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DESIGN STUDY OF RL10 DERIVATIVES

FINAL REPORT

VOLUME III, PART 2

OPERATIONAL AND FLIGHT SUPPORT PLAN

Approved by:
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Prepared for
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
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ABSTRACT

Volume III, Part 2 contains the results of the study conducted under NASA Contract NAS8-28989 by Pratt & Whitney Aircraft Florida Research and Development Center. This volume is divided into eight sections, Section A - Space Tug Operation, Section B - Program Objective, Section C - Organization, Section D - Program Schedule and Facility Requirements, Section E - Flight Support and Anomaly Resolution, Section F - Maintainability, Section G - Logistics, Section H - Field Support, Section I - Maintenance and Refurbishment, Section J - Transportation Plan.

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FOREWORD

This technical report presents the results of the Design Study of RL10 Derivatives for Space Tug propulsion. The study was conducted by the Pratt & Whitney Aircraft Division of United Aircraft Corporation for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center under Contract NAS8-28989.

The results of this study are contained in the following four volumes, which are submitted in accordance with the data requirements of Contract NAS8-28989.

Volume I	Program Summary
Volume II	Engine Design Characteristics
Volume III, Part 1	Preliminary Interface Control Document
Volume III, Part 2	Operational and Flight Support Plan
Volume IV	Development Plans and Program Costs

This program was initiated in the middle of February 1973, with the technical effort being completed in seven months and the delivery of the final report on 15 December 1973. The study effort was conducted under the direction of the George C. Marshall Space Flight Center Science and Engineering organization with Mr. Frederick W. Braam as Contracting Officer's Representative. This effort was carried out by Pratt & Whitney Aircraft at their Florida Research and Development Center under the direction of Mr. J. P. B. Cuffe, Study Manager.

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INTRODUCTION

The Preliminary Operational and Flight Support O&FS Plan presented in this volume has been formulated in response to Study Contract NAS8-28989 and is for the three RL10 derived engines selected by NASA, the Derivative IIA, IIB and Category IV. A preliminary O&FS plan for the RL10 Category I engine was generated during the previous study Contract NAS8-29314 and is included in FR-5523, Volume III, dated 31 January 1973.

The scope of this plan includes all work associated with operational use of the Space Tug engine from the maintainability studies conducted during design through field maintenance and overhaul. The purpose has been to identify those elements of the P&WA™ organization that can support operation of the engine and to plan the management system to consolidate these efforts over the life of the Space Tug.

The Pratt & Whitney Aircraft reusable Space Tug Main Engine Program will be planned to provide to the Government the low operating cost goals that must be obtained to achieve a successful Space Tug Program. To achieve this, the Operational and Flight Support Plan described in this volume is based upon a concept that support planning must (1) start with engine design, (2) be refined and detailed during engine development, and (3) be implemented by experienced support personnel.

SECTION A
SPACE TUG ENGINE OPERATION

INTRODUCTION

In this section, the Space Tug engine configurations are summarized and their operation during the various phases of the Space Tug mission are described. These phases are defined as:

Turnaround
Launch Pad
In Orbit Deployment
In Operation
Recovery

and are illustrated in figure A-1 Engine Operational Activities.

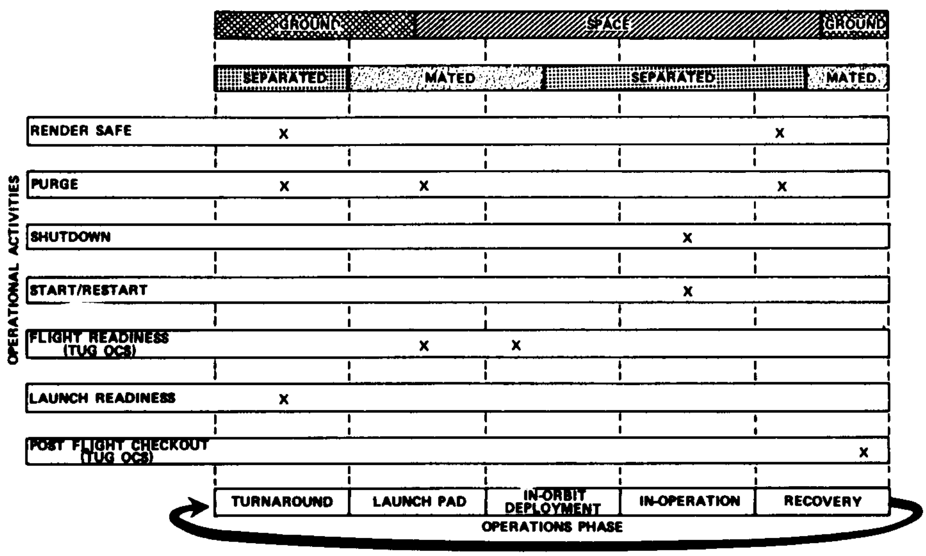

Figure A-1. RL10 Derivative Engine Operational Activities FD 72090

1. SPACE TUG ENGINE CONFIGURATIONS

Three RL10 derived engines, the Derivative IIA, IIB and Category IV, have been selected by NASA for this study. These reusable engines have been modified and/or designed specifically for use in the cryogenic Space Tug. They are expander cycle powered and have two-position bell nozzles that can operate at three thrust levels, and their design characteristics, which are fully defined in Volume II of this report, are summarized in table A-1.

Table A-1. Design Definition of Baseline Engines

	Derivative IIA	Derivative IIB	Category IV
Full Thrust Operation			
Thrust, lb vac	15,000	15,000	15,000
Mixture Ratio	6.0	6.0	6.0
Chamber Pressure, psia	400	400	915
Specific Impulse, sec	459.2	459.2	470.0
Required Inlet Condition			
Fuel	≤40% Vapor	≥14′NPSH	≤40% Vapor
Oxidizer	≤40% Vapor	≥7.5′NPSH	≤40% Vapor
Reduced Thrust Levels			
Tank Head Idle Thrust	157	157	73
Maneuver Thrust	3,750	3,750	3,750
Envelope			
Length, in.	70/127	70/127	57/114
Nozzle Exit Dia., in.	40/79.6	40/79.6	37/66.2
Area Ratio	66.3/262	66.3/262	125/401
Weight, lb	513	474	424
Life			
Firings/hr	≥190/5	≥190/5	300/10

2. TURNAROUND

All necessary engine scheduled and unscheduled maintenance will be carried out during this phase, when the Tug is separated from the Shuttle and is in its maintenance area. Checkout of the engine prior to installation of the Tug in its docking adapter can be limited to the following actions.

2.1 Removal of Environmental Closures and Protective Covers

Environmental closures and protective covers are nonflight items and are easily identifiable for removal prior to flight by means of color coding. The closures and covers include desiccant assemblies on all engine openings requiring protection for internal portions of the engines from atmospheric moisture contamination; dust covers on openings that may be susceptible to foreign object contamination; and protective covers over areas that may be easily damaged because of their particular design or location on the engine.

2.2 Initiation of Standby Purges

Standby gaseous purges of the Space Tug Engine are required for storage when the environmental closures are removed and the docking adapter is installed, and for Space Tug installation in the Shuttle Payload Bay to prevent moisture contamination in the engine. Purges are not required during the Space Shuttle launch pad phase as long as the payload bay environment is controlled to provide a safe, inert atmosphere. These purges will be required during the Space Tug descent phase when the shuttle payload bay is vented. For further information on the gaseous purge refer to Volume III, Part 1.

2.3 Removal of Gimbal Locking Mechanism

If mechanical thrust vector control (TVC) system locks, to prevent engine damage due to inadvertent swinging of the engine about its gimbal axis during ground transportation of the vehicle, are required, then they must be removed prior to the installation of the Space Tug into the docking adapter. Checkout of the TVC system prior to flight by the vehicle system must be accomplished prior to Tug installation in the Shuttle Payload Bay. While the Space Tug is being installed in the Payload Bay and during transportation to the launch pad, locking of the gimbal must be provided through the vehicle gimbaling system.

2.4 Inspection of Engine

Immediately prior to securing the propulsion area in preparation for installation in the Tug docking adapter, a walkaround inspection of the engine and all interfaces with the vehicle is accomplished to ensure that all environmental closures and protective covers have been removed, proper connections with the Space Tug vehicle exist, and no inadvertent damage has occurred to any engine system during the Space Tug vehicle preparations.

2.5 Engine Checkout

When integrated with the Tug Onboard Checkout System (OCS), the engine has the capability for diagnostic analysis. During the turnaround phase, the OCS can perform a checkout program at any time upon receipt of a preflight checkout request. Any malfunction conditions encountered during these checks are relayed to the vehicle readout system.

Removal of protective covers and gimbal locking mechanisms, a walkaround inspection, and verification of standby purge are the only Space Tug preinstallation activities planned for the operational Space Tug. There is no requirement for monitoring any engine parameter other than OCS operation. Therefore, no radio or telemetry signals to ground displays are required for the engine, other than through the Tug or orbiter readout system. The deletion of umbilical and external engine monitoring requirements greatly reduces the required ground support facilities and technical personnel for efficient and low cost operations.

3. LAUNCH PAD PHASE

The launch pad operation begins when the Space Tug is installed in the Payload Bay of the Space Shuttle and this vehicle is then erected on the launch pad. The activities on the P&WA™ Space Tug engine during this time period will only be limited to monitoring engine condition, since the Space Tug docking adapter does not allow access to the Space Tug engine. Consideration of this criteria during the initial engine design phase and establishing an engine maintenance concept that will permit early analysis, assessment, and accomplishment of maintenance and servicing requirements are therefore necessary. Unscheduled, as well as scheduled, maintenance operations must therefore be performed before the vehicle is installed in the Space Tug docking adapter and the Space Shuttle Payload Bay. Space Tug vehicle prevalves prevent propellants from getting to the engine and with engine electrical and helium supply inhibited by the Tug, a triple failure is necessary before propellants can enter the payload bay through the engine. The inhibit on power to the engine will only be removed after the shuttle has gone into orbit, the Tug has been deployed and the shuttle has separated to a safe distance from the Tug. After the nozzle has been extended and the Tug prevalves opened, the engine is ready for its final checkout prior to committing to the Tug mission. These in-orbit engine checkouts will be by automatic checkout with the OCS and will be fed back to the Space Shuttle orbiter Tug readout system. The requirements for this checkout will be a verification of the following prior to initiation of the operating signal and "GO" signal from the Tug OCS system:

a. 28 vdc electrical supply for the engine

b. Required pneumatic pressure to the engine pneumatic system by use of pressure transducer

c. Required propellant temperatures and pressures to the engine inlets by use of temperature probes and pressure transducers

d. That the extendible nozzle is extended and locked; and verified by use of contact switches.

4. IN-OPERATION PHASE

A typical operational sequence for the Derivative IIA, IIB and Category IV engines is shown in table A-2 and figure A-2 for the Space Tug Synchronous Retrieval Mission. Prior to each burn, an engine checkout with the OCS will be performed.

For other operational characteristics of the engine, see the Interface Control Document, Part 1, in this volume and also Volume II of this study report.

Table A-2. Typical Sequence of Events for Payload Retrieval Space Tug Synchronous Mission (15,000 lb Thrust Engine)

Event	Delta Time Mission hr	Burn Time (Tug Main Engine) hr	Total Time Mission hr
Shuttle Lift Off			
Shuttle Burn Out			0.14
Coast to 100 N mi	0.73		
Shuttle 100X 160 N mi Insert			0.87
Coast to 160 N mi	0.76		
Circularize at 160 N mi			1.63
Tug Deploy and Coast (1)	13.11		
Phasing Orbit Insert (2)		0.07	14.74
Coast to TOI	1.92		
Transfer Orbit Insert (2)		0.16	16.66
Coast to 19,323 N mi	5.27		
Mission Orbit Insert (2)		0.10	21.93
Retrieve P/L and Coast	11.15		
Transfer Orbit Insert (2)		0.084	33.08
Coast to POI	5.27		
Phasing Orbit Insert (2)		0.036	38.35
Coast	3.02		
Circularize for Rend (2)		0.033	41.37
Shuttle Rend and Coast (3)	4.53		
Shuttle Retriever Tug			45.90
Shuttle Deorbit (4)			46.60
Touch Down			

Engine Sequence of Events Derivative IIA, IIB and Category IV

(1)
1. Supply electrical power
2. Supply pneumatic
3. Supply propellants
4. Automatic go/no-go checkout
5. Deploy extendible nozzle

(2)
1. Supply propellants at required temperature and pressure for tank head idle
2. Initiate start in tank head idle operation
3. Accelerate to pumped idle or maneuver thrust operation
4. Pumped idle or maneuver thrust OPS
5. Accelerate to full thrust operation
6. Full thrust operation
7. Decelerate to pumped idle or maneuver thrust operation
8. Pumped idle or maneuver thrust OPS
9. Initiate engine shutdown
10. Complete engine shutdown (burn completed)

(3)
1. Verify that electrical power is disarmed
2. Verify no pneumatic pressure to engine
3. Verify no propellants to the engine
4. Verify extendible nozzle retracted and stowed

(4)
1. Verify standby purge on prior to descent phase

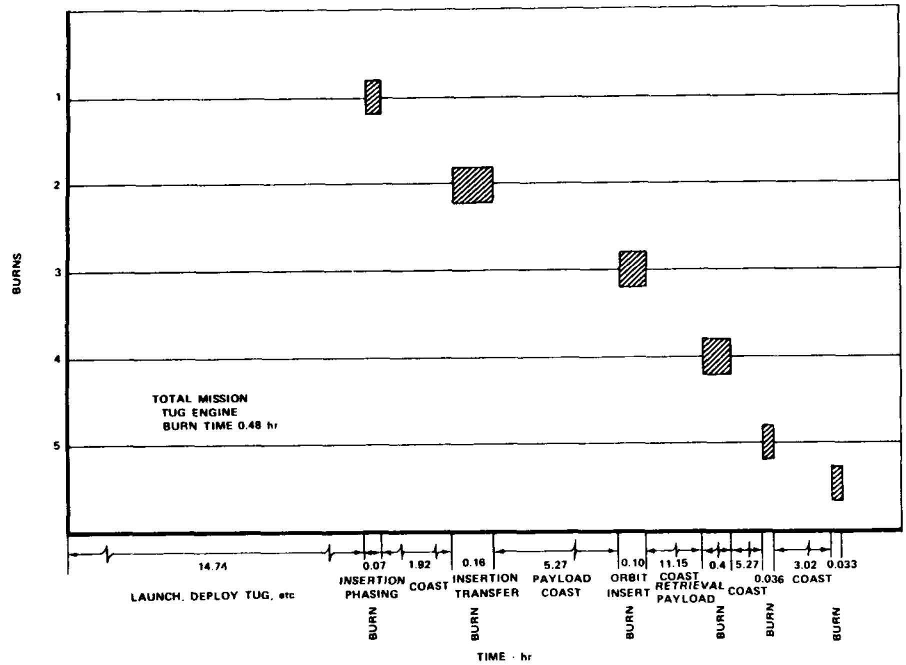

Figure A-2. Space Tug Engine Typical Burn Time Line (15,000 Pound Thrust Engine): Geosynchronous Mission Retrieval - Derivative IIA, IIB, and Category IV Engines

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5. RECOVERY PHASE

5.1 Prior to Docking

On completion of the Tug mission, the vehicle must be inerted and made safe prior to docking with the Space Shuttle. The engine's nozzle is retracted, Tug prevalves are closed and the engine electrical and helium supplies from the Tug are inhibited. To confirm that the engine is safe and ready for being brought back to the Shuttle's payload the following automatic engine checkout with the Tug OCS verifies:

a. That the 28 vdc electrical supply has been disarmed and no engine electrical components are active

b. That no pneumatic pressure is available to the engine to actuate the components - readout from the engine helium supply pressure transducers

c. That propellants in the engine have been vented from the system - read out the engine pressures to assure that they are within an allowable range

d. The extendible nozzle is retracted and locked in the stowed position - readout the required contact switches.

5.2 Reentry and Landing

The Space Tug vehicle is docked to the Space Shuttle by use of the Tug docking adapter. The standby purges must be initiated through this docking adapter prior to the Space Shuttle descent phase in order to prevent the engine from being contaminated by moist air as the Shuttle Payload Bay is repressurized by ambient air. Since the engine has been inerted prior to docking, these purges are not required for safety reasons.

Subsequent to landing, the inflight data recorder is removed and analyzed in order to plan for the engine inspection and maintenance during the turnaround phase.

SECTION B
PROGRAM OBJECTIVE

1. PROGRAM OBJECTIVE

The objective of the Preliminary Operational and Flight Support (O&FS) Program is to provide all the necessary services to assure that the integrity, quality, and performance of the Pratt & Whitney Aircraft Space Tug Engine are maintained during any activity or associated activities involving the engine after delivery to the Government. In accomplishing this objective, major consideration must be given to the cost and time constraints not only on the Space Tug Program, but to the overall Space Shuttle Program as well.

2. ABSTRACT OF PLAN

To meet the objective of the O&FS Program, P&WA has developed the preliminary plan presented in this volume. The plan has been designed to provide for each of the major areas of effort which must be considered, while taking advantage of existing P&WA support capabilities. P&WA has proven experience in integrating propulsion systems into reusable flight vehicles and for providing operational and flight support groups within the company organization. A space Tug Program organization will be formed to consolidate the support services required to meet the objectives and needs of the Space Tug Program. Tailoring P&WA's existing capabilities to the Space Tug Program needs, results in the following responsibilities for the four element organizations listed below:

	Organization Element	Program Responsibilities
a.	Development Engineering	GSE Development, Flight Support and Anomaly Resolution
b.	Requirements Coordination Group	Government and Vehicle Contractor Interface Coordination
c.	Integrated Logistics Support Team	Logistical Support and Operational Planning
d.	Site Operations Teams	Operational and Flight Support at the Sites

The responsibilities of each of these groups and their interfaces during the Operational and Flight Support programs are detailed in the following section (Section C, Organization) of this Operational and Flight Support Plan.

Chronologically, the Space Tug Engine Program can be divided into three major phases: Engine Design and Development, Engine Delivery and System Operation.

2.1 Design and Development Phase

During the Engine Design and Development Phase, the Maintainability Program and the Maintenance Engineering Analysis effort begun in this study will be continued. Through maintainability, GSE, and human engineering reviews of design layouts and completion of maintenance engineering analyses, various elements of the support team are able to influence the engine and GSE design to obtain the most maintainable configurations practical. The Maintenance Engineering

Analysis (MEA) is a systematic and controlled process for assessment and analysis of engine and GSE design features. Results of the MEA provide the basis for maintenance planning and determination of logistical requirements by supplying data on maintenance tasks times, skill levels required, frequency of task occurrence, spare (support) parts required, etc. Followup observations of engine maintenance during the engine development program are used to refine the initial MEA data and update maintenance and logistics plans.

The Requirements Coordination Group, with resident field engineers at Government Centers and vehicle contractor plants, will keep the Government Space Tug agency and the vehicle contractors in close technical contact with the Space Tug Engine design and development program through the inhouse coordinators. The many technical interfaces with the Government agency and the vehicle contractors which are required to assure a reliable and maintainable integration of the engine with the overall vehicle system are achieved through the exchange of technical data, engine mockups and technical conferences.

2.2 Delivery Phase

Engineering support of the manufacturing program by the Development Engineering Group will be continued after FFC as a part of the support effort. Establishment of an engine refurbishment and repair capability will occur early in the manufacturing phase using the same equipment, personnel, and procedures and the Manufacturing Program. Also, early in the manufacturing phase, procurement of engine spare (support) parts, GSE, and GSE spare parts will be accomplished. This early procurement is required to allow placing support parts and GSE at the operational site prior to initial engine delivery. Based on maintenance and operational planning, procurement of support parts and GSE will be time phased to take advantage of "in production" status during the Manufacturing Program. Likewise, personnel selection and training for support at the operational sites and preparation of required technical manuals will be accomplished during the latter part of the engine development program and early phase of the delivery program to provide onsite support when the initial engine deliveries are made. Warehousing services and inventory control procedures for support parts at the refurbishment repair facility (FRDC) will be initiated with the start of support parts delivery.

2.3 Operations Phase

During the operations phase, the flight support (both technical and logistical) will be supplied at the operational site by Site Operations Teams and by Space Tug Program organizational elements shown below:

a.	Development Engineering	Flight Support and Anomaly Resolution
b.	Maintenance Engineering	Maintenance Planning and Routine Technical Support
c.	Technical Publications	Operational and Maintenance Manuals and Service Bulletins
d.	Refurbishment/Repair	Refurbishment and Repair Capabilities for Engines and Components

e.	Spare Parts	Support Parts, warehousing and inventory control for Refurbishment Program parts, consumption data analysis, procurement, and field support for supply data and parts
f.	GSE	GSE field support
g.	Service Records	Collection, storage, and retrieval of engine historical data, configuration and status plus discrepancy report data
h.	Transportation	Shipment of engines and parts to and from field
i.	Training	Preparation of training material for formal and on-the-job training for new techniques and configuration changes

Prior to the activation of an operational site, a site support team consisting of field engineers, field service representatives, logistics specialists, and performance analysts will be organized and based at the site being manned and will supply all the needed engine and GSE technical assistance to Government and vehicle personnel on engine installation and operation maintenance support parts warehousing and inventory control services, and coordination on engine related planning and scheduling. A P&WA Site Manager will be in charge of the support team and will provide a single focal point for Government and vehicle contractor coordination on engine matters at the site.

Onsite field engineers and field service representatives will provide technical lines of communication with the Space Tug Engine Development Engineering Group at FRDC regarding flight support and anomaly resolution matters. They also supply service engine status reports, discrepancy reports inputs, and configuration status reports on engines and GSE to the Space Tug Engine Program Management.

3. O&FS PROGRAM MASTER SCHEDULE

Using NASA-supplied Space Tug Engine Program guidelines, a program planning schedule was constructed to use as a basis for detailed plans for each support element. Experience from the F-15/PWA 100, SR-71/J58 and other programs was used in conjunction with the planning schedule to make the detailed support plans. To assure coordination and integration of the various support function plans, a master schedule was constructed by combining key events from the plans and schedules for each category engine and are shown in figures B-1, B-2, and B-3. These master schedules provide program management overview visibility for planning, scheduling and tracking of major Space Tug Engine development operational and logistical events. The schedule can also be used to quickly evaluate the impact of actual or anticipated changes in the Space Tug Program.

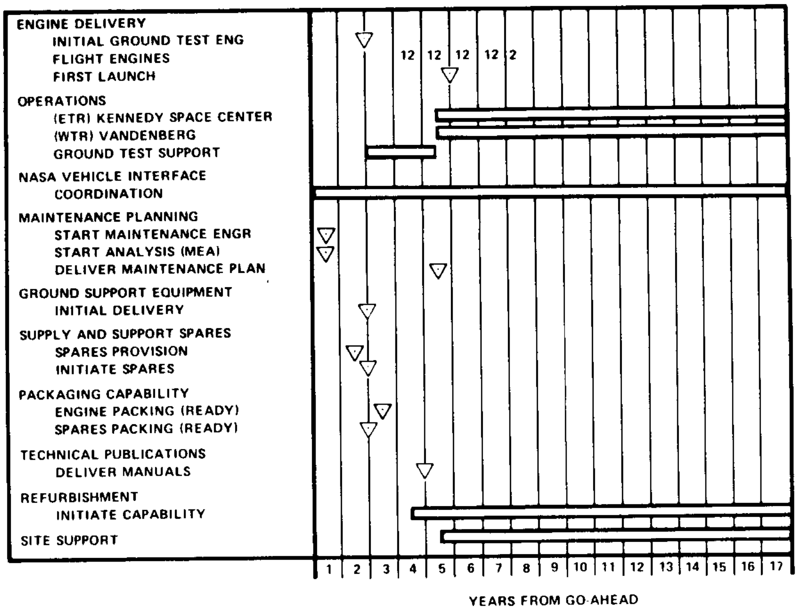


Figure B-1. Master Operations and Flight Support Schedule for Derivative IIA Engine FD 74150A

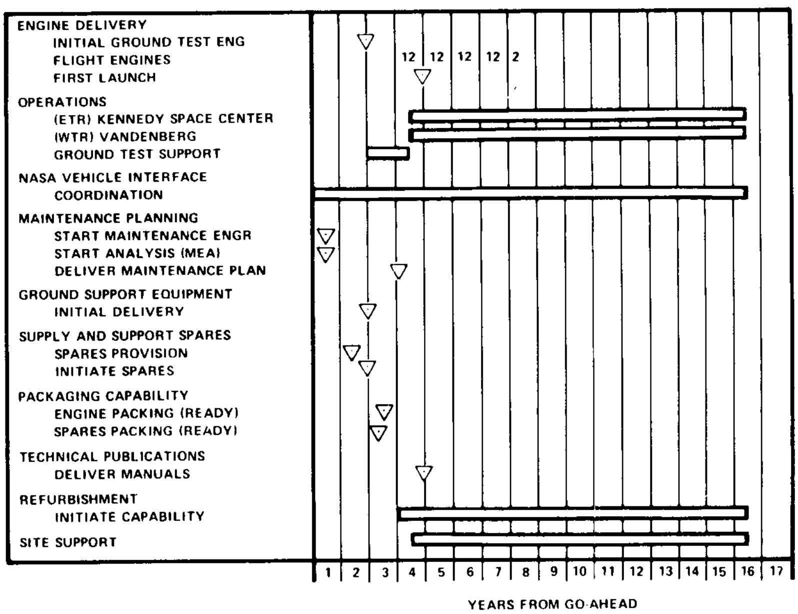


Figure B-2. Master Operations and Flight Support Schedule for Derivative IIB Engine FD 74150B

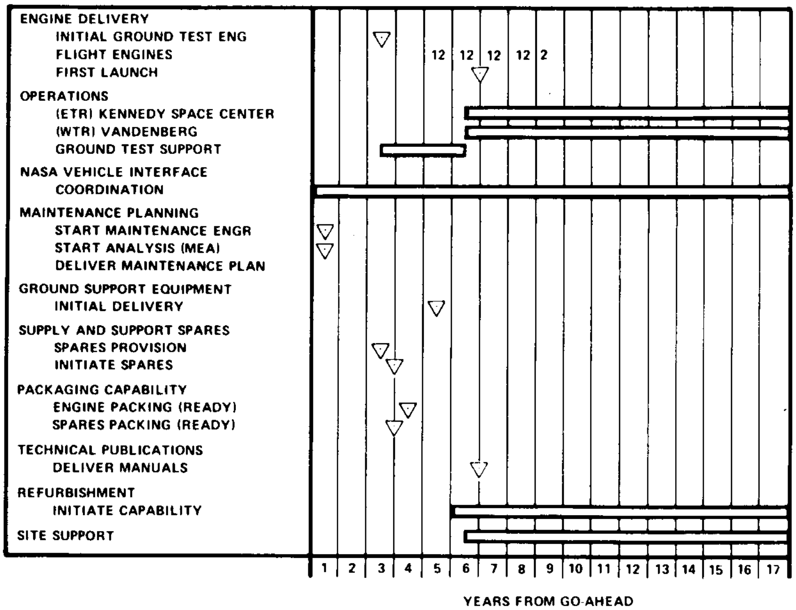


Figure B-3. Master Operations and Flight Support Schedule for Category IV Engine FD 74150C

SECTION C
ORGANIZATION

1. METHOD OF ORGANIZATION

Direction and management of a project within P&WA™ is the responsibility of a program organization structured to the particular needs of the program and staffed by personnel from the functional departments. These people take their program direction from within the program organization through a supervisor who, though appointed from the functional group, is rated as the program manager and is responsible for the cost, schedule and performance of work in his department. They retain administrative ties with their functional departments so that the resources of the department are available to them, and to the program.

