CONTRACT NAS8-25140
MSFC-DPD-235/DR NO. MP-03
INTEGRATED MISSION MANAGEMENT OPERATIONS
NOVEMBER 1971
MDC G2600

APPROVED BY:

VERN D. KIRKLAND
PROGRAM INTEGRATION/OPERATIONS DIRECTOR
SPACE STATION PROGRAM

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
5301 Bolsa Avenue, Huntington Beach, CA 92647
PREFACE

The work described in this document was performed under the Space Station Phase B Extension Period Study (Contract NAS8-25140). The purpose of the extension period has been to develop the Phase B definition of the Modular Space Station. The modular approach selected during the option period (characterized by low initial cost and incremental manning) was evaluated, requirements were defined, and program definition and design were accomplished to the depth necessary for departure from Phase B.

The initial 2-1/2-month effort of the extension period was used for analyses of the requirements associated with Modular Space Station Program options. During this time, a baseline, incrementally manned program and attendant experiment program options were derived. In addition, the features of the program that significantly affect initial development and early operating costs were identified, and their impacts on the program were assessed. This assessment, together with a recommended program, was submitted for NASA review and approval on 15 April 1971.

The second phase of the study (15 April to 3 December 1971) consists of the program definition and preliminary design of the approved Modular Space Station configuration.

A subject reference matrix is included on page v to indicate the relationship of the study tasks to the documentation.

This report is submitted as Data Requirement MP-03.
## DATA REQUIREMENTS (DR's)
### MSFC-DPD-235/DR NOs.
### (contract NAS8-25140)

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<td>Performance Review Documentation</td>
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<td>Letter Progress and Status Report</td>
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<td>Space Station Program (Modular) Cost Estimates Document</td>
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<td>MP-01</td>
<td>Space Station Program (Modular) Mission Analysis Document</td>
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<td></td>
<td>MP-02</td>
<td>Space Station Program (Modular) Crew Operations Document</td>
</tr>
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<td></td>
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<td>Integrated Mission Management Operations Document</td>
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<td>SE</td>
<td>SE-01</td>
<td>Modular Space Station Concept Information Management System</td>
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<td></td>
<td>SE-02</td>
<td>Study Results Documentation</td>
</tr>
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<td></td>
<td>SE-03</td>
<td>Technical Summary</td>
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<td></td>
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<td>Modular Space Station Detailed Preliminary Design</td>
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<td>SE-06</td>
<td>Crew Cargo Module Definition Document</td>
</tr>
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<td></td>
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<td>Modular Space Station Mass Properties Document</td>
</tr>
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<td></td>
<td></td>
<td>SE-08</td>
<td>User's Handbook</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SE-10</td>
<td>Supporting Research and Technology Document</td>
</tr>
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<td></td>
<td></td>
<td>SE-11</td>
<td>Alternate Bay Sizes</td>
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<td></td>
<td></td>
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<td>SE System Engineering and Technical Description</td>
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<td></td>
<td></td>
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### 2.0 Contractor Tasks

#### 2.1 Develop Study Plan and Review Past Effort (MA-01)
- Document

#### 2.2 Space Station Program (Modular) Mission Analysis
- Document

#### 2.3 Modular Space Station Configuration and Subsystem Definition
- Document

#### 2.4 Technical and Cost Tradeoff Studies
- Document

#### 2.5 Modular Space Station Option Summary
- Document

#### 2.6 Crew Operational Analysis
- Document

#### 2.7 Crew Cargo Module
- Document

#### 2.8 Integrated Mission Management Operations
- Document

#### 2.9 Hardware Commonality Assessment
- Document

#### 2.10 Program Support
- Document

#### 2.11 Requirements Definition
- Document

<table>
<thead>
<tr>
<th>Requirement</th>
<th>CM</th>
<th>MA</th>
<th>MF</th>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
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#### 2.12 Plans
- Document

#### 2.13 Costs and Schedules
- Document

#### 2.14 Special Emphasis Task Information Management (MTS)
- Document

<table>
<thead>
<tr>
<th>Special Emphasis Task Information Management (MTS)</th>
<th>CM</th>
<th>MA</th>
<th>MF</th>
<th>MP</th>
<th>SE</th>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>User's Handbook</td>
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<td>MOD 40</td>
<td></td>
</tr>
</tbody>
</table>
Page intentionally left blank
## CONTENTS

<table>
<thead>
<tr>
<th>Section 1</th>
<th>INTRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Background</td>
</tr>
<tr>
<td>1.2</td>
<td>Scope of this Volume</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section 2</th>
<th>GROUND OPERATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Space Station Operations</td>
</tr>
<tr>
<td>2.1.1</td>
<td>Test Philosophy</td>
</tr>
<tr>
<td>2.1.2</td>
<td>Space Station Integration</td>
</tr>
<tr>
<td>2.1.3</td>
<td>Launch Site Activation Operations</td>
</tr>
<tr>
<td>2.1.4</td>
<td>Transportation</td>
</tr>
<tr>
<td>2.1.5</td>
<td>Prelaunch and Launch Operations</td>
</tr>
<tr>
<td>2.1.6</td>
<td>Ground Crew Staffing and Training</td>
</tr>
<tr>
<td>2.1.7</td>
<td>Module Access</td>
</tr>
<tr>
<td>2.1.8</td>
<td>Ground Operations Requirements Summary</td>
</tr>
<tr>
<td>2.2</td>
<td>Logistics and Crew Cargo Module Operations</td>
</tr>
<tr>
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<td>Site Activation</td>
</tr>
<tr>
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<td>Transportation</td>
</tr>
<tr>
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<td>Logistics Module Prelaunch and Launch Operations</td>
</tr>
<tr>
<td>2.2.4</td>
<td>Crew Cargo Module Prelaunch and Launch Operations</td>
</tr>
<tr>
<td>2.2.5</td>
<td>Contingency Capabilities (Rescue)</td>
</tr>
<tr>
<td>2.2.6</td>
<td>Logistics Module Ground Operations Requirements Summary</td>
</tr>
<tr>
<td>2.3</td>
<td>Experiments</td>
</tr>
<tr>
<td>2.3.1</td>
<td>Site Activation</td>
</tr>
<tr>
<td>2.3.2</td>
<td>Transportation</td>
</tr>
<tr>
<td>2.3.3</td>
<td>Prelaunch and Launch Operations</td>
</tr>
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<td>Description</td>
</tr>
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<td>4.2.3</td>
<td>Launch Site Biological Laboratory (LSBL)</td>
</tr>
<tr>
<td>4.2.4</td>
<td>Flight Integration Tool (FIT) Area</td>
</tr>
<tr>
<td>4.2.5</td>
<td>Shuttle Orbiter Maintenance Area</td>
</tr>
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<td>4.2.6</td>
<td>Mission Operations Support</td>
</tr>
</tbody>
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**Appendix A**

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
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</thead>
<tbody>
<tr>
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<td>ALTERNATIVE LAUNCH SITE OPERATIONS FLOW</td>
<td>531</td>
</tr>
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**Appendix B**

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
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<tr>
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<td>SHUTTLE-PAYLOAD GROUND OPERATIONS INTERFACE</td>
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</tr>
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<table>
<thead>
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<th>FIGURES</th>
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</tr>
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<tbody>
<tr>
<td>2-1</td>
<td>Power/Subsystems Module</td>
</tr>
<tr>
<td>2-2</td>
<td>Crew/Operations Module</td>
</tr>
<tr>
<td>2-3</td>
<td>Baseline General Purpose Laboratory</td>
</tr>
<tr>
<td>2-4</td>
<td>Space Station Buildup Module Delivery Schedule</td>
</tr>
<tr>
<td>2-5</td>
<td>Initial Space Station (Maximum Cluster Size during Quarter 13)</td>
</tr>
<tr>
<td>2-6</td>
<td>Growth Space Station (Maximum Cluster Size during Quarter 28)</td>
</tr>
<tr>
<td>2-7</td>
<td>Module-to-Module Interfaces</td>
</tr>
<tr>
<td>2-8</td>
<td>Initial Space Station Flight—Module Integration</td>
</tr>
<tr>
<td>2-9</td>
<td>Interface Verification Using Split Interface Adapter</td>
</tr>
<tr>
<td>2-10</td>
<td>Universal Interface Considerations</td>
</tr>
<tr>
<td>2-11</td>
<td>Modular Space Station—Initial Space Station Hardware Flow</td>
</tr>
<tr>
<td>2-12</td>
<td>Typical Module Operational Flow</td>
</tr>
<tr>
<td>2-13</td>
<td>Battery Installation</td>
</tr>
<tr>
<td>2-14</td>
<td>Space Station Module Loading</td>
</tr>
<tr>
<td>2-15</td>
<td>Mission Management Manning during Buildup</td>
</tr>
<tr>
<td>2-16</td>
<td>Phasing of Mission Management Function</td>
</tr>
<tr>
<td>2-17</td>
<td>View A—Mockup Interior</td>
</tr>
<tr>
<td>2-18</td>
<td>View B—Mockup Interior</td>
</tr>
<tr>
<td>2-19</td>
<td>Logistics Module</td>
</tr>
<tr>
<td>2-20</td>
<td>Logistics Operations Summary</td>
</tr>
<tr>
<td>Page</td>
<td>Description</td>
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<tr>
<td>2-21</td>
<td>Logistics Module Prelaunch and Launch Operations</td>
</tr>
<tr>
<td>2-22</td>
<td>Preliminary Master Schedule—Logistics Module</td>
</tr>
<tr>
<td>2-23</td>
<td>Preliminary Master Schedule—Crew Cargo Module</td>
</tr>
<tr>
<td>2-24</td>
<td>KSC Flow-Group A FPE's and FPE Subgroups</td>
</tr>
<tr>
<td>2-25</td>
<td>KSC Flow-Group B FPE's and FPE Subgroups</td>
</tr>
<tr>
<td>2-26</td>
<td>KSC Flow-Group C FPE's and FPE Subgroups</td>
</tr>
<tr>
<td>2-27</td>
<td>KSC Flow-Group D FPE's and FPE Subgroups</td>
</tr>
<tr>
<td>2-28</td>
<td>KSC Flow-Group E FPE's and FPE Subgroups</td>
</tr>
<tr>
<td>2-29</td>
<td>KSC Flow-Group F FPE's and FPE Subgroups</td>
</tr>
<tr>
<td>2-30</td>
<td>Support Elements of an Integrated Scientific Orbital Program</td>
</tr>
<tr>
<td>2-31</td>
<td>Space Station Program and Mission Management</td>
</tr>
<tr>
<td>2-32</td>
<td>Space Station Mission Management Operational Functions</td>
</tr>
<tr>
<td>2-33</td>
<td>Space Station Cargo Flow</td>
</tr>
<tr>
<td>2-34</td>
<td>Space Station Logistics Subelements</td>
</tr>
<tr>
<td>2-35</td>
<td>Crew Utilization and Training</td>
</tr>
<tr>
<td>2-36</td>
<td>Space Station Integrated Data Support System</td>
</tr>
<tr>
<td>2-37</td>
<td>Postlaunch Data Processing</td>
</tr>
<tr>
<td>2-38</td>
<td>Space Station Experiment Support Configuration</td>
</tr>
<tr>
<td>2-39</td>
<td>Mission Operations Support Center Configuration Concept at KSC</td>
</tr>
<tr>
<td>2-40</td>
<td>KSC Facilities Interrelationships</td>
</tr>
<tr>
<td>2-41</td>
<td>10-Meter-Dia Space Station—Sustaining Ground Operations Functional Interrelationships (PVM Operation)</td>
</tr>
<tr>
<td>2-42</td>
<td>Modular Space Station—Sustaining Ground Operations Functional Interrelationships</td>
</tr>
<tr>
<td>2-43</td>
<td>Modular Space Station—Sustaining Ground Operations Functional Interrelationships Showing Locations</td>
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<td>Chapter</td>
<td>Description</td>
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<tr>
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<td>3-1</td>
<td>Digital Data Terminal Integrated Checkout Equipment</td>
</tr>
<tr>
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<td>Portable Display and Control Unit</td>
</tr>
<tr>
<td>3-3</td>
<td>Radio Frequency Interface Unit</td>
</tr>
<tr>
<td>3-4</td>
<td>Communications Ground Station</td>
</tr>
<tr>
<td>3-5</td>
<td>Magnetic Tape Recording Unit</td>
</tr>
<tr>
<td>3-6</td>
<td>Electrical Load Unit</td>
</tr>
<tr>
<td>3-7</td>
<td>Timing Reference Unit</td>
</tr>
<tr>
<td>3-8</td>
<td>Ground Measurement and Switching Unit</td>
</tr>
<tr>
<td>3-9</td>
<td>Metabolic Simulator</td>
</tr>
<tr>
<td>3-10</td>
<td>Radio Frequency Interference Test Set</td>
</tr>
<tr>
<td>3-11</td>
<td>Ground Coolant Thermoconditioning System</td>
</tr>
<tr>
<td>3-12</td>
<td>P/RCS Pneumatic Equipment System</td>
</tr>
<tr>
<td>3-13</td>
<td>Portable Vacuum Pumping Unit</td>
</tr>
<tr>
<td>3-14</td>
<td>Space Radiator Service Unit</td>
</tr>
<tr>
<td>3-15</td>
<td>Potable and Coolant Water Servicer</td>
</tr>
<tr>
<td>3-16</td>
<td>Pressurization and Leak-Detection Unit</td>
</tr>
<tr>
<td>3-17</td>
<td>Insulation Purge System</td>
</tr>
<tr>
<td>3-18</td>
<td>Liquid Sampling Kit</td>
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<tr>
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<td>Refrigerant Service Unit</td>
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<tr>
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<td>Docking Port Access Kit</td>
</tr>
<tr>
<td>3-21</td>
<td>Internal Lighting Kit</td>
</tr>
<tr>
<td>3-22</td>
<td>Space Station Command Simulator</td>
</tr>
<tr>
<td>3-23</td>
<td>Flight Integration Tool</td>
</tr>
<tr>
<td>4-1</td>
<td>Kennedy Space Center</td>
</tr>
<tr>
<td>4-2</td>
<td>Logistics Module Maintenance, Checkout, and Loading</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
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<tr>
<td>4-3</td>
<td>Experiments and Experiment Modules Flow through Facilities</td>
</tr>
<tr>
<td>4-4</td>
<td>Experiment Support Complex Area Plan, Kennedy Space Center</td>
</tr>
<tr>
<td>4-5</td>
<td>MMC Facility Element and Complex Relationships, Highlighting the Experiment Support Complex</td>
</tr>
<tr>
<td>4-6</td>
<td>Experiment Payload Integration Center Operation</td>
</tr>
<tr>
<td>A-1</td>
<td>Typical Module Alternative Operational Flow</td>
</tr>
<tr>
<td>A-2</td>
<td>Portable Display and Control Unit</td>
</tr>
<tr>
<td>A-3</td>
<td>Battery Installation</td>
</tr>
<tr>
<td>B-1</td>
<td>Payload Interface with Shuttle Operations</td>
</tr>
<tr>
<td>B-2</td>
<td>Integration Device</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>2-1</td>
<td>Integration Method Comparison Matrix</td>
</tr>
<tr>
<td>2-2</td>
<td>Alternatives for Mission Support Requirements</td>
</tr>
<tr>
<td>2-3</td>
<td>Transportation Mode Selection</td>
</tr>
<tr>
<td>2-4</td>
<td>Space Station Capability During Buildup</td>
</tr>
<tr>
<td>2-5</td>
<td>Module Subsystem Status at Lift-Off</td>
</tr>
<tr>
<td>2-6</td>
<td>FPE/Subgroup Identification and Accommodation Type (Case 534G)</td>
</tr>
<tr>
<td>2-7</td>
<td>General Categorization Analysis</td>
</tr>
<tr>
<td>2-8</td>
<td>KSC Requirements Grouping Summary</td>
</tr>
<tr>
<td>2-9</td>
<td>Experiment Group Description</td>
</tr>
<tr>
<td>2-10</td>
<td>Support Requirements at KSC (Group A)</td>
</tr>
<tr>
<td>2-11</td>
<td>Group A Continuous Service Requirements</td>
</tr>
<tr>
<td>2-12</td>
<td>Group A Requirements for Servicing at the Shuttle Launch Pad</td>
</tr>
<tr>
<td>2-13</td>
<td>Support Requirements at KSC (Group B)</td>
</tr>
<tr>
<td>2-14</td>
<td>Continuous Service Requirements (Modules)</td>
</tr>
<tr>
<td>2-15</td>
<td>Support Requirements at KSC (Group D)</td>
</tr>
<tr>
<td>2-16</td>
<td>Support Requirements at KSC (Group F)</td>
</tr>
<tr>
<td>2-17</td>
<td>KSC Facility Utilization—Preflight</td>
</tr>
<tr>
<td>2-18</td>
<td>KSC Facility Utilization—Postflight</td>
</tr>
<tr>
<td>2-19</td>
<td>Potential Hazards</td>
</tr>
<tr>
<td>2-20</td>
<td>Comparison of Space Station to Expendable Booster Programs</td>
</tr>
<tr>
<td>2-21</td>
<td>Summary of Ground Support Requirements</td>
</tr>
<tr>
<td>------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>2-22</td>
<td>Inventory Control</td>
</tr>
<tr>
<td>2-23</td>
<td>Configuration Management</td>
</tr>
<tr>
<td>3-1</td>
<td>Station GSE</td>
</tr>
<tr>
<td>3-2</td>
<td>Functional Model GSE</td>
</tr>
<tr>
<td>3-3</td>
<td>Guidance and Control Subsystem Mechanical Test and Checkout Set Components</td>
</tr>
<tr>
<td>3-4</td>
<td>Structures Subsystem Mechanical Test and Checkout Set Components</td>
</tr>
<tr>
<td>3-5</td>
<td>Equipment Module Transportation Kit Components</td>
</tr>
<tr>
<td>3-6</td>
<td>Experiment Payload Integration Center Optical Laboratory GSE</td>
</tr>
<tr>
<td>3-7</td>
<td>Experiment Payload Integration Center Electronics Laboratory GSE</td>
</tr>
<tr>
<td>3-8</td>
<td>Payload Integration Center Machine Shop GSE</td>
</tr>
<tr>
<td>3-9</td>
<td>Launch Site Biological Laboratory GSE</td>
</tr>
<tr>
<td>4-1</td>
<td>KSC General Support Facilities</td>
</tr>
<tr>
<td>4-2</td>
<td>Experiment Payload Integration Center Physical Characteristics</td>
</tr>
<tr>
<td>4-3</td>
<td>Operations and Checkout Facility Physical Characteristics</td>
</tr>
<tr>
<td>A-1</td>
<td>Selected Subsystem Test by Module</td>
</tr>
<tr>
<td>B-1</td>
<td>Shuttle-Payload Integration</td>
</tr>
</tbody>
</table>
Section 1
INTRODUCTION

1.1 BACKGROUND
With the advent of the Space Shuttle in the late 1970's, a long-term manned scientific laboratory in Earth orbit will become feasible. Using the Shuttle for orbital buildup, logistics delivery, and return of scientific data, this laboratory will provide many advantages to the scientific community and will make available to the United States a platform for application to the solution of national problems such as ecology research, weather observation and prediction, and research in medicine and the life sciences. It will be ideally situated for Earth and space observation, and its location above the atmosphere will be of great benefit to the field of astronomy.

This orbiting laboratory can take many forms and can be configured to house a crew of up to 12 men. The initial study of the 33-foot-diameter Space Station, launched by the Saturn INT-21 and supporting a complement of 12, has been completed to a Phase B level and documented in the DRL-160 series. Recently completed studies are centered around a Space Station comprised of smaller, Shuttle-launched modules. These modules could ultimately be configured to provide for a crew of the same size as on the 33-foot-diameter Space Station—but buildup would be gradual, beginning with a small initial crew and progressing toward greater capability by adding modules and crewmen on a flexible schedule.

The Modular Space Station Phase A-level study results are documented in the DRL-231 series. Recent Modular Space Station Phase B study results are documented in the DPD-235 series, of which this is a volume.

The Space Station will provide laboratory areas which, like similar facilities on Earth, will be designed for flexible, efficient changeover as research and experimental programs proceed. Provisions will be included for such functions as data processing and evaluation, astronomy support, and test and
calibration of optics. Zero gravity, which is desirable for the conduct of experiments, will be the normal mode of operation. In addition to experiments carried out within the station, the laboratories will support operation of experiments in separate modules that are either docked to the Space Station or free-flying.

Following launch and activation, Space Station operations will be largely autonomous, and an extensive ground support complex will be unnecessary. Ground activities will ordinarily be limited to long-range planning, control of logistics, and support of the experiment program.

The Initial Space Station (ISS) will be delivered to orbit by three Space Shuttle launches and will be assembled in space. A crew in the Shuttle orbiter will accompany the modules to assemble them and check interfacing functions.

ISS resupply and crew rotation will be carried out via round-trip Shuttle flights using Logistics Modules (Log Modules) for transport and on-orbit storage of cargo. Of the four Log Modules required, one will remain on orbit at all times.

Experiment modules will be delivered to the Space Station by the Shuttle as required by the experiment program. On return flights, the Shuttle will transport data from the experiment program, returning crewmen, and wastes.

The ISS configuration rendering is shown in the frontispiece. The Power/Subsystems Module will be launched first, followed at 30-day intervals by the Crew/Operations Module and the General-Purpose Laboratory (GPL) Module. This configuration will provide for a crew of six. Subsequently, two additional modules (duplicate Crew/Operations and Power/Subsystems Modules) will be mated to the ISS to form the Growth Space Station (GSS) (shown in the frontispiece), which will house a crew of 12 and provide a capability equivalent to the 33-foot INT-21-launched Space Station. GSS logistics support will use a Crew Cargo Module capable of transporting a crew of six.

During ISS operations, five Research Applications Modules (RAM's) will be assembled to the Space Station. Three of these will be returned prior to
completion of the GSS. In the GSS configuration, 12 additional RAM's will augment the two remaining from the ISS phase. Three of the RAM's delivered to the GSS will be free-flying modules.

During the baseline 10-year program, the Space Station will be serviced by Shuttle-supported Logistics Module or Crew Cargo Module flights.

1.2 SCOPE OF THIS VOLUME

This volume describes the operations required to launch a Modular Space Station and provide the sustaining ground operations for support of that orbiting station throughout its 10-year mission. The buildup of a Modular Space Station in orbit and the subsequent launch of two additional modules approximately five years later will pose some unique problems in flight vehicle integration which are discussed in this volume. The 10-year continuing mission, resupply, configuration change capability, and multiproject involvement identified a need for a mission management concept which would support a low-cost program while providing the capability to meet the critical scheduling demands of the resupply requirements.

The baseline experiment program assumed for this analysis is Case 534G as defined in Section 2 of the Space Station Program (Modular) Mission Analysis (MP-01). Though this experiment program will probably not fly as defined, it is representative of operations that any selected experiment program will impose on ground operations.

The ground support equipment (GSE) is defined and the Kennedy Space Center (KSC) facilities identified which could be used to accomplish the mission operations. Many of these functions should be accomplished at the Shuttle launch site, assumed here to be KSC; however, certain other functions do not have a specific requirement to be located at the launch site. For those functions which might have alternative locations, a KSC facility is identified in the event that function were to be located at KSC.
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Section 2
GROUND OPERATIONS

Analysis of ground operations as part of the Modular Space Station integrated mission management would normally address launch site, prelaunch, and launch operations with little mention of operations prior to delivery to the launch site. However, the possibilities for streamlining operations and reducing costs inherent in the Modular Space Station concept require a broad overview of the total ground operations if the prelaunch and launch operations at the launch site are to be fully understood. Hence, the following discussion of Space Station module operations delves deeper into predelivery activities and overall test philosophy than would be ordinarily expected. Also included in the discussion are prelaunch and launch activities related to experiments and experiment modules (RAM's), logistics modules, crew cargo modules, mission operations support, flight crew activities, and safety considerations.

2.1 SPACE STATION OPERATIONS
Space Station operations include all launch site activities necessary to activate the site and to process (receive, service, and install in orbiter, and launch) all modules required to complete the orbital buildup of the Space Station. These modules will be of three different types; power, crew, and general-purpose laboratory, as shown in Figures 2-1 through 2-3. Three modules launched first (see Figure 2-4, overall launch schedule) will comprise the Initial Space Station shown in Figure 2-5, while a second group of two modules that may be launched five years later would provide for growth to the full 12-man capability or Growth Space Station shown in Figure 2-6. The operations will span several years; hence, the concepts for training and maintaining ground personnel and the disposition of GSE form an important part of prelaunch and launch operations. Note that KSC is assumed to be the launch site for this analysis.
Figure 2-1. Power/Subsystems Module

Figure 2-2. Crew/Operations Module
GROUP I

LOGISTIC LAUNCHES

1981 • 1982 • 1983 • 1984 • 1985

GROUP II

LOGISTIC LAUNCHES

1986 • 1987 • 1988 • 1989

Figure 2-4. Space Station Buildup Module Delivery Schedule

Figure 2-5. Initial Space Station (Maximum Cluster Size during Quarter 13)
2.1.1 Test Philosophy

Although prelaunch and launch operations begin with the first module activity at the launch site and end when the last Space Station module has been launched, integration of the modules which could be performed prior to delivery to the launch site and transportation to the launch site must also be considered. The test philosophy developed for the Space Station embraces all aspects of testing in the categories of development tests, qualification tests, acceptance tests, prelaunch and launch tests, and on-going mission tests. Some of the most important guidelines for testing are as follows:

A. Imposed environment testing, both development and qualification, will be concentrated at the assembly and subsystem hardware level. All hardware will be environmentally tested, but only one environmental demonstration will be required.

B. There will be no environmental testing at higher hardware levels.
C. Testing of assembled modules or assembled clusters will be limited to the following:

1. Design-development tests utilizing a functional model which is a breadboard of the electrical/electronic and data subsystems of the ISS modules.

2. Design-qualification demonstrations utilizing an integration fixture that is a physical and functional replica of the ISS modules (also used for sustaining support of mission operations, discussed later).

3. Hardware-acceptance tests of flight modules.

Implicit in this philosophy is the intent to eliminate qualification testing of the environmental mission profile at the module level or above, and to minimize repetition of integrated systems tests, whether performed at the factory or launch site.

D. A policy of shipping an orbit-ready module from the factory will be followed with regard to launch site testing. However, should any launch site testing be unavoidable, it will be confined to and no more rigorous than acceptance testing performed at delivery or at the factory. Tests will be end-to-end. Major disassembly and tests at lower levels of assembly will not be permitted in the field except when necessary to isolate malfunctions. Launch checkout will be accomplished with onboard checkout instrumentation (although complete onboard checkout capability does not exist in single modules, and the instrumentation will have to be supplemented with external GSE for control and monitoring purposes).

E. Tests will be assembled into an overall test plan covering all aspects of testing so that: (1) tests conducted at lower hardware levels are not repeated at higher levels unless inherent in hardware operation and unavoidable, and (2) development testing will be constructed to provide sensors and parameters which will ultimately be used for acceptance testing to have a credible data base. Similarly, acceptance and prelaunch testing will be constrained to those sensors and parameters properly explored and previously developed in the development-qualification testing programs.
2.1.2 Space Station Integration

Prelaunch operations for the modules (Section 2.1.5) are dependent upon both the method of integration and the location at which it is performed. This section describes the recommended integration concept on which the prelaunch operations are based.

Integration can be separated into two distinct but related categories; (1) ground activities designed to ensure the orbital compatibility of Space Station modules and their successful buildup into the complete station, and (2) activities devoted to ensuring successful integration and implementation of new hardware and software (both station and experiment), including any changes in hardware and software throughout the 10-year mission.

2.1.2.1 Module Integration, Orbital Compatibility

Figure 2-7 illustrates the interfaces between the ISS module and indicates the need to verify the integrated operations of all the modules prior to module launch. The need is especially evident when the nature of the data bus is considered; it is a dynamic data link between subsystems within the modules and between modules for the transmission of control commands and

![Module-to-Module Interfaces](image)

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<table>
<thead>
<tr>
<th>CREW/OPERATIONS MODULE</th>
<th>POWER MODULE</th>
<th>GPL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 IN. O₂</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>1/2 IN. N₂</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>3 IN. VACUUM</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>2 IN. AIR ACCUMULATOR</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>2 IN. AIRLOCK REPRESSURIZATION</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>6 IN. AIR</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>3/4 IN. COOLANT H₂O</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>3/4 IN. HEATING H₂O</td>
<td>●</td>
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<tr>
<td>1/2 IN. URINE</td>
<td>●</td>
<td>●</td>
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<tr>
<td>1/2 IN. CONDENSATE H₂O</td>
<td>●</td>
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<tr>
<td>1/2 IN. POTABLE H₂O</td>
<td>●</td>
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<tr>
<td>1/2 IN. WASH H₂O</td>
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<td>3/8 IN. GN₂</td>
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<td>3/8 IN. N₂H₄</td>
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<tr>
<td>1/2 IN. N₂H₄</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>1/4 IN. CO₂ (2)</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>CAUTION AND WARNING (2)</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>THRUSTER CONTROL (2)</td>
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<td>●</td>
</tr>
<tr>
<td>DATA BUS (2)</td>
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<tr>
<td>115 VDC (4)</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>115 VAC (2)</td>
<td>●</td>
<td>●</td>
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Figure 2-7. Module-to-Module Interfaces
feedback data, communications, status monitoring and checkout. Several alternative techniques for verifying the integrated operation of Space Station modules exist. These include: (1) mating the initial cluster of modules together and verifying their integrated operation, then treating the remaining modules five years later by another method; (2) mating each module with a breadboard of the complete station and verifying the integrated operation of module and breadboard; (3) mating each module with a physical and functional replica of the station and verifying integrated operation of the module and replica; (4) using interface substitutes, considering each module an individual payload; and (5) analysis of engineering drawings and procedures. Although analysis as a technique for total system integration is included as a possible alternative, it is difficult, if not impossible, to accomplish because of the unknown factors affecting functional interfaces (e.g., stray capacitance in electrical connections). Therefore, this alternative is not considered viable, and has not been investigated further.

Other variations may also be possible, but the four analyzed illustrate the basic principles involved, and point out the relative merits of various concepts. The advantages and disadvantages of each of these four approaches to integration are listed in Table 2-1. The foremost considerations in judging the desirability of a technique are the fidelity of integration or confidence in integration and the additional cost of implementing the technique.

Initial Cluster Mating
Three Space Station modules comprise the initial cluster (IC/ISS). These modules will exist in nearly the same time frame, since they will be scheduled for launch at one-month intervals. Thus, the third module will be launched only two months after the first. It would therefore be possible to phase the manufacturing schedule of the modules so that the finished modules would be available for mating on the ground simultaneously. The modules would be checked out individually and then mated together and verified as a whole (Figure 2-8) to accomplish integration and acceptance of the ISS. The two modules launched five years later can be treated this way with respect to each other as a separate group, but obviously cannot be treated in this manner with respect to the first group.

This approach approximates the conventional approach typical of contemporary spacecraft (including the 10-m (33-ft)-dia Space Station) in which
<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Cluster Matting</td>
<td>The initial cluster of flight modules (the most important toward ensuring success) would actually be operated together before flight, giving highest confidence possible in flight performance.</td>
<td>Flight interfaces between modules would be demated after integrated testing, thereby invalidating the real advantage of mating, which in the verification of integrated operation results.</td>
<td>Physical Functional Replica Matting (FTR)</td>
<td>High-fidelity integration of modules would give highest confidence in integration results.</td>
<td>Program cost may be increased since integration structures for every module may not be available, i.e., two structurally identical modules would not both have wire and tube run development; thus, an additional structure would have to be manufactured, or obtained elsewhere for the Flight Integration Tool.</td>
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<tr>
<td>Breadboard Matting (Functional Model)</td>
<td>The basic Functional Model (FM) as an integration tool would be available at little additional cost to the program, since it is a product of engineering development of the Space Station design.</td>
<td>Development hardware would not necessarily be equivalent to flight hardware in design performance or reliability and could not be expected to last long enough to be used with the latter modules, especially if the Functional Model is also used for mission support. Hence, fidelity of integration would be only fair for early modules, with no guarantee for future modules.</td>
<td>Interface Substitutes</td>
<td>GSE could be obtained at no extra development cost, since it would be needed anyway for individual module acceptance testing.</td>
<td>Additional sets of GSE at extra cost would be required if integration is accomplished at other than the manufacturing and acceptance location.</td>
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<td>Additional GSE requirements would be minimized since the combined breadboard and module would have OCS capability.</td>
<td>Some continuing mission support functions could be partially accomplished using the FM, i.e., functional configuration, troubleshooting, functional integration of hardware and software, maintenance plan and procedure development and revision, and software qualification, although not as well as if an FM were used.</td>
<td></td>
<td>Onboard checkout system would not be used for checkout; hence, its operational capability to determine and isolate faults would not be verified.</td>
<td>Onboard checkout system would not be used for checkout, but its operational capability to determine and isolate faults would not be verified.</td>
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<td>Some continuing mission support functions would have to be accomplished by other means. Those that could be accomplished are done with a loss of capability, and with dubious validity, e.g., troubleshooting on development hardware may lead to erroneous results due to differences between development and flight hardware design.</td>
<td>Actual flight interfaces would never be mated and verified.</td>
<td></td>
<td>Fidelity of integration testing would be the lowest of any of the alternatives.</td>
<td>Actual flight interfaces would never be mated and verified.</td>
</tr>
</tbody>
</table>
| | Actual flight interfaces would never be mated and verified. | A special facility would be required for the duration of the program. | | Continuing mission support functions would have to be accomplished by other means. | **Table 2-1**

**INTEGRATION METHOD COMPARISON MATRIX**
Figure 2-8. Initial Space Station Flight Module Integration
the entire craft is fully assembled on the ground. Its operation as a whole is verified through a series of integrated testing activities which closely resembles flight operations, and it is launched as a unit with all flight interfaces mated. The significant difference resulting from modularization is that checked and verified flight interfaces between modules would have to be demated in order to launch the individual modules, thereby partially invalidating test results and negating an advantage of this method.

Note that hard docking of modules is not required to verify the mechanical docking mechanisms. These can be verified against a standard docking mechanism tool (Figure 2-9), since if up to five equivalent docking ports per module can be built, an extra standard mechanism of physical integrity can be built with equal ease. This mechanism can be physically mated with each docking port with less chance of damage, since it will be smaller and considerably less weight than a complete module. Also, this tool will verify all docking ports on a module (not just those with which another Space Station module will mate) since all will be physically identical, as illustrated.
in Figure 2-10. This is the same technique developed for verifying the physical compatibility of the 10-m (33-ft)-dia Space Station and experiment modules. (For further information, see MSFC-DRL-160, Line Item 22, Analysis of Space Station Impact on KSC, December 1970.)

Breadboard Mating (Functional Model)

Initial development of module systems and software will require an engineering breadboard or functional model of each module. These breadboards will be composed of development hardware mounted in racks in the approximate relationship that would exist in the Space Station module. The aggregate of these breadboards could be assembled into a complete Space Station functional model. As a new module is developed, its breadboard would be added to those already existing as part of the functional model of the Modular Space Station. Hence, the modular station functional model could be continually revised to represent the next stage of orbital buildup and could be used for integration. Integration would be accomplished in this method by
substituting the actual flight module for its respective breadboard and then verifying the integrated operation of the flight module and breadboards of other modules. Once integration of a module has been accomplished, it would be disconnected from the functional model, and the breadboard circuits representing it would be reconnected for use in integration checks of later modules.

Use of a functional model for integration has several drawbacks. The functional model would be primarily a static load electrical model. As such, it would have limited ability to simulate dynamic functions crossing the module-to-module interfaces during integration tests of actual flight hardware. It would have no capability to verify fluid interface functions without additional hardware being added to it. Also, it could lead to quality assurance conflicts arising from the mating of flight hardware with relatively uncontrolled hardware. The method would have considerably lower fidelity than actual flight module mating or the use of replicas; however, it would be of benefit if a better method was not available.

**Physical and Functional Replica (Flight Integration Tool)**

In this concept for the Modular Space Station, ground-based physical and functional replicas of each module would be assembled and mated together in the orbital configuration. Use of these replicas for module integration would be accomplished by substituting a flight module for its replica in the cluster of replicas and then verifying integrated operation of the total cluster. The fidelity of this method would be indistinguishable from the method of using actual flight modules provided the replica modules were built to the same specifications and subjected to the same change control as the orbiting station modules.

The replica technique has several attractive features. One is that replicas could be obtained at little cost from qualification hardware and integration structures used to develop wire and tube routing. Flight article spares are also available. Another is that replicas will be needed anyway to form the flight integration tool (FIT) used for final development of software and hard-
ware in flight configuration. And the method is equally applicable to the ISS modules and GSS modules. Note also that the method will allow early verification and development of the GSS software. This can be accomplished by mating the crew module replica and power module replica to the three ISS flight modules and operating the five modules together as a unit. Additional hardware development would not be necessary since the ISS and additional GSS modules are nearly identical in design. The configuration across the interface during use would be the same as shown for actual flight modules in Figure 2-7.

Interface Substitutes
Interface substitutes would consist of GSE designed so that it could be connected to a module and furnish stimuli, signals, and loads similar to those provided by the flight module normally connected at the same interface. Note that the breadboards and replicas mentioned earlier would be special maximum-fidelity cases of interface substitutes that use actual flight hardware designs. Fidelity can range from very low (simple GSE) to very high (a replica). Integration would be accomplished by connecting the GSE to the appropriate module interfaces and simulating the presence of the other Space Station modules while exercising the module under test as if it were on-orbit as part of the station. This method would require additional sets of GSE be added to the program.

2.1.2.2 Continuing Mission Support Integration
A number of requirements for continuing mission support in the area of test and integration were derived as a part of the 33' Space Station study efforts (MSFC-DRL-160, Line Item 22). These requirements, listed below, are still valid for continuing mission support of the Modular Space Station.

A. Aid real-time configuration control and tracking of the orbiting Space Station.
B. Aid trouble-shooting of orbital problems which cannot be solved by the flight crew.
C. Provide for functional and physical integration of new or modified Space Station flight hardware, experiments, and experiment modules (RAM's).
D. Provide for functional integration of new or modified software.
E. Aid flight-crew proficiency training (although training requirements are considerably reduced since cargo modules are no longer docked under station control).
F. Provide for verification of the functional interface between the Space Station and flight control center.
G. Aid in development and revision of maintenance plans and procedure.
H. Aid orientation of the principal investigator.
I. Qualification testing of software.
J. Indoctrination of the scientific community.

Availability of the hardware and technical excellence of the replica method of flight module integration suggest that the same concept would be equally applicable to satisfying continuing mission support integration requirements when the flight modules are in orbit and physically unavailable. However, several of the flight module integration methods will not necessarily result in a replica of the modular station, and if chosen as the flight module integration method, could result in abandonment of the replica concept for continuing mission support. Before a method of flight module integration can be recommended, the effects of satisfying mission support requirements by alternative means must be evaluated.

All the mission support requirements satisfied by a ground-based replica can be satisfied to some measure by a number of alternative methods or combinations of methods, as shown in Table 2-2. This list of alternatives is not necessarily complete, but represents only typical alternatives. Certain key points should be noted regarding the alternatives: many are traditional methods that have been proven, but also have known faults (e.g., computerized accounting system for hardware changes, engineering analysis of drawings and procedures). A replica would supplement these methods by providing a reference configuration for direct visualization of the problem and by enabling actual fit and functional testing of proposed changes, thereby eliminating or reducing the effects of the faults.
Some of the alternatives appear attractive on the surface but on closer examination are impossible or will in actuality be similar to a replica. For example, if a breadboard functional model were used to aid functional configuration control, then it would have to accurately track the configuration of the orbiting modules for the duration of the Space Station program. This would be impossible with development hardware due to variations in development and flight hardware design (as mentioned earlier in Table 2-1). Use of qualification hardware in the functional model would violate its concept as an engineering development tool and would essentially result in a replica except for structure.

Use of the functional model has other drawbacks with respect to satisfying mission support functions. Principally, the reliability of the equipment cannot be expected to measure up to that of flight hardware. Accordingly, it will be subjected to a higher failure rate than a replica assembled from qualification hardware. Also, should a failure occur, spares might not be available since the development hardware would not be identical to flight hardware. It is evident that the functional model would not be available for mission support duty as much of the time as a replica under these conditions, although a quantitative assessment of the difference cannot be made at this time.

