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CR-171850

(NASA-CR-171850-Vol-3) SPACE  
TRANSPORTATION SYSTEM (STS) PROPELLANT  
SCAVENGING SYSTEM STUDY. VOLUME 3: COST  
AND WORK BREAKDOWN STRUCTURE-DICTIONARY  
Final Report (Rockwell International Corp.)

N85-20002

Unclas  
18783

G3/16

STS 84-0570

SPACE TRANSPORTATION SYSTEM (STS)  
PROPELLANT SCAVENGING SYSTEM STUDY FINAL REPORT  
VOLUME III  
COST AND WORK BREAKDOWN  
STRUCTURE/DICTIONARY

JANUARY 1985

Contract NAS9-16994  
DRL T-1811



Rockwell International

Space Transportation  
Systems Division

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## 1. COSTING APPROACH, METHODOLOGY, AND RATIONALE

Fundamentally, the volumes of the oxidizer and fuel propellant scavenged from the orbiter and external tank (ET) determine the size and weight of the scavenging system. The optimization of system dimensions and weights is stimulated by the requirement to minimize the use of partial length of the orbiter payload bay. Thus, the cost estimates begin with weights established for the optimum design.

Both the design, development, test, and evaluation (DDT&E) and theoretical first unit (TFU) hardware production costs are estimated from parametric cost-weight scaling relations for four subsystems. For cryogenic propellants, the widely differing characteristics of the oxidizer and the fuel lead to two separate tank subsystems, in addition to the electrical and instrumentation subsystems. Hardware costs also involve quantity, as an independent variable, since the number of production scavenging systems is not firm. For storable propellants, since the tankage volume of the oxidizer and fuel are equal, the hardware production costs for developing these systems are lower than for cryogenic propellants. Scaling factors are presented for the storable propellant tanks relative to cryogenic systems. These cost data are presented at the third level of the work breakdown structure (WBS).

In addition, isolated estimates are included as responses to questions beyond those of DDT&E and TFU hardware costs of the propellant scavenging system. Examples of such estimates are spare parts provisioning, orbiter vehicle modification costs, and ground operations costs for the propellant scavenging systems.

The WBS used in structuring the costs is presented in Section 6. Also, a complete WBS indented list and dictionary is found in this section.

### 1.1 PARAMETERIZED SCAVENGING SYSTEM COSTS

The tank developments for DDT&E and TFU are costed for both the compact, high-density cylindrical  $\text{LO}_2$  tank and the large-volume, low-density ring-shaped  $\text{LH}_2$  tank. Transfer lines, pumps, and pressurization systems, as well as thrust transmitting structure weights, are added through Saturn S-II stage weight cost estimating relationships (CER's).

$$\frac{\$84}{\text{lb}} \text{ DDT\&E} = 91,000 W^{-0.282}$$

lb                      tank system

$$\frac{\$84}{\text{lb}} \text{ TFU} = 46,200 W^{-0.420}$$

lb                      tank system

Electrical subsystem costs are estimated from the CER's:

$$\begin{array}{r} \$84 \text{ DDT\&E} = 153,100 \text{ W}^{-0.416} \\ \text{lb} \qquad \qquad \qquad \text{elec} \end{array}$$

$$\begin{array}{r} \$84 \text{ TFU} = 21,540 \text{ W}^{-0.216} \\ \text{lb} \qquad \qquad \qquad \text{elec} \end{array}$$

The instrumentation system includes equipment such as capacitance probes, bubble detectors, pressure transducers, remote power controllers, multiplex interface adapters, signal conditioners, and a microprocessor. Instrumentation CER's were developed by adjusting the level of published CER's with point values from the Orbiter program. These CER's are given by:

$$\begin{array}{r} \$84 \text{ DDT\&E} = 269,000 \text{ W}^{-0.404} \\ \text{lb} \qquad \qquad \qquad \text{instr.} \end{array}$$

$$\begin{array}{r} \$84 \text{ TFU} = 87,500 \text{ W}^{-0.404} \\ \text{lb} \qquad \qquad \qquad \text{instr.} \end{array}$$

The DDT&E CER assumes prequalified components and allows for design, integration, and testing of the subassembly. A completely new system would have a substantially higher CEP. The TFU CER is based on Apollo command and support module data as well as Saturn S-II data at a complexity and cost about 40 percent that of orbiter.

Production hardware costs versus quantity are determined from Saturn S-II production data on a 91.1-percent cumulative average (Wright) curve:

$$\begin{array}{r} \$84 \text{ Hardware} = \$84 \text{ TFU} \text{ Q}^{-0.1342} \\ \text{lb} \qquad \qquad \qquad \text{lb} \end{array}$$

The relationship between cryogenic propellant and storable propellant system DDT&E and TFU hardware costs was defined.<sup>1</sup> For unmanned vehicles, the CER's are:

$$\begin{array}{l} \$ \text{ DDT\&E (Stor)} = 0.833 \$ \text{ DDT\&E (Cryo)} \\ \$ \text{ TFU (Stor)} = 0.625 \$ \text{ TFU (Cryo)} \end{array}$$

<sup>1</sup>Klemetson, R.W., and P.W. Garrison. Space Station Propulsion Technology Study. Jet Propulsion Laboratory (December 1983).

The provisioning (spares) costs are based on Shuttle contract experience and are given by the following CER:

$$\$84 \text{ PROV} = 0.115 (\$ \text{ DDT\&E} + \$ \text{ TFU})$$

## 1.2 COST GROUND RULES

The ground rules used in developing the cost data for the propellant scavenging systems are:

- Costs presented in 1984 dollars
- Cost of orbital maneuvering vehicle (OMV) propellant at \$120/lb
- OMV development or deployment costs not included
- Cost two tankage sets for each tankage size
- Checkout/refurbishment costs are \$0.25 million per flight
- Cost modifications to four orbiters for either cryogenic or storable systems
- Cost of additional Space Transportation System (STS) flights at \$101.4 million each

## 2. SUMMARY COST PRESENTATIONS

The total program costs developed from the CER's listed in Section 1.1 are presented in Table 1. The data includes information for the baseline flight manifest, which consists of 202 flights for both cryogenic and storable propellant scavenging systems. Data for cryogenic propellant systems with a relaxed manifest of 216 flights are also included. A discussion of the relaxed manifest is presented in Volume I of this report. The data presented include the cost of the OMV propellant required to transfer the scavenged propellant from 160 nautical miles to the space depot on those STS missions that only go to the 160-nautical mile altitude. A breakdown of the OMV propellant costs is presented in Section 3. Any costs associated with deployment of the OMV have not been included.

The last column of Table 1 presents the cost of delivering the propellant to the space depot in dollars per pound. This column indicates cryogenic propellant can be delivered cost effectively if the quantity required is no greater than 1.25 million pounds. If the 2.5-million-pound target is required for orbital transfer vehicle (OTV) purposes, the cost increases substantially. For storable propellants, the cost-effective maximum quantity is 1.5 million pounds. All of the cost values presented in the table can be compared to the same value for a dedicated tanker, which would be \$2,030 per pound, not including the cost of DDT&E or TFU for the tanker development.





Table 1. Propellant Scavenging Program Cost Summary

Propellant System	Flight Manifest	Number of Tank Sizes	Propellant Delivered (klb)	Total Cost (\$M)	Propellant Cost (\$/lb)
Cryogenic	● Baseline (202 flights)	1	926	75.6	82
		2	1,042	91.3	88
		3	1,182	106.5	90
		4	1,220	119.1	98
		5	1,247	128.4	103
		15	1,321	223.4	169
	● Relaxed (216 flights)	5	2,507	1,583.7	632
Storable	Baseline (202 flights)	1	1,403	159.1	113
		2	1,491	175.9	118

The data presented in Table 1 can also be interpreted to determine the propellant costs for different quantities of propellant delivered to the space depot. This data was specifically requested for cryogenic propellant systems and is presented in Figure 1. The smallest cost for obtaining propellant occurs at about 0.75 to 1.25 million pounds. For delivered quantities below this range, the hardware development and production costs cause the propellant

