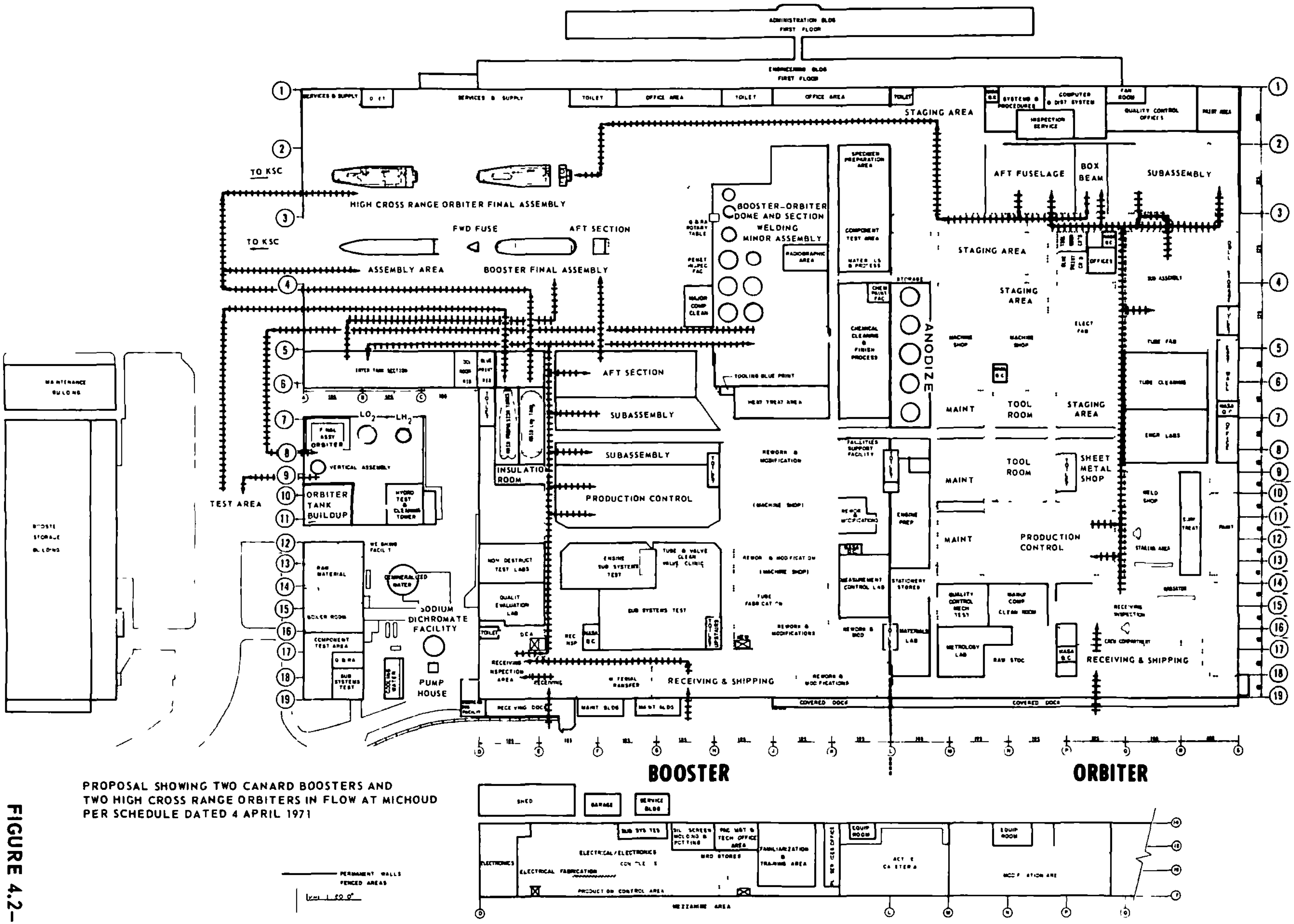


FIGURE 4.2-5

4.2.2.5 Chamber of Commerce Information - The following data has been supplied by the New Orleans Chamber of Commerce in support of utilizing Michoud for a major manufacturing facility on the Shuttle Program.

It has been estimated that an influx of 8,000 new employeed in the 1973-75 perior will bring a total of 26,000 new people (3.2 persons per household) to the New Orleans area. This will increase the demand for local housing, especially in the eastern New Orleans area. This area consists of 32,000 acres, or fifty square miles, which are being actively developed within the city's municipal limits. New Orleans East is about 15 to 20 minutes automobile time from the Central Business District, as well as conveniently accessible by public transportation.

A normal rate of growth of 5,127 households per year for the New Orleans area has been projected through 1980. A higher household rate of growth, due to a larger-than-expected population growth and housing demand, would increase the previous figure to 5,634 new households per year. This will result in 23,000 to 26,000 new households in the New Orleans area between mid-1971 and 1975, of which about 55% will be single-family units and 45% will be multi-family units. The total number of households in the 1970-75 period will then increase from the 1970 figure of 318,423 to an estimated range of 341,423 to 344,423 total households. Applying a projected ratio of 5.52% adequate vacant units/households units to these figures results in an almost constant number of vacant units of 19,000 fit for occupancy each through 1975.[3] Therefore, it can be expected that the housing supply in the New Orleans area through 1975 will be sufficient to accommodate an influx of 15,000 new households during

(3) Smolkin-Sugel Corporation

Housing (Continued)

this period of time. It follows that New Orleans will have the capability to handle about 57,000 new households during the three-year period 1973-1975.

The availability of homes and their average prices depend on location desired, size of home required, and type of construction. Many good homes are available in the metropolitan area, in good existing neighborhoods, as well as in newly developed and developing subdivisions. The price of a middle income home averaging 2,000 sq. ft. in area in one of the new subdivisions, urban or suburban, would sell in the $30,000 to $40,000 bracket. Average rentals for middle income, new apartments are:

$125 - $175 per month for 1 bedroom unit.

$165 - $250 per month for 2 bedroom units.

$240 - $300 per month for 3 bedroom units.

II. SCHOOLS

The number of schools in Orleans Parish was 247 as of May, 1971. There were 175 elementary schools, 26 senior high schools, 24 elementary-high and 19 junior-high among the total. Fifty four percent of the Orlean Parish schools total were public schools, 28% were Catholic and 18% were private ones. There were 153,334 students enrolled in kindergarten through twelfth grade in Orleans Parish in the first trimester of the 1970-1971 school year. Of this total, 72% were enrolled in public schools, 23% in Catholic schools and 5% in private schools. Also, there were 4,851 teachers and principals in the Orleans Parish school system in the 1969-1970 school year.

The combined efforts of the Orleans Parish School Board, Catholic and private schools were capable of handling over 160,000 students in the 1966-1967 school year; therefore, it is expected that the combined system will adequately provide for the additional educational needs of 8,000 new households in the Greater New Orleans area during the 1973-75 period. The Orleans Parish School Board shares this opinion, especially since plans are underway to open a new elementary school close to the NASA-Michoud facilities in August 1973. This new school will handle about 1,000 new elementary students. Also, the influx of people will be spread over three years which will make this change to be a smooth one, and a much easier one for the local school system to accommodate.

New Orleans also has many fine higher educational institutions. These include Tulane and Loyola Universities, Louisiana State University in New Orleans, Newcomb College for Women, and St. Mary's Domican College. Most of these universities offer evening graduate and undergraduate programs, and are nationally recognized as institutions of higher learning. In total, there are more than 380 private, parochial, public and business schools in metropolitan New Orleans.

III. UTILITIES

A. Electrical Facilities

The New Orleans Public Service Inc. provides the city of New Orleans with electricity, gas and transit services. The surrounding suburban areas in Jefferson and St. Bernard parishes are served by Louisiana Power & Light Company, Louisiana Gas Service Company, and several transit companies. The New Orleans Public Service Inc. and the Louisiana Power & Light Company are subsidiaries of Middle South Utilities, Inc. and their electric systems are tied in with the facilities of other member companies. There has never been any critical power shortage or failures in the area. The total current electric generating capability of the Louisiana Power & Light Company is 1,887,000 kilowatts, and the present electric generating capacity of New Orleans Public Service Inc. is 1,260,000 kilowatts. According to the Middle South 1970 annual report, the total system's capability is 7,699,000 kilowatts, which includes total net owned generating capability of 6,643,000 kilowatts and 1,056,000 kilowatts available under firm contracts.[1] The system had a 1970 reserve capacity of 1,301,000 kilowatts, or 20% over their customers' requirements. Middle South's projections indicate that &269 million will be spent for new construction in 1971, and an additional $925 million in the 1972-1974 period. Additions to generating capacity in the 1971-1974 period will increase Middle South's generating capacity to a total of more than 12 million kilowatts capability.

B. Natural Gas

Marketed production of natural gas in the Middle South states is over 7.5 trillion cubic feet annually, about 36% of the nation's production.[2] Natural gas is the primary fuel currently used by Middle South Utilities for generating electricity, although it is anticipated that the future fuel mix for the System's generating units may be natural gas, oil, coal and nuclear. The Middle South area's crude petroleum production is over 900 million barrels per year, approximately 27% of the nation's production. Concerning non-electric additions, New Orleans Public Service Inc. spent $3.1 million in 1970 to improve its natural gas distribution system and transit service in the city of New Orleans.

C. Local Transit Service

The public transportation system provides extensive coverage of New Orleans; the basic fare is 15¢, express fare is 20¢, and there is no extra charge for transfers. The Public Transit System operates 24 hours a day and covers 500 route miles with over 600 buses and 35 streetcars. There are also 30 taxicabs companies in the city and they offer a wide variety of touring cars, buses, and limousines.

(1) The System's total net capability at year-end 1970 was 6,734,000 kilowatts.
(2) The Middle South Utilities System serves Louisiana, Missippi and Arkansas.

D. Communications

South Central Bell Telephone Company serves the New Orleans Area with more than half a million telephones listed in 1970. A computerized operating system enables customers in New Orleans to dial most long distance calls without operator assistance. New Orleans is one of the very few large cities in the United States still offering 5¢ calls from public phone booths. In addition, South Central Bell will be able to provide telephone service for influx of 25,000 new people the 1973-75 period with no trouble. Also, Western Union, ITT World Communications, RCA Global Communications and Tropical Telegraph Company provides adequate telegraphic communications to the New Orleans area.

E. Municipal Services

Police and fire protection and other municipal services provided by the New Orleans Area governments are generally comparable to those of other metropolitan areas of equivalent size. Forty-four percent of the City of New Orleans operating budget is presently spent in police, fire and sanitation services.

F. Water, Drainage and Sewerage Facilities

The water supply from the Mississippi River is the largest available in the United States, 309 billion gallons daily. Less than 1/2 of one percent is presently used by industries and for municipal purposes, leaving an abundance of water for future needs. Ground water in this area is another source of industrial water. Some wells produce as high as 2,500 gallons per minute. Most of the ground water is potable. Also, water and sewerage rates in the New Orleans area are among the lowest in the nation. There are 13 drainage pumping stations in the New Orleans drainage system which provide assured drainage protection for approximately 57,145 acres of land. The stations house some 76 drainage pumps with a combined capacity of approximately 33,200 cubic feet per second. Water and sewerage facilities are provided by the Sewerage and Water Board of New Orleans and the Jefferson Parish Waterworks. Water is supplied at pressure to supply all industrial, commercial and residential needs.

4.2.2.6 Space Shuttle Component Transportation - The size of the components comprising the Space Shuttle booster and orbiter is a very real constraint. A detailed transportation analysis has been conducted (See Appendix, Section 4.8.5) and a summary of the results is shown in Figure 4.2-6. It is shown that the major components of both the booster and orbiter, once fabricated, must be moved by barge transport. This means that the tank-fuselage-wing fabrication facility must have barge water access and also that the final assembly site must have similar barge terminal connections. It also should be noted that the shallow draft barge fleet currently available to NASA is not capable of transporting either the booster or orbiter when fully assembled. We therefore conclude that final assembly, i.e. fittings of wings, fins, some thermal protection system, and possibly other components must be done at the launch site or at least in very close proximity to a 10,000 ft. runway to permit ferrying of compelted vehicles.

Commercial cargo aircraft are available for carrying outsize cargo which is too bulky for rail or highway shipment. In some cases it may be preferable to ship Shuttle components by air, even though rail or highway transport is feasible. The capacity of specialized cargo aircraft is also described in the Appendix, Section 4.8.5. The vertical fin and cargo doors of the orbiter and the engines for both orbiter and booster will be moved by rail or motor transport because they are small enough to permit this less costly mode.

SPACE SHUTTLE TRANSPORTATION ANALYSIS

TRANSPORTATION CAPABILITIES

Structure / Transportation Mode	Ferry W/A.B. Engines	Barge	Airaft	Rail	Road
Booster (Assembled)	X				
Booster Fuselage (less crew compartment)		Selected Mode			
LH2 Tank		X			
LO2 Tank		X			
Intertank Structure		X			
Aft Section		X			
Forward Fuselage		X	Selected Mode		
Canards		X	Selected Mode		
Wings		Selected Mode			
Engines		X	X	X	Selected Mode
Orbiter (Assembled)	X				
Fuselage		Selected Mode			
Fuel Hyd. & Elect. System		X	X	X	X
Main Propulsion Tank (H2 & O2)		X			
Secondary LH2 Tank		X	X	X	X
Nose Cap		X	Selected Mode	X	X
Crew Station/Airlock Module		X	Selected Mode		
Wings		Selected Mode			
Vertical Fin			Selected Mode	X	X
Engines		X	X	X	Selected Mode

X - possible or feasible

FIGURE 4.2-6

4.2.3 Facility and Manufacturing Requirements

4.2.3.1 Facilities Requirements - The Contractor will provide clear definition of the Government owned and Contractor facilities required to support the Space Shuttle C/D Program phases. Government facilities so identified may be either existing facilities which are suitable for the shuttle, possibly with modifications,or they may be entirely new facilities. The Government will supervise new or modified construction and will contract directly with the construction contractor. The prime contractor will provide the following:*

A. Initial identification of the need for new or modified facilities necessary for shuttle booster and orbiter manufacture, ground and flight test.

B. Detailed criteria and preliminary specification requirements for facilities. The criteria and specification will conform to the NASA Facilities Engineering Handbook NHR 7320.1 dated January 1971.

C. Schedule and planning support to the Government so that facilities are built to meet program needs in a timely manner.

D. Support to the Government to review construction drawings and monitor the construction of facilities so that they meet the requirements for shuttle manufacture and test. Any shuttle design changes which impact facility construction or modification will be brought to the attention of the Government so that the facility contract modification may be initiated in a timely manner.

E. Initial definition of Government owned manufacturing, handling and test equipment and specifications on such equipment, its location, access, etc.

*These requirements have been written in general terms across the Shuttle program even though the actual requirements may vary depending upon the particular controlling NASA Center.

F. The Government may elect to contract through a construction agency such as the Booster contractor or other Government agency.

G. Housekeeping functions, including responsibility for any relocation, refurbishment, modification, or maintenance of facilities assigned to the contractor after initial installation and acceptance of the facilities and equipment. The contractor will maintain real property records and prepare reports with regard to facility maintenance and equipment.

4.2.3.2 Manufacturing Requirements - The contractor will provide manpower material and facilities necessary to plan, manufacture and functionally test flight hardware and ground support equipment within the time and cost constraints imposed by project management. Specific detail requirements include:

A. The contractor shall provide and describe a production planning function which is capable of efficiently translating all product design information into working documents for tool design and fabrication, detail piece-part fabrication, and assembly, installations and checkout for all flight and test hardware plus contractor manufactured GSE. This function shall also have the capability of producing manufacturing work plans, and determining the most efficient use of methods and processes to assure proper and economical use of manpower and facilities.

B. The contractor shall provide and describe a production scheduling function capable of efficiently scheduling all required manufacturing and tooling activity including establishing priorities for vendor deliveries of components. This will also include a system for schedule position status and progress reporting.

C. The contractor shall provide and describe a tooling function for efficient design and construction of all required special contract tooling necessary to produce the project hardware. Items of special tooling for testing, inspection, and handling shall be included in this category, along with the required production tools.

D. The contractor shall provide and describe a production control function, which efficiently directs and controls the release of all work orders for tooling and hardware, and the movement of all material, tooling, piece parts, vendor parts, and assemblies to their respective usage points. This function shall also maintain and report pertinent information regarding status and schedule position.

E. The contractor shall provide and describe a manufacturing operations control function, capable of efficient preparation of estimates plus the monitoring and reporting of budget expenditures for all project work in process in the manufacturing areas in conjunction with the work breakdown structure (W.B.S.).

F. The contractor shall provide and describe a status and progress reporting function for furnishing statistical reports on program manufacturing progress and status to various functional levels of project managemen.

G. The contractor shall provide the necessary manpower, tools and material necessary to fabricate three (3) flight-worthy Shuttle Booster Spacecraft with associated AGE.

H. The contractor shall provide the necessary manpower, tools and material necessary to fabricate four (4) flight-worthy Shuttle Orbiter Spacecraft with associated AGE.

I. The contractor shall modify one model of both the booster and the orbiter as necessary to perform specialized Horizontal flight tests and to restore the vehicles to original flight-worthy condition.

4.2.4 Facility Construction Schedule and Budgetary Requirements

Tables 4.2-1 & 4.2-2 depict the facility budgetary requirements and their respective time frames. This schedule is keyed to provide facilities in the time frame required by the major program milestones shown on the master schedules for Booster and Orbiter. These master schedules are included in the Appendix (Section 4.8.8).

TABLE 4.2-1

FACILITY CONSTRUCTION SCHEDULE & BUDGETARY REQUIREMENTS

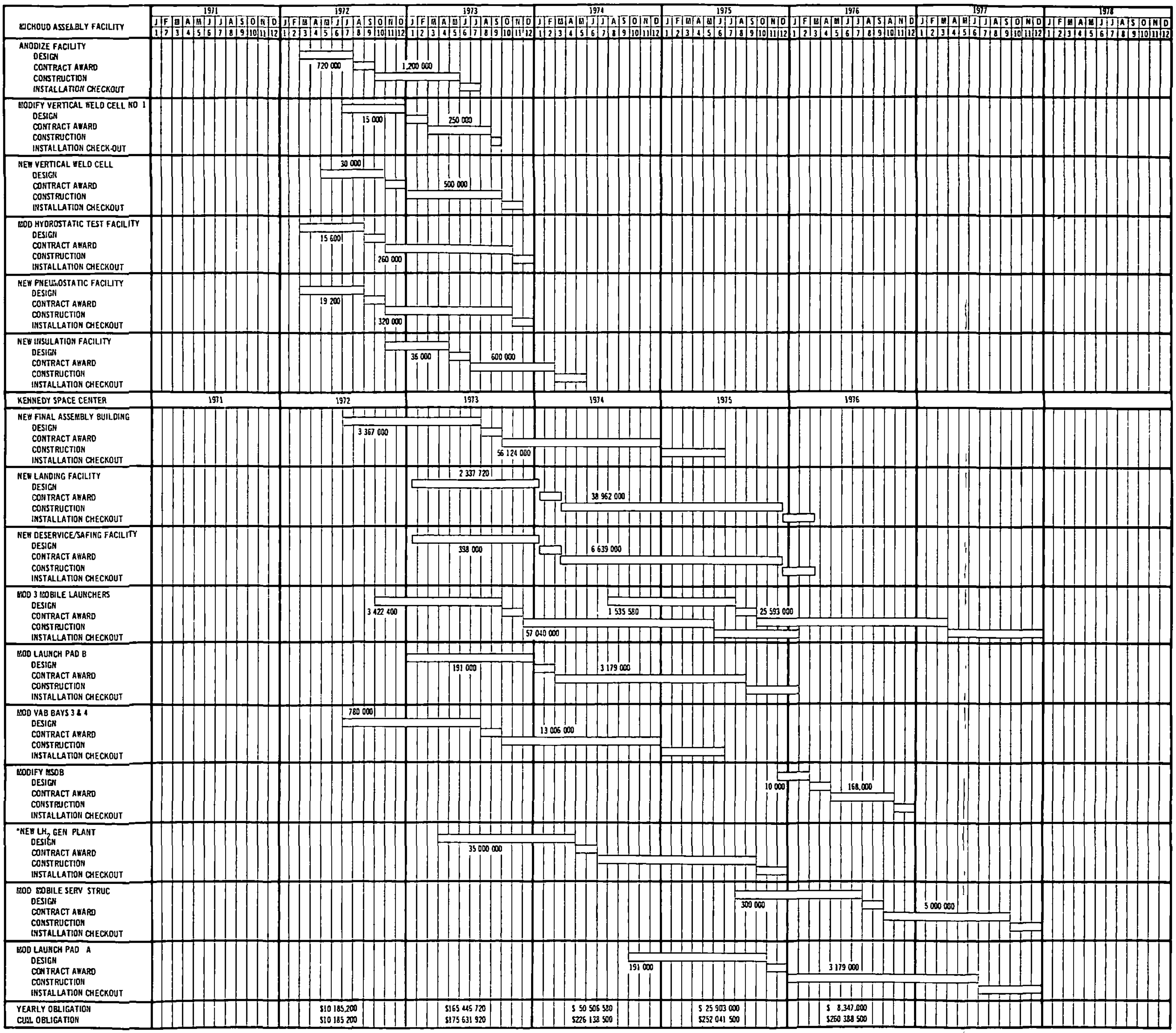


TABLE 4 2-2

MAJOR FACILITIES COST ESTIMATE

Operations (KSC)		
Maintenance/Assembly Facility	59,491,000	
Propellant Production Facility	35,000,000	
Prime Landing Site	48,337,000	
Modify Launch Complex (VAB & 2 Pads)	20,526,000	
Modify Mobile Launchers (3 Units)	87,591,000	
Modify Mobile Service Structure	5,300,000	
Modify MSOB	169,000	
Subtotal	256,414,000	
Manufacturing (Michoud)		
Modify Hydrostatic Test & Cleaning Facility	276,000	
Modify Vertical Weld Fixture	265,000	
New Vertical Weld Fixture	530,000	
New Anodize Facility	1,920,000	
New Pneumostatic Facility	339,000	
New Insulation Facility	636,000	
Subtotal	3,966,000	
Test		
Modify Acoustic Test Facility (MDC St. Louis)	100,000	
Modify S-IC Stand MSFC 4670	325,000	
Modify Bldg. MDC St. Louis (Cargo Mechanism Test)	375,000	
Subtotal	800,000	
Baseline Total		257,813,000

4.3 BOOSTER FACILITY UTILIZATION AND MANUFACTURING PLAN

The Booster vehicle as planned is approximately 270 feet long, has a wing span of 166 feet, and an overall height of approximately 60 feet. Figure 4.3-1 shows the major components comprising the Booster which will be assembled at Michoud, Louisiana, and Kennedy Space Center.

BOOSTER DESCRIPTION

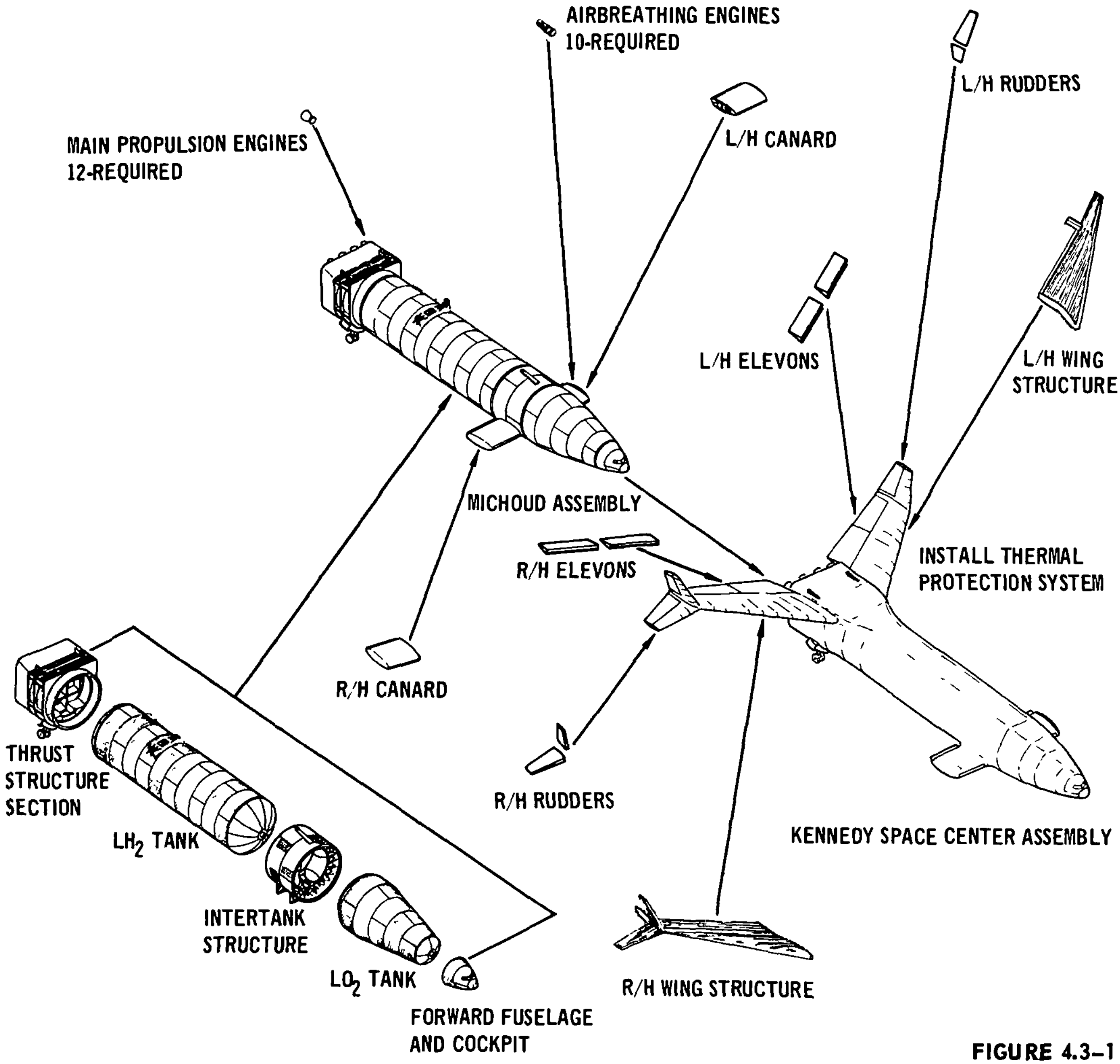


FIGURE 4.3-1

4.3.1 LH2 Tank

4.3.1.1 Tank Description - The LH2 tank assembly (Figure 4.3-2) will be made up of ten isogrid-machined cylindrical sections, two isogrid-machined "Y" rings and two dome assemblies. The cylindrical sections, "Y" rings and domes will be welded together to make up the LH2 tank assembly. An illustrated Manufacturing Flow Sequence is shown in Figure 4.3-3. A Manufacturing Flow Chart and Schedule is shown in Figure 4.3-4.

4.3.1.2 Manufacturing Site - Several sites were evaluated for LH2 tank manufacture. Details of the evaluation are provided in Paragraph 4.2. As a result of the evaluation, it is recommended that the tanks be assembled at the NASA owned Michoud Assembly Facility (MAF) in Louisiana (See Figure 4.3-5), with fabrication support by Contractor facilities.

LH_2 TANK ASSEMBLY

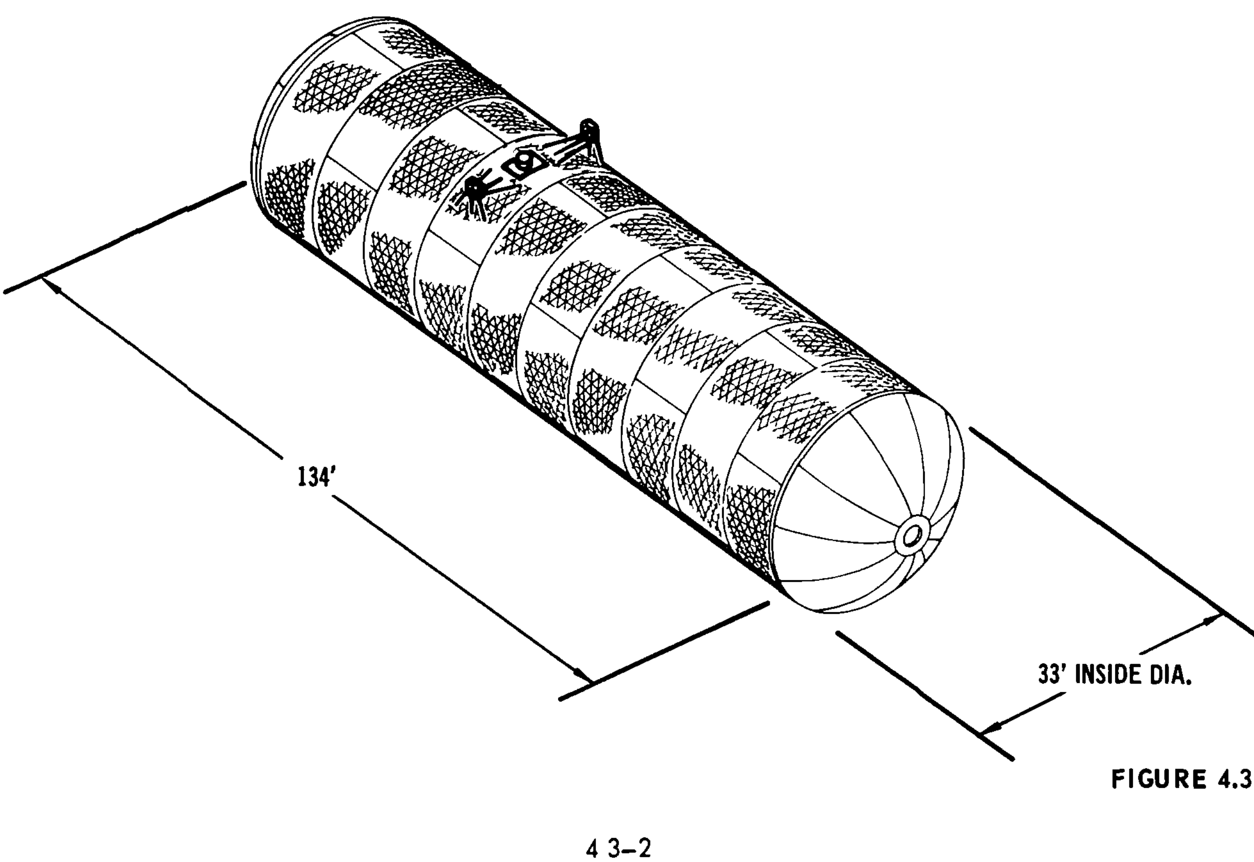


FIGURE 4.3-2

LH_2 TANK
Manufacturing Assembly Sequence – Booster

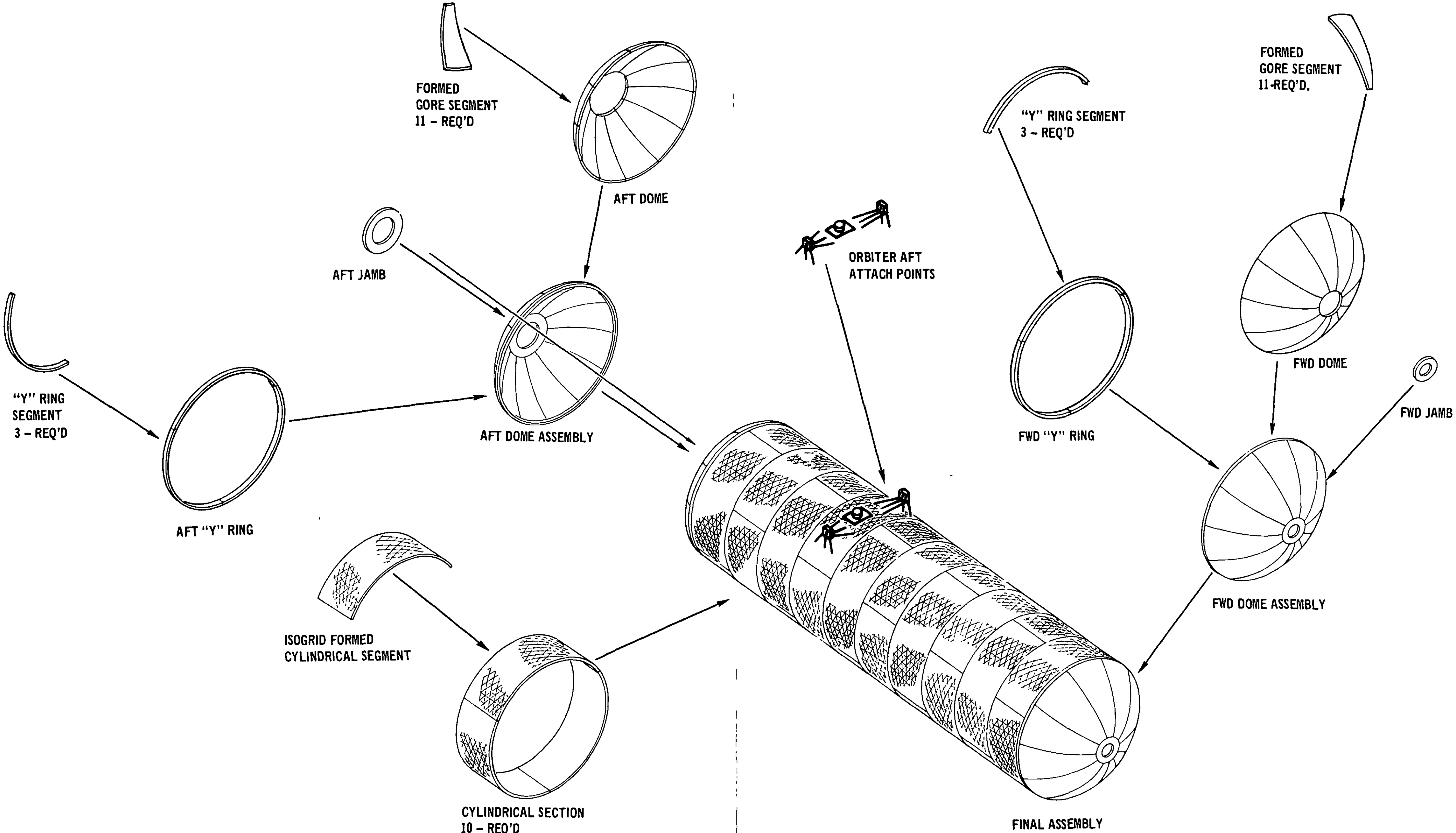


FIGURE 4.3-3

LH_2 TANK ASSEMBLY
MANUFACTURING FLOW CHART AND SCHEDULE

BOOSTER

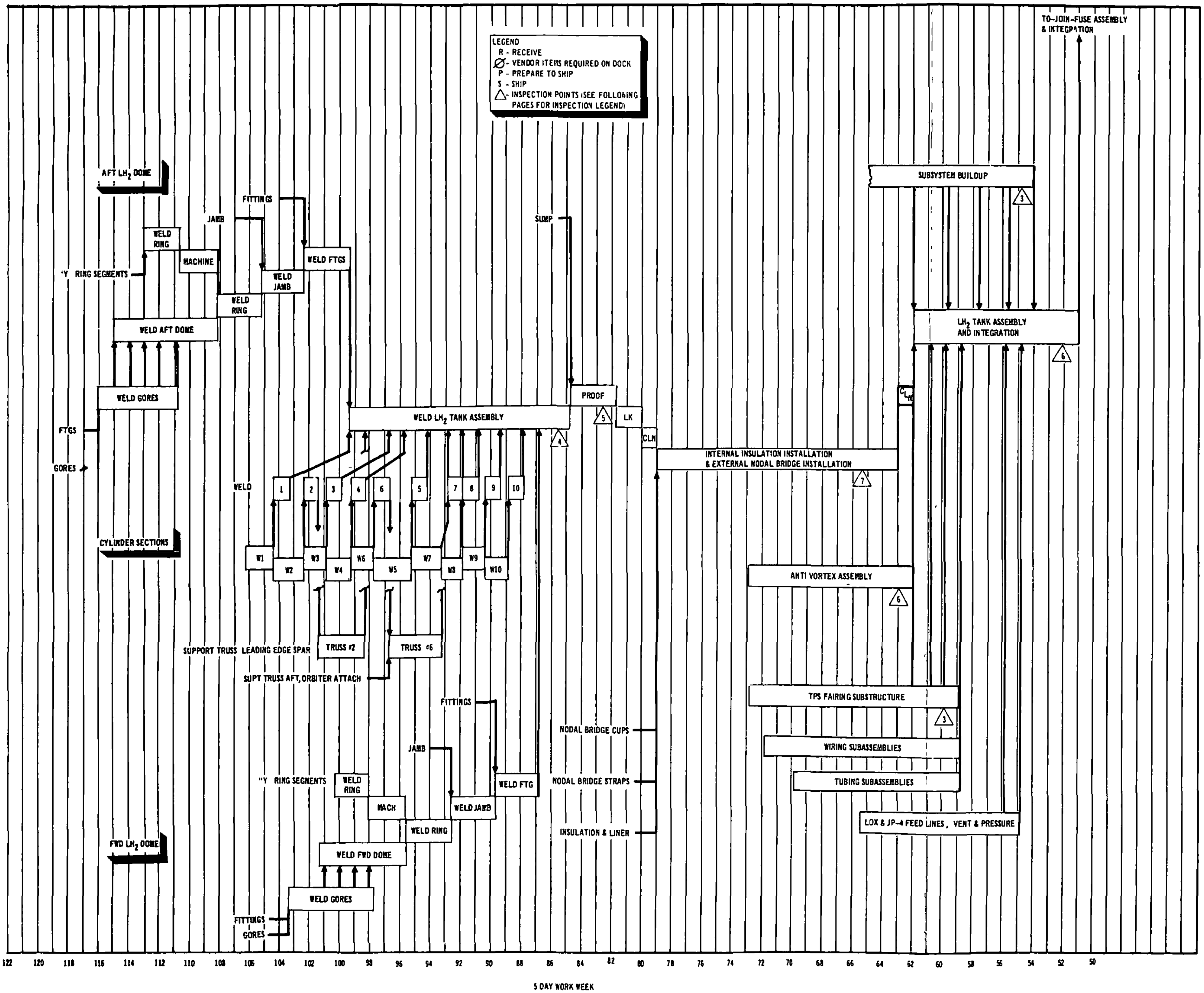


FIGURE 4.3-4

4.3.1.3 Manufacturing Approach - Piece-part fabrication and processing will be accomplished largely in Contractor owned facilities. This will include forming, cleaning and anodizing tank dome gores and tank skin pocket milling. Subassembly will take place both at Contractor facilities and at Michoud. Final Assembly welding of the tanks will be accomplished at Michoud. Most operations at Michoud will utilize existing Saturn tooling and GSE, modified as required.

4.3.1.4 Manufacturing Operations

Cylindrical Sections - The cylindrical sections of the LH2 tank shell will be fabricated of three plates of 2-1/2 x 144 x 400 in. aluminum. The plates will be isogrid-machined (Figure 4.3-6) using N/C 3 axis profilers, such as the one shown in Figure 4.3-7, and then rough trimmed to size.

Using a power brake, or age forming, each plate will be contoured to the correct curvature and then anodized. The forming operation will be accomplished

SITE PLAN – MICHOUD ASS'Y FACILITY

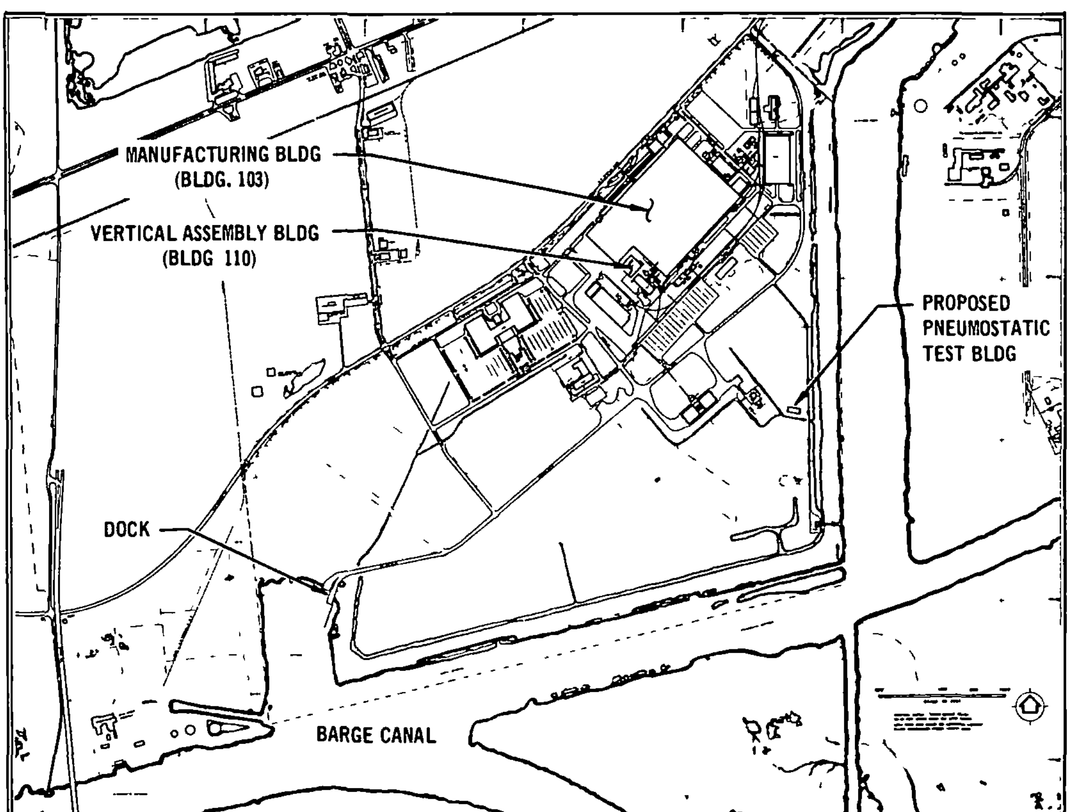


FIGURE 4.3-5

TYPICAL ISOGRID SKIN

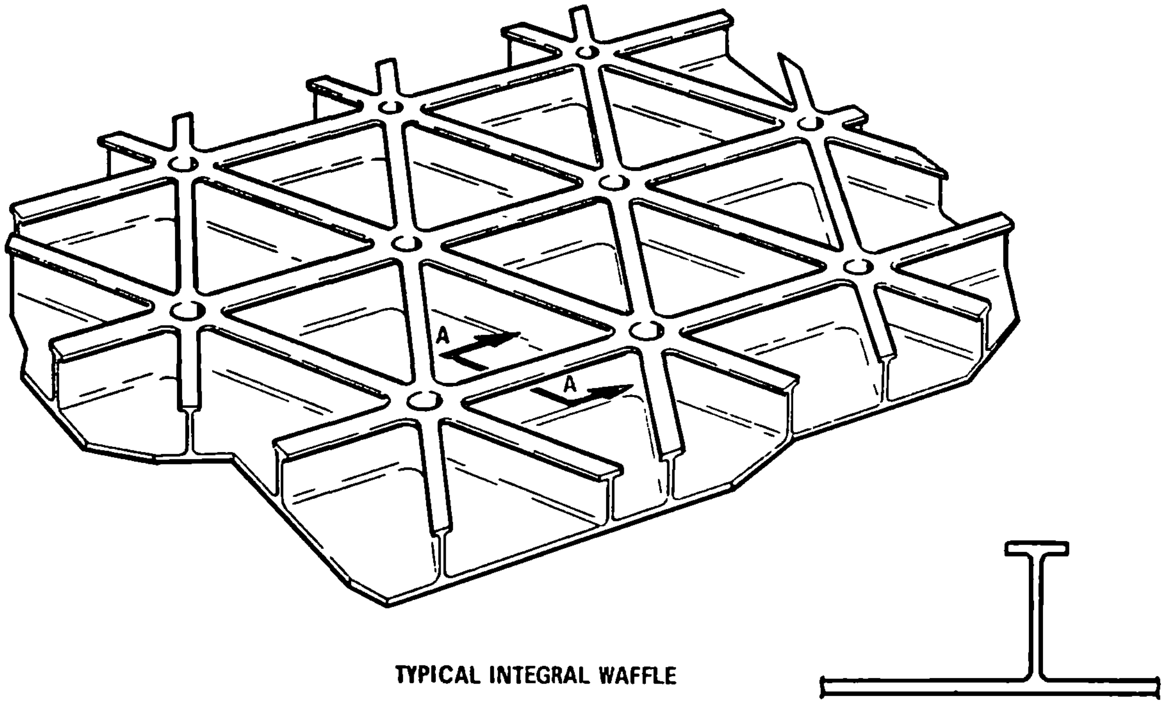


FIGURE 4.3–6

TYPICAL 3 AXIS PROFILER

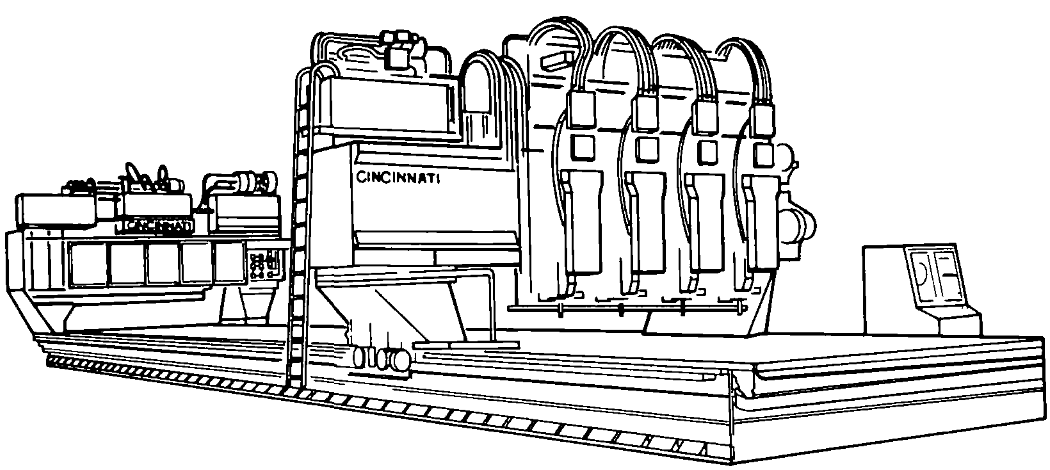


FIGURE 4.3–7

in a Contractor facility, if the power brake method of forming is used. If it is necessary to age form the plates, the aging and anodizing will be accomplished at Michoud in new facilities presently being planned for the Shuttle Orbiter.

At Michoud, welding of the three plates into a cylindrical shape will be performed in a vertical position using MIG welding equipment. Each weld will be shaved and X-Rayed. Forward and aft edges of each section will be trimmed to a station plane, preparatory to welding to the adjacent component.

One of the cylindrical sections will incorporate a beam and truss assembly for the aft orbiter attach points. This assembly, consisting of plate stock machined for a cylindrical truss with tubular supports, is attached to the tank wall by bolts.

"Y" Rings - The "Y" Rings, (Figure 4.3-8) which will be fabricated at Michoud, will be made up of purchased rolled and heat treated forgings which are welded together to form a 33 foot diameter ring. After aging, the ring will be machined to the required diameter and cross section on a boring mill similar to the one shown in Figure 4.3-9. The previously described isogrid pattern will then be machined into the outer circumference of the ring, using a tracer attachment on the boring mill. After machining operations are completed, the ring will be cleaned and anodized.

Domes - The dome assemblies (Figure 4.3-10) will be made up of gore segments which are welded into a spherical shape and trimmed.

The forward and aft dome gore segments will be made from aluminum plate stock that has been formed on a stretch form die.

After forming, the gore segments will be rough trimmed, chem-milled and then anodized. These operations will be accomplished at Contractor facilities on modified existing equipment.

TYPICAL "Y" RING

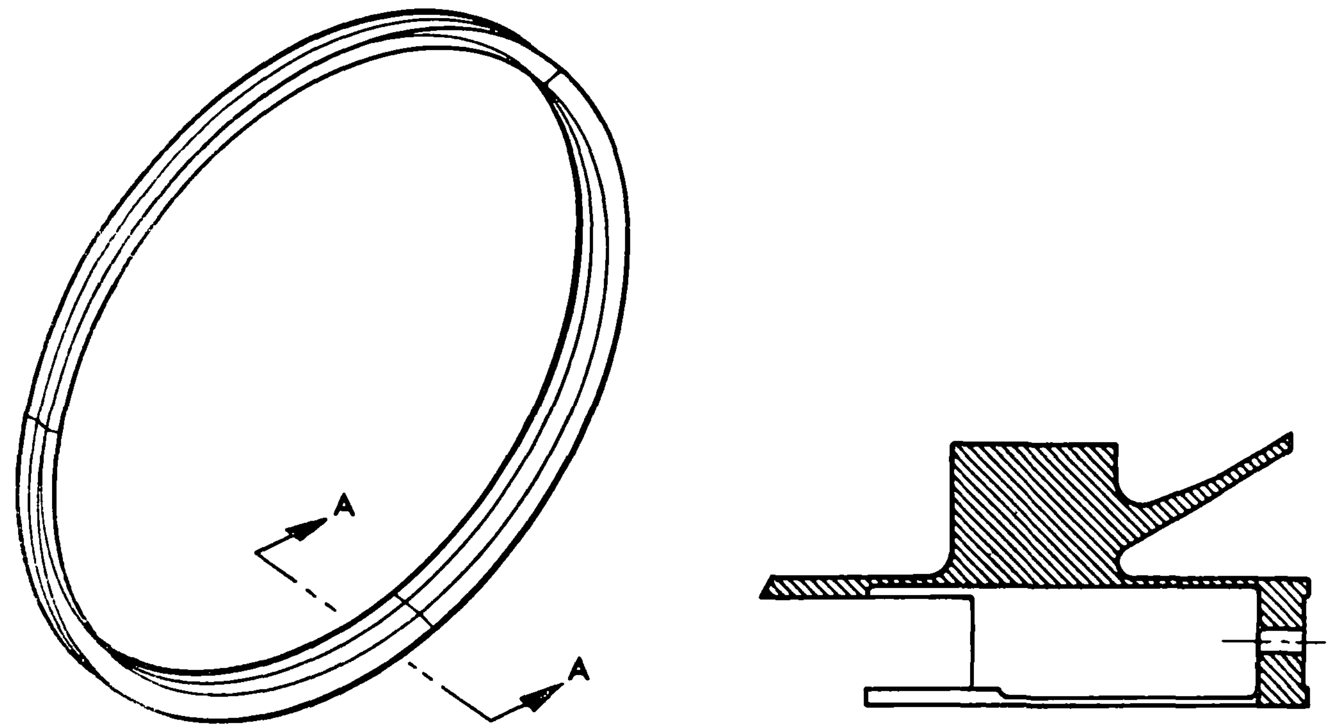


FIGURE 4.3-8

NILES BORING MILL

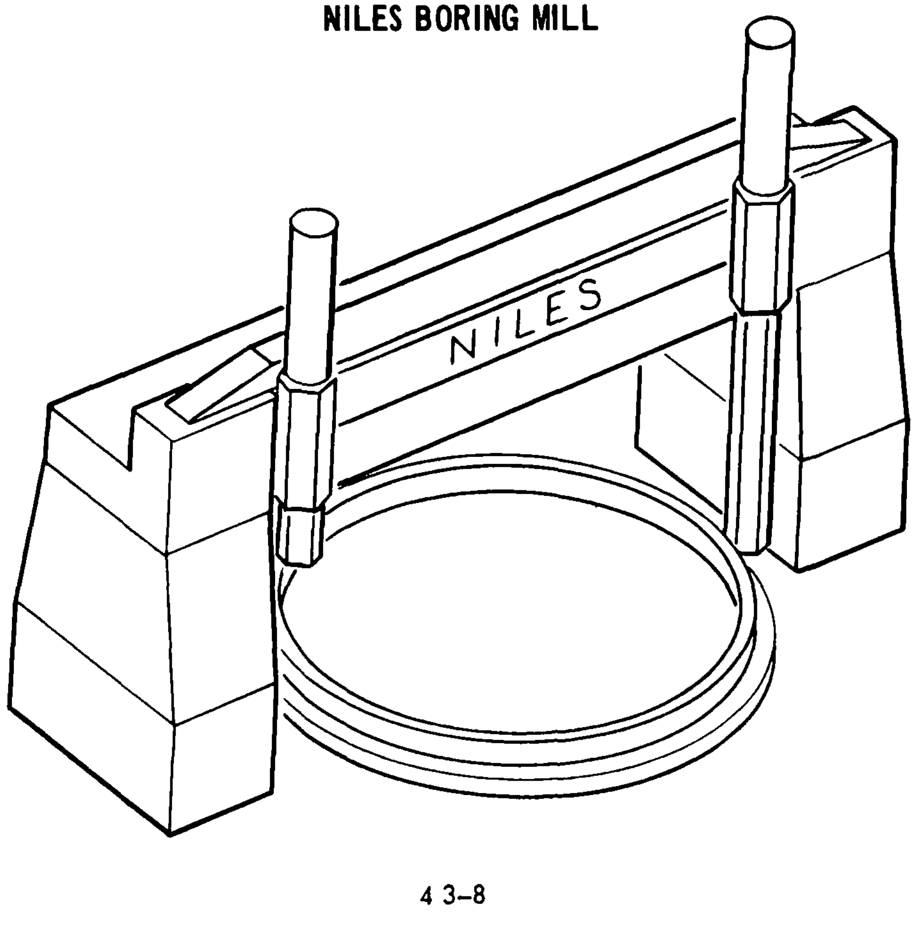


FIGURE 4.3-9

At Michoud, the gore segments will be trimmed, beveled and welded together.

The aluminum fitting that forms the closure, or apex, of the dome is machined oversize. The fitting will be shrunk by dry ice to an interference fit with the dome, and will then be welded into place. See Figure 4.3-11.

The dome will then be placed on a trim fixture and trimmed preparatory to welding to the "Y" ring.

Subassembly - Dome and "Y" Ring - The "Y" ring will be placed in a weld fixture and trimmed to match the dome. The dome assembly will be lowered into the "Y" ring, trimmed to match the "Y" ring and welded from the inside using MIG welding equipment. See Figure 4.3-12. This procedure will be common to both the forward and aft dome/ring subassemblies.

Tank Assembly - The LH2 tank will be assembled by an inverse stacking procedure. Assembly will take place in the VAB in Weld Station No. 1. See

DOME ASSEMBLY

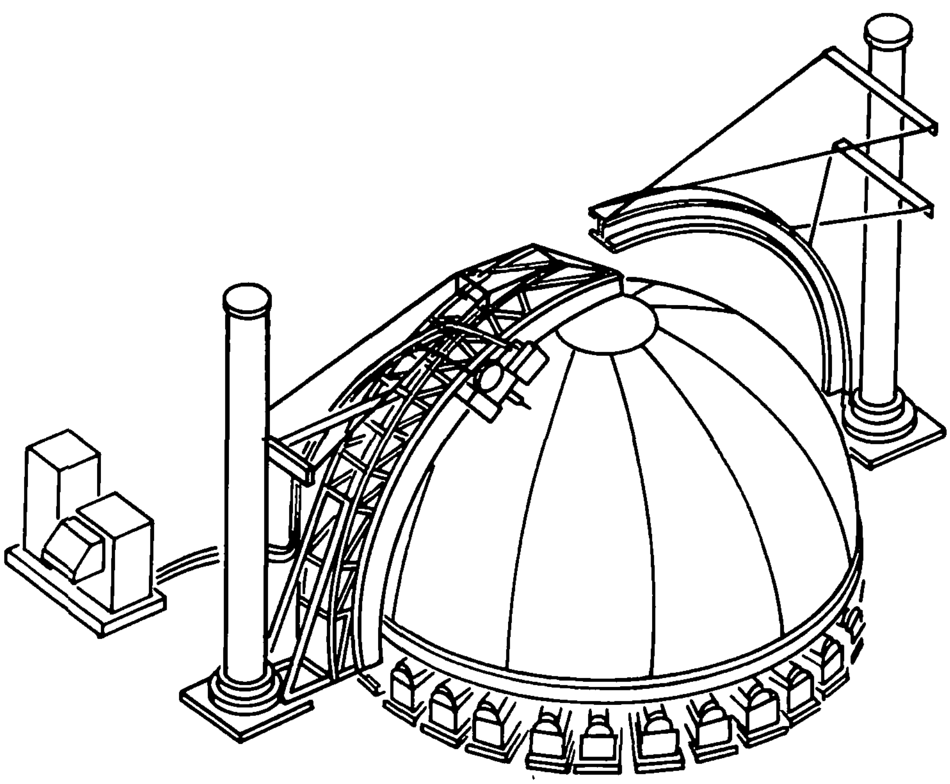


FIGURE 4.3-10

WELD FIXTURE, APEX

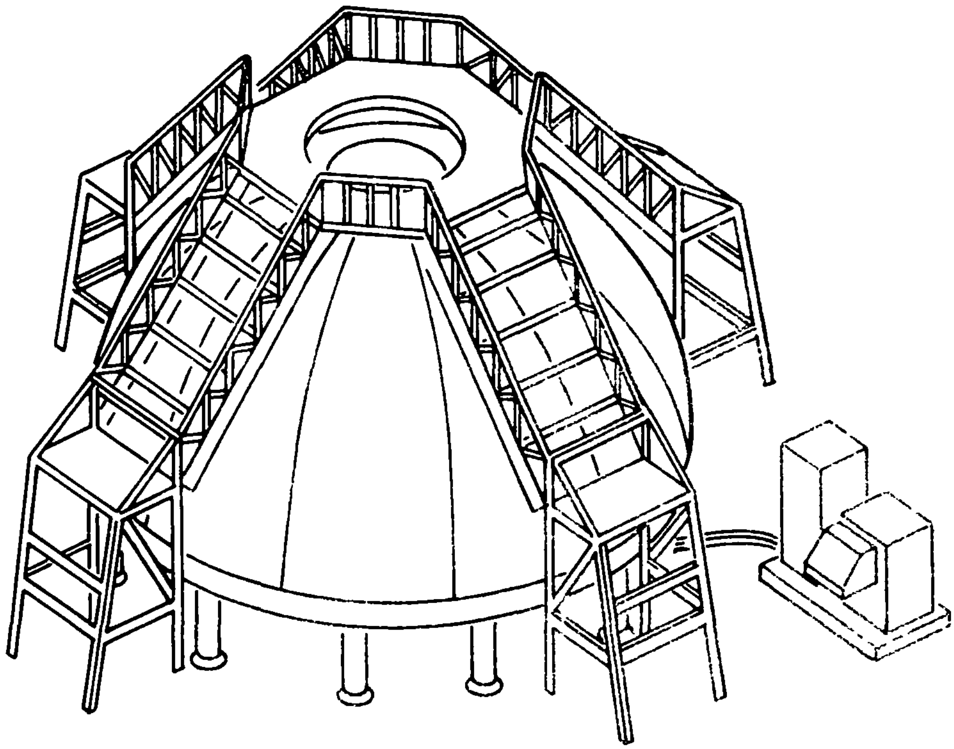


FIGURE 4.3-11

WELD FIXTURE, DOME TO "Y" RING

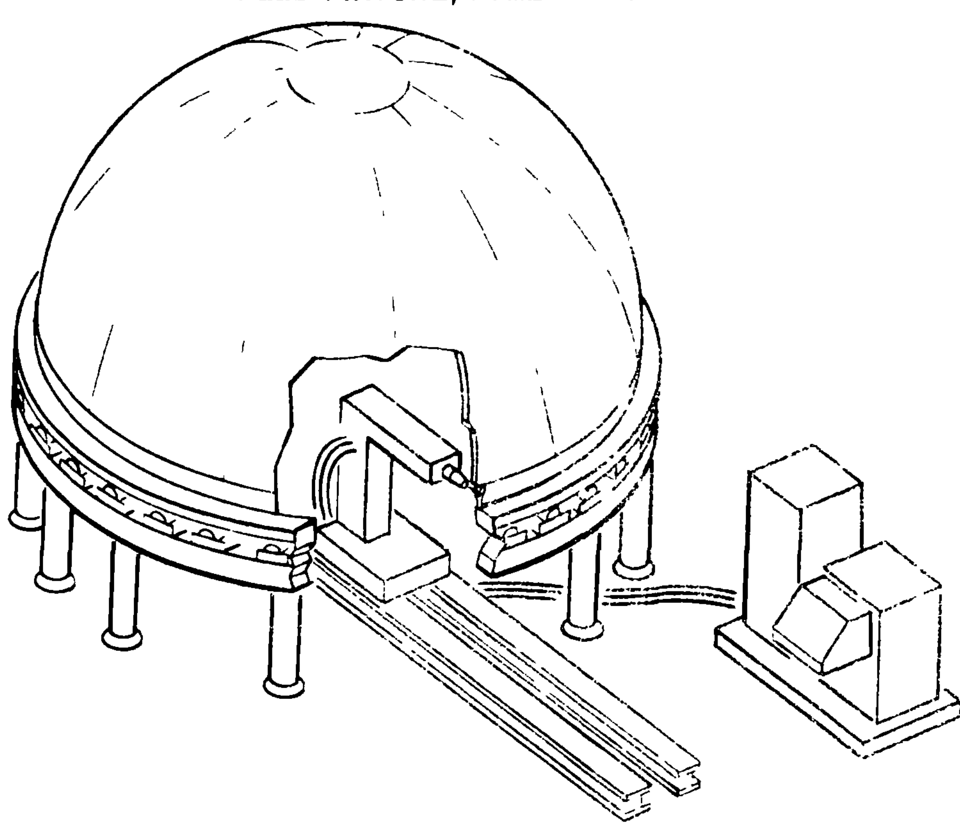


FIGURE 4.3-12

Figure 4.3-13. The forward No. 1 cylindrical section is transferred at grade level to the weld station turntable from a transporter which is in existing GFE inventory. The forward dome will be positioned on top of the No. 1 section. Girth welding will be accomplished by power rotating the turntable and the work past the welding head. See Figure 4.3-14. When welding is completed the outside bead is machined, in place to near flush, with a mill head attachment. X-Ray and penetrant inspection follows until flaw analysis is complete. Figure 4.3-14 shows a modified Saturn GSE lifting spider which interfaces with the normal section joining ring. This protects the "Y" ring surfaces and provided optimum lifting with minimum part stress. The crane hook is attached to the spider lifting hook and the completed dome No. 1 section is lifted to allow placement of the No. 2 cylindrical section which is centered and welded in the manner shown in Figure. 4.3-14. This process is repeated until all ten sections and the aft dome are welded in place.

Attach Holes - The final operation on the LH2 tank prior to removal from the tank welding fixture will be the drilling of the forward and aft attach holes. Using optical alignment equipment, four index holes will be located and drilled near the "X" and "Z" axis. From these index holes, the remaining attach holes will be drilled undersize using a 90° quadrant drill plate. These holes will be reamed full size when the mating sections are joined in the final assembly of the fuselage. This procedure will be common to the forward and aft rings.

The completed tank is then lifted clear of the weld fixture, rotated to the horizontal position, and moved to the pressure test area for leak and proof pressure testing.

Handling the LH2 can be accomplished by use of Modified Saturn GSE. This usage is shown pictorially in Figures 4.3-44 through 4.3-51.

MODIFIED WELD STATION NO. 1 – VAB

NOTE

MODIFICATION CONSISTS OF INCREASING WELD STATION NO. 1 HEIGHT AS SHOWN

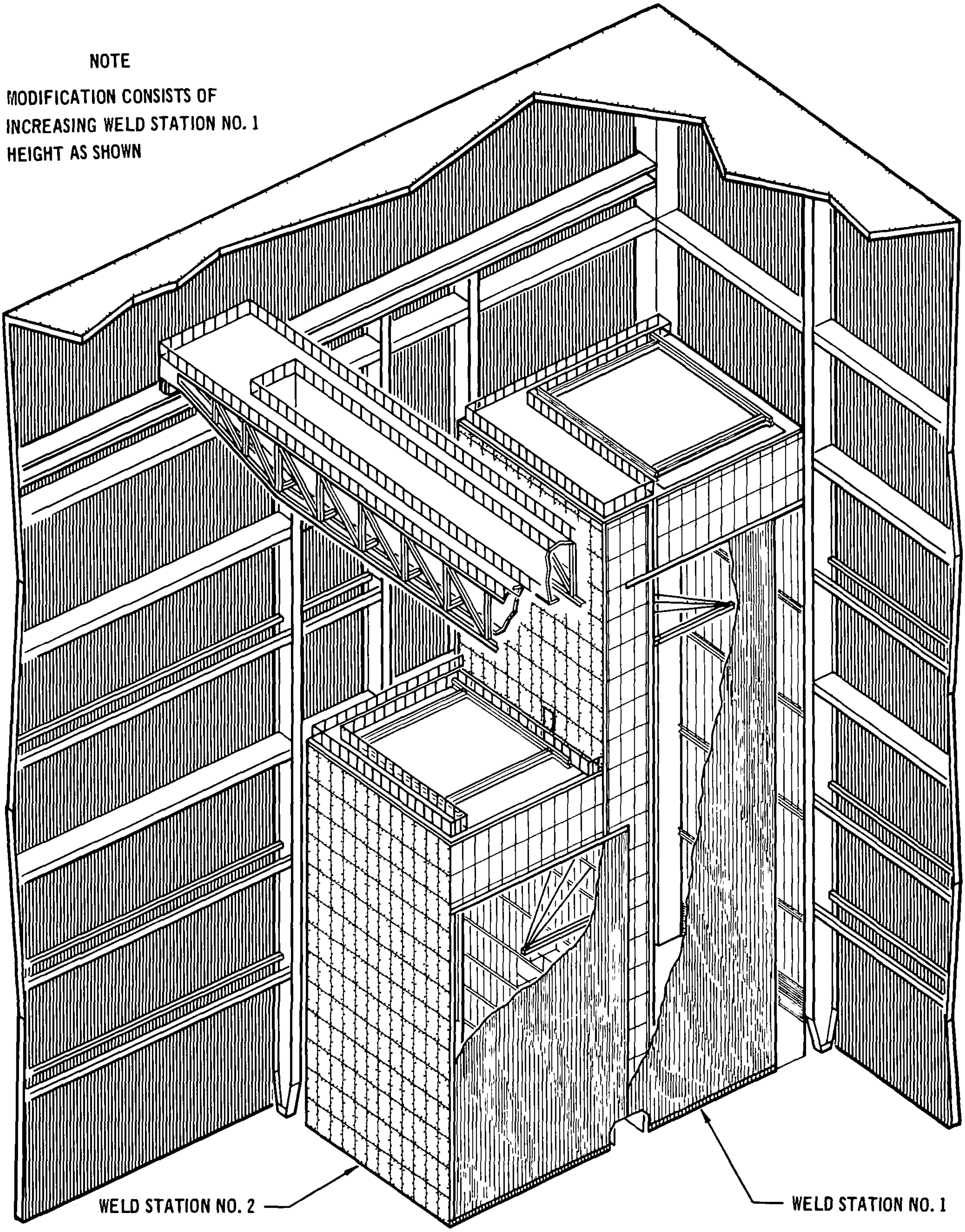
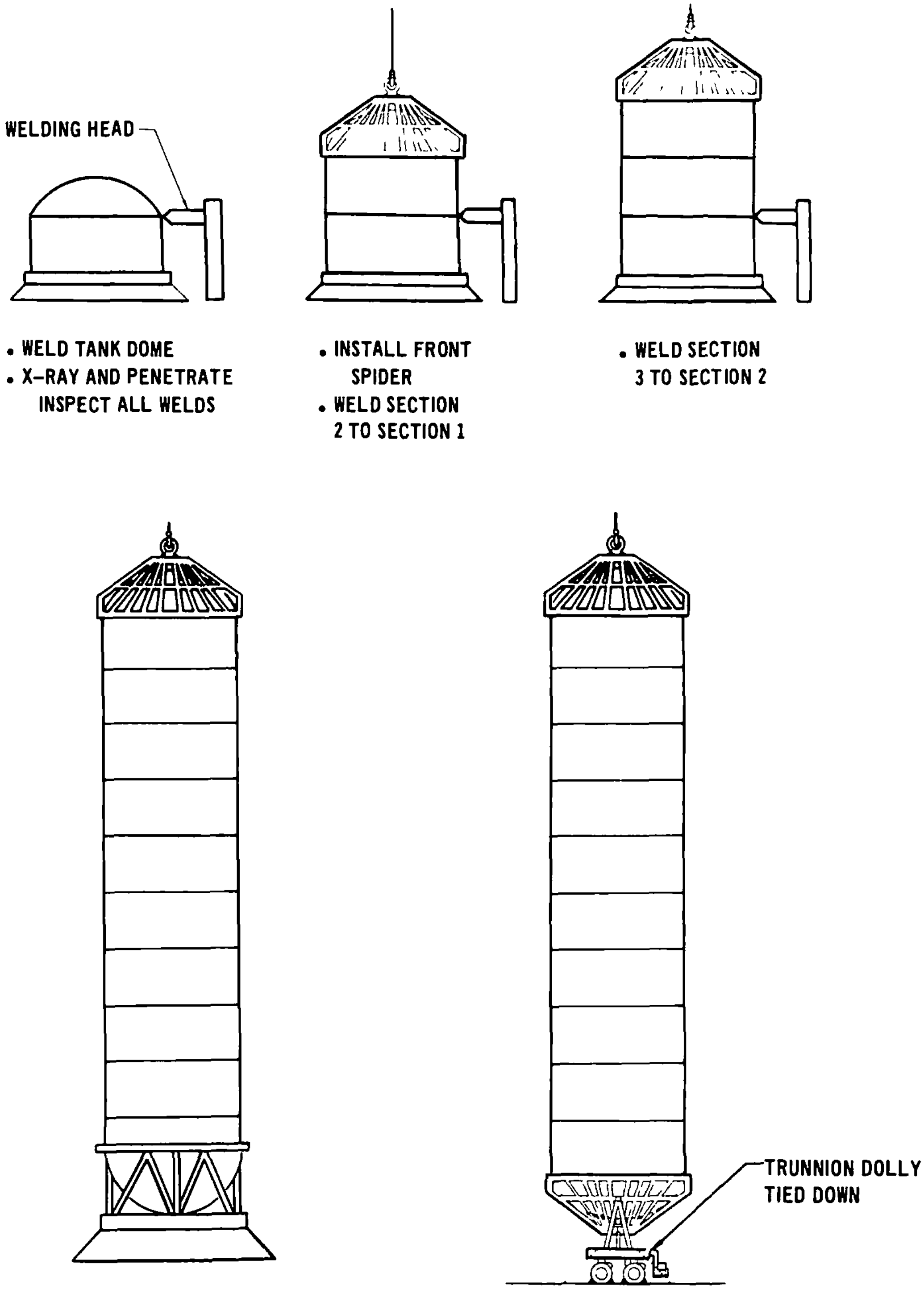


FIGURE 4.3-13

LH_2 TANK ASSEMBLY SEQUENCE



• INSTALL TEST FLANGE COVERS
• REMOVE TANK FROM FIXTURE

• LOAD TANK ON TRUNNION DOLLY

FIGURE 4.3–14

4.3.1.5 Tank Testing

Pressure Test - Leak and proof pressure tests will be accomplished in accordance with detailed test procedures which will insure the adequacy and safety of the tests.

Basically, the test will consist of filling the LH2 tank to progressively higher pressures using missile grade air, monitoring for leaks. Any leaks detected would be located by introducting a trace gas (helium) into the tank and probing externally with a mass spectrometer, or sniffer.(Figure 4.3-15)

After completion of leak pressure tests, the tank is ready for cleaning.

The present facility at Michoud is not capable of safely supporting pneumatic pressure tests. Detailed requirements, construction schedule, and cost estimates for a suitable facility (Figure 4.3-16) are given in Paragraph 4.3.1.8.

PROPOSED PNEUMOSTATIC TEST FACILITY

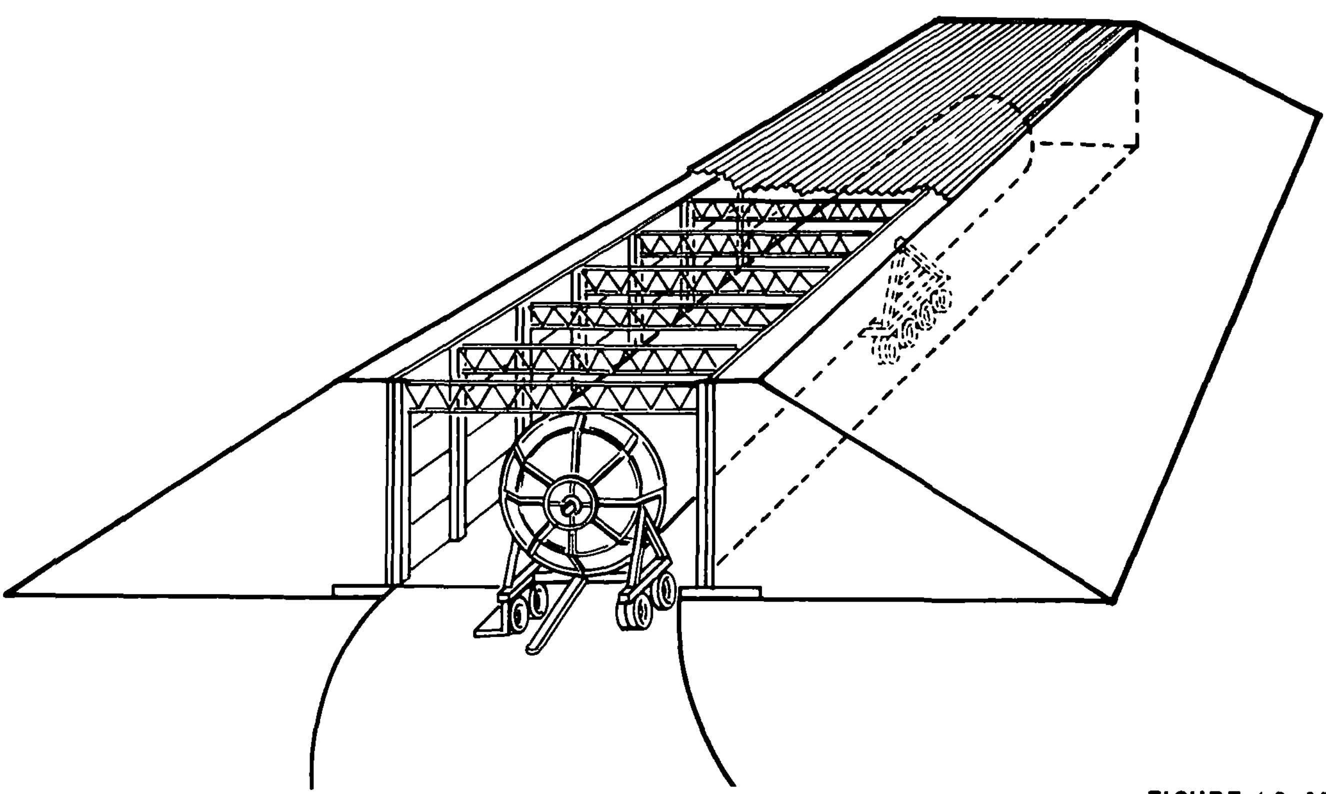


FIGURE 4.3-15

MODIFIED CLEANING STATION – VAB

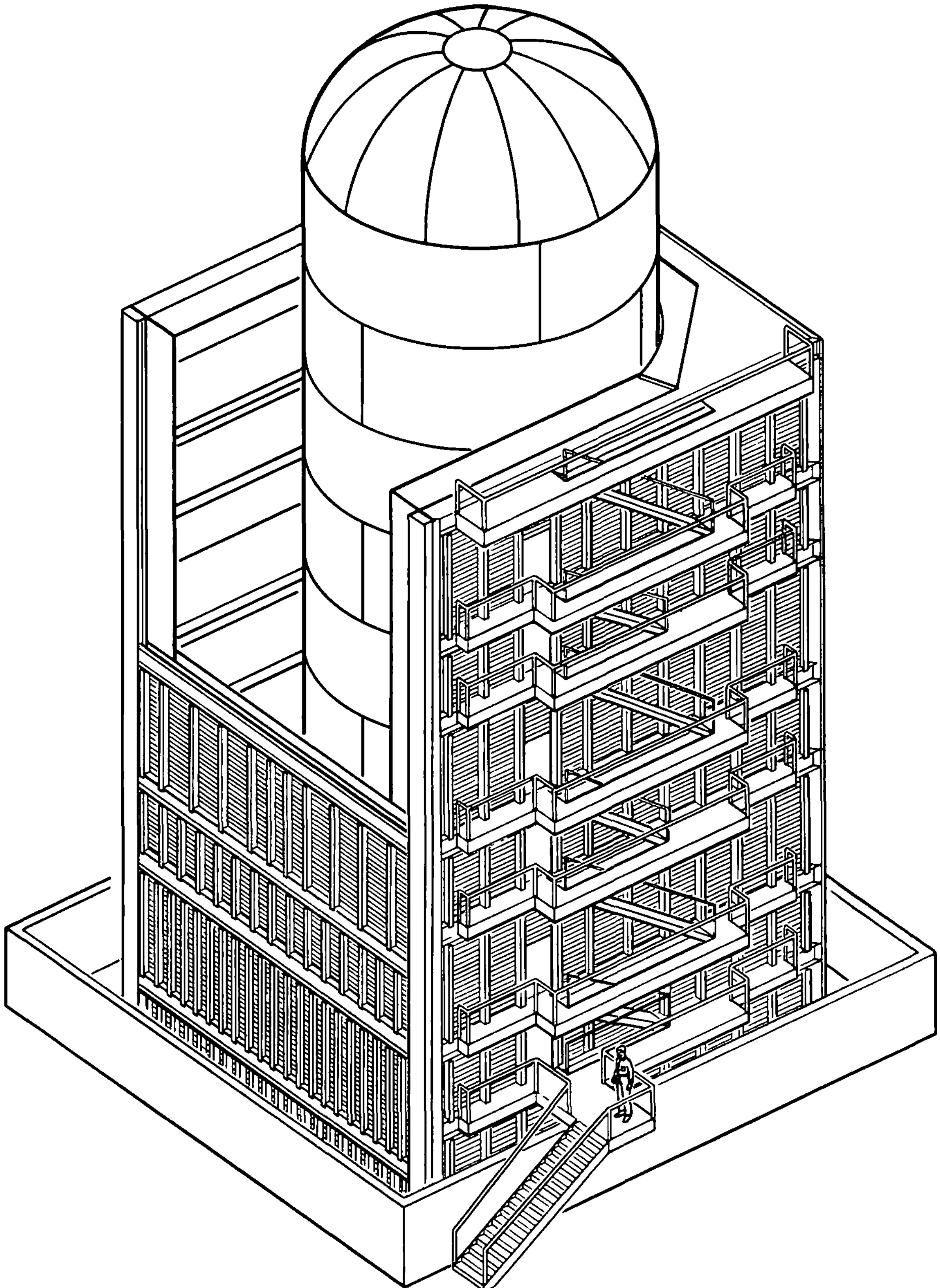


FIGURE 4.3–16

4.3.1.6 Insulation Installation - The interior of the LH2 tank will be insulated by applying pre-cut tiles to the skin and then covering the tiles with glass cloth. The insulation adhesives will be "cured" by raising the temperature in the tank for a specified time. After insulation is completed, the interior of the tank is again cleaned.

No facility presently exists at Michoud, which is capable of supporting insulation installation. MDAC proposes to modify an area of Michoud, Bldg. 103, as shown in Figure 4.3-17 to support this operation. Detailed requirements, construction schedule and estimated costs for such modifications are given in Paragraph 4.3.1.8.

4.3.1.7 Facility Requirements

Facility Requirement

Tank Fabrication - See Table 4.3-1

Tank Assembly - See Table 4.3-2

PROPOSED INSULATION INSTALLATION FACILITY

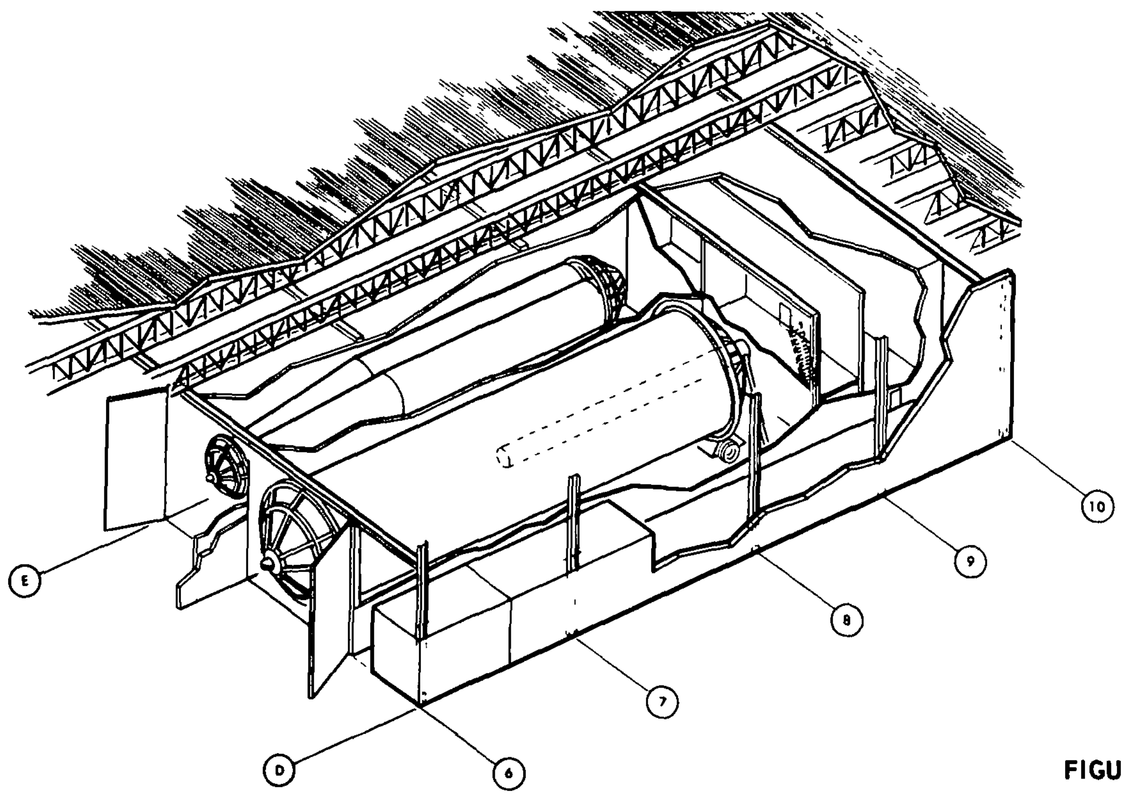


FIGURE 4.3-17

TABLE 4.3-1

TANK FABRICATION FACILITY REQUIREMENTS

FACILITY REQUIREMENT	FACILITY AVAILABILITY
AREA	
Approx. 20,000 sq. ft.	Existing Contractor
MAJOR EQUIP.	
STRETCH PRESS forming dome gore segments 3 AXIS PROFILER milling isogrid in skin POWER BRAKE forming cylindrical skin segments	Existing Contractor
VERTICAL BORING MILL machining "Y" Rings WELD FIXTURE weld "Y" Ring segments	Existing Michoud
WELDING EQUIP.	
ELECTRON BEAM welding "Y" Rings	New Michoud (See Orbiter Plan)
LABORATORY	
NON-DESTRUCTIVE TEST METAL FINISH PROTECTIVE COATINGS	Existing Contractor
PROCESSING FACILITIES	
CLEAN AND RINSE SYSTEM CHEM-MILL	Existing Contractor
ANODIZING SYSTEM	New Michoud (See Orbiter Plan)
X-RAY	
AUTOMATIC SYSTEM X-Ray "Y" Ring welds	Existing Michoud
SPECIAL	
INDUCTION HEATERS stress relief "Y" Ring welds	Existing Michoud

TABLE 4.3-2

LH_2 TANK ASSEMBLY FACILITY REQUIREMENTS

FACILITY REQUIREMENT	FACILITY AVAILABILITY
AREA	
Approx. 40,000 sq. ft. required. To maintain weld integrity, this area must be environmentally controlled to 75 ± 5°F with 50% max. RH. Foundation under weld stations should be vibration free.	Existing Michoud, Bldg. 103, "Gray Box" and Bldg. 110 Vertical Assembly Bldg. (VAB).
MAJOR EQUIP.	
WELD FIXTURE trim and weld gore-to-gore WELD FIXTURE weld domes to "Y" Ring WELD FIXTURE trim and weld cylindrical segments WELD FIXTURE trim cylinder ends	Existing Michoud, Bldg. 103, "Gray Box"
WELD FIXTURE (WELD TOWER) stack and weld domes and cylinders ALIGNMENT FIXTURE maintain alignment during stack and weld and for locating attachment holes	Existing Michoud, Bldg. 110, Bay 1 (MOD req'ts, costs and schedule given in Para. 4.3.1.8).
FACILITY cleaning and hydrostat	Existing Michoud, Bldg. 110. (MOD req'ts, cost est, and schedule given in Para. 4.3.1.8).
FACILITY insulation installation with ancillary vacuum pumps, recorders, etc.	NEW. Contractor proposes to modify an area in Michoud, Bldg. 103 as shown in Figure 4.3-17. (Req'ts, cost est, and schedule given in Para. 4.3.1.8)
FACILITY pneumatic testing	NEW. Contractor proposes a new construction at Michoud as shown in Figure 4.3-15. (Req'ts, cost est, and schedule given in Para. 4.3.1.8)
WELDING EQUIP.	
AUTOMATIC MIG AUXILLARY EQUIP. (weld heads provided as components of weld fixtures)	Exist Michoud, Bldg. 103 and 110. (Will require modifications to power supplies)

TABLE 4.3-2 (Cont.)

LH_2 TANK ASSEMBLY FACILITY REQUIREMENTS

FACILITY REQUIREMENT	FACILITY AVAILABILITY
LABORATORY	
NON-DESTRUCTIVE TEST METAL FINISH PROTECTIVE COATING	Existing Michoud
PROCESSING FACILITY	
CLEAN AND RINSE SYSTEM ALODINE SYSTEM	Existing Michoud
X-RAY	
(X-Ray heads provided as component of weld fixtures)	Existing Michoud
UTILITIES	
90-100 PSI FILTERED FACTORY AIR 115V 60 CYCLE ELECT. OUTLETS 440V 60 CYCLE ELECT. OUTLETS ARGON, HELIUM SUPPLIES WELDER COOLING WATER NORMAL LIGHTING	Existing Michoud

4.3.1.8 Modifications, Specifications, Costs and Schedules

Vertical Weld Station Modification - The existing VAB weld station (No. 1) has the gross capability of accepting the 134 foot long LH2 tank, but will require modification. In the present configuration, the weld station is protected by a thermal curtain up to the 112 foot level with a removable cap at that level. The purpose of the curtain and cap is to maintain the environmental control required for the welding operation. The required modification consists of adding an additional 38 feet of thermal curtain, and relocating the cap proportionately. (See Figure 4.3-13).

Modification of Weld Station:

Design Start Date	1 July 1972
Construction Completion Date	1 October 1973
(Based on Master Schedule)	
Estimated Cost	$265,000.00

Cleaning Facility - The Cleaning Workstand will be modified to accept the 33 foot diameter x 135 foot Hydrogen Tank. Modification of framing will provide clearance when the tank is lifted to maximum hook height (183 feet). Modification will consist of removing floor framing at 3 levels on the north elevation to provide an opening roughly 36 ft. W x 34 ft. H. The height of framing is then reduced to 39 ft. thus assuring approximately 9 ft. vertical clearance from tank to framing when crane hook is at maximum height. A door will be added to cover the opening. It will be lowered vertically on the outside face of the stand, by an electrically driven actuator. Bracing between new and existing columns, and in the level below the new columns, will be added to restore rigidity lost by the removal of floor framing. Platforms will be removed in the area of the modified opening. (See Figure 4.3-16).

Modification -

Design Start Date	1 March 1972
Construction Completion Date	1 January 1974
Estimated Cost	$60,000

Pneumostatic Test Facility - The present high-pressure test facility at Michoud lacks the capability to support either LH2 or LOX tank testing. A new facility will be required.

It is proposed that a three-sided revetment be constructed. (Figure 4.3-15 shows typical structure). Dimensions at floor level will be 60 x 150 ft; clear height will be 40 ft. The area is to be covered by a steel-framed weather cover.

The estimate is predicated on a concrete lined earth back-filled revetment. The interior surface is assumed to be precast concrete slabs supported by retaining precast concrete columns, with restraining dead man ties back into the earth fill. The fill, which is to be obtained by regrading the surrounding area, will be placed with a 1:2 slope, covered with jute mat and seeded to control erosion. To obtain adequate foundation conditions for the revetment, a trench will be excavated 10' deep and back filled with sand under the heaviest portion of the revetment. The floor will be a 9 in. concrete slab. Four driven piles will be used as tie-down restraints against vertical upward reactions. Other piles provide support for interior revetment surfaces as required. Friction piles will develop sufficient bearing for structures.

Modification High-Pressure Facility -

Design Start Date	1 March 1972
Construction Complete Date	1 January 1974
Estimated Cost	$339,000

Insulation/Installation Room - The present manufacturing plan calls for the booster LH2 tank to be insulated on the inside. There is presently no improved facility at Michoud which can perform this task. To satisfy this requirement, it is proposed that Bldg. 103 be modified as follows: (See Figure 4.3-17). The facility shall be constructed within existing Bldg. 103. The facility will be 190 ft. long, 77 ft. wide and 40 ft. high.

A new DX air conditioning system will be installed with air cooled condensers on the roof to maintain 50°F $\pm$ 5°F within the room during application. The 350°F required for the cure cycle will be by gas fired makeup units. Air conditioning will be shut down during cure cycle. System components in the air stream shall be explosion proof due to the presence of MEK.

The ceiling shall be cement asbestos board suspended at the lower chord.

Lighting to be 50 F.C. maintained at the 5'-0" level using explosion proof mercury vapor lamps.

Walls shall be constructed of steel stud and cement asbestos board with 3" insulation bats. Supplementary steel framing to be used for wall support.

Personnel door, 12' vertical lift door, will be provided and (2) 35' motorized sliding doors are included.

Approximately 200 KVA of power panels will be installed for 480V, 3PH, 60HZ power.

Floor to be sealed.

Fire protection will be a high hazard wet type sprinkler system.

Power run outs and occupancy costs are not part of this estimate.

Design Start Date	1 November 1972
Construction Complete Date	1 June 1974
Estimated Cost	$636,000

4.3.2 LOX Tank Manufacturing

4.3.2.1 Tank Description

The LOX Tank Assembly (Figure 4.3-18) will be made up of four isogrid-machined truncated sections, one isogrid-machined cylindrical section, two isogrid-machined "Y" Rings and two dome assemblies. The truncated sections, cylindrical section, "Y" Rings and dome assemblies will be welded together to make up the LOX Tank Assembly. An illustrated Manufacturing Flow Sequence is shown in Figure 4.3-19. A Manufacturing Flow Chart and Schedule are shown in Figure 4.3-20.

LOX TANK ASSEMBLY

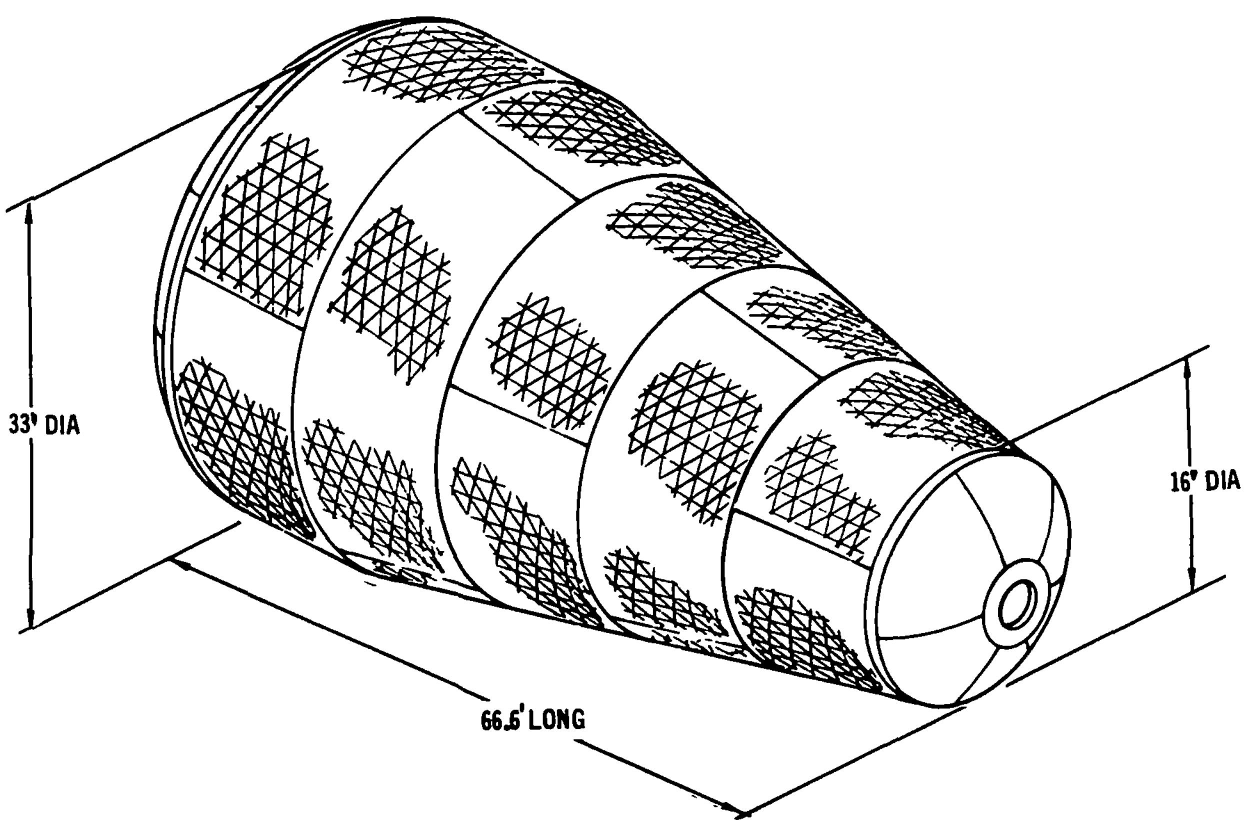


FIGURE 4.3-18

LO_2 TANK

Manufacturing Assembly Sequence – Booster

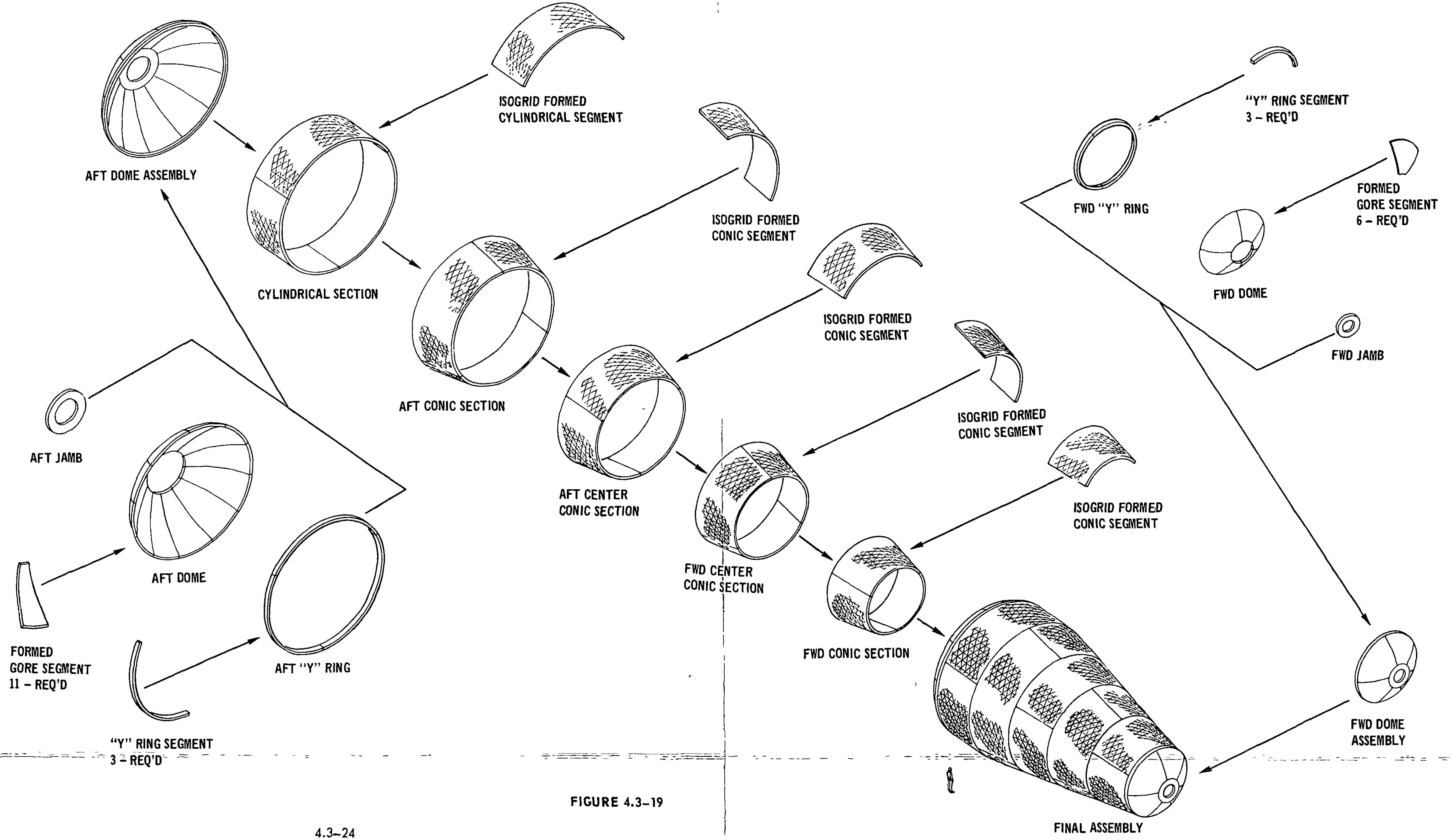


FIGURE 4.3–19

LOX TANK ASSEMBLY
MANUFACTURING FLOW CHART AND SCHEDULE
Booster

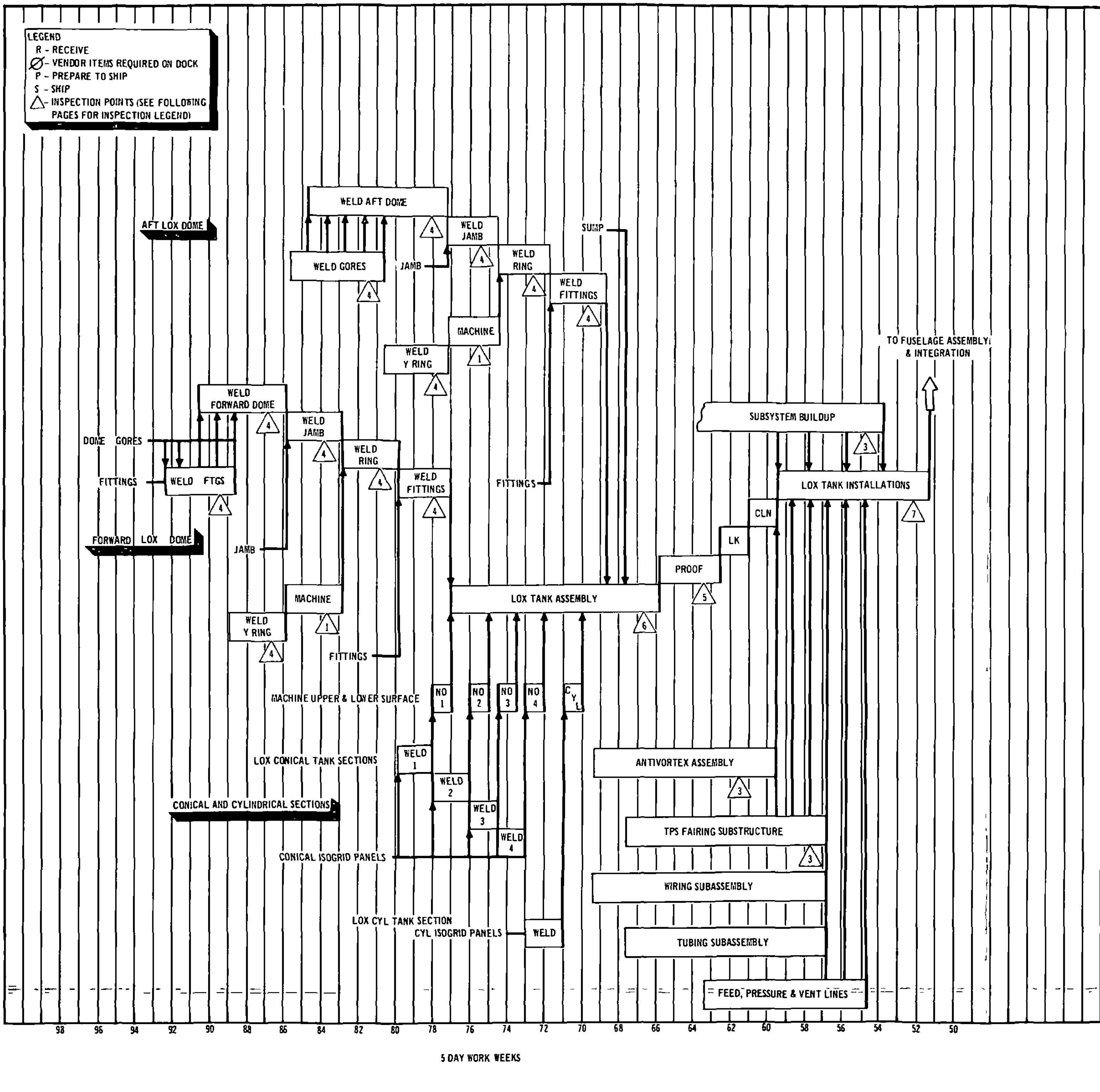


FIGURE 4.3-20

4.3.2.2 Manufacturing Site

Several sites were evaluated for LOX tank manufacture. Details of the evaluation are provided in Paragraph 4.2. As a result of the evaluation, it is recommended that the tanks be assembled at the NASA owned Michoud Assembly Facility (MAF) in Louisiana (See Figure 4.3-5), with fabrication support by Contractor Facilities.

4.3.2.3 Manufacturing Approach

Piece-part fabrication and processing will be accomplished largely in Contractor owned facilities. This will include forming, cleaning and anodizing tank dome gores and tank skin pocket milling. Subassembly will take place both at Contractor facilities and at Michoud. Final assembly welding of the tanks will be accomplished at Michoud. Most operations at Michoud will utilize existing Saturn Tooling and GSE, modified as required.

4.3.2.4 Manufacturing Operations

Cylindrical and Conical Sections - The cylindrical section and conical sections of the LOX tank shell will each be fabricated of three plates of 2-1/2 x 144 x 400 in. aluminum. The plates will be isogrid-machined (See Figure 4.3-6) using N/C 3 axis profiles, such as the one shown in Figure 4.3-7, and then rough trimmed to size.

Using a power brake or age forming, each plate will be contoured to the correct curvature and then anodized. The forming operation will be accomplished in a Contractor facility, if the power brake method of forming is used. If it is necessary to age form the plates, the aging and anodizing will be accomplished at Michoud in new facilities presently being planned for the Shuttle Orbiter.

At Michoud, welding of the three plates into the cylindrical or conical shape will be performed in a vertical position using MIG welding equipment. Each weld will be shaved and X-Rayed. Forward and aft edges of the section will be trimmed preparatory to welding to the adjacent component.

The No. 3 conical section will be fabricated oversized to permit the welding and subsequent removal of a test dome.

"Y" Rings - The "Y" Rings (See Figure 4.3-8), which will be fabricated at Michoud, will be made up of purchased rolled and heat treated forgings which are welded together to form a ring. The forward ring is 16 feet in diameter. The aft ring is 33 feet in diameter. After aging, each ring will be machined to the required diameter and cross section on a boring mill similar to the one shown in Figure 4.3-9. The previously described isogrid pattern will then be machined into the outer circumference of each ring, using a tracer attachment on the boring mill. After machining operations are completed, the rings will be cleaned and anodized.

Domes - The forward dome, which is 16 feet in diameter, consists of six gore segments and a disk, or "dollar" closure. The aft dome, which is 33 feet in diameter, consists of eleven gore segments, with a closure. Additional penetrations are provided in the aft dome for LO_2 feed lines, pressurant lines, and instrumentation.

The forward and aft dome gores will be made from aluminum plate stock that has been formed on stretch form dies. After forming, the gore segments will be rough trimmed, chem-milled and anodized.

All the foregoing operations will be accomplished at existing Contractor facilities on modified existing equipment.

At Michoud, the gore segments will be trimmed, beveled and welded together. See Figure 4.3-10.

The aluminum fitting that forms the closure, or apex, of the dome will be machined oversize. The fitting will be shrunk by dry ice to an interference fit with the dome, and will then be welded in place.

Subassembly - Dome and "Y" Ring - The "Y" Ring will be placed in a weld fixture and trimmed to match the dome. The dome assembly will be lowered into the "Y" Ring, trimmed to match the "Y" Ring and welded from the inside using MIG welding equipment. See Figure 4.3-12. This procedure will be common to both the forward and aft dome/ring subassemblies.

Tank Assembly - LOX Tank assembly sequence is influenced by the requirement to perform hydrostatic tests on the partially completed tank.

The LOX tank will be assembled by a modified inverse stacking procedure. The No. 3 conical section is transferred at grade level to the weld station turntable from a transporter which is in existing GFE inventory. The test dome/adapter will be positioned on top of the No. 3 section. Girth welding will be accomplished by power rotating the turntable and the work past the welding head. (See Figure 4.3-21) X-Ray and penetrant inspection follows until flaw and analysis is complete. The crane hook will be attached to the test dome lifting hook. The dome and No. 3 conical section will be lifted to allow placement of the No. 4 conical section which will be centered and welded in the manner shown in Figure 4.3-21. This process will be repeated for the cylindrical section and the aft dome. In all cases except the test dome weld, the outside bead is machined in place with a mill head attachment to near flush.

This intermediate assembly will then be moved to the hydrostat test tower. Refer to Paragraph 4.3.2.5 for hydrostatic test procedure.

Upon completion of hydrostatic testing, the intermediate assembly will be returned to the weld station and positioned on the turntable. The test dome/adapter will be cut off and removed from the area.

The remaining two forward conical sections and the forward dome assembly will

LOX TANK ASSEMBLY

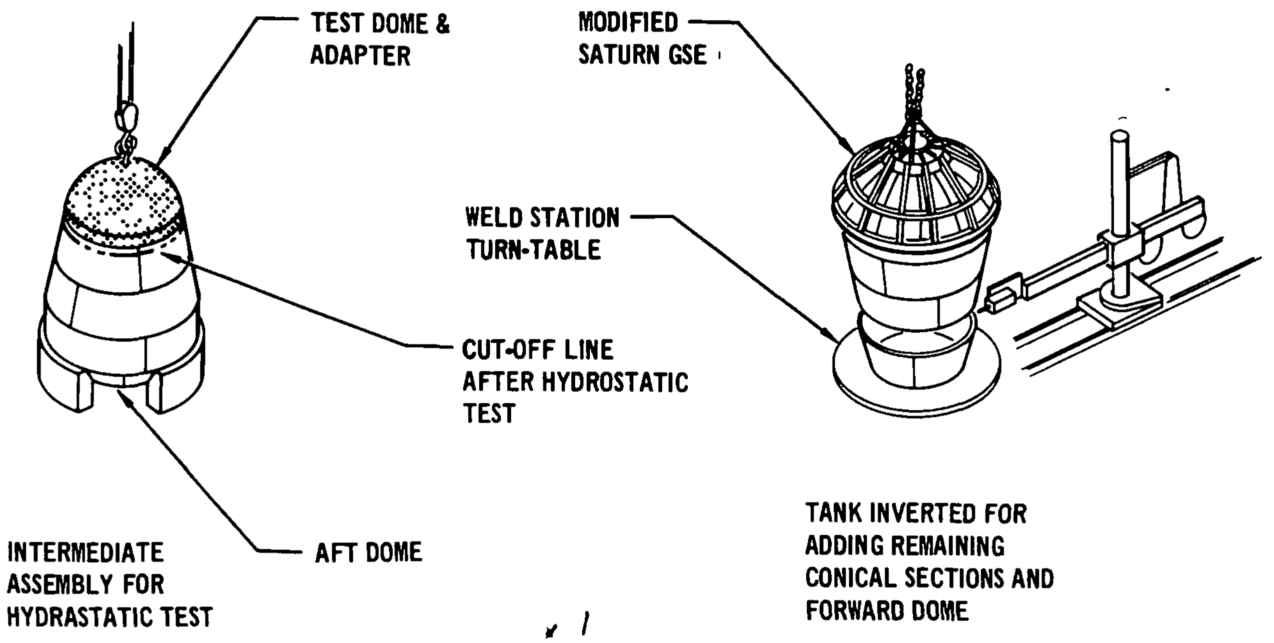


FIGURE 4.3-21

then be added sequentially in a continuation of the inverse stacking procedure previously described.

Attach Holes - The final operation of the LOX tank prior to removal from the tank welding fixture will be the drilling of the forward and aft attach holes. Using optical alignment equipment, four index holes will be located and drilled near the "X" and "Z" axis. From these index holes, the remaining attach holes will be drilled undersize using a 90° quadrant drill plate. These holes will be reamed full size when the mating sections are joined in the final assembly of the fuselage. This procedure will be common to the forward and aft rings.

The completed tank is now ready for pneumostatic testing. Refer to Paragraph 4.3.2.5 for test procedure.

After pneumostatic testing, the tank will be returned to the VAB cleaning station where it will be LOX cleaned, then sealed.

4.3.2.5 Tank Testing

Hydrostatic Testing - Intermediate Assembly - Testing will be accomplished in accordance with detailed procedures which will insure the adequacy and safety of the test. Basically the test will consist of filling the partial tank with a suitable medium (sodium dichromate) and then applying pressure using a standpipe into the test dome. Tank pressure will be adjusted as required by the test profile.

Upon completion of the test, the tank will be drained, rinsed and dried, and returned to the weld station for final assembly.

The existing hydrostatic test facility at Michoud must be modified to adequately support tests on the LOX tank. Detailed requirements, construction schedule and cost estimates for modifications to this facility are given in Paragraph 4.3.2.7.

Pneumostatic Testing - Leak and prooof pressure tests will be accomplished in accordance with detailed test procedures which will insure the adequacy and safety of the tests.

Basically, the test will consist of filling the LOX tank to progressively higher pressures using missile grade air, and monitoring for leaks. Any leak detected would be located by introducing a trace gas (helium) into the tank and probing externally with a mass spectrometer, or sniffer.

After completion of leak and proof pressure tests, the tank is ready for LOX cleaning.

The existing facility at Michoud is not capable of safely supporting pneumatic pressure tests. Detailed requirements, construction schedule, and cost estimates for a suitable facility (Figure 4.3-15) are given in Paragraph 4.3.1.8.

LOX Cleaning - The LOX tank will be inserted into the VAB cleaning tower where cleaning to LOX specifications will be accomplished. The existing cleaning facility is adequate. After cleaning and sealing, the LOX tank is ready for assembly into the booster fuselage.

4.3.2.6 Facility Requirements

Tank Fabrication - See Table 4.3-3

Tank Assembly - See Table 4.3-4

4.3.2.7 Modifications, Specifications, Costs and Schedules

Hydrostatic Test and Cleaning Facility - Cleaning Facility - The existing cleaning facility is basically acceptable for LOX tank cleaning. Extensive modifications to the facility are required for LH_2 tank cleaning.

Hydrostatic Testing - The existing hydrostatic test facility will require extensive modification to support LOX tank testing. Modifications will include:

- Rework of tank supports in test bay. (This MOD is also required for LOX and LH_2 tank cleaning.)
- Installation of a 250,000 gallon sodium dichromate tank. The tank will be supported on piling and will incorporate safeguards for controlling leaks, spillage or rupture.
- Installation of pumps, pump house, valves, regulator, filters and piping for transferring test medium.
- Installation of a standpipe system for accurately controlling test pressures.

Design Start Date	1 March 1972
Construction Completion Day	1 January 1974
Estimated Cost	$212,000

TABLE 4.3-3

LOX TANK FABRICATION FACILITY REQUIREMENTS

FACILITY REQUIREMENT	FACILITY AVAILABILITY
AREA	
Approx. 20,000 sq. ft.	Existing Contractor (partially shared with LH_2 Tank Fabrication).
MAJOR EQUIP.	
STRETCH PRESS forming dome gore segments	
3 AXIS PROFILER mil ing isogrid in skin	Existing Contractor
POWER BRAKE forming cylindrical skin segments	
VERTICAL BORING MILL machining "Y" rings	Existing Michoud
WELD FIXTURE weld "Y" Ring segments	
WELDING EQUIP.	
ELECTRON BEAM EQUIPMENT welding "Y" Rings	New Michoud (See Orbiter Plan)
LABORATORY	
NON-DESTRUCTIVE TEST	Existing Contractor
METAL FINISH	Existing Michoud
PROTECTIVE COATINGS	
PROCESSING FACILITIES	
CLEAN AND RINSE SYSTEM	Existing Contractor
CHEM-MILL	
ANODIZING SYSTEM	New Michoud (See Orbiter Plan)
X-RAY	
AUTOMATIC SYSTEM X-Ray "Y" Ring welds	Existing Michoud
SPECIAL	
INDUCTION HEATERS stress relief "Y" Ring welds	Existing Michoud

TABLE 4.3-4

LOX TANK ASSEMBLY FACILITY REQUIREMENTS

FACILITY REQUIREMENTS	FACILITY AVAILABILITY
AREA	
Approx. 40,000 sq. ft. required. To maintain weld integrity, this area must be environmentally controlled to 75 ± 5°F with 50% max. RH. Foundation under weld stations should be vibration free.	Existing Michoud, Bldg. 103, "Gray Box" and Bldg. 110, Vertical Assembly Bldg. (VAB) (shared with LH_2 Tank Assembly).
MAJOR EQUIP.	
WELD FIXTURE trim and weld gore-to-gore WELD FIXTURE weld domes to "Y" Ring WELD FIXTURE trim and weld cylindrical segments WELD FIXTURE trim cylinder ends	Existing Michoud, Bldg. 103, "Gray Box" (shared with LH_2 Tank Assembly).
WELD FIXTURE (WELD TOWER) stack and weld domes and cylinders ALIGNMENT FIXTURE maintain alignment during stack and weld and for locating attachment holes	Existing Michoud, Bldg. 110, Bay 2.
FACILITY cleaning and hydrostat	Existing Michoud, Bldg. 110. (MOD req'ts, cost est, and schedule given in Para. 4.3.1.8)
FACILITY pneumostatic testing	NEW. Contractor proposes new construction at Michoud as shown in Figure 3.4-15. (Req'ts, cost est, and schedule given in Para. 4.3.1.8)
WELDING EQUIP.	
AUTOMATIC MIG W/ANCILLARY EQUIP. (weld heads provided as components of weld fixtures)	Exist Michoud, Bldg. 103 and 110.
LABORATORY	
NON-DESTRUCTIVE TEST METAL FINISH PROTECTIVE COATING	Existing Michoud

TABLE 4.3–4 (Cont.)

LOX TANK ASSEMBLY FACILITY REQUIREMENTS

FACILITY REQUIREMENT	FACILITY AVAILABILITY
PROCESSING FACILITY	
CLEAN AND RINSE SYSTEM ALODINE SYSTEM	Existing Michoud
X-RAY	
(X-Ray heads provided as component of weld fixtures)	Existing Michoud
UTILITIES	
90-100 PSI FILTERED FACTORY AIR 115V 60 CYCLE ELECT. OUTLETS 440V 60 CYCLE ELECT. OUTLETS ARGON, HELIUM SUPPLIES WELDER COOLING WATER NORMAL LIGHTING	Existing Michoud

4.3.3 Forward Fuselage

4.3.3.1 Forward Fuselage Description

The forward fuselage assembly (Figure 4.3-22) will consist of a cockpit assembly, aft cockpit support cone, lower cockpit support cone, nose cap assembly, access hatch, and various installations, i.e. catwalks, equipment bays, insulation, and subsystem build-up. Actual interfaces either between or within these items will be controlled using coordinated tooling.

An illustrated Manufacturing Flow Sequence is shown in Figure 4.3-23. A Manufacturing Flow Chart and Schedule is shown in Figure 4.3-24.