2.1.2.3 Recommended Module Integration Concept
The concept recommended for satisfying integration requirements, illustrated in Figure 2-11, is a hybrid of flight module mating and use of the physical and functional replica or flight integration tool. Highlights of the concept are as follows:

A. Qualification hardware, flight article spares, and integration structures will be used to assemble replicas of the ISS and GSS flight modules.
B. Assemble FIT for final development of software and hardware and later for continuing mission support activities.
C. Mate the FIT modules in the ISS configuration.
D. Soft-dock the modules to reduce facility and GSE requirements for access, to aid in substitution of modules, and to increase flexibility.
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Alternative</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real-time configuration control and tracking</strong></td>
<td>Use a computerized accounting system similar to present-day methods</td>
<td>Needed anyway, even with Project Verification Model. The Project Verification Model is an aid to this system to remove its deficiencies, i.e., enable visualization and trial fitting with drawings and change orders only</td>
</tr>
<tr>
<td></td>
<td>Use Functional Model for functional configuration control and tracking</td>
<td>Functional configuration control only would be meaningless; another system must be also used</td>
</tr>
<tr>
<td><strong>Troubleshooting</strong></td>
<td>Computer simulation of Space Station systems</td>
<td>Costly, may not simulate the particular characteristic giving rise to the problem, i.e., if sufficient analyses were performed to define all subsystem characteristics for a computer program, then the problem could probably be defined directly for the crew</td>
</tr>
<tr>
<td></td>
<td>Engineering analysis of drawings and procedures on ground to support flight crew</td>
<td>Time-consuming, costly if enough men are assigned to the problem to reduce time. Obtaining adequately knowledgeable engineers late in the program may be difficult unless a large staff is maintained for the duration of the program</td>
</tr>
<tr>
<td></td>
<td>Breadboard and simulation of critical functions or Functional Model</td>
<td>Breadboard or Functional Model does not accurately represent Space Station systems, may lead to erroneous results</td>
</tr>
<tr>
<td></td>
<td>Increased crew training for flight crews to increase their orbital troubleshooting capabilities</td>
<td>May be used regardless</td>
</tr>
<tr>
<td></td>
<td>Shuttle special repair crews to orbit</td>
<td>May be used regardless</td>
</tr>
<tr>
<td></td>
<td>Return malfunctioning module to earth</td>
<td>May be used regardless</td>
</tr>
<tr>
<td><strong>Functional integration of new or modified hardware, experiments, and software</strong></td>
<td>Use the Functional Model</td>
<td>OK provided Functional Model accurately tracks functional characteristics of orbiting station</td>
</tr>
<tr>
<td></td>
<td>Engineering analysis</td>
<td>Difficult to accomplish (if not impossible) as demonstrated many times in the past</td>
</tr>
<tr>
<td></td>
<td>Use interface substitutes</td>
<td>Design of an adequate substitute will result in the equivalent of flight subsystems</td>
</tr>
<tr>
<td></td>
<td>Accurate mockups of physical configuration (nonfunctional)</td>
<td>Equivalent to building a flight-type structure</td>
</tr>
<tr>
<td></td>
<td>Engineering analysis of configurations</td>
<td>Difficult to accomplish (if not impossible); as demonstrated many times in the past</td>
</tr>
<tr>
<td></td>
<td>Part-task trainers, with simulation of selected functions</td>
<td>These alternatives are probably needed with the modular station due to increased difficulty of access, operations in a 0-g configuration</td>
</tr>
<tr>
<td></td>
<td>Mockups</td>
<td>The traditional way of accomplishing this function. Still required if Project Verification Model is not located at the launch site</td>
</tr>
<tr>
<td><strong>Physical integration of new or modified hardware and experiments</strong></td>
<td>Use actual Space Station module</td>
<td>These alternatives have the same drawbacks, i.e., lack of fidelity in visualizing the physical layout of the station will result in errors in procedures that will have to be corrected on-orbit</td>
</tr>
<tr>
<td></td>
<td>Use mockups and Functional Model</td>
<td>Probably will be used anyway, low priority for Project Verification Model</td>
</tr>
<tr>
<td><strong>Flight crew proficiency training</strong></td>
<td>Engineering analysis with verification on functional model</td>
<td>Traditional method, use of Project Verification Model is better, but low priority</td>
</tr>
<tr>
<td></td>
<td>Mockups and user handbook</td>
<td>Probably will be used anyway. Project Verification Model use would not be allowed if this function interfered with higher-priority functions</td>
</tr>
<tr>
<td><strong>Space Station-flight control center interface verification</strong></td>
<td>Use actual Space Station module</td>
<td>The traditional way of accomplishing this function. Still required if Project Verification Model is not located at the launch site</td>
</tr>
<tr>
<td><strong>Maintenance plan and procedures development</strong></td>
<td>Use mockups and Functional Model</td>
<td>These alternatives have the same drawbacks, i.e., lack of fidelity in visualizing the physical layout of the station will result in errors in procedures that will have to be corrected on-orbit</td>
</tr>
<tr>
<td><strong>Principal investigator orientation</strong></td>
<td>Engineering analysis with verification on functional model</td>
<td>Probably will be used anyway</td>
</tr>
<tr>
<td><strong>Software qualification</strong></td>
<td>Mockups and user handbook</td>
<td>Project Verification Model use would not be allowed if this function interfered with higher-priority functions</td>
</tr>
<tr>
<td><strong>Scientific community indoctrination</strong></td>
<td>Use Functional Model</td>
<td>Probably will be used anyway</td>
</tr>
<tr>
<td></td>
<td>User handbook</td>
<td>Project Verification Model use would not be allowed if this function interfered with higher-priority functions</td>
</tr>
<tr>
<td></td>
<td>Mockups</td>
<td>Project Verification Model use would not be allowed if this function interfered with higher-priority functions</td>
</tr>
</tbody>
</table>
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Figure 2-11. Modular Space Station - Initial Space Station Hardware Flow
E. Use a standard docking port tool to verify mechanical compatibility of modules.

F. Interchange flight modules with FIT counterparts and verify operations.

G. Mate flight modules and verify operations.

H. Remove items to be off-loaded because of Shuttle payload limitations and ship separately to the launch site for delivery of the first two logistics flights.

I. Disassemble cluster and send individual modules to launch site for preflight servicing, loading in the Shuttle orbiter, and launch.

The overall concept and any constraints of the program and schedule are presented in the following text.

The three ISS modules will be launched 30 days apart and over a 60-day period. Current weight estimates require that items not critical to buildup or initial operations be off-loaded to reduce each module to the current payload weight limit of the Shuttle orbiter. Though the subsystems will be divided among the three modules for ISS, they will be designed, developed, tested, and delivered as complete subsystems. Once delivered, these subsystems will be separated and the appropriate portion installed in the designated module. Both the concurrent subsystem delivery and the close launch dates of the modules eliminate any benefit in staggering the module production or testing; thus, the selected integration concept can be based on the three ISS modules being completed at essentially the same time.

The first articles off the production line will be all three FIT modules. At this stage of development, they are used as production prototypes to develop cable and wire runs and assembly techniques. Each of these modules will be tested utilizing production GSE, after which it will be substituted for its counterpart in the Functional Model. After all three have been substituted in the Functional Model, they will be assembled into the ISS configuration utilizing the split interface adapters shown in Figure 2-9. The production flight articles will be next off the production line. They will be substituted for the FIT modules, one by one, and operations verified. The flight articles
will be assembled into the ISS configuration and integrated operation verified. By this technique, both the FIT modules and the flight articles are proven to operate as assembled ISS configurations. The interchange of modules between the two verifies the intermodule interface and overall operation of the flight articles and the FIT, which will support the 10-year program on the ground for integration of subsequent changes or new hardware.

After this integrated test which verifies readiness for orbital operations, the modules will be disassembled, the items to be off-loaded removed, and the modules individually shipped to the Shuttle launch site for flight servicing, loading in the orbiter and subsequent launch.

Mating of the ISS flight modules for integration could be performed at one of several sites; (1) at a site convenient to the overall Space Station contractor; (2) at an integration facility at the launch site; or (3) at an independent integration facility situated at neither the launch site nor the manufacturing location. Mating at the launch site would allow integration to be accomplished immediately before launch of the first module without cross-country transportation between integration and launch sites and the accompanying possibility of transportation effects damaging the modules or invalidating integration test results. Mating at an independent site doubles the transportation requirements, i.e., shipment from factory to independent site to launch site instead of factory to launch site. Another concept requires the integration to be accomplished at the manufacturing site, which minimizes program cost and development risk. To realize the economies and advantages of this concept, the flight articles must be orbit-ready when they leave the manufacturing site. Mating the modules and verifying ISS integrated operation at the manufacturing site is recommended to minimize costs, as no damage or invalidation of results would be expected unless the modules are subjected to severe transportation environments which can be easily measured.

Failure to do this will move duplicate operations to the launch site with the resultant increase in manpower, schedule extensions, and launch date slip. Unfortunately, this has been the experience in past programs. This condition
has been caused by early establishment of a specific shipping date tied heav-
ily to payment incentives and a multitude of late changes by both the customer
and contractor, thus forcing the bidding contractor to plan for this contingency
and expect to ship the flight article with mission or nonfunctional elements
(i.e., ship short) and deliver this article to the launch site supported by a
crew of significant size in facilities specifically prepared to complete the
manufacture and perform acceptance tests. Admittedly, if the vehicle is not
ready on the planned ship date from the manufacturing site, the launch date
could slip. However, any operation that must be accomplished prior to
launch can be performed faster with existing personnel and equipment at the
manufacturing site rather than shifting operations, personnel, and equipment
to the launch site and dedicating modifying facilities to perform these tasks.
Lead times on launch site facility preparation preclude a last-minute decision
to perform any task at the launch site and preplanning such activity would
expend manpower and money in anticipation of performing a function at the
launch site that may not be required.

An alternative scheme would be to perform the integration at both the factory
and launch site. However, this would duplicate testing and require the off-
loading to be done at the launch site where the installation experience does
not exist. Performing the integrated testing of the flight module at the launch
site only invites schedule slip and cost increase in that the flight modules
would be assembled first there and any difficulties encountered in initial
assembly of modules would have to be accomplished at locations remote
from the engineering and production sites. All the integrated module GSE
will be retained at the manufacturing site and only necessary module GSE
would be shipped to the launch site. This would require all the GSE to
operate the FIT and the flight module cluster would have to be shipped to the
launch site and set up in a specific facility.

The FIT could also be located at one of the three types of sites indicated
earlier. However, development of the Space Station, particularly software,
will require extensive use of the FIT by engineering personnel during final
development phases for the initial cluster of modules. Thus, from a develop-
ment view, locating the FIT at the manufacturing site is the logical choice.
Otherwise, development engineering personnel would have to be temporarily assigned to the FIT location, thereby increasing development costs. It is recommended that the FIT be located at the manufacturing site until development of the ISS has been completed.

After ISS development, the FIT should be located at a site that most conveniently accommodates the majority of the continuing activities. Note that locating the FIT at other than the manufacturing site does not materially interfere with development of the GSS modules since they should be essentially identical in design to their ISS counterparts and would require little to no additional hardware development.

Integration of GSS modules and new changed GSS software is included in the continuing mission functions. However, locating the FIT at other than a factory or launch site will double transportation risks for GSS modules similarly to ISS modules as mentioned above. If the FIT were used only to verify hardware prior to delivery to orbit, it would be best located at the launch site. However, the FIT has other functions, both in the development cycle and in the 10-year program. It will be used for Space Station and experiment change verification and to verify future RAM's, in addition to mission management uses. Development of new software programs will also utilize the FIT. Contractors or NASA centers involved in experiment integration might require the FIT at their facility. New hardware delivery will probably be subjected to acceptance testing on the FIT and in this case, location at a contractor facility could reduce the number of personnel and hardware to be relocated to perform this function at other than a contractor site.

In short, the location of the FIT should be left open until the requirements of the Space Station, RAM and Shuttle projects can be integrated. These requirements should be made available to the bidding contractors, who should be permitted the option of proposing a location that their resources and implementation planning indicates would be most cost-effective for the program.
Note that if flight module mating and integration or FIT operations were to be performed at the launch site, then the manned spacecraft operations building (MSOB) checkout area would be an ideal facility, with a suitable environment, more-than-adequate space, adjacent offices, and overhead cranes, and would require little modification to its present configuration. Space would be adequate for RAM modules and the FIT. Other existing facilities (e.g., PIB) could also accommodate these activities if modified.

2.1.3 Launch Site Activation Operations

Site activation consists of those functions to be accomplished at the launch site (KSC) and other integrated mission management facilities from first receipt of electrical and mechanical GSE through arrival of the first flight module. Site activation will present no new major or unique problems. Activation will consist of preparing the site for the ensuing on-going program and will include facility preparations and modifications, receiving and installing GSE, collecting personnel and preparing them for operational tasks, organizing the administrative and engineering/technical resources for operational tasks, and verifying that the totally integrated site possesses the capability for accomplishing its purpose.

Facility modifications will be accepted, or beneficial occupancy will be allowed prior to installation of GSE. In any case, modification work will be sufficiently advanced to allow installation activities to proceed without contractor or labor conflict.

GSE will be unpacked, inspected, and prepared for moving to its installation or utilization area after arrival at receiving inspection areas set up temporarily at the launch site in existing facilities. GSE will be moved from its receiving inspection area to the installation or utilization area. If the GSE requires under-floor plenum air conditioning or under-floor cable hookup, holes will have previously been provided in the elevated floor or they will be prepared at this time. The GSE will then be positioned over these cut-outs and fixed to the floor as necessary. If the GSE does not require elevated floor installation, it will simply be moved in place and fixed to the floor as required. After the GSE is installed in place, fluid lines, vents, and
air conditioning ducting will be attached as required. After installation of
the electrical GSE and cable hookup, power will be applied and the GSE will
be given a systems checkout through use of interface substitutes. This
checkout will verify continuity of the GSE-Space Station interfaces.

Mechanical GSE will be verified as necessary without actually interfacing
with the Space Station.

Additional support and services preparations will be completed apart from
the facility and GSE activities directly related to activation of the Space
Station launch ground system and integrated mission management facilities.
These will include preparing and equipping offices, engineering work areas,
laboratories, and shops for support of the ground system and operating
personnel.

2.1.4 Transportation
When dealing with complex spacecraft and systems, the particular items
cannot be designed expressly for ground handling and transportation func-
tions. The first criterion for selecting a particular transportation mode is
whether or not it has the capability to accommodate the transported item's
size, weight, and configuration. A variety of transportation modes can
accommodate the Space Station modules since their maximum parameters
relative to these criteria are approximately 17.7m (58 ft) long by 4.3m (14 ft)
in diameter, and cylindrical shape of 9,100 kg (20,000 lb) mass maximum.
These parameters fall within capabilities of all contemporary transportation
modes—air, road, rail, and water.

Secondary selection criteria which must be considered in transportation
selection can also be met by all modes, but in varying degrees. Table 2-3
summarizes the relative merits of the four transportation modes for various
secondary criteria, and shows how they compare to each other.

The air mode of transportation has been selected as the recommended
primary means of transporting the modules because of its convenience and
speed, which is desirable for reasons of hardware safety, security, and
scheduling. The air mode also enables greater flexibility and confidence in
operations. Water transportation should be considered as a backup to air transportation (assuming modules will be manufactured at a site with deep water access).

2.1.4.1 Aircraft Alternatives
The only existing aircraft that can carry the modules are the Super and Mini Guppies owned by Aerospace Lines, Santa Barbara, California. The projected fleet of guppies available through the 1978-1984 period will be adequate to handle shipping rates of one module per month. The cargo bay of the only other existing potential aircraft, the C-5A, is of insufficient height—4.1 m (13.5 ft)—to accommodate the modules although the length—42.5 m (140 ft)—and width—5.8 m (19 ft)—are more than adequate for the modules.

2.1.4.2 Space Station Module Transportation
Modules will be surrounded by a protective cover having either an active or passive environmental control system (S-IVB as used on 10 m (33 ft) station). Modules will be protected from excessive shock and vibration during transportation and will be provided with shielding which protects against accidental impact. On completion of acceptance test, items to be off-loaded will be removed and the modules prepared in the assembly and integration areas. The modules will then be shipped to KSC.

During preparation for shipment at the final assembly and integration area, the modules will be installed on its transporter and a prime mover attached. The module will then proceed from that area over a predetermined route to the aircraft loading areas. The module will move via convoy consisting of a prime mover, a transporter maintenance vehicle, and leading and following vehicles equipped with wide-load signs, flashing amber lights, and communications. In addition, equipment will be available as necessary to perform emergency road maintenance. The speed of the module and transporter will be held to a minimum to prevent traffic accidents and to minimize shock and vibration transmitted to the module. The route will be selected to ensure safe, smooth, and unobstructed passage to the module and transporter envelope and to minimize traffic interference. Transportation will be during periods of low traffic activity.
<table>
<thead>
<tr>
<th>Table 2-3</th>
<th>TRANSPORTATION MODE SELECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distance between Departure and Arrival Points</strong></td>
<td><strong>Air</strong></td>
</tr>
<tr>
<td></td>
<td>Excellent for long distances</td>
</tr>
<tr>
<td><strong>Size, Weight, and Configuration of Cargo</strong></td>
<td>Satisfactory for Modular Space Station modules. Very limited relative to certain maximum envelopes</td>
</tr>
<tr>
<td><strong>Quantity (Total Repetitions of Transportation)</strong></td>
<td>Turnaround qualities, single items excellent. Very limited for multiple items on single trip</td>
</tr>
<tr>
<td><strong>Environment Required by Cargo</strong></td>
<td>Excellent. Less time for exposure</td>
</tr>
<tr>
<td><strong>Time Allowed for Transportation</strong></td>
<td>Excellent, very short transportation time</td>
</tr>
<tr>
<td><strong>Availability of Mode</strong></td>
<td>Good. Requires long-range planning for multiple items (aircraft availability)</td>
</tr>
<tr>
<td><strong>Terminal and Docking Facilities</strong></td>
<td>Excellent (KSC)</td>
</tr>
<tr>
<td><strong>Hardware Safety</strong></td>
<td>Excellent. Less time for exposure</td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>Excellent. Less time for exposure</td>
</tr>
<tr>
<td><strong>Cost of Mode</strong></td>
<td>Expensive</td>
</tr>
</tbody>
</table>
On arrival at the aircraft loading area, the module and transporter will be positioned to the best advantage for loading and the prime mover disengaged. Loading will be accomplished in such a manner as to reduce shock and vibration transmitted to the module.

Contractor personnel will accompany the module during transportation to KSC. They will be charged with monitoring the environmental status of the module and inspecting the condition of the protective covering, tie-downs, transporter, and attendant equipment to further ensure safe transportation of the module.

On arrival at KSC, the module and transporter will be unloaded as a unit and placed on the ground where a prime mover will be attached. This combination will then proceed over the launch site ramp and roadway system to the Shuttle maintenance area, where receiving inspection will be accomplished.

2.1.4.3 Space Station Spares Transportation
Spares will be shipped to the launch site or refurbishment sites as needed. Schedules will be based on forecasted needs and special requisitions. Spares will be protected during transportation by covers, sealed "baggies," and hard and soft containers. Transportation containers will be designed to ensure that reliability is not degraded during transport. Dessicants will be employed to keep the humidity of the atmosphere surrounding the item at a low level. Sensitive items will be protected from excessive shock and vibration during transportation and will be provided with shielding to protect against accidental impact. In general, spares will not require special GSE transportation equipment as they will be mounted on pallets or packaged and shipped with passive environmental control. Transportation of spares from their manufacturing location to their utilizing activity will be accomplished in the surface or air mode through commercial lines or the military.

2.1.4.4 Space Station GSE Transportation
Some GSE must accompany the modules in their travel to the launch site. Other items may be shipped before or after the modules. In general, GSE
shipping schedules will be keyed to launch site utilization. GSE will be protected during transportation by covers, sealed baggies, and hard and soft containers. Dessicants will be employed to keep the humidity of the atmosphere surrounding the item at a low level. GSE will be protected from excessive shock and vibration during transportation and will be provided with shielding to protect against accidental impact. GSE transportation will be accomplished in the surface or air mode through commercial lines or the military.

2.1.5 Prelaunch and Launch Operations
Prelaunch and launch operations include all launch site activities (at KSC) required to prepare and launch the Space Station modules. It is assumed that launch will be from Complex 39 (LC-39) by a Shuttle launch vehicle (LV). Space Station operations described herein have been developed according to the overall test philosophy and integration concepts delineated earlier (Sections 2.1.1 and 2.1.2). The three ISS modules equipped with the integral experiment hardware installed in the GPL will be fully assembled and a complete integrated test performed at the manufacturing site. The entire Space Station will be acceptance-tested, the three modules demated, and preestablished items off-loaded to bring the module gross weight within the Shuttle cargo weight limit. The off-loaded items will be limited to those which will not impair Space Station buildup or initial operation.

The modules will be transported by air, and since the modules were fully operational at the factory in integrated test, they will only be serviced for flight, loaded in the Shuttle orbiter, and interfaces verified.

The launch of the ISS Space Station is essentially a one-time launch and as such does not warrant the buildup of a field station crew to repeat testing that should be performed at the manufacturing site where facilities, equipment, procedures, and manpower already exist to perform this function. Since the Space Station is only the first of many closely scheduled launches in the Space Station program, shipment of nonflight-ready hardware to the field station is an unacceptable alternative, both from cost and schedule points of view.
This is a departure from past programs in that the flight article is shipped from the manufacturing site in an orbit-ready state.

Three basic types of modules will be launched. The capabilities of each module at the time of launch will differ considerably, as shown in Table 2-4. The overall general operational flow for each type of module (Figure 2-12) will be identical, nevertheless, differing only in details. This results from delivering to the launch site fully checked and integrated modules that are orbit-ready except for preflight servicing. Note that the off-loaded items in Figure 2-11 are delivered to orbit later in Logistics Modules. Though not specifically timelined, the time from module receipt to launch is expected to range from 15 to 21 working days, depending on which module is being processed.

2.1.5.1 Detailed Prelaunch Operations

The following paragraphs describe the detailed prelaunch operations accomplished at the launch site. These operations are defined as the module operations prior to interfacing with the Shuttle. Hence, the descriptions trace the operations from arrival of the modules at the launch site through loading the module in the Shuttle orbiter maintenance area.

Receive and Off-load Module; Inspect and Verify Configuration

The modules will be shipped to KSC by air and will arrive at the Shuttle landing runway. The Cape Kennedy Air Force Station (CKAFS) runway can be used as a backup for landing if a Shuttle landing or other interfering activity prevented the use of the Shuttle runway. The modules will be removed from the aircraft and towed over the KSC roads on a transporter to the Shuttle maintenance area. Here, covers will be removed and the module exterior will be inspected. Note that fluid systems will be pressurized with inert fluids (to a nonhazardous pressure) at the factory and that the pressures will be measured during inspection to determine if there has been any leakage. Gauges for measuring pressure will be installed at the factory and connected to the fluid systems at the docking port interfaces. This equipment will be removed during flight servicing activities. Shock, vibration, and other outputs from the transportation environment monitoring equipment will be analyzed to determine if the module may have been damaged during shipment.
### Table 2-4
**SPACE STATION CAPABILITY DURING BUILDUP**

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Launch/Module</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First/Power</td>
</tr>
<tr>
<td>Habitability</td>
<td>Shirtsleeve Shuttle air</td>
</tr>
<tr>
<td>Power</td>
<td>Solar array, No. 1 battery set</td>
</tr>
<tr>
<td>Attitude Control</td>
<td>RCS No. 1</td>
</tr>
<tr>
<td>Communications</td>
<td>VHF S-Band</td>
</tr>
<tr>
<td>Data Management</td>
<td>Central Computer</td>
</tr>
<tr>
<td>Onboard Checkout</td>
<td>Central computer, Portable control and display unit</td>
</tr>
<tr>
<td>Thermal Control</td>
<td>Operable for each module</td>
</tr>
</tbody>
</table>
Flight Servicing of Modules
All subsystems requiring servicing will be serviced at this time except for propellant and high-pressure subsystems which will be serviced on-pad. Any carry-on equipment not previously installed (i.e., batteries, and cargo or loose experiment equipment to be launched with the module) will be loaded and secured in the module at this time. However, due to Shuttle payload weight limitations, no such items have been identified, except batteries for the power module. The power module will have to be entered for battery installation. To accomplish this, a portable airlock will be set up to enable opening a power module hatch without contaminating the interior. Ground crew personnel will not be allowed to enter the module until all safety precautions have been implemented and escape routes established. A buddy system will be used for personnel onboard in closed compartments. Interior ventilation will be established before entry. Communications, lighting, and emergency breathing equipment will be provided. Personnel will never be more than approximately 3 m (11 ft) from a hatch that could be opened for emergency escape. Once access has been established, battery installation will be relatively easy, since the batteries will be designed for routine replacement on orbit (Figure 2-13). A momentary load will be applied to the main power bus after hookup to verify proper installation. The access equipment will be removed and the hatch will be closed. No real checkout will have been performed, in keeping with the "orbit ready from the factory" concept. If some unavoidable checkout is discovered in the development phase of the program, an alternative flow outlined in Appendix A should be followed. This should be permitted only when all other means have been exhausted.

Installation of Ordnance
No ordnance items have been identified for any module. However, if tie-down releases, latches, and deployment mechanism final designs require ordnance, the ordnance will be installed just prior to loading the module into the orbiter.
2.1.5.2 Detailed Launch Operations

Launch operations depend on the launch vehicle since the modules are flight-ready at the conclusion of prelaunch operations, with the exception of hazardous fluid servicing. Access to the module interior is restricted in each case except for emergency repairs. Launch operations will commence when the module has been prepared for loading into the orbiter and proceed through lift-off. As shown in Figure 2-12, the launch operations for the Shuttle-launched modules include the following:

Install Module in Orbiter

The modules will be attached to an overhead crane and top-loaded into the Shuttle orbiter while it is still horizontal in the hangar area, according to baseline Shuttle operations (Figure 2-14). Handling equipment will be disconnected and removed after the module has been secured in the orbiter. Portable monitoring capabilities will be provided throughout loading operations to ensure no damage occurs due to excessive shock or vibration during
loading. Installation of modules in the orbiter will be essentially the same for each type of module.

**Mate and Verify Interfaces**

Functional interfaces between the Shuttle orbiter and the Space Station module will be made and proper mating verified during this period. Module design philosophy dictates that such functional interconnections be minimized. The interface between the Space Station and Logistics Modules and the Shuttle at lift-off is limited to (1) a Shuttle-compatible data bus connection, (2) atmosphere through 6 in. lines for feed and return, and (3) dual redundant power lines (120 vdc). The power module will be self-powered by batteries and will have no power interface with the orbiter, however, the crew and GPL modules will be powered by the orbiter. Some command, control, communications, and monitoring functions cross the interface for each module, although they differ for each module. The module intercom must be connected to the Shuttle intercom so that the activation crew can communicate with the orbiter pilots when in the module during activation prior to release on orbit. Note that activation flight crews can participate in these test activities, manning the panels in the orbiter passenger compartment. It is assumed that the Shuttle-module interfaces will remain simple, and that the 10-day Shuttle turnaround capability will not be enforced for Space Station module launches. If these assumptions prove false, an additional integration operation with additional GSE (as described in Appendix A) will be required to verify the interface prior to installing the module in the orbiter. If the 10-day turnaround is enforced, the facilities and GSE described in Appendix A should be furnished by the Shuttle program since they would be applicable to all classes of payloads, and are not unique for the Space Station.

**Erect Shuttle**

This operation is primarily a Shuttle activity, although Space Station participation is required. Shuttle operations include closing and securing the cargo bay door, performing a combined system test (CST) of the orbiter, erecting the orbiter and mating it with the previously erected booster, verifying the booster-orbiter interface, and connecting orbiter umbilicals in preparation for a Shuttle integrated system test (IST).
Connect Umbilicals and Verify

Space Station umbilicals will be connected at the same time as Shuttle umbilicals. Access arms will be positioned adjacent to umbilical access doors in the sides of the orbiter, the doors will be opened, umbilicals passed through and connected to the module, and the connections verified. Any portable module monitoring equipment will be installed on the umbilical tower at this time. The total space vehicle is ready for the Integrated Systems Test (IST) after all umbilicals have been connected. It is assumed that the Shuttle, as a general-purpose operational launch vehicle for many classes of payloads will furnish swing arms to the access ports in the Shuttle skin, and that outfitting the arms with umbilical functions peculiar to the payload will be accomplished by the payload, in this case, the Space Station.

Integrated System Test

Space Station modules are essentially passive relative to this operation, supporting it as required by the Shuttle.

Prepare and Move to Pad; LUT-Pad Mate and Interface Verification

These operations will be similar in concept to those of the present-day Saturn-Apollo program. Preparations will include disconnecting GSE located in the high bay, retracting high-bay platforms, disconnecting interfaces between the launch umbilical tower (LUT) and vertical assembly building (VAB) and securing them, bringing the crawler-transporter to the high bay. Movement to the pad will be accomplished using the crawler-transporter to carry the LUT with Shuttle vehicle and module in position on-pad. LUT-pad interface connections will then be mated and verified. These operations will be carried out by the Shuttle program (assuming it will have attained fully operational status), and supported by the Space Station.

Countdown

Countdown activities for the modules will parallel those for the Shuttle, and will be phased with Shuttle operations so that similar hazardous operations can be accomplished during the same pad-clear periods.
Countdown includes the final vehicle and ground system preparations for launch and Shuttle launch. Details of countdown operations cannot be specified at this time. Nevertheless, certain generalized operations can be described, as follows:

A. Space Station module attitude control propellants will be loaded on-pad for those modules with attitude control capability.
B. High-pressure and other hazardous fluid systems, if present in the module, will be serviced and charged on pad.
C. Module systems will be turned on, checked for functional status, and placed in their proper launch stage (on, off, or standby). See Table 2-5.
D. Module status will be monitored continuously on telemetry and through umbilicals after final system checks have been completed. Monitoring will continue through lift-off.
E. Range interfaces with the vehicle (the Shuttle with module) will be given final open-loop checks.
F. Ordnance, if any, will be connected and armed during countdown.

2.1.6 Ground Crew Staffing and Training
Shuttle launches associated with the Space Station will occur approximately every 30 days, as shown in Figure 2-4. These launches will encompass a variety of modules on a noninterference basis; that is, if there is a series of Space Station module launches, Logistics Module and RAM activities will slow down and vice versa. This suggests that a general-purpose or universal prelaunch and launch operations crew could be assembled to handle all Shuttle payload modules. Applying this principle to the station-related modules indicates a virtually constant, relatively small, direct employee work force can be established and maintained, as shown in Figures 2-15 and 2-16. In order to accommodate the idiosyncrasies and special problems associated with individual modules, a special traveling crew would be established for each module to supplement the permanent crew. This traveling crew would participate in factory checkout and Space Station integration operations as well as in prelaunch and launch activities. The crew would be made up of personnel drawn from the permanent universal prelaunch and
Figure 2-15. Mission Management Manning during Buildup
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launch operations crew, as well as factory personnel. The factory personnel will be selected from persons responsible for Space Station design, test procedure generation, flight crew handbooks, and test technique development. Hence, they will be thoroughly familiar with the module for which they will be responsible. The result will be a prelaunch and launch crew with the combined expertise of the factory checkout and launch operations which will maintain continuity of operational knowledge.

In addition to launch operations described, there are four functions of mission support operations (described in a later section): Mission Planning and Analysis, Logistics Operations Support, Flight Operations Support, and Experiment Operations Support.

Of these, logistics operations support should be located at the launch site due to critical schedules and the actual cargo to be delivered to orbit. As illustrated in Figure 2-16, the Space Station module supplemental crew decreases after the third module launch and the launch crew for the Logistics
Modules is increased in anticipation of the first of many Logistics Modules. This provides an essentially flat-loaded task between the logistics and single launch crews for all modules.

The other three functions of mission support also tend to flat-load the manpower. Mission planning and analysis at the first launch will involve a smaller crew than that required for preflight planning. Flight operations support crew will increase at the first launch and decrease in numbers after shakedown operations and arrival of the first two RAM's. The crew for experiment operations support crew, a project-oriented function with a mix similar to the orbiting scientific crew, will increase at the arrival of each of the first two RAM's and then stabilize.

2.1.7 Module Access
Normally, there will be no access to the module interior except for battery installation in the power module. If access is required in a contingency situation, then it may be accomplished in different ways, and under different guidelines and rules, depending on the conditions at the time.

2.1.7.1 General Personnel Access Guidelines and Controls
Space Station interior access control and safety will be of prime importance at KSC. General guidelines outlined below will be used to determine access requirements:

A. Only personnel trained for Space Station interior operations for the module in question will be allowed access to the module interior.
B. Only personnel attired for interior operations (attire to be determined) will be allowed access to the module interior.
C. Only personnel required to perform specific tasks in accordance with approved procedures will be allowed access to the module interior.
D. Only materials and equipment identified in an approved procedure will be allowed in the module interior.

A control monitor will be located at each module interior access point. Training, outer attire, and requirement for access will be certified by the monitor for each person prior to entry of the person into a module. In
addition, all materials and equipment entering a module will be inventoried and accounted.

2.1.7.2 Prelaunch Operations Access
Access to the modules, if required during prelaunch operations, will be relatively simple after transportation covers have been removed. The modules will remain on their transporters and portable airlock work stands would be set up that would allow entrance to the modules through the docking port hatches. Interior arrangement will follow certain rules whenever possible without unduly compromising orbital requirements in order to facilitate ground operations at the factory, and in an emergency at the launch site. The goals of these rules are to:

A. Orient as many panels, displays, and other items of equipment as possible so that they will be head up with respect to the ground when the module is horizontal on its transporter.

B. Orient all controls and displays requiring heavy usage during ground operations or which are critical to module operation, so that they will be head up with respect to the ground when the module is horizontal on its transporter.

C. Orient all storage bins, cabinets, and drawers in which loose flight equipment and supplies will be stored on the ground so that they will be head up with respect to the ground when the module is horizontal on its transporter.

D. Locate only that equipment requiring little or no access during ground operations on the interior surfaces which will assume the floor or ceiling positions when the module is horizontal on its transporter.

E. Provide hard-points on the module interior structure to which the access kit equipment can be attached if necessary.

Figures 2-17 and 2-18 are photographs of module mockup interiors illustrating the extent that these goals have been achieved in the layout of the modules. (Figures 2-1 through 2-3 also illustrate this point.)
Once the module hatches have been opened, it will be necessary to protect the openings from damage due to traffic through them, and to provide supporting structures within the module in any areas where the floors will not support personnel in the 1-g environment. Neither of these requirements will offer unusual problems. Note that interior and exterior access, if necessary, will be virtually unlimited with regard to operational constraints during prelaunch activities until after servicing.

2.1.7.3 Launch Operations Access

Obviously, access will not be possible during hoisting of a module into the Shuttle cargo bay. Access to the exterior after loading will be limited to the external surfaces exposed by the open cargo bay door and by open access doors in the Shuttle skin provided for payload umbilical connections. Internal access will be possible through the Shuttle passenger compartment, airlock, and flexible tunnel. Such access will be allowed only for extreme emergencies. Any internal access kit equipment must pass through the Shuttle passenger compartment airlock and flexible tunnel, in this case.

No access will be possible during orbiter stacking. After stacking, external module access will be only through the umbilical panels in the orbiter skin except in extreme emergency when the cargo bay door could be opened. Internal access will only be possible through the passenger compartment, airlock, and flexible tunnel of the Shuttle and will require special vertical access equipment including ladders and hoists. It is assumed that if the cargo bay door is opened, with the Shuttle vertical (either in the VAB or on-pad), the Shuttle will provide general access to the bay, while the payload will provide any special access within the bay.

2.1.8 Ground Operations Requirements Summary

Ground operations will impose a number of requirements upon the Space Station and, in turn, will be constrained by the Space Station design and the design of existing facilities. These requirements and constraints, implied or stated explicitly in the preceding subsections, are summarized in this subsection.
1. Space Station module launches shall be from the Shuttle launch site.
2. No checkout shall be performed at the launch site.
3. Modules shall be shipped to the launch site fully flight-ready with the exception of expendables and batteries that must be loaded at the launch site. "Shipping short" shall not be permitted. The only permissible missing hardware items in the modules will be those items deliberately removed at the factory to meet Shuttle payload weight limitations and planned for later delivery to orbit by a logistics flight.
4. Required Space Station module operations shall be performed in the orbiter maintenance area.
5. The mobile service structure shall not be used.
6. Space Station modules shall accommodate performance of all ground processing in a horizontal position prior to Shuttle stacking and after stacking in a vertical position.
7. Space Station modules shall provide for direct attachment of hoisting GSE while in the orbiter cargo bay (with orbiter horizontal or vertical, although attach points need not be the same for each orientation).
8. Space Station module umbilical connections shall be accessible through access doors provided in the orbiter skin after module installation in the orbiter.
9. Interior panels, displays, and controls shall have as a goal a head-up orientation when the module is in a horizontal position.
10. The Space Station modules shall not require a clean-room environment. If special cleanliness protection is required by some module hardware, provisions shall be built into the module to protect the sensitive equipment or individual covers will be provided.
11. Nonhazardous fluid serving equipment shall be portable, and shall be temporarily located in the orbiter maintenance area during Space Station prelaunch and launch operations.
12. Servicing equipment for hazardous fluids shall be located on-pad.
13. It shall be possible, although not normally done, to open all docking port hatches during ground operations except when modules are in the shuttle.
14. Space Station module subsystems shall operate in a 1-g environment with the module horizontal or vertical.

15. Active thermal control of module subsystems shall not be required on the ground when the subsystems are off.

16. Any ordnance arming or connecting points shall be accessible with the module installed in the orbiter on-pad.

17. Module design shall not require installation of flight hardware on pad (except ordnance igniters, if used).

18. Access to the vicinity of modules during ground processing shall be controlled and limited.

19. No access to module interiors shall be permitted except in an emergency or for loading power module batteries.

20. Hazardous liquids and gases shall be loaded on-pad.

21. Integral experiment equipment launched with the GPL shall be installed and checked at the factory.

22. Flight interfaces previously mated and functionally verified at the factory shall not be demated at the launch site unless necessary to effect repairs. In this case, interfaces shall be completely reverified after remating.

23. Modules shall be designed for transportation in a horizontal position (i.e., the long-axis horizontal).

24. Space Station module subsystems shall be used to accomplish ground functions whenever possible.

25. GSE shall supplement module subsystems for:
   A. Handling and transportation.
   B. Servicing.
   C. Module subsystems turn-on and status verification during countdown.
   D. Checkout of repaired subsystems in the event of a malfunction during normal operations.

26. Perishables shall not be launched in Space Station modules.

27. All prelaunch and launch operations shall be controlled by detailed procedures (manual, automatic, or both).

28. The same GSE shall be used at the factory and launch site when possible.
29. No less than two people (buddy system) shall be allowed in the power module during battery installation, or any module during emergency repairs.

30. Space Station ground operations shall comply with the safety requirements of the launch site (KSC) and range (ETR).

2.2 LOGISTICS AND CREW CARGO MODULE OPERATIONS

Two types of modules will be used with the Space Station program for logistics. The first, the Logistics Module (Figure 2-19), used during ISS operations, will be unmanned while in the Shuttle and will be docked to the orbiting station by the Shuttle. Two Space Station crewmen will ride in the Shuttle passenger compartment or each flight to effect crew rotation. The second type, the Crew Cargo Module (CCM) will be used during GSS operations and will be similar to the first except it will contain a life support system and carry six passengers to accommodate rotation of the larger crew. In both cases, the subsystems onboard are simple, requiring little in the way of ground checkout. The basic concept for Logistics and Crew

Figure 2-19. Logistics Module
Cargo Module operations is similar to that developed for the 10-m (33-ft) dia station. The concept features:

A. Existing facilities will be used for Logistics Module and CCM operations (the VAB low bay area).

B. Logistics Module and CCM operations will be a continuing effort for the duration of the Space Station program (with up to one launch per month except when superseded by a Space Station module or research and applications module launch).

C. There will be no effect on flight operations support (in terms of Logistics Module and CCM mission control facilities and GSE) beyond that required for Space Station and Shuttle mission control operations.

The nature of Logistics Module and CCM activities at KSC is described in more detail in the following text.

2.2.1 Site Activation

Site activation consists of functions to be accomplished at the launch site from the arrival of electrical and mechanical GSE to arrival of the first module.

2.2.1.1 Facility Modification Acceptance

Facility modifications will have been accepted or beneficial occupancy will have been allowed before installation of GSE. In any case, modification work will be sufficiently advanced to allow installation activities to proceed without contractor or labor conflict.

2.2.1.2 GSE Installation and Acceptance

Upon arrival at receiving inspection areas, GSE will be unpacked, inspected, and prepared for moving to its installation or utilization area. GSE discrepancies caused by transportation will be noted at the time of inspection and correction or other disposition will be made prior to moving to the installation area. GSE will be moved from its receiving inspection area to the installation or utilization area. If the GSE requires under-floor plenum air
conditioning or under-floor cable hookup, holes will have previously been
provided in the elevated floor or they will be prepared at this time. The
GSE will then be positioned over these cutouts and fixed to the floor as
necessary. If the GSE does not require elevated floor installation, it will
simply be moved in place and fixed to the floor if necessary. After the GSE
is installed in place, fluid lines, vents, and air conditioning ducting will be
attached as required. On installation of the electrical GSE and cable hookup,
power will be applied and the GSE will be given a systems checkout through
use of a GSE-facility verification vehicle or interface substitutes. This
checkout will verify continuity of the GSE to the Logistics Module or CCM
interfaces. Mechanical GSE will be verified in the same manner.

2.2.1.3 Support and Services
Other support and services preparations will have been completed in addition
to the facility and GSE activities directly related to activation of the Logis-
tics Module and CCM launch ground system. This support includes prepar-
ing and equipping offices, engineering work areas, laboratories, and shops
for support of the ground system and operating personnel.

2.2.2 Transportation
Investigation of methods available for transporting the module from factory
to the KSC launch site indicates that transportation by air should be the
primary method because of its relative simplicity, with surface transporta-
tion as a backup (Subsection 2.1.4 contains a detailed discussion of module
transportation).

2.2.2.1 Logistics Module Transportation
Modules will be shipped to KSC on completion of acceptance test and prepara-
tion for shipment at their assembly and integration areas. During prepara-
tion for shipment at the final assembly and integration area, the module will
be installed on its transporter and a prime mover attached. The module will
then proceed from that area over a predetermined route to the aircraft load-
ing areas. The module will move via convoy consisting of a prime mover,
a transporter maintenance vehicle, and leading and following vehicles
equipped with wide-load signs, flashing amber lights, and communications.
In addition, equipment will be available to perform emergency road maintenance. The speed of the Logistics Module and transporter will be held to a minimum to prevent traffic accidents and to minimize shock and vibration transmitted to the module. The route will be selected to ensure safe, smooth, unobstructed passage to the module and transporter envelope and to minimize traffic interference. Transportation will be during periods of low traffic activity.