2. SPACE TUG ENGINE SUPPORT PROGRAM ORGANIZATION

The Operational and Flight Support Program required for the Program can logically be divided into four different subject areas: (1) Coordination, (2) Logistics, (3) Site Operations, and (4) Flight Support and Anomaly Resolution. Because the inhouse Engineering effort required for flight support and anomaly resolution after Final Flight Certification (FFC) can most effectively be performed by the engineering team that developed the Space Tug Engine and provided this service prior to FFC, this task will be assigned to the Assistant Program Manager - Development. His organization will act as an in-depth support team to assist the engineers of the site operations staff. The responsibility for the balance of the support tasks (coordination, logistics, and site operations) will be assigned to the Assistant Program Manager, Program Support. To meet these requirements an organization consisting of the Requirements Coordination Group, the Integrated Logistics Support (ILS) Group, and Site Operations Teams, will be organized as shown in figure C-1. The Assistant Program Manager, Program Support receives his authority and direction from the Program Manager and is responsible for making the Support Program responsive to the Government Space Tug agency directions. Except for the in house Engineering effort, all the support program funds and policies are the responsibility of the Assistant Program Manager, Program Support. To assist him in planning, directing, and administering the Operational and Flight Support Program, he has a staff consisting of a Requirements Coordination Manager, an Integrated Logistics Support Manager, and Site Managers for each of the operating sites.

Though the Assistant Program Manager for Program Support will have interfaces with the Assistant Program Managers for Program Controls and Delivery Engines to monitor support program contracts and budget controls and to resolve production scheduling problems, the major interface will be with the Assistant Program Manager Development for Flight Support and Anomaly Resolution. Because the in house Engineering effort for Flight Support and Anomaly Resolution will have a major impact on the support program, constant coordination between these two Assistant Program Managers and their respective personnel is required to assure Engineering effort is directed to achieve maximum benefits for the Operational and Flight Support Program. Coordination between site operations engineers and the inplant engineers will be documented by Space Tug Engine coordination sheets with information copies to the Government.

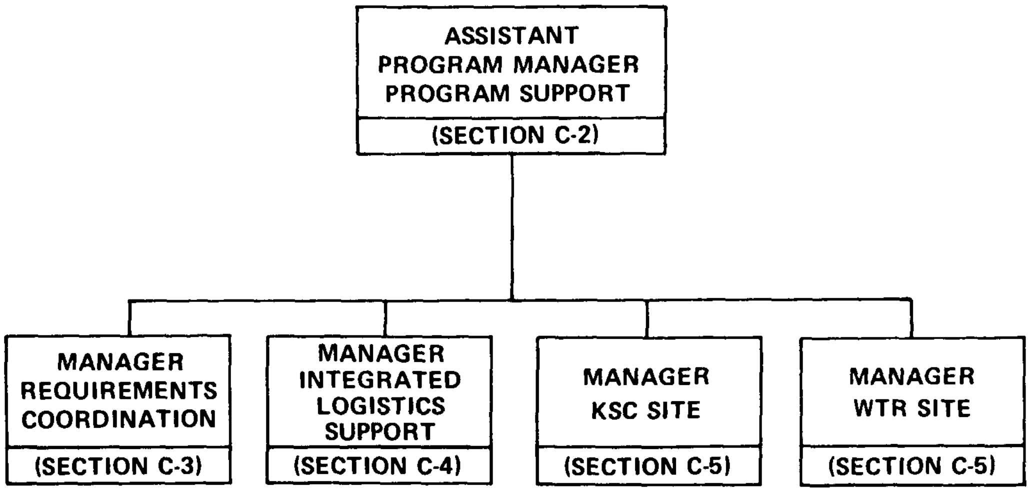


Figure C-1. O&FS Program Support Organization FD 52135B

Planning, control, information systems, and reporting functions in the support organization are a combination of existing P&WA systems and new procedures developed for the Space Tug Program. Each of the managers in the support organization is responsible for planning in his area of responsibility. Detailed plans are made within the various sections of each support area, and are coordinated with and approved by the Manager of that area. In areas where the plans can be formalized, they are presented in this volume.

Control of the Operational and Flight Support Program is accomplished financially through the P&WA Engineering Order/Delivery Order procedures. Administrative control of support efforts is exercised through the Program Organization previously shown in figure C-1. Other controls that will be used result from program organizational requirements, such as the program Management Information System, which will include a program Control Room with Schedule, Cost, Manpower, and Program Planning information. As an example, much of the information collected by the configuration control organization, such as service engine status and configuration changes, are reported through the Management Information System.

3. REQUIREMENTS COORDINATION GROUP

The Requirements Coordination Group is organized under the Requirements Coordination Manager who reports directly to the Assistant Program Manager, Program Support and is responsible for all coordination effort between the Government, the vehicle contractors, and P&WA. A series of teams, each consisting of a field-based Engineering Representative and an inhouse Interface Coordinator, act as the prime line of communication and single-point contact for coordination as shown in figure C-2. The P&WA Representative that will be assigned to a Government center or a vehicle contractor's plant maintains contact with all elements of the activity that interface with the Space Tug Engine. Interface Coordinators at P&WA are assigned to follow activities at a particular Government Center or at a vehicle contractor's plant through the P&WA Engineering Representative and through interface with the System Engineering Group to complete the coordination of requirements. Through interfaces with NASA or Vehicle

Contractor Resident Representatives, the Interface Coordinator avoids duplications or gaps in coordination requirements. With all of the coordination effort being handled by people reporting directly to him, the Requirement Coordination Manager is in a position to keep program management informed of the latest coordination status at any time and assures that all coordination effort is responsive to program management direction.

The Support Organization is structured to provide managers for each of the major functional areas of the support program, with these managers reporting directly to the Assistant Program Manager, Program Support. All Requirements from the NASA or the vehicle contractors are coordinated by a team of personnel, both in-house and field based who are organized under the Requirements Coordination Manager. All logistical elements required to support the Space Tug Engine are organized under the ILS Manager. The Site Managers for the operating sites will be responsible for all the activity and personnel on the site and will report directly to the Assistant Program Manager, Program Support. This overall support organization will provide direct lines of responsibility and communications that will permit rapid dissemination of management directives and timely reporting of operating level information to program management.

Information supplied by support elements to persons outside the Program organization will be documented by using the coordination sheet system. However, an Integrated Logistics Support/Scheduling and Data Control group will be organized to handle the collection of the many detailed and technical logistics types of information. This group has an operating interface with the Data Manager to avoid duplication of effort. Daily and weekly informal reports to the Assistant Program Manager, Program Support, from each manager reporting to him, will supplement the more formal reports from the Data Manager.

4. INTEGRATED LOGISTICS SUPPORT ORGANIZATION

The ILS Organization utilizes a program/functional team, organized and integrated under the ILS Manager, reporting directly to the Manager, Program Support.

Pratt & Whitney Aircraft selected a fully Integrated Logistics Support Organizational Team concept for the logistics program because this approach efficiently utilizes existing P&WA Product Support Department functions to provide the specific Space Tug operations and logistics requirements. This approach will provide a team of experienced logistics support specialists for the reusable Space Tug. Providing logistics support for engines on military programs and commercial airline operations has built for the P&WA Product Support Department an experienced group of specialists from which all programs can draw. This ensures the experience gained from previous programs can be rapidly applied to new programs.

Elements of the ILS Organization established for the Space Tug logistics program were selected to cover each of the requirements found necessary from experience on other reusable support programs such as the J58/SR71, F100/F-15 and F401/F-14B. Applicable elements have been included to assure a complete, economical logistical support program for the Space Tug.

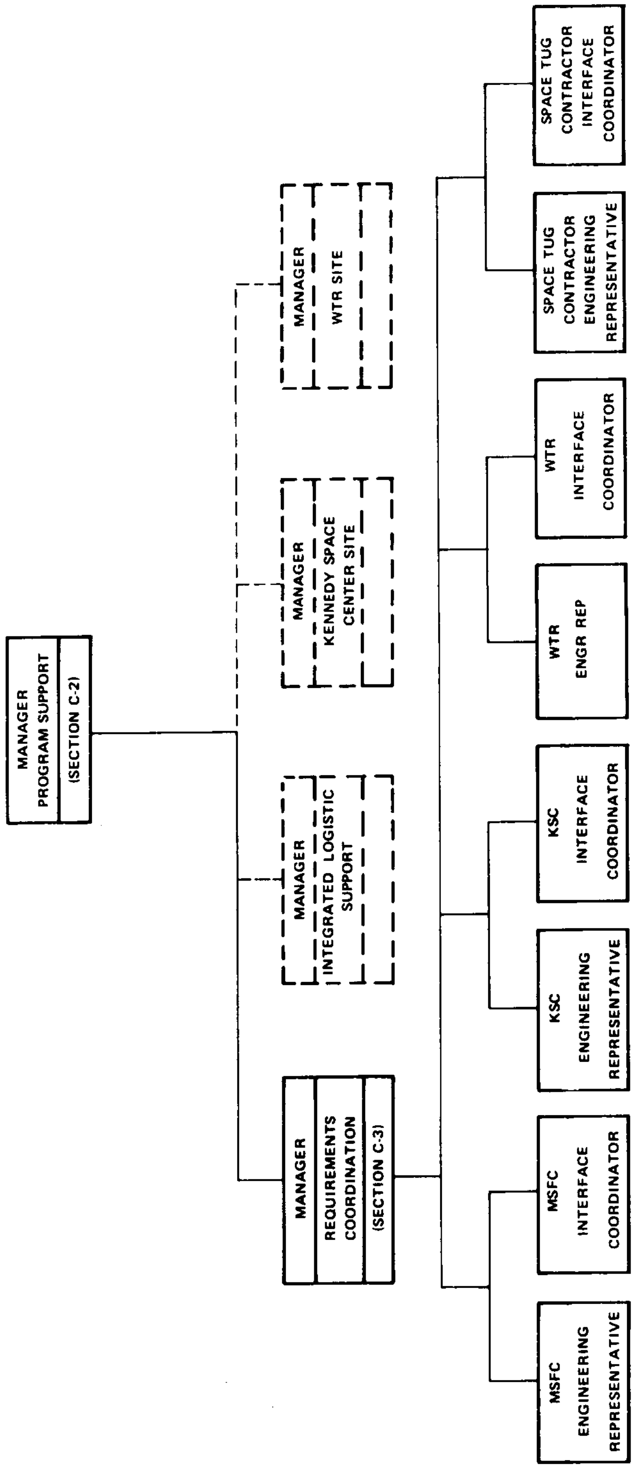


Figure C-2. Coordinators Are Stationed at Each Vehicle and Government Facility

FD 48466A

The ILS Manager is responsible for the planning, directing, implementation and integration of the Logistics Support Program. Through interfaces with Systems Engineering, Configuration Control, and the Data Manager, the ILS Manager is kept informed of program developments which could influence the logistical support of operational sites. The ILS Manager ensures that the impact of proposed engineering changes on logistical support requirements will be defined, evaluated, and specified in all engineering change proposals.

The ILS organizational structure provides the means for delegation of authority and responsibility, and establishes essential channels of communication to ensure that operational logistical support requirements are considered during the design phase and continuously throughout the engine life cycle. This is accomplished by direct coordination between the ILS organization and the Assurance Disciplines Manager and through the Maintenance Engineering Analysis (MEA) process which is described in the Maintenance Engineering Section of this volume.

Within each of the ILS Organization elements shown in figure C-3, Technical Administrators directly responsible to the ILS Manager have an established group of support specialists to meet the logistical support requirements.

Elements of the ILS Organization, their functions, and responsibilities in responding to Space Tug operational and logistics program requirements are described in the following paragraphs.

4.1 Maintenance Engineering Group

The Maintenance Engineering Group is responsible for all Space Tug Support Engineering and Maintenance Planning activities. This includes operation and control of the Maintenance Engineering Analysis (MEA) Program which is a systematic and controlled process for analysis and assessment of engine and Ground Support Equipment (GSE) design features. The MEA serves as the basis for maintenance planning and determination of all logistical support requirements. The MEA process also ensures that logistical support requirements are considered and reflected in the hardware designs. Through interfaces with Assurance Discipline Manager and the Design Department, the Maintenance Engineering Group develops the Engine Maintenance Plan and influences the maintainability of the engine design by study and analysis of accessibility, malfunction detection, fault isolation, maintenance task frequencies, and maintenance task time-line analysis.

4.2 Refurbishment/Repair Group

The Refurbishment/Repair Group implements scheduling of services and facilities to provide engine and component overhaul or refurbishment as required at the factory. These services include component overhaul or refurbishment at Vendor Facilities as necessary to support the Space Tug Program requirements.

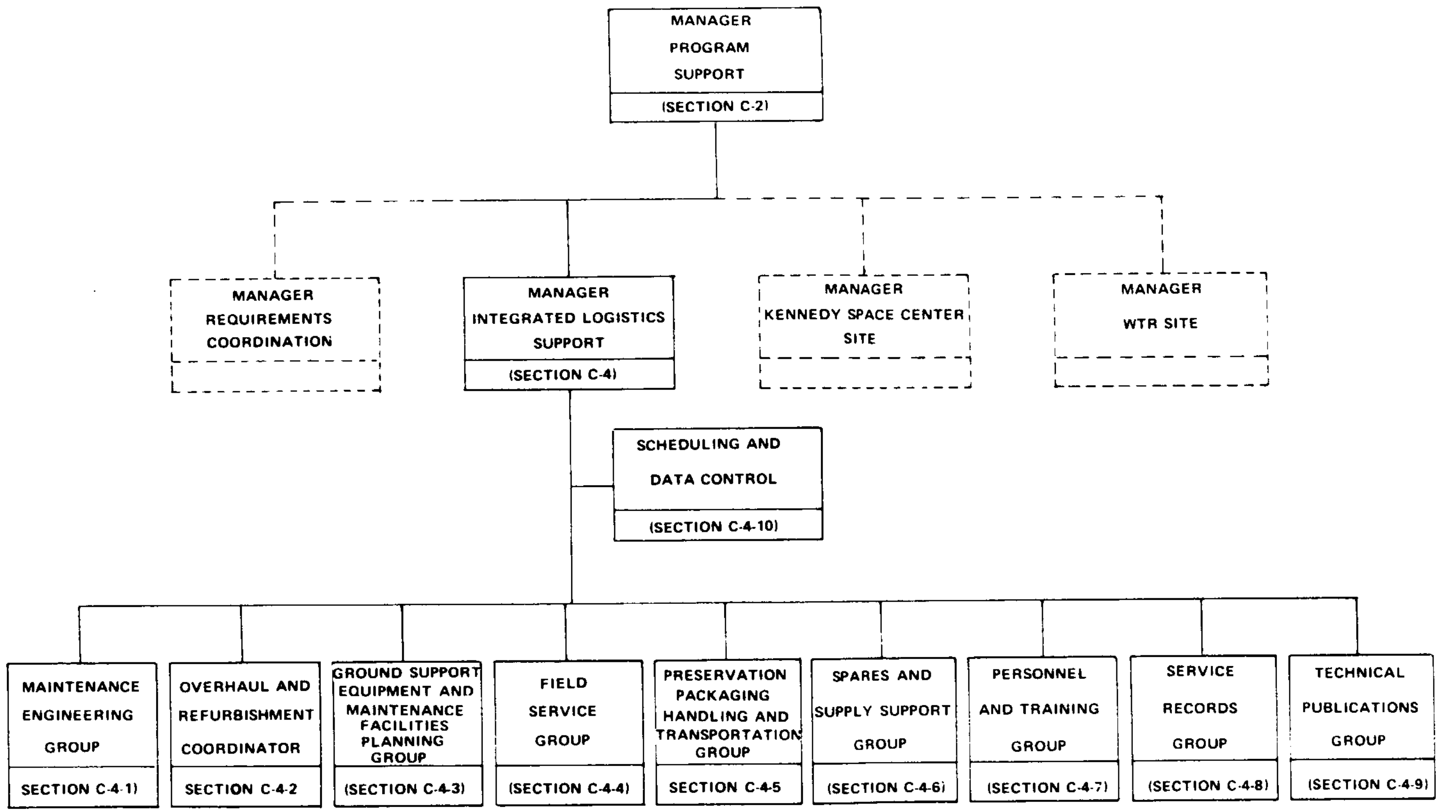


Figure C-3. Integrated Logistics Support Organization

FD 48467A

4.3 Ground Support Equipment and Maintenance Facilities Planning Group

The Ground Support Equipment and Maintenance Facilities Planning Group assists in identifying GSE required for support of the Space Tug, monitors GSE provisioning and delivery, and provides the necessary training for operation and maintenance. The group will be organized to make site surveys and formulate Maintenance Facilities and Institutional Services (Site Installation) Plan for existing or new maintenance facility requirements.

4.4 Field Service Group

The Field Service Group provides the in-house technical personnel to plan, evaluate and monitor the technical aspects of engine maintenance and operations. This includes onsite technical assistance and liaison services on the Space Tug vehicle contractor facilities, NASA activities, and test and operation sites. The Field Service Group is also responsible for providing technical personnel for field site operational support as required by the Government.

4.5 Packaging, Preservation, Handling and Transportation Group

The Packaging, Preservation, Handling and Transportation Group prepares and implements plans for the design and development of preservation procedures, packaging requirements, handling devices and reusable shipping containers. Requirements are derived through analysis of engine design, mission and logistics data in accordance with applicable specifications, and standards. This group also prepares transportation planning data defining primary and alternate methods of transportation for end items and major assemblies.

4.6 Spare Parts Group

The Spare Parts Group is responsible for identification and provisioning of engine spare and support parts, follow-on GSE, and GSE spare parts to support Space Tug Program requirements. All supply support and spares requirements will be approved and provisioned through recommended Government control and provisioning procedures. This group also provides warehousing and inventory control management services.

4.7 Personnel Training Group

The Personnel Training Group is responsible for planning, management, and implementation of the human factors engineering analysis, personnel requirements analysis, and the Training Program. The group provides the quantitative and qualitative manpower requirements, data, training, training equipment, human factor engineering and biomedical support requirements. These support requirements are determined through analysis of engine design features and Maintenance Engineering Analysis (MEA) data and are updated throughout the program life to reflect changes in engine design and program requirements.

4.8 Service Records Group

The Service Records Group provides the services necessary to achieve the acquisition, control, storage, updating, retrieval and reporting of all technical support documentation for the Space Tug Program. This includes historical data on the engine, engine components, modules/subassemblies, accessories and GSE. Through interfaces with other program functions, the essential data input and feedback networks are established to provide services for configuration status accounting, maintenance data collection, reporting systems for Configuration Control and the control and traceability requirements of the support program.

4.9 Technical Publications Group

The Technical Publications Group prepares and implements plans for the development, preparation and delivery of technical publications and manuals to support operation, maintenance and repair of the Space Tug and its supporting equipment (GSE). Technical Publications requirements are derived through analysis of Maintenance Planning data and MEA data. Effective program support is assured by time-phased delivery of technical data in accordance with program data management requirements.

4.10 ILS Scheduling and Data Control

Effective management, scheduling and control of all operational/logistics support resources requires the ILS Manager to have ready access to program logistics data, support schedules and milestones, cost control data, vehicle contractor support data, and internal ILS support requirement data. The ILS Scheduling and Data Control Section acquires, stores, and reports the information necessary to provide the ILS Manager with the visibility to plan, schedule, and Manage the Space Tug logistical support program. The ILS Scheduling and Data Control section will also function as a data control interface between all elements of the ILS organization and program management functions, such as Systems Engineering, Configuration Control and Data Management. The ILS Scheduling and Data Control Section also functions as an interface between the ILS organization and the Program Data Management Office for the receipt and transmittal of logistics data outside Pratt & Whitney Aircraft to Subcontractors, the Government and the Vehicle Contractors.

The selected ILS elements will encompass the complete range of logistic activities required to provide timely and effective operational support of the Space Tug throughout its life cycle. In addition, the composite ILS organization approach provides the necessary channels for effective management and communication.

5. SITE OPERATIONS ORGANIZATION

All P&WA personnel at the Space Tug operating sites will be under the direction and control of a Site Manager, who will report directly to the Manager, Program Support. Each site will be staffed by a Product Support Team and an Engineering Support Team as shown in figure C-4. The Product Support Team will be under the direction of the Senior Field Service Representative and will consist of the necessary Field Service Representatives, Vendor Service Representatives, Technicians, and Parts Support and Warehousing personnel. An engineering support team consisting of necessary Field Engineers, Performance Engineers and Data Analysts, reports to the Site Manager through the Senior Field Engineer. These two team type organizations permit the Site Operations Team to be tailored to the specific needs of the site being supported and to the site support requirements as they periodically vary.

The Site Manager is responsible for all activity at the site and coordinates such engine requirements as maintenance, scheduling, and data analysis with Government and Vehicle Contractor Site Managers. In this position of responsibility and control, the Site Manager assures that the engine support program at the site is responsive to both Space Tug Program Management and Government Site Management directives, as well as vehicle contractor site manager requests. Through interfaces with the ILS Manager and the Assistant Program Manager, Development, the Site Manager is capable of drawing upon all the logistical and inhouse engineering resources and talents required to provide complete Space Tug site support.

5.1 Site Manager

Provides all necessary onsite engine support by directing the efforts of all engine support personnel assigned to or visiting the operation site. The site manager will have overall responsibility for coordination of all engine related matters with both the Government and vehicle contractor personnel onsite and with the Space Tug Engine Program management at the plant.

5.2 Field Engineer

Provide engineering support for the operation of the Space Tug Engine by:

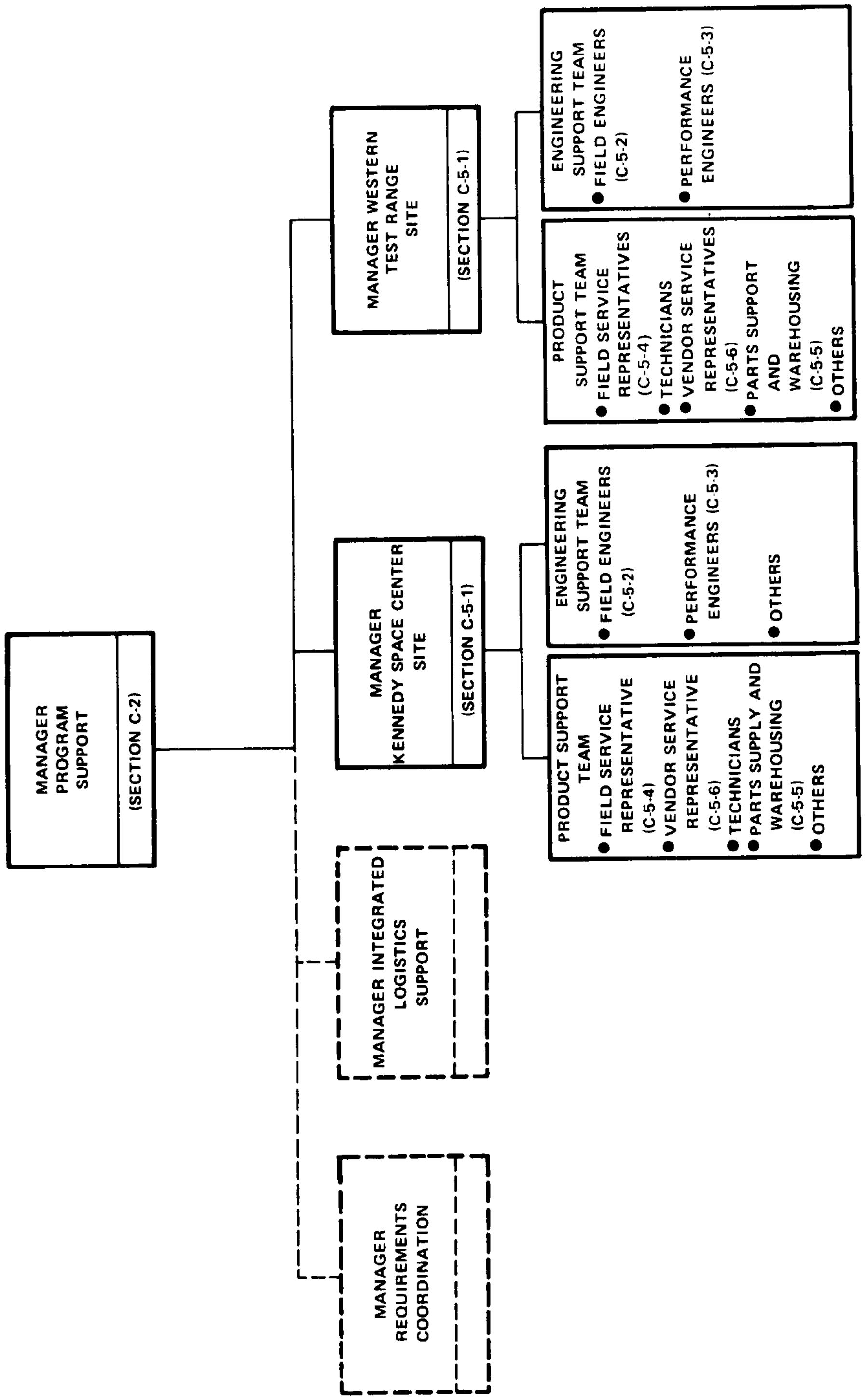
a. Investigation and resolution of engine operational problems at the site

b. Liaison of operational problems with the inplant Flight Support and Anomaly Resolution Group when they cannot be solved at the site

c. Coordinating changes to engine operating instructions and procedures as may be necessary during the flight test periods

d. Conducting investigations for deficiency reporting and incidents or accident reports

e. Directing onsite performance analyses.



FD 48468A

Figure C-4. Managers at Each Operations Site Provide Total P&WA™ Service to the Vehicle Contractor and the Government

5.3 Performance Engineer

Provides Space Tug Engine operational support by:

a. Conducting analysis and evaluation of engine operational data and directing engine data reduction efforts

b. Coordination of performance problems with the Flight Support and Anomaly Resolution Group

5.4 Field Service Representative

Provides technical assistance on Space Tug Engine and GSE operation and maintenance by:

a. Providing on-the-job training to maintenance technicians to improve skills and techniques

b. Resolving unique Engine/GSE operational and maintenance problems

c. Assisting in incident or accident investigations

d. Providing guidance on safety in handling, operating, and maintaining engine and GSE

e. Assisting in data collection and deficiency reporting, Engine and GSE

f. Performing liaison services between the site and P&WA by reporting on problem areas by telephone, telegrams and written reports according to the magnitude of the problem. All telephone calls of a technical nature must be followed up by a formal written report; these liaison services include the following:

    (1) Resolving unique engine/GSE operational and maintenance problems requiring P&WA engineering review

    (2) Resolving interface problems between engine and vehicle that cannot be resolved at the local level

    (3) Providing data to the Government, Vehicle Contractor and P&WA on Engine/GSE configuration.

5.5 Spare Parts Representative

Provides onsite spares data and controls onsite spares inventory. In performing these functions he will:

a. Perform onsite spares inventory and warehousing management duties for P&WA supplied items

b. Record spares consumption and provision for resupply

c. Perform liaison services between the site and P&WA Spare Parts Group.

5.6 Vendor Representative

Provides onsite technical assistance and performs liaison services relative to specific components. Such services will consist of:

a. Providing special assistance in the operation and maintenance of his company's product

b. Performing liaison services between the site and vendor facility.

6. RETAINED DATA

Much Contractor, Government, vehicle contractor and vendor data are generated and used in the implementation of the Operational and Flight Support Program. Typical examples of these data are depicted in figure C-5 and are used as the source data from which all data requirements for the Government are prepared.