FORWARD FUSELAGE ASSEMBLY

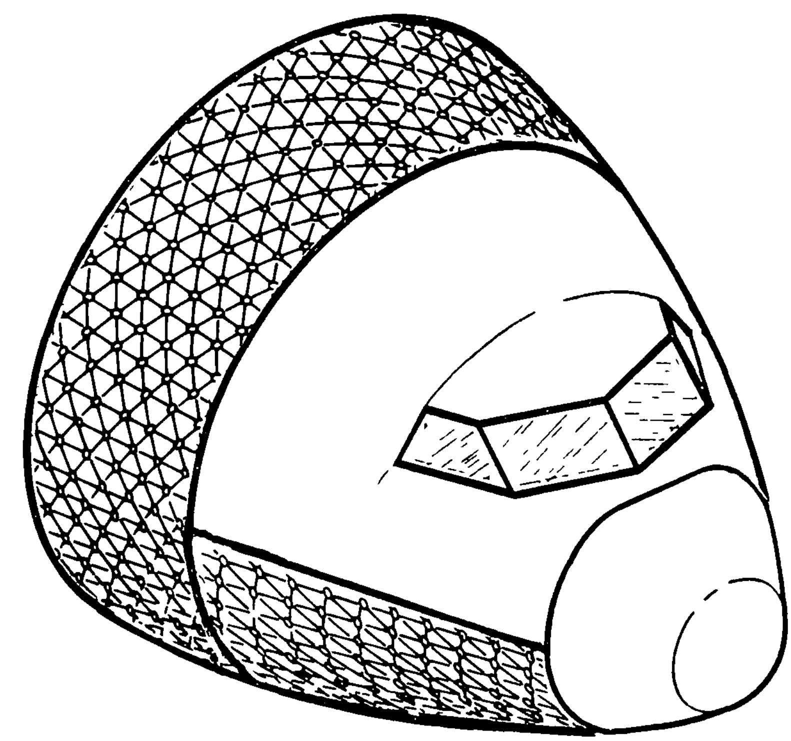


FIGURE 4.3-22

FORWARD FUSELAGE

Manufacturing Assembly Sequence – Booster

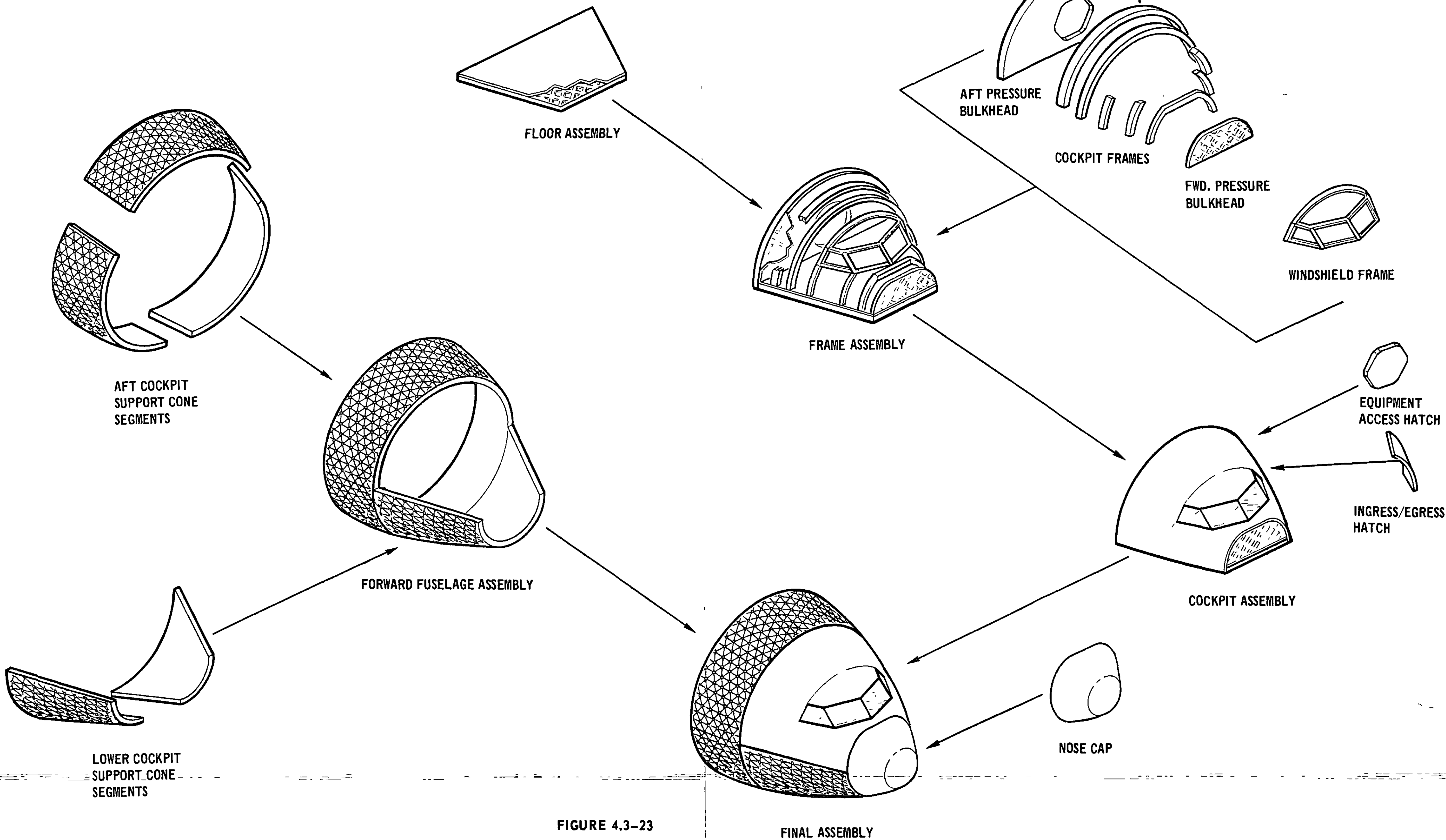


FIGURE 4.3–23

BOOSTER
FUSELAGE NOSE SECTION
Manufacturing Flow Chart & Schedule

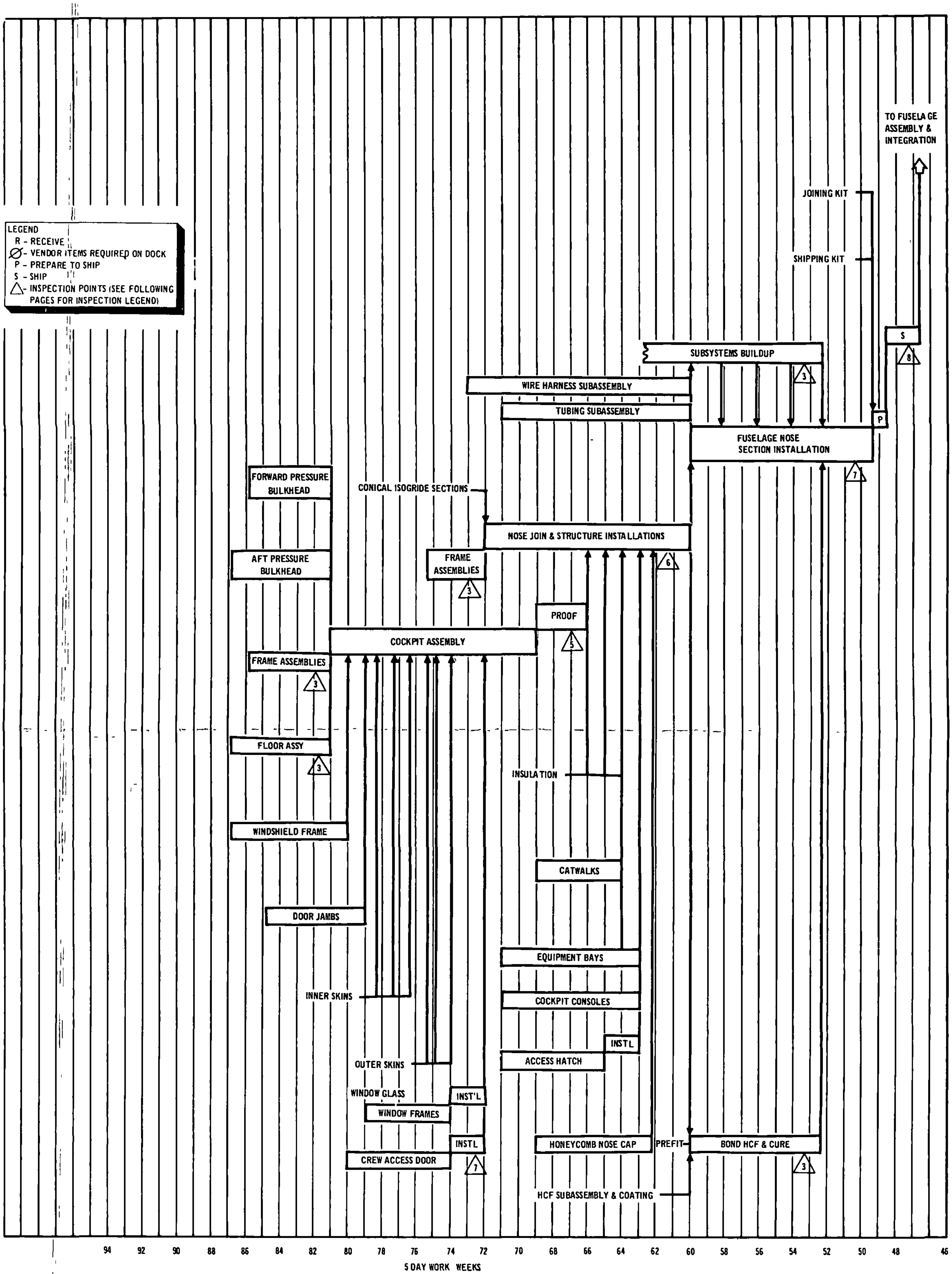


FIGURE 4.3-24

FORWARD FUSELAGE
MANUFACTURING FLOW CHART AND SCHEDULE
Fuselage Assembly and Checkout
Booster

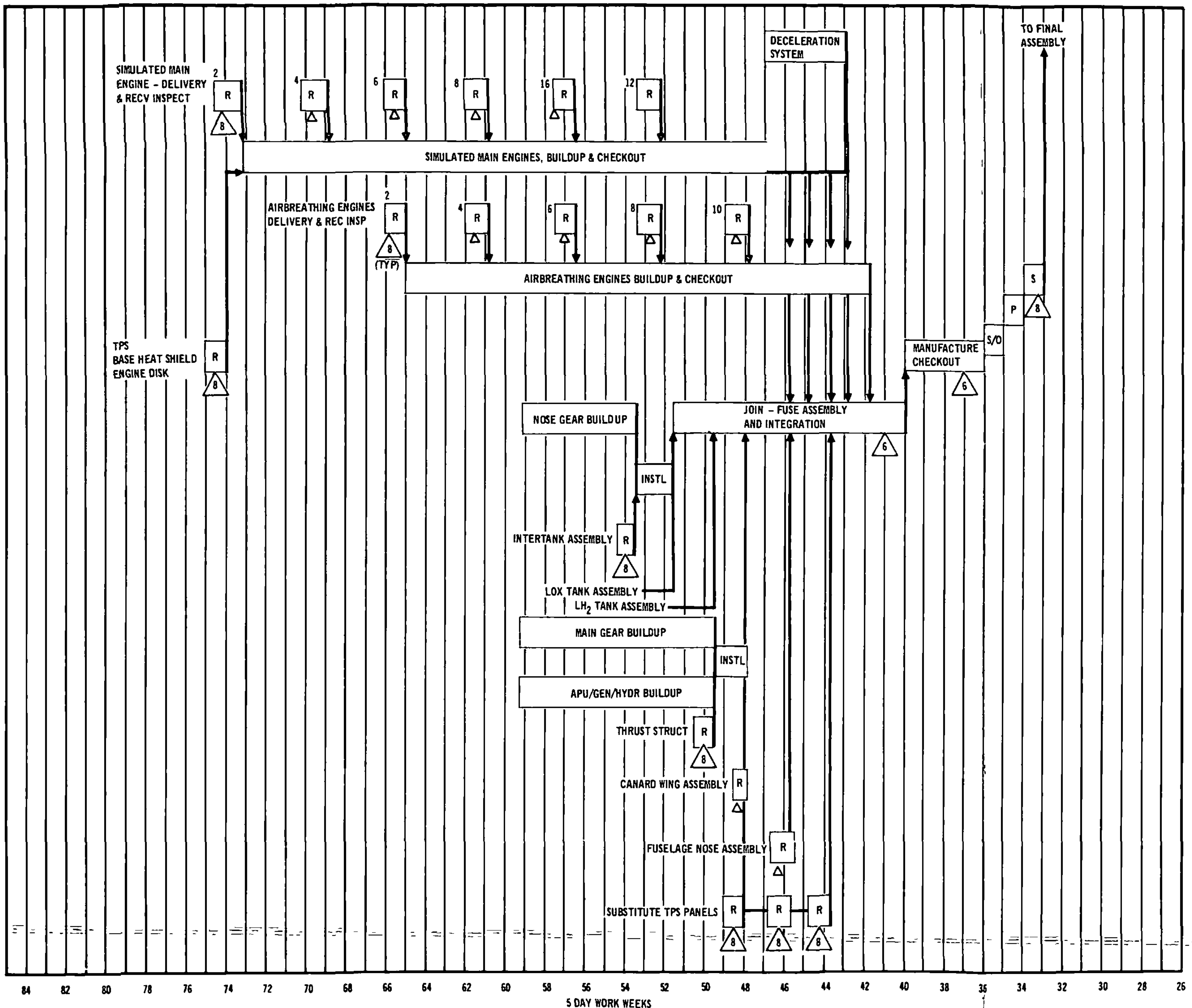


FIGURE 4.3-24 (Cont.)

4.3.3.2 Manufacturing Site

It is recommended that the forward fuselage be assembled at Contractor facilities.

4.3.3.3 Manufacturing Approach

Piece-part fabrication and processing is to be accomplished in contractor owned facilities. This will include skin and bulkhead pocket milling and forming, anodizing and processing. Sub-assembly and final assembly will also take place at contractor facilities. The completed forward fuselage will be shipped to Michoud for assembly into the fuselage assembly.

4.3.3.4 Manufacturing Operations

Cockpit Assembly - The cockpit assembly will be comprised of a forward and an aft pressure bulkhead, floor assembly, windshield frames, enclosure frame assemblies, inner and outer skins, door jamb and crew access door.

The machined windshield frames will be joined together and drilled in an assembly tool, with openings controlled by master tooling to provide interchangeability of windshield glass. Windshield frames are machined from titanium forgings.

The door jamb and crew access door are assembled in separate assembly tools. Door jamb panels include frames, skins and other details, fabricated from titanium and made into subassemblies.

There are approximately seven frame stations in the cockpit enclosure. Frame assemblies will be fabricated in sections and require skin attach flanges of varying bevels to fit the enclosure contours developed from loft lines. The frames and bevels will be held to close tolerances using form block tooling and existing hydro presses. Frame tolerances are critical since the cockpit enclosure assembly does not incorporate stringers.

The forward and aft pressure bulkheads will consist of isogrid-machined plate faced with stiffened sheets. These components, which form part of the cockpit enclosure primary structure, are built up as sub-assemblies prior to going into the major assembly fixture.

The inner skins will be formed from aluminum sheet using existing stretch presses.

The outer skin will be made up of titanium fabricated on form dies and a hot press.

Assembly of the cockpit enclosure structure will consist of fit-up and installation of the forward and aft bulkhead subassemblies, floor assembly, frame assemblies, windshield frame and window panels, door jamb, crew access door and inner and outer skins. After installation and checkout of the wiring and tubing the enclosure will be pressure and leak tested.

Pressure and leak testing will be accomplished in the assembly jig, which provides necessary structural support which is later provided by the forward fuselage structure. Upon completion of the testing, the enclosure will be ready for final assembly to the cockpit support cone and lower half assembly.

Aft Cockpit Support Cone - The aft cockpit support cone will be made up of three 120° isogrid machined and formed truncated cone segments. Each segment will be fabricated from aluminum plate. Using N/C equipment, these plates will be machined with a standing leg isogrid pattern, similar in design to the skins of the existing Thor/Delta vehicle presently being fabricated at the Santa Monica plant.

After machining, each sheet will be rough trimmed. Forming will be accomplished using a power brake or AGE forming fixtures. Each segment will then be finish trimmed and anodized preparatory to assembly into the support cone.

Assembly of the cockpit support cone will be performed in a vertical subassembly fixture. Sections are bolted together. After assembly into its truncated shape, the assembly will be placed in the main assembly jig.

Lower Cockpit Support Cone - The lower support cone will consist of two 90° isogrid segments similar in design to the aft support cone segments. Each segment will be fabricated from aluminum plate using manufacturing processes and equipment similar to those used for the support cone. Assembly will be accomplished in the vertical subassembly fixture.

Nose Cap - The nose cap assembly will consist of a spin formed titanium cap, with internal frames, covered with Hardened Compacted Fiber (HCF) blocks. After spin forming, the cap will be trimmed and the internal frames installed.

HCF blocks (3 in. x 24 in. x 24 in.) will be contour-machined using existing mill and tracer equipment. The blocks will be spray coated and cured at 2,300° F in an oven. The completed blocks will be bonded to the cap assembly using the bonding fixture, then cured again in the oven at 2,300°F.

Final Assembly - Forward Fuselage - Final Assembly will be accomplished in a horizontal major assembly jig. This will include fit-up of isogrid sections, cockpit enclosure, nose cap, and subsystem build-up. After assembly, the aft attach holes of the forward fuselage section will be drilled in the structure. Using optical tooling, four full-size holes will be drilled on the "X" and "Z" axis. From these index holes, the remaining holes will be drilled undersize in the structure. These holes will be reamed to full size when the mating sections are joined in the final assembly of the fuselage.

Facility Requirements

Forward Fuselage Fabrication - See Table 4.3-5

Forward Fuselage Assembly - See Table 4.3-6

TABLE 4.3-5

Forward Fuselage Fabrication Facility Requirements

Facility Requirement	Facility Availability
Area	
Approximately 4,000 Sq. Ft.	
Major Manufacturing Equipment	
5 AXIS OMNI MILL for machining windshield frames	
STRETCH PRESS for forming inner skins on structural "sandwich" panels	
HOT FORM PRESS for forming outer skins on structural "sandwich" panels	
SKIN MILL (N/C) for milling isogrid pattern into skins	All available at existing Contractor facility.
2300° F OVEN for curing HCF blocks	
BRAKE PRESS (POWER) forming aft cockpit support cone segments	
HYDRO PRESS (VERSON) for forming frames	
Major Manufacturing Tools	
ASSEMBLY FIXTURE, Door	
ASSEMBLY FIXTURE, Windshield	
HANDLING FIXTURE, Lower Cockpit Support Cone	All New
ASSEMBLY FIXTURE, Bulkheads to Floor	
TRIM FIXTURE, Lower Cockpit Support Cone	
ASSEMBLY FIXTURE, Cockpit	

TABLE 4.3-5 (Cont.)

Facility Requirement	Facility Availability
Major Process Requirements	
Bonding and Curing HCF Blocks	
Spin Forming Nose Cap	All New. To be located at existing Contractor facilty.
Machine HCF Blocks	
Skin Anodizing and Cleaning	Available at existing Contractor facility.

TABLE 4.3-6

Forward Fuselage Assembly Facility Requirement

Facility Requirement	Facility Availability
Area	
Approximately 4,000 sq. ft.	Available at existing Contractor facility
Major Manufacturing Tools	
MAJOR ASSEMBLY JIG - Final Assembly of Forward Fuselage Components	New

4.3.4 Intertank Structure

4.3.4.1 Intertank Structure Description

The Intertank Structure (Figure 4.3-25) is that portion of the Booster fuselage that will connect the LOX tank to the LH2 tank. This section will house two large JP-4 tanks, the nose landing gear, the Orbiter forward attach point, and portions of various Booster sub-systems. The structure will consist of two cylindrical sections, each made up of three isogrid machined skin segments; a wheel-well assembly made up of isogrid-machine top and side panels, and forward and aft normal frame assemblies, forward and aft canted frame assemblies, and canard-to-fuselage structural attach fittings--all made up of a series of machined, capped diagonals, and an Orbiter attach reaction beam. An illustrated Manufacturing Flow Sequence is shown in Figure 4.3-26. A Manufacturing Flow Chart and Schedule is shown in Figure 4.3-27.

INTERTANK STRUCTURE ASSEMBLY

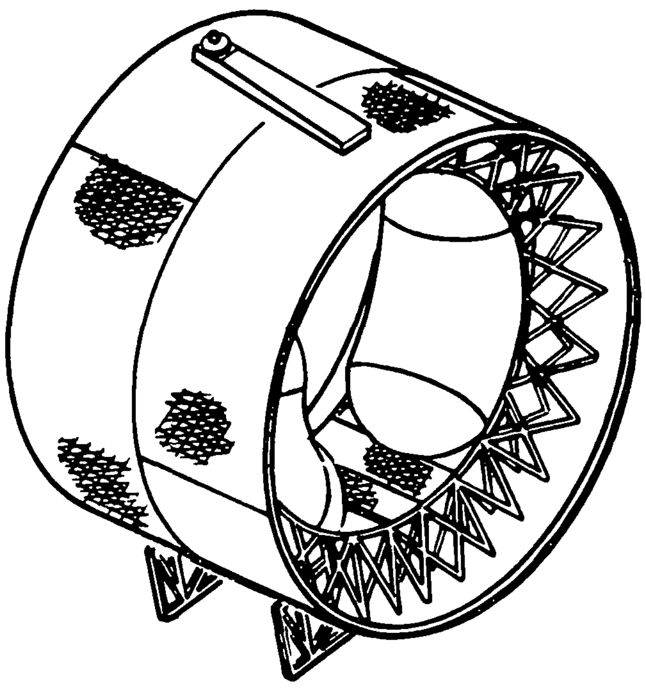


FIGURE 4.3-25

INTERTANK STRUCTURE

Manufacturing Assembly Sequence – Booster

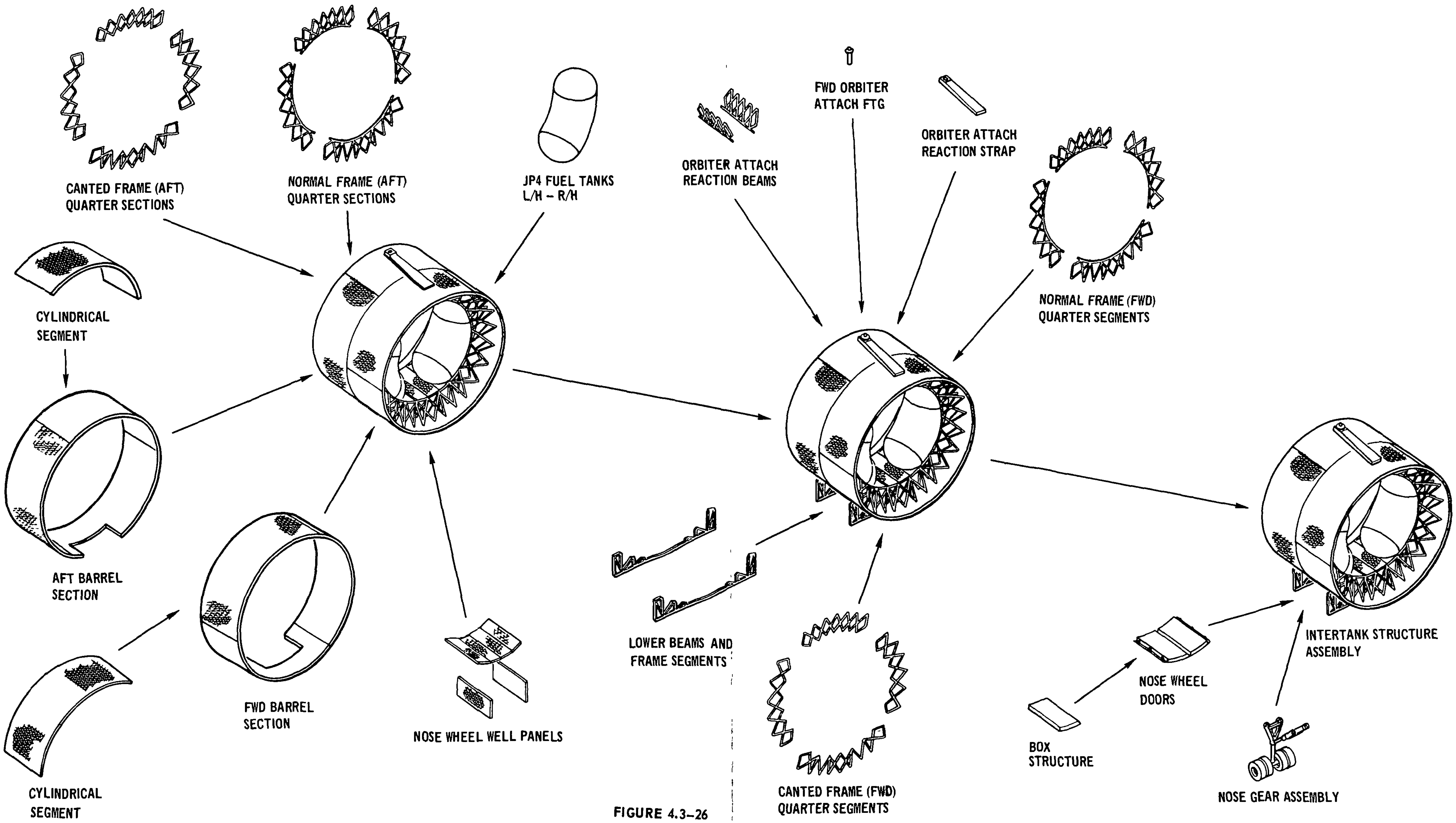


FIGURE 4.3–26

INTERTANK STRUCTURE
MANUFACTURING FLOW CHART AND SCHEDULE
Booster

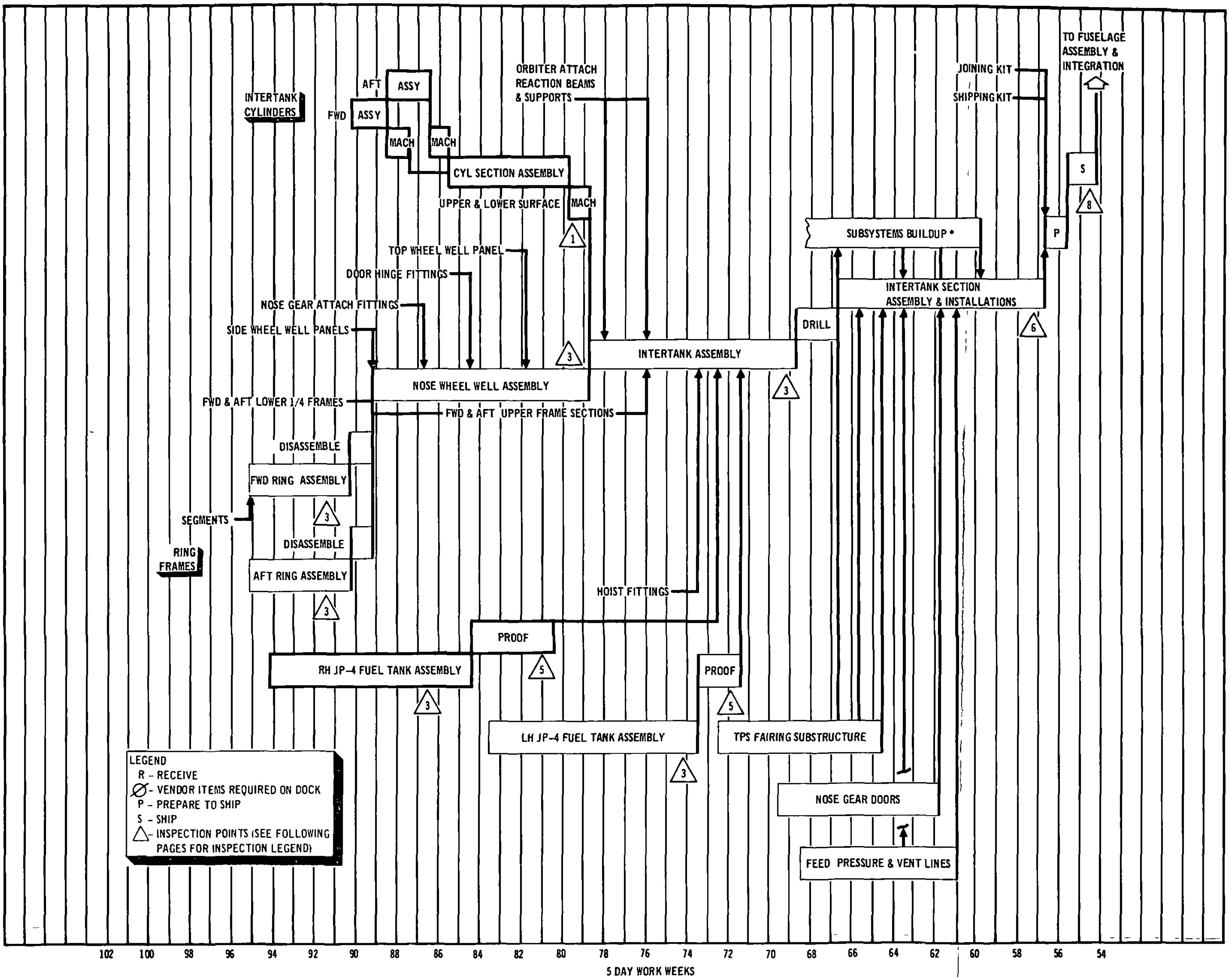


FIGURE 4.3-27

4.3.4.2 Manufacturing Site

It is recommended that the Intertank Structure be assemblied at the NASA owned Michoud Assembly Facility (MAF) in Louisiana (See Figure 4.3-5) with fabrication support by Contractor facilities.

4.3.4.3 Manufacturing Approach

Piece-part fabrication is to be accomplished largely in Contractor owned facilities. This will include machining frames and attach fittings, pocket milling skins, and forming and processing operations. If skins are to be formed by power brake, this will be performed in Contractor facilities. If skins must be formed by AGE forming, the forming and anodizing will be performed at Michoud in new facilities presently being planned for the Shuttle Orbiter. Final Assembly of the Intertank Structure will be accomplished at Michoud. Installation of the JP-4 tanks must be accomplished at the time of Intertank Structure assembly. Whenever practical, operations at Michoud will utilize existing Saturn tooling and GSE, modified as required.

4.3.4.4 Manufacturing Operations

Cylindrical Section - This section will consist of two barrel sections with three isogrid skin segments (See Figure 4.3-26) per barrel. Each skin segment will be NC machined from 2.5 in. x 144 in. x 420 in. aluminum plate. After machining, the segments will be formed, trimmed, and processed. Attach holes will be located and drilled undersize.

The individual barrel sections will then be bolted up, using three skin segments each. Using the assembly tool, the barrel-to-barrel attach holes will be located and drilled undersize.

The two barrels will be joined during final assembly of the intertank structure assembly. A final assembly tool and a handling sling (modified Saturn GSE) will be required for this operation.

Normal Frames - Each of the normal frames will consist of four bolted-together quarter sections. Each section will be N/C machined from 2.63 x 100 x 190 in. aluminum plate stock. The assembled frame constitutes a radial truss arrangement that bolts to the skin.

After the frames are assembled, attach holes will be located and drilled undersize.

Canted Frames - Each of the canted frames will also consist of four bolted-together quarter sections. The canted frames are N/C machined from flat plate stock, similar to the normal frames, then rolled to form the canted, or conical, configuration. The canted frames bolt to the normal frames and to the intertank structure skin.

Forward Orbiter Attach Point - This assembly will consist of a reaction strap plate and the attach point fitting N/C machined and drilled from aluminum forgings. The attach point hole pattern will be drilled full size and the frame and beam holes undersize. When the assembly is located in the center fuselage assembly tool, the holes will be drilled and reamed to full size.

Orbiter Reaction Beams - The reaction beams will be located between the two main frames and will bolt through the skin to the forward orbiter attach assembly. The beams will be N/C machined from two inch thick aluminum plate and the attach holes are drilled undersized. When located in the center fuselage assembly tool, the holes will be reamed full size to mating parts.

Wheel Well - The wheel well structure will consist of isogrid side walls, end skins and a cover. Landing gear hinge and actuating points will be integral in the side wall. Hinge and activating points for the nose wheel doors will also be located in this wheel well structure.

Side walls will be N/C machined from 2.38 x 55 x 140 in. aluminum plate stock.

The cover will be N/C machined from 1.00 x 70 x 145 in. plate and formed to match the normal frame cap. The forward and aft well ends will be integrally machined skins bolted to the normal frames and side beams.

Canard to Fuselage Structure - This structure will be a truss type assembly that bolts to the underside of the Intertank Structure through the isogrid outer skins and into the two normal frame assemblies. This structure will extend approximately 140 inches front to back and 162 inches outboard from each side of the center line. The truss structure will be made from two sets of frame segments N/C machined from 2.63 x 80 x 100 in. aluminum plate stock and two sets of lower beams N/C machined from 2.63 x 10 x 70 inch aluminum plate stock. The frame segments will have integral inner caps and diagonal structures that bolt to the skins and the internal frames. The lower beams will bolt to the frame segments, the outer skin and the internal frames. After the frames are assembled to the lower beam, the skin attach holes will be drilled, using a drill fixture, and the beams attached.

Nose Wheel Doors - Nose wheel doors will consist of N/C machined panels and structure with hinges and operating mechanism. The majority of the hinges, latch fittings and operating mechanism are N/C machined fittings. The doors require a major assembly Tool and a hinge master to insure the correct location of the door and wheel well hinge points.

JP-4 Tanks (See Figure 4.3-28). The JP-4 tanks consist of an upper dome, lower dome, and a three segment center section.

The three segments of the center section will be stretch formed, trimmed and anodized, then welded together.

The domes will be flow-turned, trimmed and anodized.

A new fixture will be required to permit final trim and welding of the domes to

JP–4 TANKS
Manufacturing Assembly Sequence – Booster

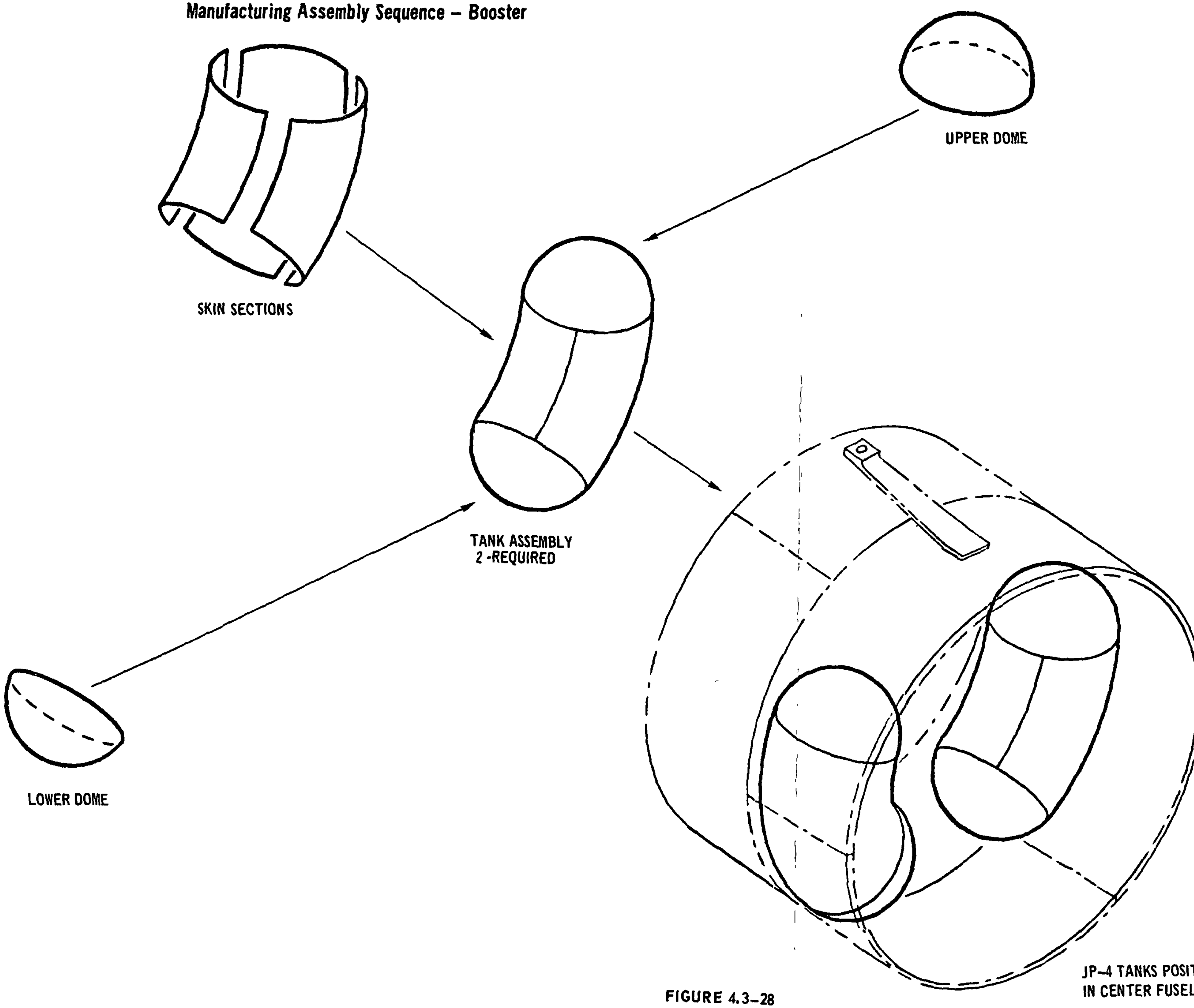


FIGURE 4.3–28

the center sections.

Tanks will be leak and proof tested using existing facilities at Michoud.

Intertank Structure Assembly Tool - The assembly tool will locate the structure in the vertical position with the frames held horizontal. All the final assembly and the drilling of the LOX tank attachment hole pattern, the LH2 tank hole pattern, and the canard attach patterns will be established in this controlled tool.

The first assembly operation will be to locate the aft cant frame, two normal frames, the wheel well side walls and the orbiter reaction beams. After attachments are made the barrel segments will be hoisted and lowered over the frames. The longitudinal bolt pattern will be opened up to slip the barrels over the frames.

The next operation will include locating the forward cant frame, the orbiter attach fitting assembly, the canard-to-fuselage structure, and finally the wheel well cover.

When the assembly has been completed, the LOX tank and LH2 tank attach holes will be drilled from the assembly tool with a controlled hole pattern. The final operation will be to machine the canard attach face, drill the 4 index attach holes full size to match the canard, and then drill the remaining attach holes undersize. A mating gage will be required to insure that the center section matches the canard.

Installation Position - The section will then be hoisted, turned and located on the installation and joining fixture (GSE). A turning sling is required for the operation. The landing gear and doors will then be installed and checked out in this position.

4.3.4.5 Facility Requirements

Intertank Structure Fabrication - See Table 4.3-7

Intertank Structure Assembly - See Table 4.3-8

TABLE 4.3-7

INTERTANK STRUCTURE FABRICATION FACILITY REQUIREMENTS

Facility Requirement	Facility Availability
Area	
Approx. 16,000 sq. ft. 40' clear ceiling height. Environmentally controlled to 75 ± °F, 50% max. RH	Exists at Contractor's Facilities, and at Michoud Bldg. 103
Crane Capacity	
10 Tons	Exists at Contractor's Facilities, and at Michoud Bldg. 103
Major Manufacturing Equipment	
N/C SKIN MILLS; milling isogrid in skins, machining frames, attach fittings	Exists at Contractor's Facility
STRETCH PRESS; forming JP-4 tank skins	
FLOW TURN EQUIPMENT; FORMING JP-4 Tank Domes	
POWER BRAKE; forming cylindrical skin segments	
AGE FORMING EQUIPMENT; Alternate to power brake for forming skin segments	
Major Manufacturing Tooling	
TRIM FIXTURE, Cylindrical Skins	
DRILL FIXTURE, Normal Frames	
DRILL FIXTURE, Canted Frames	

TABLE 4.3-7 (Cont.)

Facility Requirement	Facility Requirement
Major Processing Equipment	
ANODIZING SYSTEM	Exists at Contractor Facilities and at Michoud
CHEM-MILLED SYSTEM	
CLEAN & RINSE SYSTEM	
Welding Equipment	
AUTOMATIC MIG; for welding JP-4 Tanks	
Laboratory	
NON-DESTRUCTIVE TESTS	Existing at Contractor's Facility and at Michoud
METAL FINISH	
PROTECTIVE COATINGS	
X-Ray	
Automatic System for X-Raying JP-4 Tank Welds	

TABLE 4.3-8

INTERTANK STRUCTURE ASSEMBLY FACILITIES REQUIREMENTS

Facility Requirement	Facility Availability
Area	
Approx. 8,000 sq. ft. 40' clear ceiling ht. Environmentally controlled to 75 ±5°F and 50% max. RH	Exists at Michoud
Crane Capacity	
10 Tons	Exists at Michoud
Major Assembly Tooling	
ASSEMBLY TABLE, Cylindrical Skins	Existing
DRILL FIXTURE, Cylindrical Skins	New
ASSEMBLY TABLE, Barrel Assembly	Existing
ASSEMBLY TABLE, Frames	New
DRILL FIXTURE, Orbiter Attach Fittings	New
DRILL FIXTURE, Orbiter Attach Strap	New
DRILL FIXTURE, Reaction Beams	New
SPECIAL FIXTURE, Wheel Well Beams, (Bearing Locators)	New
ASSEMBLY FIXTURE, Nose Wheel Doors	New
ASSEMBLY FIXTURE, Center Section Assy.	Existing
DRILL FIXTURE, Center Section Assy.	New
DRILL FIXTURE, Center Section-to-Canard Attach Points	New
DRILL FIXTURE, Center Section Interface Holes	New

TABLE 4.3-8 (Cont'd)

Facility Requirements	Facility Availability
Major Assembly Tooling - Continued	
HOISTING FIXTURE, Center Section	New
PRODUCTION TEST EQUIPMENT (PTE) Nose Wheel Doors	New
CANARD ATTACH POINTS, Master Tool	New

4.3.5 Aft Body Structure Assembly

4.3.5.1 Aft Body Structure Assembly Description

(See Figure 4.3-29). This unit forms the aft section of the booster fuselage.

It consists of four major structural assemblies (See Figure 4.3-30) which are: the forward body thrust cylinder section, including an integral flanged ring for interface attachment to the LH2 tank fuselage section; a second body thrust cylinder section that includes the wing carry-thru structure and main gear wheel wells; a thrust beam assembly section that includes the engine mount body frame and thrust structure; and the aft fuselage fairing section.

An illustrated Manufacturing Flow Sequence in shown in Figure 4.3-30.

A Manufacturing Flow Chart and Schedule is shown in Figure 4.3-31.

AFT BODY STRUCTURE ASSEMBLY

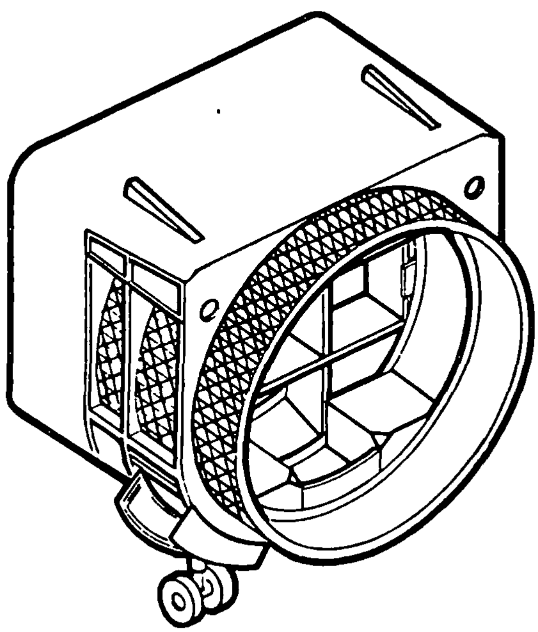


FIGURE 4.3-29

AFT BODY STRUCTURE
Manufacturing Assembly Sequence – Booster

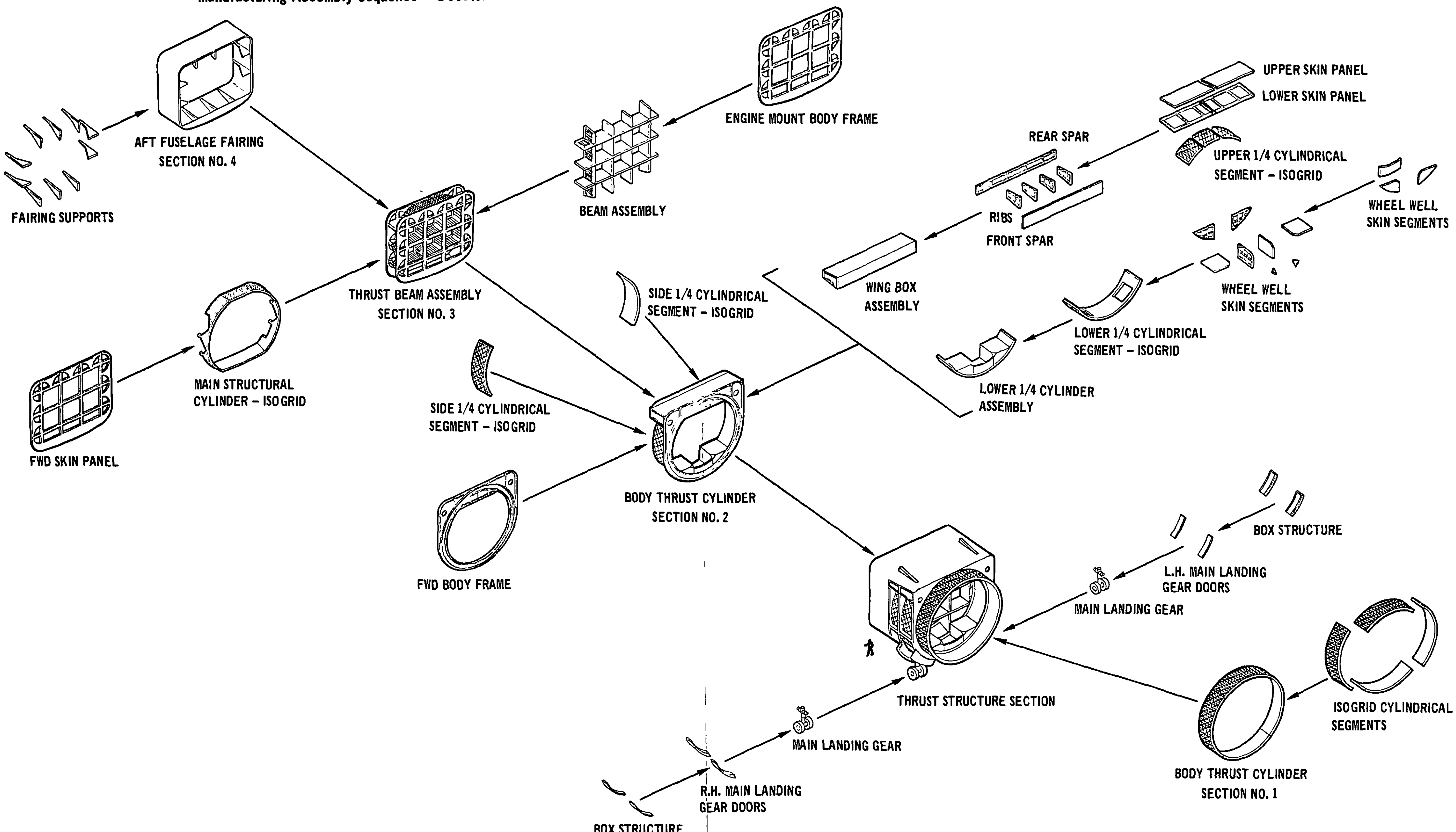


FIGURE 4.3–30

AFT BODY STRUCTURE
MANUFACTURING FLOW CHART AND SCHEDULE
Booster

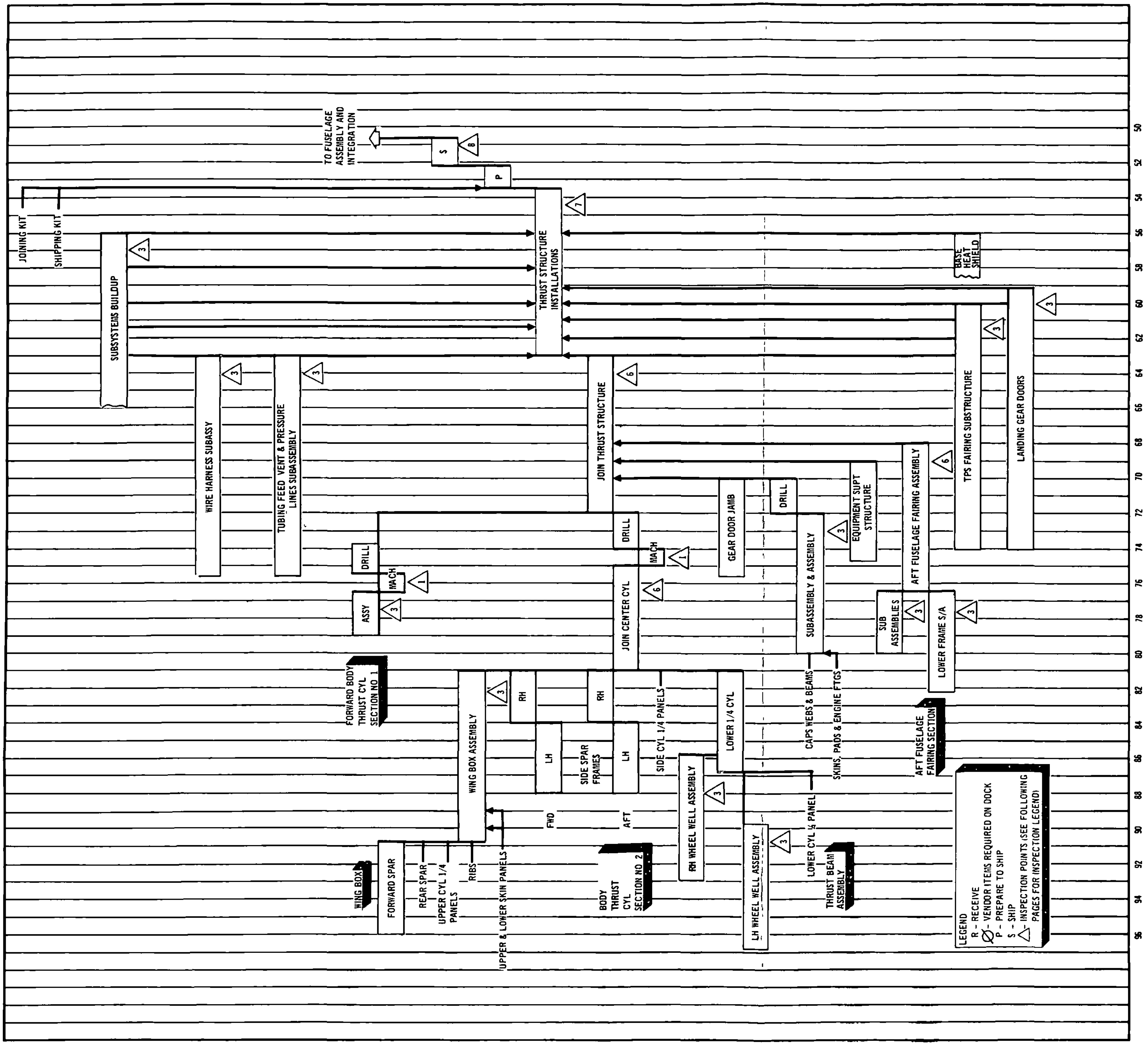


FIGURE 4.3–31

4.3.5.2 Manufacturing Site

It is recommended that the aft body structure be assembled at the NASA owned Michoud Assembly Facility (MAF) in Louisiana (See Figure 4.3-5), with fabrication support by Contractor facilities.

4.3.5.3 Manufacturing Approach

Piece-part fabrication and processing will be accomplished largely in Contractor owned facilities. This would include machining of beams, skin milling and forming, anodizing, etc. Sub-assembly work will take place both at Contractor facilities and at Michoud. Items such as skin segments which require AGE forming will be formed and processed at Michoud in facilities presently being planned for the Shuttle Orbiter.

Final assembly of the aft body structure will be at Michoud. Whenever practical, operations at Michoud will utilize existing Saturn tooling and GSE modified as required.

4.3.5.4 Manufacturing Operations

General - In general, all structural skin panels, body frames, thrust beams, supports, engine mount pads, spars, ribs, and intercostals will be pocket machined from aluminum plate stock, and will have integral stiffeners, caps, and flanges. The main cylindrical skin panels are machined with an isogrid pattern like the cryogenic tank skins. All shaped skin panels will be formed to contour on a press brake or age forming dies. The engine mount pads will be "value engineered" to determine whether forgings would be more economical for the quantity required. Landing gear trunnion fittings will be machined from rough forgings.

Sub-Assemblies - As required detail parts are completed, build-up of subassemblies such as the wheel wells, lower quarter cylinder, wing box, beam assembly, etc., as shown in Figure 4.3-26, will begin. Subassembly work will be accomplished in fixtures which will accurately locate the parts for joining.

For the wing box assembly, spars, ribs, and cylindrical skin segments will be located in the fixture, and joined to form a substructure. As the assembly progresses, upper and lower skin panel attachment will be accomplished. Inspection for quality and specification conformance, plus installation of the correct fasteners will occur progressively.

For the engine thrust structure, subassembly of the upper, center and lower horizontal thrust beams with the four vertical thrust beams will be accomplished in a horizontal fixture. This validated fixture will maintain interface and parallelity for the engine gimbal mount pads without additional machining after assembly.

As subassemblies are completed, they will be moved to the major assembly fixtures along with required detail parts and components for build up of the four major structural assembly sections previously described. Assembly of these major structural sections will be accomplished in controlled fixtures whose accuracy has been validated. These fixtures will control moldline profile as well as critical attach points and interface locations. Quality acceptance of the structure will be required prior to removal from the fixture.

Final Assembly

As the structural sections are completed, they will be progressively mated and joined together in a vertical final assembly splice fixture.

This will essentially complete the structure and the unit will be ready for assembly installations, after the assembly has been rotated to horizontal.

This transition will require use of an "A"-frame device.

Assembly Installation

Assembly installations will include the aft fairing, main landing gears and their doors, plus installation of engine actuator, hydraulic, electrical, and mechanical subsystems. Base heat shield modules will be prefitted from graphite phenolic honeycomb panels, structurally stabilized with formed titanium edge channels and base structure beams. The face of the heat shield will be covered with 3/4" thick HCF for thermal protection. Support struts, fabricated from graphite phenolic laminate tubes, will be attached by brackets and clevis ends to the engine thrust beams. Prefitting and drilling of the struts will be accomplished in the assembly tool. After prefit, the modules will be removed and shipped separately to the fuselage final assembly location, where they will be installed after the engines are attached to the thrust structure.

Following equipment installations, the thrust structure section will be subjected to manufacturing checkout, subsystems test, and final inspection acceptance.

Facility Requirements

Fabrication Facilities - See Table 4.3-9

Assembly Facilities - See Table 4.3-10

TABLE 4.3-9

Aft Body Structure Fabrication Facility Requirements

Facility Requirement	Facility Availability
Area	
Approximately 16,000 sq. ft. 40' ceiling height. Environmentally controlled to 75 $\pm$ 5°F, 50% max. RH	Exists at Contractor Facilities and at Michoud Bldg. 103
Crane Capacity	
10 Tons	Exists at Contractor's Facilities and at Michoud Bldg. 103
Major Manufacturing Equipment	
AUTOCLAVE	
POWER BRAKE PRESS	
STRETCH PRESS	All existing at Contractor's Facilities
AGE OVEN	
SQ-SHEAR	
HYDRO-PRESS (VERSON)	
G AND L SKIN MILL	
5 AXIS N/C MILL	
Major Manufacturing Tooling	
MILL FIXTURES, Rear Spar Body Frame	
MILL FIXTURES, Thrust Beam Supports	
MILL FIXTURES, Landing Gear Intercostal	All New
MILL FIXTURES, Engine Fairing (Isogrid)	
MILL FIXTURES, Front Spar	
DRILL FIXTURES, Front Spar	
MILL FIXTURES, Center Spar	

TABLE 4.3-9 (Cont'd)

DRILL FIXTURE, Center Spar	
MILL FIXTURES, Rear Spar	
DRILL FIXTURE, Rear Spar	
MILL FIXTURES, Intercostal Spar	All New
MILL FIXTURES, Skins (Isogrid)	
MILL FIXTURES, Center Horiz. Beam	
MILL FIXTURES, Outbd. Vert. Beam Components	
MILL FIXTURES, Inbd. Vert. Beam Components	
MILL FIXTURES, Engine Mount Body Frame	
Major Processing Equipment	
Cleaning and Drying	
Anodizing System	Available at Contractor's Facility and at Michoud
Bonding, Curing	
Heat Treating	
Laboratory	
Non-Destructive Test	Available at Contractor's Facility and at Michoud
Metal Finish	
Protective Coatings	

TABLE 4.3-10

Aft Body Structure Assembly Facility Requirements

Facility Requirement	Facility Availability
Area	
Approx. 9,000 sq. ft., 40' min. clear ceiling height. Environmentally controlled to 75 ± 5°F, 50% max. RH	Available at Michoud
Crane	
Major Assembly Tooling	
FINAL ASSEMBLY FIXTURE, Vertical	
MAJOR ASSEMBLY FIXTURE, Center Wing Box	New
HANDLING FIXTURE, Center Wing Box	
TRIM FIXTURE, Box Beam Assembly	
MAJOR ASSEMBLY FIXTURE, Box Beam Assembly	
WORK STAND, Engine Thrust Structure Subassembly	
ASSEMBLY FIXTURE, Upper Horizontal Beam	
TRIM FIXTURE, Engine Fairing (Isogrid)	
ASSEMBLY FIXTURE, Heat Shields Assembly	
BONDING FIXTURE, Heat Shields Panels	

4.3.6 Wings and Control Surfaces

4.3.6.1 Wing and Control Surface Description

The left and right wings (See Figure 4.3-32) will be of conventional construction, each consisting of a torque box, leading edge and elevon. Certain areas of the torque box will be sealed in order to serve as JP-4 fuel tanks.

The dorsal and ventral fins will also be of conventional construction, each consisting of a torque box, leading edge and a rudder.

An illustrated Manufacturing Flow Sequence is shown in Figure 4.3-33. A Manufacturing Flow Chart and Schedule is shown in Figure 4.3-34.

WING

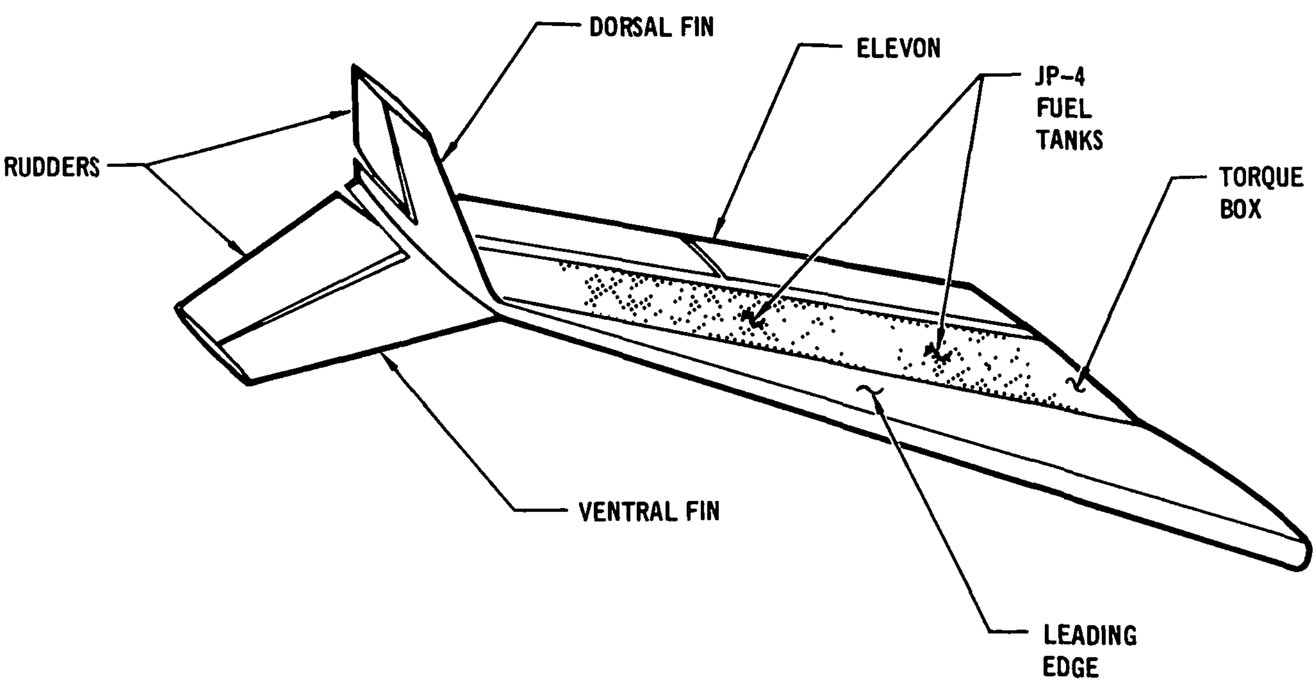


FIGURE 4.3-32

WING AND CONTROL SURFACES

Manufacturing Assembly Sequence – Booster

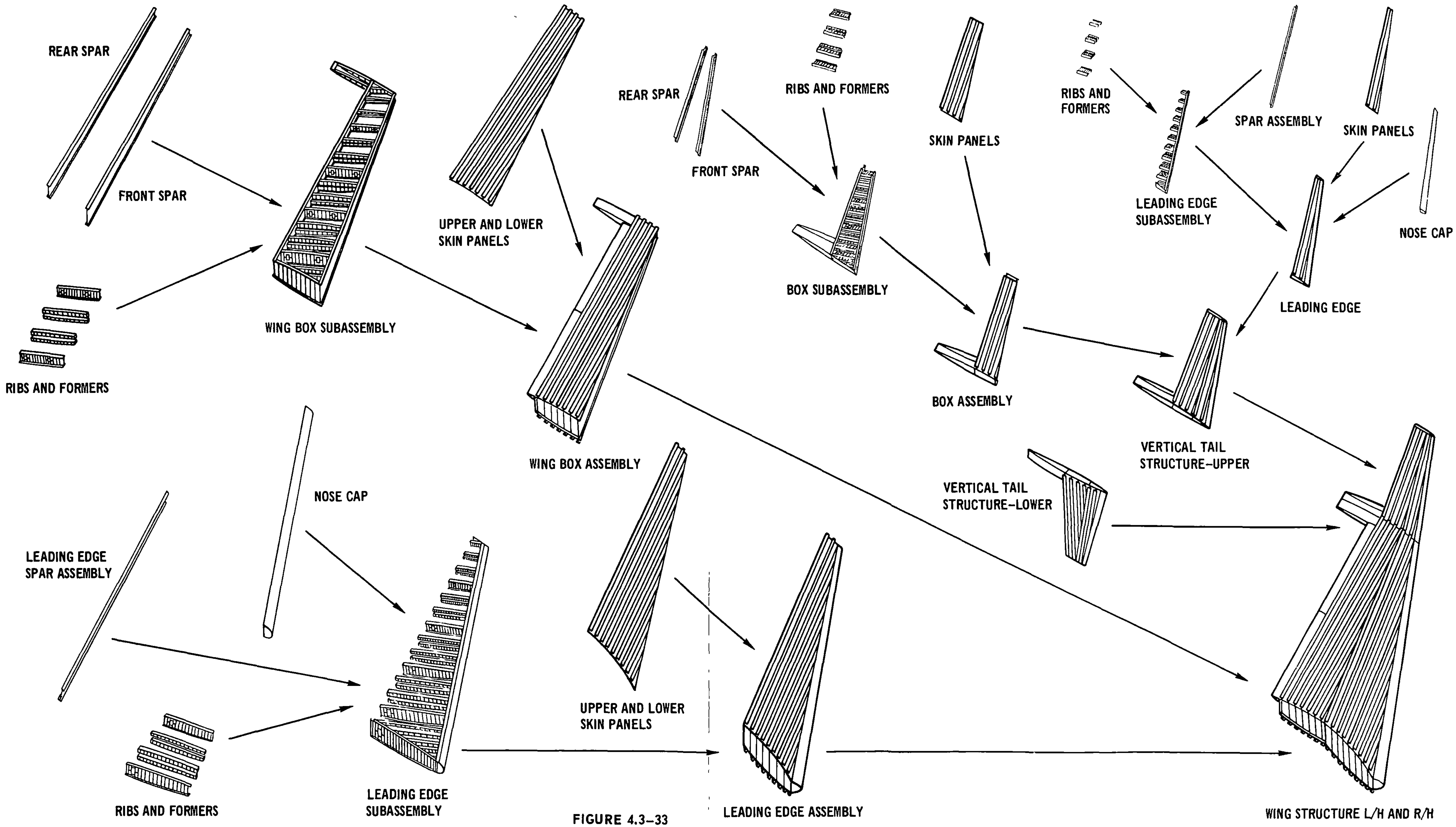


FIGURE 4.3–33

WING AND CONTROL SURFACES

Manufacturing Assembly Sequence – Booster

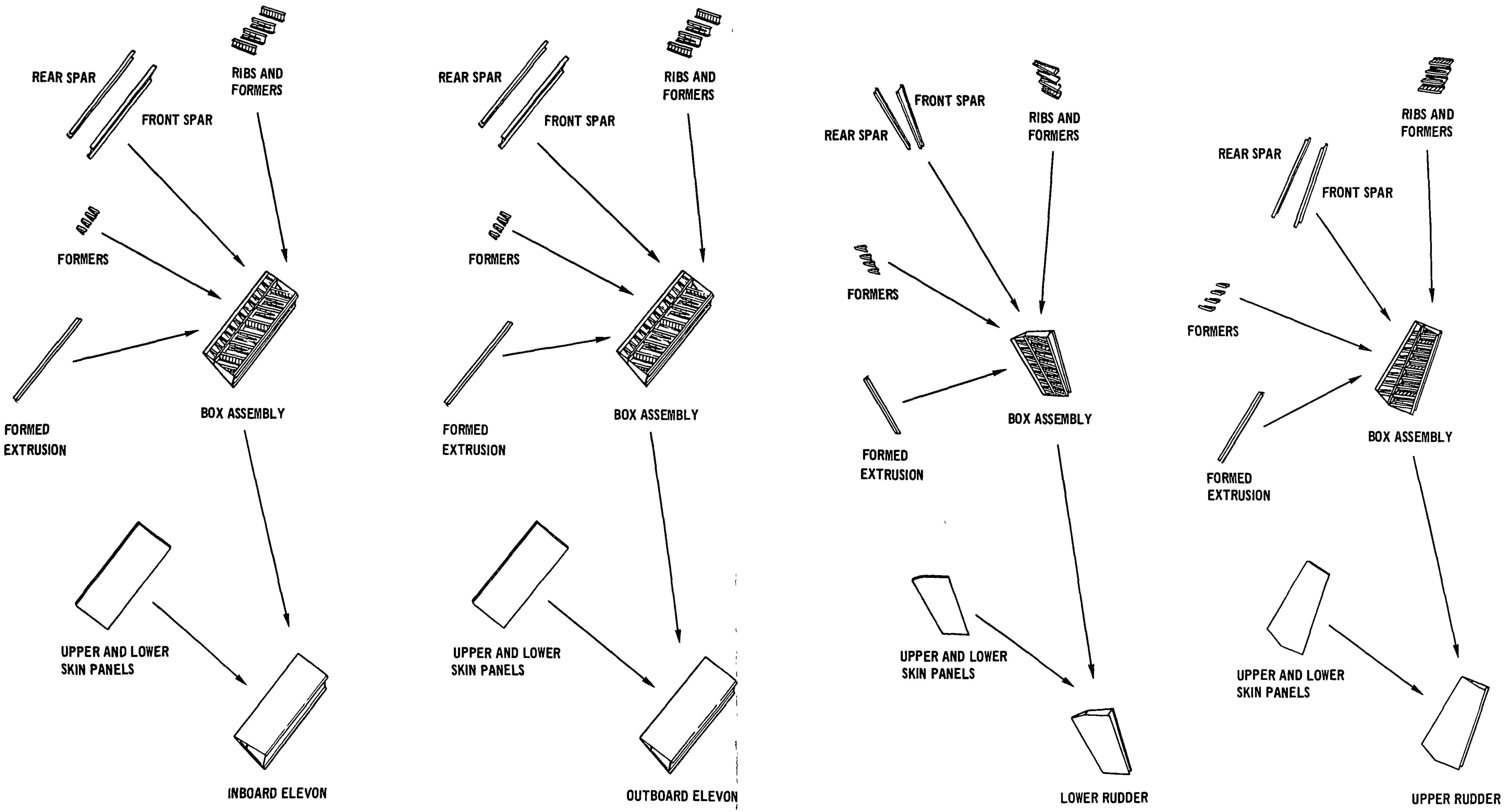


FIGURE 4.3–33 (Cont'd)

WINGS & TIP FINS & MANUFACTURING FLOW CHART SCHEDULE
Booster

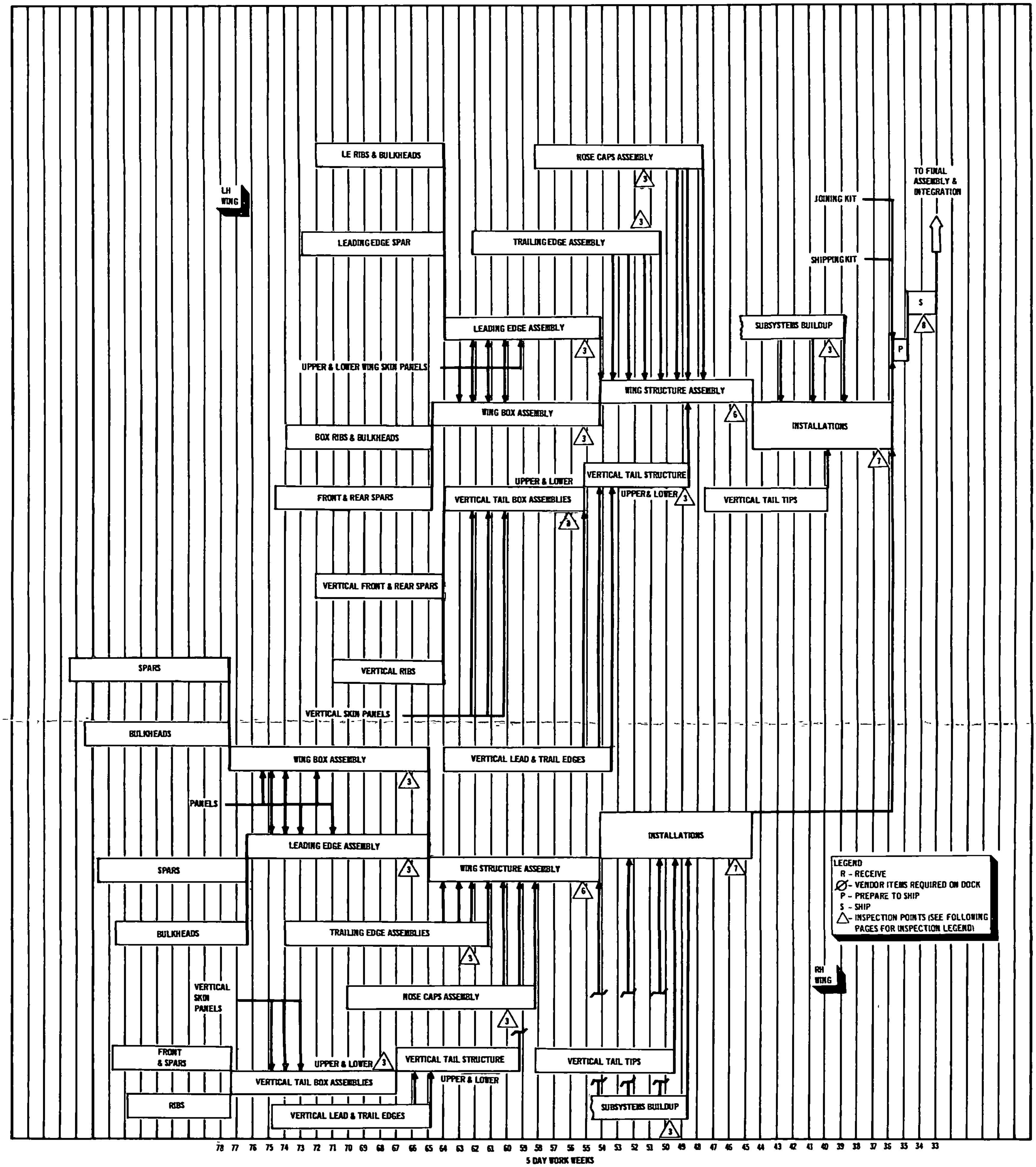


FIGURE 4.3-34

WING AND CONTROL SURFACES
Booster
Manufacturing Flow Chart & Schedule

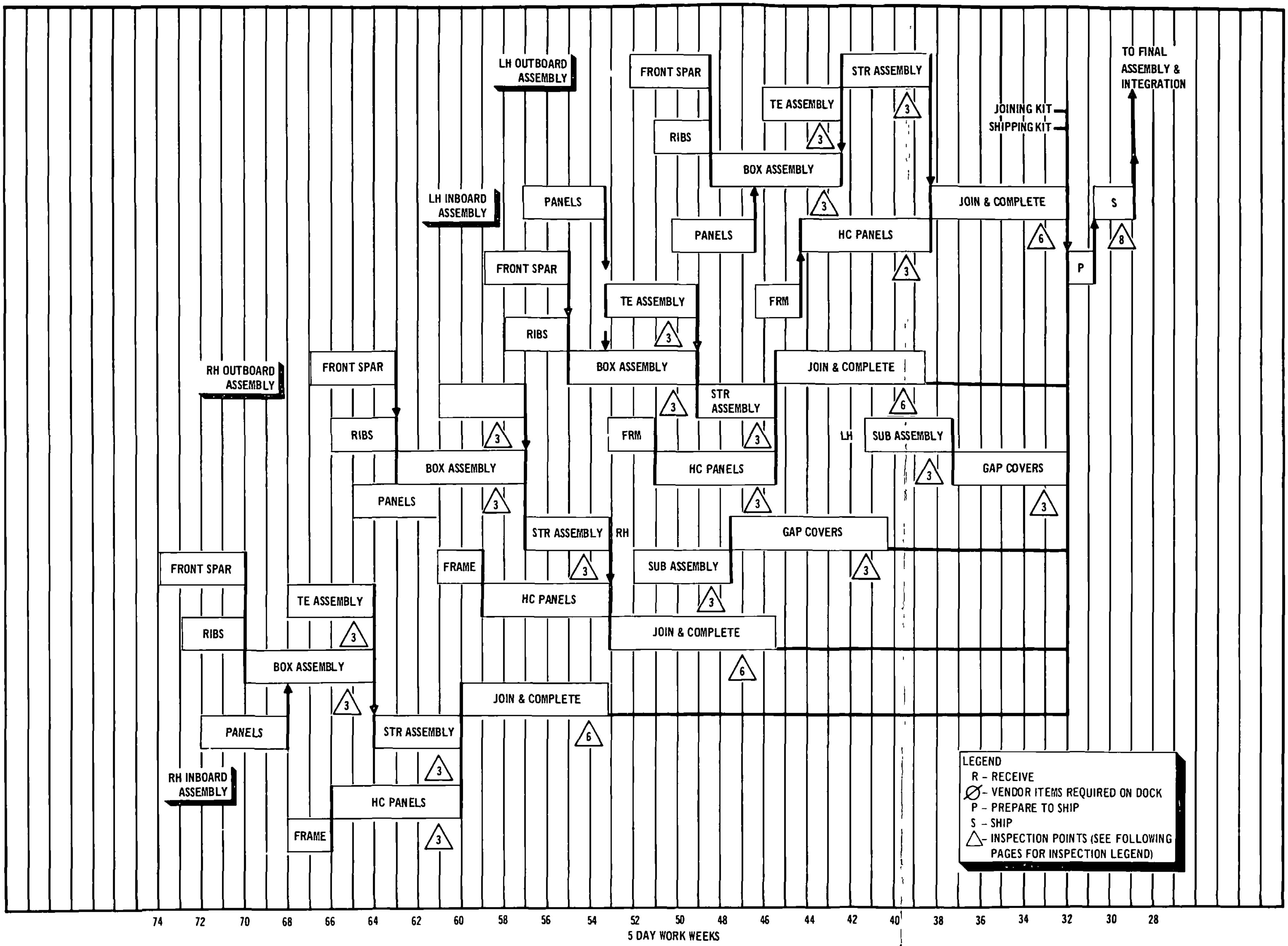


FIGURE 4.3–34 (Cont'd)

RUDDERS
CONTROL SURFACES
MANUFACTURING FLOW CHART & SCHEDULE
Booster

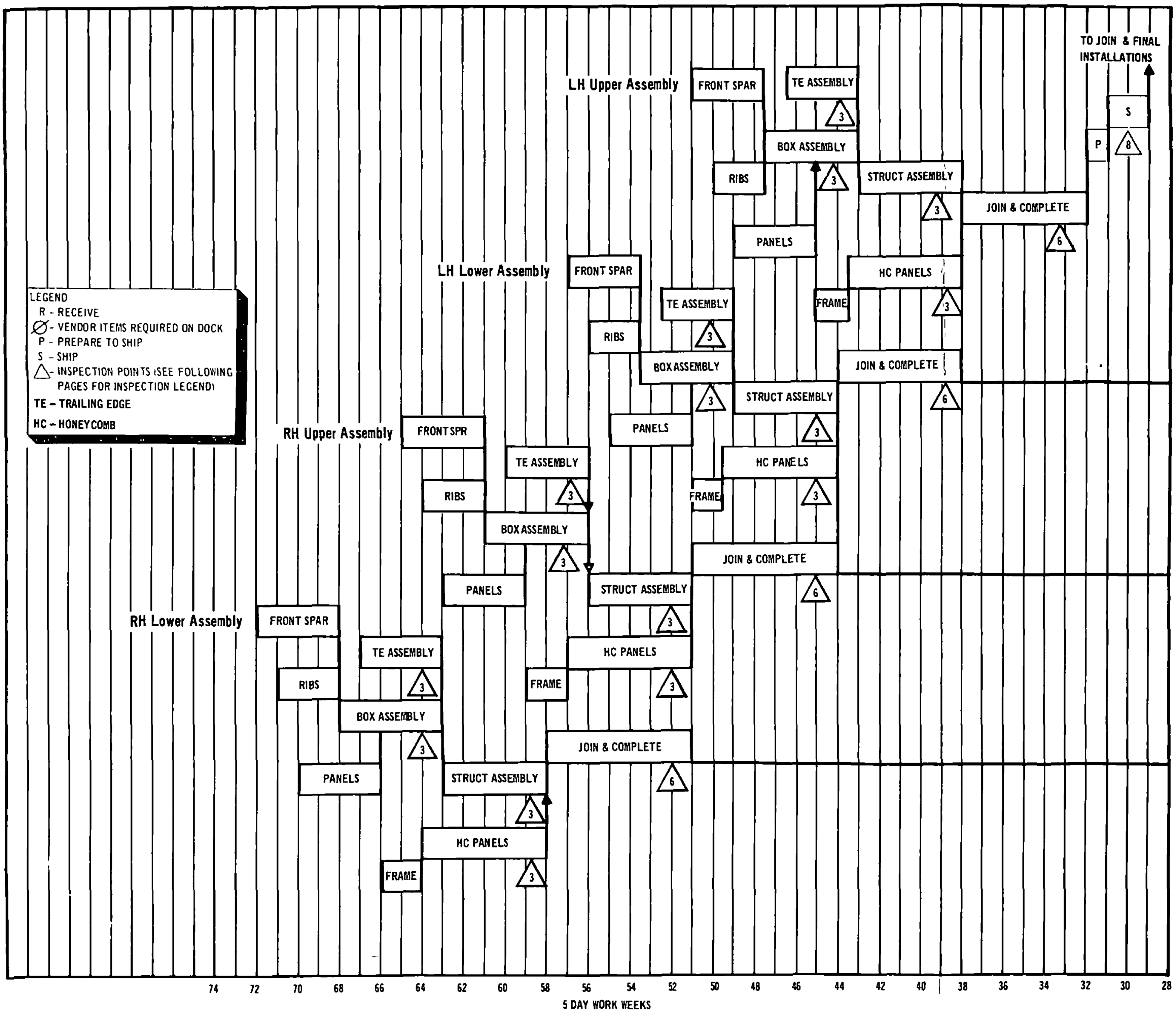


FIGURE 4.3–34 (Cont'd)

4.3.6.2 Manufacturing Site

It is recommended that the wings and control surfaces be manufactured at a Contractor Facility.

4.3.6.3 Manufacturing Approach

As previously mentioned, the wings and control surfaces will be of conventional construction. Conventional techniques for sheet metal, machining processing and assembly operations will be employed.

4.3.6.4 Manufacturing Operations

BUILD UP OF SUB-ASSEMBLIES

Wing Leading Edges - The Leading Edge consists of:

- o Replaceable Nose Section
- o Front Spar
- o Ribs
- o Upper and Lower Formers
- o Corrugated Skins

o Replaceable Nose Section

The assembly consists of nose ribs, clips, skins and stringer rails for attachment to the front spar of the main leading edge assembly.

A locating fixture will be required to assemble the parts and control mold line of the ribs and alignment of the attach rails.

The ribs will be made on form block using Hydro-Press.

The rails will be machined (N.C.) from oversize extrusion.

The skins will be stretch-formed on skin stretch press with form blocks.

o Front Spar

Consists of upper and lower chords, webs and stiffners.

Chords will be machined on spar mills with tracers.

A locating fixture will position parts for fastening and maintain upper and lower mold line for spar assembly.

o Rib Assemblies

Consists of upper and lower chords, webs, stiffners and reinforcements.

A locating fixture will position all parts for assembly and maintain rib mold line requirements.

Chords will be machined on tracer spar mills and stretch formed on extrusion, stretch press. Web outlines and cut-outs will be routed or sawed.

o Former Assemblies - Upper and Lower

Each former assembly consists of inner and outer chords, webs and stiffners.

Locating tools will hold parts for assembly and control mold line.

Chords will be machined on tracer spar mills.

The outer chords will be formed on extrusion stretch press--inner chords are straight.

o Skins - Upper and Lower

Corrugated panels will be formed in dies on press brake.

Panel trim will be sawed to layout.

Wing Leading Edge requires major assembly fixture to locate and position all subassemblies and skins for mechanical joining.

Handling sling required.

Storage and transportation dolly required.

Wing Torque Box - The Wing Torque Box consists of:

- o Front Spar
- o Rear Spar
- o Ribs
- o Formers
- o Skins - Integrally Stiffened
- o Flap Hinge Fittings

o Front and Rear Spars

Consists of upper and lower chords, webs, stiffners.

Assembly and locating fixtures will be required to position parts for joining and splicing.

Upper and lower chords will be machined on tracer controlled spar mills with holding fixture.

Webs and stiffners will be fabricated by conventional sheet metal methods.

o Formers - Upper and Lower

Consists of inner and outer chords, webs and stiffners.

Locating tools will hold parts for assembly, fastening and control of mold line.

Chords will be machined by N.C. and/or on tracer mills with holding fixtures.

The outer chords will be formed on blocks with an extrusion stretch press - inner chords are straight.

- <u>Rib Assemblies</u>

  Consists of upper and lower chords, webs, stiffners and reinforcements.

  A locating fixture will position all parts and control mold line requirements.

  Chords will be machined on profile mills with holding fixtures and formed on blocks by extrusion stretch press.

  Web outlines and cutouts will be routed or sawed.

- <u>Skins - Upper and Lower</u>

  Skins are machined from plate and contain integral stiffening ribs. Machining is done by N.C. skin mill utilizing vacuum plates for holding fixtures.

  Slings and dollies are required for handling, storage and transportation.

- <u>Fittings - Elevon Hinges</u>

  Machined from forgings on N.C. equipment using holding fixture.

Drill and bore using drill jig.

Special shop handling pallets required.

Wing Torque Box requires major assembly fixture to position and locate all spars, ribs, formers, skins and fittings for mechcanical fastening and dimensional control. Coordinated match drill plate required for splice hole locations which must mate to fuselage stub end rib. After structural work is completed, sealing will be accomplished at all interfaces of parts in order to make the torque box "fuel-tight" between the front and rear spars. Testing of the fuel area will be performed. Electrical harnesses will be installed and tested. Plumbing lines, valves, regulators and pumps for the cruise propulsion system will be installed and tested.

Handling sling required.

Storage and transportation dolly required.

Vertical Fin (Typical for Ventral and Dorsal) - The Vertical Fins consist of:

- o Leading Edge Assembly
- o Torque Box Assembly
- o Rudder Assembly
- o Hinge Fittings - Rudder
- o Base Rib Assembly
- o Splice Support
- o Splice Panels and Supports

o Vertical Fin Leading Edge Assembly - Consists of replaceable nose section, front spar, ribs, upper and lower formers, and skins.

- Replaceable Nose Section

  The assembly consists of nose ribs, clips, skins and stringer rails for attachment to the front spar of the main leading edge assembly.

  A locating fixture will be required to assemble the parts and control mold line of the ribs and alignment of the attach rails.

  The ribs will be made on form blocks using Hydro-Press.

  The rails will be machined (N.C.) from oversize extrusion.

  The skins will be stretch-formed on skin stretch press with form blocks.

- Front Spar

  Consists of upper and lower chords, webs and stiffners.

  Chords will be machined on spar mills with tracers.

  A locating fixture will position parts for fastening and maintain upper and lower mold line for spar assembly.

- Rib Assemblies

  Consists of upper and lower chords, webs, stiffners and reinforcements.

  A locating fixture will position all parts for assembly and maintain rib mold line requirements.

  Chords will be machined on tracer spar mills and stretch formed on extrusion, stretch press. Web outlines and cutouts will be routed or sawed.

o Former Assemblies - Upper and Lower

Each former assembly consists of inner and outer chords, webs and stiffners.

Locating tools will hold parts for assembly and control mold line.

Chords will be machined on tracer spar mills.

The outer chords will be formed on extrusion stretch press - inner chords are straight.

o Skins - Upper and Lower

Corrugated panels will be formed in dies on press brake.

Panel trim will be sawed to layout.

Fin Leading Edge Assembly requires major assembly fixture to locate and position all subassemblies and skins for mechanical joining.

Handling sling required.

Storage and transportation dolly required.

o Vertical Fin Torque Box Assembly - Consists of Front Spar, Rear Spar, Ribs, Formers, Skins - Integrally stiffened, and Rudder Hinge Fittings.

o Front and Rear Spars

Consists of upper and lower chords, webs, stiffners.

Assembly and locating fixtures will be required to position parts for joining and splicing.

Upper and lower chords will be machined on tracer controlled spar mills with holding fixtures.

Webs and stiffners will be fabricated by conventional sheet metal methods.

- <u>Formers - Upper and Lower</u>

  Consists of inner and outer chords, webs and stiffners.

  Locating tools will hold parts for assembly, fastening and control of mold line.

  Chords will be machined by N.C. and/or on tracer mills with holding fixtures.

  The outer chords will be formed on blocks with an extrusion stretch press - inner chords are straight.

- <u>Rib Assemblies</u>

  Consists of upper and lower chords, webs, stiffners, and reinforcements.

  A locating fixture will position all parts and control mold line requirements.

  Chords will be machined on profile mills with holding fixtures and formed on blocks by extrusion stretch press.

  Web outlines and cutouts will be routed or sawed.

o Skins - Upper and Lower

Skins are machined from plate and contain integral stiffening ribs. Machining is done by N.C. skin mill utilizing vacuum plates for holding fixtures.

Slings and dollies are required for handling, storage and transportation.

o Fittings - Rudder Hinges

Machined from forgings on N.C. equipment using holding fixture.

Drill and bore using drill jig.

Special shop handling pallets required.

Vertical Fin Torque Box Assembly requires major assembly fixture to position and locate all spars, ribs, former, skins and fittings for mechanical fastening and dimensional control. Coordinated match drill plate required for splice hole locations which must mate to fuselage stub end rib.

Handling sling required.

Storage and transportation dolly required.

o Vertical Fin Rudder Assembly - Consists of Front Spar, Rear Spar, Ribs, Tip Ribs, Skins and Hinge Fittings

Conventional manufacturing and processing techniques for sheet metal, machining and assembly operations will be employed in the fabrication of the rudder sub-assemblies and components - spars, ribs, skins, etc.

Requires assembly fixture to position all structural components for joining and to align and attach the hinge fittings.

Handling sling required.

Hinge line coordination to fin assembly required.

Storage and transportation dolly required.

Vertical Fin Final Assembly requires Major Assembly Fixture to locate all structural subassemblies, splice plates, splice ribs, drill wing to fin attach holes and maintain all critical control dimensions. Installation and testing will be done for the ACPS harnesses, plumbing and thrusters.

Handling sling required.

Storage and transportation dolly required.

Booster Elevons - Booster Elevons consist of:

- o Front Spar
- o Trailing Tip
- o Rib Assemblies
- o Hinge Fittings
- o Gap Cover
- o Formers
- o Skins and Stringers
- o Linkage

o Front Spar - Consists of upper and lower chords, webs, stiffners, stub ribs, and rails.

Assembly fixture required to position all parts for joining and maintaining mold line control. Stub ribs and rails to be located and fastened to forward face of spar.

Upper and lower chords will be machined on tracer-controlled mills with holding fixtures.

Stub ribs will be formed on blocks in the Hydro-Press.

Rails will be brake-formed.

o Trailing Tip - Consists of rear spar, formed ribs, tip fitting, skins, and gussets.

Assembly fixture required to locate parts for joining and mold line control.

The Rear Spar will be fabricated and assembled in the same manner as the Front Spar.

The Tip Ribs will be formed on blocks in the Hydro-Press.

The Tip Fitting will be machined (N.C.) from extrusion with holding fixture.

The Tip Fitting attach gussets will be brake-formed.

The Skins will be sheared to size and offset on the press brake.

o Rib Assemblies - Contain chords, webs and stiffners and will be fabricated and assembled in the same manner as the fin ribs utilizing assembly fixtures, holding fixtures and machining fixtures.

- Gap Cover - Will be fabricated from a series of formed ribs and skins. Conventional sheet metal and assembly techniques will be used. Form blocks and a locating fixture will be provided.
- Formers - Will be sheared, brake-formed and off-set with hand form blocks.
- Stringers - Will be sheared to size and brake formed.
- Hinge Fittings - Will be forgings or welded assemblies and machined by N.C. with holding and boring fixtures.

Requires major assembly fixture to position all subassemblies and structural components and locate and maintain hinge alignment with the torque box.

Coordination media is required to control hinge fitting locations.

Handling slings required.

Transportation and storage dollies required.

Wing and Control Surface Final Assembly

The Leading Edge Assembly and Torque Box Assembly will be brought to a Wing Splice position on their respective shop transportation dollies. They will be removed by overhead handling and placed in Wing Splice Cradles. The Leading Edge attachment will be made at the Torque Box Front Spar leg. The Trailing Edge Cove will be attached to the Torque Box Rear Spar leg. The Elevons will be brought into position and a fit check made for hinge attachment and mold line splice. The Fin will likewise be fit checked at the base rib splice connection and mold line fairing.

The Fin and Elevons will be removed and prepared for shipment to the Booster Final Assembly Site.

Installations and acceptance shall be conducted on the wing assembly and then it will be prepared for shipment to the Booster Final Assembly site.

Tooling requirements are Wing Cradles, Slings, Scaffolding and Contour Boards.

Existing assembly processes will be used.

4.3.6.5 <u>Facility Requirements</u>

Fabrication Facilities - See Table 4.3-11

Assembly Facilities - See Table 4.3-12

TABLE 4.3-11

WING AND CONTROL SURFACE FABRICATION FACILITY REQUIREMENTS

Facility Requirement	Facility Availability
Area	
Approx. 100,000 sq. ft., 40' clear ceiling height.	Available at Contractor Facility
Cranes	
	Available at Contractor's Facility
Major Manufacturing Equipment	
Hydro Press	
N.C. Mills-Profile	
Skin Stretch Press	
Spar Mills-Tracer	
Extrusion Stretch Press	Existing at Contractors Facilities
Press Brake	
Routers	
Band Saws	
N.C. Skin Mills	
Jig Borer	
Shears	
Form Presses	
Chemical Milling Tanks	
Drop Hammers	
Form Rolls	
Aging Equipment	

TABLE 4.3-11 (Cont'd)

Facility Requirement	Facility Availability
Major Manufacturing Tooling	
Wing Leading Edge	
Locating Fixture, Nose Ribs	
Locating Fixture, Front Spar	
Locating Fixture, Rib Assemblies	New
Locating Fixture, Former Assemblies	
Major Assembly Fixture, Wing Leading Edge	
Wing Torque Box	
Assembly Fixture, Front & Rear Spars	
Locating Fixture, Front & Rear Spars	
Locating Fixture, Front & Rear Spars	
Locating Fixture, Rib Assemblies	New
Holding Fixture, Hinge & Fitting Machining	
Major Assembly Fixture, Wing Torque Box	
Vertical Fins	
o Leading Edge Assembly	
Locating Fixture, Leading Edge Assembly	
Locating Fixture, Front Spar Assembly	
Locating Fixture, Rib Assembly	
Locating Fixture, Former Assembly	New
Major Assembly Fixture - Vertical Fin Leading Edge	

TABLE 4.3-11 (Cont'd)

Facility Requirement	Facility Availability
o Torque Box	
Assembly Fixture, Front & Rear Spars	
Locating Fixture, Front & Rear Spars	
Locating Fixture, Upper & Lower Foremers	
Locating Fixture, Rib Assembly	
Holding Fixture, Hinge & Fitting Machining	
Major Assembly Fixture, Vertical Fin Torque Box	
o Vertical Fin - Rudder	
Assembly Fixture, Rudder	
o Vertical Fin Assembly	New
Major Assembly Fixture - Vertical Fin	
Elevons	
o Front Spar	
Assembly Fixture, Front Spar	
Holding Fixture, Spar Mill	
o Trailing Tip	
Assembly Fixture, Trailing Tip	
Holding Fixture, Tip Fitting Machining	New
Holding Fixture, Rib Assembly	
Holding Fixture, Gap Gover	

TABLE 4.3-11 (Cont'd)

Facility Requirement	Facility Availability
Holding Fixture, Hinge Fitting Machining	New
Major Assembly Fixture, Elevon	
<u>Major Processing Equipment</u>	
Clean and Rinse System	
Chem-Mil System	Exists at Contractor Facilities
Anodizing System	
<u>Laboratory</u>	
Non-Destructive Test	Exists at Contractor Facilities
Metal Finish	
Protective Coating	

TABLE 4.3-12

WING AND CONTROL SURFACE ASSEMBLY FACILITY REQUIREMENT

Facility Requirement	Facility Availability
Area	
Approx. 60,000 sq. ft., 40' clear ceiling height	Available at Contractor Facility
Major Assembly Tooling	
Major Splice Fixture, Wings and Control Surfaces	New
Handling Slings, All Subassemblies	New
Transportation Dollies, All subassemblies	New
Storage Dollies, All Subassemblies	New
Special	
Leak and Pressure Test Facility for Integral JP-4 Tanks	Exists at Contractor Facilities

4.3.7 Canard

4.3.7.1 Canard Description

The left and right canards (See Figure 4.3-35) are of conventional aircraft construction, each consisting of the following:

Fixed Leading Edge Assembly

Intake Leading Edge Assembly

Trailin g Edge Assembly

Jet Flap Assemblies

Main Engine Ribs

Intermediate Formers

Stringers

Skins

Door Panel Assemblies

Thrust Fittings

Tip Assembly

Actuator and Linkage Mechanisms

An illustrated Manufacturing Flow Sequence is shown in Figure 4.3-36. A Manufacturing Flow Chart and Schedule is shown in Figure 4.3-37.

CANARD ASSEMBLY

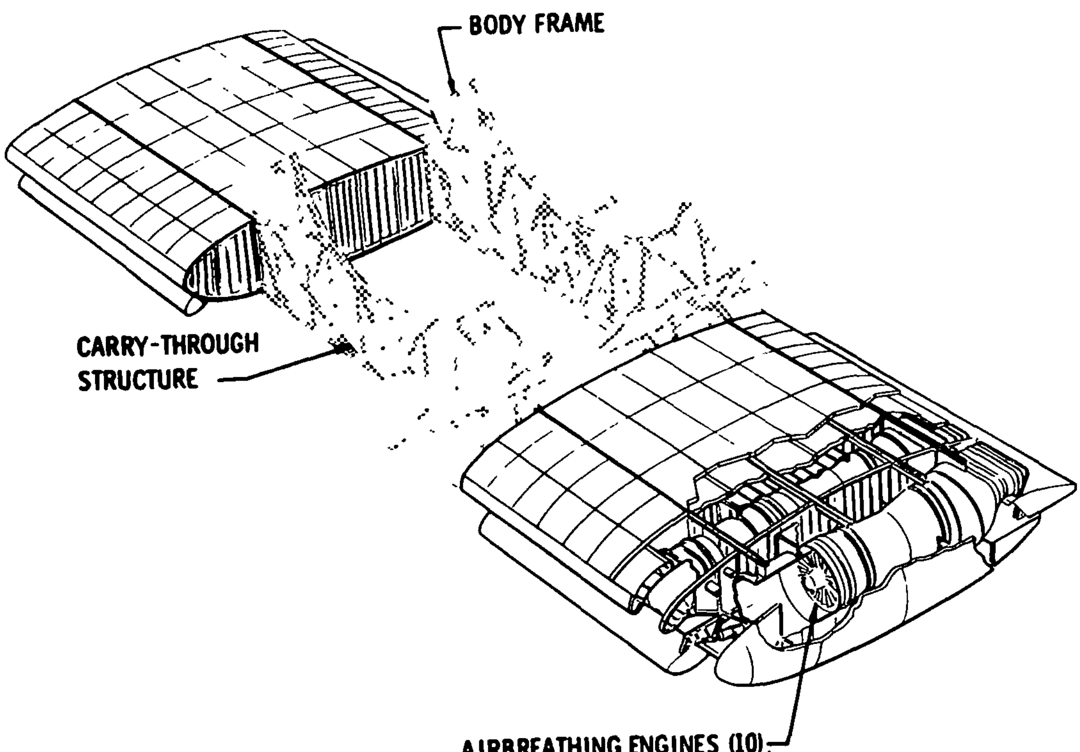


FIGURE 4.3-35

CANARD
Manufacturing Assembly Sequence – Booster

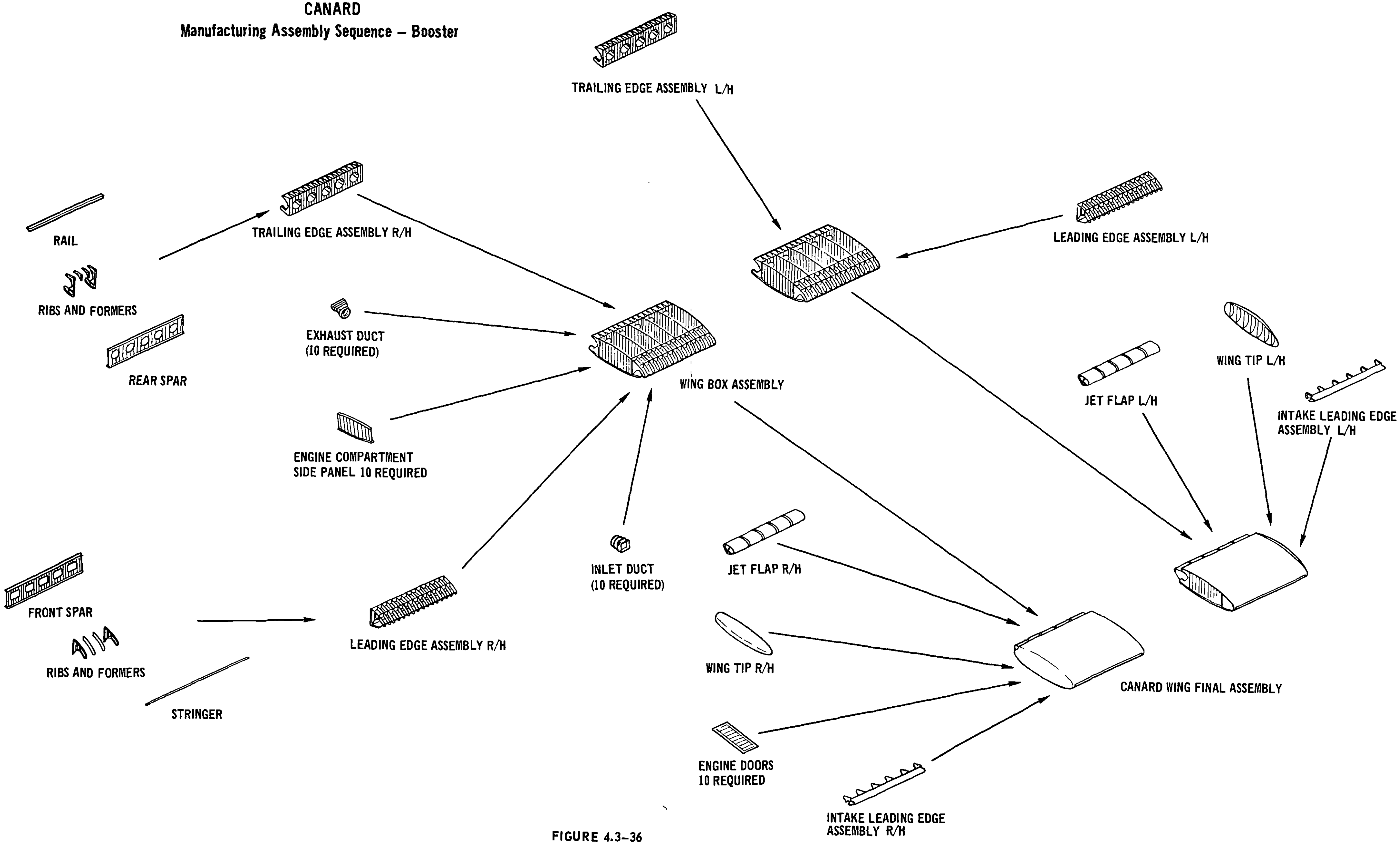


FIGURE 4.3-36

MANUFACTURING FLOW CHART & SCHEDULE
Canard

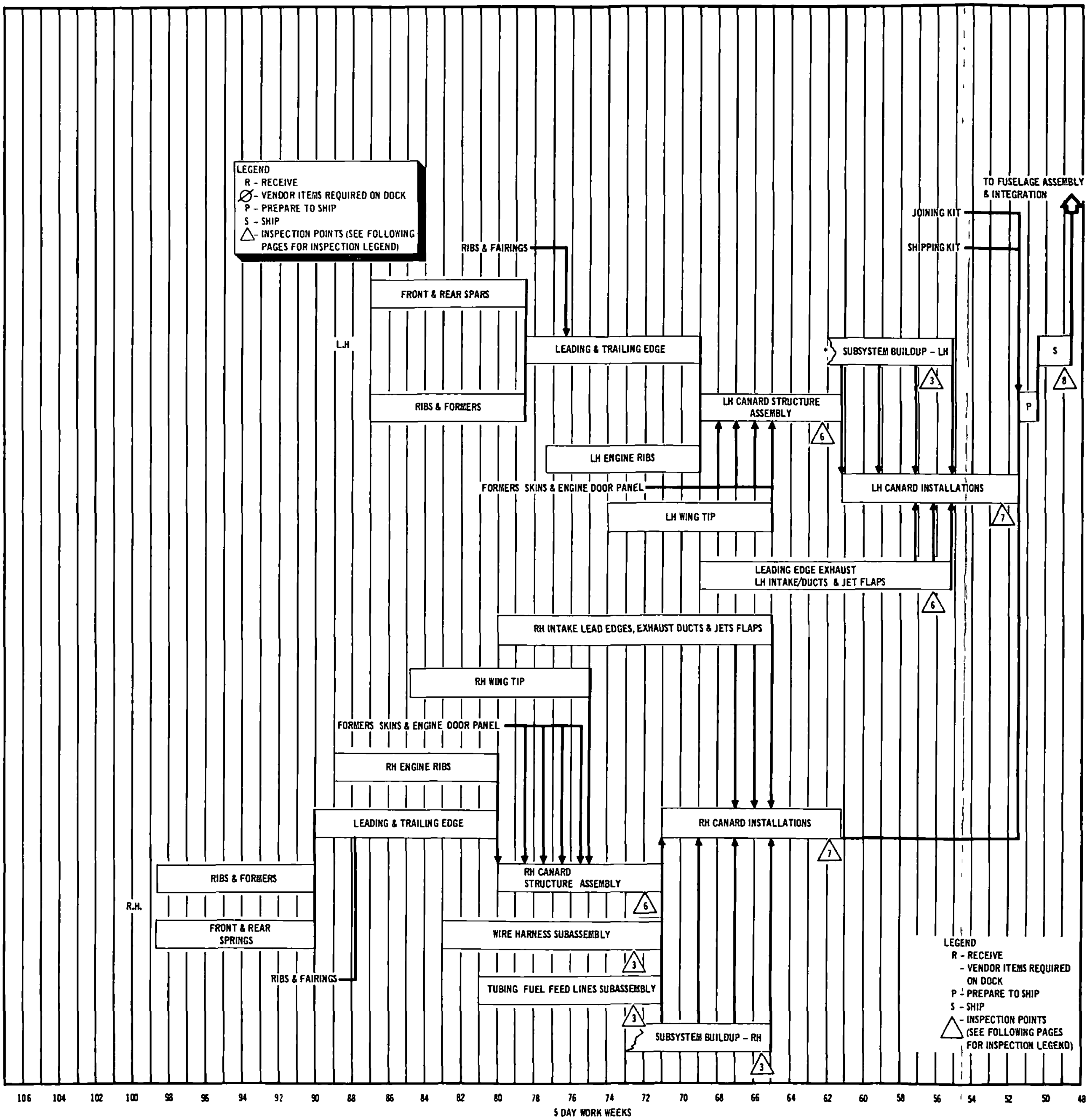


FIGURE 4.3-37

4.3.7.2 Manufacturing Site

It is recommended that the canards be fabricated and assembled at a Contractor Facility.

4.3.7.3 Manufacturing Approach

As previously mentioned, the canards will be of conventional aircraft construction. Conventional techniques for sheet metal, machining, processing and assembly operations will be employed in the manufacture of canard sub-assemblies and components.

4.3.7.4 Manufacturing Operations

BUILD UP OF MAJOR SUB-ASSEMBLIES

Fixed Leading Edge - The Fixed Leading Edge consists of:

Front Spar

Fixed Nose Section

Hinge Ribs

Inlet Fairings

Inlet Ducts

Skins

- o Front Spar Assembly: The assembly consists of upper and lower chords, webs, stiffeners, ring frames.

  A holding fixture will be required to position all parts for joining and maintaining mold line control.

  The spar chords will be machined from extrusions on taper controlled mills and holding fixtures.

  The spar webs will be chem-milled to obtain double thickness requirements.

The ring frames will be standard extrusion stretch formed to a block on an extrusion stretch press.

- Fixed Nose Section: consists of Nose Beam, Front Beam, Corrugated skin, upper skin, and stub rib plates

  Assembly fixture will be supplied to position and hold all parts for joining and contour control.

  Nose Beam and Front Beams will be tapered on spar mills from extrusion.

  Corrugated skin will be brake formed and sawed to size.

  The upper skins will be sheared to size and slip-roll formed on Farnham Rolls.

  The intermediate stub ribs will be machined from plate stock. The main stub rib plates will be N/C machined from plate stock using holding fixtures.

- The Hinge Ribs will be N/C machined from plate stock using holding fixtures and then the hinge and actuator holes wil be jig-bored.

- The sheet metal inlet fairings will be hot formed to shape on press and sawed to size with trim templets.

- The Inlet Ducts sections will be hot formed on press trimmed to size by sawing and resistance welded together. The external hoop frames will be stretch formed on blocks and resistance welded to the duct assembly.

o The External Leading Edge skins are stretch formed on blocks using a skin stretch press.

Fixed Leading Edge requires Assembly Fixture to position and secure all assemblies and detail parts for joining. The structural components will be assembled and fastened, the outer skins installed along with the inner corrugated skins for the lip portion. The installation of the ducts and fairings will complete the unit.

No detail or assembly tooling in existance.

No new manufacturing processes required.

All equipment requirements exist in the team/corporate house.

Handling sling required.

Storage and transportation dolly required.

Intake Leading Edge - The Intake Leading Edge consists of:

Beam Assembly

Ribs

Formers

Skins

Rails

Hinge Fittings

o Beam Assembly: The beam assembly consists of upper and lower rails, webs, nose ribs and skins.

Requires a locating fixture to position all parts for joining and control of mold line requirements.

The rails will be machined from basic extrusions on spar mills with holding fixtures.

The webs will be sheared and then the reinforcing beads formed by beading dies or Hydro-Press blocks.

The nose ribs will be routed to size and formed on blocks in the Hydro-Press.

The nose skins will be formed on blocks in skin stretch press and trimmed on bond saw.

- The intermediate sheet metal ribs will be sized on router boards and formed over blocks on the Hydro-Press.
- The main ribs will be N/C machined from plate stock with holding fixture.
- The hinge and actuator fittings will be N/C machined from plate stock using holding fixtures and then all holes machined by jig-boring.
- The two rear cove rails will be extrusions sawed to length.
- The skins will be sheared to size and hand wrapped to the rib contours at assembly.
- The stringers will be brake formed or extrusions sawed to length.

Intake Leading Edge requires assembly fixture to locate all of the above listed parts for joining and establishing contour requirements. The Beam will be positioned followed by the nose ribs, ribs, formers and tip rails. The structure will be fastened, skins attached and then the hinge fittings assembled after all structural fastening is completed.

No detail or assembly tooling is in existence.

No new manufacturing processes required.

All equipment requirements exist.

Handling sling required.

Storage and transportation dolly required.

<u>Trailing Edge Assembly</u> - The Trailing Edge Assembly consists of:

Rear Spar

Machined Ribs

Hinge Fittings

Formers

Rails

Skins

- Rear Spar Assembly consists of upper and lower chords, webs and stiffners and will be built in the same manner as the Leading Edge Front Spar.

- The machined ribs (two-piece) are N/C machined from plate stock utilizing holding fixtures.

- o The hinge fittings will be machined by N/C from plate stock utilizing holding fixture.
- o The sheet-metal formers will be cut to size on router boards and formed over blocks in the Hydro-Press.
- o The intermediate and tip rails will be sawed to length from extrusion.
- o The skins will be sheared to size and require no forming.

Trailing Edge Assembly fixture will be required to position all parts for joining and mold line dimensional control. The Rear Spar will be positioned, the Ribs, Formers and Rails will be positioned and joined. Skins will be added and all structural connections made. The hinge fittings will be located and fastened. Hinge alignment is critical in this assembly.

Handling sling will be required.

Transportation and storage dolly will be required.

Jet Flap Assembly - Each left and right Jet Flap Assembly consists of five identical sections. Each section consists of:

Beam Asembly

Front Rail

Rear Rail

Stringers

Formers

Skins

Hinge Ribs

Lock-Up Fittings

- o The Beam Assembly consists of an upper and lower Tee section member sawed to length from extrusion and a web sheared to size and riveted all fastened as an assembly.
- o The Front Rails, Rear Rails and Stringers will be sawed to length from extrusions or sheared and brake formed from sheet metal.
- o The intermediate sheet metal formers will be hot formed in dies.
- o The closing Hinge Ribs will be machined by N/C from plate stock utilizing holding fixtures.
- o The lock-up fittings will be N/C machined from bar stock with holding fixtures.
- o The skins will be stretch formed on blocks and trimmed to size by sawing.

Jet Flap Assembly fixture will be provided to position all parts for assembly and joining. The Beam Assembly will be located and then the Front and Rear Rails along with the two piece sheet metal formers and structural fastening completed. The closing Hinge Rigs and stringers will be assembled and the skins installed. After all joining operations the assembly will be placed on a horizontal boring mill and the hinge holes machined in each end closing rib.

Handling sling will be required.

Storage and transportation dollies will be required.

BUILD-UP OF MINOR SUB-ASSEMBLIES AND COMPONENTS

- Main Engine Rib Assemblies - Consists of: upper and lower chords, thrust fitting beams, and webs and stiffners.

  The assembly fixture provided will build all the engine rib assemblies. The tool will locate all parts for fastening and mold line contour control.

  The thrust beam fittings will be machined from bar stock on N/C mills utilizing holding fixtures.

- Intermediate Formers - Consist of: Chords, Webs, Stiffners.
- Assembly Fixture - will be provided.
- Chords - will be formed on blocks on stretch press.
- Stringers - will be sawed to length from extruded shapes.
- Skin Panels - Will be chem-milled as required and formed at assembly.
- Thrust Fittings - Will be machined by N/C from bar stock or forgings and holding fixture will be provided.
- Engine Door Panel Assemblies - Will be conventional skin and stringer sheet metal construction with latching mechanisms.
- Tip Assembly - Will comprise die formed skins made into a welded assembly with ribs.

Canard Final Assembly

An Assembly Fixture with contour boards will be provided to assemble the Canard in the following sequence - Position the Fixed Leading Edge and Trailing Edge assemblies in place and clamp to the locators and contour boards. Install and clamp the Main Engine Rib assemblies to the Front and Rear Spars. Install the Intermediate Formers and Clamp in place. Make all initial mechanical fastening attachments. Install the skins and stringers and attach. Complete all structural fastening. Install the outboard Tip Assembly and join. Install and fasten the firewall shields and Engine Thrust Fittings using optics and/or a simulated dummy engine for interface control.

The Canard Assembly will be removed from the assembly fixture and placed on Cradles. The movable Intake Leading Edge and its associated linkage, plumbing, harnesses and actuators will be installed for fit check and mold line check. The Jet Flap Assemblies, actuators, plumbing, harnesses and linkage will be installed and fit checked and tested. Cruise propulsion system items--plumbing, valves, regulators and pumps--will be installed and tested. The engine access Door Panel Assemblies will be installed and all fastener locations drilled and inserted. (NOTE: A/B engines will be installed at fuselage final assembly site).

The assembly will be removed from its cradles and prepared for shipment to the Booster Final Assembly site.

A sling for the Canard Assembly will be required.

4.3.7.5 Facility Requirements

Fabrication Facilities - See Table 4.3-13

Assembly Facilities - See Table 4.3-14

TABLE 4.3-13

CANARD FABRICATION FACILITY REQUIREMENTS

Facility Requirement	Facility Availability
Area	
Approx. 20,000 sq.ft. 40' Clear ceiling height	Existing at Contractor Facility
Crane	
2 Tons	Existing at Contractor Facility
Major Manufacturing Equipment	
Hydro-Press	All Existing at Contractor Facility
N.C. Mills-Profile	
Skin Stretch Press	
Spar Mills-Tracer	
Extrusion Stretch Press	
Press Brake	
Routers	
Band Saws	
N.C. Skin Mills	
Jig Borer	
Shears	
Form Presses	
Chemical Milling Tanks	
Drop Hammers	
Form Rolls	

TABLE 4.3-13 (Cont'd)

Major Manufacturing Tooling	
Assy Fixt, Rib Nose	
Holding Fixt. Stub Rib Plates	
Holding Fixt. Hinge Ribs	
Locating Fixt., Beam Joining	New
Locating Fixt., Beam Rails	
Locating Fixt., Beam Main Rib	
Locating Fixt., Hinge/Actuator Fitting	
Locating Fixt., Rib Machining	
Locating Fixt., Hinge Fitting Machining	
Locating Fixt., Closing Hinge Rib Machining	
Locating Fixt., Lock-up Fitting Machining	
Locating Fixt., Thrust Beam Fitting Machining	
Locating Fixt., Thrust Fitting Machining	
Major Processing Facilities	
Chem Cleaning Tanks	Existing at Contractor Facilities
Chem Processing Tanks	
Heat Treat Equipment	
Ageing Equipment	
Welding	
Automatic MIG	Existing at Contractor Facilities
Automatic TIG	
Resistance Welders	

TABLE 4.3-13 (Cont'd)

<u>Laboratory</u>	
Non-Destructive Test	Existing at Contractor Facilities
Metal Finish	
Protective Coatings	

TABLE 4.3-14

Canard Assembly Facility Requirements

Facility Requirement	Facility Availability
Area	
Approx. 10,000 sq. ft. 40' clear ceiling height	Existing at Contractor Facilities
Crane	
2 Tons	
Major Assembly Tooling	
Assembly Fixt., Fixed Leading Edge	
Assembly Fixt., Intake Leading Edge	New
Assembly Fixt., Trailing Edge	
Assembly Fixt., Jet Flap	
Assembly Fixt., Main Engine Rib	
Final Assembly Fixture - Canard	
Optical Tooling	
Cradle - Canard Holding	
Handling Slings	
Storage Dollies	
Transportation Dollies	

4.3.8 Thermal Protection System (TPS)

4.3.8.1 TPS Description - The Thermal Protection System (TPS) consists essentially of hardened compacted fiber (HCF) tiles bonded to substructure panels. These panels cover the wetted surfaces of the vehicle, attaching to the basic structure. (Figures 4.3-38, 4.3-39, 4.3-40 and 4.3-41). HCF tiles are made up of mullite fibers, a silica filler and silica binder.

4.3.8.2 Manufacturing Site - It is recommended that TPS components be manufactured at a Contractor facility.

4.3.8.3 Manufacturing Approach - A brief description of the Tile Manufacturing Sequence is given in Figure 4.3-39. A Manufacturing Flow Chart and Schedule is shown in Figure 4.3-40.

Laboratory fabrication techniques for fabricating H.C.F. tiles have been developed; however, additional development of methods and manufacturing process will be required to effect transition from laboratory to manufacturing shops. This will be a continuing evolution during current NASA funded studies, and Phase C/D.

The critical processes for fabricating H.C.F. tiles are vacuum felting, heat treating, coating, and fitting or alignment of TPS panels prior to final installation. These are items of concern that could become program impact items if development programs are delayed. Obviously, not all H.C.F. manufacturing problems have been identified at this time due to the limited depth of design information available.

4.3.8.4 Manufacturing Operations - The H.C.F. tiles are fabricated by mixing mullite fibers with the silica filler and binder. The basic tiles are

THERMAL PROTECTION SYSTEM – PANEL SUMMARY

Area	Number of Panels	Types of Panels
WING		
Upper Surface	282	84
Lower Surface	606	82
FIN		
Inboard Surface	118	46
Outboard Surface	116	38
BODY		
Nose Section	86	14
Forebody Section	544	53
Constant Section	1272	13
Aft Section	670	110
CANARD		
Upper Surface	156	12
Lower Surface	120	4
Total	3970	456

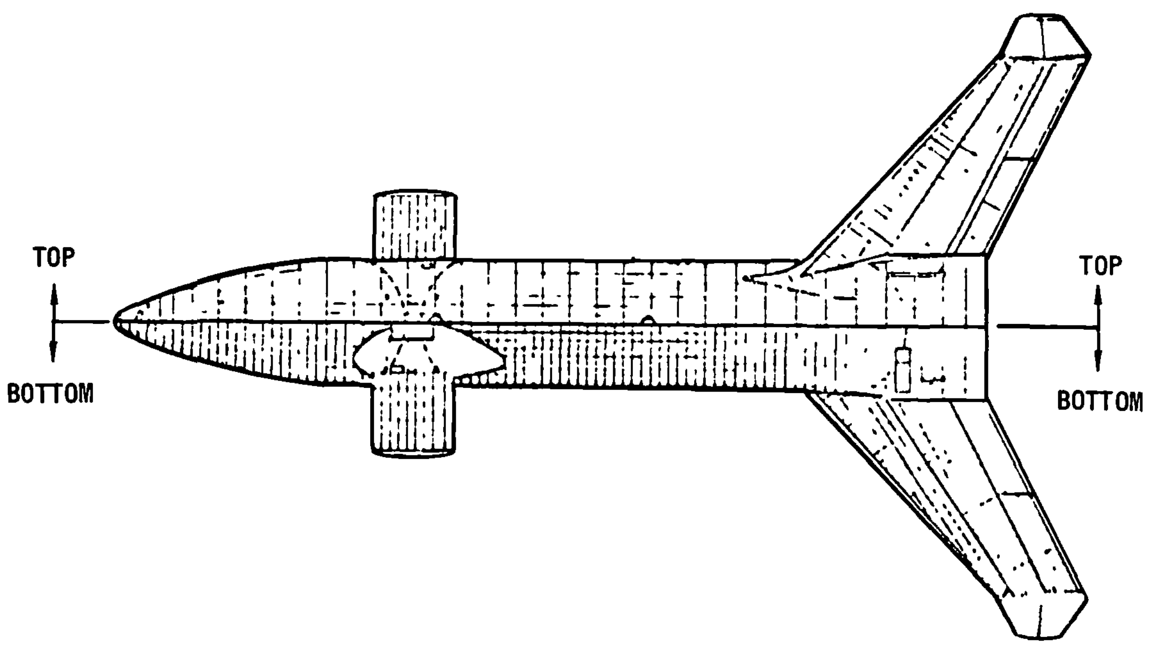
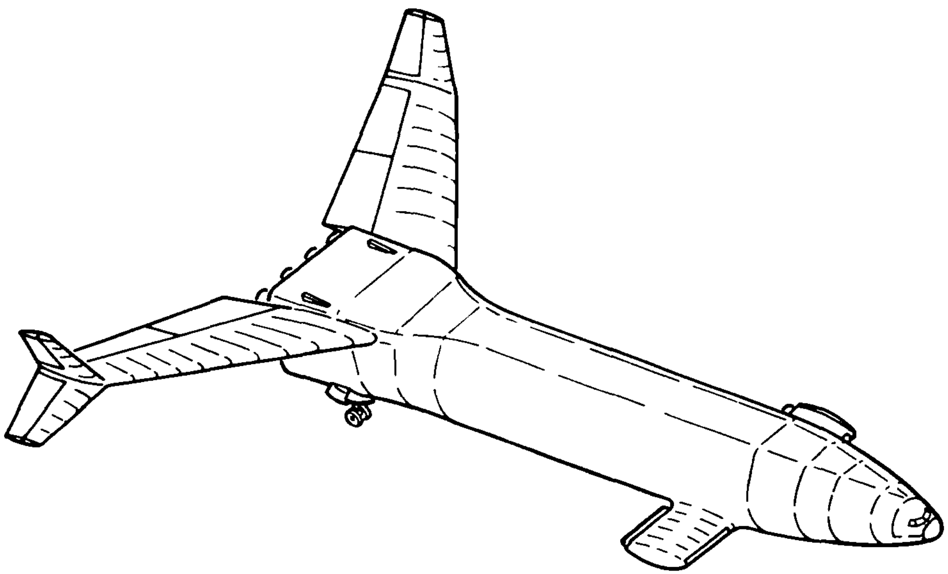


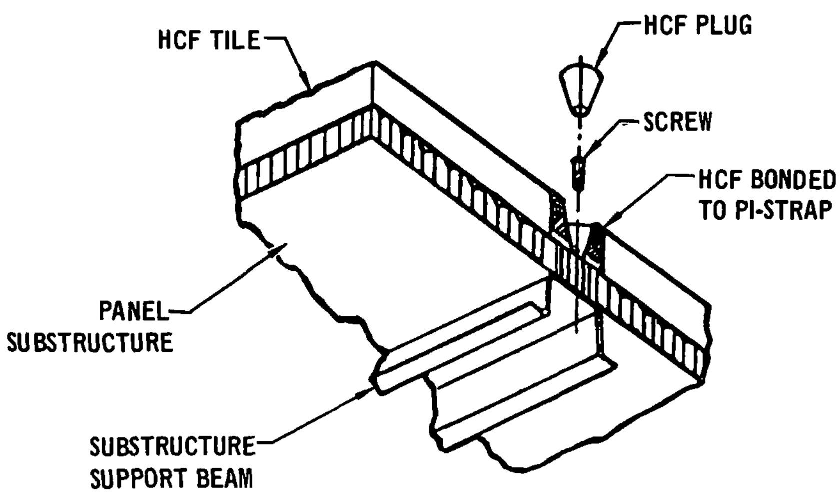
FIGURE 4.3–38

THERMAL PROTECTION SYSTEM (TPS)



HCF TILE MANUFACTURING SEQUENCE

- RAW MATERIALS CONTROL (MULLITE FIBERS FILLER AND BINDER)
- MATERIAL PREPARATION (DISPERSE FIBERS AND FILLER INTO BINDER)
- MIXING (DISPERSE FIBERS AND FILLER INTO BINDER)
- VACUUM FELT
- RELEASE HCF FELT FROM MOLD
- OVEN CURE
- HEAT TREAT AT ELEVATED TEMPERATURES
- MACHINE
- PRELIMINARY INSPECTION
- APPLY WATER, HANDLING RESISTANT COATING CURE AT ELEVATED TEMPERATURE AND FIRE
- APPLY HIGH EMITTANCE COATING, CURE AND FIRE
- FINAL INSPECTION



TYPICAL PI-STRAP ATTACHMENT

FIGURE 4.3-39

TPS – THERMAL PROTECTION SYSTEM – SUBSTITUTE TPS PANELS
MANUFACTURING FLOW CHART & SCHEDULE
Booster

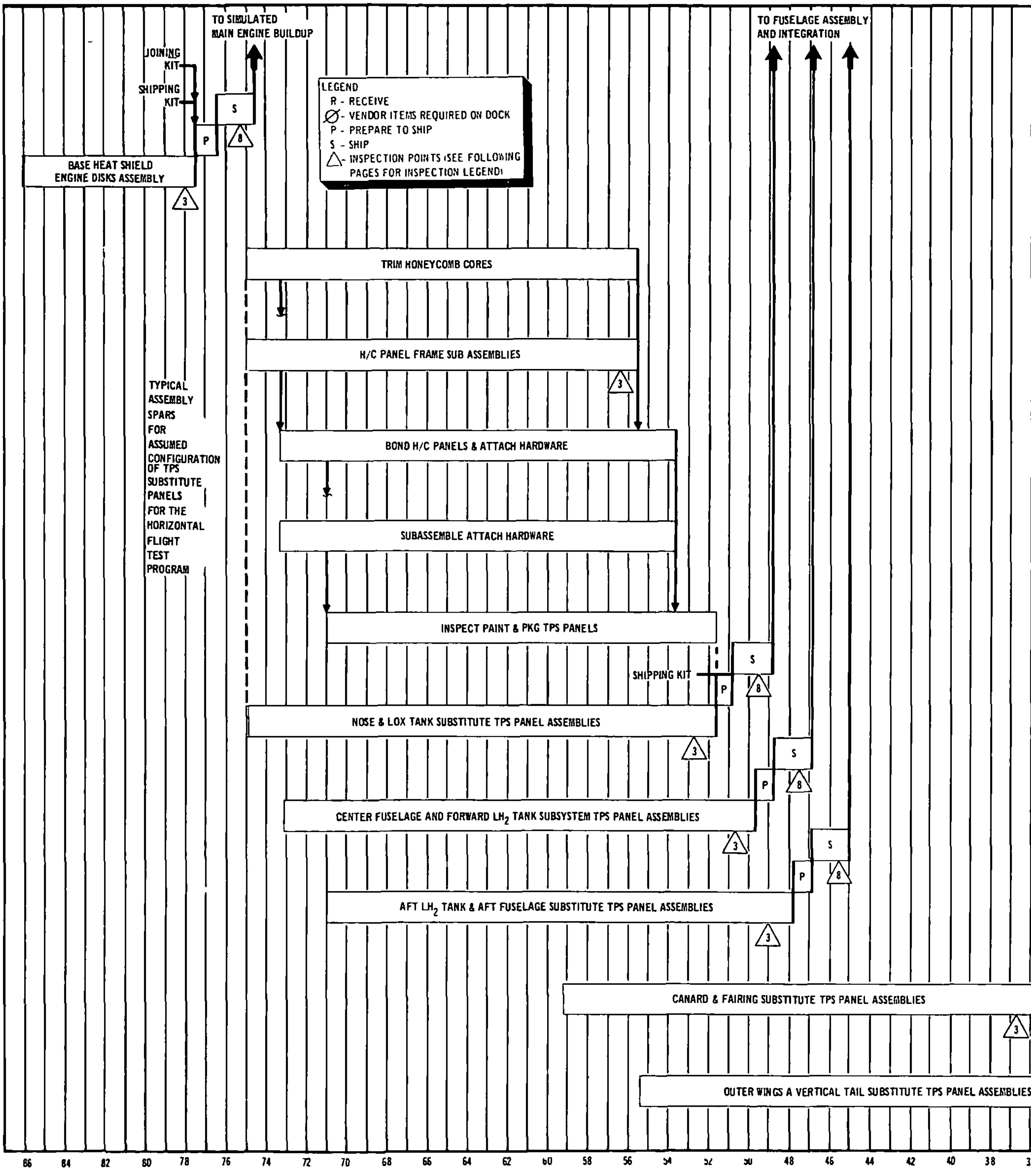


FIGURE 4.3-40

TPS – THERMAL PROTECTION SYSTEM – SUBSTITUTE TPS PANELS MANUFACTURING FLOW CHART & SCHEDULE
Booster

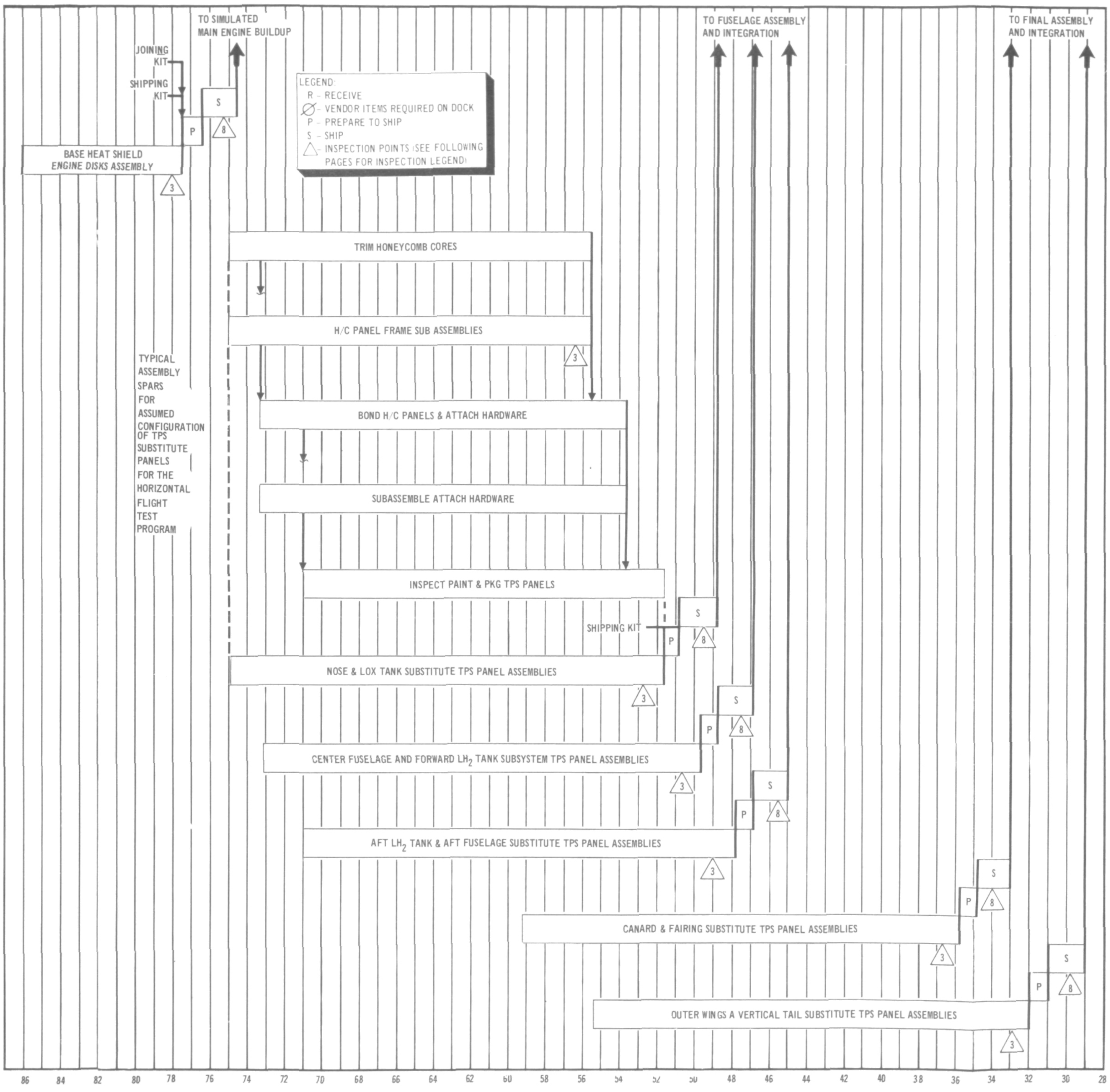
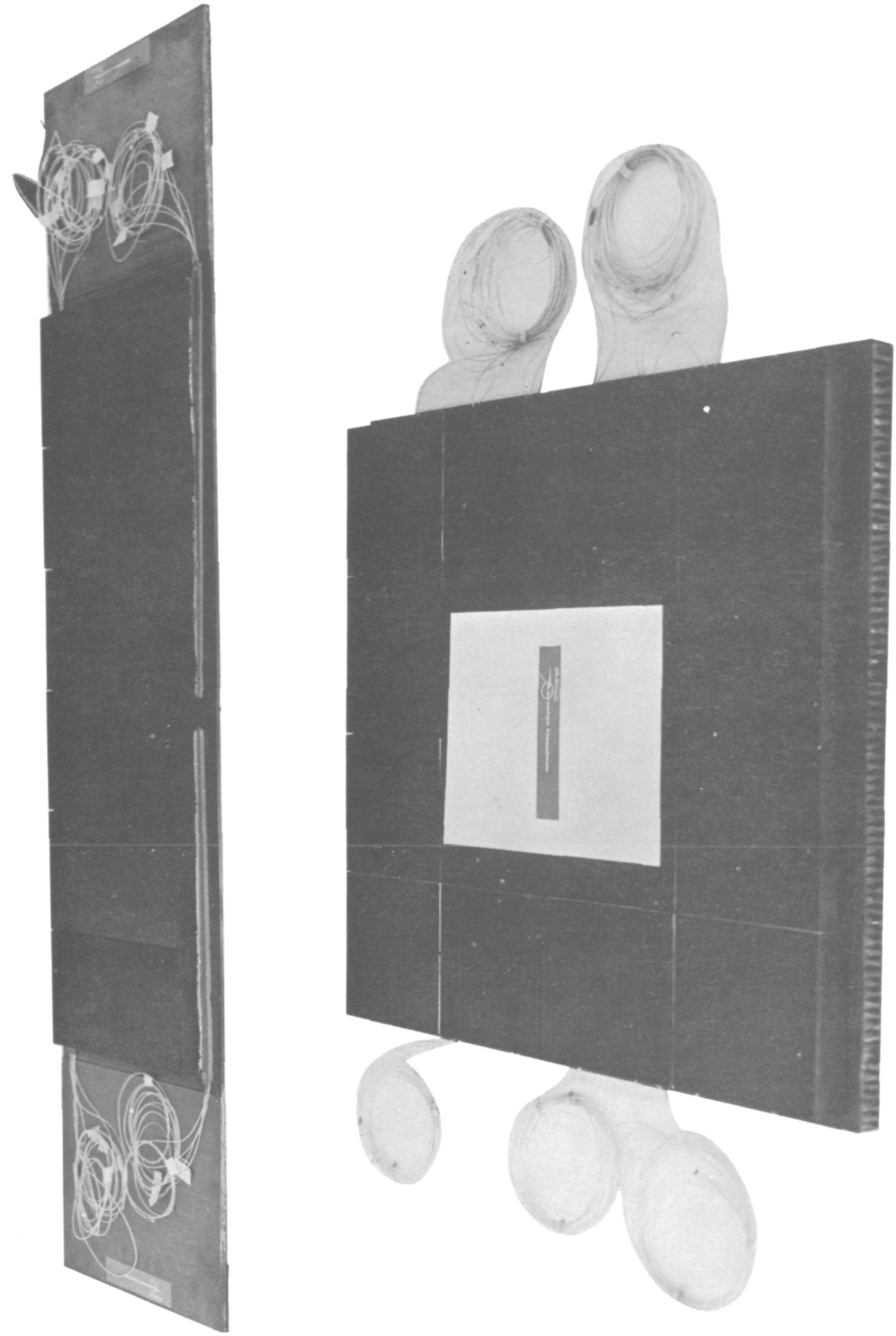


FIGURE 4.3–40



TPS TYPICAL HCF TILE

FIGURE 4.3–41

formed by a process of vacuum felting, oven curing, and heat treating. After basic forming, tiles are machined to proper size, a water/handling coating is applied and elevated temperature curing and firing is performed. Tiles are then completed by applying a high emittance coating and a final curing and firing cycle is accomplished followed by inspection. H.C.F. tiles have a relatively low thermal expansion; however, the T.P.S. panels made from H.C.F. will require closely controlled joints between panels because of expansion and contraction of the vehicles basic structure.