On arrival at the aircraft loading area, the module and transporter will be positioned to best advantage for loading and the prime mover disengaged. Loading will be accomplished in such a manner as to reduce shock and vibration transmitted to the module.

Contractor personnel will accompany the module during transportation to KSC. They will be charged with monitoring the environmental status of the Logistics Module or CCM inspecting the condition of the protective covering, tie-downs, transporter, and attendant equipment to further ensure safe transportation of the module.

On arrival at KSC, the module and transporter will be unloaded as a unit and placed on the ground, where the prime mover will be attached. This combination will then proceed over the launch site ramp and roadway system to the refurbishment and turnaround area in the VAB low bay area, where receiving inspection will be accomplished.

2.2.2.2 Logistics Module Spares Transportation
The quantity of spares required for Logistics Module and CCM resupply presents a minor transportation consideration due to the simplicity of subsystems. Replaceable spares will be fully qualified prior to shipment from contractor facilities, and transportation containers will be designed to ensure that reliability is not degraded during transport.

Certain spares will require special attention during packaging, shipping, and handling. If required, special containers will be provided to protect specific
equipment from weather and maintain cleanliness standards during transportation. In addition, covers and heaters or coolers will be supplied so that equipment reliability is not degraded. Transportation of spares from their manufacturing location to their area of utilization will be accomplished in a surface or air mode through commercial lines or the military.

2.2.2.3 Logistics Module GSE Transportation
Transportation of GSE from its manufacturing location to its area of use will be accomplished in the surface or air mode through commercial lines or the military (with exception of GSE, which must accompany flight hardware when it is transported to KSC).

Because GSE is used in more than one location, it may be delivered to some other location before being sent to the launch operations site. Certain GSE will be utilized during acceptance testing of the module prior to being shipped to the launch site, while other GSE will be transported directly to KSC. In any case, standard practices for handling and shipment of GSE will be used in transportation to the particular utilization activity.

2.2.3 Logistics Module Prelaunch and Launch Operations
Logistics Module operations at KSC have several unique features which depart significantly from previous manned and unmanned spacecraft programs. The modules will carry a large quantity of cargo relative to their overall size (4.3 m (14 ft) in dia and approximately 9 m (30 ft) long). They will be placed in orbit by the Shuttle orbiter, and on return from orbit cannot reenter the atmosphere unilaterally, but must be returned to Earth by the Shuttle orbiter. They will be returned to KSC after their mission. As reusable vehicles, they will be returned to orbit many times during their lifetimes. In addition, the later versions (CCM's) for use with the GSS will provide life support for six crewmen for several days.

As a result, Logistics Module ground operations must consider orbiter post landing activities, including refurbishment and maintenance, cargo loading and unloading as well as the more familiar prelaunch and launch operations.
associated with any launch. The operational flow typical of Logistics Module processing at KSC and illustrating these features is summarized in Figure 2-20. Operations interfacing with Logistics Module operations are shown for reference in the figure (connected with dashed flow lines). Logistics Module operations marked with an asterisk are new to KSC and will have a significant effect.

Logistics Module ground operations must be accomplished efficiently, as the launch rate will approach one every 30 days, on the average.

2.2.3.1 Operational Flow

Overall operational flow proposed for the Logistics Module at KSC and the related cargo handling flows are shown in Figure 2-21. The figure shows three major branches; the flow for the initial flight of a Logistics Module originating at the factory with manufacturing and shipment to KSC; the flow for repeated flights of a Logistics Module returned from orbit; and the flow for cargo and supplies to be loaded on the Logistics Module. These branches converge to a common flow for later stages of Logistics Module operations, beginning with final checkout of the Logistics Module and terminating with launch.

Significant features of the operational flow include:

A. First-flight flow branch for the unmanned Logistics Module is extremely simple—it is received and off-loaded, inspected, verified for proper configuration, and given very limited checks (since there are few functional subsystems on the Logistics Module). No unique requirements are evident for this phase of Logistics Module operations other than facilities necessary for accomplishment of the operations. The nominal means of shipping the Logistics Module to KSC will be by air, although other means will be possible. The facility proposed for conducting operations is the VAB low bay.

B. A Logistics Module may be severely damaged as a result of a Shuttle landing mishap or may require major overhaul after (TBD) flights. The Logistics Module would be returned to the manufacturer or to KSC shops with remanufacturing capabilities, and
Figure 2-20. Logistics Operations Summary
treated as a new Logistics Module arriving at KSC for its first flight when it is returned to operational status.

**C.** The repeat-flight flow branch for the Logistics Module has several unusual features:

1. The Logistics Module will be returned to KSC by the Shuttle orbiter. Time-critical data will be removed as soon as the Shuttle orbiter rolls to a stop. Returning Space Station crew members will also egress from the Shuttle passenger compartment at this time. Portable stairs similar to those used by airlines or other means for passenger removal will be required at the Shuttle rollout area. It is assumed that the Shuttle will provide any equipment for crew ingress and egress.

2. The Logistics Module must be safed when it lands at KSC, since it will contain residual Space Station propellants and EC/LS expendables and residual experiments expendables. This will be accomplished as soon as the Shuttle crew and passengers have left and the Shuttle has cooled. Servicing equipment will be required at end of the Shuttle runway for safing of the Logistics Module.

3. The Logistics Module will contain cargo of various types (experiment data and samples, Space Station parts which have malfunctioned, waste, reusable packaging, etc.) which must be unloaded and given proper disposition. Unloading will be accomplished more easily after Logistics Module removal from the orbiter, since access to all hatches will then be possible.

4. A postflight inspection and check of the Logistics Module will be performed to determine if there are any malfunctions or defects which must be repaired, in addition to scheduled maintenance. Subsystem tests will ensure that all repairs and reconfiguration have been successfully accomplished, and that the Logistics Module is again flight ready except for loading.

5. Logistics Module reconfiguration will be required occasionally as dictated by changes in cargo mix. Therefore, Logistics design must be capable of quick-change accommodation of different types cargo (e.g., palletized fluid tank complexes).
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D. Operations occurring in the common part of the flow also have several unique features:

1. Logistics Module cargo status (e.g., expendable tank pressures or valve positions) will be continuously monitored after checkout has been completed until countdown and liftoff.

2. Cargo loading will include loading of all solid and fluid cargo except time-sensitive and hazardous items which will be loaded during countdown. Weight and cg equipment must be located at the cargo loading area to verify the actual weight and cg of the flight-loaded Logistics Module.

3. The Logistics Module will be top-loaded in the Shuttle orbiter while it is still horizontal in the Shuttle maintenance area, although it will be possible to load the Logistics Module into the orbiter with the orbital vertical in the VAB high bay.

4. Shuttle operations pace the Logistics Module operations after it is installed in the orbiter.

5. Logistics Module countdown will be integrated with the Shuttle countdown. Logistics Module activities during this period will include loading of propellants, cryogenics, and other hazardous fluids, activation of Logistics Module flight systems and verification of status, and time-sensitive cargo ingress.

Several operations which interface with Logistics Module operations are shown as reference blocks in Figure 2-21. Experiment integration includes mating experiments with the FIT before delivery to the Logistics Module. Logistics control operations track supply usage, plan procurement of cargo and supplies, and determine cargo mixes, as described in Subsection 2.5. Shuttle operations include refurbishment and preparation of booster and orbiter for the next flight, erection and stacking, and Shuttle countdown. Space Station replacement crew and the returned crew are processed through the crew training and accommodation operations block. Biological laboratory operations care for live experiment specimens until launch (described in a later section) and support orbital experimentation by performing control experiments on the ground in parallel with orbital experiments.
Figure 2-22 is an estimated timeline of Logistics Module operations. Note that approximately 18 working days (3.6 weeks) will be required from time of arrival of the module through liftoff to turn a module around.

2.2.3.2 Ground Handling Approach
It is obvious that handling and transporting of a Logistics Module returned from orbit will be necessary, considering the impracticality of accomplishing Logistics Module repair, checkout, and cargo loading while it is in the Shuttle cargo bay. A number of module handling options were investigated during earlier study efforts (DRL 160, Line Item 22, Appendix 0). The option which results in the least handling and thus the least risk of damage during ground operation is one in which the module is shipped installed on a transporter or dolly or installed on one immediately upon removal from the Shuttle, and remains on this transporter throughout all subsequent operations until it is loaded into a Shuttle craft.

2.2.3.3 Turnaround and Maintenance Activities
Logistics Modules will be maintained through an airline method of operation as illustrated in the flow (i.e., preflight and postflight checks, correction of malfunctions experienced during flight, and periodic maintenance). However, this ideal, as in the case of aircraft, cannot be realized initially. Early repeat flights of the Logistics Module will require extensive post- and preflight testing similar to the testing required for the first flight. These early flights are analogous to certification flights of aircraft before they are put in regular service. As experience and confidence in test procedures are gained, the amount and complexity of inspection and test will be reduced.

Corrective maintenance of fluid cargo handling equipment can be performed on the modules during flight as well as during postflight turnaround. Certain critical spares will be carried onboard the Logistics Module and the Space Station to allow in-flight removal and replacement. The bulk of preventive and corrective maintenance performed on the modules will be accomplished on the ground between flights. Regardless of where maintenance is accomplished, removed hardware will be inspected and refurbished if possible.
Figure 2-22. Preliminary Master Schedule - Logistics Module
Refurbishment operations include the activities necessary to rework, repair, and recommission Logistics Module subsystems, subassemblies, and components which have been removed because of failure or limited-life considerations.

The items to be refurbished will be sent to inventory control and then shipped to the refurbishment centers operated by contractors or by the Government.

Refurbishment begins with receipt and inspection of the returned items at the refurbishment centers. This activity will determine the reusability of the item and its future disposition. Some returned equipment will have been so badly worn or damaged that it will be used only in further destructive testing and analysis, for display, and to satisfy other needs. Other equipment will be in such a condition that it can be returned to serviceability after some repair or rework. On determination that the returned equipment can be returned to serviceability, it will be sent to either the contractor or Government repair and rework agencies. Factors influencing selection of the rework and repair agency will include the ability to handle the job in terms of personnel, equipment, and facilities, cost, and the time required to return the item to the spares inventory.

Returned items will be repaired and reworked to the same specifications as when first produced. Standards and testing will be the same to ensure that the refurbished item will perform as satisfactorily as a new item. All items will undergo final acceptance testing.

New facilities and equipment will be developed only if repair and rework requirements are heavier than originally estimated.

On completion of repair and rework and after acceptance testing, the items will be delivered to inventory control. This facility will provide storage for the items until they are required at Logistics Module maintenance areas or on orbit. A capability for further testing the newly received spares to verify that they have not been damaged during transportation from the refurbishment locations will be available at the inventory control or Logistics Module turnaround or maintenance area.
After the spares have been returned to inventory control for storage and have been certified by further testing that they are in commission, they will be returned to the in-commission status and assigned to the available spares inventory. This will consist of an accounting function which simply adds the particular item to the listing of available spares. The spares will remain in inventory control until required during ground maintenance or until required to be carried onboard the Logistics Module or Space Station as in-flight spares.

2.2.4 Crew Cargo Module Prelaunch and Launch Operations
Crew Cargo Module prelaunch and launch operations will be essentially the same as those for the Logistics Module. The primary difference will be the additional servicing and checkout required for the six man EC/LS subsystem onboard. An estimated timeline of CCM operations is shown in Figure 2-23. In this case, approximately 23 working days (4.6 weeks) will be required to turn around a module. The additional week (over and above the 3.6 weeks required for the Logistics Module) is a direct result of accommodating the six passengers.

2.2.5 Contingency Capabilities (Rescue)
Two Space Station crew members will normally be rotated at one time during ISS operations. They will ride in the Shuttle passenger compartment with life support and protection provided by the Shuttle. However, should a contingency arise on orbit requiring rescue of the crew, it will be necessary to return all six crew members simultaneously. A quick installation seat pallet will be available for use in a Logistics Module to accommodate the orbiting crew. A 96-hour life support pallet (the same as the one onboard the station to support the crew until rescue arrives) will also be installed in the "rescue" Logistics Module. Installation of the rescue seat pallet and life support pallet will require three to six hours, depending on the status of the Logistics Module to be used (i.e., loaded, empty, in the Shuttle, etc.).

A similar situation exists for the CCM. It will normally be outfitted to transport six men. In case of rescue, however, the rescue seat pallet and life support pallet will also be installed, thereby increasing CCM passenger capability for rescue to 12 men.
Figure 2-23. Preliminary Master Schedule - Crew Cargo Module
2.2.6 Logistics Module Ground Operations Requirements Summary

A number of requirements and constraints for both the ground system and the Log Module are inherent in this operational concept and are listed below. Note that some of these requirements were not stated explicitly in the preceding analysis, but are necessary to implement the recommended concept.

A. Log Modules shall accommodate performance of all ground processing in a horizontal position.

B. Log Modules shall provide for direct attachment of hoisting GSE while in the orbiter cargo bay (with orbiter horizontal or vertical - although attach points need not be the same for each position).

C. Umbilical connections shall be accessible for Log Module servicing when the Log Module is installed in the Shuttle orbiter; with the orbiter vertical (for loading of hazardous fluids on pad and final top off of others during countdown); and with the orbiter horizontal (for safing after landing and initial servicing).

D. Interior equipment, cargo stowage racks, etc., shall be in a heads-up position during ground processing of the Log Modules in the horizontal position.

E. The Log Modules shall be provided with a cargo loading hatch (or hatches) other than docking ports for loading and unloading cargo pallets.

F. The Log Modules shall not require a clean-room environment.

G. Log Module design will provide that reconfiguration due to cargo mix changes will be minimal, i.e., the Log Module cargo carrying accommodations shall be as independent of cargo mix as practical.

H. Reconfiguration of Log Modules, when necessary, shall be easy to implement. Access to all joints and interfaces which must be broken or mated shall be provided. Simple standardized interfaces shall be a goal.

I. Readily accessible test connectors shall be provided for checkout. It shall not be necessary to disconnect flight connectors during ground processing (except for repairs).

J. Umbilical connections shall be provided for monitoring CCM system status after checkout has been completed.
K. Log Module fluid-cargo servicing equipment shall be located at the Shuttle landing site, the pad, or will be portable.

L. All Log Module assembly, integration, and acceptance testing shall be accomplished prior to delivering the Log Module to KSC.

M. Log Module interior arrangements and provisions shall allow ground personnel easy access, in a 1-g environment, to all cargo securing and tie-down areas, and all maintenance areas.

N. It shall be possible to open all Log Module docking ports and hatches during ground operations, except when the Log Module is installed in the shuttle orbiter.

O. Active Log Module equipment shall operate in the 1-g earth environment with the Log Module horizontal or vertical.

P. Special atmospheric cleanliness provisions (i.e., cleanroom-type air conditioning) shall not be required for Log Module exterior and interior access in the VAB. Air supplied currently in the VAB (as follows) shall be adequate:
   1. Humidity: 0 to 100 percent, adjustable to a specific desired value to within ±5 percent.
   2. Temperature: 40°F minimum, adjustable to a specific desired value to within ±5°F.

Q. Active thermal control of the Log Module shall not be required on the ground.

R. Any ordnance arming or connecting points shall be accessible with the Log Module installed in the orbiter on pad.

S. The Log Module design shall not require installation of flight hardware on pad (except ordnance igniters).

T. Prelaunch testing of the Log Module shall be structured to duplicate actual launch and flight operation to the extent practical.

U. Log Module checkout procedures shall be standardized to the extent possible for use at the factory, at KSC, and on orbit.

V. Access to the Log Module during ground processing shall be controlled and limited.
W. Log Module preventive and corrective maintenance shall be accomplished by the removal and replacement of plug-in modules.

X. Installation/loading of hypergolics, cryogenics, and ordnance initiator devices in the VAB shall not be permitted. Installation of any ordnance should be planned as late as possible in the processing flow.

Y. Ground access shall be provided for loading live specimens and perishables in the Log Module while on the launch pad.

Z. Hazardous liquids and gases shall be loaded in the Log Module on the launch pad.

2.3 EXPERIMENTS

The experiments analyzed in this study of impact on KSC were derived from the Reference Earth Orbital Research and Applications Investigations (Blue Book), NHB 7150.1, preliminary edition, dated 15 January 1971. Consideration was given to available data and the baseline experiment flight schedule generated in the Modular Space Station, Phase B Extension study.

The January Blue Book identified experiments in seven discipline areas of research as follows:

- A - Astronomy
- MS - Materials Science and Manufacturing
- P - Physics
- T - Technology
- ES - Earth Observations
- LS - Life Sciences
- C/N - Communications/Navigation

In these seven disciplines 77 Functional Program Elements (FPE's and FPE subgroups) were identified in the Modular Space Station study. Finally, these 77 elements were reduced to 50 FPE's and subgroups for determining accommodations modes and scheduling in an experiment flight plan. See Table 2-6. As noted in the Introduction (Subsection 1.2), Case 534G was assumed as baseline for this analysis. The accommodation rationale which selected Case 534G for the Modular Space Station is described in Section 2.0 of MP-0.1 Space Station program (Modular) Mission Analysis. The study approach for FPE's or FPE Subgroups and experiment modules consisted of three major steps:
(1) Determine the requirements that must be provided for each FPE or FPE Subgroup in established categories of pertinent KSC operations. Then, identify groups of FPE's or FPE Subgroups having similar general KSC requirements;

(2) Determine a typical sequence of operations at KSC for each group identified above; and

(3) Identify GSE and supporting facilities required at KSC for each group.

The approach was based on the following ground rules and assumptions:

A. The Modular Space Station general purpose laboratory (GPL) will include equipment for FPE Subgroups P-1D, T-4A, T-4B, and LS-1A on the initial launch. This equipment will be installed during module fabrication. Therefore, these subgroups were not included in these experiments analyses, but were considered in the requirements for the GPL module. (Refer to Subsection 2.1)

B. The Case 534G, Experiment Flight Schedule, is baseline for schedule and accommodations mode.

C. Checkout and test of experiment modules will include those subsystems and functions that are critical to achieving a satisfactory rendezvous and docking with the Space Station.

D. Checkout and test of experiments will be determined for each FPE, considering the criticality of the function to orbit operations, the difficulty or impossibility of adjustment or repair on orbit, and the validity of a ground-verification exercise.

E. The philosophy of "Orbit-Ready from the factory" is considered a goal and will be followed where technically feasible.

In the first step of the approach, established criteria were applied to the FPE's for grouping experiments with common or similar KSC requirements. These criteria and their rationale were as follows:

I. Specialized or Unique Facilities—Are specialized or unique facilities such as laboratories, clean rooms, or shops required? FPE's requiring special or unique launch site facilities significantly impact
<table>
<thead>
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<th>Final FPE/Subgroup Designations (WICK)</th>
<th>Original FPE/Subgroup Designations</th>
<th>Type of Accommodation</th>
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<td>and Physical Growth</td>
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<td>MS-1C Space Station Group</td>
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<td>MS-1D Space Station Group</td>
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<td><strong>T-4B</strong> Medium Duration Tests</td>
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<td><strong>T-5B</strong> Functional Manipulation</td>
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<td>Integral (Carry-On)</td>
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<td><strong>LS-ST/A</strong> Minimal Medical Research Facility</td>
<td>Integral (Initial GPL)</td>
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<td><strong>LS-1B</strong> Minimal Life Science Research Facility</td>
<td><strong>LS-ST/B</strong> Minimal Life Science Facility</td>
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<td><strong>LS-1C</strong> Intermediate Life Science Research Facility</td>
<td><strong>LS-ST/C</strong> Interim Life Science Facility</td>
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<td><strong>LS-1D</strong> Dedicated Life Science Research Facility</td>
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<td>Attached Module (Not Scheduled)</td>
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program planning because of the long lead time associated with the design, construction, and activation of new facilities.

III. Maintenance of Unique Protective Environment—Does the FPE or module require continuous maintenance of a protective environment not provided normally by launch site facilities? Experiments in this category must be monitored continuously, replenishment consumables provisioned, and operational and maintenance procedures established.

IV. Test and Checkout Requirements—Is test and checkout required at the launch site? If test and checkout is required (consistent with the Orbit-Ready-from-factory philosophy, facilities must be provided or modified and provisions must be made to accommodate associated GSE.

V. Prelaunch Servicing of Consumables—Is prelaunch servicing of consumables required? If servicing is required, consumables must be stored and GSE may be required.

VI. Lift-Off Status—Is the FPE or module active at lift-off? If the equipment is active at lift-off, countdown activities requirements must be defined.

VII. Installation During Countdown—Is installation during the launch countdown required? Requirements for installation during the launch countdown imply interfaces with KSC launch-pad facilities and require integration with other program elements.

VIII. Program-Peculiar Functions—Are program-peculiar functional activities required? Requirements for experiment electrical and mechanical interface verification with the Flight Integration Tool (FIT) must be met and coordinated with FPE Installation in the module carrier.

These criteria were applied individually to each of the FPEs or FPE Subgroups scheduled in the Case 534G Flight Plan, except those launched integrally with the GPL. (FPEs launched with the GPL were considered as a subsystem of the Station and accordingly were included with the GPL for impact on KSC.) The result of applying these criteria is shown in Table 2-7. When the FPEs and FPE Subgroups are rearranged and grouped according to
common criteria, six distinct groups become apparent as shown in Table 2-8. A summary of significant factors and commonalities of these groups is shown in Table 2-9.

The second part of the study approach was to determine a typical sequence of operations at KSC for each of the groups. This analysis resulted in functional-flow block diagrams presented in Subsection 2.3.3, together with descriptions of the activities that will be required.

The third part of the approach, to identify the supporting facilities and GSE required at KSC, was then accomplished. Data derived in this analysis are presented in Sections 3 and 4.

2.3.1 Site Activation
Major facility that must be activated at KSC to support experiment requirements will be the Launch Site Biological Laboratory. The facility must be operable prior to receipt of bioscience specimens from suppliers several days prior to flight schedule. Activation of this facility will involve activities needed for handling living specimens and providing their life support expendables. Preparation for operation will include special training of technicians, especially in support of unique functions such as surgical implantation of instrumentation.

2.3.2 Transportation
Experiment module and FPE transportation kits will be required to support movement of experiments to KSC, and during transit between facilities at KSC. These kits will be designed to provide all the unique support need for experiments, equipment, detectors, and specimens but will require resupply of expendables and power from KSC sources. Cranes, lifts, elevators, etc., will be provided by KSC facilities, but adapter, slings, brackets, etc., will be provisioned with the transportation kits.
<table>
<thead>
<tr>
<th>Category</th>
<th>FPE Subgroup</th>
<th>General Description</th>
<th>Maintenance of Protective Environment Not Provided Normally by Launch Site Facility</th>
<th>Test &amp; Checkout Required at Launch Site</th>
<th>Prelaunch Servicing of Consumables</th>
<th>FPE Subgroup or Module Active at Liftoff</th>
<th>Installation During Countdown Required</th>
<th>Program - Peculiar Functions Required</th>
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<tr>
<td>A-1</td>
<td>X-Ray Stellar Astronomy</td>
<td></td>
<td>Refrigerated Storage for X-Ray Polarimeter; Inert gas blanket</td>
<td>Electrical; OCS; Controls and Displays Checkout; Docking Electrical Interface</td>
<td>LN$_2$ Loading for Cryostat; Monopropellant</td>
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<td>A-2</td>
<td>Advanced Stellar Astronomy</td>
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<td>Inert gas blanket</td>
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<td>Monopropellant</td>
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<td>A-2A</td>
<td>Intermediate Stellar Astronomy</td>
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<td>Inert gas blanket</td>
<td>Electrical; OCS, Controls and Displays Checkout; Docking Electrical Interface</td>
<td>Monopropellant</td>
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<td>A-3AA</td>
<td>Advanced Solar Astronomy</td>
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<td>Inert gas blanket</td>
<td>Electrical; OCS, Controls and Displays Checkout; Docking Electrical Interface</td>
<td>Monopropellant</td>
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<td>A-3CC</td>
<td>ATM Follow-on</td>
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<td>Inert gas blanket</td>
<td>Electrical; OCS, Controls and Displays Checkout; Docking Electrical Interface</td>
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<td>A-4A</td>
<td>0.7M Narrow-Field UV Telescope</td>
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<td>UV Instrument Laboratory; Optics Lab</td>
<td>Inert gas blanket</td>
<td>Electrical; OCS, Controls and Displays Checkout; Docking Electrical Interface</td>
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<tr>
<td>A-4B</td>
<td>0.3M Wide-Field UV Telescope</td>
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<td>UV Instrument Laboratory; Optics Lab</td>
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<td>Electrical; OCS, Controls and Displays Checkout; Docking Electrical Interface</td>
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<tr>
<td>A-4C</td>
<td>Small UV Survey Telescope</td>
<td></td>
<td>UV Instrument Laboratory; Telescope</td>
<td>Inert gas blanket</td>
<td>Electrical; OCS, Controls and Displays Checkout; Docking Electrical Interface</td>
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### Table 2-7
GENERAL CATEGORIZATION ANALYSIS (Continued)

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<td>A-5A X-Ray Telescope</td>
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<td>Service Cryogenics Loop</td>
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<td>A-6 IR Telescope</td>
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<td>Refrigerated storage for IR sources; inert gas blanket</td>
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<td>Service Cryogenics Loop LHe &amp; LHe</td>
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<td>Refrigerated storage for IR Spectrometer</td>
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<td>Particle Source &amp; vacuum chamber for calibration</td>
<td>Storage Environment Control</td>
<td>Electrical, OSC, Controls and Displays Checkout</td>
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Table 2-7
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<td>Program - Peculiar Functions Required</td>
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<td>Prelaunch Servicing of Consumables</td>
<td>FPE Subgroup or Module Active at Liftoff</td>
<td>Installation During Countdown Required</td>
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<td>T-2A Long-Term Cryo System</td>
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<td>N₂ Pressurization</td>
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### Table 2-7
#### GENERAL CATEGORIZATION ANALYSIS (Continued)

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<tr>
<th>FPE Category</th>
<th>Subgroup</th>
<th>I</th>
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<th>VII</th>
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<tbody>
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<td>T-5A Initial Flight Teleoperator</td>
<td>Specialized or Unique Facilities</td>
<td>Maintenance of Protective Environment Not Provided Normally By Launch Site Facility</td>
<td>Test &amp; Checkout Required at Launch Site</td>
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**Table 2-8**

KSC REQUIREMENTS GROUPING SUMMARY
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Table 2-8
KSC REQUIREMENTS GROUPING SUMMARY (Continued)
Table 2-9
EXPERIMENT GROUP DESCRIPTION

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<th>Group</th>
<th>Description</th>
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<tr>
<td>A—(Modules)</td>
<td>• Five astronomy, three earth observations, one physics, and three technology FPE Subgroups;</td>
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<tr>
<td></td>
<td>• Free-flyer or attached module accommodation;</td>
</tr>
<tr>
<td></td>
<td>• Driver was module accommodation mode and status of equipment during countdown and at lift-off.</td>
</tr>
<tr>
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<td>Group A differs from Group B mainly in that specialized laboratories or facilities are not needed for Group A, but are required for Group B.</td>
</tr>
<tr>
<td>B—(Modules)</td>
<td>• Six astronomy, three communications/navigation, and one physics FPE Subgroups;</td>
</tr>
<tr>
<td></td>
<td>• Attached or free-flyer module accommodation;</td>
</tr>
<tr>
<td></td>
<td>• Driver was module accommodations mode; status of equipment during countdown and at lift-off and requirement for specialized laboratories or</td>
</tr>
<tr>
<td></td>
<td>facilities.</td>
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<tr>
<td>C—(Carry-On)</td>
<td>• Four physics and five technology FPE subgroups;</td>
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<td>• Launched in a logistics module for carry-on to Space Station GPL;</td>
</tr>
<tr>
<td></td>
<td>• Driver was requirement for electrical and mechanical checkout with FIT. Group C differs from Group D mainly in that specialized laboratories or</td>
</tr>
<tr>
<td></td>
<td>facilities are not needed for Group C, but are required for Group D.</td>
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<td>D—(Carry-On)</td>
<td>• Five physics and two technology FPE Subgroups;</td>
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<td></td>
<td>• Launched in a logistics module for carry-on to space station GPL;</td>
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<td></td>
<td>• Driver was requirement for electrical and mechanical checkout with FIT and requirement for specialized facilities.</td>
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<td>E—(MS/MS</td>
<td>• Five materials science and manufacturing FPE Subgroups;</td>
</tr>
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<td>Carry-On)</td>
<td>• Launched in a logistics module for carry-on to Space station GPL</td>
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<tr>
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<td>• Driver was no requirement for checkout and servicing except for verification with FIT.</td>
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<td>F—(Life-Science Modules)</td>
<td>• Three life-sciences FPE Subgroups;</td>
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<tr>
<td></td>
<td>• Attached module accommodation;</td>
</tr>
<tr>
<td></td>
<td>• Driver was need for specialized facilities, installation of specimens during countdown, and life-support equipment active at lift-off.</td>
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</table>
Access by personnel to equipment within the module will be required for FPEs in attached and free-flying modules and will be supported by access ladders, braces, platforms, etc. Specialized equipment of this type will be provisioned as GSE.

2.3.3 Prelaunch and Launch Operations

Functional-flow block diagrams for each group with descriptions of operations are presented in this subsection. Conventions observed in these block diagrams are as follows:

A. Columns indicated by heavy dashed lines represent the facilities or locations at which the operations functions (shown as blocks in the columns) will be performed. Facilities or locations are requirements and may or may not exist currently.

B. Solid-outline blocks indicate functions for which KSC will be (or may be) responsible. Functions to be performed at facilities that will be located at Contractor's option, in accordance with requirements to be established later are also shown as solid outline blocks, because KSC is a candidate location for performing these operations. The functions include experiment payload integration, operations, and checkout, and FIT activities.

C. Dashed-outline blocks show other related functions, not performed at KSC, but which KSC will monitor.

D. Unconnected blocks, shown for the Mission Operations Support, will be performed when functions being monitored or coordinated are in progress. There is no sequence for these operations.

In addition to prelaunch and launch operations, on-orbit and return operations are shown in the functional-flow diagrams to identify the continuing KSC requirements for mission support of experiments.

2.3.3.1 Sequence Descriptions, Group-A FPE's (Modules)

Descriptions of operations at KSC facilities are presented for Group A FPEs and FPE Subgroups described in Table 2-9 in this section. See Figure 2-24.
Figure 2-24. KSC Flow-Group A FPE's and FPE Subgroups
Experiment Payload Integration Center
The module will be received at the Experiment Payload Integration Center (EPIC) for incorporation of experiment equipment. The module transportation kit will provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment. The Receiving operation will include securing the module in a storage, service, and test area having environmental control, housing space for GSE, and providing support requirements shown in Table 2-10. Transportation packaging will then be removed. Preparation will be made to provide inert gas blankets and refrigerator service for experiment equipment to be installed.

Experiment equipment will be received from the laboratories for installation in the module. Portions of the experiment transportation kit will be used as necessary to support the equipment during transfer.

Integration of experiment equipment includes mechanical installation and securing of components in the module and hookup of power, control and instrumentation cabling. Integration will be verified using appropriate operations checkouts and alignment measurements will be made as required.

Portions of the experiment and module transportation kits will be used to maintain support services and environmental control indicated in Tables 2-10 and 2-11.

Operations and Checkout (O & C) Area
The module, with integrated FPEs and FPE Subgroups, will be received at the O & C area from the EPIC. The experiment module transportation kit will provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment. Portions of the experiment transportation kit will be used in conjunction with the module transportation kit equipment. Receiving
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<th>Temperature Humidity, and Cleanliness</th>
<th>Utility Services</th>
<th>GSE (2 x 2 x 6 ft Racks)</th>
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<td>7° to 27°C ≤55% Class 100,000</td>
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<td>Size (ft)</td>
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<td>20,000</td>
<td>14 Dia 37.5 Long</td>
<td>10° to 30°C ≤50% Class 100,000</td>
<td>1,330 w; 28 vdc</td>
<td>5</td>
</tr>
<tr>
<td>T-2BB Short Term Cryogenics</td>
<td>20,000</td>
<td>14 Dia 37.5 Long</td>
<td>10° to 30°C ≤50% Class 100,000</td>
<td>1,408 w; 28 vdc</td>
<td>5</td>
</tr>
<tr>
<td>T-3B Manned Work Platform</td>
<td>20,000</td>
<td>14 Dia 38.6 Long</td>
<td>20° to 35°C ≤50% Class 100,000</td>
<td>919 w; 28 vdc</td>
<td>4</td>
</tr>
</tbody>
</table>
Table 2-11
GROUP A CONTINUOUS SERVICE REQUIREMENTS

<table>
<thead>
<tr>
<th>FPE Subgroup</th>
<th>Service</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>GN₂ blanket for optical train to control cleanliness and humidity</td>
<td>Transportation Kit (Portion)</td>
</tr>
<tr>
<td></td>
<td>Refrigeration storage for X-Ray Polarimeter</td>
<td>Transportation Kit (Portion)</td>
</tr>
<tr>
<td>A-2, A-2A, A-3AA, A-3CC</td>
<td>GN₂ blanket for optical train to control cleanliness and humidity</td>
<td>Transportation Kit (Portion)</td>
</tr>
<tr>
<td>ES-1, ES-1AA, ES-1G, P-3</td>
<td>Storage environmental control for temperature, cleanliness, and humidity</td>
<td>Transportation Kit (Portion)</td>
</tr>
</tbody>
</table>

operations will include securing the integrated module in a storage, service, and test area having environmental control, housing space for GSE, and providing utility services shown in Tables 2-10 and 2-11. Then transportation packaging will be removed. Inert gas blankets or purges and refrigeration loops will be transferred from transportation kit equipment to facility supplies and power. Flight equipment shipped separately will be installed and connected mechanically and electrically to the module.

Checkout of modules and experiment equipment at the operations and checkout area will include only those essential functions that will not be verified later during or after integration of the module with the shuttle. Module subsystems and experiment equipment that must be operated during storage and servicing at the operations and checkout area will be monitored using GSE to assure proper performance.
Flight Integration Tool (FIT) Area

The integrated module will be transferred to the FIT area after checkout at the EPIC and O & C facilities. Portions of the experiment and module transportation kits will provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during transfer.

Using the FIT operation, the electrical interface at the docking port will be verified with appropriate cable assemblies and connection to GSE. Mechanical docking will not be required. Interface adapters or substitutes will be used to verify both sides of the docking assemblies. (Refer to Figure 2-9.)

Shuttle Orbiter Maintenance Area

The module and experiments with supporting equipment will be transferred to the Shuttle orbiter maintenance area for integration with the orbiter. Checkout of the orbiter will have been performed, confirming readiness to receive the experiment module.

Support requirements that must be provided for integrated Group A FPEs or FPE Subgroups and modules include the utility services shown in Tables 2-10 and 2-11. The temperature, humidity and cleanliness constraints listed in Table 2-10 will be necessary whenever experiment equipment is not protected fully by the Module structure. GSE required will be that necessary to support integration of the module into the orbiter including the handling fixture of the experiment module transportation kit and experiment handling equipment and personnel access equipment of the experiment handling and access kit.

Module subsystems and experiment equipment that must function properly to achieve successful transfer of the Module from the Shuttle to the Space Station in orbit will be checked using the OCS. The Shuttle with its Module integrated will be checked by the OCS in a subsystems verification test sequence. Upon completion of the verification, the Shuttle vehicle with the
integrated experiment module payload will be secured for transfer to the shuttle launch pad. During transfer, the services shown in Table 2-11 must be maintained continuously using the equipment indicated. Requirements to support the GSE maintaining these services during transit will be provided by KSC facilities.

Shuttle Launch Pad
The Shuttle vehicle with the integrated experiment module payload will be supported and serviced in preparation for launch at the launch pad. The continuous support services indicated in Table 2-11 will be maintained and monitored during the prelaunch phase using GSE, with transfer to Shuttle supported module systems prior to launch.

Servicing of experiment and module fluid systems will proceed, beginning with the least time critical, non-cryogenics. Critical functions will be monitored to assure proper status. The pressurizing, servicing, and loading operations will include hydrazine propellant for each free-flying module and the specific FPE requirements summarized in Table 2-12.

Table 2-12
GROUP A REQUIREMENTS FOR SERVICING AT THE SHUTTLE LAUNCH PAD

<table>
<thead>
<tr>
<th>Requirement</th>
<th>FPE Subgroup</th>
</tr>
</thead>
<tbody>
<tr>
<td>LN₂ Loading</td>
<td>A-1, ES-1, ES-1AA, ES-1G, P-3</td>
</tr>
<tr>
<td>LHe, Argon Methane Loading</td>
<td>P-3</td>
</tr>
<tr>
<td>LH₂ Loading (2500 lb)</td>
<td>T-2A</td>
</tr>
<tr>
<td>Slush Hydrogen (175 lb)</td>
<td>T-2B</td>
</tr>
<tr>
<td>LH₂ Loading (850 lb)</td>
<td></td>
</tr>
<tr>
<td>Other Fluids (2465 lb)</td>
<td></td>
</tr>
</tbody>
</table>
During the countdown, continuous support functions will be transferred from ground to module systems and critical functions will be monitored. Checkout sequences will be performed at the launch pad only when part of critical functions. Checkout sequences that are mandatory will be performed by OCS. Completion of the countdown with a successful lift-off of the Shuttle will result in orbiting of the module for flight operations. Then, at the launch pad, post-launch operations will be initiated to prepare for the next Shuttle launch.

A Shuttle abort on the launch pad will result in the requirement to implement corrective action to recover with minimum impact. An abort causing heavy damage may require substitution of a backup shuttle or experiments module, as well as refurbishment of the launch pad. If a backup module and experiments are required, they will require checkout and integration in the operations and checkout area and shuttle orbiter hangar (similar to that performed for the flight article) followed by prelaunch and launch operations at the shuttle launch pad.

Orbit
The orbiter with Module and experiment equipment will be inserted into orbit for phasing with the modular space station. Then the orbiter will rendezvous with the Space Station and the module will be separated and docked to the Space Station. A Logistics Module or experiment module that is ready for return will be loaded into the shuttle. Orbit operations will proceed, and the Shuttle with module will de-orbit and land. Each Group A module will be returned after completion of operations on a subsequent Shuttle flight.

These orbital operations will be monitored at KSC as necessary to support the mission.

Shuttle Landing Site
The orbiter with a Group-A module and experiment equipment will de-orbit and land at the KSC Shuttle landing strip. The module will provide all support services required by the FPEs until support equipment is connected after landing.
The module will then be off-loaded from the Shuttle and the services shown in Table 2-11 will be provided by portions of the transportation kit at the landing site to preserve FPE equipment. These services will be required from the time of separation of the module from the Shuttle until the module with experiments is removed to one of the KSC laboratories or to the EPIC.

The Shuttle, after removal of the module, will be secured for transfer to the Shuttle orbiter maintenance area to be prepared for a subsequent flight.

**KSC Laboratories**

The module and experiments, with supporting equipment providing services required for preservation of FPEs and data, will be transferred to one of the KSC laboratories or to the EPIC for analysis, refurbishment, and disposal. The KSC Environmental Test Laboratory and any of the following facilities and equipment may be required for test and analysis of some of the Group-A FPEs.

- A. Optical Laboratory
- B. Electronics Laboratory
- C. Analysis Laboratory
- D. Cleaning Laboratory
- E. Machine Shop

Upon completion of analysis and refurbishment, the module and experiments will be prepared for a follow-on flight if necessary to accomplish FPE objectives. KSC operations as shown in Figure 2-24 will be repeated in this case until objectives of the experiment are satisfied. When the FPE objectives are met, the experiment and module will be returned to the manufacturer or principle investigator, or will be salvaged in accordance with values and safety constraints.

**Mission Operations Support**

Mission operations support will include monitoring, coordinating, and controlling ground operations for experiments and modules throughout all mission phases. The following will be required:

- A. **Flight Operations Support**—Provides support of space station flight operations, communications, configuration control, telemetry,
B. **Mission Analysis and Planning**—Provides accommodation for the mission analysis functions of mission design, mission operations planning, and for planning in support of actual flight operations.

C. **Logistics Operations Support**—Provides control of total logistics activities, including experiment and module requirements planning and scheduling, and real-time support for flight operations.

D. **Experiment Operations Support**—Provides for activities required for experiment operational support and data collection; real-time experiments data display; experiments monitoring; planning and coordination; and experiments data analysis.

2.3.3.2 **Sequence Descriptions, Group-B FPEs (Modules)**

Descriptions of operations at KSC facilities are presented for Group-B FPEs and FPE Subgroups (described in Table 2-9) in this section. Refer to Figure 2-25.

**Support Laboratories**

Experiment equipment will be received at the appropriate laboratory. The experiment transportation kit will provide support services until these essential functions are transferred to facility sources. Receiving will include securing the experiment equipment in an area having the temperature, humidity, and cleanliness capabilities, and providing the utility services indicated in Table 2-13. Experiment calibration and checkout which must be completed prior to integration in the module will be performed.

**Experiment Payload Integration Center**

The module will be received at the EPIC for incorporation of experiment equipment. The module transportation kit will provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment. Receiving operations will include securing the module in a storage, service and test area having
Figure 2-25. KSC Flow - Group B FPE's and FPE Subgroups
environmental control, housing space for GSE, and providing support requirements shown in Tables 2-13 and 2-14. Transportation packaging will then be removed. Preparation will be made to provide inert gas blankets and refrigerator service for experiment equipment to be installed.