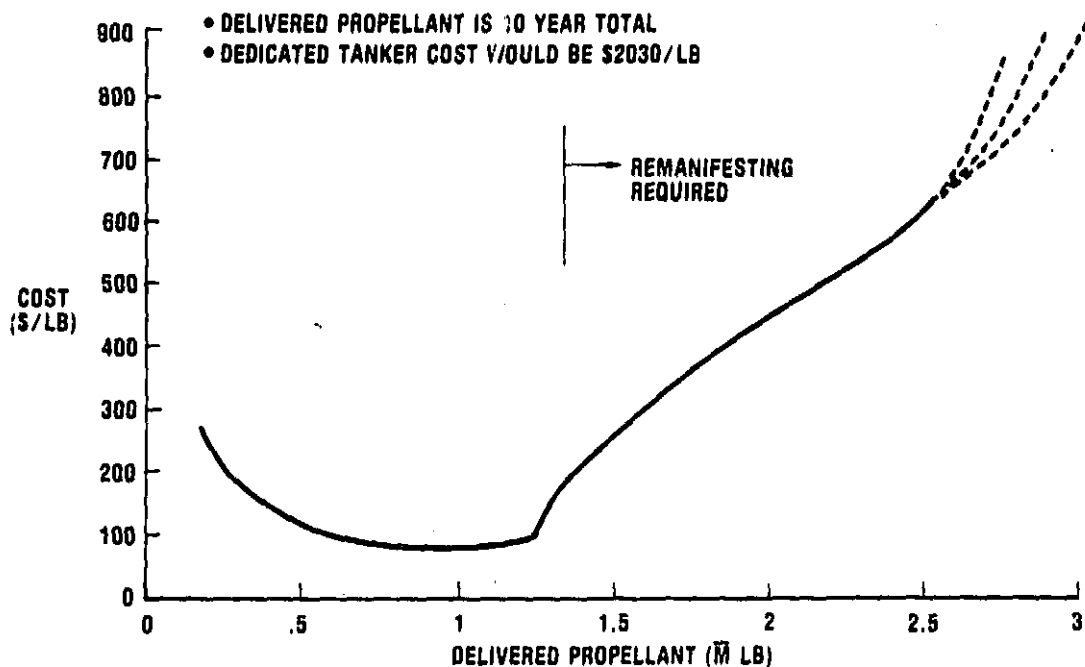


Figure 1. Cryogenic Propellant Cost Sensitivity



costs to increase. Above this range, the available space in the orbiter payload bay limits the available quantity; therefore, remanifesting the flight schedule is required to increase the quantity. The remanifesting causes considerable increases in the propellant cost. The concept of remanifesting can only be applied opportunistically within the flight manifest. At some point above 2.5 million pounds of propellant, a much steeper slope is obtained because increasingly smaller quantities of propellant are made available for scavenging as flights are remanifested.

In conclusion, the data presented herein can be utilized to define a cost-effective system for delivering either cryogenic or storable propellant to a space-based propellant depot. The type of propellant system (cryogenic or storable) required, use of a baseline manifest or some relaxed version that includes more STS flights, and the number of tank sizes required are all questions that cannot be answered until a definition is provided for on-orbit propellant requirements.

### 3. COST ESTIMATES BY WBS ELEMENT

The program costs for each of the WBS elements are shown in Table 2. The total cost data shown in this table is the same as that presented in Table 1. The cost data is presented for the baseline flight manifest for both cryogenic and storable propellants and for the relaxed manifest for cryogenic propellants only. The scavenging system costs are provided for the appropriate WBS headings shown in the WBS in Section 6. The costs associated with modifying the existing orbiters and for the propellant required by the OMV to transfer the scavenged propellant from a 160-nautical mile orbit to the space depot are shown as other costs. The OMV propellant cost does not include any values for DDT&E, production, or deployment of the OMV. The orbiter modification costs assume all four orbiters are modified for either cryogenic or storable propellant scavenging.

The study ground rules required that the propellant scavenging systems be treated separately. Therefore, no attempt was made to account for scar weight and/or costs of a storable system in the evaluation of the deliverable propellant and costs of a cryogenic scavenging system. The opposite is also true in evaluating a storable scavenging system. The ground rules used for developing the system costs are presented in Section 1.1.

The individual cost elements for DDT&E and production are presented in Table 3. The data in this table also indicate the weights used to evaluate the CER for each parameter. In cases with multiple tankage, the weight of the largest tank was used for all the tankage costs. It was assumed that two units of each tank size would be procured so sufficient tankage would exist to satisfy vehicle turnaround requirements.



Table 2. Propellant Scavenging Program Element Costs

Propellant System	Flight Manifest	Number of Tank Sizes	Number of Scavenging Flights	Costs (\$M)						
				Scavenging System				Other		
				DDT&E	Production	Provisioning	Operations	Orbiter Mods	OMV Propellant	Total
Cryogenic	● Baseline (202 flights)	1	69	31.2	10.4	4.8	17.3	4	7.9	75.6
		2	89	31.2	18.9	5.8	22.3	4	9.1	91.3
		3	89	34.1	28.8	7.2	22.3	4	10.1	106.5
		4	89	35.9	38.2	8.5	22.3	4	10.2	119.1
		5	89	35.9	46.3	9.5	22.3	4	10.4	128.4
Storable	● Relaxed (216 flights)	15	93	38.6	127.3	19.1	23.3	4	11.1	223.4
		5	107	45.9	55.8	11.7	1446.4	4	20.9	1584.7
Storable	Baseline (202 flights)	1	165	43.0	15.5	6.7	41.3	40	12.6	159.1
		2	165	44.2	28.8	8.4	41.3	40	13.2	175.9

Table 3. Propellant Scavenging DDT&E and Production Costs

Propellant System	Flight Manifest	Number of Tank Sizes	Weight (lb)						Cost (Millions of Dollars)			
			DDT&E			Production						
			Tank-age	Elec-trical	Instrumen-tation	Tank-age	Instrumen-tation	Elec-trical	Tank-age	Instrumen-tation		
Cryogenic	● Baseline (202 flights)	1	2,985	20	20	28.7	0.9	1.6	8.7	0.6	1.1	
		2	2,985	20	20	28.7	0.9	1.6	15.9	1.0	2.0	
		3	3,407	20	20	31.6	0.9	1.6	24.6	1.4	2.8	
		4	3,688	20	20	33.4	0.9	1.6	32.8	1.8	3.6	
		5	3,688	20	20	33.4	0.9	1.6	39.7	2.2	4.4	
Storable	● Relaxed (216 flights)	15	4,110	20	20	36.1	0.9	1.6	110.2	5.7	11.4	
		5	5,310	20	20	43.4	0.9	1.6	49.2	2.2	4.4	
Storable	Baseline (202 flights)	1	4,790	746	32	33.6	7.3	2.1	7.1	7.1	1.3	
		2	5,037	746	32	34.8	7.3	2.1	13.6	12.9	2.3	



#### 4. TOTAL PROGRAM FUNDING

A representative propellant scavenging system schedule for a Phase C/D design and production contract is presented in Figure 2. The operational support for the flight decade from 1991 through 2000 is not included in this figure. The schedule is valid for both cryogenic and storable propellant scavenging systems.

The time-phased cost expenditures for DDT&E, production, and operations are shown in Figures 3 and 4. Provisioning costs are included with production costs. The data in Figure 3 for a cryogenic propellant system is valid for the concept of the baseline manifest utilized with five different tankage sizes. For a storable propellant system (Figure 4), the data is for the concept of one tankage size. Both figures indicate peak funding in late FY 1989, with a demonstration flight in the middle of FY 1990 and the first operational flight in January 1991. The costs associated with orbiter modifications or OMV propellant requirements are not included in these figures.

#### 5. ECONOMIC ANALYSIS

The cost trades associated with propellant scavenging are shown in Table 2, which presents the program costs for delivered propellant based on the quantity of propellant delivered to the space-based depot on orbit. Figure 1 presents the cost in dollars per pound for differing quantities of cryogenic propellant delivered. These data can be utilized when on-orbit propellant requirements are finalized.

SCHEDULE ITEM	FISCAL YEAR	1986	1987	1988	1989	1990	1991	1992
AUTHORITY TO PROCEED		▽						
PRELIMINARY DESIGN		▬						
DETAILED DESIGN		▬	▬	▬	▬	▬		
GROUND TESTING		▬	▬					
DEVELOPMENT TESTING			▬	▬				
PROCUREMENT (INCL PROVISIONING)		▬	▬	▬	▬	▬		
FAB, ASSY, C/O, & TEST			▬	▬	▬	▬		
INSTALL. INTEGRATION, & C/O						▬	▬	
DEMONSTRATION FLIGHT						▽		
FLIGHT OPS SUPPORT							▬	▬
FIRST OPER FLIGHT							▽	