A preliminary survey has been made of industry capabilities to produce the T.P.S. materials in quantities required for the Space Shuttle. This survey indicated ample capacity exists to supply full requirements for the program.

4.3.8.5 Facility Requirement

See Table 4.3-15

4.3.8.6 TPS Installation - After the tiles are completed and trial fitted, but prior to final installation, they will be given a surface protective coating. This hardens the surfaces and will help prevent damage to H.C.F. panels. However, special handling method and packaging techniques will also be used and additional parts will be made to allow for breakage.

Final installation will consist of re-installing H.C.F. panels which have previously been trimmed, drilled, fitted, coated, and trial installed at their assembly location point on the structure.

The panels will be adjusted to meet alignment requirements during final installation, using built in adjustments provided in the panel attachment design.

TPS panels will be installed on the fuselage during final assembly at Michoud.

TPs panels on wings, control surfaces and special access areas will be installed at KSC.

TABLE 4.3-15

HCF TILE FABRICATION FACILITY REQUIREMENTS

Facility Requirement	Facility Availability
Area	
60,000 Sq. Ft.	
Major Manufacturing Equipment	
Multi-Felting Tower Plant	
2500° Furnaces	
Micro-wave Ovens	All New
Curing Ovens	
Cleaning Tanks	
Grit Blasting Equipment	
X-Ray Equipment	
Major Manufacturing Tooling	
BONDING FIXTURES, Bonding HCF Tiles to Sub-strate panels	
SAW FIXTURES, Trimming tiles and panels	All New
ROUTER FIXTURES, Trimming tiles and panels to final size	
DRILL FIXTURES, Drilling panel attach holes	
TEMPLATE SET-UPS, used in making bonding fixtures, router fixtures, saw fixtures, drill fixtures	

TABLE 4.3-15 (Cont'd)

Major Processing Equipment	
Felting	
Cleaning	All New
Bonding	
Coating	
Machining	

4.3.9 Final Assembly - Booster Fuselage

4.3.9.1 General

Final Assembly of the fuselage will take place at Michoud, with the fuselage sections positioned horizontally. Each section will have previously undergone the maximum practical checkout of installed equipment. The handling equipment for each section will provide positive rotational capabilities about the appropriate axes and will be equipped with leveling devices and optical equipment to permit rapid and accurate alignment and mating. Handling and Final Assembly procedures are predicated on maximum practical use of Saturn GSE and tooling, modified as required. An illustrated Manufacturing Assembly Sequence is shown in Figure 4.3-42. The Final Assembly and Checkout Flow Chart and Schedule is shown in Figure 4.3-43.

It is recognized that delivery scheduling conflicts may require modification of the assembly sequences described in this section. Certain operations, particularly installation of airbreathing and main propulsion engines, may subsequently require re-identification as KSC operations.

4.3.9.2 Fuselage Assembly Sequence

The fuselage consists of five (5) major sections. The basic building block section is the LH_2 tank. Each section contains all of its installed systems. Joining of the sections is accomplished progressively about the LH_2 tank. All sections are joined in the horizontal position by a unique system which utilizes a center of gravity (CG) shift technique. This technique utilizes the Orbiter aft attach points for primary support during test of the LH_2 tank and assembly of the fuselage. The fuselage is underslung from a cross truss beam assembly which duplicates the Orbiter interface and provides for precision transverse alignment necessary to achieve joining. Figure 4.3-44 shows the truss beam installed when the LH_2 tank is in the high bay area. The cross truss beam bears on two "A" frame structures which interface with the existing S1C rear transporter. Figure 4.3-45

FINAL ASSEMBLY
Manufacturing Assembly Sequence – Booster

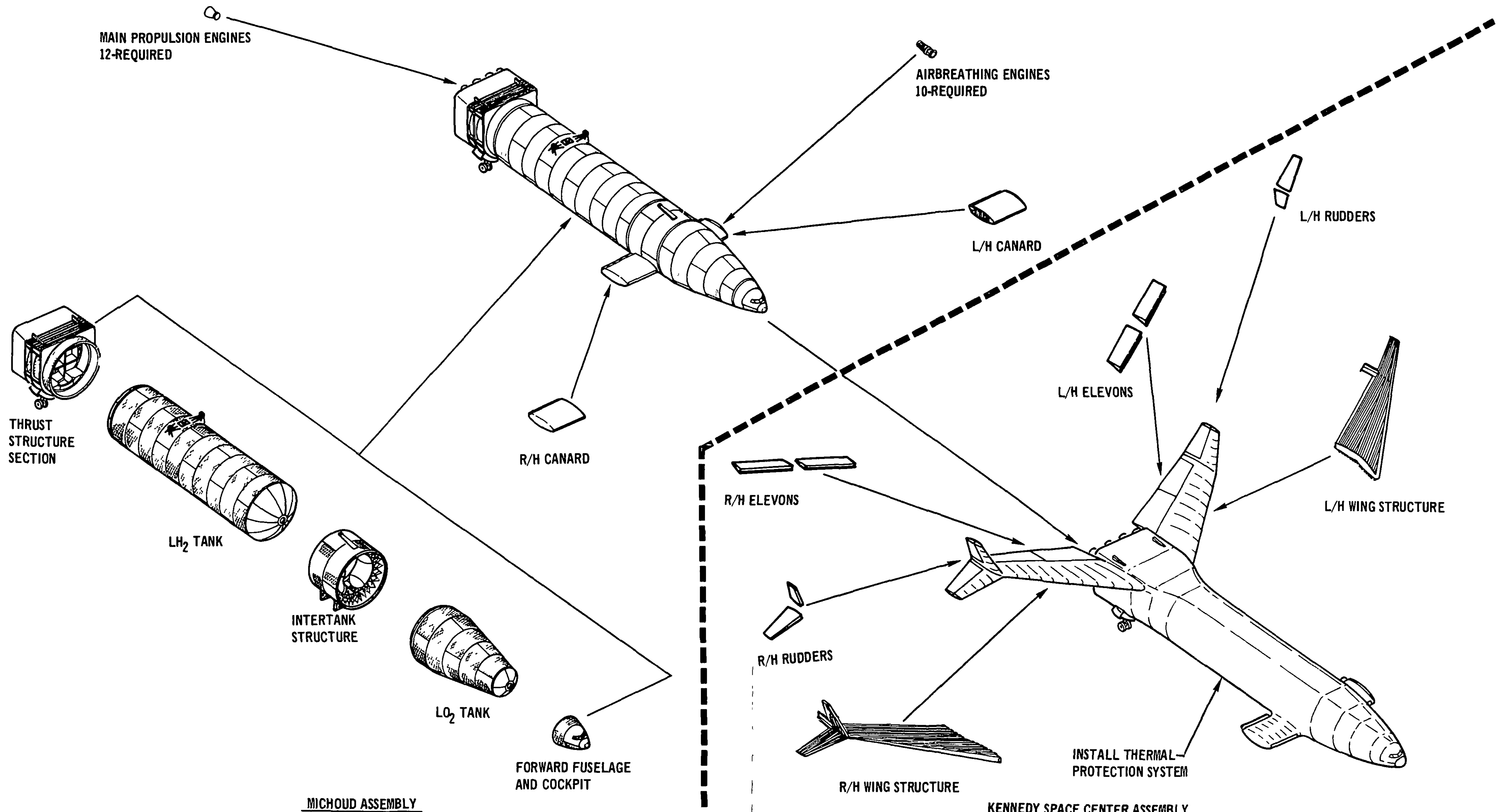


FIGURE 4.3–42

FINAL ASSEMBLY
MANUFACTURING FLOW CHART AND SCHEDULE
Booster

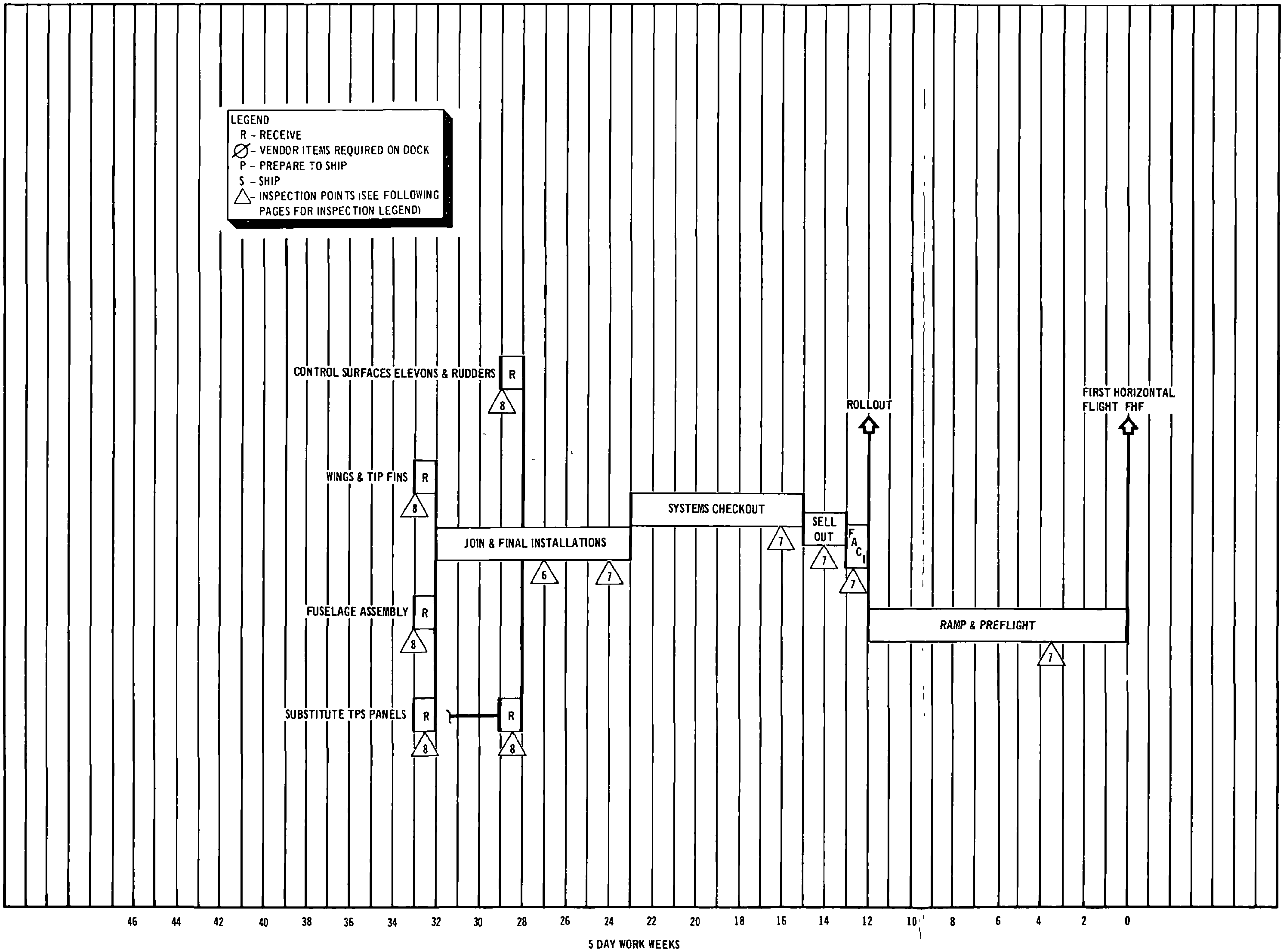


FIGURE 4.3–43

LH_2 TANK VERTICAL HANDLING

- INSTALL HORIZONTAL TRANSPORTER CROSS TRUSS BEAM
- REMOVE LH_2 TANK FROM WELD FIXTURE

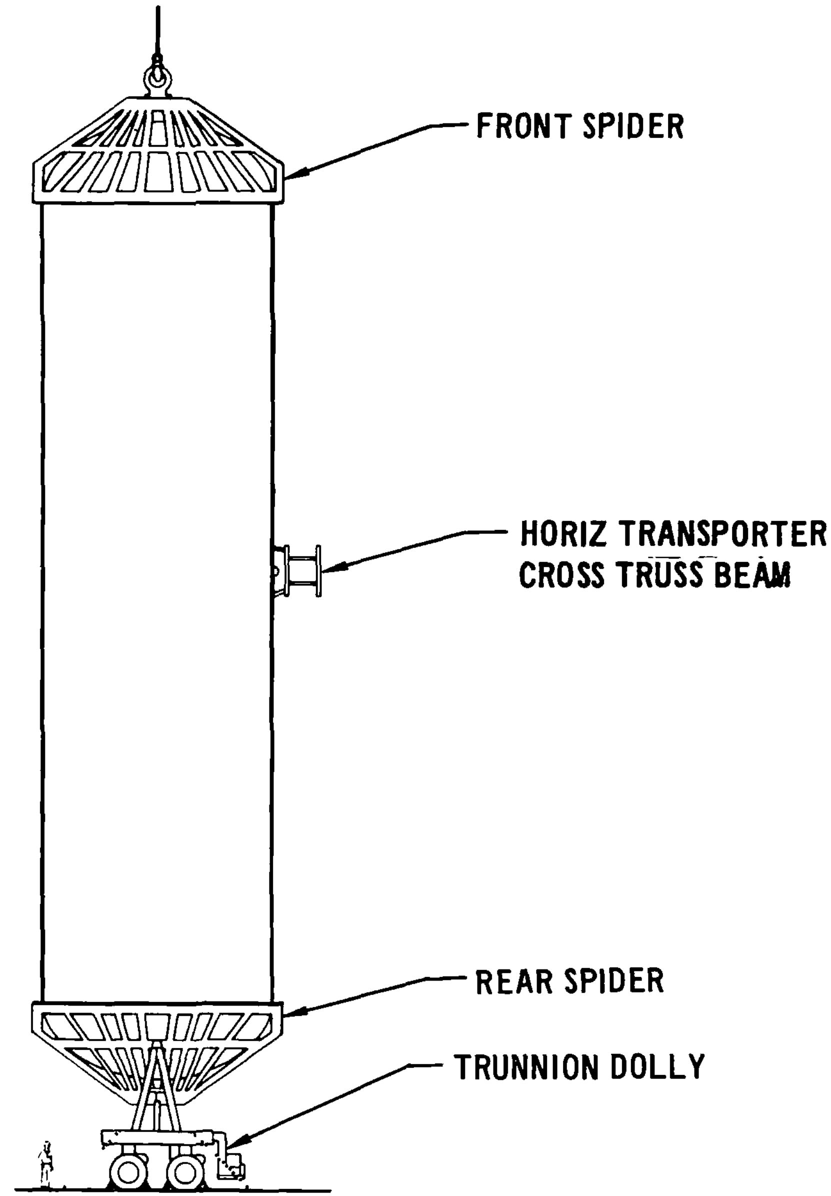


FIGURE 4.3-44

shows how the LH_2 tank is rotated and loaded onto the S1C main transporter. The LH_2 tank is transported to the pneumostatic test facility, insulation facility and main assembly bay with supporting GSE as shown in Figure 4.3-46. The combined CG of the LH_2 tank and GSE is aft of the interstage tie points so the unbalanced load bears on the aft LH_2 rear transporter. This allows the forward Spider to be removed thus freeing the forward LH_2 interface for joining with the Intertank Structure. The Intertank Structure is moved into position on a modified S1B transporter(Fig.4.3-47). Existing S1B jacks are moved into position so that the Intertank Structure can be adjusted to accommodate joining with the LH_2 tank bolt pattern. Figure 4.3-48 shows final joining being accomplished by maneuvering the LH_2 tank into position and making precision adjustments by combining the articulation built into the S1C Main Transporter and the S1B Transporter jacking system. Optics or lazers determine when axial alignment is achieved. The sections are then pulled together by a hydraulic "come along" which connects to the two transporters. Undersized joining bolts establish the initial connection. Final alignment, ream and bolt up completes the Intertank Structure.

The CG of the assembly has now shifted so that the front transporter bears the unbalanced load. Figure 4.3-49 shows the rear S1C transporter and Spider being removed which frees the Thrust Structure Section to LH_2 Tank interface for joining. The Thrust Structure Section is moved into joining position on the main landing gear and a modified S1B transporter. Figure 4.3-50 shows joining being accomplished by maneuvering the Thrust Structure into approximate joining position, as determined by the optical/lazer alignment system. To achieve alignment the precision adjustment capability of the transporter is utilized. Transverse alignment is accomplished by a hydraulically driven cross head adjustment capability which is built into the truss beam. Precision lateral adjustments are accomplished

LH_2 TANK ROTATION TO HORIZONTAL

- INSTALL CROSS TRUSS BEAM TO ORBITER AFT ATTACH POINTS
- POSITION LH_2 MAIN TRANSPORTER
- ROTATE TO HORIZONTAL

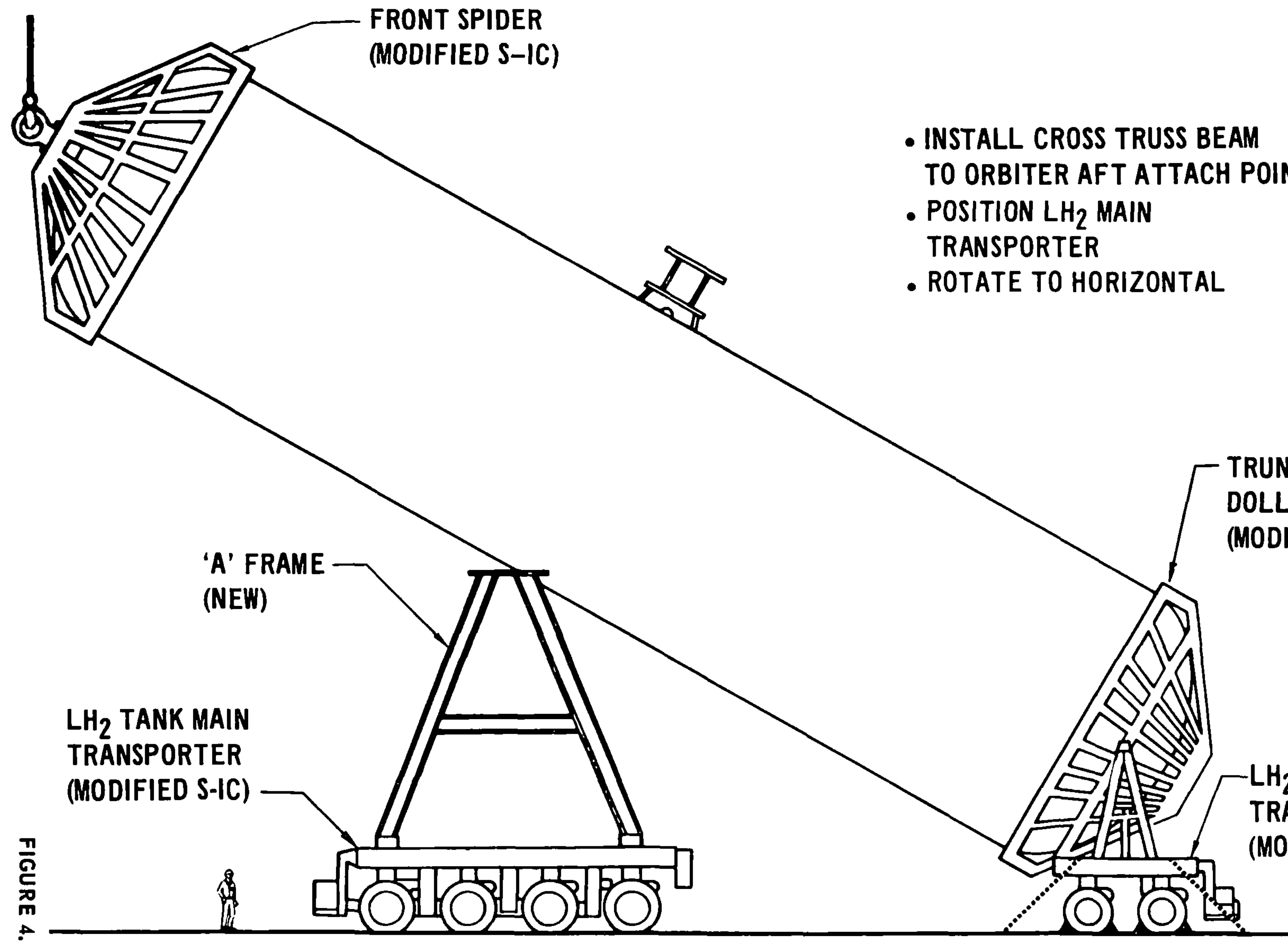
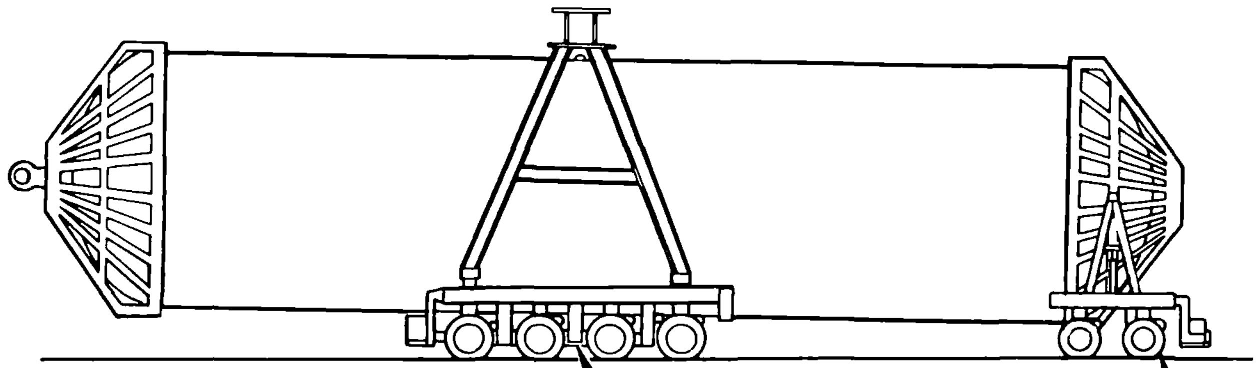


FIGURE 4.3–45

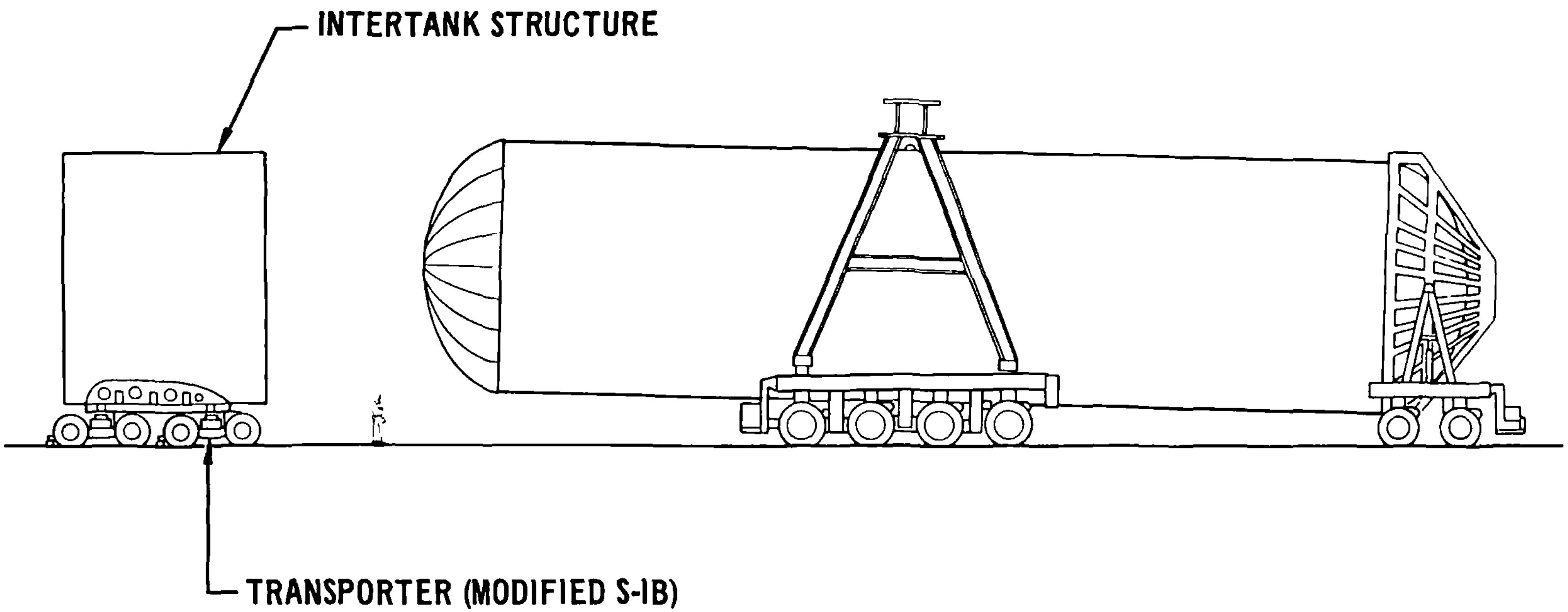
LH_2 TANK HORIZONTAL HANDLING



- LOCK MAIN TRANSPORTER FRAME AND SECURE HORIZONTAL CROSS TRUSS BEAM
- REMOVE FRONT SPIDER
- PREPARE TO MOVE TO TEST AND ASSEMBLY AREA

FIGURE 4.3–46

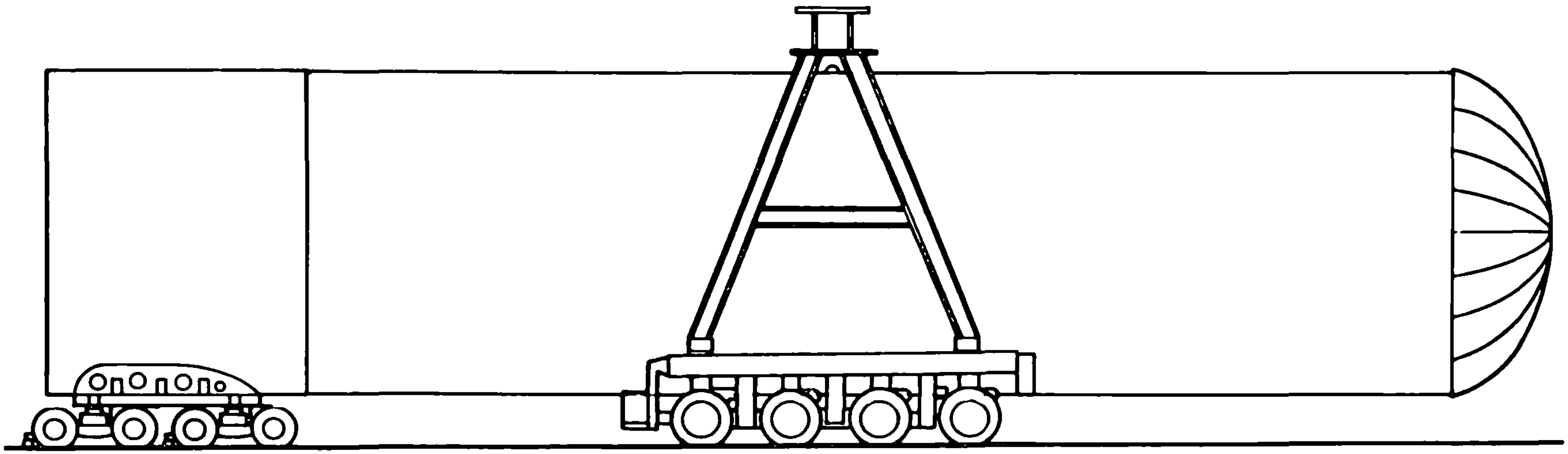
INTERTANK STRUCTURE TO LH_2 TANK ALIGNMENT



- REMOVE FRONT SPIDER
- MOVE INTERTANK STRUCTURE INTO POSITION
- ADJUST LH_2 MAIN TRANSPORTER TO CORRECT MATING INTERFACE POSITION

FIGURE 4.3-47

LH_2 TANK MATE TO INTERTANK STRUCTURE

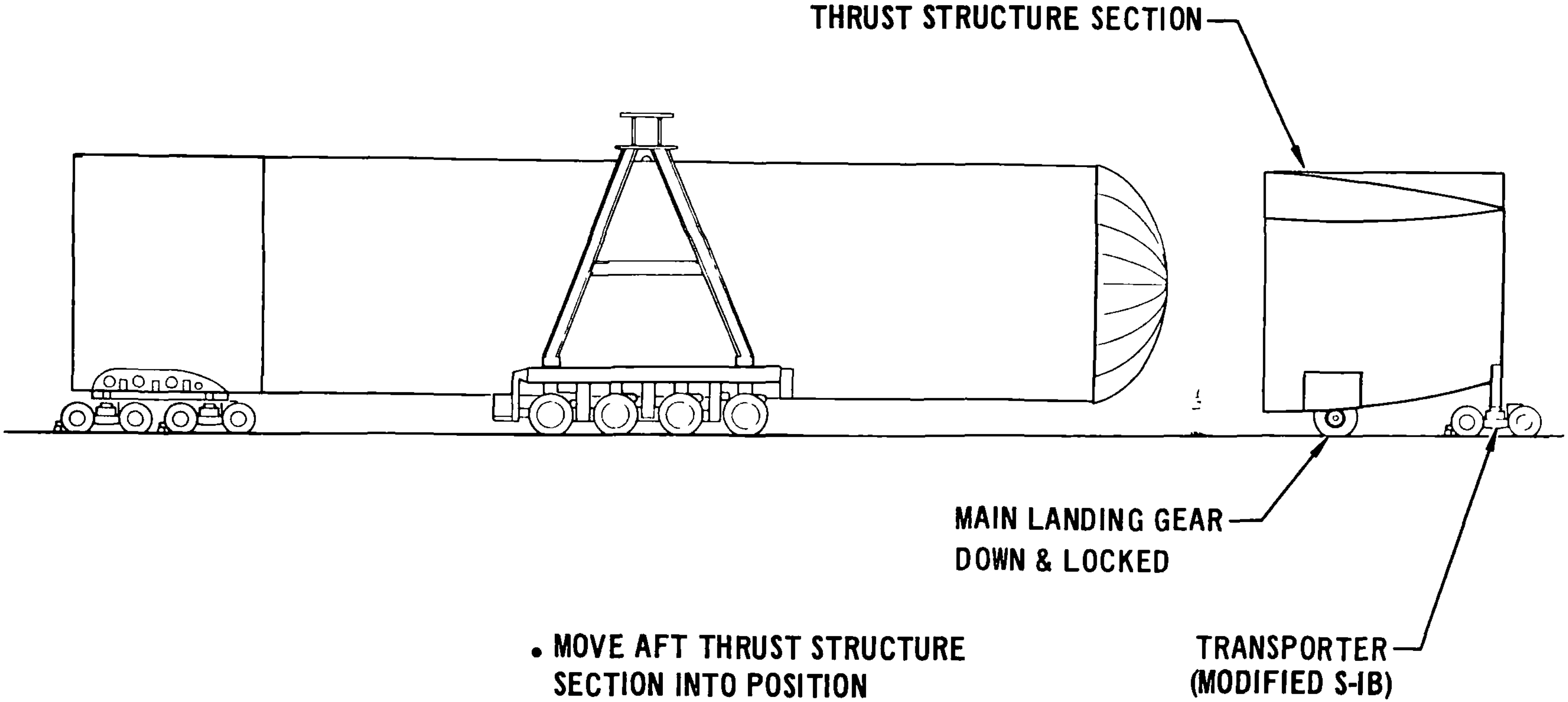


4.3-124

- MATE INTERTANK STRUCTURE TO MAIN LH_2 TANK ASSEMBLY
- REMOVE TRUNNION DOLLY AND REMOVE FROM AREA

FIGURE 4.3-48

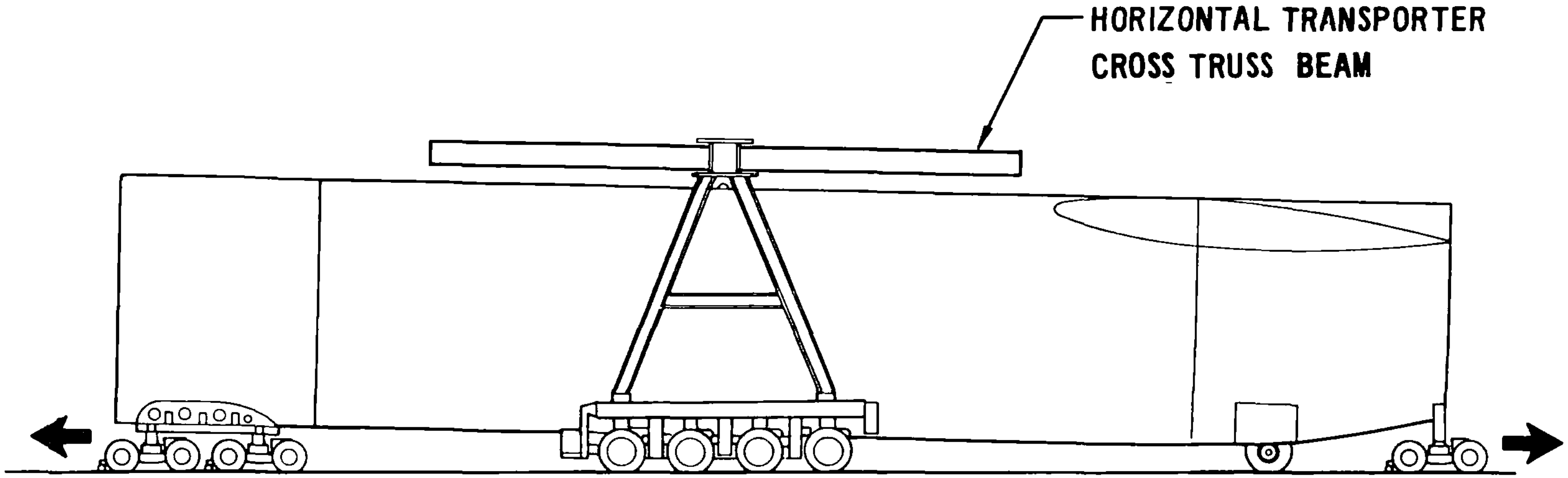
AFT BODY STRUCTURE TO LH_2 TANK ALIGNMENT



- MOVE AFT THRUST STRUCTURE SECTION INTO POSITION
- ADJUST LH_2 MAIN TRANSPORTER TO CORRECT MATING INTERFACE POSITION

FIGURE 4.3-49

LH_2 TANK MATE TO AFT BODY STRUCTURE



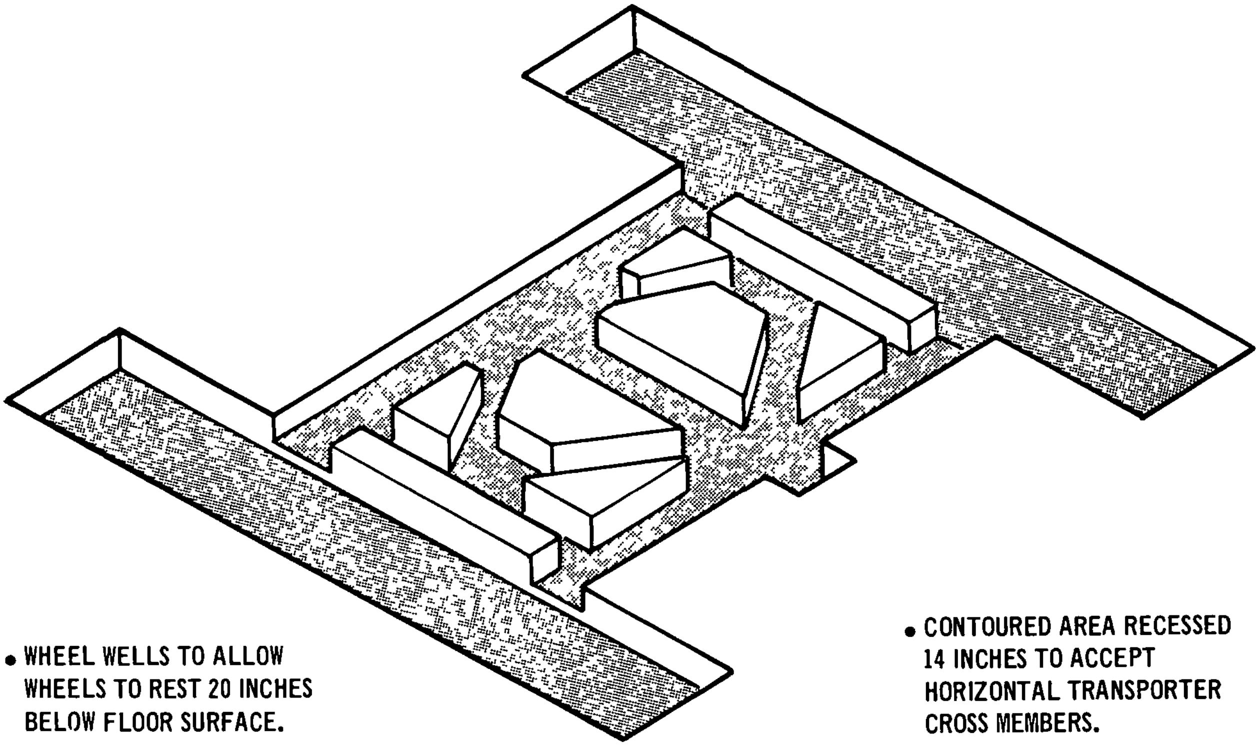
- MATE THRUST STRUCTURE SECTION TO MAIN LH_2 TANK ASSEMBLY
- REMOVE INTERTANK STRUCTURE DOLLY
- LOWER AND LOCK NOSE LANDING GEAR
- ROTATE HORIZONTAL TRANSPORTER CROSS TRUSS BEAM 90^0

FIGURE 4.3-50

by moving the LH_2 interface across the truss beam. The sections are then pulled together by a hydraulic "come along" which connects to the two transporters. Undersized joints bolts establish the initial connection. Final alignment, ream and bolt up completes the joining.

The CG of the assembly has now shifted so that the main landing gear bears the unbalanced load. Figure 4.3-52 shows the Intertank Section Transporter and the Thrust Structure Transport being removed and the nose gear lowered. Entrapment of the Main Transporter between the nose landing gear and the main landing gear is inherent to the assembly sequence. Figure 4.3-51 shows a minor modification of the floor surface necessary to accommodate the removal of the main transporter. This floor depression is located on the centerline of the assembly bay and slightly ahead of the nose gear. It is contoured to match the structural cross member pattern of the S1C main transporter. Suitable filler material is added to fill the depression when it is not in use. Figure 4.3-52 shows the truss beam separated from the interface and rotated 90° to allow removal of the main transporter. Figure 4.3-53 shows the transporter being removed. The fuselage is positioned so that the main transporter floor depression lies immediately ahead of the main transporter. The transporter is moved until the forward wheel bogies overhang the floor depression. The wheels are then lowered approximately twenty (20) inches to the bottom of the floor depression. The main transporter is again moved forward until the third row wheel bogies overhand the floor depression. They are then lowered to the bottom of the floor depression. The main transporter is now moved forward until the cross members register with the floor depression. The transporter is then lowered until the top of the cross-members are flush with the assembly bay floor. The fuselage is then towed backwards until the front landing gear wheels pass over and clear the recessed main transporter. The main transporter is then walked out of the floor depression in reverse order and moved clear of the area.

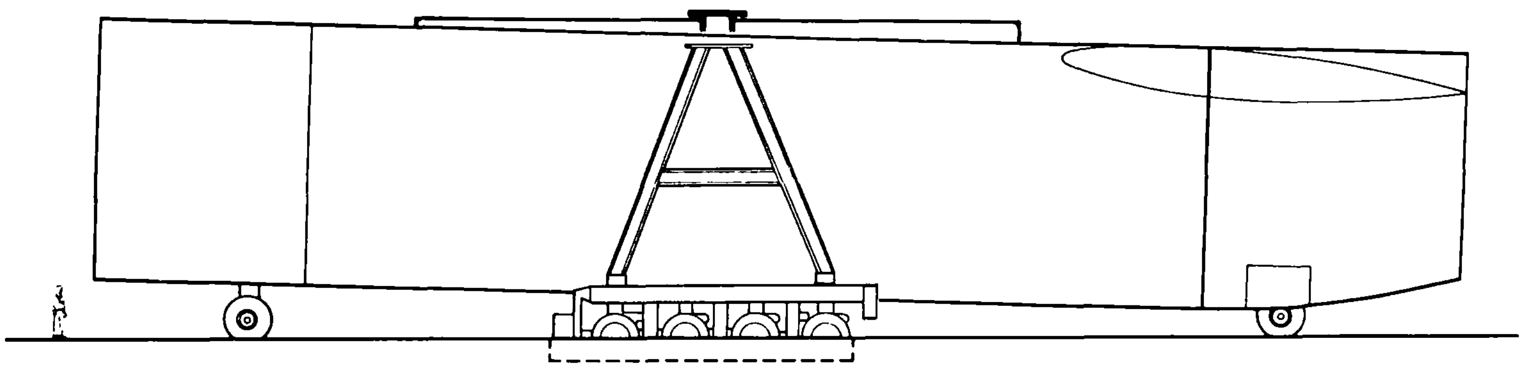
FACILITY FLOOR MODIFICATION



- WHEEL WELLS TO ALLOW WHEELS TO REST 20 INCHES BELOW FLOOR SURFACE.
- CONTOURED AREA RECESSED 14 INCHES TO ACCEPT HORIZONTAL TRANSPORTER CROSS MEMBERS.

FIGURE 4.3–51

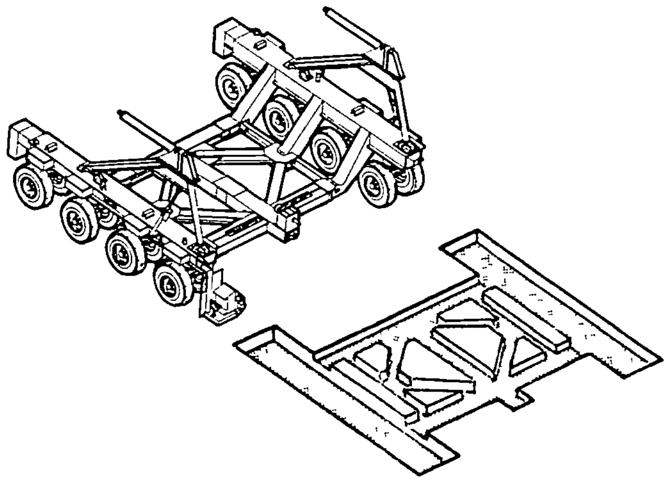
REMOVAL OF LH_2 TANK MAIN TRANSPORTER



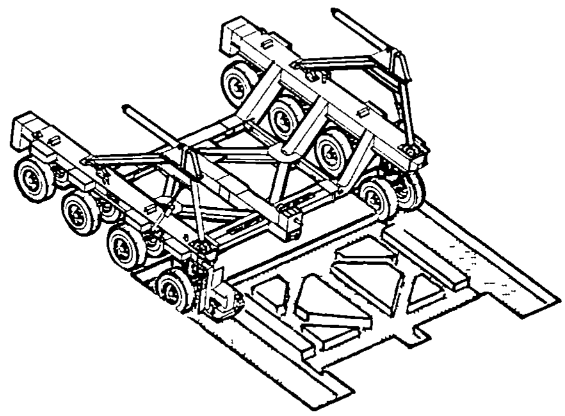
- LOWER LH_2 TANK MAIN TRANSPORTER INTO FACILITY FLOOR DEPRESSION
- PULL FUSELAGE BACK TO CLEAR MAIN TRANSPORTER
- RAISE MAIN TRANSPORTER AND REMOVE FROM AREA

FIGURE 4.3-52

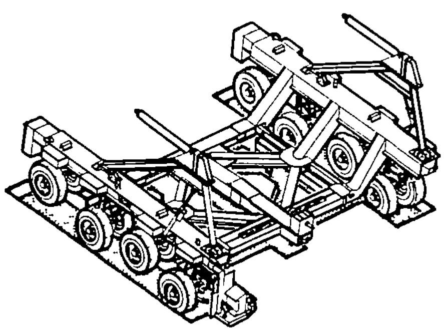
MAIN TRANSPORTER REMOVAL



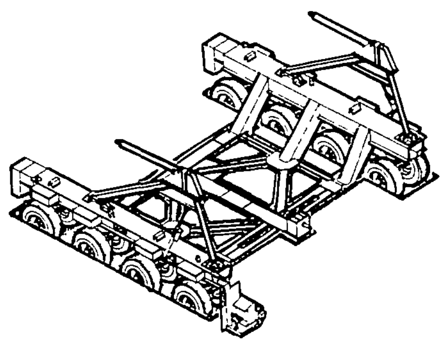
- MOVE TRANSPORTER FORWARD UNTIL FRONT WHEELS OVERHANG WHEEL WELLS.



- LOWER FRONT TRANSPORTER WHEELS TO BOTTOM OF WHEEL WELLS.



- MOVE TRANSPORTER FORWARD UNTIL THIRD ROW WHEELS OVERHANG WHEEL WELLS.
- LOWER THIRD ROW WHEELS TO BOTTOM OF WHEEL WELLS.



- MOVE TRANSPORTER FORWARD UNTIL CROSS MEMBER REGISTER WITH CONTOURED CUTOUT LOWER TRANSPORTER FLUSH WITH FLOOR.
- REMOVE IN REVERSE ORDER

FIGURE 4.3–53

Figure 4.3-54 shows the LO_2 tank being positioned for joining with the Intertank Structure. The LO_2 Tank Transporter is precision aligned by optics or lazers utilizing the articulation capabilities built into the LO_2 Tank Transporter. Undersize bolts establish the initial connection followed by a final align and ream of the hole pattern. Precision bolts are then installed which complete the LO_2 tank to Intertank joints.

The Forward Fuselage is installed utilizing standard positioning trailers similar to those used for installing airbreathing engines. Conventional techniques are used to align and connect the Forward Fuselage to the LO_2 tank.(Figure 4.3-56).

4.3.9.3 Canard Installation

Canards will be received at Michoud from the Contractor's Facility. Canards will be removed from the shipping and handling fixtures and will be placed on movable fixtures, where they will undergo a detailed receiving inspection. These movable fixtures will incorporate the leveling devices and rotational capabilities required to mate the canards to the fuselage. Optical tooling will be available for use prior to and during the final bolting sequence. (Figure 4.3-55).

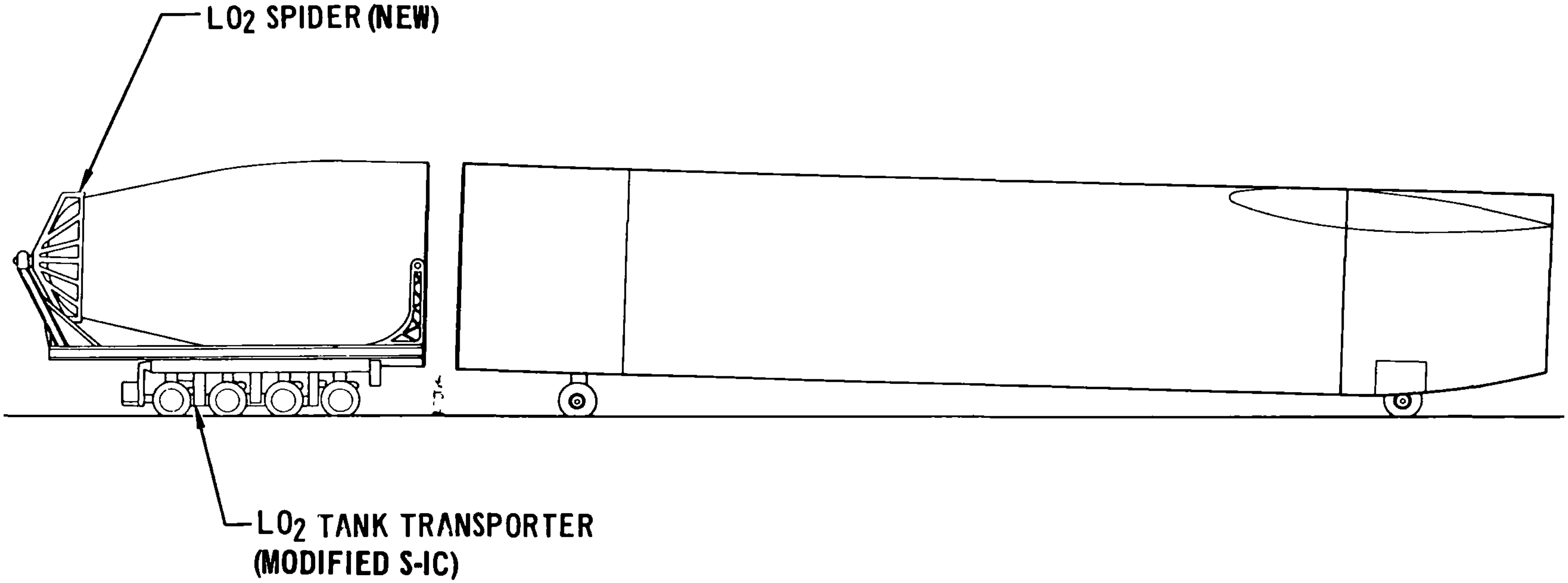
4.3.9.4 Air-Breathing Engine Installation

Air-breathing engines will be received at Michoud from the engine manufacturer. Engines will be removed from the shipping containers and undergo a detailed receiving inspection. After build-up of accessories and further inspection, the engines will be individually test run. After test run is completed, engines will be preserved, and then installed in the canards. (Figure 4.3-56).

4.3.9.5 Main Propulsion Installation

Main propulsion engines will be received at Michoud from the engine manufacturer. They will be removed from the shipping containers and undergo a detailed receiving inspection. After acceptance and build-up of accessories and further inspection the engines will be ready for installation into the Booster. Special handling and

LOX TANK TO INTERTANK STRUCTURE ALIGNMENT



- MOVE LO_2 TANK ASSEMBLY INTO POSITION
- ADJUST LO_2 TANK TRANSPORTER TO CORRECT MATING INTERFACE POSITION

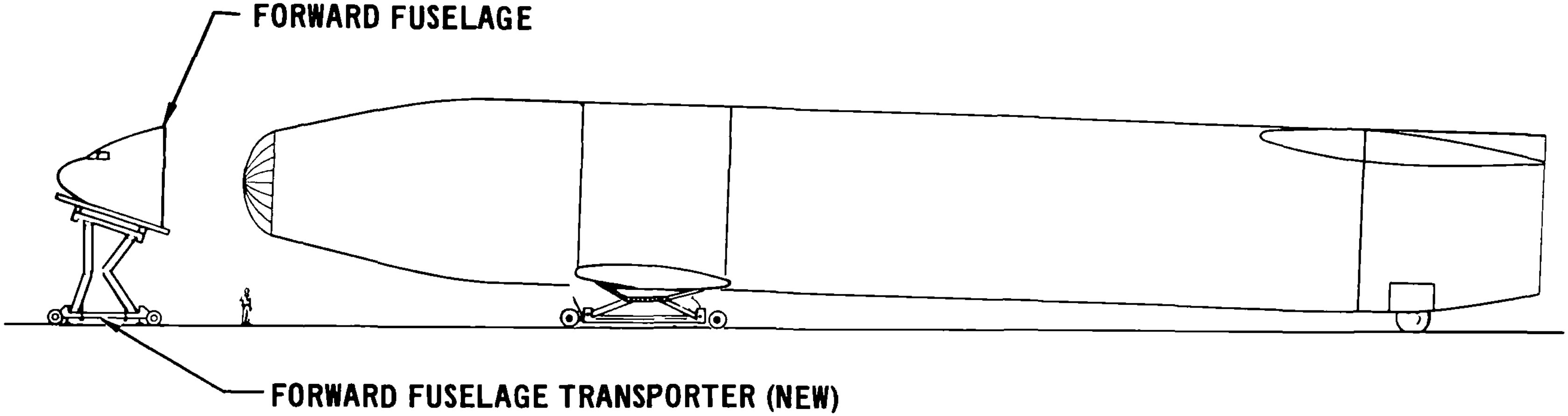
FIGURE 4.3-54

LOX TANK MATE TO INTERTANK STRUCTURE

- MATE LO_2 TANK ASSEMBLY TO INTERTANK STRUCTURE
- REMOVE LO_2 TANK ASSEMBLY TRANSPORTER FROM AREA
- INSTALL ROCKET ENGINES
- INSTALL CANARDS

FIGURE 4.3-55

FORWARD FUSELAGE TO LOX TANK ALIGNMENT



- MOVE FORWARD FUSELAGE INTO POSITION
- ADJUST FORWARD FUSELAGE TRANSPORTER TO CORRECT MATING INTERFACE POSITION
- MATE FORWARD FUSELAGE TO LO_2 TANK
- INSTALL AIR BREATHING ENGINES

FIGURE 4.3-56

installation GSE utilizing a "balanced beam" fixture similar to existing GSE is used to install the engines. Suitable framing and scaffolding surround the engine installation area to allow personnel to accomplish precision adjustment of the mating interfaces prior to installation. Figure 4.3-55 shows a typical engine being installed utilizing an existing "A" frame hoist to lift engines to installation height.

4.3.9.6 Post-Assembly Checkout

After fuselage assembly is complete and all structural and systems installations have been made, the flight systems will be activated and a series of preliminary checks performed. Systems include hydraulic, pneumatic, electrical, landing gear, rudders, flaps and elevons. Simulators will be required for tests involving wings and control surface checks.

The preliminary checks are made with the vehicle still in the assembly area.

After the preliminary checks indicated above, the vehicle is moved to a checkout area for more extensive tests.

These tests will include the following:

- Leak Check - LOX Lines
- Leak Check - LH2 Lines
- Leak Check - JP4 Fuel Tanks
- Leak Check - Hydraulic Systems
- Leak Check - Forward Fuselage Section
- Leak Check - Oil and Water Tanks
- Electrical Continuity Checks
- Communications Systems Check
- Orbiter Release System Check
- Landing Gear Check
- Flight Control Systems Check

4.3.9.7 TPS Installation

As equipment installations and checks are completed, TPS panel installations will be started. (Refer to Paragraph 4.3.8.) The maximum practical number of panels will be installed on the Booster fuselage at the time of final assembly. Certain areas such as wing attach points and any other area where further access to substructure will be required will be left exposed.

Because of varying mission requirements, the actual TPS installation configuration will also vary from Booster to Booster.

4.3.9.8 Formal Acceptance

Upon completion of all scheduled installations and tests, formal acceptance of the Fuselage Assembly will be made by NASA.

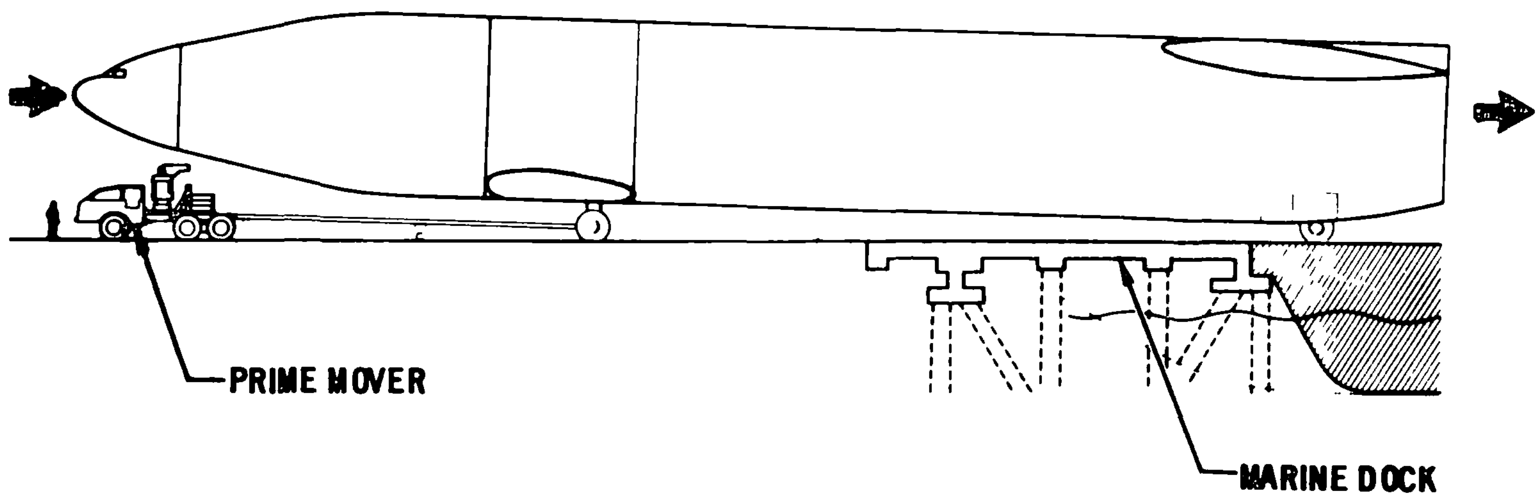
4.3.9.9 Preparation and Shipment

After all scheduled installations and factory tests are completed, the assembled fuselage will be moved, on its own landing gear, to the Michoud dock for shipment to KSC. (Figure 4.3-57).

4.3.9.10 Facility Requirements

See Table 4.3-16

LOADING FUSELAGE ASSEMBLY ON BARGE



- ATTACH PRIME MOVER
- MOVE TO MARINE DOCK
- MOOR BARGE IN SLIP
- BALLAST BARGE TO LOAD POSITION

FIGURE 4.3-57

TABLE 4.3-16

BOOSTER FUSELAGE FINAL ASSEMBLY FACILITY REQUIREMENTS

Facility Requirements	Facility Availability
Area	
Fuselage Assembly - 70,000 sq. ft.	Available at Michoud Bldg. 103
A/B Engine B/U - 4,000 sq. ft.	Available at Michoud Bldg. 103
Main Propulsion Engine B/U 6,000 sq. ft.	Available at Michoud Bldg. 103
Crane	
Not Required	
Major Tooling	
Note: Major assembly tooling will consist of existing Saturn GSE, either as is or modified. All such tooling is indicated in Figures 4.3-43 through 4.3-57.	
Special	
A/B Engine Run-Up Area	New at Michoud

4.3.10 Wing and Control Surface Installation (KSC)

4.3.10.1 General

Wings and control surfaces will be manufactured in contractor owned facilities. All components of the wings and control surfaces will be completely assembled at the manufacturing site. To facilitate shipping and handling, leading edges, elevons and vertical fins will be removed prior to shipment to KSC.

4.3.10.2 Installation Site

Wings and control surfaces will be attached to the fuselage in the proposed extension to the VAB at Complex 39. Performance of this operation at this site does not generate a requirement for new facilities. The basic requirement for the VAB extension is identified in Paragraph 4.7 "Operations Site Facilities" as a maintenance and overhaul facility.

4.3.10.3 Installation Approach

With the fuselage assembly supported on hard points, the wing torque box will be lowered onto jacks adjacent to the fuselage. The jacks will provide the final adjustment required to align the attach points. Mating and attaching hardware will have been pre-drilled and/or machined full size. (Figure 4.3-58).

Workstand will be required to permit personnel access to the attach points.

Wing leading edges, elevons and vertical fins will be installed in a similar manner.

After wings and control surfaces have been installed, alignment will be optically checked.

WING AND CONTROL SURFACE INSTALLATION

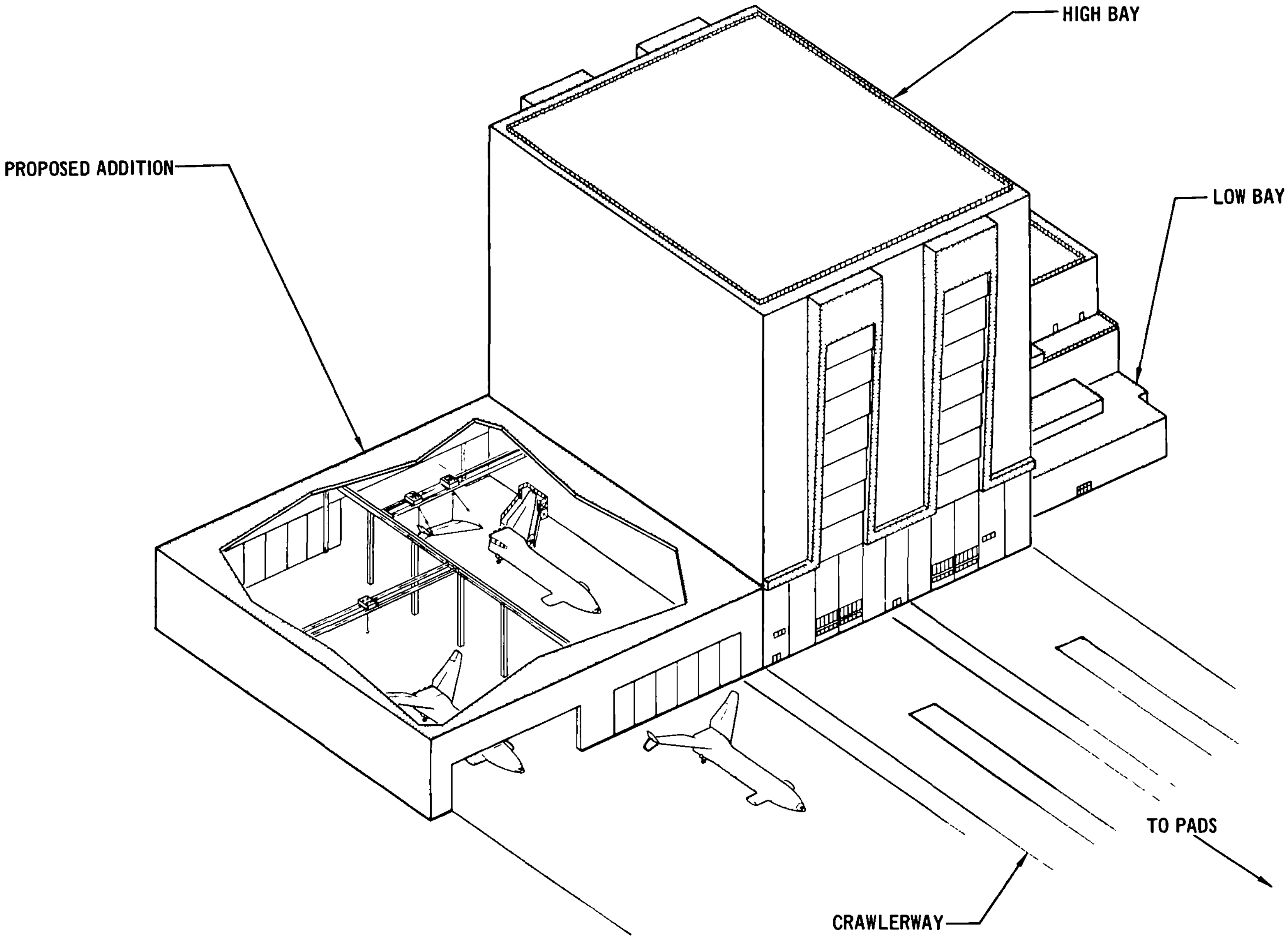


FIGURE 4.3-58

4.3.10.4 TPS Installation

The maximum practical number of TPS panels will have been previously installed. At this time, the remaining panels will be installed and aligned. For additional information, refer to Paragraph 4.3.8 and 4.3.9.7.

4.3.10.5 Facility Requirements

See Table 4.3-17

4.3.11 Acceptance Tests - KSC

Dependent on the specific booster, a series of detailed acceptance tests will have been scheduled since receipt of the booster fuselage at KSC. These tests will culminate with final installation and alignment of TPS. Upon satisfactory completion of all acceptance tests, the booster will be considered to be ready for ramp and/or flight test operations.

TABLE 4.3–17

Wing and Control Surface Installation Facility

Requirements

Facility Requirement	Facility Availability
Area 250,000 sq. ft. 90 ft. clear ceiling height	Addition to VAB at KSC will satisfy this requirement.
Crane 15 Tons	Addition to VAB at KSC will satisfy this requirement.
Major Tooling Hardstands, fuselage support Hardstands, wing support Hoist fixture, wing torque box Hoist fixture, wing leading edge Hoist fixture, elevon Hoist fixture, vertical fins Workstands, crew	

4.4 ORBITER FACILITY UTILIZATION AND MANUFACTURING PLAN

The Orbiter vehicle as planned is approximately 160 feet long, has a wing span of 102 feet, and an overall height of approximately 71 feet. Figure 4.4-1 shows the major components comprising the Orbiter which will be assembled at Michoud, Louisiana, and Kennedy Space Center.

ORBITER DESCRIPTION

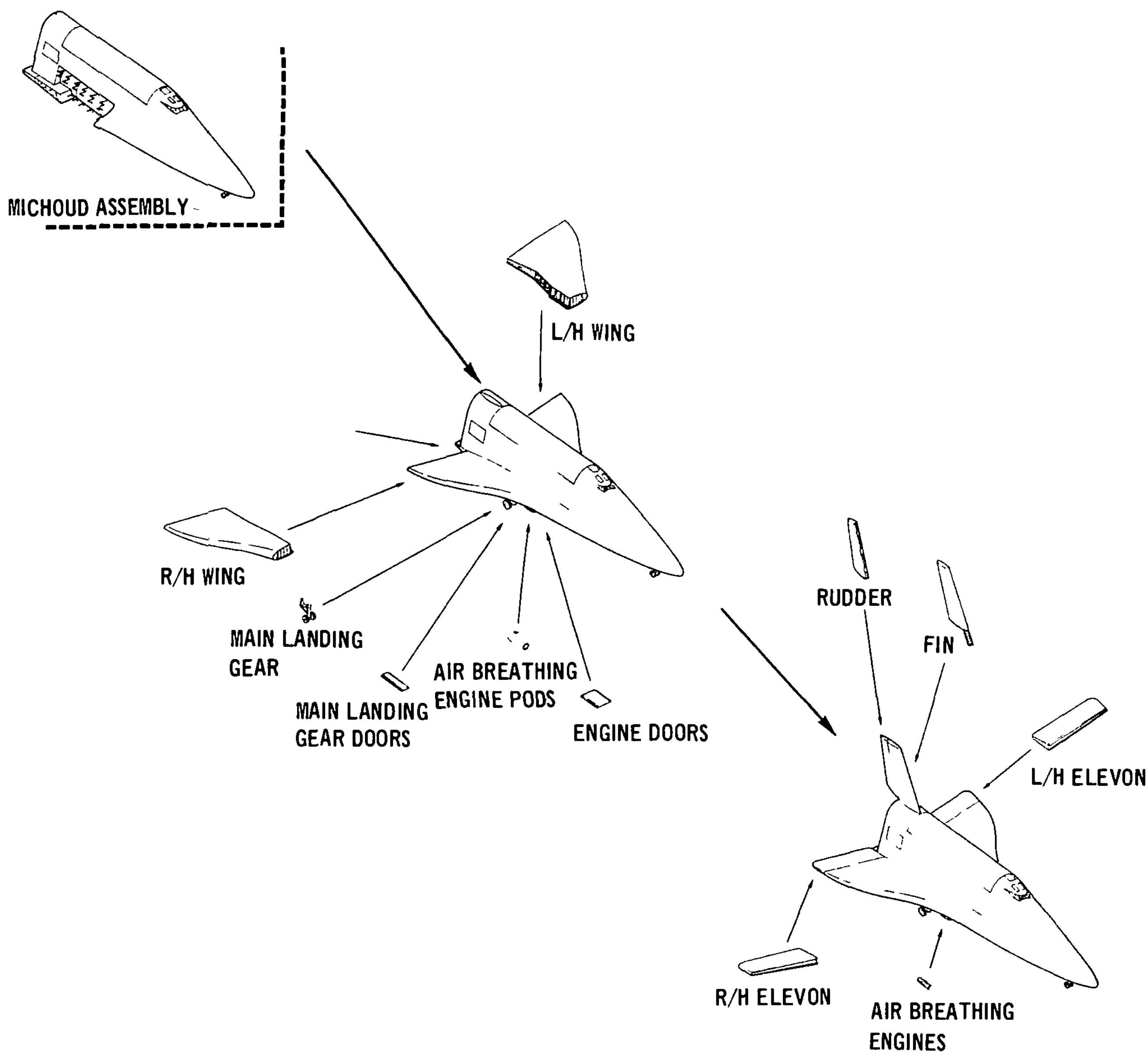


FIGURE 4.4-1

Orbiter Main Propulsion Tank Manufacturing

4.4.1 Main Propulsion Tank Description

4.4.1.1 The orbiter features an integral siamese main propulsion tank concept. This concept consists of two cylindrical sections, intersecting at approximately 60 percent of each cylinder's radius, joined by a common keel member which extends the full length of the tank. The tank is divided into separate compartments for liquid oxygen and liquid hydrogen by a spherical segment common bulkhead, and tank end closures consisting of ellipsoidal domes.

Figure 4.4-2 - Final assembly of the main propulsion tank will be at the Michoud Assembly Facility. Operations at Michoud will use existing S-1B transporters modified as required. The existing S-1B final assembly fixtures will be used to mount and rotate the main tank during the installation operations of the insulation.

ORBITER MAIN PROPULSION TANK

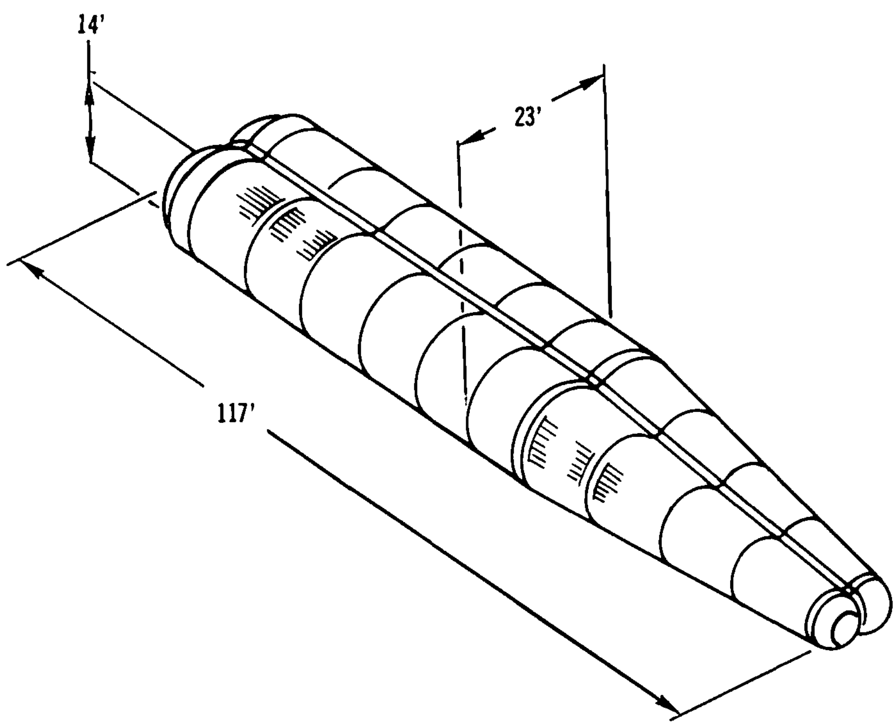


FIGURE 4.4-2

4.4.1.2 Manufacturing Approach

The approach for manufacturing this tank is to build up sectional siamese assemblies consisting of the common bulkhead, forward and aft end domes, and straight and conical barrel sections. These in turn are progressively joined in a specific sequence, circumferentially welded, and proof pressure tested. This progressive joining of the sections is coordinated to support a modified pneumosatic test technique for the LH_2 section, and a hydrostatic test technique for the LOX section. All weld seams are radiographically inspected (X-Ray) along the completed weld seam and after each weld pass. A pictorial illustration and the manufacturing flow chart and schedule for the orbiter delta wing are shown in Figures 4.4-3 and 4.4-4.

MAIN PROPULSION TANK ASSEMBLY

Manufacturing Assembly Sequence – Delta Wing Orbiter

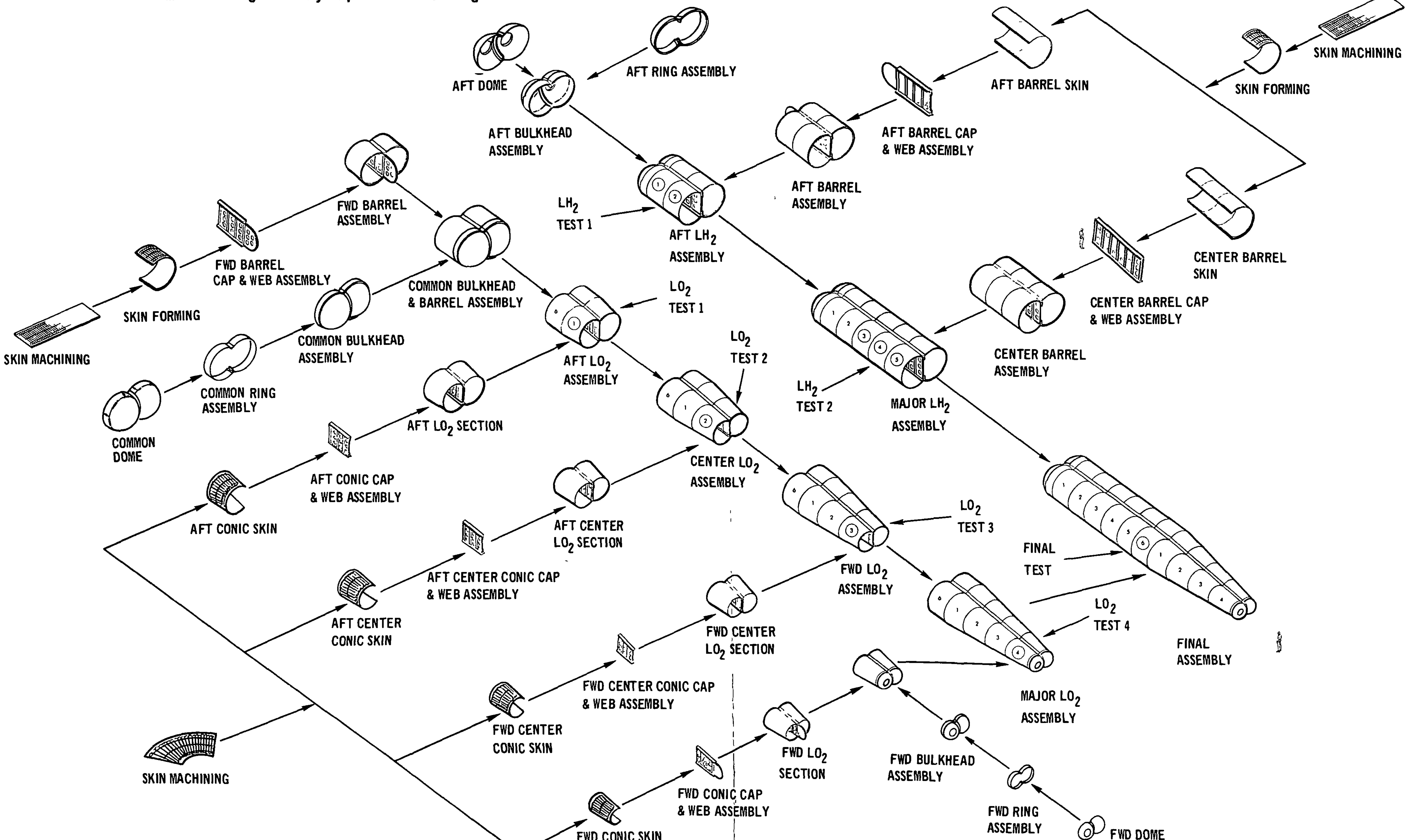


FIGURE 4.4-3

MAIN PROPULSION TANK
MANUFACTURING FLOW CHART & SCHEDULE
DELTA WING ORBITER

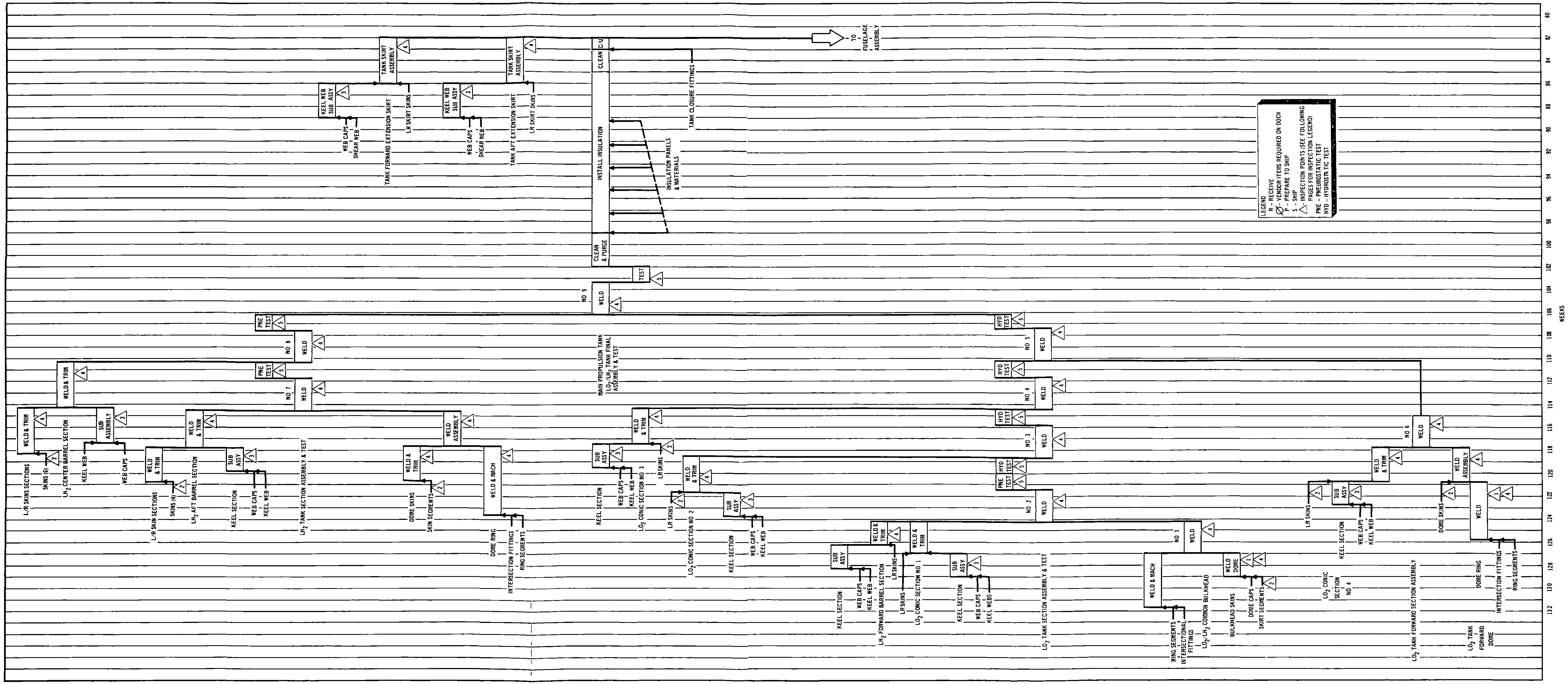


FIGURE 4.4-4

Manufacturing Operations

4.4.1.3 Tank Skin Fabrication - The tank features integral stiffened skins having external rectangular waffle pattern pockets which provide flanges both longitudinally and circumferentially. Ref. Figure 4.4-5.

FLAT MACHINED SKIN PANEL

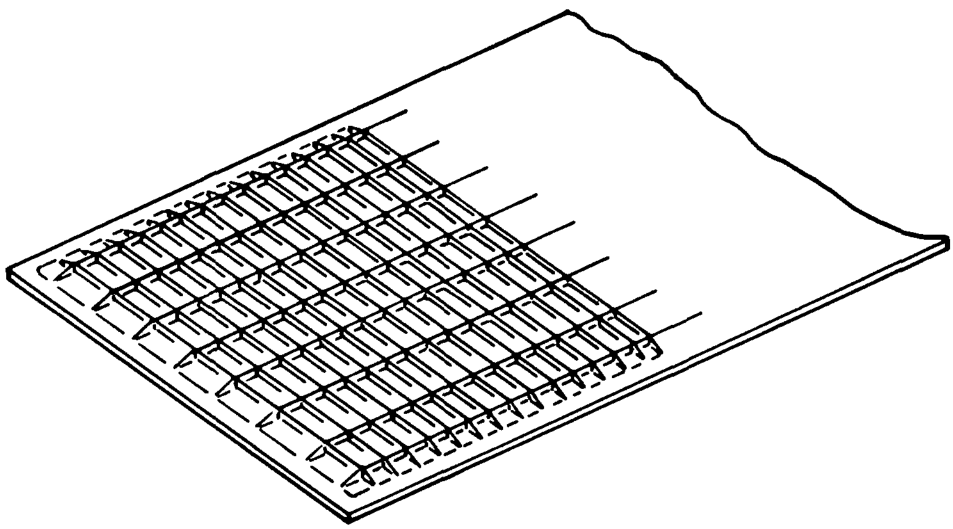


FIGURE 4.4–5

The fabrication approach in general is to machine the selected skin panel sizes in the flat, prior to chemical processing and forming.

Machining of the panels is accomplished on numerically controlled profile milling machines, an example of which is shown in Figure 4.4-6. Panels are machined from 2219 aluminum plate stock in the solution heat treated condition (T-37) and in sizes up to 12 ft. wide x 34 ft. long. Machining of the aluminum plate stock in the T37 condition later allows the use of the artificial ageing cycle (to T87) to facilitate the skin forming process.

CINCINNATI N.C. PROFILER

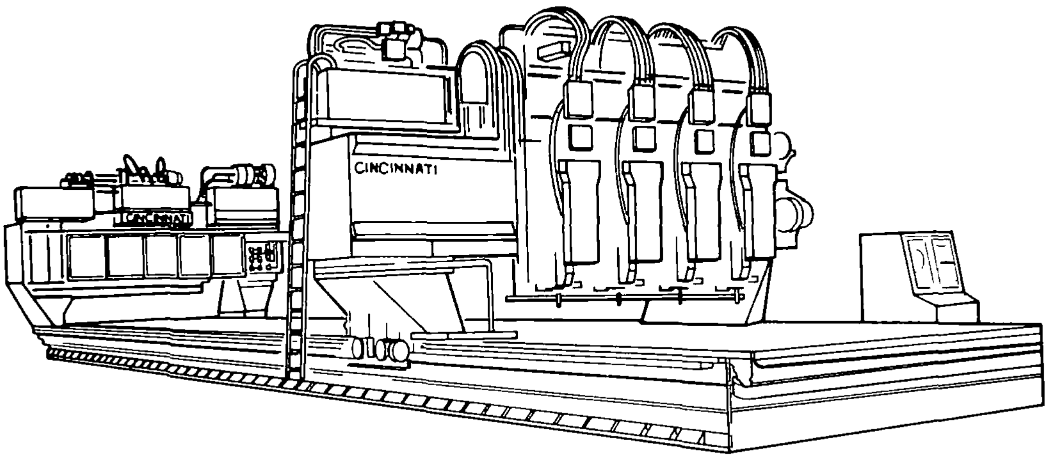


FIGURE 4.4-6

The panels are formed into approximately 270° circumferential segments, Figure 4.4-7. These are later joined to each other and to keel members by welding, to form sectional siamese tank subassemblies.

FORMED SKIN SEGMENT

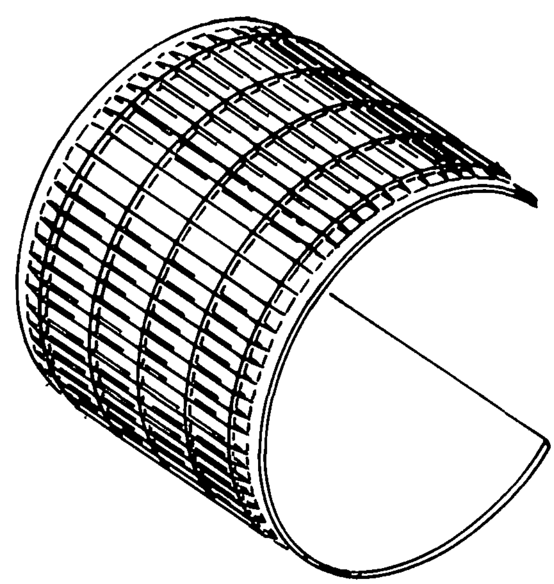


FIGURE 4.4-7

A number of methods have been considered for forming of the 270° circumferential cylinder and conic skin sections. Among these were: bumping the panels to contour in matched dies on a power brake; forming them to contour on power rolls; drape forming where the panel is draped over a shaped die and pulled down to the dies contour using come-alongs or weights; AGE forming which is basically drape forming performed during the artificial ageing cycle; and wrap forming where the panel is wrapped around a shaped drum to form the required contour.

In both the power brake and power roll forming methods, a filler material is required in the panel pockets to support and protect their flanges during the forming operation. This greatly adds weight to the panels during forming and thereby complicates their handling. Also with the pockets on the O.D., it is difficult to retain the filler material in place throughout the forming operation.

The drape and age forming methods offer good results in forming circumferential shapes up to the 180° point (or less). Beyond the 180° point, the practicality of these methods becomes questionable. In order to form the approximate 270° shapes required in the case at hand, the direction of the forming forces necessary to pull the panels around the die have to cross one another. This factor greatly complicates consideration of these approaches.

The wrap forming method offers good results to achieve the 270° shapes required, as the forming tool can virtually go to a full 360° circumference. It also allows the forming without applying external forces directly to the vulnerable O.D. flanges of the panel. Forming forces are applied only to the edges of the panel, where excess material is provided for this purpose during panel fabrication.

Through evaluation of the previously discussed forming methods, a method of wrap-age forming is considered as the optimum approach to be used. This approach takes advantage of the wrap forming ability to form circumferential shapes well beyond the 270° point required, without applying forces to the O.D. surface of the panel. It also takes advantage of the age forming feature of performing the elevated temperature artificial ageing cycle, while the panel is restrained in shape. This relieves much of the stress induced into the part during forming, and provides highly predictable and consistent spring back characteristics in the alloy to be used (Ref. NASA

It is obvious that the wrap-age forming method requires design and development of special fixturing during Phase C/D, an example of which is shown in Figure 4.4-8. However, since it is an application of existing metal forming principles, the approach is considered state-of-the-art.

WRAP-AGE FORMING MACHINE

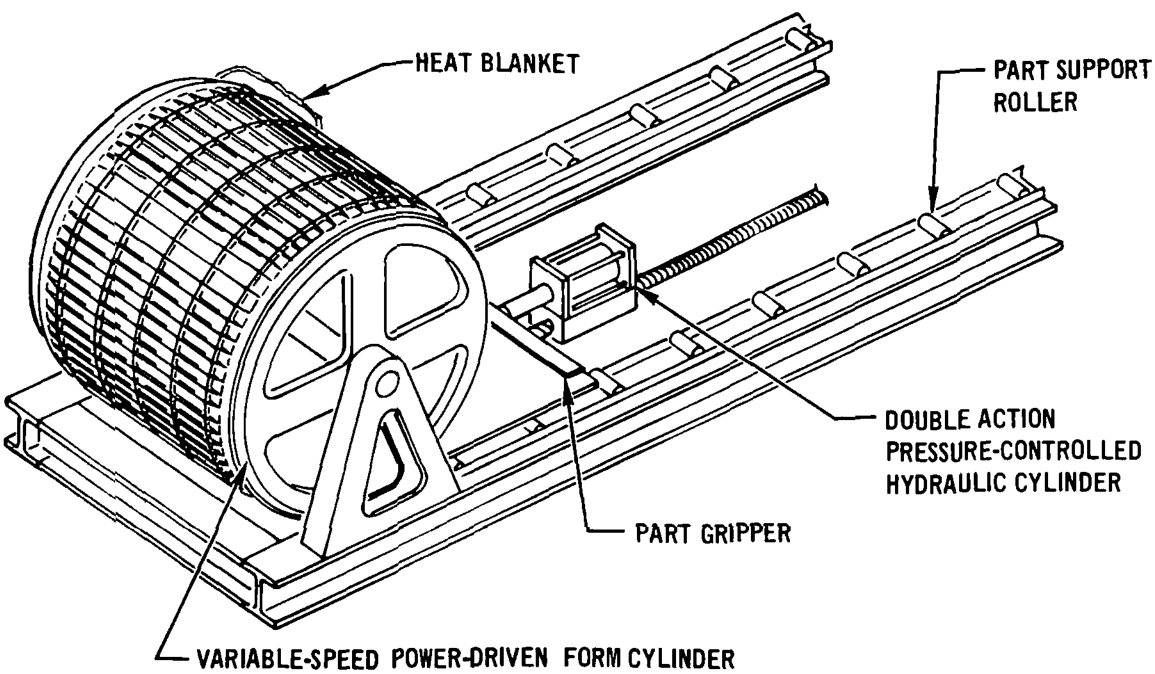
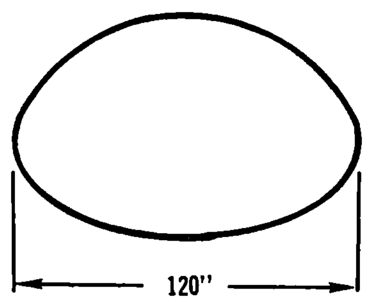


FIGURE 4.4-8

4.4.1.4 <u>Common Bulkhead (Dome Fabrication)</u> - The domes will be procured as a 120" base diameter spherical sector of 168" diameter sphere (Figure 4.4-9) which will be a spin forging made of 2219 T81 aluminum.

TOP DOME SECTION

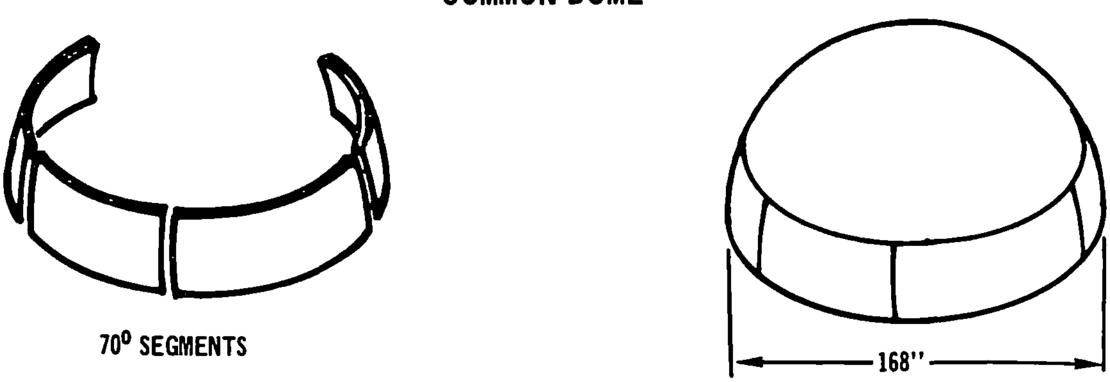


SPHERICAL DOME SECTOR

FIGURE 4.4-9

The 120" base diameter spherical sector does not meet the design diameter requirements; therefore, additional sectors will be procured. These sectors will then be cut in (4) 70° segment skirt sections; then the sections will be trimmed, fitted, and welded to the base of the 120" base diameter spherical sector to form the completed bulkhead (dome). Figure 4.4-10.

COMMON DOME



COMPLETE COMMON DOME

FIGURE 4.4-10

The inside surface of the completed welded up dome or bulkhead section is then milled to form an isogrid pattern of pockets. The proposed design concept for the milling is shown in Figure 4.4-11.

COMMON DOME ISOGRID MACHINING

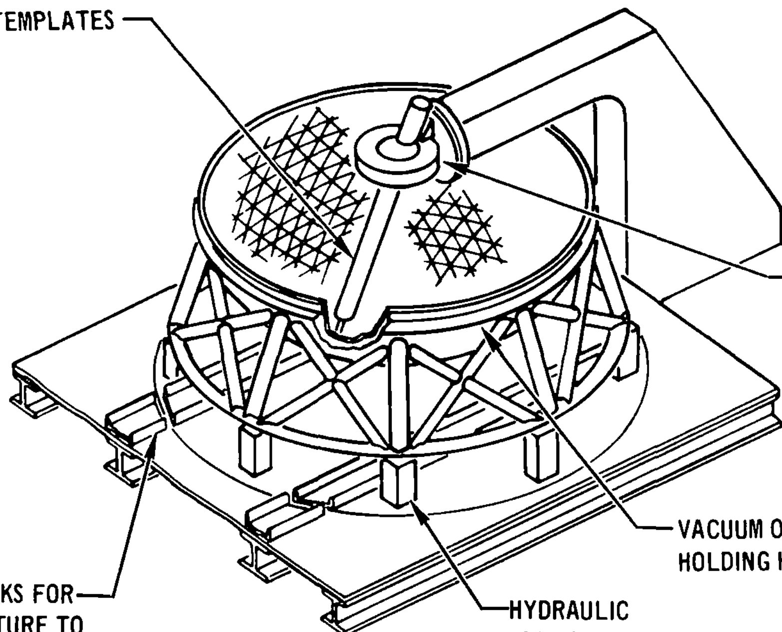


FIGURE 4.4-11

Obviously this will become a development item during Phase C/D. However, it does appear to be state of art through application of proven machining principles. After completion of the machining operations the part is cleaned and given a surface treatment for corrosion prevention.

Study of the common bulkhead or dome forming problem is continuing and our contacts with a spinning vendor indicate good possibilities of our procuring this part in one piece. This also would become a development item during Phase C/D

4.4.1.5 Forward LO2 Dome Fabrication - The baseline approach to forming the forward ellipsoidal dome for the orbiter main LO_2 tank is to procure a one piece 2219 AL, alloy spin forging. It will be necessary to machine the outer surface to the final configuration. Extra spin forgings will be procured for use as blanks to fabricate the tank access panels.

4.4.1.6 Aft LH2 Dome Fabrication - The aft ellipsoidal LH_2 dome for the main tank will be fabricated by a combination of spin form and explosive forming techniques.

In order to secure a piece of material large enough to perform the spin form operation, it is necessary to butt weld two pieces of plate stock together to form a blank approximately 180" x 180". After shaving the weld bead to a flush condition, the blank will be spun to the approximate shape of the part. The part is then heat treated to the T-62 condition and explosive formed to the finished shape. A light machine cut on the outside surface will be necessary to remove the spin form tool marks. The parts are then trimmed along with the sump fitting and fitted, and surface treated, preparatory to welding. These parts are then welded to form the dome sub-assemblies.

4.4.1.7 Siamese Dome Bulkhead Assembly - The common bulkhead, aft LH_2 bulkhead and the forward LO_2 bulkhead are of similar design, and use the same manufacturing technique. These bulkheads will be fabricated at Michoud.

A dome "Y" ring will be machined from a purchased 2219-T62 alloy cylindrical section (170" O.D. x 5" wall x 40" length). The cylinder will be rough machined forming a 360^{o} dome "Y" ring. Figure 4.4-12.

DOME "Y" RING

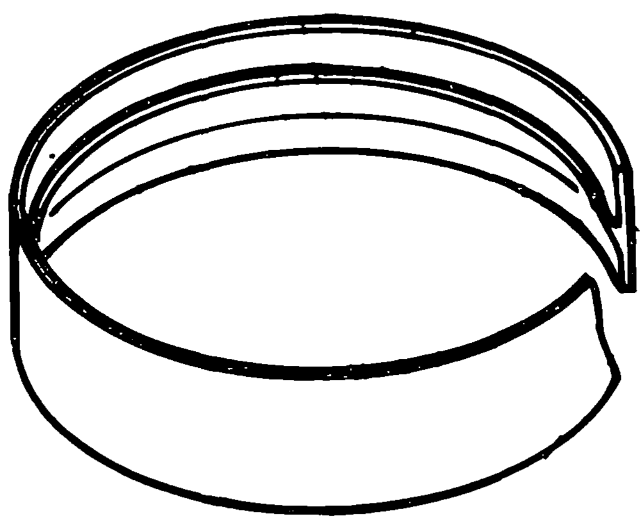


FIGURE 4.4-12

The Dome "Y" ring will then be trimmed in preparation for mating to the keel ring frame transition fitting. Figure 4.4-13.

DOME "Y" RING SEGMENT

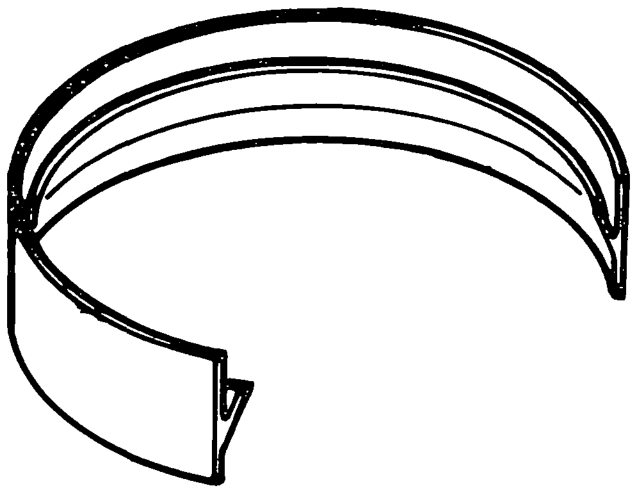


FIGURE 4.4–13

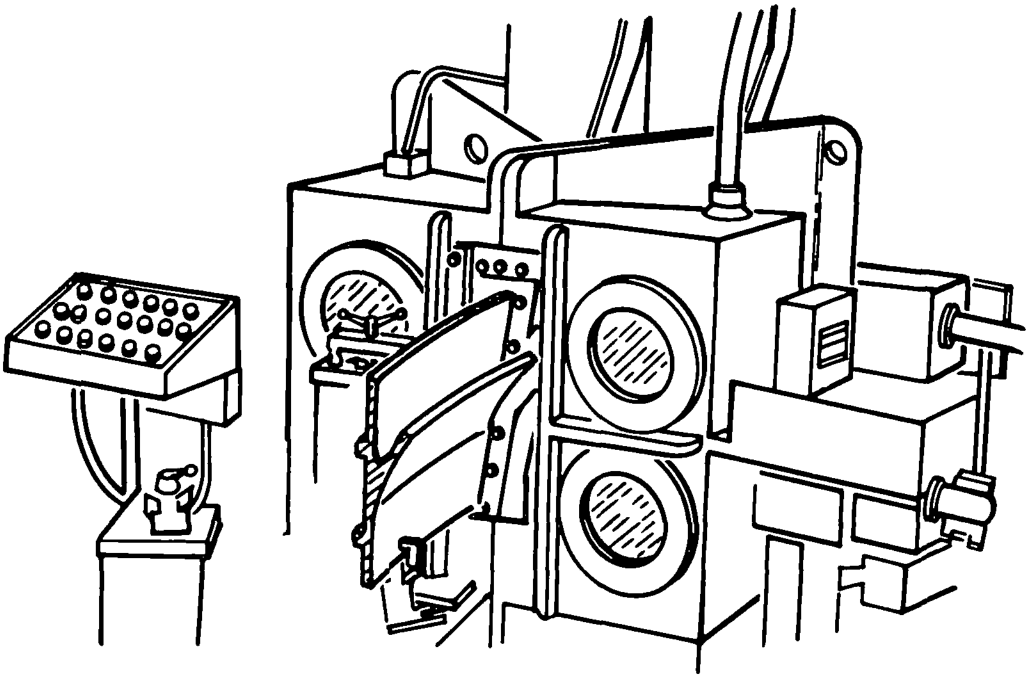
Two dome "Y" ring segments and two keel ring frame transition members are placed in a weld fixture, trim, fitted and E.B. (Electron Beam) welded in a localized vacuum chamber (Figure 4.4-14) completing the siamese dome ring frame assembly. Figure 4.4-15.

The dome "Y" ring frame assembly is then placed on a 5 axis profiler for final machining . After final machining the ring is anodized.

The transition keel cap, Figure 4.4-16, and previously machined domes are placed in a weld fixture, trimmed, fitted and welded to form the siamese dome assembly. Figure 4.4-17.

The siamese dome ring frame assembly is placed in a weld fixture, then the siamese dome assembly is placed on the "Y" portion of the ring frame, trimmed, fitted and welded; completion of this operation completes the siamese dome common bulkhead subassembly. Figure 4.4-18.

ELECTRON BEAM WELDER



ELECTRON BEAM WELDING
KEEL-RING FRAME TRANSITION TO DOME
"Y" RING SEGMENT

FIGURE 4.4-14

DOME "Y" RING FRAME ASSEMBLY

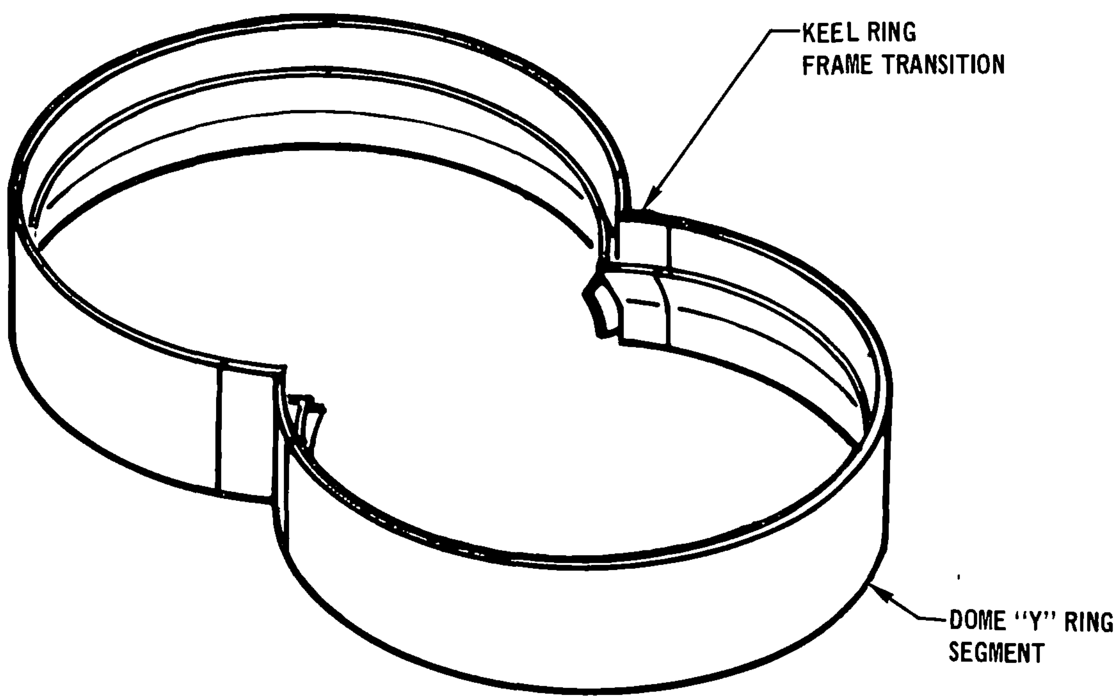


FIGURE 4.4-15

TRANSITION KEEL CAP

FIGURE 4.4–16

SIAMESE DOME ASSEMBLY

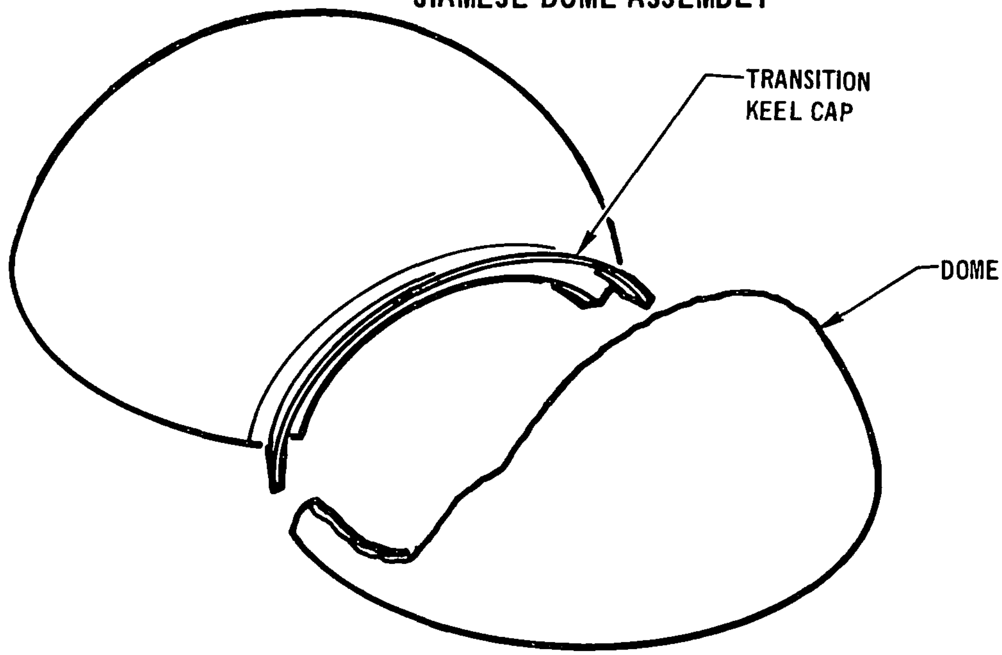


FIGURE 4.4–17

SIAMESE DOME COMMON BULKHEAD

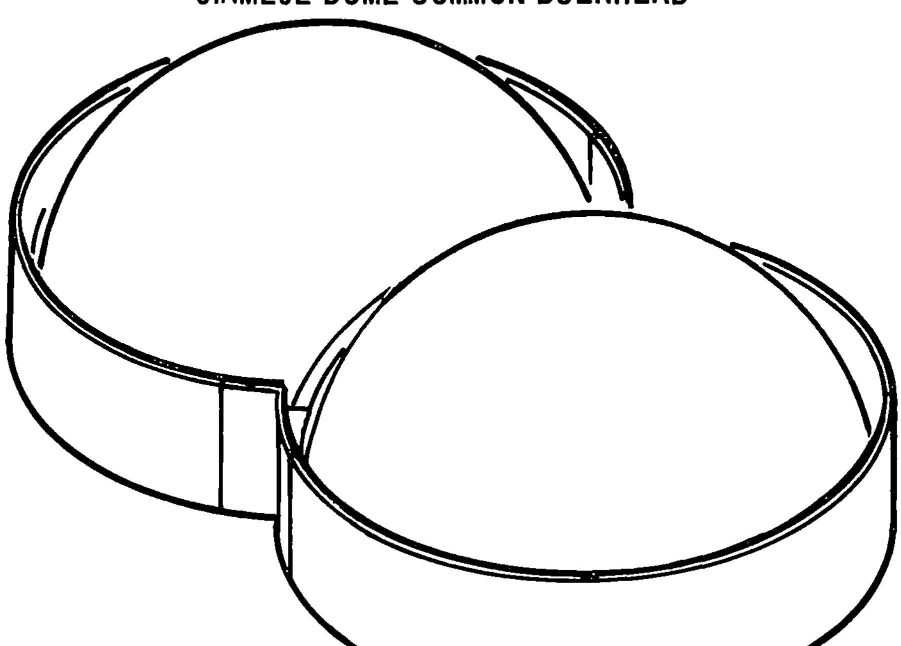


FIGURE 4.4–18

4.4.1.8 Anodizing Facility - The present anodizing facility at Michoud lacks the capability to anodize the completed dome "Y" ring frame assembly. A new facility will be required; this facility will have dual usage for both orbiter dome "Y" ring frame assembly and booster "Y" ring and skin sections.

The tank line shall consist of seven process tanks for anodizing of aluminum parts.

The tanks shall be as follows:

- Two cold water rinse tanks, mild steel and epoxy lined.
- One hot water rinse tank, mild steel epoxy lined.
- One alkaline clean tank, mild steel heated and vented.
- One deoxidizer tank PVC lined.
- One anodize seal tank PVC lined.
- One sulfuric acid anodize tank lead lined, cooled to $72^{O}F\pm2$, vented, pump circulated, and fumes shall be scrubbed.

A non-stabilized double grirder bridge shall be installed on existing building steel to service this tank line.

The vent system shall be by an overhead hood and a tank perimeter slot draw off ducted to a fan for discharge out of the building. The alkaline tank will be a mild steel system, the anodize system shall be a corrosion proof system and will be equipped with a fume scrubber.

Heating of the hot water rinse and the alkaline clean tank will use plate coils and building steam supply.

Gas fired make up air units are included as well as a load center, and miscellaneous controls and safety devices.

A rectifier and bus bars are included for the anodize tank.

DX units with lead coils will cool the anodize tank, plating action and coil protection will be handled by perforated plates in the tank.

Rinse waters shall be collected and piped to an existing disposal system.

Design start date	1 August 1971
Construction complete date	1 August 1973
Estimated Cost	$1,920,000

4.4.1.9 Barrel Section Subassembly - Buildup of the barrel section subassemblies, Figure 4.4-19, consists of joining and welding pairs of machined and formed skin panels to keel web subassemblies. This is accomplished using a relatively simple straight-line automatic welding technique.

SUB-ASSEMBLY WELDING

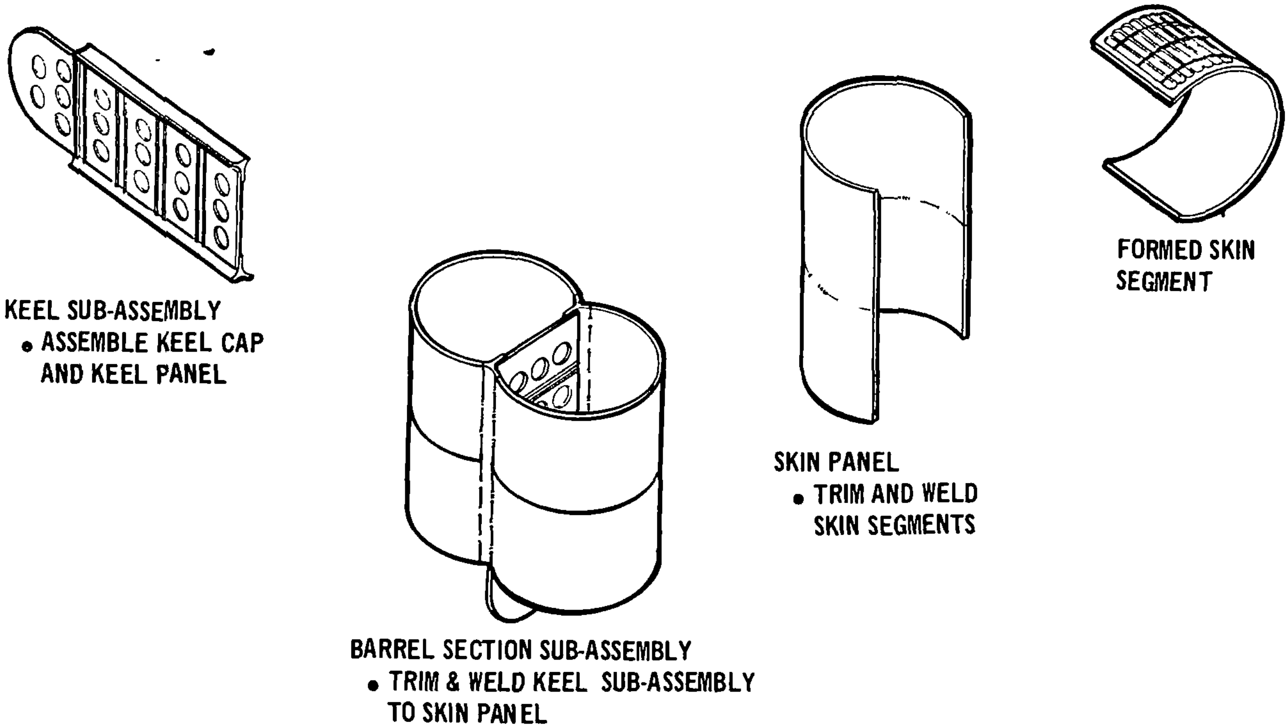


FIGURE 4.4-19

4.4.1.10 Tank Assembly Sequence - The planned sequence of assembly for the main propulsion tank is pictorially shown in Figure 4.4-20.

TANK ASSEMBLY SEQUENCE

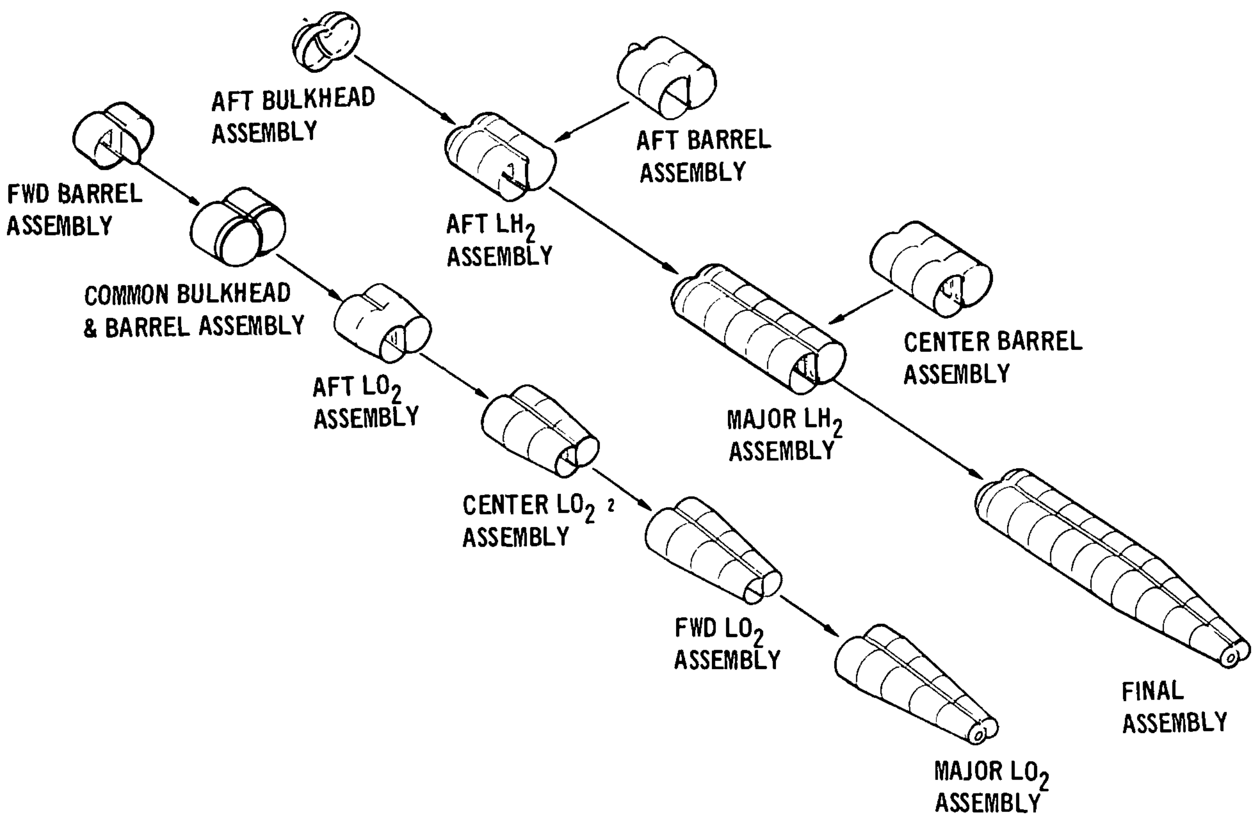


FIGURE 4.4-20

As shown, buildup of the LO_2 and LH_2 compartments of the tank are parallel vertical weld operations until complete assembly and testing of the LO_2 compartment is accomplished.