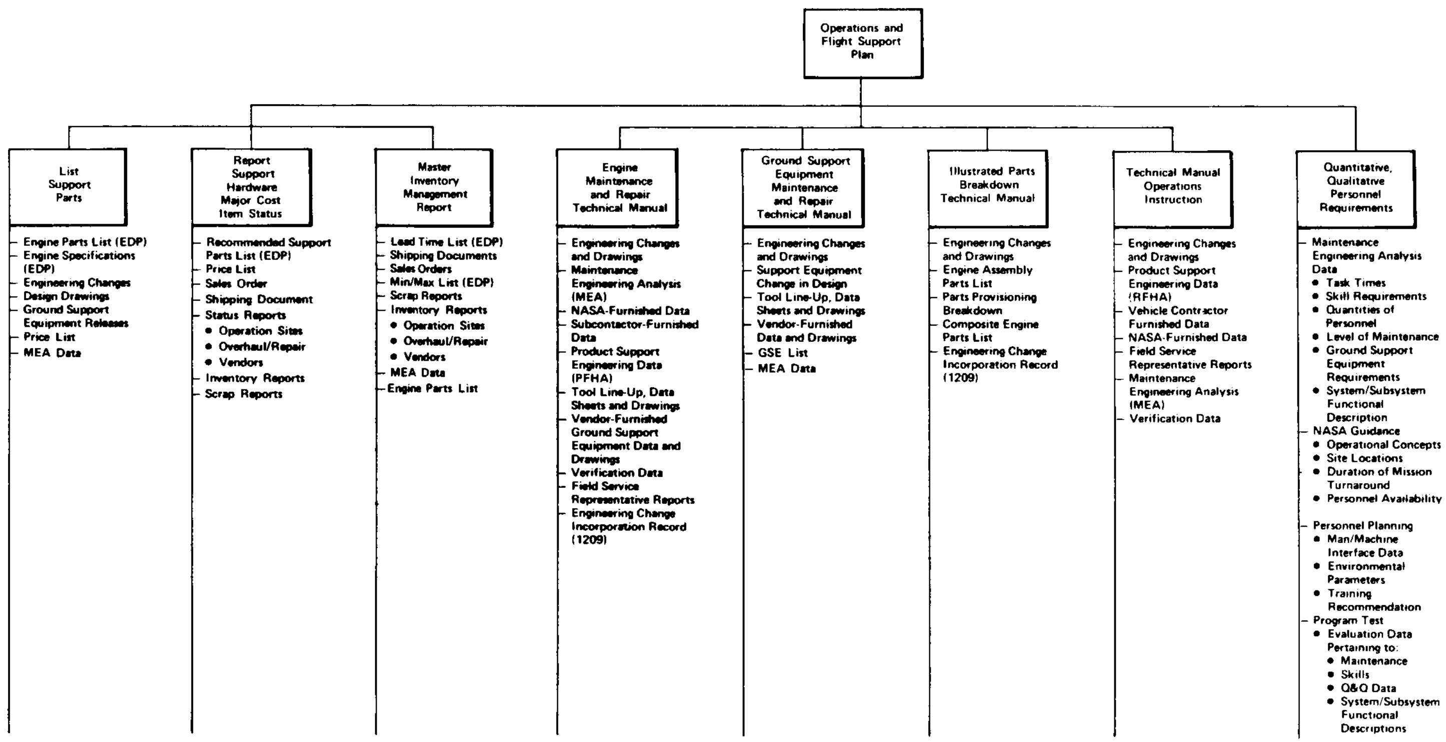


Figure C-5. Typical Contractor-Retained Data

FD 49395

SECTION D
PROGRAM SCHEDULE AND FACILITY REQUIREMENTS

A successful operational and flight support (O&FS) program for the Space Tug requires planning, and identification of requirement to carry out the plans. This Section presents the program planning schedule for the Derivative Engine, the points where the Product Support Program interfaces with the Development Program, and the facility requirements needed to implement the Space Tug (O&FS) Plan.

1. PLANNING SCHEDULE

The planning schedule for each Derivative Engine is shown in figures D-1, D-2 and D-3, and shows when the product support program will interface.

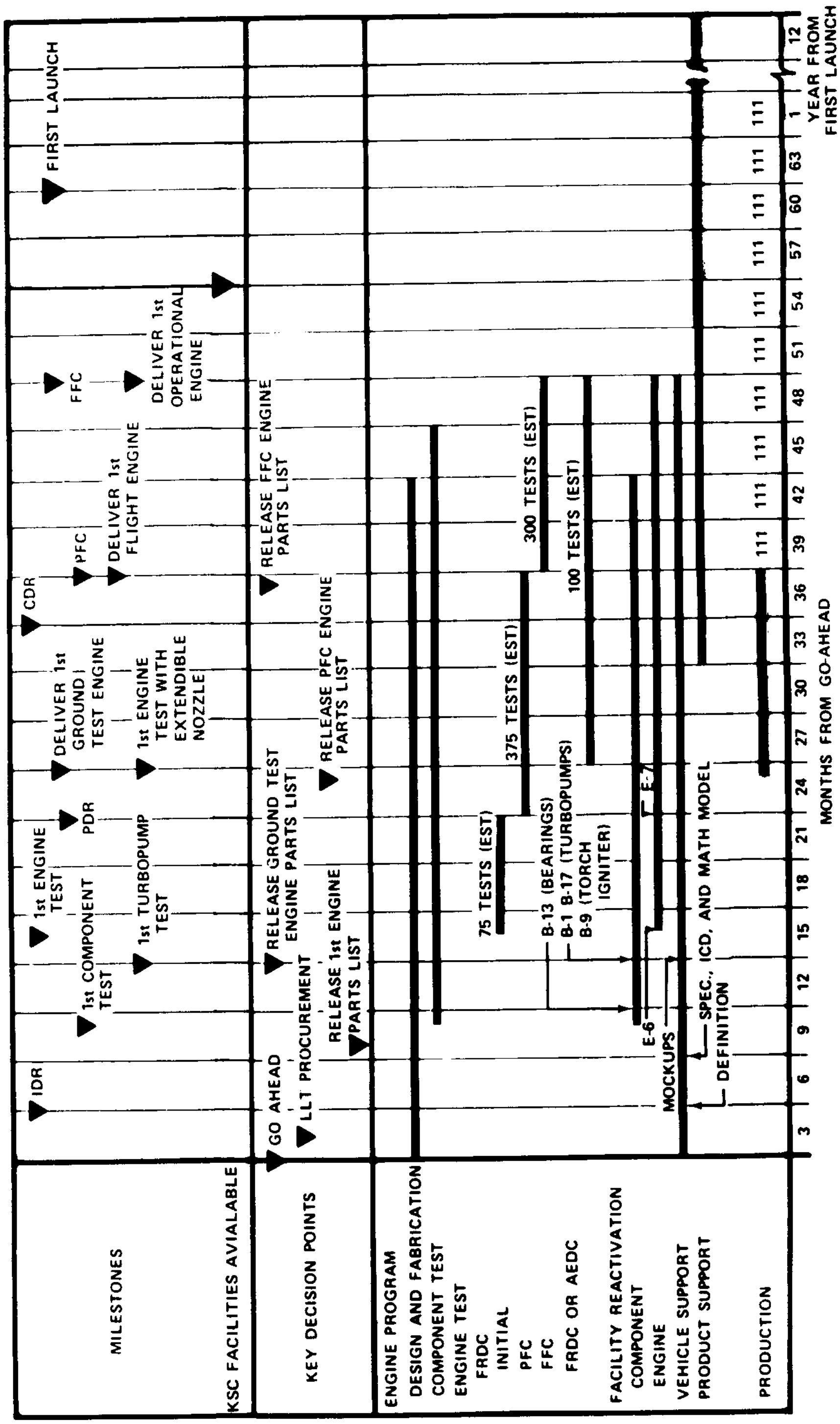
2. FACILITIES REQUIREMENTS

Most of the resources required to implement the O&FS Program are available within P&WA or its vendors; however, the one exception to this is that the facilities required at the operational sites can be shared with the Space Tug vehicle operation, using the Tug Maintenance and Checkout Facility at KSC and the Payload Processing Facility at WTR. Figure D-4 shows the Tug Ground Operations Facility Interface.

First and second level maintenance will be performed at the TMCF and/or PPF maintenance facility which will be shared with the vehicle personnel and are shown in figures D-5 and D-6. Clean rooms suitable for processing liquid oxygen engine assemblies and parts will be required in KSC and WTR, and are shown in figures D-5 and D-6. Third level maintenance will be performed at the refurbishment facility (P&WA FRDC).

Cleaning facilities along with this clean room will be required for cleaning tools and those parts specified by the maintenance instructions. This area will include a solvent spray booth, a small immersion tank, and an ultrasonic generator for use in the cleaning area.

A small second room will also be required to store a ready spare Space Tug engine for immediate use.



FD 72912B

Figure D-1. Baseline Derivative IIA Engine Development Program

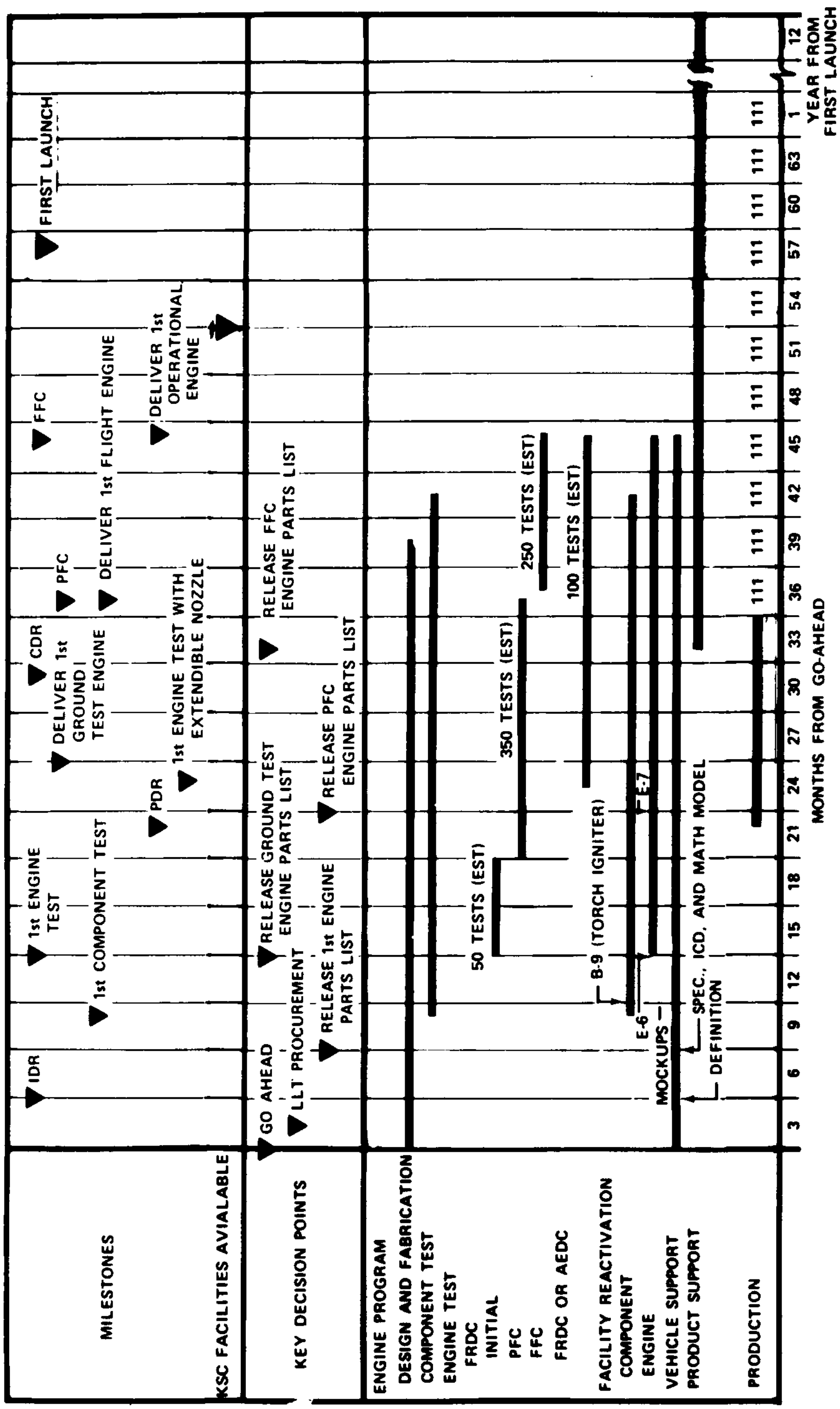


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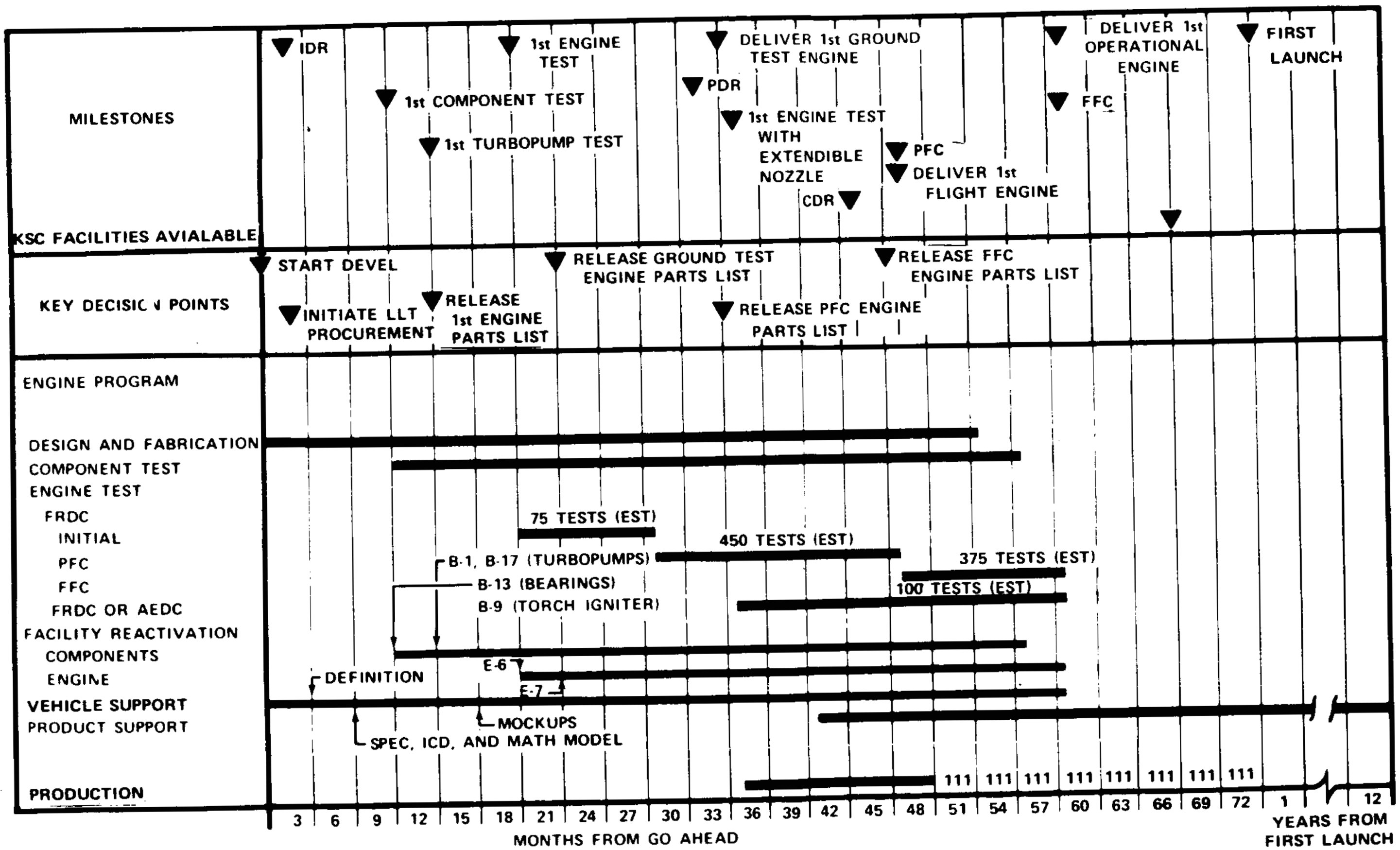
Figure D-2. Baseline Derivative IIB Engine Development Program



FD 72914B

Figure D-3. Baseline Category IV Engine Development Program

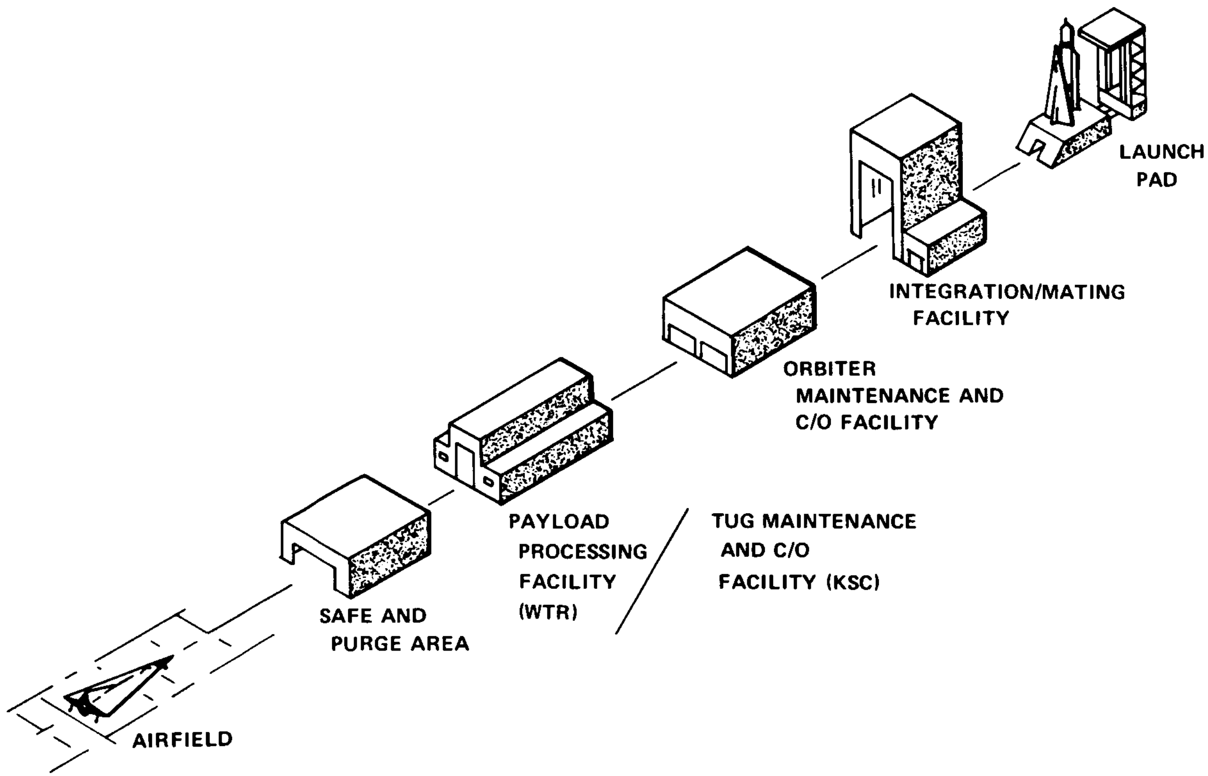
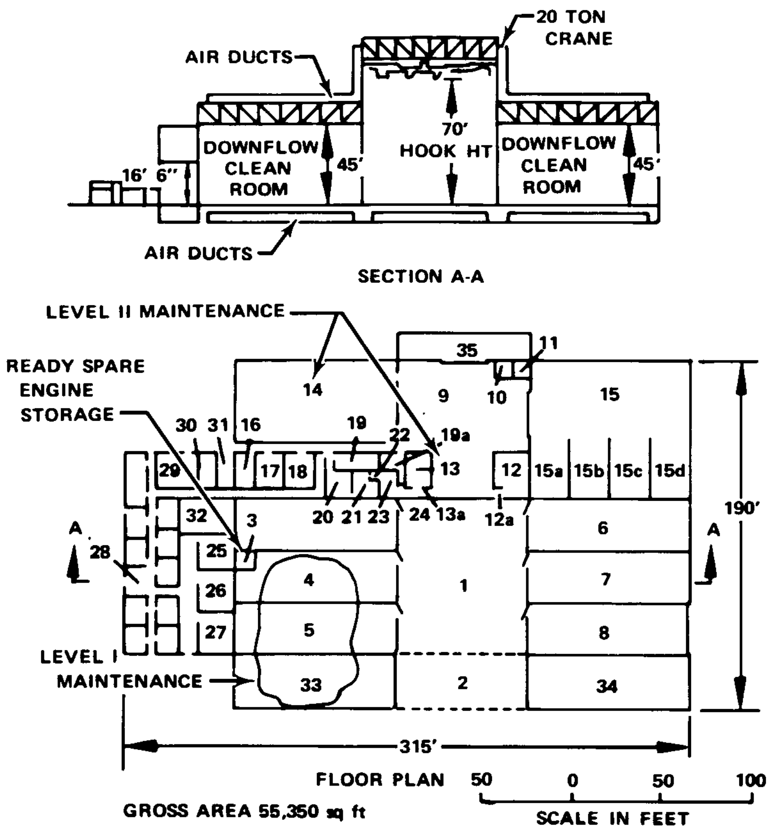
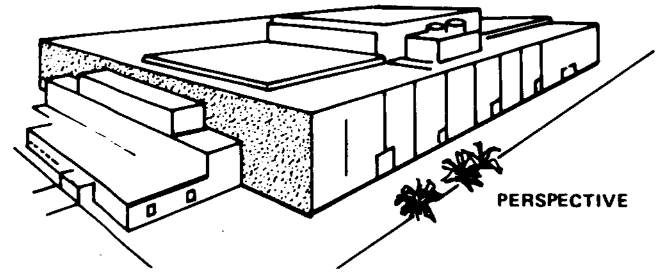


Figure D-4. Space Tug Ground Operation Facility Interface

FD 74901





1 HIGH BAY ASSEMBLY AREA
2 RF TESTING AND HANDLING EQUIPMENT STORAGE
3 ASSEMBLY AND CHECKOUT CLEAN ROOM
4 ASSEMBLY AND CHECKOUT CLEAN ROOM
5 ASSEMBLY AND CHECKOUT CLEAN ROOM
6 CLEANING INSPECTION AND DEMAINING CLEAN ROOM
7 CLEANING INSPECTION AND DEMAINING CLEAN ROOM
8 CLEANING INSPECTION AND DEMAINING CLEAN ROOM
9 RECEIVING AND SHIPPING AIR LOCK
10 SECURITY STATION
11 SHIPPING AND RECEIVING OFFICE
12 CONTAMMANT CONTROL AND MONITORING LABORATORY
13 TOOL CRIB AND MATERIALS CLEANING ROOM
14 AIR LOCK
15 SATELLITE STORAGE
15a STORAGE CUBICLE
15b SOTRAGE CUBICLE
15c STORAGE CUBICLE
15d STORAGE CUBICLE
16 MEN'S REST ROOM
17 COMPONENT STORAGE
18 COMPONENT SOTRAGE
19 QUALITY CONTROL AND SECURITY STATION
19a PROTECTIVE CLOTHING STORAGE
20 PERSONNEL LOCKER ROOM
21 PERSONNEL WASH ROOM
22 PERSONNEL AIR LOCK AND AIR SHOWER
23 PERSONNEL DRESSING ROOM
24 PERSONNEL AIR LOCK
25 CONTROL ROOM
26 CONTROL ROOM
27 CONTROL ROOM
28 LOBBY AND ADMINISTRATION OFFICES
29 FACILITIES REMOTE CONTROL AND MONITORING
30 WOMEN'S REST ROOM
31 MEN'S REST ROOM
32 CLASSIFIED STORAGE
33 MECHANICAL ROOM
34 MECHANICAL ROOM
35 CANOPIED LOADING DOCK

Figure D-5. Payload Processing Facility (WTR)

FD 74902

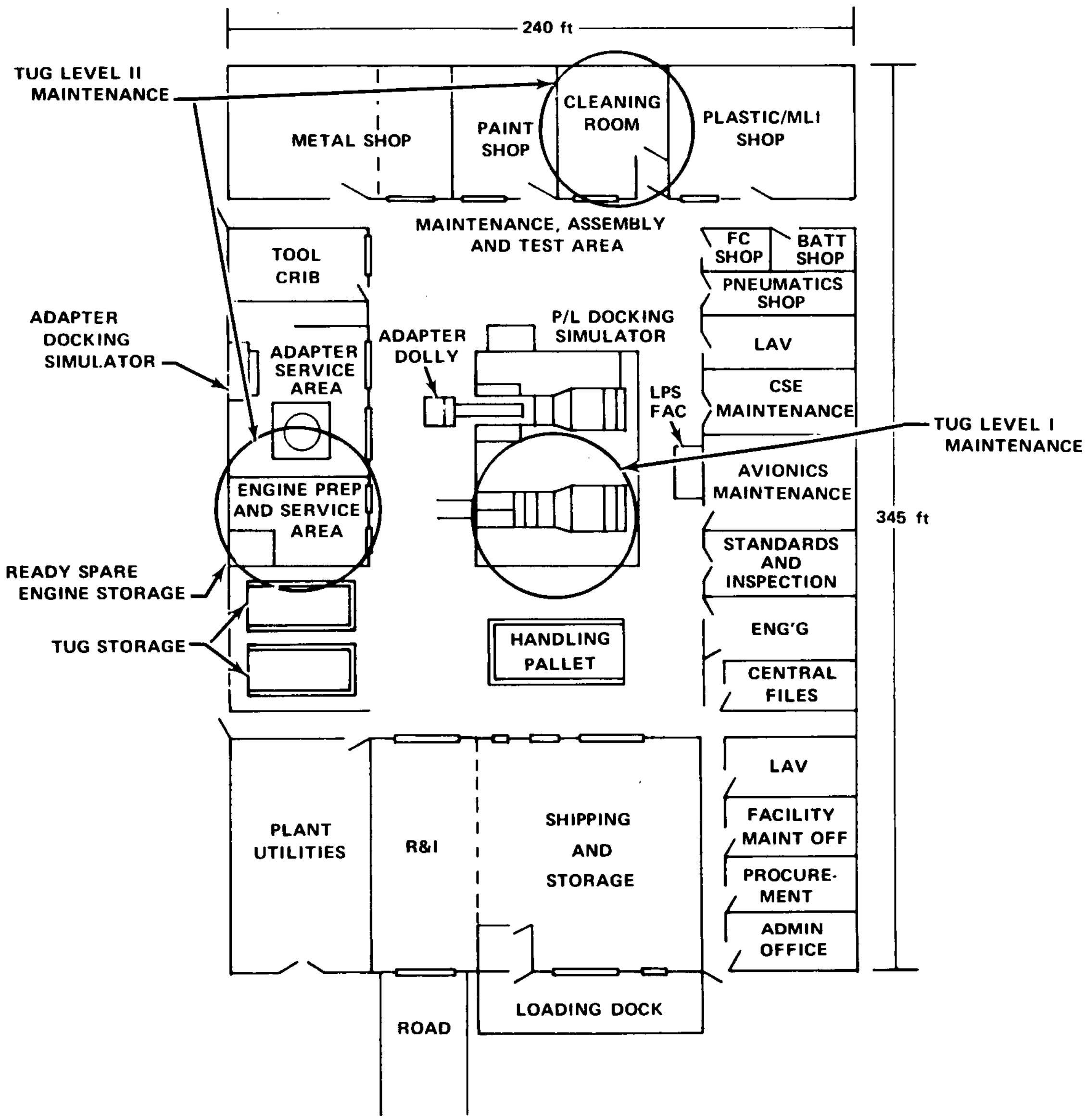


Figure D-6. Space Tug Maintenance and Checkout Facilities (ETR) at Kennedy Space Center FD 74903

SECTION E
FLIGHT SUPPORT AND ANOMALY RESOLUTION

Anticipated field problems and operational support of the flight program beyond FFC required a management and engineering team. This team will resolve problems related to delivered engines, support hardware, other end items and GSE at Government Facilities, Vehicle Contractor's Facilities and at P&WA (FRDC).