Figure 2. Summary Schedule for STS Propellant Scavenging System

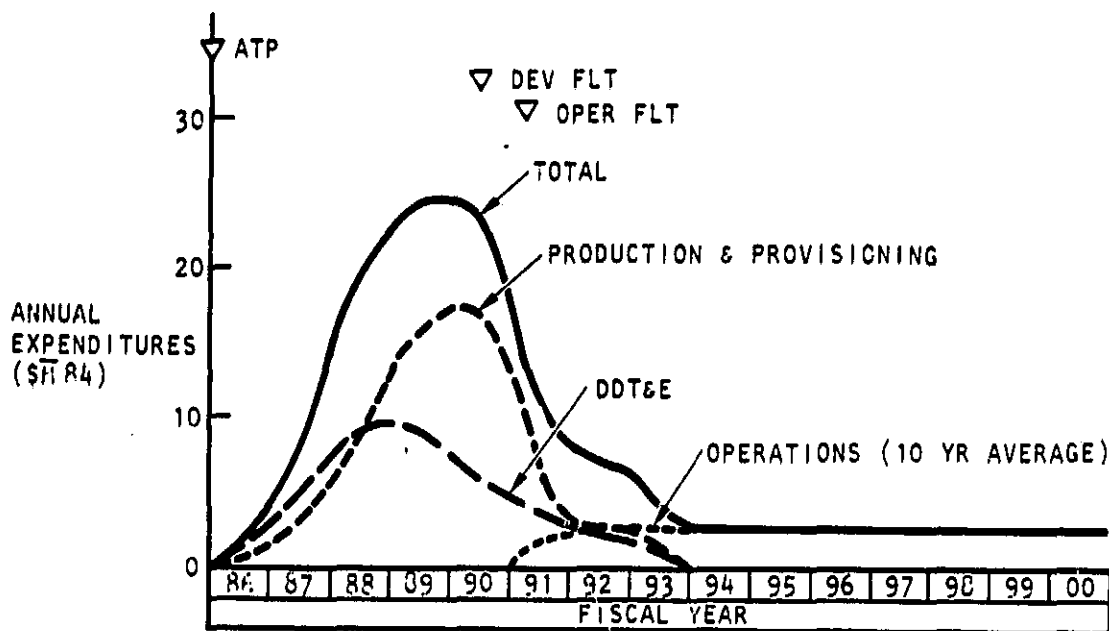


Figure 3. Cryogenic Propellant Scavenging System Funding

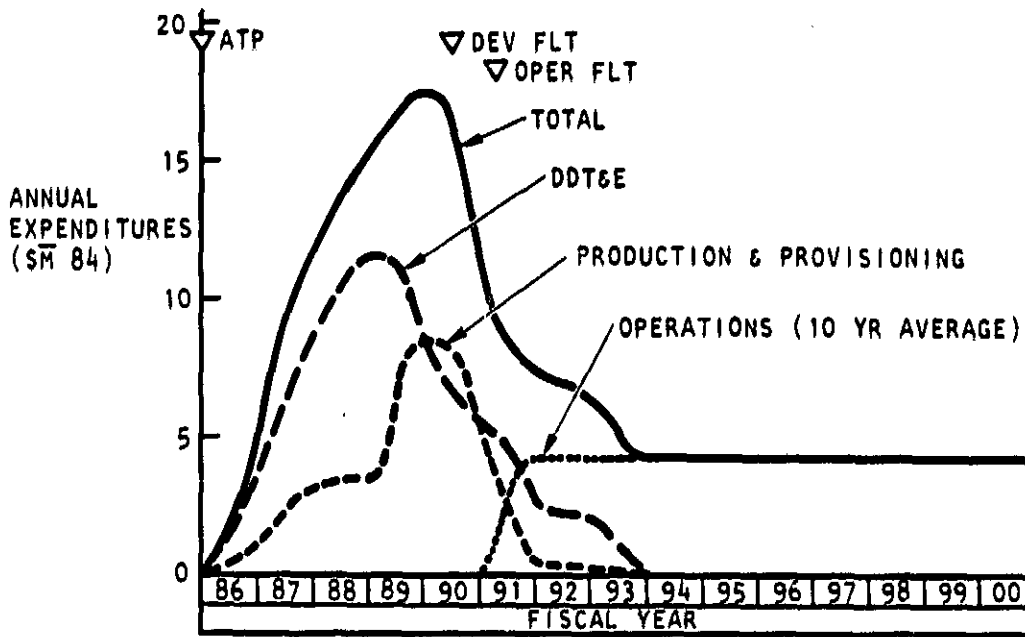


Figure 4. Storable Propellant Scavenging System Funding

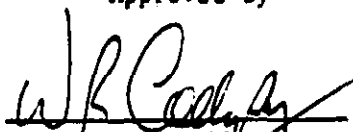


6. WORK BREAKDOWN STRUCTURE AND DICTIONARY

STS PROPELLANT SCAVENGING  
SYSTEM PHASE C/D  
WORK BREAKDOWN STRUCTURE  
(PS.0)

Contract NAS9-16994  
Task 6  
DRL Line Item 4  
DRD MA935T

Approved by

  
W.R. Collopy



Rockwell International

Space Transportation  
Systems Division





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## INTRODUCTION

This document contains the expanded contract work breakdown structure (WBS) for the propellant scavenging system Phase C/D program.

The WBS consists of an indentured list of WBS elements, a dictionary of element definitions, and an element logic diagram. The indentured list and logic diagram identify the interrelationships of the elements. The dictionary defines the types of work that may be represented by or be classified under each specific element. The currently identified elements are sufficient to classify all foreseen work under the statement of work, including on-site, off-site, supplier, subcontractor, and interdivisional effort and material.

The WBS is neither a statement of work nor a work authorization document. Rather, it is a framework around which to define requirements, plan effort, assign responsibilities, allocate and control resources, and report progress, expenditures, technical performance, and schedule performance. The WBS element definitions are independent of make-or-buy decisions, organizational structure, and activity locations unless exceptions are specifically stated.

INDENTURED LIST

LEVEL

2 3 4 5

PS.0 PROPELLANT SCAVENGING SYSTEM

PS.1 DESIGN, DEVELOPMENT, TEST, AND EVALUATION

PS.1.1 MANAGEMENT AND SUPPORT

- PS.1.1.1 BUSINESS MANAGEMENT
- PS.1.1.2 CONFIGURATION MANAGEMENT
- PS.1.1.3 QUALITY MANAGEMENT AND SUPPORT
- PS.1.1.4 PROCUREMENT AND IDWA MANAGEMENT
- PS.1.1.5 PRODUCT SUPPORT
- PS.1.1.6 TECHNICAL MANAGEMENT
- PS.1.1.7 LOGISTICS AND GFE MANAGEMENT
- PS.1.1.8 FACILITIES

PS.1.2 SYSTEM ENGINEERING

- PS.1.2.1 SYSTEM REQUIREMENTS AND SYNTHESIS
- PS.1.2.2 FLIGHT TECHNOLOGY ANALYSIS
- PS.1.2.3 SAFETY AND RELIABILITY
- PS.1.2.4 DESIGN AND PROJECT CONTROL
- PS.1.2.5 LABORATORY AND TEST SUPPORT
- PS.1.2.6 SPECIAL STUDIES
- PS.1.2.7 MAINTENANCE ENGINEERING ANALYSIS

PS.1.3 FLIGHT HARDWARE DESIGN, DEVELOPMENT, AND QUALIFICATION

- PS.1.3.1 STRUCTURES
- PS.1.3.2 FLUID SYSTEM
- PS.1.3.3 AVIONICS SYSTEM
- PS.1.3.4 MECHANICAL SYSTEM
- PS.1.3.5 SYSTEM INTEGRATION
- PS.1.3.6 INTEGRATED MOCKUP AND TRAINER

PS.1.4 GROUND SUPPORT EQUIPMENT (GSE)

PS.1.5 TOOLING

- PS.1.5.1 DIMENSIONAL AND FABRICATION TOOLING
- PS.1.5.2 INTERFACE CONTROL TOOLING



## LEVEL

2 3 4 5

## PS.2 PRODUCTION AND GROWTH

## PS.2.1 MANAGEMENT AND SUPPORT

- PS.2.1.1 BUSINESS MANAGEMENT
- PS.2.1.2 CONFIGURATION MANAGEMENT
- PS.2.1.3 QUALITY MANAGEMENT AND SUPPORT
- PS.2.1.4 PROCUREMENT AND IDWA MANAGEMENT
- PS.2.1.5 PRODUCT SUPPORT
- PS.2.1.6 TECHNICAL MANAGEMENT
- PS.2.1.7 LOGISTICS AND GFE MANAGEMENT
- PS.2.1.8 FACILITIES

## PS.2.2 ENGINEERING SUPPORT

## PS.2.3 FLIGHT HARDWARE PRODUCTION

- PS.2.3.1 FLIGHT UNIT NO. 1
- PS.2.3.2 FLIGHT UNIT NO. 2
- PS.2.3.3 FLIGHT UNIT NO. 3
- PS.2.3.4 FLIGHT UNIT NO. 4
- PS.2.3.5 FLIGHT UNIT NO. 5

## PS.3 PROVISIONING

## PS.3.1 MANAGEMENT AND SUPPORT

- PS.3.1.1 BUSINESS MANAGEMENT
- PS.3.1.2 CONFIGURATION MANAGEMENT
- PS.3.1.3 QUALITY MANAGEMENT AND SUPPORT
- PS.3.1.4 PROCUREMENT AND IDWA MANAGEMENT
- PS.3.1.5 PRODUCT SUPPORT
- PS.3.1.6 TECHNICAL MANAGEMENT
- PS.3.1.7 LOGISTICS AND GFE MANAGEMENT
- PS.3.1.8 FACILITIES

## PS.3.2 ENGINEERING SUPPORT

## PS.3.3 PROVISIONED FLIGHT SPARES

## PS.3.4 PROVISIONED GSE SPARES

## PS.3.5 PROVISIONED OVERHAUL AND REPAIR

## PS.3.6 PROVISIONED MODIFICATIONS

## PS.3.7 SPECIAL PROVISIONED HARDWARE

## PS.3.8 OPERATION AND MAINTENANCE DOCUMENTATION

## PS.3.9 MAINTENANCE ENGINEERING ANALYSIS



**LEVEL**

**2 3 4 5**

**PS.4 OPERATIONS SUPPORT**

**PS.4.1 MANAGEMENT AND SUPPORT**

- PS.4.1.1 BUSINESS MANAGEMENT**
- PS.4.1.2 CONFIGURATION MANAGEMENT**
- PS.4.1.3 QUALITY MANAGEMENT AND SUPPORT**
- PS.4.1.4 PROCUREMENT AND IDWA MANAGEMENT**
- PS.4.1.5 PRODUCT SUPPORT**
- PS.4.1.6 TECHNICAL MANAGEMENT**
- PS.4.1.7 LOGISTICS AND GFE MANAGEMENT**

**PS.4.2 OPERATIONS SUPPORT ENGINEERING**

**PS.4.3 IDENTIFIED PROJECTS**

## DICTIONARY

## PS.0 PROPELLANT SCAVENGING SYSTEM

This element encompasses tasks associated with development, production, and support of the propellant scavenging system. The tasks include system design, fabrication, assembly, installation and check-out, and quality control; engineering studies and testing; support equipment; tooling; procurement activities; facility activation; system interface definition; control and integration of government-furnished equipment (GFE) into the propellant scavenging system; spares provisioning; operations support; and requisite program management activities.