4.4.1.11 Vertical Weld Station - Due to the design configuration of the orbiter main propulsion tank and the schedule requirement, it is necessary that another weld station be added to the vertical assembly Bldg. 110. This structure will utilize an existing open area and will be a 130 foot high air conditioned station similar to the existing stations except that the pit and hydraulic lift existing in the present stations will not be duplicated. Figure 4.4-21.

Design start date	1 May 1972
Construction complete date	1 December 1973
Estimated cost	$530,000

NEW WELDING STATION

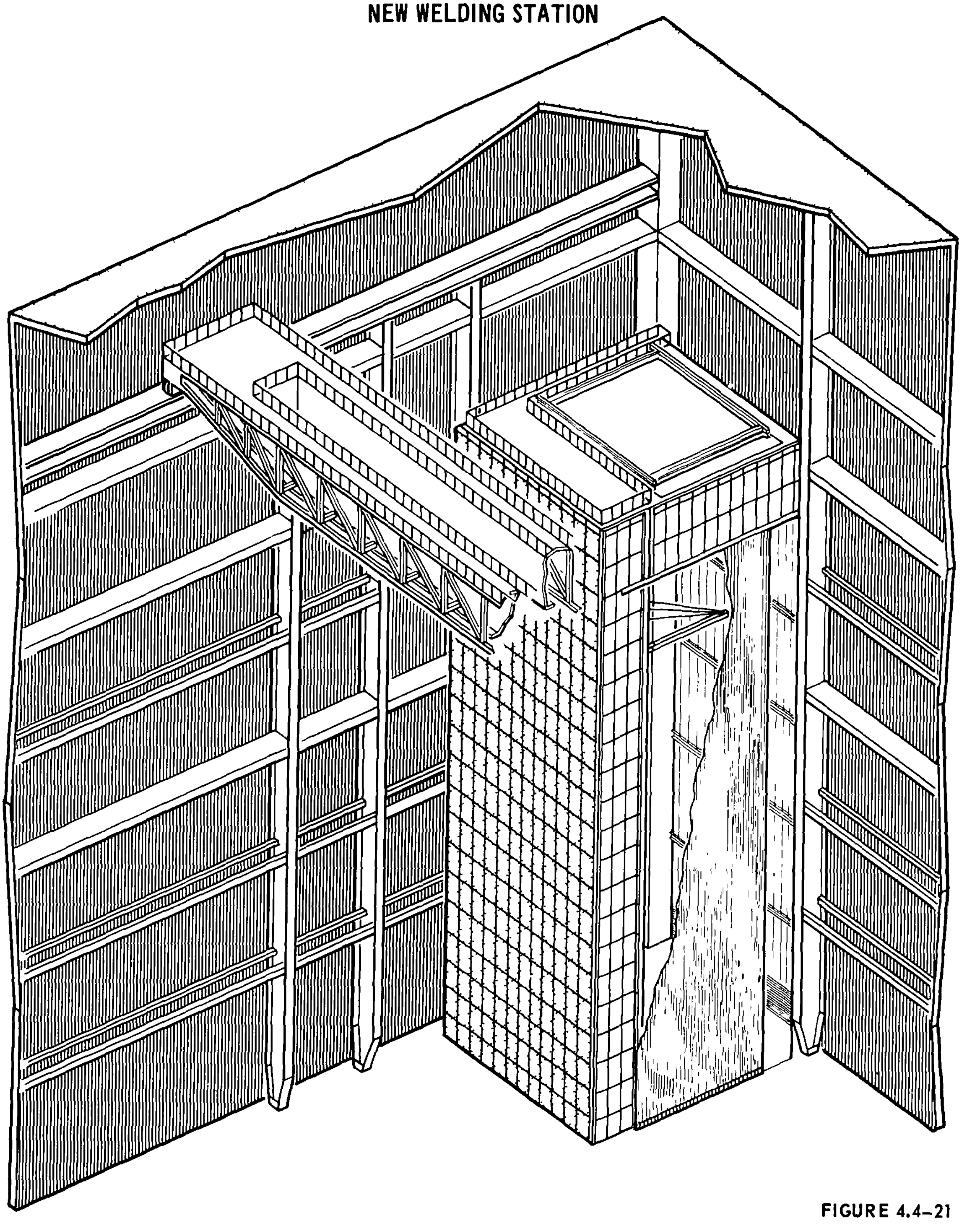


FIGURE 4.4–21

4.4.1.12 Circumferential Welding Technique - The joining of sectional siamese subassemblies in build up of the complete tank is accomplished in the vertical position using a circumferential weld technique. The circumferential welding for joining the common bulkhead, forward and aft end domes and the straight and conical barrel sections is accomplished using modified machining, welding and X-Ray equipment.

This equipment is used with specially design figure eight tracks; a set of tracks for each weld is required to meet production schedule and the weld requirements of the barrel and conical sections.

When joining the straight barrel section the weld set-up is as shown in Figure 4.4-22.

CIRCUMFERENTIAL WELDING

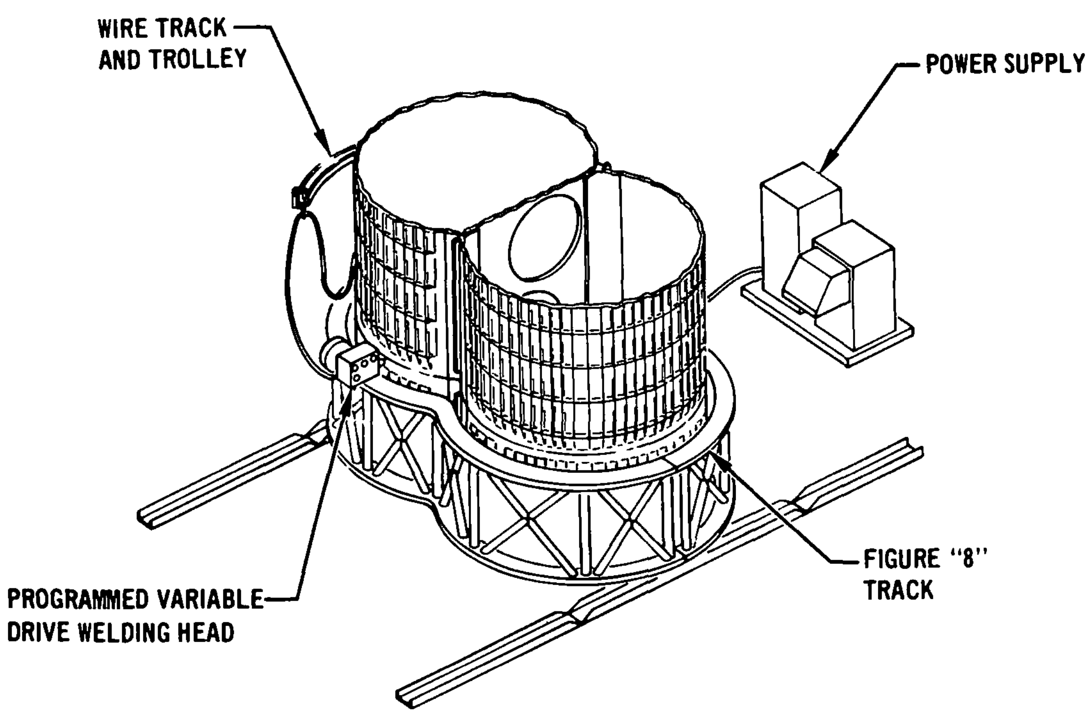


FIGURE 4.4-22

The figure eight track follows the contour of the barrel section except in the area of the 5" radius. In this area the arc length sensor is utilized to control the weld.

The welding head has a programmed variable drive. The program is developed to compensate for any variations of surface feed as the head enters the 5" radius transition area.

The figure eight tracks are used with a motorized milling head, and "X-Ray" unit, for preparing the weld joint, shaving the weld, and X-Raying the weld.

Additional vertical adjustment is built into the track framework to compensate for variation of section length.

The framework and track is split (as a clam shell) and moved into place around the tank, then fastened to the tank and weld cell structure. This sequence is reversed for removing the framework and track after welding and inspection of the joint is completed.

The circumferential welding of the LO_2 tank conic barrel sections uses the same type of equipment as the straight barrel sections. An exception is that a programmed vertical movement is added to accomplish the "V" type directional change across the 5" radius transition area.

During the assembly of the tanks, the LO_2 tank is progressively hydrostatically tested in sections and the LH_2 tank is progressively pneumostatically tested in sections. These tests will be in accordance with the manufacturing test plan. See Figure 4.4-23 and 4.4-24 for weld and test sequence.

LO_2 WELD AND TEST SEQUENCE
Manufacturing Assembly Sequence – Delta Wing Orbiter

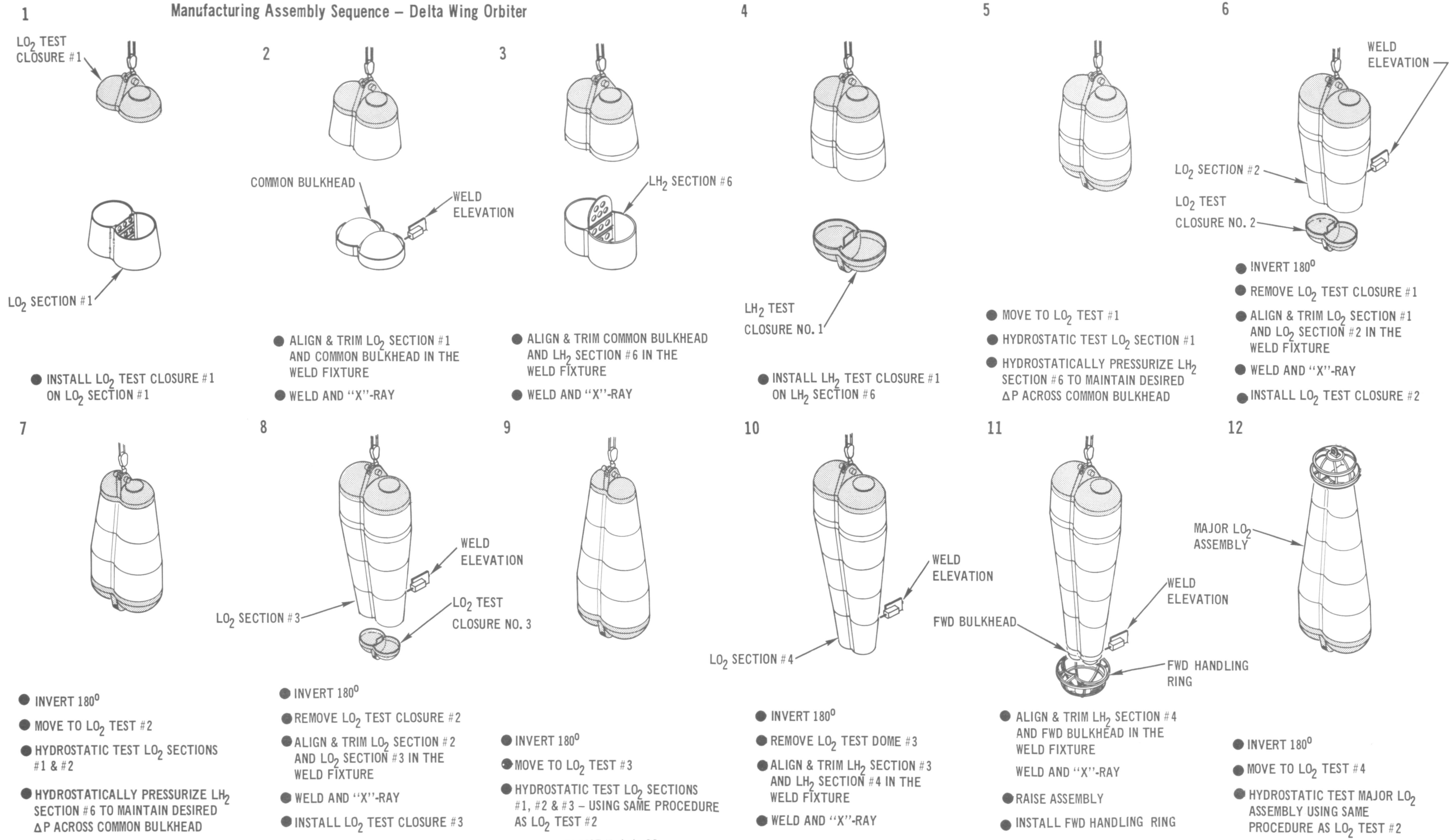


FIGURE 4.4–23

LH_2 WELD AND TEST SEQUENCE
Manufacturing Assembly Sequence – Delta Wing Orbiter

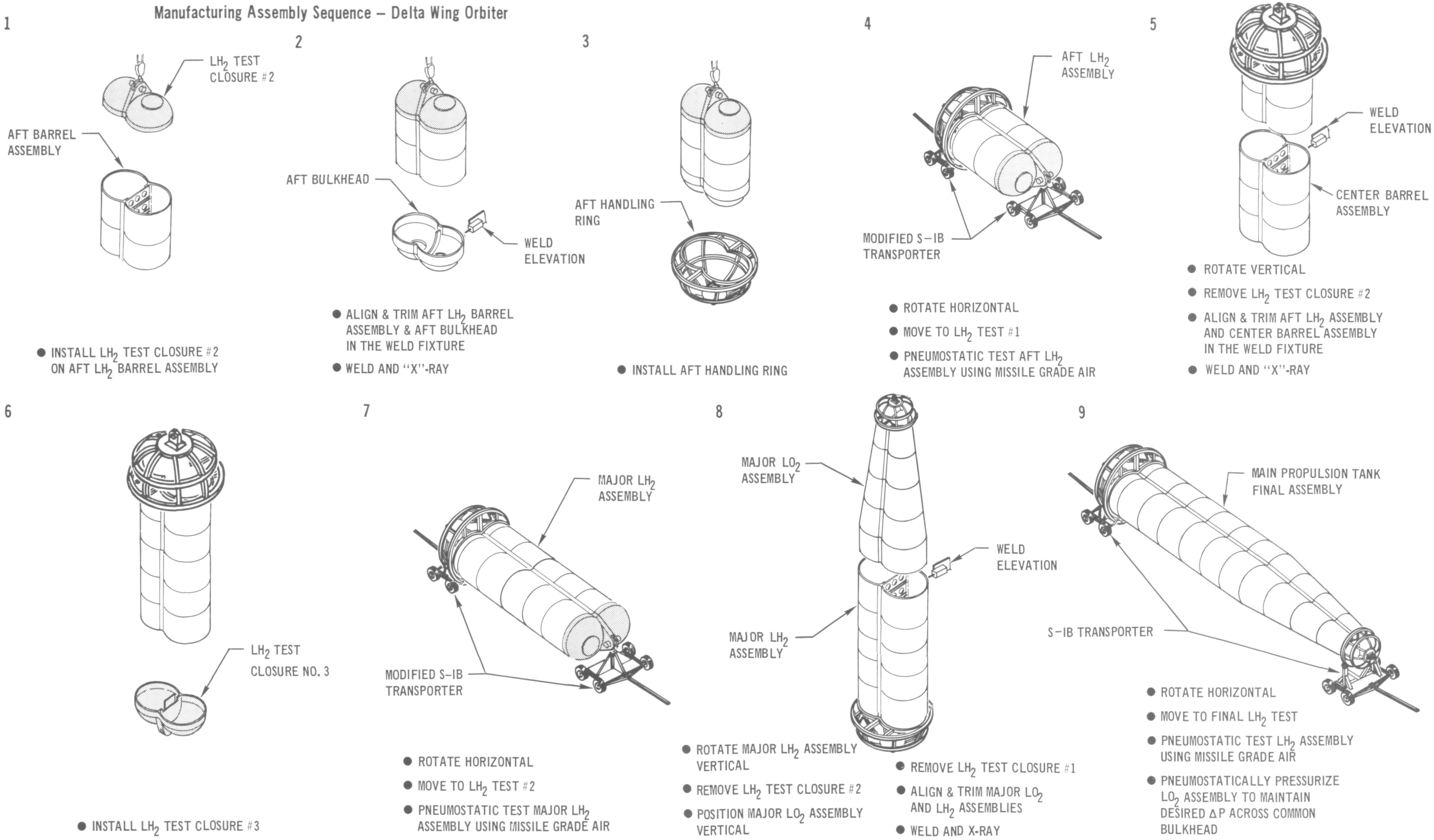


FIGURE 4.4-24

4.4.1.13 Pneumostatic Test Facility - The present high-pressure test facility at Michoud lacks the capability to support either LH_2 or LOX tank testing. A new facility will be required, (this facility will have dual usage for both orbiter main tank and booster LH_2 tank).

It is proposed that a three-sided revetment be constructed. (Figure 4.4-25 shows typical structure). Dimensions at floor level will be 60 x 150 ft.; clear height will be 40 ft. The area is to be covered by a steel-framed weather cover.

The estimate is predicted on a concrete lined earthback-filled revetment. The interior surface is assumed to be precast concrete slabs supported by retaining precast concrete columns, with restraining dead man ties back into the the earth fill. The fill, which is to be obtained by regrading the surrounding area, will be placed with a 1:2 slope, covered with jute mat and seeded to control erosion. To obtain adequate foundation conditions for the revetment, a trench will be excavated 10 ft. deep and back filled with sand under the heaviest portion of the revetment. The floor will be a 9 in. concrete slab. Four driven piles will be used as tie-down restraints against vertical upward reactions. Other piles provide support for interior revetment surfaces as required. Friction piles will develop sufficient bearing for structures.

Modification High-Pressure Facility

Design Start Date	1 July 1972
Construction Complete Date	1 July 1973
Estimated Cost	$320,000

PNEUMOSTATIC TEST FACILITY

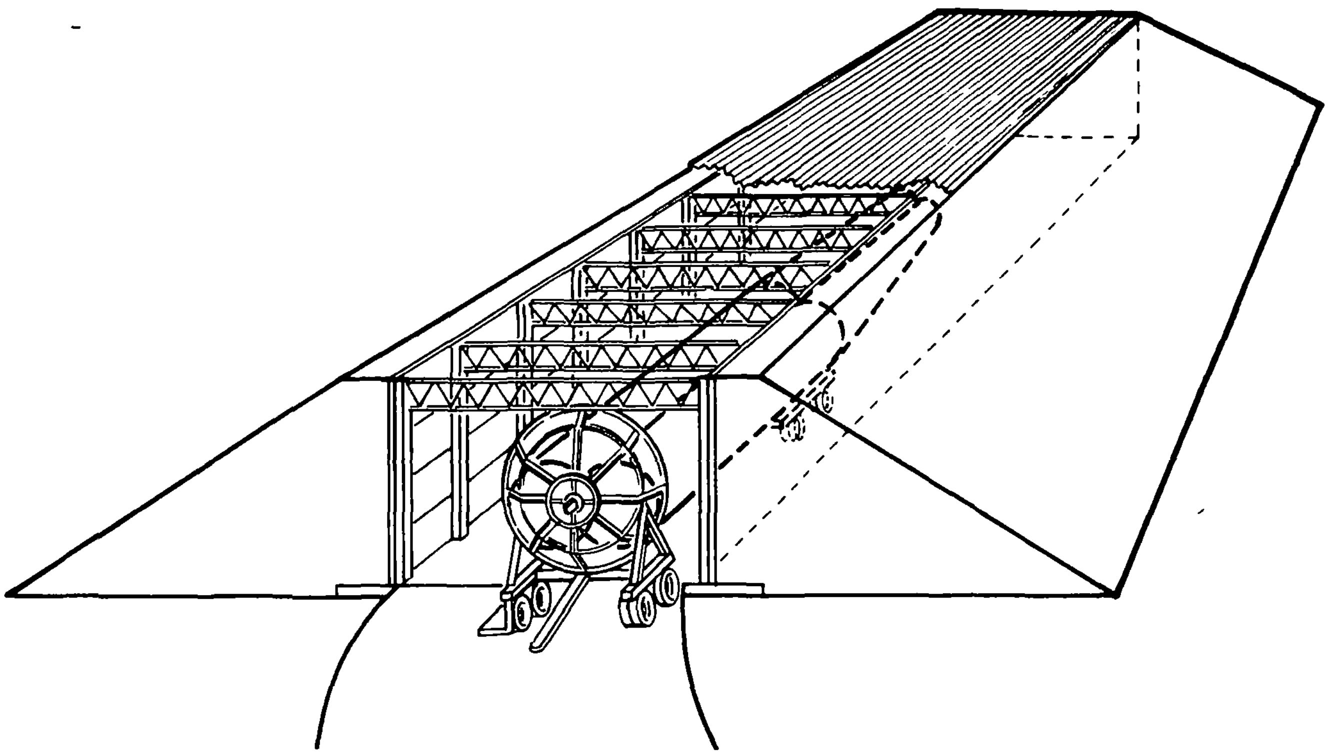


FIGURE 4.4-25

Upon completion of the pneumostatic testing, the tank is taken to the cleaning station to be cleaned prior to insulation.

4.4.1.14 Hydrostatic Test/Cleaning Facility - The cleaning workstand will be modified to accept the 33 ft diameter x 135 ft. long booster hydrogen tank. These modifications also make the facility suitable for cleaning the orbiter tank.

Modification of framing will provide clearance when the tank is lifted to maximum hook height (183 feet). Modification will consist of removing floor framing at 3 levels on the north elevation to provide an opening roughly 36 ft W x 34 ft H. The height of framing is then reduced to 39 ft. thus assuring approximately 9 ft. vertical clearance from tank to framing when crane hook is at maximum height. A door will be added to cover the opening. It will be lowered vertically on the outside face of the stand, by an electrically driven actuator. Bracing between new and existing columns, and in the level below the new columns, will be added to restore rigidity lost by the removal of floor framing. Platforms will be removed in the area of the modified opening. See Figure 4.4-26.

Modification

Design Start Date	1 April 1973
Construction Completion Date	1 May 1974
Estimated Cost	$60,000

HYDROSTATIC TEST/CLEANING FACILITY

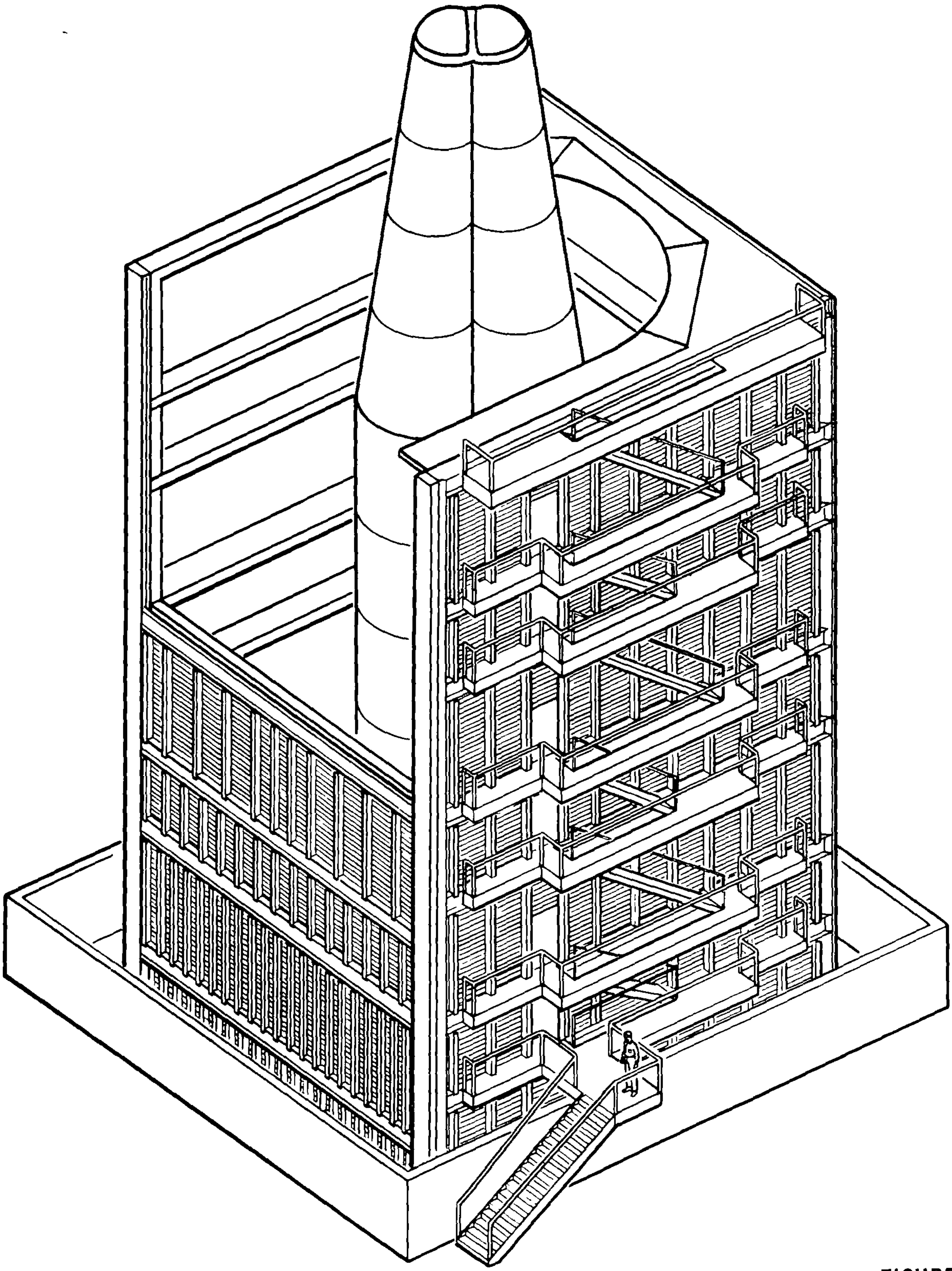


FIGURE 4.4-26

Upon completion of the cleaning operation the tank is removed from the clean cell and moved to the insulation installation room in Bldg. 103. Installation will involve the fitting, bonding, and curing of prefabricated insulation panels (tiles) into the tank, plus the overlay membrane which in turn seals and isolates the insulation panels from the liquid hydrogen.

4.4.1.15 Insulation Installation Facility - There is presently no facility at Michoud in which this task can be performed, therefore, Building 103 will be modified as follows. (This facility will have dual usage for both Orbiter and main tank and Booster LH_2 tank.) Figure 4.4-27.

INSULATION ROOM

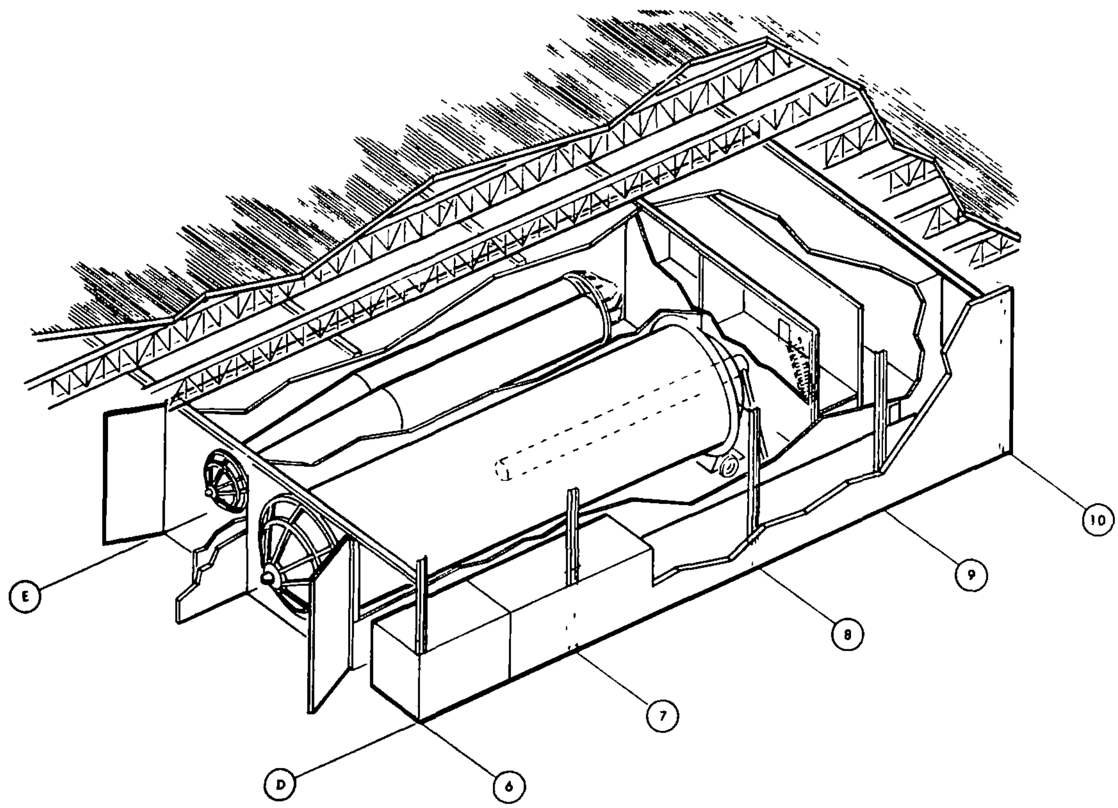


FIGURE 4.4-27

CRITERIA:

The room shall be constructed within an existing building that is air conditioned and has a 40 foot lower chord height.

The room will be 190 ft. long, 77 ft. wide and 40 ft. high.

A new DX air conditioning system will be installed with air cooled condensers on the roof to maintain 50°F ± 5°F within the room during application. 250°F during cure cycle will be by gas fired makeup units. Air conditioning will be shut down during cure cycle. System components in the air stream shall be explosion proof due to the presence of MEK.

The ceiling shall be cement asbestos board suspended at the lower chord.

Lighting to be 50 F.C. maintained at the 5'-0" level using explosion proof mecury vapor lamps.

Walls shall be constructed of steel stud and cement asbestos board with 3" insulation bats. Supplementary steel framing to be used for wall support.

Personnel door, 12' vertical lift door, will be provided and (2) 35' motorized sliding doors are included.

Approximately 200 KVA of power panels will be installed for 480 V, 3PH, 60HZ power.

Floor to be sealed.

Fire protection will be a high hazard wet type sprinkler system.

Power run outs and occupancy costs are not part of this estimate.

Design Start Date	1 November 1972
Construction Complete Date	1 June 1974
Estimated Cost	$636,000

4.4.1.16 Tank Close-Up - When the installation of insulation into the tank is completed, the tank is given a final cleaning operation and will be closed up using tank closure fittings to prevent contamination during subsequent assembly operations. At this point, the main propulsion tank assembly is ready for movement to the fuselage assembly area to begin fuselage buildup.

4.4.1.17 Major Facilities, Tools and Equipment - Major tool, equipment and process requirements for manufacture of the main propulsion tank are shown in Tables 4.4-1 and 4.4-2, respectively.

TABLE 4.4-1

MAIN ORBITER TANK FABRICATION
FACILITY AND EQUIPMENT REQUIREMENTS

Facility and Equipment Requirement	Facility and Equipment Availability
Area	
Approx. 40,000 sq. ft.	Existing Contractor
Crane Capacity	
5 Tons	Existing Contractor
Major Equipment	
3 Axis Profiler Skin Mill	Existing Contractor
Skin Wrap Forming Machine	New Contractor
5 Axis Omni Mill	(2) New Contractor
Laboratory	
Non-Destructive Test	Existing Contractor
Metal Finishing	Existing Contractor
Protective Coating	Existing Contractor
Processing Facilities	
Clean & Rinse	Existing Contractor
Chemical Milling	Existing Contractor
Anodizing	Existing Contractor
X-Ray	
	Existing Contractor
Special	
Induction Heater	New Contractor

TABLE 4.4–1 (Cont'd)

Utilities	
90-100 PSI Filtered Factory Air	Existing Contractor
115V 60HZ Electrical Outlets	Existing Contractor
440V 60HZ Electrical Outlets	Existing Contractor
Normal Lighting	Existing Contractor

TABLE 4.4-2

MAIN ORBITER TANK FABRICATION
FACILITY AND EQUIPMENT REQUIREMENTS

Facility and Equipment Requirements	Facility and Equipment Availability
<u>Area</u>	
20,000 Sq. Ft. "Gray Box"	Existing Michoud Bldg. 103
7,000 Sq. Ft. "Gray Box" 2 Vertical	Existing Michoud (with modifications)
Weld Station	Bldg. 110 (VAB)
<u>Crane Capacity</u>	
15 Ton "Gray Box"	Existing Michoud
185 Ton "VAB"	Existing Michoud
<u>Major Equipment</u>	
Modified S-1B Transporter	Existing Michoud
Vertical Boring Mill	Existing Michoud
Modified S-1B Assembly Fixture	Existing Michoud
Modified Rack & Pinion	New Michoud
Facing Equipment for Dome Ring Frame	New Michoud
Anodizing Facility	New Michoud
<u>Welding Equipment</u>	
Electron Beam with Localized Vacuum Chamber	New Michoud
MIG Pulse Arc	New Michoud
<u>Major Tools</u>	
Aft Dome Trim & Weld Fixture	New Michoud
Circumferential Weld & Trim Fixture	New Michoud
Aft Barrel Cap & Weld Assembly Fixture	New Michoud
Center Barrel Cap & Web Assembly Fixture	New Michoud

TABLE 4.4-2 (Cont'd)

Major Tools (Continued)	
Forward Barrel Cap & Web Assembly Fixture	New Michoud
Aft Barrel Assembly Longitudinal Weld Trim & Weld Fixture	New Michoud
Center Barrel Assembly Longitudinal Weld Trim & Weld Fixture	New Michoud
Forward Barrel Assembly Longitudinal Weld Trim & Weld Fixture	New Michoud
Aft Conic Cap & Web Assembly Assembly Fixture	New Michoud
Aft Center Conic Cap & Web Assembly Assembly Fixture	New Michoud
Forward Center Conic Cap & Web Assembly Assembly Fixture	New Michoud
Forward Conic Cap & Web Assembly Assembly Fixture	New Michoud
Laboratories	
Non-Destructive Test	Existing Michoud
Metal Finishing	Existing Michoud
Protective Coating	Existing Michoud
Processing Facilities	
Clean & Rinse	Existing Michoud
Chemical Milling	Existing Michoud
Anodizing	Existing Michoud

TABLE 4.4–2 (Cont'd)

X-Ray	
Manual and Automatic	Existing Michoud
Utilities	
90-100 PSI Filtered Factory Air	Existing Michoud
115V 60HZ Electrical Outlets	Existing Michoud
440V 60HZ Electrical Outlets	Existing Michoud
Argon, Helium Supplies	Existing Michoud
Welder Cooling Water	Existing Michoud
Normal Lighting	Existing Michoud

NOTE:

To maintain weld integrity and dimensional tolerance, this area must be environmentally controlled to 75 ± 5°F with 50 percent max. relative humidity. (Michoud "Gray Box" weld tower meets this criteria). All weld and heavy machine bases must be vibration free.

4.4.2 Orbiter Crew Station/Airlock Module Manufacturing

4.4.2.1 Crew Station/Airlock Module Description

The Crew Station/Airlock Module (Figure 4.4-28) is a Pressure Vessel Assembly which consist of a cockpit/aırlock common bulkhead, aft airlock bulkhead, forward cockpit bulkhead, intermediate bulkhead, sidewell bulkhead, windshield frame, airlock overhead panel, cockpit overhead panel, waste and food management areas and various hatches, etc. An illustrated manufacturing flow sequence is shown in Figure 4.4-29. A Manufacturing Flow Chart and Schedule is shown in Figure 4.4-30.

CREW STATION/AIRLOCK MODULE

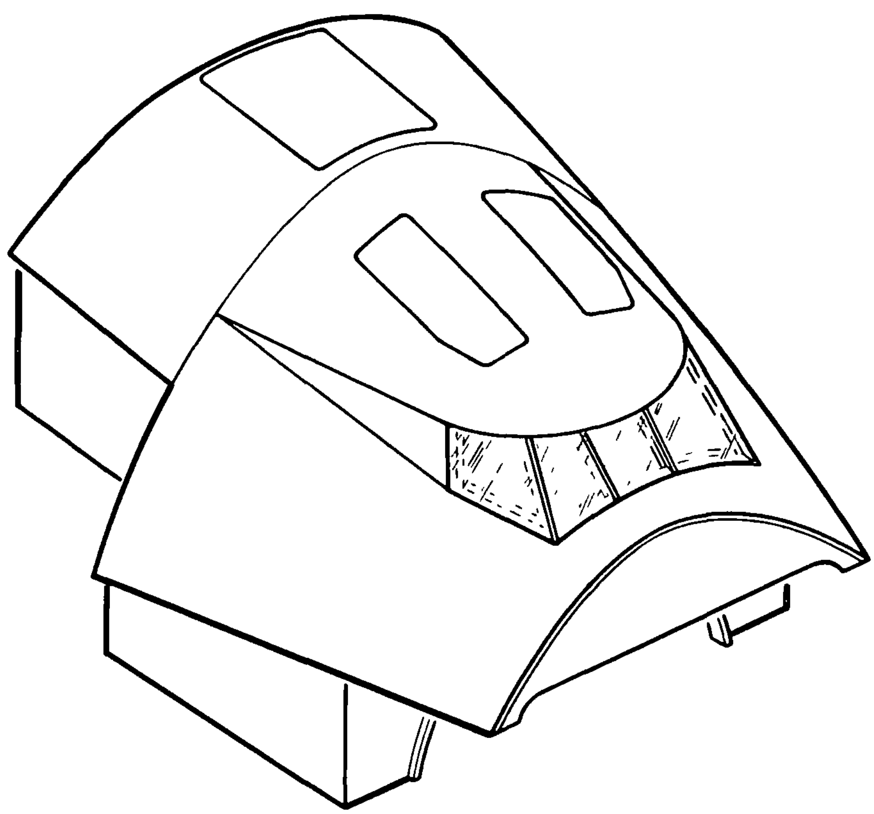


FIGURE 4.4-28

CREW STATION/AIRLOCK MODULE

Manufacturing Assembly Sequence – Delta Wing Orbiter

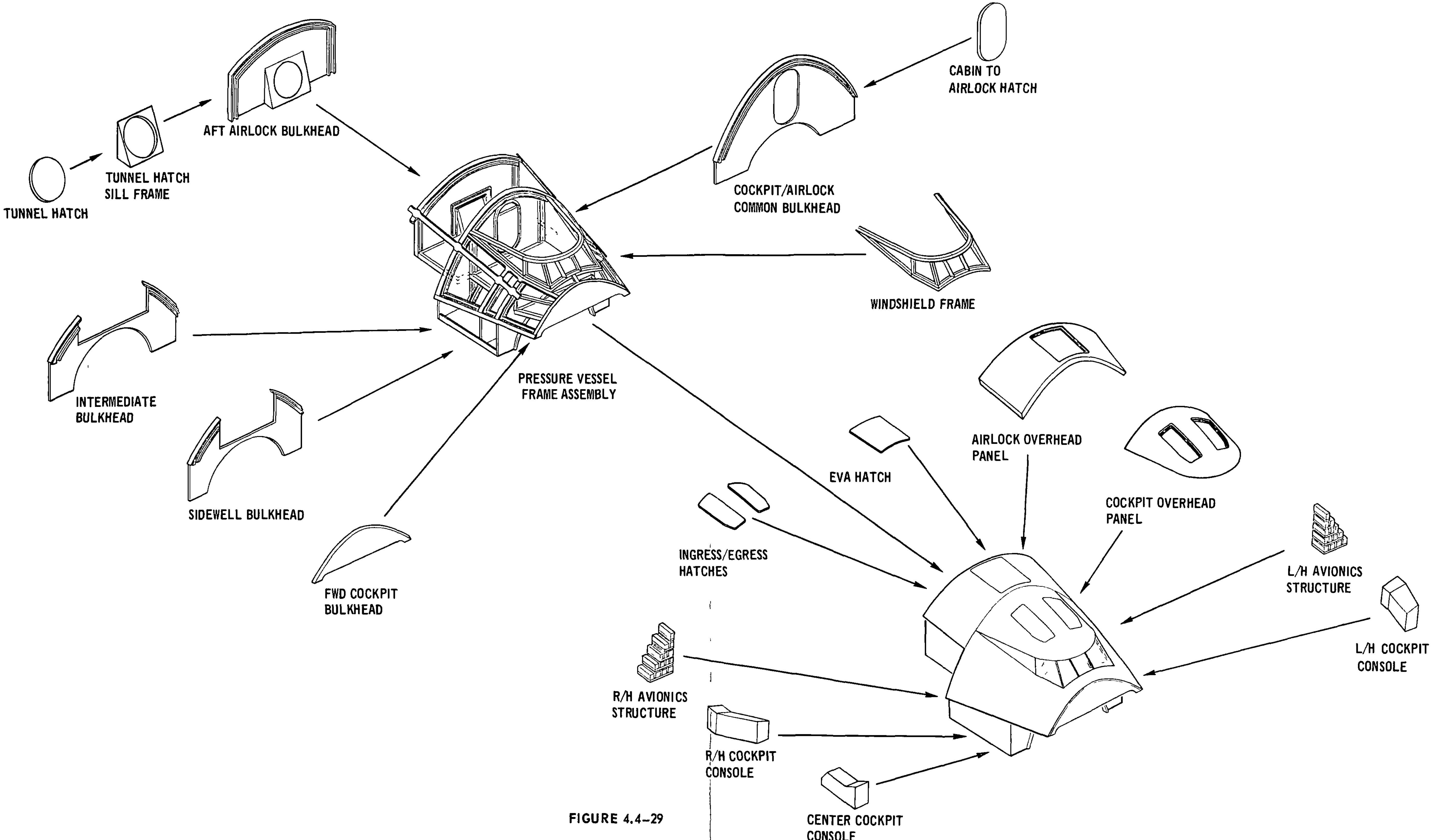


FIGURE 4.4–29

CREW STATION/AIRLOCK MODULE
MANUFACTURING FLOW CHART & SCHEDULE
DELTA WING ORBITER

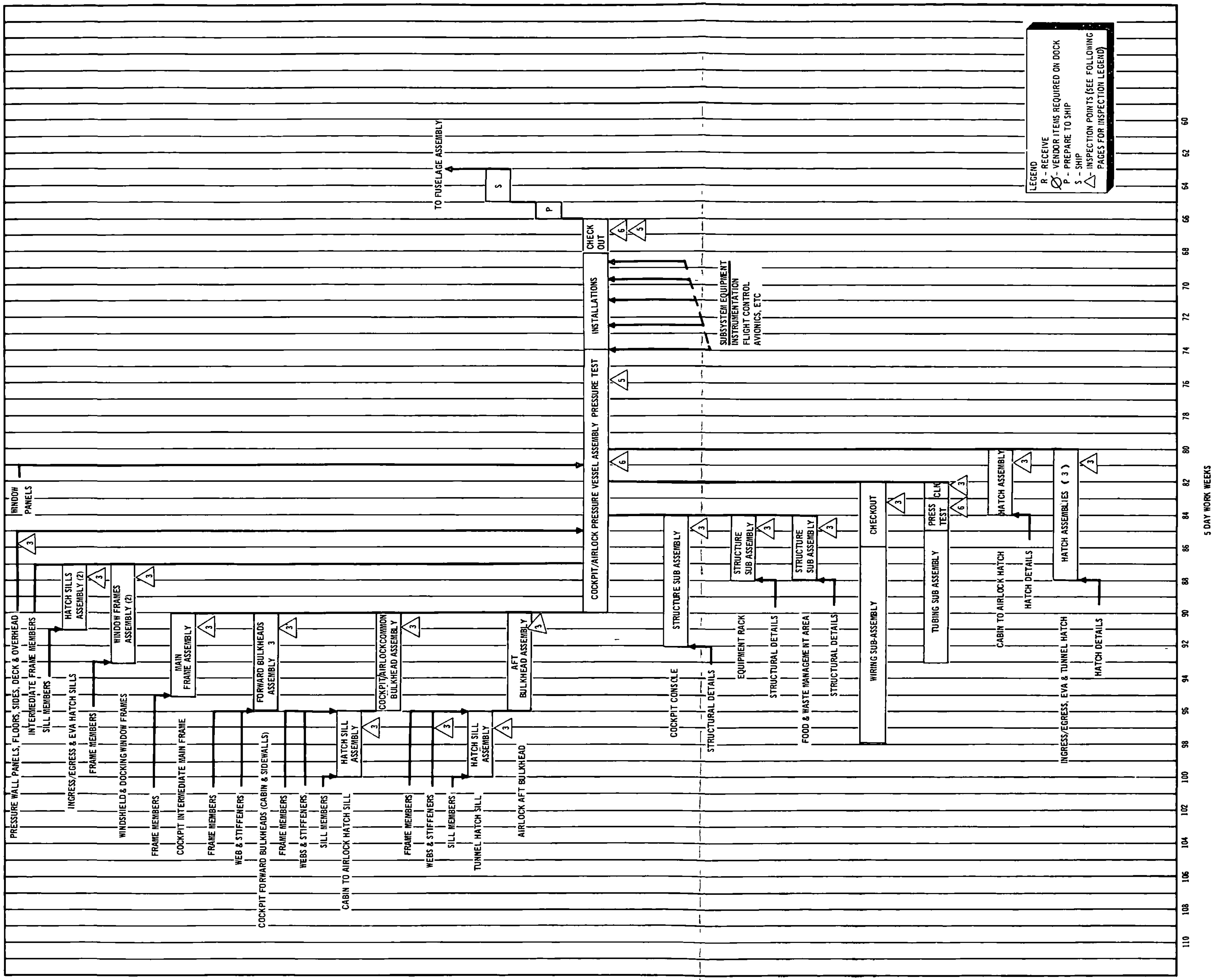


FIGURE 4.4-30

4.4.2.2 Manufacturing Site -

It is recommended that the Orbiter Crew Station/Airlock Module be manufactured at the contractor's facility and be shipped to Michoud for installation into the Orbiter Fuselage Assembly.

4.4.2.3 Manufacturing Approach -

Crew Station/Airlock Module - The approach here is to build up and test the pressure vessel structure of the Crew Station/Airlock Module at the contractor's facility prior to its assembly splice into the fuselage, that is, performing most of the assembly work in one major fixture in order to minimize coordinated tooling requirements.

4.4.2.4 Manufacturing Operations -

Readily identifiable items such as hatches and their sills, windshield and window panels and their frames, consoles, equipment racks, etc., are built up as subassemblies. Critical interfaces either between or within these items, are controlled using coordinated tooling with validated accuracy.

Main pressure vessel bulkheads and frames, which form a part of the fuselage primary structure, are built up as subassemblies prior to going into the major assembly fixture. Conformance of subassemblies with controlled tooling, specifications, and assembly orders, is required prior to final assembly. Loft lines are used extensively for establishing profile control of the locators in the fixtures for these subassemblies. Mating at attach points is assured by structural conformity with tooling whose accuracy has been validated.

When main bulkheads and frame subassemblies are completed, they are positioned in the major assembly fixture. Predetermined fuselage station locators establish their longitudinal positions, while optics is used to establish lateral positions and elevation. Once set in position, intermediate frame members, hatch sills, window frames, etc., are located, fitted, and joined to the bulkheads and frames. Pressure wall panels (Floors, decks, sidewalls, and overhead) and their components, are installed, fitted and joined to the framework. Progressive inspections, for quality and specification conformance, plus proper installation of the correct fasteners, is required for close up. Internal structures such as cockpit consoles, equipment racks, etc., which form an integral part of the structure, are then installed, fitted and joined. Concurrent with this, installation of wiring and tubing subassemblies takes place.

Final assembly of this pressure vessel structure consists of fit-up and installation of windshield and window panels, and the required hatch assemblies. After necessary inspections and clean-up work, manufacturing checkout of the wiring and tubing is accomplished, and the unit is ready for pressure and leak testing.

Pressure and leak testing of the Crew Station/Airlock Module is accomplished in a test fixture which simulates the structural support which will later be provided by the fuselage structure. Satisfactory completion of the pressure vessel testing is validated by inspection personnel. Installation of the modules subsystems equipment is then accomplished. The module is then subjected to subsystems inspection, testing, and checkout. After successful completion of this checkout, the unit is prepared for shipment to the final assembly site for mating and splicing to the Fuselage.

4.4.2.5 Major Facilities, Tools and Equipment -

Major tools, equipment and process requirements for manufacturing of Crew Station and Airlock Module are shown in Table 4.4-3.

TABLE 4.4-3

ORBITER CREW STATION/AIRLOCK MODULE FABRICATION

FACILITY AND EQUIPMENT REQUIREMENTS

Facility and Equipment Requirements	Facility and Equipment Availability
Area	
78,000 sq. ft.	Available at Contractor Facility
30' Clear Height	
Crane Capacity	
10 Ton	Available at Contractor Facility
Major Equipment	
Milling Machines	Existing at Contractor Facility
Lathes	Existing at Contractor Facility
Furnace (Strain Relief)	New (Contractor)
Chemical Milling Equipment	Existing at Contractor Facility
Extrusion and Sheet Metal Equipment for Hot Forming Titanium Sheet Metal	New (Contractor)
Chemical Processing Equipment	Existing at Contractor Facility
Optical Equipment	Existing at Contractor Facility
Welding Equipment	
T.I.G. Welders	Existing at Contractor Facility
Major Tools	
Airlock Aft Bulkhead Assembly Assembly Fixture	New (Contractor)

TABLE 4.4-3 (Cont'd)

Major Tools (Continued)

Tunnel Hatch Sill Assembly	Assembly Fixture	New (Contractor)
Tunnel Hatch Sill	Weld Fixture	New (Contractor)
Cockpit/Airlock Common Bulkhead Assembly	Assembly Fixture	New (Contractor)
Cabin to Airlock Hatch Sill	Weld Fixture	New (Contractor)
Cockpit Intermediate Main Frame Assembly	Assembly Fixture	New (Contractor)
Side Panel Bulkhead	Assembly Fixture	New (Contractor)
Cockpit Forward Bulkhead	Assembly Fixture	New (Contractor)
Airlock Overhead Panel	Assembly Fixture	New (Contractor)
EVA Hatch Frame	Assembly Fixture	New (Contractor)
Payload Viewing Window Frame	Assembly Fixture	New (Contractor)
Cockpit Overhead Panel	Assembly Fixture	New (Contractor)

TABLE 4.4-3 (Cont'd)

Major Tools (Continued)

Ingress/Egress Hatch Frame	Assembly Fixture	New (Contractor)
Cockpit/Airlock Pressure Vessel Frame Assembly	Assembly Fixture	New (Contractor)
Center Window Frame	Assembly Fixture	New (Contractor)
Front Window Frames L.H. and R.H.	Assembly Fixture	New (Contractor)
Side Window Frames L.H. and R.H.	Assembly Fixture	New (Contractor)
Avionics & Food & Waste Management Area Assembly L.H. and R.H.	Assembly Fixture	New (Contractor)
Center Console	Assembly Fixture	New (Contractor)
Side Consoles	Assembly Fixture	New (Contractor)
Tunnel Hatch	Assembly Fixture	New (Contractor)
EVA Hatch	Assembly Fixture	New (Contractor)
Ingress/Egress Hatch	Assembly Fixture	New (Contractor)

TABLE 4.4-3 (Cont'd)

Major Tools (Continued)		
Cabin to Airlock Hatch	Assembly Fixture	New (Contractor)
Crew Station/Airlock Module	Hoist Tool	New (Contractor)
Crew Station/Airlock Module	Transporter	New (Contractor)
Laboratories		
Non-Destructive Test		Available at Contractor Facility
Metal Finishing		Available at Contractor Facility
Protective Coating		Available at Contractor Facility
Processing Facility		
Chemical Milling		Available at Contractor Facility
Burr		Available at Contractor Facility
Black Oxide Finish		Available at Contractor Facility
Alkaline Cleaning		Available at Contractor Facility
Bulk Stress Relieve		Available at Contractor Facility
Mill Mack Stripping		Available at Contractor Facility
Protective Coating		Available at Contractor Facility
Pickle		Available at Contractor Facility
Liquid Howe		Available at Contractor Facilty
Abrasive Cleaning		Available at Contractor Facility
Degrease		Available at Contractor Facility
Brazing		Available at Contractor Facility

TABLE 4.4-3 (Cont'd)

Utilities

90-100 PSI Filtered Factory Air	Available at Contractor Facility
115V 60HZ Electrical Outlets	Available at Contractor Facility
440V 60HZ Electrical Outlets	Available at Contractor Facility
Argon, Helium Supply	Available at Contractor Facility
Welder Cooling Water	Available at Contractor Facility
Normal Lighting	Available at Contractor Facility

4.4.3 Orbiter Wings Manufacturing

4.4.3.1 Wing Description -

The basic fabrication and assembly techniques required for the Orbiter Delta Wing are considered state of the art with the exception of certain TPS items such as carbon/carbon and the boron aluminum. However, it is anticipated that we will be able to effect a smooth transition of these items from laboratory practice to the manufacturing shops. This assembly is roughly triangular in shape and approximately 36-1/2 feet x 48-1/2 feet x 56-1/2 feet with a maximum 7 feet chord depth. See Figure 4.4-31.

WING – L/H

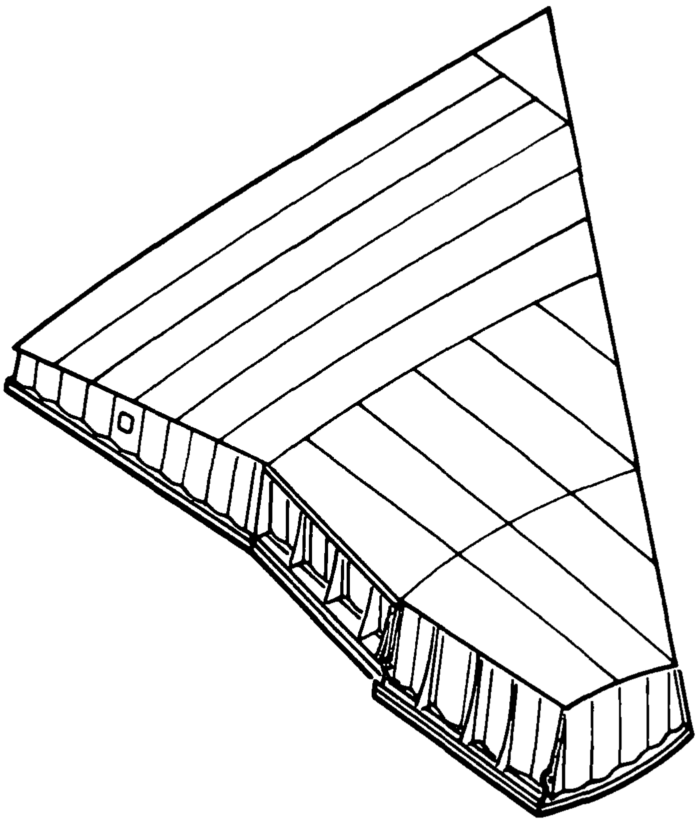


FIGURE 4.4-31

The design of the Orbiter Delta Wing lends itself to a multiplicity of sub-assemblies. The design approach offers considerable advantage in division of manufacturing work effort. A pictorial illustration and the Manufacturing Flow Chart and Schedule for the Orbiter Delta Wing are shown in Figures 4.4-32 and 4.4-33.

WINGS

Manufacturing Assembly Sequence – Delta Wing Orbiter

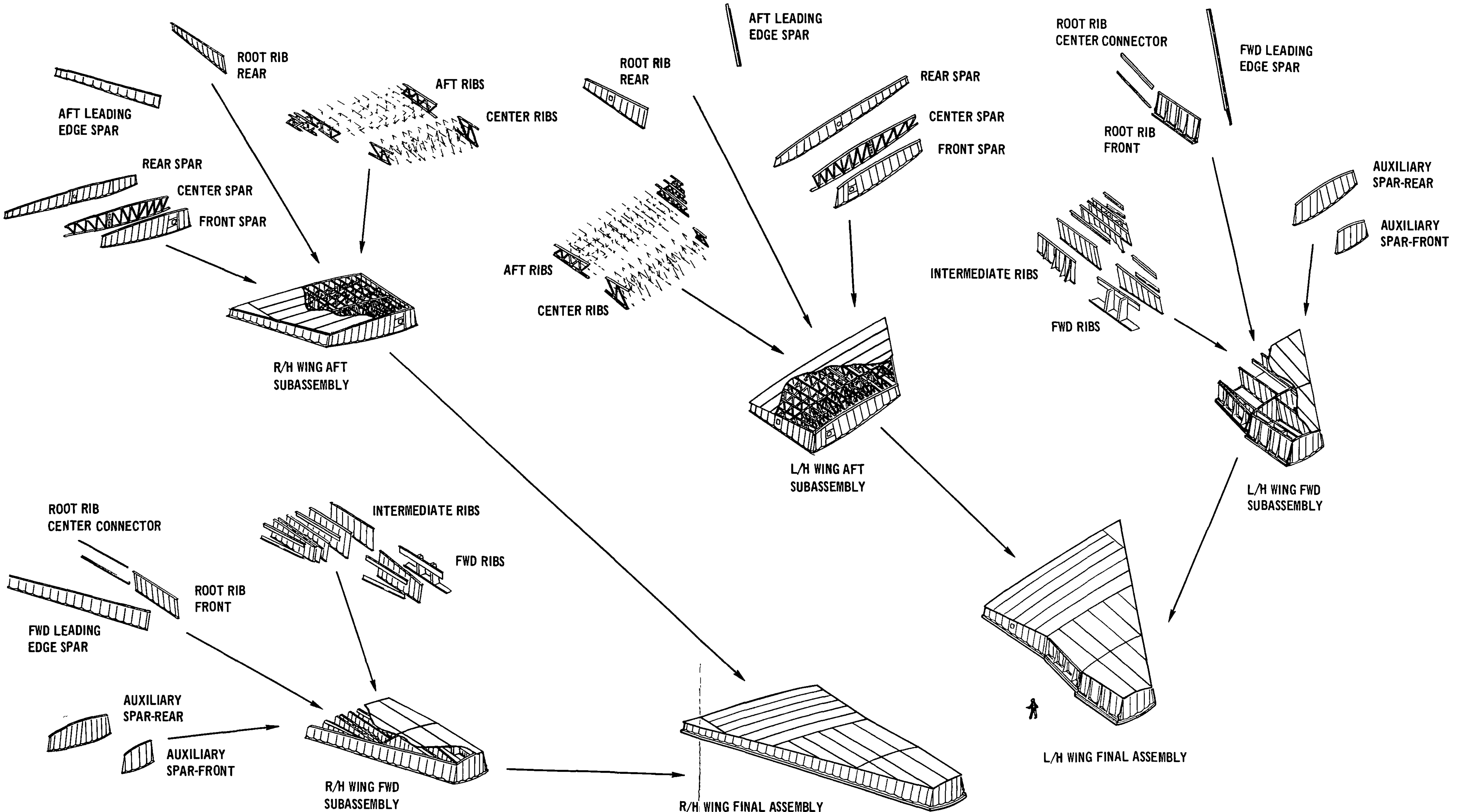


FIGURE 4.4-32

WING ASSEMBLY
MANUFACTURING FLOW CHART & SCHEDULE
Delta Wing Orbiter

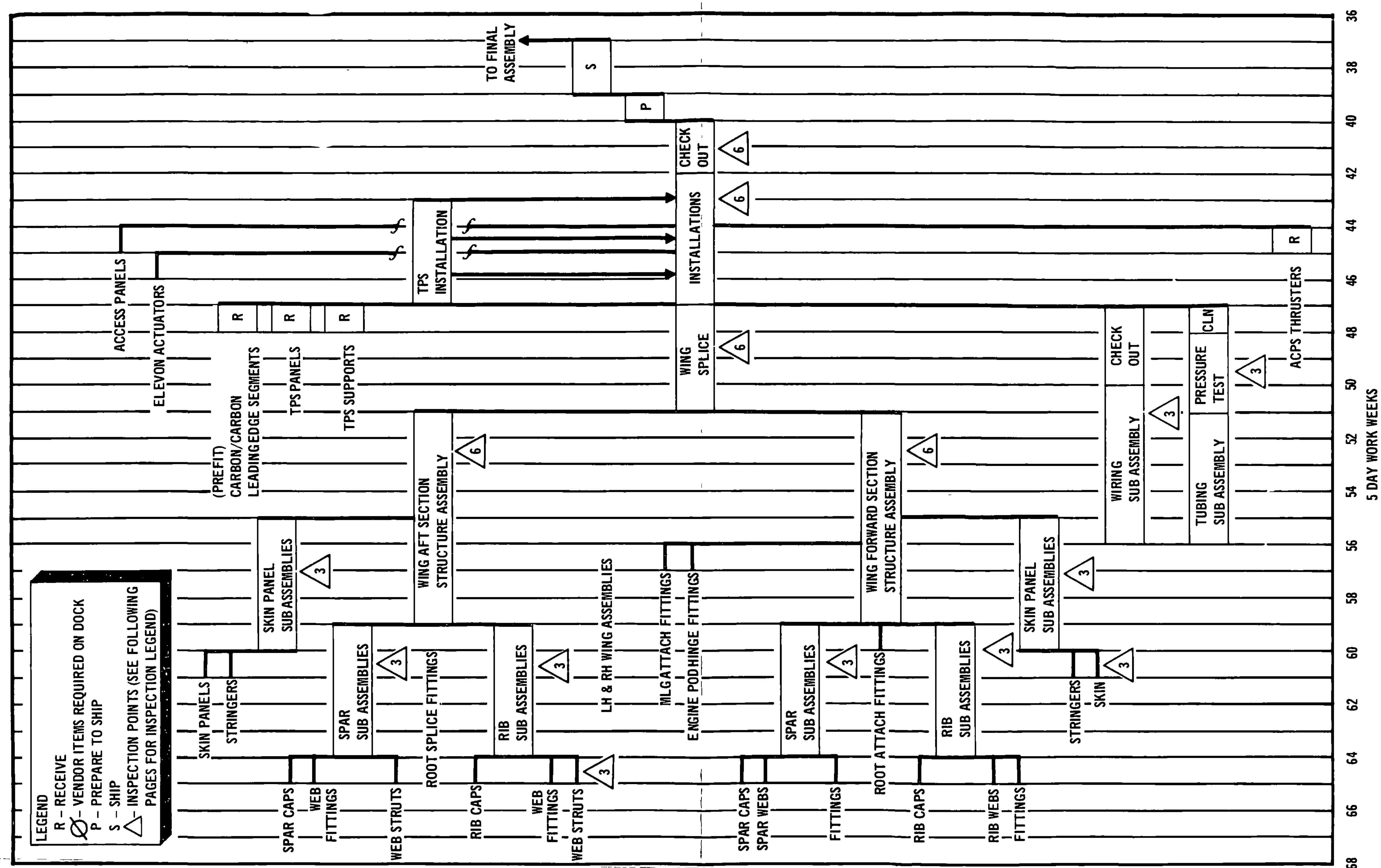


FIGURE 4.4–33

4.4.3.2 Manufacturing Site

It is recommended that the wing be manufactured at the Contractor's facility, then be shipped to K.S.C. for installation on the Orbiter.

4.4.3.3 Manufacturing Approach

The basic approach is to make two major sub-assemblies of the wing assembly proper. These two main sections are divided or spliced at the front main spar. Numerous sub-assemblies are planned of ribs, spars, closure beams, skins and stringers and fittings. The main spar carry through structures are included as, and integrated into, the aft fuselage structure.

4.4.3.4 Manufacturing Operations

BUILD-UP OF SUB-ASSEMBLIES

The carry through main spars are made up of flat webs and spar caps, whereas the wing ribs, spars and closure beams are made up of rippled webs and flat sheet or plate strips for caps. These items are welded together to form a complete rib or beam.

The boron aluminum stringers are fabricated in lengths up to thirty feet for attachment to skins of similar length. The stringers are made by laying up boron aluminum tape to the required thickness and configuration after which it is eutectically bonded through heat and pressure. Also, the skins are chemically etched between the stringers leaving a land for stringer attach.

After fabrication of the preceding skin and stringer details they are combined into a subassembly. During this operation they are drilled together and the stringers are attached to the skins (except in the area of attachment to spars) with temporary fasteners.

Control of major interface points is maintained through coordinated tooling to properly locate such items as elevon hinge line, main landing gear, and air-breathing engines and wing to fuselage attach points.

4.4.3.5 Assembly of Major Sub-Assemblies

The approach to assembling each of the two major sub-assemblies is to provide jig or tooling locators for the main framing members such as spars and closures. These sub-assembly framing members are planned to provide pre-determined structural attach points for locating intersecting rib pieces. Through incorporation of these locating or attach points on the hardware parts we are able to reduce the cost and complexity of the major assembly tooling.

The skin and stringer sub-assemblies are moved into place and fitted onto the structural framework of rib, and spars and drilled. These panels are then removed and the opposite side is likewise fitted and drilled and removed. Finally the upper skin panels are reinstalled and riveted in place. After this the lower surface is skinned panel by panel using firm rivets for most of the area. However, in the outer and trailing edge areas it will be necessary to close out the assembly through use of blind rivets. Proper in process inspection is made prior to close-out of blind areas.

After the forward and aft structural assemblies are completed they will be moved to a splice fixture for alignment and joining. This splice is made at the forward main spar line.

4.4.3.6 Installation of all Sub-Systems and TPS

Upon completion of the structural work, installation proceeds for such items as wiring, tubing, actuators and TPS support framework. Subsequently, the carbon/carbon leading edge is fitted, removed, and stored for final installation later in the assembly sequence. After this the TPS panels are fitted and installed except in the area of wing to fuselage splice. Here, it will be necessary to fit these panels after wing to fuselage splice is accomplished.

4.4.3.7 Major Facilities, Tools, and Equipment - Major tools, equipment and process requirements for manufacturing of the wing assembly tanks are shown in Table 4.4-4

TABLE 4.4-4

WING FABRICATION FACILITY AND EQUIPMENT REQUIREMENTS

Facility and Equipment Requirements	Facility and Equipment Availability
Area	
100,000 sq. ft.	Available Contractor
40' clear height	Available Contractor
Crane	
10 Ton	Available Contractor
15 Ton	Available Contractor
Major Equipment	
Milling Machines	Available Contractor
Spar Mill	Available Contractor
Chemical Processing Equipment	Available Contractor
Boron Aluminum Chemical Mill Line	New Contractor
Hi-Temp Furnace (3100°F)	New Contractor
Autoclave (Hi-Temp. Press.)	New Contractor
Major Tools	
Wing Hoist Tool (Sling)	New Contractor
Wing Ribs and Spar Hoist Tool (Sling)	New Contractor
Wing and Hoist Tool (Sling)	New Contractor

TABLE 4.4-4 (Cont'd)

Laboratories	
Non-Destructive Test	Available Contractor
Metal Finishing	Available Contractor
Protective Coating	Available Contractor
Quality Assurance	Available Contractor
Processing Facility	
Degreasing	Available Contractor
Abrasive Cleaning	Available Contractor
Liquid Hone	Available Contractor
Pickle	Available Contractor
Mill Mark Stripping	Available Contractor
Protective Coating	Available Contractor
Bulk Stress Relief	Available Contractor
Chemical Mill	Available Contractor
Burr	Available Contractor
Alkaline Clean	Available Contractor
Zyglo	Available Contractor
AGE	Available Contractor
X-Ray Film Processing	Available Contractor
Black Oxide Finish	Available Contractor
Heat Treat	Available Contractor
X-Ray	
Manual, Automatic	Available Contractor

TABLE 4.4-4 (Cont'd)

Utilities	
90-100 PSI Filtered Factory Air	Available Contractor
115V 60HZ Electrical Outlet	Available Contractor
440V 60HZ Electrical Outlet	Available Contractor
Normal Lighting	Available Contractor

4.4.4 Orbiter Cargo Compartment Door

4.4.4.1 Cargo Compartment Door Description

The Cargo Compartment Door is approximately 16-1/2 feet wide x 6-1/2 feet high x 65 feet long. See Figure 4.4-34.

CARGO COMPARTMENT DOOR

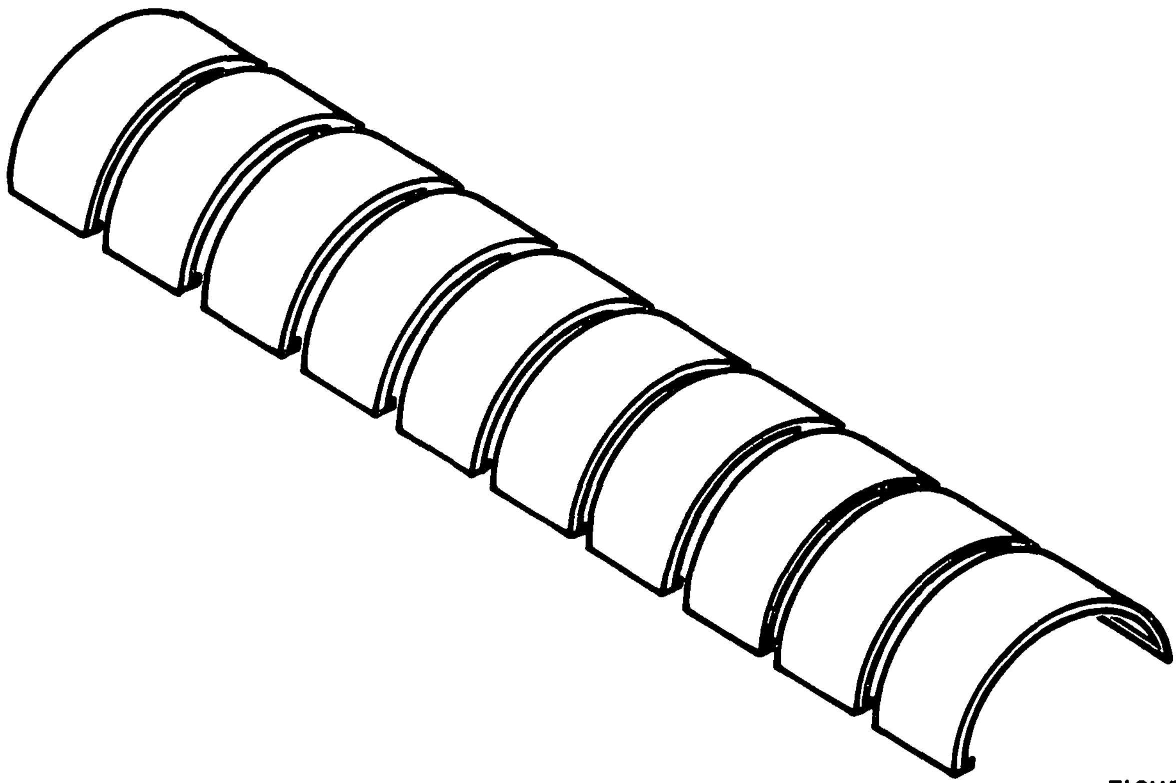


FIGURE 4.4-34

4.4.4.2 Manufacturing Site -

It is recommended that the Orbiter Cargo Compartment Door be manufactured at the contractor's facility and shipped to Michoud for installation.

4.4.4.3 Manufacturing Approach -

The assembly approach is to minimize tooling complexity and cost. The assembly is divided into ten modules or segments, which are interconnected through shear pins. We anticipate using one assembly tool for assembling nine of the modules and a separate tool for the tenth module. The individual modules or segments are about 9 feet long. These modules are subsequently assembled in an abbreviated Major Fixture where the shear pin holes between modules are match drilled and the hinge line fittings are installed. An illustrated Manufacturing Flow Sequence is shown in Figure 4.4-35, Manufacturing Flow Charts and Schedule are shown in Figure 4.4-36.

CARGO COMPARTMENT DOOR ASSEMBLY SEQUENCE

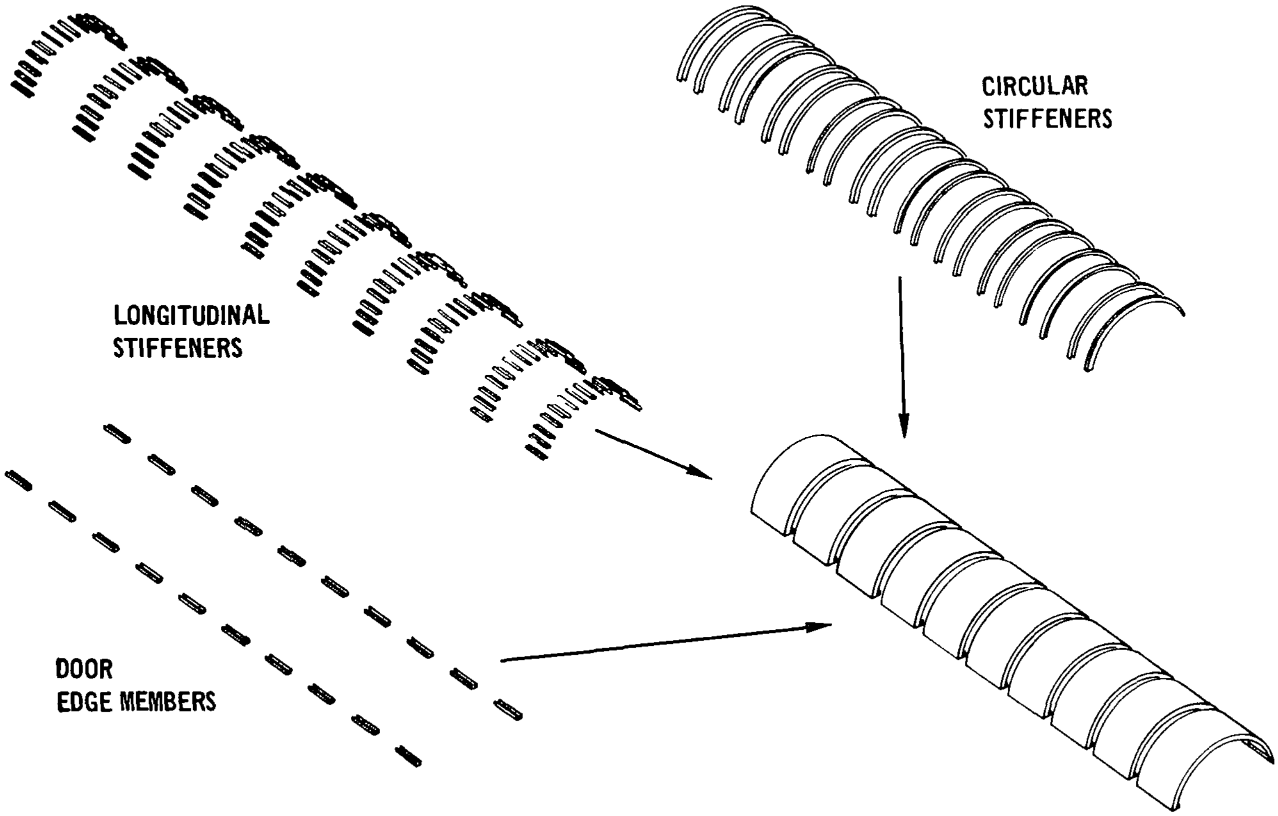


FIGURE 4.4-35

RADIATORS & MISC. DOORS MANUFACTURING FLOW CHART & SCHEDULE ORBITER

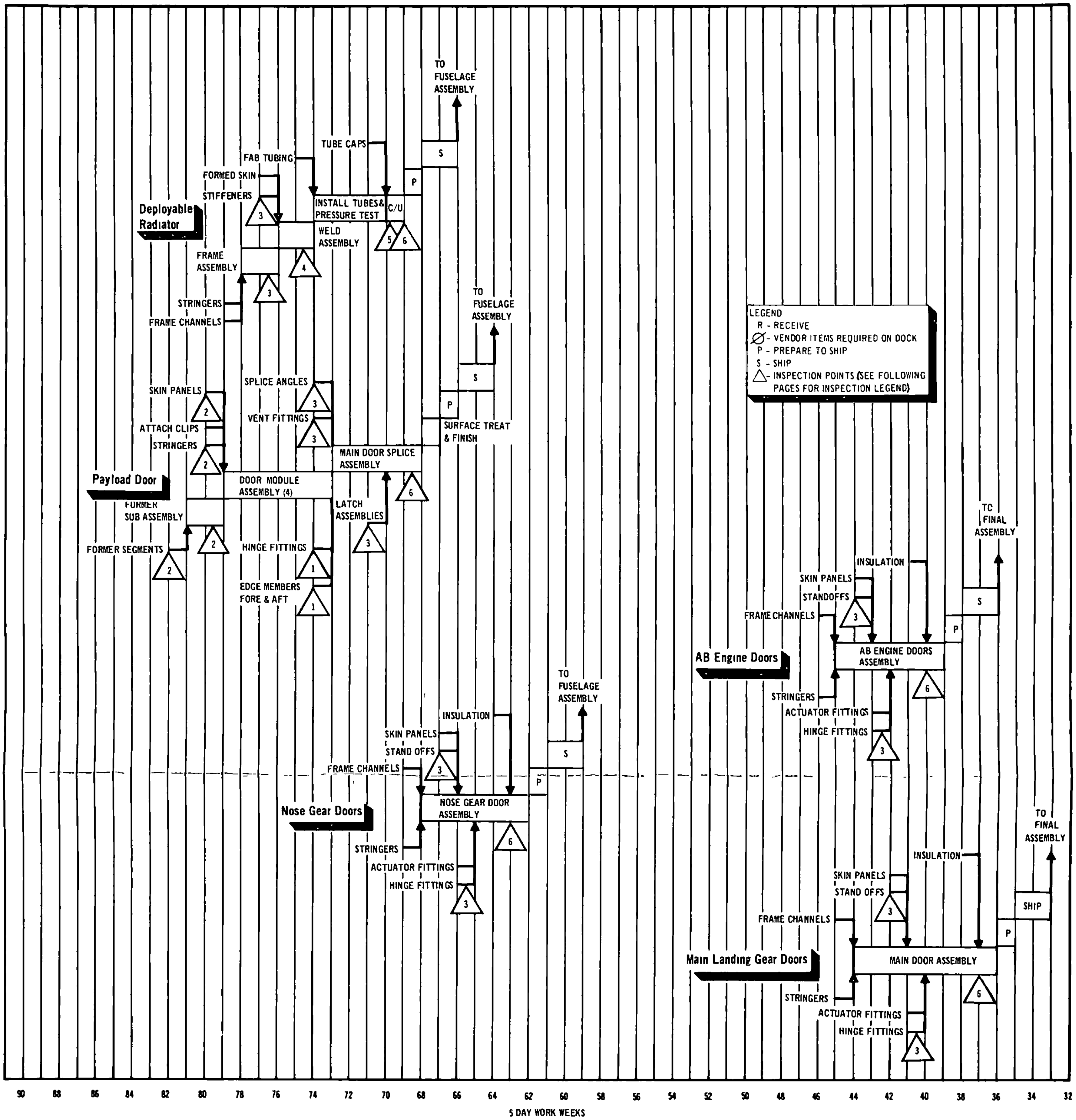


FIGURE 4.4-36

4.4.4.4 Manufacturing Operations -

Segments of the formers, "Z" Stringers and other parts requiring from operations will be done on hot dies, except for the skin pieces which are roll formed.

Assembly of the basic modules is accomplished in sub assembly tools, which control, contour, skin trim, location of formers, "Z" Stringers shear pin holes, edge members, etc.

These parts placed in the tools and drilled and riveted to complete the assembly. After completion of the door assembly it is cleaned and prepared for shipment to the point of installation.

The assembly tools used for these operations are checked and approved for accuracy, prior to use, also in process inspection is done at appropriate points to insure quality assemblies.

4.4.4.5 Major Facilities, Tools and Equipment -

Major tools, equipment and process requirements for manufacturing of the main propulsion tanks are shown in Table 4.4-5

TABLE 4.4–5

ORBITER CARGO COMPARTMENT DOOR FABRICATION
AND EQUIPMENT REQUIREMENTS

Facility and Equipment Requirements	Facility and Equipment Availability
Area	
6,000 sq. ft.	Available Contractor
40' clear height	Available Contractor
Crane Capacity	
5 Ton	Available Contractor
Major Equipment	
Milling Machines	Available Contractor
Lathes	Available Contractor
Chemical Processing Equipment	Available Contractor
Furnace (Strain Relief)	New Contractor
Major Tools	
Main Assembly Door Assembly Fixture	New Contractor
Partial Frame End Section Assembly Fixture	New Contractor
Partial Frame Intermediate Section Assembly Fixture	New Contractor

TABLE 4.4-5 (Cont'd)

Laboratories	
Non-Destructive Test	Available Contractor
Metal Finishing	Available Contractor
Processing Facilities	
Chemical Processing	Available Contractor
Burr	Available Contractor
Black Oxide Finish	Available Contractor
X-Ray	Available Contractor
Zyglo	Available Contractor
AGE	Available Contractor
Alkaline Clean	Available Contractor
Bulk Stress Relieve	Available Contractor
Mill Mark Stripping	Available Contractor
Protective Coating	Available Contractor
Pickle	Available Contractor
Liquid Hone	Available Contractor
Abrasive Clean	Available Contractor
Degrease	Available Contractor

TABLE 4.4-5 (Cont'd)

Utilities

90-100 PSI Filtered Factory Air	Available Contractor
115V 60 HZ Electrical Outlet	Available Contractor
440V 60 HZ Electrical Outlet	Available Contractor
Normal Lighting	Available Contractor

4.4.5 Orbiter Deployable Radiator

4.4.5.1 Radiator Assembly Description

The Radiator Assembly is approximately 15 feet wide x 6-1/2 feet high x 41 feet long. See Figure 4.4.-37.

DEPLOYABLE RADIATOR

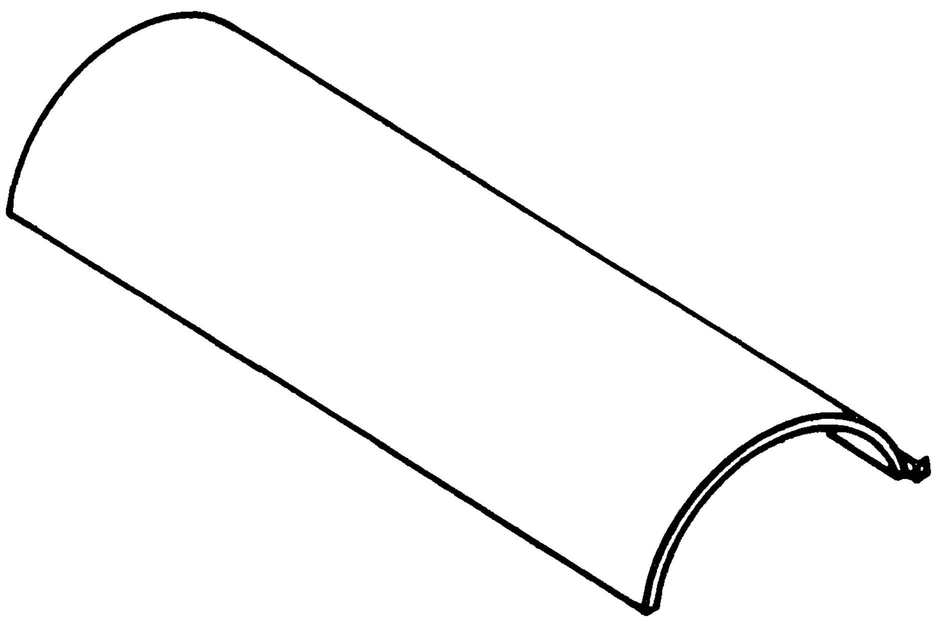


FIGURE 4.4-37

4.4.5.2 Manufacturing Site

It is recommended that the Orbiter Deployable Radiator be manufactured at the contractor facility and shipped to Michoud for installation.

4.4.5.3 Manufacturing Approach

In a manner similar to the payload door, we anticipate minimizing the tooling cost and complexity for the Radiator Assembly. In order to accomplish this the Radiator is broken into modular panels, which are brazed and assembled in common tools. An illustrated Manufacturing Flow Sequence is shown in Figure 4.4.-38. Manufacturing Flow Chart and Schedule are shown in Figure 4.4.-39.

DEPLOYABLE RADIATOR ASSEMBLY SEQUENCE

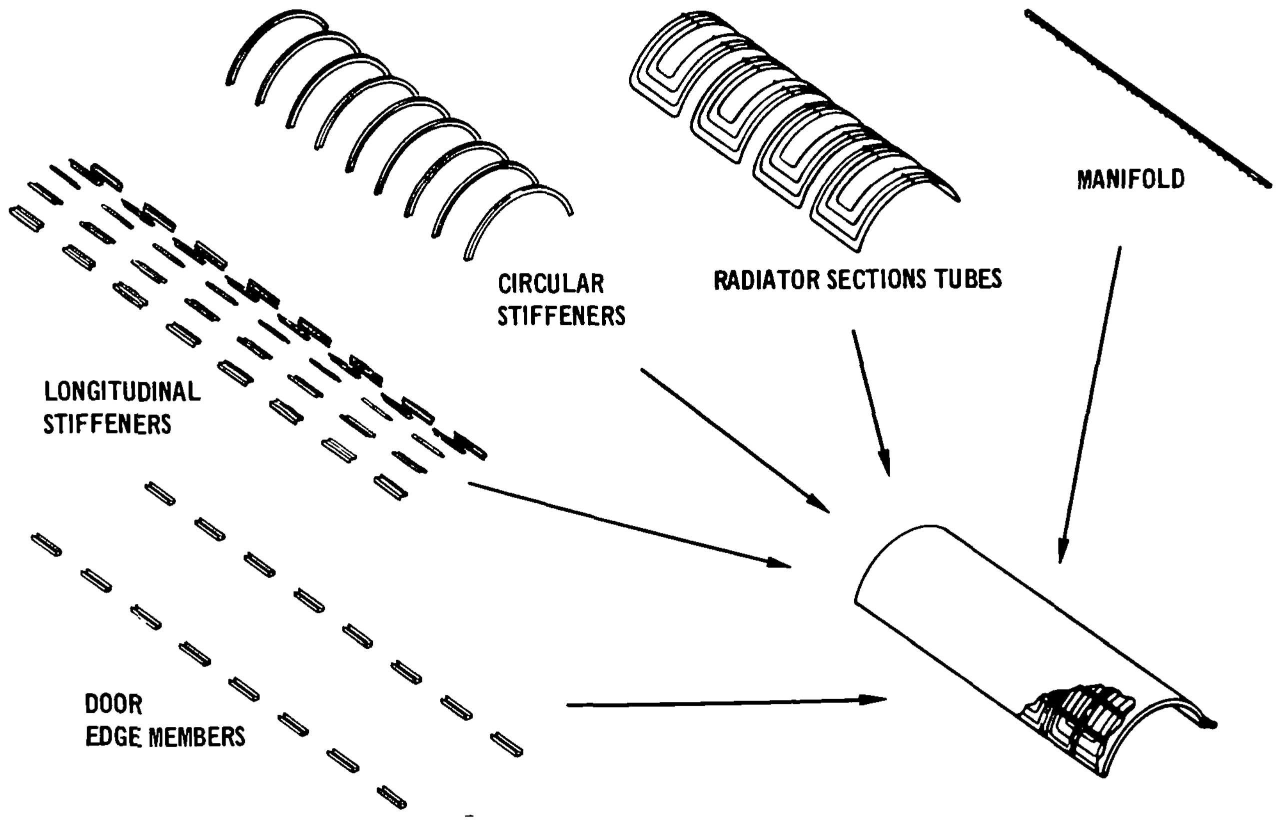


FIGURE 4.4–38

RADIATORS & MISC. DOORS
MANUFACTURING FLOW CHART & SCHEDULE
ORBITER

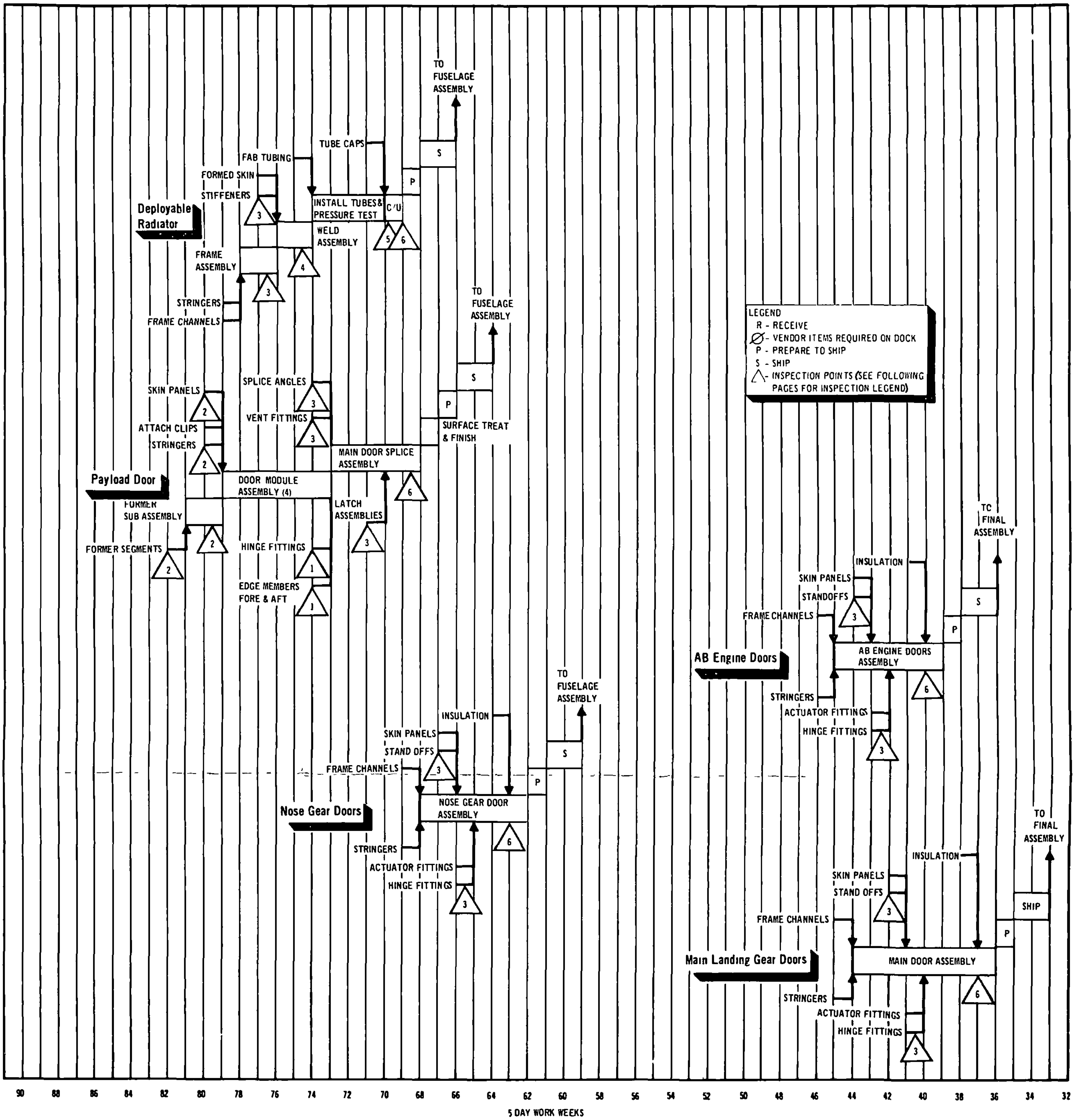


FIGURE 4.4-39

4.4.5.4 Manufacturing Operations -

The basic structural framework of the door will likewise be assembled in Modular sub-sections. Subsequently the Radiator Modular Panels and the framework Modules are placed in a splice fixture where the assembly is completed.

Such items as hinges size configuration, manifold assembly are also located at this point.

The tubing details will be formed according to sample parts and assembled on to the Radiator Fin in a brazing fixture. This tool will hold the parts in position for furnace brazing the tubing to the fin.

Details of the structural framework are formed on Hydro Press Form Blocks or by brake forming.

Upon completion of the assembly it is cleaned and prepared for shipment to the point of installation.

The assembly tooling used for these operations are checked and approved for accuracy prior to use. Also, in process inspection is done at appropriate points to insure quality assemblies.

4.4.5.5 Major Facilities, Tools, and Equipment - Major tools, equipment, and process requirements for manufacturing of the main propulsion tanks are shown in Table 4.4-6.

TABLE 4.4-6

ORBITER DEPLOYABLE RADIATOR FABRICATION
AND EQUIPMENT REQUIREMENTS

Facility and Equipment Requirements	Facility and Equipment Availability
<u>Area</u>	
4,500 sq. ft.	Available Contractor
40' clear height	Available Contractor
<u>Crane Capacity</u>	
5 Ton	Available Contractor
<u>Major Equipment</u>	
Milling Machines	Available Contractor
Lathes	Available Contractor
Chemical Processing Equipment	Available Contractor
Furnace (Strain Relief)	New Contractor
<u>Major Tools</u>	
Main Assembly Door Assembly Fixture	New Contractor
Partial Frame End Section Assembly Fixture	New Contractor
Partial Frame Intermediate Section Assembly Fixture	New Contractor
<u>Laboratories</u>	
Non-Destructive Test	Available Contractor
Metal Finishing	Available Contractor

TABLE 4.4-6 (Cont'd)

Processing Facilities	
Chemical Processing	Available Contractor
Burr	Available Contractor
Black Oxide Finish	Available Contractor
X-Ray	Available Contractor
Zyglo	Available Contractor
AGE	Available Contractor
Alkaline Clean	Available Contractor
Bulk Stress Relieve	Available Contractor
Mill Mark Stripping	Available Contractor
Protective Coating	Available Contractor
Pickle	Available Contractor
Liquid Hone	Available Contractor
Abrasive Clean	Available Contractor
Degrease	Available Contractor
Utilities	
90-100 PSI Filtered Factory Air	Available Contractor
115V 60 HZ Electrical Outlet	Available Contractor
440V 60 HZ Electrical Outlet	Available Contractor
Normal Lighting	Available Contractor

4.4.6 Control Surface Manufacturing

4.4.6.1 Vertical Fin Description

This assembly is approximately 11 feet wide x 32 feet high x 2 feet thick (maximum chord). (See Figure 4.4-40). (Exclusive of carbon/carbon leading edge, but including the spar extensions.) Manufacturing Flow Plan and Schedules reference Figure 4.4-43.

VERTICAL FIN ASSEMBLY SEQUENCE

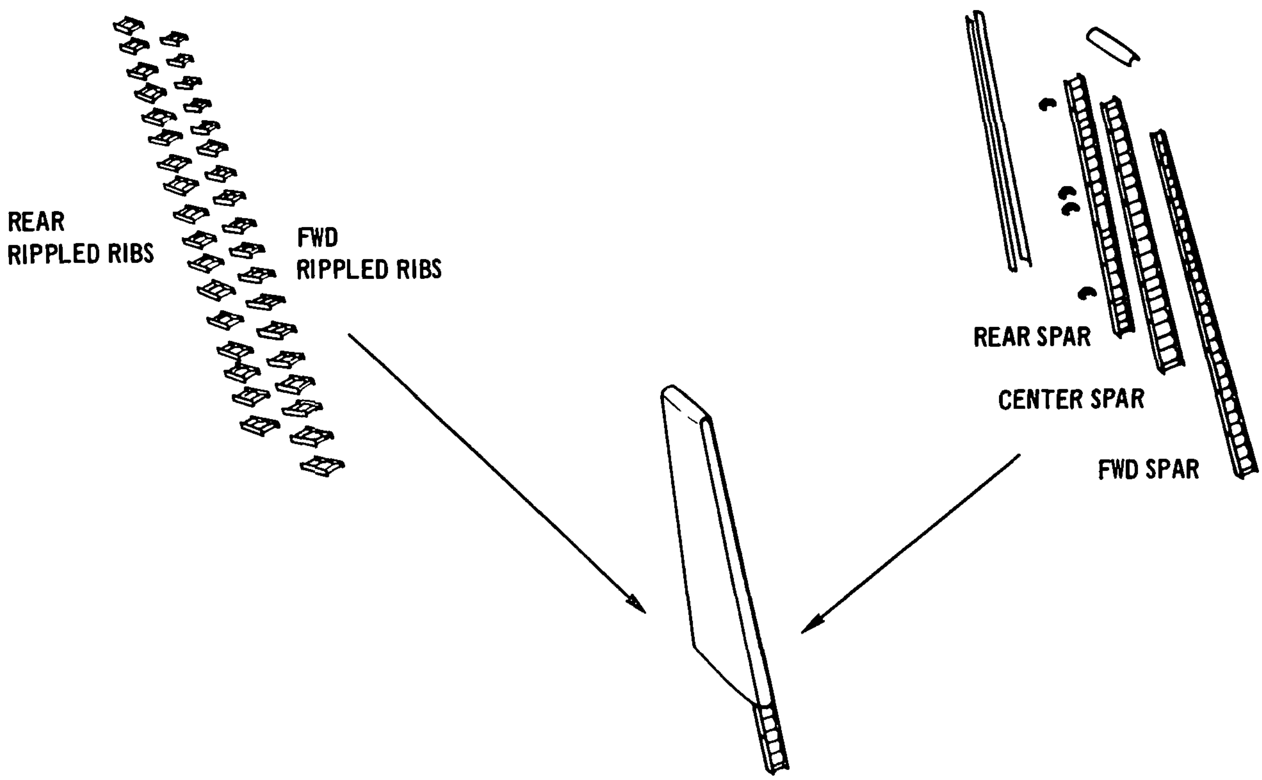


FIGURE 4.4-40

4.4.6.2 Manufacturing Site

It is recommended that the Vertical Fin be manufactured at the Contractor Facility, then shipped to K.S.C. for installation on the Orbiter.

4.4.6.3 Manufacturing Approach

The assembly approach is to subassemble the ribs and main spars and in turn use the spar subassemblies for locating the ribs in proper relationship. The ribs and spar subassemblies, along with skin panels, closures, hinge fittings, etc., are subsequently integrated to form a complete fin assembly. Inspection, for quality and specification conformance, plus proper installatin of correct fasteners occurs progressively.

4.4.6.4 Manufacturing Operations

The spar and rib subassemblies are assembled by welding machined caps to the rippled webs. Also, the spar assemblies would include those clip angles which subsequently become attach points for the rib subassemblies. Controlled tooling, whose accuracy has been validated, plus appropriate Non-Destructive Test (NDT) techniques, will assure specification conformance.

The structural framework of spars, hinge fittings, etc., are located in assembly tooling and the skin panels with stiffeners, are applied, drilled and attached. Final close-out of blind areas is accomplished through "peeling on" of skins, use of blind fasteners, or a combination of the two techniques. Progressive inspections, for quality and specification conformance, plus proper installation of the correct fasteners, is accomplished prior to close-out. As the assembly progresses the closure fairing and tip assembly are incorporated, and doors fitted. After this the unit is cleaned in preparation for installation. Quality control checks are made prior to closure of blind areas.

4.4.6.5 Installation of all Subsystems and T.P.S.

During the installation cycle, hydraulic lines and wire bundles are installed. Insulation is applied to the actuator cavity prior to installation of the actuator. Subseuquently, the antennas and access doors are installed. Also, the carbon/carbon leading edge is installed. Installation of the insulation, actuator, antennas and doors, plus the carbon/carbon leading edge is inspected for specification conformity using appropriate NDT techniques or visually, or both. Upon completion, the unit is prepared for shipment to the point of installtion on the vehicle.

4.4.6.6 Rudder Assembly Description

Rudder Assembly - This assembly is approximately 27-1/2 feet high x 7-1/2 feet wide x 2 feet thick (maximum chord). (Figure 4.4-41). Manufacturing Flow Plan and Schedule reference Figure 4.4-43.

RUDDER ASSEMBLY SEQUENCE

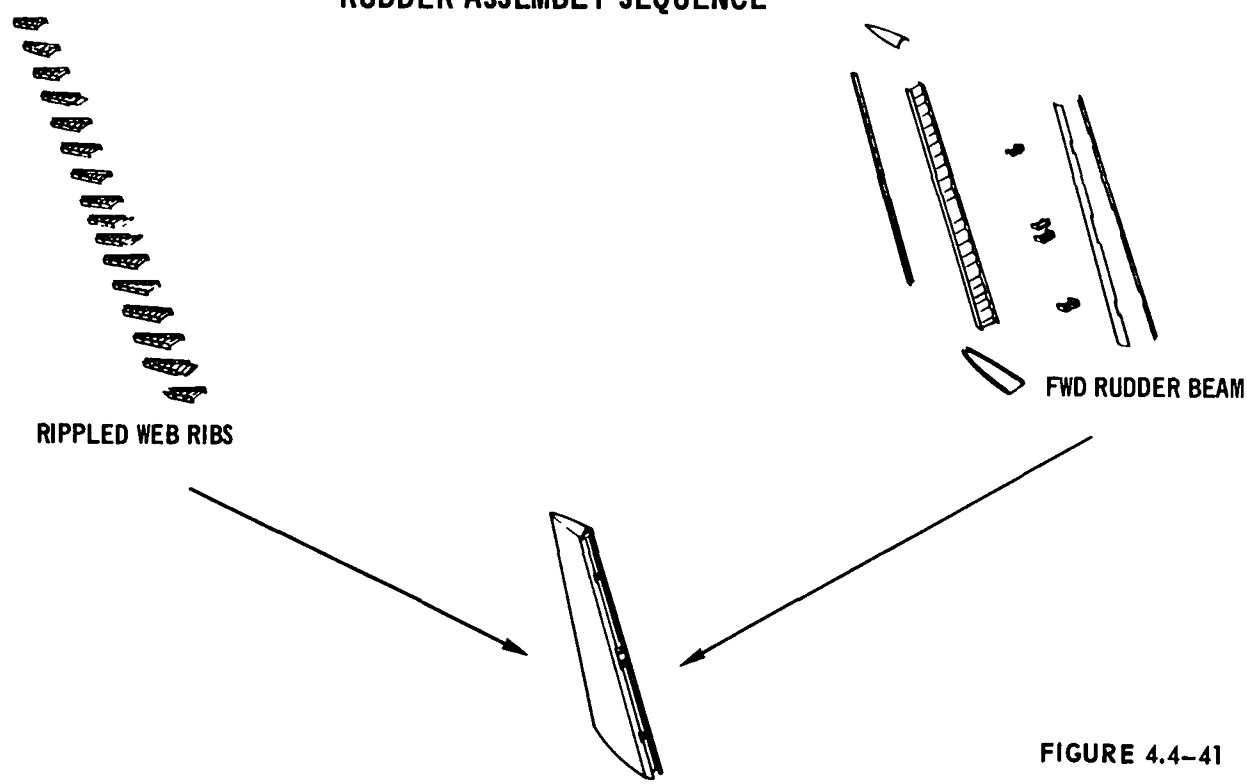


FIGURE 4.4-41

4.4.6.7 Manufacturing Site

It is recommended that the Rudder Assembly be manufactured at the Contractor facility, then shipped to K.S.C. for installation on the Orbiter.

4.4.6.8 Manufacturing Approach

The approach to assembling this unit is to develop basic substructural units which are in turn located in a fixture to form a framework. This includes the leading edge spar, aft beam, hinge fittings, etc. The skin panels with their stiffeners are applied, drilled and attached. Close out of the asssembly is accomplished by "peeling on" the skin panels, blind fasteners, or a combination of the two techniques. Inspection for quality and specification conformance, plus proper installation of correct fasteners occurs progressively.

4.4.6.9 Manufacturing Operations

The leading edge spar assembly is made up as a subassembly consisting of the caps and rippled webs which are welded together. The rib attach angles are also a part of this assembly. The trailing edge beam and rib subassembly are constructed in similar manner with welded caps and webs, while the beam carries the aft rib tie or attach angles. Controlled tooling, whose accuracy has been validated, plus appropriate NDT techniques, assure specification conformance.

The spar, beam and rib subassemblies plus hinge and actuator fittings, trailing edge member and skin panels are assembled in a main assembly fixture in proper sequence. Prelocated clip angles on the spar and beam subassemblies provide locating points for the ribs.

As the skin panels are applied and the closure members are installed, progressive inspections for quality and specification conformance, plus proper installation of correct fasteners, is required for close-up.

4.4.6.10 LH and RH Elevon Description

LH and RH Elevon Assembly - The elevon assembly (left and right hand) is a unit with approximate envelope dimensions of 13 feet wide x 38 feet long x 40 inches thick (at maximum chord depth). (Figure 4.4-42). Manufacturing Flow Plan and Schedule reference Figure 4.4-43.

ELEVON ASSEMBLY SEQUENCE

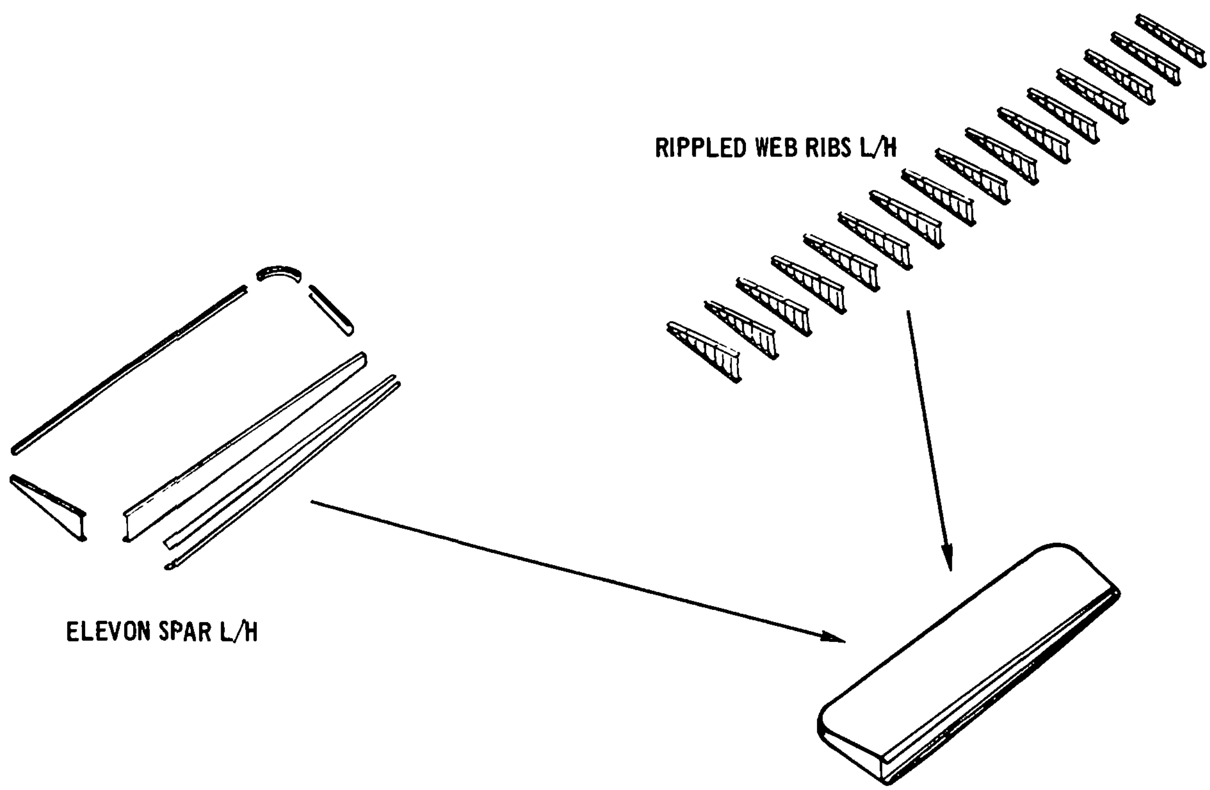


FIGURE 4.4-42

4.4.6.11 Manufacturing Site

It is recommended that the RH and LH elevons be manufactured at the Contractor facility, then be shipped to K.S.C. for installation on the Orbiter.

CONTROL SURFACES
MANUFACTURING FLOW CHART AND SCHEDULE
DELTA WING ORBITER

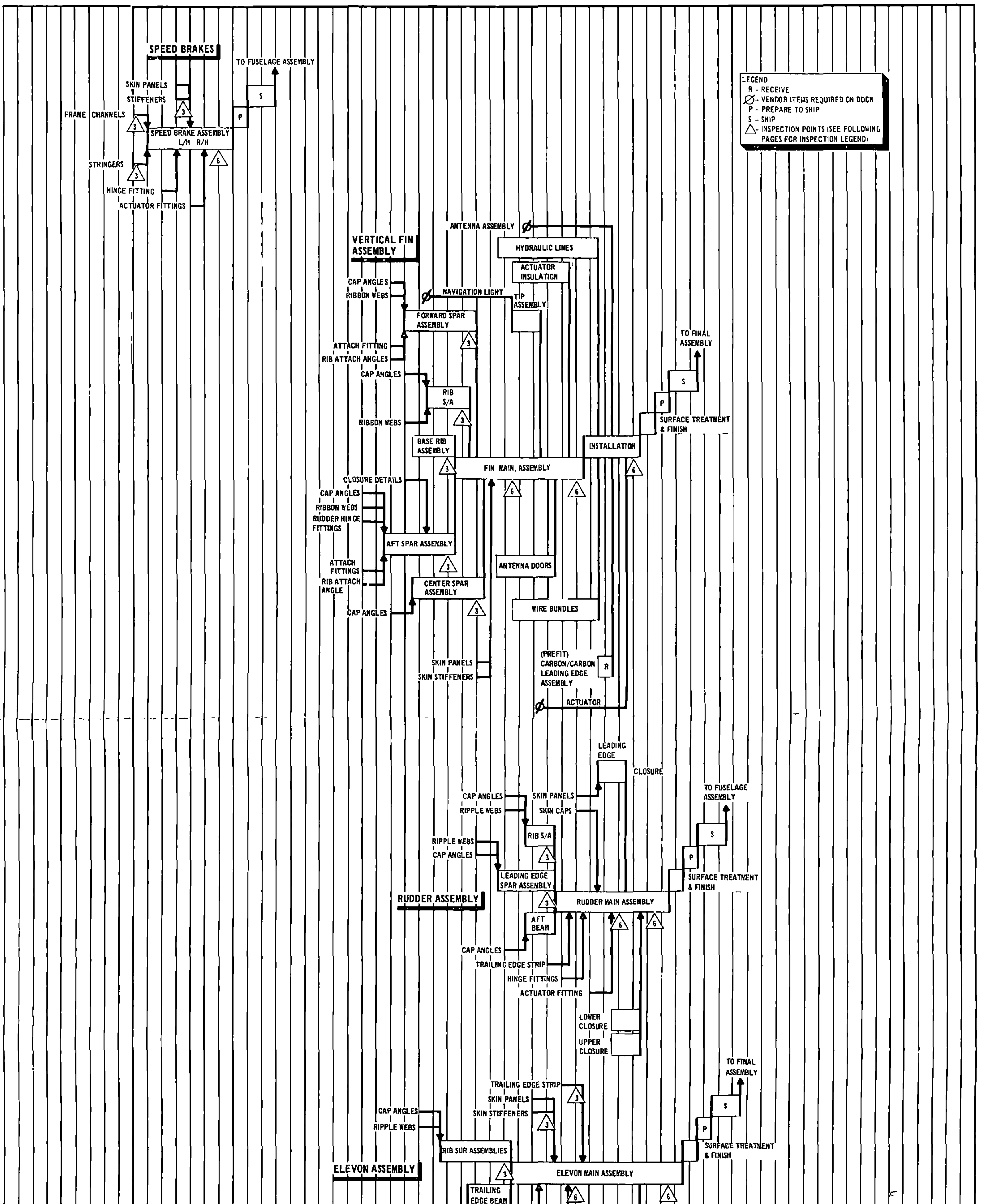


FIGURE 4.4-43

4.4.6.12 Manufacturing Approach

This assembly is built by beginning with a framework consisting of the leading edge spar and trailing edge beam, and rib subassemblies. The skin panels are then added along with closure members, tip assembly, etc., to complete the assembly. Close out of the assembly is accomplished by "peeling on" the skins, blind fasteners or a combination of the two techniques. Inspection, for quality and specification conformance, plus proper installation of correct fasteners occurs progressively.

4.4.6.13 Manufacturing Operations

The leading edge spar subassembly is made up of the machined caps and the rippled web. These details are welded together to form a spar. The rib attach angles are located and affixed to the web. The rib assemblies are assembled in a similar fashion. The trailing edge beam is a formed part to which the rib attach angles are prelocated. Controlled tooling, whose accuracy has been validated, plus appropriate NDT technique, assure specification conformance.

The main assembly begins with location of the leading edge spar and trailing edge beam subassemblies, plus hinge and actuator fittings which are all located by the assembly tool. However, the rib subassemblies are located by the spar and beam subassemblies. As the assembly progresses the skins are applied, closure members, tip assembly and skin stiffeners are included, drilled and attached.

Progressive inspections, for quality and specification conformance, plus proper installation of the correct fasteners, is required for closeout. Close out is accomplished by "peeling on" the skin, blind fasteners or a combination of the two techniques. Upon completion of the assembly, it is again inspected and moved to an area where it is cleaned and prepared for shipment to the installation point.

4.4.6.14 Major Facilities, Equipment and tools are listed in Table 4.4-7

TABLE 4.4–7

ELEVONS, FIN AND RUDDER FABRICATION
FACILITY AND EQUIPMENT REQUIREMENTS

Facility and Equipment Requirements	Facility and Equipment Availability
Area	
15,000 sq. ft.	Available Contractor
40' clear height	
Crane	
5 Ton	Available Contractor
Major Equipment	
Mill Machines	Available Contractor
Spar Mill	Available Contractor
Chemical Processing Equipment	Available Contractor
Furnace (Oxide Finish)	New Contractor
Hi-Temp Furnace	New Contractor
Autoclave (Hi-Temp AI Press.)	New Contractor
Tracer Controlled Automatic TIG Welding Equipment	New Contractor
Major Tools	
Fin	
Forward Spar (Rippled Webs) Trim Fixture & Weld Fixture	New Contractor
Center Spar (Rippled Webs) Weld Fixture	New Contractor
Rear Spar (Rippled Webs) Weld Fixture	New Contractor

TABLE 4.4–7 (Cont'd)

Forward Rippled Ribs	New Contractor
Weld Fixture	
Rear Rippled Ribs	New Contractor
Weld Fixture	
Vertical Fin Final Assembly	New Contractor
Assembly Fixture	
<u>Rudder</u>	
Forward Rudder Beam (Rippled Web)	New Contractor
Weld Fixture	
Rippled Web Ribs	New Contractor
Weld Fixture	
Final Assembly Rudder	New Contractor
Assembly Fixture	
<u>Elevons</u>	
Elevon Spar Assembly Fixture	New Contractor
Rippled Web Ribs	New Contractor
Weld Fixture	
Final Assembly	New Contractor
Assembly Fixture	
<u>Laboratories</u>	
Non-Destructive Test	Available Contractor
Metal Finishing	Available Contractor
Protective Coating	Available Contractor
Quality Assurance	Available Contractor

TABLE 4.4-7 (Cont'd)

Processing Facility	
Degreasing	Available Contractor
Abrasive Cleaning	Available Contractor
Liquid Hone	Available Contractor
Pickle	Available Contractor
Mill Mark Stripping	Available Contractor
Protective Coat	Available Contractor
Bulk Stress Relieve	Available Contractor
Chemical Mill	Available Contractor
Burr	Available Contractor
Alkaline Clean	Available Contractor
Zyglo	Available Contractor
AGE	Available Contractor
X-Ray Processing	Available Contractor
Black Oxide Finish	New Contractor
Heat Treat	Available Contractor
Welding Machining Forming	Available Contractor
Nickle Super Alloys	
Welding	
Automatic TIG	New Contractor
X-Ray	
Manual and Automatic	Available Contractor

TABLE 4.4–7 (Cont'd)

Utilities	
90-100 PSI Filtered Factory Air	Available Contractor
115V, 60HZ Electrical Outlet	Available Contractor
440V, 60HZ Electrical Outlet	Available Contractor
Argon, Helium Supplies	Available Contractor
Welder Cooling Water	Available Contractor
Normal Lighting	Available Contractor

4.4.7 Air Breathing Engine Pods

4.4.7.1 Description of Air Breathing Pods - The A/B engine pods are of conventional aircraft engine cowling construction, Figure 4.4-44.

ENGINE POD

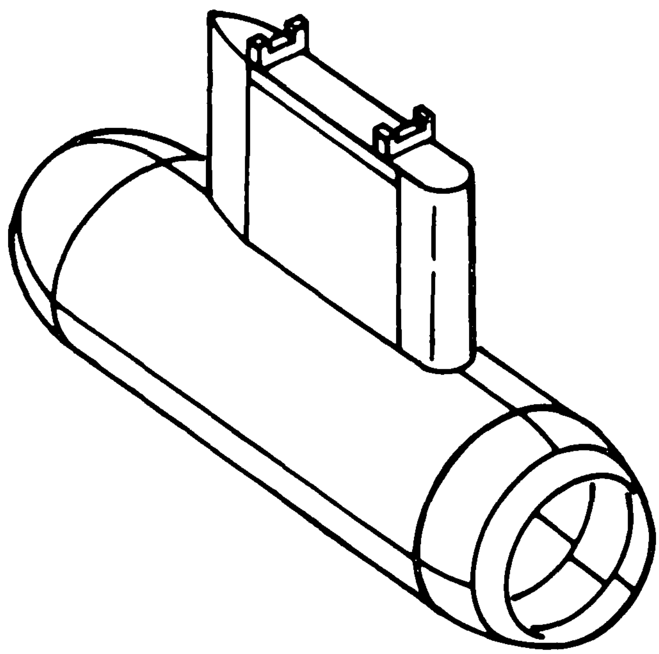


FIGURE 4.4-44

4.4.7.2 Manufacturing Site - It is recommended that the A/B engine pods be manufactured at the contractor facility, then shipped to the point of installation.

4.4.7.3 Manufacturing Approach

Air Breathing Engine Pods - A preliminary manufacturing approach for the Orbiters air breathing engine pods is presented in this section. It is based on design indications that these pods are very similar in both design and construction to air breathing engine pods currently used on large commercial type aircraft. It is also based on the use of titanium as the primary material used in their construction.

4.4.7.4 Manufacturing Operations - A pictorial illustration and manufacturing flow chart and schedule for the A/B engine pods are shown in Figures 4.4-45 and 4.4-46.