Engine system and component testing will be continued to support this program as will analyses, investigations, laboratory tests, design activities, manufacturing and assembly, and configuration control procedures.

1. APPROACH

The development and management team will provide the manpower to direct the testing and analyses required for the Flight Support and Anomaly Resolution Program. The residual hardware from the development program will be used and updated as necessary.

Exact definition of the engineering tasks during the Flight Support and Anomaly Resolution Program cannot be determined at this time, but the major expenditure of time and money will be during the first months following the first orbital flight. During this time the propulsion system will be refined, the operational capability of the Space Tug will grow, and vehicle/engine operational integration problems and flight and ground test anomalies exposed and rapidly corrected.

1.1 Flight Support and Anomaly Resolution Tasks

The tasks that are likely to be included in the Flight Support and Anomaly Resolution Program are:

a. Engine System Tests

(1) Start transient tests to resolve propulsion system interactions such as acceleration losses in the main propellant supply ducts, thrust buildup rate effects, simulation of abort situations and malfunctions, and unique problems such as out-of-limits propellant conditions

(2) Combustion stability tests - simulating field test conditions

(3) Mechanical/electrical/fluid panel integration - simulation of actual vehicle system transients and/or checkout with vehicle equipment

(4) Tests to substantiate engineering changes to engine and GSE hardware and/or procedures.

b. Component/Subsystem Testing

(1) Tests to substantiate engineering changes to engine and GSE hardware and/or procedures.

(2) Simulation of specific interface/integration field problems.

c. Analyses

(1) Failure/malfunction analysis
(2) Mathematical model simulation of field problems
(3) Unsatisfactory condition analyses
(4) Continued development of flight data analysis and engine simulation programs such as the engine/control model and engine data reduction/prediction programs.

d. Investigations

(1) Reproduction of field malfunctions/anomalies to resolve sources and effects of incidents
(2) Evaluation of human element in special field problems
(3) Maintenance procedure revision investigations and experiments
(4) Accident/incident investigations.

e. Design

(1) Redesign of engine, GSE and other end item hardware as required from results of the above tests, analyses and investigations
(2) Incorporation of Engineering Changes
(3) Design studies to support anomaly resolution

f. Laboratory Tests

(1) Materials testing to resolve field problems and assess possible alternatives
(2) Analysis of fluid samples for contamination
(3) Identification of foreign materials.

g. Reports/Specifications

(1) Monthly and Quarterly Status Reports
(2) Failure/Malfunction Reports
(3) Maintenance of Acceptance Test Procedures, DVS's, PVS's and CEI Specifications
(4) Maintenance of the Flight Support and Anomaly Resolution Plan.

Engineering effort for flight support and anomaly resolution after Final Flight Certification will be regulated by the number of engine related problems discovered in the operation of the Space Tug. Prior experience on reusable engine programs has revealed a pattern of decreasing requirements for engineering support, starting about two years after first flight. The rate of decrease varies from program to program, but eventually levels off at a minimum level of effort of engineering support. Engineering support of an operational program cannot be reduced below a given level of effort or the ability to react to operational problems will be lost. At this level, the flight support and anomaly resolution requirements will be spasmodic, but efficient use of the engineering support capability can be made toward the additional goals compatible with the flight support program requirements. These additional goals include:

a. Improvement of operational readiness and effectiveness of the engine with current model specification performance ratings
b. Increasing the operational flexibility of the engine beyond FFC requirements
c. Reduction of operating and maintenance costs
d. Extension of the service life of parts.

The effort required to achieve these goals will level between peaks that normally occur in a flight support program; therefore, the engineering team has a useful and meaningful purpose and is kept technically current. This feature also allows the experimental hardware and test facilities required for flight support to be used effectively and efficiently toward the overall Space Tug goals of reducing the cost of placing a payload in orbit.

Additional engine improvement programs to increase thrust or specific impulse or to reduce weight could be included in this program if the Government so desires.

2. ORGANIZATION

Experienced engineers from the development organization will provide continuity of direction and implementation of the Flight Support and Anomaly Resolution Program. The program management organization is shown in figure E-1. Functional department support will be provided as required.

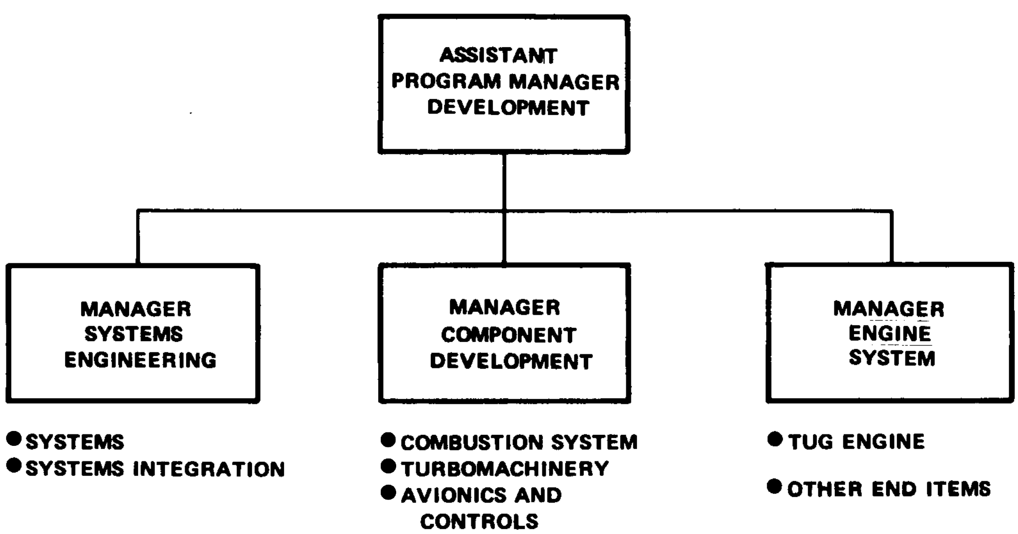


Figure E-1. Flight Support Engineering Works from Development Engineering Group FD 52156A

SECTION F
MAINTAINABILITY

This section provides a review of the plans for the maintainability support for the Space Tug Engine.

1. MAINTAINABILITY PROGRAM

The objective of the Pratt & Whitney Aircraft Maintainability Program is to produce an engine design that requires the least amount of maintenance effort and cost while providing the ability to readily verify engine flightworthiness. To meet this objective, the engine design for the Space Tug combines a self-test fault isolation system with a construction, where possible, that permits maintenance to be accomplished at the lowest level possible with regard for quality, cost, and time. The levels of maintenance are defined as:

a. First Level - Engine installed in the vehicle
b. Second Level - Engine shop at operational site
c. Third Level - Engine factory.

The concept of accomplishing maintenance at the lowest level possible is basic to achieving low maintenance and operational costs on the Space Tug Engine. Being able to accomplish maintenance on an installed engine saves engine removal, installation, and checkout time, and manpower. Accomplishment of minor maintenance in the engine shop at the operational site, rather than returning the engine to the factory, saves transportation time and expense, and decreases the engine down time.

This Maintainability Program is designed to accomplish the objectives outlined above by having specific maintainability features incorporated into the engine design such as foolproofed assemblies, standardization of hardware, and construction aimed at minimum task time. Besides having maintainability features incorporated into the engine design, the program is formulated to monitor maintainability aspects of developmental design, engineering changes, and operational problems.

The Maintainability Program is targeted at providing an engine that requires the least amount of maintenance effort and cost, consistent with high reliability and safety. Some of the many aspects of the program are: (1) "do's and don'ts" guidlines to designers based upon previous experience; (2) specific requirements for handling of given design situations; (3) Human Factors Engineering design layout reviews; (4) GSE compatibility reviews; and (5) specific goals.

1.1 Foolproofed Assemblies

The Space Tug design will incorporate many assembly features that have been instroduced into component or engine design to prevent misassembly of parts or components. These features can be incorporated during the initial engine design phase without any degradation of performance, reliability, safety, or cost. Regardless of the skill level used in the assembly of precision machinery, human errors can occur that allow misassembly of parts or components unless foolproofing features are incorporated.

Examples of some of the foolproofing features that will be incorporated into the Space Tug Engine as a part of the Maintainability Program are listed below:

a. Offset holes in housing flanges to prevent misorientation of two mating flanges

b. Differently sized snap diameters on stacked assemblies to prevent out-of-sequencing stacking

c. Differently sized, and in some cases differently shaped, inner races on bearings used on the same shaft to prevent improper location

d. Different spline diameters on a shaft to prevent mislocation of parts on the shaft

e. Stepped inside diameters on seals to prevent reverse assembly.

1.2 Commonality of Hardware

Whenever the design requirements permit, common hardware will be used throughout the design to reduce the number of different parts and tooling that must be stocked to support the engine. Using the same hardware (i.e., bolts, nuts, and seals) in as many applications as practical on an engine permits cost savings to be gained in both procurement and warehousing of parts. Because these types of parts are frequently a high replacement item on reusable engines, the policy of commonality allows for reduction in support and operational costs.

1.3 Minimum Task Time Construction

As part of the Maintainability Program, a selection of construction features for the design will be made to provide the lowest maintenance task times. In cases where alternate methods of assembly are possible, the method that provides the lowest calculated assembly and disassembly times will be selected. Incorporation of puller grooves, jackscrew holes, and flange handling features, will be incorporated into many parts of the engine system to reduce the maintenance task times.

1.4 Repairability

The Space Tug Engine design will be influenced by a maintainability guideline on repairability that calls for expensive parts to have repairability while low cost units should be considered throw-away items and designed for low production cost rather than having repairability. Increases in labor cost will make this a practical approach in reducing maintenance cost.

2. IMPLEMENTATION OF MAINTAINABILITY PROGRAM

Achievement of the P&WA Space Tug Maintainability Program goals and objectives will be accomplished during the following four phases: (1) engine design phase, (2) engine development phase, (3) engine/vehicle installation phase, and (4) in service phase.

2.1 Design Phase

2.1.1 Use of Checklist and Standards

During the engine design, the basic maintainability concepts are provided to the designers through recommendations specified in the Maintainability Checklist, as shown in figure F-1.

ENGINE-GENERAL
ESSENTIAL MAINTAINABILITY CHARACTERISTICS
(TO AID IN ASSEMBLY/DISASSEMBLY/ACCESSIBILITY)

- MODULAR ENGINE CONSTRUCTION IS ESSENTIAL TO FLEXIBLE MAINTAINABILITY. THE THRUST CHAMBER INJECTOR ASSY. AND THE TURBOPUMP ASSY. MUST EACH BE INDEPENDENT MODULES. (UNIT IS REMOVABLE WITHOUT DISASSEMBLY OF THE UNIT.)
- MODULES, MAJOR ASSEMBLIES AND COMPONENTS MUST BE DESIGNED TO ALLOW ASSEMBLY IN EITHER A HORIZONTAL OR VERTICAL POSITION.

(FOOLPROOFING)

- ALL ASSEMBLIES, COMPONENTS, ACCESSORIES AND DETAIL PARTS MUST BE FOOLPROOFED SO THAT THEY CANNOT BE INSTALLED INCORRECTLY.

(TO AID IN HANDLING)

- IT IS REQUIRED THAT ENGINE GROUND HANDLING POINTS BE PROVIDED TO ALLOW (a) INSTALLATION OR REMOVAL FROM VEHICLE (b) ENGINE TRANSPORTATION AND (c) ENGINE BUILDUP OR TEARDOWN. GROUND HANDLING POINTS MUST BE CAPABLE OF WITHSTANDING 4.0 g HANDLING LOADS APPLIED IN ANY DIRECTION WHILE INSTALLED IN THE ENGINE HANDLING FRAME WITHOUT DETRIMENTAL DEFORMATION OR STRUCTURAL FAILURE.

(TO AID IN IDENTIFICATION)

- PROVIDE LEGIBLE AND PERMANENT COMPONENT LABELING. ALL EXTERNAL COMPONENTS MUST HAVE IDENTIFYING DATA VISIBLE WHEN ENGINE IS FULLY ASSEMBLED.

Figure F-1. Sample Maintainability Checklist FD 72910A

2.1.2 Design Layout Reviews and Trade Studies

Participation of the maintainability group in the Maintenance Engineering Analysis program assures the influence of maintainability features in the engine concurrent with the initial design. All layouts are reviewed and the assessment is documented on a Maintainability Engineering Layout Review form, a sample of which is shown in figure F-2. This documentation informs program management to what extent desired maintainability features are incorporated into the engine design and identifies specific maintainability problems that require trade studies for resolution.

Incorporation of desired maintainability features often compromises other characteristics such as weight, cost and performance. All phases of engine design are considered in trade studies to relate maintainability recommendations to other design considerations such as Reliability and Safety. Design modifications resulting from trade studies are also reviewed to ensure that existing maintenance capabilities are not unduly compromised and that the modifications do not create new maintenance problems in the engine design.

MAINTAINABILITY ENGINEERING LAYOUT REVIEW

MODEL RL10 Derivative II PAGE 1 OF 1

LAYOUT NO. 228402 TITLE Primary Nozzle Preliminary Design
SHT. 1 OF 1 CHG. NC DESIGNER W. Eastman
REVIEWED BY W. Quigley EXT. 3240 DATE 6/19/73

Intent: Provide a preliminary design of the primary nozzle for the RL10 Derivative II engine.

1. Ref View "G", ballscrew gearbox cut-outs show threaded welded on bosses which are difficult to repair if they are damaged. Suggest using riveted on nut plates to facilitate repair of the nozzle.

2. The sheet metal nozzle seals are readily replaceable if they become worn or damaged.

FOLLOW UP

Figure F-2. Sample Maintainability Engineering Layout Review (MELR) Form FD 74904

Specific maintainability recommendations are outlined on a Maintainability Engineering Proposal (MEP) form, figure F-3. When applicable, it specifies the maintenance manhour savings and weight changes involved. Anyone can submit an MEP, providing a traceable record of a request for improved maintainability. All MEP's are screened for applicability and the engineering action taken becomes part of the permanent record.

Initial MEP's are reviewed and signed by the appropriate component Manager, and then transmitted to the Design Engineer, the cognizant Project Engineer and Program Management for review and comment. A file of all MEP's for followup action is maintained. The responsible Design Engineer is required to submit a responsive action to the Maintainability Group within 10 working days. This response is required to be an accurate detailed report that can be used for planning purposes.

Assembly and test personnel are indoctrinated to point out all problem areas and particularly maintainability problems. Because they perform the maintenance tasks, they are able to identify problems that a casual observer could miss. Similarly, assembly errors are reviewed to ensure that hardware design is not involved. Assembly personnel are also periodically rotated to different tasks within the department to avoid having a mechanic become so proficient on a given task that he instinctively compensates for an assembly design deficiency.

All assembly/disassembly problems and recommendations for modification are documented by the Maintainability Group. This documentation is then transmitted to the Manager, Assurance Disciplines, who completes the "Engineering action" section. Upon receipt of the form from the Manager, Assurance Disciplines, the Design Maintainability Group will generate a Maintenance Engineering Proposal.

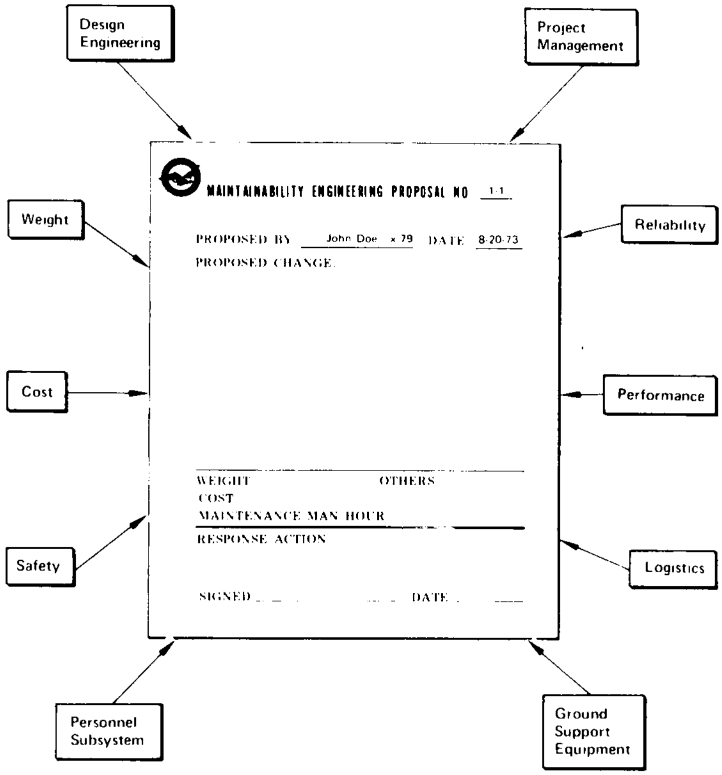


Figure F-3. Sample Maintainability Engineering Proposal (MEP) FD 48471A

Early recognition and correction of maintainability problem areas during the initial engine development phase is the key essential element to significant reductions of problems that will be encountered in later stages of the Space Tug program, and reduces overall program costs by reducing the possibility of costly retrofits and design changes.

2.1.3 ECP's Reviewed for Maintainability Considerations

Engineering Change Proposals (ECP) to the engine design may compromise maintainability features incorporated in the initial design. Therefore all Engineering Releases and Engineering Changes are reviewed by Project Management and the Maintainability Group to determine whether maintainability of the engine has been compromised, and to determine that changes initiated by the Maintainability Group have been fully incorporated.

Maintainability review of all Engineering Releases and Engineering Changes provides for continued monitoring of the design to ensure the full implementation of maintainability throughout the life cycle of the Space Tug program.

2.2 Installation Phase

2.2.1 Engine/Vehicle Interface Verification

Physical interface compatibility between the engine and vehicle is accomplished early in the Space Tug development stage through use of a full scale mockup. The full scale mockup is used to define interfaces, assess maintenance accessibility, and to substantiate predicted inspection capabilities. A three-dimensional mockup provides an accurate assessment of possible engine/vehicle interferences that are not identified on two-dimensional drawings.

The Space Tug mockup will permit the Maintainability Group to accomplish the following:

a. Determine accessibility of controls and accessories relative to assembly, wrench clearances, and ease of installation and removal

b. Review control mounting flanges for application of disconnect features to reduce maintenance manhours associated with component removal

c. Prevent locations of components that require unnecessary removal of other equipment to gain access to the component

d. Prevent component and accessory location over engine flanges

e. Prevent components and accessories from interfering with inspection provisions, such as borescope access ports

f. Review all plumbing and harness bracketing to determine greatest extent of logistical commonality that can be incorporated.

The Space Tug Engine mockup will be reviewed with the Space Tug vehicle contractors for compatibility of engine to vehicle installation. Clearance between the Space Tug vehicle, docking adapter and engine can be assessed to determine adequacy to accommodate removal and installation of engine Replaceable Units. The components can be removed when the engine is on the Space Tug vehicle and nozzle extended. Engine/vehicle interface connections can be analyzed for accessibility to determine if engine installation and removal time goals have been compromised.

Coordination between the Government, Space Tug vehicle contractors and P&WA has been in effect from design inception and will continue throughout the life of the program. The mockup will provide a three-dimensional assessment of all the coordinated efforts between the Government, Space Tug vehicle contractors and P&WA and exposes all maintainability/maintenance problems that remain unresolved. This exposes interface maintenance problems that would go undetected until actual installation of flight hardware. The cost associated with correction of such problems on flight hardware can be saved through closely coordinated mockup reviews.

In addition to using a three-dimensional mockup of the Space Tug Engine to avoid engine/vehicle interfacing conflicts, P&WA will assign representatives to the Space Tug contractor to observe, recognize, and assess problem areas affecting engine maintainability features during and subsequent to engine installation in the Space Tug vehicles.

SECTION G
LOGISTICS

1. SPARES AND SUPPLY SUPPORT PLAN

1.1 Summary

The Spare Parts Support Plan can be divided into three functional areas of operation that work together to deliver the needed support part to the correct location at the right time. The three parts of the Spare Parts Plan will be:

a. Provisioning, which deals with the selection of parts to be procured and scheduling when they must be ordered

b. Procurement, which is the ordering, manufacturing, expediting, and delivery of parts

c. Inventory Management, which deals with the distribution, storage or warehousing, and stock level control of delivered parts, plus the technical assistance and local inventory control provided at the operational site.

Provisioning includes the identification, and selection of support parts needed for support of a particular end item (i.e., Ground Test Engine, Flight Engine) and must be accomplished at the start of the program to "stock the shelf."

The basic logistics philosophy recognizes Maintenance Engineering Analysis information as the source of prime data replacement factors that result in realistic and economic procurement of spare parts and GSE. These factors are presented to the Government at a provisioning conference to identify the required spares, in a "meeting-of-the-minds" effort, prior to any expenditures of spares money. In addition, a prescreening of Government inventories is made prior to provisioning to eliminate unnecessary procurement of spares or GSE already available in Government inventories.

After the Government has approved the selection of the range and depth of spares at a provisioning conference, P&WA's Spare Parts Group initiates procurement action within existing systems to ensure delivery of parts to all levels of maintenance on a timely basis commensurate with need date. Long lead time items not selected for procurement by the Provisioning Conference will be reviewed for candidacy as "buffer stock" items. Selected buffer stock items will be added to the production schedule and made available by diversion only when dictated by maintenance and overhaul site experience. As the end of the engine production schedule approaches, buffer stock items will be procured outright for spares (if experience dictates) or frozen for use in engine production. All initial spares procurements are initiated concurrently with the engine production procurements to take maximum advantage of economical quantity buys. The Support Hardware Release Notice (SHRN) is employed to notify NASA and documents adjustments of undelivered parts on order.

Pratt & Whitney Aircraft's inventory management systems in use on such programs as the RL10, J58 and F100/F401 Engine will be customized to ensure proper distribution and resupply of parts as dictated by Space Tug Engine requirements. Spare Parts Representatives will be assigned to the operational sites and will monitor and transmit parts usage information to the P&WA Spare Parts Group. As usage experience becomes defined, "min-max" levels will be established for each part and reordering done only as consumption creates demand. The Spare Parts Representative will supervise the warehousing and accounting functions as they relate to Spare Parts and GSE. Site warehousing and accounting functions will be accomplished by the NASA or the vehicle or facilities contractor with logistics advisory services only to be furnished by P&WA.

The P&WA Spare Parts Group will perform parts application research, delivery follow-up, inventory management, and monetary surveillance of spares ordered and delivered, and EDP of manual records. The Spare Parts Group maintains up-to-date records for NASA and P&WA Space Tug Engine Program management.

2. PACKAGING, HANDLING, AND PRESERVATION PLAN

Preservation, packaging, and containers/devices will be designed and methods of handling and transport will be established to provide cost effective protection for engines and support items over the Space Tug Engine Program life cycle. Scheduling of design, procurement, and transportation activities will be compatible with the Space Tug Engine Program schedule.

GSE transporters will be designed to provide shock and vibration protection during shipment of the Space Tug Engines. It is recommended that low cost GSE maintenance stands with dehydrated flexible containers be used for engine storage, thereby permitting the recycling of the high dollar value GSE transporters. Components of Space Tug Engine oxygen, hydrogen, helium, and nitrogen systems will be cleaned in accordance with Government specifications. All support items will be protected from the environmental extremes of shipment and storage by the application of preservation, packaging, and packing procedures that establish reliable, universally recognized standards of protection. This approach offers the benefit of a proven procedure, developed to protect critical items subjected to worldwide distribution and storage on many reusable engine programs.

P&WA's approach to PPH&T is designed to meet the requirements and low cost targets of the Space Tug Engine Program. Economical packaging and container designs, lowest cost transportation, and proper scheduling of all PPH&T events are assured by a customized program.

2.1 Physical Cleanliness and Corrosion Protection

Effective environmental protection will be provided for the Space Tug Engine transportation, handling, and storage life cycle requirements to prevent mechanical damage, foreign particle contamination, and chemical deterioration that could jeopardize engine reliability.

2.2 Support Item Packaging

Preservation, packaging, and containers for Space Tug Engine support items will provide cost effective protection against natural and induced environments during shipment and storage over the life cycle of the Space Tug Engine Program.

Maintenance Engineering Analysis will identify major spare subassemblies, spare parts, GSE, and training materials required for support. These part numbers will be forwarded to the Spares and GSE Packaging Design Group and be evaluated from the standpoint of criticality, fragility, material type, complexity, repairability, and transportability prior to initiating packaging design action.

The selection of the appropriate level of protection for each item is based on analysis of the anticipated environmental extremes of shipment and storage and will eliminate delays and cost associated with damaged or deteriorated material.

Spare major repairable subassemblies will be shipped and stored in reusable containers/devices that will minimize repackaging costs and provide effective protection over the Space Tug Engine life cycle. In addition, these reusable containers will permit the rapid return of repairable units to the overhaul and repair site. Containers common to more than one subassembly will be provided whenever practicable.

Packaging and packing for large percentage of spare parts other than major subassemblies will incorporate the use of low cost, lightweight, containers and dunnage. The use of skin packing, lightweight plastic dunnage, and lightweight fiberboard boxes whenever permitted by the nature, dimensions, and weight of the items to be shipped, and by the anticipated conditions of environmental exposure will provide minimum transportation costs and storage cube requirements.

3. GROUND SUPPORT EQUIPMENT AND FACILITIES PLANNING

A complete and comprehensive Support Program will require adequate planning for Ground Support Equipment (GSE) and Maintenance Facilities services. To provide for these two specialized areas of operational support, the ILS Team includes a GSE and Maintenance Facilities Planning Group under the direction of a technical administrator who reports directly to the ILS Manager. As a part of the ILS Team, the GSE and Facilities Planning Technical Administrator has the necessary interfaces and communication channels with other support functions such as Maintenance Engineering, Field Services, Packaging and Transportation, Training and Spares and Supply Support.

3.1 Ground Support Equipment (GSE)

This preliminary subsection lists in numerical order the function of special equipment applicable to the work required on Derivative IIA, IIB and Category IV engines. The GSE Section of the GSE and Maintenance Facilities Planning Group has the responsibility for (1) planning, (2) technical publications data, (3) on site training and (4) support of operational GSE. In addition to these prime duties the GSE Section provides a major assistance to the Manager of GSE Development by supplying the following technical and functional services as needed:

a. Identification of GSE requirements through engine design layout reviews and the Maintenance Engineering Analysis (MEA)

b. Technical assistance in the preparation of GSE Specifications

c. Research and Screening services of NASA, Government, and company GSE type inventories

d. Design, development, and test services for GSE items

e. GSE vendor coordination, procurement, and monitoring services.

The other GSE that may be required is to be established and this preliminary list expanded.

3.1.1 Tools

a. Numerical List (Preliminary)

Table G-1 presents by tool number estimated tools required for ground support of the Derivative IIA, IIB and Category IV engines.