This element is subdivided into the following Level 3 elements, each representing a program phase:

- PS.1 Design, Development, Test, and Evaluation
- PS.2 Production and Growth
- PS.3 Provisioning
- PS.4 Operations Support

## PS.1 DESIGN, DEVELOPMENT, TEST, AND EVALUATION

This element encompasses those tasks associated with the design, development, test, and evaluation (DDT&E) of the propellant scavenging system and tasks associated with demonstration of system performance capabilities. The tasks include operations analysis, study, and testing; establishing facility requirements and planning, designing, constructing, and activating facilities; providing training equipment and services; defining system interfaces; designing and building tooling and support equipment; and management activities.

This element is subdivided into the following Level 4 elements:

- PS.1.1 Management and Support
- PS.1.2 System Engineering
- PS.1.3 Flight Hardware Design, Development, and Qualification
- PS.1.4 Ground Support Equipment
- PS.1.5 Tooling

## PS.1.1 MANAGEMENT AND SUPPORT

This element contains tasks associated with management and support of the propellant scavenging system. The tasks include planning, organizing, and defining requirements; establishing schedules and allocating resources to attain objectives; reporting progress and providing program status visibility; and controlling the program activities.



This element is subdivided into the following Level 5 elements:

- PS.1.1.1 Business Management
- PS.1.1.2 Configuration Management
- PS.1.1.3 Quality Management and Support
- PS.1.1.4 Procurement and IDWA Management
- PS.1.1.5 Product Support
- PS.1.1.6 Technical Management
- PS.1.1.7 Logistics and GFE Management
- PS.1.1.8 Facilities

**PS.1.1.1 BUSINESS MANAGEMENT**

This element contains tasks required to implement and operate an integrated performance management system that will ensure integrated planning, scheduling, budgeting, work authorization, cost accumulation, and management visibility of all propellant scavenging system activities. Included are the tasks of consolidating program requirements; preparing budgets and schedules; analyzing, summarizing, and reporting performance measurement data; identifying problems; recommending solutions; and tracking problem resolutions.

Included also are coordination and analysis of contract change authorizations (CCA's), schedule change documents, and other related change documents to develop cost projections. In addition, this element includes the analysis, coordination, processing, and statusing of contract specification and end-item documentation; the preparation and review of shipping and acceptance documentation; the coordination and preparation of contract data and engineering and contract change proposals; the fact-finding and conduct of proposal negotiations; and the preparation and submittal of reports on contract status. This element also includes propellant management system information management tasks required to identify, define, schedule, control, and disseminate documentation produced by the contractor; to receive and maintain documentation accountability records and files; and to maintain the information requirements document, which contains the DDT&E descriptions and schedules for information required by NASA.

**PS.1.1.2 CONFIGURATION MANAGEMENT**

This element includes the tasks required to establish and maintain the definition of the propellant scavenging system hardware configuration. The tasks include identifying the propellant scavenging system configuration baselines, controlling changes to those baselines, maintaining current accountability of the status of those baselines, and progressively verifying that the as-built configuration agrees with the current configuration baselines or that differences are identified.



**PS.1.1.3 QUALITY MANAGEMENT AND SUPPORT**

This element includes all quality assurance effort and resources related directly to production of the propellant scavenging system and ground system, except inspection. (The inspection tasks are included under applicable hardware-related WBS elements.) This element also includes tasks, such as resource management and visibility, quality information and visibility, and source surveillance, which are not identifiable to a specific subsystem.

**PS.1.1.4 PROCUREMENT AND IDWA MANAGEMENT**

This element includes a system for management and technical control of subcontractors, suppliers, and IDWA's. The tasks include providing contractual direction, authorizing subcontractor tooling and equipment, and analyzing subcontractor and IDWA reports. Additional tasks include subcontractor reviews, on-site coordination and evaluation, assessment of subcontractor technical schedule and cost performance, and the management and negotiation of subcontract changes and their integration into the Rockwell change control system.

**PS.1.1.5 PRODUCT SUPPORT**

This element encompasses propellant-scavenging-system-related production planning, production control, and resource planning; support related to the definition of vehicle packaging and transport requirements; and material preparation and kitting activities. This element also includes usage material and other low-value material not ordinarily charged to a specific subsystem, part, or assembly.

**PS.1.1.6 TECHNICAL MANAGEMENT**

This element includes tasks required to provide engineering technical direction, prepare detailed engineering technical schedules, support the performance management system, manage resources, maintain the engineering release system, and support the Technology Utilization Program. Test management and planning are also included.

**PS.1.1.7 LOGISTICS AND GFE MANAGEMENT**

This element includes logistics management for the propellant scavenging system and ground system. It also includes logistics support for mortality spares, modification hardware, equipment, and repair services for maintenance requirements.





This element also includes internal property management of government equipment, property, fluids, propellants, and pressurants issued to Rockwell. The management of equipment and documentation furnished by the government includes identification of requirements, analysis, scheduling, tracking, and problem resolution. Also included are maintenance of the propellant scavenging system and ground system GFE requirements documentation; development of Rockwell internal GFE property management procedures, including procedures for receiving, inspecting, maintaining, storing, and accounting for GFE; and preparation of acquisition documentation.

#### PS.1.1.8 FACILITIES

This element includes specific tasks related to required facilities: (1) preproduction effort (i.e., plant rearrangements, minor facilities modifications, and consolidation or establishment of areas to support manufacturing and test activities involving initial occupancy of buildings; installation of equipment; and installation of secondary utilities); and (2) maintenance of manufacturing test systems for the propellant scavenging system, subsystems, and GSE. Additional tasks are preparation and maintenance of the overall facilities plan; planning, scheduling, and control required to manage facilities activities; resource management activities; transportation planning; support to safety and environmental pollution control programs; support to surveys of major subcontractor fabrication and testing capability; and installation of new support equipment and tooling.

#### PS.1.2 SYSTEM ENGINEERING

This element defines requirements for the design, development, production, and test of the propellant scavenging system, including analyses that support the development of designs and verify compatibility of designs with requirements and tasks required to control and direct engineering activities related to the design of the system.

This element is subdivided into the following Level 5 elements:

- PS.1.2.1 System Requirements and Synthesis
- PS.1.2.2 Flight Technology Analysis
- PS.1.2.3 Safety and Reliability
- PS.1.2.4 Design and Project Control
- PS.1.2.5 Laboratory and Test Support
- PS.1.2.6 Special Studies
- PS.1.2.7 Maintenance Engineering Analysis

#### PS.1.2.1 SYSTEM REQUIREMENTS AND SYNTHESIS

This element includes those tasks required to perform analyses and studies to further define the performance and configuration requirements (including subsystem requirements) for the propellant scavenging system during all flight and mission phases; perform technical integration activities for propellant scavenging system performance



and configuration requirements and interfaces; prepare, maintain, and control propellant scavenging system technical plans, requirements, document specifications, measurement lists, and interface documents; perform studies of alternatives to design approaches to develop parametric design tradeoffs; perform selected analyses to determine propellant scavenging system characteristics and capabilities during all flight and mission phases and during abort conditions, and determine the impact of uncertainties; and define test requirements for the propellant scavenging system and prepare test procedures and test plans for the conduct of such tests.

#### PS.1.2.2 FLIGHT TECHNOLOGY ANALYSIS

This element includes analysis of data and design requirements to support evaluation of performance against performance requirements set forth in the propellant scavenging system specifications. Included are activities associated with thermodynamics and heat transfer analysis to establish thermal response and thermal design requirements for thermal control.

#### PS.1.2.3 SAFETY AND RELIABILITY

This element encompasses establishing, implementing, and maintaining safety standards and hardware reliability in the design and development process of the propellant scavenging system through systematic evaluation, analysis, review, and assessment. Safety includes system safety in regard to subsystem and system design, and design of propellant scavenging-related support equipment. Also, safety includes related support to mishaps, accidents, and incidents, support to program reviews; definition and control of safety guidelines, constraints, and requirements; performance of hazard analysis and risk assessments; safety review and analysis of changes; participation in design and postflight reviews; and support of analysis. Safety also includes test operation safety activities.