AIR BREATHING ENGINE POD

Manufacturing Assembly Sequence – Delta Wing Orbiter

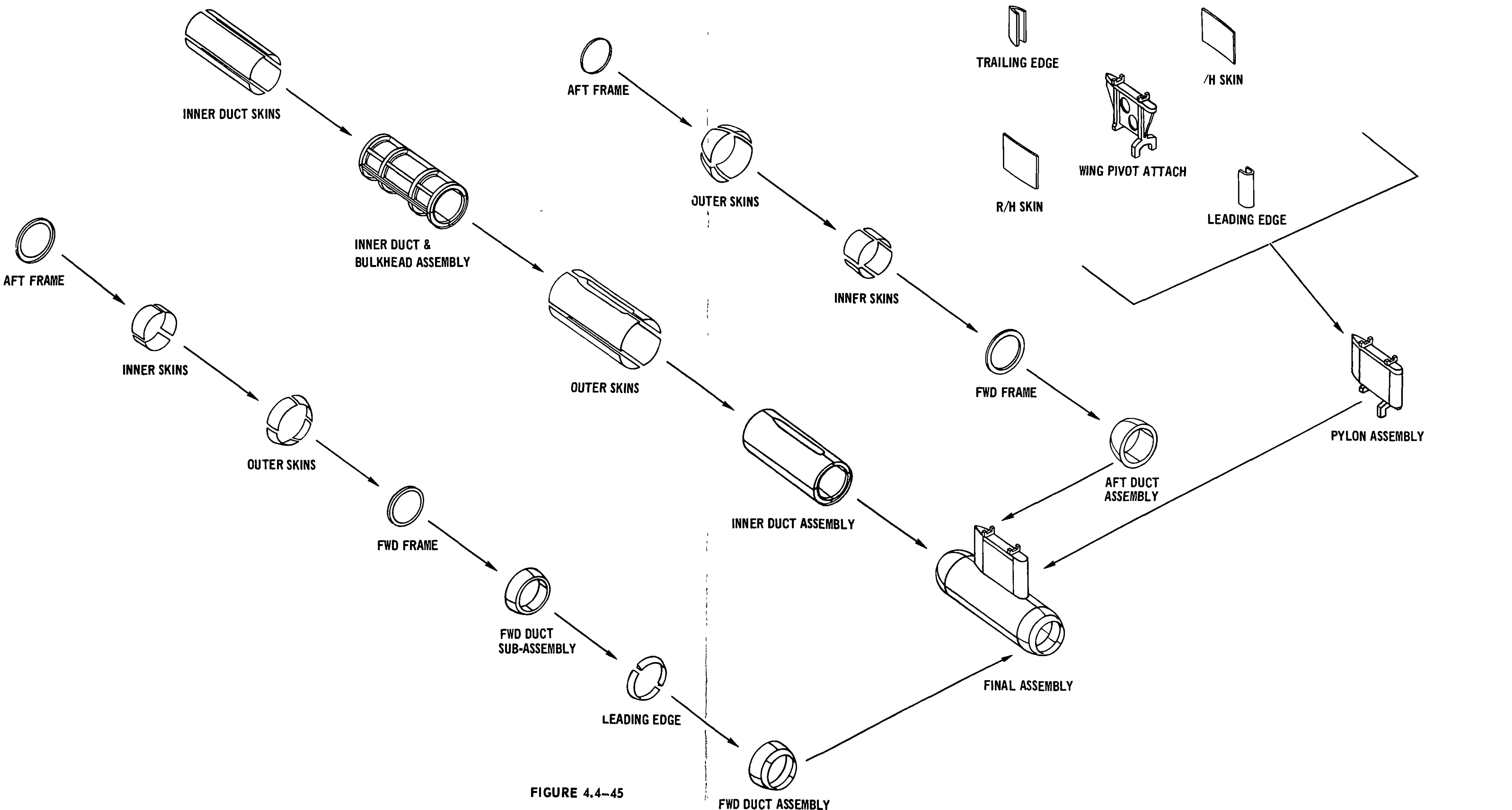


FIGURE 4.4–45

AIR BREATHING ENGINE PODS

MANUFACTURING FLOW CHART & SCHEDULE
ORBITER

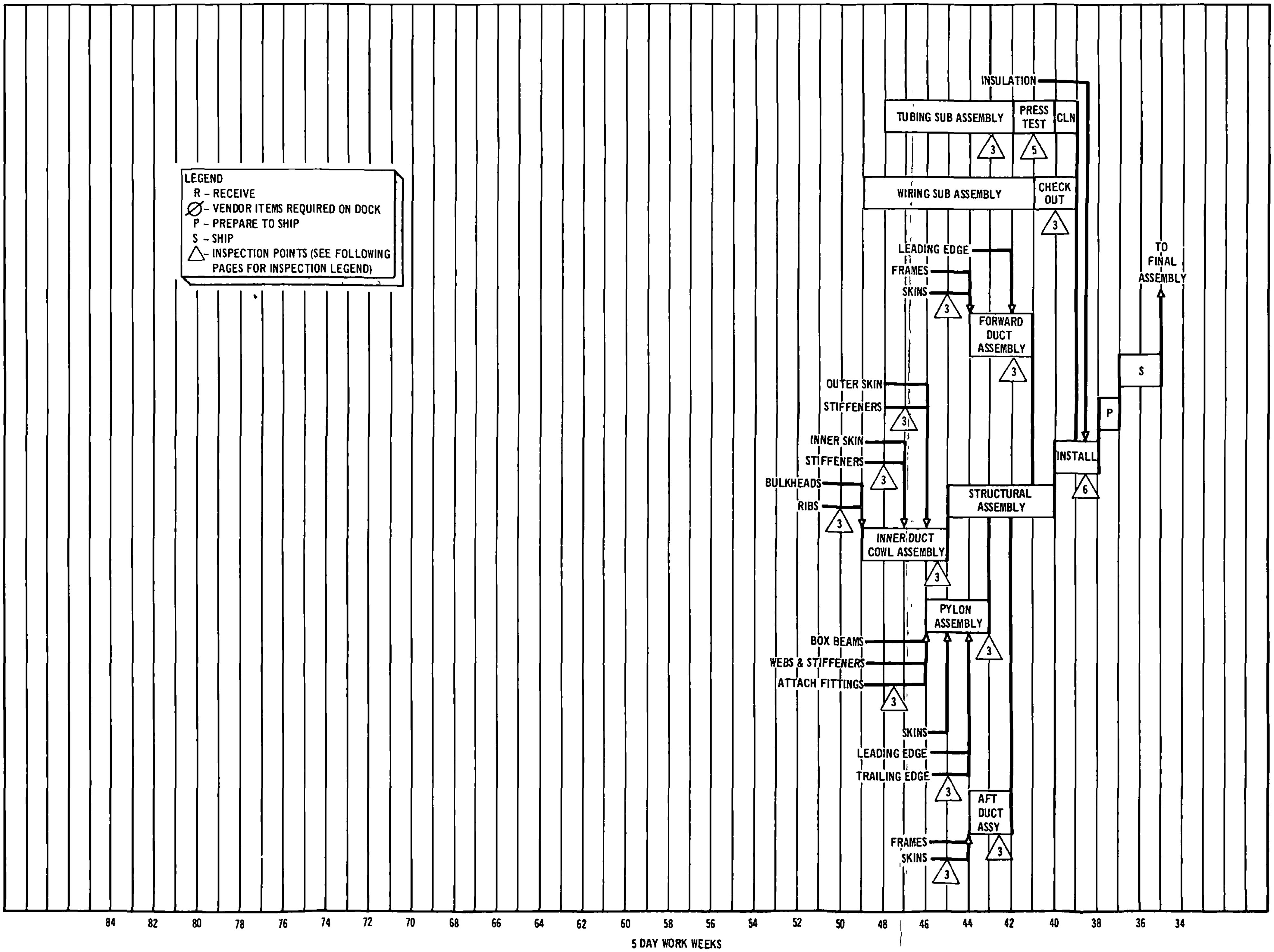


FIGURE 4.4–46

As shown, engine pod build up consists of the fabrication, mating, and joining of detail parts and subassemblies which make up the main body and forward and aft duct assemblies of the engine nacelles. Also, the fabrication and assembly of piece parts which make up the pylons. These are subsequently joined to form the completed engine pod structures. In conjunction with their structural build up, the fabrication, assembly, and installation of tubing and wiring assemblies which form engine fuel lines, control circuits, etc., will occur at appropriate times. When engine pods are completed, manufacturing checkout will be accomplished prior to shipment of the pods to their next assembly locations.

Based on preliminary analysis of requirements, existing manufacturing state-of-the-art techniques, methods, processes and equipment are considered adequate for producing the engine pods. Since their design and construction are similar to those presently used for large commercial aircraft, no significant problems are anticipated in their manufacture.

Preliminary lists of major tool, equipment, and process requirements for the engine pods are identified in Table 4.4-8

TABLE 4.4-8

Facility & Equip. Requirements		Facility & Equip. Availability
Area		
15,000 sq. ft.		Available Contractor
20' Clear Height		
Crane		
2 Ton		Available Contractor
Major Equipment		
Milling Machines		Available Contractor
Lathes		Available Contractor
Furnace (Strain Relief)		Available Contractor
Chemical Processing Equip.		Available Contractor
Major Tools		
Pylon	Assembly Fixture	New Contractor
Leading Edge Pylon	Mach. Tools	New Contractor
Trailing Edge Pylon	Mach. Tools	New Contractor
Wing Pivot Attach	Mach. Tools	New Contractor
Skins	Forming and Mach. Tools	New Contractor
Inner Duct and Bulkhead Assy.	Assembly Fixture	New Contractor
Outside Skins		New Contractor
Inner Duct Panels		New Contractor
Fwd. Cowl Duct. Assy.	Assembly Fixture	New Contractor
Fwd. Cowl Frame No. 1	Assembly Fixture	New Contractor
Fwd. Cowl Frame No. 2	Assembly Fixture	New Contractor
Inner Cowl Skin	Forming and Mach. Tools	New Contractor
Outer Cowl Skin	Forming and Mach. Tools	New Contractor
Leading Edge	Forming and Mach. Tools	New Contractor

TABLE 4.4-8 (Cont'd)

Facility & Equip. Requirements		Facility & Equip. Availability
Major Tools (cont)		
Assembly Fixture	Aft Cowl Duct. Assy.	New Contractor
Assembly Fixture	Aft Cowl Frame No. 1	New Contractor
Assembly Fixture	Aft Cowl Frame No. 2	New Contractor
Forming and Mach. Tools	Inner Cowl Skin	New Contractor
Outer Cowl Skin	Forming and Mach. Tools	New Contractor
Laboratories		
Nondestructive Test		Available Contractor
Metal Finishing		Available Contractor
Protective Coating		Available Contractor
Quality Assurance		Available Contractor
Processing Requirements		Available Contractor
Machining		Available Contractor
Forming		Available Contractor
Welding		Available Contractor
Chemical Milling		Available Contractor
Burr		Available Contractor
Black Oxide Finish		Available Contractor
X-ray		Available Contractor
Zyglo		Available Contractor
Age		Available Contractor
Alkaline Cleaning		Available Contractor
Bulk Stress Relieve		Available Contractor
Mill Mark Stripping		Available Contractor

TABLE 4.4-8 (Cont'd)

Facility & Equip. Requirements	Facility & Equip. Availability
Processing Requirements (cont)	
Protective Coating	Available Contractor
Pickle	Available Contractor
Liquid Hone	Available Contractor
Abrasive Cleaning	Available Contractor
Degrease	Available Contractor
Installation of Fastners	Available Contractor
Electrical Installation	Available Contractor
Welding	
Automatic T.I.G.	New Contractor
X-Ray	
Manual Automatic	Available Contractor
Utilities	
90-100 PSI Filtered Factory Air	Available Contractor
115V 60 ∿ Elect. Outlet	Available Contractor
440V 60 ∿ Elect. Outlet	Available Contractor
Argon, Helium Supplies	Available Contractor
Welder Cooling Water	Available Contractor
Normal Lighting	Available Contractor

4.4.8 Main Landing Gear Doors, Nose Gear Doors, Air Breathing Engine Doors

4.4.8.1 Approach - The assembly approach for the main landing gear doors, nose gear doors, and air breathing engine doors is basically the same. The approach is to assemble a complete door in one assembly fixture. A pictorial illustration and Manufacturing Flow Chart and Schedule for the Main Doors are shown in Figure 4.4-47 and 4.4-48.

4.4.8.2 Manufacturing Site - It is recommended that the doors be manufactured at the Contractor Facility.

4.4.8.3 Manufacturing Operations - With this approach, build up begins with locating the edge frame channels and intermediate stringers in the fixture to form a box frame. Hinge and actuator fittings are located to the box frame for joining, by fixture locators. As the assembly progresses, skins are applied, drilled and attached.

Close out of the assemblies is accomplished by "peeling on" the skins, blind fasteners, or a combination of both techniques. Inspection, for quality and specification conformance, plus proper installation of correct fasteners occurs progressively. Upon assembly completion, the thermal protective shingles are installed on the doors and prepared for shipment to their installation point on the Orbiter.

4.4.8.4 Major Facilities, Tools and Equipment - Major facilities, tools, equipment and process requirements for manufacturing of the Main Doors are shown in Table 4.4-9

LANDING GEAR AND ENGINE DOORS ASSEMBLY SEQUENCE

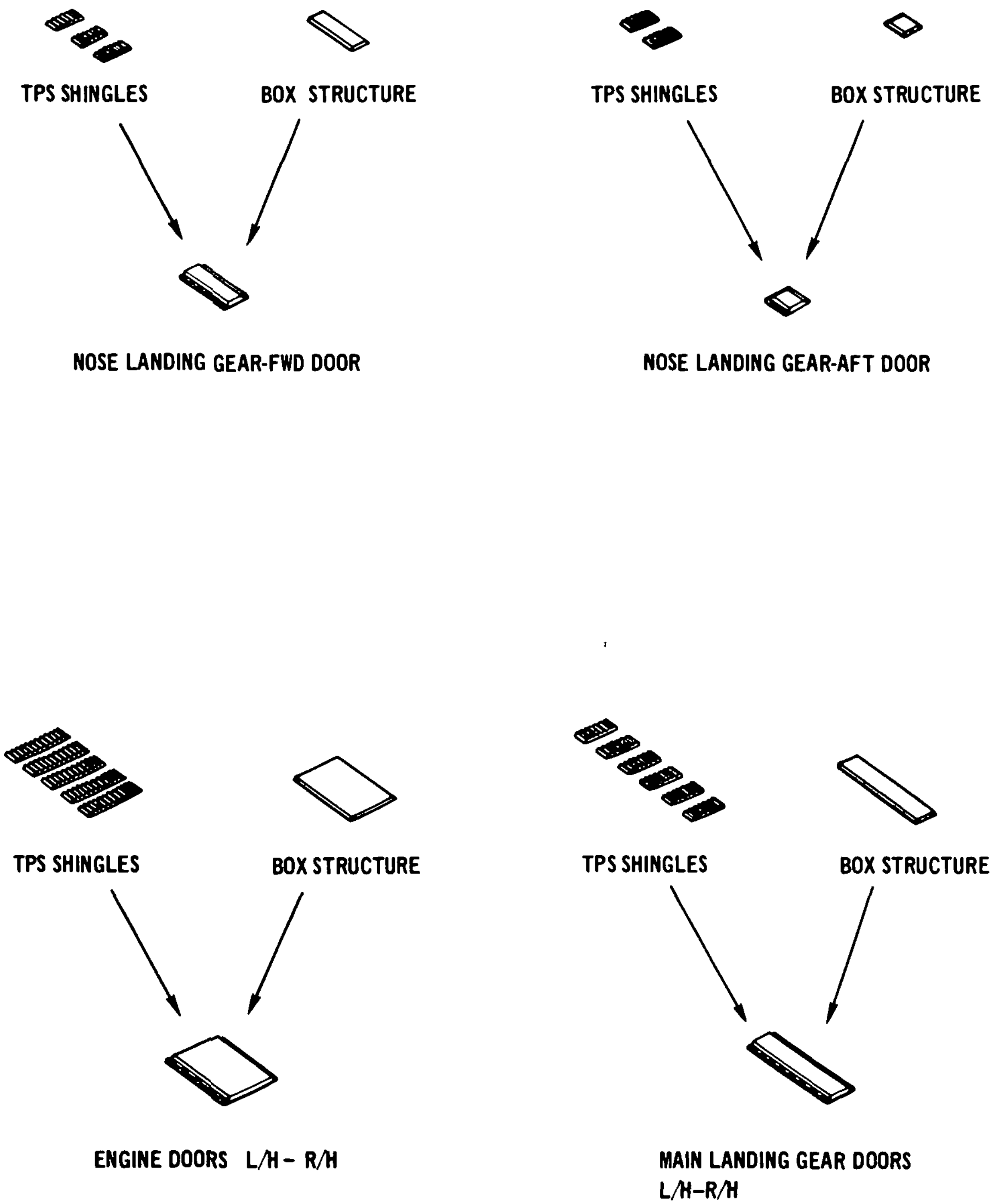


FIGURE 4.4–47

RADIATORS & MISC. DOORS
MANUFACTURING FLOW CHART & SCHEDULE
ORBITER

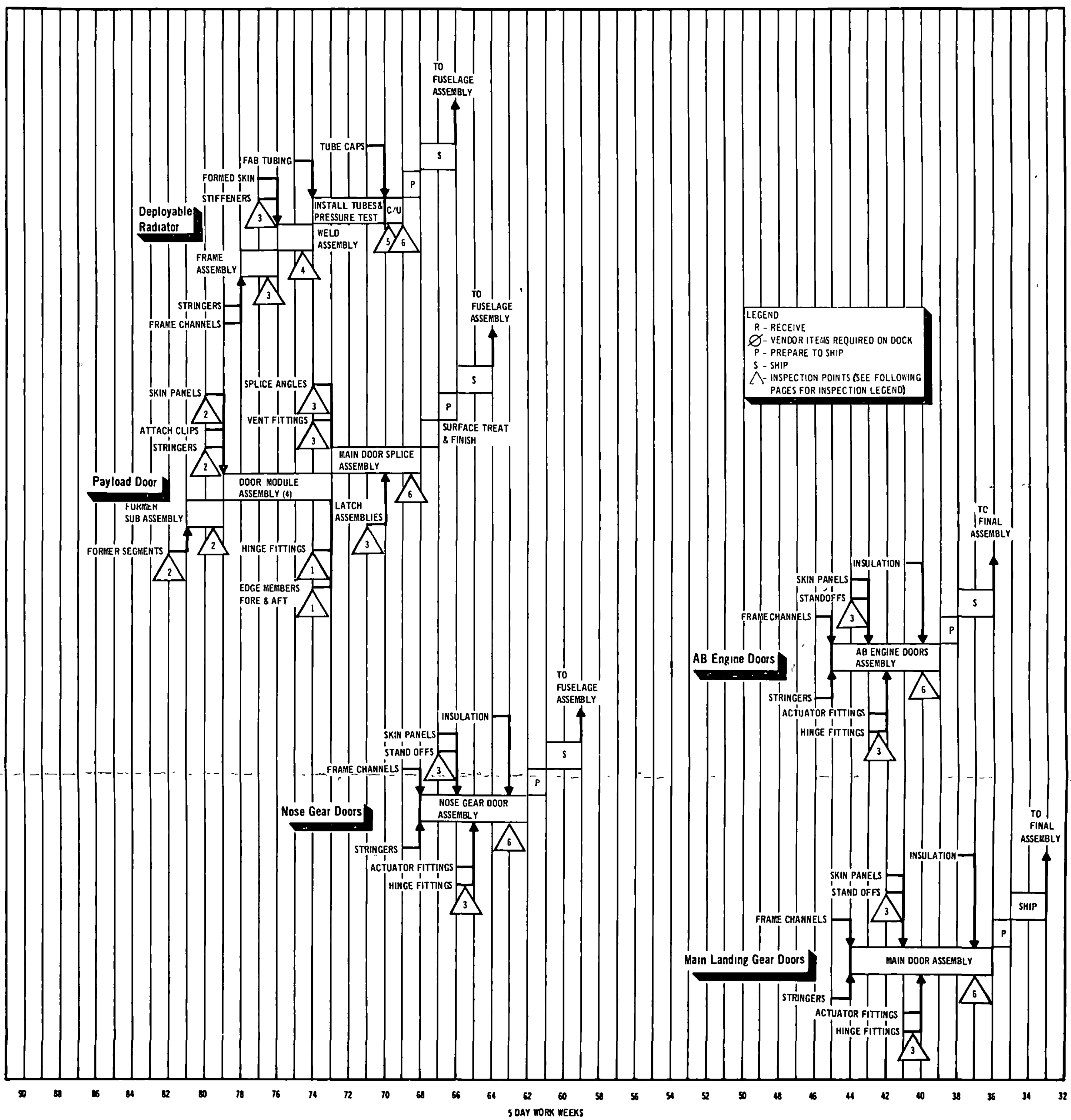


FIGURE 4.4-48

TABLE 4.4-9

LANDING GEAR DOORS, NOSE GEAR DOORS
AND AIR BREATHING ENGINE DOORS

FACILITY AND EQUIPMENT REQUIREMENTS

Facility and Equipment Requirements	Facility and Equipment Availability
Area	
10,000 Sq. Ft.	Available Contractor
Crane	
2 Ton	Available Contractor
Major Equipment	
Milling Machines	Available Contrator
Lathes	Available Contractor
Chemical Processing Equipment	Available Contractor
Furnace (Strain Relief)	New Contractor
Major Tooling	
Main Landing Gear Door Assembly Fixture	New Contractor
Nose Landing Gear Door Assembly Fixture	New Contractor
Air Breathing Engine Door Assembly Fixture	New Contractor
Laboratories	
Non-Destructive Test	Available Contractor

4.4.9 Secondary Tanks Description

4.4.9.1 Secondary Tanks - This section covers the on-orbit LH_2 tank and LO_2 tanks plus the cruise fuel tanks for the air-breathing engines. These tanks grouped together are herein referred to as the secondary tanks, Figure 4.4-49. A pictorial illustration and manufacturing flow plan and schedule are shown in Figures 4.4-50, 4.4-51, 4.4-52 and 4.4-53.

SECONDARY TANKS

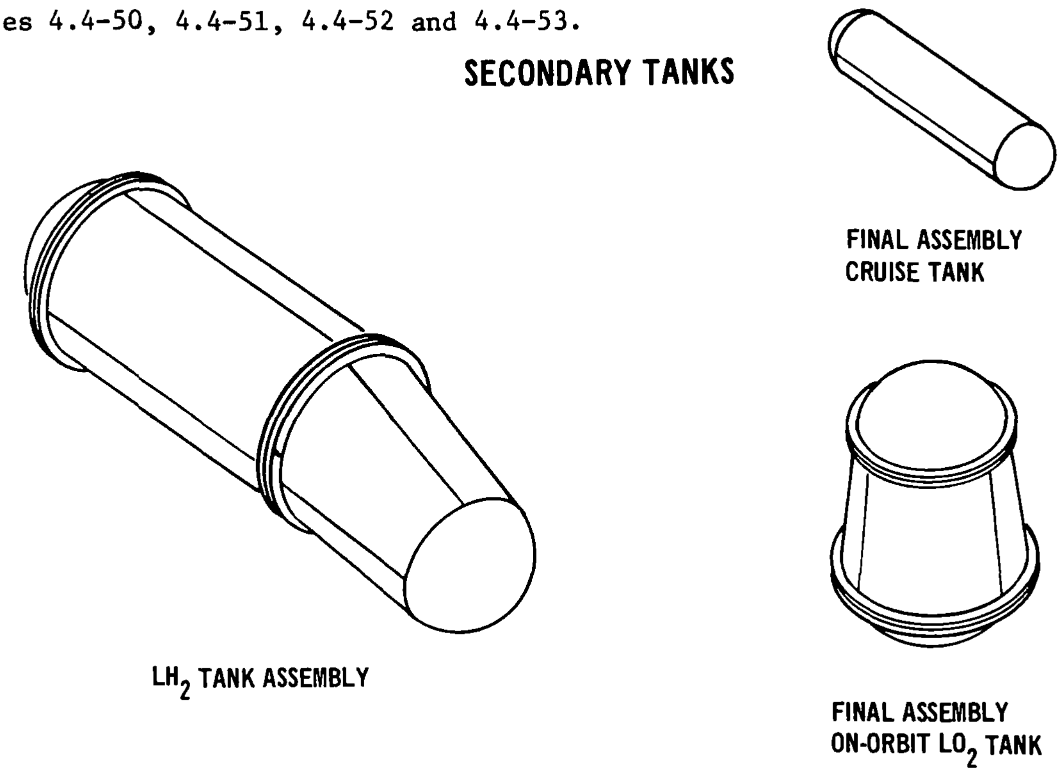


FIGURE 4.4-49

4.4.9.2 Manufacturing Site - It is recommended that the secondary tanks be manufactured at the contractor's facility, then shipped to Michoud for installation on the Orbiter.

4.4.9.3 Manufacturing Approach - The manufacturing approach for these tanks at the present time is preliminary, due to a limited amount of detailed structural design definition. Present design definition indicates that existing state-of-the-art techniques for producing cylindrical and spherical pressure vessels are adequate for manufacture of these tanks; therefore, no significant problems are anticipated. These state-of-the-art techniques in general will consist of the following:

ON-ORBIT LH_2 TANK
Manufacturing Assembly Sequence – Delta Wing Orbiter

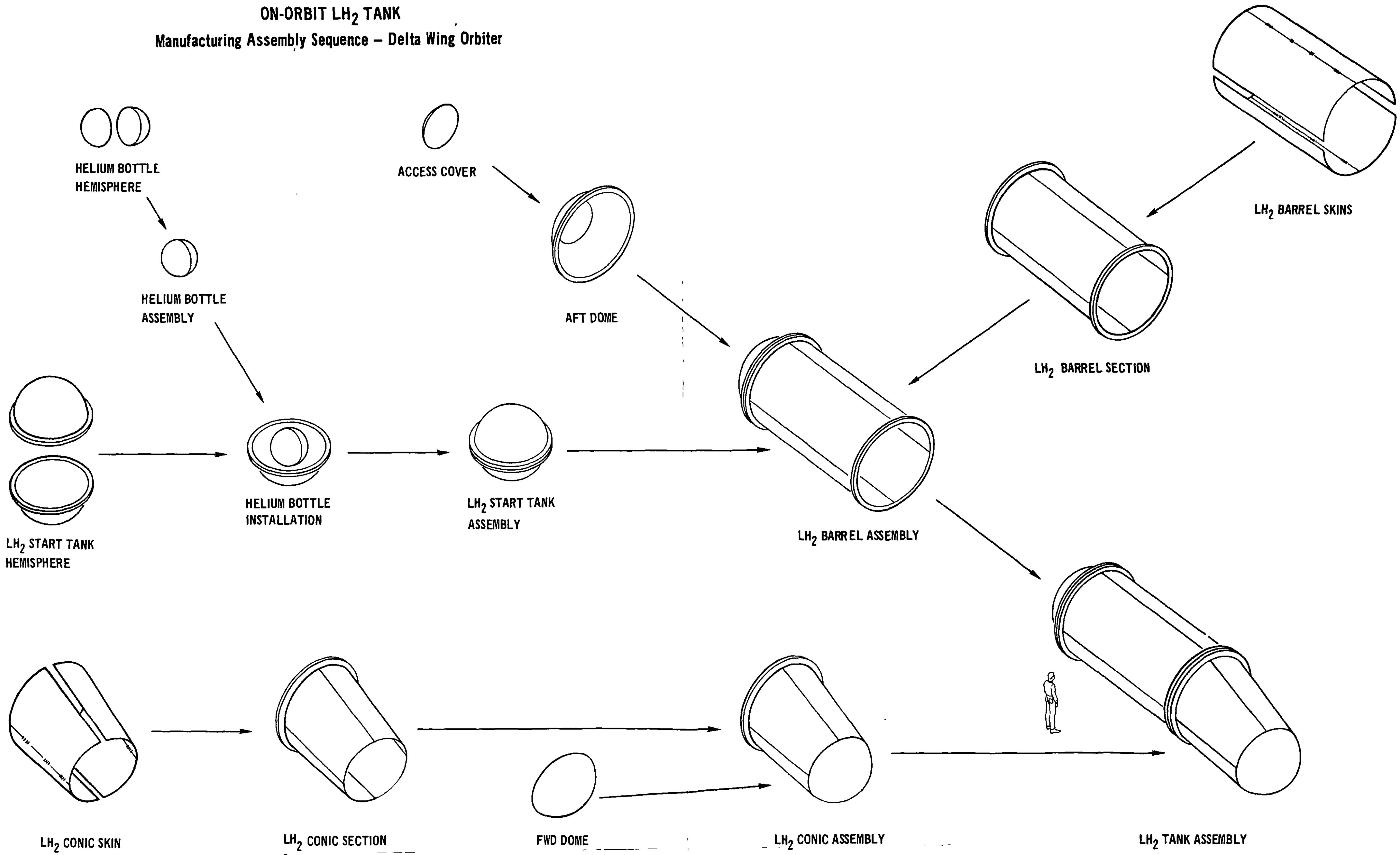


FIGURE 4.4–50

ON-ORBIT LO_2 TANK
Manufacturing Assembly Sequence – Delta Wing Orbiter

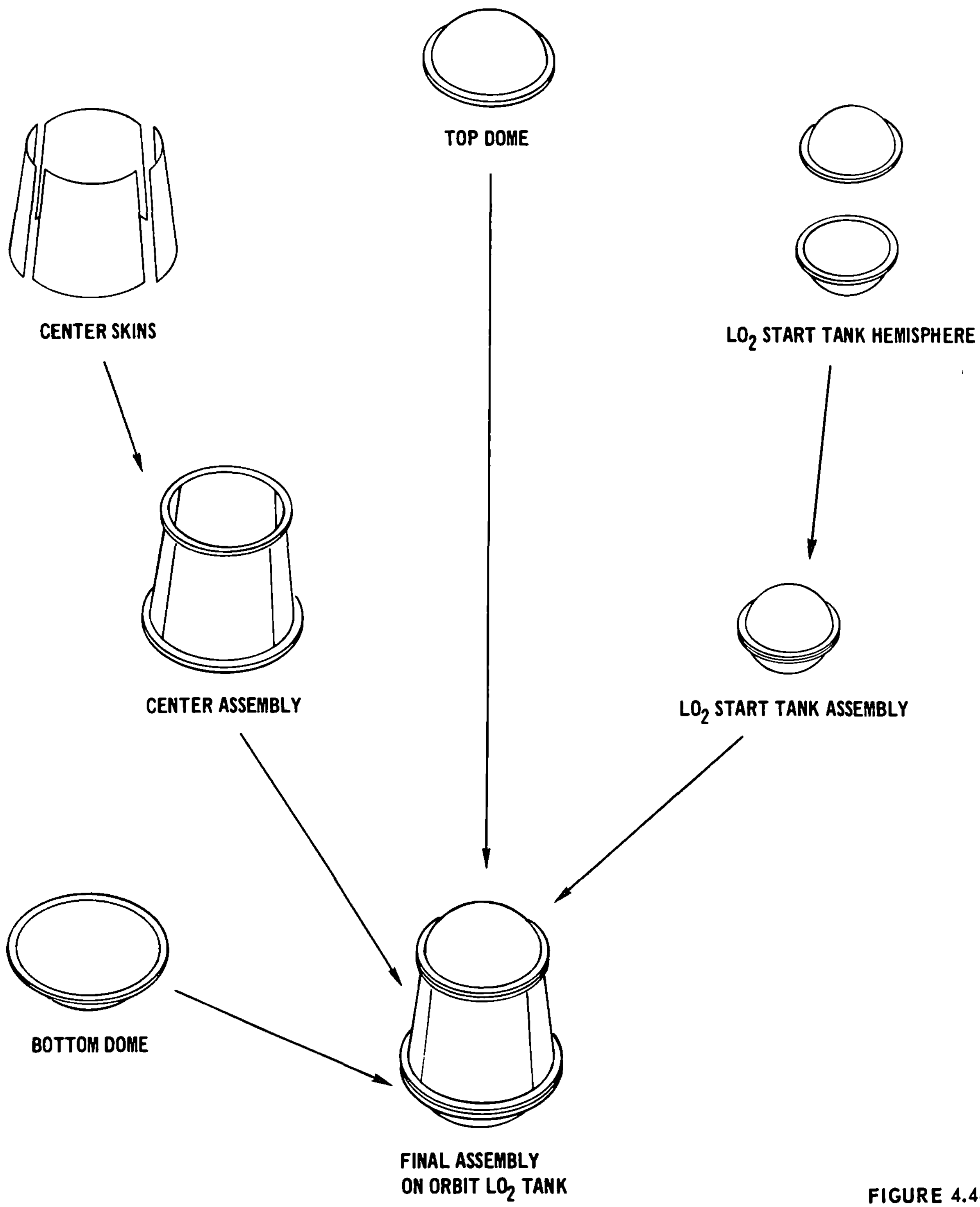


FIGURE 4.4-51

CRUISE TANK

Manufacturing Assembly Sequence – Delta Wing Orbiter

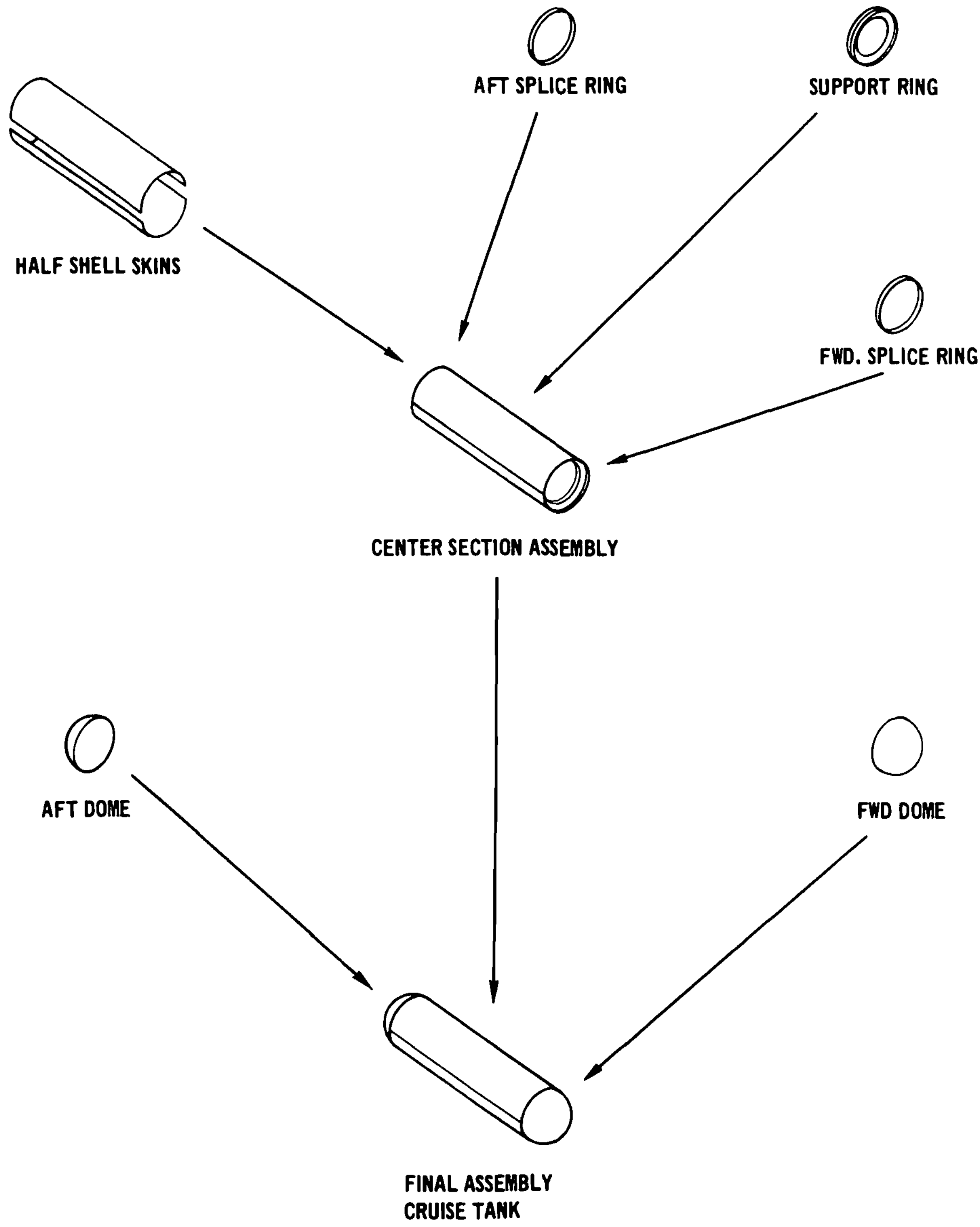


FIGURE 4.4–52

SECONDARY TANKS
CRUISE FUEL TANKS & ON ORBIT LO_2 TANKS
MANUFACTURING FLOW CHART & SCHEDULE
ORBITER

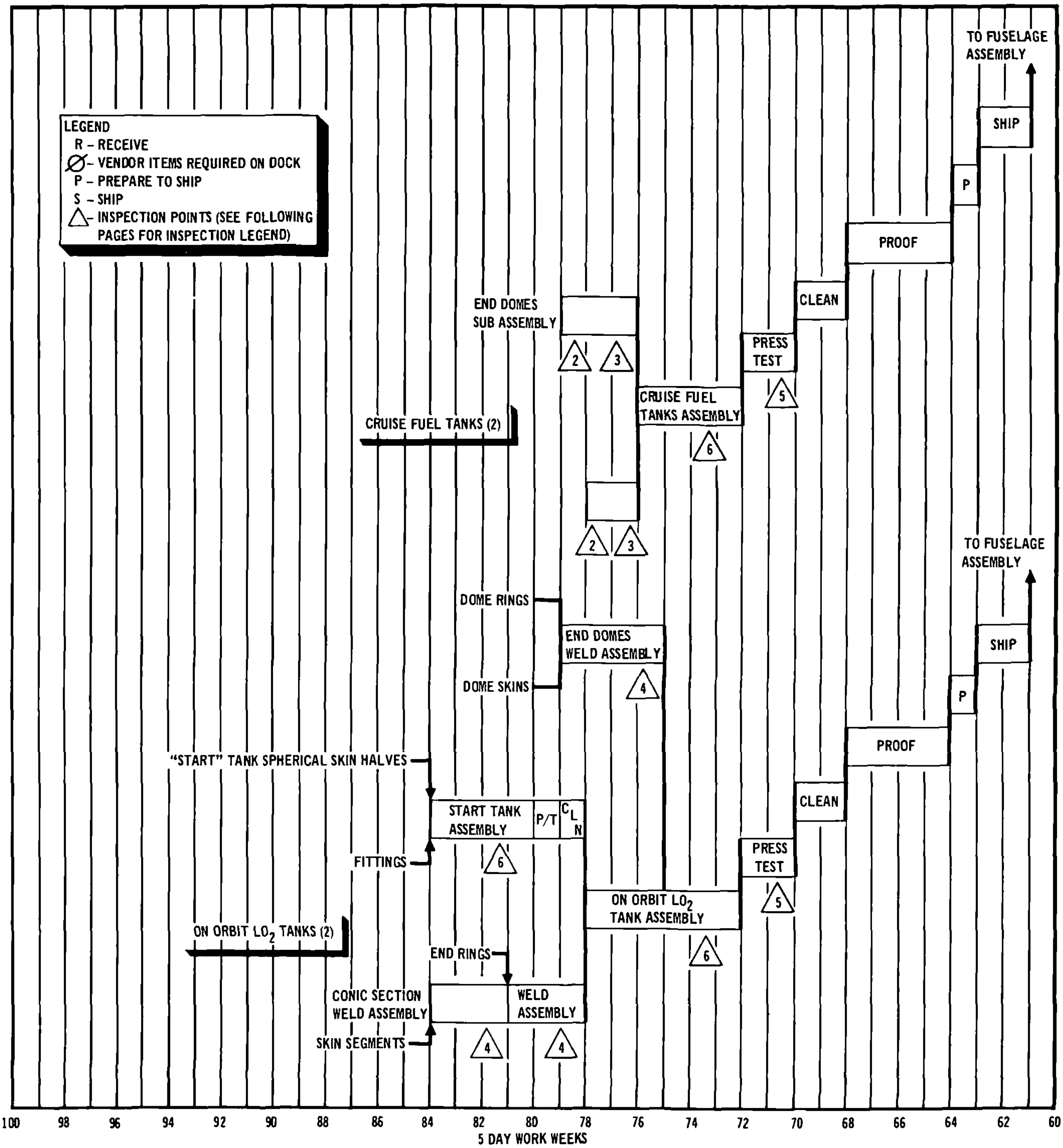


FIGURE 4.4-53

ON ORBIT LH_2 TANK MANUFACTURING FLOW CHART & SCHEDULE ORBITER

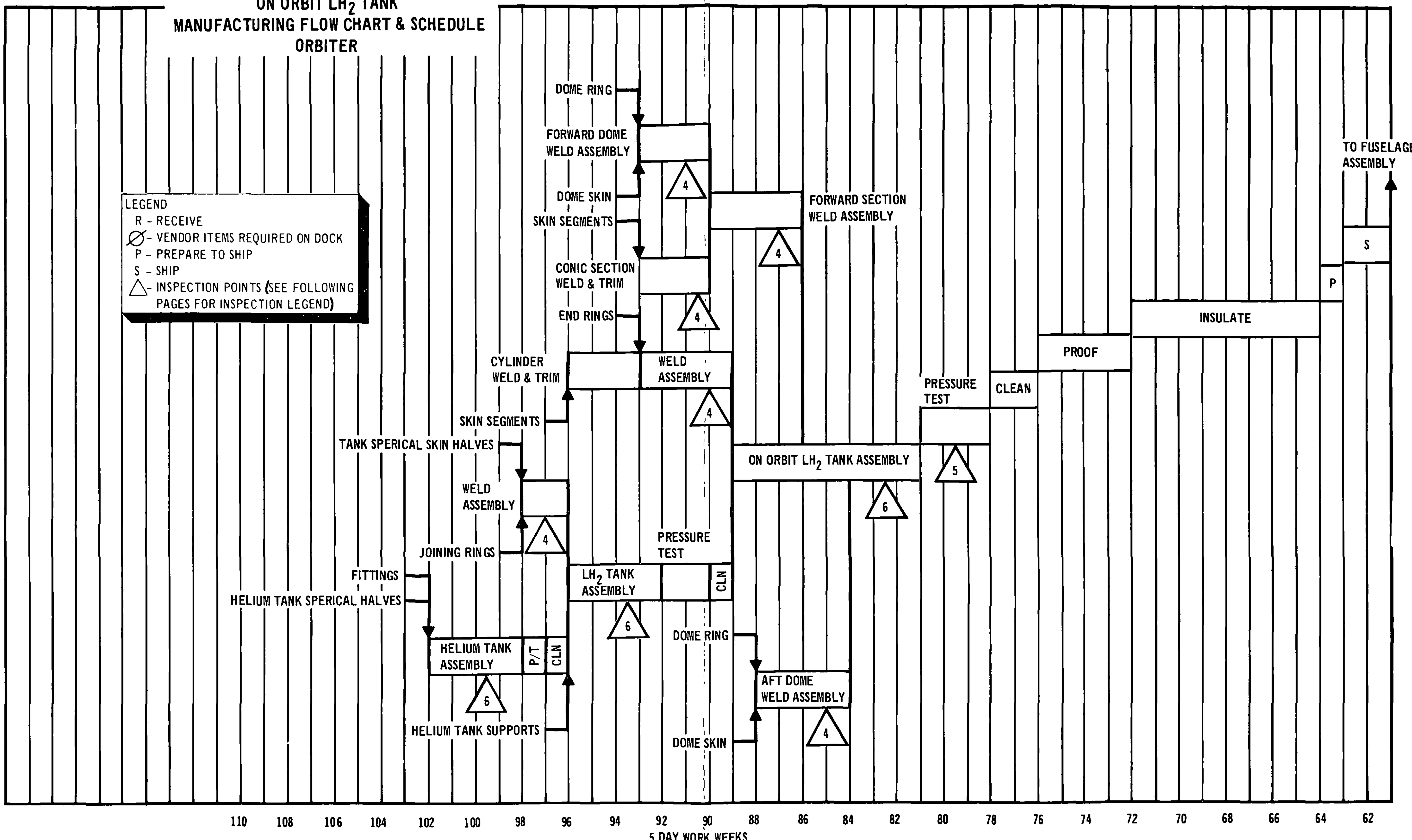


FIGURE 4.4-53 (Cont'd)

- Spin forging techniques for producing tank end dome skins for cylindrical tanks and half-section skins for spherical tanks.
- Power roll forming and chemical machining techniques for producing longitudinal skin segments for cylindrical and conical sections of the tanks.
- Rolled ring forging techniques for producing dome base and cylinder end rings plus mechanical joining rings.
- Standard machining techniques for turning dome skins, cylinder sections, and forged rings to rough and finish dimensions.
- Automatic welding techniques for joining skin segments, cylinder sections, and domes to end rings.
- Proof pressure, leak, and nondestructive (radiographic) test techniques for validation of materials, welding, manufacturing methods, and unit quality.
- Processing techniques for surface preparations and protection.

4.4.9.4 Manufacturing Operations - The manufacturing approach for the secondary tanks is graphically and pictorially illustrated in Figures 4.4-50, 4.4-51 and 4.4-52. The Manufacturing Flow Chart and Schedual are shown in Figure 4.4-53.

With this approach, the tanks are built up of welded sectional subassemblies and machined parts. These are subsequently joined together by additional welding or mechanical means (as applicable) to form completed tank structures. The sectional subassemblies and machined parts in general will consist of the following:

4.4.9.5 On-Orbit LH_2 and LO_2 Tanks - Tank end domes consisting of spin-forged dome skins welded to machined rings at the dome base.

Conical and cylindrical barrel sections consisting of machined and formed skin panels joined together by welding and subsequently welded to section end rings.

Fill, drain, and vent fittings fitted and welded to tank mechanical joining rings.

Spherical half sections consisting of spin-forged domes for the internal "start" and helium tanks.

Miscellaneous supporting struts, fittings, brackets, and tubing assemblies, for mounting and assembly of the internal tanks.

4.4.9.6 Cruise Fuel Tanks - Tank end domes consisting of spherical segment spin forgings.

Cylinder sections consisting of formed longitudinal skin half segments joined by welding.

Miscellaneous fittings, brackets, etc.

As the tanks are structurally completed, they will be cleaned and pressure tested using specific procedures in accordance with the development and production test plans. Following satisfactory completion of testing, the tanks will be purged and sealed to prevent subsequent internal contamination. The tanks are then completed by the application of external insulation (as applicable), and are prepared for shipment to their manufacturing next assembly location.

4.4.9.7 Major Facilities, Equipment and Tooling - Major facilities, equipment and tooling required for manufacturing of the Secondary Tanks are listed in Table 4.4-10

TABLE 4.4-10

FACILITY & EQUIPMENT REQUIREMENTS		FACILITY & EQUIPMENT AVAILABILITY
Area		
25,000 Sq Ft		Available Contractor
Crane		
10 Ton		Available Contractor
Major Equipment		
Milling Machines		Available Contractor
Spar Mill		Available Contractor
Chemical Processing		Available Contractor
Major Tools		
Helium Bottle Assembly	Weld Fixture Mach. Tools	New Contractor
LOX Tank	Form Tools Mach. Tools	New Contractor
LH_2 Barrel Skins	Form Tools	New Contractor
LH_2 Barrel Section	Weld and Trim Fixture	New Contractor
Access Cover	Mach. Tools	New Contractor
Aft Dome	Form Tools Mach. Tools	New Contractor
LH_2 Barrel Assembly		New Contractor
LH_2 Tank	Assembly Tools	New Contractor
LH_2 Conic Skin	Form Tools	New Contractor
Forward Dome	Form Tools	New Contractor
LH_2 Conic Assembly	Weld and Trim Fixture	New Contractor

TABLE 4.4–10 (Cont'd)

	FACILITY & EQUIPMENT REQUIREMENTS	FACILITY & EQUIPMENT AVAILABILITY
On-Orbit LO_2 Tanks		
LO_2 Start Tank Assy.	Form Tools Mach. Tools	New Contractor
Top Dome	Form Tools Mach. Tools Weld Fixture	New Contractor
Center Skins	Form Tools Weld Fixture Mach. Tools	New Contractor
Bottom Dome	Form Tool Mach. Tools Weld. Fixture	New Contractor
Cruise Fuel Tanks		
Aft Splice Ring	Mach. Tools	New Contractor
Support Ring	Mach. Tools	New Contractor
Fwd. Splice Ring	Mach. Tools	New Contractor
Half Shell Skins	Form Tools Mach. Tools	New Contractor
Fwd. Dome	Form Tool Mach. Tool	New Contractor
Aft Dome	Form Tool Mach. Tool	New Contractor
Secondary Tank		New Contractor
Secondary Tank	Hoist Tool Transporter	New Contractor
Laboratories		
Nondestructive Test		Available Contractor
Metal Finishing		Available Contractor
Protective Coating		Available Contractor

TABLE 4.4–10 (Cont'd)

FACILITY & EQUIPMENT REQUIREMENTS	FACILITY & EQUIPMENT AVAILABILITY
Quality Assurance	Available Contractor
Processing Facilities	
Machining	Available Contractor
Forming	Available Contractor
Welding	Available Contractor
X-Ray	Available Contractor
Zyglo	Available Contractor
Vapor Degreasing	Available Contractor
Abrasive Cleaning	Available Contractor
Anodizing	Available Contractor
Identification	Available Contractor
Alkaline Cleaning	Available Contractor
Brazing	Available Contractor
Pickling	Available Contractor
Heat Treat	Available Contractor
Pressure Test	Available Contractor
*Installation of Insulation	Available Contractor
*Sonic Inspection	Available Contractor
*Requires Modification of Existing Facility	
Welding	
Automatic TIG	New Contractor
X-Ray	
Manual & Automatic	Available Contractor

TABLE 4.4-10 (Cont'd)

FACILITY & EQUIPMENT REQUIREMENTS	FACILITY & EQUIPMENT AVAILABILITY
Utilities	
90-100 PSI Filtered Factory Air	Available Contractor
115V 60 ∿ Electrical Outlets	Available Contractor
440V 60 ∿ Electrical Outlets	Available Contractor
Argon, Helium Supplies	Available Contractor
Welder Cooling Water	Available Contractor
Normal Lighting	Available Contractor

4.4.10 Fuselage Assembly

4.4.10.1 Description of Fuselage - The Orbiter fuselage is approximately 31 feet high, 28 feet wide and 150 feet long. Figure 4.4.-54.

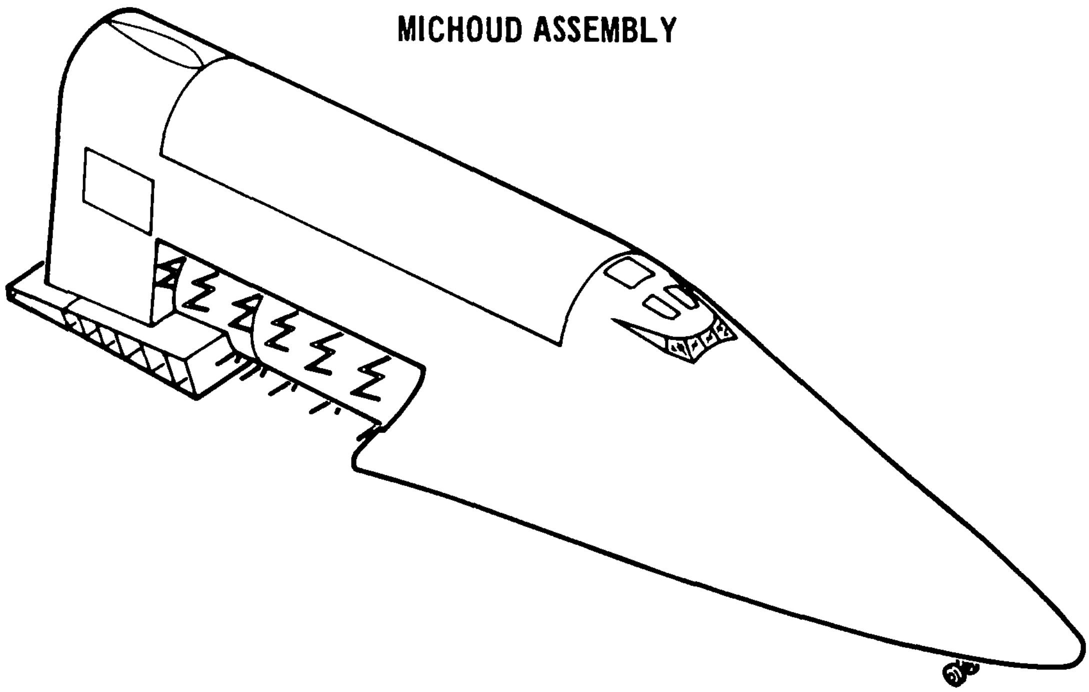


FIGURE 4.4-54

4.4.10.2 Manufacturing Site - It is recommended that the Orbiter fuselage be assembled at the Michoud Assembly Facility Reference Paragraph 4.2.1.3.

4.4.10.3 Fuselage Assembly Approach - The fuselage assembly approach takes advantage of the Orbiters unique design. This design features a main propulsion tank which forms an integral part of the lower fuselage structure, and extends almost the full length of the vehicle.

The assembly approach utilizes this tank to serve as the base in the tooling set-up, on which to build up the fuselage structure. Existing S-IB transporters (modified) and S-IB assembly fixture will be used extensively in the fuselage assembly operations. Figure 4.4.-55. In addition, secondary accessory type tooling in conjunction with preestablished hard points on the tank, plus "line-of-sight" (optics and/or laser beam) type tooling are used.

MAIN FUSELAGE ASSEMBLY – TOOLING CONCEPTS

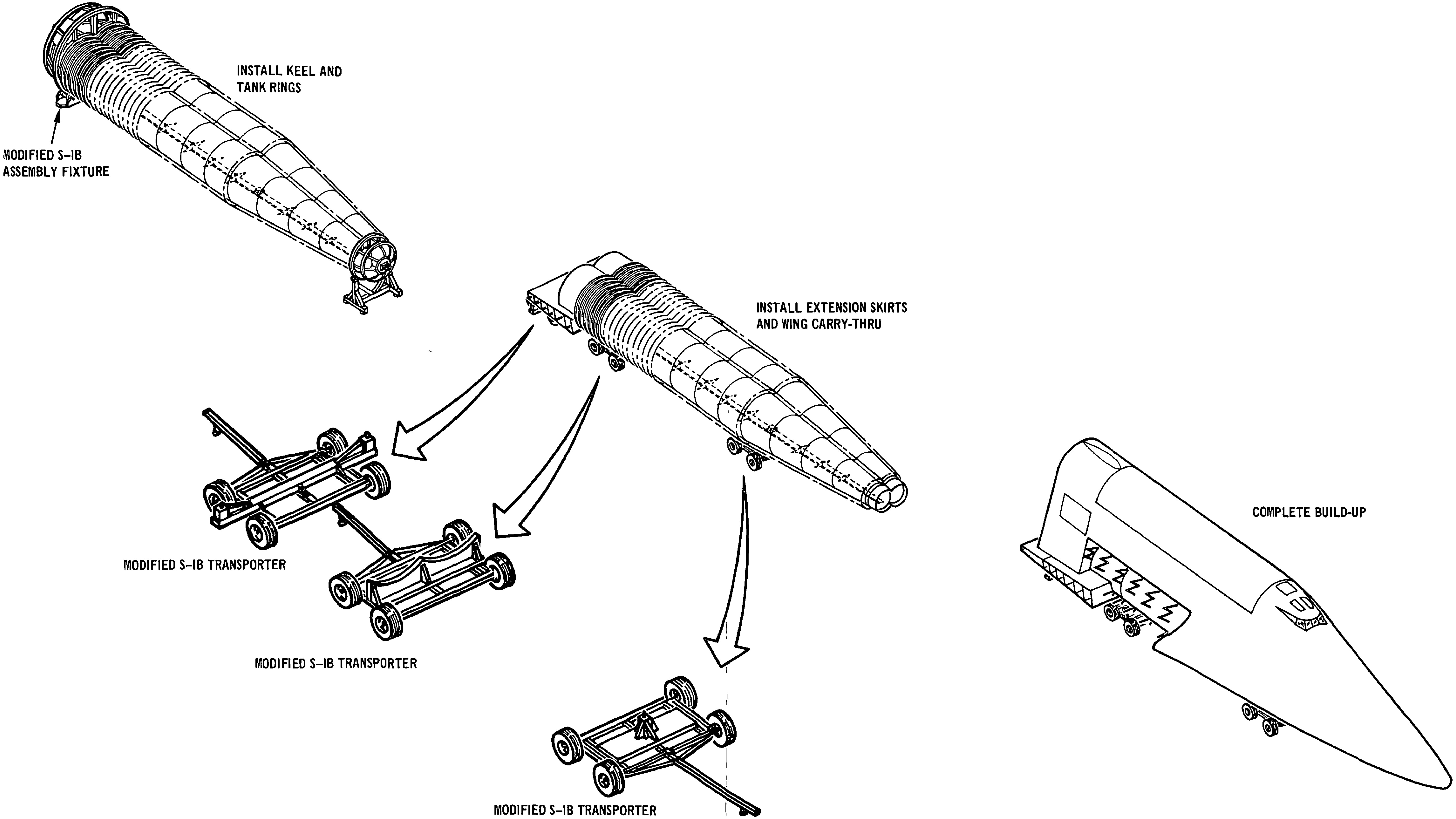


FIGURE 4.4–55

MAIN FUSELAGE ASSEMBLY – MICHOUD

Manufacturing Assembly Sequence – Delta Wing Orbiter

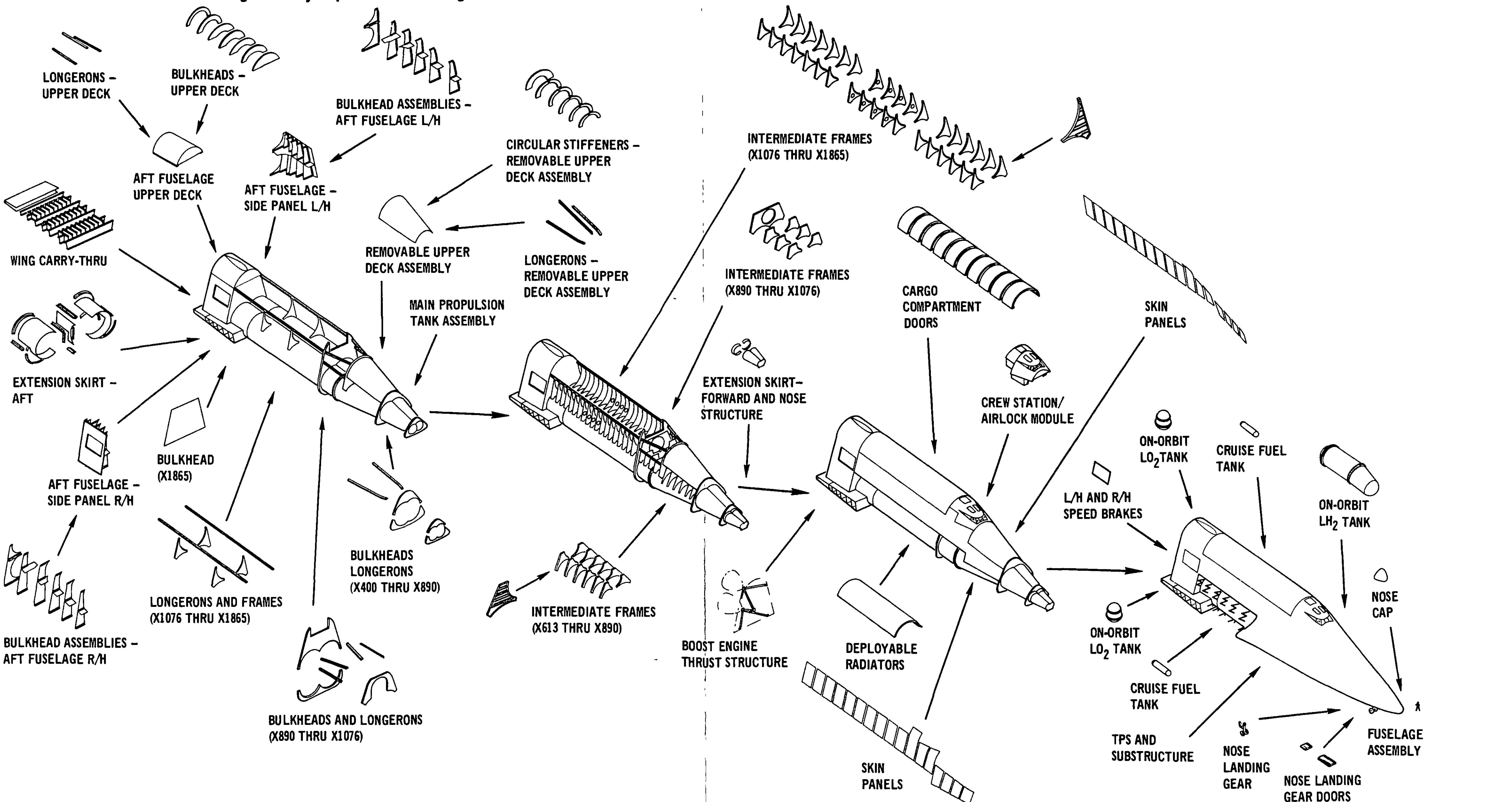


FIGURE 4.4-56

FUSELAGE ASSEMBLY
MANUFACTURING FLOW CHART & SCHEDULE
DELTA WING ORBITER

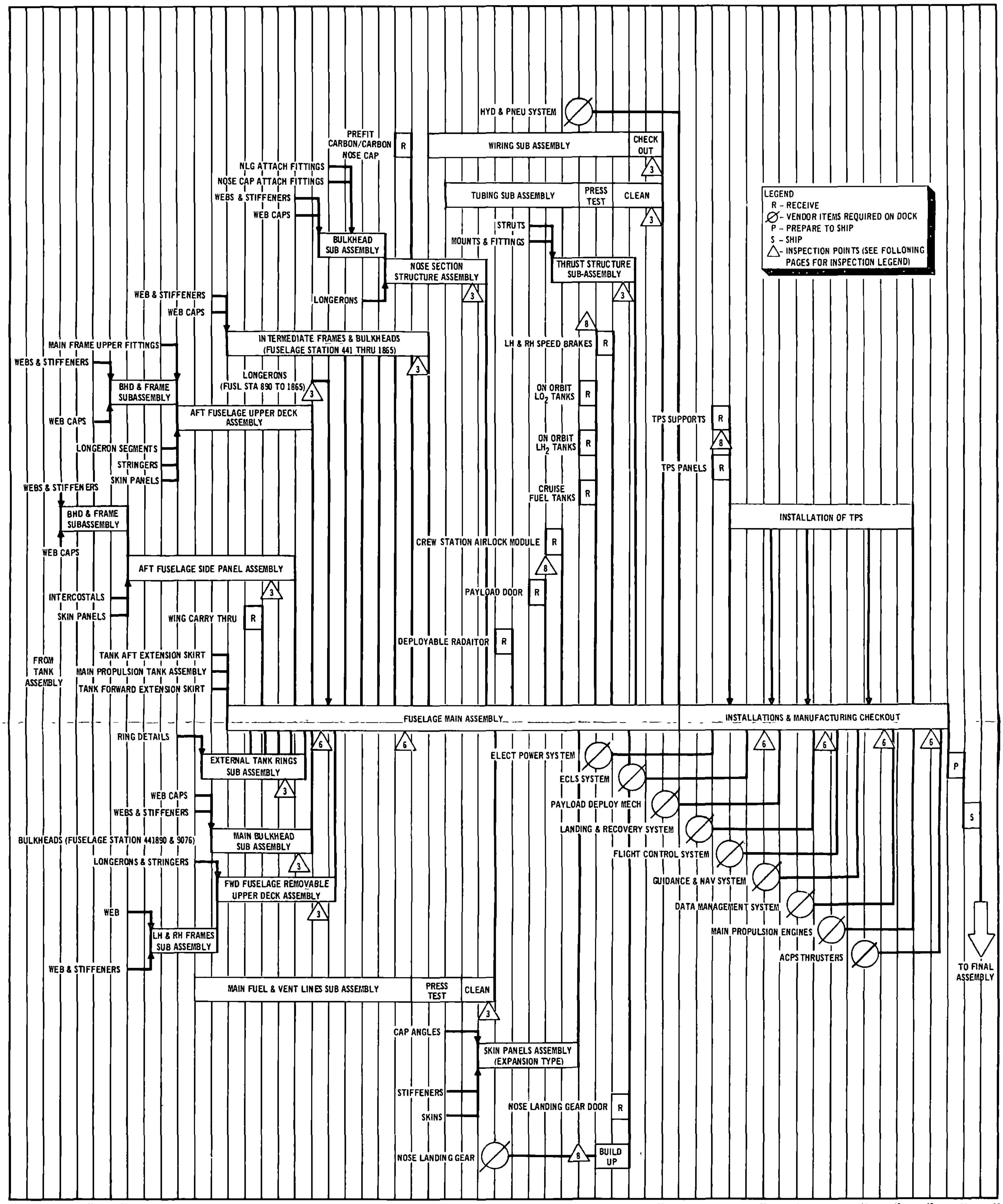


FIGURE 4.4-57

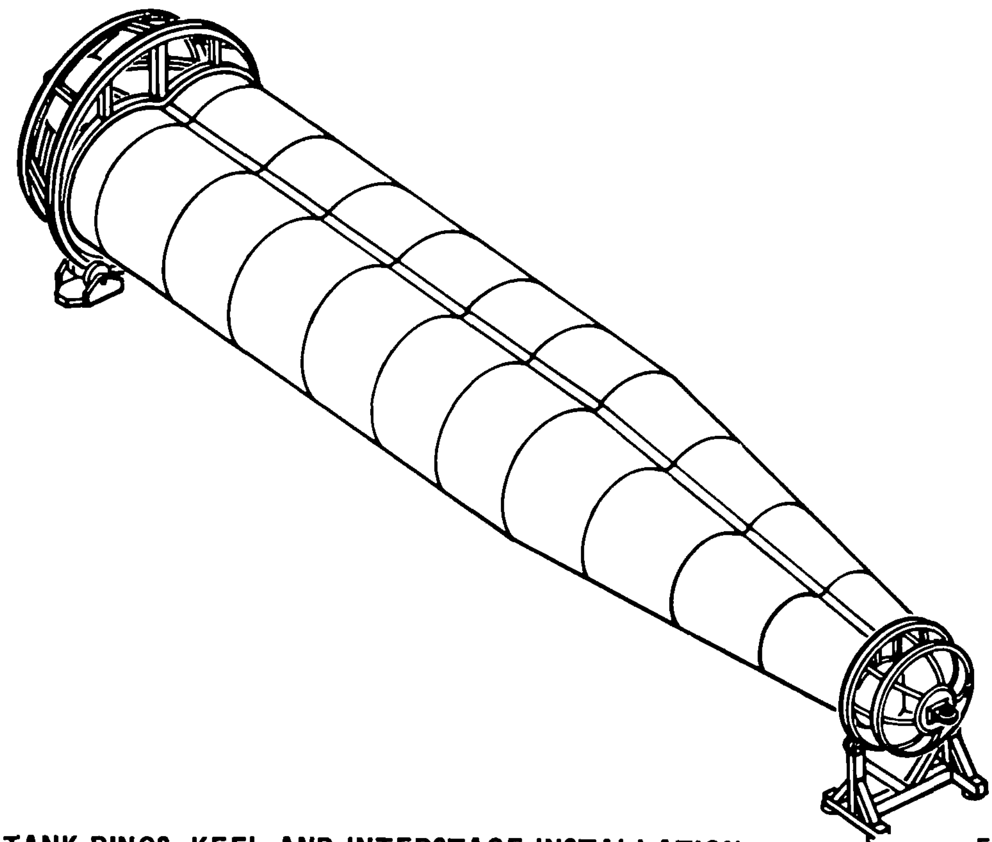
This tank usage approach reduces the quantity and complexity of major assembly fixturing which would normally be required, while the accessory and "line-of-sight" types of tooling eliminate much of the need for large fixtures with numerous locators. These tooling techniques have known, validated accuracy, and through proper application form the basis for quality acceptance or rejection.

Separable items, such as the aft fuselage upper deck and side panels, fwd fuselage removable upper deck, fuselage nose structure, etc., are built up in major subassembly fixtures prior to joining to the main assembly. Also, the fuselage main and intermediate bulkheads and frames are built up in subassembly fixtures. Extensive use of loft tooling is the primary source for establishing moldline control of locators for parts in these fixtures. These fixtures have known, validated accuracy, therefore, structural conformance with the fixtures becomes the acceptance criteria. A pictorial illustration and the manufacturing flow chart and schedule for the fuselage assembly are shown in Figures 4.4-56 and 4.4-57.

4.4.10.4 Positioning Main Tank - With this approach, activity begins with movement of the main propulsion tank from the tank insulation area to the fuselage assembly station. This movement of the tank is accomplished on two modified S-IB transporters which support the tank by the spiders that are attached to the tanks front and rear interfaces. Once located in the modified S-IB assembly fixture, the transporters are removed by engaging the spiders rims in supporting rollers which allow rotation of the tank about its centerline. This rotation capability is used to facilitate early fuselage assembly activity. Figure 4.4-58.

4.4.10.5 Fuselage Buildup - Buildup begins with assembly of the external tank rings and external structural members to the tank, and in particular, buildup of the Orbiter forward interstage tie onto the tank. Figure 4.4-59.

MAIN PROPULSION TANK



TANK RINGS, KEEL AND INTERSTAGE INSTALLATION

FIGURE 4.4-58

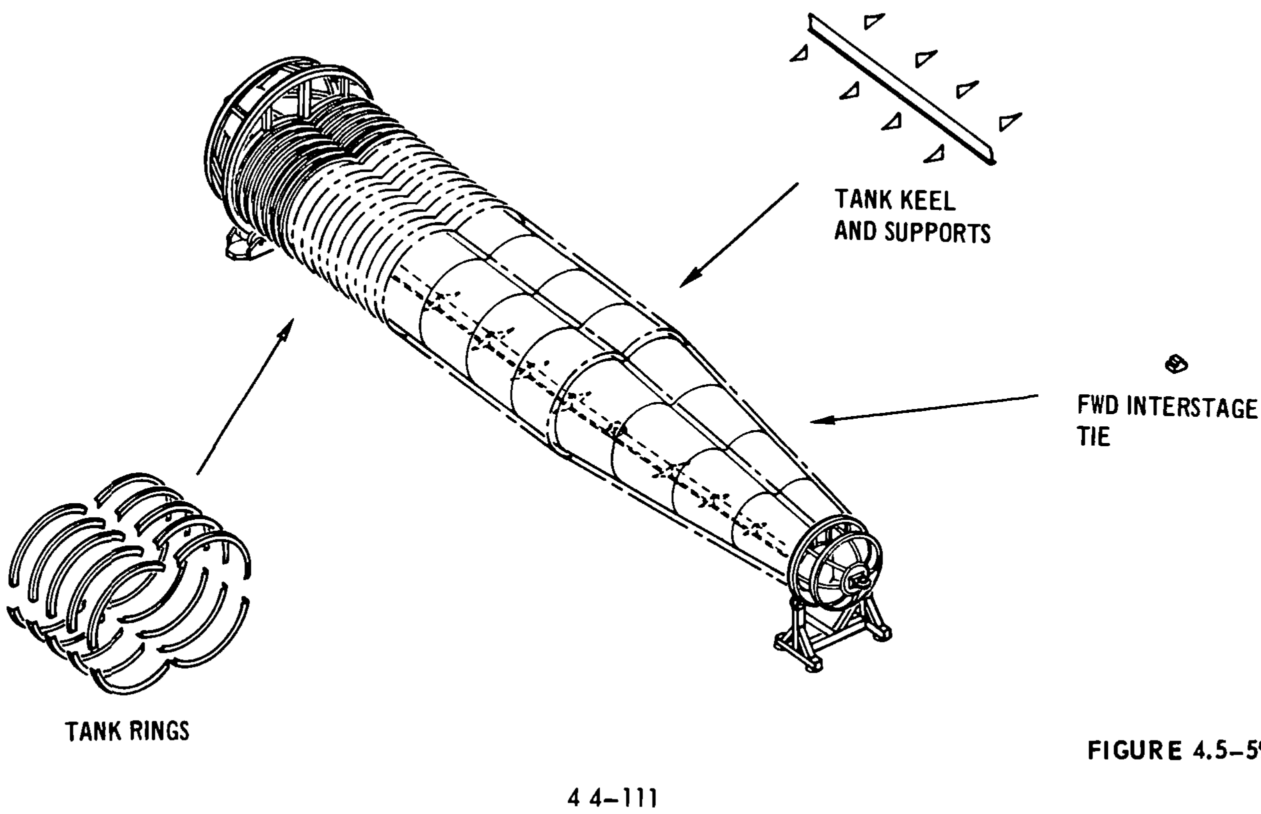


FIGURE 4.5-59

4.4.10.6 Installation of Tank Extension Skirts and Wing Carry Through - Next, with the tank in a horizontal position, two modified S-IB transporters are moved into place engaging the assembly at the orbiter forward interstage tie and one on a contour header under the aft body. This permits removal of the handling spiders at the forward and aft ends of the body.

At this point work begins to install the tank extensions at the forward and aft ends. As work progresses the wing carry through structure is added to the aft end. This structure includes the aft interstage tie points (three points). It now becomes possible to also add a modified transporter to pick up the aft interstage tie points.

Assembly operations up to this point forms the complete base on which buildup of the remaining fuselage structure takes place. Also, the above mentioned transporters are utilized as the major supporting fixtures for subsequent operations, and in conjunction with optics or laser beam and secondary tooling, are capable of tank leveling, alignment, etc. This set-up is monitored periodically to assure proper alignment is maintained. Figure 4.4-60.

EXTENSION SKIRTS AND WING CARRY-THRU

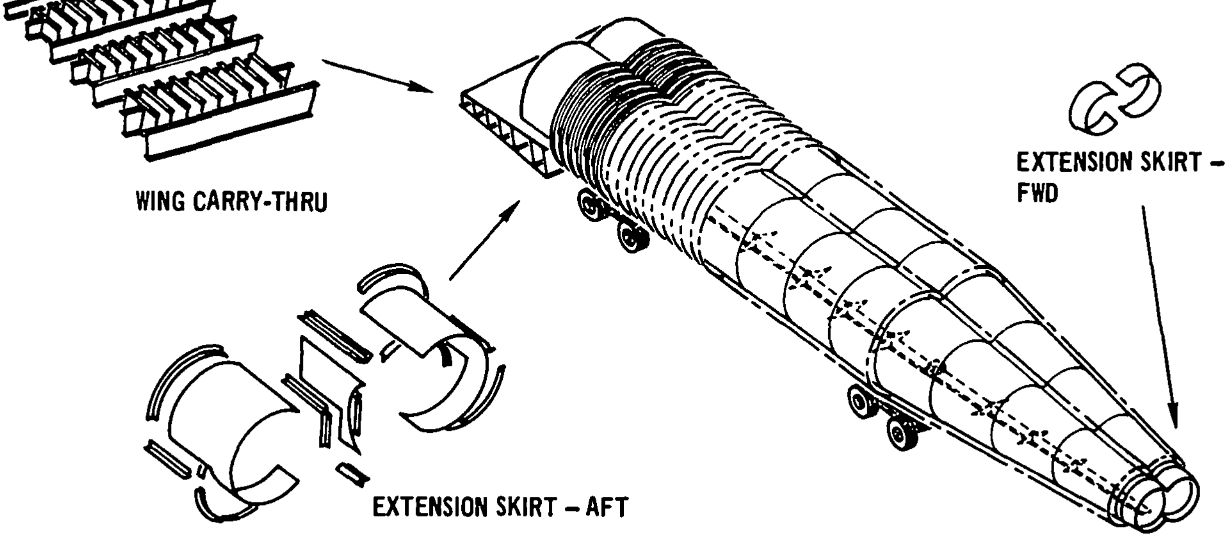


FIGURE 4.4-60

4.4.10.7 Installation of Main Bulkheads, Intermediate Frames, Aft Fuselage Upper Deck, Side Panels, and Removable Deck - Next the aft fuselage upper deck and side panels are located, aligned and joined to the base structure and one another also the main bulkheads and certain intermediate frames are positioned in the main assembly set-up. Preestablished fuselage station locations (tank rings) establish their longitudinal positions, while optics are used to establish their lateral positions and elevation. Once properly set in position, the validity of these positions is verified by Quality Assurance personnel using optical tooling as appropriate, then the longerons for the cargo compartment and crew cabin areas, plus the fwd fuselage removable upper deck, are located, positioned, and joined to them. Figure 4.4-61.

AFT FUSELAGE, FRAMES, BULKHEADS & REMOVABLE DECK BUILDUP

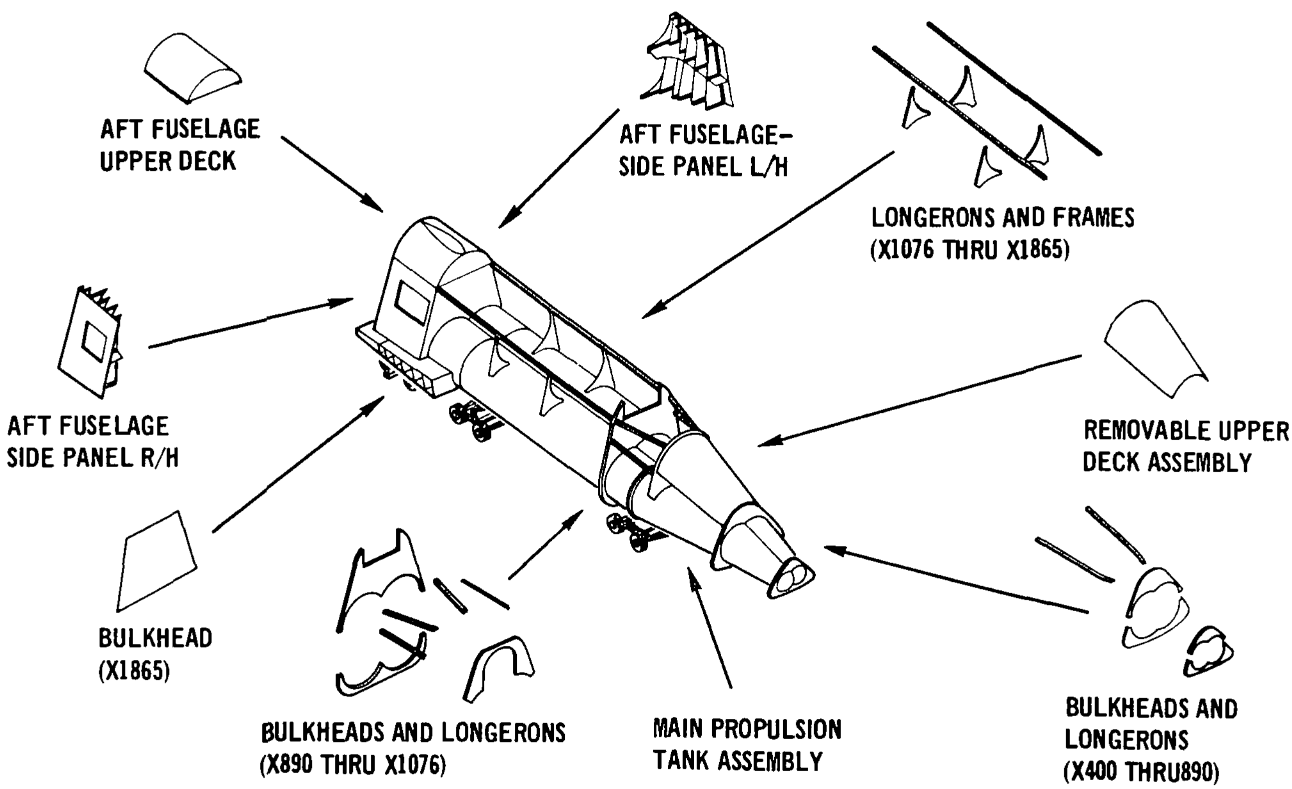


FIGURE 4.4–61

This forms an overall fuselage frame to which all remaining intermediate bulkheads and frames are subsequently positioned and joined. Also at this point, the fuselage nose structure is joined to the main assembly. Figure 4.4-62.

INTERMEDIATE FRAMES AND NOSE STRUCTURE BUILDUP

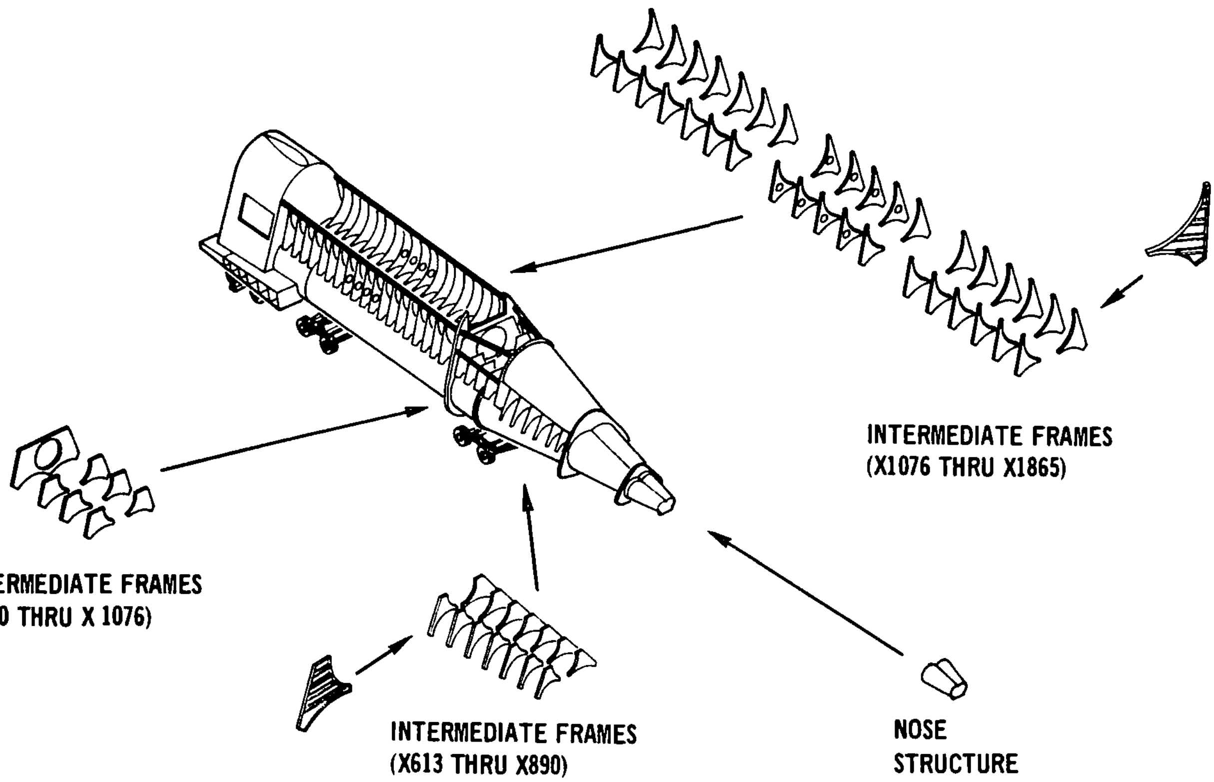


FIGURE 44-62

4.4.10.8 Installation of Crew Station/Airlock Module, Radiator and Cargo Compartment Door - When the fuselage structural frame buildup is complete to this point, installation of the main fuel and vent lines which run the full length of the tank is accomplished. This is followed by application and attachment of the skin panels, joining and splicing of the crew station/airlock module into the fuselage, and installation and attachment of the deployable radiator and cargo compartment door as shown. Assembly of the boost engine thrust structures into the fuselage then essentially completes the structure buildup. Figure 4.4-63.

MAJOR SUBASSEMBLIES AND FINAL STRUCTURAL BUILDUP

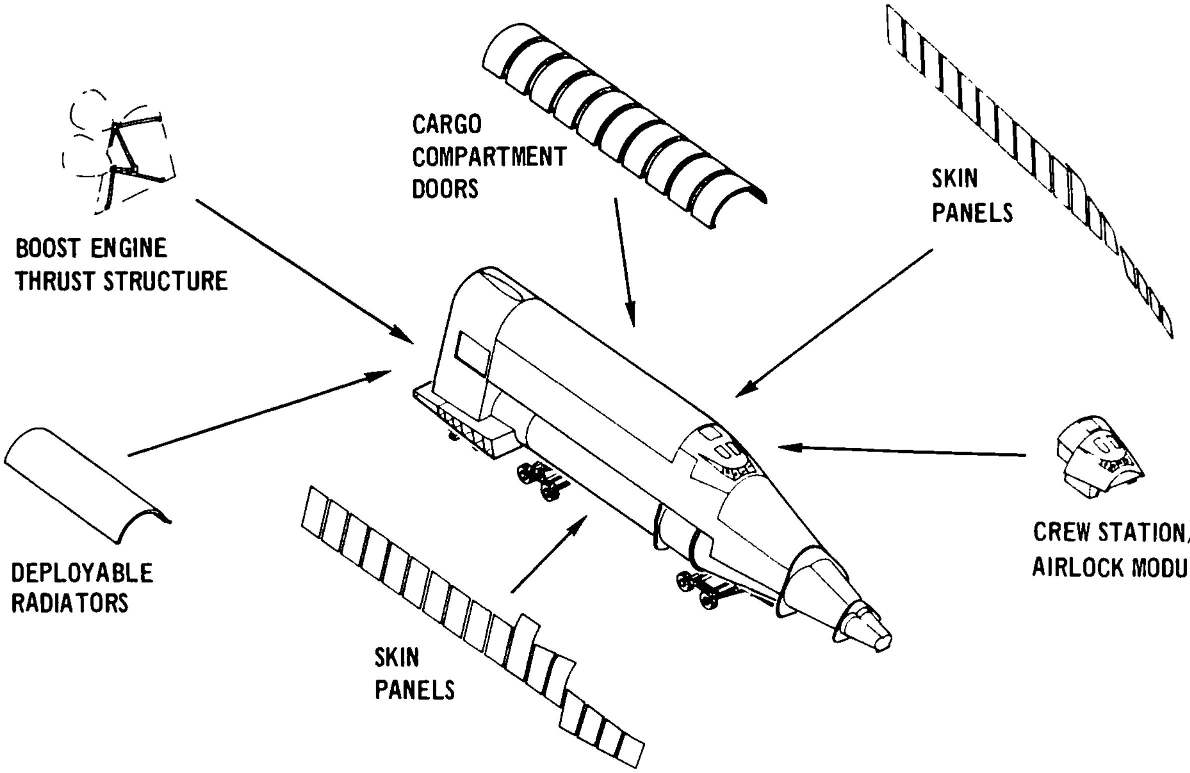


FIGURE 4.4-63

4.4.10.9 Fuselage Main Assembly Closeout - Following structural buildup major fuselage items are installed, as shown in Figure 4.4-64, along with their related hydraulic and pneumatic lines and wire bundles. This will include such items as the on orbit LOX and LH_2 tanks, cruise fuel tanks, nose landing gear and its doors, and speed brakes. Also, other items incroporated at this time are certain avionic equipment packages, ACPS components, fuel system equipment and flight test instrumentation. As these items plus their associated tubing and wiring are installed and hooked up, progressive manufacturing checkout occurs. This consists primarily of such checks as pressure and leak testing of hydraulic and pneumatic systems, plus continuity checks of electrical systems. It also includes rigging and cycle checks of such items as the nose landing gear and speed brakes to assure proper performance and travel.

FUSELAGE MAIN ASSEMBLY CLOSE-OUT

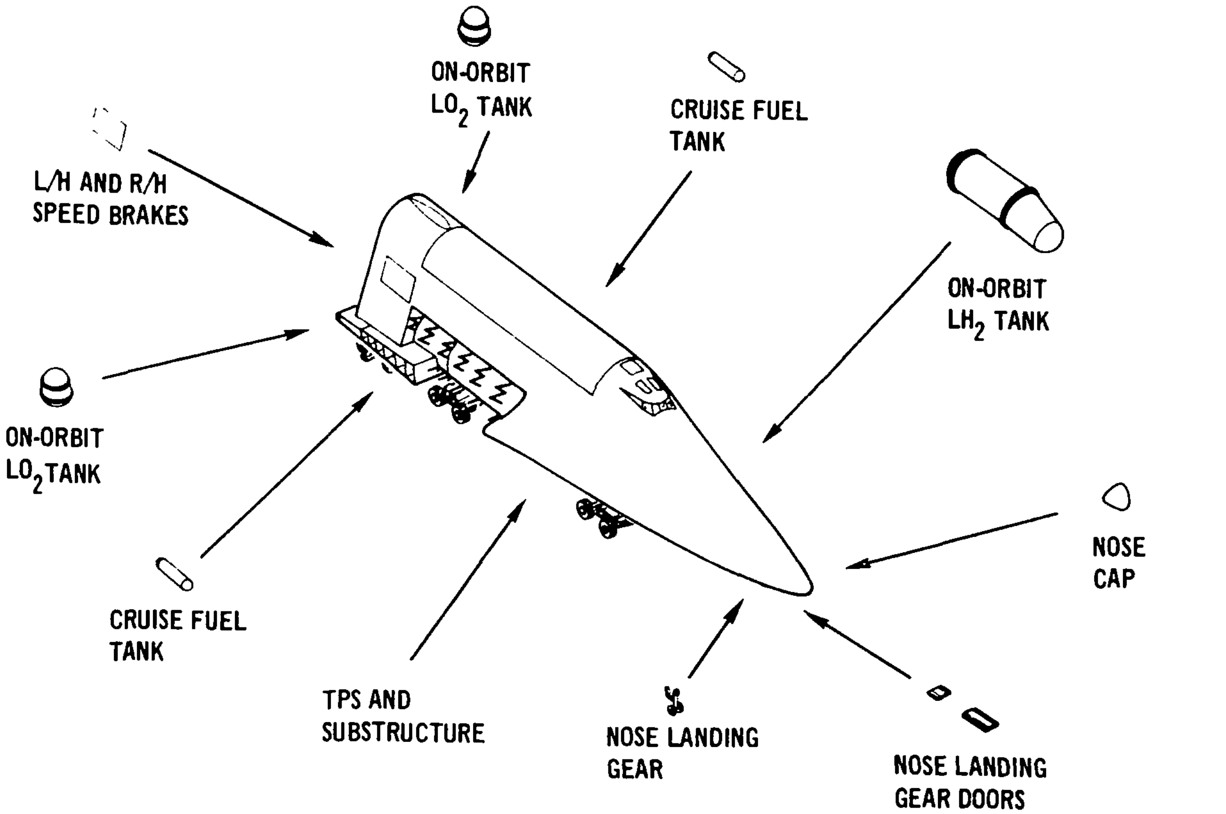


FIGURE 4.4-64

Concurrent with the installation of equipment into the fuselage structure, the installation and attachment of the Thermal Protection System (TPS) supporting structure and its surface panels occurs externally. This includes complete installation of the fuselage TPS, except in the wing attach areas. In these areas close-out of the TPS is delayed until after final assembly splice of the wings to the fuselage.

Completion of the equipment and TPS installations completes the fuselage assembly buildup.

4.4.10.10 Post Assembly Checkout - After fuselage assembly is complete and all structural and systems installations have been made, the flight systems will be activated and a series of preliminary checks performed. Systems include hydraulic, pneumatic, electrical, landing gear, rudders, flaps and elevons. Simulators will be required for tests involving wings and control surface checks.

The preliminary checks are made with the vehicle still in the assembly area.

After the preliminary checks indicated above, the vehicle is moved to a checkout area for more extensive tests.

These tests will include the following:

- Leak Check - LOX Lines
- Leak Check - LH_2 Lines
- Leak Check - JP4 Fuel Tanks
- Leak Check - Hydraulic Systems
- Leak Check - Forward Fuselage Section
- Leak Check - Oil and Water Tanks
- Electrical Continuity Checks
- Communications Systems Check
- Orbiter Release System Check
- Landing Gear Check
- Flight Control Systems Check

Upon completion of all scheduled installations and tests, formal acceptance of the Fuselage Assembly will be made by NASA.

4.4.10.11 Preparation and Shipment - After all scheduled installations and factory tests are completed, the assembled fuselage will be moved, on its own landing gear, to the Michoud dock for shipment to KSC.

4.4.10.12 Major facilities, equipment and tools are listed in Table 4.4-11 and Table 4.4-12

TABLE 4.4-11

MAIN FUSELAGE SUBASSEMBLIES FABRICATION FACILITIES
AND EQUIPMENT REQUIREMENT

FACILITY AND EQUIPMENT REQUIREMENTS	FACILITY AND EQUIPMENT AVAILABILITY
AREA	
250,000 Sq. Ft.	Available Contractor
30 Ft. Clear Height	Available Contractor
CRANE	
5 and 10 Ton	Available Contractor
MAJOR EQUIPMENT	
Milling Machines	Available Contractor
Lathes	Available Contractor
Furnace (Strain Relief)	New Contractor
Chemical Milling Equipment	Available Contractor
Equipment for Stretch	Available Contractor
Forming Titanium Extrusion and Preformed Sheet Metal	New Contractor
Equipment for Hot Forming Titanium Sheet Metal	Available Contractor
Punch Presses	Available Contractor
Power Shears	Available Contractor
Chemical Processing Equipment	Available Contractor
X-Ray (Inspection) Equipment	Available Contractor

TABLE 4.4-11 (Cont'd)

FACILITY AND EQUIPMENT REQUIREMENTS	FACILITY AND EQUIPMENT AVAILABILITY
MAJOR TOOLING	
LABORATORIES	
Nondestructive Test	Available Contractor
Metal Finishing	Available Contractor
Protective Coating	Available Contractor
Quality Assurance	Available Contractor
X-Ray Processing	Available Contractor
PROCESSING FACILITIES	
Chem Milling	Available Contractor
Burr	Available Contractor
Black Oxide Finish	Available Contractor
X-Ray	Available Contractor
Zyglo	Available Contractor
Age	Available Contractor
Alkaline Cleaning	Available Contractor
Bulk Stress Relieve	Available Contractor
Mill Mark Stripping	Available Contractor
Protective Coat	Available Contractor
Pickle	Available Contractor
Liquid Hone	Available Contractor
Abrasive Cleaning	Available Contractor
Degrease	Available Contractor

TABLE 4.4–11 (Cont'd)

FACILITY AND EQUIPMENT REQUIREMENTS	FACILITY AND EQUIPMENT AVAILABILITY
X-RAY	
Manual	Available Contractor
UTILITIES	
90-100 PSI Filtered Factory Air	Available Contractor
115V 60 ∿ Elect. Outlet	Available Contractor
440V 60 ∿ Elect. Outlet	Available Contractor
Normal Lighting	Available Contractor

TABLE 4.4-12

MAIN FUSELAGE SUBASSEMBLIES FABRICATION FACILITIES
AND EQUIPMENT REQUIRED

FACILITY AND EQUIPMENT REQUIREMENTS		FACILITY AND EQUIPMENT AVAILABILITY
AREA		
130,000 Sq. Ft.		Available Michoud
40' Clear Height		Available Michoud
CRANE		
10 Ton		Available Michoud
MAJOR EQUIPMENT		
S-1B Transporter (Modified)		Available Michoud
S-1B Assembly Fixture (Modified)		Available Michoud
MAJOR TOOLING		
NOSE SECTION		
Main Assembly of Nose Section	Assy. Fixt.	New Michoud
Forward Bulkhead Assy.	Assy. Fixt.	New Michoud
Interm. Bulkhead Assy.	Assy. Fixt.	New Michoud
Interm. Bulkhead Assy.	Assy. Fixt.	New Michoud
Interm. Bulkhead Assy.	Assy. Fixt.	New Michoud
Aft Bulkhead Assy.	Assy. Fixt.	New Michoud

TABLE 4.4-12 (Cont'd)

FACILITY AND EQUIPMENT REQUIREMENTS	FACILITY AND EQUIPMENT AVAILABILITY
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Bulkheads - Assy. Fixt.	New Michoud
Full Bulkhead - Fwd (X1076) - Assy. Fixt.	New Michoud
Full Bulkhead - Aft (X1865) - Assy. Fixt.	New Michoud
Half Bulkheads - Intermediate - Assy. Fixt.	New Michoud

TABLE 4.4-12 (Cont'd)

FACILITY AND EQUIPMENT REQUIREMENTS	FACILITY AND EQUIPMENT AVAILABILITY
Skin Panel Between Bulkheads - Assy. Fixt.	New Michoud
Closure Skin Panel Between - Assy. Fixt.	New Michoud
AFT FUSELAGE SECTION	
Top Assembly of Aft Fuselage Section - Assy. Fixt.	New Michoud
Fwd (X1865.0) Bulkhead - Assy. Fixt.	New Michoud
Intermediate Bulkhead - Assy. Fixt.	New Michoud
Intermediate Bulkhead - Assy. Fixt.	New Michoud
Intermediate Bulkhead - Assy. Fixt.	New Michoud
Intermediate Bulkhead - Assy. Fixt.	New Michoud
Intermediate Bulkhead - Assy. Fixt.	New Michoud
Aft (Canted) Bulkhead - Assy. Fixt.	New Michoud
Lower LH Assy. of Aft Fuselage Section - Assy. Fixt.	New Michoud
Lower RH Assy. of Aft Fuselage Section - Assy. Fixt.	New Michoud
LABORATORIES	
Nondestructive Test Quality Assurance	Available Contractor
Quality Assurance	Available Contractor
X-RAY	
Manual	Available Contractor

TABLE 4.4-12 (Cont'd)

FACILITY AND EQUIPMENT REQUIREMENTS	FACILITY AND EQUIPMENT AVAILABILITY
UTILITIES	
90-100 PSI Filtered Factory Air	Available Contractor
115V 60 ∿ Elect. Outlet	Available Contractor
440V 60 ∿ Elect. Outlet	Available Contractor
Normal Lighting	Available Contractor

4.4.11 Thermal Protection System

4.4.11.1 Thermal Protection System Description - The basic fuselage thermal protection system (TPS) is passive and consists of single face corrugated panels, supported by a series of struts and transverse beams. The struts and beams are of the same material as the panels. The support structures are made statically determinant to minimize thermal stresses. Fibrous insulation, placed at the back side of the metallic panels, protects the primary structure from the moldline temperatures. The majority of the lower surface experiences temperatures less than 2000°F therefore panels of nickel alloy (Hastelloy X) can be used. Where temperatures exceed 2000°F Columbium (FS-85) is used. The lower sides incorporate Titanium (Ti-6AL-4V) shingles while the upper surface is a Titanium hot structure. (Ti Skin with Boron-AL Stiffeners).

The TPS employed upon the wing is quite similar to that of the fuselage in that single face corrugated panels, transverse beams, fibrous insulation and support struts are utilized. In general the support struts are of a shorter length than those of the fuselage due to depth required for primary structure as related to the overall thickness of the wing. The majority of the lower surface of the wing is approximately 1900°F therefore nickel alloy (Hastelloy X) is used for panels. Figure 4.4-65 shows the orbiter temperature zones.

The metallic chines are of the same material as the lower surface panels. The nose cap and most of the leading edges of the wing are of carbon/carbon. The remaining small portion of the wing leading edge is Columbium (FS-85). The vertical tail is nickel alloy (Rene' 41) hot structure with a carbon/carbon leading edge. Figures 4.4-66 through 4.4-69 show details of the basic system. The wetted (mold line) area of the orbiter as shown in Figure 4.4-70 is approximately 37% titanium hot structure, 28% nickel superalloy panels, 13% columbium (FS-85) panels, 6%

TEMPERATURE PROFILE

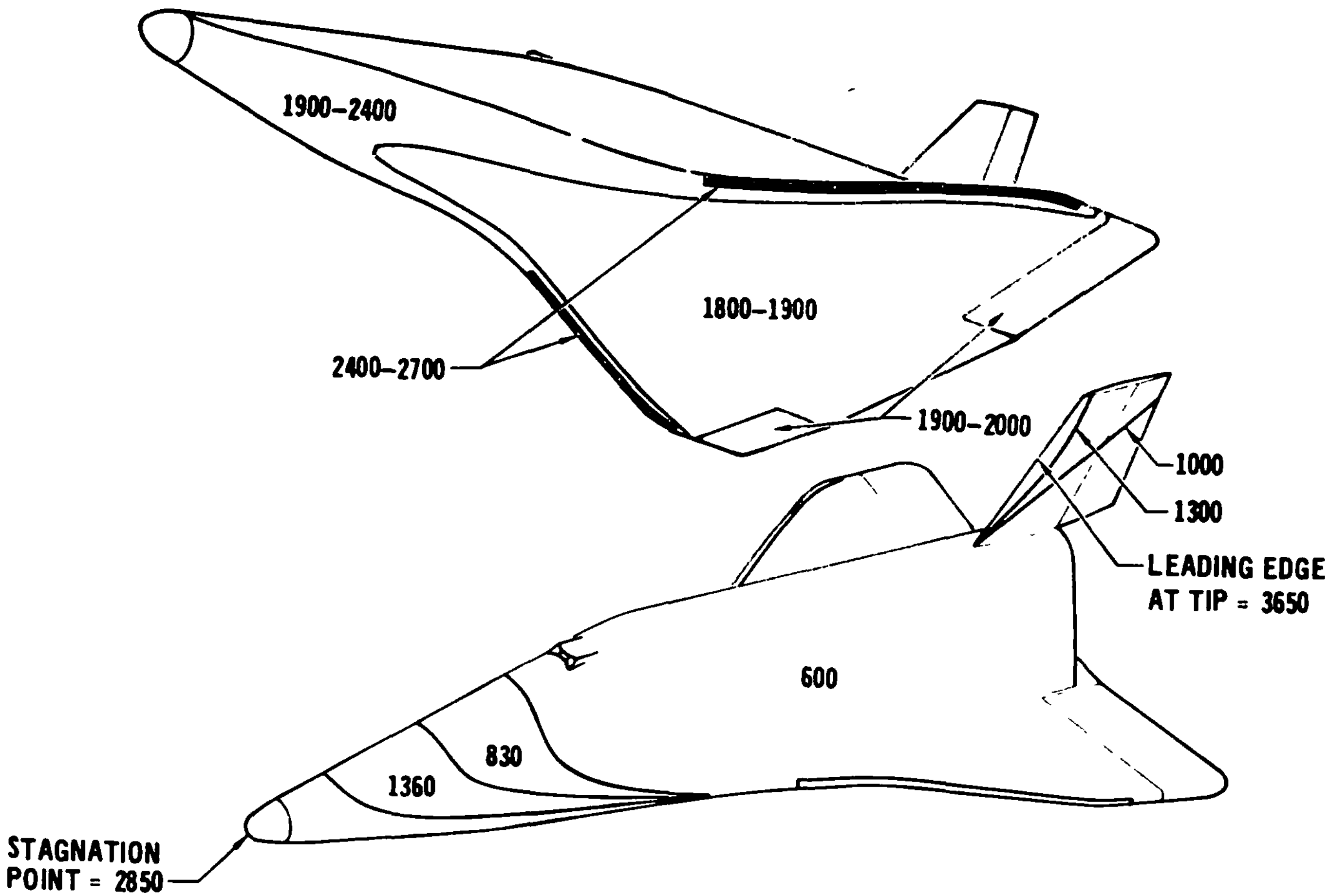


FIGURE 4.4-65

DETAIL OF BASIC SYSTEM
(T.P.S. Definition)

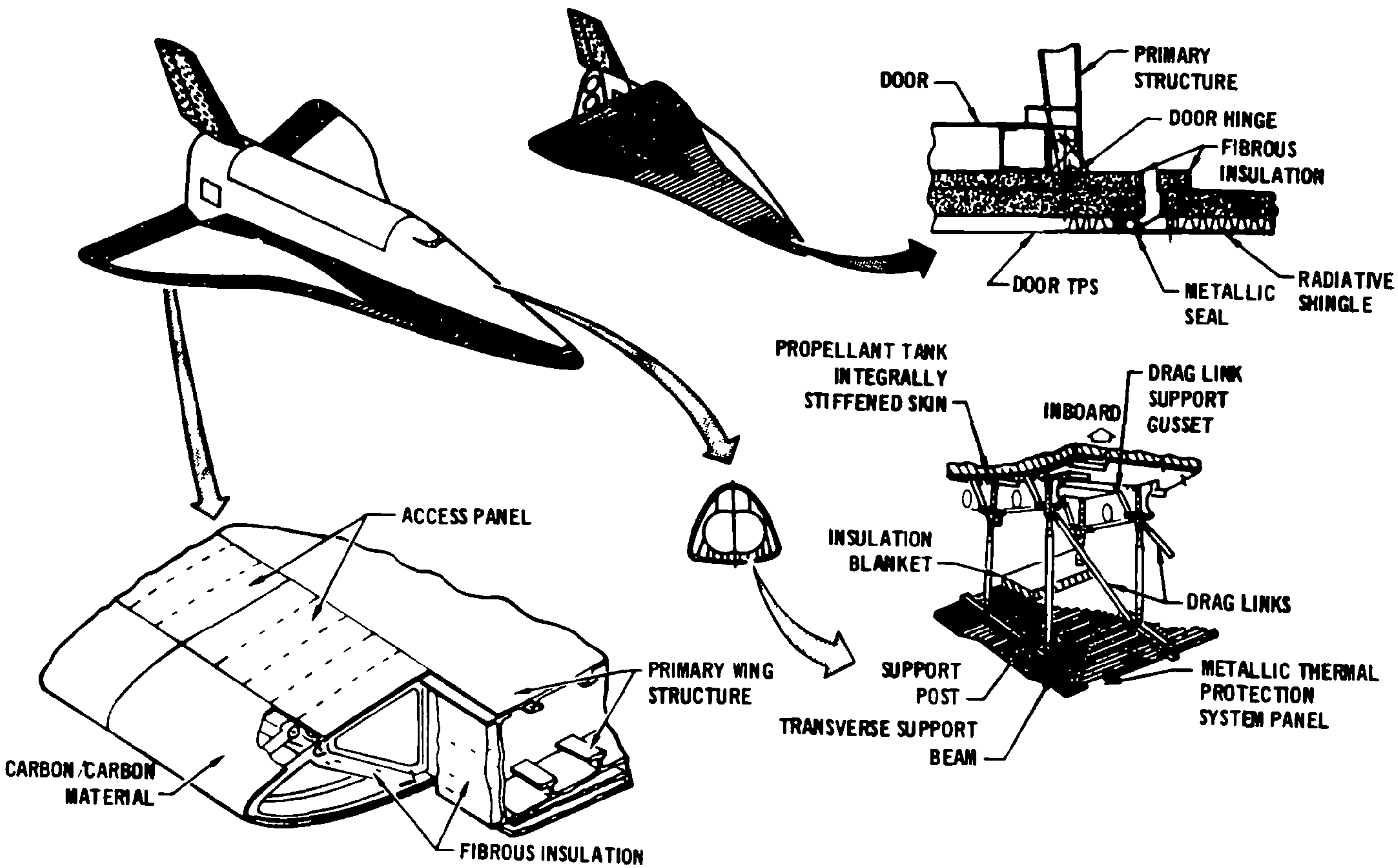


FIGURE 4.4-66

DETAIL OF BASIC SYSTEM
T.P.S. Panel Support Structure

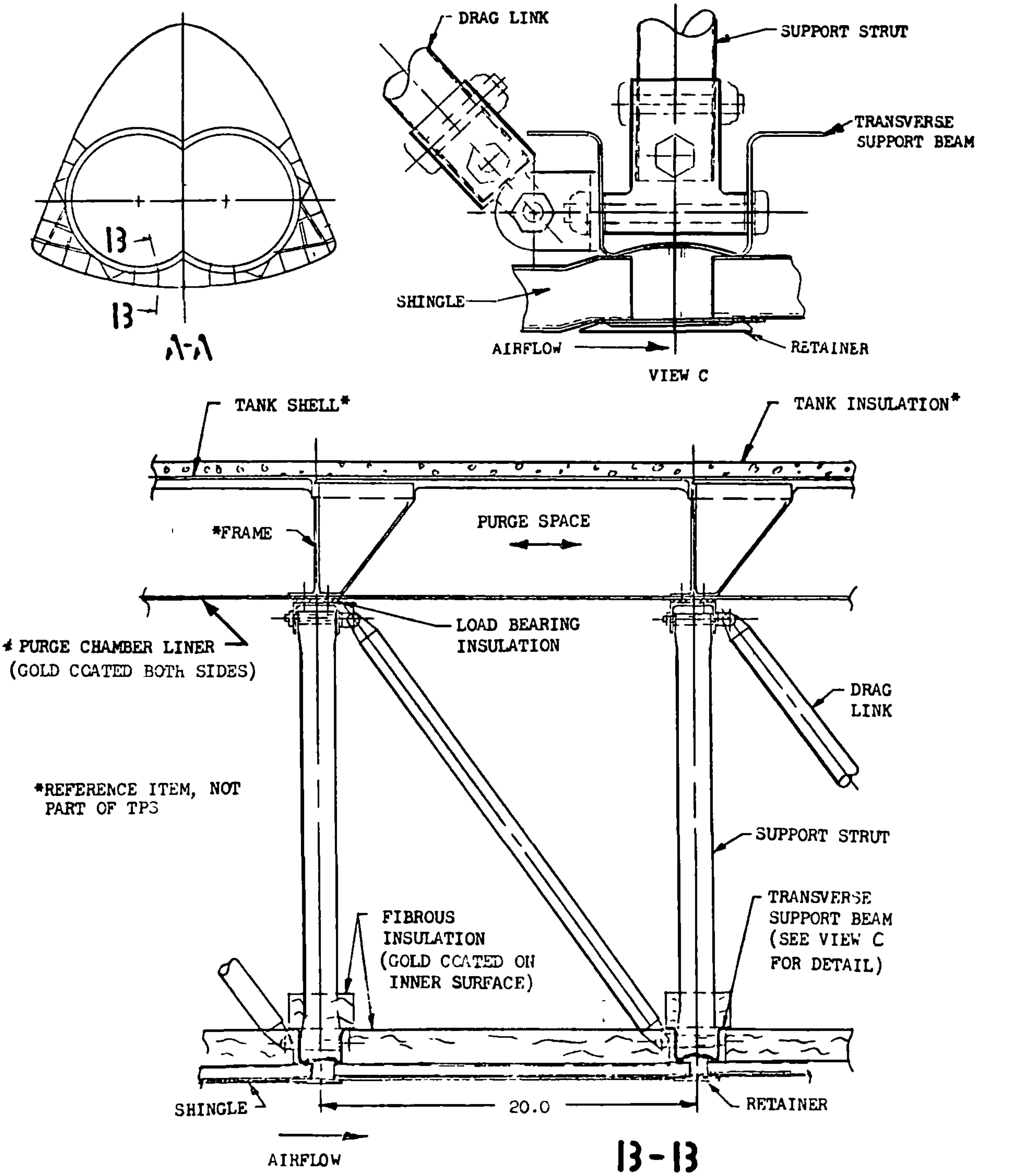


FIGURE 4.4-67

DETAIL OF BASIC SYSTEM
Wing T.P.S. Panel Support Structure

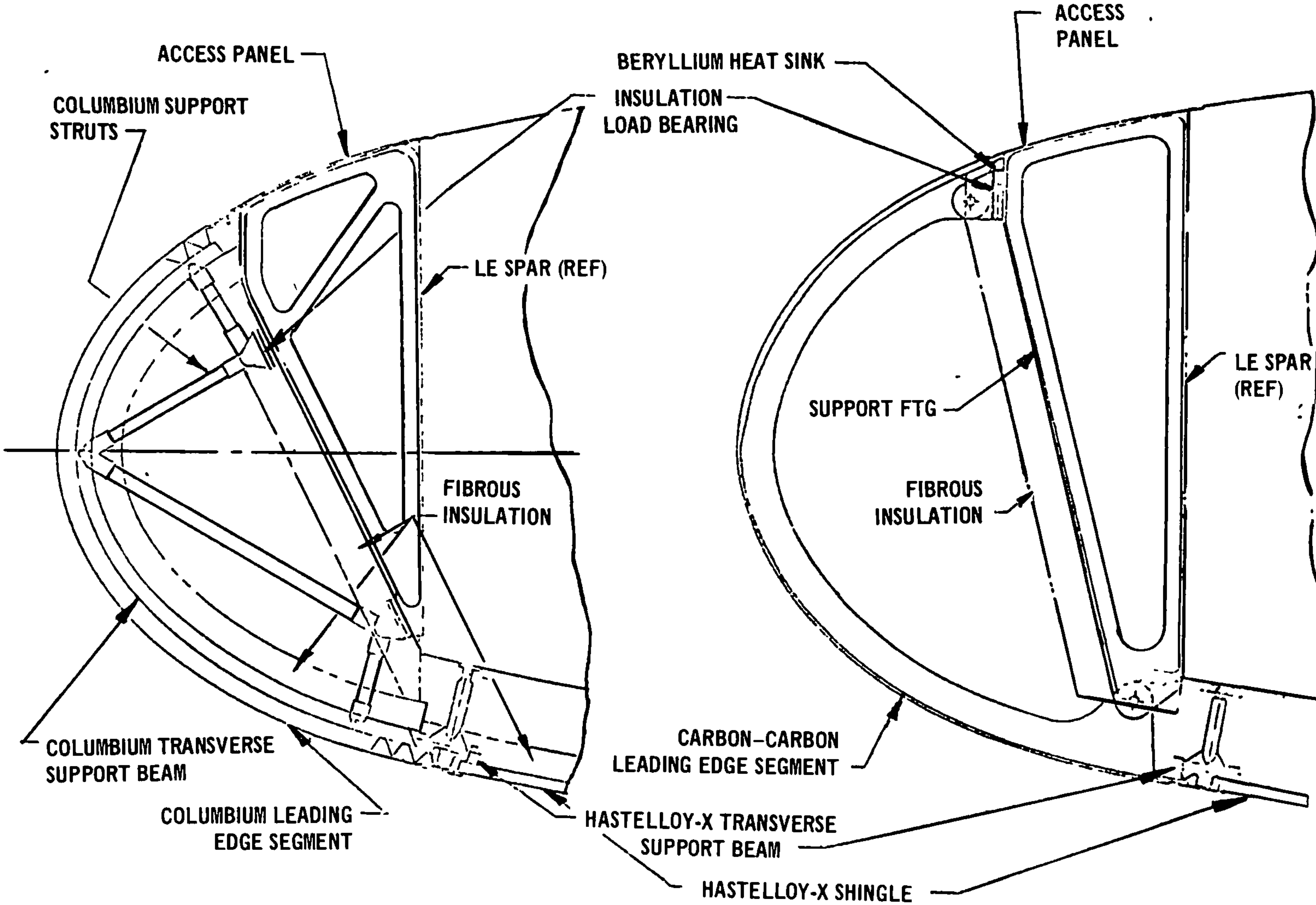


FIGURE 4.4-68

DETAIL OF BASIC SYSTEM
Typical T.P.S. Panel Joint

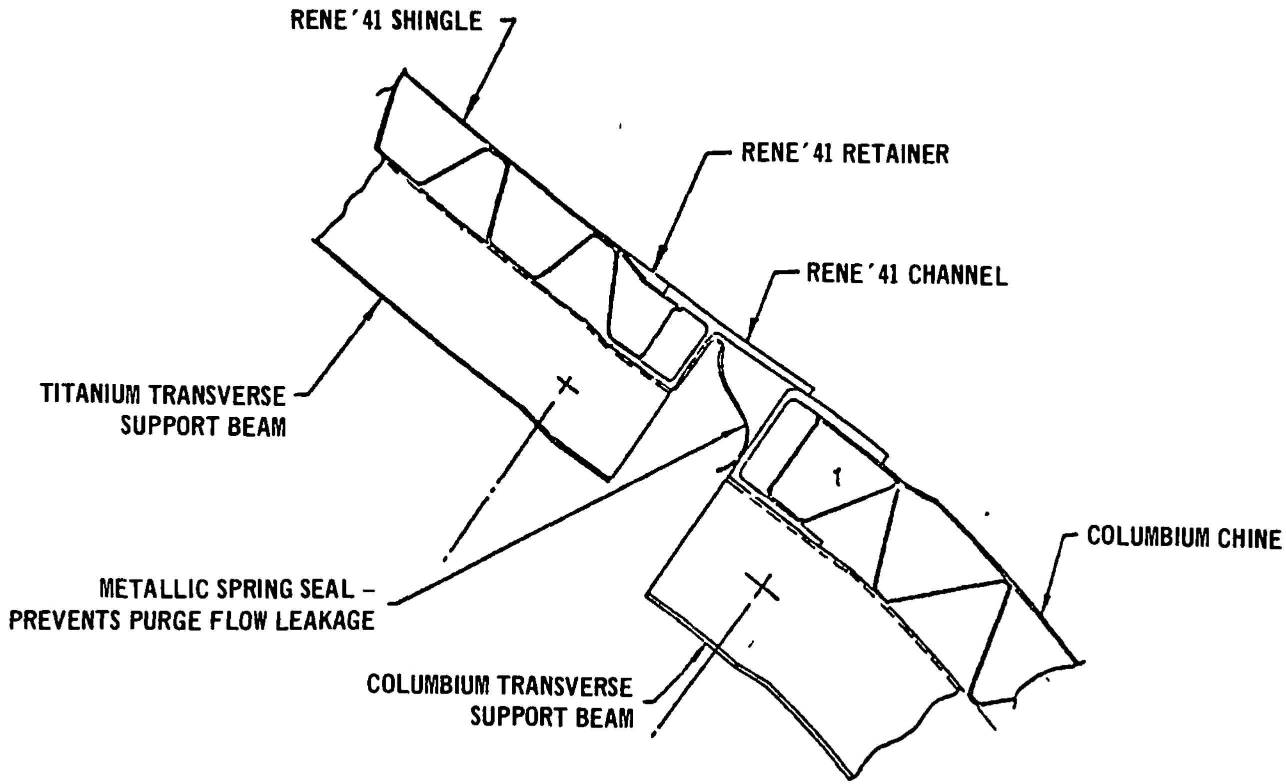
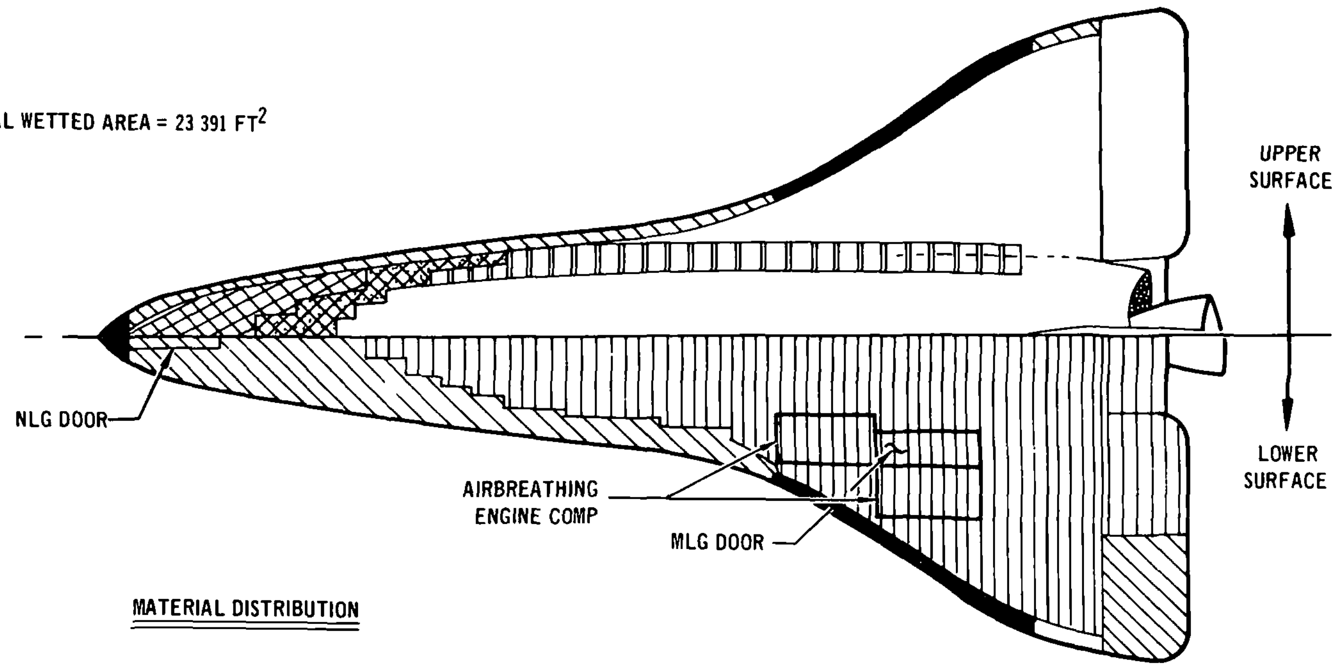


FIGURE 4.4-69

MOLDLINE MATERIAL DISTRIBUTION

TOTAL WETTED AREA = 23 391 FT^2



MATERIAL DISTRIBUTION

MATERIAL	% AREA USED
CARBON CARBON ⚠1	2 7
COLUMBIUM (FS-85) SHINGLES	13 0
HASTELLOY X SHINGLES	21 3
RENE 41-SHINGLES	3 8
INCONEL 718-SHINGLES	3 2
RENE 41-HOT STRUCTURE ⚠1	4 6
Ti (6AL-4V)-SHINGLES	5 7
Ti (6AL-6V-2Sn) SKIN ⚠1 *(BORON-AL STIFFENERS)*-HOT STRUCTURE	37 2
INCONEL 702 BASE AND ENGINE SHROUD	8 5
TOTAL	100 00

⚠1 NOT DEFINED AS TPS SHOWN FOR REFERENCE ONLY

FIGURE 4.4-70

titanium panels, 5% Rene' 41 hot structure, 3% carbon/carbon panels and 8% inconcel 702 base and engine thermal protection surfaces.

The metallic panels are keyed to the transverse support beams at one location and are free to expand (thermally) inboard and outboard from this point. In the longitudinal direction, which is the direction of the corrugations, the panels are fixed at the aft end and allowed to expand forward. The transverse support beams are located at approximately 20 inch intervals with the struts being located at approximately 24 inch intervals. There are approximately 1276 metallic panels (approximately 978 different shapes) and 83 carbon/carbon segments on the orbiter. Figures 4.4-71 and 4.4-72 summarize the panels as to size and shape. It can be seen that the panels vary in size from 20 inches by 24 inches to 20 inches by 104 inches.

4.4.11.2 Manufacturing Site - Due to the past experience of MDC in Thermal Protection Systems, it is recommended that the Thermal Protection panels be manufactured at the Contractor's facility, and then shipped to their installation point.

4.4.11.3 Manufacturing Operations & Experience - Most of the materials used as TPS on the orbiter have been used at MDC on various other vehicles. Examples of this are shown in Figure 4.4-73 through 4.4-81. This usage and experience is summarized on Figure 4.4-82. As may be seen, carbon/carbon is perhaps the area of least experience. This material will require further development of methods and manufacturing techniques to effect a smooth transition from laboratory to manufacturing shop. Also, it will be necessary to expand our capabilities to produce this material in larger quantities. This will include such items as pre-pregger equipment, vacuum/pressure impregnation equipment, curing ovens (6000°F), pyrolization argon furnaces (2000°F), argon atmosphere furnaces (4000°F) and ultra sonic inspection equipment.