Experiment equipment will be received from the laboratories for installation in the module. Portions of the experiment transportation kit will be used as necessary to support the equipment during transfer.

Integration of experiment equipment includes mechanical installation and securing of components in the module and hookup of power, control, and instrument cabling. Integration will be verified using appropriate operations checkouts and alignment measurements will be made as required.

Portions of the experiment and module transportation kits will be used to maintain support services and environmental control indicated in Tables 2-13 and 2-14.

**Operations and Checkout Area**

Transfer of the integrated module to the operations and checkout area will be made only if further checkout is required after integration and prior to verification with the Flight Integration Tool. If transfer from the EPIC to O&C facility is required, required portions of the experiment and module transportation kits will provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during transfer. At the operations and checkout area checkout will include only those essential functions that will not be verified later during or after integration of the module with the shuttle.

Module subsystems and experiment equipment that must be operated during storage and servicing at the O&C area will be monitored using GSE to assure proper performance.
<table>
<thead>
<tr>
<th>FPE</th>
<th>Weight (lb)</th>
<th>Size</th>
<th>Temperature Humidity, and Cleanliness</th>
<th>Utility Services</th>
<th>GSE (2 x 2 x 6 ft Racks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-4A</td>
<td>15,653</td>
<td>14 Dia 38.6 Long</td>
<td>-10° to 25°C ≤40% Class 10,000</td>
<td>1,297 w; 28 vdc</td>
<td>6</td>
</tr>
<tr>
<td>A-4B</td>
<td>15,081</td>
<td>14 Dia 38.6 Long</td>
<td>-10° to 25°C ≤40% Class 10,000</td>
<td>1,359 w; 28 vdc</td>
<td>6</td>
</tr>
<tr>
<td>A-4C</td>
<td>14,726</td>
<td>14 Dia 38.6 Long</td>
<td>-10° to 25°C ≤40% Class 10,000</td>
<td>1,034 w; 28 vdc</td>
<td>6</td>
</tr>
<tr>
<td>A-5A</td>
<td>19,666</td>
<td>14 Dia 44.2 Long</td>
<td>-10° to 20°C ≤40% Class 10,000</td>
<td>1,292 w; 28 vdc</td>
<td>6</td>
</tr>
<tr>
<td>A-5B</td>
<td>18,289</td>
<td>14 Dia 38.6 Long</td>
<td>-10° to 20°C ≤40% Class 100,000</td>
<td>1,243 w; 28 vdc</td>
<td>6</td>
</tr>
<tr>
<td>A-6</td>
<td>19,296</td>
<td>14 Dia 38.6 Long</td>
<td>-10° to 20°C Approx. 0% Class 10,000</td>
<td>1,378 w; 28 vdc</td>
<td>6</td>
</tr>
</tbody>
</table>
Table 2-13
SUPPORT REQUIREMENTS AT KSC (GROUP B) (Continued)

<table>
<thead>
<tr>
<th>FPE</th>
<th>Weight (lb)</th>
<th>Size (ft)</th>
<th>Temperature</th>
<th>Utility Services</th>
<th>GSE (2 x 2 x 6 ft Racks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/N-1</td>
<td>14,989</td>
<td>14 Dia</td>
<td>17° to 27°C</td>
<td>1,178 w; 28 vdc</td>
<td>6</td>
</tr>
<tr>
<td>Communications/Navigation Facility</td>
<td>38.6 Long</td>
<td>≤40%</td>
<td>Class 100,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C/N-1A</td>
<td>14,612</td>
<td>14 Dia</td>
<td>17° to 27°C</td>
<td>1,103 w; 28 vdc</td>
<td>6</td>
</tr>
<tr>
<td>Communications/Navigation Subgroup A</td>
<td>38.6 Long</td>
<td>≤40%</td>
<td>Class 100,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C/N-1B</td>
<td>14,713</td>
<td>14 Dia</td>
<td>17° to 27°C</td>
<td>1,124 w; 28 vdc</td>
<td>6</td>
</tr>
<tr>
<td>Communications/Navigation Subgroup B</td>
<td>38.6 Long</td>
<td>≤40%</td>
<td>Class 100,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-2BB</td>
<td>20,000</td>
<td>14 Dia</td>
<td>-30° to 60°C</td>
<td>1,153; 28 vdc</td>
<td>2</td>
</tr>
<tr>
<td>Wake, Plasma, Wave Particle, Electron Beam</td>
<td>38.6 Long</td>
<td>≤80%</td>
<td>Class 100,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2-14
CONTINUOUS SERVICE REQUIREMENTS (MODULES)

<table>
<thead>
<tr>
<th>FPE</th>
<th>Service</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-4A, A-4B, A-4C and A-5A</td>
<td>GN\textsubscript{2} blanket for optical train to control cleanliness and humidity</td>
<td>Transportation Kit (Portion)</td>
</tr>
<tr>
<td>A-5B</td>
<td>Refrigeration storage for Gamma-Ray Spectrometer</td>
<td>Transportation Kit (Portion)</td>
</tr>
<tr>
<td>A-6</td>
<td>GN\textsubscript{2} blanket for optical train to control cleanliness and humidity</td>
<td>Transportation Kit (Portion)</td>
</tr>
<tr>
<td></td>
<td>Refrigeration storage for IR sources</td>
<td>Transportation Kit (Portion)</td>
</tr>
<tr>
<td>CN-1, CN-1A, CN-1B and P-2BB</td>
<td>Storage environmental control for temperature, cleanliness and humidity</td>
<td>Transportation Kit (Portion)</td>
</tr>
</tbody>
</table>

**Flight Integration Tool Area**

The integrated module will be transferred to the FIT area after checkout at the EPIC and O&C areas. Required portions of the experiment and module transportation kits will provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during transfer.

Using the FIT, the electrical interface at the docking port will be verified with appropriate cable assemblies and connection to GSE. Mechanical docking will not be required. Interface adapters or substitutes will be used to verify both sides of the docking assemblies. (Refer to Figure 2-9.)

**Shuttle Orbiter Maintenance Area**

The module and experiments with supporting equipment will be transferred to the Shuttle orbiter maintenance area for integration with the orbiter. Checkout of the orbiter will have been performed, confirming readiness to receive the experiment module. Support requirements that must be provided for integrated Group-B FPEs or FPE Subgroups and modules include the
utility services shown in Table 2-13 and 2-14. The temperature, humidity and cleanliness constraints listed in Table 2-13 will be necessary whenever experiment equipment is not fully protected by the module structure. GSE required will be that necessary to support integration of the module into the orbiter including the handling fixture of the experiment module transportation kit and experiment handling equipment and personnel access equipment of the experiment handling and access kit.

Module subsystems and experiment equipment that must function properly to achieve successful transfer of the module from the Shuttle to the space station in orbit will be checked out using the OCS. The Shuttle with integrated module will be checked by the OCS in a subsystems verification test sequence. Upon completion of the verification, the shuttle and the integrated experiment module payload will be secured for transfer to the shuttle launch pad. During transfer, the services shown in Table 2-13 must be maintained continuously using the equipment indicated. Requirements to support the GSE maintaining these services during transit will be provided by KSC facilities.

Shuttle Launch Pad

The shuttle vehicle with the integrated experiment module payload will be supported and serviced in preparation for launch at the launch pad. The continuous support services indicated in Table 2-14 will be maintained and monitored during the prelaunch phase using GSE, with transfer to shuttle-supported systems prior to launch.

Servicing of experiment and module fluid systems will proceed, beginning with the least time critical, non-cryogenics. Critical functions will be monitored to assure proper status. The pressurizing, servicing, and loading operations will include hydrazine propellant for each free-flying module and the specific FPE requirements summarized in Table 2-14.

During countdown, continuous support functions will be transferred from ground to module systems and critical functions will be monitored. Checkout sequences will be performed at the launch pad only when part of critical functions. Checkout sequences that are mandatory will be performed by OCS.
Completion of the countdown with a successful liftoff of the Shuttle will result in orbiting of the module for flight operations. Then, at the launch pad, post-launch operations will be initiated to prepare for the next Shuttle launch.

A Shuttle abort on the launch pad results in the requirement to implement corrective action to recover with minimum impact. An abort causing heavy damage may require substitution of a backup Shuttle or experiments module, as well as refurbishment of the launch pad. If a backup module and experiments are required, they will require checkout and integration in the operations and checkout facility and Shuttle orbiter hanger, similar to that performed for the flight article, followed by prelaunch and launch operations at the Shuttle launch pad.

**Orbit**

The orbiter with module and experiment equipment will be inserted into orbit for phasing with the Modular Space Station. Then the orbiter will rendezvous with the Space Station and the module will be separated and docked to the Space Station. A Logistics Module or experiment module that is ready for return will be loaded into the Shuttle. Orbit operations will proceed, and the shuttle with module will de-orbit and land. Each Group-B module will be returned after completion of operations on a subsequent Shuttle flight. These orbital operations will be monitored at KSC as necessary to support the mission.

**Shuttle Landing Site**

The orbiter with a Group-B module and experiment equipment will de-orbit and land at the KSC Shuttle landing strip. The module will provide all support services required by the FPEs until support equipment is connected after landing.

The module will then be off-loaded from the shuttle and the services shown in Table 2-14 will be provided by portions of the transportation hit at the landing site to preserve FPE equipment. These services will be required from the time of separation of the module from the Shuttle until the module with experiments is removed to one of the KSC laboratories or to the EPIC.

The Shuttle, after removal of the module, will be secured for transfer to the shuttle orbiter maintenance area to be prepared for a subsequent flight.
KSC Laboratories
The module and experiments, with supporting equipment providing services required for preservation of FPEs and data, will be transferred to one of the KSC laboratories or to the EPIC for analysis, refurbishment, and disposal. The KSC Environmental Test Laboratory and any of the following facilities and equipment may be required for test and analysis of some of the Group-B FPE's:

A. Optical Laboratory -
B. UV Instrument Laboratory -
C. Electronics Laboratory -
D. Analysis Laboratory -
E. Cleaning Laboratory -
F. Machine Shop -

Upon completion of analysis and refurbishment, the module and experiments will be prepared for a follow-on flight if necessary to accomplish FPE objectives. KSC operations (shown in Figure 2-25) will be repeated in this case until objectives of the experiment are satisfied. When the FPE objectives are met, the experiment and module will be returned to the manufacturer or principal investigator, or will be salvaged in accordance with values and safety constraints.

Mission Operations Support
Mission operations support will include monitoring, coordinating, and controlling ground operations for experiments and modules throughout all mission phases. The following will be required:

A. Flight Operations Support - Provides support of space station flight operations, communications, configuration control, telemetry, ground-tracking data processing, systems-status parameters processing, uplink data processing, and information presentation.
B. Mission Analysis and Planning - Provides accommodation for the mission analysis functions of mission design, mission operations planning, and for planning in support of actual flight operations.
C. Logistics Operations Support - Provides control of total logistics activities, including experiment and module requirements planning and scheduling, and real-time support for flight operations.
D. Experiment Operations Support - Provides for activities required for experiment operational support and data collection; real-time
experiments data display; experiments monitoring; planning and coordination; and experiments data analysis.

2.3.3.3 Sequence Descriptions, Group-C FPEs and Subgroups (carry-on)

Descriptions of operations at KSC facilities are presented for Group C FPEs (described in Table 2-9) in this section. Refer to Figure 2-26.

**Flight Integration Tool Area**

Experiment flight equipment will be received from the principal investigator or fabricator. Portions of the experiment transportation kit will be used for each FPE subgroup to provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment. Receiving will include securing the experiment equipment in a storage and service area near the FIT having environmental control. Transportation packaging will then be removed. Means will be provided to protect the experiment flight equipment from an adverse environment while being moved to the FIT for installation. The protective material will be removed just prior to installation in the FIT. Experiment equipment, will then be installed in the FIT for operational verification. This verification will include mechanical integration and connection of electrical power, controls, displays, and checkout functions. An onboard checkout sequence (OCS) will be performed to confirm status and interfaces in the flight configuration. Proper manual and automatic experiment functions and responses will be verified for the mechanisms that can be operated in the one-g, pressurized environment. GSE will be used to provide functions and responses of experiment equipment that will be degraded by activation.

After completion of verification with the FIT, the experiments will be removed and packaged for transport to the logistics module loading area. Appropriate portions of the experiment transportation kit will be used to support and protect the experiment equipment during transit.

**Logistics Module Loading Area**

Experiment equipment, secured and passively packaged for flight, will be installed and secured in the logistics module. FPE Subgroups in Group C will require only flight restraints and tie-downs when loaded in the logistics module.
Figure 2-26. KSC Flow - Group C FPE's and FPE Subgroups
Shuttle Orbiter Maintenance Area
The logistics module and experiments will be transferred to the shuttle orbiter maintenance area for integration with the orbiter vehicle. Experiments are passive and require no services or special handling during installation of the logistics module in the shuttle orbiter.

Shuttle Launch Pad
The Shuttle vehicle with the integrated logistics module payload will be supported in preparation for launch at the launch pad. Experiments are passive and require no services or special handling during shuttle launch pad operations.

An abort causing heavy damage may require substitution of a backup Shuttle and/or Logistics Module as well as refurbishment of the launch pad. If a backup logistics module and experiments are required, they will checkout with the FIT, integration in the logistics module loading area, and integration with the orbiter in the Shuttle orbiter maintenance area similar to that performed for the flight article, followed by prelaunch and launch operations at the Shuttle launch pad.

Orbit
The Shuttle with the Logistics Module and experiment equipment will be inserted into orbit for phasing with the space station. Then the shuttle will rendezvous with the Space Station and the Logistics Module will be docked to the Space Station. A Logistics Module or experiment module that is ready for return will be loaded into the Shuttle. Orbit operations will proceed, and the Shuttle with module will de-orbit and land.

Orbit operations for Group-C experiments will include transfer or carry-on of equipment from the Logistics Module into the Space Station. Space in the Logistics Module may then be used for storage of experiment equipment for which operations have been completed, or which are to be returned to ground for repair or modification.
Each Group-C experiment will be returned in a Logistics Module after completion of operations on a subsequent Shuttle flight. These orbital operations will be monitored at KSC as necessary to support the mission.

Shuttle Landing Site
The Shuttle, with a logistics module and secured and passivated Group-C experiment equipment, will deorbit and land at the KSC Shuttle landing strip. The Logistics Module will then be off-loaded from the Shuttle orbiter and the services required by the experiments will be provided by GSE at the landing site to preserve FPE equipment and specimens. These services will be required from the time of separation of the Logistics Module from the Shuttle orbiter until the experiments are removed to one of the KSC laboratories.

KSC Laboratories
FPE Subgroups of Group C, with supporting equipment providing services required for preservation of equipment and data, will be transferred to one of the KSC laboratories for analysis, refurbishment and disposal. Laboratory requirements are similar to those described previously for Group-A FPEs.

Mission Operations Support
The Mission Operations Support Center, as described previously for Group A FPEs, is the KSC focal point for monitoring, coordinating and controlling ground operations for experiments and the Logistics Module throughout all mission phases.

2.3.3.4 Sequence Description, Group D FPE Subgroups (Carry On)
Descriptions of operations at KSC facilities are presented for Group D FPE subgroups (described in Table 2-9) in this section. Refer to Figure 2-27.

Support Laboratories
Experiment equipment will be received at the appropriate laboratory. The experiment transportation kit will provide support services until these
essential functions are transferred to facility sources. Receiving will include securing the experiment equipment in an area near the FIT having the temperature, humidity, and cleanliness capabilities, and providing the utility services indicated in Table 2-15. Experiment calibration and checkout which must be performed prior to integration in the FIT will be performed.

**Flight Integration Tool Area**

Experiment flight equipment will be received from the support laboratories. Portions of the experiment transportation kit will be used for each FPE subgroup to provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment. Receiving will include securing the experiment equipment in a storage and service area near the FIT having environmental control. Transportation packaging will then be removed. Means will be provided to protect the Experiment flight equipment from adverse environment while being moved to the FIT for installation. The protective material will be removed just prior to installation in the FIT. Experiment equipment, including flight packaging, will then be installed in the FIT for operational verification. This verification will include mechanical integration and connection of electrical power, controls, displays, and checkout functions. An OCS checkout sequence will be performed to confirm status and interfaces in the flight configuration. Proper manual and automatic experiment functions and responses will be verified for the mechanisms that can be operated in the one-g, pressurized environment. GSE will be used to provide functions and responses of experiment equipment that will be degraded by activation.

After completion of verification with the FIT, the experiments will be removed and packaged for transport to the Logistics Module loading area. Appropriate portions of the experiment transportation kit will be used to support and protect the experiment equipment during transit.
<table>
<thead>
<tr>
<th>FPE</th>
<th>Weight (lb)</th>
<th>Size (ft)</th>
<th>Temperature Humidity, and Cleanliness</th>
<th>Utility Services</th>
<th>GSE (2 x 2 x 6 ft Racks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1A Atmospheric and Magneto Science</td>
<td>562</td>
<td>38 ft³</td>
<td>17° to 27°C ≤50% Class 100,000</td>
<td>640 w; 28 vdc</td>
<td>4</td>
</tr>
<tr>
<td>P1-B Cometary Physics</td>
<td>233</td>
<td>20.6 ft³</td>
<td>17° to 27°C 50% Class 100,000</td>
<td>1.6 kw; 28 vdc</td>
<td>3</td>
</tr>
<tr>
<td>P1-C Meteoroid Science</td>
<td>111</td>
<td>34.6 ft³</td>
<td>17° to 27°C ≤50% Class 100,000</td>
<td>19 w; 28 vdc</td>
<td>3</td>
</tr>
<tr>
<td>P-1E Small Astronomy Telescopes</td>
<td>210</td>
<td>18 ft³</td>
<td>17° to 27°C ≤50% Class 100,000</td>
<td>458 w; 28 vdc</td>
<td>3</td>
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<tr>
<td>P-2A Wake Measurement From Station &amp; Booms</td>
<td>519</td>
<td>1.6 x 3.3 x 4.6 ft</td>
<td>-10° to 40°C 80% Class 100,000</td>
<td>438 w; 28 vdc</td>
<td>3</td>
</tr>
<tr>
<td>T-1A Contamination Experimental Package</td>
<td>353</td>
<td>21.1 ft³</td>
<td>17° to 27°C ≤50% Class 100,000</td>
<td>255 w; 28 vdc</td>
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</tr>
<tr>
<td>T-1B Contamination Monitor Package</td>
<td>76</td>
<td>2.4 ft³</td>
<td>17° to 27°C ≤50% Class 100,000</td>
<td>100 w; 28 vdc</td>
<td>3</td>
</tr>
</tbody>
</table>
Logistics Module Loading Area
Experiment equipment, secured and passively packaged for flight, will be installed and secured in the logistics module. FPE subgroups in Group D will require only flight restraints and tie-downs when loaded in the logistics module.

Shuttle Orbiter Maintenance Area
The Logistics Module and experiments will be transferred to the Shuttle orbiter maintenance area for integration and checkout with the orbiter vehicle. Experiments are passive and require no services or special handling during installation of the Logistics Module in the Shuttle orbiter.

Shuttle Launch Pad
At the launch pad, the Shuttle vehicle with the integrated Logistics Module payload will be supported in preparation for launch. Experiments are passive and require no services or special handling during Shuttle launch pad operations.

An abort causing heavy damage may require substitution of a backup Shuttle or Logistics Module as well as refurbishment of the launch pad. If a backup logistics module and experiments are required, they will require checkout with the FIT, integration in the Logistics Module loading area, and integration with the orbiter in the shuttle orbiter maintenance area, similar to that performed for the flight article, followed by prelaunch and launch operations at the shuttle launch pad.

Orbit
The Shuttle, with the Logistics module and experiment equipment, will be inserted into orbit for phasing with the space station. The Shuttle will then rendezvous with the Space Station and the Logistics Module will be docked to the Space Station. A Logistics Module or experiment module that is ready for return will be loaded into the shuttle. Orbit operations will proceed, and the shuttle with module will de-orbit and land.
Orbit operations for Group-D experiments will include transfer or carry-on of equipment from the Logistics Module into the space station. Space in the Logistics Module may then be used for storage of experiment equipment for which operations have been completed, or which are to be returned to ground for repair or modification.

Each Group-D experiment will be returned in a Logistics Module after completion of operations on a subsequent shuttle flight. These orbital operations will be monitored at KSC as necessary to support the mission.

Shuttle Landing Site
The Shuttle, with a Logistics Module and secured and passivated Group-D experiment equipment will de-orbit and land at the KSC Shuttle landing strip.

The Logistics Module will then be off-loaded from the shuttle orbiter and the services required by the experiments will be provided by GSE at the landing site to preserve FPE equipment and specimens. These services will be required from the time of separation of the Logistics Module from the shuttle orbiter until the experiments are removed to one of the KSC laboratories.

KSC Laboratories
FPE subgroups of Group D, with supporting equipment providing services required for preservation of equipment and data, will be transferred to one of the KSC laboratories for analysis, refurbishment and disposal. Laboratory requirements are similar to those described previously for Group-A FPEs.

Mission Operations Support
Mission Operations Support as described previously for Group-A FPEs will include monitoring, coordinating, and controlling ground operations for experiments and Logistics Module throughout all mission phases.
2.3.3.5 Sequence Descriptions, Group E-FPE Subgroups (carry-on)

Descriptions of operations at KSC facilities are presented for Group E FPE subgroups (described in Table 2-9) in this section. Refer to Figure 2-28.

Flight Integration Tool (FIT) Area

Experiment flight equipment will be received from the principal investigator or fabricator. Portions of the experiment transportation kit will be used for each FPE subgroup to provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment. Receiving activity will include securing the experiment equipment in a storage and service area near the FIT having environmental control. Transportation packaging will then be removed. Means will be provided to protect the experiment flight equipment from adverse environment while being moved to the FIT for installation. The protective material will be removed just prior to installation in the FIT. Experiment equipment will then be installed in the FIT for operational verification. This verification will include mechanical integration and connection of electrical power, controls, displays, and checkout functions. Proper experiment functions and responses will be verified for the mechanisms that can be operated in the one-g, pressurized environment. GSE will be used to provide functions and responses of experiment equipment that will be degraded by activation.

After completion of verification with the FIT, the experiments will be removed and packaged for transport to the Logistics Module loading area. Appropriate portions of the experiment transportation kit will be used to support and protect the experiment equipment during transit.
Figure 2-28. KSC Flow - Group E FPE's and FPE Subgroups
Experiment equipment, secured and passively packaged for flight, will be
installed and secured in the Logistics Module. FPE subgroups in Group E
will require only flight restraints and tie-downs when loaded in the Logistics
Module.

**Shuttle Orbiter Maintenance Area**
The Logistics Module and experiments will be transferred to the Shuttle
orbiter maintenance area for integration and checkout with the orbiter
vehicle. Experiments are passive and require no services or special
handling during installation of the logistics module in the shuttle orbiter.

**Shuttle Launch Pad**
The Shuttle vehicle with the integrated logistics module payload will be
supported in preparation for launch at the launch pad. Experiments are
passive and require no services or special handling during Shuttle launch
pad operations.

An abort causing heavy damage may require substitution of a backup Shuttle
or Logistics Module as well as refurbishment of the launch pad. If a
backup Logistics Module and experiments are required, they will require
checkout with the FIT, integration in the logistics module loading area, and
integration with the orbiter in the Shuttle orbiter maintenance area, similar
to that performed for the flight article, followed by prelaunch and launch
operations at the Shuttle launch pad.

**Orbit**
The shuttle with Logistics Module and experiment equipment will be inserted
into orbit for phasing with the Space Station. Then the Shuttle will
rendezvous with the Space Station and the Logistics Module will be docked
to the Space Station. A Logistics Module or experiment module that is ready for return will be loaded into the Shuttle. Orbital operations will proceed, and the shuttle with module will de-orbit and land.

Orbital operations for Group-E experiments will include transfer or carry-on of equipment from the logistics module into the Space Station. Space in the Logistics Module may then be used for storage of experiment equipment for which operations have been completed, or which are to be returned to ground for repair or modification.

Each Group-E experiment will be returned in a Logistics Module after completion of operations on a subsequent Shuttle flight. These orbital operations will be monitored at KSC.

**Shuttle Landing Site**

The Shuttle with a Logistics Module and secured and passivated Group-E experiment equipment will de-orbit and land at the KSC Shuttle landing strip.

Then the Logistics Module will be off-loaded from the Shuttle orbiter and the services required by the experiments will be provided by GSE at the landing site to preserve FPE equipment and specimens. These services will be required from the time of separation of the Logistics Module from the Shuttle orbiter until the experiments are removed and transported to the PI for analysis, refurbishment, and disposal. In the case of biological samples, the services will be required until the samples are received at the PI facilities.

**Mission Operations Support**

Mission Operations Support as described previously for Group A FPEs will include monitoring, coordinating, and controlling ground operations for experiments and Logistics Module throughout all mission phases.
2.3.3.6 Sequence Description, Group F FPE Subgroups (Life Science Modules)

Descriptions of operations at KSC facilities are presented in this section for Group-F FPE subgroups. Refer to Figure 2-29.

Experiment Payload Integration Center

The module will be received at the EPIC for incorporation of experiment equipment. The module transportation kit will provide specialized handling equipment; an environmental control system, and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment. Receiving operations will include securing the module in a storage, service, and test area having environmental control, housing space for GSE, and providing support requirements shown in Table 2-16. Transportation packaging will then be removed. Preparations will be made to provide atmosphere control and refrigerator service for experiment equipment to be installed.

Experiment equipment will be received for installation in the module. Portions of the experiment transportation kit will be used as necessary to support the equipment during transfer. Integration of experiment equipment includes mechanical installation and securing of components in the module and hookup of power, control, and instrumentation cabling. Integration will be verified using appropriate operations checkouts and alignment measurements will be made as required. Portions of the experiment and module transportation kits will be used to maintain support services and environmental control.

Operations and Checkout Area

Transfer of the integrated module to the operations and checkout area will be made only if further checkout is required after integration and prior to verification with the Flight Integration Tool. If transfer from the EPIC to the O&C area is required, the required portions of the experiment and module transportation kit will provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts
Figure 2-29. KSC Flow - Group F FPE's and FPE Subgroups
Table 2-16
SUPPORT REQUIREMENTS AT KSC (GROUP F)

<table>
<thead>
<tr>
<th>FPE</th>
<th>Weight (lb)</th>
<th>Size (cu ft)</th>
<th>Temperature, Humidity, and Cleanliness</th>
<th>Utility Service</th>
<th>GSE (No. of 2 x 2 x 6 ft racks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS-1B Minimal Life Science Research Facility</td>
<td>2,660</td>
<td>265</td>
<td>20° to 30°C 50 ± 5% Class 100,000</td>
<td>1,146 w; 28 vdc</td>
<td>5</td>
</tr>
<tr>
<td>LS-1C Intermediate Life Science Research Facility</td>
<td>4,100</td>
<td>534</td>
<td>20° to 30°C 50 ± 5% Class 100,000</td>
<td>2,165 w; 28 vdc</td>
<td>7</td>
</tr>
<tr>
<td>LS-1D Dedicated Life Science Research Facility</td>
<td>6,600</td>
<td>1,103</td>
<td>20° to 30°C 50 ± 5% Class 100,000</td>
<td>4,257 w; 28 vdc</td>
<td>9</td>
</tr>
</tbody>
</table>

of the equipment during transfer. At the operations and checkout area, checkout will include only those essential functions that will not be verified later during or after integration of the module with the shuttle.

Module subsystems and experiment equipment that must be operated during storage and servicing at the operations and checkout area will be monitored using GSE to assure proper performance.

Flight Integration Tool Area
The integrated module will be transferred to the FIT area after checkout at the EPIC and/or O&C facilities. Portions of the experiment and module transportation kits will provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during transfer.
Using the FIT, the electrical interface at the docking port will be verified with appropriate cable assemblies and connection to GSE. Mechanical docking will not be required. Interface adapters or substitutes will be used to verify both sides of the docking assemblies. (Refer to Figure 2-9).

Shuttle Orbiter Maintenance Area
The module and experiments with supporting equipment will be transferred to the Shuttle orbiter maintenance area for integration with the orbiter vehicle. Checkout of the orbiter will have been performed, confirming readiness to receive the experiment module.

Support requirements that must be provided for integrated Group-F FPE subgroups and modules include the utility services shown in Table 2-16. The temperature, humidity, and cleanliness constraints listed in Table 2-16 will be necessary whenever experiment equipment is not fully protected by the module structure. GSE required will be that necessary to support integration of the module into the orbiter including the handling fixture of the experiment module transportation kit and experiment handling equipment and personnel access equipment of the experiment handling and access kit.

Module subsystems and experiment equipment that must function properly to achieve successful transfer of the module from the shuttle to the space station in orbit will be checked out using the OCS. The shuttle with integrated module will be checked by the OCS in a subsystems verification test sequence. Upon completion of the verification, the shuttle with the integrated experiment module payload will be secured for transfer to the shuttle launch pad. During transfer, the services shown in Table 2-16 must be maintained continuously using the equipment indicated. Requirements to support the GSE maintaining these services during transit will be provided by KSC facilities.

Biological Laboratory Facility
Living specimens are required for each of the Group-F FPE subgroups. These specimens will be received from the suppliers at the Launch Site.
Biological Laboratory (LSBL). Required portions of the experiment transportation kit will be used for each FPE to provide specialized handling equipment; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the specimens or equipment during transport. Receiving will include securing the specimens in their cages or containers in a storage, service, and testing area having environmental control, life-support services, housing space for GSE, and providing utility services shown in Table 2-16. Transportation packaging and support will then be removed.

The LSBL will include a duplicate of the biological equipment that will be integrated into the Space Station. This facility will be used, together with other laboratory equipment and GSE, to prepare specimens and their containers for flight. Flight preparation requirements may include surgical procedures, depending on the FPE and specimens, and will verify interfaces of the specimens' containers with the duplicate Space Station biological equipment. Checkouts with the duplicate Space Station equipment will be prerequisite to installation of the specimens in the module at the launch pad.

Ground-control experiments will be conducted at the LSBL during orbit operations of the Group-F FPE subgroups. These experiments will use equipment which duplicates Space Station equipment as much as practical. Equipment and specimens that are returned from orbit will be delivered to the KSC Biological Laboratory for preservation, analysis, and disposal.

**Shuttle Launch Pad**

The Shuttle vehicle with the integrated module payload will be supported in preparation for launch at the launch pad. The ECLS systems that were serviced at the Shuttle orbiter maintenance area will be monitored to verify readiness of the equipment to receive and support living specimens.

The living specimens in their cages or containers will be transferred directly from the LSBL to the launch pad for installation. Installation will
include mechanical securing of the cages or containers, connection of EC/LS services, electrical connections, and restraining of specimens in launch position.

During the countdown, continuous support functions will be transferred from ground to module systems and critical functions will be monitored. Checkout sequences will be performed by the OCS at the launch pad only when part of critical functions. Completion of the countdown with a successful lift-off of the Shuttle will result in orbiting of the module for flight operations. Then, at the launch pad, postlaunch operations will be initiated to prepare for the next Shuttle launch.

A Shuttle abort on the launch pad will result in the requirement to implement corrective action to recover with minimum impact. Living specimens may be replaced, depending on the conditions they have experienced and the duration of recovery activities. An abort causing heavy damage may require substitution of a backup Shuttle or module, as well as refurbishment of the launch pad. If a backup module and experiments are required, they will require the functions shown in the Figure 29 flow at the LSBL, Operations and Checkout, FIT, and the Shuttle Orbiter maintenance area, similar to that performed for the flight article, followed by prelaunch and launch operations at the Shuttle launch pad.

Orbit
The orbiter with module and experiment equipment will be inserted into orbit for phasing with the Modular Space Station. Then the orbiter will rendezvous with the Space Station and the module will be separated and docked to the Space Station. A Logistics Module or experiment module that is ready for return will be loaded into the Shuttle. Orbit operations will proceed, and the Shuttle with module will de-orbit and land. Each Group-F module will be returned after completion of operations on a subsequent Shuttle flight. These orbital operations will be monitored at KSC as necessary to support the mission.
Shuttle Landing Site
The Shuttle with a module and Group-F experiment equipment and specimens will de-orbit and land at the KSC Shuttle landing strip. The module will provide all support services required by the FPEs until support equipment is connected after landing.

The module will then be off-loaded from the Shuttle, and the services required by the experiments will be provided at the landing site to preserve FPE equipment and specimens. These services will be required from the time of separation of the module from the Shuttle until experiments are removed to the LSBL.

The module will then be prepared for return to its processing facility for checkout preparatory to being loaded for a subsequent flight. The Shuttle, after removal of the module, will be secured for transfer to the Shuttle orbiter maintenance area to be prepared for the next flight.

Mission Operations Support
Mission Operations Support as described previously for Group-A FPEs includes monitoring, coordinating, and controlling ground operations for experiments and the modules throughout all mission phases.

2.3.4 Experiment Support Operations
KSC requirements to support experiments during flight operations consists primarily of monitoring to establish coordination for follow-on events.

2.3.4.1 Information Management
Selected data collected from orbital sources and certain real-time experiments data displays will be required at KSC for coordination with Principal Investigators. KSC will also coordinate the Principal Investigators support required to handle specimens being returned from orbit and to perform data analyses. Experiment requirements for communications, configuration...
control, telemetry, ground tracking data processing, subsystems status parameters processing, uplink data processing, and information presentation will be provided at KSC as required.

2.3.4.2 Mission Analysis and Planning
The experiment community will support the mission analysis functions of mission design, mission operations planning, and planning to support actual flight operations. Actual orbital data including trajectory, ephemeris, state vector, and other orbit dependent parameter inputs to planning for mission-mode changes that will be implemented to achieve desired results. These functions will be required throughout the ongoing mission to assure production of desired data from experiments. The overall function of mission planning and analysis for the space-station program is described in Subsection 2.5.2.2.

2.3.4.3 Logistics Operations Support
A central control of all logistics activities, including experiment and module requirements planning and scheduling, and real-time support for flight operations will be required at KSC for the Space Station program. The functions are described in Subsection 2.5.2.1.

The logistics support requirements for the experiment FPE's and subgroups are identified in the Experiment Requirements Summary for Module Space Station (the Green Book) and will not be repeated here. The FPE subgroups identified in the Green Book must be combined as shown in Table 2-7 for correlation to the designations used in this document.

2.3.5 Ground Operations Requirements Summary
Prelaunch and launch operations for experiments will normally be confined to the monitoring of certain critical parameters such as inert gas blankets on optical systems. Specific exceptions and associated launch site operational concepts are as follows:

- Space Biology Experiments
  The operational activities associated with the specimens for the space
biology experiments represent the major impact of the experiment program on the launch site. A biological laboratory must be provided for specimen storage, care, feeding, and flight preparation. As far as possible, it is desirable that this facility duplicate the orbital configuration. This similarity has the following inherent advantages:

A. It minimizes transients imposed on specimens in transition from one facility to another.
B. The ground unit can serve as a configuration-control article.
C. The ground facility can serve as the required one-g experiment control laboratory.

Because specimens are time-sensitive, they must be installed in their flight containers at the launch pad. Transportation at KSC will be within the flight cage or specimen container, serviced by a portable life support system. The life support system for the flight must be kept active at all times subsequent to installation of the specimens in the launch vehicle. Permanent accommodations for space-biology principal investigators will be required at the launch site.

Continuous Active Support Required
Four of the FPE detectors will require continuous active support. One of the detectors in both FPE A-1 (Grazing Incidence X-ray Telescope) and A-5B (Gamma Ray Telescope) must be kept at dry-ice temperatures when not operating and must operate at LN$_2$ temperatures. The crystals will be transported in dry ice and installed at KSC after activation and functional verification of the.
cryogenic loops. In addition, a continuous GN2 blanket will be maintained on the optical trains of many FPEs (See Table 2-7, Category II) to meet environmental requirements for cleanliness and humidity.

- Time-Sensitive Installations
  All films and emulsions will be received at the launch site and stored in a refrigerated and radiation-shielded vault. These items will be installed just prior to flight carrier/orbiter mate.

The impact of the Case 534G flight schedule on KSC for preflight operations is shown in Table 2-17. The postflight impact is shown in Table 2-18.

2.4 SYSTEMS SAFETY
A preliminary evaluation of the proposed Space Station project ground operations has identified a number of potential hazards that could occur at various locations. These hazards are listed in Table 2-19 for each applicable module (power, crew, GPL, logistics, and crew cargo) and location, MSOB, VAB low bay, VAB high bay, crawler–LUT combination, and pad–LUT combination). The hazards are segregated by type as follows:

A. Radiation—hazards due to the presence of radioactive materials.
B. Operational—hazards resulting from the performance of the operation as opposed to those inherent in the operation.
C. Escape Route—hazards which would not normally exist in unconfined spaces.
D. Fire—Self-explanatory
E. Explosive—self-explanatory
F. Environmental—hazards resulting from the local environment.

For each hazard identified in the table, there is also listed at least one method of control for eliminating it if possible, or reducing the effect of the hazard. In addition, each potential hazard has been classified in accordance with NASA Safety Program Directive Number 1, Revision A, dated 12 December 1969.
Analyses for the experiment and experiment module projects identified the following operations and/or commodities services for which systems safety requirements are a factor:

A. LN$_2$ servicing and loading.
B. Hydrazine propellant loading.
C. Argon, methane, Freon 12 servicing.
D. Neon, helium servicing.
E. LH$_2$ servicing and loading.

The applicable portions of System Safety Requirements for Manned Space Flight, Safety Program Directive 1—Revision A, dated December 12, 1969, will be followed for experiments and experiment modules. Experiment and experiment module contractors will conform to the provisions of Section 4, REQUIREMENTS, of this directive. KSC will implement the appropriate portions of Subsections 5.2, 5.3, 5.4, 5.5, and 5.6 of the directive.

2.5 MISSION SUPPORT OPERATIONS

Mission support operations, as exemplified by the mission management concept and requirements derived during the original 10-m (33 ft) Space Station Phase B study, are also applicable to the modular Space Station. The impact of these mission support operations, if they were all to be located at KSC, was determined during the KSC impact study supplement to the original Phase B study (Refer to DRL-160, Line Item 22, Analysis of Space Station Impact on KSC, Volume 1, dated December 1970). The operations will impact KSC similarly, should they all be located there for the modular station. However, it may be that some mission support functions will be performed at KSC, and some at other locations such as MSC. Therefore, part of the following discussion emphasizes how the mission support functions as defined by the earlier study efforts could be split logically between the Shuttle launch site and other locations if required.