Reliability includes analysis and surveillance over the propellant scavenging system and ground systems. It also includes the implementation of a design drawing check, a design release-cycle approval system, and an analysis and reporting system related to the measurement of engineering product quality.

#### PS.1.2.4 DESIGN AND PROJECT CONTROL

This element includes those tasks required to provide design control of the propellant scavenging system, such as design control of the overall system, configuration definition of the basic internal arrangement and the interrelationship between the structure and subsystems, and design control of the major manufacturing and operational assemblies and field joints. This element also includes supporting the chief program engineer to ensure that engineering tasks, procedures, policies, and interface activities are carried out concerning vehicle and test articles, engineering change control, and NASA interfaces.

#### PS.1.2.5 LABORATORY AND TEST SUPPORT

This element includes laboratory equipment and test activities that support propellant scavenging system engineering but cannot be identified to one subsystem. Three main functions are included: (1) acquisition (design, fabrication, and procurement) of noncapital propellant-scavenging-system-unique engineering special test equipment (STE), development of STE checkout specifications and operations manuals, and maintenance of configuration control records; (2) maintenance, repair, and checkout of engineering STE used for propellant scavenging system development, and qualification testing, STE troubleshooting, and replacement of failed components to maintain propellant scavenging system engineering STE; and (3) test management and planning tasks, such as central project control, facility and equipment assurance, engineering test requirements planning, support, and control, and disposition of engineering test hardware.

#### PS.1.2.6 SPECIAL STUDIES

This element encompasses the effort to perform program- and NASA-directed studies of nonbaseline approaches to the propellant scavenging system, ground support systems, and interfaces, and for selected analyses of the performance, cost, operation, configuration, material, and development of nonbaseline system and subsystem options that conceptually enhance or improve the propellant scavenging system performance beyond current specification parameters.

#### PS.1.2.7 MAINTENANCE ENGINEERING ANALYSIS

This element provides for maintenance engineering analysis to determine propellant scavenging system and GSE hardware maintenance requirements and procedures.

#### PS.1.3 FLIGHT HARDWARE DESIGN, DEVELOPMENT, AND QUALIFICATION

This element includes detailed design of structures, system components, and interface hardware for the propellant scavenging system; fabrication and testing of development and qualification units; and evaluation and utilization of test results to finalize production designs. Work effort includes inspection, procurement, and support to safety and reliability.

This element is subdivided into the following Level 5 elements:

- PS.1.3.1 Structures
- PS.1.3.2 Fluid System
- PS.1.3.3 Avionics System
- PS.1.3.4 Mechanical System
- PS.1.3.5 System Integration
- PS.1.3.6 Integrated Mockup and Trainer

**PS.1.3.1 STRUCTURES**

This element includes design, development, and qualification of structural components for the propellant scavenging system, including primary and secondary structures and thermal protection items for structures. Also included are assembly of the structural test article, structural tests, and structural, dynamic, and material analysis to support the structural design effort.

**PS.1.3.2 FLUID SYSTEM**

This element includes design, development, and qualification of propellant storage and transfer components, including fluid lines, disconnects, valves, tanks, and component thermal protection items. Also included are assembly and testing of the complete fluid system.

**PS.1.3.3 AVIONICS SYSTEM**

This element includes design, development, and qualification of instrumentation, displays, controls, data processing, and electrical distribution and control components of the propellant scavenging system. Also included are assembly and testing of the complete avionics system.

**PS.1.3.4 MECHANICAL SYSTEM**

This element includes design, development, and qualification of latches and other mechanisms of the propellant scavenging system.

**PS.1.3.5 SYSTEM INTEGRATION**

This element includes assembly, testing, and analysis of multisystem hardware. Included are laboratory testing of the propellant scavenging system, installation and testing of the first unit in the payload bay of the orbiter vehicle, and flight test support.

**PS.1.3.6 INTEGRATED MOCKUP AND TRAINER**

This element includes design and fabrication of the propellant scavenging system mockup for fit check in the orbiter payload bay and subsequent use for training purposes.

**PS.1.4 GROUND SUPPORT EQUIPMENT (GSE)**

This element includes design, development, manufacture, and checkout of GSE and GSE modifications. GSE includes equipment for handling, installing, and providing access to propellant scavenging system components; servicing fluid systems; applying and controlling electrical power; and purging, draining and safing systems. Also included are special off-highway transport equipment, packaging and transport designs, and GSE installation and station activities.



Excluded are dimensional and fabrication tooling (see WBS PS.1.5.1), material handling equipment, parts protection equipment, and facilities and laboratory test fixtures and equipment. Also excluded are launch-site-peculiar USE and GSE provided by the government.

**PS.1.5 TOOLING**

This element encompasses propellant scavenging system tooling and interface control tooling. Included are the services and materials necessary to furnish, modify, or repair tooling.

This element is subdivided into the following Level 5 elements:

- PS.1.5.1 Dimensional and Fabrication Tooling
- PS.1.5.2 Interface Control Tooling

**PS.1.5.1 DIMENSIONAL AND FABRICATION TOOLING**

This element includes the services and materials necessary for the design, development, and fabrication of propellant scavenging system Level III dimensional and fabrication tooling (both system tooling and GSE tooling) to support the propellant scavenging system production requirements. Excluded is Level II interface control tooling, which is included under WBS Element PS.1.5.2.

**PS.1.5.2 INTERFACE CONTROL TOOLING**

This element includes the services and materials necessary to furnish, modify, or repair Level II interface control tooling to meet the requirements of other propellant scavenging system element contractors and NASA centers. Excluded are the design, development, and fabrication of Level III interface control tooling, as this is contained in WBS Element PS.1.5.1.

**PS.2 PROPELLANT SCAVENGING SYSTEM PRODUCTION AND GROWTH**

This element encompasses all unique activities necessary to produce and deliver propellant scavenging system flight units. This system includes the propellant tanks, all subsystems, and installed and integrated GFE. Tasks include unique design, manufacturing, quality control testing, assembly, installation, checkout, and procurement effort required during the production phase to produce complete propellant scavenging system flight units as well as in-line and retrofit modifications for the purpose of providing capability growth.

This element is subdivided into the following Level 4 elements:

- PS.2.1 Management and Support
- PS.2.2 Engineering Support
- PS.2.3 Flight Hardware Production

**PS.2.1 MANAGEMENT AND SUPPORT**

This element contains tasks associated with management and support of the propellant scavenging system production phase. The tasks include planning, organizing, and defining requirements; establishing schedules and allocating resources to attain objectives; reporting progress and providing program status visibility; and controlling the program activities.

This element is subdivided into the following Level 5 elements:

- PS.2.1.1 Business Management
- PS.2.1.2 Configuration Management
- PS.2.1.3 Quality Management and Support
- PS.2.1.4 Procurement and IDWA Management
- PS.2.1.5 Product Support
- PS.2.1.6 Technical Management
- PS.2.1.7 Logistics and GFE Management
- PS.2.1.8 Facilities

**PS.2.1.1 BUSINESS MANAGEMENT**

This element contains tasks required to operate an integrated performance management system that ensures integrated planning, scheduling, budgeting, work authorization, cost accumulation, and management visibility of all propellant scavenging system activities. Included are the tasks of consolidating program requirements; preparing budgets and schedules; analyzing, summarizing, and reporting performance measurement data; identifying problems; recommending solutions; and tracking problem resolutions.

Included also are coordination and analysis of contract change authorizations (CCA's), schedule change documents, and other related change documents to develop cost projections. In addition, this element includes the analysis, coordination, processing, and statusing of contract specification and end-item documentation; the preparation and review of shipping and acceptance documentation; the coordination and preparation of contract data and engineering and contract change proposals; the fact-finding and conduct of proposal negotiations; and the preparation and submittal of reports on contract status. This element also includes propellant management system information management tasks required to identify, define, schedule, control and disseminate documentation produced by the contractor; to receive and maintain documentation accountability records and files; and to maintain the information requirements document, which contains the DDT&E descriptions and schedules for information required by NASA.

**PS.2.1.2 CONFIGURATION MANAGEMENT**

This element includes the tasks required to maintain the definition of the propellant scavenging system hardware configuration. The



tasks include identifying the propellant scavenging system configuration baselines, controlling changes to those baselines, maintaining current accountability of the status of those baselines, and progressively verifying that the as-built configuration agrees with the current configuration baselines or that differences are identified.

**PS.2.1.3 QUALITY MANAGEMENT AND SUPPORT**

This element includes all quality assurance effort and resources related directly to production of the propellant scavenging system and ground system, except inspection. (The inspection tasks are included under applicable hardware-related WBS elements.) This element also includes tasks, such as resource management and visibility, quality information and visibility, and source surveillance, which are not identifiable to a specific subsystem.

**PS.2.1.4 PROCUREMENT AND IDWA MANAGEMENT**

This element includes a system for management and technical control of subcontractors, suppliers, and IDWA's. The tasks include providing contractual direction, authorizing subcontractor tooling and equipment, and analyzing subcontractor and IDWA reports. Additional tasks include subcontractor reviews, on-site coordination and evaluation, assessment of subcontractor technical schedule and cost performance, and the management and negotiation of subcontract changes and their integration into the Rockwell change control system.