TPS PANEL SUMMARY

PANEL MATERIAL	APPROX SIZE (IN.)	QUANTITY			
		FLAT	SINGLE CURVE	DOUBLE CURVE	TOTAL
HASTELLOY-X	52 x 20	80	56	32	165
	70 x 20	54	29	106	189
	104 x 20	–	–	40	40
	40 x 20	–	–	20	20
	80 x 20	–	–	24	24
	93 x 20	–	–	18	18
	SPECIAL	–	–	66	66
HASTELLOY-X					525
F3-85	80 x 20	–	–	46	46
	70 x 20	–	–	86	86
	40 x 20	–	–	19	19
	10 R.X20 (CHINE)	–	–	112	112
	30 x 20 (LE)	–	–	22	22
	SPECIAL	–	–	112	112
F3-85					397
RENE'41	60 x 20	–	–	12	12
	50 x 20	–	–	20	20
	SPECIAL	–	–	40	40
RENE'41					72

FIGURE 4.4-71

TPS PANEL SUMMARY

PANEL MATERIAL	APPROX SIZE (IN.)	QUANTITY			
		FLAT	SINGLE CURVE	DOUBLE CURVE	TOTAL
INCONEL 718	90 x 20	–	–	18	18
	60 x 20	–	–	38	38
	SPECIAL	–	–	32	32
INCONEL 718					88
Ti-6AL-4V	SPECIAL	88	–	106	194
Ti-6AL-4V					194
CARBON-CARBON	24 x 20	–	–	60	60
	31 x 16	–	18		18
	SPECIAL (NOSE CONE)	–	–	5	5
CARBON-CARBON					83

FIGURE 4.4-72

F-4 HOT STRUCTURE AND THERMAL PROTECTION SYSTEM

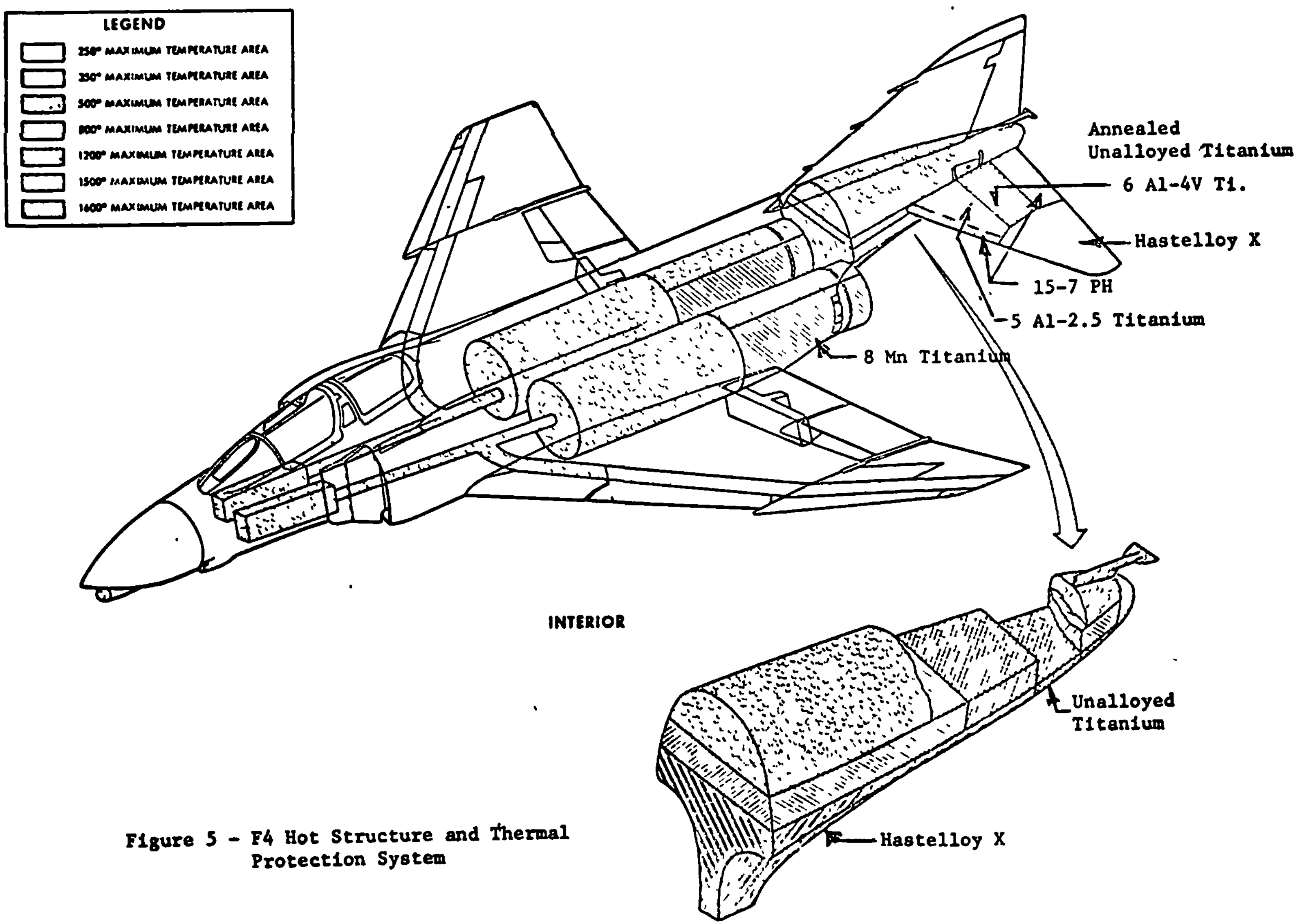


Figure 5 - F4 Hot Structure and Thermal Protection System

FIGURE 4.4-73

INCONEL 718 CRYOGENIC PRESSURE TANK

FIGURE 4.4–74

MERCURY RENE' SHINGLES

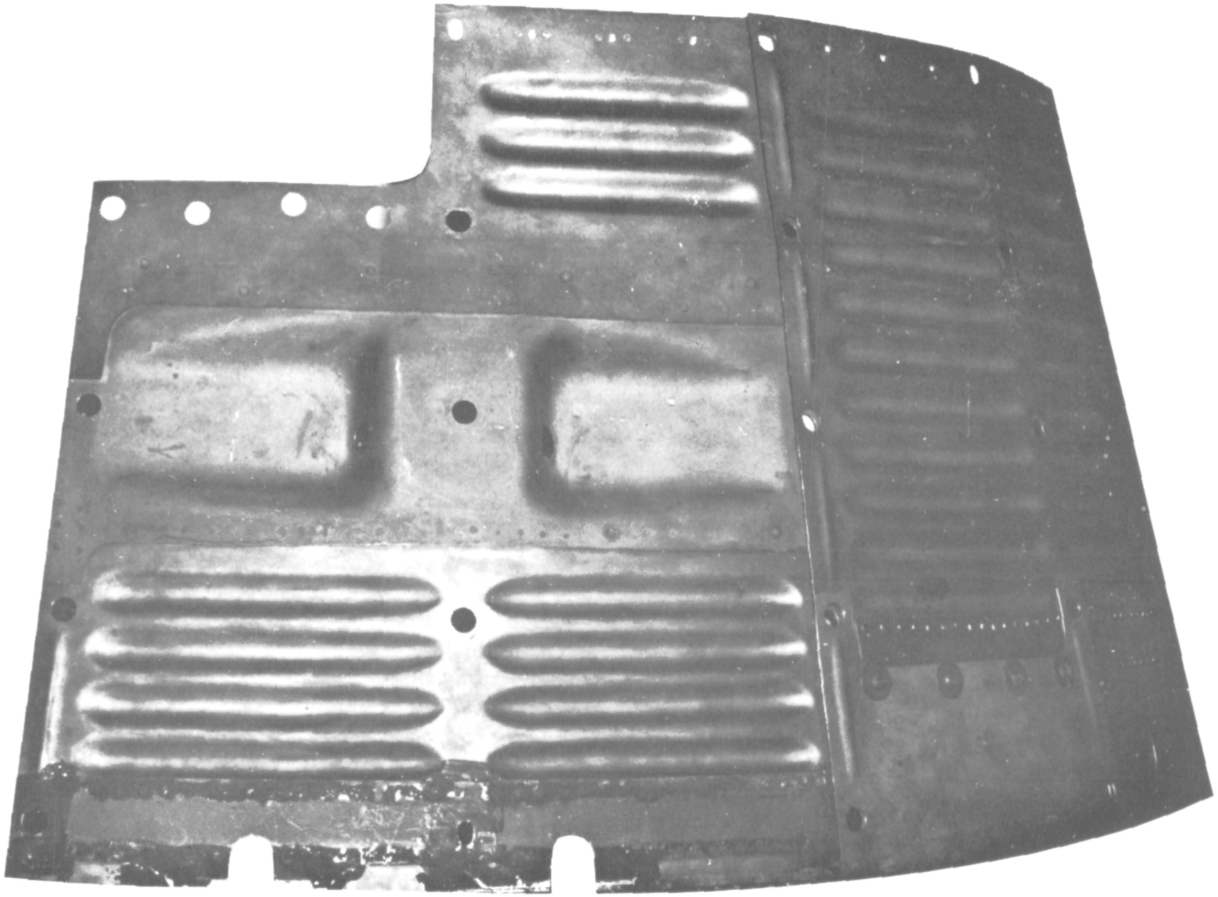


FIGURE 4.4-75

RESISTANCE WELDING (GEMINI CABIN) TITANIUM

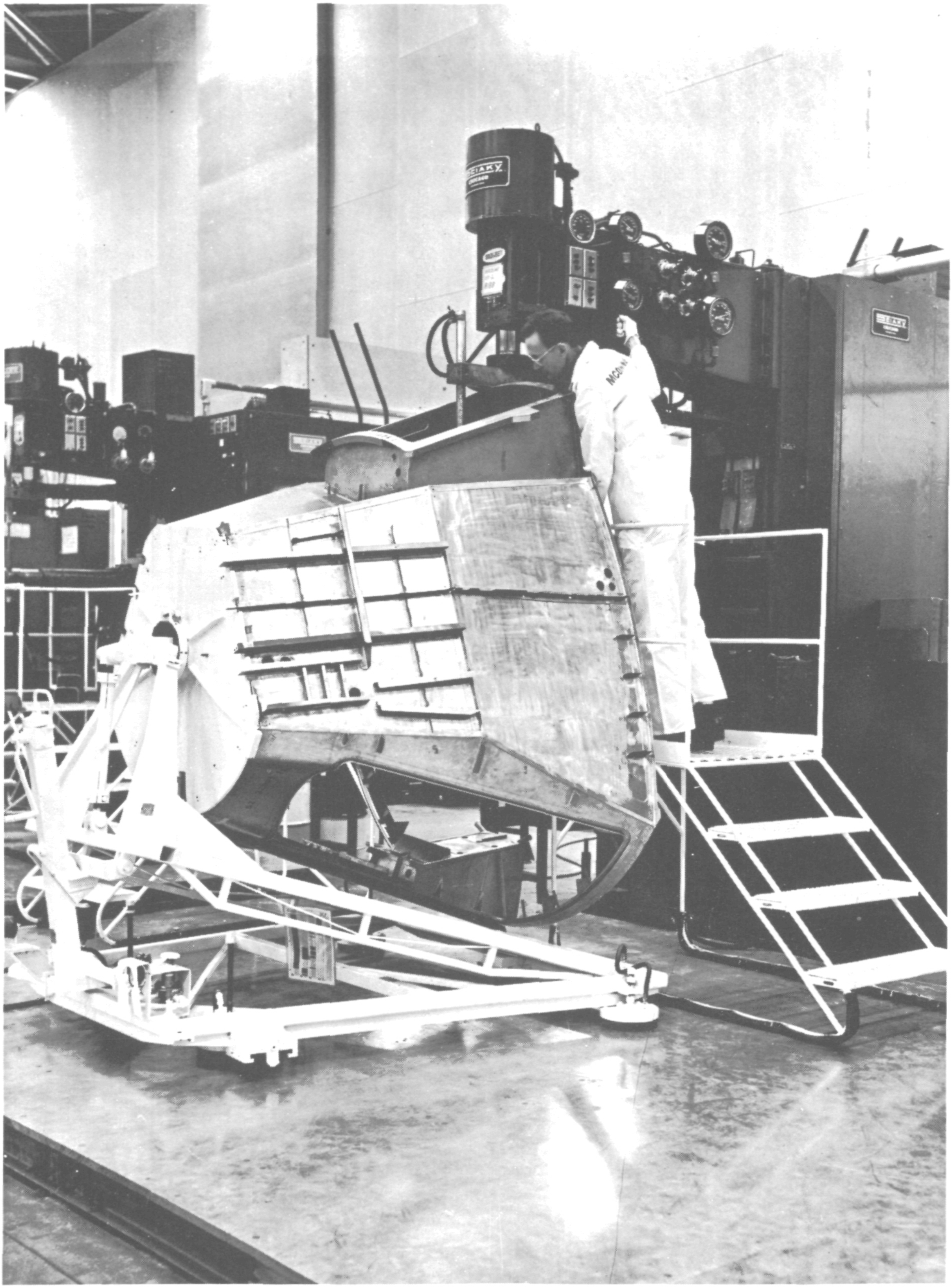


FIGURE 4.4–76

COLUMBIUM (CB752) COATED ASSEMBLY

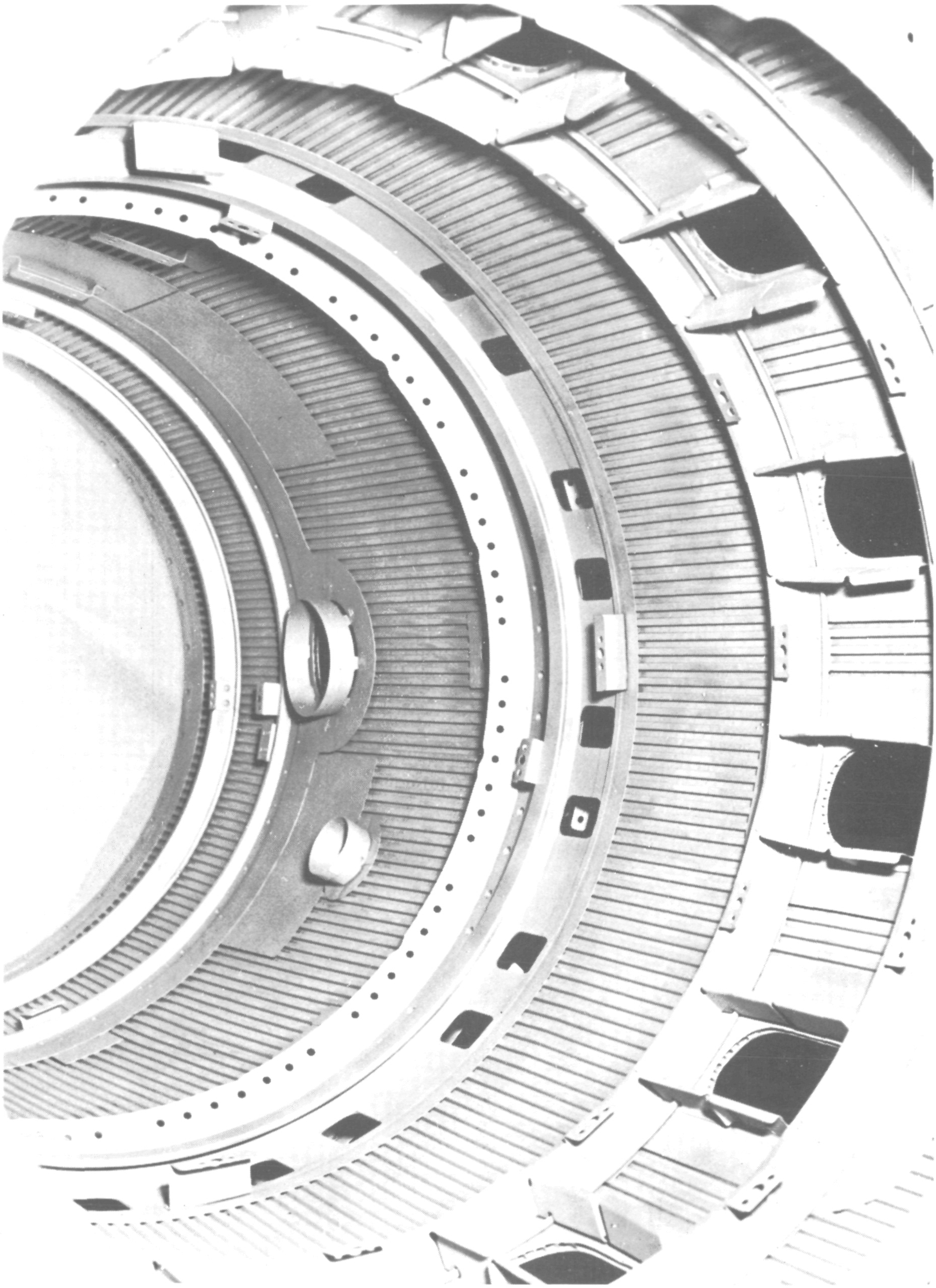


FIGURE 4.4–77

ELECTRON BEAM WELDED COLUMBIUM SECTION

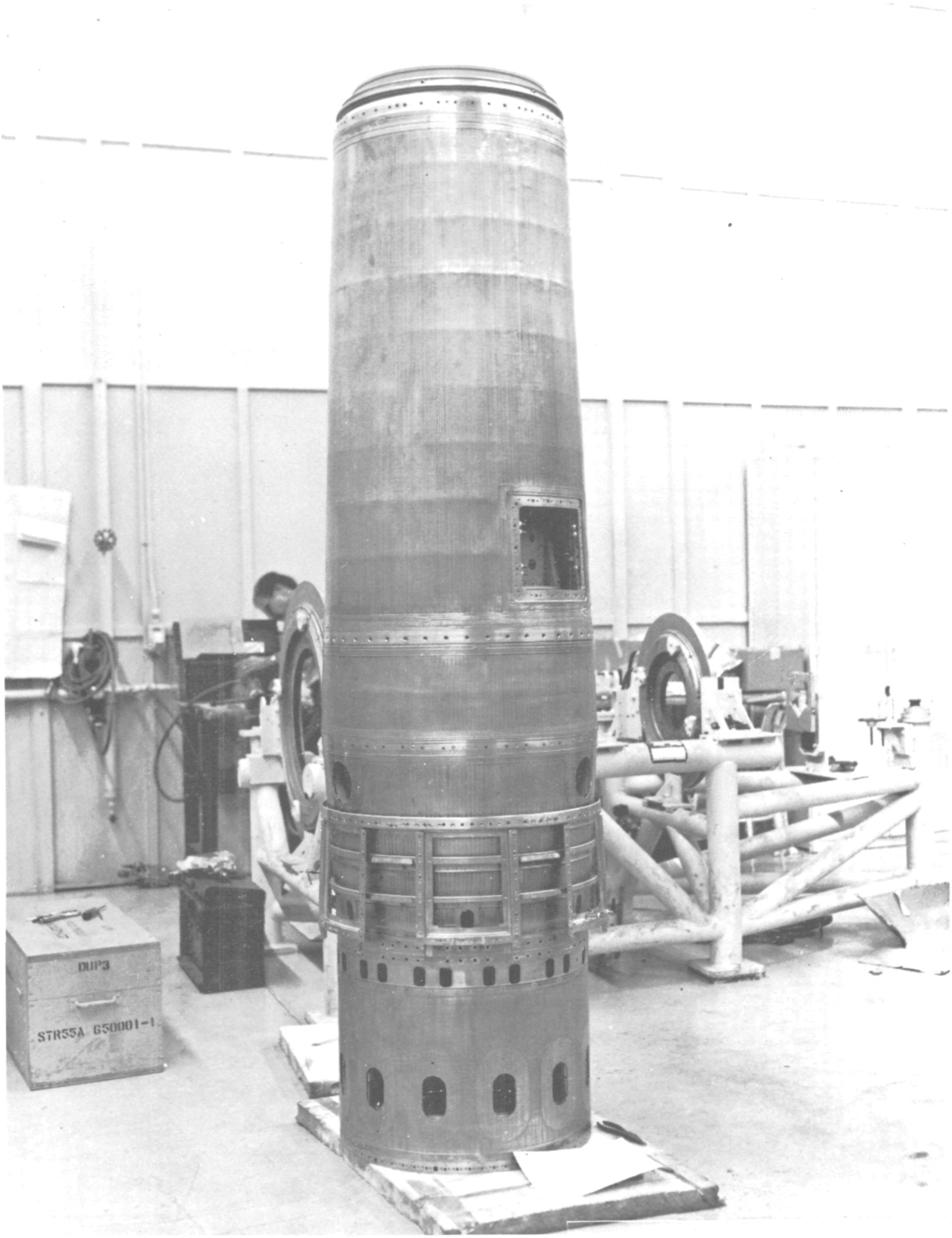


FIGURE 4.4–78

ASSET STRUCTURE TPS

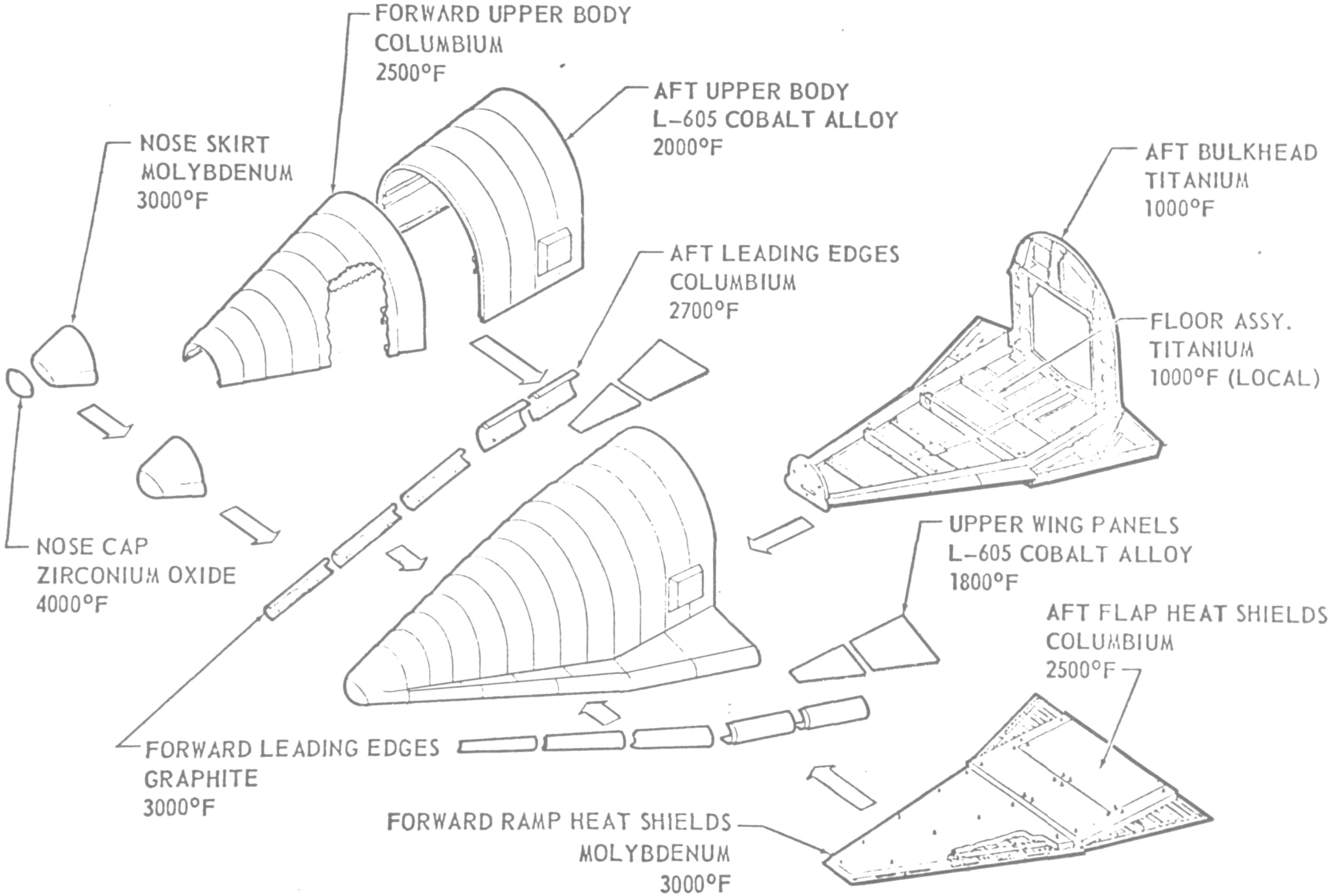


FIGURE 4.4-79

RECOVERED ASSET VEHICLE

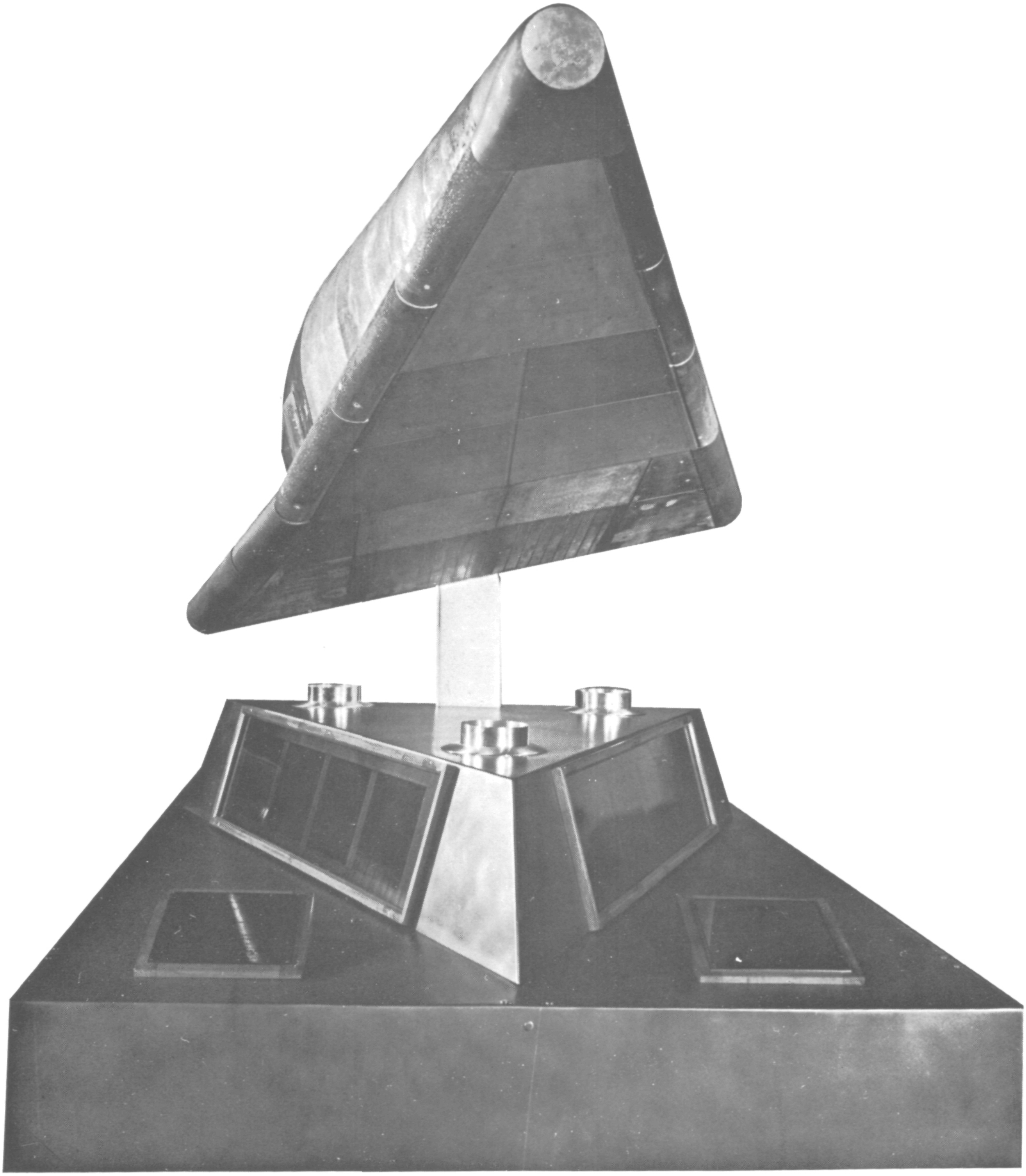


FIGURE 4.4–80

CARBON/CARBON ASSEMBLY

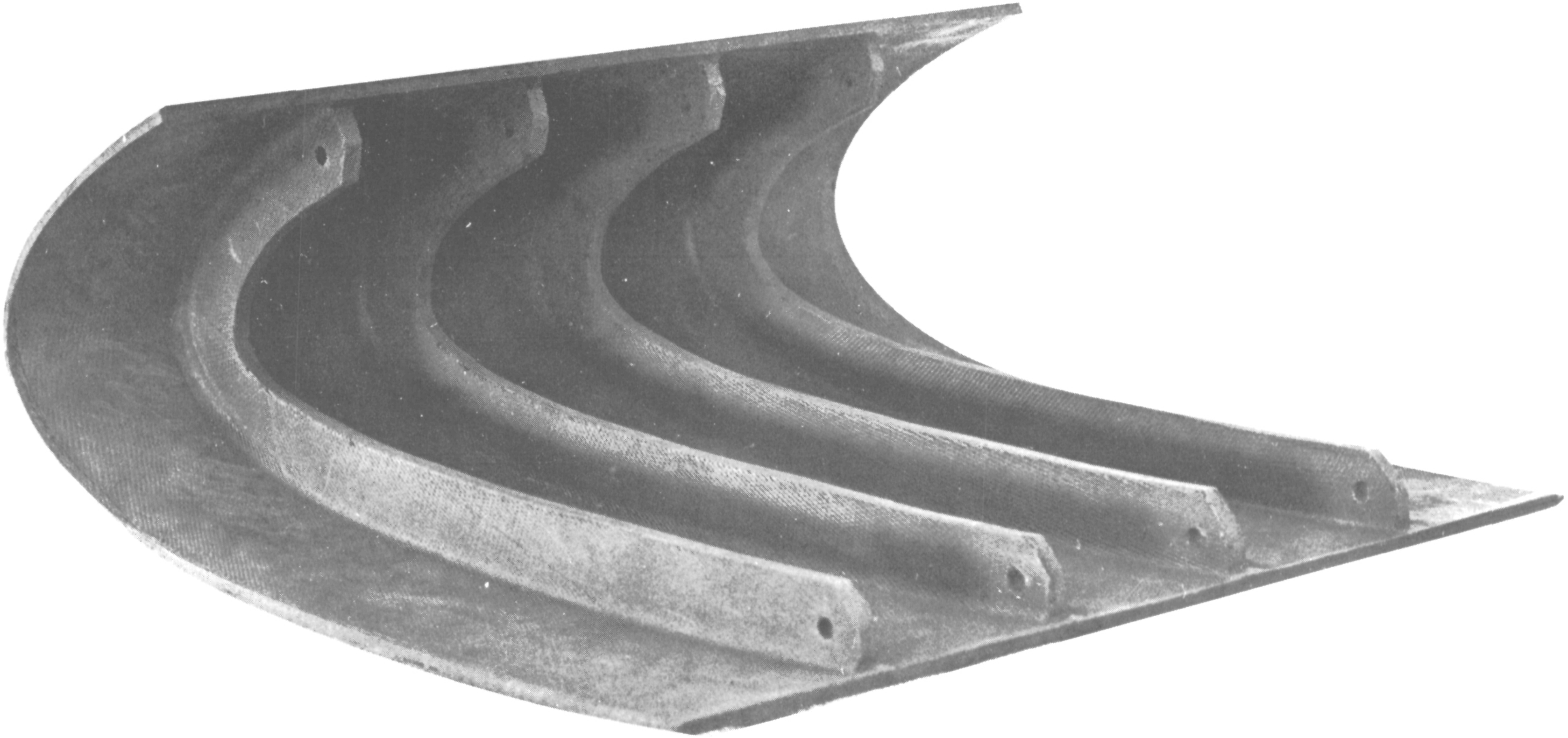


FIGURE 4.4-81

MCDONNELL DOUGLAS ASTRONAUTICS
FABRICATION EXPERIENCE

(Each material cell gives METHODS / SINCE.)

Category	Process	H.C.F.	BULK GRAPHITE	CARBON/CARBON COMPOSITE	CARBON/PHENOLIC COMPOSITE	QUARTZ PHENOLIC	GRAPHITE EPOXY	BORON/EPOXY COMPOSITE	BORON/ALUMINUM COMPOSITE	GRAPHITE POLYIMIDE	BORON POLYIMIDE	BERYLLIUM	RENE' 41	L 605	INCONEL-718	TD NICKEL	CRYO STRETCH ST. STL. 301	TITANIUM	COLUMBIUM 752	D14	FS82	FS85	MOLYBDENUM	TANTALUM	TUNGSTEN
RAW MATL	BAR											▲ 1960	▲ 1959	▲ 1959				▲ 1956	▲ 1964	▲ 1960	▲ 1959	▲ 1967	▲ 1955	▲ 1966	
	SHEET								▲ 1968			▲ 1960	▲ 1959	▲ 1959	▲ 1955	▲ 1964		▲ 1956	▲ 1964	▲ 1960	▲ 1959	▲ 1967	▲ 1955	▲ 1966	▲ 1968
	CAST	▲ 1965																							
	MOLD	▲ 1965	▲ 1960	▲ 1965	▲ 1960	▲ 1962	▲ 1968	▲ 1968	▲ 1968	▲ 1969	▲ 1969														▲ 1964
	FORGE																	▲ 1956	▲ 1964						
	PROD. IN PLANT	▲ 1971		▲ 4					▲ 4																
FABRICATION – REMOVAL	DRILL	▲ 1970	▲ 1960	▲ 1968	▲ 1965	▲ 1962	▲ 1968	▲ 1968	▲ 1969	▲ 1969	▲ 1969	▲ 1960	▲ 1960	▲ 1960	▲ 1955	▲ 1964	▲ 1955	▲ 1956	▲ 1965	▲ 1960	▲ 1960	▲ 1967	▲ 1955	▲ 1964	▲ 1968
	MILL	▲ 1963	▲ 1960	▲ 1968	▲ 1965	▲ 1962	▲ 1968	▲ 1968	▲ 1969	▲ 1969	▲ 1969	▲ 1960	▲ 1960	▲ 1960	▲ 1955	▲ 1964	▲ 1955	▲ 1956	▲ 1965	▲ 1960	▲ 1960	▲ 1967	▲ 1955	▲ 1964	▲ 1968
	SAW	▲ 1970	▲ 1960	▲ 1968	▲ 1965	▲ 1962	▲ 1968	▲ 1968	▲ 1969	▲ 1969	▲ 1969		▲ 1960	▲ 1960	▲ 1955	▲ 1964	▲ 1955	▲ 1956	▲ 1965	▲ 1960	▲ 1960	▲ 1967			
	GRIND	▲ 1965	▲ 1960	▲ 1968	▲ 1965	▲ 1962	▲ 1968	▲ 1968	▲ 1969	▲ 1969	▲ 1969	▲ 1960	▲ 1960	▲ 1960	▲ 1955	▲ 1964	▲ 1955	▲ 1956	▲ 1965	▲ 1960	▲ 1960	▲ 1967	▲ 1955	▲ 1964	▲ 1968
	EDM ECM								▲ 1970				▲ 1960		▲ 1955		▲ 1955	▲ 1956	▲ 1965	▲ 1960	▲ 1960	▲ 1967			
	SHEAR							▲ 1968					▲ 1960	▲ 1960	▲ 1955	▲ 1964		▲ 1956	▲ 1965	▲ 1960	▲ 1960	▲ 1967			
	PUNCH							▲ 1968					▲ 1960	▲ 1960	▲ 1955	▲ 1964		▲ 1956	▲ 1965	▲ 1960	▲ 1960	▲ 1967			
	CHEM. MILL											▲ 1960	▲ 1960	▲ 1960	▲ 1955		▲ 1955	▲ 1956	▲ 1965	▲ 1960	▲ 1960	▲ 1967			
	ECG								▲ 1968																
FABRICATION – FORM	COLD	▲							▲ 1970				▲ 1960	▲ 1965	▲ 1955	▲ 1964		▲ 1956	▲ 1965	▲ 1960		▲ 1960			
	HOT											▲ 1960	▲ 1960	▲ 1965	▲ 1955			▲ 1956	▲ 1965	▲ 1960		▲ 1960	▲ 1955	▲ 1964	▲ 1968
ASSEMBLY – MISC	BOND ADHES.	▲ 1965				▲ 1962	▲ 1968	▲ 1968				▲ 1960						▲ 1958	▲ 1965	▲ 1960	▲ 1960	▲ 1960			
	BOND DIFF.								▲ 5																
	BRAZE								▲ 1970			1 1960	▲ 1960	▲ 1960		▲ 1964	▲ 1955								▲ 1968
	MECH. FAST								▲ 1968			▲ 1960	▲ 1960	▲ 1960		▲ 1964	▲ 1955	▲ 1958							
ASSEMBLY – WELDING	WELD E.B.											2	▲ 1963	▲ 1965	▲ 1955		▲ 1955	▲ 1958	▲ 1965	▲ 1960	▲ 1960	▲ 1960	▲ 1955		
	T.I.G.												▲ 1960	▲ 1960			▲ 1955	▲ 1958	▲ 1965	▲ 1960	▲ 1960	▲ 1960	▲ 1955		▲ 1968
	M.I.G.												▲ 1960		▲ 1955		▲ 1955	▲ 1958	▲ 1965	▲ 1960	▲ 1960	▲ 1960		▲ 1964	▲ 1968
	RESISTANCE								▲ 4				▲ 1960	▲ 1960			▲ 1955	▲ 1958	▲ 1965	▲ 1960	▲ 1960	▲ 1960	▲ 1955		
	ARC SPOT												▲ 1963	▲ 1960	▲ 1960					▲ 1960	▲ 1960	▲ 1960			
	EXPLOSIVE								▲ 3																
FINISH	COATING	▲ 1969	▲ 1960	▲ 1969									▲ 1963						▲ 1965						
	PLATING								▲ 4			▲ 1964													
PROGRAM		Shuttle Technology	ASSET	Shuttle Technology Proprietary Program	RVTO Studies for Voyager	Gemini		F4	Shuttle Technology			Mercury Gemini F4 Test LMP IRAD	Mercury Gemini	BGRV ASSET Typhon	BGRV F4 MOL	ASSET BGRV	BGRV	Mercury Gemini RVTO F4 BGRV	BGRV	ASSET	ASSET	Shuttle Technology	ASSET	Gemini BGRV ASSET	RVTO BGRV

1. R&D Test Procedures in Lab
2. R&D Test Showed Promise (Requires Modification of Tooling)
3. No Inplant Facilities – Technical Data Available
4. Development in Process
5. Eutectic Bond

Revised 11 May 1971

FIGURE 4.4–82

CARBON/CARBON DETAILS

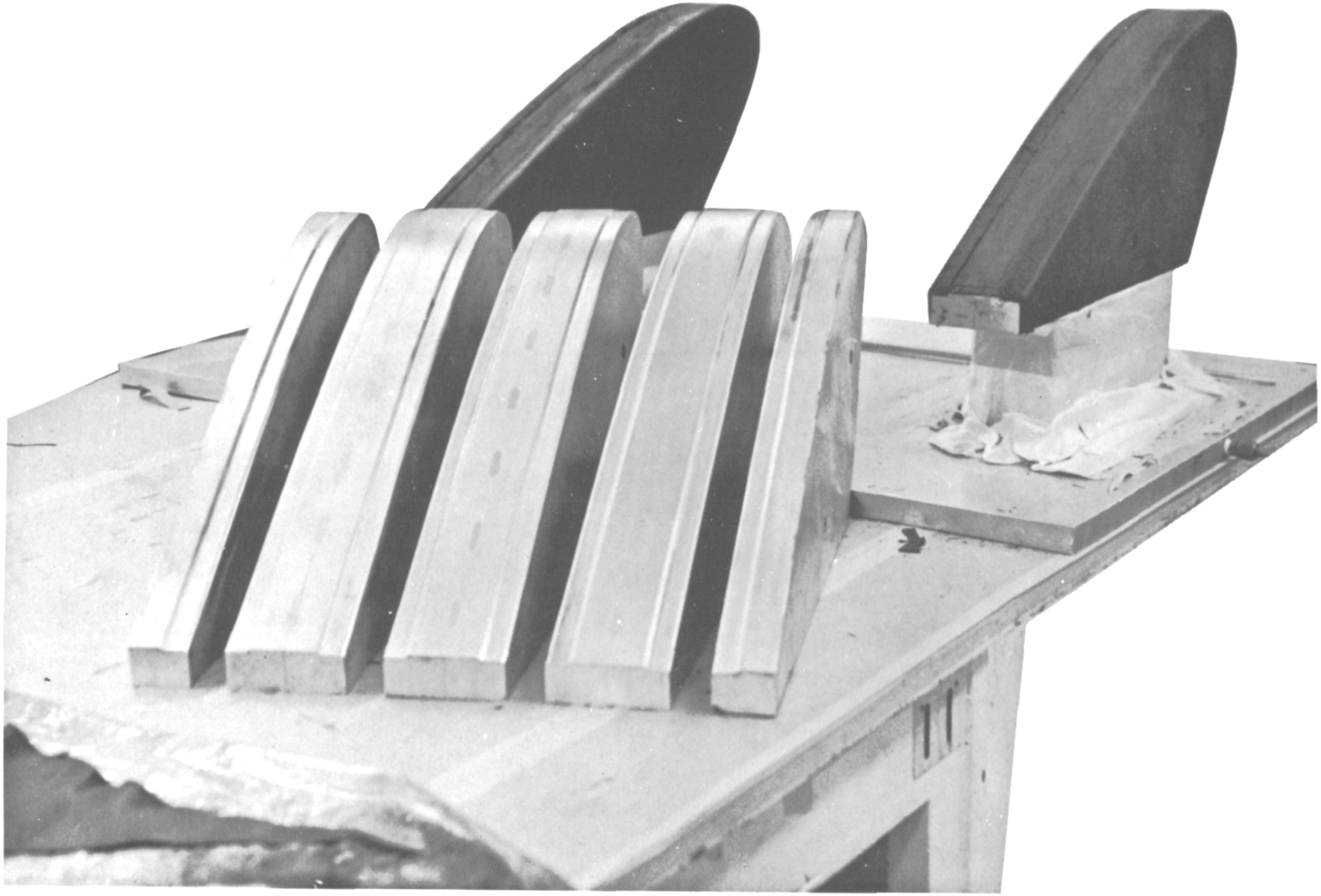
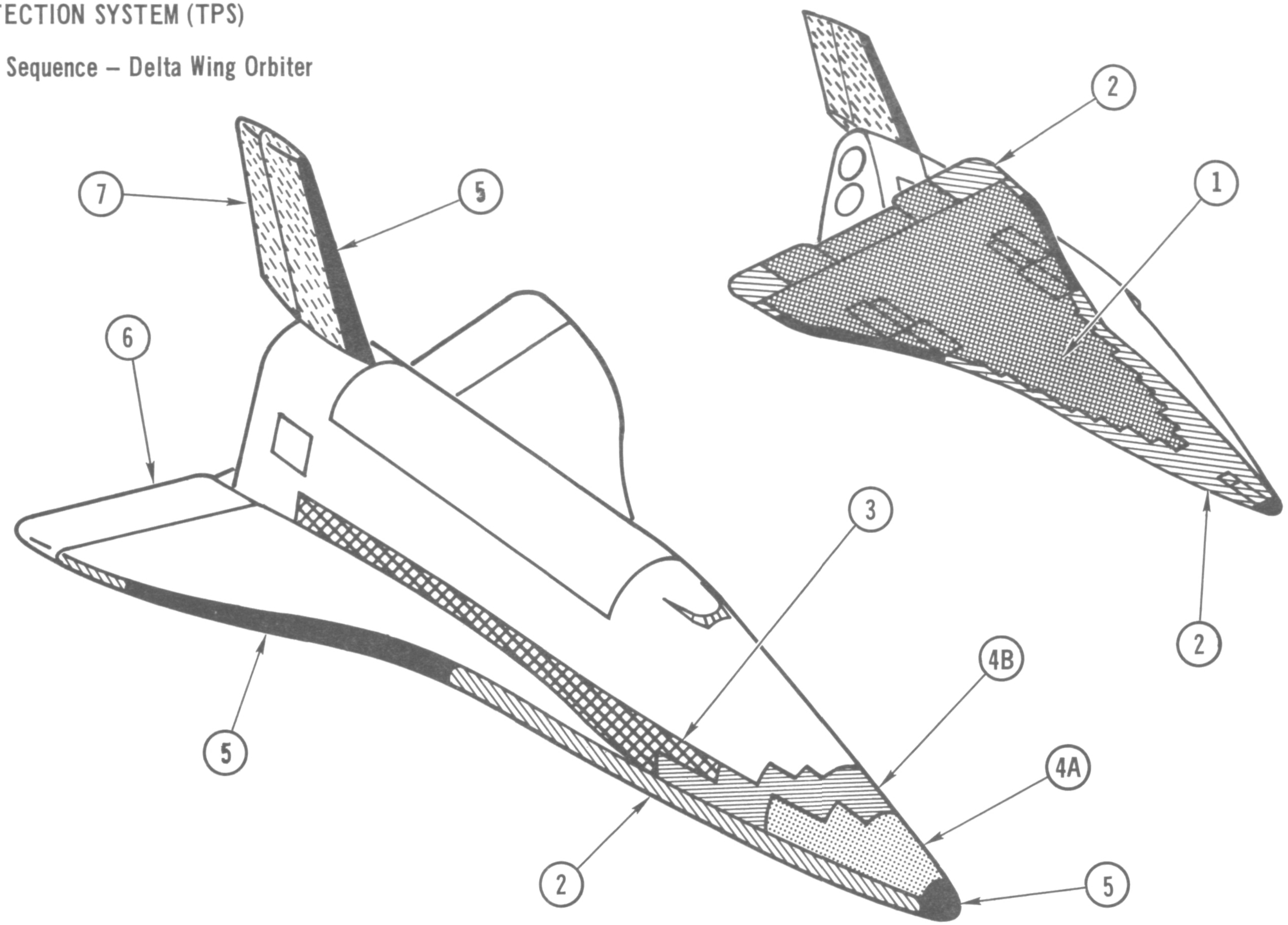


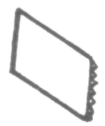
FIGURE 4.4-83

THERMAL PROTECTION SYSTEM (TPS)

Manufacturing Assembly Sequence – Delta Wing Orbiter



1. Nickel Superalloy Shingles (Hastelloy –X– Shingles)



- FORM CORRUGATIONS
- RESISTANCE WELD SKIN TO CORRUGATIONS
- HOT SIZE WELDED ASSEMBLY

2. Columbium Shingles

- FORM CORRUGATIONS
- ELECTRON BEAM WELD SKIN TO CORRUGATIONS
- STRESS RELIEVE PANELS
- APPLY PROTECTIVE COATING

3. Titanium Shingles

- FORM CORRUGATIONS
- RESISTANCE WELD SKIN TO CORRUGATIONS
- HOT SIZE WELDED ASSEMBLY

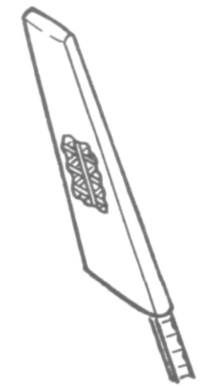
4A. Inconel 718 Shingles
4B. Rene´41 Shingles

- FORM CORRUGATIONS
- RESISTANCE WELD SKIN TO CORRUGATIONS
- HOT SIZE WELDED ASSEMBLY
- APPLY PROTECTIVE COATING

5. Carbon Bonded Carbon

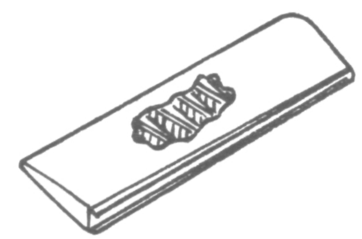
- LAY-UP TO SHAPE AND CURE UNDER PRESSURE
- PYROLYZE IN FURNACE
- REIMPREGNATE WITH RESIN AND PYROLYZE
- APPLY PROTECTIVE COATING
- ATTACH MOUNTING RINGS, FITTINGS, ETC.

7. Nickel Superalloy Hot Structure (Rene´41)



- FORM RIPPLED WEBS
- WELD CAPS TO WEBS TO FORM RIBS
- STRESS RELIEVE
- APPLY COATING
- ASSEMBLE RIBS IN STRUCTURE BUILD-UP
- ATTACH SKINS TO COMPLETE ASSEMBLY

6. Titanium Hot Structure (Columbium and Hastelloy –X– Shingles)



- FORM RIPPLED WEBS
- WELD CAPS TO RIPPLED WEBS TO FORM RIBS
- STRESS RELIEVE
- ASSEMBLE RIBS IN STRUCTURE BUILD-UP
- ATTACH SKIN TO COMPLETE ASSEMBLY

FIGURE 4.4–84

The more critical metallic TPS panel fabrication processes are: welding, coating, and fitting or alignment of the panels prior to final coating and installation. Again, these are items of concern, but do not appear at this time to be major impact items. We anticipate that continuing IRAD activities coupled with current NASA funded studies will minimize these problems.

Laboratory fabrication approaches and techniques for blanking, forming, drilling, welding, coating, inspecting and repairing have been developed for the various metallic panels, including coated columbium. It will be necessary, however, to optimize these for application to the manufacturing shops. This will be a continuing evolution during Phase C/D.

Carbon/carbon segments of formed shapes will be fabricated on tooling similar to that shown in Figure 4.4-83. They are then trimmed, drilled and fitted at the assembly or installation point. These techniques are considered state-of-the-art. After the parts are complete and trial fitted, but prior to final installation, they are given a surface protective coating. To avoid damage to carbon/carbon parts from handling, special handling methods and packaging techniques are planned. Also, additional parts will be made to allow for breakage.

A preliminary survey has been made of industry capabilities to produce the TPS materials in quantities required for the Space Shuttle. This survey indicated ample capacity exists to supply full requirements for this program.

A brief description for manufacturing of the TPS is presented in condensed form on the Manufacturing Assembly Sequence Chart Figure 4.4-84. The chart pictorially identifies specific areas on the vehicle where particular materials are to be used. Also, through the material identification code, brief manufacturing operations requirements for the particular material are indicated.

The Manufacturing Flow Assembly Sequence and Schedule are shown in Figure 4.4-85 while preliminary major tool, equipment, and process requirements are identified in Table 4.4-13

THERMAL PROTECTION SYSTEM (TPS)
METALLIC & CARBON/CARBON MANUFACTURING FLOW CHART & SCHEDULE
DELTA WING ORBITER

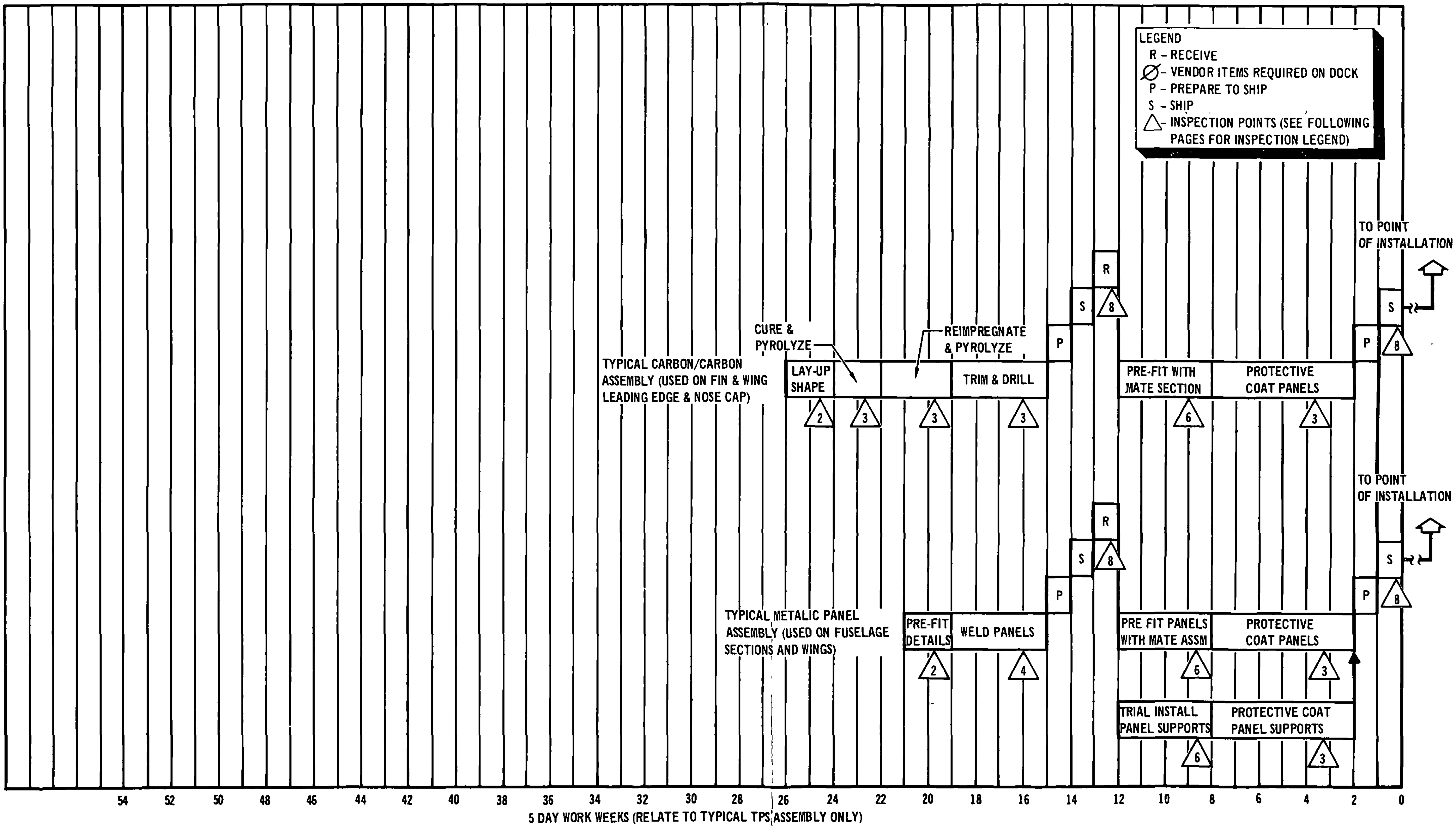


FIGURE 4.4–85

TABLE 4.4-13

THERMAL PROTECTION FABRICATION
AND EQUIPMENT REQUIREMENTS

Facility and Equipment Requirements	Facility and Equipment Availability
Area	
50,000 Sq. Ft.	Available Contractor
Crane	
5 Ton	Available Contractor
Major Equipment (Metallic Panels)	
Electron Beam Welders 2800°F Vacuum Heat	New Contractor
Treating and Coating Furnace (with Retort)	New Contractor
Temperature and Atmosphere Control Scurry Dip Tank	New Contractor
Cleaning Tanks	Available Contractor
Pickling Tanks	Available Contractor
Solvent Immersion Tank	Available Contractor
Resistance Seam and Spot Welders	Available Contractor
Grit Blast Cleaning Equipment	Available Contractor
Coating Curing Ovens	Available Contractor
Normally Equipped Aerospace Fabrication and Machine Shop	Available Contractor
(Carbon/Carbon Panels)	
4000°F Argon Atmosphere Furnace	New Contractor
Vacuum/Pressure Inpregnation Equipment	New Contractor
Curing Ovens (600°F)	New Contractor
Pyrolization Argon Furnace (4000°F)	New Contractor
Argon Atmosphere Furnace (4000°F)	New Contractor

TABLE 4.4-13 (Cont'd)

THERMAL PROTECTION FABRICATION
AND EQUIPMENT REQUIREMENTS (Continued)

Facility and Equipment Requirements	Facility and Equipment Availability
Laboratories (Continued)	
Quality Assurance	Available Contractor
X-Ray	
Manual and Automatic	Available Contractor
Processing Facility	
Carbon/Carbon Molding	New Contractor
Carbon/Carbon Machining	New Contractor
Boron Epoxy Molding	New Contractor
*Plating	New Contractor
*Bonding	Available Contractor
*Cleaning	Available Contractor
Sonic Inspection	Available Contractor
Identification	Available Contractor
Form Columbium	Available Contractor
Welding Columbium	Available Contractor
Stress Relieve Columbium	Available Contractor
Slurry Coating Columbium	Available Contractor
Forming Titanium	Available Contractor
Welding Titanium	Available Contractor
Forming Nickel Superalloy	Available Contractor
Welding Nickel Superalloy	Available Contractor
Stress Relieving Nickel Superalloy	Available Contractor
Coating Nickel Superalloy	Available Contractor

TABLE 4.4-13 (Cont'd)

THERMAL PROTECTION FABRICATION
AND EQUIPMENT REQUIREMENTS (Continued)

Facility and Equipment Requirements	Facility and Equipment Availability
Major Equipment (Continued)	
Dip Tank	Available Contractor
Ultrasonic Testing Equipment	Available Contractor
Major Tools (Nickel Superalloy Panels)	
Various Templates, Rough Blanks, Flat Pattern, Applied Trim, etc.	New Contractor
Template Set Ups	New Contractor
Power Brake Dies	New Contractor
Stretch Form Blocks	New Contractor
Form Dies	New Contractor
Trim Fixtures	New Contractor
Saw Fixtures	New Contractor
Assembly Fixtures	New Contractor
Weld Fixtures	New Contractor
(Carbon/Carbon Panels)	
Metal Molds	New Contractor
Trim Fixtures	New Contractor
Drill Fixtures	New Contractor
Saw Fixtures	New Contractor
Laboratories	
Non-Destructive Test	Available Contractor
Metal Finishing	Available Contractor
Protective Coating	Available Contractor

TABLE 4.4-13 (Cont.)

THERMAL PROTECTION FABRICATION
AND EQUIPMENT REQUIREMENTS (Continued)

Facility and Equipment Requirements	Facility and Equipment Availability
Processing Facility (Continued)	
Fastner Installation	Available Contractor
*Requires Modification of Existing Process	
Utilities	
90-100 PSI Filtered Factory Air	Available Contractor
115V 60∿ Electrical Outlet	Available Contractor
440V 60∿ Electrical Outlet	Available Contractor
Argon and Helium Supply	Available Contractor

4.4.12 Orbiter Final Assembly

4.4.12.1 Final Assembly - Upon receipt of the Orbiter fuselage and other major subassemblies flight systems. The Orbiter will be final assembled Figure 4.4-86.

FINAL ASSEMBLY

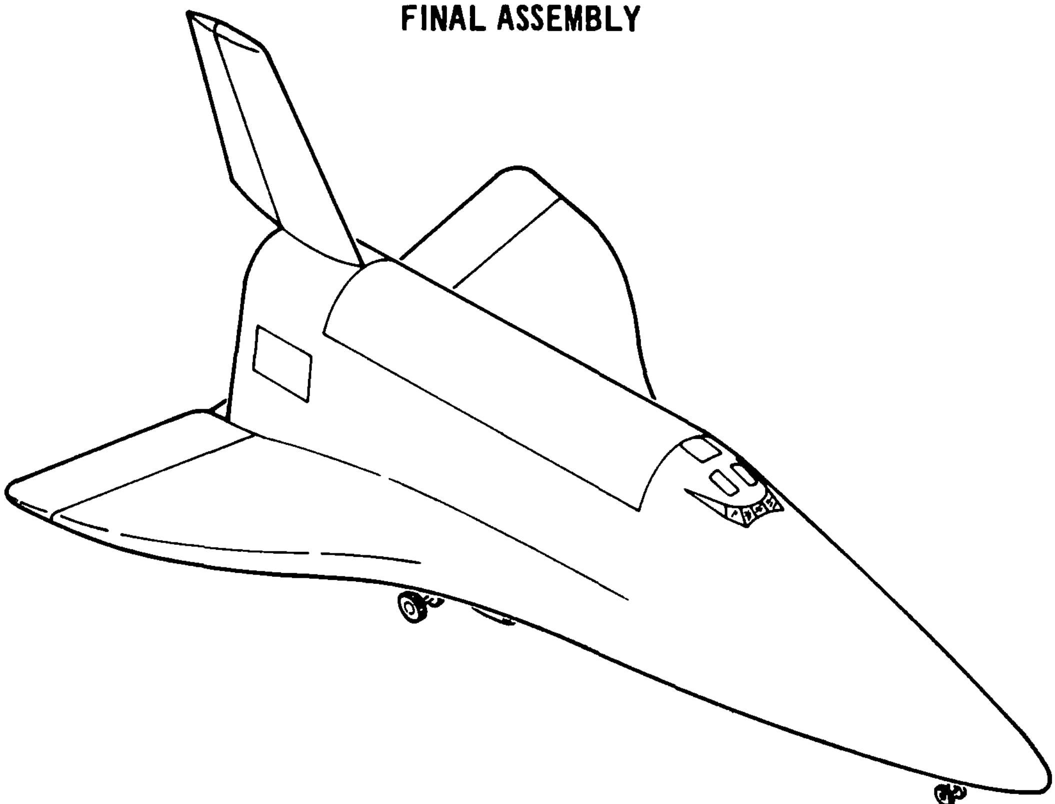


FIGURE 4.4-86

4.4.12.2 Manufacturing Site - It is recommended that the Orbiter be final assembled utilizing two of the existing bays of the vertical assembly building at K.S.C.

4.4.12.3 Manufacturing Approach - The final assembly approach include the installation of wings, elevons, vertical fin, and rudder assemblies, main landing gear, air breathing engines/pods and certain deleted portions of the thermal protection system. Also, preliminary manufacturing system test are performed.

4.4.12.4 Manufacturing Operations - A pictorial illustration of the manufacturing flow and a flow chart and schedule are shown in Figures 4.4-87 and 4.4-88.

FINAL ASSEMBLY – KSC

Manufacturing Assembly Sequence – Delta Wing Orbiter

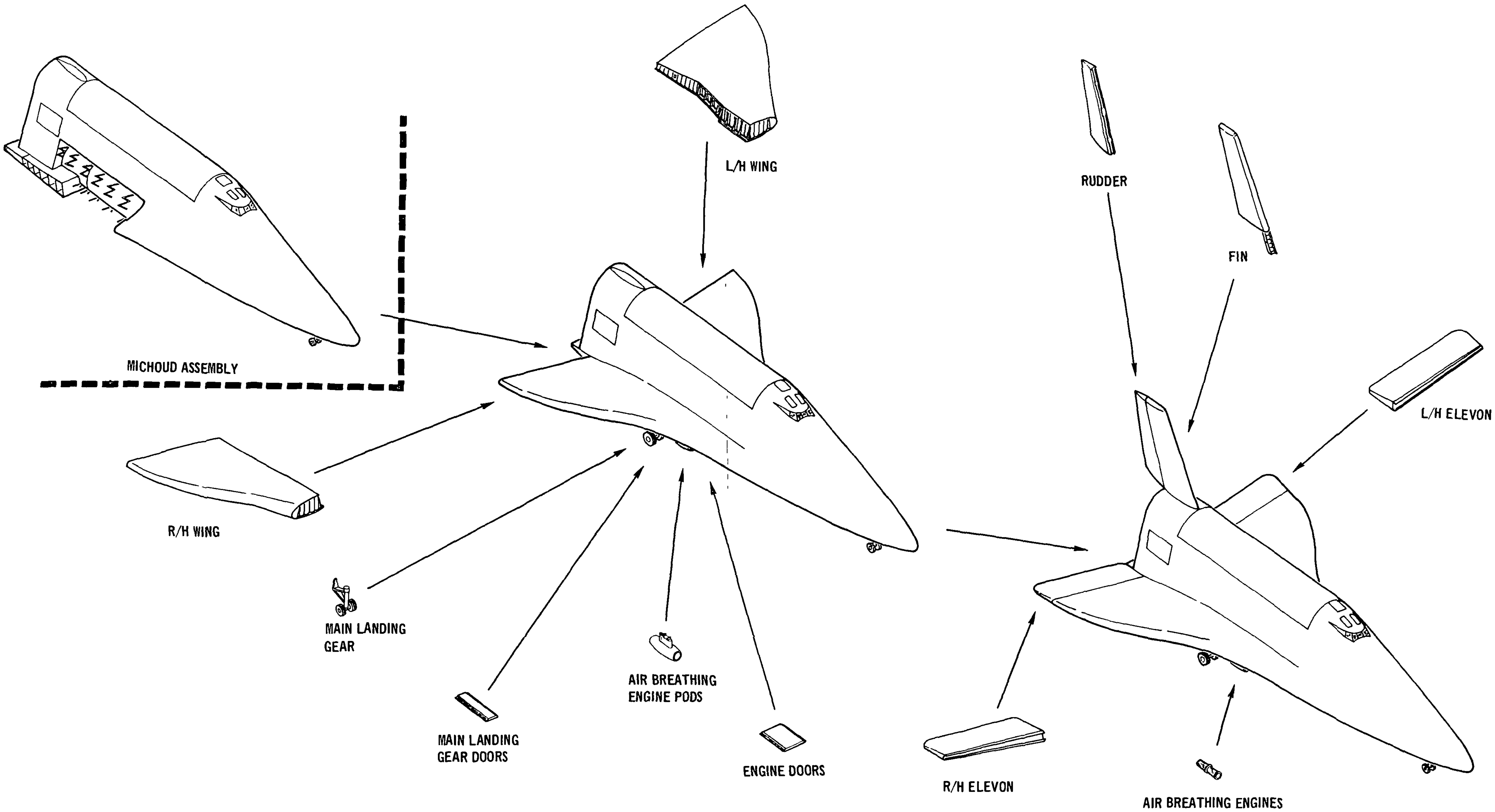


FIGURE 4.4–87

FINAL ASSEMBLY
MANUFACTURING FLOW CHART & SCHEDULE
DELTA WING ORBITER

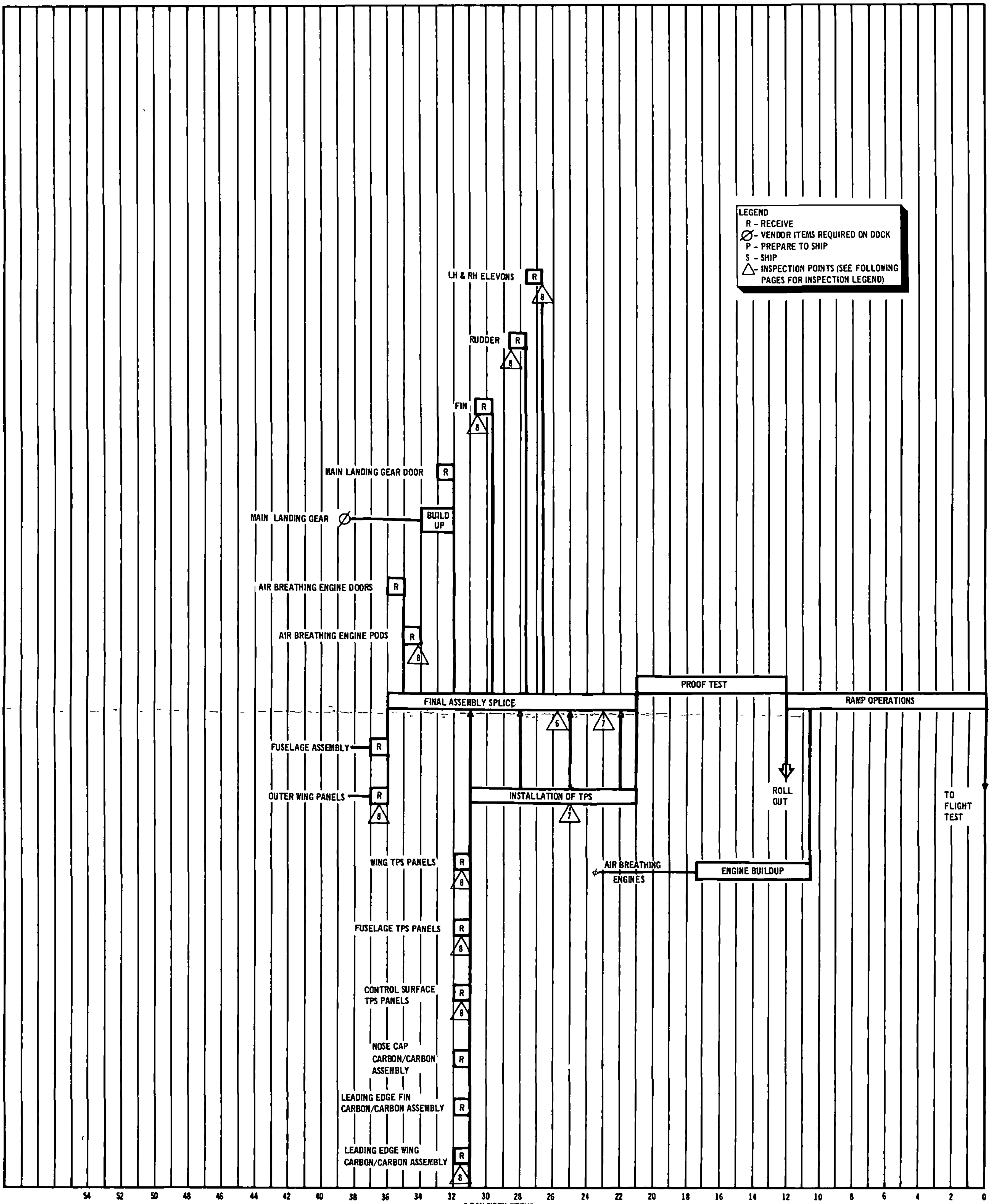


FIGURE 4.5-88

The fuselage assembly is placed on tools which will provide the necessary adjustment to effect proper alignment prior to final attachment of the wing assemblies. The left and right hand wing assemblies are removed from their shipping containers and placed on the tools reference Figure 4.4-89. These are simple tripod support members and afford proper movement to null out the errors incurred during wing and fuselage construction. Also, it will stabilize the wings in the correct position while structural attachment to the fuselage is completed. This set up is monitored periodically during the splice cycle to insure conformance to the tolerance parameters.

After the wings have been affixed in their proper position the main landing gear and doors are installed, cycled and checked for clearance and function.

Concurrent with installation of the main landing gear, the fin assembly is hoisted into position and lowered into the fuselage cavity. Also, the elevons are installed and operated for functional checkout. Subsequently the rudder is likewise installed, given proper functional checks. (Figure 4.4-87)

After completion of the preceding major splice functions the vehicle is lowered onto the landing gear and moved to the next work position. At this point work stands are moved into place and the remainder of the TPS at wing to fuselage and fin to fuselage splice is installed. Also, the carbon/carbon leading edges and chines are installed.

Progressively, as the previous assembly and structural installation operations are completed, their respective pneumatic, hydraulic, mechanical, and electrical systems hook-ups occur. Systems hook-ups are validated and preliminary manufacturing check out of the systems accomplished. This includes such things as electrical systems continuity/discontinuity and resistance checks, pneumatic and hydraulic systems pressure and leak checks, landing gear cycle checks, control surface functional checks.

FINAL ASSEMBLY – TOOLING CONCEPTS

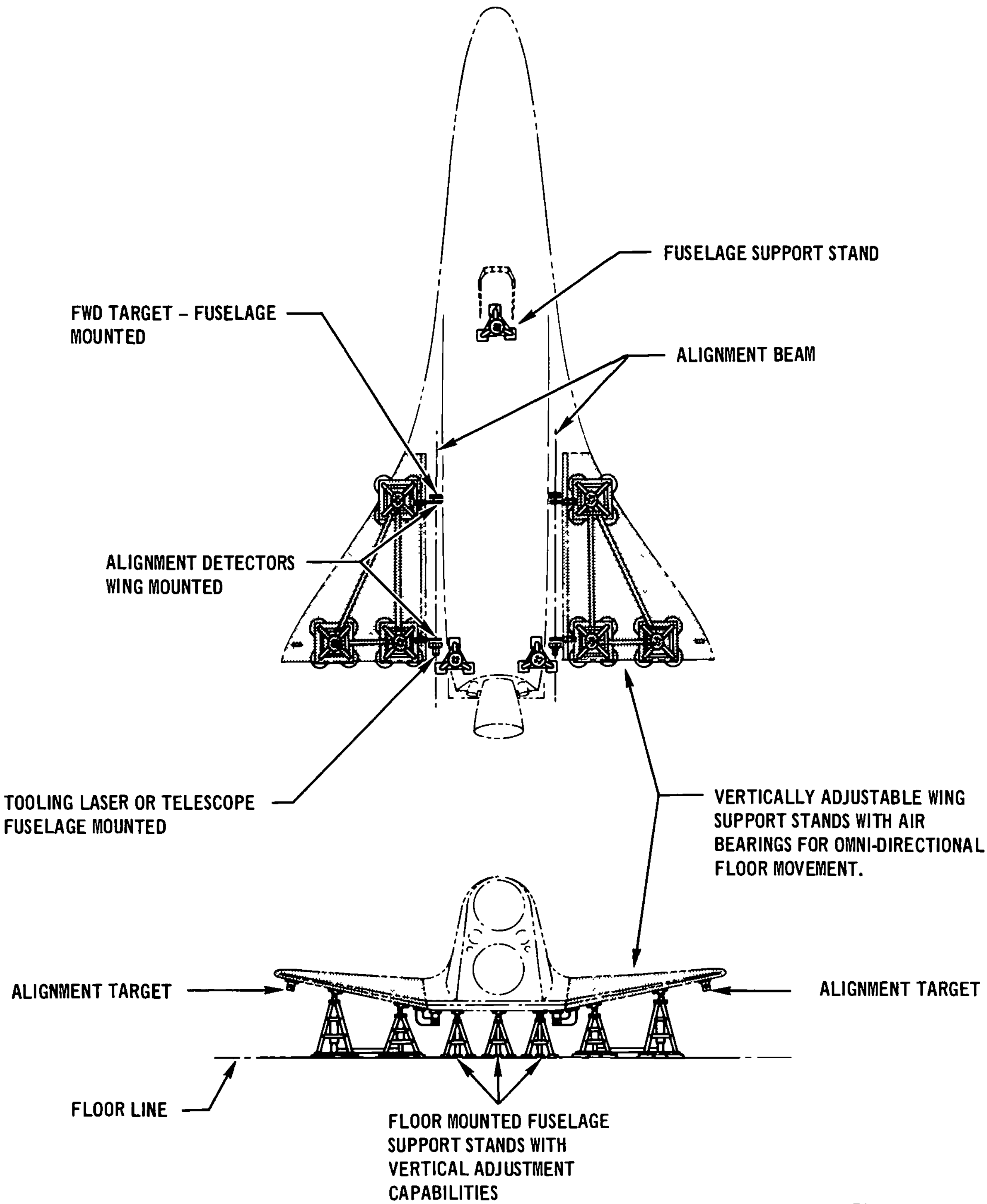


FIGURE 4.4–89

After completion of the Thermal Protection System installations, the vehicle moves to a theoretical ramp operations position where installations of the vehicle's engines and thrusters occur.

Rigging functions will be performed in a manner similar to the DC-10 where precise angle indicators are applied to the surface controls. Read out is through digital displays and is controlled at a central position and the rigging crew is directed by intercommunication.

Also during ramp operations, final systems tests and check out will be performed, as well as final preparations and installation of equipment and sensors, for flight test operations.

4.4.12.5 Major facilities, equipment, and tools are listed in Table 4.4-14

TABLE 4.4-14

ORBITER FINAL ASSEMBLY FACILITY AND EQUIPMENT REQUIREMENTS

Facility and Equipment Requirements	Facility and Equipment Availability
Area	
52,000 sq. ft.	Available K.S.C. 2 bays of V.A.B.
Clear Height	90'
Crane Capability	
15 tons	Available K.S.C.
Major Equipment	
(Modified) SIB Transporter	Available Michoud
Quick Response	Available K.S.C.
Major Tools	
Leak Check Equipment	Available K.S.C.
For LOX, LN_2 Tank Lines, DPU Fuel Tanks and Crew Station Module	Available K.S.C.
Functional Check Out Equipment for On-Board Systems, such as Hydraulic, Electrical, Communication, Avionics, Flight Controls, Landing Gear, Engine Run, Etc.	Available K.S.C.
Utilities	
90-100 PSI Filtered Factory Air	Available Contractor
115V 60HZ Electrical Outlets	Available Contractor
440V 60HZ Electrical Outlets	Available Contractor
Normal Lighting	Available Contractor

4.5 GROUND DEVELOPMENT AND VERIFICATION TESTS - The Space Shuttle ground and flight test programs are divided into four major types: (1) Development, (2) Verification, (3) Acceptance, and (4) Launch Site. Development and Verification are primarily engineering tests and Acceptance and Launch Site are manufacturing and operational tests.

Ground Development and Verification Tests will be conducted on certain test articles, components and engineering test setups to the extent necessary to obtain design data and performance requirements. All testing will be done to satisfy engineering test requirements and will verify functional integration, dynamic characteristics, structural adequacy, reusability and/or ultimate strength.

There are seven test groups which require test articles for the Space Shuttle Development test program. They are: (1) Airframe, (2) Propulsion, (3) Avionics, (4) Crew Station (includes ECLS and Crew System), (5) Power Supply, (6) Integrated Vehicle, and (7) Flight Simulators and Mockups.

Test Group number (8) is for Ground Support Equipment (GSE) which will not require dedicated test articles, with the exception of approximately 70% of the new GSE propulsion components which will be development tested primarily by the vendor. The Logic and Arithmetic Modules of the Monitor, Display and Control Unit (MDAC) will be tested in conjunction with the ground support software. GSE facility support requirements for fluids, power, handling and pneumatics are identified in report MDC E0388 Ground Support Equipment.

The selection of test facilities will be based on the size of the test article, and the test to be performed vs individual facilities availability. Prime consideration has been given to the utilization of existing contractor and government facilities with minimum cost for construction and/or modification to meet specific test requirements.

4.5.1 Wind Tunnel Group Testing

4.5.1.1 Facility requirements for wind tunnel group testing are: Space Shuttle wind tunnel testing will be conducted in existing NASA and contractor facilities with Aerodynamic, Thermodynamic, Loads, Structural Dynamics and Propulsion testing capabilities. Candidate wind tunnel facilities have been evaluated based upon test conditions and model size. Final test site locations will be selected based upon multiple objective satisfaction and test model scales that are compatible with a wide range of facilities and test conditions.

4.5.2 Airframe Group Testing

4.5.2.1 Facility Requirements - Facility requirements for Space Shuttle airframe group testing are: Engineering structures test laboratories, which include all or part of the following capabilities: Pressure, Mechanical and Aerodynamic Loads; Thermal Environments; Mechanical Vibration, Acoustic, Shock/Acceleration Loads; Zero "G" Simulation; Vacuum Environments; plus all ancilliary data acquisition and reduction equipment.

In making the baseline test facility selections, uppermost consideration was given to the utilization of existing government and contractor structural test facilities based on test requirements recognition and integration to formulate basic test objectives. Test article selections and test implementation plans were generated as discussed in Report E0308, Part 111-5. After establishing the physical size and test parameters for the individual test articles, structural test facilities were reviewed and selections were made based upon their applicability and availability at the time of test. While the study scope does not permit definition of equipment requirements such as size and/or quantities, the noted facilities are all associated with and have been used for testing articles similar to Space Shuttle vehicle components. Until further definitions of testing are generated it is implied that applicable test equipment exists at each of the selected test facilities.

Airframe Group Testing (Booster)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Left (or Right) Side Wing & Fins with Aft Thrust Structure and Wing Carrythrough	Structural & Dynamic	MMC-Baltimore	X				10-74	5-76
Left (or Right) Rudder	Structural & Dynamic	MMC-Baltimore	X				11-74	4-75
Left (or Right) Elevon	Structural & Dynamic	MMC-Baltimore	X				11-74	4-75
Main LH2 Tank Assembly (Not Insulated)	Structural & Dynamic	MSFC Dynamic Test Stand Bldg. 4557	X				10-74	2-76
Intertank Section with Left (or Right) Canard	Structural & Dynamic	MSFC-Bldg. 4619	X				9-74	12-75
Main LO2 Tank Section	Structural & Dynamic	Michoud Hydro/Test	X				12-74	5-75
Forward Fuselage Section	Structural & Dynamic	MDC-ST. Louis	X				12-74	8-75
	Acoustic	MSC-Houston	X					
Main Landing Gear	Metering Pin Devel.	Vendor	X				4-75	7-75
	Structural & Dynamic	MDC-Long Beach	X					
Nose Landing Gear	Metering Pin Devel.	Vendor	X				4-75	9-75
	Shimmy	WPAFB	X					
	Structural & Dynamic	MDC-Long Beach	X					

Airframe Group Testing (Booster) (continued)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Airbreathing Engine Forward Fuel Tank, Left (or Right) Side	Structural & Dynamic	MDC-Huntington Beach	X				11-74	4-75
TPS Panels and Leading Edge Segments (equal to 20% of Vehicle TPS Weight)	Thermal, Structural & Dynamic	MDC-St. Louis, NASA & AFFDL Labs	X				1-75	3-76

Airframe Group Testing (Orbiter)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Wing-Aft Fuselage. Left (or Right) Wing Structure, Wing Carrythrough, Thrust Structure, Aft LH2 Tank Section with Frames, Fin Root Support and Aft Vehicle Tie	Structural & Dynamic	MSFC-Bldg. 4619 Load Test Annex Extension	X				3-75	3-77
	Heat Balance	NASA Lewis	X					
50% Section of Wing Leading Edge	Structural & Dynamic,	MDC-St. Louis	X				1-75	5-75
	Compatibility	MSFC-4619	X					
	Thermal	WPAFB	X					
Airbreathing Engine Pods with Mechanism	Functional & Dynamic	MDC St. Louis	X					
	Structural	MSFC-4619	X				1-75	7-75
Elevon (& Elevon Element)	Structural & Dynamic	MSFC-4619	X				1-75	5-75
	Thermal Acoustic	MDC-St. Louis	X	X		100K		
Main Landing Gear	Metering Pin Devel.	Vendor	X				1-75	5-75
	Structural & Dynamic	MDC-Long Beach	X					
Vertical Fin Torque Box	Structural & Dynamic	MDC-St. Louis	X				1-75	6-75

Airframe Group Testing (Orbiter) (continued)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Vertical Fin Leading Edge	Compatibility Structural & Dynamic	MDC-St. Louis	X				1-75	6-75
	Thermal	WBAFB	X					
Rudder (& Rudder Element)	Compatibility Thermal, *Acoustic, Structural & Dynamic	MDC-St. Louis	X	X			1-75	6-75
On-Orbit LO2 Tank	Structural & Dynamic	MDC-St. Louis	X				4-74	2-75
On-Orbit LH2 Tank	Structural & Dynamic	MDC-St. Louis	X				3-74	4-75
	Vibro Acoustic	MSFC	X					
	Heat Balance	MSC	X					
Airbreathing Engine Fuel Tank	Structural & Dynamic	MDC-Huntington Beach	X				6-74	11-74
Nose Landing Gear	Metering Pin Devel.	Vendor	X				1-75	9-75
	Shimmy	WPAFB	X					
	Structural & Dynamic	MDC-Long Beach	X					
Nose Cap	Structural & Dynamic	MDC-St. Louis	X				5-75	8-75
	Thermal	WPAFB	X					
Center Fuselage LO2 & LH2 Tank Sections with Frames Crew Compartment and Airlock Forward Vehicle Tie, Secondary LH2 Tank and Access Door	Structural, Dynamic, & Acoustic	MSFC-4670 S-IC Stand	X	X		325.K	7-75	1-78

* Mod cost shown on Elevon/Elevon Element.

Airframe Group Testing (Orbiter) (continued)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Forward Fuselage Section with Nose Landing Gear Backup Structure	Structural, Dynamic, & Heat Balance	MDC-St. Louis	X				10-74	6-77
Cargo Door	Structural & Dynamic	MDC-St. Louis	X				9-74	7-75
Radiator	Structural & Dynamic	MDC-St. Louis	X				8-74	5-75
Speed Brake	Structural & Dynamic	MDC-St. Louis	X				2-75	10-75
Nose Landing Gear Doors	Structural & Dynamic	MDC-Long Beach	X				2-75	8-75
	Compatibility	St. Louis	X					
Main Landing Gear Door	Structural & Dynamic	MDC-Long Beach	X				2-75	9-75
	Compatibility	MSFC-4619	X				2-75	9-75
Airbreathing Engine Door	Structural & Dynamic	MDC-St. Louis	X				2-75	9-75
	Compatibility	MSFC-4619	X					
ECLS N2 + 02 Tanks	Structural	MDC-St. Louis	X				4-74	8-74
Helium Tank	Structural	MDC-St. Louis	X				4-74	8-74
Water Tank	Structural	MDC-St. Louis	X				4-74	8-74
Cargo Deployment Mechanism	Structural, Dynamic & Functional	MDC-St. Louis	X	X*		375.K	7-75	5-76

* Modification of test facility consists of installation of a reinforced concrete slab to make a zero "g" bed for air bearings.

Airframe Group Testing (Orbiter)(continued)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Drag Chute	Thermal	MDC- St. Louis,	X				9-74	7-76
	Functional	China Lake Sled Test	X					
Selected TPS Panels and Backup Structure (equal to 20% of Total Vehicle TPS Weight)	Thermal, Structural & Dynamic	MDC NASA & AFFDL Labs	X				9-75	5-77

4.5.3 Propulsion Group Testing - Facilities requirements for Space Shuttle Propulsion Group Testing are:

4.5.3.1 Main Propulsion Integration Testing - facilities capable of mounting the fuselage section of the respective vehicles and reacting the thrust loads resulting throughout the main engines gimballing envelope and full firing duration. This includes flame deflectors with adequate cooling water. Propellant and gases storage and transfer requirements are essentially the same as required for the operational launch complex.

4.5.3.2 Attitude Control Propulsion System and Auxiliary Power Unit Integration Testing (and Including Orbit Maneuvering System Integration Testing for Orbiter) - Since these systems have common propellant storage systems in both the Booster and Orbiter, they are tested in conjunction with each other for each vehicle to evaluate systems interactions and to minimize the quantity of test hardware required. The test facilities must be capable of accepting the test system in the respective spatial arrangements of the Booster and Orbiter installations. Fluids and instrumentation requirements are stated in Report MDC E0308, Part III-5. In addition, the facilities for the Orbiter systems testing must also be capable of providing altitude simulation for the two RL-10 engines of the Orbit Maneuvering System.

4.5.3.3 Air Breathing Engines Fuel Subsystem Integration Testing - facilities capable of accepting the subsystem test articles which are arranged spatially as in the flight vehicle installation (except reduced fuel capacities of the test tankage in the case of the Booster) and storing, supplying, and receiving JP-4 fuel at system operational conditions.

4.5.3.4 Air Breathing Engine Installation Compatibility Testing - a propulsion wind tunnel capable of accepting a single air breathing engine installation test article and providing altitude and air flow simulation of the air breathing engines flight regime.

4.5.3.5 Main Engine Testing - Facilities should be provided by the main engine manufacturer or by the NASA to the main engine manufacturer for their testing. These facilities would also be employed for tests of compatibility between the main engine and pertinent interfacing Booster and Orbiter hardware.

4.5.3.6 Flight Readiness Firing (FRF) Tests of Complete Vehicles - Facilities required are similar to those for the Main Propulsion Integration Testing although firing durations will be shortened and the vehicles will be completely assembled. In addition, the facilities for the Orbiter testing must be capable of providing altitude simulation for the two RL-10 engines of the Orbit Maneuvering System. Facilities for Booster testing are identical to those required for the operational launch complex.

4.5.3.7 Facilities Construction/Modification - The following table identifies facilities baselined for propulsion group facilities. Because of the similarities in requirements for Main Propulsion Integration Testing and FRF testing, and the commonalities of these requirements with operational launch complex requirements, these test operations are baselined for the KSC Launch Complex #39. Scheduling compatibility exists and this approach offers the advantages of developing flight vehicles, GSE, and launch complex compatibility. Modification costs for the operational launch complex are presented in Report MDC E0308, Part III-3, "Operations." Modification costs in the following table are delta costs for the noted tests and include:

4.5.3.8 Booster Main Propulsion Integration Testing - Modify Pad B to increase strength of flame deflector anchorage to resist unbalanced load of engines gimballing. Provide higher strength vehicle holddown pins for high forces when near propellant depletion on one existing mobile launcher that is otherwise modified for Space Shuttle operational use.

4.5.3.9 Orbiter Main Propulsion Integration Testing and FRF Testing - Modify one existing mobile launcher to have a special superstructure for mounting either the propulsion test article or the complete Orbiter vehicle in a manner similar to that of the operational vehicle mounting on the Booster; and, to position the main engines over the Pad B flame deflector. For FRF testing only, add an altitude simulation system for the two RL-10 engines.

Propulsion Group Testing (Booster)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Interim use of fuselage section of #2 production flight vehicle with main propulsion system installation and 12 prototype main engines.	Develop and verify tank loading and system performance characteristics	Operational Launch Complex #39 at KSC Pad "B"	X	X		$50.K*	5-76	4-77
ACPS - System Integration Test Unit	Verify ACPS System	MDC** Sacramento	X				4-75	8-77
Single Air Breathing Enging/Canard Segment Test Unit	Evaluate Air Start Modes and Fire Suppression System	USAF AEDC 16-T Wind Tunnel	X				10-74	1-75
APU - Test Unit	Verify APU System	MDC** Sacramento	X				3-75	2-56
ABES - Fuel Subsystem Test Unit	Demonstrate System Capabilities	MDC-DAC Fuel System Laboratories	X				12-74	11-75
Interim use of each complete Booster prior to first vertical flight	Flight Readiness	Operational Launch Complex #39 KSC (existing Pad "B")	X Δ				1-78 (not continuous)	2-79

* Cost Δ over operational modification
** NASA-WSTF to be evaluated Post Phase B
Δ As modified for operational use.

Propulsion Group Testing (Orbiter)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Interim use of fuselage section of flight vehicle with main propulsion system and 2 prototype main engines	Develop and verify tank loading and system performance characteristics	Operational Launch Complex #39 at KSC Pad "B"	X	X		$2.1M**	6-76	5-77
ACPS - System Integration Test Unit	Verify ACPS System	MDC* Sacramento	X				2-75	1-78
Air Breathing Engine Installation Compatibility Unit	Verify Compatibility	USAF AEDC-16T Wind Tunnel	X				1-75	5-75
APU - Test Unit	Verify APU System	MDC* Sacramento	X				2-75	3-76
ABES - Fuel Subsystem Test Unit	Demonstrate System Capabilities	MDC-St. Louis Fuel System Laboratory	X				2-75	3-76
OMS - Test Unit	Demonstrate System Capabilities	MDC* Sacramento	X				10-75	8-77
Interim use of each complete Orbiter prior to first vertical flight	Flight Readiness Firing	Operational Launch Complex #39 KSC (existing Pad "B")		X		$1.0M**	1-78	2-79

* NASA-WSTF to be evaluated Post Phase B.
** Cost Δ over operational modification.

4.5.4 Avionics Group Testing (Booster)

4.5.4.1 Facility Requirements for Space Shuttle Avionics Group testing are:

Engineering facilities laboratories for development and integration of the complete Avionics, flight control, electrical and hydraulic components and systems.

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Avionics System Test Unit (ASTU)* including electrical system	Development and Integration of the Avionics System	MDC-Huntington Beach Avionics Laboratory	X				10-74	4-78
Software Verification Complex (employing ASTU hardware) and computational equipment	Verification of Software	MDC-Huntington Beach Avionics Laboratory	X				1-76	4-78

Avionics Group Testing (Orbiter)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Avionics System Test Unit (ASTU)* including electrical system	Development and Integration of the Avionics System	MDC-St. Louis Avionics Laboratory	X				10-74	7-79
Software Verification Complex (employing ASTU hardware) and computational equipment	Verification of Software	MDC-St. Louis Avionics Laboratory	X				1-76	3-76
		Same	X				10-77	4-78

* The test unit will be available until 7-79 for Flight Test Support.

4.5.5 Crew Station Group Testing (Booster)

4.5.5.1 Facility Requirements for Space Shuttle Crew Station Group testing are: Engineering test laboratories for Environmental Control and Life Support system development and performance verification.

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Cabin Air Subsystem Test Unit	Development and Verification	MDC-Huntington Beach (ECLS) Laboratory	X				7-74	6-75
Cabin Cooling Subsystem Test Unit	Development and Verification	MDC-Huntington Beach (ECLS) Laboratory	X				7-74	6-75
Equipment Cooling Subsystem Test Unit	Development and Verification	MDC-Huntington Beach (ECLS) Laboratory	X				7-74	6-75
Crew Station Group Testing (Orbiter)								
Cabin Air Subsystem Test Unit	Development and Verification	MDC-St. Louis (ECLS) Laboratory	X				7-74	6-75
Cabin Cooling Subsystem Test Unit	Development and Verification	MDC-St. Louis (ECLS) Laboratory	X				7-74	6-75
Equipment Cooling Subsystem Test Unit	Development and Verification	MDC-St. Louis (ECLS) Laboratory	X				7-74	6-75
Crew Compartment (Escape System sled test)	Functional Verification	Hurrican Mesa	X				10-74	1-75
Radiator (TVT) fullscale	Verification of Heat Rejection Efficiency	NASA Chamber MSC	X				10-74	1-75

4.5.6 Power Supply Group Testing (Booster)

4.5.6.1 Facility Requirements for Space Shuttle Power Supply Group testing are: Engineering test laboratories capable of testing Electrical and Hydraulic components, subsystems and integrated systems including FCS and Avionics.

Test Article (One Each	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Hydraulics and Controls Test Unit* (HCTU)	Development and Integration of the Hydraulic System and FCS	MDC-Huntington Beach Control Dynamics Laboratory	X				7-74	12-75
Power Supply Group Testing (Orbiter)								
Hydraulics and Controls Test Unit* (HCTU)	Development and Integration of the Hydraulic System and FCS	MDC-St. Louis Control Dynamics Laboratory	X				7-74	12-75

* The test unit will be available for Flight Test Support after 12-75.

4.5.7 Integrated Vehicle Testing

4.5.7.1 Facility Requirements for Space Shuttle Integrated Vehicle testing are: Hangar and/or Ramp space for one (1) Booster and one (1) Orbiter vehicle to perform integrated vehicle systems testing and ground vibration testing and suitable launch pad facilities to perform First Vertical Flight Vehicle Ground Firing Tests.

4.5.7.2 Facilities Construction/Modification - Integrated vehicle (systems) testing of the Space Shuttle, Booster and Orbiter vehicles, will be accomplished in the new addition to the vertical assembly building at KSC. Tests will verify integration of Electrical, Hydraulic, Avionics and ECLS systems, Flight test instrument calibration, vehicle Dynamic Response (ground vibration test) and First Vertical Flight Vehicle. Ground Firing tests which will be conducted on Pad "B" of Launch Complex #39. *Construction and modification costs will be shown in Report MDC E0308, Part III-3, Operations.

Integrated Vehicle Testing (Booster)

Facility Requirements for Space Shuttle Integrated Vehicle Testing are: the new addition to the VAB at Kennedy Space Center will be utilized for these tests.

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Interim use of Flight Vehicle #1	Systems Integration and Verification and Ground Vibration Testing	*New addition to VAB KSC	X				2-76	5-76
Same	Flight test Instrument Calibration	Same	X				2-77	3-77
Same	Dynamic Response	Same (Use U.S.A.F. Structural Dynamic GVT Test Rig)	X				2-76	5-76
Same	Electrical Power System Integration	Same	X				2-76	5-76
Same	Hydraulic System Integration	Same	X				2-76	5-76
Same	Avionics System Integration	Same	X				2-76	5-76
Same	ECLS System Integration	Same	X				2-76	5-76

Integrated Vehicle Testing (Booster) (continued)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Same	First Verticle Flight Vehicle Ground Firing Test	*LC#39 Pad "B" KSC	X				10-77	12-77

Integrated Vehicle Testing (Orbiter)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Interim use of Flight Vehicle #1	Systems Ingegration and Verification and Ground Vibration Testing	*New addition to VAB KSC	X				2-76	5-76
Same	Flight Test Instrument Calibration	Same	X				2-77	3-77
Same	Dynamic Response	Same (use USAF Structural Dynamic GVT Test Rig)	X				2-76	5-76
Same	Electrical Power System Integration	Same	X				2-76	5-76
Same	Hydraulic System Integration	Same	X				2-76	5-76
Same	Avionics System Integration	Same	X				2-76	5-76
Same	ECLS System Integration	Same	X				2-76	5-76
Same	1st Vertical Flight Vehicle Ground Firing Test	*LC#39 Pad "B" KSC	X				10-77	12-77

4.5.8 Flight Simulators and Mockups

4.5.8.1 Facilities Requirements for Space Shuttle Flight Simulators and Mockups are: Engineering flight simulation laboratories to perform design and human factors evaluation and crew system integration and verification of procedures, functionality and habitability.

Flight Simulators and Mockups (Booster)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Man-in-the-Loop Flight Simulator	Engineering and Design Analysis Support	MDC-St. Louis	X				7-72	6-76
One "G" Habitability Mockup •Flight Deck, Controls and Displays •Lighting •Crew Ingress/Egress	Design and Human Factors Evaluation	MDC-Huntington Beach	X				4-72	10-75

Flight Simulators and Mockups (Orbiter)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Man-in-the-Loop Flight Simulator	Engineering and Design Analysis Support	MDC-St. Louis	X				7-72	6-76
One "G" Habitability Mockup •Flight Deck, Controls and Displays •Lighting •Crew Ingress/Egress	Design and Human Factors Evaluation	MDC-St. Louis	X				4-72	9-75
Crew Station Zero "G" Mockup	Same	NASA 0 "g" Aircraft	X				9-75	9-76
Part Task Zero "G" Mockup	Same	Same					9-75	9-76

Flight Simulators and Mockups (Orbiter) (continued)

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Habitability Neutral Bouyancy Mockup	Same	NASA Water Tank	X				1-75	12-75
Part Task Neutral Buoyancy Mockup	Same	Same	X				1-75	12-75

4.5.9 Mated Vehicle Test

4.5.9.1 Facility Requirements of the Space Shuttle mated vehicle test are: Engineering laboratories to verify system operation and structural, dynamic and ultimate strength of the vehicle separation system and verify dynamics of the mated vehicles using a scale model of the vehicle structural arrangement.

Electromagnetic Compatibility tests will be conducted on Launch Complex #39 Pad "A" at KSC prior to first VTO, Vehicle Low Level Modal Response to establish dynamic characteristics and vehicle coupling effects will be conducted at KSC.

4.5.9.2 Facilities Construction/Modification - *Construction costs for the new addition to the VAB and modification cost to LC#39 Pad "A" will be shown in Report MDC E0308, Part III-3, Operations.

Test Article (One Each)	Test Type	Test Facility	Existing	Modified	New	Cost	Test Start	Test Complete
Electromagnetic Compatibility	Verify EMI	*KSC LC#39 Pad "A"	X	X			4-78	5-78
Separation System (Engineering Test Setup)	Verify System and Structural Dynamics	MDC St. Louis	X	X			4-75	4-76
Dynamics of Mated Vehicles (Scaled Model of Vehicle Structural Arrangement)	Verify Dynamics	MDC St. Louis	X	X			7-73	12-74
Low Level Modal Response	Establish Dynamic Characteristics	New addition to the VAB KSC USAF Dynamic Test Equip.	X				3-78	4-78

4.6 HORIZONTAL FLIGHT TESTS (AIRPLANE MODE) - Five (5) candidate locations have been evaluated for the Space Shuttle Booster and Orbiter Horizontal Flight Development and Verification test programs.

- Kennedy Space Center (KSC) Florida, because it has been recommended as the primary location for vehicle final assembly and operational launch.
- Eglin AFB, Florida because of its existing test facilities, and proximity to the final assembly site.
- Edwards AFB, California because of its existing flight test facilities, which can support a vehicle of the size and weight of the Space Shuttle Booster and Orbiter, with minimum expense for new construction and/or modification of existing facilities.
- Holloman AFB, New Mexico because of its existing test facilities.
- Patuxent River (NAS) Maryland because of its existing test facilities and proximity to the final assembly site.

These sites were compared on the basis of:

- Availability of test and support facilities and services for category I Flight Testing.
- Weather conditions conducive to experimental (VFR) flying.
- Normal and emergency landing areas, with minimum population overflight.
- Impact on other program activities.
- Cost for new facilities or modification to existing facilities.

4.6.1 High Risk Testing - Based upon the existing facilities and services available at Edwards AFB and the assumption that the horizontal flight test program could produce an all out emergency flight condition, due to high risk testing of propulsion (ABE) and/or flight control systems it is mandatory that adequate emergency landing sites are available within the test area. Figure 4.6-1, Test Support Facilities Comparison for Horizontal Test Sites, shows that of the three (3) prime test sites (KSC, Eglin AFB and Edwards AFB) considered, only Edwards AFB has suitable natural landing areas available for emergency landings of Space Shuttle size vehicles. Therefore, from an existing facilities and test requirement

HORIZONTAL FLIGHT TEST SUMMARY

TEST CATEGORY	TEST VEHICLE						TEST SITES	
	BOOSTER			ORBITER			KSC	FRC
	1	2	3	1	2	3		
Pre-Ferry	9			9			18	
Pre-First VTO*	260	13	61	253	13	60	165	495
Post-First VTO	87			59			132	14
Total on Site	347	13	61	312	13	60	297	509
Ferry	17			17				
TOTAL	438			402			840	

* Pre First-VTO Includes Pre-Ferry Hours

WHERE HORIZONTAL TEST

TEST TYPE	RECOMMENDED SITES	
	KSC	FRC
Shakedown, Acceptance	X	
Inflight Verification of Operational Cruise-Back and Landing Procedures and Navaids Both Vehicle and Operations Site	X	
High Risk Testing (Engine Airstarting, Engine Handling, Engine out Performance, Limits of Controlability, High Energy Landing Evaluation, Braking Tests)		X

Considerations

- o Emergency Facilities
- o Weather
- o Existing Test Facilities
- o Airspace
- o Common Test Base
- o Support Requirements

Test Support Facilities Comparison

Horizontal Test Site

Facility Requirement	Test/Vehicle Requirement	Candidate Test Site KSC	Eglin AFB	Edwards AFB
Hangar	75,000 Sq. Ft. 70 Ft. Clear Height	T		X
Punways/Taxiways	10,000 Ft. Long 300 Ft. Wide	T	X	X
Support Shops & GSE	Avionics, Electronics, Hydraulics, Jet Engine Machine, tube & cable, work stands, power carts, floor jacks, etc.	X	X	X
Office Space	60 Engineering & Technical Personnel	X	X	X
Shop Space	75 Mech. Insp. & Lab Technicians	X	X	X
Take Off & Land Photo Optics	Test Support		X	X
Space Position/ Tracking Communications Date Processing Telemetry	Category I Flight Test	X	X	X
Engine Thrust Stands	Turbo-Jet Engines			X
Weight & Balance	Large Vehicles			X
Instrument Calibration	Test Support	X		X

FIGURE 4.6-1

Test Support Facilities Comparison

Horizontal Test Site

(Continued)

Facility Requirement	Test/Vehicle Requirement	Candidate Test Site KSC	Eglin AFB	Edwards AFB
Weather	High ceiling and visibility, minimum precipitation	35% Marginal	35% Marginal	344 days per year acceptable (test) flying weather
Emergency Landing	Minimum obstructions Extra Length Extra Width Any Direction High Visibility	None	None	Rogers Dry Lake Rosamond Dry Lake Harpers Dry Lake Mirage Dry Lake Cuddle Back Dry Lake

X Available and Adequate

T To be constructed for operational phase

FIGURE 4.6–1 (Cont'd)

standpoint Edwards AFB is recommended as the primary horizontal flight test program test site for high risk testing. **Figure 4.6-3**

4.6.1.1 Facilities Requirements relative to existing facilities at Edwards AFB are:

1. Hangar Space. For one (1) Booster and one (1) Orbiter Vehicle.

   There are three aircraft hangars at EAFB which are large enough to accommodate the Space Shuttle vehicles, they are:

   #1. The modification and maintenance (M&M) hangar which is 600' long and 300' wide with 75' clear height.

   #2. The weight and balance hangar which is 400' long, 300' wide with 75' clear height.

   #3. The C-5 hangar which is 274' long, 260' wide with 76' 8" clear height.

2. Office Space. To support sixty (60) engineering and technical personnel.

   There are adequate office areas available at EAFB to accommodate the noted personnel.

3. Shop Space. To support seventy-five (75) mechanics, inspectors and lab technicians.

   There are adequate shop and laboratory areas adjacent to and within the hangars.

4. Runways. (Operational-Controlled)

   The main operational runway at EAFB is poured reinforced concrete 15,000' long, 300' wide, running from southwest to northeast, the west to east overrun on to Rogers Dry Lake is in excess of 40,000 ft. The dry lake has a nominal surface crust thickness of 40 ft.

5. Taxiways. The operational taxiways are poured reinforced concrete, 150' wide and are connected to all operational and ramp areas.

6. Space Position. (Tracking and Communications)

The Air Force Systems Command and NASA provide Radar and Telemetry services for flight test programs.

7. Fuel and Other Expendables. Adequate controlled storage areas are maintained for fuels pyrotechnics and consumables (LO2 etc.).

8. Instrument Calibration. An instrument calibration laboratory is maintained for repair and calibration of normal flight and special flight test instrumentation.

9. Data Reduction and Computation. The Air Force Data Systems Engineering Branch is responsible for the planning, development and implementation of range and test instrumentation facilities and equipment necessary to support Air Force and Contractor flight test programs. Branch personnel, principally engineers, are engaged in the continuing process of developing or upgrading data acquisition capabilities in such areas as radar, telemetry, airborne data collection, long range data transmission, data processing and computation, and data display. In short there are adequate facilities available for receiving and processing flight test data.

10. Engine Thrust Stands. For airbreathing engine thrust calibration.

The static thrust calibration facility consists of four movable flush-mounted platforms that are instrumented to measure and record 125,000 pounds normal or reverse thrust. This system incorporates provisions for determining weight (300,000 pounds each platform) and weight loss (54,000 pounds) during thrust calibration. Thrust data is presented by strip-chart recorders for each platform, with totalized indications digitally displayed, typed and paper tape coded by Flexowriter.

11. Weight and Balance Facilities. This capability is installed in a 300 by 400 ft. clearspan hangar, a flush-mounted set of vehicle weighing scales consisting of four tables with 300,000 pounds capacity each reading in increments of 20 pounds throughout this range. The largest platform incorporates provisions for longitudinal leveling of the vehicle under test to determine its center of gravity.

12. Takeoff and Land Photo-Optics. The Air Force Photography Branch provides complete photographic support for the AFFTC, tenant military organizations, and civilian contractors engaged in Air Force, NASA and other testing and development programs. Complete services are available for photographic, and photo-optic flight test coverage including automatic film processing, ground to air, air to air, air to ground, (Photo Resolution Range) and flight analyzer plate for takeoff and landing.

13. Flying, Ground Safety and Emergency Facilities. The Air Force flying and ground safety office maintains a comprehensive safety program for all organizations and contractor tenants. The following services are provided relative to flying, industrial, ground, missile and nuclear safety procedures, technical guidance for Air Force requirements, technical orders, and applicable codes, investigate accidents or incidents when required, and coordinate and approve operating procedures in research and development areas. Also available are emergency crash and fire equipment and trained personnel for fire fighting and pilot and flight crew rescue.

14. Emergency Landing Facilities. (Areas)

There are numerous emergency landing areas either on or adjacent to EAFB. They are Rogers and Rosamond dry lakes, which are located on the base proper and Cuddleback, Harpers and Mirage dry lakes which are within 50 miles of Edwards. In addition to the dry lakes there are three airfields that are capable of landing Space Shuttle size vehicles: they are Palmdale Airport, George AFB and China Lake NAF.

15. Medical Facilities. (Emergency)

There is a 45 bed Air Force hospital, with surgical, dental and internal medicine care, which is available to contractor personnel on an emergency basis only, contractor personnel will be admitted for emergency treatment of incurred injuries, but will be transferred to the civilian hospital at Lancaster, Calif. (Antelope Valley Hospital) as soon as conditions permit. Med/Evac. ambulances and helicopters are used for transport of injured personnel depending upon the severity of the injuries.

16. Weather Conditions. (Field elevation 2302 ft.)

The normal weather conditions at EAFB are such that approximately 344 days per year can be utilized for VFR flying, the remaining 21 days are marginal because of low cloud formations and/or wind and blowing dust. Winter temperatures at EAFB average low forties in the morning, warming to the sixties by afternoon. Summer temperatures average from the mid sixties in the morning to one hundred plus during the afternoon, precipitation is normally light, the relative humidity is low 2% to 5% prevailing winds are west to east 8 to 12 mph nine months per year and 30 mph or more three months per year.

4.6.1.2 Facilities Construction/Modification - The only new construction required at EAFB will be a vehicle deservice/safing area to be located off the taxi strip adjacent to the hot gun line at the east end of the main (#4) runway. This area will be used for fueling, safing, engine-run (ABE) and check out of the

APU and other vehicle systems. If the APU in the test vehicles uses LO2 and LH2 for fuel a high pressure gas storage, distribution, regulation, and tank purging (GN2) system will be required, if the APU systems are fueled with JP-4 the LO2 and LH2 facilities will not be required.

The vehicle deservice/safing should be reinforced concrete 450 ft. by 250 ft. with Firex water system and up to 440V 3 phase power, Ground Support Equipment will be utilized whenever possible in order to minimize this facility cost. At the present time and considering that the APU will utilize LO2 and LH2 fuels, the estimated cost of this facility is .5M dollars. Figure 4.6-2 shows EAFB projected dates for construction/modification, site activation, test start and test finish.

Horizontal Flight Test Program Facility Schedule, EAFB

Test Vehicle	Facility-Const/Mod. Date	Site Activation	Test Start	Test Finish
Booster S/N-1	Deservice/Safing Area 9-75	6-76	7-76	4-78
Orbiter S/N-1	Same	Same	Same	Same

FIGURE 4.6-2

4.6.2 Low Risk Testing - Low risk testing (airplane flight mode) of Space Shuttle vehicles will be accomplished at the Operational Launch site KSC, Florida. The test program will evaluate operational cruiseback and landing procedures and navigational aids. The low risk testing program will be programmed to begin after vehicle flight worthiness has been verified.

4.6.2.1 Facilities Construction/Modification - The Operational Launch site as modified for Space Shuttle will be utilized for the low risk flight test program.

This will include the new maintenance building addition to the VAB and the new runway and deservicing area. Construction/modification costs for the Operational Launch site are presented in Report MDC E0308, Part III-3, Operations.

EDWARDS AIR FORCE BASE RUNWAY AND SAFING AREA

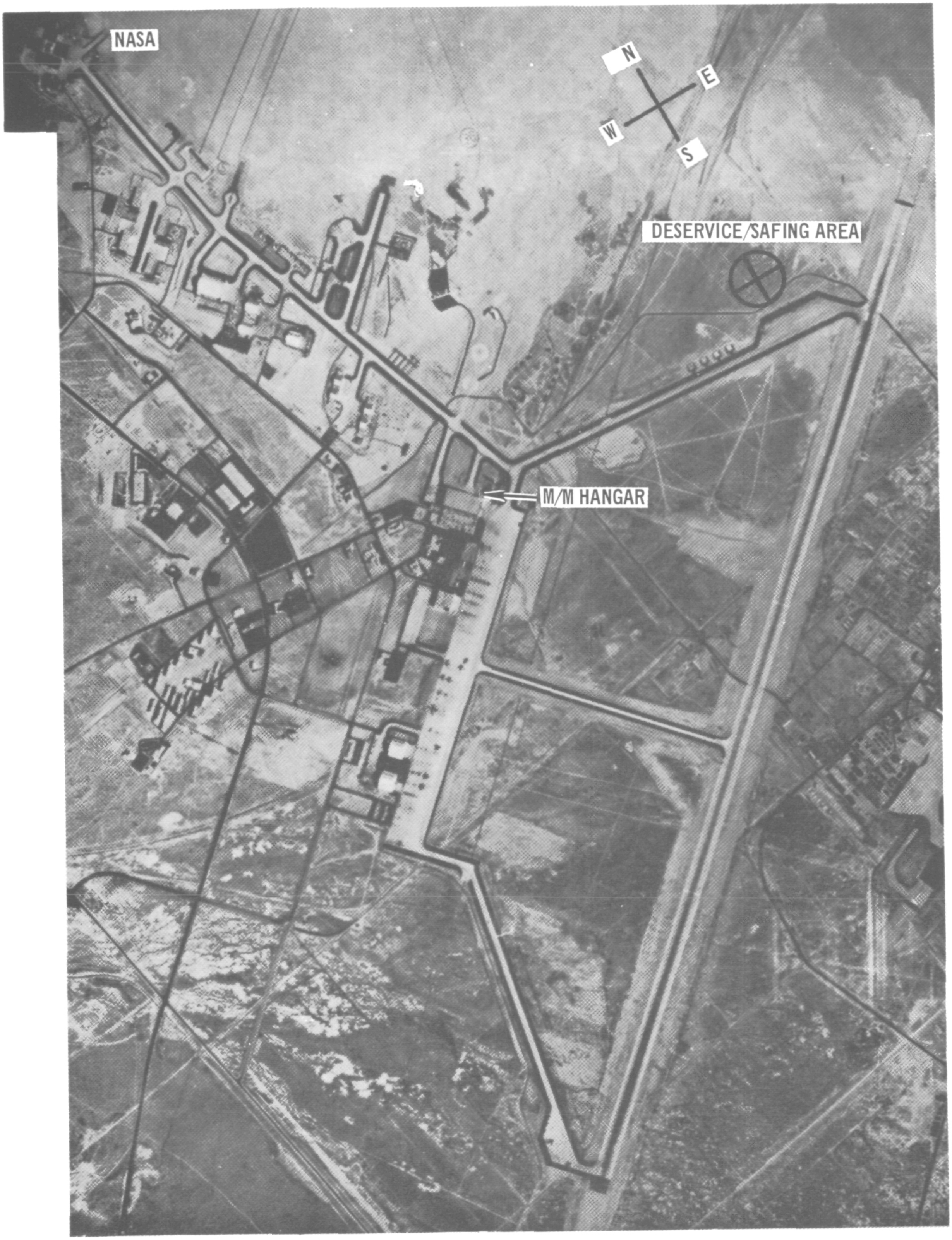


FIGURE 4.6–3

4.7 OPERATIONS

KSC has been selected as the Space Shuttle Operations Site for the following primary reasons:

- o Minimum implementation costs
- o Minimum new construction
- o No new land acquisition
- o Favorable area social and economic conditions
- o Transportation modes (air, rail, road, water) exist
- o Support facilities and services are adequate
- o Primary launch facilities are adaptable with modification rather than a magnitude of new construction
- o Range network and services exist

A complete trade study leading to this selection may be found in MDAC Design Note No. I-EAST-GLO-20. The study includes the detail evaluation of candidate sites based upon sixteen (16) primary factors. For each site an optimum configuration is identified which utilizes the advantages of each site. In support, detail cost estimates of facility construction and modification requirements are provided.

This section defines the facility utilization and requirements for the Operations Site of the Space Shuttle Program.

4.7.1 Ground Operations Facility Requirements

This section identifies the facilities necessary to support the Shuttle vehicle activities at the operations site. Table 4.7-1 defines the facility nomenclatures and planned utilization by Shuttle element. The following criteria/objectives were used in the development of facility requirements:

- o Cost effective
- o High flexibility
- o Maximum utilization of existing facilities
- o OC baseline in second half of 1979
- o Operational maximum yearly launch rate is 75
- o Vehicle ground turnaround time will be two weeks or less
- o The launch pad, primary landing site and servicing facility will be in the same location
- o Use of specialized facilities will be minimized
- o Systems sensitivity to weather will be minimized
- o Area social and economic conditions
- o Suitable climate
- o Available commercial utilities
- o Minimum terrain clearance problems
- o Adequate commercial access

TABLE 4.7-1

FACILITY NOMENCLATURE	REQUIREMENTS		
	EXISTING	MODIFIED	NEW
1. Passenger Facility		X (MSOB)	
2. Nuclear Facility		X	
3. Landing Facility			X
4. Deservicing Area			X
5. Taxiway			X
6. Maintenance (Vehicles) Facility		X (VAB)	X
7. Integration Facility/Area		X (VAB)	
8. Mobile Transporters and Structures		X	
9. Compressor Converter Facility	X		
10. Launch Pads		X (LC-39)	
11. Launch Control Center	X (LC-39)		
12. Instrumentation Facility	X		
13. Tracking Facilities	X		
14. Optical Sites	X		
15. Cargo Operations Facility		X (MSOB)	
16. Flight Crew Facility	X		
17. Training Facility	X		
18. Ordnance Storage and Test Facility	X		
19. Warehouses and Storage Facilities	X		
20. Electromagnetic Laboratory	X		
21. Auditorium	X		

TABLE 4.7-1 (Cont'd)

FACILITY NOMENCLATURE	REQUIREMENTS		
	EXISTING	MODIFIED	NEW
22. Communications Facility	X		
23. Propellants Systems Laboratory	X		
24. Azimuth Alignment Facility	X		
25. Unified S-Band Facility	X		
26. Weather Tower	X		
27. Power Distribution Facility	X		
28. Railroads	X		
29. Roadways and Parking Area	X		
30. Sewage Treatment Facility	X		
31. Central Heating facility	X		
32. Fire Station	X		
33. Cafeteria	X		
34. Parachute Facility		X	
35. Communications Maintenance and Storage Facility	X		
36. Heavy Equipment Maintenance Facility	X		
37. Base Maintenance Facility	X		
38. Occupational Health Facility	X		
39. Administration and Engineering Offices	X		
40. Central Supply	X		
41. Barge Canal and Terminals	X		
42. Industrial Water Facility		X	
43. Propellant and Gas Storage Facility	X		
44. Security Facilities	X		

TABLE 4.7–1 (Cont'd)

FACILITY NOMENCLATURE	REQUIREMENTS		
	EXISTING	MODIFIED	NEW
45. Photographic Laboratory	X		
46. Library and Reproduction Facility	X		
47. Hydrogen Production Facility			X

4.7.1.1 Shuttle Facility Descriptions

PASSENGER FACILITY - This facility will provide living quarters for passenger personnel prior to launch operations. The area will also include receiving for personnel and equipment, preparation, certification and records storage.

NOTE: This facility could be combined with the cargo operations facility.

NUCLEAR FACILITY - This facility will be used for storage, maintenance and test of nuclear cargo packages. The facility will be remotely located and constructed in accordance with AEC criteria.

LANDING FIELD - A landing field is required adjacent to the maintenance area. This facility will include a 10,000 ft. runway (300 ft. wide) with paved overuns. A control tower and adjacent structures for approach control systems will be included.

DESERVICING AREA - This area will be located between the runway and maintenance facility. The facility will include provisions for vehicle deservicing, cargo unloading and personnel egress.

TAXIWAY - The taxiway is required between the landing field and maintenance facility. The requirements include a 200 foot wide clear/graded area with 80 foot wide rigid pavement strip. Vehicles will be towed on their landing gear.

MAINTENANCE FACILITY - This facility will provide sufficient area for ground maintenance of Booster and Orbiter vehicles. The area will include checkout equipment, fixtures, vehicle jacking and general support work areas. The Orbiter area will include sufficient overhead space for loading of the cargo module.

NOTE: This may be separate facilities for Booster and Orbiter and could be used for final assembly and/or refurbishment activities.

INTEGRATION FACILITY - A facility (or area) is required for integration and checkout of the Shuttle vehicles. The area will include a crane(s), access platforms, utility services and structural hardpoints for mobile transporters. Environmental protection will be provided. This requirement could be combined with the maintenance function.

MOBILE TRANSPORTERS - Three mobile transporters are required. Each unit will include a base area with structural hardpoints, access, service connections and interface connections for ground service systems. A tower will be provided for access to vehicle stations, platforms for ground equipment and egress provisions.

COMPRESSOR CONVERTER FACILITY - This facility is required in the launch complex area. It provides for the conversion of liquid to gaseous cryogenics, pressurization of gaseous nitrogen and helium and supplies the GN_2 and GHe to storage and launch pad facilities.

LAUNCH PADS - Two launch pads are required to support the Shuttle traffic model. Each pad will include the launch hardstand with flame trench and deflectors, structural hardpoints, equipment areas and fluid/gas storage. The adjacent area will include propellant farms, personnel protection area, roadways, fencing and approach ramp.

LAUNCH CONTROL CENTER - This facility will house the equipment and support areas required for prelaunch and launch operations. It will be located a minimum of three miles from the launch pad area. Sufficient area will be included for equipment, launch and support contractors and existing personnel.

INSTRUMENTATION FACILITY - This facility will be used in support of ground checkout and launch operations. Space will be provided for electronic instrumentation and laboratory equipment, computers, automatic data processing and general office areas.

TRACKING FACILITIES - Local and remote sites are required for vehicle tracking during early launch phase and flight. A typical site will include equipment housing facility, utility building, antenna tower and antennas.

OPTICAL SITES - These sites will be located adjacent to the launch pad and at other strategic positions for optimum coverage of the terminal countdown and initial launch trajectory. Each site will be provided with roadway, and elevated hardstand area for equipment and utility services.

CARGO OPERATIONS FACILITY - Both routine and special cargo will require a large area for receiving, inspection, processing and packaging. Cargo modules will be stored, tested and maintained for cargo installation. Special cargo will require checkout area, servicing, etc. It may be necessary for a separate area or facility to be provided. Sterilization may be necessary also. Detailed facility requirements are presently unknown until additional cargo information is provided.

FLIGHT CREW FACILITY - This facility will have several crews and be equipped for training and prelaunch activities. Areas will be provided for crew quarters, procedures and mockup training, familiarization and simulators.

TRAINING FACILITY - A facility is required to support government and contractor personnel. Facility requirements will include large conference, briefing, lecture and presentation rooms. It will be air conditioned and heated, equipped with screens, motion and still projectors and sound systems.

ORDNANCE STORAGE AND TEST FACILITY - This facility could be separate. For storage the facility will be bunker type with environmental control. Ordnances will be stored on pallets. Typical ordnances include small pyrotechnics, shape charges, fuses, detonators and initators. The test area will include a test cell, control room and laboratory. It will be sited at a safe distance from adjoining buildings. Distance to be determined by quantity potential in accordance with standard safety regulations.

WAREHOUSES AND STORAGE FACILITIES - These facilities can be separate or combined. Space provisions will be required for general service, offices, spares, bonded area staging and miscellaneous storage.

ELECTROMAGNETIC LABORATORY - A laboratory and support areas are required for checkout of antennas and radiation patterns.

AUDITORIUM - A general usage auditorium will provide sufficient space for large quantities of personnel. It will have environment control and be designed for sound system distribution. Screen and projection equipment and a raised stage will be provided.

COMMUNCATIONS FACILITY - This central facility will provide for controlling, coordination, patching, switching, testing of television, operational intercom, telephones, wide band data and special circuits.

PROPELLANTS SYSTEMS LABORATORY - This facility will be used for cleaning, analysis and testing of high pressure gas equipment. A maintenance and storage area for cryogenics will be included.

AZIMUTH ALIGNMENT FACILITY - Within the pad area this facility will house the auto-collimator for vehicle alignment. A pedestal will be provided for equipment mounting.

UNIFIED S-BAND FACILITY - This facility will be used for pre-mission and mission support, software development and network training and familiarization. Space and services will be provided for antennas, transmitters, computers, data display, receivers and recorders.

WEATHER TOWER - The tower will be used for weather observations and prediction data with platforms for instrumentation to measure wind velocities and temperature gradients. Adjacent to the tower will be a recording station and antenna base for mobile communications sytems.

POWER DISTRIBUTION FACILITY - This facility will provide distribution of commercial and locally generated power to all industrial and launch complexes. The system will include industrial (general use), instrumentation (voltage sensitive), emergency and isolated power.

RAILROADS - Railroad services will be required from off-site tracks into the central area. Additional spur lines will be provided to strategic site locations.

ROADWAYS AND PARKING AREA - Roadways are required to connect with off-site areas and will interconnect all major facilities and areas on the site. Additional secondary roadways will be provided within major facility areas. Parking will be provided at each facility and will be sized in accordance with anticipated facility personnel quantities.

SEWAGE TREATMENT FACILITY - A centralized facility with supporting substations is required for treatment and disposal of on-site generated sewage.

CENTRAL HEATING FACILITY - A centrally located facility with a substation will be required to provide controlled heating supply.

FIRE STATION - A central station is required with truck cells, office space and quarters for personnel. Secondary stations may be required depending on overall facility layout distances.

CAFETERIA - A centralized food service center is required with cafeteria style servicing and adequate area for government and contractor personnel. Additional small areas may be provided at major distant facilities.

PARACHUTE FACILITY - This facility is required for inspection, repair and repacking of vehicle deceleration chutes. Equipment will include manometer, sewing machines, packing table, scales inflator/deflator, etc. The facility will be divided in shop area, packing table area and office.

COMMUNICATIONS MAINTENANCE AND STORAGE FACILITY - This facility will serve as a maintenance area for receiving, inspection and repair of cable and equipment. A portion of the area will be humidity controlled for storage of electronic equipment.