Table G-1. Tools Required for Derivative IIA and IIB engines and Similar Tools for Category IV - Listed by Tool Number

Tool Number	Name	Group Number
PWA™ -15241	Torque Wrench Adapter	12
PWA-15256	Pressure Check Nozzle	13
PWA-15260	Adjustment Indicator Torque Adapter	1
PWA-15400	Oxidizer Pump Oxidizer Cavity Pressure Tap Adapter	9
PWA-15413	Purge Relief Valve Pressure Test Fixture	11
PWA-15415	Exciter Box Deflection Gage	11
PWA-15416	Spark Igniter Protector	11
PWA-15428	Thrust Chamber Exit Cover	5,6,7
PWA-15429	Pressure Check Plug	3,4,8
PWA-15430	Thrust Chamber Throat Desiccant Plug	2,4,5,6,7
PWA-15431	Pressure Check Plate	3
PWA-15432	Oxidizer Pump Fuel Cavity Pressure Tap Adapter	9
TBD	Nozzle Extension Tools	14
TBD	Checkout Console Engine Stand	16

b. Group List

Table G-2 presents by group number tools required for ground support of the Derivative IIA and IIB engines and similar tools for Category IV.

Table G-2. Tools Required for Derivative IIA and IIB Engines and Similar Tools for Category IV - Listed by Group Number

Group No.	Functional Nomenclature	Tool No.	Figure No.
1	Oxidizer Flow Control Valve (propellant utilization) torque check adjustment indicator torque adapter	PWA-15260	C-1
2	Removal of Thrust Chamber Handling and Shipping Plug - thrust chamber throat desiccant plug	PWA-15430	C-2
3	Engine Systems Pressure and Leak Checks		
	pressure check plug	PWA-15429	C-3
	pressure check plate (two required)	PWA-15431	C-4
4	Engine Preservation		
	thrust chamber throat desiccant plug	PWA-15430	C-2
	pressure check plug	PWA-15429	C-3
5	Engine Installed in Vehicle		
	thrust chamber throat desiccant plug	PWA-15430	C-2
	thrust chamber exit cover	PWA-15428	C-5
6	Installation of Vehicle and/or Engine in Test Stand		
	thrust chamber throat desiccant plug	PWA-15430	C-2
	thrust chamber exit cover	PWA-15428	C-5
7	Valve Actuation Check		
	thrust chamber throat desiccant plug	PWA-15430	C-2
	thrust chamber exit cover	PWA-15428	C-5
8	Oxidizer Pump Seal Leakage Checks		
	pressure check plug	PWA-15429	C-3
9	Preparation for Engine Operation (test stand)		
	Oxidizer pump oxidizer cavity pressure tap adapter	PWA-15400	C-6
	Oxidizer pump fuel cavity pressure tap adapter	PWA-15432	C-7
10	Oxidizer Flow Control Valve Purge Relief Valve		
	purge relief valve pressure test fixture	PWA-15413	C-8
11	Ignition System		
	spark igniter protector	PWA-15416	C-9
	exciter box deflection gage	PWA-15415	C-10
12	Turbopump Torque Check		
	torque wrench adapter	PWA-15241	C-11

Table G-2. Tools Required for Derivative IIA and IIB Engines and Similar Tools for Category IV - Listed by Group Number (Continued)

Group No.	Functional Nomenclature	Tool No.	Figure No.
13	Thrust Control Motor and Reference Bellows Check pressure check nozzle	PWA-15256	C-14
14	Installation of Extendable Nozzle Handling Frame	TBD	TBD
15	Maintenance Checkout console	TBD	TBD
16	Maintenance engine stand	TBD	TBD
17	Borescopes	TBD	TBD
18	Installation of Tug Engine and Extendible Nozzle Assembly on to the Space Tug Vehicle	TBD	TBD

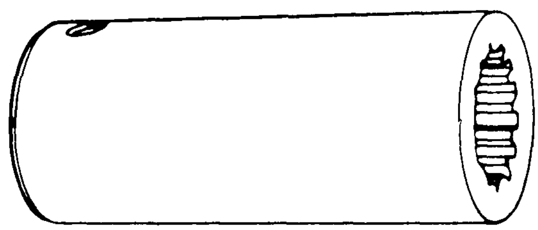


Figure C-1. PWA™ 15260 Adjustment Indicator Torque Adapter FD 68770

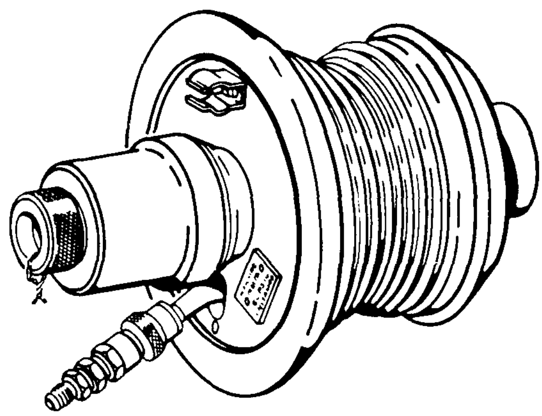


Figure C-2. PWA™ 15430 Thrust Chamber Throat Desiccant Plug FD 67642

Table G-2. Tools Required for Derivative IIA and IIB Engines and Similar Tools for Category IV - Listed by Group Number (Continued)

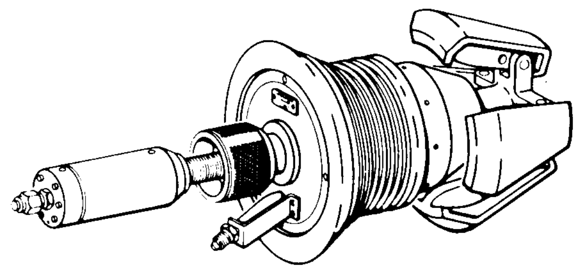


Figure C-3. PWA™ 15429 Pressure Check Plug FD 67643

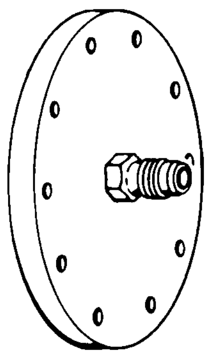


Figure C-4. PWA™ 15431 Pressure Check Plate FD 67644

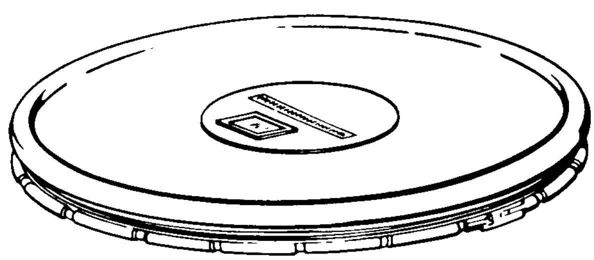


Figure C-5. PWA™ 15428 Thrust Chamber Exit Cover FD 67645

Table G-2. Tools Required for Derivative IIA and IIB Engines and Similar Tools for Category IV - Listed by Group Number (Continued)

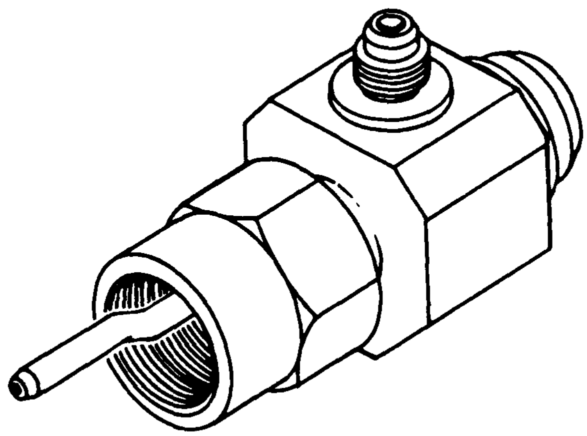


Figure C-6. PWA™ 15400 Oxidizer Pump Oxidizer Cavity Pressure Tap Adapter — FD 67646

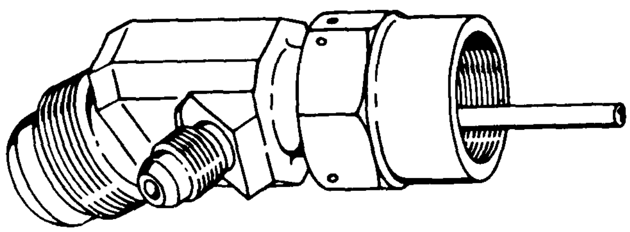


Figure C-7. PWA™ 15432 Oxidizer Pump Fuel Cavity Pressure Tap Adapter — FD 67647

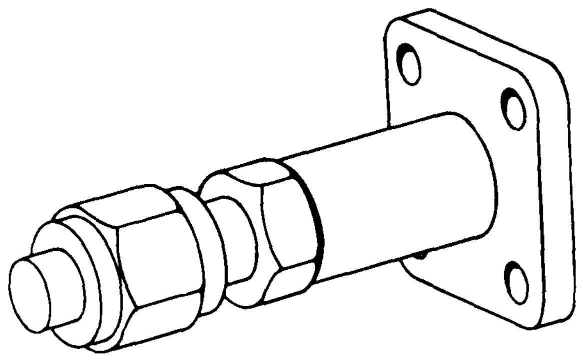


Figure C-8. PWA™ 15413 Purge Relief Valve Pressure Test Fixture — FD 67648

Table G-2. Tools Required for Derivative IIA and IIB Engines and Similar Tools for Category IV - Listed by Group Number (Continued)

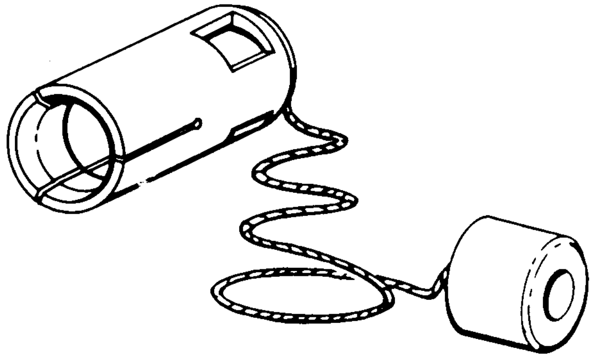


Figure C-9. PWA™ 15416 Spark-Igniter Protector FD 67649

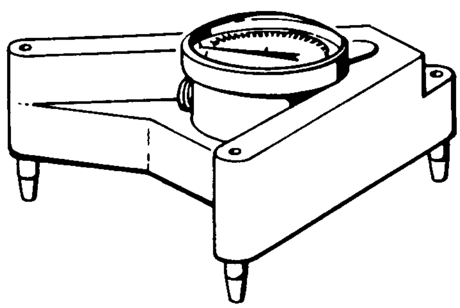


Figure C-10. PWA™ 15415 Exciter Box Deflection Gage FD 67650

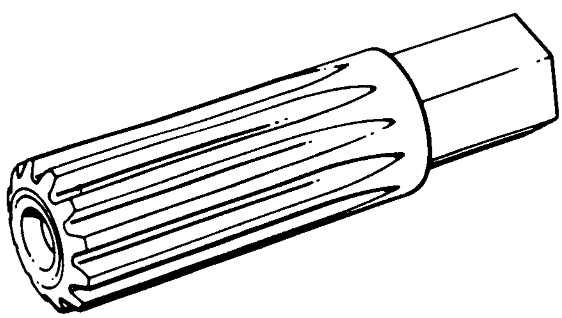


Figure C-11. PWA™ 15241 Torque Wrench Adapter FD 67651

Table G-2. Tools Required for Derivative IIA and IIB Engines and Similar Tools for Category IV - Listed by Group Number (Continued)

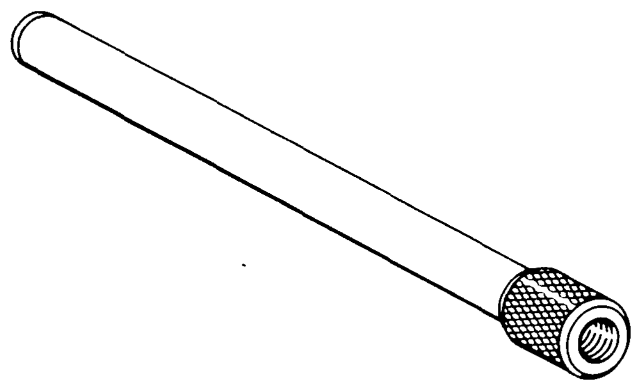


Figure C-12. PWA™ 15256 Pressure Check Nozzle FD 67652

3.2 Handling Equipment

In addition to being used for shipping Derivative IIA and IIB engines in a container or on the Space Tug vehicle, handling equipment shown in table G-3 may be used for engine-to-vehicle installation or removal and for other handling requirements. Category IV engine requirements are yet to be determined, but will be similar to the Derivative engines.

Table G-3. Handling Equipment for Derivative IIA and IIB Engines

Part Name	Part Number
Handling Frame Engine and Extendible Nozzle Installation	TBD
Handling Frame Assembly (Complete)	P-2001424
Handling and Shipping Plug	P-2001423
Shipping Plug Tightening Band	P-2001431
Tightening Band Shim	P-2001433
Tightening Band Shim	P-2001434
Tightening Band Shim	P-2001435
Rear Thrust Chamber Cover Assembly	P-2001299
Intermediate Rear Thrust Chamber Cover Assembly	P-2001298
Front Thrust Chamber Cover Assembly	P-2001296
Front Thrust Chamber Cover Assembly	P-2001297

CAUTION: The above covers should remain installed on the thrust chamber at all times except when protected areas are being checked or during engine operation and vehicle testing which necessitate removal.

3.2.1 Ground Handling Equipment

Ground handling equipment provided for the Derivative IIA, IIB, and Category IV engines consists of a handling and shipping frame, a handling and shipping plug, an engine shipping container and nozzle extension shipping container. The handling and shipping plug, as shown in figure G-1, consists of a cone-shaped rubber-cushioned, fiberglass nozzle plug that permits the engine to be transported short distances in the vertical position. The handling and shipping frame, figure G-2, attaches to the engine and in turn may be attached either to a transporting dolly, as shown in figure G-3, or to a shipping container, as shown in figure G-4, for transportation in a horizontal position. The extension nozzle is shipped in a separate container (description and handling requirements are to be determined). The engine ground handling equipment will be further defined from these preliminary definitions when the engine designs are finalized.

3.2.2 Engine Shipping and Handling

For engine shipment and for handling the engine (without the nozzle extension) in a horizontal position, both the handling frame and handling plug are required. The following procedure must be followed:

a. Remove front ring and tube assembly from the handling frame

b. Attach lift bar

c. Lift engine in horizontal attitude

d. Position and attach gimbal

e. Support rear of engine by inserting a shaft through center bushing of handling plug and a pin through one of eight bushings in handling plug ring

f. Remove remainder of handling frame

g. Do not attach gimbal actuators.

The engine may be shipped, using only the handling plug, provided that the maximum loads listed are not exceeded and the engine and handling plug are supported as described above. The two-position nozzle is shipped in a separate container and is to be installed at the vehicle site. Other handling frames must be used to install the engine with the extendible nozzle attached onto the Space Tug vehicle.

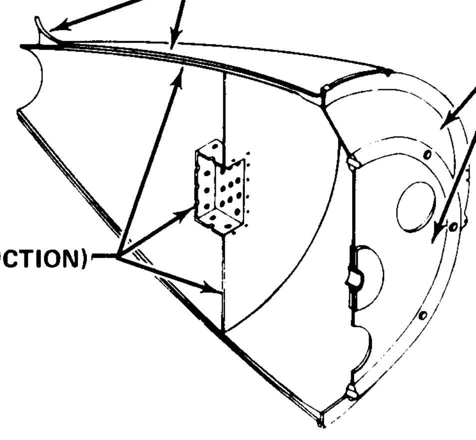


Figure G-1. Cutaway of Handling and Shipping Plug FD 66805

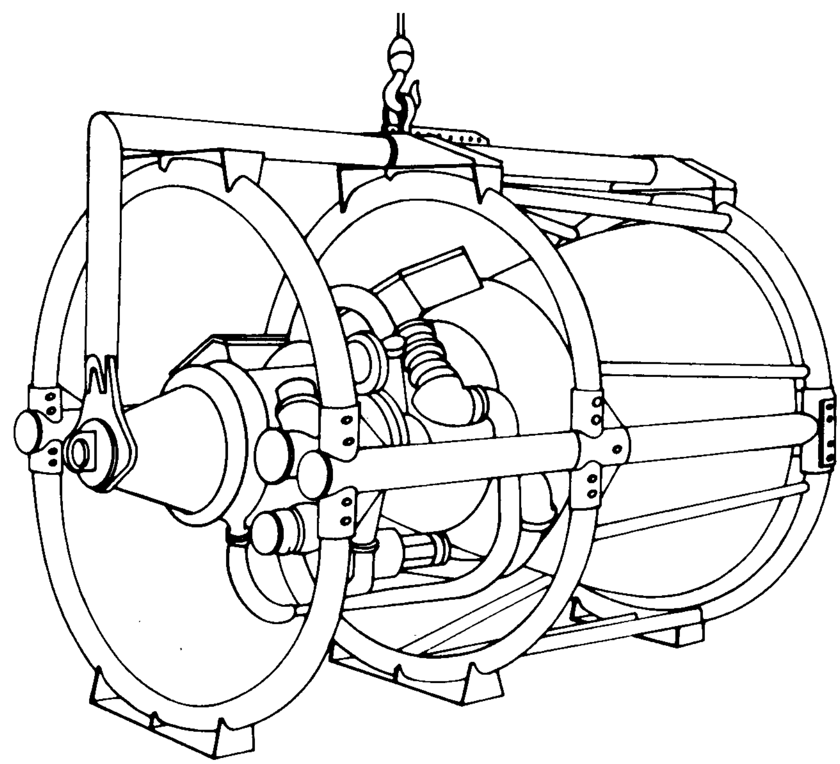


Figure G-2. Handling and Shipping Frame FD 66806

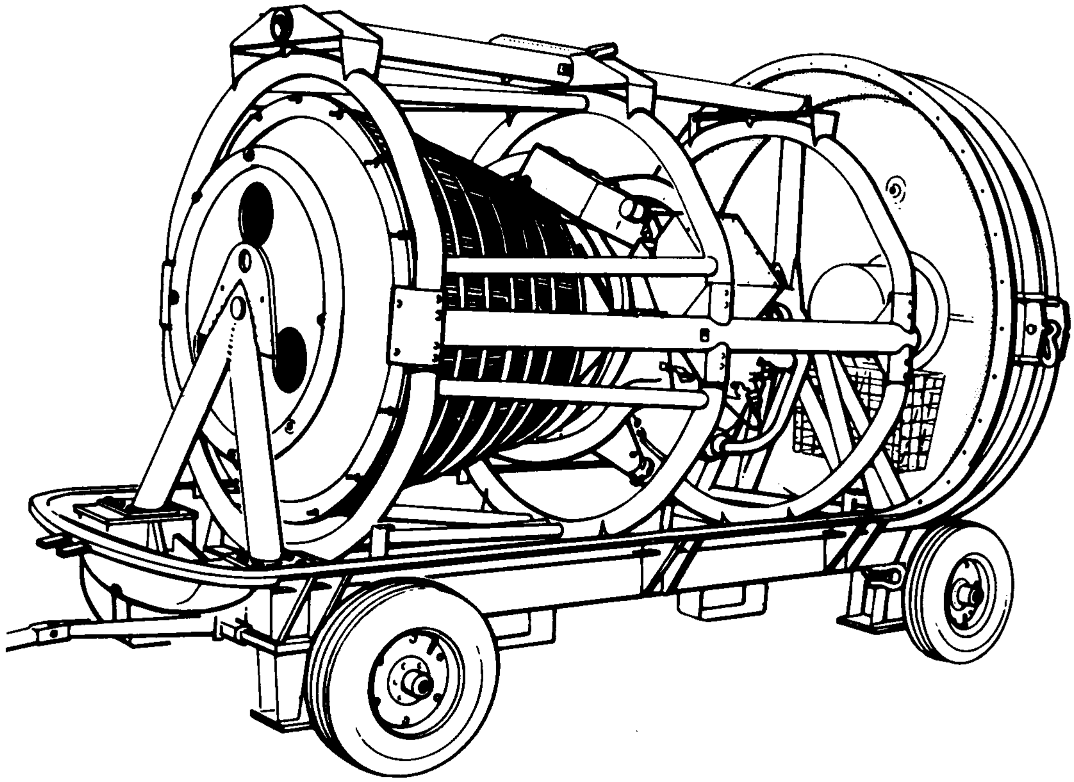


Figure G-3. Handling Plug, Frame, and Transporting Dolly FD 66807

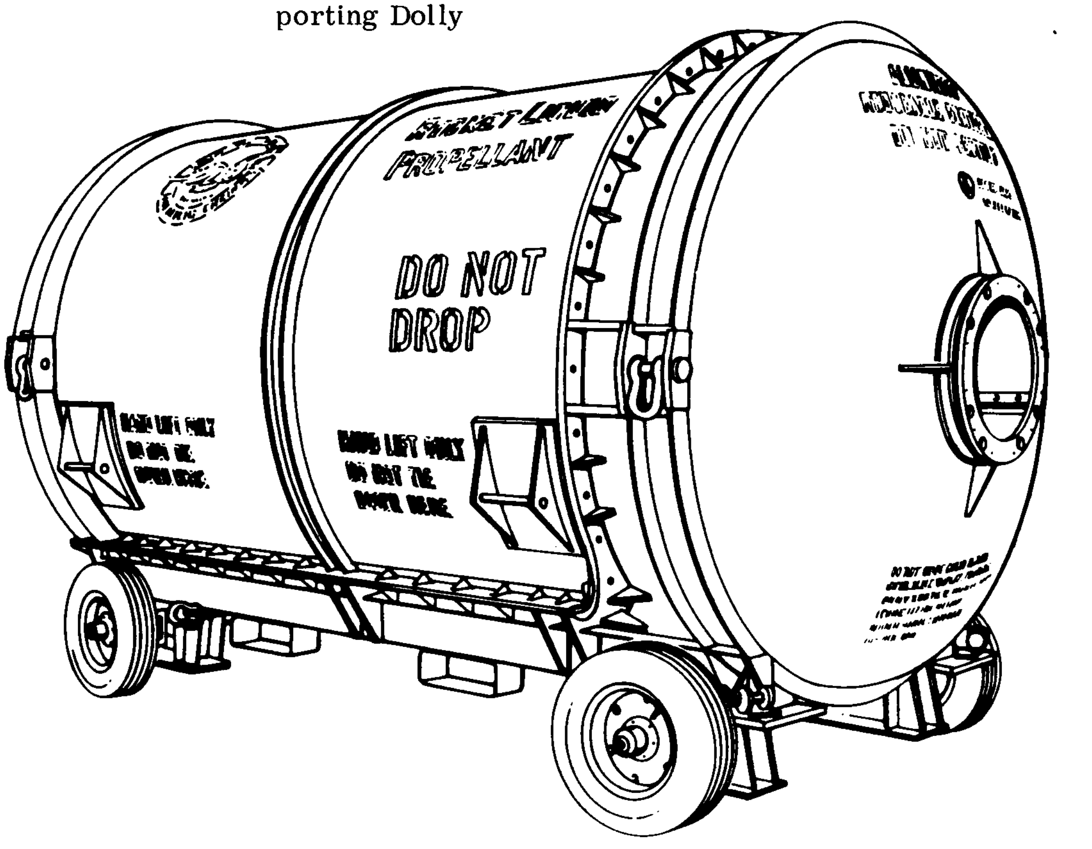


Figure G-4. Shipping Container FD 66808

SECTION H
FIELD SUPPORT

1. FIELD SERVICES

1.1 In-Plant Support

1.1.1 Support (Maintenance) Engineering Plan

The in-plant support engineering effort will be conducted in four different but integrated areas: Maintenance Planning, Human Engineering, Personnel Planning, and Field Service in-house technical support. Maintenance Planning accomplished by the Maintenance Engineering Group centers about the Maintenance Engineering Analysis which involves all the logistics elements. Members of the Personnel Training Group cover the Human Engineering and Personnel Planning tasks required to provide an effective and complete support program. The in-house element of the Field Service Group provides the technical support and liaison necessary to support the Field Service Representatives located at the operational site.

1.1.2 Maintenance Planning

The on-condition maintenance concept is recommended for the Space Tug Engine to provide a cost effective maintenance program. This concept embraces the philosophy of performing a maintenance action only when it has been determined necessary by diagnosis of the engine's operational parameters and mechanical condition.

The on-condition maintenance concept is supported by an onboard checkout and diagnostic system designed into the Space Tug. This diagnostic system provides for identification of discrepant Line Replaceable Units (LRU) to permit planning and accomplishment of unscheduled maintenance tasks within the Space Tug vehicle turnaround time cycle.

Effective maintenance planning also requires a system for accurate assessment of total maintenance requirements. The MEA process initiated concurrently with the Space Tug Engine design provides this discipline. During the early stages of the MEA process, Maintenance Significant Items (MSI's) are identified as candidates for MEA. An MSI is an item which, by its application or inherent characteristics, can be expected to require maintenance during normal operations or maintenance of the end item. The MSI's processed by the MEA are selected only after careful consideration has been given each item with respect to the economics of repair or discard.

The MEA performed repetitively throughout the Space Tug Engine life cycle will establish a firm maintenance concept, a maintenance plan, and will identify resources required to complete the maintenance cycle on each selected MSI. The maintenance plan for the engine will become the basis for operational predictions that indicate the frequency of scheduled and unscheduled maintenance and categories of scheduled maintenance tasks performed at the three levels of maintenance.

1.1.3 Human Engineering

Human Engineering provides man/machine compatibility through considering the skills, capabilities, and limitations of maintenance test and operating personnel. These considerations are included in Space Tug Engine design, tests, facilities, and GSE throughout the life of the program.

Human Engineering is that aspect of design that considers the capabilities and limitations of man. Some examples of Human Engineering include access and reach to Space Tug Engine components in relation to body dimensions and limb flections, "foolproofing" in hardware considering habit patterns and training of personnel, and design of components to prevent inadvertent exposure to hazards.

Human Engineering will be started with "over the shoulder" review of engine design in process and continues through formal design reviews and into the test program. The application of Human Engineering involves the use of standards, handbooks, checklists, and other guides to the designs in process. Data are supplemented by Human Engineering experience with other cryogenic hydrogen engines and turnaround experience with aircraft engines in use on commercial and military aircraft.

A review of designs under consideration gives an initial estimate of the operating and maintenance tasks as a basis for Human Engineering. System Engineering and ILS data provide additional review information in the form of reliability data, fault tree analyses, GSE, MEA, etc. The task requirements, proposed support equipment, facilities, and other data are compared with the capabilities of personnel to give an evaluation of designs and, if necessary, suggestions for changes. This review also provides inputs to the determination of training and personnel requirements.

The effectiveness of Human Engineering is verified through observations of the performance of tasks in relation to engine designs during Space Tug Engine development. The engine development program results in confirmation of design or the recommendation for revisions.

The Human Engineering effort is phased to the Space Tug Program to be most effective. Human Engineering will be started early in the program when design changes are most easily made. It will continue throughout the program to take into consideration design changes, test results, and MEA data.

This application of Human Engineering on a continuous basis and keyed to personnel requirements and training will provide a Space Tug Engine designed to be easily operated, tested, and maintained by assigned personnel.

1.1.4 Personnel Planning

Personnel Planning Data provides early requirements of skills and quantities of personnel on an incrementally phased scheduled basis. Utilizing ILS inputs, MEA, and pertinent incrementally phased program milestones, manpower and training requirements to support the maintenance and operation will be defined early to aid ILS management in personnel planning.

Definition of skills and quantities of manpower are necessary to ensure adequate lead time for planning the selection and training of the personnel required to support the maintenance and operation of the propulsion system GSE.