2.5.1 Mission Support Operations Requirements

The 10-year continuous operation of the orbiting Space Station, the multiple project interfaces and the capability for continued resupply generated a requirement for a different form of mission management to that employed in
<table>
<thead>
<tr>
<th>KSC Facility Utilization - Preflight</th>
<th>Flight Plan 534G</th>
<th>Launch Schedule - Quarters</th>
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<tbody>
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<td>P-4A</td>
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<td>P-4C</td>
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<td></td>
<td>T-5C</td>
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<td>P-1B</td>
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Table 2-18
KSC FACILITY UTILIZATION—POSTFLIGHT

<table>
<thead>
<tr>
<th>KSC Facility</th>
<th>Flight Plan 534G</th>
<th>Return Schedule—Quarters</th>
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<tbody>
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<td>A- 4C 2B B A A A A A A</td>
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<tr>
<td></td>
<td>C</td>
<td>T- 4C 4B 4A 3C 5A 4C 5B 5C</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>T- 1A 2A 2A 2A 1E 1B 1C</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>MS- 3A 3B 3C 3D 3E</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>LS- 1B LS- 1C</td>
</tr>
</tbody>
</table>

149
<table>
<thead>
<tr>
<th>Hazard Type</th>
<th>Potential Hazards</th>
<th>Hazard Category</th>
<th>Applicable Module</th>
<th>Location</th>
<th>Hazard Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Radiation</td>
<td>None identified</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B. Operational</td>
<td>Non-flight equipment inside module at liftoff.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>A</td>
<td>Armed ordnance devices</td>
<td>C</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>B</td>
<td>Mating and demating electrical connectors without removing power.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>B</td>
<td>Incompatibility of SS/GSE functions crossing interface</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>B</td>
<td>Short circuiting electronic circuits, shock, during trouble-shooting of faulty electrical/electronic systems.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>A</td>
<td>Explosive vapor buildup.</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>O</td>
</tr>
</tbody>
</table>

KEY: X = Space Station Modules; O = Logistics or Crew Cargo Modules; - = No Hazard Identified
<table>
<thead>
<tr>
<th>Hazard Type</th>
<th>Potential Hazards</th>
<th>Hazard Category</th>
<th>Applicable Module</th>
<th>Location</th>
<th>Hazard Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Operational (Continued)</td>
<td>Pressure vessel and lines damaged due to impact of tools, overlength screws and bolts.</td>
<td>A</td>
<td>X X X O</td>
<td>X O X O</td>
<td>Individual personnel training and certification in proper use of tools; location of pressure vessels and lines.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Use of protective covers (GSE) during ground operations.</td>
</tr>
<tr>
<td></td>
<td>Critical Module Subsystems not operationally ready for flight.</td>
<td>B</td>
<td>X X X O</td>
<td>X O X O</td>
<td>Detailed procedural analysis before use.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Failure modes and effects analysis to determine potential ground failures which must be verified.</td>
</tr>
<tr>
<td></td>
<td>Failure of pressure vessels</td>
<td>A</td>
<td>X X X O</td>
<td>X O X O X O X O</td>
<td>Required that radiographic inspections be made after proof tests of pressure vessels.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pressurize to operating pressure on pad.</td>
</tr>
<tr>
<td></td>
<td>Overstressed module hardware (result of testing)</td>
<td>C</td>
<td>X X X O</td>
<td>X O X O</td>
<td>Perform safety review of test procedures and results.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Limit checks to nominal value in high bay, on pad.</td>
</tr>
<tr>
<td></td>
<td>Shift change during a continuing test or operation.</td>
<td>C</td>
<td>X X X O</td>
<td>X O X O</td>
<td>Training and certification of personnel to insure adequate exchange of technical data regarding test status, and results to point of changeover.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Schedule activities to avoid.</td>
</tr>
<tr>
<td></td>
<td>Uncalibrated pressure relief devices</td>
<td>A</td>
<td>X X X O</td>
<td>X O</td>
<td>Required that inspection be performed upon arrival at KSC.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Calibration if necessary before use.</td>
</tr>
</tbody>
</table>

KEY: X = Space Station Modules; O = Logistics or Crew Cargo Modules; = No Hazard Identified
<table>
<thead>
<tr>
<th>Hazard Type</th>
<th>Potential Hazards</th>
<th>Hazard Category</th>
<th>Power</th>
<th>Crew</th>
<th>GPL</th>
<th>Log M</th>
<th>C/CM</th>
<th>MSOB</th>
<th>Lo Bay</th>
<th>Hi Bay</th>
<th>Crawler/ LUT</th>
<th>PAD/ LUT</th>
<th>Hazard Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Operational</td>
<td>Working on live electrical equipment near pressure lines or tanks containing hazardous fluids, or high pressure gases.</td>
<td>A</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>-</td>
<td>Load hazardous fluids and pressurize to full pressure on pad.</td>
</tr>
<tr>
<td>(Continued)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Individual training and certification.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Safety review and inspection of operation.</td>
</tr>
<tr>
<td></td>
<td>Inadvertent actuation of panel switches and manual valves in module and on GSE during test.</td>
<td>B</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>-</td>
<td>Provide adequate guards and sufficient spacing between switch and valves to preclude inadvertent activation (Human Engineering and Safety Engineering of Panels).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Individual training and certification.</td>
</tr>
<tr>
<td></td>
<td>Entry of tools and small hardware items into confined sections of the module</td>
<td>C</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>-</td>
<td>Provide protective screens over openings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Individual training and certification.</td>
</tr>
<tr>
<td>C. Escape Route</td>
<td>Personnel trapped in closed compartment by fire or other hazard external to the compartment</td>
<td>B</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>-</td>
<td>Provide multiple escape routes from each deck of the Space Station during ground operations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Limit personnel allowed onboard.</td>
</tr>
<tr>
<td></td>
<td>Personnel onboard unaware of impending or existing hazard (fire, toxic atmosphere, etc.)</td>
<td>B</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>-</td>
<td>Provide warning system, verify it is operational before allowing personnel onboard for any length of time.</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Hazard Type</th>
<th>Potential Hazards</th>
<th>Hazard Category</th>
<th>Applicable Module</th>
<th>Location</th>
<th>Hazard Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. Escape Route</td>
<td>Personnel panic or improper action during emergency.</td>
<td>B</td>
<td>X</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>Closed and jammed hatches and docking ports.</td>
<td>B</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>D. Fire</td>
<td>Flammable material in module.</td>
<td>B</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Static discharge (spark).</td>
<td>B</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Overheating of wiring and other electronic components due to excessive current.</td>
<td>C</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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### Table 2-19
**POTENTIAL HAZARDS (Continued)**

<table>
<thead>
<tr>
<th>Hazard Type</th>
<th>Potential Hazards</th>
<th>Hazard Category</th>
<th>Applicable Module</th>
<th>Location</th>
<th>Hazard Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D. Fire</strong></td>
<td><strong>(Continued)</strong> Exposure of titanium to liquid or high pressure $O_2$</td>
<td>B</td>
<td>Power</td>
<td>Lo Bay</td>
<td>Design Space Station so that titanium pressure vessels are not used for containment of high pressure $O_2$. Design evaluation of location of titanium components; with respect to high pressure $O_2$ lines and vessels.</td>
</tr>
<tr>
<td></td>
<td>Other ignition sources in vicinity of propellant system vents, lines.</td>
<td>B</td>
<td>Crew GPL Log M C/CM</td>
<td>Hi Bay</td>
<td>Propellants allowed only on pad. Design evaluation of location of vents, lines. Leak check all hazardous fluid lines and vessels.</td>
</tr>
<tr>
<td><strong>E. Explosive</strong></td>
<td>RDX explosive trains for release mechanism operation.</td>
<td>A</td>
<td></td>
<td></td>
<td>Install ordnance rate in VAB operational sequence. Clear area of unnecessary personnel. Safety review and inspections of procedures and operations. Install initiators on pad. Design must include circuit protection. Proper procedures to prevent during ground test. Failure mode and effect analysis shall be performed on all ordnance circuitry. Design circuitry so that redundancy can be verified during ground test.</td>
</tr>
<tr>
<td></td>
<td>Short circuiting of power supplies after pyrotechnic device firing (or simulated firing during ground operations).</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Insufficient redundancy for pyrotechnic device initiation.</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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### Table 2-19

**POTENTIAL HAZARDS (Continued)**

<table>
<thead>
<tr>
<th>Hazard Type</th>
<th>Potential Hazards</th>
<th>Hazard Category</th>
<th>Applicable Module</th>
<th>Location</th>
<th>Hazard Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. Explosive</td>
<td>Pressurized lines and vessels rupture.</td>
<td>A</td>
<td>X X X O O</td>
<td>X O X O -</td>
<td>X O Insure design includes proper relief valves.</td>
</tr>
<tr>
<td></td>
<td>X O Safety review and inspections of procedures and operations to insure proper verification of relief valve operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limitation of personnel in area of pressurized lines and vessels.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressurize to operating pressures on pad.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F. Environmental</td>
<td>Exposure of sensitive equipment to moisture, corrosive liquids or vapors, shrapnel, etc.</td>
<td>A</td>
<td>X X X O O</td>
<td>- O X O X O X O</td>
<td>X O Evaluate equipment placement within the module to insure sensitive equipment is not located below (in the launch configuration) plumbing lines, cold plates, etc., and not protected from dripping, leakage, or condensed moisture.</td>
</tr>
<tr>
<td></td>
<td>Location of hazardous environment generating equipment and sensitive equipment in separated compartments.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Condition atmosphere.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X O Provide seals and covers.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control humidity and temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Positive pressure purge.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Design of modules is for 14.7 psia N₂-O₂ atmosphere.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provide emergency breathing equipment, or external ventilation when repair crew is onboard.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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the past. The Shuttle-supported Space Station program is compared to the expendable booster—single mission payloads referenced in Table 2-20.

Mission management for the Space Station must address the areas of orbital and support operations. Before developing these functions within the Space Station Program, the relationship to other projects/programs and NASA functions must be established. Figure 2-30 identifies the overall relationship of the Space Station to the mission management of other programs, the directive relationship to program management and the influence of program hardware development on the operations functions. As indicated, the scientific program interfaces directly with program management and for experiments which are established to be flown with the Space Station or the Shuttle, the relationship is then established at a working level within mission management to implement the requirements.

Table 2-20
COMPARISON OF SPACE STATION TO EXPENDABLE BOOSTER PROGRAMS

<table>
<thead>
<tr>
<th>Space Station</th>
<th>Expendable Booster Payloads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple projects over long mission—multiple support and multi-payload capability.</td>
<td>Minimal inter-project involvement after booster separation, i.e., independent payload.</td>
</tr>
<tr>
<td>Continuing resupply</td>
<td>No resupply.</td>
</tr>
<tr>
<td>Dynamic planning of missions, resupply, schedule, interfaces.</td>
<td>Essentially preplanned single missions</td>
</tr>
<tr>
<td>High autonomy on-orbit with smaller ground crew in-flight operations.</td>
<td>Minimal to no autonomy in orbit.</td>
</tr>
<tr>
<td>Assembly in-orbit of initial and subsequent hardware.</td>
<td>Launched as integral functional unit.</td>
</tr>
<tr>
<td>Integration of new hardware and repair on orbit.</td>
<td>No resupply.</td>
</tr>
</tbody>
</table>
Figure 2-30. Support Elements of an Integrated Scientific Orbital Program
As indicated in Figure 2-31, the scientific programs are independent of the support elements shown on the right. The Space Station supports only a part of the scientific payloads. The common denominator is the ground network which will provide and process all data for the scientific program management and provide mission data to the support agencies. Integrated scientific orbital program management does not exist as shown, but does consist of the functional elements illustrated. Mission management, then, must support the appropriate scientific payloads.

Space Station mission management must provide for mission planning, logistics resupply, and orbital operations support. The latter must recognize the support for the Space Station itself as well as the support of the scientific payloads.

2.5.2 Mission Support Operations Concept

As shown earlier, Space Station program is unique with respect to current manned space flight program. It must operate as an orbiting operational...
facility (as opposed to an R&D program) that is both economical and convenient to use by the scientific community, commercial enterprise, and anyone else who might need to perform activities in an orbital environment. It must provide this operational facility for 10 years. Obviously, the 10-year operations cannot be predicted accurately to any depth in advance; shifting emphasis in National goals, new techniques, scientific breakthroughs (perhaps brought about by the experiments on board the station), and new equipment that may become available will result in a dynamic program characterized by change. Therefore, an overall mission management concept is required that will integrate all Space Station mission support operations in a manner responsive to any program changes that may develop during the 10 year program.

There are three separate activities associated with management of the operational Space Station program. The first is coordination with user agencies, the second is development of new program elements, and the third is conduct and support of the active program. Orderly accomplishment of these activities requires an overall Space Station Program management structure whose job will be to plan and control the future directions of the program. The first two are the responsibility of NASA program management. It is the third activity, however, has significant potential impact on KSC, and is the subject of the following discussion on Space Station mission management.

As shown in Figure 2-32, the task of managing the active conduct of the program will consist of ground operations support, and performance of the on-orbit activities. Ground operations support is subdivided further into; (1) Logistics Operations Support, (2) Mission Analysis and Planning, (3) Flight Operations Support, and (4) Experiment Operations Support. A summary of the requirements for these four ground support functions is given in Table 2-21.

2.5.2.1 Logistics Operations Support
Logistics operations support includes inventory management to insure that all crew, materials, and supplies required are delivered to the Space Station
Figure 2-32. Space Station Mission Management Operational Functions
<table>
<thead>
<tr>
<th>Ground Support Functions Category</th>
<th>Support Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight operations support</td>
<td>Mission coordination</td>
</tr>
<tr>
<td></td>
<td>Monitor and control of space station (unmanned phases)</td>
</tr>
<tr>
<td></td>
<td>Cognizance of space systems status</td>
</tr>
<tr>
<td></td>
<td>Central point for flight crew/ground contact</td>
</tr>
<tr>
<td></td>
<td>Ground management for acquiring systems and trajectory specialists support</td>
</tr>
<tr>
<td></td>
<td>Long-term space systems parameter trends analysis</td>
</tr>
<tr>
<td></td>
<td>Data and information uplink transmission management</td>
</tr>
<tr>
<td></td>
<td>Communication configuration control</td>
</tr>
<tr>
<td></td>
<td>Trajectory support</td>
</tr>
<tr>
<td></td>
<td>Operations data processing control</td>
</tr>
<tr>
<td></td>
<td>Simulation</td>
</tr>
<tr>
<td></td>
<td>Crew training</td>
</tr>
<tr>
<td></td>
<td>Space Station flight control personnel</td>
</tr>
<tr>
<td></td>
<td>Space Station ground experiments control personnel</td>
</tr>
<tr>
<td></td>
<td>Flight operations support personnel</td>
</tr>
<tr>
<td></td>
<td>Personnel onboard orbiting Space Station</td>
</tr>
<tr>
<td></td>
<td>Operations data processing control</td>
</tr>
<tr>
<td></td>
<td>Flight support software</td>
</tr>
<tr>
<td></td>
<td>Space Station flight software verification</td>
</tr>
<tr>
<td>Ground Support Functions Category</td>
<td>Support Requirements</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Experiment operations support</td>
<td>Experiment operations</td>
</tr>
<tr>
<td></td>
<td>Quality checking of experiments data</td>
</tr>
<tr>
<td></td>
<td>Time tagging of experiments data</td>
</tr>
<tr>
<td></td>
<td>Merging of SS status and dynamics data</td>
</tr>
<tr>
<td></td>
<td>Calibration of data</td>
</tr>
<tr>
<td></td>
<td>Sorting of FPE and user</td>
</tr>
<tr>
<td></td>
<td>Experiments data analysis processing</td>
</tr>
<tr>
<td></td>
<td>Data reconstruction</td>
</tr>
<tr>
<td></td>
<td>Image enhancement</td>
</tr>
<tr>
<td></td>
<td>Real-time program modification</td>
</tr>
<tr>
<td></td>
<td>Batch processing</td>
</tr>
<tr>
<td></td>
<td>Experiments data base management</td>
</tr>
<tr>
<td></td>
<td>Storage</td>
</tr>
<tr>
<td></td>
<td>Retrieval</td>
</tr>
<tr>
<td></td>
<td>Maintenance</td>
</tr>
<tr>
<td></td>
<td>Display processing for ground P.I.'s</td>
</tr>
<tr>
<td></td>
<td>Command and display request processing</td>
</tr>
<tr>
<td></td>
<td>Correlation of physical data</td>
</tr>
<tr>
<td>Mission analysis and planning support</td>
<td>Mission design</td>
</tr>
<tr>
<td></td>
<td>Mission operations planning</td>
</tr>
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<td>Flight planning</td>
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<td>Resource utilization planning</td>
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<td>Trajectory analysis</td>
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<td>Ground Support Functions Category</td>
<td>Support Requirements</td>
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<td>Mission analysis and planning support (Cont)</td>
<td>Crew rotation scheduling</td>
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<td>Training planning</td>
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<td>Experiments integration and utilization planning</td>
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<td>Logistics support functions</td>
<td>Support on-orbit inventory control</td>
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<td>Support return cargo mass control</td>
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<td>Spares and supplies procurement</td>
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<td>New major hardware procurement coordination</td>
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<td>Transportation</td>
<td>Maintain configuration control</td>
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<td>GSE and ground facility maintenance</td>
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<td>Cargo/ALS compatibility responsibility</td>
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<td>Inventory management and control</td>
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<td>Preflight testing/certification</td>
<td>Maintain mockups/FIT</td>
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<tr>
<td>Interface control</td>
<td>Preflight hardware integration</td>
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<td>Return cargo disposition</td>
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at the proper time and in the proper quantity so that all missions can be conducted at maximum capability to provide disposition of all returned cargo as shown in Figure 2-33. The logistics support operations will provide configuration management so that there will always be knowledge, on the ground, of what the exact orbital configuration is, including experiment hardware.
The logistics operations also will perform the more classical logistics functions of cargo handling, packaging, procurement, and transportation. Space Station hardware will be procured by this function where, in the case of experiment hardware, coordination with their procuring agency is required to assure program hardware and software compatibility. Another function of logistics is testing, particularly testing or certification of new equipment to assure that it will fit and that it will function properly. In the case of experiment hardware, adequate certification of testing for compatibility is required.

Spares refurbishment of Space Station hardware will be provided as required. The experiment hardware will be refurbished separately, but the configuration and compatibility with other Space Station hardware must be verified. All hardware to be flown with the Space Station is subject to interface control. Verification will be by preflight hardware integration on the FIT.
of returned cargo for all orbiting elements will be accomplished by Logistics Operations Support. Hard data, returned spares, waste, etc., must all be accounted for before dissemination. The total accountability of these returned items is key to successful inventory control and accounting. The Logistics Module refurbishment, loading, and launch operation fails entirely in this function. As items under configuration control and hardware integration, both the mockups and flight integration tool are under the control of logistics operations support. A description of the mission support functions of the FIT are contained in Subsection 2.1.2.2.

Centralized logistics control is a management function performed in parallel with flight operations support, mission planning, and analysis, and experiment operations support. As shown in Figure 2-34, it will consist of inventory control, materiel, maintenance, transportation, configuration control, and personnel management subelements. Included are any hardware that interfaces physically with the Space Station. Each of these subelements is
charged with management and control of its particular activities and for integration and interfacing with other technologies within and external to the logistics structure.

Elements and tasks which collectively fulfill the complete logistic obligation for the Space Station support are identified further under several functional disciplines: provisioning of spares, source coding, technical orders, high-value time identification and control, hardware and software improvement, packaging, preservation, warehousing, inspection, skill requirements, and training and associated curriculum and equipment.

Inventory Control

Continuation of Space Station operations from phase to phase and year to year will depend largely on the logistics network providing the correct quantity and mix of resupplies. To achieve maximum operational efficiency of the Space Station and transfer operations from crew to crew, it will be imperative that precise information be known as to the amount and type of spares, expendables, and consumables onboard the Space Station and what additional logistics payload is required to continue operations for the next mission phase. The success of these goals will depend on the ability of the crew, together with supporting ground operations, to maintain and track the utilization of spares; and of the ground crew, in coordination with experiment operations, to identify adequately the resupply requirements for new equipment scheduled for the next mission phase. This operation will be necessary, because the limited storage space onboard the Space Station will not permit large inventories to backup operations. The procedure used to keep track of orbital inventory are shown in Table 2-22.

Table 2-22

<table>
<thead>
<tr>
<th>INVENTORY CONTROL</th>
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<tr>
<td>Ground record of Space Station/IF configuration</td>
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<tr>
<td>Ground record of Space Station inventory sent to orbit and returned</td>
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<tr>
<td>On-orbit receipt of inventory</td>
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<tr>
<td>Ground comparison of inventory sent with orbit inventory</td>
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<tr>
<td>Attention given to exceptions</td>
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<tr>
<td>Ground record of materiel ordered and backup inventory</td>
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173
Inventory control will be responsible for tracking the Space Station utilization of consumables and expendables and providing resupplies necessary for continuous operations. Inherent in this responsibility is a close interrelation with other program elements—Shuttle and Experiments—and the command, communications, and data functions. Effective control will depend on timely and accurate knowledge of Space Station use rates and stores inventory.

The inventory function will commence with initial provisioning of the Space Station and the first logistics flight. This provisioning will be based on estimates of crew consumption, use of expendables, and experiment activity. The estimates will be updated periodically, based on actual consumption rates for use in determining future provisioning requirements. The system will be structured around a ground-based control center which receives the use date from the Space Station. These data will be processed automatically to yield next resupply flight cargo mix and procurement information. Special computer programs will allow immediate analysis of use trends and of certain items carried in inventory, both on orbit and on the ground.

The inventory control system will be designed and mechanized to reduce flight crew responsibilities to the lowest level practicable. Occasional regularly scheduled inventory checks to verify proper operation of the system and weekly utilization and consumption reports will be the maximum requirements for flight crew participation. The flight crew will transmit utilization and consumption rates by voice communications or data link. The flight crew will keep track of utilization and consumption through data cards attached to the particular hard cargo items. These cards will be collected as each item is utilized or consumed and the data processed weekly. Fluid reserves will be determined by reading quantitative instruments and the information transmitted the same as hard cargo utilization and consumption.

Because there is a requirement to maintain a minimum level of supplies on board the Space Station, certain items might not be used for long periods of time, thus an accumulation of aged items is created. To prevent this, the policy will be to use first those items which have been in storage on the
Space Station the longest. Proper storage of supplies will enhance this first-in first-out (FIFO) use and consumption policy.

The resupply mix will be established through evaluation of priorities versus cargo-carrying capability and Space Station storage capability. The life and mission-sustaining reserves will not be allowed to drop below a six man-year minimum. To minimize the number of resupply flights and cost per pound of cargo transferred to-orbit, logistics vehicles will be loaded with the maximum cargo consistent with the Space Station storage capability.

Material
Procurement of Space Station resupplies will be one of the major functions of the logistic process. Plans conceived originally and estimates of resupplies will have to be very accurate to preclude shortages or overstocks. Some long-lead ordering will be accomplished prior to the Space Station being placed on-orbit. Sufficient spares will be kept in inventory to allow contingency resupply before their normally scheduled preventive maintenance cycle. Procurement of items of this nature will consider premature failure contingencies; later, they will be influenced by actual case histories. Lead time for procuring resupply items will be the aggregate time from when they are loaded on the logistics vehicle back through preparation for shipment, transportation, manufacture, production, test, design (if necessary), to procurement contract negotiation. Experiment hardware including spares is procured via a separate agency; however, the Space Station logistics function must coordinate configuration, schedule, testing, etc. to assure compatibility with the orbiting Space Station.

Space Station resupplies will undergo special sorting, batching, and packaging for ready adaptation to the needs of the on-orbit environment. Test loading the aggregate cargo in a simulated logistics module and through simulated docking ports into areas simulating the Space Station will verify proper sizing of containers and ability to be handled satisfactorily.

Extensive ground operations in support of the Space Station Program will necessitate traditional terrestrial supply activities also. Functions
performed by terrestrial supply will include material identification, material selection and procurement, refurbishment and spares control, stock control, high-value control, documentation, publications, and the necessary warehousing, preservation, packaging, and packing. Terrestrial supply will be managed through the materiel subelement of Space Station logistics. Although Space Station resupply activities are required to use the same functional techniques for materials acquisition and control, management will be maintained through the Inventory Control Subelement because of the critical orbital interface.

Maintenance
Maintenance control will be established as a management subelement directly under logistics management. Maintenance control's responsibility will include scheduling preventive maintenance, tracking of failures and trends, planning, and supporting maintenance activities.

Ground support maintenance will include preventive and corrective maintenance performed on grounded vehicular equipment, GSE, and facilities. Spares will be carried in inventory for periodic maintenance and to allow for failures and breakdowns. Ground support maintenance assumes greatest importance during launch activities and as associated with items in direct support of the orbiting Space Station.

Transportation
Space Station Program transportation will be responsible for identifying and providing for transportation and shipping needs. Major Space Station Program elements require special handling, equipment, and means of transportation. It will plan, coordinate, and perform the ground movement of materiel and personnel; perform the ground movement of materiel and personnel; and perform Logistics Module (and Crew Cargo Module) cargo handling, loading and unloading operations. GSE and other hardware and software will utilize standard techniques and methods of transportation.

Configuration Control
Configuration control will track, supervise, and establish the Space Station hardware and software configuration at any given point in time during the
operational program. Space Station subsystem and experiment hardware will change configuration throughout the 10-year mission as a function of:

A. Subsystem design changes to improve performance and reliability.
B. New or modified subsystems to incorporate new technology or an advanced state-of-the-art design.
C. New or modified subsystems to maintain compatibility with new experiment subsystems and hardware.
D. Failure of Space Station or experiment hardware requiring a change in hardware configuration (wiring, plumbing, etc.) to continue operations.

Long-range mission planning may include the installation of modification kits during certain phases as a result of one or more of the functions discussed above. Serialization of orbital equipment will be maintained and all changes are tracked as a result of periodic maintenance reports from the flight crew.

Individual specifications for the Space Station, experiments, and experiment modules will establish the baseline for control of future changes in system performance and design. These specifications will be prepared by contractors and approved formally by the procuring agency. The specifications will state the performance, design, interface, and acceptance-test requirements in quantitative and measurable physical terms.

Each specification item will be identified for configuration management by the use of standard configuration identification numbers. These numbers will be implemented at the time the product configuration baseline is approved. All subsequent changes to the specification item will change the configuration identification numbers. The configuration identification numbers will be attached to the product produced.

A condition requiring change coordination and control may arise when an equipment change is proposed to a module or experiment which is in orbit. If the change is approved, it will first be installed and verified on the flight integration tool. The steps of configuration management to assure compatible
hardware is delivered to orbit are illustrated in Table 2-23. The mission planning and analysis function will be advised of the time span required to make the change, the recommended experiment time phase in which to implement the change, and the earliest Shuttle flight which could deliver the mod kit to the Space Station. From this information, the appropriate 90-day mission plan will contain a work schedule for installing the change.

Table 2-23
CONFIGURATION MANAGEMENT

- Ground record of Space Station configuration at launch
- Integration Fixture maintained to orbital configuration
- Changes/new hardware authorized by MM change board
- Change made to Integration Fixture
- Change verified on Integration Fixture
- New hardware logged to orbit
- Space Station records received hardware, makes change
- New configuration logged for Integration Fixture/Space Station
- Ground comparison of Integration Fixture/Space Station configurations
- Integration Fixture/Space Station parts returned used to verify changes made

**Personnel**
Personnel management within logistics will be responsible for recruiting and accommodating flight crew personnel. Also included in this responsibility are the specialized ground support personnel who are involved in launch and orbital sustaining operations.

2.5.2.2 Mission Analysis and Planning
Mission planning will involve all planning, working documentation, and procedures required to support the total program including operations, ground,
and vehicle resource utilization, simulation, logistical functions and the experiment program. These planning functions will begin at the mission-design level and continue until the mission is terminated; they will involve development of and modifications to mission rules and constraints, hardware, and software. As data are collected, the performance of the crew, system hardware, and experiments will be evaluated continuously to verify that program goals and objectives are being satisfied. Real-time reprogramming of the experiment activities will be performed by the appropriate principal investigator but will be coordinated with mission planning.

Manned missions accomplished to date (Mercury, Gemini, and Apollo) have consisted of relatively small, discrete periods of time in which the crew, flight vehicles, and ground support elements performed activities to satisfy specific predetermined objectives. Each event in the conduct of the mission, as well as all foreseen contingencies, was planned well ahead of the actual flight operations. Even with such detail in planning, real-time contingencies were encountered which resulted in unforeseen changes to the mission plan. Space Station planning must depart from the past planning approach because of the relative long and flexible mission. The approach followed for Space Station mission analysis and planning will be split into two levels. First, there will be a 10-year plan which will generally structure the total Space Station mission. This 10-year plan will be broken down into 90-day segments, each one of which, for planning purposes, will be considered a separate mission. The 90-day plan, comprising the second level, will establish what the objectives for that mission are and what has to be done to accomplish these objectives. The on-orbit crew, as a result of their high degree of autonomy, will not be working to predetermined timelines but to this mission plan, which will provide them with general requirements for conduct of the mission from which they will develop their own timelines every 24 to 48 hours. The crew will also perform maintenance functions (such as checkout and repair) as required and will participate in overall inventory control. Automated techniques will be used to the maximum cost effectiveness, through use of computerized mission planning models. If required, these models will be adaptable for use in on-line or real-time planning functions in support of the overall program.
Mission Design

Mission design will commence with the development of requirements to conduct a mission. Objectives will be stated, candidate vehicles selected, crew complement (mix) determined, and general mission guidelines established. The iterative process of comparing mission objectives to the constraints and guidelines will result in the modification of objectives and the revision of constraints. Analyses will be performed to establish priorities of objectives; determine the validity of the constraints related to flight systems, crew, and mission and ground support elements; and determine mission schedule feasibility. The results of this analysis and planning will constitute a preliminary reference mission design from which mission operations planning will be able to proceed.

Mission Operations Planning

The planning and analysis functions required to effect an optimum mission will involve the task of integrating all mission elements into an operational mission with the greatest probability of success to accomplish the established objectives. The major task, essentially, will be that of optimizing the use of the total mission resource including the flight systems, crew, and ground support element. The following major detail plans, which must be developed prior to flight, will be monitored continuously to assure timely implementation and current applicability of the mission operations plan:

A. Hardware and software development and acquisition plan (as applicable)
B. Mission activity timeline
C. Alternative (contingency) mission operations plan (as applicable).
D. Mission operations priority plan.
E. Crew flight plan (involves task simulations and crew/systems integration planning).
F. Ground support operations plan.
G. Training and simulations plan:
   1. Crew
   2. Ground personnel
   3. Systems test
Mission Planning During Flight Operations

Planning functions will be accomplished during mission operations and will provide the means for modification or revisions to the plans developed before the next mission. These changes would be a result of near real-time assessment by the crew and ground of the mission status and would include the following major planning tasks:

A. Resource utilization planning:
   1. Crew and flight systems
   2. Ground support elements (personnel, equipment, and facilities).
   3. Communications and tracking plans.

B. Trajectory:
   1. Rendezvous planning for logistics vehicles and unmanned modes.
   2. Planning for emergency return and recovery operations.

C. Assessment of objective priorities and alternative plans development and planning for integration of new experiment elements into mission operations.

The tasks noted above will require a coordinated, on-line effort between the onboard personnel (operations and experimenters) and their ground-support counterparts. To effect the autonomy goals of Space Station operations, many of the above tasks must be accomplished by the onboard crew. For example, a real-time modification of the flight plan decision must lie with the Space Station commander (within major mission rules); however, the long-range assessment of the impacts of this modification could best be accomplished by the ground element and its resources.

2.5.2.3 Flight Operations Support

During the orbit operations phase Flight Operations Support will perform what has in the past been called the mission control functions: support on-board status monitor and fault isolation and analysis. The Space Station flight crew will be utilized in the flight and experiment operations support areas as shown in Figure 2-35. Flight Operations will also coordinate all systems status and trend data for crew training, simulation, and other activities associated with preparation for flight operations. Figure 2-36 illustrates
Figure 2-35. Crew Utilization and Training

Figure 2-36. Space Station Integrated Data Support System
the manner in which various supporting functions (depending upon the nature and final location of the appropriate resource) are related and how they will interact with each other and the Space Station.

Flight operations will have the primary goal of maximizing use of mission resources. This function will begin during the prelaunch phase and continue throughout the life of the Space Station Program. However, the duties performed and the number of personnel required vary according to mission phase. During the prelaunch and launch phases the primary duties will be to support systems integration and flight readiness testing, verify status of that portion of the tracking capability which has been called up to support the mission, verify the capability of the communications system to support the mission, and participate in the generation of launch and flight mission rules and procedures. It will provide a means of analyzing long-term performance trends and Space Station trajectory data. This will require acquisition, logging, storing, and retrieving of Space Station systems data. Space Station and Shuttle trajectory data will be analyzed periodically for degradation of onboard guidance system parameters. Tracking parameters, computed by the ground tracking systems, will be compared with those generated by the onboard guidance systems to evaluate and verify the performance of the onboard guidance and navigation equipment.

Early Orbit Operations
From lift-off through early orbit, the flight operations personnel will perform limited flight control duties. The mission director and his staff will run the mission during buildup operations and until the first operational flight crew boards the Space Station and has it fully operational. During the powered flight and early orbit phases, trajectories will be monitored to verify that the Space Station achieves the desired orbit. Range safety will be controlled by DOD; however, the mission director may support an abort if his personnel indicate that such an action is imminent. After initial manning, the flight operations personnel will revert to a low activity level and after the first year only periodic ephemeris updates will be prepared for comparison with onboard data. Subsystem status will be monitored for long-term trend analysis and consumables management.
Flight Operations

Space Station flight operations support will provide capabilities for communications configuration control, telemetry, and ground tracking data processing; Space Station systems status parameters processing; receipt, storage, and routing of data; uplink data processing; and information presentation required by the various mission operations support groups. It will accept inputs from the mission operations support groups in form of display information requests, systems configuration control commands, and space vehicle uplink data. It will also provide for the storage and analysis for scientific data generated by experiments. The storage and data reduction capability will allow online analysis of select data by principal investigators or their representatives. Computations which require a large amount of storage and/or processing are performed by the experiments data systems.

Experiments systems data will be received in raw and/or status form for analysis by experiment specialists for predicting long-term systems' health. Support of integration of newly developed experiment systems into the Space Station will be provided. This effort involves support of checkout and testing of new hardware and software items prior to flight and during on-orbit installation.

A prime operational function accomplished by the ground systems operations is effective control of communications. This control is required to adequately support the wide range of Space Station Program mission objectives as illustrated by the following functions for control of the communications network.

During powered flight, all flight telemetry data can be recorded in real-time at the ground network and sent to all interested parties for delayed, post-flight evaluation. The location of this function at the launch site and the deletion of a real-time evaluation requirement leads to great cost savings through elimination of the HOSC at MSFC, the MOCR at MSC, and the ALDS wide-band data system.
Ascent tracking and insertion verification can be performed by the two USB tracking sites at KSC (MLA) and Bermuda (BDA). During the first year of the mission, it will be necessary to perform ground tracking to provide daily ephemeris updating to the onboard guidance and navigation system to verify its capability for future autonomy, as well as to track the orbiting modules when unmanned during Space Station buildup.

In the event of contingency situations, the flight operations support personnel will serve as consultants to the flight crew and assist them in fault isolation and maintenance tasks. They will also contact individual experts to bring their knowledge to bear.

Simulation and Training
The simulation requirements, plans, and programs will be developed for flight simulation and part-task trainers by this element of the flight support effort. All simulation and training for both flight crews and ground personnel will be performed utilizing ground simulation equipment. This equipment together with the appropriate procedures and training manuals will provide a man-to-machine interface to train future Space Station controllers or to retrain flight crews prior to rotation, provide a capability to integrate and test new hardware and software, and generate and control simulation data for training, test, and checkout. Simulation control consoles will be used to monitor and control the individual computer and display and control (D/C) systems provided to train personnel. These consoles will contain displays of the status of replica consoles and special control displays to evaluate simulated systems performance and vehicle trajectory.

2.5.2.4 Experiment Operations Support
The fourth function of mission management is experiment operations support; the prime function here is to plan experiments, establish their procedures, and provide the capability for principal investigators to participate (on the ground) in real-time activities of their experiment while it is in orbit.
The experiment operations will provide the bulk of the requirements for storage and analysis of data which will be downlinked by the Space Station-to-ground communication link. Reception and storage of these data will be a nearly continuous real-time function. Ground-based computers will store and reduce data to allow real-time analysis of it by principal investigators. Computations which require a large amount of storage or processing time will be performed by the experiments data systems. The magnitude of the ground data management function at maximum capacity is illustrated in Figure 2-37.

The experiments data systems will receive experiment systems data in raw and status form which will be analyzed by experiment module specialists to predict long-term failures. Ground support of experiment modules may be more critical than Space Station systems data because of the developmental nature of the experiment modules.

Figure 2-37. Postlaunch Data Processing
A continuing effort of the ground support system will be to provide development of new experiment systems and provide for the integration of these systems into the Space Station systems. This effort will involve support of checkout and testing of new hardware and software items. Transportation of these modifications to the Space Station will be provided by logistics vehicles and Space Station and ground communications link. Experiment operations will coordinate with both mission planning and logistics to assure timely delivery and accommodation of new experiment hardware and software.

The experiment support system will require facilities and equipment necessary to provide experiment operational support and data collection; real-time experiments data pre-processing, storage, and distribution; experiments monitoring, planning and coordination; and experiments data analysis. These experiment support activities will require support subsystems configured as shown in Figure 2-38.

The Experiments Support Display and Control Consoles will provide experiment principal investigators and their teams with monitor and control capability via console-mounted, CRT-type displays and flexible entry devices. This system will provide for the retrieval of experiments data and operational data pertinent to the experiments support requirements and will provide update initiation for experiments control as required. Additional display terminals at remote locations will provide remoted principal investigators with access experiments data received and processed by the data systems.

The real-time experiments data downlinked from the Space Station, together with Space Station and FPE status data, will be input to the communication processor (CP) via the Communications Interface Equipment. The CP will perform standard pre-processing of this data including quality checking, time tagging, merging of required status data (including space station state vector), and calibration.

The Mission Operations Computer Complex (MOCC) will receive selected experiment data from the communications processor and inputs from the experiment controllers in a control room. The MOCC will perform display processing for on-line experiment controllers, scientific data processing, and experiment housekeeping data processing as requested to assess the quality
Figure 2-38. Space Station Experiment Support Configuration
of the experiment data, to ascertain the status of the experiments module, and to assist in on-line planning and coordination with the onboard experimenters. Processing for real-time monitoring and command and control will be required for detached free-flying astronomy FPE's. The MOCC will also provide the computational support required to manage the Experiments Data Base, where real-time experiment data is logged. At times, a high-rate experiments data (viz, imagery data) will be routed directly from the Communications Interface Equipment to special equipment in the Experiments Support Display and Control Subsystem where it will be hard-copied or displayed for quick-look analysis.

2.5.3 Mission Operations Support Differentiation
Ground functions in support of modular Space Station mission operations, as summarized in the preceding subsections (2.5.1 and 2.5.2), are essentially the same as those developed for the 10-m (33-ft) Space Station. It was assumed that all mission support operations would be accomplished at KSC and would be centered around a Mission Operations Support Complex (MOSC) located at KSC. The MOSC will perform the real-time integration of flight support; mission analysis and planning; logistics management and control; experiment functions; and interfacing with the Shuttle, the Manned Space Flight Network (MSFN) and Data Relay Satellite System (DRSS). The functions of the MOSC will be located in the MSOB and CIF as shown in Figure 2-39, and in other KSC facilities as shown in Figure 2-40.
Figure 2-39. Mission Operations Support Center Configuration Concept at KSC
However, it may be necessary to separate the functions and disperse them to various locations other than KSC (in violation of the basic assumption stated above in order to achieve an early viable program). For example, during the buildup operations the activities are closer to those performed on the Apollo and with unmanned payloads. After the Space Station is operational, the phasing of the operations to the shuttle launch site could be considered for long-term manned operations. Not all functions are separable; therefore, it is necessary to examine the interfaces and interrelationships between functions to define logical separation planes.
The interrelationships between the functions shown in Figure 2-41 were developed in previous studies of long-term ground support (33' Space Station) as directed to assume location of the functions at KSC to clarify, explain, and assist the assignment of ground functions to existing facilities at KSC. The blocks shown in Figure 2-41 represent packages of activity having distinct characteristics which set them apart from other functions. Activities to be performed within a particular block have common requirements, tasks, and goals, and the interconnecting lines indicate inputs and outputs or interfaces. These interfaces differ in complexity and function, and though they do not represent all interfaces between the functions, they do represent the most prominent. For example, all the functions have communication interfaces with others. In some cases, the interface will be quite complex while in others, it may be merely the exchange of general information through telephone conversations.

Functional distinctness of the blocks permits grouping or separating in common or remote physical locations with least impact on cost, safety and performance of ground operations. Note that the functions are not all on the same level of authority or responsibility. Some are subordinate to others in terms of control (i.e., Inventory Control is under the overall direction of Mission Operations Support, considering the Mission-Management concept). However, characteristics of the functions define distinct entities between which natural separation planes can be established. Thus, the resulting vertical or horizontal interfaces between the functions are kept as simple as possible.
Figure 2-41. 10-Meter-Dia Space Station – Sustaining Ground Operations Functional Interrelationships (PVM Operation)
The logic used to locate functions in facilities at KSC can be used to analyze the effect of location of the same functions at some other site. Because the functions have not nor will not change significantly, any impact of relocating the functions is most certain to be felt in the area of the more complex interfaces. Although it was recognized during the 10-m (33-ft) dia Space Station study that interface complexities might vary with changes in separation between the ground support elements, it was not necessary to delve deeply into the subject because all the elements were baselined to be located at KSC. Now, however, it is important to evaluate the effect of separation to provide the visibility necessary; in turn, this will permit optimization of element division and separation more fully suiting the needs of the Space Station Program.

A revision of Figure 2-41 to reflect the ground support functions necessary for the Modular Space Station Program is shown in Figure 2-42. The main difference between the two ground support schemes is that some of the functions have had their designations changed to reflect slight program differences. Instead of a Project Verification Model (PVM), there is now a Flight Integration Tool (FIT), and a Logistics Module (Log M) will be used during the Interim Initial Space Station (ISS) phases of the program instead of a CCM. A simplified version of a CCM will be used during GSS mission phases.

The following is a discussion of the more complex functional interfaces and the impact resulting from various degrees of separation between the functions identified in Figure 2-42. Communications interfaces are only identified or discussed where they are unique or extensive. The interfaces are discussed in the order of identification shown in Figure 2-42.

2.5.3.1 Flight Crew—Transportation From Accommodations Area to the Shuttle Launch Site

This interface involves movement of flight-ready crew personnel and their personal effects between the Crew Accommodations Area and the Shuttle launch site. The interface could be considered as a periodic short-term involvement, requiring only a means for transporting crew members and their gear to the Shuttle launch site on the day of launch or returning them...
to the Crew Accommodations Area after Shuttle return. A contingency case also exists where the crew members might have to be returned to the accommodations area in event of an extensive launch hold or postponement. New factors affecting this interface include:

A. Fewer Crew Members per Shuttle Flight—Flight activities for the ISS, a span of about five years, call for a maximum of only six personnel on-orbit at any single time. Additionally, because the flight crew will be transported to the Space Station in the orbiter having a passenger capacity of two personnel, a maximum of only two station crew members will be subjected to flight preparations at any one time. A maximum of 12 personnel will be required on-orbit with a maximum of six being transported on an adapted CCM each rotation flight upon buildup to the GSS phase.

What this means operationally is that the interface (as well as the crew accommodations function) will have to consider the transportation of only two crew members at a time for about five years of the program and six crew members at a time for the remainder, as opposed to the earlier program which called for a full 12-man crew rotation on 90-day centers for 10 years.

It will be much easier to arrange the critical countdown transportation for two to six personnel than for 12 personnel. Where, on the 10-m (33-ft) dia program, there was concern for precisely moving 12 crewmen in isolation from the MSOB (the crew accommodations location) to the launch pad by a bus or transporter, it may now be more feasible to transport the two to six crewmen from a more distant accommodations area with the same preciseness through means of aircraft—either conventional or helicopter. Factors which increase the feasibility of the latter are less change for delays which would impact launch countdown (the more personnel, the more delays...
due to physical problems and equipment malfunctions); and greater feasibility for long-distance transportation adaptation (use of a smaller craft and only one flight required for the total crew contingent).