HEAVY EQUIPMENT MAINTENANCE FACILITY - This area will perform maintenance on such equipment as scrapers, bulldozers, mobile cranes, forklifts, power units, trailers, etc. Space will be required for cranes, high lifts and general handling equipment.

BASE MAINTENANCE SHOPS - General purpose shop area is required for general maintenance services of facilities. The shops will include electrical, mechanical, paint, wood and machine capability.

OCCUPATIONAL HEALTH FACILITY - A centralized dispensary in the industrial area is required with remote smaller dispensaries and first aid stations. The main dispensary will include areas for instruction, lockers, pharmacy, laboratory, treatment, X-Ray, nurse stations, supply, administration, emergency, eye examination, and audio examination room.

ADMINISTRATIVE AND ENGINEERING OFFICES - Adequate government and contractor areas will be located in the industrial area and at remote locations.

CENTRAL SUPPLY - This facility will be the initial receiving site for incoming base supplies. Area will support storage of parts, spares and general base supplies.

BARGE CANAL AND TERMINALS - Access canals and terminal basins are required for delivery of large vehicle components and propellant logistics. Sizing will be determined when further definition of barge requirements are defined.

INDUSTRIAL WATER FACILITY - Two primary facilities are required. One will be located in the industrial area for support of these facilities. The second will be located at the launch site to provide a reservoir and pumping station for personnel use, vehicle deluge, fogging, cooling and flushing.

PROPELLANT AND GAS STORAGE - A launch support facility (or facilities) is required to store, convert, distribute and handle liquids, gases, cryogenics, and specialized gases. Typical systems will include LOX, JP-4, LH2, LN2, GN2, GHe, and GH2.

SECURITY FACILITIES - A central security center with office area, badging control, interview areas and filing will be required, with secondary areas at strategic locations. In addition, small mobile stations will be located at various facilities for local control.

PHOTOGRAPHIC LABORATORY - This facility will provide laboratories for processing, storage areas and offices for administrative and technical personnel.

LIBRARY AND REPRODUCTION FACILITY - A centralized facility will house a technical library, micro fill storage and display and reproduction equipment.

HYDROGEN PRODUCTION FACILITY - a 60 ton per day facility is required. It will be located adjacent to water and road access and is classified as a supplier contractor owned and operated facility.

4.7.2 Ground Operations Facility Utilization

The baseline operations site is Kennedy Space Center, Florida. This site provides the maximum in available facilities which are usable for the Shuttle program. Table II provides identification of the required facilities and planned utilization. For Shuttle facility operating concept refer to the Operations Plan, MDC Section Report E0308-III-3. Figure 4.7-1 presents the Shuttle operations site preliminary layout. The new facilities for landing field, taxiway and deservicing area, maintenance and the hydrogen production facility as well as the existing facilities and access systems are identified. Figure 4.7-2 shows the maintenance facility addition to the Vertical Assembly Building and planned utilization of existing areas. Figure 4.7-3 is the existing Manned Spacecraft Operations Building, which is adaptable for use as: (1) Program Contractors Administrative and Engineering offices, (2) Cargo Operations, and (3) Passenger Housing.

TABLE 4.7-2

SHUTTLE FACILITY REQUIREMENTS	VEHICLE ELEMENT UTILIZATION		
	BOOSTER	ORBITER	CARGO
1. Passenger Facility			X
2. Nuclear Facility			X
3. Landing Field	X	X	
4. Deservicing Area	X	X	X
5. Taxiway	X	X	
6. Maintenance Facility	X	X	
7. Integration Facility/Area	X	X	X
8. Mobile Transporters and Structures	X	X	X
9. Compressor Converter Facility	X	X	X
10. Launch Pads	X	X	X
11. Launch Control Center	X	X	X
12. Instrumentation Facility	X	X	X
13. Tracking Facilities	X	X	
14. Optical Sites	X	X	
15. Cargo Operations Facility			X
16. Flight Crew Facility	X	X	
17. Training Facility	X	X	X
18. Ordnance Storage and Test Facility	X	X	
19. Warehouses and Storage Facilities	X	X	X
20. Electromagnetic Laboratory	X	X	X
21. Auditorium	X	X	X
22. Communications Facility	X	X	X
23. Propellant Systems Laboratory	X	X	

TABLE 4.7-2 (Cont'd)

SHUTTLE FACILITY REQUIREMENTS (CONTINUED)	VEHICLE ELEMENT UTILIZATION		
	BOOSTER	ORBITER	CARGO
24. Azimuth Alignment Facilities	X	X	X
25. Unified S-Band Facility	X	X	
26. Weather Tower	X	X	
27. Power Distribution Facility	X	X	X
28. Railroads	X	X	X
29. Roadways and Parking Area	X	X	X
30. Sewage Treatment Facility	X	X	X
31. Central Heating Facility	X	X	X
32. Fire Station	X	X	X
33. Cafeteria	X	X	X
34. Parachute Facility	X	X	
35. Communications Maintenance & Storage Facility	X	X	X
36. Heavy Equipment Maintenance Facility	X	X	X
37. Base Maintenance Shops	X	X	X
38. Occupational Health Facility	X	X	X
39. Administration and Engineering Offices	X	X	X
40. Central Supply	X	X	X
41. Barge Canal and Terminals	X	X	
42. Industrial Water Facility	X	X	X
43. Propellant and Gas Storage Facility	X	X	X
44. Security Facilities	X	X	X
45. Photographic Laboratory	X	X	X
46. Library and Reproduction Facility	X	X	X
47. Hydrogen Production Facility	X	X	

KSC SHUTTLE PLAN VIEW

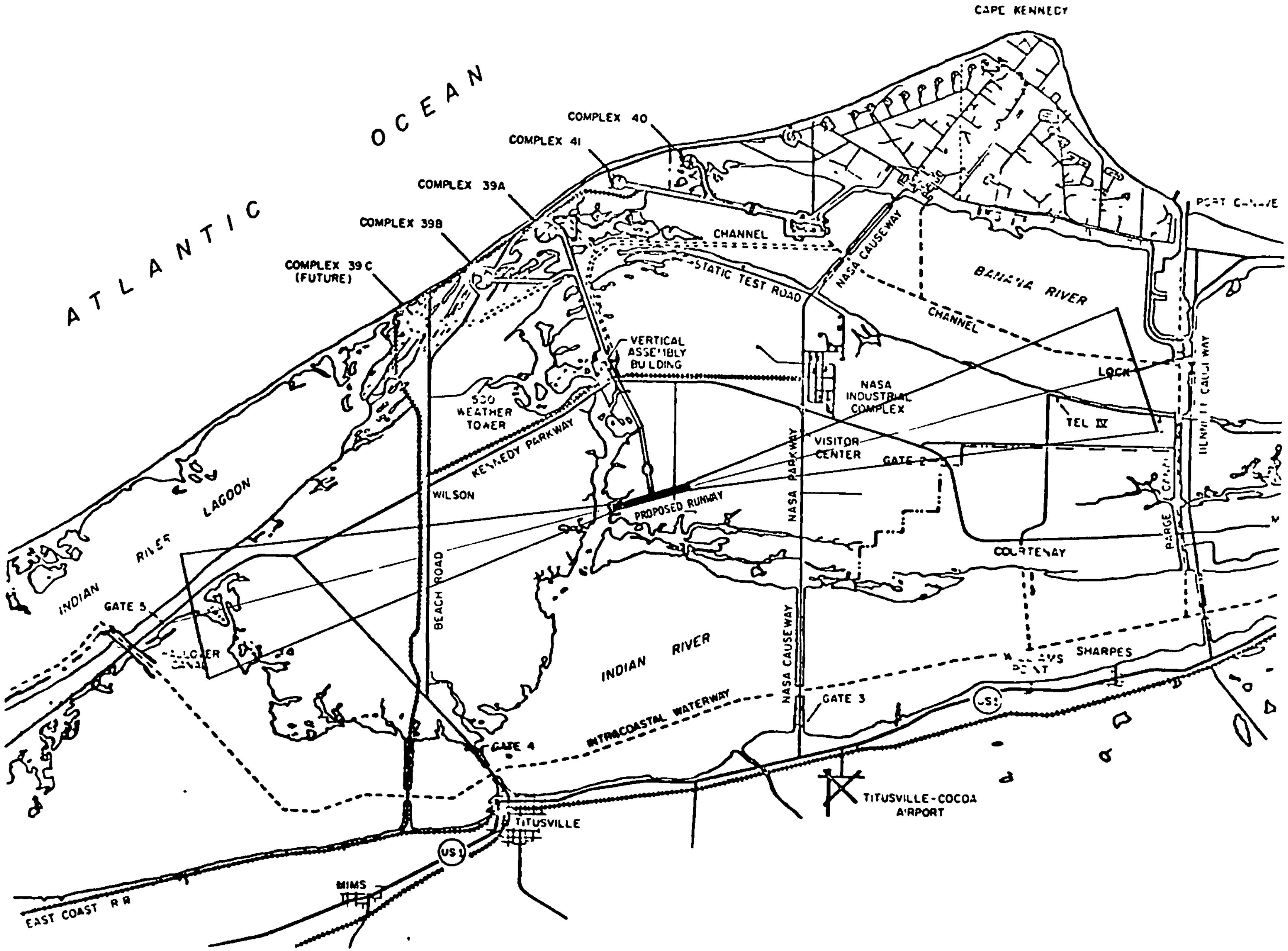


FIGURE 4.7-1

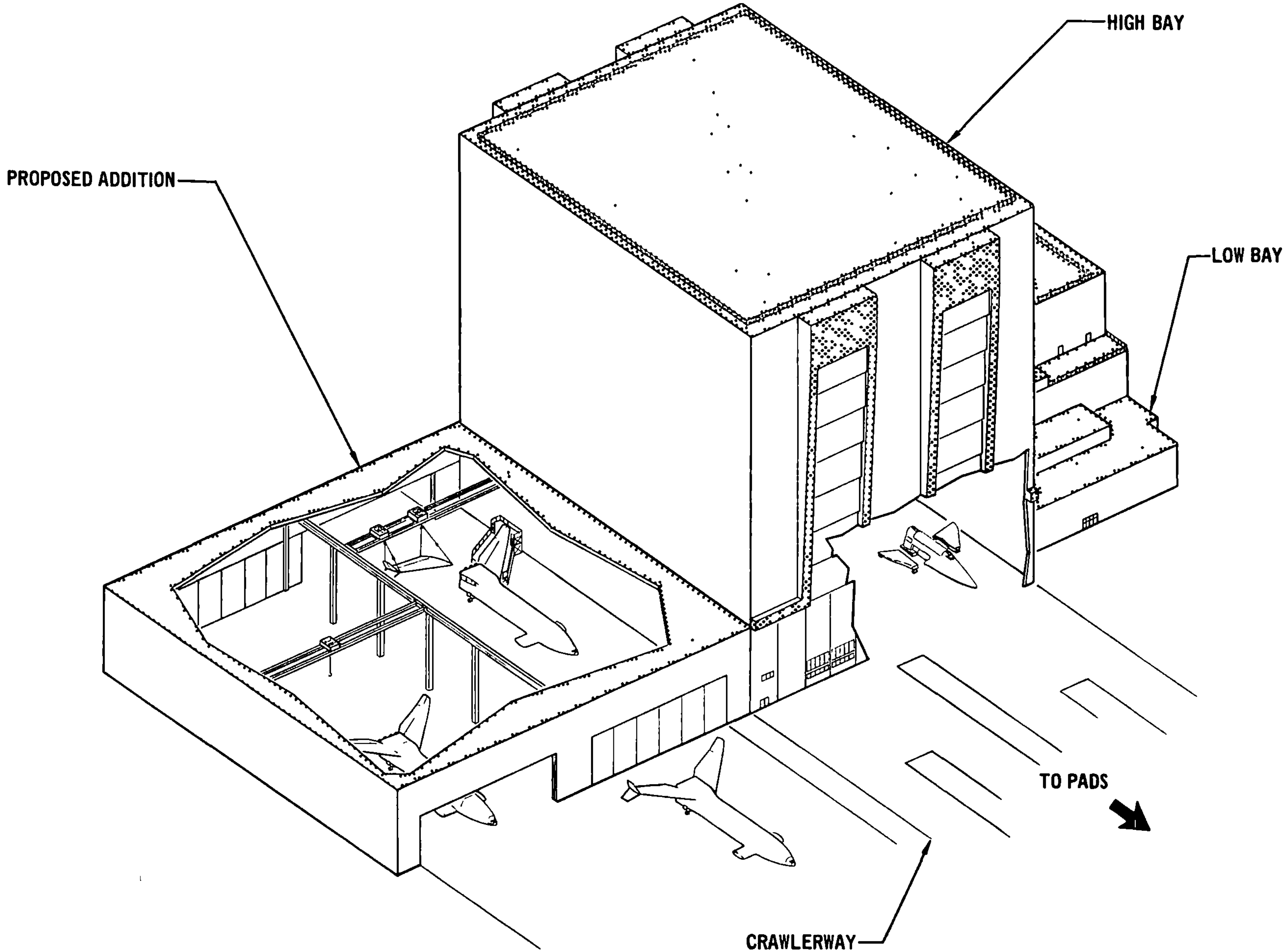
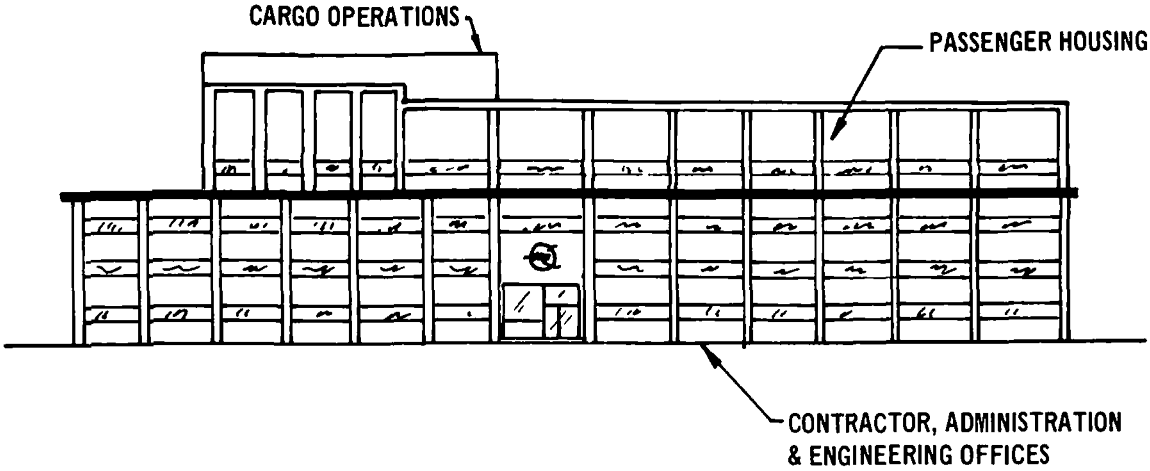


FIGURE 4.7-2

1ST FLOOR GENERAL ARRANGEMENT
MANNED SPACECRAFT OPERATIONS BUILDING (MSOB)
KENNEDY SPACE CENTER



VIEW LOOKING SOUTH

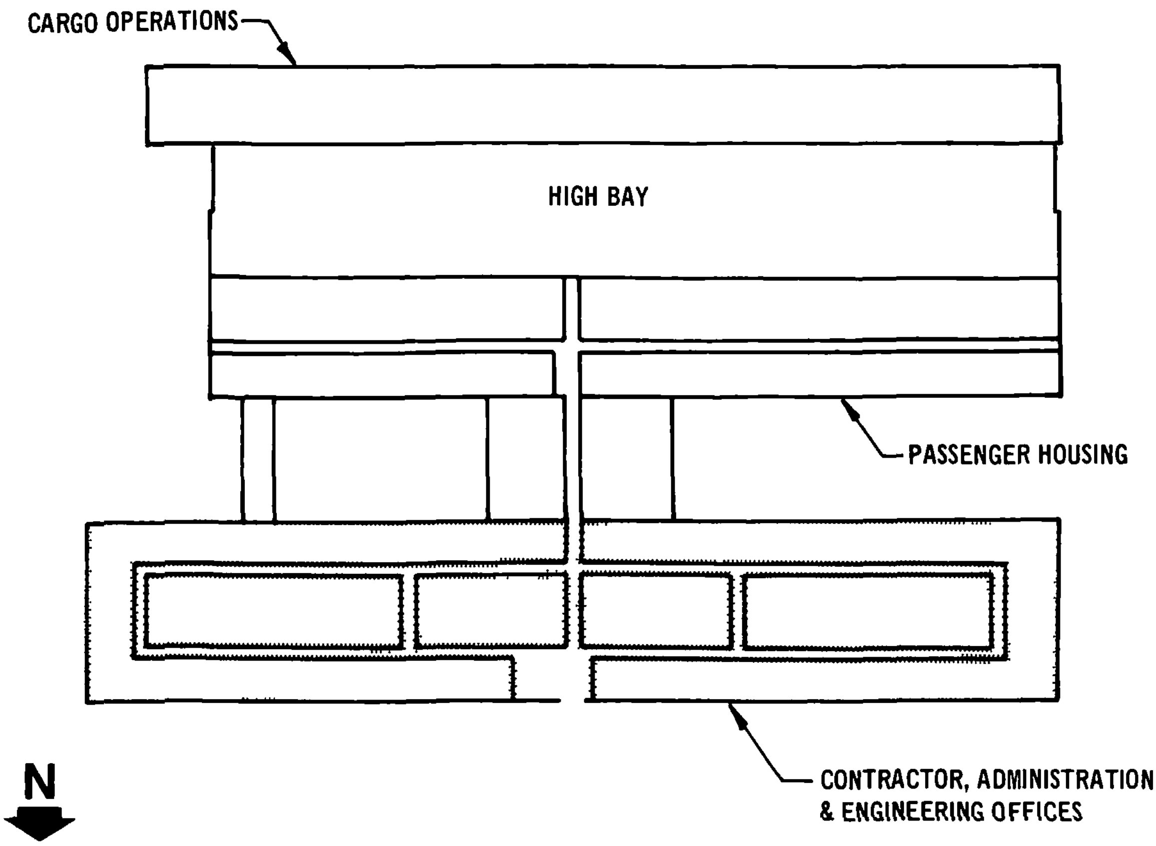


TABLE 4.7-3

4.7.2.1 Construction Schedule - The preliminary schedule is oriented to our baseline operations center. The schedule includes the construction/modification and activation phases. Where no facility activity is required only activation or outfitting is shown. Primary target rationale is included for each item. For continuity purposes the readiness milestones for off-site requirements including propellant logistics are included. See Figure 4.7-4.

NOTE: The activation portion is included for reference only.

4.7.2.2 Ground Operations Facility Construction/Modification Cost Estimate - This estimate includes facility construction and modification cost requirements. Activation costs and maintenance estimates are also included. Costing of ground support equipment and supporting systems are not included. Table 4.7-3

NOTE: Refer to Section 3.3.1.12 of the Operations Plan for Ground Support Equipment Information.

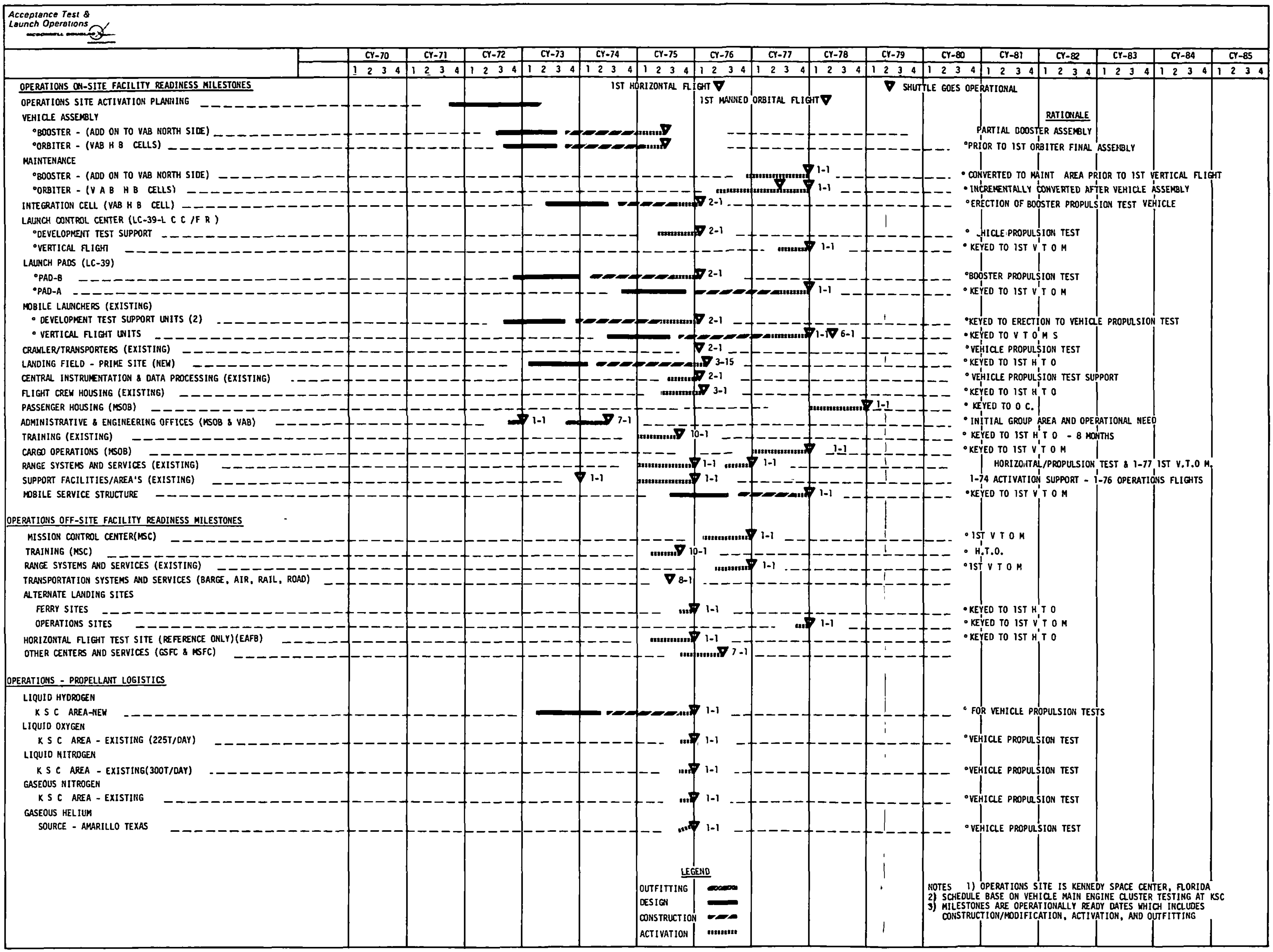

Acceptance Test & Launch Operations
CY-70 CY-71 CY-72 CY-73 CY-74 CY-75 CY-76 CY-77 CY-78 CY-79 CY-80 CY-81 CY-82 CY-83 CY-84 CY-85
1 2 3 4
OPERATIONS ON-SITE FACILITY READINESS MILESTONES
1ST HORIZONTAL FLIGHT
1ST MANNED ORBITAL FLIGHT
SHUTTLE GOES OPERATIONAL
OPERATIONS SITE ACTIVATION PLANNING
VEHICLE ASSEMBLY
°BOOSTER - (ADD ON TO VAB NORTH SIDE)
°ORBITER - (VAB H B CELLS)
MAINTENANCE
°BOOSTER - (ADD ON TO VAB NORTH SIDE)
°ORBITER - (V A B H B CELLS)
INTEGRATION CELL (VAB H B CELL)
LAUNCH CONTROL CENTER (LC-39-L C C /F R)
°DEVELOPMENT TEST SUPPORT
°VERTICAL FLIGHT
LAUNCH PADS (LC-39)
°PAD-B
°PAD-A
MOBILE LAUNCHERS (EXISTING)
° DEVELOPMENT TEST SUPPORT UNITS (2)
° VERTICAL FLIGHT UNITS
CRAWLER/TRANSPORTERS (EXISTING)
LANDING FIELD - PRIME SITE (NEW)
CENTRAL INSTRUMENTATION & DATA PROCESSING (EXISTING)
FLIGHT CREW HOUSING (EXISTING)
PASSENGER HOUSING (MSOB)
ADMINISTRATIVE & ENGINEERING OFFICES (MSOB & VAB)
TRAINING (EXISTING)
CARGO OPERATIONS (MSOB)
RANGE SYSTEMS AND SERVICES (EXISTING)
SUPPORT FACILITIES/AREA'S (EXISTING)
MOBILE SERVICE STRUCTURE
OPERATIONS OFF-SITE FACILITY READINESS MILESTONES
MISSION CONTROL CENTER(MSC)
TRAINING (MSC)
RANGE SYSTEMS AND SERVICES (EXISTING)
TRANSPORTATION SYSTEMS AND SERVICES (BARGE, AIR, RAIL, ROAD)
ALTERNATE LANDING SITES
FERRY SITES
OPERATIONS SITES
HORIZONTAL FLIGHT TEST SITE (REFERENCE ONLY)(EAFB)
OTHER CENTERS AND SERVICES (GSFC & MSFC)
OPERATIONS - PROPELLANT LOGISTICS
LIQUID HYDROGEN
K S C AREA-NEW
LIQUID OXYGEN
K S C AREA - EXISTING (225T/DAY)
LIQUID NITROGEN
K S C AREA - EXISTING(300T/DAY)
GASEOUS NITROGEN
K S C AREA - EXISTING
GASEOUS HELIUM
SOURCE - AMARILLO TEXAS
1-1
2-1
3-15
3-1
7-1
10-1
6-1
8-1
RATIONALE
PARTIAL BOOSTER ASSEMBLY
°PRIOR TO 1ST ORBITER FINAL ASSEMBLY
° CONVERTED TO MAINT AREA PRIOR TO 1ST VERTICAL FLIGHT
° INCREMENTALLY CONVERTED AFTER VEHICLE ASSEMBLY
°ERECTION OF BOOSTER PROPULSION TEST VEHICLE
°VEHICLE PROPULSION TEST
° KEYED TO 1ST V T O M
°BOOSTER PROPULSION TEST
° KEYED TO 1ST V T O M
°KEYED TO ERECTION TO VEHICLE PROPULSION TEST
°KEYED TO V T O M S
°VEHICLE PROPULSION TEST
° KEYED TO 1ST H T O
° VEHICLE PROPULSION TEST SUPPORT
°KEYED TO 1ST H T O
° KEYED TO O C.
° INITIAL GROUP AREA AND OPERATIONAL NEED
° KEYED TO 1ST H T O - 8 MONTHS
°KEYED TO 1ST V T O M
HORIZONTAL/PROPULSION TEST & 1-77 1ST V.T.O M.
1-74 ACTIVATION SUPPORT - 1-76 OPERATIONS FLIGHTS
°KEYED TO 1ST V T O M
° 1ST V T O M
° H.T.O.
°1ST V T O M
°KEYED TO 1ST H T O
° KEYED TO 1ST V T O M
°KEYED TO 1ST H T O
° FOR VEHICLE PROPULSION TESTS
°VEHICLE PROPULSION TEST
°VEHICLE PROPULSION TEST
°VEHICLE PROPULSION TEST
°VEHICLE PROPULSION TEST
LEGEND
OUTFITTING
DESIGN
CONSTRUCTION
ACTIVATION
NOTES 1) OPERATIONS SITE IS KENNEDY SPACE CENTER, FLORIDA
2) SCHEDULE BASE ON VEHICLE MAIN ENGINE CLUSTER TESTING AT KSC
3) MILESTONES ARE OPERATIONALLY READY DATES WHICH INCLUDES CONSTRUCTION/MODIFICATION, ACTIVATION, AND OUTFITTING

FIGURE 4.7-4

FIGURE 4.7-3

KENNEDY SPACE CENTER MAJOR FACILITIES COST ESTIMATE

FACILITY AREA	FACILITY ESTIMATE	ACTIVATION ESTIMATE	MAINTENANCE ESTIMATE
Maintenance/Assembly Facility	33,548,000.00	2,000,000.00	1,656,600.00
Cargo Operations Facilities	100,000.00	1,000,000.00	1,961,467.00
Propellant Production Facility	35,000,000.00	0.00	1,320,000.00
Prime Landing Site	23,290,000.00	2,000,000.00	500,000.00
Launch Complex (VAB and 2 Pads)	11,575,000.00	58,000,000.00	3,476,550.00
Launch Control Center	0.00	2,000,000.00	919,842.00
Support Facilities	0.00	10,000,000.00	800,000.00
Mobile Launchers (3 Units)	46,500,000.00	6,000,000.00	803,880.00
Mobile Service Structure	5,000,000.00	0.00	500,000.00
	155,013,000.00	81,500,000.00	12,438,339.00
	Construction Estimate Only	Installation Only	Routine and Janitorial Only For 10 Years

NOTE: The above cost data does not include the following:

Area Cost Factor	1.15
Cost Contingencies	15%
Overhead	15%
Profit	10%
Design-Fee	6%

4.7.2.3 Kennedy Space Center Facility Capability Descriptions - The following general facility descriptions are included to identify intended utilization, usage clarification, and existing capabilities. The existing capabilities are not to be considered as actual shuttle requirements. For clarification purposes the descriptions are keyed to the figure listing.

PASSENGER HOUSING FACILITY - This requirement can be assigned to the Manned Spacecraft Operations Building in the KSC industrial area. Figure 4.7-3 identifies the area, adjacent to the assembly and test section for this purpose. Presently the area is including approximately 14,375 square feet for astronaut transit quarters. This area can be expanded for additional quantities of passenger personnel. Three (3) levels are available, if required, for these requirements.

NUCLEAR FACILITY - Details of this facility are presently unknown. Numerous isolated facilities are available. Past programs have used this concept by adding protective shielding, monitoring systems and providing local security. Accurate sizing will be determined when meaningful definitions of nuclear materials classifications and radiation potential are identified.

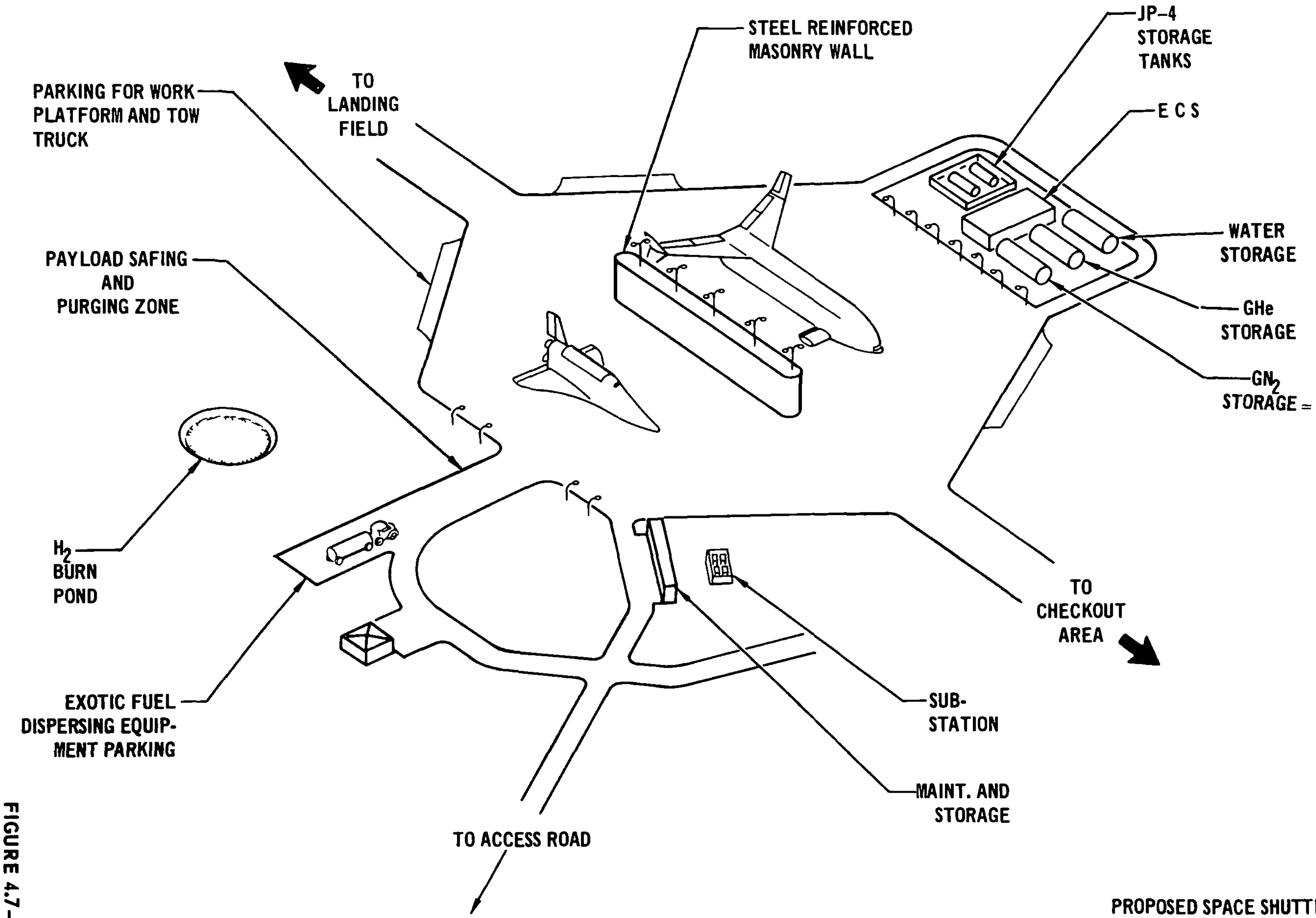
LANDING FACILITY - Figure 4.7-1 shows the planned siting west of the existing VAB. A 10,000 ft. long by 300 ft. wide rigid pavement (concrete) runway, with 1,500 ft. paved overruns will be provided. At each end a 300 ft. diameter turnaround will be used as parking aprons and air breather engine runup area. It is not expected at this time that traffic density will require a parallel taxiway. The runway, turnarounds and overruns will be enclosed, symmeterically, in a cleared 13,000 ft. long surface measuring 1,000 ft. wide. This area will consist of the runway, drainage gutters, stabilized shoulders, sloped sodded/seeded and graded surfaces on either side of the runway. Runway lighting will consist of high intensity edge, centerline and touchdown zone (narrow gauge) lights. Approach lighting will consist of threshold, terminating and light bars with sequenced strobbeacon flashing lights. Power requirements for the airfield and control tower is approximately 150 KVA. A 50 ft. high control tower, adjacent to the runway, will have a rotating beacon and a glass enclosed control room. The control room will include space for electronic/communication equipment, air conditioning, power supply distribution controls and automatic transfer switches to a standby generator. Small structures adjacent to the runway will be provided for localizer and glide slope equipment.

DESERVICING AREA - This area will be integral to the new taxiway. It will be an area approximately 450 ft. by 750 ft. in size to deservice two vehicles in parallel (if required). The area will contain JP-4 storage/drain capability, ECS facilities, storage tanks for purging gas, burn ponds, shelter for GSE and control center. See Figure 4.7-5.

TAXIWAY - A 80 ft. wide rigid pavement taxiway will be constructed from the runway to the maintenance facility. This area will be enclosed in a 200 ft. wide cleared and graded surface.

MAINTENANCE FACILITY - This facility will be located on the north side of the VAB facility. The area is planned to support booster vehicles assembly and maintenance. Figure 4.7-2 provides the general locations and layout. Preliminary sizing is approximately 513 ft. x 490 ft. x 100 ft. The area will require new pilings and foundations. A surfaced taxiway may be around the building for maximum access. Internally three booster vehicles can be handled simultaneously, with surplus area for an additional vehicle. The adjacent VAB will provide support service areas and utility services.

INTEGRATION FACILITY/AREA - The Vertical Assembly Building high bay cells 3 and 4 will be designated for this activity. The north cells will be widened



PROPOSED SPACE SHUTTLE
DESERVICE/SAFING AREA

FIGURE 4.7–5

by performing modifications to the doors and wall structure. New cranes will be installed. The extendable platforms, jib cranes and secondary structure will be removed. Electrical and mechanical equipment will be relocated.

MOBILE TRANSPORTERS AND STRUCTURES - The three (3) existing mobile launchers will be modified for use during the Propulsion Cluster Fire Tests and the Vertical Flight program. Two (2) units are required for propulsion testing with one (1) assigned to each vehicle (booster or orbiter). The orbiter unit will remain in this configuration until the receipt of the fourth orbiter. There after, it will be reconfigured for use in the vertical flight program. The third unit will be modified for the first vertical launch. The baseline modification concepts, Figures 4.7-6 and 4.7-7 , are based upon vehicle orientation with the orbiter outboard from the tower (booster belly towards the tower). Modifications will include: (1) removal of existing ground support equipment, lines and cabling; (2) removal of the swing arms; (3) shortening of the umbilical tower (approximately one hundred feet); (4) new swing arms and (5) launch deck area structure, hard-points and propellant servicing provisions. For cargo replacement on the pads, one (1) Mobile Service Structure (MSS) will be modified to remove obstructing structure and incorporate the structure and supporting systems at the cargo level. One unit will support both launch pads and will be handled in the same manner as for the Apollo Program.

An alternate concept (Figure 4.7-8) under study is based on vehicle orientation with the orbiter inboard to the area of the existing umbilical tower location. This concept provides several advantages related to swing arms and cargo replacement requirements. The existing units would have the umbilical towers completely removed and replaced with two towers while leaving sufficient space envelope

MOBILE LAUNCHER CONFIGURATION

SWING ARMS TO IDEALIZED HATCH AND UMBILICAL PLATE LOCATIONS

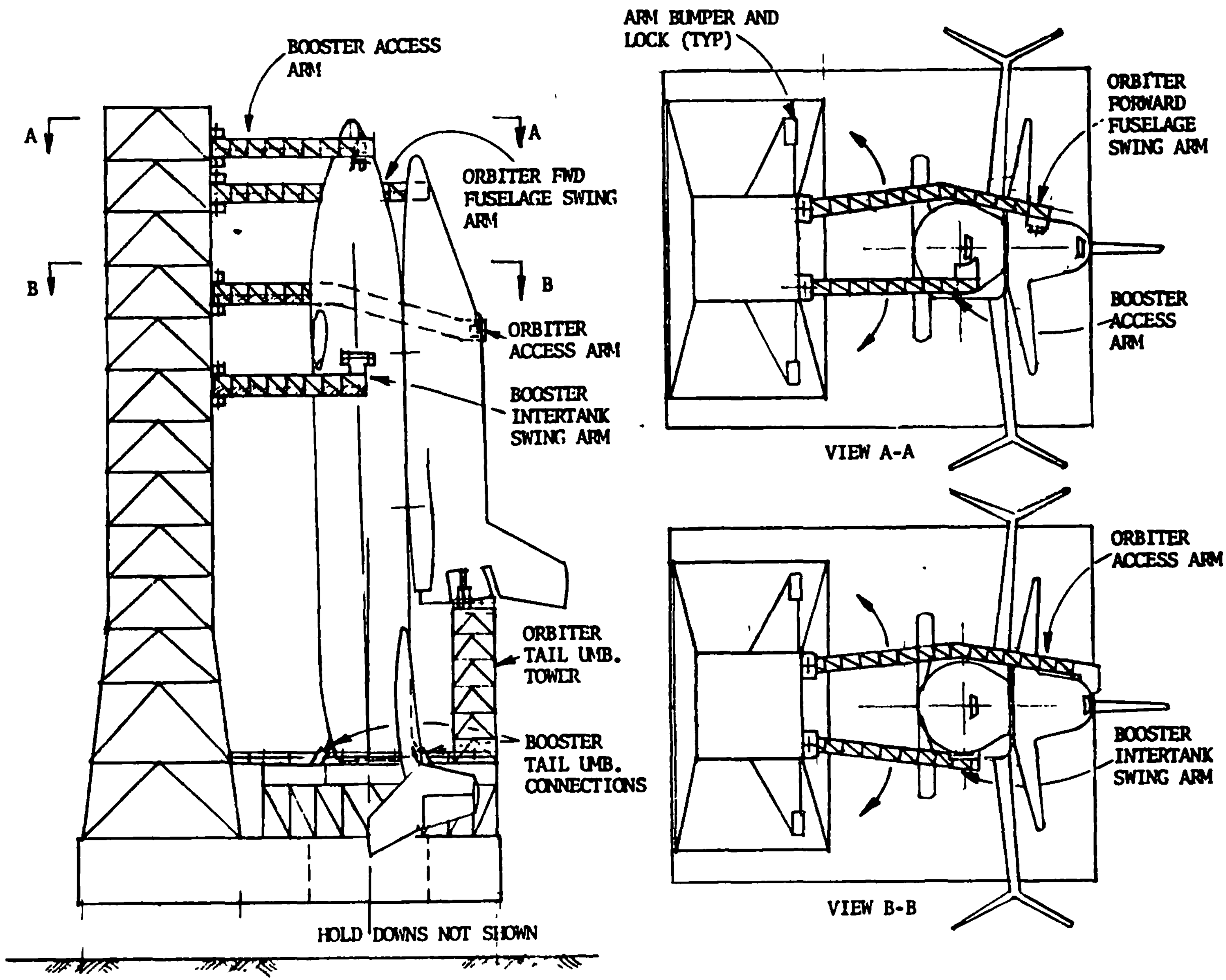


FIGURE 4.7-6

FEASIBILITY STUDY

UTILIZATION OF EXISTING MSS FOR ON-PAD CARGO HANDLING

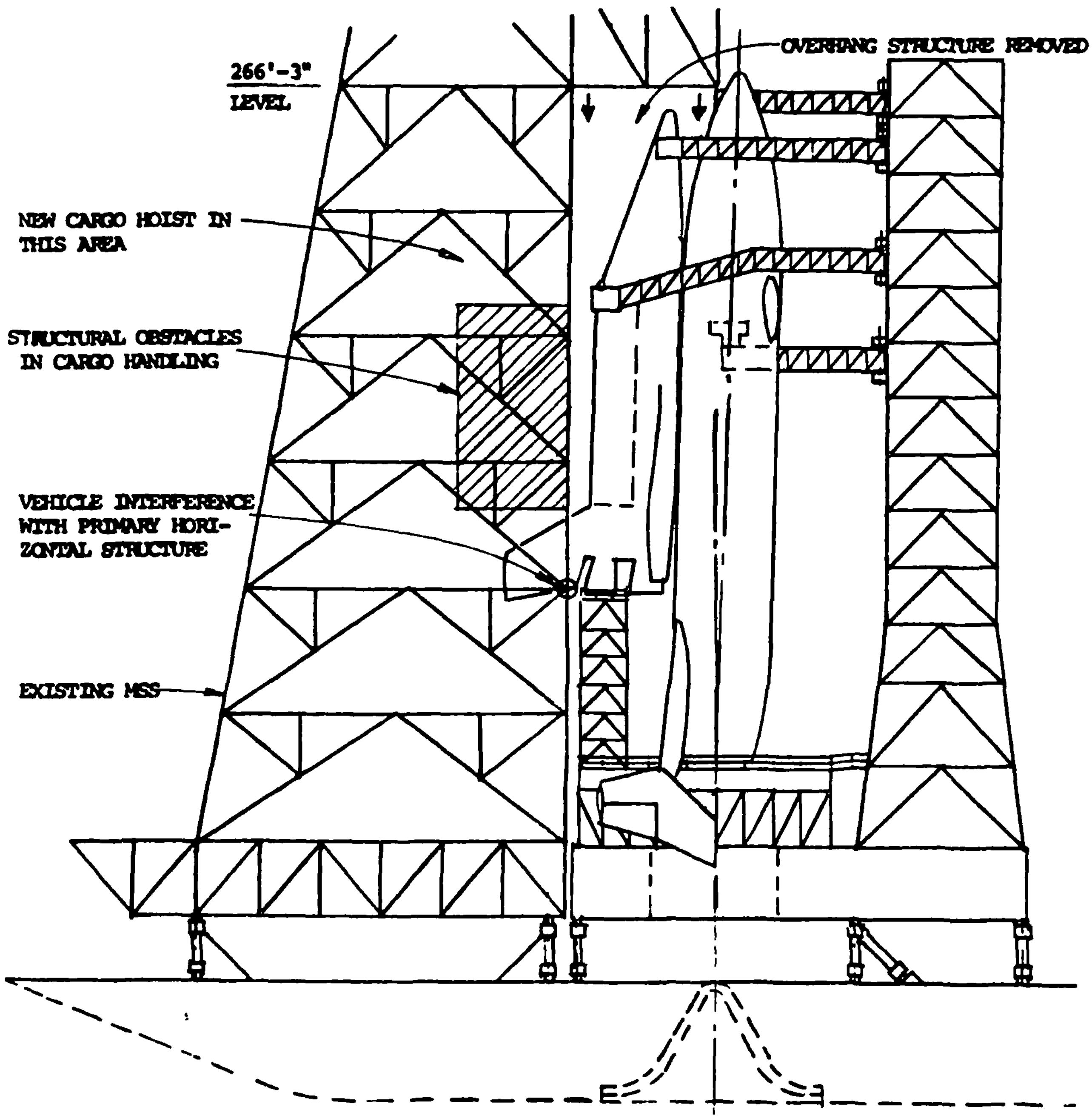


FIGURE 4.7-7

LAUNCH CONFIGURATION CONCEPT

NEW TWIN TOWER LUT (EXISTING ML)

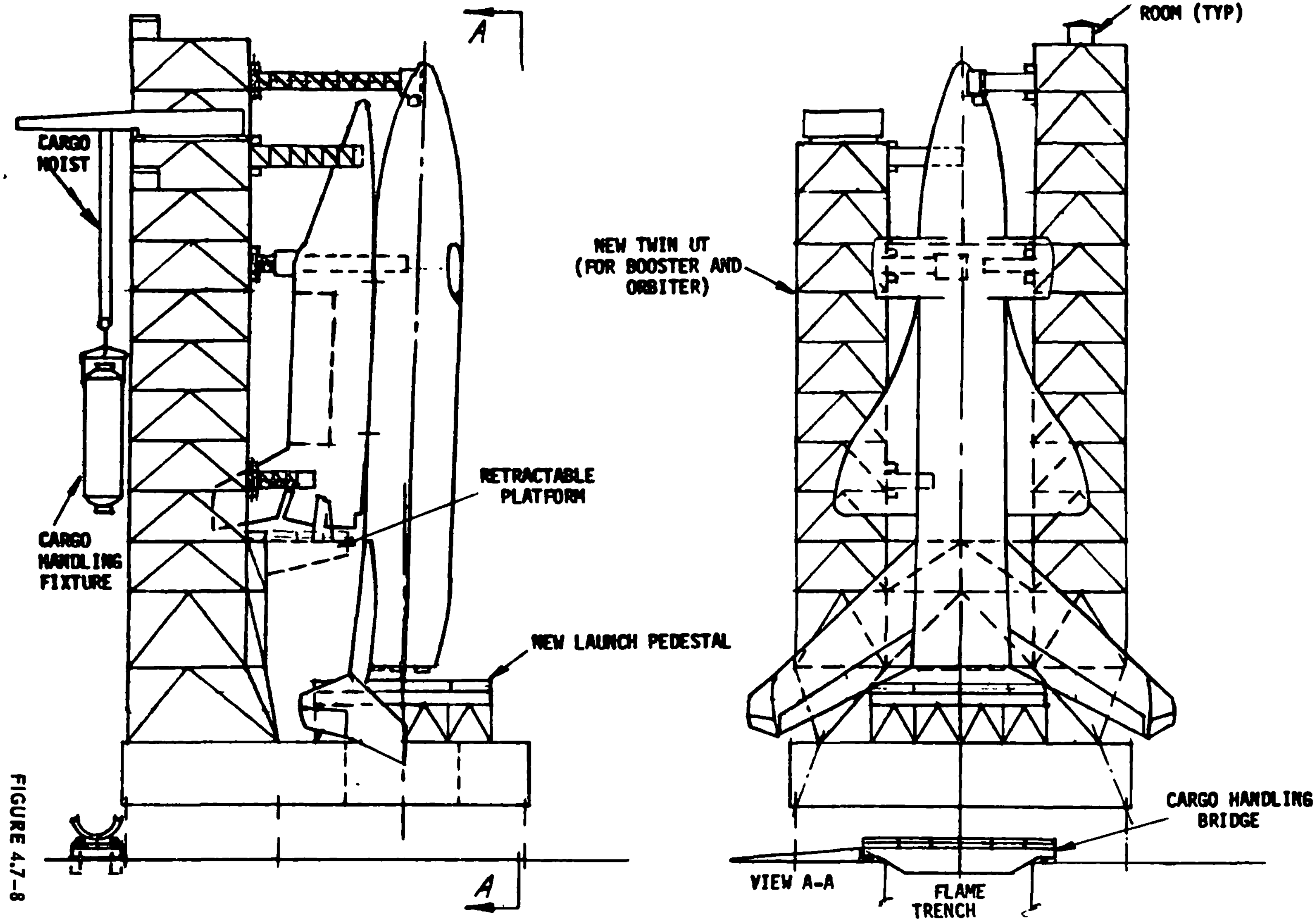


FIGURE 4.7-8

clearance for the vehicle during launch operations. Work platforms would provide access between towers and to the vehicle work areas. Cargo module replacement would be performed using this structure which eliminates the need for the Mobile Service Structure. The swing arms would be considerably shorter thereby enabling minimum time for retraction and extension during launch operations.

COMPRESSOR CONVERTER FACILITY - The existing launch complex -39 facility is located approximately mid-way between the VAB and launch pad. A 9,152 sq. ft. area consists of office, maintenance and equipment area. Primary equipment includes cryogenic converters, gas compression devices and storage tanks. These systems convert liquid cryogenics to gaseous form, pressurized GN2 and GHe to 6,000 psig and supplies storage facilities and launch pads. Liquid nitrogen storage tank has a capacity of 500,000 gallons. Helium storage is by use of railway cars.

LAUNCH PADS - Launch Pads 39A and B will be modified for the Shuttle. Each pad is approximately 20,000 sq. ft. in a polygon shape. Approximate distance between pads is 8,900 ft. with pad A. and B at 18,000 ft. and 25,000 ft. from the VAB area. Each pad consists of a raised hardstand at 40 ft. above surrounding grade, with transportable wedge type flame deflectors emplaced in the trench running through the hardstand centerline north to south. Adjacent areas include propellant storage, transfer and control equipment, hydrogen burn pond and high pressure gas storage for helium and nitrogen. Six camera sites, holding pond and supports for the mobile launcher are included. The primary modifications are to increase the propellant storage capability, water system and personnel blast room and protective systems.

LAUNCH CONTROL CENTER - The LC-39 control center will be used for control and monitoring of shuttle prelaunch and launch operations. Three fire control rooms are available with one more set up as a schedule and briefing area. Lower levels provide office space, cafeteria and general support areas. The four floor areas provide approximately 193,900 sq. ft. of useable space. Floor no. 1 is designated for offices, shops and a cafeteria. Floor no. 2 houses telemetry and data processing. The third floor is the fire control room and computer area. Floor no. 4 provides display area and mechanical support areas.

INSTRUMENTATION FACILITY - The industrial area control instrumentation facility provides 136,400 sq. ft. of area for use of ground instrumentation systems for telemetry and onboard flight television operations. The total area consists of calibration and standards, laboratory, central computation complex, telemetry station, data display, presentation and evaluation room, antenna site, generalized concept receiver, television station and measurement laboratories.

CARGO OPERATIONS FACILITY - The requirements can be supported in the MSOB facility. Figure 4.7-3 identified the assembly and test area and adjacent shop areas which provides approximately 100,000 sq. ft. of usage area. The low bay area height is 71 ft. with bridge type cranes at a hook height of 50 ft. The high bay height is 106 ft. with a bridge crane hook height of 85 ft. This area is classified as a class 100,000 environment. The adjacent service area provides general work shops.

FLIGHT CREW FACILITY - This facility provides training and simulation for flight crew personnel. The 65,315 sq. ft. area consists of simulator areas, instructor stations, computer complex, film graphics library, suit rooms, and special experiments training area.

AUDITORIUM AND TRAINING FACILITY - This 9,224 sq. ft. facility consists of space for large conferences, briefings, lectures and presentations. Equipment includes air conditioning and heating, theatre seating, screen, motion and still projectors and stage sound systems.

ORDNANCE STORAGE AND TEST FACILITY - The LC-39 area provides 2,600 sq. ft. for testing, shipping and receiving. Six adjacent storage areas provide approximately 2,400 sq. ft. This site is located north east of the VAB, connected by roadway to the crawlerway.

WAREHOUSE AND STORAGE FACILITIES - The KSC industrial area has numerous facilities and areas for this requirement. The prime area provides 500,000 sq. ft. icluding spare, bonded and staging area. Included are 55,000 sq. ft. of air conditioned area and 300,000 sq. ft. of miscellaneous storage of which 50% is air conditioned.

ELECTROMAGNETIC LABORATORY - This facility provides 9,486 sq. ft. for checkout of antennas and radiation patterns. The area is basically divided into a laboratory and support areas.

COMMUNICATION FACILITY - The Communication Distribution And Switching Center provides 25,989 sq. ft. area for the control, coordination, patching, switching, testing, monitoring, recording and programming of systems for television, intercom, phones, wideband data and special circuits. Equipment includes interconnections to all launch and test centers, transmission, receiving and repeater equipment, links to GSFC and MSFC, microwave antennas , sound powered and portable RF equipment.

PROPELLANTS SYSTEM LABORATORY - One facility provides 6,800 sq. ft. for cleaning and testing of contaminated components. Another facility provides 25,124 sq. ft. for cleaning maintenance analysis and testing of high pressure equipment. This area provides clean room and disassembly areas and an additional 15,000 sq. ft. of paved area for parking of tube-bank trailers, offices and shops.

UNIFIED S-BAND FACILITY - This facility provides mission support for orbital coverage in the KSC area, pre-mission support. software development and network training and familiarization. Equipment includes S-band 30 ft. antenna, 10 Kw transmitters UHF-VHF antennas, UNIVAC computers, data decommutators, and displays.

POWER DISTRIBUTION FACILITY - This facility distributes commercial and locally generated 60 cycle power to all site areas. The system is divided into industrial instrumentaion, emergency, and isolated (short-transient susceptible equipments) systems. Equipment includes stations, substations, distribution and switching equipments to provide 70,000 KVA at the industrial area and 100,000 KVA to LC-39 area substations. The distribution circuit forms a closed loop system with Florida Power and Light at the CKAFS and space center interconnections.

ADMINISTRATIVE AND ENGINEERING OFFICES - Contractors requirements can be assigned to the Manned Spacecraft Operations Building with remote areas in the Vertical Assembly Building, Launch Control Center areas. The MSOB provides approximately 250,000 sq. ft. of office space.

NOTE: Several facilities identified on Table I have been omitted from the above descriptions, where nomenclatures were self explanatory, facilities were minor areas, or information is unavailable.

4.8 APPENDIX

4.8.1 Manufacturing Management and Control - The Manufacturing Director has responsibility for implementation and management of the Manufacturing Project. His organization is shown in Figure 4.8-1. This chart is related only to those personnel which are directly assigned to this project. The line organization will be comprised of experienced personnel with proven managerial abilities and broad aerospace technical backgrounds. However, all of the experience, background, and technical "know how" of the entire MDC manufacturing and development organizations are available in an advisory or consultation capacity. A group of staff specialists will advise and aid in promoting the following functions:

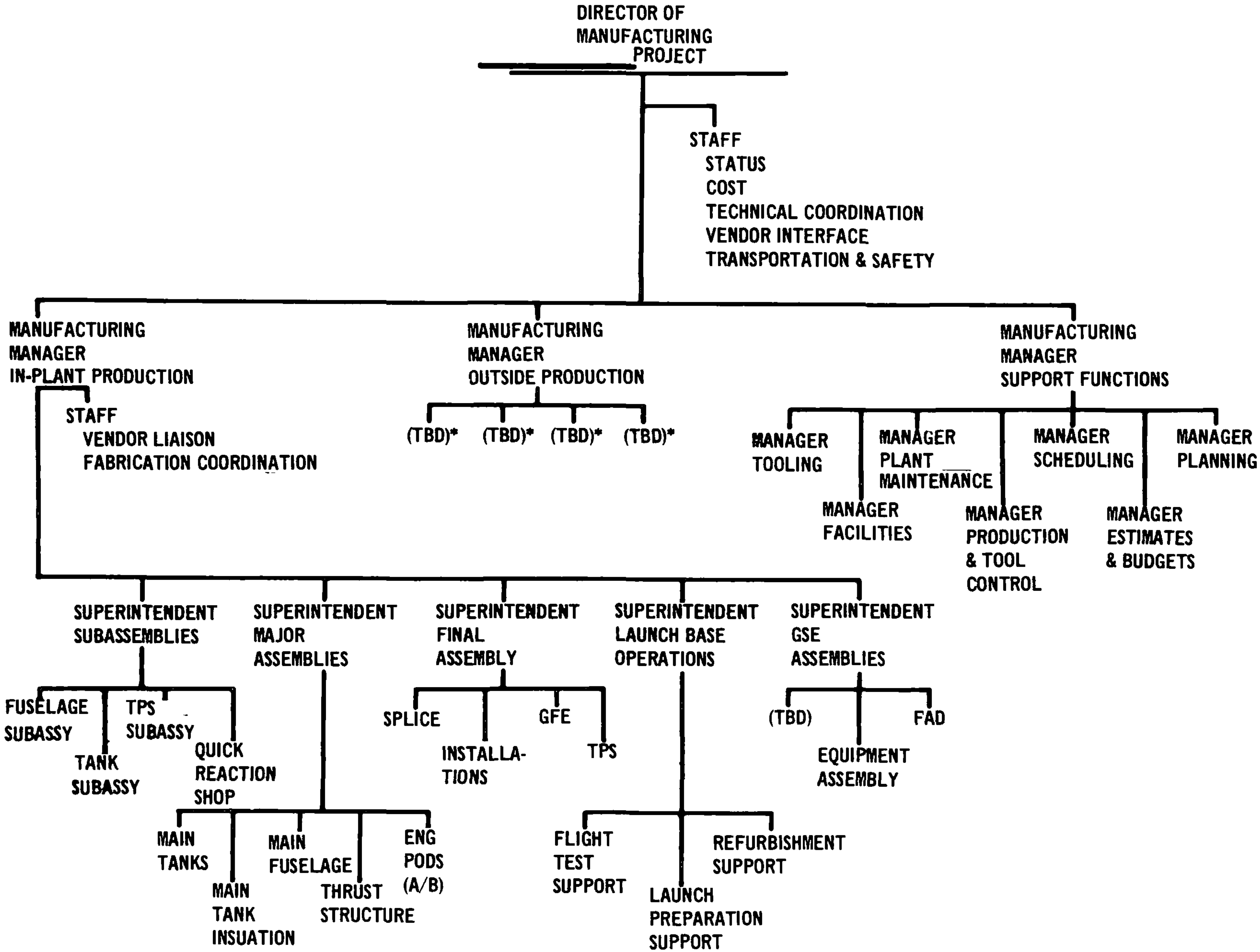
Primary Functions

- Planning
- Tool Design
- Fabrication
- Assembly
- Production Control
- Scheduling

Secondary Functions

- Program Control and Reporting
- Vendor Interface
- Manufacturing Program Schedule Coordination
- Transportation and Safety
- Evaluation of Program Status and Progress
- Vendor Performance Analysis
- Corrective Action for Budget Deviations

MANUFACTURING MANAGEMENT ORGANIZATION



(*) NOTE. OUTSIDE PRODUCTION ITEMS TO BE DETERMINED BY "MAKE OR BUY" COMMITTEE

FIGURE 4.8-1

The Manufacturing Director will provide leadership and direction in attaining cost effective operations which result in quality hardware on schedule, and within the budgeted cost.

Interfaces within manufacturing organization and with engineering is shown as an overview in Figure 4.8-2. This chart depicts the flow of infomation and reporting. The following brief summaries describe the functions of the various elements of the manufacturing line and staff groups.

4.8.1.1 Production Planning - The Production Planning Department, working from approved Engineering drawings, prepares tool orders to initiate tool design and fabrication. Production work orders for piece part fabrication, assemblies, and installations of the test units and flight articles are also prepared for release to Manufacturing. Figures 4.8-3 and 4.8-4 are examples of these documents.

Throughout the program, this department establishes production requirements, prepares work plans, and determines the most efficient methods and procedures for maintaining schedule position.

Additionally, this group assures the proper and economical use of manpower and facilities for the Manufacturing Program. Figure 4.8-5 shows the functional flow of information through this group.

4.8.1.2 Production Scheduling - The Production Scheduling Department prepares all schedules for manufacturing and tool activity. These schedules, which are based upon the master schedules and customer requirements, are used to establish priorities for tooling, production, and vendor deliveries. In addition, manufacturing budgets, manpower forecasts, allocations of floor space, and use of facilities are determined from these schedules.

The Production Scheduling Department also aids configuration control management in selecting the most economical and/or optimum point for incorporation

MANUFACTURING IMPLEMENTATION FLOW

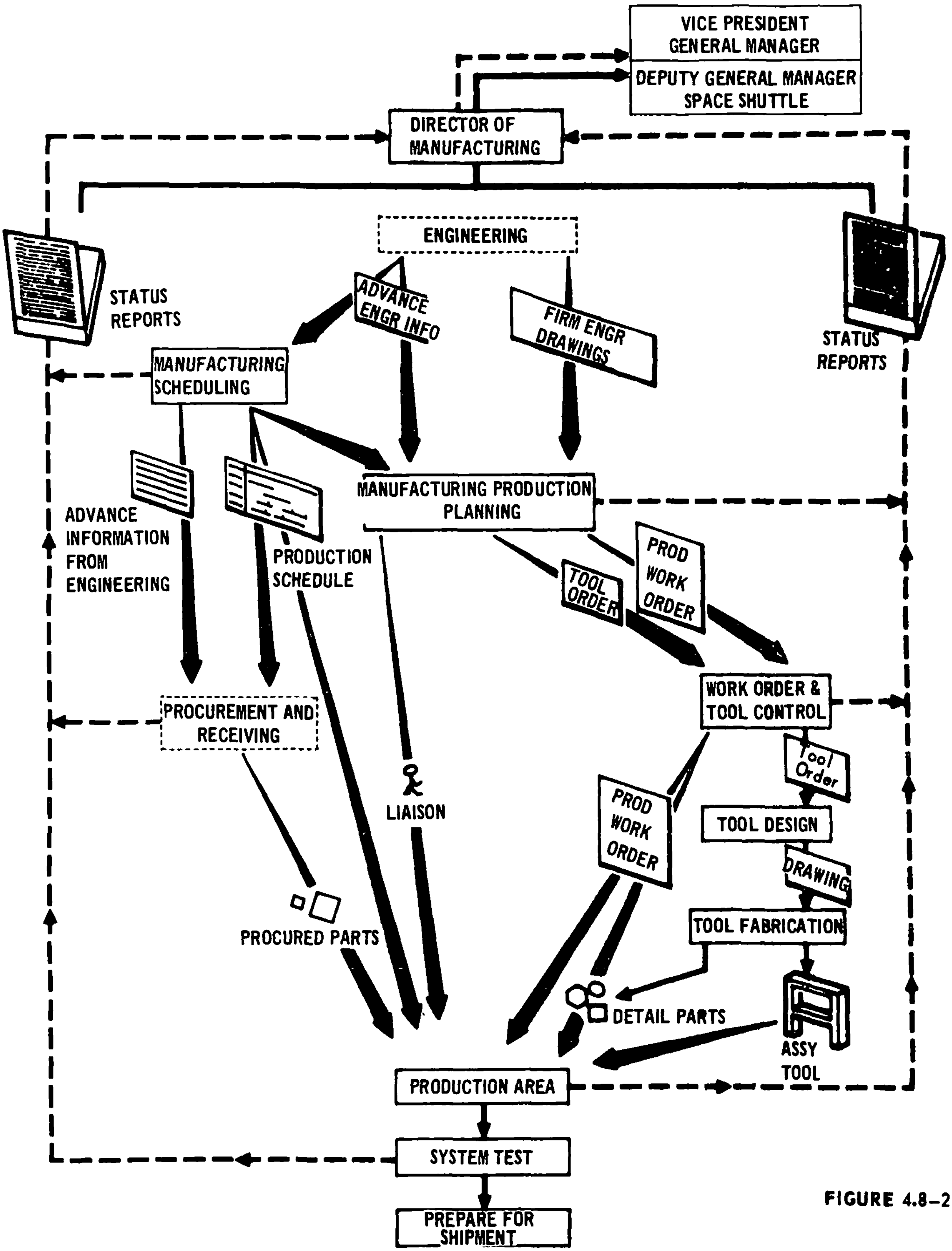


FIGURE 4.8–2

MAC 1288V4 (REV 23 OCT 63) MCDONNELL PRODUCTION WORK ORDER

Part Number (Prefix / Basic / 1st Dash)	65 / 27311 / 3
Part Name	DOUBLER
Codes	J
Material	TITANIUM
Specification	AMS4901
Size	.020 x 2.9 x 9.3

Next Assembly Prefix	Basic	1st Dash	Alpha	2nd Dash	Model	/Ship	Effectivity
65		-1			128	1	1 & UP

TITANIUM SPECIAL HANDLING

NO	DEPT	OPERATION	MACHINE OR FIXTURE	TOOLS
1	782	Rough shear per temp	SH31	DT-3
2	161I	Scribe trim lines per temp	BT11	DT-3
3	161I	Trim per scribe lines (Deposit scrap in titanium container)	BT11	
4	161I	Sand per scribe lines & burr	BD11	
5	162	Alkaline clean per PS12030	PC35	
6	161I/	Identify per B/P & PS 16001.5 - Ink stamp with part no. &this W/O ser. no. prefixed W/O	BI11	
7		Inspect	IN11	DT-3
8		Assemble		

SAMPLE

FIGURE 4.8-3

MCDONNELL DOUGLAS
SAINT LOUIS

ASSEMBLY ORDER

JOB ORDER	ITEM NO.	COST CODE	ASSEMBLY NAME	ASSEMBLY NO.	PAGE / OF
			BONDED ASSY. INLET MUFFLER OWS MODULE	61A830260-503	PAGE 1 OF 1

REMARKS	NEXT ASSEMBLY	MODEL	SHIP	EFF. NEXT ASSY.	PLANNER & DATE	CHANGE LETTER
FOR P.S.14210 USE PROCESS BULLETIN 4-177 EJS61-0845	61A830260-3	1003	1	U1 & Up Sta-3	WFR 10/29/70	
					PLANNING EFFECTIVITY	
					DEPT	TO DEPT.

SEQ. NO.	☐ PARTS LIST ASSEMBLY ORDER ☐ LINE STATION ASSEMBLY ORDER — OPERATION OR PART NAME	DRAWINGS SHOWN ON	ZONE	PART NUMBER DRAWING NO.	DASH NO.	SOURCE CODE	QTY. PER ASSY.	EFFECTIVITY	STAMPS REWK. REQ'D.	SHOP	MDC AGENCY CUST. INSP.
	E805 REVIEWED FOR QA RQMTS										
	RECORD WORK ORDER SERIAL NUMBER OF EACH ITEM										
	CODED AS "M" OR "A" IN THE SOURCE CODE COLUMN										
	AFTER DETAILS ARE CLEANED HANDLE ALL DETAILS WITH WHITE GLOVES.										
	NOTE: WITHIN 16 HOURS OF COATING WITH ALODINE, PARTS MUST BE CLEANED AND PRIMED. PRIMED										
	DETAILS MUST BE ASSEMBLED WITHIN (7) DAYS. DO NOT DELAY ONCE ASSY HAS BEEN "OKED" BY										
	INSPECTION TO START PROCESSING. SCHEDULE SHOP-TIME SO THAT ADHESIVE LIFE AND CLEANING										
	LIMITS ARE NOT EXCEEDED. ALL ADHESIVE BONDING OPERATIONS SHALL BE PERFORMED BY										
	QUALIFIED PERSONNEL AS DEFINED BY PS23410. REF P.B.4-177-PS14210 BEFORE STARTING WORK										
	CONTACT E457 TO WITNESS ALL OPERATIONS.										

SAMPLE

MAC 943 (REV 9 MAY 69)

FIGURE 4.8-4

PRODUCTION PLANNING FUNCTIONAL FLOW CHART

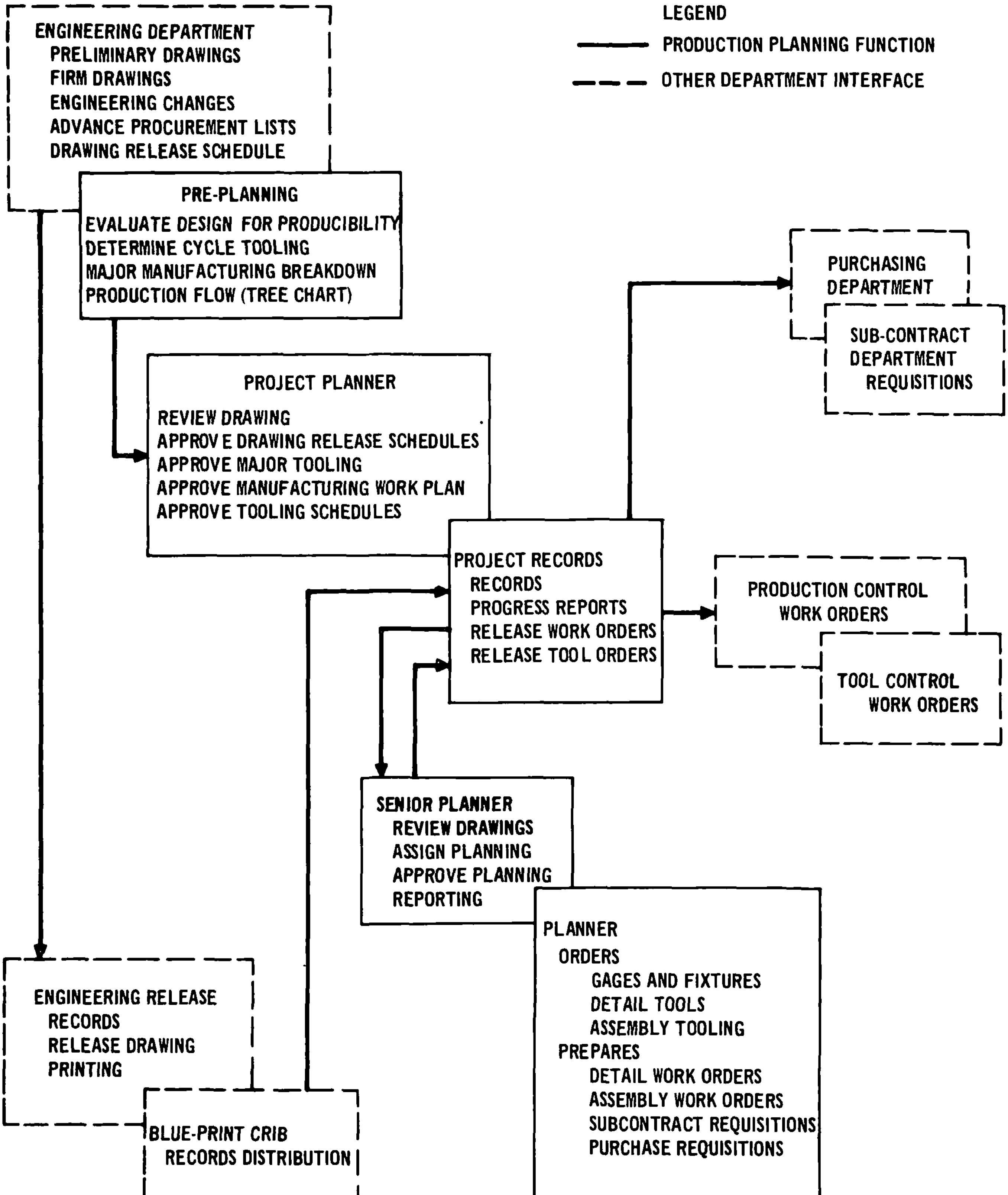


FIGURE 4.8-5

of Engineering change orders. The department supplies information for costing these changes as well as progress reports versus the schedule. Figure 4.8-6 shows the functional flow of information through this group.

4.8.1.3 Tooling - The Tooling Department works from tool orders and hardware designs to design and furnish the special tools required for the Production Program. An example of this tool order is shown in Figure 4.8-7 This information is the basis for design, development, construction and tryout of all special tools. Items of special tooling for testing, inspection and handling are included in this category. Figure 4.8-8 shows the functional flow of information through this department.

4.8.1.4 Production Control - The Production Control Department controls the release and flow of all work orders for hardware and tooling. This control is accomplished by directing the movement of all material, tooling, piece parts, assemblies, and vendor parts to their respective usage point and by maintaining and reporting pertinent information regarding status and schedule position of all manufacturing and tooling work. Figure 4.8-9 shows the functional flow of information through this department.

4.8.1.5 Manufacturing Operations Control - This department prepares estimates for all new or proposed work in the manufacturing and tooling areas. They monitor and report actual expenditures for all work in process in these areas. This information is supplied to the Manufacturing Director through the following standard reports:

- o Divisional level, budget vs actual, total of all projects
- o Divisional level, budget vs actual, by project
- o Department level, budget vs actual, by project

Actual costs are accumulated according to the Work Breakdown Structure (WBS) for comparison with predicted expenditures. This information is furnished

SCHEDULING DEPARTMENT – FUNCTIONAL FLOW

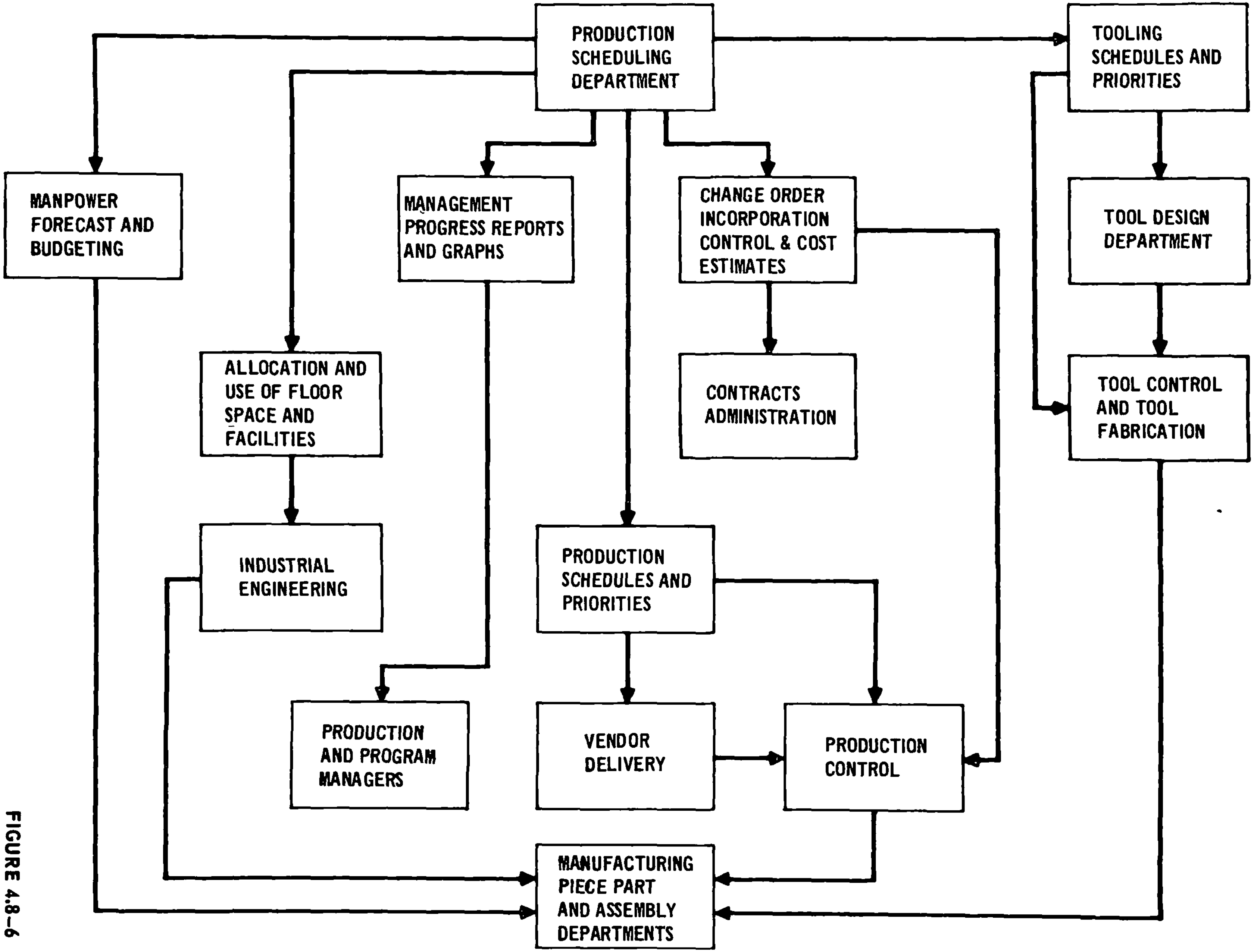


FIGURE 4.8-6

MFG 3708 ☐ MFG 3720 ☒ **MCDONNELL** TOOLING ORDER SHEET 1 OF 2

TOOL NUMBER			TD	TOOL CODE	TT NO	S	SCR	DUP	GRP	SECT	C	DESIGN EST HRS
AOA	200002	503	D	AF					91	E	A	

PREL FAB EST

CC	QTY	TYPE	REQ D	TOOL FUNCTION
1				ASSEM. FIXTURE - FWD. TUNNEL SECTION

FAB SPAN

CC	RATE	USED IN STATION			USAGE CODE (01-09) (11-19)	MOD
2		AOA	200002	651		25

PLANNER DATE: XX

TCO	MOD	CIGE CODE	UFF	JOB	ITL	COST CODE	T O	C C	FAB START	FAB COMP	ORDER TYPE (CIRCLE ONE) 1 MAKE 2 RWK 3 R&R 4 RPL	E C	RESP DEPT	M I
	25	11	91	439	11	106							124	A

CONCURRENCE: XX

SHIP NO EFFECTIVITY	AMT REQ'D	DES START	ADV REL REQ'D	DES FIRM	T/C CODE AND CYCLE	DATE REC TOR
1 & UP	1					

DRAWING NO.	EJS NO	REMARKS	REQ'D TFIM	REQ'D TPIM
A0A20002	XXXX		NONE	NONE

CH C	INVENTORY DATE	BLDG LOC	A.C	NC	TOOL COST DESIGN	FAB	JOB ORDER	USING DEPT	IC
							639	E185	

MAC 207 (REV 3 SEP 68)

SAMPLE

MCDONNELL TOOLING ORDER SHEET 2 OF 2

TOOL NUMBER			TD	TOOL CODE	SET	SER	DUP	TCO	PLANNER DATE
AOA	200002	503	D	AF					XX

DEPT	INSP	TECOM	INSTRUCTIONS
187D			Design AF-503 TD for use to locate -7 inner skin & A0A200051-1 skin by E.O.P. stops on AFT E.O.P. Locate 02 tank support fittings by threaded studs also locate all horizontal zees at both ends. NOTE: Location of 02 fittings controls location of A0A200055-1 & -3 rings coord. to AF-501
114			Layout & make floor provisions for AF-503TD
124			Make per T.D. & identify
866			Inspect
144			188/Use N/A A0A200002-051

FIGURE 6A

MAC 207 (REV 1 AUG 69)

FIGURE 4.8-7

TOOLING DEPARTMENT FUNCTIONAL FLOW CHART

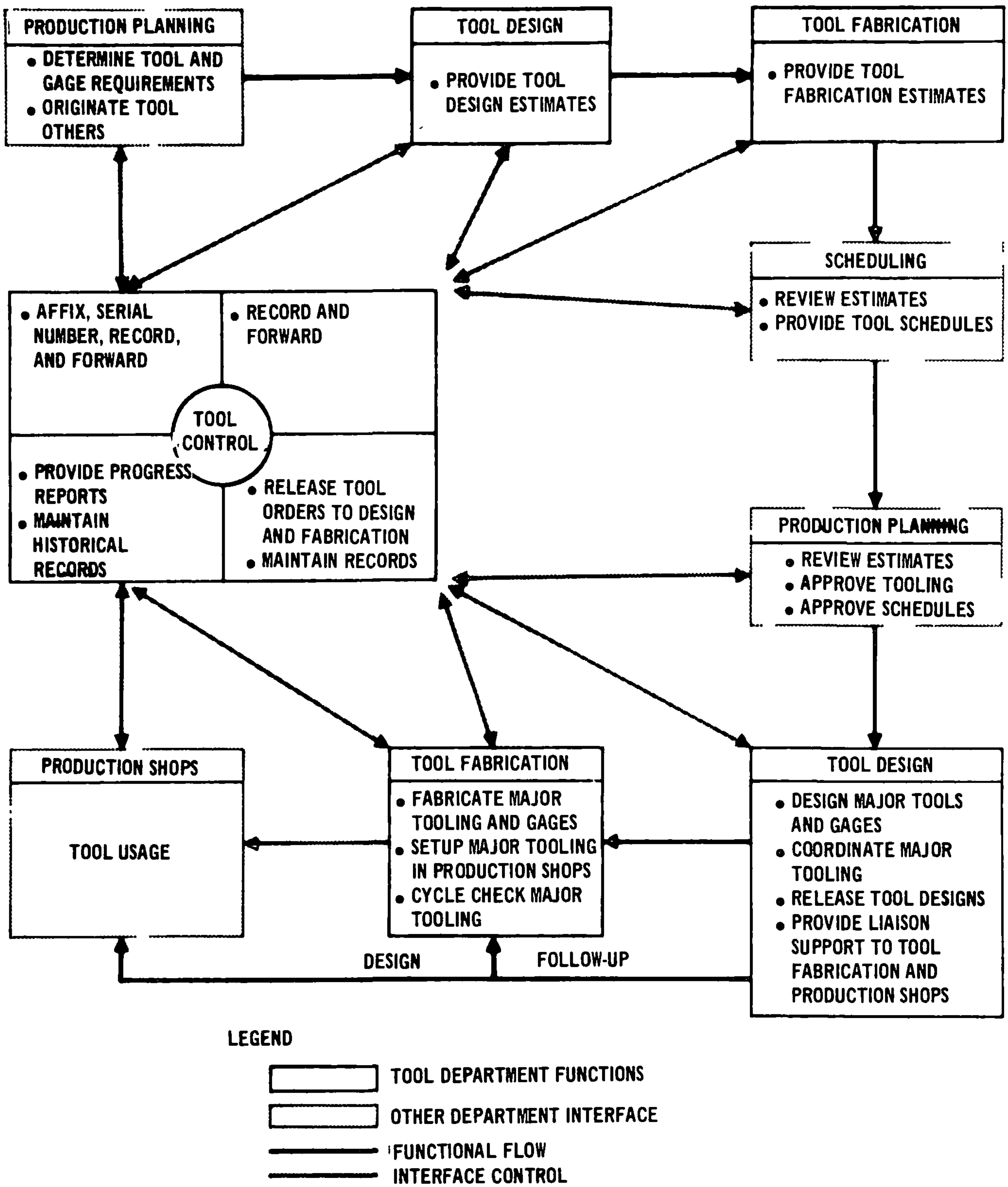


FIGURE 4.8-8

PRODUCTION CONTROL FUNCTIONAL FLOW CHART

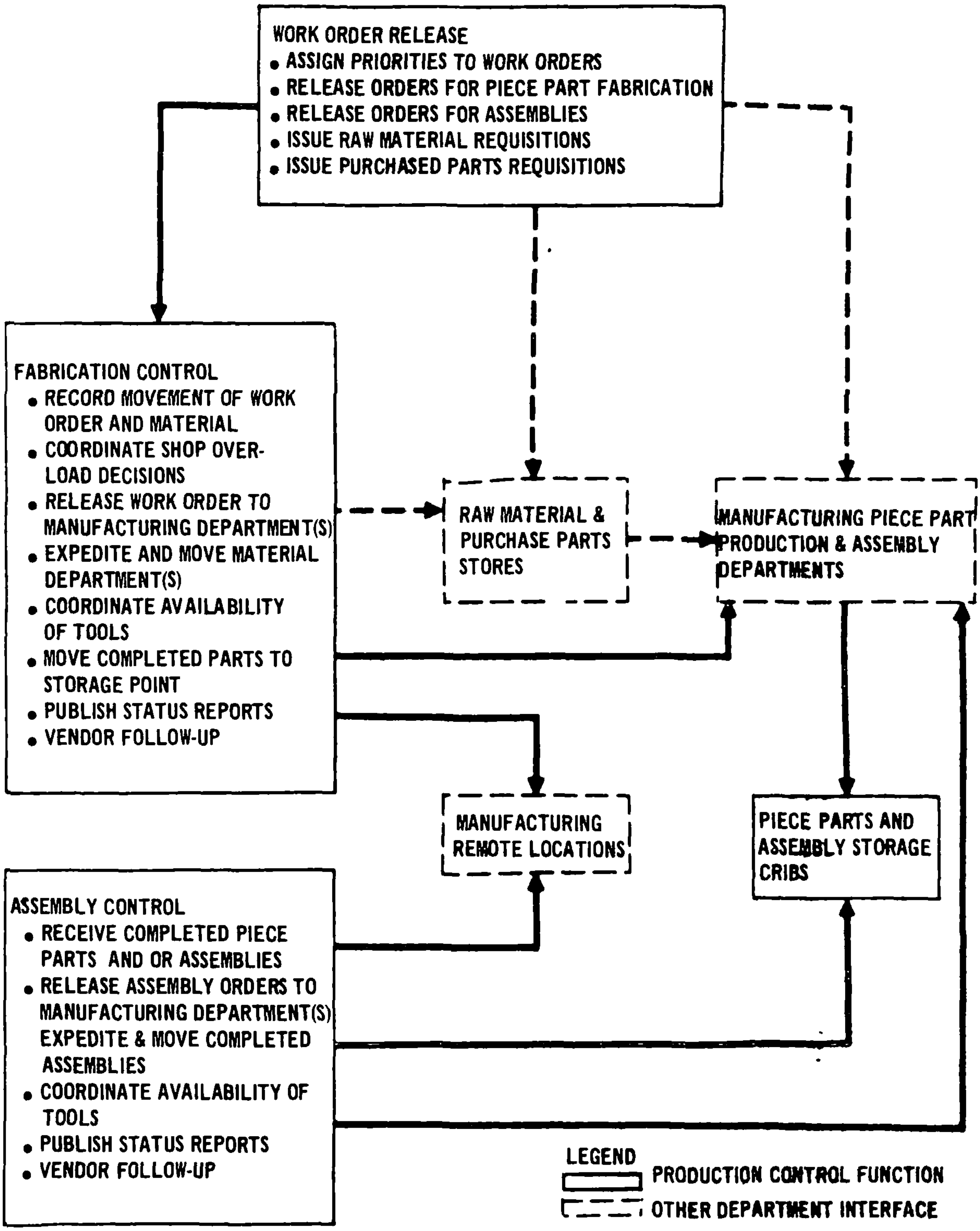


FIGURE 4.8-9

to the functional groups for appropriate action. Figure 4.8-10 shows the functional flow of information through this department.

4.8.1.6 Manufacturing Status and Progress Reporting - This department furnishes statistical reports of program progress and status to the various levels of functional management. This information is divided into the following categories: fabrication, structure, installations, test items, vendor delivery and KSC. These are issued weekly; however, for more critical items requiring closer control, they may be issued daily.

Probably the most influential single factor regarding selection and implementation of a Manufacturing Program Control System for the Space Shuttle Project is the size of the vehicles. This is apparent from consideration of facilities, equipment, and manpower requirements at a particular manufacturing facility or location and its program impact. As a result, it is advantageous to disperse the work over a wide range of locations. This emphasizes the need for a manufacturing control system which has capability of securing, correlating and publishing meaningful information rapidly. This information should provide good visibility regarding status, cost, delivery and quality from in-house and vendor performance.

Similar requirements from previous programs at McDonnell Douglas have resulted in the development of a management control system called Management Information System (MIS). This system relates the total program effort to identifiable work packages in the Work Breakdown Structure and in the schedules. Also, it furnishes costing, budgeting, and work progress analysis information to the appropriate level of in-house and subcontract activity. An overview of this system, as described in the MDAC Standard Practices Manual, is shown on the following pages.

OPERATIONS CONTROL FLOW CHART

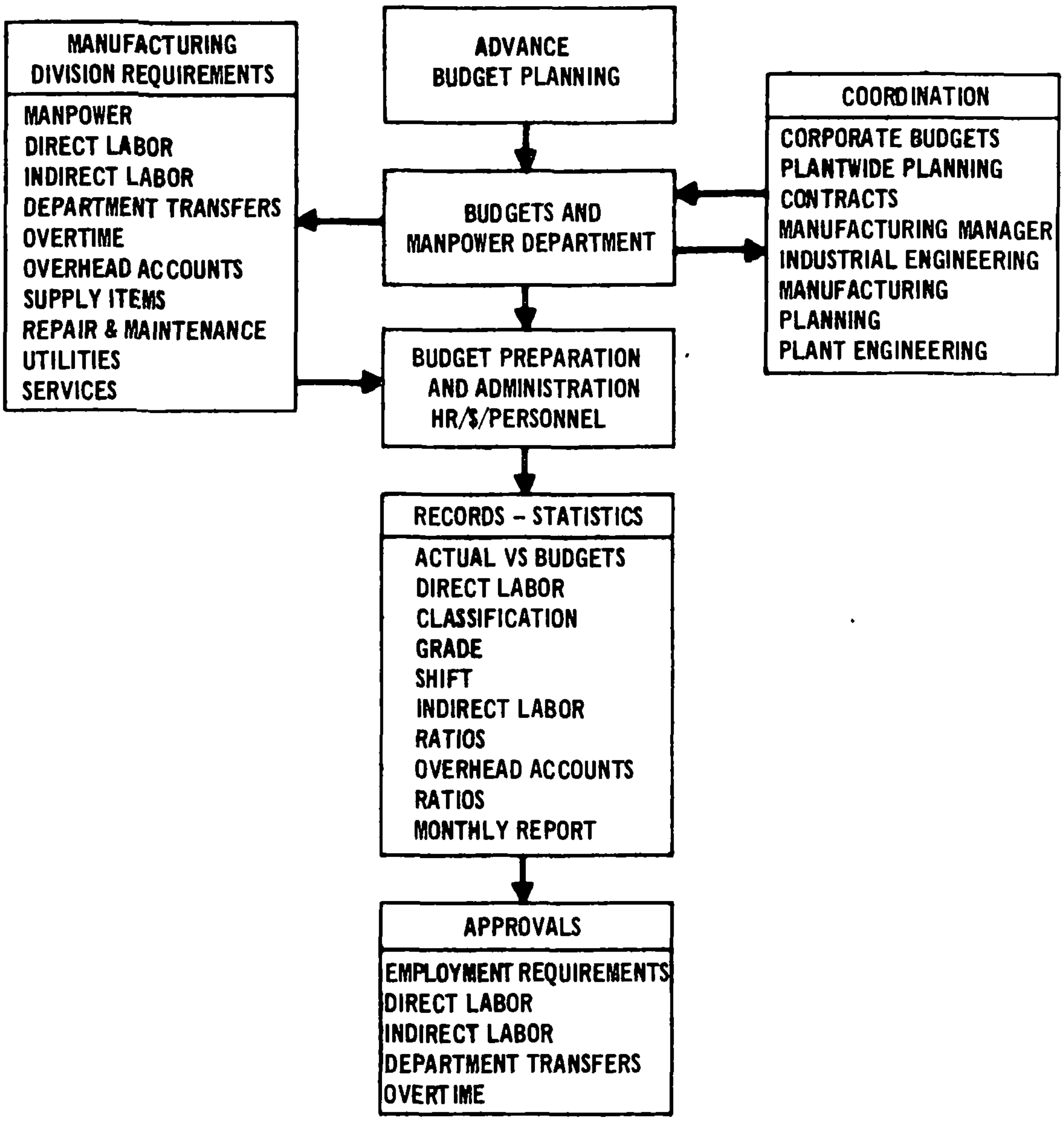


FIGURE 4.8–10

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
EASTERN DIVISION
MCDONNELL DOUGLAS CORPORATION

STANDARD PRACTICE

NO 1.200-AEC
PAGE 1 OF 6
DATE 22 Sept. 1970
SUPERSEDES SP 1.200-AEC
Dated: 14 July 1970

ORGANIZATION Operations

SUBJECT MANAGEMENT INFORMATION SYSTEM OVERVIEW

A. SUMMARY:

The Management Information System is employed to plan, record and report labor and material cost and schedule and variance data for internal management control and customer reporting.

B. APPLICABLE TO.

Manufacturing
Materiel
Operations Control
Product Support
Quality Assurance

C. DEFINITIONS:

1. Apportioned Effort (AE). Work that has the same characteristics as a specific Work Package (WP) but is planned and controlled in direct proportion to that WP. N

2. Budget: The resources (dollars or manhours) which are assigned for the accomplishment of a specific identity of work.

3. Budgeted Cost of Work Scheduled (BCWS): The estimated value of resources to be consumed in the performance of planned work.

4. Budget Cost of Work Performed (BCWP): The BCWS value earned for work performed as milestones as accomplished.

5. Contract Budget Baseline (CBB): The contract target cost plus the estimated cost of contractually authorized changes.

6. Contractor Work Statement (CWS): A compilation of detailed descriptions of products and services furnished by the functional divisions in accordance with the Work Breakdown Structure (WBS).

7. Cost Account (CA). The lowest focal point within the WBS identified to a specific organization where responsibility is assigned for planning and measuring work performance.

8. Division Baseline Budget (DBB). The sum of the CA budgets established by the Divisions. The sum of the DBB plus management reserve equals the CBB.

9. Estimate at Completion (EAC): Actual recorded costs to date plus estimate of costs for authorized work remaining to be completed.

10. Job Authorization Document (JAD): A document issued by the Program Control Office to authorize work at the CA level. The JAD includes the scheduled start and completion dates, work description and approved budget. The description of work on the JAD will describe the work to be performed within the job-item-cost code. N

11. Level of Effort (LOE). Contract work, identified to CAs which are planned and controlled through time-phased budgets, with the following characteristics: N

a. definable,

N

b. uneconomical to a work package,

c. time phase budgeted, and

d. within one cost account.

12. Master Schedule Graphic or tabular presentation, on a time scale of signigicant events, or milestones, and activities required to develop and deliver specific end item(s) or to perform an assigned effort or any portion thereof.

13. Program Control Office (PCO). The organizational element responsible for monitoring authorized work and status reporting internally and to the customer.

R

14. Undistributed Budget: A budget identified for a specific identity of work but not assigned to a specific operating organization. The Program Director is responsible for monitoring the undistributed budget for the life of the contract.

15. Work Breakdown Structure (WBS) A framework within which total program requirements have been delineated to identify and define hardware and services. The WBS is the basis for correlating schedules, budget, pricing, performance measurement, financial reporting, actual cost accounting and responsibilities for all program elements.

16. Work Package (WP). A discrete unit of work which has the following characteristics:

a. within one cost account,

b. clearly delineated from all other work,

c. a planned value (in dollars or manhours),

d. start and completion milestones, and

e. limited to a relatively short time span.

D. REGULATIONS.

1. Operations Division uses the MANAGEMENT INFORMATION SYSTEM (MIS), as prescribed in CP 1.200-AE.

R

2. As a program is initiated, a WBS is constructed (Reference CP 2.210-AE) taking into account hardware, software and service elements. The MIS measures performance, determine variances, etc., to the customer desired level of the WBS.

3. The CWS follows development of the WBS, describing the specific WBS elements. (Reference CP 2.211-AE) The functional Divisions compile work statements, hardware descriptions, sketches, etc., for incorporation into the CWS.

4. From the WBS and CWS, cost estimates are prepared to the requirements specified in the MAC 1367, REQUEST FOR ESTIMATE (RE), and in accordance with CP 7.250-AE and CP 7.253-AE.

5. Work authorizations are released on a new program by the MAC 754, JOB ORDER (JO), and divisional activity is authorized by the MIS Report 18.21.13, JOB AUTHORIZATION DOCUMENT (JAD), in accordance with CP 7.245-AE. Changes, either Customer or Contractor - Directed, are authorized by the MAC 754, JOB ORDER SUPPLEMENT (JOS), and a revised JAD in accordance with CP 7.245-AE.

6. MIS combines schedule and cost estimates into a budget baseline for performance measurement, internal reporting and management

control. The Program Master Schedule (CP 2.013-AE) establishes the milestones for major events and subsequent scheduling of effort in the functional organizations. (Reference SP 9.055-AECA)

7. DBB is distributed and values are assigned to WBS elements down to the CA level as specified in CP 7.255-AE. MIS identifies through WBS levels the responsibilities, both internal and subcontracted, for each CA. WPs are used and developed to establish the BCWS and BCWP as monthly analyses of each CA are made.

8. WPs are planned as far into the future as visibility allows. Most WPs are three months or less in length. Planning extends six months into the future as far as practical. Work is not authorized until budgets are authorized. Interim budgets are used for work authorized but not yet negotiated or until official budgets are prepared and released. N

9. Level of Effort CAs are established for work which cannot be planned in detail and is impractical to a WP or cannot be established as an AE. If the entire CA cannot be subdivided into detail WPs, planning packages are established within the CA to the maximum extent possible for budgeting and scheduling purposes. N

10. Work progress is reported monthly through the MIS by an automated COST/SCHEDULE PERFORMANCE REPORT (C/SPR), in accordance with CP. 1.205-AE.

11. Operations Division Management reports cost and schedule variances with an explanation and necessary corrective action as outlined in CP 1.210-AE.

12. Deriving a realistic estimate of the cost (manhours or dollars) of the remaining work to be completed in open/unopen CAs is performed. (Reference CP 7.252-AE) The value of the CAs completed is added to the estimate of the remaining CAs to arrive at the total Operations Division estimated cost at completion.

13. Management of material cost under the MIS is at the point of usage. The usage price and cost variances are determined and reported. A Cost/Schedule Control System (C/SCS) requirement is placed on those suppliers designated Major Subcontractors when requested by MDAC-East as stated in CP 1.200-AE.

14. The incorporation of the MIS from the proposal phase through the production and support phases (contract life) is authorized by MDAC-East Management as specified in CP 1.200-AE.

E. PROCEDURE

Operations Control

1. Receive the Request for Proposal (RFP), Customer's Statement of Work (SOW), etc., coordinate with the Subdivisions on requirements to support proposal effort and make formal request, with justification, for the Operations Division proposal budget.

All Subdivisions - Program Managers

2. Receive the assignment for the specific program and initiate action required as follows.

   a. designate individuals to

serve on the WBS Control Board (Reference SP 2.210-AEC),

b. delegate work statement preparation. (Reference SP 2.211-AEC)

Designated Individuals

3. Participate directly on WBS Control Board in the formulation of the WBS.

4. Prepare functional work statement defining the WBS element.

All Subdivisions

5. Commence scheduling functional activities from the WBS and CWS.

6. Review the RE from Contract Administration and response to RE as described in SP 7.250-AEC.

7. From the established master schedule, schedule hardware and software events in accordance with WBS requirements.

8. Submit cost estimates, copies of work plans, etc., to Operations Control.

Operations Control

9. Finalize cost estimates and secure approvals in accordance with SP 7.250-AEC.

10. Upon contract go-ahead, receive JO and proceed in accordance with SP 7.245-AEC.

11. Upon receipt of JAD, distribute the DBB in accordance with SP 7.255-AEC and establish the baseline budget for each CA to be input into the MIS. (Reference SP 7.256)

All Subdivisions

12. Issue the work authorizing documents as described in SP 7.246-AEC and SP 7.247-AEC.

Operations Control

13. As the work authorizing documents are released and received, establish the following WPs:

a. Tool WP (Reference SP 7.266-AEC)

b. Fab WP (Reference SP 7.262-AEC)

c. Subcontract WP (Reference SP 7.262-AEC)

d. Subassembly WP (Reference SP 7.263-AEC)

e. Support WP (Reference SP 7.264-AEC)

f. Assembly WP (Reference SP 7.265-AEC)

14. Provide other monitoring devices during the life of the program as·

a. Overhead budgets (Reference SP 7.258-AEC)

b. Direct labor budgets (Reference SP 7.257-AEC and SP 7.259-AEC)

c. Overtime requesting (Reference SP 5.118-AEC and SP 10.053-AECD)

d. Manufacturing and reporting (Reference SP 1.411-AEC and SP 7.300-AEC)

Materiel Subdivision

15. Implement the C/SCS with Major Subcontractors as set forth in SP 6.527-AECB.

Operations Control

16. As the MIS furnishes cost and schedule data from the baseline

budget file and WP file, analyze the data and prepare control charts.

17. Receive C/SPR and provide Operations Management with a detail status and analysis report of the actual versus BCWS and BCWP. (Reference SP 7.280-AEC)

18. For those out of tolerance CAs, prepare an estimate to complete and an EAC to determine CA status. (Reference SP 7.285-AEC)

19. Submit monthly reports to Subdivision Heads and Division Head on significant variances.

20. Forward corrective action resolutions received from the Subdivisions, to the PCO. (Reference SP 7.290-AEC)

<u>All Subdivisions</u>

21. Throughout the life cycle of the program, maintain the course of events, i.e., estimating, scheduling, budgeting, work completion, performance measurement, variance analysis, re-estimating, changes, etc.

F. REFERENCES

1. <u>Authority</u>

   a. CP 1.200-AE, Management Information System

2. <u>General</u>

   a. CP 1.205-AE, Cost/Schedule Performance Reporting System

   b. CP 1.210-AE, Variance Analysis

   c. CP 2.013-AE, Program Master Schedule System

   d. CP 2.210-AE, Work Breakdown Structure

   e. CP 2.211-AE, Contractor Work Statement

   f. CP 7.245-AE, Work Authorization - Job Order, Job Order Supplement, and Job Authorization Document

   g. CP 7.250-AE, Estimating System

   h. CP 7.252-AE, Estimate at Completion

   i. CP 7.253-AE, Request for Estimate

   j. SP 1.411-AEC, Weekly Labor Distribution Report

   k. SP 2.210-AEC, Work Breakdown Structure Support

   l. SP 2.211-AEC, Preparation of Function Work Statements

   m. SP 5.040-AECC, Extended Workweek and Overtime Submittal and Authorization

   n. SP 5.118-AEC, Authorization and Scheduling of Extended Workweek and Overtime

   o. SP 6.527-AECB, Implementation of C/SCS with Major Subcontractors

   p. SP 7.245-AEC, Job Order, Job Order Supplement and Job Authorization Document

   q. SP 7.246-AEC, Work Authorizing Documents and Release of

   r. SP 7.247-AEC, Support Work Authorization

   s. SP 7.250-AEC, Estimating System

   t. SP 7.255-AEC, Budgeting System

   u. SP 7.256-AEC, Establishing the Baseline Budget

v. SP 7.257-AEC, Direct Labor and Material Budgets

w. SP 7.258-AEC, Indirect Cost Control

x. SP 7.259-AEC, Direct Cost Tracking/Reporting - Product Support

y. SP 7.262-AEC, Fabrication and Subcontract Work Packages, Estimating and Processing

z. SP 7.263-AEC, Subassembly Work Packages, Estimating and Processing

aa. SP 7.264-AEC, Estimating Work Packages, Product Support

bb. SP 7.265-AEC, Assembly Work Packages, Estimating and Processing

cc. SP 7.266-AEC, Tooling Work Packages, Estimating and Processing

dd. SP 7.280-AEC, Performance Measurement Reporting

ee. SP 7.285-AEC, Estimating Cost at Completion

ff. SP 7.300-AEC, Manpower Forecast Reporting

gg. SP 9.055-AECA, Manufacturing Schedules and Work Plans

hh. SP 10.053-AECD, Overtime Scheduling and Authorization

3. Forms

a. MAC 754, Job Order (JO)

b. MAC 754, Job Order Supplement (JOS)

c. MAC 1367, Request for Estimate (RE)

4. Reports

a. Contractor Work Statement

b. Cost/Schedule Performance Report

c. Work Breakdown Structure

d. 18.21.13, Job Authorization Document

Director - Manufacturing

Director - Materiel

Manager - Operations Control

Director - Product Support

Director - Quality Assurance

Director - Operations

4.8.2 Quality Assurance

4.8.2.1 General - To achieve a high quality product a conscientious production team effort by Engineering, Procurement, Manufacturing and Facilities personnel is required. The following summary identifies the basic tasks which are accomplished by Quality Assurance personnel during contractor fabrication, assembly and test operations. The overall quality program for Phase C/D will be delineated within the Contractor's Quality Plan.

4.8.2.2 Design and Development Controls - Quality Assurance personnel shall support the design and development phase to the degree required to assure understanding of and compliance with Shuttle quality criteria. Drawings and specifications are reviewed in conjunction with selective review of production planning and the preparation of inspection instruction sheets. Problems are resolved by direct coordination with the applicable design group and follow-up is performed to assure resolution. Quality Assurance shall also participate in Design Change Board activities.

4.8.2.3 Identification and Data Retrieval - The correlation of hardware to software and the means for locating and retrieving articles and materials will be accomplished using written procedures. The implementation of these procedures will be monitored by Quality Assurance, including verification of the correct identification of the articles or material.

Quality Assurance shall maintain a records center for the retention, processing and control of completed production and Quality Assurance documentation packages required to support review meetings and end item data packages to accompany vehicle shipments shall be prepared and validated as part of this function.

4.8.2.4 Procurement Controls - The contractor is responsible for the quality of purchased articles, materials or services. Quality Assurance personnel shall perform or participate in the following:

- o Make or Buy Meetings
- o Defining of quality requirements for each procured product
- o Review and approval of procurement documents
- o Coordination with selected suppliers to assure understanding of quality requirements
- o Survey of selected suppliers when sufficient historical data is not available to ascertain competence of the supplier
- o Assignment of itinerant or resident quality representatives at the supplier as required
- o Review of supplier quality plans and inspection procedures
- o Coordination of problems to assure timely and effective corrective action

4.8.2.5 Receiving Inspection - The contractor shall maintain a receiving inspection function which includes the following controls as required:

- o Verification of the receipt of required data substantiating supplier inspection and test results when required by purchase agreement
- o Verification of contractor or Government acceptance when source inspection is required
- o Inspection for possible damage in transit
- o Verification of quantities and identification (including lot and serial numbers when required)
- o Witnessing or performance of required physical or functional tests to verify acceptance

- Segregation of articles and materials as:
  - Awaiting inspection or test results
  - Conforming/Nonconforming
- Identification of articles and materials to distinguish acceptable items from nonconforming items
- Verification of required packaging and protection prior to release of items from receiving.

4.8.2.6 Fabrication Controls - The fabrication, assembly and test of Shuttle vehicles shall be verified for compliance with the Engineering Drawings, Specifications and test procedure by progressive, timely inspections. These inspections shall be a sequential part of the manufacturing and test documentation which shall include as appropriate:

- The nomenclature and part number identification of the items
- The identification of tooling fixtures or test equipment required
- Part characteristics and tolerances
- Applicable Process Specification requirements
- Provisions for indicating inspection acceptance
- Provisions for recording pertinent data - i.e., serial or lot numbers, actual data measurements, etc.

Article and Material Control - Articles and materials which have critical characteristics as identified by drawing or specification shall be adequately controlled to identify the characteristic (date, time/cycle) which is critical. Quality Assurance personnel shall monitor these items and shall document nonconformities and perform required follow-up to assure corrective action.

Cleanliness Control - Quality Assurance personnel shall monitor production facilities to assure facility environmental controls and work areas are maintained in a manner to prevent detrimental contamination of the product.

Process Control - Contractor quality shall review process specifications prior to issuance, and shall monitor their application to assure compliance. Quality is responsible for the application of NDE techniques during production including hardness testing and radiographic, ultrasonic, penetrant and magnetic particle inspections as specified.

Inspection and Test - Quality Assurance is responsible for the validation of test results from the component level to the totally integrated system. This is accomplished by monitoring or witnessing test operations in a systematic and progressive manner in accordance with contractor approved procedures Contractor Quality shall notify NASA of pending tests when NASA witnessing is specified. Anomalies shall be documented and corrective action follow-up shall be performed as required. Retest shall be performed and reverified to the level required to assure operational compliance. Quality Assurance shall retain test records and data which shall be available for NASA review on request.

Nonconforming Article and Material Control - Contractor Quality Assurance personnel are responsible for the detection and reporting of nonconforming articles or materials. Major nonconforming articles and materials shall be withheld from manufacturing until disposition by the Material Review Board (MRB). Quality Assurance shall participate in the MRB disposition of all nonconforming articles and materials. Follow-up corrective action to avoid repetitive conditions shall be performed.

4.8.2.7 Metrology Controls - Quality Assurance shall verify that calibration standards are maintained in accordance with applicable specifications, including environmental requirements, to assure that the required degree of accuracy is maintained. Regularly scheduled maintenance, inspection and recertification shall be continued for the duration of the Phase "D" production program.

4.8.2.8 Handling, Storage and Shipping - Quality Assurance shall verify that the storage, packaging and shipping of Shuttle items is accomplished in accordance with established requirements. Storage is accomplished in a manner which will not adversely affect the product.

4.8.3 Long Lead Facility and Equipment Requirements

In order to insure satisfactory compliance with the requirements of the Master Schedule, there are certain Facility and Equipment items that cause the development of critical paths to completion of certain major components or functions.

Some of the causes considered in determining long lead items are:

- Poor history or marginal quality for application
- Complex cyclical paths
- Length of processing time
- New or unique materials or processes
- Complexity in fabrication processes
- Time delivery limitations

A complete listing can be prepared only after finalization of the Vehicle Design and the plans for implementation of the program. We are herewith presenting those items of criticality that have become apparent to us at this stage of the program and this list will be revised as the program progresses and the need arises.

Candidates for items of this category are:

LONG LEAD ITEMS (EQUIPMENT)

	ITEM	LOCATION	ACTIVITY	NEED DATE	EST. COST
1.	35' Anodize Facility	Michoud	Orbiter & Booster Tank Skin & "Y" Ring Surface Preparation	7-1-73	1,920,000
2.	Age Forming Oven	Michoud	Tank Skin Hot Forming	7-1-73	*
3.	Insulation Conveyor	Michoud	LH_2 Tank Insulation	6-21-74	*
4.	Wrap Age Former	Michoud	Tank Skin Hot Forming	7-1-73	*
5.	Figure 8 Weld Fixture	Michoud	Orbiter Tank Welding	12-1-73	*
6.	High Temp & Press.	Contractor	Booster Aft Structure & Struts Orbiter Wing & Control Surface	7-1-73	*
7.	Boron/Al Chem Mill Line	Contractor	Orbiter Longerons, etc.	7-1-73	*
8.	Electron Beam Welder W/Localized Chamber	Michoud	Orbiter Dome Ring Frames	7-1-73	*
9.	Strain Relief Furnace	Contractor	Orbiter Fuselage Detail Parts	7-1-73	*
10.	Extrusion Forming Equipment	Contractor	Orbiter Fuselage Detail Parts	7-1-73	*
11.	Titanium Hot Forming Equip.	Contractor	Orbiter Fuselage Detail Parts	7-1-73	*
12.	Oxide Finish Furnace	Contractor	Orbiter Vertical Fin	7-1-73	*
13.	Tube Forming Equipment	Contractor	Orbiter Radiator	7-1-73	*
14.	Felting Towers (HCF)	Contractor	T.P.S. Fabrication	6-6-73	50,000
15.	Tunnel Kiln (HCF)	Contractor	T.P.S. Fabrication	2-1-74	*
16.	Microwave Oven (HCF)	Contractor	T.P.S. Fabrication	2-1-74	16,000
17.	Batch Drying Ovens(HCF)	Contractor	T.P.S. Fabrication	2-1-74	125,000
18.	Ball Mills (HCF)	Contractor	T.P.S. Fabrication	2-1-73	12,500
19.	Autoclave (HCF)	Contractor	T.P.S. Fabrication	2-1-74	2,100,000

LONG LEAD ITEMS (EQUIPMENT) (Continued)

	ITEM	LOCATION	ACTIVITY	NEED DATE	EST. COST
20.	Vacuum/Pressure Impregnation Equipment Carbon/Carbon	Contractor	T.P.S. Fabrication	2-1-74	*
21.	Walk-In Oven (Carbon/Carbon)	Contractor	T.P.S. Fabrication	2-1-74	*
22.	Pyrolization Argon Furnace (Carbon/Carbon)	Contractor	T.P.S. Fabrication	2-1-74	*
23.	Argon Atmosphere Furnace (4000°F) (Carbon/Carbon)	Contractor	T.P.S. Fabrication	2-1-74	200,000
24.	Electron Beam Welders (3) Metallic & Refractory	Contractor	T.P.S. Fabrication	2-1-74	1,000,000
25.	Spot/Beam Welder Foil Gauges (Metallic)	Contractor	T.P.S. Fabrication	6-3-73	50,000
26.	Coating Vacuum Furnace	Contractor	T.P.S. Fabrication	ASAP	500,000
27.	Slurry Coating Equipment	Contractor	T.P.S. Fabrication	2-1-73	25,000
28.	Plasma Spray Equipment	Contractor	T.P.S. Fabrication	2-1-73	25,000
29.	Electro Chemical Grinder (Metallic) (4)	Contractor	T.P.S. Fabrication	6-3-73	350,000

*Final part configuration to dictate size and cost of equipment.

LONG LEAD ITEMS (FACILITIES)

	ITEM	LOCATION	ACTIVITY	NEED DATE	EST. COST
1.	Modify Vertical Weld Station	Michoud VAB	Booster LH_2 Tank Welding	10-1-73	265,000
2.	Construct New Vertical Weld Station	Michoud VAB	Orbiter Main Propulsion Tank Weld	12-1-73	530,000
3.	Modify Hydrostatic Test Facility	Michoud VAB	Booster LOX Tank Sodium Dichromate Proof Test	1-1-74	275,600 (items 3 & 4)
4.	Modify Hydrostatic Test Facility	Michoud VAB	Booster LH_2 Tank Internal Cleaning	1-1-74	
5.	Construct New Pneumostatic Test Facility	Michoud Remote Area	Booster & Orbiter LH_2 Tank Proof Test	1-1-74	339,200
6.	Construct New LH_2 Tank Insulation Room (Booster & Orbiter)	Michoud Bldg 103	Booster & Orbiter LH_2 Tank Internal Insulation	6-1-74	636,000
7.	Construct New Final Assembly Bldg.	KSC	Final Assembly Booster and Orbiter	7-1-75	59,441,000
8.	Construct New Landing Facility	KSC	Horizontal Flight Test	3-15-76	41,299,000
9.	Construct New Deservice & Safing Facility	KSC	Defueling Flight Vehicles	3-15-76	7,037,000
10.	Modify Mobile Launches (3)	KSC	Ground Test and (2) Vertical Launch (1)	2-1-76 1-1-78	87,591,000
11.	Modify Launch Pads (2)	KSC Pads 39A & B	Ground Test & Vertical Launch	2-1-76 1-1-78	6,740,000
12.	Modify Bays 3 & 4 of VAB	KSC	Vertical Stacking & Integration/Mating	7-1-75	13,786,000
13.	Modify MSOB	KSC	Cargo Handling Facility	1-1-77	178,000

4.8.4 Major Manufacturing Problems and Proposed Solutions - During Phase B, MDAC manufacturing specialists and producibility engineers have continuously evaluated and analyzed the Booster and Orbiter configuration to establish the preliminary baseline manufacturing approaches for implementation during Phase C/D. These evaluations and analyses, which were commensurate with the depth of engineering design information available, have revealed several manufacturing problem areas. For purposes of this report references to a "major manufacturing problem" will infer that a potential substantial program impact could evolve. All other references to "manufacturing problems" will indicate that various degrees of "concern" are involved rather than to be considered a program impact "problem". These problems represent those areas where concerted effort will be expended in the preparation and planning for the manufacture of the Booster and Orbiter. Obviously, not all manufacturing problem areas have been identified at this time due to the limited depth of design information available.

Since a large majority of the identified problems tend to be applicable to both the Booster and the Orbiter the following discussions are structured to eliminate repetition. The manufacturing problems and proposed solutions have been categorized by functions, as indicated below, to allow easier identification with individual interested counterpart functions at NASA.

- Tooling Problems
- Fabrication Problems
- Assembly and Installation Problems
- Processing Problems
- Testing Problems
- Handling and Shipping Problems

Manufacturing problems and proposed solutions have been discussed in other sections of this report, hence, this section is essentially a summary.

A majority of the identified problems are directly related to three inherent qualities of the Booster and Orbiter - extremely large size of piece parts and assemblies; design of reusability of vehicles indirectly creates items which have not previously been manufactured; thermal protection requirements have caused use of materials which necessitate the transition of R & D methods and processes to production methods and processes.

Figure 4.8.-11 presents an overview of MDAC manufacturing analyses as related to problems concerning the production of the Booster and Orbiter.

OVERVIEW OF MANUFACTURING ANALYSES

ACTIVITY	BOOSTER MAJOR ASSEMBLIES										ORBITER MAJOR ASSEMBLIES								
	FINAL ASSEMBLY	FORWARD FUSELAGE	LOX TANK	CENTER FUSELAGE	LH_2 TANK	THRUST STRUCTURE	WING	CONTROL SURFACES	CANARD	THERMAL PROTECTION SYSTEM	FINAL ASSEMBLY	MAIN PROPULSION TANK	CREW STATION	MAIN FUSELAGE	WINGS AND CONTROL SURFACES	CARGO DOORS	SECONDARY TANKS	AIRBREATHING ENGINE PODS	THERMAL PROTECTION SYSTEM
TOOLING	P	D	P	P	P	P	D	P	P	D	D	D	P	D	D	P	P	P	D
FABRICATION	N	P	P	P	D	P	P	P	P	D	N	D	P	P	D	P	P	P	D
ASSEMBLY	P	P	P	P	P	P	P	P	P	D	P	D	P	P	D	D	P	P	D
PROCESSING	N	N	P	N	P	N	N	N	N	D	N	D	N	N	N	N	D	N	D
QUALITY CONTROL	P	P	P	P	P	P	P	P	P	D	P	D	P	P	P	P	D	P	D
HANDLING	D	P	P	P	P	P	P	P	P	D	D	D	P	D	P	P	P	P	D

LEGEND: P = PRESENT MANUFACTURING TECHNOLOGY APPLICABLE

D = FURTHER DEVELOPMENT OF MANUFACTURING TECHNOLOGY REQUIRED

N = NOT APPLICABLE

FIGURE 4.8-11

	APPLICABLE TO	
	BOOSTER	ORBITER
TOOLING		
PROBLEM:		
Establish an economical tooling approach for the manufacture and splicing of Shuttle assemblies and prime structures, which because of their size and resulting cost, cannot utilize conventional-type tooling.	X	X

PROPOSED SOLUTION:

The use of localized tooling, positioned on the production units and aligned to one another through the use of optics and/or lasers will substantially reduce overall tooling costs. See Figure 4.8 -12. Instead of constructing a large assembly fixture for the wing-to-fuselage splice, a different approach must be taken. Tooling which is mounted on the fuselage will establish the reference line of sight. Similar tooling is located on the wing structure relative to the wing chord reference planes. L.O.S. of the wing are positioned coincident with the L.O.S. of the fuselage, while both structures are secured on support stands.