ILS elements such as Maintenance Engineering, GSE, Technical Publication, Service Records, and Personnel Training Groups provide data through the medium of the MEA.

These analyses will be started during initial design efforts to provide design influence and guidance relative to logistic support.

These early manpower estimates will provide personnel planning data for managing the manpower and training requirements. It allows early visibility to cross-check the projected manpower estimates against P&WA Engine maintenance manpower requirements during ground and flight test phases of the program. This cross-check will reflect the future requirements for changes in skills or quantities of potential engine contractor personnel to support the operational phases of the Program. The potential changes in skills provide visibility of specialized training requirements as derived from the Personnel Planning Data Analysis.

These early estimates are further refined and utilized for firm personnel requirements as the program evolves through the increments of Development, Test and Operational Phases. By utilizing the advancement of the MEA from the initial design development, through operational hardware, and integrating this MEA information with engine test and flight test data from Service Records, a current composite of data is always available for personnel and training analysis. This availability and use of data is planned to be accomplished progressively to ensure adequate manning and training to support all phases of the Space Tug Engine Program.

1.1.5 Technical Support

The in plant element of the Field Service Group provides technical support for Field Service Representatives based at the operational sites and serves as the primary line of technical communication between the sites and the plant. In addition to being in continual contact with the field, the in plant element monitors the technical program conducted in-plant to ensure proper consideration to field activities at all times.

1.2 Maintenance Engineering

The Maintenance Engineering Group operates under the direction of a Technical Administrator with authority and responsibility delegated to him by the Integrated Logistics Support (ILS) Manager. The Maintenance Engineering Group is responsible for the identification of Space Tug Engine maintenance requirements and the development of a maintenance plan to satisfy these requirements.

The Maintenance Engineering Analysis (MEA) Section of the Maintenance Engineering Group acquires data necessary to accomplish effective maintenance planning by interfacing with Systems Engineering, Design, and other ILS elements.

The MEA Section staffed with Maintenance Analysts, is responsible for coordinating and controlling MEA documentation. To accomplish this, the MEA Section must:

a. Acquire Maintainability and Reliability data inputs from Assurance Disciplines Group

b. Prepare initial MEA package for each selected Maintenance Significant Item (MSI)

c. Coordinate MEA data input with other ILS elements

d. Select MSI's requiring off-vehicle maintenance tasks

e. Establish a maintenance plan for each MSI

f. Coordinate revisions to the MEA

g. Prepare and publish an engine maintenance plan.

The Maintenance Engineering Analysis Section also will have the responsibility for coordinating maintenance activity and requirements with subcontractors and vendors and will impose upon them the MEA process.

1.3 Maintenance Engineering Analysis Process

To meet program objectives of (1) low cost reusability, (2) high launch rate, and (3) short turnaround and reaction times, P&WA will utilize the Maintenance Engineering Analysis process as the key element to logistics support planning for the Space Tug Engine and its supporting equipment. The MEA is a systematic and controlled process for analysis of the total logistics effort, for the assessment of controlled process for analysis of the total logistics effort, and for the assessment of engine and Ground Support Equipment maintainability design features to ensure that logistics support requirements are considered and integrated into the hardware designs. The MEA process also provides all elements of the Integrated Logistics Support organization with the necessary support engineering design data to allow early assessment of maintenance and servicing requirements, provide design guidance and identify and quantify all logistics support requirements. Logistics Support organization with the necessary support engineering design data to allow early assessment of maintenance and servicing requirements, provide design guidance and identify and quantify all logistics support requirements.

This MEA process was selected because it provides logistics support baseline requirements determinations, and it provides for cost effective implementation by utilizing existing internal system and procedures. Table H-1 provides MEA documentation guidelines for all aspects of the MEA process.

Table H-1. Maintenance Engineering Analysis Documentation

Exhibit	Title	Scope
	MEA Cover Sheet	Provides top sheet for engine part or assembly MEA including identity of next higher assembly, subordinate MEA's, MEA change record, and logistics support data.
I	Maintenance Plan	Provides maintenance concept for MSI and function.
II	Failure Analysis	Provides information pertaining to item reliability, effect of failure, and relation of maintenance actions.
III	Maintainability Analysis	Provides item maintainability characteristics and factors in relation to support of engine.
IV	Maintenance Requirements	Provides scheduled/unscheduled maintenance requirements at the three levels of maintenance.
V	Maintenance Tasks	Describes maintenance tasks sequence and personnel requirements; is basic outline for technical manuals.
VI	Time Line Analysis	Provides, in graphic form, the elapsed time relationship for complex maintenance items.
VII	Ground Support Equipment (GSE)	Identifies GSE required to accomplish maintenance requirements.
VIII	Provisioning Parts Breakdown	Provides part numbers for spares required to accomplish tasks on MEA subject item.
IX	Personnel Planning Data	Identifies personnel requirements by job title and skill level, and identifies work effort as a function of mission requirements.

Phase I of the MEA Program, initiated concurrently with the Space Tug Engine design, provides design guidance with emphasis on the selection and feasibility of design approaches by trade study analysis. The responsibility for incorporating maintainability and reliability features into the engine design is with the Maintainability Section of Development Engineering, assisted by the various elements of Integrated Logistics Support (ILS). Implementation of the MEA process early during the engine design phase yields the following results:

a. Incorporation of maintainability and reliability features into the engine design that are consistent with the on-condition maintenance concept

b. Determination of the maintenance concept, including maintenance task allocations for each Maintenance Significant Item (MSI)

c. Integration of MEA into the design process as an important design tool and a device for bridging any existing gaps in timing/scheduling and data flow between design and logistics support

d. Quantitative and qualitative definition of maintainability and reliability figures and maintenance tasks permitting detailed and accurate determinations of specific logistics support requirements, such as maintenance levels, spare parts required, maintenance intervals, elapsed task time, type and number of personnel required, and identification of GSE required

e. Traceability, accountability, and justification of requirements

f. Establishment of the MEA providing a trade study technique for evaluating performance/design changes

g. Establishment of the MEA as the procedure by which ILS elements are considered in design evaluation and design change procedures.

Maintenance requirements for scheduled and unscheduled action on a Maintenance Significant Item (MSI) are delineated on MEA forms or exhibits (shown on figure H-1) that provide a record that defines spare parts, GSE maintenance tasks, and personnel skills and levels required for each maintenance requirement. The MEA establishes a maintenance concept for each MSI and provides the method for allocating quantitative objectives to all functional subsystem levels. The maintenance concept describes the item, the function of the item, maintenance plan, and maintenance justification for the item early during the engine program.

Part I of Phase I of the MEA package originates in Design where reliability and maintainability data are entered into the applicable columns of the exhibits and the data cover sheet. These data will list all unscheduled maintenance tasks, estimates of maintenance man-hours for these tasks, mean time between maintenance actions, and failure analysis for each MSI. The MEA package is then processed for maintenance tasks analysis by the Maintenance Engineering Section where scheduled maintenance tasks data are entered. The input from the maintenance task analysis into the Maintenance Plan provides the basis for determining the level of maintenance for each MSI. The data generated by Phase I of the MEA provide other ILS elements with information necessary to implement the second phase of the MEA process.

Phase II of MEA provides data for determining quantitative and qualitative logistics requirements in the areas of GSE, spare parts, training, and technical publications during the operational phase of the Space Tug Program, as presented in table H-1.

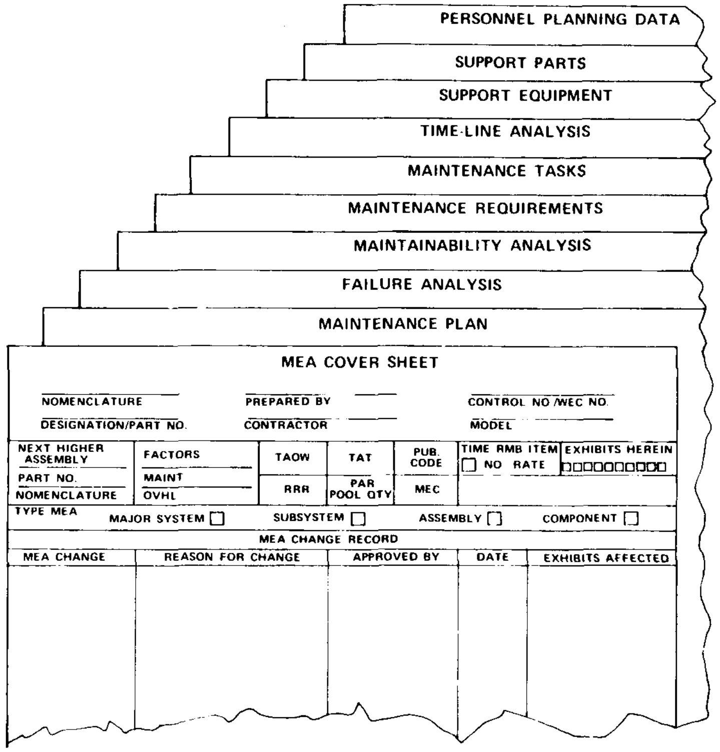


Figure H-1. Maintenance Engineering Analysis (MEA) Exhibits FD 48304

1.3.1 Maintenance Planning Requirements

During the later effort, preliminary MEA data (Part I, exhibits I-V) will be generated to support early logistics and maintenance planning requirements. Tables H-2 through H-7 present examples of the preliminary MEA documents for the Space Tug engine. The preliminary MEA documents will be processed as the engine design continues. Continuation of the MEA program during later phases will yield the following results:

a. Translation of maintenance requirements into detailed first, second and third level maintenance procedures in the form of maintenance manuals

b. Qualitative and quantitative personnel requirements information

c. Time line analyses for all maintenance functions

d. Further identification of GSE requirements

e. Definition of training and training equipment requirements

f. Establishment of discard lists, spares, and repair parts for provisioning recommendations and life cycle costing

g. Establishment of a formal system to integrate logistics requirements and analyses into design change (EC and ECP) activities and procedures

h. Early establishment of a data collection, analysis, and reporting system for the maintenance program, including data collection during preoperational support

i. An automated maintenance analysis and reporting system that will aid the NASA and engine and vehicle contractors in establishing and refining their maintenance programs.

Table H-2. LRU Maintenance Task Times (RL10 Space Tug Engine Maintenance Task Time List) FD 74153

RL10 SPACE TUG ENGINE MAINTENANCE TASK TIME LIST

		ENGINE CONFIG				MMH	MMH		TOTAL	TOTAL	
	COMPONENT	2A	2B	4	ML	TO REMV	TO INST	QUAL INSP	MMH R/R	ELAPD MMH	
1	FUEL INLET SHUT-OFF VALVE	X	X	X	1	0.14	0.23	0.08	0.45	0.45	
2	FUEL LOW SPEED INDUCER			X	1	0.30	0.68	0.17	1.15	1.15	
3	FUEL PUMP & TURBINE ASSY	X	X	X	2	0.65	1.57	0.50	2.72	1.61	(2 MEN)
4	FUEL TURBO PUMP			X	2	0.50	0.95	0.50	1.95	1.22	(2 MEN)
5	FUEL VENT VALVE	X	X		1	0.25	0.76	0.17	1.18	1.18	
6	MAIN FUEL SHUT-OFF VALVE	X	X		1	0.23	0.38	0.08	0.69	0.69	
7	TURBINE BYPASS VALVE	X	X		1	0.22	0.40	0.08	0.70	0.70	
8	FUEL TANK PRESSURIZING VALVE	X	X	X	1	0.03	0.13	0.08	0.24	0.24	
9	FUEL FLOW CONTROL VALVE			X	1	0.22	0.50	0.08	0.80	0.80	
10	OXIDIZER INLET SHUTOFF VALVE	X	X	X	1	0.14	0.23	0.08	0.45	0.45	
11	OXIDIZER LOW SPEED INDUCER	X		X	1	0.28	0.56	0.17	1.00	1.00	
12	OXIDIZER PUMP AND GEARDRIVE	X	X		2	0.65	1.53	0.50	2.68	1.59	(2 MEN)
13	OXIDIZER TURBO PUMP			X	2	0.35	1.03	0.50	1.88	1.19	(2 MEN)
14	OXIDIZER FLOW CONTROL VALVE	X	X	X	1	0.23	0.49	0.08	0.80	0.80	
15	OXIDIZER TANK PRESSZG VALVE	X	X	X	1	0.03	0.13	0.08	0.24	0.24	
16	GOX HEAT EXCHANGER	X	X	X	1	0.40	0.65	0.25	1.30	1.30	
17	GASEOUS OXIDIZER VALVE	X	X	X	1	0.12	0.23	0.08	0.43	0.43	
18	NOZZLE COOLANT VALVE	X	X	X	1	0.03	0.13	0.08	0.24	0.24	
19	THRUST CONTROL VALVE	X	X		1	0.10	0.37	0.08	0.55	0.55	
20	SOLENOIDS (4)	X	X	X	1	0.14	0.19	0.08	0.41	0.41	(PER UNIT)
21	IGNITION EXCITER (2)	X	X	X	1	0.06	0.17	0.08	0.31	0.31	(PER UNIT)
22	TORCH IGNITER	X	X	X	1	0.10	0.34	0.08	0.52	0.52	
23	THRUST CHAMBER/INJECTOR	X	X	X	3	2.70	5.80	1.50	10.00	5.75	(2 MEN)
24	EXTENDIBLE NOZZLE	X	X	X	2	0.52	0.63	0.17	1.32	0.74	(2 MEN)
25	EXTENDIBLE NOZZLE TRANS SYS	X	X	X	2	0.82	1.23	0.50	2.55	1.52	(2 MEN)
26	GIMBAL MOUNT	X	X	X	2	0.55	1.47	0.50	2.52	1.51	(2 MEN)
27	FLIGHT INSTRUMENTATION	X	X	X	1	0.73	1.35	0.75	2.83	1.79	(2 MEN)
28	ENGINE PLUMBING	X	X	X	1	1.30	3.50	0.50	5.30	2.90	(2 MEN)
29	TRANSDUCER BOX	X	X	X	1	0.27	0.56	0.25	1.08	1.08	

Table H-3. Sample Space Tug Engine Preliminary MEA Documentation

1\. **MEA COVER SHEET AND SUPPLEMENTAL DATA**

1a. QUANTITY PER NEXT HIGHER:

SYSTEM	SUBSYSTEM	ASSEMBLY	COMPONENT
1			

Engine - Space Tug
NOMENCLATURE

1234567
DESIGNATION/PART NO.

John Doe
PREPARED BY

DATE

PRATT & WHITNEY AIRCRAFT
CONTRACTOR

25000
MEA CONTROL NO.

Space Tug
MODEL

2. NEXT HIGHER ASSEMBLY PART NO. Space Shuttle NOMENCLATURE	3. FACTORS MAINTENANCE Refurbishment OVERHAUL	4. TIME ALLOWED OFF ENGINE (DAYS)	5. TURN AROUND TIME (DAYS)	6. MILITARY ESSENTIALITY CODE	7. TIME REMOVAL ITEM ☐ NO RATE/1000 ENGINE FLIGHT HOURS	8. TOTAL DIRECT MAINTENANCE MAN HOURS/ENGINE FLIGHT HOUR
		9. REWORK REMOVAL RATE (%)	10. OVERHAUL POOL QUANTITY	11. ROTATABLE POOL QUANTITY	12. EXHIBITS HEREIN I ☑ II ☑ III ☑ IV ☑ V ☑ VI ☐ VII ☐ VIII ☐ IX ☐ X ☐	
13. PROCUREMENT SPECIFICATION/DRAWING ☐ PROCESS SPEC DWG ____ ☐ PROCURE SPEC DWG ____ ☐ DESIGN SPEC DWG ____	14. RECOVERABILITY RB SYSTEM RECOVERY FACTOR	15. VENDORS CODE 21. CFE ☒ GFE ☐	16. UNIT COST 22. LEAD TIME	17. CUBE 23. WEIGHT	18. SHELF LIFE 24. PUBLICATION CODE	19. PUBLICATIONS AVAILABLE 20. PUBLICATIONS REQUIRED
25. REPAIR KIT REQUIRED/AVAILABLE ORGANIZATIONAL ☐ C ☐ F INTERMEDIATE ☐ C ☐ F ☐ D DEPOT ☐ C ☐ F ☐ D	26. ALLOWANCE & QUANTITY 7 8 9 10 11 12		27. MATERIAL IDENTIFICATION See Subordinate MEA's	28. SUPPORT EQUIPMENT APPROVED AVAIL. REQ. RECOMMENDED AVAIL. REQ.		29. TYPE MEA ☐ SYSTEM ☐ COMPONENT ☒ SUBSYSTEM ☐ PROCEDURAL ☐ ASSEMBLY

30\. MEA CHANGE RECORD

MEA CHANGE NO.	REASON FOR CHANGE	APPROVED BY	DATE	EXHIBITS AFFECTED

31\. COMPONENT PILOT REWORK/REPAIR CANDIDATE
REWORK ☐ YES ☐ NO
REPAIR ☐ YES ☐ NO

32\. TRAINING REQUIREMENTS

PERSONNEL	DEVICES
☐ NOT REQUIRED	☐
☐ LEVEL I	☐ MAINT. TRAINING
☐ LEVEL II	☐ FLIGHT TRAINING
☐ LEVEL III	☐ OTHER

33\. SUBORDINATE MEAS

MEA CONTROL NO.	NOMENCLATURE	GFE/CFE

34\. APPROVED BY DATE

COVER SHEET

MEA CONTROL NO. 25000
SHEET ___ OF ___

Table H-4. Sample Space Tug Engine Preliminary MEA Documentation

MAINTENANCE PLAN

1.

Engine Space Tug	John Doe	25000
NOMENCLATURE	PREPARED BY / DATE	MEA CONTROL NO.
1234567	Pratt & Whitney Aircraft	Space Tug
DESIGNATION/PART NO.	CONTRACTOR	MODEL

2. FUNCTION

The RL10 derivative rocket engine generates thrust for propelling the space tug vehicle.

3. MAINTENANCE PLAN

Level I accomplish inspections, both scheduled and unscheduled, review and interpret historical data. Remove & replace the engine and replace component parts allocated to Level I maintenance.

Level II remove, replace, repair, and refurbish the engine or components as required.

Level III refurbish the engine and component parts as required.

4. PLAN JUSTIFICATION (INCLUDE REASON FOR ANY "NO" ANSWERS IN BLOCK 3A)

All inspection points are accessible on installed engines. The engine and components can be replaced by Level I skills using available equipment.

Remove, repair, refurbish, and replace those items beyond the capability of Level I maintenance.

Equipment and skills required to refurbish the engine and components are not authorized for lower level maintenance activities.

3A. COMPATIBILITY - DOES THIS PLAN SUPPORT:

THE MAINTENANCE PLAN FOR THE NEXT HIGHER ASEMBLY? YES ☒ NO ☐

THE MAINTENANCE CONCEPT FOR THE CONTRACT END ITEM? YES ☒ NO ☐

5. APPROVED BY	DATE	6. SOURCE/MAINTENANCE/RECOVERABILITY CODE					

MEA CONTROL NO. 25000

SHEET ___ OF ___

MEA EXHIBIT I

Table H-5. Sample Space Tug Engine Preliminary MEA Documentation

1.

FAILURE ANALYSIS

Engine Space Tug	John Doe	25000
NOMENCLATURE	PREPARED BY — DATE	CONTROL NO./WUC NO
	PRATT & WHITNEY AIRCRAFT	Space Tug
DESIGNATION/PART NO.	CONTRACTOR	MODEL

2. MEC

MISSION		REDUNDANCY		ALTERNATIVES	
TOTAL	(2) ☐	NONE	(2) ☐	NONE	(2) ☐
PARTIAL	(1) ☐	SOME	(1) ☐	SOME	(1) ☐
NONE	(0) ☐	COMPLETE	(0) ☐	EQUIV.	(0) ☐

3. PROBABLE MODES OF FAILURE OR DEGRADED OPERATION

4. PROBABLE RESULTS OF FAILURE OR DEGRADED OPERATION

5. FAIL SAFE CHARACTERISTICS

6. SECONDARY SYSTEM

7. FAILURE HISTORY

8. OPERATING DATA

TOTAL OPERATING TO FLIGHT TIME RATIO (T O /F T) ______

TIME BETWEEN REFURBISHMENT 5

STARTS BETWEEN REFURBISHMENT 190

9. RELIABILITY RATES

MTBF		MTBMA	
ALLOCATED	______	ALLOCATED	______
PREDICTED	______	PREDICTED	______
MEASURED	______	MEASURED	______

10. APPROVED BY: ______ DATE ______

MEA EXHIBIT II

CONTROL NO. 25000

SHEET ______ OF ______

Table H-6. Sample Space Tug Engine Preliminary MEA Documentation

1.

MAINTENANCE TASKS

ENGINE - SPACE TUG	JOHN DOE	3-24-71	25000
NOMENCLATURE	PREPARED BY	DATE	MEA CONTROL NO.
	Pratt & Whitney Aircraft		SPACE TUG
DESIGNATION/PART NO.	CONTRACTOR		MODEL

2. TASK NO.	3. TASK	4. WORK AREA	5. ELAPSED TASK TIME MINS	6. OPTIONAL MEN	MINS

7. APPROVED BY	DATE

MEA EXHIBIT V

MEA CONTROL NO. 25000
SHEET ___ OF ___

Table H-7. Sample Space Tug Engine Preliminary MEA Documentation

1. MAINTAINABILITY ANALYSIS

Engine - Space Tug NOMENCLATURE	John Doe PREPARED BY / DATE	25000 MEA CONTROL NO.
1234567 DESIGNATION/PART NO.	Pratt & Whitney Aircraft CONTRACTOR	Space Tug MODEL

2. MAINTAINABILITY VALUES

	MEAN TIME TO REPAIR	MEAN DIRECT EFFORT TO REPAIR	MEAN TIME BETWEEN MAINTENANCE ACTION	MEAN DOWN TIME/ ENGINE FLIGHT HR	DIRECT MAINTENANCE EFFORT/ENG FLT HR
ALLOCATED					
PREDICTED					
MEASURED					

3. FAVORABLE FACTORS

The engine diagnostic features provide rapid assessment of maintenance requirements. All valves, plumbing, and most pump components are readily replaced by Level I maintenance facilities.

4. ADVERSE FACTORS

The fuel & oxidizer systems will require purging prior to maintenance.

5. NEW OR ADDITIONAL SKILL REQUIREMENTS

TBD

6. NEW OR ADDITIONAL TRAINING REQUIREMENTS

TBD

7. PECULIAR TOOL, TEST OR SUPPORT EQUIPMENT REQUIREMENTS

Purging & leak check equipment

8. COST RESTRAINT OR INFLUENCES

TBD

9. APPROVED BY ____ DATE ____

MEA EXHIBIT III

MEA CONTROL NO. 25000
SHEET ___ OF ___

The completed MEA package is reviewed for data requirements by the Maintenance Engineering Group and submitted to the ILS Scheduling and Control Center for transmittal to the vehicle contractors and the Government as required.

1.4 Utilization of MEA for Personnel Planning

MEA are the prime source of preliminary data used in personnel planning. Development of MEA is through P&WA procedures involving Systems Engineering and ILS elements. Personnel planning factors are extracted from the MEA's, analyzed, and converted to quantitative and qualitative personnel planning data.

The use of the MEA's provides an effective method in compiling personnel planning data. Tasks, task times, quantities of personnel, and skills of personnel, are derived from the MEA's. These data, when evaluated against the maintenance plan, provide analytical personnel requirements relative to the maintenance and operational concept.

Using P&WA System Engineering procedures, the Human Engineer reviews preliminary design layouts for compatibility of man to effectively operate and maintain the Space Tug. After layout review the Human Engineer accepts the man/machine interface or submits his finding to Project Management on a Maintenance Evaluation Proposal (MEP) for project review and action or trade studies. Concurrently with or immediately subsequent to the Human Engineering review of design, the Maintainability section provides input to Part I of the MEA exhibits. Part I and Part II of these exhibits are then completed by the ILS elements of Maintenance Engineering, Personnel/Training, and Ground Support Equipment Groups. Each ILS element prepares input after careful analysis of the exhibits as they pertain to the design and the ILS element specific field of responsibility. The Personnel Planning Group utilizes ILS elements inputs that directly affect the skills or quantities of personnel required to operate or maintain the Space Tug Engine or GSE.

The Personnel Planning Group uses specific data such as task descriptions, task times, complexity of tasks, criticality of tasks (tasks when performed incorrectly could cause several degrees of mission failure) to evaluate the skills needed to perform the operational or maintenance actions required to support the Space Tug Engine. Maintenance factors as derived from the Maintenance Plan involve scheduled, unscheduled maintenance, levels of maintenance where maintenance will be performed, and any operational or maintenance direction that may be imposed by NASA. These specific personnel planning factors, when utilized with reliability data found in the MEA's provide necessary information to compile and formulate the quantitative personnel needed to support the maintenance and operation of the Space Tug Engine.

These projected estimates of skills and quantities of manpower will be evaluated against P&WA personnel that will be used in support of the Space Tug Engine ground and flight test phases. The resultant findings will substantiate personnel training recommendations for skill and quantities of manpower. These manpower projections will be available early enough in the program to aid management in planning for acquisition and training of manpower to support the operational phase of the Space Tug Engine Program.

1.5 Inhouse Technical Support

The Field Service Group will provide inhouse technical support for onsite Field Representatives to ensure accurate and rapid response on technical matters related to engine and GSE operation and maintenance. This technical support includes coordination effort for Operations and Flight Support in the logistics area and Space Tug Engine and GSE and deficiency reporting for anomaly resolution.

The inhouse Support Group is comprised of specialists for various parts of the engine, such as turbomachinery, combustion system, and avionics. This group is familiar with onsite logistical support activities, and their prime concern is to support the man in the field. By providing this inhouse support, the operational site's requirements are recognized and satisfied, and at the same time P&WA is kept informed of operational progress.

1.5.1 Inhouse Support Group

The inhouse Support Group is the basic line of communication on technical matters between the field activities and P&WA. Depending on the severity of the situation, all means of communications are utilized to transmit data and other vital information to and from personnel in the field. Services provided to personnel in the field include the following:

a. Resolutions for unique Space Tug/GSE problems requiring engineering review

b. Latest technical manuals and other technical literature affecting Space Tug Engine/GSE operation and maintenance

c. Latest information on Space Tug Engine/GSE configuration brought about by engineering changes or repair actions accomplished at P&WA or vendor facilities

d. Availability of Space Tug Engine/GSE spares that might have an impact on the operations being conducted at the site

e. Deliveries status of engines, GSE, and reparables for planning purposes

f. Analysis of parts returned from the field for investigation to assist field personnel in future diagnostic evaluations.

1.5.2 Inhouse Field Service Group

All technical activities occurring at field sites are reported through the inhouse Field Service Group. These communications result in action accomplished by the inhouse Support Group. Such actions include the following:

a. Technical analyses by the Field Service Inhouse Support Group

b. Engineering reviews to provide analysis and solution for anomalies

c. Distribution of field communications to Program Management, Development, Design, and other ILS elements

d. Conduct field problem liaison with Space Tug Engine Program and functional groups such as Engineering and Quality Assurance

e. Review and approve Engineering Change Proposals, Service Bulletins, Technical Publications/Manuals, and Manual Change Notices

f. Provide M/R Technical Administrator with technical information of configuration status of material received in the M/R Program

g. Coordinate with Quality Assurance, Maintainability, Safety, and Reliability groups on any and all discrepant material affecting the operation or maintenance of the SSME

h. Assist Spare Parts group by making recommendations for spare/repair parts provisioning

i. Conduct liaison with P&WA vendors relative to the operation and maintenance of their products

j. Periodically visit sites and vendor facilities to assess problem areas and to gain better insight for problem evaluation and resolution.