B. Changing Philosophies of Crew Isolation—Practices prevalent prior to and during early lunar missions were geared to isolation of the flight crew (and their alternates) before launch and after recovery. The resulting Crew Accommodations Center requirements for the 10-m (33-ft) dia Space Station Program reflected those ideas, with the exception that isolation after return from a Space Station mission was never a strong consideration as any contamination would have originated from the earth in the first place. Instead, post-flight isolation was considered more to provide a period during which the flight crew could be observed for any bad effects of the extended weightless environment they had just experienced and for debriefing. Now, however, and possibly more so in the future, isolation of the flight crew before and especially after return from orbit may not be so stringent as during those earlier days of space travel.

The extreme case would be if the requirements reduce to such an extent that an accommodations area per se would not be required at all. In this case, adapted training facilities, existing medical facilities, and home/motel living quarters will suffice for the crew accommodations function. Then, if these are located remote to the launch site, the crew members would simply board a transportation vehicle and fly or be driven to the launch site in time to allow phasing into launch countdown operations. Then, they would be delivered to a suit-donning area or other preparation area, perform necessary preflight tasks, transfer to the LUT, and board the Shuttle.

Effect of the foregoing factors on contingency return of crew members in instances of a launch hold or postponement is about the same as on the standard cases. Although, an inconvenience would exist if transportation
time between pad and accommodation area were lengthy, this could be
resolved by not returning the crew members to the accommodations area,
but by moving them to a specially adapted area at the launch site where they
could comfortably await resumption of launch operations. This technique
would create the need for a special area to suit the purpose. Considering
this particular stage of launch operations, however, with the understandable
accompanying psychological stresses, it may be necessary to have some type
of flight personnel-holding area at the launch site in any event.

Finally, if stringent isolation requirements are necessary as well as
remotely locating the accommodations area, the location of the space suit
donning area (if required for Shuttle launches) will have to be given considera-
tion. Should it be located at the accommodations area or at the launch site?
Comfort of the crewmen wearing the suits while being transported long
distances will have to be weighed against costs of a launch site donning area
or sharing the Shuttle flight crew donning area.

2.5.3.2 Logistics Modules—Transport Between Support
Area and Shuttle
Logistics Modules or CCM's will be installed in the orbiter in either the
orbiter maintenance area (VAB high bay) or other suitable place at the
Shuttle launch site according to current concepts of Shuttle ground handling
operations. This activity will follow cargo loading on the Logistics Modules
or CCM's in their support area (Logistics Staging Area in the VAB bay).
Offloading will simply be the reverse of these operations. As long as the
requirement exists for loading and offloading the Logistics Modules or
CCM's on the Shuttle orbiter, it will be most advantageous to have as short
a transport distance as possible between the Shuttle loading area and the
Logistics Module or CCM support area. Reasons supporting the close
proximity of the two areas are as follows:

A. Logistics Modules will be required for repeated flights through-
out the program's 10-year lifetime. Although there will be
periodic overhauls, it will be important to safeguard the
Logistics Modules against accidental ground damage (however
slight) between overhauls which could remove a single unit
or more from service. Removal from service would cause
difficulty in meeting resupply flight schedules which could lead to various other dire impacts. Therefore, to provide that additional measure of protection against accidental damage on the ground, Logistics Modules should be handled as little as possible. A long-distance ground transportation situation (e.g., return to the manufacturer for cargo loading) is feasible but would expose the Logistics Module and its cargo to a potentially hazardous environment for a longer period than would a short transportation distance. If it were necessary to ship the Logistics Module by aircraft to a remote location for service or cargo loading, the additional handling and transfer operations on and off the aircraft could prove excessive. Also, coupled with extra weight added by cargo installed at a remote location, long-distance transportation of the loaded Logistics Module could put unwarranted strains on the Logistics Module structure, e.g., stress cycles caused by transporting aircraft landings in addition to those of Shuttle landings.

B. If it becomes necessary to regularly transport Logistics Modules over long distances, special types of GSE may be required to provide additional protection. This does not fit the scheme of adapting existing and possibly sharing Modular Space Station ground handling GSE and will add to program costs.

C. Close proximity of the shuttle loading area and Logistics Module support area will permit the Logistics Module or CCM to be returned to its own area in the event of malfunction determined during Shuttle loading operations for quick repair. If the areas are not close to one another, a special area would be required in the Shuttle hangar for this contingency or the module would have to be transported to its remote support area.

D. Close proximity of the shuttle loading area and Logistics Module support area will enhance meeting of schedules. Less coordination effort will be required for scheduling necessary lead times for surface transportation convoys, route selection, and aircraft availability, especially when all activities are contained within the confines of the launch site.
E. Close proximity of the areas will facilitate Shuttle to Logistics Module interface activities. If it should become necessary to verify interfaces or even perform practice loadings, the close-in proximity would permit easy access and scheduling as compared to a remote Logistics Module support area.

2.5.3.3 Research and Application Modules—Transport Between Operations/Checkout Area and Shuttle Loading Area/FIT Area

The interface between the RAM operations and checkout area and the Shuttle loading area and FIT areas is almost identical with the Logistics Module and CCM interfaces between their support area and the Shuttle loading area but with a significant difference; RAM's will not be shipped back and forth repeatedly. Both involve the transport of modules to and from an area where they are loaded, handled, or subjected to verification test activities. RAM's will have much the same configuration (cylindrical shape, length, diameter, and weight) as the Logistics Modules, and there will possibly be a sharing of ground handling equipment with either the Logistics Modules or Space Station modules. All factors covered in the Logistics Module interface discussion (Subsection 2.5.2.2) apply to RAM's with the exception noted above and the fact that there will not be as many flights as forecasted for Logistics Modules. These factors plus the possible need to locate the Experiment Operations and Checkout (EOC) function at a site more suitable to other requirements, i.e., experiment payload integration may result in a long-distance transportation interface. Aside from ground handling and scheduling advantages, other factors which might impact proximity of the RAM support area and the Shuttle loading area and FIT area include the following:

A. RAM's may contain such sensitive apparatus and biological specimens that extensive transportation after final preloading checkout will not be desirable.

B. Also, in some cases, RAM's may require servicing and/or monitoring once they are loaded on the Orbiter. If this is required, not only the transportation interface will exist, but also, a data and man-equipment interface will be necessary. Depending on the checkout and/or monitor equipment and the
it may be necessary to have a hard-wired interface between the FIT area, Shuttle loading area, every other area where the Shuttle passes through, and the EOC area. This, of course, would be enhanced by close proximity of the areas involved. It would be possible, however, to handle this interface through RF or other data transmission means. Then, the problem goes away, except for transmission equipment needs. Still, there would be the personnel-equipment interface which might require certain experiment personnel or principal investigators to be constantly available or attending the RAM's until launch. These personnel could perform better if their offices and work areas were closer to the Shuttle support and FIT areas.

2.5.3.4 Trainees—Transportation Between Crew Training Areas and Accommodation Area

Flight crew personnel will be involved in training practically until launch preparation activities. The interface between the training areas and the accommodations area is mainly one of personnel movement. If there is a need or the possibility that training equipment would be installed in the accommodations area, there might be a data interface with other training areas or the Mission Operations Support Center (for on- and off-line computer support). Clearly, fewer numbers of flight crew personnel requiring training, and the changing complexion of pre- and post-mission quarantine are factors which will affect this interface.

A. Fewer Number of Crew Members—As related earlier, fewer flight crew personnel will require lesser preflight accommodations than required during the 10-m (33-ft) dia Space Station Program. Also as explained, this will permit greater flexibility in transporting the personnel to other activity locations—in this case, possibly remotely located training facilities.

B. Changing Philosophies of Crew Isolation—Also, as discussed earlier, there may not be stringent isolation requirements for prospective modular Space Station flight crews. This would permit relaxation of isolation requirements on personnel, training equipment, and facilities and further facilitate ease
of the transportation interface. This factor would also be instrumental in reducing the need for duplicating training equipment in the accommodations area. If there are no quarantine requirements for the crewmen, then they will be able to travel easily to existing training areas and perform training alongside other personnel not in preparations for flight.

2.5.3.5 Trainees—Transportation Between FIT Operations Area and Accommodations Area

Another personnel transportation interface involving training will exist between the FIT area and the accommodations area. Factors influencing this interface will impact location considerations to about the same degree as in the previous subsection (2.5.2.4) in that the fewer number of flight personnel involved and the possible relaxation of isolation requirements will reduce complexities of the transportation interface—allowing greater separation of the functions will less problems. Note also that use of the FIT as a training device has been reduced considerably as compared to the 10-meter station, since the onboard crew no longer controls Logistics Module, CCM, and RAM docking (docking will be controlled and implemented by the Shuttle). This would have been a major part of the FIT training use.

2.5.3.6 Controllers and Handover—Transportation Between Mission Operations Support and Accommodations Area

Under the mission management concept of operations, there will be a close association of flight crew personnel with the mission operations ground support function. Crew members scheduled for the next flight will work directly as controllers with mission operations personnel in the Mission Operations Support Center until time for final preparations. The activity is designed to increase understanding and familiarization with ongoing activities, to prevent interruption of experiments already underway, and to permit general ease of Space Station operations handover from one flight crew to the next.

Under a concept of strict isolation, this activity would be difficult to satisfactorily perform because of the necessity for personal contacts and
access to special equipment located only in the MOSC. With possibility of these requirements being relaxed, as discussed in subsection 2.5.2.1, controller and handover operations will be made much simpler. The situation will also be aided by the fewer number of crew members and relaxation of isolation requirements; hence there is reason to believe that the interface can be accomplished during the modular program with greater separation between functions than during the 10-m (33-ft) dia program.

Either of two innovations could be incorporated to make accomplishing the function easier in the event that isolation requirements turns out to be as stringent as ever. First, certain display and control equipment could be installed in the accommodations area to permit the flight crews to perform the function without leaving the isolated complex. Secondly, a special glass-walled, isolated room could be provided in the MOSC within or adjacent to the control room, and having certain repeater equipment but visually accessible to large displays of the control room. Although both of these conveniences might relieve complexities for accomplishing the function, each would present different interface considerations as follows:

A. **Install Display/Control Equipment in the Accommodations Area**—This approach would remove the transportation interface requirement between the accommodations area and the MOSC. Costs would be incurred in the additional display and control equipment and a communications and data interface would be created with the MOSC. As in previous discussions of the data interface, close proximity is required for certain types of equipment. However, in this case, either land-line or transmission would be satisfactory, thus supporting a case of hundreds of miles of separation between the two functions.

B. **Provide an Isolated Area in the MOSC**—This approach depends on a personnel transportation interface between the accommodations area and MOSC. Costs would be incurred in the additional facilities (for the isolated area) and for certain repeater equipment. It is possible that costs would not exceed those of the first innovation, (Item A above) because not as much equipment would be required, long-distance transmission would not be required, and facility costs for the isolated area should not
be excessive. However, if it were necessary to allow the crew members to remain overnight, (in case of extremely long distances between the accommodations area and the MOSC), and if isolation were in effect, some type of quarters would be required—along with dining function and possible medical functions. Costs would be incurred to provide for this contingency. This approach would lend itself to close proximity of the accommodations area and the MOSC.

2.5.3.7 Proficiency Trainees—Transportation Between Crew Training Areas and FIT Operations Area

An interface involving personnel transportation will exist between crew training areas and the FIT operations area. The interfaces will not be necessarily complicated by crew isolation requirements as would be the case for transportation between the accommodations area and each of these functions because the function will be accomplished prior to any isolation requirements. However, the interface exists, and even with less personnel travel involved in the modular program, scheduling will be impacted as separation between the two functions increase.

There is a remote possibility that a data interface might exist between the functions. The interface would link the MOSC computer interface equipment with part task trainers. If this interface were needed, there would more than likely be a requirement for a land-line, transmission link between the MOSC and the training areas or as relayed to the training areas from the FIT operations area. Although extreme separation could be tolerated, cost impact would dictate close proximity of the functions.

2.5.3.8 Data—Transmission Between the MOSC and the FIT Operations Area

This interface will consist of data transmission to and from the MOSC and the FIT operations area. Data may consist of high-speed and wideband outputs from computer-interface equipment. This interface will remain quite similar to that envisioned during the 10-m (33-ft) dia program, i.e., inputs to the FIT to drive certain flight equipment or to cause other equipment responses. This degree of complexity represents the maximum impact case on the functions involved as well as the interface.
Data transmission between the functions would be handled by interconnecting cabling (probably less than 2,000-foot separation) in the integrated case with all functions at KSC. Extreme separation was not considered because of availability of facilities in close proximity at KSC. Although this close-together siting is desirable, it is not an absolute requirement. A case in existence today is the Apollo simulator at KSC which has a data link with the MSC (similar to the one required for the Space Station Program). Economics will probably dictate the separation of these functions as they impact other functions which have more restricting close-proximity characteristics. In general, costs attributed to this interface could be expected to increase as separation increases.

2.5.3.9 Data—Transmission Between MOSC and LSBL
This interface is the same type as that discussed in the preceding subsection (2.5.2.8). It involves transmission of high-speed or wideband data between the MOSC and LSBL. Unlike the previous case, however, this link is an absolute requirement. Requirements for relay of orbital data to the biological experiment laboratory are still the same as established during the original Phase B study. Unless there is a complete change of concept in the near future for loading of biological specimens late in the countdown, requirements still exist for locating the laboratory at the Shuttle launch site (hence, the designation Launch Site Biological Laboratory (LSBL)). If these requirements remain unchanged, the LSBL will be located at the Shuttle launch site, and real-time orbital data will have to be relayed to the LSBL. If this is the case and the MOSC cannot be located at the launch site, extra costs may be incurred because of the provisions for long-distance data transmission. Then again, if the MOSC is situated remote to the launch site, the economy involved in the siting decision probably will more than offset the data transmission costs. In terms of feasibility, however, the MOSC can be separated from the LSBL by hundreds of miles.

It may be necessary to have a long-distance interface between these functions regardless; therefore, it may be more feasible to route biological experiment data directly from the down-link data ground terminal instead of an additional relay through the MOSC. The feasibility of this approach will depend on the data relay system and location of the ground terminal with
respect to the MOSC and LSBL. However, in this case, a communications capability would still be required which would have to be relayed through the MOSC. Again, this standard communications capability might be arranged more economically through the MOSC with the large volume of experiment data being handled by a direct interface with the ground terminal.

2.5.3.10 Biological Experiments—Transport Between the LSBL and Logistics Module Loading Area

This interface involves moving biological experiments between the LSBL and the Logistics Module/CCM loading area. Loading may be accomplished either in the Logistics Module/CCM support area or on the launch pad depending on the particular biological experiment. Items such as microorganisms may be packaged within containers having self-contained environments and nutrients which will enable them to be loaded in advance of Shuttle operations, while larger specimens will have to be loaded at the last minute, much like the flight crew, because of the necessary life-support considerations and other attentions. The net effect of the complexities involved in handling biological experiments at the launch site is the requirement for establishing the supporting laboratory at the launch site. This location still appears to be quite firm; however, if the biological laboratory were to be located remotely with respect to the launch site, there would be considerable transportation between the launch and laboratory functions of both specimens, their attendant equipment, and personnel. Probably there would be additional transportation and handling equipment cost. Quite a bit of attention to schedule, transportation precautions, and tracking of personnel and experiments would also be required. How much more attention than the launch site location can only be speculated as actual increase in difficulty of operating would probably be a step function of a range of distances from the launch site, i.e., as you move from the KSC, etc you experience a step of difficulty; as you move away from immediate surrounding area, you experience another step of difficulty; as you move away to between 100 and 500 miles, you experience another step of difficulty, etc. However, it cannot be denied that the closer you get to the launch site, the less the impact becomes on scheduling, transportation, and accounting.
2.5.3.11 Experiment Hardware—Transport Between the LSBL and Inventory Area

This interface involves the transport of biological experiment hardware and software from the LSBL to the inventory area. This interface is a companion of the biological experiments interface discussed in subsection 2.5.3.10, but does not have similar sensitivities as the experiments themselves. Biological experiments will be prepared for shipment at the LSBL, while attendant hardware and software will be delivered to the inventory area after preflight checkout and testing to make use of the broad shipping preparations capability of the inventory area. Should the LSBL be remotely situated with respect to the Shuttle launch site, the possibility of performing preparations for shipment hardware and software at the LSBL location should be considered. Depending on philosophies for ground usage of flight-type shipping containers, it might be more practical and result in less handling of items to simply prepare for shipment at the LSBL. In this case, the containerized items would be directly delivered to the Logistics Module loading area (Logistics Staging Area) and loaded as necessary, thus bypassing the inventory area function. Remote siting effect on this interface is the same as explained in subsection 2.5.3.10. Long-distance separation will require greater coordination and transportation precautions to assure timely delivery of in-commission biological experiment hardware and software.

2.5.3.12 Biological Experiments and Hardware—Transport Between the LSBL and the EOC Area

This interface involves transport of biological experiments and hardware/software from the LSBL to the EOC area. In a sense, this interface combines characteristics of the two interfaces noted previously. The purpose is different, however, in that these experiments and equipment will be installed in RAM's and left in that status throughout prelaunch Shuttle loading and integration operations.

This interface offers good justification for close proximity of the EOC area and the LSBL which, in turn, would be situated more advantageously at the Shuttle launch site.

Remote siting effect on this interface is the same as discussed in subsections 2.5.3.10 and 2.5.3.11. As separation of the functions increase,
resulting impact on the interface is the need for greater coordination and transportation precautions to assure timely delivery of incommission biological experiments and hardware and software.

2.5.3.13 Experiment Hardware, Software, and Spares—Transport Between EOC Area and Inventory Area

This interface involves movement of experiment hardware/software and spares between the EOC area and the inventory area. Experiments involved in this case are those received and checked-out in the EOC area and then sent to the inventory area to be prepared for shipment to the Space Station in the Logistics Module or CCM. Biological experiments are not included in this interface.

Although this is an important interface, other interfaces of the associated functions will govern separation. The effect of this interface as separation of the functions increase is that greater coordination and transportation precautions are required to assure timely delivery of serviceable experiment hardware, software and spares.

2.5.3.14 Experiment Hardware, Software, and Spares—Transport Between EOC Area and Logistics Module Support Area

This interface involves movement of experiment hardware/software and spares between the EOC area and the Logistics Module support area. This interface is exactly the same as that discussed in subsection 2.5.3.13 with exception that hardware/software and spares concerned are those irregular or special items which either cannot or need not be packaged within flight-type containers. In this case, a special preparation capability such as the inventory area is not required to assure timely delivery of servicable experiment hardware, software, and spares.

2.5.3.15 Cargo—Transport Between the Inventory Control Area and the Logistics Module Support Area

This interface involves moving of Space Station resupply cargo from the inventory control area to the Logistics Module/CCM support area, and it has not changed from concepts developed for the 10-m (33-ft) dia Space Station program. The inventory area will be fragmented among three
existing facilities at KSC—storage and preparation activities in the Supply, Shipping, and Receiving Building; preparation and loading activities in the VAB Low Bay adjacent to the Logistics Module or CCM support area (Logistics Staging Area); and control and management in the MSOB. Although fragmented, operations will be grouped along sub-functional separation planes and under centralized control at KSC. Having the inventory activity at the Shuttle launch site as much as possible will enhance the personal exchange of data through face-to-face contacts, shorten delivery distances between storage/preparation areas and loading areas, and simplify the scheduling of cargo delivery. Chances for shipping damage and reduced problems of scheduling/accountability will result.

Resupplies will be received in the Logistics Staging area and further prepared for delivery or held in readiness for Logistics Module or CCM loading operations. Some resupplies will be prepared for shipment in various inventory storage areas, i.e., selected, batched, packaged, and containerized. Others will be moved to the Logistics Staging area where they will undergo final packaging and/or just containerizing preparatory for loading. Where the cargo will be prepared for shipment will depend on the particular items. Items sensitive to shock/vibration, environment, cleanliness, etc., will be prepared in the areas where they were stored—a concept in line with economy of facilities but which increases responsibility of the preparations activity and necessary inspection/control. Experiment functions interfacing with the inventory function will do so mainly with respect to preparations and accounting activities. This is just one aspect of the inventory function, however, as one of its biggest responsibilities will be to procure the voluminous types and quantities of resupplies necessary for sustaining Space Station operations.

Should it be necessary to separate fragmented subfunctions even more (possibly remote to KSC), impact on the interface could vary as follows:

A. **Storage and Preparation Activities**—As distance between storage/preparation activities and the Logistics Module support function increases, the impact will become one of an increase in coordination and transportation precautions required to assure safe and timely delivery of necessary items. There are no
reasons why these subfunctions should be absolutely located at the Logistics Module support site, and if an off-setting advantage can be gained by remote siting, this possibility should be given careful consideration.

B. Procurement Control and Management—There should be little impact from separation of control and management activities from other inventory subfunctions. Provided that the control and management subfunction is adequately represented at the action levels—purchasing, inspection, packaging, storage, etc., there is reason to believe that separation of hundreds of miles would not create a problem. Although not identified as an interface, a relationship exists between this subfunction and mission operations. This relationship may be enhanced and permit smoother operations if the subfunction is located closer to mission operations.

C. Logistics Staging Area Preparation and Loading Activities—There is a definite need for a cargo preparation, collection, holding, and loading area adjacent to where the Logistics Module or CCM will be loaded. This subfunction performs the same activities as do loading docks in present day cargo loading experiences. But because of uniqueness of the program and the need to be prepared for various contingencies, i.e., center-of-gravity adjustments, off-loadings, last minute preparations and loadings, etc., the Logistics Staging area is more than a loading dock. Any separation would create problems which would compromise its purpose.

2.5.4 Mission Support Function Separation Planes
Based on the preceding discussion, separation planes for mission support functions, should they be needed, are recommended as shown on Figure 2-43. Note that three general divisions have been made: functions that must remain at the launch site; functions that must be grouped together but that can be removed from the launch site and performed elsewhere (mission control functions primarily); and functions for which there is no overriding consideration and which may be located at the launch site, with the mission control group, or independently.
Figure 2.43. Modular Space Station – Sustaining Ground Operations Functional Interrelationships Showing Locations
2.5.5 NASA Functions in Space Station Mission Management

The activities described in subsections 2.5.1 and 2.5.2 are envisioned as the day-to-day operations and could most logically be done by contractor and the flight crew performing ground operations on a rotational basis. The successful accomplishment of these functions depends on the administrative and management relationship of the Space Station mission management to other projects and programs and the scientific community. These NASA administrative and management functions for each of the elements of mission management are described below:

**Mission Operations Support**—Mission operations support includes NASA effort required to administer the mission operations support function comprised of mission analysis planning, flight operations support, experiment operations support and logistics operations support. Included are: Administrative and Management Functions, Project planning, and inter-program and agency planning.

**Mission Analysis and Planning**—Includes the NASA effort required to administer the planning function for the Space Station project. This task includes: Coordination with NASA Center, users, etc., Establishment of priorities; Mission planning and scheduling direction; and Overall requirements of mission operations.

**Flight Operations Support**—Includes the NASA effort required to provide the real time ground support of the Space Station orbital
operations and crew training. This task includes: Administration
of Flight Operations function; Ground network provisioning and
operations; Data acquisition; Hardware change authorization;
Flight crew training (personnel and hardware provisioning);
Simulation provisioning; and Data distribution.

Experiment Operations Support—Includes NASA effort required to
provide real-time ground support of Space Station orbital operations.
This effort includes: Coordination with user agencies and NASA
Center; and Direction of the experiment operations function.

The Ground network is provided by NASA and Hard copy data is
distributed by the Logistics Operations support function. Soft
data is reduced and distributed by ground network provided by
NASA.

Logistics Operations Support—Includes NASA effort required to
replenish expendable supplies and equipment needed to maintain
ground and orbital operations. This activity includes: Management of Logistics operations support, facility operations,
procurement administration, Inter- and intra-program coordination
for logistics functions, and establishment of Shuttle schedules,
availability, and services for the Space Station.
Section 3
GROUND SUPPORT EQUIPMENT

3.1 SPACE STATION PROJECT
In accordance with the Work Breakdown Structure (WBS) the Space Station Project GSE is identified in the categories listed below:

A. Space Station Modules
B. Integral Experiments
C. Launch Operations
D. Logistics Modules
E. Flight Operations
F. Test Article

These categories and the associated equipments are defined in the following sections.

3.1.1 Space Station Module
GSE defined in this section includes all equipment required to support the Space Station modules during factory acceptance test and servicing operations and during transportation to KSC. The same equipment is also used, in conjunction with the launch operations GSE described in Subsection 3.1.3, to support KSC prelaunch and launch activities.

The Station GSE design is predicated on maximum utilization of onboard capabilities. Orbital checkout and fault isolation procedures and computer software are used to the greatest extent practical. Ground equipment is also required to perform the usual handling, transportation, and servicing functions.

The launch of the three Space Station modules on 30-day launch centers allows additional savings to be realized through multiple usage of equipment, since all modules are produced in the same time frame. A single set of
Station GSE is used to support both the flight integration tool (FIT) and the flight vehicle at the manufacturing location, and is then transported with the flight vehicle to KSC for prelaunch and launch support. The equipment designs feature transportability to allow relocation with a minimum of effort and down-time.

Guidelines and assumptions used in development of GSE requirements and definitions are summarized below:

A. GSE will supplement the onboard systems to provide additional functions and services as required.

B. Unique capability to provide ground peculiar functions will not be included in the vehicle system.

C. Where possible, orbital checkout and fault isolation procedures and computer software will be utilized for ground testing.

D. GSE-peculiar software will be common to the onboard software to the greatest extent practical.

E. Fault isolation/replacement level during ground tests will normally be the same as for on-orbit repair.

F. Resupply provisions of the Space Station (e.g., fluid resupply connections) will be utilized to the greatest extent practical for ground-servicing operations.

G. GSE will be transportable to allow use at multiple locations.

H. Where practical, GSE will be provided in lieu of building specialized facilities equipment for support of these launches. Space Station module GSE is listed in Table 3-1.

Table 3-1
STATION GSE

<table>
<thead>
<tr>
<th>Item</th>
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<tbody>
<tr>
<td>Integrated Checkout Equipment</td>
</tr>
<tr>
<td>Digital Data Terminal</td>
</tr>
<tr>
<td>Portable Control and Display Unit</td>
</tr>
<tr>
<td>Item</td>
</tr>
<tr>
<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td>GSE Control-Display Console</td>
</tr>
<tr>
<td>RF Interface Unit</td>
</tr>
<tr>
<td>Communications Ground Station</td>
</tr>
<tr>
<td>Data Processing Unit</td>
</tr>
<tr>
<td>Magnetic Tape Recording Unit</td>
</tr>
<tr>
<td>Ground Power Source</td>
</tr>
<tr>
<td>Electrical Load Unit</td>
</tr>
<tr>
<td>Interface Simulation Group</td>
</tr>
<tr>
<td>Timing Reference Unit</td>
</tr>
<tr>
<td>Ground Measurement and Switching Unit</td>
</tr>
<tr>
<td>Metabolic Simulator</td>
</tr>
<tr>
<td>Electrical Distribution Group</td>
</tr>
<tr>
<td>Electrical Equipment</td>
</tr>
<tr>
<td>RFI Test Set</td>
</tr>
<tr>
<td>Servicing Equipment</td>
</tr>
<tr>
<td>Ground Coolant Thermoconditioning System</td>
</tr>
<tr>
<td>Pneumatic Equipment System, P/RCS</td>
</tr>
<tr>
<td>Portable Vacuum Pumping Unit</td>
</tr>
<tr>
<td>Space Radiator Service Unit</td>
</tr>
<tr>
<td>Ground Air Distribution System</td>
</tr>
<tr>
<td>Potable and Coolant Water Servicer</td>
</tr>
<tr>
<td>Pressurization and Leak Detection Unit</td>
</tr>
<tr>
<td>Insulation Purge System</td>
</tr>
</tbody>
</table>
Table 3-1
STATION GSE (Continued)

<table>
<thead>
<tr>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checkout Umbilical Kit</td>
</tr>
<tr>
<td>Liquid Sampling Kit</td>
</tr>
<tr>
<td>Refrigerant Service Unit</td>
</tr>
<tr>
<td>Access Equipment</td>
</tr>
<tr>
<td>External Work Stands Kit</td>
</tr>
<tr>
<td>Internal Access Kit</td>
</tr>
<tr>
<td>Internal Personnel Rescue Kit</td>
</tr>
<tr>
<td>Dicking Port Access Kit</td>
</tr>
<tr>
<td>Internal Lighting Kit</td>
</tr>
<tr>
<td>Handling and Protection Equipment</td>
</tr>
<tr>
<td>External Hoist Kit</td>
</tr>
<tr>
<td>Internal Hoist Kit</td>
</tr>
<tr>
<td>Module Handling Ring</td>
</tr>
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<td>Module Handling Kit</td>
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<tr>
<td>Space Radiator Cover</td>
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<td>Module Protective Cover</td>
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<tr>
<td>Module Passive Environment Control Kit</td>
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<tr>
<td>Transportation Equipment</td>
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<tr>
<td>Space Station Module Transporter</td>
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<tr>
<td>Transportation Status Monitoring Unit</td>
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<tr>
<td>Miscellaneous Support Equipment</td>
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<tr>
<td>Space Radiator Surface Test and Refurbish Kit</td>
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<tr>
<td>Docking Port to Docking Port Interface Substitute/Adapter</td>
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3.1.1.1 Integrated Checkout Equipment

Integrated checkout equipment is designed to accomplish subsystem and system checkout of the individual and assembled Space Station modules. The applicable requirements are as follows:

A. Provide electrical power.
B. Verify the power distribution and regulation system, including power transfer across experiment and docking interfaces.
C. Verify the operation of attitude and navigational sensors such as star trackers, horizon sensors, landmark trackers, etc., which require external stimuli.

D. Verify the integrity of data interfaces across docking ports.

E. Verify RF communications across the Ground Network, shuttle, and experiment module interfaces.

F. Provide external control and monitoring of onboard systems during propellant loading, launch, and other unmanned ground operations.

G. Provide control and monitoring as backup to critical onboard systems during all ground operations.

H. Provide external recording of status and test conditions to assist in engineering analysis and to assure availability of records in the event that onboard data is lost due to accident or malfunction.

I. Monitor and control ground checkout and servicing equipment.

The elements of the integrated checkout equipment described in this section are as follows:

3. 1. 1. 1. 1 Digital Data Terminal.
3. 1. 1. 1. 2 **Control and Display.
3. 1. 1. 1. 3 *Radio Frequency Interface Unit.
3. 1. 1. 1. 4 *Communications Ground Station.
3. 1. 1. 1. 5 *Data Processing Unit.
3. 1. 1. 1. 6 *Magnetic Tape Recording Unit.
3. 1. 1. 1. 7 Ground Power Source.
3. 1. 1. 1. 8 Electrical Load Unit.
3. 1. 1. 1. 9 Interface Simulation Group.
3. 1. 1. 1. 10 *Timing Reference Unit.
3. 1. 1. 1. 11 *Ground Measurement and Switching Unit.
3. 1. 1. 1. 12 Metabolic Simulator.
3. 1. 1. 1. 13 Electrical Distribution Group.

*These functions can be provided by existing KSC capability for flight articles.

**The control/display unit provided for orbital use will provide this capability.
3.1.1.1 Digital Data Terminal

Requirements — Provide external control and monitoring of onboard systems and data bus during hazardous operations, during launch countdown, and as backup to critical onboard systems during ground operations.

Verify data bus operation across the docking interfaces.

Verify digital data communications via RF link across the Ground Network, ground, shuttle, and experiment module interfaces.

Provide external recording of test data for engineering analysis.

Monitor and control the ground servicing and checkout equipment. Provide ground timing reference data to the onboard system from WWV.

Functional Description — The digital data terminal (DDT) (Figure 3-1) provides a central distribution point for all Space Station digital data handled or processed on the ground during checkout, servicing, and launch operations. This includes data to and from the onboard systems and to and from the ground servicing and checkout equipment.

A serial interface with the onboard data bus is provided to allow the control of onboard systems and the direct acquisition of onboard data. The bus interface is via coaxial cable through the ground measurement and switching unit (GMSU) to the flyaway umbilical. A buffer amplifier in the GMSU provides the amplification required to drive the GSE lines between the spacecraft...
and the checkout/control center. The data bus modulators/demodulators and control logic are contained in the DDT.

Similar capability is provided to allow transfer of data to and from the docking port data bus interfaces. This interface is implemented through test cables rather than through the umbilical and is disconnected prior to launch.

The DDT also provides a two-way serial data interface via coax with the communications ground station. This allows the transfer of digital data to/from the onboard communications system (via the RF interface unit) to verify the ability of the Space Station to receive, process, and transmit commands and data.

The unit interfaces with the portable control and display unit (part of the flight hardware) to allow input for display of status and test results information via CRT and discrete displays on the console.

A serial interface is provided with the GMSU to allow control and monitoring of remote servicing and checkout equipment. This interface is via ground data bus and is independent of the Space Station data bus interface described previously.

Data formatting, control, and error-checking functions for the various interfaces described above are performed by the ground data processing unit (DPU). The digital data interface between the DDT and the processor is assumed to be parallel. The DDT provides the required control logic, timing synchronization, and parallel/serial and serial/parallel conversion.

**Physical Description**—The DDT is housed in a two-bay equipment enclosure approximately two feet deep, four feet wide, and six feet high. It requires 115-vac electrical power and conditioned room air or underfloor plenum air for cooling.
3.1.1.1.2 Portable Control and Display Unit

**Requirements**—Provide the capability for external monitoring and control of the Space Station onboard systems. This capability is required to provide primary monitoring and control during the launch pad operations.

**Functional Description**—The control and display unit (Figure 3-2) provides ground controls and displays for the onboard systems. One section of the console contains a CRT display, an alphanumeric keyboard, and multifunction switches similar to those provided at the onboard consoles. The interface with the onboard systems is via the DDT. The multifunction keyboard and CRT display provide communication between the operator and the DPU for input of instructions and readout of data associated with computer-controlled elements. Manual capability is provided for direct control and monitoring of critical functions and of those functions for which computer control is not required. Voice communications to both the Space Station and to the remote ground support equipment is provided.

**Physical Description**—The portable control and display unit is a flight article which will be used on the Space Station. The unit is a small tabletop unit, as illustrated in Figure 3-2.

3.1.1.1.3 GSE Control and Display Console

**Requirements**—Provide monitoring and control of the supplementary ground checkout and servicing equipment.

**Functional Description**—The GSE control and display console provides ground controls and displays for both the onboard systems and the supplementary ground checkout and servicing equipment. One section of the console contains a CRT display, an alphanumeric keyboard, and multifunction switches similar to those provided at the onboard consoles. The interface with the onboard systems is via the DDT. The console also contains a limited number of manual control and display devices which are directly wired to the Space Station systems and which operate independent of the data bus and the onboard
data management system (DMS). These provide the capability to safe the Space Station (i.e., vent tanks, remove power, etc.) in the event that control via the data bus is lost.

A separate section of the console provides those functions necessary to control and monitor the ground servicing and checkout equipment. A multifunction keyboard and CRT display provide communication between the operator and the ground DPU for input of instructions and readout of data associated with computer-controlled elements of the GSE. Manual capability is provided for direct control and monitoring of critical ground functions and of those functions for which computer control is not required. Voice communication to both the Space Station and to the remote ground support equipment is provided.

Physical Description—The control and display console is a two-bay sitdown unit approximately 2 ft deep, 4 ft wide, and 4 ft high. One of the bays contain CRT display and alphanumeric/function keyboards. The other contains manual controls and displays such as switches and indicator lights, and voice communication (intercom) stations. Facility interface requirements include conditioned room air or underfloor plenum air for cooling, and 115-vac electrical power.

3.1.1.1.4 Radio Frequency Interface Unit

Requirements—Provide radiated and hardline transmitting and receiving capability for the Space Station Communications subsystem. This capability is required to verify the operational communications interfaces during factory and prelaunch operations. These interfaces include the following:

A. Space Station/DRSS, Ku band.
B. Space Station/ground, S-band.
C. Space Station/experiment module, Ku band.
D. Space Station/shuttle, VHF.
E. Space Station/EVA, VHF.
**Functional Description**—The Radio Frequency Interface Unit (RFIU) (Figure 3-3) provides test receivers and transmitters for each of the frequency bands utilized by the Space Station. The capability for interfacing either open-loop (radiated) or hard-line (coax cable or waveguide) is included. The receiver outputs, containing multiplexed television, voice, ranging, and digital data are routed from the RFIU to the communications ground station (CGS) for processing and analysis. The RFIU receives television, voice, ranging, and digital data from the CGS for transmission to the Space Station. Spectrum analyzers, frequency counters, and RF power meters are provided to allow qualitative analysis of the RF signals. The unit also contains an intercom station to allow voice communications between the test operator and the Space Station or other ground test personnel.

**Physical Description**—The unit is housed in a four-bay standard equipment enclosure approximately 2 ft deep, 8 ft wide, and 6 ft high. The contained equipment includes test transmitters, test receivers, spectrum analyzers, frequency counters, RF power meters, coaxial switching and patch panels, and an intercom station for voice communications with the Space Station and other test personnel. The unit requires conditioned air for cooling and 115-vac electrical power.

3.1.1.1.5 Communications Ground Station

**Requirements**—Verify the capability of the Space Station to transmit and receive communications in the following modes:

A. **Space Station to/from DRSS (Ku band).**
   1. Voice, 8 channels.
   2. Television, 2 channels, or 1 channel and 10 megabits digital.
   3. Digital, 100 kilobits/sec.
   4. Ranging.

B. **Space Station to ground direct (S-band).**
   1. Voice, 1 channel.
   2. Television, 1 channel (or 1 megabit/sec digital).
   3. Digital, 51.2 kilobits/sec.
   4. Ranging.
Figure 3-3. Radio Frequency Interface Unit
C. Ground direct to Space Station (S-band).
   1. Voice, 1 channel.
   2. Digital, 1 kilobit/sec.
   3. Ranging.

D. Space Station to/from Shuttle (VHF).
   1. Voice, 1 channel.
   2. Digital, 10 kilobits/sec.
   3. Ranging.

E. Space Station to free-flying module (FFM); digital, 10 kilobits/sec.

F. Free-flying module to Space Station.
   Video (TBD) channels, and Digital Data (TBD) channels, dependent
   on quantity of free-flyers in experiment program.

G. Space Station to EVA; voice.

H. EVA to Space Station.
   1. Voice.
   2. Biomedical data.

**Functional Description**—The communications ground station (CGS)
(Figure 3-4) receives voice, television, digital, and ranging data in multi-
plexed baseband form from the receivers in the RFIU and demultiplexes them.
Digital data are routed to the DDT which performs frame and message syn-
chronization, and then routes the data to the DPU for error-checking and
processing. Voice is routed to a distortion analyzer and to an audio
amplifier/speaker in the ground station for intelligibility tests. A video
waveform monitor and display monitor are provided for evaluation of the
downlink TV.

The unit provides the capability of supplying uplink signals for verification
of the receiving portions of the onboard systems. This includes the capa-
bility for generating audio and video test signals and of handling digital test
data formatted by the Data Processing Unit. The appropriate signals and
combinations thereof are multiplexed and routed to the RF Interface Unit
where they are used to modulate the test transmitters.
Figure 3-4. Communications Ground Station
Range (tone or pseudo-random noise [PRN]) generation and ranging simulation is provided to verify active and passive elements of the Space Station ranging equipment.

An intercom station is included to allow voice communications between the unit operator and other test personnel.

**Physical Description**—The unit is housed in a three-bay standard equipment enclosure approximately 2 ft deep, 6 ft wide, and 6 ft high (Figure 3-4). The contained equipment includes baseband multiplexers and discriminators, signal switching networks, television monitor, video waveform monitor, video test pattern generator, audio monitor and distortion analyzer, audio signal generator and microphone input, amplifiers, ranging signal generation and range simulation equipment, bit synchronizer, digital logic, and an intercom panel. The facilities requirements include conditioned room air or underfloor plenum air for cooling and 115-vac electrical power.

3.1.1.1.6 Data Processing Unit

**Requirements**—Verify capability of Space Station to receive and process digital commands and/or data transmitted from the ground (direct and via DRSS), from the experiment modules, and from the shuttle, with data rates to 10 megabits per second (Mbps).

Verify the capability of the Space Station to transmit digital commands and/or data to the ground (direct and via DRSS), to the experiment modules, and to the shuttle, with data rates to 10 Mbps.

Verify data bus interfaces across docking ports.

Provide ground control of data bus as backup to onboard system during ground operations.
Provide data management functions during initial system integration and checkout.

Provide control and monitoring of ground servicing and checkout equipment.

**Functional Description**—The data processing unit (DPU) is a general-purpose digital computer which provides the capability of formatting digitally coded commands and data for transmission to the Space Station via the various RF interfaces and the data bus docking port and ground umbilical interfaces. The accurate reception of these data by the Space Station and correct response to them is verified using the combined capabilities of the onboard and ground data systems. The unit also provides the capability of performing bit error testing and other qualitative analysis of digital data transmitted from the Space Station via the RF and docking interfaces.

The DPU provides a means of controlling the onboard data bus by way of the umbilical interface. This capability is utilized during initial checkout and integration of the onboard systems and provides a backup to the onboard data bus control system during all ground operations. The DPU is fully compatible with the onboard processors in terms of word structure, data rates, and software.

The DPU allows automated control of the ground servicing and checkout equipment, thereby providing compatibility with the automated onboard checkout operations. Coordination between ground-controlled operations and onboard operations is accomplished by computer-to-computer data transfer via the umbilical data bus.