FINAL ASSEMBLY – TOOLING CONCEPTS

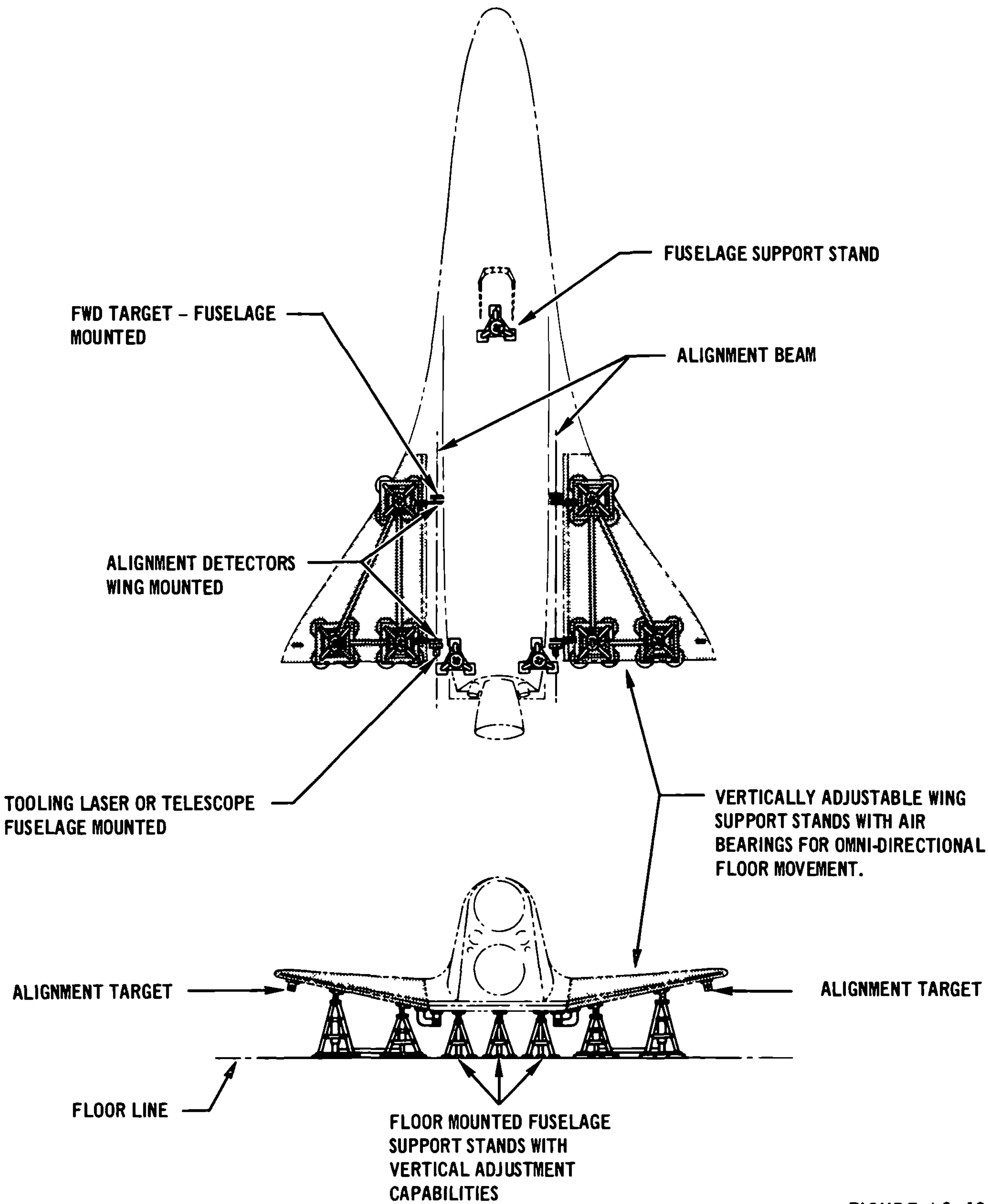


FIGURE 4.8-12

APPLICABLE TO	
BOOSTER	ORBITER

TOOLING

PROBLEM:

Due to the large number of proposed subcontractors and the inherent problems created by the size of assemblies, the integrity of transfer gages supplied to subcontractors will be an item of manufacturing concern. X X

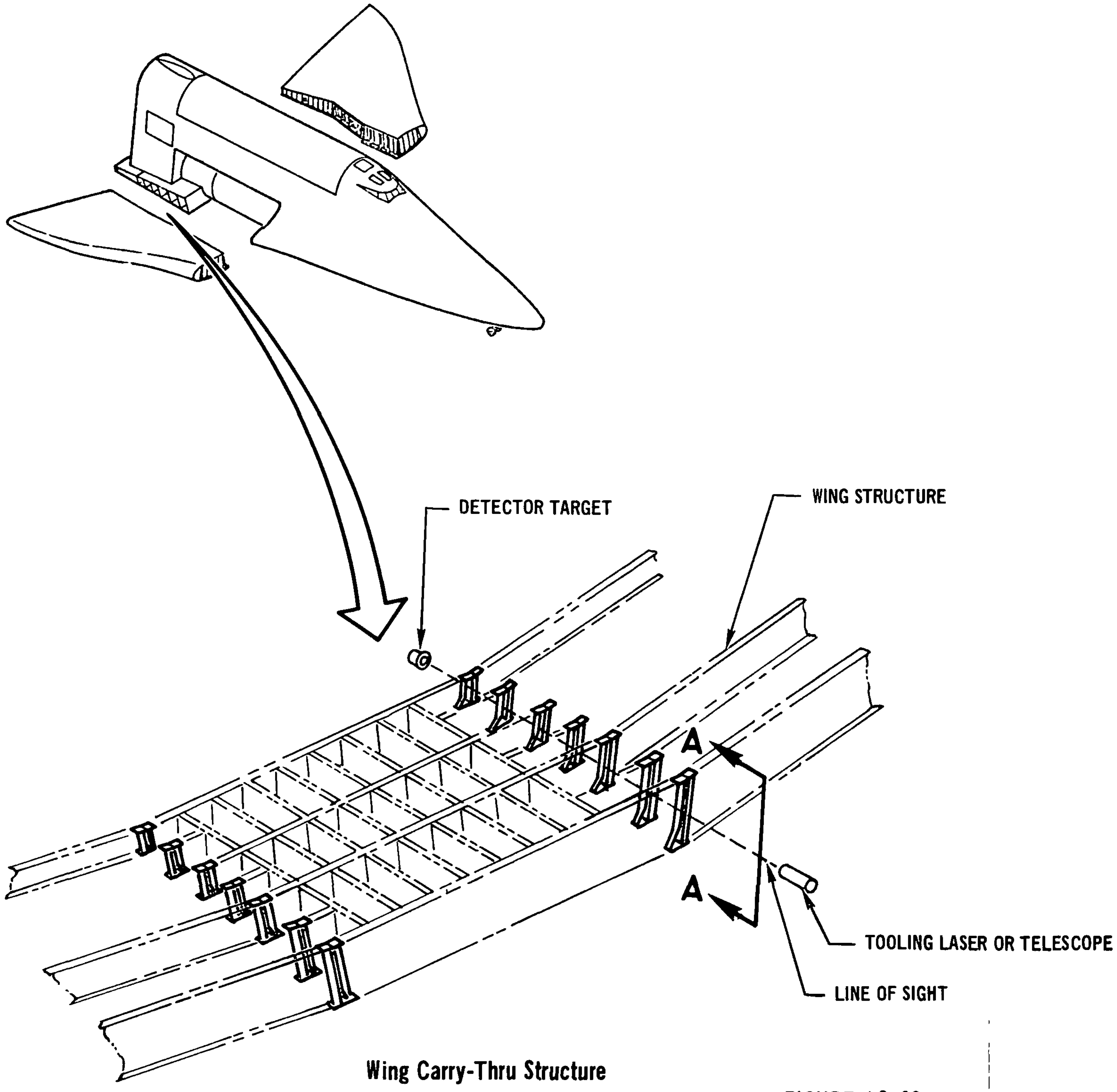
PROPOSED SOLUTION:

Transfer gages will be constructed dimensionally, with hole patterns and contours numerically controlled machined. Actual dimensions will be recorded at first inspection for use in subsequent inspections. This will minimize the need for control masters. The mastering of large interface points such as wing-fuselage, fin-fuselage, rudder and elevon hinge lines, etc., will be accomplished by using segmented gages individually set with optical or laser equipment. Gages required for smaller assemblies will be of the conventional aircraft type.

As an example of wing root joint master control, see Figure 4.8-13. A pair of masters will be made at each rib to "dummy" the upper and lower mold line, end of part, and interface attachment between the wing root and wing carry-thru structure. Each detail master will have the capability of being set to the common tooling planes with either optical or

MASTER TOOLING APPROACH

Wing – Fuselage Inteface



Wing Carry-Thru Structure

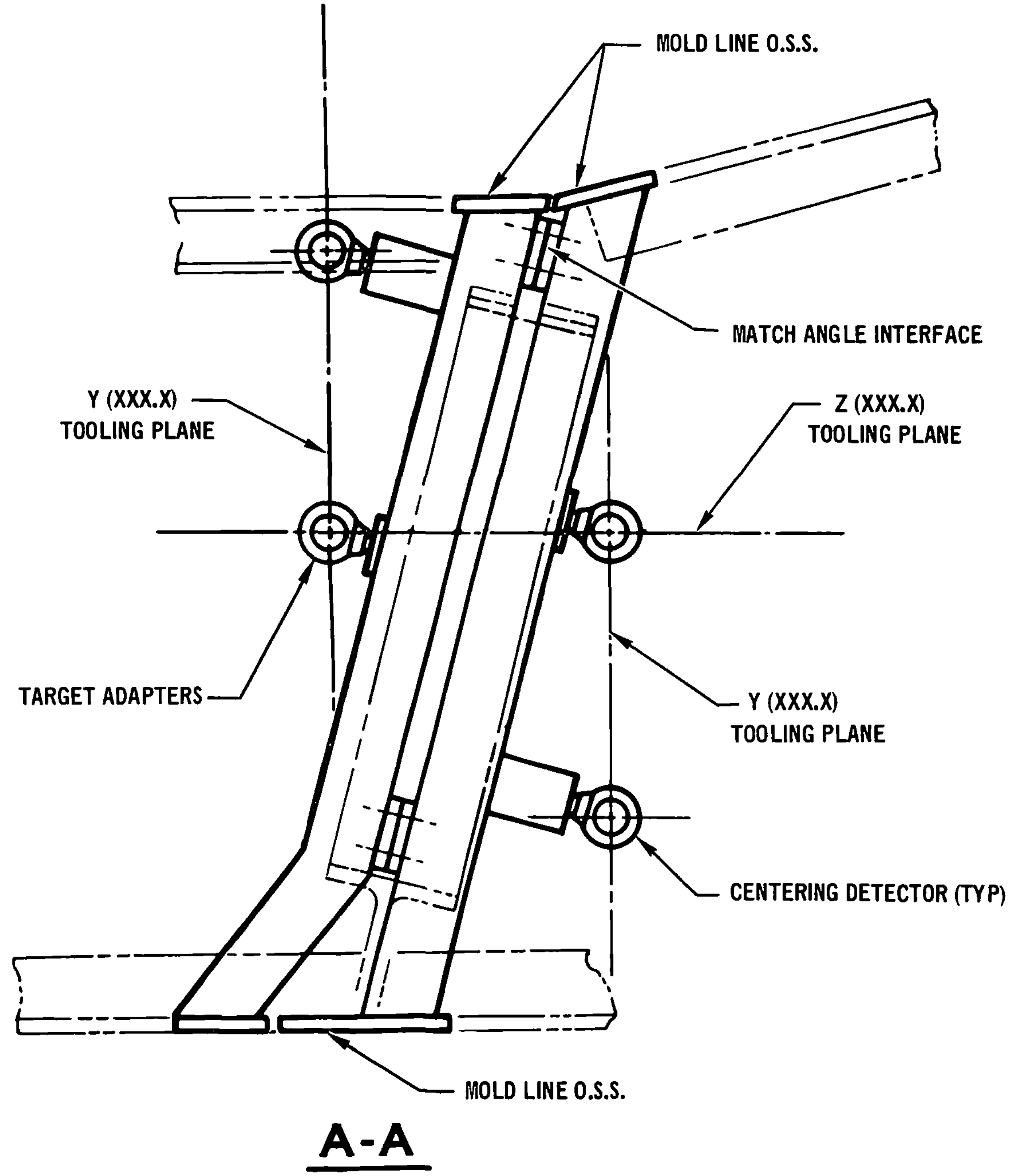


FIGURE 4.8–13

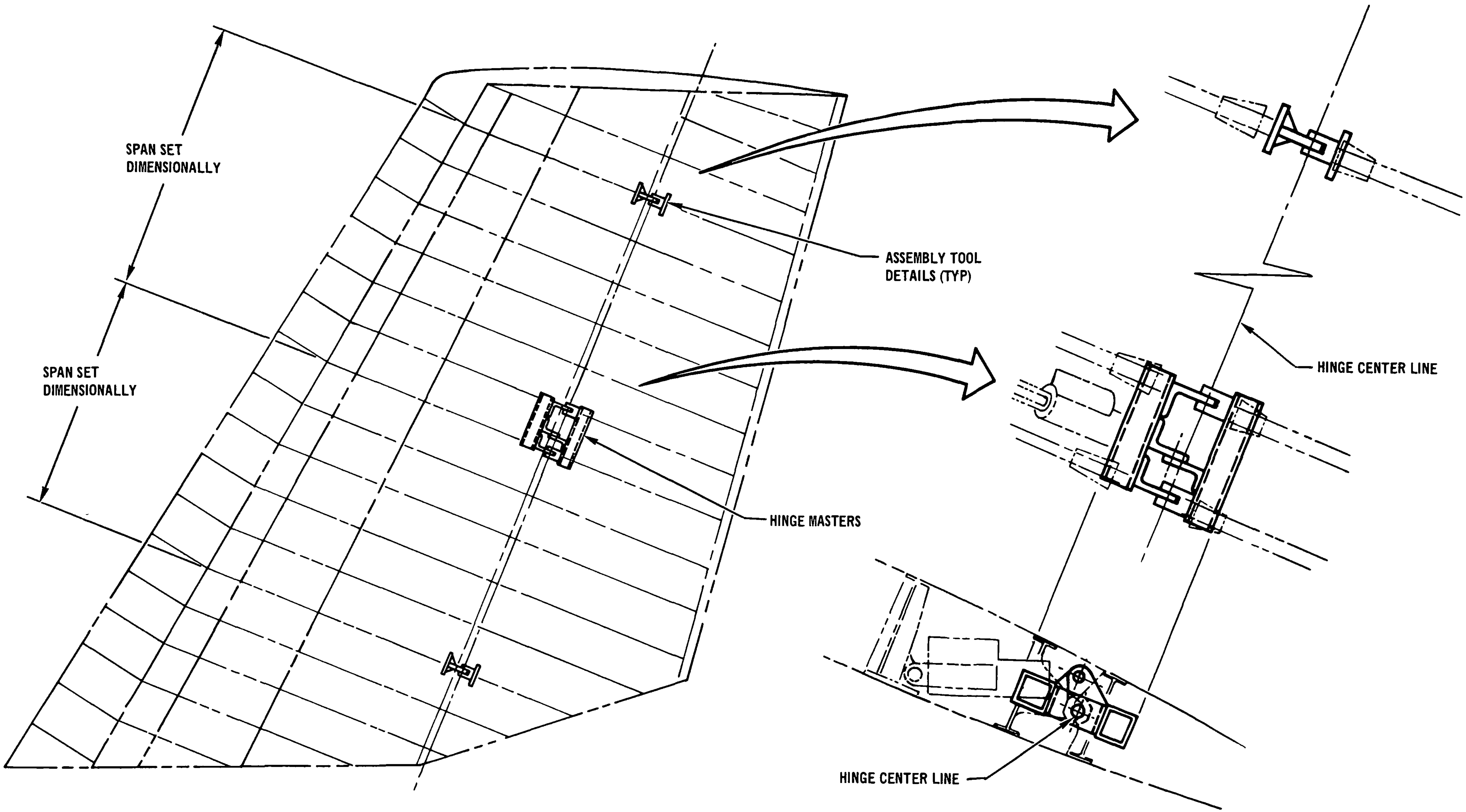
APPLICABLE
TO

BOOSTER/ORBITER

laser equipment. The paired sets of masters will then be separated and shipped to the wing and fuselage contractors to be used in the construction of assembly fixtures. A similar tooling approach will be used for the vertical fin area.

As an example of fin and rudder hinge control see Figure 4.8-14. Fin and rudder hinge point control would be accomplished by a set of master gages to "dummy" the center hinge fittings, including the actuator rod-end point. In the construction of assembly fixtures, the hinge points at each end of the fin and rudder would be located from the masters by setting the locating details on a centerline through the hinge bore using conventional optical tooling methods. Dimensional settings of the span between locators is feasible because of the latitude of adjustment in the fin and rudder hinges. The same basic approach would be used for the elevon hinge control.

MASTER TOOLING APPROACH
Fin, Rudder And Elevons Hinge



Vertical Tail Assembly

FIGURE 4.8-14

	APPLICABLE TO	
	BOOSTER	ORBITER
TOOLING		
PROBLEM:		
The possibility will exist that where large transfer gages (interface master tools) are fabricated at one location and utilized at another location, the accuracy of the gage could change due to temperature differentials.	X	X
PROPOSED SOLUTION:		
Large gages will be minimized. However, where absolutely required, construct the transfer gages and/or fixtures of materials with compatible coefficients of expansion. Document/record on the assembly tool and on the transfer gage the temperature and the minimum real time required to attain the desired readings.		

	APPLICABLE TO	
	BOOSTER	ORBITER
TOOLING		
PROBLEM:		
Handling, storage and schedule problems are foreseen due to the large sizes of the tooling required for fabrication and assembly.	X	X

PROPOSED SOLUTION:

Large fixtures will be designed to permit fabrication in sections at remote tooling areas. These sections would be small enough to eliminate handling and moving problems. These sections would be assembled at point of usage using optical or laser equipment. This would require the tool assemblies to be as complete as possible before delivery to their final assembly point, thus eliminating schedule conflicts and minimizing work in the production area.

	APPLICABLE TO BOOSTER/ORBITER
FABRICATION	
PROBLEM:	
Presently, the U.S. capability for producing Boron fibre is approximately 20,000 pounds per year of which 10,000 pounds is allocated to the F-14 and F-15 programs. A preliminary projection for Shuttle usage would be approximately 2500 pounds for stringers on the Orbiter. This, in itself, does not present a particular problem, however, there does not appear to be sufficient capability to produce enough Boron Aluminum composite monolayer tape of high quality for the Shuttle Program.	X

PROPOSED SOLUTION:

The capacity of producing Boron Aluminum Monolayer Tape is in process of being improved by several companies under the sponsorship of AFML and NASA. A firm program commitment to the usage of Boron Aluminum composites on the Shuttle Program would possibly provide incentives to the companies to invest their own funds to refine their processes to improve the quality of their tape. As an alternative to this commitment, increased funding by NASA to the tape producing companies may be required. Further monitoring of the tape quality will be maintained during the continuing Boron Aluminum process development programs.

	APPLICABLE TO BOOSTER/ORBITER
FABRICATION	
PROBLEM:	
The carbon/carbon TPS panels required for protection of the nose and leading edges have not been fabricated in a production configuration or manufacturing environment. The existing methods and processes of fabrication, machining, drilling, and trimming were performed under laboratory controlled conditions. The transition of manufacturing from an R & D environment to a production environment could present problems.	X

PROPOSED SOLUTION:

Conduct a detailed in-depth manufacturing analysis of the previously developed laboratory processes. From this analysis determine the requirements which will have to be attained during production. This study will consider changes to process or methods that could be implemented and still maintain the quality of the carbon/carbon that was previously produced. The following items will be analyzed in this study:

- Material Requirements (Quantity and quality of pre-preg carbon cloth, coatings, etc.)
- Facility Requirements (Vacuum/pressure impregnation equipment, curing ovens, argon atmosphere and pyrolization furnaces)
- Fabrication Processes (Milling, drilling, trimming, coating)

APPLICABLE
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BOOSTER/ORBITER

PROPOSED SOLUTION: (CONT'D)

- Manpower Requirements (Skills, numbers, training required)
- Handling Procedures (Protection, packaging and containers)
- Quality Assurance (Ultrasonic & N.D.T. requirements)

APPLICABLE TO	
BOOSTER	ORBITER

FABRICATION

PROBLEM:

Establishment of manufacturing standards and procedures for HCF Block fabrication, bonding to metallic panels and surface sealing. X

PROPOSED SOLUTION:

Conduct material and fabrication methods studies and development tests to resolve basic material problems and items such as repair of damaged coatings and bonding procedures. The HCF material is very fragile and a program to establish handling procedures is required to prevent damage. Repair methods will have to be developed and evaluated for both the HCF material and the external protective coating. In addition, manufacturing processes, procedures, and standard practices will have to be established for bonding HCF to metallic panels, sealing gaps and openings against moisture and thermal expansion, and the application and curing of the moisture protective coating. A program plan will be required to fabricate typical components, establish installation techniques, and test the components.

	APPLICABLE TO BOOSTER	APPLICABLE TO ORBITER
FABRICATION		
PROBLEM:		
Thermal Protection System panel arrangements and attachment, joint sealing and surface contour control.	X	X

PROPOSED SOLUTION:

Conduct a maufacturing developing analysis and test program that will verify Thermal Protection System design concepts. A manufacturer R&D program will verify design and analysis and concepts through the fabrication of sample hardware. Test items of the structure will be designed so that they can be fabricated and tested prior to the final design of full size concepts. Methods and procedures to be demonstrated include the use of adhesives, brazing mechanical fasteners, diffusion bonding, welding and forming. A static and structural dynamic testing program will be conducted on typical specimens, including all fatigue causing parameters. Test data will be evaluated to verify final design concepts, along with production tooling and facility requirements. A representative structure will be designed and fabricated and structurally tested under typical load conditions.

	APPLICABLE TO BOOSTER/ORBITER
FABRICATION	
MAJOR MANUFACTURING PROBLEM:	
Forming of dome skins for the main tank common bulkheads.	X

PROPOSED SOLUTION:

The preliminary baseline fabrication approach, in general, is to procure the domes as a 120" base diameter spherical sector of a 161" diameter sphere which will be a spin forging made of 2219-T81 aluminum. Since the 120" base diameter spherical sector is not large enough, additional sectors will have to be procured. These additional sectors will be cut into four (4) 70° segment skirt sections, trimmed, fitted, and welded to the base of the 120" base diameter spherical sector to form the completed bulkhead (dome) skin.

This baseline approach, however, is not considered to be the optimum approach. The optimum approach would be to procure the dome spin forging in a one piece, full size 161" diameter sector. The present capabilities of spin-forging suppliers does not allow the spinning of sectors to this diameter. Discussions with several suppliers, however, have indicated that the development of the capability to spin the larger diameter sector is feasible. If further investigations reveal that this capability, in fact, is feasible, the baseline approach would be changed. Unfortunately, the procurement of the full-size spun forging, as related to the Phase C/D ATP and the manufacturing "need date" for dome machinig,

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has revealed a schedule impact problem. The lead-time required by the supplier to purchase material, develop processes and tools, and deliver the spun forging to MDAC jeopardizes the MDAC "need date" for the first development test as shown on the Phase C/D Program Master Schedule. The proposed solution to this additional problem would be: grant the supplier a "letter of intent" to allow material ordering, process development, and tool development prior to receiving a formal Purchase Order from MDAC. This, admittedly, is somewhat risky since the formal, firm engineering drawings will not be available in this time period. It will, however, be mandatory that design engineering identify, for the supplier, the material type and thickness and contours. Any major changes to materials requirements will cause further problems to the supplier. More in-depth investigations and negotiations with suppliers will be conducted to reduce the over-all span time to produce the spun forgings. Analyses of other forming techniques will also be conducted.

APPLICABLE TO BOOSTER/ORBITER

FABRICATION

PROBLEM:

Machining of formed dome skins to incorporate isogrid pockets. X

PROPOSED SOLUTION:

The preliminary baseline fabrication approach, in general, is to mill the inside of the completed-welded-dome or bulkhead section to incorporate the isogrid pattern of pockets using a contractor-designed tool as shown in Figure 4.8.-15 .

COMMON DOME ISOGRID MACHINING

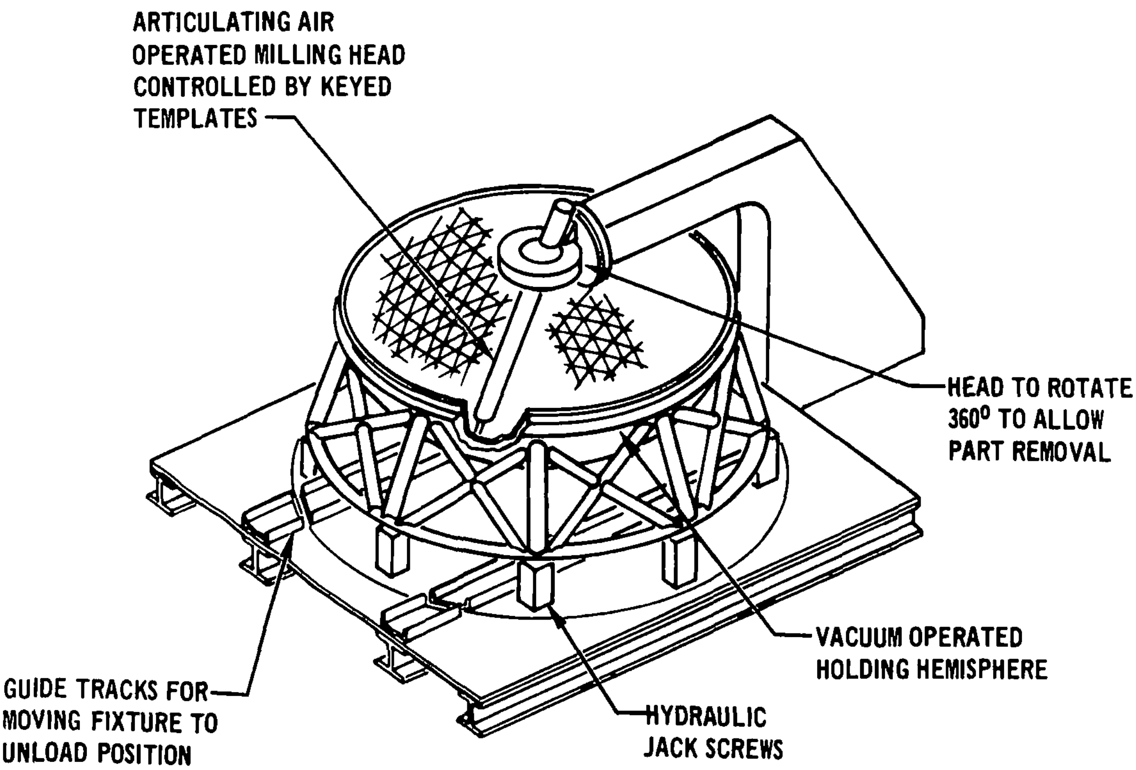

FIGURE 4.8-15

	APPLICABLE TO BOOSTER/ORBITER	
FABRICATION		
PROBLEM:		
Excessive time required for machining of isogrid (Booster) and waffle (Orbiter) patterns on tank skins to proper tolerances.	X	X

PROPOSED SOLUTION:

The preliminary baseline fabrication approach, in general, is to machine the selected skin panel sizes in the flat, prior to chemical processing and forming.

Machining of the panels is accomplished on numerically controlled profile milling machines, an example of which is shown in Figure 4.8 -16.

CINCINNATI N.C. PROFILER

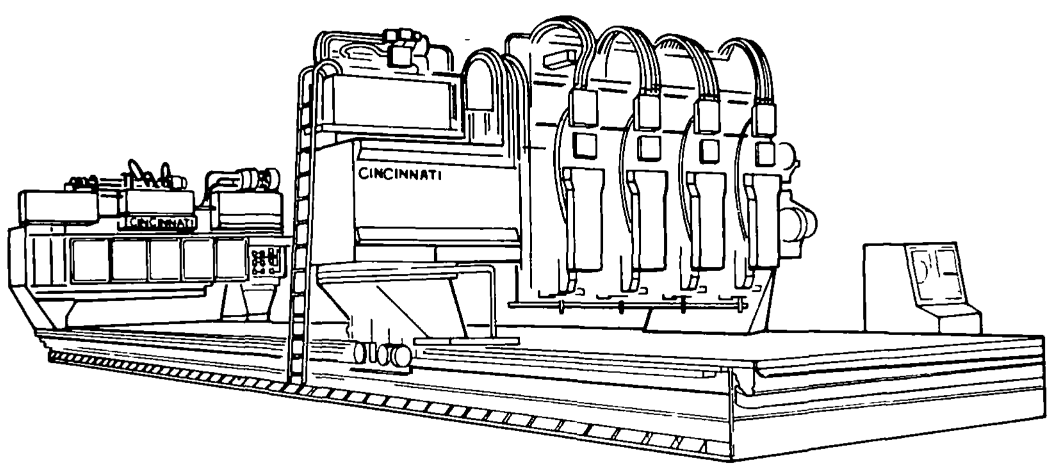

FIGURE 4.8–16

APPLICABLE
TO
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PROPOSED SOLUTION: (Cont'd.)

Panels are machined from 2219 aluminum plate stock in the solution heat treated condition (T37), and in sizes up to 12 ft. wide x 34 ft. long. Machining of the aluminum plate stock in the T37 condition later allows the use of the artificial ageing cycle (to T87) to facilitate the skin forming process. Further manufacturing development programs must be conducted to verify this approach and to determine proper feeds, speeds, depth of cuts, and cutting tool requirements. An associated problem would be the large numbers of manhours which will be required to program the numerically controlled profile milling machine. The waffle patterns of the Orbiter tank skins are not standarized as related to length, width, and depth, thus, requiring much more programming time. More studies will be conducted to optimize the programming approach and to determine program scheduling impacts.

Inquiries have been made with the rolling mills as to the feasibility of supplying material in the rough-rolled waffle forging configuration (rather than flat plate stock). This approach would tend to reduce machining time (approximately 30%) and reduce the weight (and cost) of the material. Studies are continuing in this area.

	APPLICABLE TO BOOSTER	APPLICABLE TO ORBITER
FABRICATION		
PROBLEM:		
Forming of thick aluminum tank wall skins which have been milled to an isogrid or rectangular waffle configuration, both cylindrical and conical shapes.	X	X

PROPOSED SOLUTION:

A number of methods have been considered for forming of the 270° circumferential cylindrical and conical skin sections. Among these were; bumping the panels to contour in matched dies on a power brake; forming them to contour on power rolls, drape forming where the panel is draped over a shaped die and pulled down to the dies contour using come-alongs or weights; AGE forming which is basically drape forming performed during the artificial ageing cycle; and wrap forming where the panel is wrapped around a shaped drum to form the required contour.

In both the power brake and power roll forming methods, a filler material is required in the panel pockets to support and protect their flanges during the forming operation. This greatly adds weight to the panels during forming and thereby complicates their handling. Also with the pockets on the O.D., it is difficult to retain the filler material in place throughout the forming operation.

APPLICABLE TO BOOSTER/ORBITER

PROPOSED SOLUTION (Cont'd.)

The drape and age forming methods offer good results in forming circumferential shapes up to the 180° point (or less). Beyond the 180° point, the practicality of these methods becomes questionable. In order to form the approximate 270° shapes required in the case at hand, the direction of the forming forces necessary to pull the panels around the die have to cross one another. This factor greatly complicates consideration of these approaches.

The wrap forming method offers good results to achieve the 270° shapes required, as the forming tool can virtually go to a full 360° circumference. It also allows the forming without applying external forces directly to the vulnerable O.D. flanges of the panel. Forming forces are applied only to the edges of the panel, where excess material is provided for this purpose during panel fabrication.

Through evaluation of the previously discussed forming methods, a method of wrap-age forming is considered as the optimum approach to be used. This approach takes advantage of the wrap forming ability to form circumferential shapes well beyond the 270° point required, without applying forces to the O.D. surface of the panel. It also takes advantage of the age forming feature of performing the elevated temperature artificial ageing cycle, while the panel is restrained in shape. This relieves much of the

APPLICABLE
TO
BOOSTER/ORBITER

PROPOSED SOLUTION (Cont'd)

stress induced into the part during forming, and provides highly predictable and consistent spring back characteristics in the alloy to be used.

It is obvious that the wrap-age forming method requires design and development of special fixturing during Phase C/D, an example of which is shown in Figure 4.8-17. However, since it is an application of existing metal forming principles, the approach is considered state-of-the-art.

WRAP-AGE FORMING MACHINE

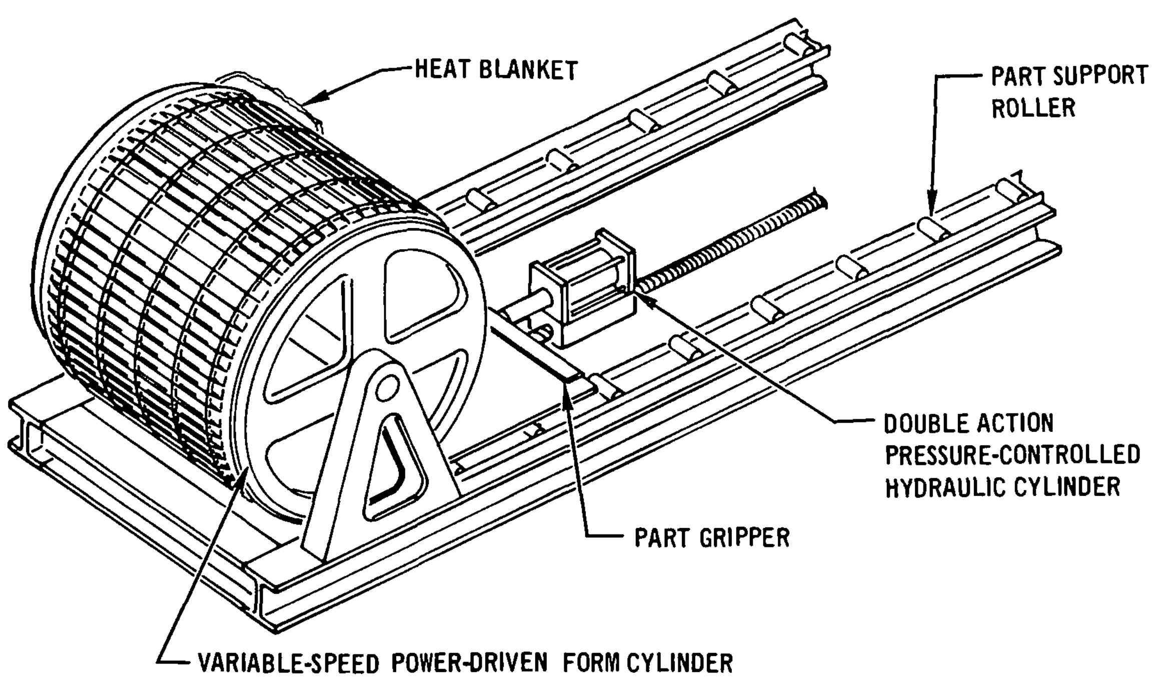


FIGURE 4.8-17

	APPLICABLE TO	
	BOOSTER	ORBITER
FABRICATION		
PROBLEM:		
Provide verification of the reliability and thermal performance repeatability of a tank structure internal insulation system similar to that used for the SIVB.	X	X

PROPOSED SOLUTION:

Design, fabricate and insulate a typical tank structure that can be tested by pressure and thermal recycling to a predetermined cycle parameter and performance degradation. Existing SIVB bonding techniques need to be evaluated and upgraded for the booster internal insulation system. Problems encountered by larger tank structures need to be resolved, i.e., heat application for curing, toxic fume evaluation, and close out attachments. Tank structure design will be determined i.e, thermal stresses plus bending and vibration loads so that insulation will be compatible with the tank structural environment.

	APPLICABLE TO BOOSTER	ORBITER
ASSEMBLY		
PROBLEM:		
Determination of the optimum methods of fabrication and assembly of tube and cable (wire harness) subassemblies prior to installation into the major vehicle assemblies.	X	X

Historically, on most aerospace programs, it has been MDAC policy to construct a full-scale, dimensionally accurate tube and cable mock-up (development fixture) to simulate the structure of the flight vehicle. Dummy wire harnesses and tubing are then routed and terminated in the mock-up to establish the optimum installations. These dummy harnesses and tubing are removed and used to create wire harness assembly boards (tools) and tubing master tools from which all subsequent wire harnesses and tubing are fabricated and assembled. This procedure allows more parallel bench-type operations to be performed rather than assembly on the actual flight structures. The construction of full-scale, dimensionally accurate tube and cable mock-ups for vehicles the size of the Booster and Orbiter (with limited quantities) does not appear to be feasible.

PROPOSED SOLUTION:

Analyses will be performed to determine benefits versus cost of tube and cable mock-ups and development fixtures. A preliminary manufacturing approach to this problem would be to

APPLICABLE TO BOOSTER/ORBITER

PROPOSED SOLUTION: (Cont'd)

construct tube and cable mock-ups only for specific modules or areas of the vehicles which are considered critical as related to wiring density, interfaces, etc. Some of the candidates would be the crew module, avionics bay, landing gear and engine wells, etc.

Other approaches to the routing of tubing and wire, e.g. .. computer programming, holography, etc., will be investigated.

	APPLICABLE TO BOOSTER	ORBITER
ASSEMBLY:		
PROBLEM:		
The panels required for the Thermal Protective Systems must be reusable and quickly replaced. The requirements of the program - (prevent hot gasses from leaking in, withstanding pressure, shed water, etc.) will cause coordination, tolerance, and replacement problems.	X	X

PROPOSED SOLUTION:

Design considerations in the C/D Phase will be directed to providing for adjustments in TPS panels to allow for maximum tolerances in fabrication. To provide for replacement and repair, additional sets of panels would be trial fitted and custom trimmed to the vehicles for spares. Studies are "in work" and will continue to allow these panels to be field repairable.

	APPLICABLE TO BOOSTER	APPLICABLE TO ORBITER
ASSEMBLY		
PROBLEM:		
Welding techniques for welding tanks, domes, etc., use of E.B., T.I.G., M.I.G., plus arc. Also, positioning for weld passes.	X	X

PROPOSED SOLUTION:

Establish a program to design, fabricate and test typical tank structures. Program will include determining applicable advanced fusion welding techniques for flat and formed isogrid tank panels. Evaluation of welds will be performed by both non-destructive and tensile tests. Mismatch and distortion control will be evaluated along with effects of weld position. Determine non-destructive testing requirements and evaluate existing test equipment capabilities to define flaws in both the weld joint and basic tank structure.

	APPLICABLE TO	
	BOOSTER	ORBITER

TESTING

PROBLEM:

The baseline design concept for the electrical distribution system specifies a quad-redundancy system which will require thousands of individual wires installed as wire harnesses throughout the vehicles. It will be required that manufacturing perform a continuity and leakage check on each wire versus all other wires within each redundant system. A potential problem could be that there would not be existing commercial semi-automatic circuit analyzing equipment with a large enough capability to test these large quantities of wires concurrently. Also, the manhours which will be required to manually program these tests and fabricate the necessary adapter harnesses could cause schedule impact as related to the engineering drawing schematics release and first manufacturing usage date. (Booster: X; Orbiter: X)

PROPOSED SOLUTION:

Perform in-depth trade studies to determine the quantities of circuit analyzers which will be required and investigate the feasibility of utilizing the many analyzers, in industry, connected "in tandem" to increase the capacity of test points available. Investigate the feasibility of applying computer programming (rather than manual programming) to decrease over-all programming manhours.

These studies cannot be performed until a more in-depth description of the electrical distribution system is available.

HANDLING - GENERAL

Vehicles of the size and complexity of the Booster and the Orbiter present unique handling problems during the process of manufacturing and final assembly. These problems require early identification and comprehensive analysis. Constraints imposed on manufacturing by the characteristics of shuttle components and the danger of structural degradation through improper handling, necessitate that tradeoff studies be conducted. A careful evaluation of these results must be obtained in order to solve these problems.

A concentrated effort will be made to define techniques to reduce the probability of damage to the structure and maximize protection by instituting handling restraints to cover all contingencies. Criteria will be established which will permit design engineers, during the design stages, to attain designs that will, in themselves, reduce and alleviate handling problems, and facilitate and expedite assembly operations.

The critical characteristics of fragile components will require study to ensure the provision of supplemental means of support for handling and transporting. Efforts will be directed toward the development of criteria for the design of handling equipment, such as, slings, handling cables, spreader bars, bails, and roll rings. The identification of handling equipment/flight component interface techniques will be outlined for engineering design implementation within the flight components.

HANDLING - GENERAL (Cont'd.)

Joining operations of major sections will create further handling problems due to the fragile nature of previously installed components. Space limitations are imposed on component installations once major sections are joined, and a minimum of such integration activities may be desired. Orientation and interface between handling points and subsequent installations must be carefully analyzed to minimize interference, and to assure the protection of fragile components.

Transporting the assembled Booster and Orbiter prior to delivery presents a unique problem due to the loads which will be imposed on the structure when in the horizontal position. Supplemental supports, which will probably be required for the support of fragile components during handling operations, must be so designed that maximum protection is achieved and yet interference for further installations is held to a minimum. Transportation equipment must be fabricated to provide mobility between work stations.

	APPLICABLE TO BOOSTER	APPLICABLE TO ORBITER
HANDLING		
PROBLEM:		
The baseline manufacturing approach has revealed that it will be necessary to procure some special alloy materials in the solution-heat-treated condition to facilitate forming during the artificial age cycle. Previous experience with these special alloys indicated that premature, natural ageing occurs unless precautionary measures are taken.	X	X
PROPOSED SOLUTION:		
The procurement of this material will be uniquely scheduled (as opposed to standard materials) to ensure that "in-house" storage life is minimized. This, of course, necessitates the procurement of smaller quantities more frequently and consequently, incurs higher costs. Adequate refrigerated storage areas will be provided, where necessary, to retard or prevent premature natural ageing. Consideration must be given to necessary precautionary measures which must be taken to control ageing of the material during the pocket machining process.		

	APPLICABLE TO	
	BOOSTER	ORBITER
HANDLING		
PROBLEM:	X	X

The high-value of and stringent quality requirements on the super alloys, e.g., columbium, inconel 718, Rene' 41, Hanes 188, etc., dictate special handling and control through fabrication.

PROPOSED SOLUTION:

Provide for special handling of high value material by a separate and unique control system. This system would use special identification, storage containers, and documentation to provide control of quality and insure proper handling. The procedures would be developed early in the C/D Phase as material requirements are projected.

In some cases, materials (non-super alloy) will be available from the rolling mills guaranteed to be within ± x of the specified thickness. To enchance the achievement of structural weight bogies, the "best" (that which is closest to ± .000) material of each lot will be selected for Space Shuttle applications. It then becomes important that this "selected" material is, in fact, used on the Shuttle vehicles and not on some other program "in house". Existing inventory systems allow for the establishment of separate and isolated storerooms for special programs, such as, the Space Shuttle Program. Carefully monitored inventory control systems will assure that "special" material allocated for the Shuttle Program will not be dispensed for any other programs.

APPLICABLE
TO
BOOSTER/ORBITER

HANDLING (Cont'd.)

When these "special" materials are dispensed from the storeroom to the fabrication shops, quality assurance personnel will verify that the material designated on the Space Shuttle work instruction sheet and the material being dispensed are identical through the use of specific coding systems, such as color coding, dye markings, adhesive tabs, lot documentation, etc.

SUMMARY

All of the previously mentioned problems cannot be solved by trade-off studies or by analytical methods. Positive answers will be required to ensure the success of the manufacturing tasks on the Shuttle Program. Since test coupons will not provide sufficient and complete data, a minimum hardware development program is required to prove competence in some areas.

Manufacturing activities which occur during development programs:

- Coordination with Design Engineering to achieve maximum manufacturability of the design.
- Survey of the industry to assimilate beneficial methods and technology.
- Perform analytical studies and prepare comparison charts.
- Establish a fact-finding committee, comprised of highly qualified technicians and manufacturing engineering personnel, to evaluate new manufacturing technologies.
- Fabricate/assemble representative hardware to verify manufacturing methods and processes.

ITEMS CAUSING SUBSTANTIAL PROGRAM IMPACT

The results of the continuing analyses and studies, conducted by manufacturing specialists and producibility engineers during Phase B of the MDAC baseline design configurations of the Booster and Orbiter indicate that there are no areas in the manufacturing approach that would cause substantial program impact. However, there are problem areas, which have been discussed earlier, which could potentially become program impact items (by jeopardizing program schedule commitments) if the recommended manufacturing development programs are delayed.

4.8.5 Transportation Modes - The transportation modes available for moving major components of the Shuttle vehicle are identified in this section. The physical size of the components is a constraining transportation factor and many of the components cannot be moved except by barge waterway. This limitation is a major consideration in the selection of major sub and final assembly locations. Figure 4.8-18 is a compilation of feasible and selected modes of transportation.

The following components are limited to barge transportation:

- o LH_2 Tank Section - Booster
- o Aft Fuselage - Booster
- o Inter Tank Structure - Booster
- o LOX Tank Section - Booster
- o Wings - Booster and Orbiter
- o Fuselage (Main) - Orbiter
- o Aft Fuselage - Orbiter

The following assemblies can be moved by either supply type aircraft or barge:

- o Canards - Booster
- o Forward Fuselage - Booster
- o Crew Compartment - Orbiter
- o Nose Section Orbiter

Other assemblies may be transported by barge, air, rail, or highway. Figure 4.8-19 is a pictorial summary of the recommended modes of transportation.

4.8.5.1 Water Transportation - The U.S. Inland and Intracoastal Waterways provide means for transporting large articles such as major Shuttle assemblies that cannot normally be handled by air, rail, or highway modes of transportation.

SPACE SHUTTLE TRANSPORTATION ANALYSIS

TRANSPORTATION CAPABILITIES

Structure \ Transportation Mode	Ferry W/A.B. Engines	Barge	Aircraft	Rail	Road
Booster (Assembled)	X				
Booster Fuselage (less crew compt.)		Selected Mode			
LH_2 Tank		X			
LO_2 Tank		X			
Intertank Structure		X			
Aft Section		X			
Fwd. Fuselage		X	Selected Mode		
Canards		X	Selected Mode		
Wings		Selected Mode			
Engines		X	X	X	Selected Mode
Orbiter (Assembled)	X				
Fuselage		Selected Mode			
Body Flap		X	X	X	X
Fuel Hyd. & Elect. Syst.		X	X	X	X
Main Propul. Tank (H_2 & O_2)		X			
Secondary LH_2 Tank		X	X	X	X
Nose Section		X	Selected Mode	X	X
Crew Compartment		X	Selected Mode		
Wings		Selected Mode			
Vertical Fin			Selected Mode	X	X
Engines		X	X	X	Selected Mode

X - possible or feasible.

FIGURE 4.8-18

TRANSPORTATION FLOW CHART
BOOSTER AND ORBITER ASSEMBLIES

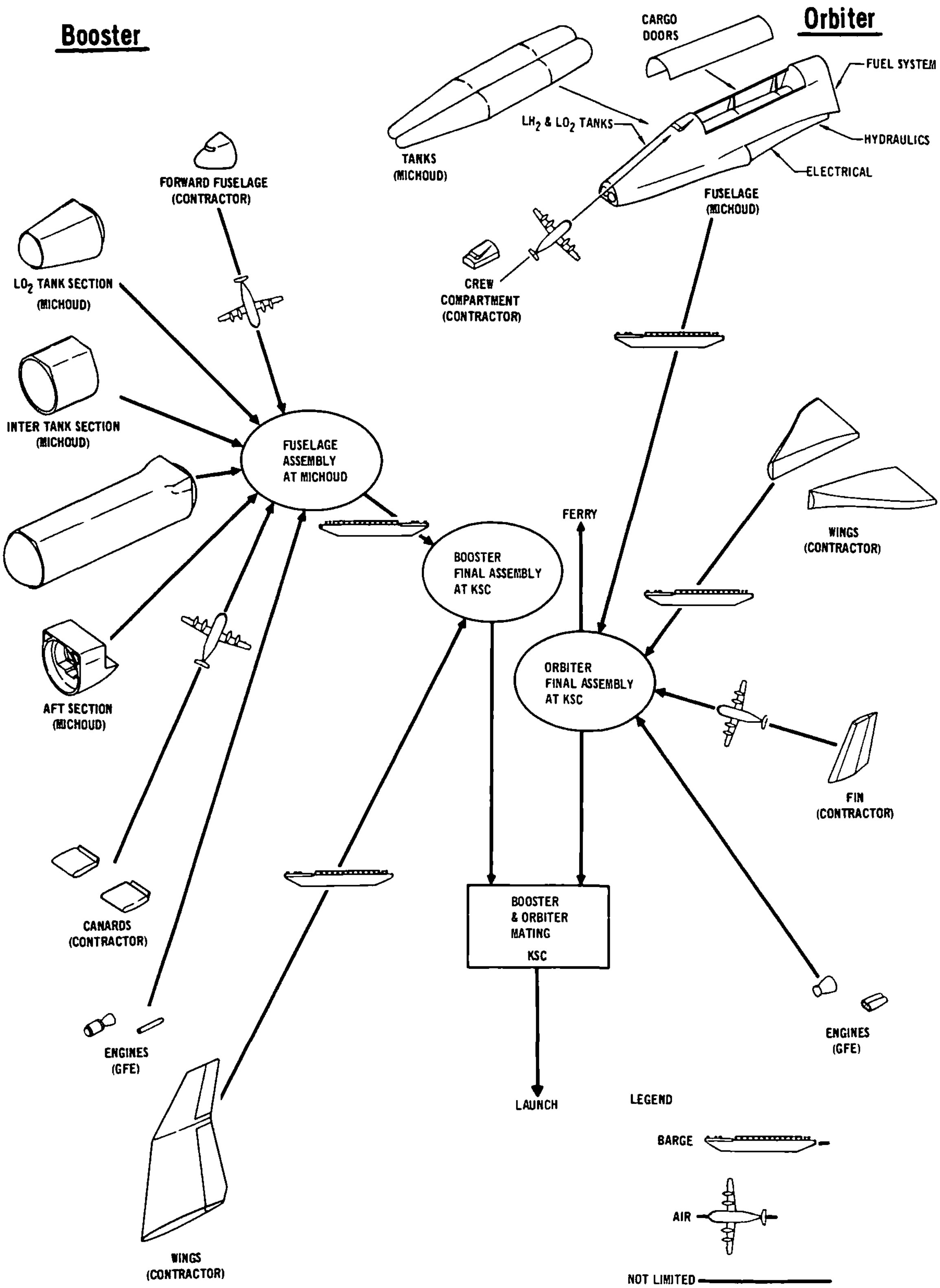


FIGURE 4.8-19

Figure 4.8 -20 is a map of the U.S.A. depciting the location and extent of these waterways. NASA has a fleet of shallow water and ocean going vessels available for transporting missile and space modules to points available to water; see Figure 4.8 -21 for specifications on these vessels.

4.8.5.2 Commercial Outsize Cargo Aircraft - There are commercial cargo aircraft available for charter that have been modified to permit carrying large bulky cargo such as missile and space modules; Figure 4.8 -22 defines the capability of these craft. These aircraft can carry sizes of cargo that are too large to be normally transported by rail or highway.

4.8.5.3 Transportation Analysis - By using the foregoing information, and from inspection, using the available dimensions of the various subassemblies of the Booster and Orbiter, the barge utilization (Figure 4.8 -23) and aircraft utilization (Figure 4.8 -24) matrices have been prepared. Combining the information on these matrices, the transportation capabilities for each of the subassembly components is depicted in Figure 4.8 -25.

NAVIGABLE LENGTHS AND DEPTHS OF UNITED STATES INLAND WATERWAY ROUTES

LENGTH IN MILES OF WATERWAYS

GROUP	UNDER 6 FT	6 TO 9 FT	9 TO 12 FT	12 TO 14 FT	14 FT AND OVER	TOTAL
Atlantic Coast Waterways (exclusive of Atlantic Intracoastal Waterway from Norfolk, Va, to Key West Fla), but including New York State Barge Canal System	**1,502** 1,563	**1,271** 1,445	**593** 549	**975** 1,005	**1,490** 1 241	**5,831** 5 803
Atlantic Intracoastal Waterway from Norfolk, Va to Key West Fla	— —	**211** 158	**65** 65	**954** 1,104	— —	**1,230** 1,327
Gulf Coast Waterways (exclusive of Gulf Intracoastal Waterway from St Marks River, Fla, to Mexican Border	**2,048** 2,142	**718** 819	**1,239** 2 097	**216** 305	**444** 372	**4,665** 5 735
Gulf Intracoastal Waterway from St Marks River Fla to Mexican Border (including Port Allen Morgan City Alternate Route)	— —	— —	— —	**1,177** 1 177	— —	**1,177** 1 177
Mississippi River System	**2,400** 4 829	**684** 1 491	**4,449** 5 058	**732** 755	**273** 268	**8,538** 12 401
Pacific Coast Waterways	**725** 733	**370** 515	**239** 237	**26** 27	**2,182** 461	**3,542** 1 973
All Other Waterways (exclusive of Alaska)	**45** 100	**58** 148	— 14	**8** 8	**286** 369	**397** 639
GRAND TOTAL	**6,720** 9 367	**3,312** 4 576	**6,585** 8 020	**4,088** 4,381	**4,675** 2 711	**25,380** 29 055

The mileages shown in this table in bold type represent the lengths of all navigable inland channels of the United States (exclusive of the Great Lakes) including those improved by the Federal Government other agencies and those which have not been improved but are usable for commercial navigation

The mileages shown in this table in light type represent the lengths authorized for improvement by the Congress of the United States in legislation known as Rivers and Harbors Acts

The sources for these tabulations are publications of the Corps of Engineers, United States Army

THE INLAND WATERWAYS OF THE UNITED STATES

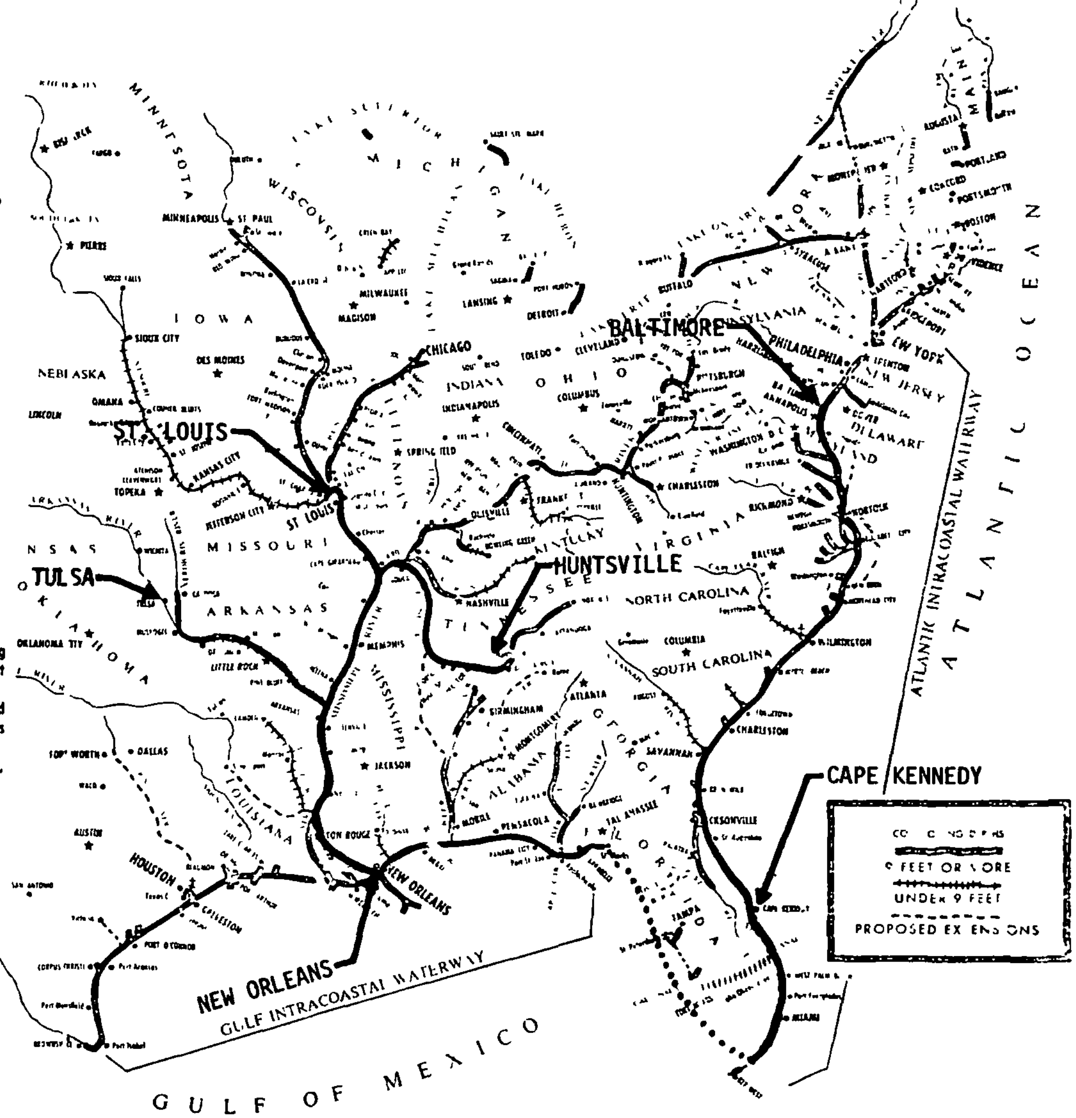


FIGURE 4.8-20

AVAILABLE TRANSPORTATION AND SHIPPING DATA
Barge Rail and Highway

BARGE	HEIGHT	WIDTH	LENGTH	DRAFT	WT LIMIT	REMARKS
PALAEMON (NASA)	32'–0"	30'–0"	116'–0"	TO BE SUPPLIED	NO CONSTRAINT	COVERED BARGE W/REMOVABLE TOP SECTIONS PROVIDED W/DEHUMIDIFIERS
PROMISE (NASA)	33'–0"	28'–0"	158'–0"	3'–12'	NO CONSTRAINT	COVERED BARGE PROVIDED WITH DEHUMIDIFIERS
ORION (NASA)	43'–0"	41'–6"	190'–0"	3'–13'	NO CONSTRAINT	COVERED BARGE PROVIDED W/DEHUMIDIFIERS AND PURGE CAPABILITY
POSEIDON (NASA)	43'–0"	41'–6"	190'–0"	3'–13'	NO CONSTRAINT	COVERED BARGE PROVIDED W/DEHUMIDIFIERS AND PURGE CAPABILITY
LITTLE LAKE (NASA)	–	44'–0"	200'–0"	3'–12'	NO CONSTRAINT	OPEN BARGE
PEARL RIVER (NASA)	–	44'–0"	200'–0"	3'–12'	NO CONSTRAINT	OPEN BARGE
POINT BARROW (USN)	48'–0"	44'–0"	202'–0"	–	NO CONSTRAINT	LEASED FROM USN MODIFIED LSD WITH COVER
COMMERCIAL	–	68'	383'	–	NO CONSTRAINT	CONVERT EXISTING AVAILABLE VESSEL
RAILROAD	13'–0" MIN 20'–0" MAX	12'–0" MIN 26'–0" MAX	65'–0" MIN 135'–0" MAX	–	154,000 LB (90' CAR)	DIM VARY – CONSULT INDIVIDUAL STATE FOR REGULATIONS
HIGHWAY	13'–6" NOMINAL	8'–0"	55'–0" NOMINAL	–	–	DIM AND AXLE LOADING VARY CONSULT APPROPRIATE MUNICIPALITY FOR REGULATIONS

FIGURE 4.8–21

AVAILABLE TRANSPORTATION AND SHIPPING DATA
Aircraft

AIRCRAFT	HEIGHT	WIDTH	LENGTH	WT LIMIT (LB)	REMARKS
GUPPY 201	25'-6" 15'-0" 7'-11"	25'-0" 13'-0" 7'-0"	32'-0" 90'-0" 110'-3"	45,000 45,000 45,000	CURVATURE OF FUSELAGE MUST BE CONSIDERED IN VEHICLE SELECTION
GUPPY 101	15'-6" 7'-6"	13'-4" 7'-1"	73'-2" 101'-11"	60,000 60,000	CURVATURE OF FUSELAGE MUST BE CONSIDERED IN VEHICLE SELECTION
MINI-GUPPY	14'-10"	13'-6"	73'-2"	32,000	CURVATURE OF FUSELAGE MUST BE CONSIDERED IN VEHICLE SELECTION
SUPER HERCULES L-100-30	9'-0"	10'-0"	55.4'	50,000	CURVATURE OF FUSELAGE MUST BE CONSIDERED IN VEHICLE SELECTION
B-747	8'-2"	15'-6"	173'-0"	236,000	
C-5A	13'-5"	19'-0"	121'-0"	220,000	DIMENSIONS ARE LOWER DECK
DC-10-AF	8'-0"	14'-6"	115'-0"	104,700	

FIGURE 4.8-22

SPACE SHUTTLE – COMPONENT TRANSPORTATION ANALYSIS
Barge Utilization

STRUCTURE \ BARGE NAME & MAX LOAD DIM.	POINT BARROW 202 x 44 x 48 FT	ORION 190 x 41 x 43 FT	POSEIDON 190 x 41 x 43 FT	PALAEMON 116 x 30 x 32 FT	PROMISE 158 x 28 x 33 FT	LITTLE LAKE 200 x 44 FT	PEARL RIVER 200 x 44 FT	COMMERCIAL 383 x 68
1. VERTICAL FIN (BOOSTER) 39 x 26 x 6 FT	●	●	●	●	●	●	●	
2. MAIN LH_2 TANKS (BOOSTER) 135 L x 33 FT	●	●	●			●	●	
3. MAIN LOX TANKS (BOOSTER) 55 x 33 FT	●	●	●			●	●	
4. AFT FUSELAGE (BOOSTER) 24 x 38 FT	●	●	●			●	●	
5. MAIN PROPULSION TANKS (ORBITER) 126 x 20 x 14 FT	●	●	●	●	●	●	●	
6. MAIN FUSELAGE (BOOSTER) 242' x 34' x 38 WIDE								●
7. MAIN FUSELAGE (ORBITER) 37 x 11 FT	●	●	●	●	●	●	●	
8. SECONDARY TANKS 37 x 11 FT	●	●	●	●	●	●	●	
9. INTER TANK STRUCTURE BOOSTER 23 x 34 FT	●	●	●	●	●	●	●	
10. WING (BOOSTER) 80 x 36 x 6 FT	●	●	●			●	●	
11. WING (DELTA ORBITER) 49'–7" x 33' x 7'–6"	●	●	●			●	●	

FIGURE 4.8–23

SPACE SHUTTLE COMPONENT TRANSPORTATION ANALYSIS
Aircraft Utilization

STRUCTURE \ AIRCRAFT NAME & MAX DIM.	GUPPY 201 32 x 13 x 25 FT	GUPPY 101 73 x 13 x 15 FT	MINI-GUPPY 73 x 13 x 14 FT	SUPER HERCULES 55 x 10 x 9 FT	C-5A 121 x 19 x 13 FT	DC-10-AF 115 x 14 x 8 FT
1. NOSE CAP 50 x 70 IN.	●	●	●	●	●	●
2. CREW COMPARTMENT (ORBITER) 10 x 14 x 15 FT	●	●	●		●	
3. CANARD (BOOSTER) 34 x 24 x 5 FT	●					
4. SECONDARY TANKS 25 x 4 FT	●	●	●	●	●	●
5. ENGINE PODS (ORBITER) 12 x 5 x 12 FT	●	●	●		●	●
6. CARGO DOORS & RADIATOR (ORBITER) 66 x 16.7 x 7 FT	●	●	●		●	
7. VERTICAL FIN (ORBITER) 28.4 x 16.7 x 9 FT	●				●	
8. CONTROL SURFACES	●	●	●	●	●	●
9. FORWARD-FUSELAGE BOOSTER 18 DIA x 17 FT Φ	●					
10. FIN (BOOSTER) 18'9" x 16'8"	●				●	

FIGURE 4.8-24

SPACE SHUTTLE – COMPONENT TRANSPORTATION ANALYSIS
Transportation Capabilities

STRUCTURE \ TRANSPORTATION MODE	BARGE	AIR	RAIL	ROAD
1. CREW COMPARTMENT (ORBITER)	●	●		
2. FORWARD FUSELAGE (BOOSTER)	●	●		
3. CANARD (BOOSTER)	●	●		
4. WING (BOOSTER)	●			
5. DELTA WING (ORBITER)	●			
6. MAIN PROPULSION TANKS (B & O)	●			
7. SECONDARY TANKS (B & O)	●	●	●	●
8. MAIN FUSELAGE (B & O)	●			
9. ENGINE PODS (ORBITER) DELTA	●	●	●	
10. CARGO DOORS (ORBITER) DELTA	●	●	●	●
11. AFT FUSELAGE (BOOSTER)	●			
12. VERTICAL FIN (ORBITER)	●	●	●	●
13. CONTROL SURFACES	●	●	●	●
14. DETAIL PARTS	●	●	●	●

FIGURE 4.8-25

4.8.6 Alternate Plan for Final Assembly of High Cross Range (HCR) Orbiter - This section presents an alternate plan for final assembly of the Orbiter vehicle at the McDonnell Douglas, St. Louis facility.

This alternate plan calls for the tanks of both the Booster and Orbiter to be fabricated with the extensive Michoud facilities as in the main stream plan. The tanks are then barged to St. Louis for complete orbital vehicle buildup and ferry flight to KSC (or to Edwards AFB).

The advantages accruing to the alternate approach (complete fabrication at St. Louis with flyaway) are:

- Better lines of coordination between engineering and manufacturing because of co-location. The low number of Orbiter vehicles scheduled means that a "production line" as such, simply will not exist and that close engineering-production coordination is essential.
- Ability to refer to the actual vehicles for interface coordination and to expedite changes.
- Manufacturing becomes a complete, one location operation after receipt of the propulsion tanks. This means less coordination and overall cost because fuselage assembly and final assembly are both accomplished at one geographic location.
- Ample supply of skilled manufacturing manpower is available in St. Louis.

An obvious disadvantage is the barge trip for the main tanks and short overland movement of barge transported components but this may be slight compared to the advantages listed above. St. Louis has a quite adequate 10,000 ft. runway, however, there may be community objection to the short horizontal flight test required prior to transfer to Edwards. If this creates a problem, the Orbiter can be flown to Blytheville, Arkansas (165 miles South) for preliminary flight tests. The overland route from the Missouri River to the MDC plant has been checked for clearances and obstructions and is adequate and feasible for transfer of the tanks and even the completed Orbiter fuselage.

Figure 4.8 -26 indicates the various assemblies involved and possible fabrication locations to implement this plan.

Due to the size of some of the major subassemblies, water transportation is the only feasible mode of transportation available. This is particularly true for the wings and main propulsion tanks. Consequently, they must either be built at the point of fuselage assembly or at a point where they can be transported by water, in this instance, to St. Louis. We suggest that the wings be built at MDC Tulsa and the main propulsion tanks at Michoud, Louisiana with barge transportation from these locations to St. Louis. (See Figure 4.8 -27.)

A headwall would be constructed at a point immediately south of the old St. Charles Rock Road Bridge on the Missouri River where the barge would dock for transfer of cargo to land transportation. The wings and composite tank would be moved overland on a modified SIB transporter or other appropriate vehicle, following the route shown on Figure 4.8 -28 to the MDC plant at the St. Louis Municipal Airport.

Building 66 would be used for Orbiter fuselage buildup and final assembly. This building contains 130,000 sq ft of 40 ft clear truss height, 23,000 sq ft of machine shop and support cribs and 22,000 sq ft of second level air conditioned office area.

ALTERNATE PLAN – MODULE BREAKDOWN
With Recommended Subassembly Locations
Final Assembly at St. Louis

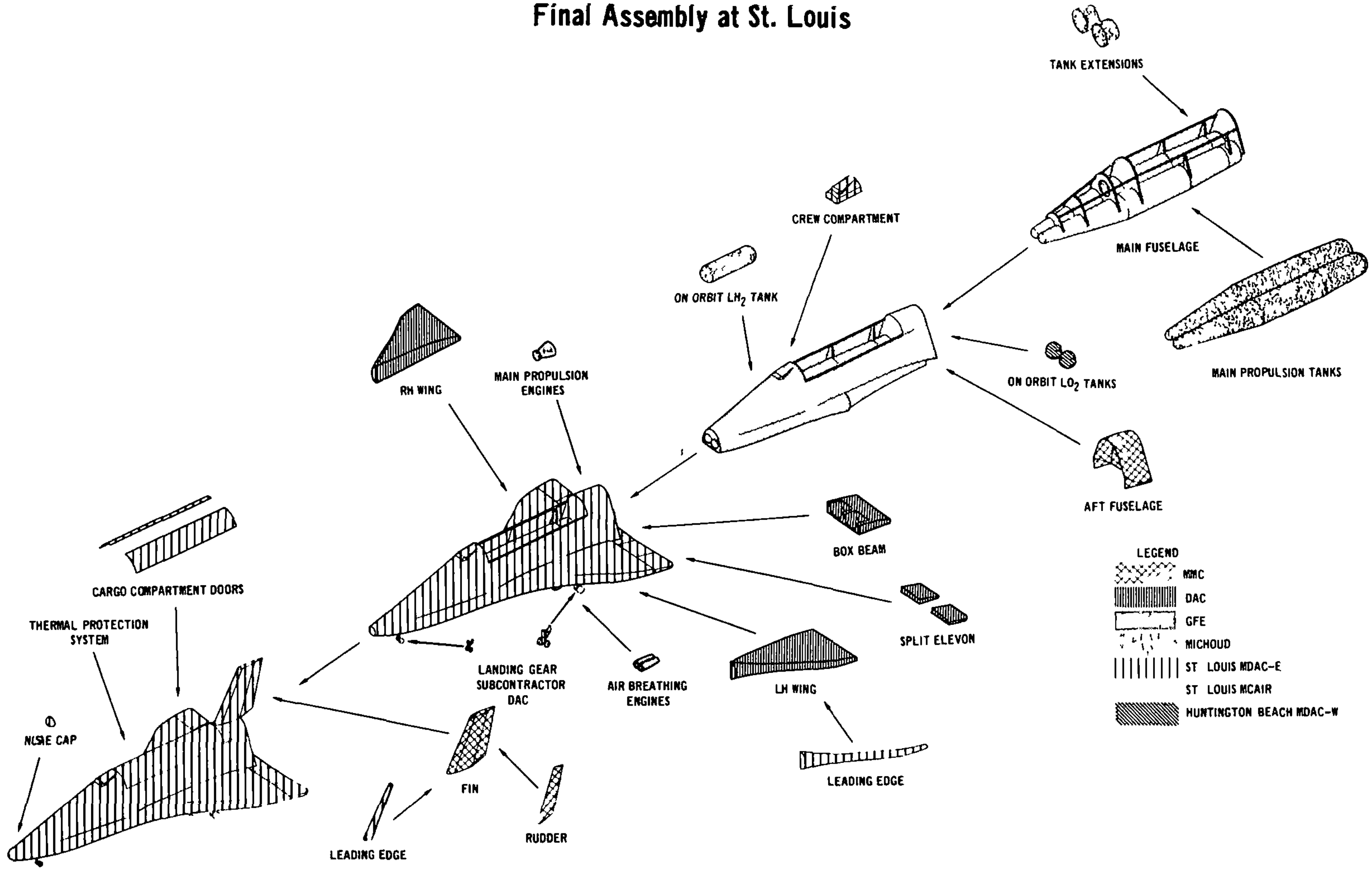


FIGURE 4.8-26

TRANSPORTATION FLOW CHART – ORBITER ASSEMBLIES
St. Louis Alternate Recommended Mode of Transportation

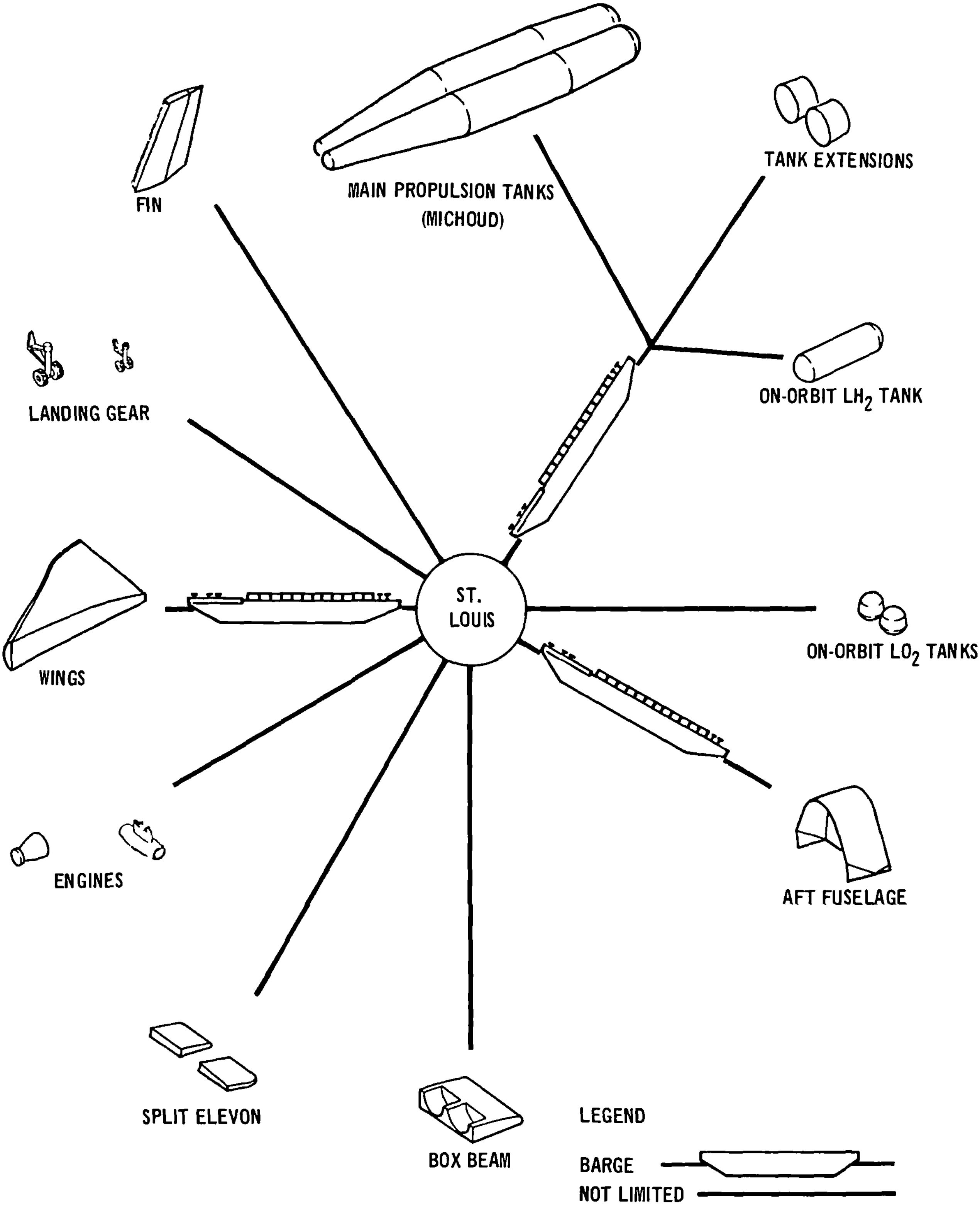


FIGURE 4.8–27

ALTERNATE PLAN
HIGH CROSS RANGE ORBITER SPACE SHUTTLE SHIPPING ROUTE
Primary Route

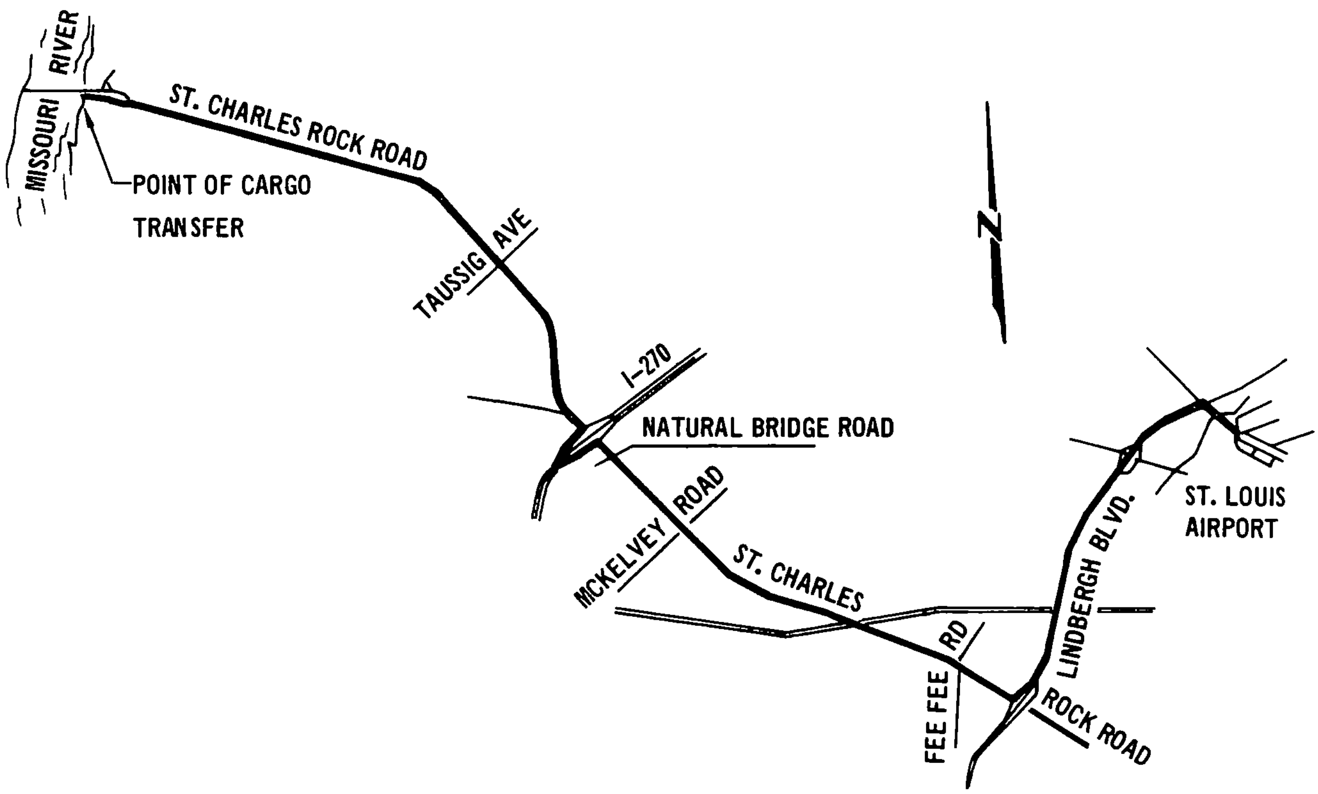


FIGURE 4.8-28

4.8.6.1 Requirements

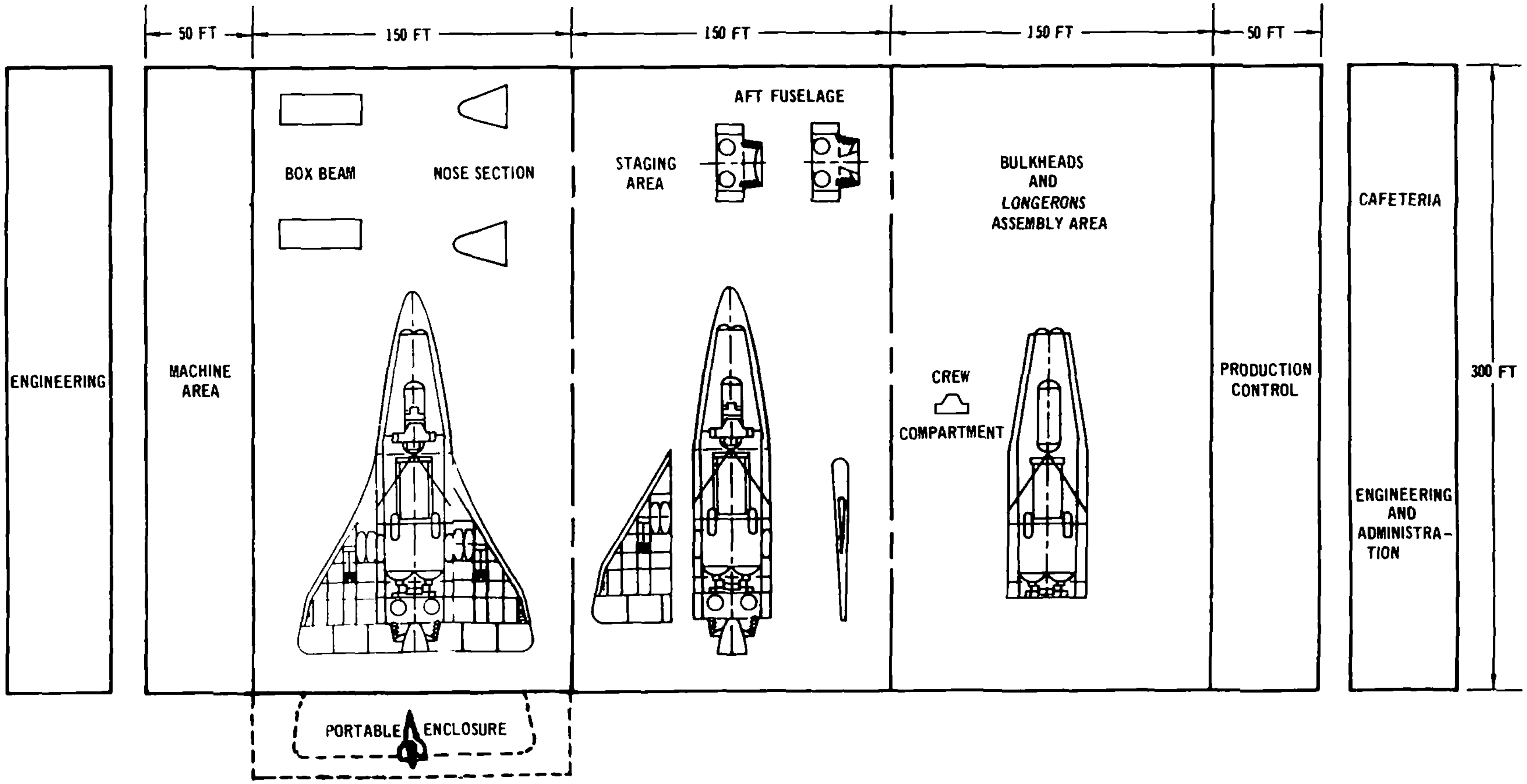
a.	Water Transportation - Mississippi, Missouri Rivers	Available
b.	10,000 ft runway - St. Louis Municipal Airport	Available
c.	Final Assembly Building - See Figure 4.8 -29 for layout	Available
d.	Appropriate skills - (employees have been recently laid off and are available for re-employment)	Readily Avail.
d.	SIB Transporter	Modified
e.	Headwall on Missouri River	New Construction
f.	Revamp Overhead and Wire Obstructions on the route from the Missouri River to the plant	Modified
g.	Portable Enclosure for Final Assembly	New Construction

4.8.6.2 Construction Requirements - One portable enclosure 150Lx45Wx80H: Construct a portable enclosure in which to install the vertical fin since the 40 ft clear height in Building 66 is insufficient to accommodate this operation. After the final assembly is substantially complete except for the fin, the portable enclosure would be put in place as shown in Figure 4.8.6-4 and the fuselage partially moved into it for installation of the fin and preflight checkout. The portable enclosure can be moved to the next bay for a repeat operation on the next ship.

4.8.6.3 Construction Costs and Schedules

o Additional portable structure to house the orbital tail assembly. This enclosure would be required March 1975.	$400,000
o Headwall at the Missouri River and permanent relocation of overhead and wire obstructions on the route from the Missouri River to the plant. Required April 1974.	175,000
o Modify SIB Transporter for orbiter propulsion tanks	150,000
Total	$725,000

ALTERNATE PLAN
MANUFACTURING BUILDING LAYOUT OF SHUTTLE ORBITER FINAL ASSEMBLY
BUILDING 66



PROPOSAL SHOWING THREE HIGH CROSS RANGE ORBITERS IN FLOW AT ST LOUIS
DATE 25 JANUARY 1971

FIGURE 4.8-29

4.8.7 Contractor Facilities - The McDonnell Douglas combined team facilities have been analyzed considering the known and anticipated requirements that have been established through the examination of preliminary design drawings and study of the manufacturing plan and production techniques required to produce the Shuttle vehicle hardware.

The team facilities presents a vast backlog of aerospace hardware production capability. These coupled with the capability of the Government-owned facilities as set forth in the foregoing plan, we feel satisfies all the hardware requirements of the program with the least expenditure of capital funds and maintaining a maximum of capability.

In support of and coupled to our highly mechanized machine, fabrication and processing shops is MCAUTO, the computer and data processing arm of our company. This facility has complete automation service capability and has the capability of directly controlling the production equipment, obtaining extreme accuracy with a minimum of set-up tooling and time of fabrication resulting in minimum costs.

The following is a partial summary of facilities and major manufacturing equipment available or that which we might expect to employ in the manufacture and test of Shuttle vehicles:

MCDONNELL DOUGLAS TEAM
FACILITIES SUMMARY

	MCAIR	DAC	DACAN	MDAC	MCAUTO	MDEC	MARTIN	TOTAL
Land (Acres)	640.75	1433.85	110.50	6,148.64	-	13.46	6,053	14,400.20
Bldg Area (Gr Sq Ft)	6,293,871	13,239,796	1,732,903	5,433,319	49,616	336,040	5,625,000	32,710,545
Office Area (Gr Sq Ft)	1,627,438	3,671,257	107,841	1,728,094	49,616	153,573	880,000	8,217,819
Mach. Shop (Gr Sq Ft)	725,162	1,149,072	749,170	354,242	-	14,000	1,666,000	4,657,646
Mfg Area (Gr Sq Ft)	2,961,341	4,140,208	840,208	622,211	-	113,200	960,000	9,637,168
Paint Shop (Gr Sq Ft)	59,058	228,396	7,272	-	-	3,600	390,000	688,326
Hangar (Gr Sq Ft)	343,038	381,083	-	-	-	-	264,000	988,121
Laboratory (Gr Sq Ft)	380,391	168,766	2,166	1,082,719	-	14,400	347,000	1,995,442
Whse/Misc (Gr Sq Ft)	197,443	3,501,014	26,246	1,646,053	-	37,267	1,118,000	6,526,023
Truss Ht.	9 to 40'	14.5 to 101'	12.5 to 40.5'	37 to 120'	-	9 to 50'	16 to 46'	9 to 120'
CRANE:								
No. Syst	117	72	122	25	-	-	28	364
Capacities*	½ to 10	1 to 20	¼ to 7½	1 to 30	-	-	5	¼ to 30
Hook Ht.	9 to 39'	16 to 95'	7 to 35¼'	22 - 110'	-	-	16 to 26'	9 to 110'

MCAIR - McDonnell Aircraft Company, St. Louis, Missouri
DAC - Douglas Aircraft Company, Long Beach, California
DACAN - Douglas Aircraft Company of Canada, Ltd., Malton, Ontario, Canada
MDAC - McDonnell Douglas Astronautics Company, Huntington Beach, California
MCAUTO - McDonnell Automation Company, St. Louis, Missouri
MDEC - McDonnell Douglas Electronics Company, St. Charles, Missouri
MARTIN - Martin Marietta, Denver, Colorado

* - Tons

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Numerically Controlled Equipment

N/C EQUIPMENT	QUANTITY
3-Axis N/C Profilers Single Spindle	1
3-Axis N/C Profilers 2 Spindle	2
3-Axis N/C Profilers 3 Spindle	25
3-Axis N/C Profilers 4 Spindle, Gantry Type	4
4-Axis N/C Profilers Single Spindle	1
5-Axis N/C Profilers Single Spindle	4
5-Axis N/C Profilers 3 Spindle, Gantry Type	4
N/C Machining Centers	13
N/C Turret Drills	3
N/C Rail Drills	2
N/C Lathes	4
N/C Jig Borers and Boring Mills	5
Miscellaneous N/C (1)	19

Note: (1) Includes (3) Drafting Machines, (1) Moog-Hydrapoint, (1) Punch Press, (2) Template Profilers, (1) Measuring Machine, (2) Tube Benders, (11) Wire Analyzers

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Machines Tools, Metal Cutting

MILLING MACHINES

Horizontal, Knee & Column Type Models 2, 3, 4 & 5	58
Vertical, Knee & Column Type Models 2, 3, 4 & 5	54
Horizontal, Bed Type Sizes: Width 2' to 4' Length 2' to 14'	6
Vertical, Bed Type: Size 30" x 72"	1
Vertical, Turrent Type, 9" x 20"	5
Spar, 2 Carriage, Vertical & Horizontal, 65'-6 Heads, 104'-4 Heads	2
Profiler, Vertical, 3 & 4 Axis, Tracer Control, Width 16" to 48" Length 30" to 120"	5
Profiler, Horizontal, 3 Axis, Tracer Control, Width 20" to 36" Length 36" to 120"	3

GRINDING MACHINES

Cylindrical, Universal & Plain 8" to 16" x 13" to 72"	14
Internal, Capacities 1/8" to 10" ID	3
Centerless, 3" x 30"	2
Thread, 12" to 24" x 45" to 68"	2
Surface, 8" to 18" x 24" to 72"	6
Profiler, Reciprocating Spindle	2
Jig, Vertical, 24" x 48"	2

LATHES

Engine, 1309" to 2013" x 20" x 96"	28
Engine, Sliding Gap, 3323" x 120" W/Gap Open 5623" x 192"	1
Engine, Tracer Controlled 1609" to 7650" x 54" to 228"	7
Turret, Horizontal, Universal Ram Type, Bar Capacity to 2-1/2"	38
Turret, Horizontal, Universal Saddle Type, Bar Capacity 3-1/2" to 12"	14
Turret, Vertical, 42" to 54" Dia.	3
Boring & Turning, Vertical 120" Dia.	1
Screw Machine, Single & Multiple Spindle, Capacity 1" to 3"	5

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Machines Tools, Metal Cutting (Continued)

BORING & DRILLING MACHINES

Jig Borer, 10" to 20" x 20" to 54"	10
Boring, Drilling & Milling, Horizontal, 30" to 48"	3
Boring, Precision, 2 & 4 Spindle	9
Drill Press, Layout, 15" Swing	3
Drill Press, Turret, 6 Spindle	1
Drill Press, 24' Adjustable Spindle	1
Drill Press, 1 Spindle, 15" to 20" Swing	16
Drill Press, 4 & 6 Spindle, 24" to 30" Swing	24
Drill, Radial, 5', 6', & 8' Arms	9

MISCELLANEOUS

Shaper, Vertical, 12" Stroke	1
Saw, Band, 20", 26", 36" & 60" Throat	27
Saw, Radial, 16" Blade	3
Saw, Cutoff, Abrasive 20" Disc.	1
Thread Roller, Cap. 1/8" to 3" Dia.	1
Honing, 1" to 10" Dia.	6
Lapping, 12" to 60" Travel	3
Broach, 72" Ram Travel	1
Back Spot Facer, 15" Swing	2
Tapper, Torque & Leadscrew Type	5
Electrochemical, Cavity Sinker 10,000 Amp. 24" x 32"	1
Electrical, Discharge, 60 Amp. 30 Amp./10 Amp.	3
Router, Radial Arm, 15,000 RPM	2
Router, Shaper, 15,000 RPM 3/4" Collet	5
Countersinker, 3/32" to 3/8" Dia. Hole	2
Barrel, Finisher, 1/2 to 77 Cu. Ft.	13
Vibratory, Finisher, 5 to 12 Cu. Ft.	4
Router, Pin, 10,000/20,000 RPM	7
Electrochemical, Cavity Sinker - 20,000 Amp. 60 x 60 x 154	1
Planer, Tracer Controlled 6' x 26'	1

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Machine Tools, Metal Forming

Press, Hydraulic	7	500, 2500, 3000, 7000, 10,000 and 41,000 Ton, 25" Dia. Hydroform
Press, Hot Sizing	7	1100°F to 1500°F Platen, 25 to 500 Ton
Press, Stretch, Wrap	8	10 to 1666 Ton
Press, Stretch, Draw	1	150 Ton
Press, Brake, Hydraulic	4	40 and 400 Ton
Press, Brake, Mechanical	9	4-1/2 to 200 Ton
Roll, Forming	7	16 to 0 Gage, 3' to 15'
Press, Punch	14	55 to 220 Ton
Press, Punch, Horn Type	1	110 Ton
Hammer, Drop	6	3' to 5' x 4' to 8'
Fabricator, Duplicating	1	15 Ton
Fabricator, Duplicating, Turret/NC	1	30 Ton
Press, Expander	1	150 Ton
Shrinker	12	24 to 7 Gage
Swager	1	3" Diameter Tube
Shear, Squaring	10	7 Gage x 18'

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Heat Treat Equipment

Furnace, H-Temp.	1	500°F to 2500°F	48" W x 96" L x 48" H
Furnace, Lab. Type	1	1800°F to 3000°F	5" W x 12" L x 6" H
Furnace, Steel Heat Treat	6	1400°F to 2500°F	24" W x 60" L x 20" H
Furnace, Inverted Pit with Atmosphere Generator	1	1400°F to 1850°F	28" Dia. x 72" H
Furnace, Gas-Fired	2	1300°F to 2300°F	54" W x 120" L x 24" H
Furnace, Salt Bath	1	1400°F to 1650°F	30" W x 30" L x 72" D
Furnace, Draw, Aging	10	500°F to 1400°F	60" Dia. x 120" D
Furnace, Aluminum Heat Treat	2	800°F to 1200°F	60" W x 168" L x 72" H
Furnace	1	400°F to 800°F	60" W x 192" L x 60" H
Furnace, Salt Bath Aluminum	4	800°F to 1000°F	72" W x 288" L x 114" D
Oven, Aging Aluminum	7	200°F to 500°F	144" W x 144" L x 84" H
Oven, Baking	7	150°F to 500°F	20" W x 60" L x 30" H
Furnace, Car Bottom	1	500°F to 1200°F	120" W x 216" L x 144" H
Furnace, Car Bottom	1	900°F to 1800°F	48" W x 120" L x 24" H
Pot, Metal Melting	4	500°F to 1000°F	27" Dia. x 26" D
Refrigerator, Walk In	3	30°F to -10°F	10' W x 20' L x 7-1/2' H
Refrigerator, Chest	2	60°F to -130°F	30" W x 60" L x 26" D
Cooler, Chest	16	30°F to -10°F	10 to 500 cu. ft.

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Welding Equipment

TYPE		CAPACITY
Welder, Electron Beam	1	112" x 50" x 62" Chamber
Welder, Resistance Seam	4	50 KVA to 400 KVA
Welder, Resistance Spot	12	30 KVA to 150 KVA
Welder, Resistance Comb. Spot & Seam	1	50 KVA
Welder, Automatic Tungsten Inert Gas	6	300 Amps to 600 Amps
Welder, Manual DC Arc	67	150 Amps to 400 Amps
Welder, Manual AC Arc	21	200 Amps to 500 Amps
Welder, Manual AC/DC Arc	11	200 Amps to 600 Amps
Welder, Manual Metallic Inert Gas	4	300 Amps to 500 Amps
Welder, Tungsten Inert Gas Arc Spot	1	300 Amps
Gun, Welding, Arc Spot	1	200 Amps
Heater, Induction	1	25 KVA
Chamber, Inert Gas Welding	2	72" x 36" x 24"
Chamber, Inert Gas Welding	1	40" x 40" x 40"
Positioner, Welding	6	500 lbs. to 2000 lbs.
Positioner, Longitudinal Welding	2	48" Length & 72" Length
Honer, Dry	2	4' W x 3' H x 3' D
Needle, Plasma Arc	1	1-10 Amp
Welder, Plasma Arc	1	400 Amps

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Tool Room Equipment

MILLING MACHINES

Horizontal, Knee and Column Type Models 3 and 4	10
Vertical, Knee and Column Type Models 3, 4, and 5	14
Vertical, Rotary Head, No. 2 Model	1
Vertical, Turret Type, 9" x 20"	1
Profiler, Vertical, 3 Axis Tracer Control, 30" x 60"	1
Profiler, Horiz., 3 Axis Tracer Control, 36" x 20"	1

GRINDING MACHINES

Cylindrical, Universal 12" x 36"	5
Internal, Capacity 8" I.D.	1
Centerless, 3" x 30"	1
Jig, Vertical, 24" x 48"	2
Surface, Horizontal, 18" x 72"	2
Surface, Horizontal, 14" x 48"	1
Surface, Horizontal, 8" x 24"	5
Surface, Rotary, 18" Dia. and 24" Dia.	2

MOCKUP AND WOOD SHOP

Surfacer, Wood, 8" x 30"	2
Jointer, Wood, 16" x 96" and 24" x 96"	3
Saw, Band, 16" and 36" Throat	5
Lathe, Wood Turning, 1210" x 54"	1
Saw, Table, Tilting Arbor, 14" Blade	3
Drill, Press, 1 Spindle, 15" Swing	3
Drill, Press, 4 Spindle, 18" Swing	1
Sander Disc, 16" and 30" Wheel	3
Sander, 2 Spindle, 1" to 6" Dia.	2

LATHES

Toolmaker, 1309" x 20"	2
Toolmaker, 1609" x 30"	3
Toolmaker, 1910" x 54"	2
Toolmaker, 2018" x 72"	3
Engine, 3025" x 120", Tracer Controlled	1
Engine, 1910" x 54", Tracer Controlled, Rotary Master	1
Turret, Ram Type, Capacity 3-1/2" Dia.	1

GENERAL MACHINES

Router, Contour Bevel, 36" x 60" Tracer Controlled	1
Planer, 2-1/2' to 6' x 8' to 20'	3
Shaper, Horizontal, 24"	1
Shaper, Vertical, 6" and 12"	2
Saw, Band, 16", 26", 36" and 60" Throat	12
Filer, Band, 10" and 30" Throat	4
Saw, Abrasive Cut-Off, 16" Wheel	1

TOOL AND CUTTER GRINDING

Grinder, Tool and Cutter, Universal	32
Grinder, Cutter, Radius and Form	8
Grinder, Hob and Tap	2
Grinder, Saw Sharpener	2
Grinder, Microform	1
Grinder, Single Point Form Tools	1
Grinder, Cylindrical, Universal 12" x 36" and 8" x 24"	2
Grinder, Controu	3
Grinder, Surface	2
Grinder, Tap	1
Grinder, Profile	11
Grinder, Drill Point Splitter	3
Grinder, Drill, Semiautomatic	3
Grinder, Drill, Automatic	1

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Tool Room Equipment (Continued)

BORING AND DRILLING MACHINES

Jig Borer, 10" x 20"	1
Jig Borer, 24" x 54"	5
Mill, Boring, Horizontal, 48" x 72", 4" Spindle N/C	1
Drill, Radial, 4', 6', and 7' Arms	5
Drill Press, 1 Spindle, 16" and 18" Swing	20
Drill Press, 2 Spindle, 20" Swing	2
Drill Press, 4 Spindle, 24" Swing	5

HEAT TREATMENT

Furnace, Electric, 1400°F to 2500°F, 24" W x 36" L x 18" H	2
Furnace, Salt Bath, 1500°F to 1750°F, 15" W x 24" L x 32" H	1
Furnace, Draw, 400°F to 1250°F, 24" W x 36" L x 18" H	2

TOOLING SUPPORT

Measuring Machine, 3 Axis, 3' x 5'	1
Surface Plate, Steel, from 2' x 3' to 6' x 12'	37
Surface Plate, Granite, from 2' x 3' to 4' x 8'	13
Jig Transit, Optical	34
Transit, Square, Optical	57
Scope, Micro Alignment, Optical	61
Level, Precision, Optical	50
Stand, Transit	101
Tooling Bar, Optical	33
Comparator, Optical	7

Also a complete complement of dividing heads, rotary tables, adjustable angle plates, height gages, magnetic sine plates, etc.

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Quality Assurance Test Equipment

Physical and Functional Test Equipment

X-Ray Unit, Ranging from Portable Units to 400 KVA	9
Processor, X-Ray Film, Automatic, 1 Mobile Portable	3
Dryers, X-Ray Film	3
Test Stand, Hydraulic (With a Capacity up to 5000 psi and a Flow Rate of 60 Gallons per Minute)	3
Test Stand, Pneumatic (With a Capacity up to 10,000 psi)	3
Test Stand, Oxygen (With a Capacity up to 10,000 psi)	3
Test Stand, Fuel with a Capacity of 300 Gallons per Minute	1
Test Stand, Oxygen Regulator and Auxiliary Oxygen Regulator Service (2 each)	4
Test Tank, Pressure, 4' Wide x 8' Long x 2' Deep, 1000 psi Capacity	2
Simulator, Breathing Machine	1
Barometer, Manometer, 80" Hg with Standard Barometer	1
Test Bench, Electro-Hydraulic, to Test Integrated Electrical and Hydraulic Systems to 5000 psi	1
Tester, Dielectric, With an Output of 10,000 Volts AC and 1 Test Tank, 3' Wide x 15' Long x 2' Deep	3

Changer, Frequency, 20 Cycles to 2 KC	3
Inspection System C Scan Lab. Unit with Tank Size 18" x 24"	1
Inspection System, Infrared Lab. Unit Scanner Width 6" Carriage Length 72"	1
Oscilloscope, DC 59 30 MC, 0 to 100 Volts	3
Generator, DC, 30 Volts, (1) 300 Amps, (1) 1000 Amps	2
Generator, Signal, Min. Range 20 Cycles to Max. 2.6 Cycles	5
Tracer, Curve, 0 to 10 Amps, 0 to 200 Volts	2
Bridge, Impedence, 0 to 1200 MF, Frequency 225 Kz	3
Counter, Electronic, 0 to 10 KC	3
Power Supply, 0 to 6 KV	8
Leak Detector System	1
Digital Multimeter, 0 to 1000 Volts AC or DC , Resistance 0-1 Meg. Ohm	2
Tester, Capacitance Measuring	1
Tester, Thickness, Vidigages and Ultrasonic Thickness	6
Tester, Ultrasonic Sonoray and Sonizon Units	5
Tester, Conductivity	16

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Quality Assurance Test Equipment

Physical and Functional Test Equipment (Continued)

Tester, Rockwell Hardness (Bench)	21
Tester, Hardness (Portable)	11
Tester, Micro Hardness	1
Borescope, Sizes .100 4" Reach to .625 Max. 12' Reach	11
Bench Center, 12" to 48" Capacity	6
Test Tank, Ultrasonic, with Scanning Bridge, Tank Sizes 6' Wide x 8' Long x 3' Deep and 3' Wide x 6' Long x 2' Deep	2
Tester, Tensile, Ranging from 10,000 lbs to 300,000 Capacity (3 Lubular Furnaces up to 2000°F, 1 with a Controlled Chamber Size 20" x 22" x 22", and a -100° to +1000°F Capability	8
Furnace, Electric Heat Treated with Range to 2000°F, Work Chamber 18' Wide x 36" Deep x 18" High, (2) Vapor Carb. Circular	3
Lathe, 13" x 30" Centers	3
Mill, Horizontal, 12-1/4" Wide, 28" Travel, Working Surface 59-1/4" x 12-1/2"	1
Reflectoscope, Ultrasonic Tester, Ranges from 0.5 MC to 50 Mz	3
Measuring Machine, Coordinate, with Print Out Attachments, 3-Axis Capabilities, 24" x 15"	2
Measuring Machine, Roundness, Squareness, Concentricity, and Parallelism, 6" Dia. Work Table	1
Inspection Machines, Numerically Controlled, 4-Axis 3 N/C Movement, 1 Rotary Manual Movement 60" x 96" Work Surface and a 48" Rotary Portion of the Work Surface	1
Turn Table, Rotating Tilt, Ranging from 12" to 36"	5
Measuring Instrument, Surface Finish 1/2 Micro Inch to 1,000 Micro Inch Capability	7
Comparator, Ranging from 10" to 30" Screens	9
Table, Surface, Steel, Sizes from 2' x 3' to 12' x 5'	10
Table, Surface, Granite, Sizes from 2' x 3' to 12' x 4'	63
Jig Fixture, Wharton, Systems	3
Positioner, Precise Angle 0 - 360°	1
Tester, Hi-Potential AC and DC, 0-5000 Volts	11
Tester, Continuity	3
Tester, Digital Volt-ohmmeter	1

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Quality Assurance Test Equipment

Physical and Functional Test Equipment (Continued)

Analyzer, Functional Electrical DITMCO, 400 Cycle Inverter	4
Tester, Digital Temperature	1
Micrometer, Optical	8
Analyzer, Shorting Adapter, 100 Points	3
Megohmmeter, 50 Volts, 100 Volts, 500 Volts, 1 Megohm to 100,000 Megohms	6
Gage, Height 24"	43
Tester, Paint, Hard Coat and Film Thickness	4
Goniometer, 1/8" to 3" Diameter Capacity	2
Gage, Cutting Tool, Angle and Radial Measurement	4
Machine, Precision Pre-Setting Tool Angle Inspection Machine, Optical Viewing Systems, with a Capacity of 0" to 12" Dia. and 0" to 24" Long	1

Process Inspection and Laboratory Equipment

Inspection System, Zyglo, Completely Mechanized for Parts up to 3' in Length and 6 Inpsection Booths	1
Inspection System, Zyglo, Manual with Submersion Tanks, 120" x 40" and Equipped with Automatic Lifts	2
Magnaflux Unit, up to 100" Head Opening	5
Demagnetizer, (1) with 15" x 18" Opening, (1) 24" x 30" Opening	2
Spectrograph, Emission, 1 Direct Reading and Film, 1 Film Reading Only	2
Cabinet, Humidity Control, 25" W x 19" D x 20" H	1
Saw, Cutoff, 12" Capacity	2
Saw, Band, 15-1/2" Throat Depth, 10" Thickness Capacity	2
Spectrophotometer, Infrared	1
Oven, Laboratory: 1 Room Temp. to 325°F, 18" W x 18" H x 18" D; 1 Room Temp. to 1000°F, 24" W x 20" H x 20" D; 1 400°F to 1600°F, 9-1/2" W x 8-1/2" H x 13-1/2" D; 1 600°F to 2650°F, 4-1/2" W x 4-1/2" H x 8-1/4" D	4
Analyzer, Gas, Vacuum Fusion, for Analysis of Hydrogen, Oxygen, and Nitrogen Impurities in Metals	1
Cutter, Specimen, 12" Diameter Cutting Wheel	2

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Quality Assurance Test Equipment

Process Inspection and Laboratory Equipment (Continued)

Microscope, 2 Metallurgical, 2 Stero, 1 3-D, and 2 with Camera Attachments	7
Chromatograph, Gas	1
Sander, Belt, 6" W x 10" H Sanding Area	2
Balance, Analytical, Sensitivity of .1 Mg Capacity of 200 Grams	3
Press, Mounting, Specimen	3
Test Unit, Stress Corrosion, (1) Test Specimen for Applied Loads (1) for Emersion Cycling	2
Meter, Brightness Light, for Plastic Light Panels	2

Metrology Laboratory Equipment

Analyzer, Torque (1) Range 20 to 200 Inch Ounces and (1) 0-165 Ft Lbs, (1) 165-2000 Ft Lbs	3
Test Stand, Collimator, with Accessories	1
Tester, Hydraulic Dead Weight to 50,000 psi	3
Tester, Pneumatic Pressure, .0005 to 100 psi and (1) 100 to 1000 psi	3
Gage, Air Piston, .3 to 500 psi	2
Gage, Internal Check, .250" to 11" Capacity	3
Gage, Hole, .07" to 4" Diameter Capacity	1
Gage, Indi-Ron, 7" Turntable Supporting a Min. of 100 Lbs	1
Counter, Link Fringe, 0 to 2" Direct Measuring Capacity	1
Manometer, 3 Mercury with Capacity of 60" Hg and 1 Water	4
Measuring Machine, 1-12", 1-24", and 1-48"	3
Gage Block Set, Master	4
Comparator, Gage Block, 20"	1
Telescope, Alignment	1
Microscope, 1 Interference with Camera and 1 Toolmakers	2
Gage, Height, 60" Master	1
Polygon, Mechanical, 1-12 sided and 1-360°	2
Analyzer, Surface (Taly-Surf 4) with Recorder	1
Test Stand, 1 Liquid Flowmeter Calibrator Range of .15 to 270.0 Gallons per Minute and 1 Gas Flow Meter Calibrator Range of .250 to 350.0 Cubic Ft per Minute	2
Laser, Interferometer with 9' x 18" x 16" Granite Measuring Rail	1

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Quality Assurance Test Equipment

Metrology Laboratory Equipment (Continued)

Clinometer, Microptic, 0 to 360°	1
Platform, Air, 6" x 8-1/2" x 1"	4
Level, Optical	2
Cube, Optical Square	1
Square, Steel Master with Precision Legs 24" and 36" Long	1
Straight Edge, Master Granite 48" Long	1

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Digital Equipment

Our presently installed digital and analog processing equipment includes the following:

Two 360/85's
One 360/75
Two 370/155's
Five 360/65's
Four 360/50's
Four 360/40's
Twelve 360/30's
Two 360/25's
Ten 360/20's
Three IBM 1800's

Three IBM 1130's
Three IBM 7094's
Three Univac 1004's
One Univac 9300
One CDC 6600
One CDC 6500
Three CDC 915's
One GE 440
Two XDS 925's
Seven XDS 930's

Three XDS Sigma 5's
Four XDS Sigma 7's
One XDS 9300
Two RCA 70/45's
One SD 4060
One XDS 92
One CDC 8090
Two DDP 516's
One RW 300
One Meta 4
One SEL 86

Analog Equipment

Three 231 R PACE (HYDAC 2000 System)
Four EAI 131 R PACE
One ESIAC
One CEAC
One Milgo 4100

Two AD/4's
One CDC Tonal Display System
Two Beckman 2200's
One Beckman 2132

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Chemical Processing Equipment

TYPE	DESCRIPTION
Chemical Machining, Aluminum	Etch Tank, (3), 20'L x 4'W x 6'D, and associated equipment; 1,137,000 Sq. ft./month capacity
Chemical Machining, Steel & Exotic Metals	Etch Tank, (2), 96"L x 38"W x 38"D, and associated equipment
Checmical Machining, Spray Etch (2)	Conveyor Capacity 24" x 48," simultaneous etching both sides
Chrome Plate	Plating Tank, (3), part size to 12' long
Barrel, Cadium Plate	Plating Tank, (1), parts to 12' long; 18" dia. x 42" long
Chamber, Vacuum, Cadium Plate	8" dia. x 56" long; complete automatic controls
Chromate Treatment, Type II	Tank size 48"L x 36"W x 30"D
Nickel Plate	Tank size 60"L x 48"W x 48"D
Copper Plate	Tank size 60"L x 48"W x 48"D
Pickle, Hydrochloric Acid	Tank, (2), 72"L x 36"W x 48"D
Pickle, Nitric-Hydrofluiric Acid	Tank size 150"L x 41"W x 56"D
Solvent Cleaning, Ultrasonic	Tank, (2), 48"L x 14"W x 12"D, 25 kilocycles, 1,000 watts
Alkaline Cleaning, Ultrasonic	Tank size 48"L x 14"W x 12"D, 25 kilocycles, 1,000 watts
Resistant Weld Cleaning, Aluminum	Tank size 15'L x 4'W x 6'-6"D
Spot Weld Cleaning, Magnesium	Tank size 15'L x 4'W x 6'-6"D
Tube Cleaning and Decontamination	Capacity 35 feet of 3/16" to 1" tubing per 5-minute cycle; alcohol filtered to 10 microns absolute; closed system
Conversion Coating, Aluminum, Chromic Acid	Tank size 22'L x 4'W x 4-1/2'D

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Chemical Processing Equipment (Continued)

TYPE	DESCRIPTION
Chromic Acid Dip, Aluminum Brightener	Tank size 22'L x 4'W x 4-1/2'D
Chromic Acid Anodize	Tank size 22'L x 4'W x 4-1/2'D, 2,000 Amp. capacity
Sulfuric Acid Anodize	Tank size 12'L x 4'W x 6'D, 4,000 Amp. capacity
Hardcoat, Aluminum	Tank size 12'L x 3'W x 6'D, 4,000 Amp. capacity
Black Anodize	Tank size 48"L x 32"W x 36"D
Hardcoat, Magnesium, Dow-17	Tank size 144"L x 88"W x 57"D, 2,000 Amp. capacity
Electro-Chemical Deburr, Aluminum	Tank size 8'L x 4'W x 5'D, 8,000 Amp. capacity
Vapor Degreaser, Automatic, Conveyorized	15,000 lb/hr aluminum, basket size 8' x 2-1/2' x 3-1/2'; trichlorethylene, vapor, spray, vapor stages
Debark Facility, Roll Band	Tank size 25'L x 7'W x 5'D, 2-3 Ton Cranes, including heat exchanger, all stainless piping

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Plastics Fabrication Equipment

TYPE	DESCRIPTION
Plastic Forming and Curing	Press, Heated Platen (1), 100 ton capacity, 450°F, 50" x 50" platen size Press, Heated Platen (1), 40 ton capacity, 450°F, 36" x 36" platen size Oven, Curing (1), 500°F, 4' x 4' x 12' Oven, Curing (1), 500°F, 6' x 4' x 4' Furnace, Curing (1), 1000°F, 2' x 3' x 4' Pumps, Vacuum (2), 50 CFM capacity Cooler, Walk-in (1), 12' x 12' x 8', 40°F
Bonding Room	Autoclave, 7' dia. x 22' long, 500°F max., 100 psi Oven, Bonding, 600°F max., 12' x 12' x 7' Oven, Bonding, 600°F max., 6' x 6' x 6' Pumps, Vacuum, 60 CFM Press, Heated Platen, (1), 70 ton capacity, 600°F, 14" x 14" platen size Tanks, Cleaning, (3) 2' x 12' x 4', including deonized water source Lay-up area, air conditioned, 4000 $ft.^2$, temperature and humidity controlled Support equipment, including cutting machines, cold storage facilities, testing equipment
Reinforced Plastics Fabrication	Spray-up Units, (2), for fabricating low cost fiberglass reinforced plastic parts with epoxy and polyester resins
Sealant Compound	Mixer, Sealant, (7) Two-component continuous metering and mixing machines for sealant and potting compound, capacity 2-3 lbs./minute per machine

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT ST. LOUIS

Painting Facilities

TYPE	DESCRIPTION
Finish Product Paint Facility	Booth, Water Wash (8), 50'W x 86'L x 20'H, heated make-up air, complete with steam clean. Includes paint mix service facility. Booth, Water Wash (1), 100'W x 50'L x 20'H and adjacent steam clean facility.
Small Parts Paint Facility	Booth, Water Wash (5), 17', 22', 23', 25' and 30' wide, 3 variable speed conveyor systems (1 transfer system, 2 paint conveyors), conveyorized open 3'W x 4'H x 24'L, 400°F max. Drying oven 4-1/2'W x 5-1/2'H, 600°F max., +10°F (capacity 1,500,000 parts/month). Spray Unit, Hot Airless (2) Spray Unit, Cold Airless (2) Booth, Spray Paint, (1) Water Wash 40'W x 64'L, heated, filtered, make-up air; and (1) dry Filter 30'W x 8'H with variable speed conveyorized system feeding both booths, conveyorized drying oven 3'W x 4'H x 14'L, 400°F max.
Major Assembly Paint Facility	Booth, Water Wash (1) (4 sections) 85'W x 60'L, heated, filtered, make-up air.
Special Finish Booth and Humidity Cure Facility	Booth, Water Wash (1), 30'W x 35'L, for spraying toxic materials. Accelerated cure facility 25'W x 30'L x 8'H, 130°F, controlled humidity.
Prepaint Cleaning Area	Enclosed Area, 25' x 30' with steam cleaning system, detergent-water rinse, etc.
Paint Stripping Tanks	Tank, Rinse (5), 4' x 4' x 6', Epoxy, and Organic finishes.
Paint Cure Oven	(2), 600°F, 4-1/2'W x 5-1/2' x 5-1/2'

MANUFACTURING AND SUPPORT EQUIPMENT

LOCATED AT SANTA-MONICA

Numerical Control Machine Tools

3 Chemical Milling Tanks 16' x 14' x 7' deep.
2 Chemical Milling Tanks 28' x 18' x 13' deep.
1 Anodize Tank 60' x 4' x 14' deep.
1 Anodize Tank (Automatic) 60' x 4' x 14' deep.
1 Aging Oven 300°F to 1000°F 40' L x 7' H x 5' W.
1 Aging Oven 6° to 350°F.

LOCATED AT LONG BEACH

1 Titanium Facility 48" x 96" Sheet Size
Ovens - Aging
Presses
Descaling Tanks
Rinse Tanks

LOCATED AT TORRANCE AND LONG BEACH, CALIFORNIA

26-5 axis Profilers
3-4 axis Profilers
3-5 axis Omnimill
4-4 axis Omnimill
4-3 axis Dimill
7-3 axis 8 Spindle Turret Drill
2-3 axis Machining Center
8-3 axis Profiler
2-3 axis Numerimill
1-3 axis Skin Mill
2-3 axis-Mini-E-Max
1-3 axis Director Interpolator
2-3 axis Boring Mill
2-10 axis Spar Mill
2-Numericenter
1-Omnicontrol System
3-2 axis Single Spindle Tape-O-Matic Drill
2-Aircraft Precision Tube Bender
4-2 axis Profile and Drilling Machine
5-2 axis Drafting Mach
2-Automatic Bar Lathe
4-Wire Processor
3-Fastening Machine

LOCATED AT HUNTINGTON BEACH

1 Paint Booth 35' Wide x 57' High x 75' Long

4.8.8 Phase C/D Summary Master Schedules

The schedules presented herein were used as a basis in preparation of the schedules presented elsewhere in this report.

4.8.8.1 Figure 4.8-30 is the Booster functionally oriented, Phase C/D Summary Master Schedule.

4.8.8.2 Figure 4.8-31 is the Orbiter functionally oriented, Phase C/D Summary Master Schedule.

BOOSTER – PHASE C/D SUMMARY MASTER SCHEDULE (FUNCTIONALLY ORIENTED)

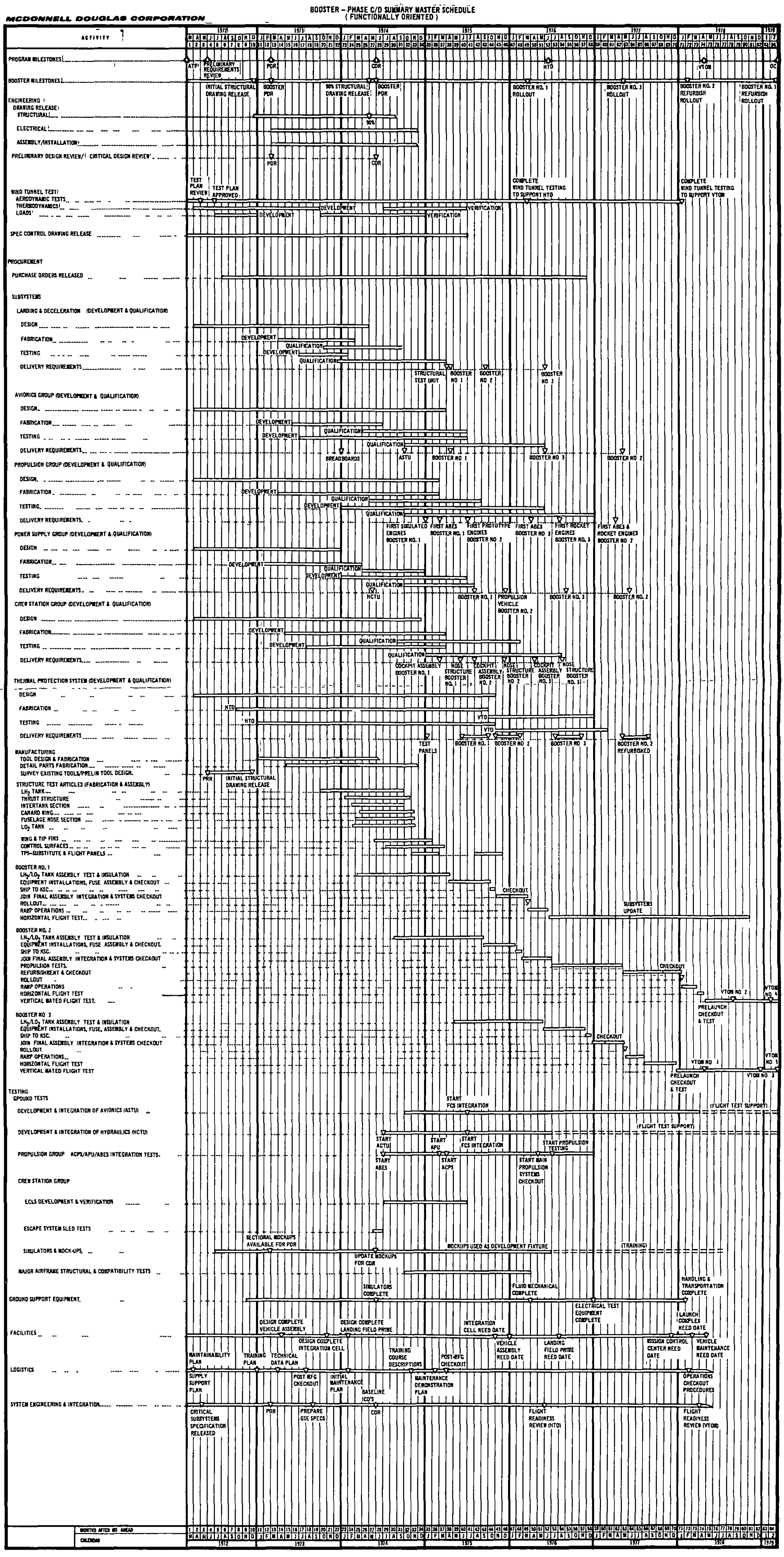


FIGURE 4.8-30

ORBITER – PHASE C/D SUMMARY MASTER SCHEDULE
(Functionally Oriented)

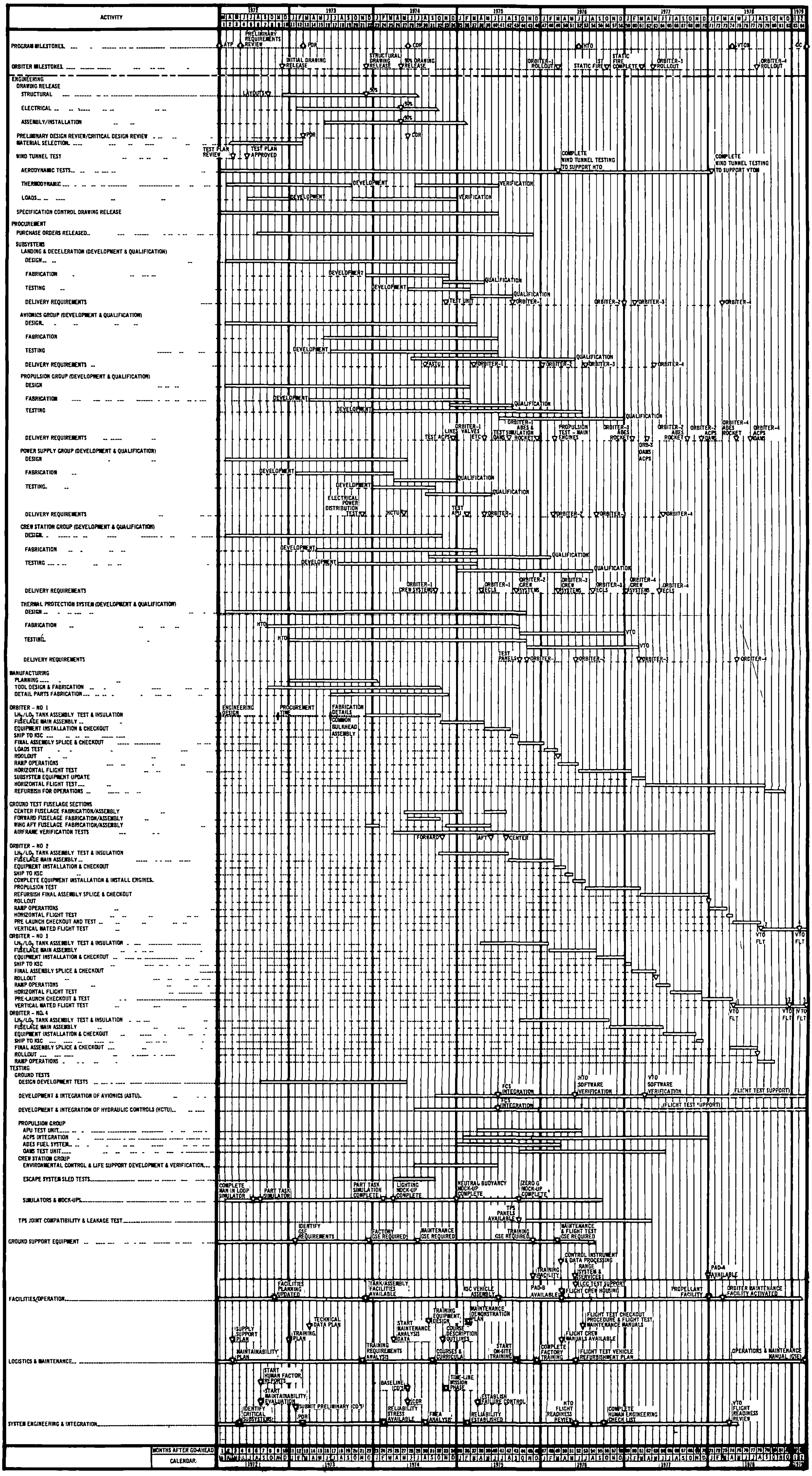


FIGURE 4.8–31