**PS.2.1.5 PRODUCT SUPPORT**

This element encompasses propellant-scavenging-system-related production planning, production control, and resource planning; support related to the definition of vehicle packaging and transport requirements; and material preparation and kitting activities. This element also includes usage material and other low-value material not ordinarily charged to a specific subsystem, part, or assembly.

**PS.2.1.6 TECHNICAL MANAGEMENT**

This element includes tasks required to provide engineering technical direction, prepare detailed engineering technical schedules, support the performance management system, manage resources, and maintain the engineering release system. Test management and planning are also included.

**PS.2.1.7 LOGISTICS AND GFE MANAGEMENT**

This element includes logistics management for the propellant scavenging system and ground system. It also includes logistics support for mortality spares, modification hardware, equipment, and repair services for maintenance requirements.



This element also includes internal property management of government equipment, property, fluids, propellants, and pressurants issued to Rockwell. The management of equipment and documentation furnished by the government includes identification of requirements, analysis, scheduling, tracking, and problem resolution. Also included are maintenance of the propellant scavenging system and ground system GFE requirements documentation; development of Rockwell internal GFE property management procedures, including procedures for receiving, inspecting, maintaining, storing, and accounting for GFE; and preparation of acquisition documentation.

#### PS.2.1.8 FACILITIES

This element includes maintenance of manufacturing test systems for the propellant scavenging system, subsystems, and GSE. Additional tasks are preparation and maintenance of the overall facilities plan; planning, scheduling, and control required to manage facilities activities; resource management activities; transportation planning; support to safety and environmental pollution control programs; support to surveys of major subcontractor fabrication and testing capability; and installation of new support equipment and tooling.

#### PS.2.2 ENGINEERING SUPPORT

This element includes system engineering tasks, multiunit design and test support, and other engineering tasks required to support propellant scavenging system production. Also included are special studies and engineering tasks necessary to analyze, define, develop and implement (either in-line or by retrofit) capability growth provisions authorized by NASA.

Excludes engineering effort that can be identified to specific production units.

#### PS.2.3 FLIGHT HARDWARE PRODUCTION

This element includes all design, manufacture, inspection, and acceptance test activities that are unique to the production of specific flight units of the propellant scavenging system. Included also are production of modification kits required to implement make-work changes as well as capability growth changes.

Excluded are provisioned spares, overhaul and repair, and modification of delivered units.

This element is subdivided into the following Level 5 elements:

- PS.2.3.1 Flight Unit No. 1
- PS.2.3.2 Flight Unit No. 2
- PS.2.3.3 Flight Unit No. 3
- PS.2.3.4 Flight Unit No. 4
- PS.2.3.5 Flight Unit No. 5





**PS.2.3.1 FLIGHT UNIT NO. 1**

This element includes all unique activities necessary to design, manufacture, inspect, and acceptance test the first propellant scavenging system flight unit.

**PS.2.3.2 FLIGHT UNIT NO. 2**

This element includes all unique activities necessary to design, manufacture, inspect, and acceptance test the second propellant scavenging system flight unit.

**PS.2.3.3 FLIGHT UNIT NO. 3**

This element includes all unique activities necessary to design, manufacture, inspect, and acceptance test the third propellant scavenging system flight unit.

**PS.2.3.4 FLIGHT UNIT NO. 4**

This element includes all unique activities necessary to design, manufacture, inspect, and acceptance test the fourth propellant scavenging system flight unit.

**PS.2.3.5 FLIGHT UNIT NO. 5**

This element includes all unique activities necessary to design, manufacture, inspect, and acceptance test the fifth propellant scavenging system flight unit.

**PS.3 PROVISIONING**

This element encompasses operational spares planning and production, overhaul and repair (O&R), hardware modification, operation and maintenance documentation, maintenance engineering analysis, GSE spares, flight spares, related management and support tasks, and special provisioned hardware.

This element is subdivided into the following Level 4 elements:

- PS.3.1 Management and Support
- PS.3.2 Engineering Support
- PS.3.3 Provisioned Flight Spares
- PS.3.4 Provisioned GSE Spares
- PS.3.5 Provisioned Overhaul and Repair
- PS.3.6 Provisioned Modifications
- PS.3.7 Special Provisioned Hardware
- PS.3.8 Operation and Maintenance Documentation
- PS.3.9 Maintenance Engineering Analysis

**PS.3.1 MANAGEMENT AND SUPPORT**

This element contains tasks associated with management and support of the propellant scavenging system provisioning operations. The tasks include planning, organizing, and defining requirements; establishing schedules and allocating resources to attain objectives; reporting progress and providing program status visibility; and controlling the program activities.

This element is subdivided into the following Level 5 elements:

- PS.3.1.1 Business Management
- PS.3.1.2 Configuration Management
- PS.3.1.3 Quality Management and Support
- PS.3.1.4 Procurement and IDWA Management
- PS.3.1.5 Product Support
- PS.3.1.6 Technical Management
- PS.3.1.7 Logistics and GFE Management
- PS.3.1.8 Facilities

**PS.3.1.1 BUSINESS MANAGEMENT**

This element contains tasks required to operate an integrated performance management system that will ensure integrated planning, scheduling, budgeting, work authorization, cost accumulation, and management visibility of all propellant scavenging system activities. Included are the tasks of consolidating program requirements; preparing budgets and schedules; analyzing, summarizing, and reporting performance measurement data; identifying problems; recommending solutions; and tracking problem resolutions.

Included also are coordination and analysis of contract change authorizations (CCA's), schedule change documents, and other related change documents to develop cost projections. In addition, this element includes the analysis, coordination, processing, and statusing of contract specification and end-item documentation; the preparation and review of shipping and acceptance documentation; the coordination and preparation of contract data and engineering and contract change proposals; the fact-finding and conduct of proposal negotiations; and the preparation and submittal of reports on contract status. This element also includes propellant management system information management tasks required to identify, define, schedule, control, and disseminate documentation produced by the contractor; receive and maintain documentation accountability records and files; and maintain the information requirements document, which contains the DDT&E descriptions and schedules for information required by NASA.

**PS.3.1.2 CONFIGURATION MANAGEMENT**

This element includes the tasks required to maintain the definition of the propellant scavenging system hardware configuration. The



tasks include identifying the propellant scavenging system configuration baselines, controlling changes to those baselines, maintaining current accountability of the status of those baselines, and progressively verifying that the as-built configuration agrees with the current configuration baselines or that differences are identified.

**PS.3.1.3 QUALITY MANAGEMENT AND SUPPORT**

This element includes all quality assurance effort and resources related directly to production of the propellant scavenging system and ground system, except inspection. (The inspection tasks are included under applicable hardware-related WBS elements.) This element also includes tasks, such as resource management and visibility, quality information and visibility, source surveillance, etc., which are not identifiable to a specific subsystem.

**PS.3.1.4 PROCUREMENT AND IDWA MANAGEMENT**

This element includes a system for management and technical control of subcontractors, suppliers, and IDWA's. The tasks include providing contractual direction, authorizing subcontractor tooling and equipment, and analyzing subcontractor and IDWA reports. Additional tasks include subcontractor reviews, on-site coordination and evaluation, assessment of subcontractor technical schedule and cost performance, and the management and negotiation of subcontract changes and their integration into the Rockwell change control system.

**PS.3.1.5 PRODUCT SUPPORT**

This element encompasses propellant scavenging system provisioning-related production planning, production control, and resource planning; support related to the definition of vehicle packaging and transport requirements; and material preparation and kitting activities. This element also includes usage material and other low-value material not ordinarily charged to a specific subsystem, part, or assembly.

**PS.3.1.6 TECHNICAL MANAGEMENT**

This element includes tasks required to provide engineering technical direction to provisioning activities, prepare detailed engineering technical schedules, support the performance management system, manage resources, and maintain the engineering release system. Test management and planning are also included.

**PS.3.1.7 LOGISTICS AND GFE MANAGEMENT**

This element includes logistics management for the propellant scavenging system and ground system. It also includes logistics support for mortality spares, modification hardware, equipment, and repair services for maintenance requirements.

This element also includes internal property management of government equipment, property, fluids, propellants, and pressurants issued to Rockwell. The management of equipment and documentation furnished by the government includes identification of requirements, analysis, scheduling, tracking, and problem resolution. Also included is maintenance of the propellant scavenging system and ground system GFE requirements documentation; development of Rockwell internal GFE property management procedures, including procedures for receiving, inspecting, maintaining, storing, and accounting for GFE; and preparation of acquisition documentation.

#### PS.3.1.8 FACILITIES

This element includes maintenance of manufacturing test systems for the propellant scavenging system, subsystems, and GSE provisioning activities. Additional tasks are preparation and maintenance of the provisioning support facilities plan; planning, scheduling, and control required to manage facilities activities; resource management activities; transportation planning; support to safety and environmental pollution control programs; and support to surveys of major subcontractor fabrication and testing capability.