Peripheral equipment associated with the DPU includes magnetic tape units and rapid access memory devices, operator control and data input devices, and a printer for hardcopy output.

**Physical Description**—The DPU consists of a digital processing unit, magnetic tape units, rapid access memory unit, and printer. The specific configuration, size, power requirements, etc., are to be determined.
Implementation alternatives under consideration include use of existing computers, use of Space Station mission management data processing capability, and use of a flight configuration computer.

3.1.1.7 Magnetic Tape Recording Unit

Requirements—Provide the capability for ground recording of Space Station checkout data. These data are required to supplement the onboard recording capabilities for post-test engineering analysis and to provide a backup test record in the event that onboard data are lost due to an accident or malfunction.

Functional Description—The magnetic tape recording unit (Figure 3-5) provides TBD channels of wide-band recording capability for digital and analog data from the Space Station. The data are input to the recorder from the CGS in either multiplexed baseband or separated form. Capability is also provided for recording digital data directly from the onboard data bus via the DDT. Playback capability is provided to allow previously recorded data to be transmitted to the vehicle by way of the CGS.

Physical Description—The unit is housed in a two-bay standard equipment enclosure approximately 2 feet deep, 4 feet wide, and 6 feet high. The unit requires conditioned room air or underfloor plenum air for cooling and 115-vac electrical power. Consideration should be given to obtaining this unit as GFE.

3.1.1.8 Ground Power Source

Requirements—Provide electrical power to the Space Station during ground operations where the solar array is neither deployed nor functional.

Functional Description—The Ground Power Source substitutes for the onboard solar array source during factory and launch site ground operations. The unit supplies 121 volts DC power at no more than 25 kw to the two Space Station distribution bus via the electrical umbilical connection. The power
Figure 3-5. Magnetic Tape Recording Unit
quality is the same as that provided by the solar array system. Control
and monitoring of the unit is provided from a remote console. Circuit
protection is provided to preclude damage to the Space Station as a result of
a fault or procedure error.

Physical Description—The unit consists of a rotary or static power supply
and the associated protection and switching circuitry. Facility three-phase
60-Hz power is required.

3.1.1.9 Electrical Load Unit

Requirements—Verify the capability of the Space Station power distribution
system to operate at rated electrical loads and to provide the specified power
at the docking interfaces. This includes verification of conductor integrity,
switching and regulation circuits, and circuit protection equipment.

Functional Description—The electrical load unit (Figure 3-6) provides the
capability of applying a dummy electrical load to the Space Station module
power distribution system to verify the capability of the system to operate at
full rated loads and to provide the specified circuit protection. The load
bank is connected to the distribution system by means of special test connec-
tors or by substitution for the normal loads. Circuit protection is provided
to preclude damage to the Space Station as a result of a fault or procedure
error. Monitoring and control is provided at the unit and/or from a remote
console.

Physical Description—The unit is housed in a standard equipment cabinet
approximately 2 feet deep, 2 feet wide, and 6 feet high. The contained
equipment includes resistive load elements and the associated mechanical
or electronic control devices. Facilities requirements include 115-vac
electrical power, and conditioned air for cooling.

3.1.1.10 Interface Simulation Group

Requirements—Verify the operation of Space Station equipment such as star
trackers, sun sensors, horizon sensors, landmark trackers, and docking
interfaces for which actual operational stimuli or loads are not available in the checkout environment. This includes one-shot devices which cannot be functionally tested during checkout due to safety or other constraints.

Functional Description—The interface simulation group provides the capability of artificially stimulating/loading the Space Station star trackers, sun sensors, horizon sensors, and landmark trackers, to provide a functional test of the associated onboard systems. This is accomplished by placing the various optical simulation devices over or near the sensors on the exterior of the spacecraft and by electrically connecting the ordnance interface test equipment to the spacecraft as required. Control and monitoring provisions for these devices are local or remote, depending upon test requirements and access constraints.

Physical Description—The equipment consists of a variety of portable equipment items which are installed on or near the spacecraft during checkout operations and removed prior to final countdown. Specific physical characteristics are TBD.

3.1.1.1.11 Timing Reference Unit

Requirements—Verify the capability of the onboard timing system to accept and synchronize to externally generated signals and to maintain the specified timing accuracy.

Functional Description—The timing reference unit (Figure 3-7) delivers an accurate timing signal to the onboard system. The timing information is transmitted to the onboard system in digital form through the RF communications system or directly over the data bus via the DDT. The unit also provides timing reference signals to the ground recorder and data processor to allow time correlation of ground and onboard data and verification of onboard system accuracy. Both internal time code generation and the capability of translating an externally supplied code such as IRIG is included.
3.1.1.1.12 Ground Measurement and Switching Unit

Requirements — Provide remote monitoring and control capability for GSE items located near the vehicle which require continuous monitoring or which must be monitored and controlled during testing hazardous operations such as high-pressure gas transfer, propellant loading, countdown, and launch.

Provide backup external control and monitoring of critical Space Station functions to allow safing in the event of an accident or malfunction which renders normal control channels inoperative.

Functional Description — The ground measurement and switching unit (GMSU) (Figure 3-8) provides switching and measurement capability for those items of ground servicing and checkout equipment which require remote monitoring and control. It also provides an interface with the Space Station for direct control and monitoring of safety critical functions for which data bus backup is required. The unit receives command/control via ground data bus from the DDT. This control may be originated by test operator or computer control either onboard the Space Station or on the ground. The digitally coded information is decoded and utilized to latch or unlatch relays in the GMSU. The contact closures are distributed by way of the electrical distribution group to the appropriate points in the GSE on Space Station. Control of critical functions is backed up by direct hardwire from switches on the ground display and control console.

Analog and bilevel measurement capability is provided by a multiplexer/digital converter similar to or identical with the remote data acquisition used in the onboard checkout system. The digitized data is transmitted via the ground data bus and is addressable by both the ground and onboard displays and data processors. Critical functions are hardwired directly to the ground display and control console to provide emergency backup.
monitoring. The GMSU contains buffer amplifiers to provide the necessary line driving capacity.

The unit also contains a programmable patch panel to provide a flexible and easily reconfigurable interface between the switching and measurement circuits and the external equipment. Power supplies in the unit provide power for the internal equipment and also to the external equipment for switching, valve operation, transducer excitation, etc.

**Physical Description**—The unit is housed in a standard three-bay equipment cabinet approximately 2 ft deep, 6 ft wide, and 6 ft high. It requires 115-vac electrical power, and conditioned room air or underfloor plenum air for cooling.

3.1.1.1.13 Metabolic Simulator

**Requirements**—Checkout of the EC/LS requires a metabolic simulator which imposes controlled EC/LS loads equivalent to the crew. Oxygen is consumed by the device and carbon dioxide, water and heat are given off. The simulator is portable and has the capability of being remotely controlled.

**Functional Description**—In order to verify performance of the CO₂ control assembly, the metabolic simulator (Figure 3-9) adds CO₂ to the cabin atmosphere in controlled amounts. Additionally, oxygen is consumed by the device to simulate the metabolic needs of the six-man crew in one-man increments. Three would be required for the ISS and five for the OSS configuration to simulate a variety of crew distribution among the modules. Water vapor is also a metabolic product and this is added to the cabin atmosphere to check out performance of the humidity control function. The unit features a local manual control panel for setup and checkout, and remote monitoring/control capability for unmanned tests.

**Physical Description**—The metabolic simulator is approximately 3 ft wide, 2 ft deep, 1-1/2 ft high and weighs 180 pounds.
3.1.1.1.14 Electrical Distribution Group

**Requirements**—Provide control and monitoring interconnection of the ground checkout and servicing equipment and the Space Station during ground operations.

**Functional Description**—The electrical distribution group provides distribution of electrical control and monitoring signals and dc power between the various items of GSE and between the GSE and the Space Station. The interface with the flyaway umbilical connector on the vehicle is via the checkout umbilical kit. Signal and power routing and distribution is provided by a standardized family of electrical cables and junction boxes.

**Physical Description**—The equipment consists of jacketed electrical cables with molded connectors and various distribution or junction boxes containing electrical connectors, terminal strips, etc.

3.1.1.2 Electrical Equipment

Electrical equipment is that required to perform preinstallation tests of selected components and subsystems and special tests on the assembled Space Station.

3.1.1.2.1 Radio Frequency Interference Test Set

**Requirements**—Verify electromagnetic compatibility between the Space Station subsystems and at the experiment and docking interfaces.

**Functional Description**—The RFI Test Set (Figure 3-10) is capable of detecting and recording steady-state and transient interference in electrical and electronic equipment. Both conducted and radiated interference measurement capability is provided. The test set interfaces with the equipment under test through adapter cables connected to equipment test points and through antennas to pick up radiated interference. The test set is manually operated.
Physical Description—The unit is housed in a two-bay equipment rack, approximately 2 feet deep, 4 feet wide, and 6 feet high. The enclosed equipment includes wide-band RF receivers, spectrum analyzers, voltage measurement equipment, transient detectors, and recorders. Peripheral equipment includes adapter cables and remote signal conditioners. Facility power of 115 vac is required.

3.1.1.3 Servicing Equipment
Servicing equipment includes that required to provide ground services such as cooling, purging, flushing, pressurizing, and filling. Specific requirements are as follows:

A. Provide ground cooling/heating of Space Station equipment.
B. Provide internal atmosphere conditioning during ground operations.
C. Purge, leak-test, and fill the Space Radiator Freon loop.
D. Purge, leak-test, and fill the potable water system.
E. Purge, leak-test, and fill the coolant water system.
F. Purge, leak-test, function, and fill the EC/LS and propulsion GN₂ systems.
G. Purge, leak-test, function, and fill the resistojet water system.
H. Purge, leak-test, function, and fill the resistojet CO₂ system.
I. Purge, leak-test, function, and fill the resistojet methane system.
J. Purge the Space Station insulation.

The servicing equipment required is as follows:

3.1.1.3.1 Ground Coolant Thermoconditioning System.
3.1.1.3.2 Pneumatic Equipment System, P/RCS.
3.1.1.3.3 Portable Vacuum Pumping Unit.
3.1.1.3.4 Space Radiator Service Unit.
3.1.1.3.5 Ground Air Distribution System.
3.1.1.3.6 Potable and Coolant Water Servicer.
3.1.1.3.7 Pressurization and Leak-Detection Unit.
3.1.1.3.8 Insulation Purge System.
3.1.1.3.9 Checkout Umbilical Kit.
3.1.1.3.10 Liquid Sampling Kit.
3.1.1.3.11 Refrigerant Service Unit.
3.1.1.3.1 Ground Coolant Thermoconditioning System

**Requirements**—During ground operations, the external space radiator is unable to dissipate the electrical/electronic and habitat head load of the vehicle. A ground thermoconditioning capability is required to remove this heat load, thus providing the proper thermal environment for the vehicle subsystems during factory checkout, acceptance test, and prelaunch and launch activities. Checkout of the control devices and functional assemblies in the thermal control system also requires that the capability be provided for variable conditioning (both cooling and heating) of the vehicle thermal control media so that the noted devices are exercised over a range of temperature, thus permitting functional verification. The unit supplies precooled coolant to a ground heat exchanger in the vehicle water-coolant loop. It is anticipated that ground cooling will be required until immediately before launch. Hence, the vehicle interface for prelaunch and launch operations is via a fly-away umbilical.

**Functional Description**—During vehicle checkout and launch operations, the ground coolant thermoconditioning system (Figure 3-11) provides a continuous heat dissipation capacity to the Space Station EC/LS System. Thermal monitoring and control within the vehicle is accomplished through the normal on-orbit function of the various EC/LS system components. Thermal load capacity of the ground system may be changed to accomplish thermal control checks by varying the output of the ground thermoconditioning unit (TCU) and by control of a flow bypass control console near the vehicle. These functions are remotely operable to permit single-point control from the launch/operations control center. Setup operations on the system are local-manual. Coolant fluid is delivered through insulated facility hard lines from the TCU to the bypass control console and between that console and the flexible umbilical lines. The bypass control console has the capacity to purge the ground half of the vehicle heat exchanger with nitrogen gas just prior to liftoff to eliminate any possible freezing problems and to prevent coolant spillage on the vehicle skin. The system interfaces with the facility for the noted distribution hardlines, gaseous nitrogen, power, and chilled water for the basic TCU.
Figure 3-11. Ground Coolant Thermoconditioning System
Physical Description—The TCU of this system includes a refrigeration unit, fluid-pumping provision, indicators, and controls needed to condition the coolant fluid. Heat rejection from the refrigeration unit is accomplished through use of facility-supplied chilled water. The bypass control console contains the valves, orifices, piping, etc., necessary for flow control to the vehicle heat exchanger. Insulated flexible umbilical lines carry the coolant to the vehicle interface. The units are mobile/portable to allow use of a single system, with appropriate facility hardlines, at the factory, the VAB, and the launch pad.

3.1.1.3.2 P/RCS Pneumatic Equipment System

Requirements—Perform functional checkout, leak tests, purging, and loading of the high-thrust propulsion and reaction control systems (P/RCS). Pressure integrity, component functional verification under load, and internal and external leakage tests of the high-thrust monopropellant hydrazine system require provisions for supplying regulated gaseous nitrogen and helium at low (100-250 psig) and high (3,500 psig) pressures. Similar functions involving the low-thrust resistojet system require carbon dioxide at approximately 300 psig. Purge and blanket pressurization of the two systems also requires low-pressure nitrogen and carbon dioxide. Filling of the systems requires charging the onboard nitrogen storage vessels to 3,500 psig and the CO₂ accumulators to 300 psig. Prelaunch charging of the methane accumulators is a potential requirement, but is not firm at this time.

Loading of the RCS water backup system requires storage and transfer of up to 450 pounds of water.

Functional Description—The pneumatic equipment system (Figure 3-12) provides control and regulation of facility-supplied gaseous nitrogen for the purpose of pressure and integrity testing, leak and functional testing, and purging of the hydrazine system, and for filling of the onboard nitrogen storage vessels. The capability of introducing helium gas into the system for leak testing is also included. Similar capability is provided for servicing the carbon dioxide and methane circuits of the resistojet system with carbon
Figure 3-12. P/RCS Pneumatic Equipment System
dioxide gas. Portable rechargeable bottles are utilized for the CO\textsubscript{2} supply. Tests for external leakage from joints, fittings, welds, etc., of these systems are made using bubble, halogen, or acoustic detection and location techniques. Internal leak tests employ pressure decay methods or pressure buildup measurements utilizing manometer-type devices to detect leakage from upstream pressurized compartments.

Prelaunch loading of the high-thrust system pressurant storage tanks utilizes the high-pressure circuits of the ground unit, which provide for regulation and transfer of gaseous nitrogen from facility storage tanks to the 3,500-psig spacecraft tanks. Charging of the resistojet CO\textsubscript{2} accumulators is accomplished using the portable bottles. Prelaunch loading of the propulsion water system utilizes the pneumatic circuits of the unit to accomplish pressure transfer from a console mounted supply to the spacecraft tank. A sequence of load/expulsion cycles is used to rid the onboard system of entrapped air.

Control and display capability for the unit is provided on a self-contained manual control panel. Remote control capability is provided for the high-pressure circuits in the interests of personnel safety. All control and regulation systems in the unit are equipped with appropriate preset burst discs and pressure relief devices to protect vehicle hardware from malfunction or control error during servicing and checkout operations.

**Physical Description**—The P/RCS pneumatic equipment system consists of a mobile control and distribution console containing all the necessary pneumatic regulation and control circuits. Mobility of the unit will permit a single unit to be used at both the factory and launch site.

A hose and accessory kit provides the hardware needed for connection of the basic console to the facility pneumatic supply and vent panels and to the vehicle interface connectors. A series of manometers and adapters packaged in carry-case enclosure provide the component internal leak measuring capability. This kit is approximately 3 feet wide, 2 feet deep, 1 foot high, and weighs 75 pounds. The control and distribution console is approximately 6 feet wide, 3 feet deep, 4 feet high, and weighs approximately 1,000 pounds.
3.1.1.3.3 Portable Vacuum Pumping Unit

Requirements—Servicing and checkout of the Space Station EC/LS and propulsion subsystems components and assembly groups requires that a vacuum capability in the order of 10 to 100 microns of mercury be provided. Evacuation of the EC/LS fluid systems to reduce the amount of air, nitrogen, helium, and other inert gases, is necessary prior to filling operations. Additionally, space-vent devices in these systems require vacuum application during functional checkout. The unit requires explosion-proofing to permit unrestricted use.

Functional Description—A single design vacuum pumping unit (Figure 3-13) is supplied to satisfy all evacuation and space-vent vacuum requirements. This unit interfaces with the various fluid servicing GSE items through switchover manifolds/hose service connections. The unit is portable and wheel-mounted for easy mobility to the various use locations, both at the factory test and at the launch site. The unit requires facility interfaces for venting and electrical power.

Physical Description—The wheel-mounted unit is approximately 3 ft wide, 2 ft deep, 4 ft high and weighs 500 pounds. Unit capacity is 21 cfm air displacement with a no-flow vacuum capability of 10 to 100 microns of mercury absolute.

3.1.1.3.4 Space Radiator Service Unit

Requirements—Purge, leak-test, fill, and pressurize the eight external space radiator circuits, interface heat exchangers, temperature control units, pumps, and accumulators which make up the Freon-21 radiator assembly group of the EC/LS system.

Functional Description—The space radiator service unit (Figure 3-14) interfaces with facility services for venting and gaseous nitrogen supply. Control of the unit is from a local manual control panel on the unit. During pressure integrity and leak tests, the unit supplies gaseous nitrogen at
Figure 3-13. Portable Vacuum Pumping Unit
Figure 3-14. Space Radiator Service Unit
controlled pressures to the radiator loops. The pressure decay method is used to determine leakage. For filling, the radiator loops are evacuated using the portable vacuum pumping unit and then supplied with Freon-21 from charged containers enclosed in the unit. The refrigerant can also be drained from the system by using the service unit.

Gaseous nitrogen supplied at controlled pressures is used to charge the system accumulator(s) and purge dry the loop of all residual Freon-21 after the system has been drained.

Physical Description—The service unit is housed in a mobile caster-mounted cabinet enclosure. All operating controls and indicators are mounted on a control panel on the front of the cabinet. The unit has approximate dimensions of 4 feet wide, 3 feet deep and 5 feet high and weighs approximately 1,800 pounds.

3.1.1.3.5 Ground Air Distribution System

Requirements—Maintain a habital working environment within the module(s) of the Space Station during ground preparation and prelaunch operations.

During servicing, maintenance, and repair operations, specifically when the vehicle is in a power-down condition, a ground system is required which provides ample control and distribution of facility-supplied filtered, humidity- and temperature-controlled air to the work areas. Aside from the habital work environment, the system maintains humidity control to prevent condensation within the vehicle.

Functional Description—The air distribution system is utilized during most ground operations. Use of the onboard air conditioning system is limited to the specific periods when verification of the EC/LS system conditioning and regeneration components is conducted. Use is made, however, of the onboard fans and blowers to assist in distribution and circulation of the conditioned air.
Conditioned facility-supplied air is routed into the vehicle through flexible ducting and portable vent-control diffusers. Placement of the diffusers, coupled with their manual control provisions, provides for local temperature control.

Physical Description—The air distribution system consists of flexible ducts for air delivery and lightweight portable diffusers. Natural convection flow through docking port and other personnel access openings in the structure, assisted by the onboard EC/LS blowers, provides the necessary air circulation. A facility interface for conditioned air is required.

3.1.1.3.6 Potable and Coolant Water Servicer

Requirements—Service and leak-check the potable and coolant water systems of the Space Station. This requires the capability to evacuate, pressurize, fill, circulate, and purge these systems. The service unit preserves bacterial control of the potable water and provides contaminant control/filtration for the coolant water.

Functional Description—The potable and coolant water servicer (Figure 3-15) provides regulation and control of helium and nitrogen gases for pressure integrity and leak tests of the Space Station water circuits. Presence and rate of leakage is determined by bubble solution and/or use of the portable leak detector (part of the refrigerant service unit). Prior to filling, the water systems are evacuated using the portable vacuum pumping unit. Filling is accomplished from storage tanks on the servicer. The servicer also provides circulation of the potable and coolant waters to aid in the removal of entrapped air. Regulation and control of facility-supplied nitrogen is provided for pressurization of the water systems storage tanks and accumulators and for draining/purge-drying of the systems. Provisions are included to prevent contamination of the water systems by the servicer. Control of the servicer is accommodated by a self-contained manual control panel.
Physical Description—The servicer contains independent systems for storage and transfer of the two waters. The pneumatic pressurization, purge, and control system are common. Stainless steel is used extensively in the tankage, components, and piping. Facility interfaces for gaseous nitrogen and helium, vent, waste disposal, and pump power are required. The unit is mobile with dimensions of 5 ft wide, 4 ft deep, 5 ft high and weighs approximately 1,000 pounds.

3.1.1.3.7 Pressurization and Leak-Detection Unit

Requirements—Servicing and checkout of the Space Station oxygen and nitrogen pneumatic systems requires the capability for purge, pressurization, and leak-check. Requirements also exist to determine leakage rates on the pressurized compartments of the station. Conformance to pressure vessel ground safety regulations will require remote control of most operations. Isolation/location of leaks will require the capability to apply a leak-test medium (helium) to these systems.

Functional Description—The pressurization and leak-detection unit (PLDU) (Figure 3-16) provides regulation and control of facility-supplied gaseous nitrogen and oxygen for pressure-integrity testing of the lines, tankage, and control components in the atmosphere supply and control group. Leakage tests of the pressurized system is accomplished using a bubble solution or by introduction of a helium trace into the system and "sniff" test using a portable leak detector.

Leakage tests on the pressurized compartment(s) utilize the pressure decay measurement capability incorporated in this unit. A carry-on reference volume unit located inside the compartment provides thermal compensation. A low-pressure regulation system within the PLDU provides nitrogen pressurant and the helium trace for leak detection.

The low-pressure pneumatic system of the PLDU is also utilized to perform functional checkout of the atmosphere relief and dump devices of the pressurized vehicle compartments.
Figure 3-16. Pressurization and Leak-Detection Unit
Physical Description—The PLDU is approximately 6 feet wide, 4 feet deep, 5 feet high and weighs 1,000 pounds. The unit features a local manual control panel for setup and low-pressure operations. Control and monitor of the high-pressure systems is designed for remote operation to preclude the presence of personnel during integrity test operations. Burst and relief devices are incorporated in the PLDU for personnel safety and protection of the vehicle hardware.

3.1.1.3.8 Insulation Purge System

Requirements—Provide the capability to maintain the aluminized mylar high performance insulation free of moisture during all ground operations when the Space Station is in an unprotected environment. The mylar insulation to be protected is installed in the area between the cabin pressure shell and the secondary meteoroid shield for the core module length. The annulus is a closed volume with the exception of open areas for launch accent venting.

Functional Description—During periods of exposure the volume in which the mylar insulation is installed is purged with dry gaseous nitrogen provided through the insulation purge system (Figure 3-17) to rid the volume of any potential entrapped moisture and to prevent migration of moisture into the volume. The nitrogen required is facility-supplied. Local and remote control and monitor capability are provided. Analysis may indicate the need for slight purge during periods of unprotected transport, e.g., VAB to pad, in which case a small portable supply will be provided.

Physical Description—The purge system includes the regulation, control, distribution piping, and adapters needed to deliver dry nitrogen from the facility supply to the annulus volume of the core module. A set of plugs or closures is provided to close the volume during periods of non-purge. One or more of these closure devices will be equipped with relief provisions to protect the thin meteoroid shield from excessive thermally produced pressure differentials.
Figure 3-17. Insulation Purge System
3.1.1.3.9 Check Out Umbilical Kit

Requirements—Provide an umbilical ground-system-to-Space-Station interface, for a limited number of command, control, and service functions which are required for factory checkout and servicing of the vehicle. Provisions shall include a hardwire electrical umbilical which includes essential command, control, and monitor functions associated with assessing condition of and safing dynamic systems of the vehicle and with accomplishing checkout functions. The umbilical kit shall also accommodate ground coolant lines interfacing with the vehicle ground heat exchanger.

Functional Description—Access to the vehicle system for the noted functions is via flexible lines and cables connecting the AGE units (control console, junction box, etc.) to appropriate connectors on the vehicle skin. Support of the cables, connectors, and lines out to and at the vehicle skin is provided by a ground umbilical plug carrier and support brackets mounted on the checkout service structure.

Physical Description—The umbilical kit includes the cables, lines, support brackets, plug carrier, and other hardware needed to accomplish the vehicle-to-AGE interface.

3.1.1.3.10 Liquid Sampling Kit

Requirements—A requirement exists to withdraw, store, and transport samples of Freon-21, potable water, and coolant water from AGE units prior to servicing, and periodically from the onboard vehicle systems for laboratory contamination and clinical analysis. Capability to withdraw up to one-gallon samples from pressurized systems is required.

Functional Description—Withdrawal of a sample from a storage tank or operating system using the proposed liquid sampling kit (Figure 3-18) units occurs under closed system conditions. Connection of a sampling line to a sampling port on the system being tested permits pressure feed or gravity drain into the sample container which is equipped with a shutoff valve to contain the sample. A simple carrying case for storage of hoses, adapters,
Figure 3-18. Liquid Sampling Kit
and containers is used to transport the sample to the laboratory for analysis. The unit used for collection of potable water samples will be sterilized and sealed prior to use to limit outside bacterial contamination.

**Physical Description**—A sampling unit consists of sample bottles, adapters, hose, valves, and pressure gage packaged in a commercial hand-carry case to provide cleanliness and bandline protection. The kit includes a sampling unit for each liquid being tested.

### 3.1.1.3.11 Refrigerant Service Unit

**Requirements**—The Space Radiator Service Unit requires charging of its Freon-21 fill system prior to servicing the external space radiator loops of the Space Station. Additionally, the ground coolant thermoconditioning system requires charging of its Freon-22 refrigerant system during maintenance and service operations. This requires that the capability of bulk storage, control, and distribution of the two noted Freons be provided.

**Functional Description**—The refrigerant service unit (Figure 3-19) provides pressurized transfer of Freon from standard K-bottles stored on the unit to the fill system of the space radiator service unit and the TCU refrigeration system. Transfer to these AGE units is manually controlled and is accomplished in a remote area to preclude requirements to explosion-proof the transfer heating elements of the refrigerant service unit. The unit has quantity measurement capability and provides refrigerant oil servicing of the TCU refrigerant system. A non-explosion-proof halogen leak detector with a sensitivity range compatible with gaseous refrigerant systems is included for leak detection checks.

**Physical Description**—The service unit is contained in a wheeled cabinet approximately 5 ft deep, 4 ft wide and 5 ft high, and weighing approximately 1,000 pounds. The unit has integral K-bottle storage, servicing hoses, and central indicator and control panel. A small vacuum pump for evaluating the oil-contaminated refrigeration systems is incorporated in the unit. Facility electrical power for the vacuum pump and heater elements is required.
Figure 3-19. Refrigerant Service Unit
3. 1. 1. 4 Access Equipment

Access equipment includes that required to provide access for personnel and equipment to the interior and exterior of the Space Station during ground operation. Specific requirements are as follows:

A. Protect docking port seals from damage by personnel and equipment.
B. Protect the Space Station interior from damage by personnel, tools, and carry-on ground equipment.
C. Provide access to installed equipment inside the Space Station.
D. Provide internal lighting during periods that normal lighting cannot be used.
E. Provide for emergency treatment and removal of injured or incapacitated crewmen from the Space Station interior.

Items included are as follows:

3. 1. 1. 4. 1 External Work Stands Kit
3. 1. 1. 4. 2 Internal Access Kit
3. 1. 1. 4. 3 Internal Personnel Rescuer Kit
3. 1. 1. 4. 4 Docking Port Access Kit
3. 1. 1. 4. 5 Internal Lighting Kit

3. 1. 1. 4. 1 External Work Stands Kit

Requirements—Provide ground crew access to external portions of the Space Station for inspection and repair functions and provide a platform and steps in the area of the docking ports for access through them.

Functional Description—The external work stand kit includes a small platform in front of each docking port. For inspection and repair of external surfaces standard, adjustable, collapsible scaffolding is provided that can be moved and emplaced as required.

Physical Description—The external work stand kit comprises step platforms with nonskid steps and working surfaces. TBD units of scaffolding are provided, of tubular-steel construction, 6 ft-high units, with 6-ft incremental building-block-type extensions. Joints are pinned or bolted.
3.1.1.4.2 Internal Access Kit

Requirements — Enable ground crew access to otherwise inaccessible interior areas of the modules during ground operations. It is also required that protection be afforded those areas inside the module that could suffer damage as a result of ground crew activity.

Functional Description — The internal access kit is used in conjunction with the docking port access kit. Once ground crewmen enter the module through the port, they will be able to move freely about the interior without damaging the structure or equipment due to the predominant 1g orientation of the modules. Inaccessible areas will require ladders, etc., for access. Fire-proof mats cover sections of the module used for walkways that are sensitive to such structural damage as scratches or dents. Those portions required for walkways which are not structurally strong enough are further provided with auxiliary structure in the form of bridges or platforms which will carry the loads to structural hard points. Small step-type ladders are provided to enable access to overhead or hard-to-reach equipment.

Physical Description — For protection of sensitive bulkhead surfaces, thick cushions constructed in the same shape as the area to be protected are provided. Auxiliary aluminum walkways, constructed in sections, are provided to protect structurally weak areas as required. One three-step, four-foot tall step-type ladder is provided for each module for overhead access.

3.1.1.4.3 Internal Personnel Rescue Kit

Requirements — Provide emergency breathing apparatus and first aid equipment to support ground personnel during assembly and checkout operations which require men inside the Space Station. Also, provide the capability of removing incapacitated personnel from the interior.
Functional Description—In the event that a ground crewman becomes injured or incapacitated he may require emergency treatment and removal to a first aid station. For treatment of stroke, shock, coronary attack, or asphyxiation, emergency oxygen bottles with masks are located on each deck. For treatment of injury, emergency first aid kits are located in each module. For removal of an incapacitated crewman, a collapsible stretcher is stored outside the core module at each level where a docking port is available for access. The stretcher has means to secure the patient firmly and handholds for carrying.

Physical Description—The kit consists of five emergency oxygen packs, five first aid kits, and three stretchers.

3.1.1.4.4 Docking Port Access Kit

Requirements—Provide ground crew access to the core module through the open docking ports while protecting the port seals from damage.

Functional Description—The docking port access kit (Figure 3-20) provides a protective liner for the ports, covering the entire area adjacent to the seals. The liner is attached to the structure for rigidity and provides a separate pass-through opening for electrical cable and air conditioning ducts. It also provides attach points for mounting handling equipment such as the internal hoist kit.

Physical Description—Liners for six docking ports are provided. Each liner is approximately the port diameter of five feet with an external rim to protect the seal area. The liners extend two feet into the core module. The bottom 18 inches of the liner is separated for cable pass-through and air conditioning ducts.

3.1.1.4.5 Internal Lighting Kit

Requirements—Provide the capability to illuminate the interior of the Space Station by auxiliary methods when it is not possible or practical to use the
onboard lighting system. This requirement exists only during ground operations. The auxiliary lighting system must be RFI-compatible with electronic systems and must be explosion-proof.

**Functional Description**—The internal lighting kit (Figure 3-21) is used independently of or to supplement the onboard lighting system during ground checkout or maintenance operations. The system is used when additional lighting is required for close work, when the onboard system is down for repair, or when the station is in a power-down condition. The kit consists of individual lamps that can be temporarily affixed to any of a number of positions on the internal vehicle structure or used as portable wands or trouble lights. The lamps provide about 80-foot-candle illumination in the immediate area of use. Sufficient lamps are provided to supply an overall work area light level of 40 foot-candles.

**Physical Description**—The internal lighting kit consists of several explosion-proof, RF-compatible fluorescent-tube-type fixtures that can be attached to structure or carried by hand. Each has an individual cord which is plugged into any one of several junction boxes. Power for the junction boxes (115 vac) is provided by the facility supply.

3.1.1.5 Handling and Protection Equipment

Handling and protection equipment includes that required to permit hoisting the Space Station modules and assemblies during manufacturing, transportation, and assembly operations and to protect the modules and assemblies during transportation and storage. Specific requirements are as follows:

A. Provide the means to crane-hoist the modules and other large assemblies during manufacturing, transportation, and assembly operations.

B. Provide structural support to the modules and during lifting and transportation.

C. Provide protection against dust, dirt, moisture, and mechanical damage during handling, transportation, and storage.

D. Provide the capability for handling of articles within the Space Station when the limitations for safe manual handling are exceeded.
Figure 3-21. Internal Lighting Kit
Items included are as follows:

3.1.1.5.1 External Hoist Kit.
3.1.1.5.2 Internal Hoist Kit.
3.1.1.5.3 Module Handling Ring Set.
3.1.1.5.4 Module Handling Kit.
3.1.1.5.5 Space Radiator Cover.
3.1.1.5.6 Module Protective Cover.
3.1.1.5.7 Module Passive Environmental Control Kit.

3.1.1.5.1 External Hoist Kit

Requirements—Provide hoisting equipment for handling of spacecraft equipment external to the Space Station module during assembly and/or repair.

Functional Description—A set of handling slings and beams is provided in the external hoist kit which interface with those items of spacecraft equipment which are so heavy or so large that manual handling is not feasible or desired. Some slings may have several uses, while others are used for a specific component. For large items, the beams and/or slings interface with the facility cranes. For smaller items, a portable hoisting device is provided that can be attached to the platform floor for stability.

Physical Description—The external hoist kit consists of a portable crane with a capacity of 1,000 pounds, a telescoping tunnel assembly sling, and a dish antenna sling.

3.1.1.5.2 Internal Hoist Kit

Requirements—Provide the capability for handling of articles within the station which exceed the weight and size limitation for safe manual handling. Safe handling refers to both personnel and equipment safety.

Functional Description—The internal hoist kit is used to hold, raise, lower, and position articles of equipment within the station which are too heavy or of a size that could result in personnel injury or damage to equipment if
handled manually. Articles which meet these criteria have integral attach points for slings and adapters which are part of the kit. The major components of the kit are:

A. A universal positioning device which can maneuver equipment into place and align it so that attach hardware can be installed.

B. A universal hoisting device which can raise and lower equipment between components and onto the positioning device.

C. A monorail-type hoist which is used to transfer equipment into and out of the station module via a docking port.

**Physical Description**—The kit contains a pedestal(s) which can be anchored to hard points on the compartment floor. A vertical hoisting adapter, consisting of hand-operated hoist and boom, can be attached to the pedestal for vertical hoisting. A mechanism with articulating arms with three degrees of movement can be attached to the pedestal for positioning of components. For transferring into and out of the station via the docking ports, a rail-type hoist with hand-operated horizontal control and electric hoist is supported at two points on the vehicle structure.

3.1.1.5.3 Module Handling Ring Set

**Requirements**—Provide a means to attach hoisting devices and provide horizontal support points to the modules during ground handling and transportation.

**Functional Description**—The module handling ring set provides the necessary stiffening to interface planes of the module so that ground handling loads can be transmitted into their structure without causing damage. The rings are of basic design that will fit all interface planes and be capable of carrying the maximum load of 20,000 pounds plus expected dynamic forces. The rings have interfacing points for attachment of hoist slings and load cells, and for support on the transporter.

**Physical Description**—The kit contains four rings, each fabricated to match the docking port interface plan.
3.1.1.5.4 Module Handling Kit

Requirements—Provide a means to lift the Space Station modules to enable placement in assembly areas, movement onto or from transport devices, and for inserting the station modules into the Shuttle orbiter. It is required that these operations be performed when the segment roll axes are either horizontal or vertical, and that it is possible to reorient the roll axes from one to the other.

Functional Description—Slings, spreaders bars, and hoists are provided in the Space Station handling kit which attach to interface points on the module handling rings. For movement of modules in the vertical (roll axis vertical) orientation, one lifting device consisting of a spreader bar and cable assemblies is fastened to the forward handling ring. For roll axis horizontal only handling, one sling is attached to each of the handling rings. Two facility cranes can be used for hoisting. If only one is available, both slings can be hooked to a common hoist. For the condition where it is required to reorient the roll axis from horizontal to vertical (or reverse) the two slings require separate facility cranes so that one can pay out or hold stationary while the other takes in or pays out, thereby rotating the module roll axis.

Physical Description—The kit consists of two spreader bars with cable slings which connect to either forward or aft handling ring, a short beam which can accept the lifting eye of both spreader bars simultaneously and then be attached to one crane hook, and the necessary attachment hardware.

3.1.1.5.5 Space Radiator Cover

Requirements—Protect the space radiator coatings from damage or contamination during ground operations.

Functional Description—The space radiator cover protects the sensitive thermal control coating from damage due to atmospheric contamination and from accidental contact with equipment, tools, and personnel. The cover is installed after surface coating at the factory and is removed prior to launch.
Physical Description — The space radiator cover consists of fiber glass panels with a Teflon coating. The panels are snapped together providing a hoop tension force that eliminates scuffing or an abrading action. A tubular aluminum handling fixture is required to support the panels during installation and removal.

3.1.1.5.6 Module Protective Cover

Requirements — Protect the module external surfaces from excessive dust, moisture, or corrosive atmosphere during periods of transportation or temporary storage.

Functional Description — The module protective cover provides a barrier between the local atmosphere and the external surfaces of the core module. It is essentially airtight, but has panels that allow the cover to breathe during temperature or pressure changes. These panels are desiccant windows with backup filters to prevent dirty or moist air from entering. The cover has adapter plates for connection of the dynamic desiccant unit and penetrations for the instrumentation cable passthroughs. It is installed in sections and connected with leakproof zippers. The inside of the cover has protective pads which prevent abrasive action on the module skin.

Physical Description — The cover is made of sections of vinyl-impregnated nylon cloth or similar material which are connected during installation with leakproof zippers. Two circular sections cover the ends of the modules and several rectangular sections fasten together to form the cylindrical portion to cover the external skin of the module.

3.1.1.5.7 Module Passive Environmental Control Kit

Requirements — Provision must be made to allow the station to breathe to ensure that no detrimental pressure differential exists because of changes in external temperature or of altitude, and it is required that incoming air be clean and of low humidity to protect against contamination and condensation.
Functional Description—The passive environmental control kit consists of an air filter and a desiccant package connected in series to dry and filter any air entering the station module because of breathing due to temperature or pressure changes. It is attached to an open port on the core module during periods when active environmental control cannot be maintained.

Physical Description—The desiccant container is connected by means of flexible ducting, to the air filter, which is approximately 24 by 24 by 36 inches, weighing 200 pounds. Another flexible duct connects the filter can to a port on the module. This duct is 12 inches in diameter with an adapter to attach to the open port. The entire unit can be mounted on the transporter during transit or on the floor during storage. Several units may be required for the large volume of the station.

3.1.1.6 Transportation Equipment
Transportation equipment includes that required to transport the Space Station modules from the manufacturing location to and at the launch site. Items included are as follows:

- Space Station Module Transporter(s)
- Transportation Status Monitoring Unit

3.1.1.6.1 Space Station Module Transporter(s)

Requirements—Provide the capability to transport the Space Station modules over improved roadways. Overland travel is required on public roads during transport from the manufacturing area to the airport and on Government-owned roads from the Shuttle Landing strip at Kennedy Space Center to the Shuttle maintenance area.

Functional Description—The Space Station module transporter has the capability of transporting the module in a "dry" stage. The power module is 14 ft in diameter, 58 ft long, and the crew operations and GPL modules each are 14 ft in diameter and 45 ft long and weigh approximately 20,000 pounds. Support for the station is through interfaces with the station forward and aft attach points. The transporter requires an auxiliary towing vehicle such as the M-106 tractor, and maximum towing speed is 5 mph. The transporter
suspension system protects the core from excessive shock, both during overroad transport and when secured on the seagoing barge during water transport. Communication between prime mover driver and stations at steerable wheels is provided. Three trailers are required.

Physical Description—The transporter is a welded steel-framed structure. It has multiple-wheeled, steerable axles at both ends. An enclosed cab at each end houses controls and seating for the operators. A communications net connects both cabs and the prime mover operator. Each set of wheels is individually brakeable. Supports are provided at both ends to interface with the station-handling rings for securing of the station onto the transporter. Provision is also made for securing the transporter to the seagoing barge if required.

3.1.1.6.2 Transportation Status Monitoring Unit

Requirements—Monitor and record the environment that the core module is exposed to during transport and handling so that an evaluation can be made of possible damage or degradation of vehicle systems while the capability exists to accomplish repair.

Functional Description— Instrumentation and recording devices are provided which will monitor and record several channels each of temperature, humidity, shock, vibration, and pressure. The monitoring sensors are attached or located at strategic areas of concern on the core module or within the environmental cover. The monitoring and recording instruments are mounted on the transporter, on the storage area floor, or in an accompanying trailer. The recordings are made directly onto readable charts or onto tapes that can be transferred onto charts.

Physical Description—The monitor unit consists of pressure, temperature, humidity, and vibration sensors, cabling, attenuator boxes, and a recording unit.
3.1.1.7 Miscellaneous Equipment

Miscellaneous equipment includes that required to perform functions such as interface alignment, weight and cg determination, and space radiator surface test and refurbishment. Items included are as follows:

3.1.1.7.1 Space Radiator Surface Test and Refurbish Kit.
3.1.1.7.2 Docking Port to Docking Port Interface Substitute/Adapter

3.1.1.7.1 Space Radiator Surface Test and Refurbish Kit

Requirements—Measure the Space Station thermal control surface coating optical properties in order to verify proper reflectivity and emissivity and to ascertain the need for refurbishment in a localized area. Provide the means to effect such refurbishment.