Vendor supplied items receive the same inhouse support as does the engine and GSE. The Field Service Inhouse Support Group performs close liaison services with a vendor's support of this equipment. This liaison service will result in providing the following:

a. Resolution of problems on equipment by direct contact with the vendor

b. Spares and reparable items status on equipment maintained by the vendor

c. Vendor item configuration and technical data resulting from engineering changes and repair actions performed at vendor facility

d. Vendor personnel requirements necessary for supporting equipment at sites.

2. SERVICE RECORDS PLAN

2.1 General

The Service Records Group functions as an element of the ILS organization to provide records of the technical support documentation for the Space Tug Engine. It supports the ILS organization and other program elements by acquiring and storing technical support documentation data for retrieval and analysis. The group also supports Configuration Control and Data Management by performing the tasks of Configuration Status Accounting and Maintenance Data Reporting. The Service Records reporting system operates through an existing data feedback network established on previous programs, to be adapted and modified as necessary to meet the requirements of the Space Tug Engine Program.

The P&WA Space Tug Engine Program will utilize the systems and services of the Service Records Group in support of status accounting and collection of historical engine operating data supplied by the ILS elements. Using experience from previous military and commercial engine programs, the Service Records Group will establish a comprehensive data bank to provide a firm base for developing dependable records. Such records are required to provide baseline configuration status, traceability, and visibility required for configuration management and control of CEI's in the inventory. Once the baseline Engine Parts List (EPL) has been incorporated in the records system, it will be maintained. This information will be stored on magnetic tapes in the data bank and retrieved in customized reports which will provide Space Tug Engine Program management the means of assessing and evaluating the program status. Complete traceability through configuration status accounting and rapid analysis of field data feedback provides additional program visibility.

2.2 Records Data Bank Input and Feedback Network

P&WA will utilize existing data input and feedback systems that are performing effectively on current programs to establish a data bank for the Space Tug Engine. These systems will be modified and expanded as required to meet specific program requirements. This data input and feedback system interfaces with other P&WA organizational functions which contribute support documentation into and receive feedback information from the Service Records data bank.

The initial baseline documentation inputs will be supplemented as data are generated during the program to keep the data bank current with the evolving engine and GSE equipment. These data will include, but not be limited to, the following:

a. Engine/Ground Support Equipment (GSE) Bill-of-Material
b. Specification Change Notices (SCN)
c. Engineering Changes/Engineering Change Proposals
d. Updated Engine/GSE Parts List
e. Service Bulletins/Modification Instructions
f. Spare Parts Status
g. Engineering Releases
h. Field Service Representative Reports
i. Engine Operations/Flight Support Data
j. Manufacturing/Overhaul/Field Level Maintenance Data
k. Projected Removals and Engine Status System (PRESS) Data
l. Maintenance Engineering Analysis (MEA) Data.

2.3 Service Records Reporting

The recurring reports evolving from the computerized data retrieval process are classified into the following categories: Configuration Status Accounting, Maintenance Data Reporting, and Projected Removals and Engine Status System (PRESS).

2.3.1 Configuration Status Accounting

The configuration identification records data are the basis for configuration control, configuration status accounting and recording. Configuration identification procedures and requirements will be applied to the Space Tug Engine Program to effectively implement and control configuration and status accounting. Configuration identification records will be maintained throughout the life cycle of each component. These records must include all configuration identification beginning with the baseline documents and reflect changes in the baseline resulting from ECP's and approved EC's to those baselines.

Configuration identification records and data provided by Configuration Control include:

a. All Specifications, Specification Control Drawings

b. The Specification Index

c. Specification Change Logs and Configuration Charts

d. Parts Lists - Drawing Releases

e. Bill-of-Material

f. Interface Control Documents (ICD) and Associated Drawings

g. Maintenance Engineering Analysis (MEA) Data

h. Consolidated GSE List

i. Engineering Change Proposals (ECP's) and Released Engineering Changes (EC's).

The Configuration Status Accounting report provides configuration control the following information:

a. Index of ECP's/EC's
b. List of applicable CEI serial numbers
c. Service Bulletin/Modification Instruction/CEI Application
d. Critical components by serial number
e. Status of EC's incorporated on production units
f. Modification kit incorporation status for all levels of maintenance.

2.3.2 Maintenance Data Reporting

Maintenance data reports are published in the form of summaries and computerized printouts for the Space Tug Engine and GSE. These reports provide information pertaining to operating time/starts/cycles on engine and components. In addition, Engine Maintenance Actions (EMA), inflight and post-flight anomalies and their resolutions on engines and components are reported for maintenance planning and engineering followup actions. Maintenance Engineering Analysis (MEA) type data are available for NASA/Vehicle Contractor interfacing requirements through an EDP program, formulated for a computer.

The Maintainability/Reliability Groups will use Configuration Status Reports, and Maintenance Data Reports for conducting maintainability/reliability analysis, trade studies and for updating program math models. In addition, these reports will be used for updating the Design Checklists for Maintainability/Reliability.

2.3.3 Projected Removals and Engine Status System (PRESS)

While providing Configuration Control with configuration status accounting capability, the Service Records Group will also provide management with pertinent engine data for program planning through the PRESS effort.

PRESS is a computerized program developed by Pratt & Whitney Aircraft to provide a management tool for forecasting maintenance, and spare engine requirements. This system, through analysis of vehicle and engine delivery schedules, engine historical data and vehicle utilization rates, simulates the specified flight program, and forecasts scheduled and unscheduled maintenance actions and availability of spare engines on a time-phased basis over the total flight program. Engine operating historical data from previous engine programs will be compiled into engine removal rates that can be adjusted for the engine to be studied. This adjustment is based on a comparison of reliability factors, exposure to hazards, operating environment, etc., between the engine to be studied and the engine from which were acquired historical data.

The PRESS computer program was designed around factors for reusable gas turbine engines. The following major items will be considered in adapting PRESS to the requirements of the Space Tug Engine:

a. Engine chargeable/nonchargeable removal ratio peculiar to the Space Tug Engine

b. Utilization rates

c. Space Tug Engine operating environment

d. Space Tug Engine design concept and operating cycle.

The system will also be utilized for Major Engine Components for which a utilization profile, scheduled maintenance intervals and repair cycle times can be provided.

- Inputs to the PRESS program include:

  a. Vehicle delivery dates
  b. Engine delivery dates
  c. Engine historical data

     (1) Premature engine removal hours (failure rates)

     (2) Disposition percentages (percent of removals to be sent to overhaul/refurbishment and field level repair)

     (3) Flow times (turnaround times for engines at each of the above locations)

     (4) Time between refurbishment (TBR).

  d. Vehicle utilization rates
  e. Vehicle deployment (location)
  f. Planned inspection/refurbishment schedules.

- Outputs from the PRESS program will include:

  a. Scheduled and unscheduled engine removal rates
  b. Scheduled and unscheduled engine maintenance rates
  c. Scheduled shop visits for periodic/phase inspections
  d. Unscheduled shop visits
  e. Availability of usable spare engines.

2.3.4 Technical Publications

The objective of the Technical Publications plan will be to provide the Space Tug Engine technical publications required to support the Operational and Flight Support Plan. In addition to printed manuals, other methods of data distribution appear desirable and will be considered. Such techniques as microfilm, videotape, taped voice instructions, and direct printout or visual display of computerized data will be reviewed for utilization.

Data retrieval capability for Technical Publications will be provided by the Product Support Data Base (PSDB) and the Engineering Base Information System (EBIS). These data bases are the major sources of information on engineering changes, part numbers, engine model configuration, materials, and ground support equipment. Both cathode ray tube (CRT) display devices and printers are available at terminals located within P&WA for instant access by writers and catalogers.

The Administrative Terminal System (ATS) will provide automatic composition. A compositor enters the rough draft of a manual into the ATS through one of several terminals, making it part of the computer memory. Entry of parts list is by key punching from code sheets prepared by catalogers. After storage and updating, a final reproducible copy may be automatically printed out as required on a high-speed printer.

The Publications Accounting Record (PAR) System is an established tracking tool for comparing actual versus estimated costs. Man-hours for each task are reported against project numbers by functional personnel. The PAR System will provide accurate cost data for each of the proposed publications on an incremental basis.

2.3.4.1 Technical Manual Program

The selection of publications proposed for the Space Tug Engine is based upon the experience gained from previous reusable engine and space program support. This experience is modified and tailored to the specific requirements of the Space Tug Program.

The manuals recommended to support the main engine, accessories, and Ground Support Equipment (GSE) in service are:

a. Service Manual
b. Installation Handbook
c. Refurbishment Manual
d. Spare Parts Manual.

3. ONSITE SUPPORT

The Field Service Group will provide all onsite logistical support for the Space Tug Engine and GSE including technical assistance, site P&WA liaison, support parts warehousing and inventory controls. This effort will be under the control of the Onsite Senior Field Service Representative.

The P&WA onsite operations team, under the direction of the P&WA Site Manager, will perform or participate in the following functions:

a. Perform interface actions with counterparts in the NASA and Vehicle Contractor in the area of logistics and operations and coordinate all such actions through the P&WA Site Manager

b. Perform field level modification, limited repair and maintenance on the Space Tug Program and GSE that fall within the concept of first and second level maintenance tasks

c. Provide the necessary type and quantity of maintenance personnel, inspectors, and equipment to assist the vehicle contractor in the installation, checkout, and operation of the Space Tug Engine. This includes providing technical advice and on-the-job-training as necessary

d. Aid in performing removal, repair, and replacement of Space Tug Engine and GSE Line Replaceable Units (LRU's) in accordance with documentation approved by the NASA and the vehicle contractor

e. Participate in engine/vehicle planning and scheduling of maintenance and operations involving the Space Tug and evaluate engine performance as necessary.

4. TRAINING

4.1 Summary

The engine training plan will be constructed to provide a comprehensive program of training for all engine oriented program personnel, customized to meet the training requirements of all related engine tasks. It will prepare personnel to meet their respective task interfaces with the engine on a timely basis. It will be designed to minimize human error element at all engine task interfaces.

SECTION I
MAINTENANCE AND REFURBISHMENT

1. SUMMARY

Pratt & Whitney Aircraft will perform maintenance and refurbishment on the Space Tug and Ground Support Equipment by utilizing tooling, facilities and personnel resources that are common to the development and production programs. The Maintenance and Refurbishment (M&R) Program will be accomplished through the coordinated effort of the Space Tug Program Management and the P&WA functional departments. The M&R capability will be established during the initial phase of the operational program and will be available as required through the life of the Space Tug.

Program Management provides guidance and direction through an M&R Technical Administrator for processing M&R items. The Technical Administrator receives his responsibility and authority from the ILS Manager. Engineering Orders (EO's) and Delivery Orders (DO's) are utilized for coordinating the efforts required to satisfy the M&R requirements which include, but are not limited to, the following functions:

a. Scheduling of material processed in the M&R Program
b. Ensuring availability of spare repair parts
c. Vendor participation in the M&R effort
d. Shop capacity loading at the M&R facility
e. M&R procedure and policy establishment.

The P&WA Delivery Engine Group is responsible for directing tasks during the M&R Program, which include those tasks performed at P&WA-operated facilities and vendor facilities. All work accomplished at vendor facilities is controlled by Purchase Orders and is monitored by the Delivery Engine Group. An M&R Board consisting of NASA and P&WA personnel will be created to provide guidance and direction for processing material during the M&R Program.

Planning, scheduling, and reporting of material processed during the Program will be accomplished through the combined efforts of the ILS Groups and the Delivery Engine Group.

Part of the reporting function during the M&R Program is to maintain Space Tug and GSE configuration data. This reporting function is accomplished by the Service Records Group. Configuration records during the M&R Program encompass the complete Space Tug, assemblies, components, and parts. Material received into the program is documented, and any changes in configuration during the process are documented and stored in the service records data bank.

P&WA will be responsible for the tasks accomplished at vendor facilities. This control is applied through Delivery Order and Purchase Order systems. All vendors are responsible for adherence to the specifications and performance standards as applied to P&WA.

Cost effectiveness in the Program results from properly utilized resources in performing M&R functions and production facilities, personnel and tooling common to those used in the Development Programs. Shop capacity at the FRDC facility and vendor facilities will be able simultaneously to accommodate the production and M&R processing of material, eliminating the need for duplication of personnel, equipment and facilities.

Costly experimentation in procedures and practices is effectively eliminated by utilization of procedures and practices in the Space Tug Program that have proven successful in existing M&R programs, such as the F100/F401 and J58. These procedures and practices apply to the performance of the tasks by the functional organizations and the parallel flow of material and associated records that accompany the material. Included in these procedures and practices is the function of management of Government Furnished Material. P&WA plans to assume warehousing responsibility of Government furnished material that is to be consumed during the M&R Program with inventory levels managed by the Spare Parts Group. This plan covers Government Furnished Equipment located at all manufacturing facilities, including vendor facilities.

2. ORGANIZATION

The Space Tug Delivery Engine Group will control, administer, and perform the refurbishment function on the Space Tug and GSE at the P&WA and vendor facilities. The maintenance/refurbishment capacity will be established early in the operational phase of the program and will be maintained throughout the life of the Space Tug. Preparations for establishment of this capability are to be started during the Development/Production Program since utilization of resources is common to both.

Coordinating with the Delivery Engine Group is a Maintenance/Refurbishment Technical Administrator who receives his authority from and is responsible to the ILS Manager. Using Engineering Orders/Supplements (EO and EOS) and Delivery Orders/Supplements (DO and DOS) as the controlling documents for accomplishing overhaul and refurbishment actions the M&R Technical Administrator performs the following duties and responsibilities:

a. Schedule Space Tug and GSE maintenance into the M&R cycle through coordination with other ILS elements and the Delivery Engine Group

b. Assist in work flow and shop capacity studies by supplying the data on incoming material

c. Provide engine, component, and parts configurations on incoming items, and define and document the desired configuration of the item undergoing the M&R process

d. Participate in material assessment and disposition recommendations

e. Monitor the M&R process to ensure the customer's requirements are recognized and satisfied by providing followup on given instructions for repair and incorporation of engineering changes

f. Provide necessary input for controlling the overhaul and refurbishment accomplished at vendor facilities through Delivery Orders/Supplements.

The Delivery Engine Group will utilize their manufacturing, assembly, test and quality assurance organizations to perform the maintenance/refurbishment process. These services are the same as provided to the engine Production Programs. The Delivery Engine Group will control the M&R Program being performed at vendor facilities by monitoring the performance as specified on vendor PO's issued by the Purchasing Department.

3. MAINTENANCE AND REFURBISHMENT

3.1 General

The RL10 derivative engines are designed to have a minimum of maintenance, called on-condition maintenance, that requires work to be accomplished only as required on installed engines. The service life starts are major factors in determining the maintenance plan for these engines. The anticipated times between refurbishment (TBR) for the various category engines are shown in table I-1. As experience is gained, the service life of limiting components will increase in much the same fashion as current commercial jet engine TBR's are extended.

Table I-1. Times Between Refurbishment

Category	TBR, hr	Starts	Periodic/Phase Inspection
IIA	5*	190*	Approximately every 1.2 hours run duration and/or 47 starts
IIB	5*	190*	Approximately every 1.2 hours run duration and/or 47 starts
IV	10*	300*	Approximately every 2 hours run duration and/or 60 starts

*Tank head idle running counts as a start but the time does not count against TBR. Rotating idle running counts as TBR time and starts.

The maintenance plan for the RL10 derivative engines is based on the following key elements:

a. High operational reliability

b. Internal inspection of critical areas without disassembly

c. Simplified component replacement

d. Continuous data assimilation and review

e. Use of ground support equipment that has been verified in use during engine development and manufacturing processes

f. An overall maintenance plan designed to ensure safe vehicle operation with the minimum effort and cost between missions.

4. MAINTENANCE LEVELS

Level "O" is where the Space Tug Engine is installed on the Tug vehicle and when the docking adapter is installed. No maintenance task can be performed on the engine at this level.

Maintenance task requirements analysis indicates the need for three levels of engine maintenance to support the Space Tug vehicle. The first level will be carried out when the Tug is out of the shuttle payload bay, in the maintenance area, with its docking adapter removed and the engine nozzle extension extended. The second level will be accomplished with the engine removed from the Tug vehicle and in an area on the operational site equipped to handle engine and components requiring special inspection, replacement, minor repair, and bench testing. The third level will be used for refurbishment and major repair requirements and because of the need for special skills, tools, equipment, and test facilities, this level will be accomplished at the P&WA Florida Research and Development Center. Specific actions necessary to revert the engine and components operating time to zero will be determined during the engine development program. The maintenance activity assigned to each maintenance level is consistent with Pratt & Whitney Aircraft's policy of grouping the maximum number possible of maintenance tasks at the lowest maintenance level. These assignments are as follows:

FIRST LEVEL

- Preflight checkout
- Postflight checkout
- Periodic/Phase inspection of the engine
- Engine installation and removal
- Replacement of engine and components (LRU's)
- Fault isolation
- Special inspection

SECOND LEVEL

- Periodic/Phase inspection of the engine
- Replacement of LRU components
- Selected LRU repair
- Modification and updating engine
- Special inspection

THIRD LEVEL

- Refurbishment/Repair complete engine
- Refurbishment/Repair major subassemblies
- Refurbishment/Repair of engine components
- Engine component, and major subassemblies testing
- Engine test, refurbishment and repair verification

During the engine development program the maintenance tasks levels indicated will be reviewed periodically with the objective of moving as many as possible to lower levels to reduce cost and down time.

5. ENGINE INSTRUMENTATION REQUIREMENTS

Table I-2 provides instrumentation required to ascertain the performance of the Space Tug engine. Selected parameters from this list must be fed to the Tug Onboard Checkout System (OCS) for mission readiness checks. The other parameters must be recorded for performance evaluation and maintenance requirements review.

Table I-2. Engine Instrumentation Requirements

	Derivative		Category
	IIA	IIB	IV
Recommended Engine Supplied			
Fuel Pump Housing Temperature	X	X	X
Fuel Pump Discharge Pressure	X	X	X
Oxidizer Pump Housing Temperature	X	X	X
Oxidizer Pump Discharge Pressure	X	X	X
Oxidizer Pump Rotational Speed	X	X	X
Thrust Chamber Coolant Discharge Temperature	X	X	X
Chamber Pressure	X	X	X
Low Range Chamber Pressure	X	X	X
Ignition Exciter Voltage	X	X	X
Thrust Control Valve Position	X	X	X
Voltage at the Solenoid Valves	X	X	X
Nozzle Extension Contact Switches	X	X	X
Gearbox Vibration Accelerometers	X	X	X
Recommended Vehicle Supplied			
Fuel Pump Inlet Temperature	X	X	X
Fuel Pump Inlet Pressure	X	X	X
Oxidizer Pump Inlet Temperature	X	X	X
Oxidizer Pump Inlet Pressure	X	X	X
Propellant Utilization Valve Required Angle	X	X	X
Helium Supply Pressure	X	X	X
Vehicle Supply Voltage	X	X	X

The Tug Vehicle Onboard Checkout System (OCS) is shown in figure I-1. The OCS is primarily responsible for inflight checkout of the Tug after separation from the Orbiter. However, its capability to perform checkout functions will be used to assist the Payload Checkout System (PCS) and Launch Processing System (LPS) in performing their tasks. The PCS or LPS will activate the OCS to perform a specific function and then will monitor the results. Control of the entire sequence will remain with the manned system, but individual tasks will be automatically accomplished by the OCS.

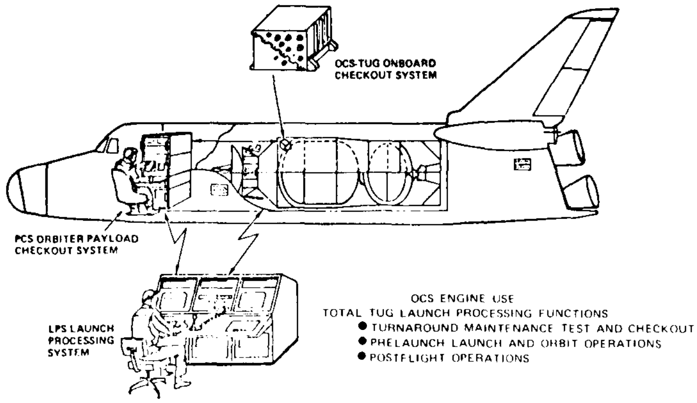


Figure I-1. Tug Onboard Checkout System FD 75257

6. ENGINE MAINTENANCE PLAN

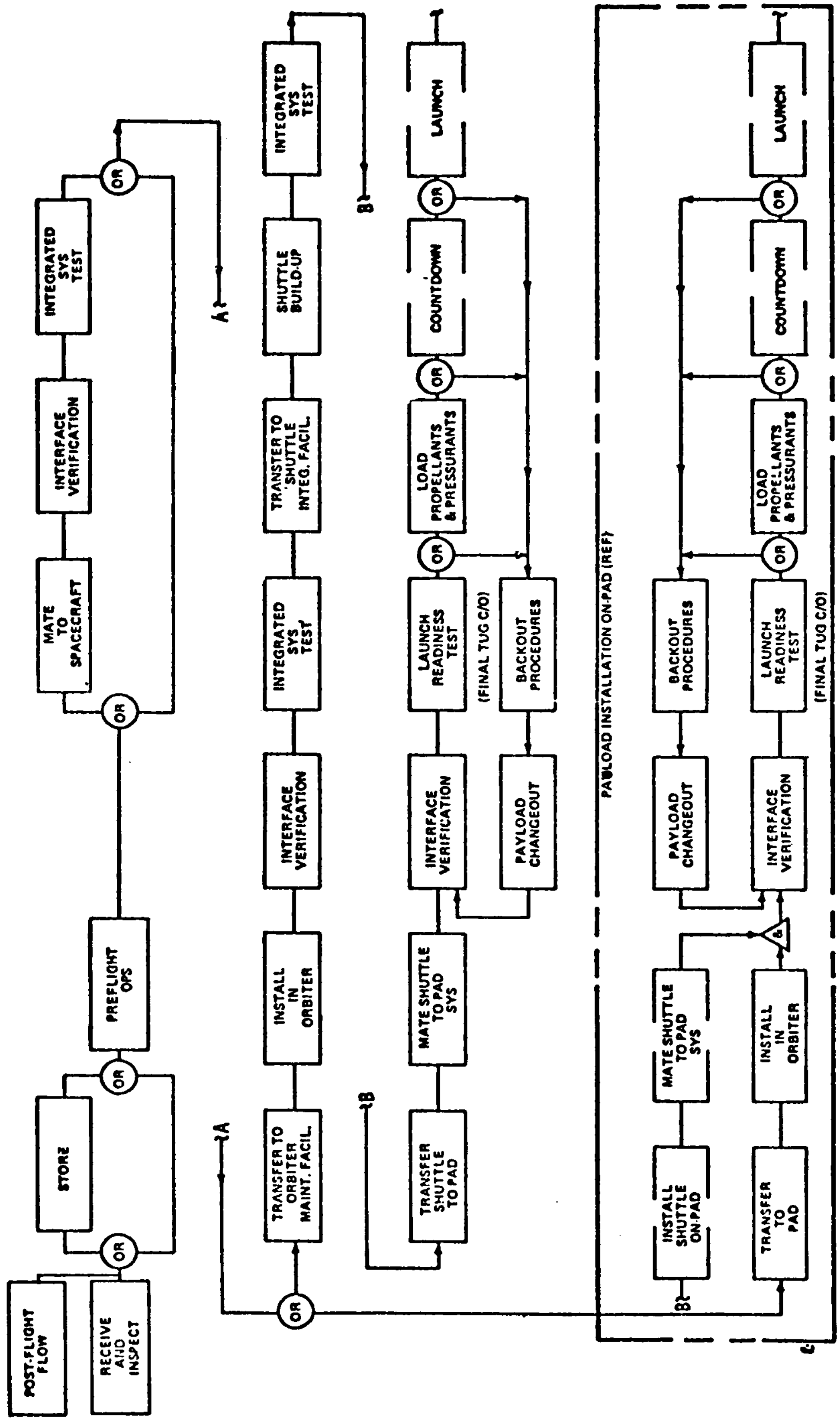
The ground based maintenance plan flow chart is shown on figures I-2, I-3, and I-4. This plan shows the line flow of all maintenance activities that will occur on any category engine. The plan is divided into three main category maintenance areas; (1) turnaround inspection, (2) periodic phase inspection, and (3) refurbishment. These items are defined in previous subsections, respectively.

6.1 Replaceable Units

A Line Replaceable Unit (LRU) is a unit that can be replaced at the operational site, Maintenance Level I.

6.1.1 Derivative IIA Engine

The following components may be replaced at Level I Maintenance in the field by spare units that have been tested at the factory in accordance with the manufacturer's specifications. The indicated components may be replaced by units that have been tested on an engine and have demonstrated the ability to provide specification performance on that engine.