#### PS.3.2 ENGINEERING SUPPORT

This element encompasses engineering support to operational spares and other provisioned activities. Tasks include support to applicable procurement, manufacturing, inspection, and logistics activities; reliability and safety; and design release activities (including both contractor-made and subcontractor-made items), material review actions, and evaluation and analysis for the selection of new suppliers.

Excluded are engineering analysis and design since these tasks are included under the hardware, maintenance engineering analysis (MEA), and operation and maintenance documentation (OMD) WBS elements.

#### PS.3.3 PROVISIONED FLIGHT SPARES

This element includes provisioned materials and services necessary to provide propellant scavenging system flight spares, both for initial layin and for replenishment. Tasks include engineering analysis and design, tooling (i.e., refurbishment, maintenance, and storage of required tooling), fabrication, procurement, assembly, functional testing, inspection, packaging, and shipment of spares. This work is directed by NASA through PO's, contract change authorizations (CCA's), and contracting officer letters and is released by Rockwell through business master change records (MCR's) and provisioning authorization records (PAR's).

Excluded are modifications to delivered operational flight spares and modification of development hardware to fulfill operational flight spares requirements (see WBS PS.3.6) and overhaul and repair activities (see WBS PS.3.5).

**PS.3.4 PROVISIONED GSE SPARES**

This element includes materials and services necessary to provide GSE spares provisioned for support of GSE located at government-operated sites. Tasks include engineering analysis and design, tooling (i.e., refurbishment, maintenance, and storage of required tooling), fabrication, procurement, assembly, functional testing, inspection, packaging, and shipment of GSE spares. This work is directed by NASA through PO's, CCA's, and contracting officer letters, and is released by Rockwell through MCR's and PAR's.

Excluded are modifications to delivered operational GSE spares and modification of development hardware to fulfill operational GSE spares requirements (see WBS PS.3.6) and overhaul and repair activities (see WBS PS.3.5).

**PS.3.5 PROVISIONED OVERHAUL AND REPAIR**

This element encompasses provisioned overhaul and repair (O&R) of delivered propellant scavenging system and GSE parts and operational spares. Tasks include teardown and evaluation, failure analysis, and repair as authorized; preinstallation testing; and overhaul of applicable and operational parts.

Excluded are hardware modifications (see WBS PS.3.6), unless the modification is authorized as part of the O&R cycle for a particular hardware item.

**PS.3.6 PROVISIONED MODIFICATIONS**

This element encompasses provisioned modifications to delivered propellant scavenging system and GSE parts and operational spares. Tasks include fabrication, assembly, inspection, in-process testing of modification kits, and acceptance testing of the modified hardware.

Excluded are modifications authorized for accomplishment as part of the O&R cycle for a particular hardware item (see WBS PS.3.5).

**PS.3.7 SPECIAL PROVISIONED HARDWARE**

This element includes special hardware provisioned by NASA in support of provisioning operations activities for the propellant scavenging system.

**PS.3.8 OPERATION AND MAINTENANCE DOCUMENTATION**

This element provides for manuals and other documentation describing the requirements and procedures for operating and maintaining the propellant scavenging system and GSE.

**PS.3.9 MAINTENANCE ENGINEERING ANALYSIS**

This element provides for maintenance engineering analysis to determine propellant scavenging system and GSE hardware maintenance requirements and procedures.

**PS.4 OPERATIONS SUPPORT**

This element encompasses unique tasks necessary to support the transition from development flights to operational flights of the propellant scavenging system, the activation of the propellant-scavenging-system-related facilities, and the operational flight and ground operations at KSC, VAFB, and designated alternative landing sites.

Also included is support to JSC activities.

This element is subdivided into the following Level 4 elements:

- PS.4.1 Management and Support
- PS.4.2 Operations Support Engineering
- PS.4.3 Identified Projects

**PS.4.1 MANAGEMENT AND SUPPORT**

This element contains tasks associated with management of propellant scavenging system operations support activities. The tasks include planning, organizing, and defining requirements; establishing schedules and allocating resources to attain objectives; and reporting progress toward the attainment of objectives.

This element is subdivided into the following Level 5 elements:

- PS.4.1.1 Business Management
- PS.4.1.2 Configuration Management
- PS.4.1.3 Quality Management and Support
- PS.4.1.4 Procurement and IDWA Management
- PS.4.1.5 Product Support
- PS.4.1.6 Technical Management
- PS.4.1.7 Logistics and GFE Management

**PS.4.1.1 BUSINESS MANAGEMENT**

This element contains tasks required to implement an integrated performance management system that will ensure integrated planning, scheduling, budgeting, work authorization, cost accumulation, and management visibility of all activities. Included are the tasks of consolidating program requirements; preparing budgets and schedules; analyzing, summarizing, and reporting performance measurement data; identifying problems; recommending solutions; and tracking problem resolutions.



Included also are coordination and analysis of contract change authorizations (CCA's), schedule change documents, and other related change documents to develop cost projections. In addition, this element includes the analysis, coordination, processing, and statusing of contract specification and end-item documentation; the preparation and review of shipping and acceptance documentation; the coordination and preparation of contract data and engineering and contract change proposals; the fact-finding and conduct of proposal negotiations; and the preparation and submittal of reports on contract status.

This element also includes operations support information management tasks required to identify, define, schedule, control, and disseminate documentation produced by the contractor; receive and process government-furnished and subcontractor documentation; maintain documentation accountability records and files; and prepare and maintain the Operations Support information requirements document, which contains the descriptions and schedules for information required by NASA. In addition, this element includes the editorial, text production, and illustration services necessary to prepare the documentation required by the Operations Support information requirements document.

#### PS.4.1.2 CONFIGURATION MANAGEMENT

This element includes the tasks required to maintain the definition of propellant-scavenging-system hardware configurations. The tasks include controlling changes to configuration baselines, and progressively verifying that the as-built configuration agrees with the current configuration baselines or that differences are identified.

#### PS.4.1.3 QUALITY MANAGEMENT AND SUPPORT

This element includes all quality assurance effort and resources related directly to propellant scavenging system operations support. This element also includes tasks, such as metrology laboratory activities, resources management and visibility, quality information and visibility, and source surveillance, that are directly related to operations support tasks.

Preparation and maintenance of Rockwell quality-assurance directive documents are also included in this element.

#### PS.4.1.4 PROCUREMENT AND IDWA MANAGEMENT

This element includes a system for management technical control of subcontractors, suppliers, and major interdivisional work authorizations (IDWA's). The tasks include providing contractual direction and analyzing subcontractor reports. Additional tasks include subcontractor or supplier reviews, on-site coordination and evaluation, assessment of subcontractor technical schedule and cost performance, and the management and negotiation of subcontract changes and their integration into the Rockwell change control system.

**PS.4.1.5 PRODUCT SUPPORT**

This element encompasses manufacturing planning, manufacturing control, resource planning, support related to the definition of packaging and transport requirements, and material preparation and kitting activities. This element also includes usage material and other low-value material.

**PS.4.1.6 TECHNICAL MANAGEMENT**

This element includes tasks required to provide engineering technical direction, prepare detailed engineering technical schedules, support the performance management system, manage resources, and maintain the engineering release system. Test management and planning are also included.

**PS.4.1.7 LOGISTICS AND GFE MANAGEMENT**

This element includes administration tasks, advance planning and technical support, change management, and budget and cost control for logistics activities supporting propellant scavenging system operations.

This element also includes internal property management of government equipment, property, fluids, propellants, and pressurants issued to Rockwell. The management of equipment and documentation furnished by the government includes the identification of requirements, analysis, scheduling, tracking, and problem identification and resolution. This element also includes maintenance of the propellant scavenging system and ground system GFE requirements documentation; development of Rockwell internal GFE property management procedures, including procedures for receiving, inspecting, maintaining, storing, and accounting for GFE; and the preparation of acquisition documentation.

**PS.4.2 OPERATIONS SUPPORT ENGINEERING**

This element encompasses technical management tasks required to provide engineering technical direction, coordinate engineering technical effort to prepare detailed engineering technical schedule and cost estimates, support the performance management system, manage resources, and maintain the engineering release system.

Propellant scavenging system and subsystem project engineering tasks are included, as are engineering support activities such as engineering work control, engineering performance management, and surveillance. These tasks are for both propellant scavenging systems and ground systems.

This element also encompasses production delivery of documentation in support of safety requirement and procedure definitions, hazard analysis, and safety-critical GSE hazard analysis. Also included are production and delivery of documentation in support of reliability analysis and surveillance activities.



**PS.4.3 IDENTIFIED PROJECTS**

This element encompasses projects for which NASA has directed separate accounting.