FD 75264

Figure I-2. Cryogenic Space Tug Ground Operations, Preflight Flow

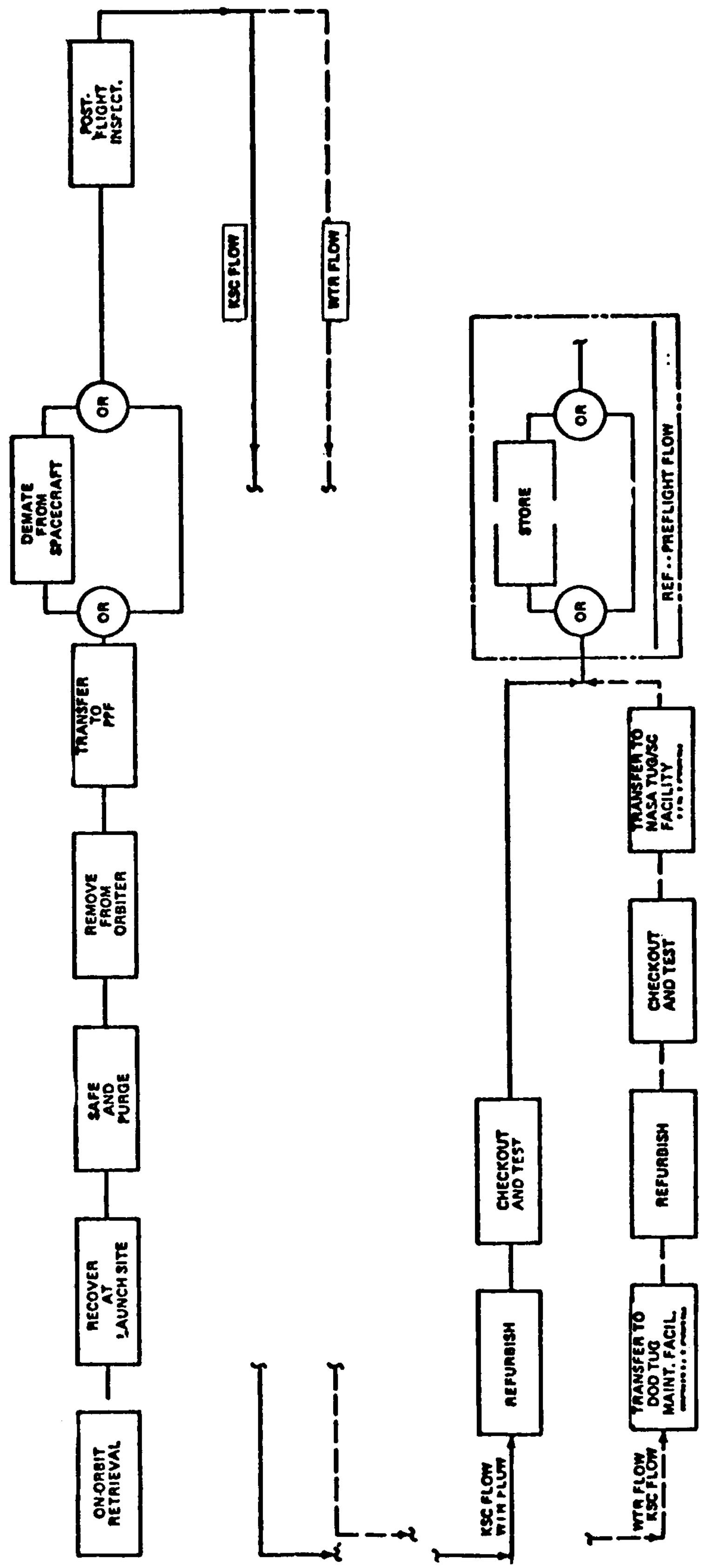


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Figure I-3. Cryogenic Space Tug Ground Operations, Post-Flight Flow

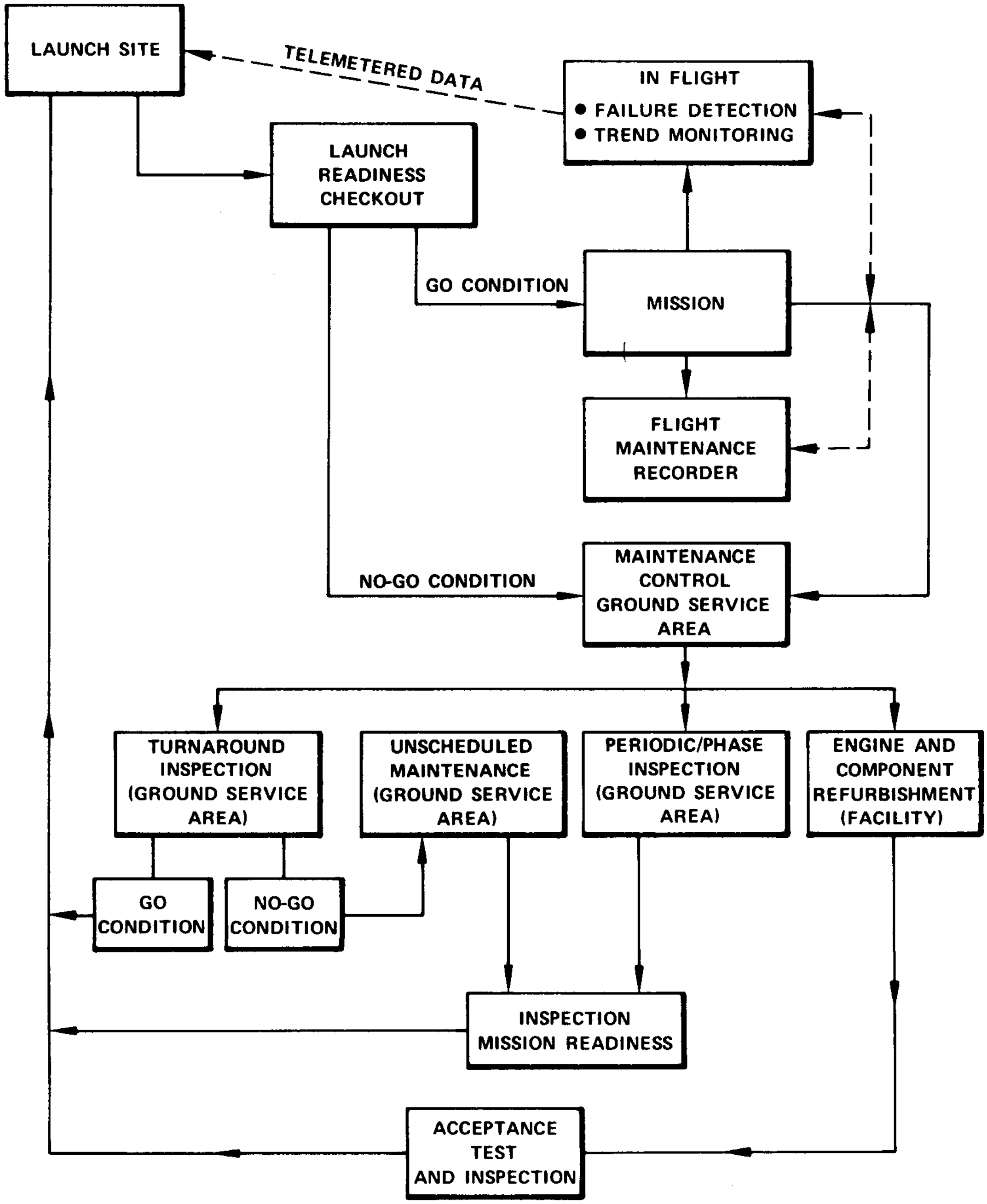

Figure I-4. Ground-Based Engine Maintenance Plan FD 66802A

a. Line Replaceable Units (Maintenance Level I) (LRU)

1. Solenoid valves
2. Fuel inlet shutoff valve
3. Oxidizer inlet shutoff valve
4. Ignition systems
5. Speed transducer
6. Temperature sensors
7. Fuel vent valve
8. Main fuel shutoff valve
9. Fuel tank pressurization valve
10. Engine plumbing
11. GOX heat exchanger
12. Turbine bypass valve
13. Oxidizer tank pressurizing valve
14. Gaseous oxidizer valve
15. Nozzle coolant valve
16. Igniter torch
17. Transducer box
18. Thrust control valve (engine tested)
19. Oxidizer flow control valve (engine tested)
20. Oxidizer boost pump (engine tested)
21. Control actuators.

b. Replacement Units (Maintenance Level II)

1. Oxidizer pump and gear drive assy (engine tested)
2. Fuel pump and turbine assy (engine tested)
3. Extendible nozzle
4. Extendible nozzle translating system
5. Gimbal mount.

c. Replaceable Units (Maintenance Level III)

The thrust chamber injector assembly component cannot be replaced in the field, but may be replaced at engine refurbishment (Maintenance Level III).

6.1.2 Derivative IIB Engine

The following components may be replaced in the field by spare units that have been tested in the factory in accordance with the manufacturer's specifications. The indicated components may be replaced by units that have been tested on an engine and have demonstrated specification performance on that engine.

a. Line Replaceable Units (LRU) (Maintenance Level I)

1. Solenoid valves
2. Fuel inlet shutoff valve
3. Oxidizer inlet shutoff valve
4. Ignition systems
5. Speed transducer
6. Temperature sensors
7. Fuel vent valve
8. Main fuel shutoff valve
9. Fuel tank pressurization valve
10. Engine plumbing
11. Control actuators
12. Oxidizer tank pressurization valve
13. Igniter torch
14. Gaseous oxidizer valve
15. GO_2 heat exchanger
16. Nozzle coolant valve
17. Turbine bypass valve
18. Thrust control (engine tested)
19. Oxidizer flow control (engine tested)
20. Transducer box

b. Replacement Units (Maintenance Level II)

1. Fuel pump and turbine assy (engine tested)
2. Oxidizer pump and gear drive assy (engine tested)
3. Extendible nozzle
4. Gimbal mount
5. Extendible nozzle translating system.

c. Replaceable Units (Maintenance Level III)

The thrust chamber injector assembly cannot be replaced in the field, but may be replaced at engine refurbishment.

6.1.3 Category IV Engine

The indicated components may be replaced by units that have been tested on an engine and have demonstrated specification performance on that engine. The other components may be replaced in the field by spare units that have been tested at the factory in accordance with manufacturing specifications.

a. Line Replaceable Units (LRU) (Maintenance Level I)

The following is a preliminary list of replaceable units.

1. Fuel inlet shutoff valve
2. Oxidizer inlet shutoff valve
3. Solenoid valves
4. Fuel tank pressurization valve
5. Oxidizer tank pressurization valve

6. GOX heat exchanger
7. Control actuators
8. Engine plumbing
9. Temperature sensors
10. Speed transducer
11. Igniter torch
12. Ignition system
13. Pressure switches
14. Nozzle coolant valve
15. Oxidizer flow control valve (engine tested)
16. Fuel flow control valve (engine tested) plus transducer box
17. Oxidizer low speed inducer (engine tested)
18. Fuel low speed inducer (engine tested)
19. Main fuel shutoff valve

b. Replacement Units (Maintenance Level II)

1. Extendible nozzle
2. Extendible nozzle translating system
3. Gimbal mount
4. Fuel turbopump (engine tested)
5. Oxidizer turbopump (engine tested)

c. Replaceable Units (Maintenance Level III)

The thrust chamber injector component cannot be replaced in the field, but may be replaced at engine refurbishment.

6.2 Methods and Procedures

The Space Tug and GSE Maintenance and Refurbishment Program will use existing practices and procedures based on P&WA experience in refurbishment and repair of reusable propulsion systems. They are readily adaptable to the Space Tug Program.

These procedures and practices are defined in Operating Procedures, technical documentation of processing material handled in the M&R Program, including engines, assemblies, components and parts. Typical procedures employed for material processing are as follows.

a. Engine Delivery Order and Supplements

The Delivery Order is the source document utilized to authorize the extent of overhaul/refurbishment process. Supplements are written, as required, during processing of the material from receipt to final delivery.

b. Refurbishment Work Order

Work Orders contain detailed instructions for accomplishing tasks. Procedures assign designated personnel to prepare the documents and specify the type of information for document content and routing requirements.

c. Parts Reworked By Vendors

Detail procedures for transferring and receiving material between P&WA and applicable vendor including details on requirements imposed on vendor for processing material.

6.3 Routing of Serviceable Material

Procedure details processing of serviceable material received from the field, vendors, and material processed at FRDC.

Procedures will also be established for scrapping of material, item job processing, handling of Government material and cost control for segregating charges.

To eliminate bottlenecks and expedite flow of material in the maintenance/refurbishment process, P&WA uses a system that features parallel hardware and paperwork flowpaths. This system will be customized to accommodate the Space Tug to cover the flow of engines, components, assemblies, and parts including marshalling of new parts as well as parts being repaired. A condensed, typical example of parallel hardware and software flow of the engine is described as follows.

Prior to receipt of engine, Field Service provides notification of returning material, and the Delivery Order is written to receive, tear down and inspect. The material is received by a Work Order which routes the engine to assembly floor for teardown, parts cleaning and inspection. During this process, a detailed teardown and findings report is documented. Following the cleaning operation, all parts are subjected to detailed inspection, and each part is tagged for its disposition and engineering change incorporation status.

If new parts are required, material requisition tickets are issued and material pulled from the Government Stockroom. Subsequent to routing parts to the engine assembly marshalling area, all parts are inspected and all paperwork checked to ensure compliance with all instructions and requirements. The parts are then released for assembly in accordance with appropriate work orders, and the engine build is initiated in accordance with configuration instructions contained on the Build Sheets. Following final engine acceptance test for repair verification and visual inspection, an engine Delivery Order is prepared and the engine is shipped.

6.4 Turnaround Inspection

Turnaround inspection and checkout will be performed after the completion of each mission at a ground based facility. This operation will combine the pre-mission inspection and checkout of flight data and the post-mission inspection and checkouts ensuring that, when the task is complete, the engine system is ready for another mission.

The checkout of the engine system starts with the review of the inflight recorder data, and the telemetry data received during the mission. These data along with other postflight inspection checks are provided to a trend analysis computer program. During this checkout all data from this and previous inspections are reviewed and the new data recorded and maintained in maintenance control. This review emphasizes life-oriented data, such as gear wear, seal wear, speeds, engine and component efficiency calculations, and joint seal integrity. These data are input into the ground-based computer equipment, which will contain an accurate engine mathematical model and an analysis routine. Comparison of the recorder parameters with predicted parameters throughout the mission permits identification of component performance deterioration, changes in thrust and mixture ratio, calibration shifts and mission-to-mission engine trends. Results of this analysis enable the maintenance organization to schedule replacement of LRU's before failures occur, thereby precluding any negative impact upon the overall mission schedule of the Space Tug Program.

All scheduled inspections will be performed with the engine installed on the vehicle at the ground service area Maintenance and checkout facility (KSC) and Payload Process Facility (WTR). Engine removal from the vehicle is only necessary when the TBR life has been reached, or when a nonfield-replaceable discrepant engine component is to be replaced.

6.5 Periodic/Phase Inspection

The periodic/phase inspection includes the replacement of line replaceable units (LRU's) as their service lives are expired. A line replaceable unit is a component that can be replaced with the engine installed on the Tug vehicle with the Tug Adapter removed.

Some of these inspections will be part of the turnaround inspection and others will be done on a periodic basis. Engine removal from the Tug vehicle is only necessary when inspection reveals an anomaly with a Level I maintenance nonreplaceable unit. The periodic inspection cycle is routinely performed as indicated in this section.

A periodic/phase inspection will be performed at the operational site prior to the first flight.

A "ready spare" engine will be kept available at each operational site and this engine will have all turnaround inspection and periodic/phase inspections performed and be ready for immediate use on the Tug vehicle. This engine will be kept in this "ready condition" at all times.

The turnaround, and periodic/phase inspections and estimated task time for the major subassemblies are listed in tables I-3, I-4, I-5 and I-6, and the anticipated inspection access ports for the turbopump are shown in figure I-5.

Inspection of the thrust chamber assembly and extendible nozzle includes an internal combustion chamber and injector face check with access through the throat by use of a borescope augmented with lights and mirrors. The thrust chamber injector assembly and extendible nozzle is visually inspected for cracks, holes, splits, and overtemperature indications. The thrust chamber tubes are visually inspected for heat discoloration and are leak tested.

The inspection procedure for the turbomachinery includes a borescope inspection for (1) signs of thermal damage and wear to bearings, and (2) gear wear. This inspection is accomplished through access ports in the turbopump assembly. A rotational torque check of the turbopump assembly is made by removing an access plate and mechanically rotating the pump with a torque measuring wrench.

Table I-3. Turnaround Inspection Operations

Inspection Area	Type of Inspection	Type of Fault	Inspection Technique	Access
Engine Assembly	External - Weldments, Ducts, Manifolds and Lines	Damage	Visual	As Installed
	Diagnostic Review	All	Computer Comparison of Operating Signature	N/A
Thrust Chamber Assembly and Extendible Nozzle	Internal - Combustion Chamber Wall and Injector Face	Signs of Thermal Damage (Corrosion, Cracking, Plugging)	Visual	Throat
"Hot Section"	Weldments, Ducts, Manifolds and Chamber Tubes	Damage	Visual	Directly Accessible
	Expansion Nozzle	Tube Cracks, Splits, Holes	Visual	Directly Accessible
	Extendible Nozzle	Signs of Thermal Damage	Visual	Directly Accessible
Ignition System	Internal - Spark Ignition	No Spark	Visual	Directly Accessible

The access ports will be small and will be leak free when capped for engine operation.

The inspection procedure for the control valves includes the following activities: (1) verification of valve actuation timing and position, and (2) visual external inspection for leakage. No internal valve servicing is required.

These inspections will also reveal any unscheduled inspections and maintenance required to investigate any anomalies with the determination of their causes and correction.

6.6 Refurbishment

Refurbishment includes maintenance activity to restore the service life of the engine and/or components. Engine refurbishment will be performed at an engine facility and the engine will require subsequent acceptance testing equivalent to new engine requirements prior to return to the mission readiness category.

Component refurbishment will occur when the service life of a component is reached (component actuations and time will be recorded in the component record cards supplied with each component) and will either be combined with engine refurbishment or performed on the individual component after removal from a field engine. The components will undergo subsequent acceptance testing after refurbishment prior to being returned to the mission readiness spares category.

Table I-4. Periodic/Phase Inspection Operations

Inspection Area	Type of Inspection	Type of Fault	Inspection Technique	Access
Thrust Chamber Assembly	External-Thrust Structure	Deformation and Structural Integrity	Tolerance Measurement Dye Penetrant and Radiography Visual	Directly Accessible
Extendible Nozzle	External-Structure	Thermal Damage		Directly Accessible
Turbopump Assembly	Internal-Bearings	Signs of Thermal Damage, Cage Damage	Use of Borescope	Typical Access Ports No. 1, 2, and 3
	Internal-Seals	Excessive Seal Leakage	Pressurize Sub-System	Turbopump As Installed
	Internal-Seals	Excessive Wear	Radioisotope	Turbopump As Installed
	Turbopump Gears	Signs of Excessive	Use of Borescope	Typical Access Ports No. 1, 2, and 3
Turbopump	Torque-Check	Bearings and Shaft Fit	Torque Tool	Oxidizer Pump Closure Plate
Helium System	Internal Configuration	Internal Leaks	Helium Consumption Rate	Engine-As Installed
Flow Control	External-Total Valve Inventory	Leak Check (Internal) and Actuation Cycle	Pressure to Verify Seal Operation and Position Indicators	Engine-As Installed
	Automatic Check-out	Actuation Timing, Position Indications	Comparison to Historical Data	Engine-As Installed
	External-Valve Weldments and Flanges	Leak Check (External)	Visual - Leaks	Engine-As Installed
Gimbal Assembly	Load Check-outs	Excessive Wear	Gimbal Power Requirement Check	Engine-As Installed
Engine Plumbing	Leak Check	Leaks	Visual	Engine-As Installed

Table I-5. RL10 Derivative Rocket Engine Inspection Task Times

Inspection Area	Type of Inspection	Type of Fault	Inspection Technique	Access	ML	Total MMH	Elapsed MMH	
			Periodic/Phase Inspection Operations					
Thrust Chamber Assembly	External-Thrust Structure	Deformation and Structural Integrity	Tolerance Measurement, Dye Penetrant and Radiography	Directly Accessible	I	1.50	0.75	2 men
Extendible Nozzle	External-Structure	Thermal Damage	Visual	Directly Accessible	I	.17	.17	
Turbopump Assembly	Internal-Bearings	Signs of Thermal Damage, Cage Damage	Use of Borescope	Typical Access Ports No. 1, 2, and 3	I	2.00	1.00	2 men
	Internal-Seals	Excessive Seal Leakage	Pressurize Sub-System	Turbopump As Installed	I	.50	.50	
	Internal-Seals	Excessive Wear	Radioisotope	Turbopump As Installed	I	1.50	.75	2 men
	Turbopump Gears	Signs of Excessive Tooth wear	Use of Borescope	Typical Access Ports No. 1, 2, and 3	I	Include with bearings		
Turbopump	Torque-Check	Bearings and Shaft Fit	Torque Tool	Oxidizer Pump Closure Plate	I	.25	.25	
Helium System	Internal Configuration	Internal Leaks	Helium Consumption Rate	Engine-As Installed	I	.17	.17	
Flow Control	External-Total Valve Inventory	Leak Check (Internal) and Actuation Cycle	Pressure to Verify Seal Operation and Position Indicators	Engine-As Installed	I	.50	.50	
	Automatic Checkout	Actuation Timing, Position Indications	Comparison to Historical Data	Engine-As Installed	I	.25	.25	
	External-Valve Weldments & Flanges	Leak Check (External)	Visual - Leaks	Engine-As Installed	I	Include with eng. plumbing		

Table I-5. RL10 Derivative Rocket Engine Inspection Task Times (Continued)

Inspection Area	Type of Inspection	Type of Fault	Inspection Technique	Access	ML	Total MMH	Elapsed MMH	
Gimbal Assembly	Load Checkouts	Excessive Wear	Gimbal Power Requirement Check	Engine-As Installed	I	.50	.50	
Engine Plumbing	Leak Check	Leaks	Visual	Engine-As Installed	I	2.00	1.00	2 men
				TOTALS		9:34	6.09	
			Turn Around Inspection Operations					
Engine Assembly	External-Weldments, Ducts, Components, Fluid Lines, and Hardware	Damage, Component Security, Loose Hardware	Visual	As Installed	I	.50	.25	2 men
	Diagnostic Review	All	Computer Comparison of Operating Signature	N/A	I	.25	.25	
Thrust Chamber Assembly and Extendible Nozzle	Internal Combustion Chamber Wall and Injector Face	Signs of Thermal Damage (Corrosion, Cracking, Plugging)	Visual	Throat	I	.17	.17	
"Hot Section"	Weldments, Ducts, Manifolds and Chamber Tubes	Damage	Visual	Directly Accessible	I	.25	.25	
	Expansion Nozzle	Tube Cracks, Splits, Holes	Visual	Directly Accessible	I	.17	.17	
	Extendible Nozzle	Signs of Thermal Damage	Visual	Directly Accessible	I	.17	.17	
Ignition System	Internal-Spark Ignition	No spark	Visual	Directly Accessible	I	.17	.08	2 men
				TOTALS		1.68	1.34	

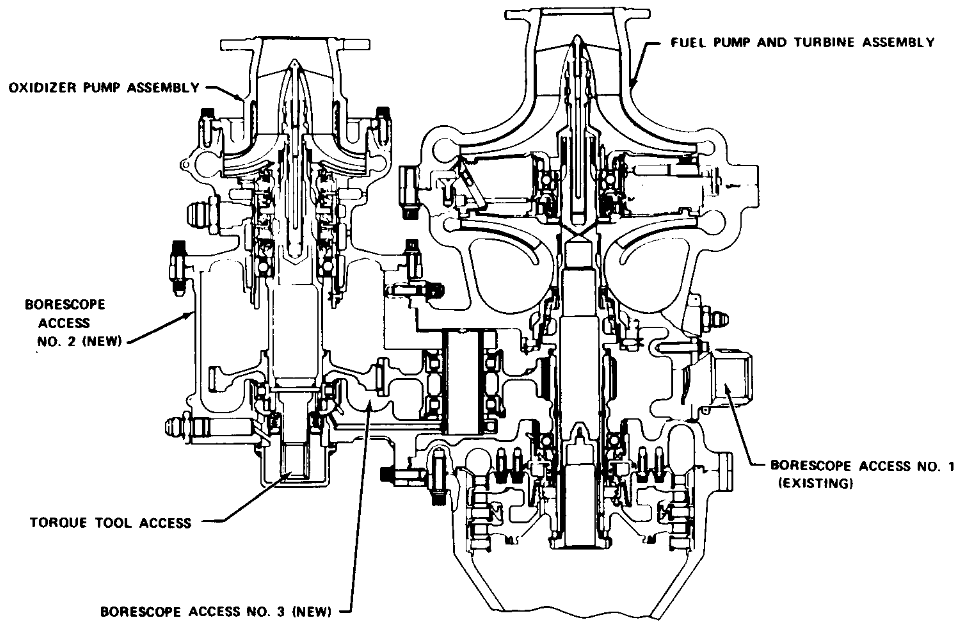

Figure I-5. Turbopump Access Locations FD 66628A

The engine refurbishment plan is shown in table I-6 for an engine returned to the refurbishment facility. The component refurbishment or repair phase is shown in table I-7.

Table I-6. Engine Refurbishment Plan at Refurbishment Facility (FRDC)

A. Receiving Engine

1. Removal from shipping container
2. Receiving inspection (visual)

B. Flow Checks

1. Flow check turbopump seals

C. Engine Disassembly

1. Disassemble engine
2. Disassemble individual components

D. Inspection (Subsequent to disassembly)

1. Dimensional reinspect of critical surfaces
2. Visual reinspect of all noncritical surfaces
3. Zyglo and/or X-ray the following:

Table I-6. Engine Refurbishment Plan at Refurbishment Facility (FRDC) (Continued)

a. Tube and manifold assemblies
b. All component housings
c. Chamber/injector assembly, i.e., tube area behind "Mae West" turbopump mount struts, brackets, flanges, welded areas, etc.
d. Extendible nozzle and translating mechanism

E. Pressure Checks (Subsequent to disassembly)

1. Bellows seal assemblies (where applicable)
2. Chamber/injector assembly
3. Extendible nozzle

F. Parts Replacement

1. Automatically replaced

a. Bearings
b. All gaskets, i.e., angle, lead and teflon-coated, etc.
c. Solenoid valve poppets
d. Thrust control cured gaskets
e. Tablocks
f. Key Washers
g. Gear train

2. Frequently replaced

a. Bellows assemblies
b. Carbon seals

3. Other parts as dictated by the inspection

G. Cleaning

1. Clean reusable and new parts per applicable procedures

H. Assembly and Test

1. Reassemble components
2. Calibrate on all mechanical and electrical components
3. Reassemble engine
4. Perform prefiring checks
5. Conduct engine firing(s) to the same level as the original engine requirements

J. Packing

Prepare engine for shipment to include the End Item Test and Inspection Procedure.

Table I-7. Component Refurbishment Plan at Refurbishment Facility (FRDC)

A. Receiving Component

1. Receiving-type inspection (visual)

B. Flow Checks

1. Individual component checks to aid in anamoly investigation

C. Disassembly

1. Disassemble the component

D. Inspection (Subsequent to disassembly)

1. Dimensional reinspect of critical surfaces
2. Visual reinspect of all noncritical surfaces
3. Zyglo and/or X-ray -(as dictated by receiving inspection and disassembly)

    a. Component housings (where applicable)
    b. Bellows (where applicable)

E. Pressure Checks

1. Bellows (where applicable)

F. Parts Replacements

1. Automatically replaced

    a. Gaskets
    b. Tablocks
    c. Key washers

2. Frequently replaced

    a. Parts as dictated by the inspections

G. Cleaning

1. Clean reusable and new parts per applicable procedures

H. Assembly and Test

1. Reassemble component
2. Calibrate all mechanical and electrical components
3. Conduct engine firings as required to satisfy the component spares replacement requirements.

SECTION J
TRANSPORTATION PLAN

1. SUMMARY

A cost effective Space Tug Program Transportation requires (1) transportation planning during the design and development of the engine and packaging, (2) an organizational structure that integrates transportation considerations with related elements within the program, and (3) an experienced functional transportation staff to implement the Space Tug Engine transportation program. To satisfy these requirements, the existing P&WA RL10 support organization will establish a transportation element in the Preservation, Packaging, Handling and Transportation (PPH&T) Group of the Integrated Logistics Support (ILS) Team, so that transportation requirements will be considered during the design and development of the engine and packaging and will be integrated with all logistical elements throughout the life of the Space Tug Engine.

2. ORGANIZATION AND PERSONNEL

The FRDC Supervisor of Traffic is the transportation member of the PPH&T Group that reports to the ILS Manager and through this channel is responsive to directions from and reports from Space Tug program management. This organizational structure provides the interfaces between the Traffic Department, the logistical elements, and other Space Tug Program elements that permit transportation requirements to be considered, and influence where practical, the design of the engine, GSE, and packaging.

The arrival of all transport equipment is closely coordinated with the availability of material to be shipped to achieve scheduled delivery. Shipments are monitored while enroute by means of daily carrier reports. The Traffic Department also receives reports of all problems related to shipments enroute that might cause delivery delays, and takes appropriate corrective action.

3. TRANSPORTATION PROGRAM

Transportation requirements are considered during the engine design layout reviews and maintenance engineering analyses. Where designs cannot be influenced to avoid transportation problems, the transportation representative is advised of the problems permitting remedies early in the program. The transportation representative will monitor and be involved in the shipment of development engine and GSE hardware between FRDC and vehicle manufacturing plant and thereby will be provided an early evaluation of the transportation plans, methods and procedures to be used in the Space Tug Support Program. Unanticipated problems discovered in the shipment of development hardware will be known early enough to permit changes in packaging designs and transportation plans before the start of production hardware and engine shipments.

All conventional transport media can be used for the movement of Space Tug Engines. However, truck transport is recommended for ready availability, variety of routes, short transit time, and low cost.

All of these factors will be considered by the P&WA Traffic Department. The selection of appropriate transport modes on the basis of available carrier equipment, allowable transit time, and lowest practical cost affects economical and on-schedule delivery.