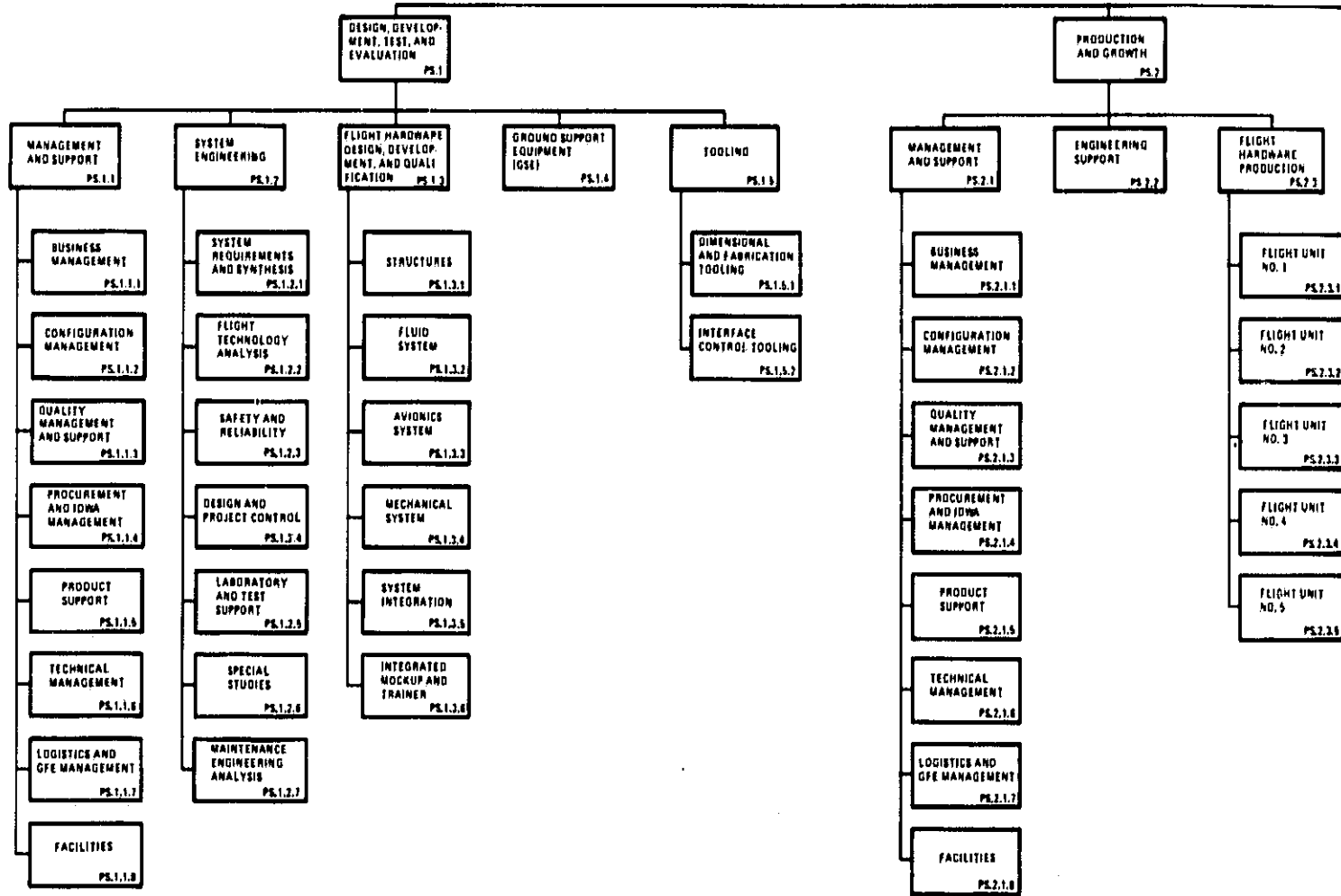
# FOLDOUT FRAME

LEVEL 2

LEVEL 3

LEVEL 4

LEVEL 5



2 FOLDOUT FRAME

PROPELLANT  
SCAVENGING  
SYSTEM  
PS.0

PROVISIONING  
PS.3

FLIGHT  
HARDWARE  
PRODUCTION  
PS.2.0

MANAGEMENT  
AND SUPPORT  
PS.3.1

ENGINEERING  
SUPPORT  
PS.3.2

PROVISIONED  
FLIGHT SPARES  
PS.3.3

PROVISIONED  
GFE SPARES  
PS.3.4

PROVISIONED  
OVERHAUL AND  
REPAIR  
PS.3.5

PROVISIONED  
MODIFICATIONS  
PS.3.6

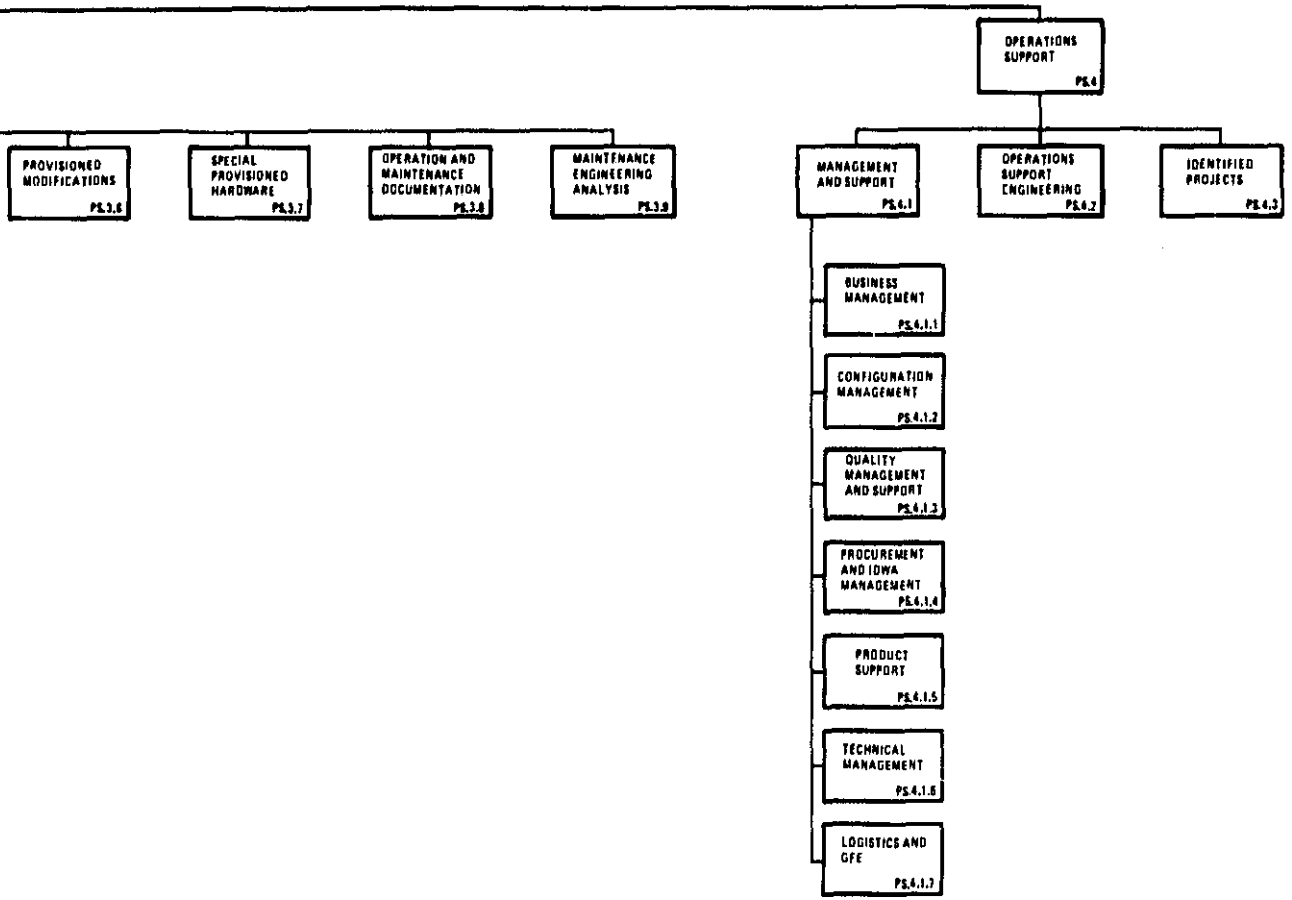
SPECIAL  
PROVISIONED  
HARDWARE  
PS.3.7

OPERATION AND  
MAINTENANCE  
DOCUMENTATION  
PS.3.8

- FLIGHT UNIT NO. 1 PS.2.11
- FLIGHT UNIT NO. 2 PS.2.12
- FLIGHT UNIT NO. 3 PS.2.13
- FLIGHT UNIT NO. 4 PS.2.14
- FLIGHT UNIT NO. 5 PS.2.15

- BUSINESS MANAGEMENT PS.3.1.1
- CONFIGURATION MANAGEMENT PS.3.1.2
- QUALITY MANAGEMENT AND SUPPORT PS.3.1.3
- PROCUREMENT AND IOWA MANAGEMENT PS.3.1.4
- PRODUCT SUPPORT PS.3.1.5
- TECHNICAL MANAGEMENT PS.3.1.6
- LOGISTICS AND GFE MANAGEMENT PS.3.1.7
- FACILITIES PS.3.1.8

FOLDOUT FRAME



STS PROPELLANT SCAVENGING  
SYSTEM PHASE C/D  
WORK BREAKDOWN STRUCTURE  
(PS.0)