Functional Description—The inspection of the surface coating is performed by measurement of coatings, emissivity, and absorptivity using special optical instruments. Areas which are damaged or out-of-tolerance are refurbished by removing the coating from that area, repainting and baking. The refinishing process requires a clean-room atmosphere which is provided by a portable plastic film enclosure.

Physical Description—The inspection equipment consists of a portable reflectometer and emissometer. The refurbishment shelter is a plastic film enclosure which can be erected against the vehicle skin and maintained at the proper cleanliness level while providing ventilation for one or two technicians inside the enclosure.

3.1.1.7.2 Docking Port to Docking Port Interface Substitute/Adapter

Requirements—Provide for intermodule physical and functional interface verification without requiring direct physical mating of the modules.

Functional Description—The Docking Port to Docking Port Interface Substitute/Adapter provides the capability for verification of physical and functional module-to-module interfaces for the Space Station modules and for
verification of Logistic Modules and RAM Module to Space Station interfaces.

Capability includes performance as either an interface substitute or an adapter to connect modules. Configuration will preclude the necessity of mechanically docking the actual flight article/FIT modules, yet permit interface verification and functional operation of the modules as an assembled unit.

Physical Description—The Docking Port to Docking Port Interface Substitute/Adapter shall consist of two docking rings with inter-connecting cables and lines including the data bus line. Provision shall be made as part of the fixture for a pressure lid to close the docking port on each end of the adapter. Provision will also be made to substitute the interfaces represented by the Logistics Modules and the RAM Modules.

3.1.2 Integral Experiments
Due to the present Shuttle payload limitation of 20,000 lb, no experiment hardware is launched integral with the GPL module of the Space Station. In the event some of the carry-on equipment listed in Section 3.2.3 could be launched with the GPL, the required GSE for that identified experiment hardware can be located in Section 3.2.3.

3.1.3 Launch Operations
Launch Operations GSE includes all equipment required to supplement the Space Station GSE during prelaunch and launch operations at KSC. Applicable requirements are as follows:

A. Flush, leak-test, function, and fill the propulsion hydrazine system.
B. Provide a flyaway umbilical interface between the Space Station and the GSE for monitoring, control, and service functions which are required up until launch.
C. Provide capability to load and unload the Space Station modules in the Shuttle orbiter when the orbiter/booster are vertical.
The equipment identified to implement these requirements is as follows:

3.1.3.1 Propellant and Cleaning Fluid Transfer System.
3.1.3.2 Launch Electrical Distribution Group.
3.1.3.3 Launch Umbilical Kit.
3.1.3.4 Shuttle Vertical Loading Kit.

3.1.3.1 Propellant and Cleaning Fluid Transfer System

Requirements—Servicing of the propulsion and reaction control subsystem (P/RCS) high-thrust monopropellant system requires the capability to store, transfer, and control hydrazine for loading. The capability to store and manage an appropriate clean-and-flush fluid is also required for flush-inerting operations on a wetted system. The transfer system must include regulation and control of facility-supplied gaseous nitrogen for pressure transfer, control equipment cabinet purge, and transfer system valve actuation. Toxic vapor monitoring of the ground system and the P/RCS compartment(s) shall be provided during transfer and post-loading operations. Provisions for normal and emergency off-load are required.

Functional Description—Prelaunch loading of the P/RCS high-thrust system is accomplished by pressure transfer of hydrazine fuel from bulk storage to the vehicle interface. The ground system provides the necessary flow-control valves and piping for closed system transfer. The system includes circulation capability and controlled venting. Control and monitor of the ground system and related vehicle functions during servicing operations occur from a remote console located in the launch control center.

Dump of the vehicle hydrazine system utilizes the basic transfer system capability, essentially in reverse, with fluid collection occurring in off-load storage tanks. Inerting of the wetted system is accomplished by introduction and circulation of flush fluid (expected isopropyl alcohol) to drive out residual and entrapped propellant. This is followed by dynamic gaseous nitrogen purge drying using the pneumatic equipment system.
A vapor detection unit with sensing elements located in critical AGE units and the vehicle P/RCS compartment(s) detects toxic concentrations and provides local and remote monitoring and alarm in the event hazardous concentrations become present.

**Physical Description**—The hydrazine and its related flush fluid are stored in semipermanent skidmounted tank assemblies located in the launch pad fuel holding area. A control and distribution panel at the holding area connects the supply tanks to the fluid lines going to the umbilical tower. The panel includes fluid shutoff and crossover valving for management of the propellant and flush fluid and for pneumatics used for pressurization and line purging. A control and distribution console located on the umbilical tower and a near-in valve complex provide the piping, control valves, and monitoring of fluids to the vehicle interface. Manual umbilical lines, connecting to the on-orbit resupply points, provide for transfer between the AGE and the vehicle. The system provides particle filtration at the vehicle interface. Facility interfaces include gaseous nitrogen, helium, and venting and interconnecting long lines between the AGE units. Design of the umbilical tower equipment units includes protection from launch-induced environment. The storage, transfer, and off-load design provides the capability to permit full loading of the vehicle system for prelaunch/preflight all-system tests or demonstrations. The design also features mobility to permit use of the equipment in support of resupply missions.

3.1.3.2 Launch Electrical Distribution Group

**Requirements**—Provide control and monitoring interconnection of the ground checkout and servicing equipment and the Space Station during ground operations.

**Functional Description**—The launch electrical distribution group provides distribution of electrical control and monitoring signals and dc power between the various items of GSE and between the GSE and the Space Station. The interface with the flyaway umbilical connector on the vehicle is via the launch
umbilical kit. Signal and power routing and distribution are provided by a standardized family of electrical cables and junction boxes.

**Physical Description**—The launch electrical distribution group consists of jacketed electrical cables with molded connectors and various distribution or junction boxes containing electrical connectors, terminal strips, etc.

### 3.1.3.3 Launch Umbilical Kit

**Requirements**—Provide a flyaway umbilical(s), ground-system-to-Space-Station interface for a limited number of command, control and service functions which must exist until liftoff of the vehicle. A hardwire electrical umbilical must include essential command, control, and monitor functions associated with assessing condition of and safing dynamic systems of the vehicle and for prior-to-launch remote command functions such as power switchover. The umbilical kit must also accommodate ground coolant lines interfacing with the vehicle ground heat exchanger and provide for transfer of cool air from ground units to the Brayton cycle power conversion units.

**Functional Description**—Access to the vehicle system for the noted functions is via flexible lines and cables connecting the AGE units (control console, junction box, etc.) to appropriate connectors on the vehicle skin. Support of the cables, connectors, and lines out to and at the vehicle skin is provided by a ground umbilical plug carrier and other support brackets mounted on an existing launch umbilical tower (LUT) swing arm. Disconnect and retraction will occur on ground command just prior to liftoff.

**Physical Description**—The umbilical kit includes the cables, lines, support brackets, plug carrier, and other hardware needed to accomplish the vehicle-to-AGE interface and the support interface with the LUT swing arm. Modifications to the existing swing arm will feature least-effort convertability back to the Saturn V/Apollo configuration flight vehicle after launch of the Space Station.
3.1.3.4 Shuttle Vertical Loading Kit

Requirements—Provide the capability to load and unload the Space Station (and logistic) modules in the Shuttle orbiter when the orbiter/booster are in a vertical orientation in the VAB high bay.

Functional Description—The Shuttle vertical loading kit is used to install and remove the Space Station modules from the open cargo bay after the Shuttle booster/orbiter are erected in the VAB. Provision for attaching to the module and translating the module into or out of the cargo bay and reorient the module to the horizontal position. This operation will be performed as a contingency rather than a routine operation.

Physical Description—TBD.

3.1.4 Logistics Module
GSE required for support of the Logistics Module ground operations is to be employed in the VAB Low Bay.

3.1.4.1 Electrical Test Equipment
GSE in this section includes that necessary to test, adjust, and calibrate flight equipment. This equipment shall include the following:
   A. Electrical Interface Test Set.
   B. Load Test Unit.

3.1.4.2 Servicing Equipment
GSE in this section includes that necessary for Logistics Module fluids servicing and loading. This equipment will probably be controlled through automatic checkout equipment existing at KSC. The equipment shall include the following:
   A. Ground Air Conditioning Unit.
   B. Pressurization and Leak Check Unit.
   C. Potable Water Servicer.
3.1.4.3 Access Equipment
GSE in this section includes that necessary for gaining access to the Logistics Module interior and exterior in both the horizontal and vertical attitude. This equipment shall include the following:

A. Internal Horizontal Access Kit and Pads.
B. Internal Lighting Kit.
C. Intercommunications Kit.
D. Vertical Access Kit.
E. External Access Kit.

3.1.4.4 Handling and Protection Equipment
GSE in this section includes that necessary for ground handling and protecting the CCM. This equipment shall include the following:

A. Hoisting Kit.
B. Logistics Module Handling Kit.
C. Logistics Module Protective Cover Kit.
D. Cargo Transfer Kit.
E. Battery Handling Fixture.

3.1.4.5 Transportation Equipment
GSE in this section includes that necessary for ground transportation—from the factory to KSC, between the Shuttle loading/unloading area to the VAB Low Bay, and from the VAB Low Bay and when required to the refurbishment area. This equipment shall include the following:

A. Transporter.
B. Transportation Kit.

* For use with the CCM in the GSS phase. At that time a life support system will be added.
3.1.5 **Mission Support (Flight Operations)**

GSE defined in this section includes all ground based equipment required to support Space Station orbital operations. Included is the GSE for Mission Operations Support (Flight operations support, mission analysis and planning, logistics support and experiment operation operations support); Crew Accommodations; Flight Crew Training; Ground Network; Inventory Control and the Flight Integration Tool.

The orbiting Space Station will be supported through the integrated efforts of the mission Operations Support Center (MOSC). The concept of integrated mission management is described in Section 2.5 of this document.

Under this concept of operations support, the MOSC provides mission planning, flight support, and mission direction. The MOSC also provides experiment ground control, and principal investigator (PI) quick-look data analysis.

The ground network provides the capability for continuous communications between the Space Station and ground support data system. The ground network provides digital data downlinks (narrow-band and wideband), digital data uplinks, multiple two-way voice links, and two-way color television links for the MOSC and Space Station information interface.

The ground network provides tracking support to the Space Station, Shuttle, and free-flying experiments modules. Tracking of these vehicles is initiated periodically or as required for verification and updated vehicle guidance and navigation systems. Tracking data are processed by the MOSC for development of the above-mentioned vehicle guidance and navigation updates and for development of communications acquisition data for the ground network.

3.1.5.1 **Mission Operations Support Center**

The GSE for the four elements of Mission Operations Support Center are included in this section; flight operations support, mission analysis and planning, logistics support and experiment operations support.
GSE for crew accommodations; flight crew training; ground network; inventory control and the flight integration tool is described in Section 3.1.5.2.

3.1.5.1.1 Flight Operations Support Equipment Group

The Flight Operations Support Equipment Group (FOSEG) provides the equipment necessary for central point-of-support for the Space Station flight operations and the other functions of mission management requiring this data and computer capability. This equipment provides the communications configuration control, telemetry, and ground tracking data processing, Space Station systems status parameters processing, uplink data processing, and information presentation required by the flight operations support team.

FOSEG provides the equipment necessary for receiving data from the Space Station and storing, processing, and routing these data to the FOS team. FOSEG also accepts inputs from the flight operations support team in the form of display information requests, systems configuration control commands and space vehicle uplink data. FOSEG consists of communications interface equipment, communications processor, and mission operations computer complex (MOCC), to be located in the CIF, and display/control equipment (D/CE) and flight operations support consoles, to be located in the MOSC FOSR and support areas of the MSOB. This equipment performs the following functions:

A. Provides flight operations support team with Space Station system data for Space Station status monitoring.
B. Provides support for activation and habitability checkout of Space Station systems during unmanned Space Station operational periods.
C. Provides necessary monitoring and control capability for controlling Space Station attitude prior to manning.
D. Provides coordination point for acquiring consultation assistance from Space Station systems and equipment specialists for resolution of problems associated with degraded or failed systems.
E. Provides long-term trend analysis for selected Space Station parameters.
F. Provides central point for voice communication for anytime access.
G. Provides trajectory support in cooperation with mission analysis and planning area.
H. Provides ground data system configuration control.

3.1.5.1.1.1 Flight Operations Support Display/Control Equipment

Requirements—Provide data display and control capability in the flight operations support area.

Functional Description—Flight Operations Support Display/Control Equipment (FOS D/CE) provides the required data display and control capability utilizing various display devices. Dynamic data displayed are in real or near-real-time form and consist of plots, indicator lights, television, and digital data (including special processed digital data, as well as biomedical data). FOS D/CE receives data from the communications processor and displays the data for cognizant support personnel. FOS D/CE generates certain data within its subsystem necessary for the proper display of the data received from the Space Station. Some of the downlinked Space Station data are specially processed in the MOCC and sent to the FOS D/CE for display. The FOS D/CE provides the necessary man/machine interface to allow the cognizant support personnel to provide the required control of the Space Station vehicle systems. Functions performed by the FOS D/CE include, but are not necessarily limited to: display of telemetered Space Station vehicle systems data; display of trajectory and specially processed data from the MOCC; display of selected experiments data; generation of internal subsystem data necessary to properly display information required by support personnel; and provision of necessary man/machine interface for flight operations support personnel to accomplish control of Space Station systems. The FOS D/CE consists of consoles with display monitors and computer I/O manual entry devices (MED's), group display equipment, display generation equipment, closed-circuit television (CCTV), video switching matrix, and other interface
equipment for rendering Space Station support. The FOS D/CE includes the following functional elements:

A. **Flight Operations Support Consoles**

FOS consoles provide the flight operations support team with display and control devices to monitor and control Space Station status both from a mission status and systems health point of view. These consoles are as near alike as practical so that they can be reconfigured from one flight support function to another as required. The console operator input/output devices interface the MOCC television equipment, voice communication equipment, and communications processor. Each console contains CRT monitors, keyboards, and indicator modules which can be reconfigured to perform any of the tasks of the FOS team by software action.

B. **Group Display Equipment**

FOS group displays consist of a ground track display, flight dynamics plots, time, and other common and continuous displays. The group display equipment is capable of displaying various formats to accommodate different mission situations. Projection TV can provide this capability and can be driven by the display generation and distribution equipment which drives the FOS console display monitors.

C. **Video Switching Matrix**

The video switching matrix (VSM) provides routing and distribution of computer-generated digital television data, closed-circuit television channels, and MOSC external television to the flight operations support console monitors, portable monitors, overhead monitors, and parts of the group display equipment. Channel selection can be either operator- or computer-initiated depending on mode of operation.

D. **Display Generation Equipment**

The display generation equipment (DGE) receives computer-formatted display data from the MOCC and performs the translation of these data into display image language and drives the display monitors of the FOSR via the VSM. Approximately 13 digital display channels provide simultaneous displays with possible dynamic updates from the MOCC. The DGE outputs alphanumeric and
graphic display data to the VSM for distribution to the FOSR monitors and hard copy devices. The DGE also provides static background display data which can be mixed with the dynamic data. These backgrounds are developed, coded, and stored in the DGE file before "callup" by the FOSR and are accessed by the DGE under control of the MOCC. Requests from the FOSR operators can initiate the callup of display, or certain data can be programmed to be displayed automatically by the MOCC as circumstances dictate. The MOCC automatically performs the digital television display channel select by scanning the display output channels and selecting one which is not busy.

E. Computer Input Multiplexer

The computer input multiplexer (CIM) provides the interface for the manual entry devices of the FOSR consoles to the MOCC. It scans the MED's and receives encoded keyboard messages which it translates into MOCC-compatible language and sends to the MOCC for processing. The CIM provides the means of interfacing a large number of MED's to the MOCC without typing up several MOCC I/O channels. By locating as near as possible to the majority of MED's, the cabling problem is reduced by multiplexing or sharing the CIM to MOCC data lines.

F. Hardcopy Devices

Hardcopy equipment provides a means for permanently recording flight operations information available to the FOS D/CE.

Physical Description—The FOS D/CE is located in two major areas. One area is the FOSR which houses the five consoles of the flight operations support team. One of the five consoles are spares to be used for simulation and training, console maintenance, and for high-level support periods. Each console is approximately 4 by 7 by 4 ft high and is configured as nearly the same as practical.

Group displays of information common to all or most of the FOS team is situated in front of the consoles. An adjacent visitor viewing area of approximately 300 sq ft is included in the FOSR. The total floor space required for
the FOSR is approximately 1,800 sq ft. This room has provisions for subfloor cable routing and ambient light control. The VSM and display generation equipment are housed in standard equipment racks and located in an area having subfloor cable routing provisions. The DGE is housed in approximately (TBD) equipment racks. The VSM is contained in TBD standard equipment racks.

3.1.5.1.1.2 Mission Operations Computer Complex

Requirements — Provide data processing required to support the sustained Space Station operations in areas of systems status monitoring, Space Station systems control, trajectory analysis, mission planning, and experiments quicklook data analysis. The equipment generates the display data required by support personnel responsible for the above functions.

Functional Description — The MOCC processes Space Station and Shuttle data and experiments data required by the FOS team for maintaining cognizance of flight vehicle status. The MOCC receives data from the communications processor, performs necessary manipulations, and generates display information for evaluation by the cognizant support personnel. The MOCC functions include processing of long-term system parameter trends; consumables analysis; replaceable module inventory; logistics and resource utilization planning; mission analysis and planning; trajectory data processing; experiments data processing; display generation; Space Station, ALS and experiments command generation; and processing of entries executed by the FOS personnel.

Space Station, Shuttle, and experiments system parameters values are available to the MOCC as required. These parameter values are nominally downlinked by the onboard data system in the form of system status information. Periodically, the MOCC parameter tables are updated with all key parameter values, providing a basis for developing systems trend analysis and for malfunction analysis.
The MOCC generates display information required by the FOS team, experiment support team, logistics support team, and mission planning and analysis team. It provides the processing required to automatically display critical status information and processing to develop display information required for displaying system health trends, and for malfunction analysis. Ground tracking data from selected MSFN sites are processed by the MOCC to provide state vector updates to the onboard guidance and navigation system. Ground tracking data and onboard guidance navigation data are processed by the MOCC to generate ephemerides which will be used for communication link acquisition and mission support planning.

The MOCC provides a computational capability for the mission analysis and planning team and the logistics support team and drives their display system. Their processing functions include trajectory analysis, consumables analysis, mission scheduling, resource utilization planning, etc.

The MOCC provides quick-look experiment data processing and drives the experiment display systems. The MOCC performs "standard" experiment data processing which gets raw experiment data into manageable form for the experimenters. The MOCC also provides the experiment data storage and retrieval function for the experiment data bank.

The MOCC receives all preprocessed experiment data from the CP and all control inputs from experiment controllers. It maintains short-term storage of the preprocessed experiment data and provides data processing as required to drive the on-line displays of the experiment controllers. It is used by mission analysis and planning personnel and, therefore, contains scheduling information which is accessed by the experiment controllers. The MOCC also stores all real-time preprocessed experiments data in the experiment data base (EDB) and distributes them to the various local and remote users as requested.

The MOCC is used to maintain the EDB files and to retrieve and distribute stored data. As physical data are received at the physical data receiving lab (PDRL), the MOCC is used to tabulate correlative data for each item.
The MOCC provides any partial-analysis processing support required to assist the remote PI's in their data analyses. However, the primary experiment support function of the MOCC is to provide the data-processing capability which, together with display/control and special equipment, enables the local PI's to monitor and control their FPE's and to analyze their experiment data.

Physical Description—The MOCC consists of the processing units, mass storage, associated peripheral devices, software, and system configuration equipment.

3.1.5.1.1.3 Communications Processor

Requirements—Receive, process, and distribute incoming and outgoing operational, simulation, and experiment data to and from the MMC as required. Accept wideband digital data, teletype data, and compressed digital data from the ground network.

Functional Description—Communications processor (CP) equipment provides the capability to receive, process, and distribute all incoming and outgoing data to and from the MOSC (except video, wideband experiments, voice, and weather data) to the proper destination within the MOSC in real time or near real time. It performs the following standard preprocessing of experiment data: quality checking, time tagging, merging of required status, including Space Station (state vector), calibration of data, and sorting of FPE.

Preprocessing is limited in extent by the constraints that no raw data are destroyed (not able to reconstruct), and the CP software can extract the necessary control information from the data stream (i.e., that control is as nearly automatic as is practical).

Physical Description—Communications processor equipment includes the following:

A. Computers provide the necessary processing and manipulation of wideband and high-speed digital data downlinked from and uplinked to the Space Station and other ancillary vehicles. The computer
provides arithmetic circuitry and several I/O channels for this processing. Synchronization signals for the computer are provided by a clock.

B. Interface peripherals provide the necessary interface equipment within the subsystem to process, distribute, buffer, and retrieve, incoming data. This interface peripheral equipment consists of communications multiplexers, input data distributor adapters, communication line terminals, channel scanners, and communication processor/mission operations computer adapters.

C. Storage and recording equipment provides data storage as well as rapid retrieval when necessary on selected downlinked and uplinked data. The storage and recording equipment consists of magnetic core memory units, magnetic drums, magnetic tape units, and card processors.

D. Transfer and switching equipment provides very rapid switching between various components with little or no loss of data. Switching and transfer equipment consists of an electronic transfer switch and a system configuration unit for computer-to-peripheral unit configuration.

E. Monitor and control equipment provides the monitoring, as well as the control and operation of the computer and computer program. The monitor and control equipment consists of a control and configuration console suitably equipped with monitoring devices.

3.1.5.1.1.4 Communications Interface Equipment

Requirements—Receive, monitor, and provide test access to all audio, high-speed-data, wideband, and television circuits entering and leaving the MOSC. Provide centralized operational transfer and switching control.

Functional Description—Communications interface equipment provides the capability to receive and monitor, and access for testing, all audio, high-speed data, wideband data, and television circuits entering or leaving the MOSC area. This equipment is responsible for centralized quality control and maintenance on all data circuits, high-speed transferring and the monitoring and testing of operational circuits.
Whenever high-rate image data requiring no processing is downlinked, it is routed directly from the communications interface equipment to special display equipment in the experiments support area for real-time display/hard-copy. Otherwise, all real-time experiments data are routed through the CP to the MOCC.

Physical Description—Communications interface equipment includes the following:

A. High-speed data and wideband data transfer and test equipment provides facility to test, transfer, and maintain the quality of these circuits within the equipment group. This equipment includes test bays, patch bays, data control units, transfer switching equipment, checkout equipment, line driver-terminator equipment, and modems (modulator-demodulators).

B. Audio patch and test equipment provides monitoring, testing, patching, and matching of audio line entering or leaving the MOSC.

C. Teletype patch and test equipment provides monitoring, testing, patching, and maintenance of the quality of the teletype circuits entering or leaving the MOSC.

3.1.5.1.2 Mission Analysis and Planning Equipment Group

Mission analysis and planning equipment group (MAPEG) encompasses tasks performed from any mission concept through mission termination and evaluation of mission results. The MAPEG participates in the mission planning functions through all phases of mission design, mission operations planning, and mission conduct.

MAPEG is required to develop preliminary reference mission design, mission operations plans, and planning in support of actual mission operations. MAPEG includes a display/control subsystem which provides the MAP team with an interactive information capability with the MOCC. The MOCC provides the MAP team with the computational capability required for trajectory planning and analysis, consumables planning, mission scheduling, crew scheduling, resource utilization planning, logistics and inventory management, and experiment integration and scheduling.
**Requirements**—Provide the MAP team with the capability to utilize the MOCC in the mission analysis and planning function. Provide an interactive loop between the MAP team and the MOCC so that they can, for example, initiate trajectory processing for upcoming flight and/or maneuvers. Provide display/control terminals (consoles) for flight crew activity planning, mission design, trajectory planning and analysis, experiment planning, resource utilization planning, and logistics inventory control.

**Functional Description**—The MAP D/C terminals (consoles) are basically the same. Each has a CRT monitor and keyboard from which MOCC actions can be initiated and information can be displayed from storage or processing functions. Each display terminal has an alphanumeric and graphic data display capability. The keyboard is interactive with the monitor so that messages can be composed and edited before entry to the MOCC. The manual entry device is an alphanumeric keyboard to satisfy the flexibility requirement of the mission planning functions. Capability is provided by the MOCC for callup of pertinent mission information required by MAP team for mission planning continuity.

The MAP DC/E provides the MAP team with an input/output interface with the MOCC. The MOCC provides the MAP team with computation and processing capabilities for mission analysis and planning in the areas of mission design and simulation planning, trajectory and maneuver scheduling, Space Station consumables and resupply inventory management, resource utilization planning, crew training and rotation scheduling, mission timeline development, logging vehicle and mission constraints, experiments integration planning, and logistics flight planning.

**Physical Description**—The MAP D/CE consists of six display terminals each having a CRT monitor and an alphanumeric keyboard MED. The majority of the MAP functions are not real-time mission related and can be managed in a decentralized manner, i.e., these display terminals could be located in offices. Floor space requirements can be met by placing these terminals on desks or tables.
3.1.5.1.3 Logistics Support Equipment Group
Logistics Support Equipment Group (LSEG) encompasses tasks performed in support of logistics ground operations and necessary flight operations interfaces. This equipment is located in the MOSC FOSR of the MSOB. Definition of the LSEG is TBD.

3.1.5.1.4 Experiment Support Equipment Group
The experiment support equipment group (ESEG) includes the experiment support area facilities and equipment necessary to provide experiment operational support and data collection; real-time experiment data preprocessing, storage, and distribution; experiment monitoring, planning and coordination; and experiment data analysis. These experiment support activities will require the following MOSC and experiment support equipment: experiment support D/CE; mission operational computer complex; communication processor; and communications interface equipment.

The experiments/support D/CE provides experiment PI's and their teams with monitor and control capability via console-mounted CRT-type displays and flexible-entry devices. This equipment provides for the retrieval of experiment data and operational data pertinent to the experiment support requirements and provides update initiate capability for experiment control as required.

The ESEG also utilizes the CP, CIE, and the MOCC.

Real-time experiment data downlinked from the Space Station, together with Space Station and FPE status data are input to the CP via the CIE. The CP will perform standard preprocessing of these data to include quality checking, time tagging, merging of required status data (including Space Station state vector), calibration of data, and sorting by FPE and eventual user.

The MOCC receives (TBD) experiment data from the CP and inputs from the experiment controllers in the control room. It performs display processing for on-line experiment controllers, scientific data processing, and experiment housekeeping data processing as required to assess the quality of the
experiment data, ascertain the status of the experiments module, and assist in on-line planning and coordination with the onboard experimenters. Processing for real-time monitoring and command/control may be required for detached free-flying astronomy FPE's.

The MOCC also provides the computational support required to manage the EDB, where all real-time experiment data are logged.

At times, high-rate image data are routed directly from the CIE to special equipment in the experiments support D/CE where it is hardcopied and displayed.

**Requirements**—Provide display/control (D/C) capabilities required for on-line support of the Space Station Program experiments. These D/C requirements can be divided into the following categories: display request, local program control, coordination of experiment operations, experiment monitoring, and experiment commanding.

**Functional Description**—The equipment consists of all D/C equipment in the various rooms (TBD) comprising the experiment support area. The following D/C equipment is provided for the experiment control room:

A. (TBD) identical, modular general purpose consoles.
B. (TBD) display request, command, and alphanumeric entry devices per console.
C. (TBD) general-purpose console and group video displays.
D. FPE-unique D/C equipment (TBD).
E. Associated interface and full vector display-generation equipment.

The D/C equipment required for the (TBD) experiment analysis rooms consists of a different mix of the above equipment types. In these rooms the predominant means of equipment utilization entails the semipermanent dedication of general-purpose D/CE to specific purposes. Emphasis is on monitoring and special equipment, and no command entry devices are required. A wide utilization of MOCC peripherals greatly supplements the D/CE in the analysis rooms.

**Physical Description**—TBD
3.1.5.2 Crew Accommodations Group
The equipment in this group, including that identified as GSE, will provide for the accommodations of the flight crew and other key personnel during final preparations for flight. This equipment will all be provided and maintained by NASA. Though not provided by the Space Station, the requirements resulting from the study are listed here for identification purposes.

The crew accommodations group equipment will support the following functions:

A. Line-in accommodations and separate isolation for two groups of crew personnel each in final preparation for space flight and two supporting personnel assigned to each group.

B. Physical restriction of final preparation flight crew members in their inter-personal contacts with medically unscreened individuals.

C. Debriefing and observation of flight crew personnel just returned from orbit. An isolation period may still be required when the crew mans the Space Station, but the trend is away from isolation.

D. Continuation of flight crew training when in this facility.

E. Continuation of flight crew physical fitness.

F. Dining and dietary management for flight crew and support personnel.

G. Recreational facilities for flight crew personnel in final preparation for space flight.

H. Medical and laboratory services for flight crew personnel.

3.1.5.3 Simulation and Training Equipment Group
The simulation and training equipment is to be developed, operated and maintained by NASA. This includes all crew training equipment, computers, simulation equipment, software and associated GSE and test equipment.

These descriptions are included in this document for identification purposes only and represents candidate functional equipment for this purpose.
The primary function of the Simulation and Training Equipment Group (STEG) is to perform simulation training of MOSC and flight personnel who have critical on-line control responsibility. Additional functions such as ground data simulation and procedure development have been assigned to this system because of the similarity of equipment required for these functions to that required for training. The STEG functions include: training of onboard control personnel for the Space Station; training of onboard experiment control personnel; training of FOSR personnel; generation of simulated downlink data for ground system checkout; support of simulations conducted onboard the orbiting Space Station; support of flight operations procedures evaluation and development; and possible supplementary display control (D/C) and computational support for the FOSR and MOCC during infrequent periods of intensive support for the Space Station.

The STEG consists of the following separate but integrable command and experiment control simulators with their associated computer subsystems, D/C subsystems, and data generation equipment located in the flight crew training building:

A. The Space Station command simulator (SSCS) provides training for Space Station command center and Space Station auxiliary command center personnel. It also supports simulations conducted in the FOSR and orbiting Space Station. This equipment also supplies additional computational and D/C capability to supplement that available in the MOCC and FOSR periods of high-level ground support of the Space Station.

B. The experiments control simulator provides training of onboard experiment control personnel and provides data for simulation training of ground-based experiments monitor and control personnel and also supports SSCS and FOSR simulations.

C. The FOSR simulation group provides training of FOSR personnel primarily by means of joint simulations with the SSCS and experiments control simulator.
The typical GSE required for this function are described in Sections 3.1.6.1 through 3.1.6.3 of this volume.

3.1.5.4 Ground Network
The ground network to provide a two-way data link to the Space Station will be provided and maintained by NASA. The existing capability is adequate to support the Space Station Program.

3.1.5.5 Inventory Control
GSE required for support of inventory control operations includes special loading, protection, conditioning, and handling equipment necessary for the resupply cargo. Definition of this equipment is TBD.

3.1.5.6 Flight Integration Tool
Flight Integration Tool (FIT) GSE includes all equipment required to support the FIT were it to be installed at KSC. The applicable requirements are as follows:

A. Provide a source of electrical power for the FIT power system.
B. Provide external cooling to remove heat generated by the onboard equipment.
C. Provide conditioned air to support onboard personnel.
D. Provide hardline transmitting and receiving capability for the onboard communications subsystem.
E. Provide external control and monitoring capability for safety critical onboard systems and for operation of the GSE.
F. Provide for personnel access to the interior of the FIT.
G. Provide for Logistic module and experiment module interface verification.

The ground support requirements of the FIT are accommodated by items of equipment identical to the Space Station GSE. These items described in Section 2.1.1 of this document.
3.1.6 Simulation and Training Equipment Group

The simulation and training equipment is to be developed, operated and maintained by NASA. This includes all crew training equipment, computers, simulation equipment, software and associated GSE and test equipment.

These descriptions are included in this document for identification purposes only and represent candidate functional equipment for this purpose.

The primary function of the simulation and training equipment group (STEG) is to perform simulation training of mission management and flight personnel who have critical on-line control responsibility. Additional functions such as ground data simulation and procedure development have been assigned to this system because of the similarity of equipment required for these functions to that required for training. The STEG functions include: training of onboard control personnel for the Space Station; training of onboard experiment control personnel; training of flight operations support room (FOSR) personnel; generation of simulated downlink data for ground system checkout; support of simulations conducted onboard the orbiting Space Station; support of flight operations procedures evaluation and development; and possible supplementary D/C and computational support for the FOSR and MOCC during infrequent periods of intensive support for the Space Station.

The STEG consists of separate but integrable command and experiment control simulators with their associated computer subsystems, D/C subsystems, and data generation equipment as follows:

A. The Space Station command simulator (SSCS) provides training for Space Station command center and Space Station auxiliary command center personnel as shown in Figure 3-22. It also supports simulations conducted in the FOSR and orbiting Space Station. This equipment also supplies additional computational and D/C capability to supplement that available in the MOCC and FOSR periods of high-level ground support of the Space Station.

B. The experiments control simulator provides training of onboard experiment control personnel and provides data for simulation
training of ground-based experiments monitor and control personnel
and also supports SSCS and FOSR simulations.

C. The FOSR Simulation Group provides training of FOSR personnel
primarily by means of joint simulations with the SSCS and experi-
ments control simulator.

3.1.6.1 Space Station Command Simulator
The SSCS provides the capability to train Space Station command center
(SSCC) and Space Station auxiliary command center (SSACC) personnel in
Space Station operation and control activities utilizing the onboard data
management system. It is a fixed-based simulator which provides realistic
data system responsiveness and aural and visual effect simulation as
required for training. It has the capability to perform training in SSCC and
SSACC operations; support simulation training of FOSR personnel; support
training simulations conducted onboard the orbiting Space Station; perform
both independent simulations and joint simulations with the ECS and FOSR;
and support flight procedure development and evaluation.

The SSCS consists of the following equipment:

A. Trainee D/C equipment provides replica onboard consoles, interior
mockups, and computer interface equipment for SSCC and SSACC
personnel training.

B. Simulation instructor D/CE provides consoles and display and
control interfaces with the simulation data generation computer for
controlling the simulation exercises, controlling simulation data
generation, and evaluating trainee performance.

C. Simulation data generation equipment generates simulation data
using a digital computer complex and provides visual and aural
sensory effects required for training.

D. Ground version Space Station data equipment provides a functionally
duplicate version of the DMS multiprocessor, guidance, navigation,
and control (GNC) computer, and data terminals for training SSCC
personnel in data system and software operation.

The SSCC utilizes approximately 10 instructor consoles, a multiprocessor
for simulated data generation, and functional duplicate or actual onboard
DMS multiprocessor and equipment for visual and aural effects generation, SSCC and SSACC mockups, and D/CE adequate for both trainee and instructor console requirements.

3.1.6.1.1 Space Station Command Simulator Trainee Display/Control Equipment

Requirements—Provide realistic, responsive operational interfaces for training SSCC and SSACC personnel in the use of the onboard systems and for development and evaluation of onboard procedures.

Functional Description—The trainee D/CE for the SSCS provides trainee stations and computer interface equipment. It is a fixed-base unit with motion cues provided only by astrionics display and external visual displays. Wherever possible, elements of the trainee D/C subsystem are also used by the simulation instruction D/CE. The following equipment comprises the trainee D/CE:

A. Trainee consoles are provided to represent those available in the SSCC and SSACC. Placement, appearance, feel, operation, and response of all controls accurately represent those onboard. Video displays are of the same type and resolution as those used onboard. All displays have accurate response times if the times are above a minimum sensory threshold. Although operationally similar to those onboard the Space Station, the displays and controls may be lesser-cost versions without the stringent reliability and environmental qualifications of flight hardware. Trainee control inputs and nonvideo display data are buffered by the simulation data generation computer to allow faulting of trainee D/C subsystem elements.

B. Trainee interior mockups of the SSCC and SSACC are provided, and contain replica seats, consoles, and mockup equipment racks. No provision for repair training of data system element is included in these interior mockups. The mockups contain accurate representations of onboard lighting systems, provision for attachment of any virtual imaging systems required, and provisions for attachment of suit pressurization hoses.
Video display generation equipment converts computer word display data to video display form. The characteristics of this trainee video display are the same as for the system used onboard the Space Station.

A video switching matrix is provided for distribution of video displays to the trainee consoles.

A computer input multiplexer is provided to accept switch and keyboard inputs from the trainee consoles. It interfaces the Simulation Data Generation Computer (SDGC), which passes the data on to the ground version DMS computer.

Indicator and digital display driving equipment is used to drive binary indicator devices on the trainee consoles.

**3.1.6.1.2 Space Station Command Simulator Simulation Instructor Display/Control Equipment**

**Requirements**—Provide appropriate displays and controls to allow simulation instructor personnel to control simulation exercises and evaluate trainee performance.

**Functional Description**—The simulation instructor D/CE provides man/machine interfaces and equipment to permit communication between the simulation instructors and the trainees, SDGC, simulation generation equipment and other simulation equipment. This equipment may also serve as additional display/control capability to supplement that available in the FOSR for the infrequent periods of high-level ground support of the Space Station which can be identified. The simulation instructor D/CE uses elements in common with that provided for the trainee D/CE wherever possible to reduce total system cost. The instructor D/CE includes the following elements:

A. Consoles provide the man/machine interface at which simulation activities are directed. Controls and displays are available to permit the following functions to be performed: simulation system configuration; trainee performance monitoring; simulation procedure control; simulated systems control; simulated system faulting; simulation data logging; simulation equipment control; simulation
equipment fault isolation; operation of instructional data playback equipment; support of simulations performed onboard the orbiting Space Station; and support of FOSR simulations. Displays and controls are primarily of a generalized, readily configurable nature to allow evolution of simulator capability without downtime for hardware modification.

B. Video display generation equipment converts computer language output from the SDGC to video for display to simulation instructors along with appropriate background information. This display equipment is compatible with that used for trainee display so as to allow trainee repeater displays to be shown at any simulation instructor's CRT.

C. A video switching matrix is provided to distribute closed-circuit TV and, if appropriate, to distribute simulation control displays and repeater trainee displays.

D. Computer input multiplexer encodes and transfers to the SDGC all simulation instructor computer entry switch actions.

E. Indicator and digital display driving equipment is used to drive binary indicator devices on the simulation instructor console.

F. Group displays, in the form of overhead monitors and digital displays, are provided to display information required by all simulation instructors.

3.1.6.1.3 Space Station Command Simulator Simulation Data Generation Equipment

Requirements—Generate the data required to train Space Station command personnel, exercise software in the ground version computer system, support simulations onboard the orbiting Space Station, and support FOSR simulations.

Functional Description—The simulation data generation equipment (SDGE) consists of the following equipment:

A. Simulation Data Generation Computer (SDGC) performs modeling, maintains equations of motion, and drives visual, aural, and communications simulation equipment. It also drives displays for
and accepts control inputs from the simulation instructor consoles, performs simulation system diagnostics, generates simulation data tapes and performs analyses of trainee performance. The SDGC for the SSCS is basically compatible with the SDGC's for the experiment simulator and uses common software modules wherever possible. The SDGC complex consists of a multiprocessor that is capable of efficient high-volume I/O.

B. Interface equipment interfaces the SDGC with the ground-version Space Station data system, visual and sound simulation drive equipment, other simulators, and the communications processor. Operations performed include line driving, voltage level conversion, data buffering, A/D and D/A conversion, serial-to-parallel and parallel-to-serial conversion, digital-to-synchro conversion, and servo driving.

C. Aural simulation equipment generates sounds associated with normal and emergency situations onboard the Space Station in response to commands from the SDGE digital computer.

D. Visual simulation equipment generates external visual displays required for training in specific onboard activities, such as rendezvous and platform alignment. The equipment for various visual display requirements is controlled by either the SDGC or by analog control equipment directly from Space Station trainee manual controls, depending on the response times required. Equipment such as models with appropriate control, virtual imaging systems, television equipment, and optical mixing systems are included.

E. Voice communications simulation equipment degrades voice quality to permit simulation of communication with other vehicles and the ground data management system (GDMS). This equipment is controlled by the SDGE digital computer.

F. Data logging equipment records data required for analysis of trainee and simulation system performance, and consists of equipment such as digital magnetic tape transports, X-T recorders, X-Y recorders, event recorders, and voice recorders.

G. Instructional data playback equipment provides video, sound, and digital data for familiarization and procedure training. This equipment includes digital tape transports, film-to-TV display
generation equipment, and voice tape transports. The equipment is capable of synchronized operation under the control of the SDGC.

**Physical Description**—The simulation data generation equipment requires an area approximately TBD square feet in area with provision for underfloor cabling and air conditioning. This area is physically separate from the area allotted for trainee and simulation instructor consoles to minimize equipment noise levels in that area.

3.1.6.1.4 Space Station Command Simulator Ground Version Data Equipment

**Requirements**—Provide the capability to execute flight software in the SSCS and to simulate the interaction of the several onboard computers and data terminals on the Space Station data bus.

**Functional Description**—The Space Station ground version data equipment can accept data in the same form as is supplied by onboard data acquisition units and other elements interfacing the various data terminals; transmit the data on the data bus in the onboard data formats; perform DMS multiprocessor and GNC computer processing and I/O functions in real time; and accept and route all computer outputs. The capability to perform these functions is incorporated in the SSCS to enable the trainees to acquire a detailed working knowledge of Space Station data system and software operation. Functional duplication of the onboard data subsystem is not to be attempted beyond the level of the data terminals; the functioning of remote digital acquisition unit (RDAU) and Space Station subsystems is modeled in software in the SSCS simulation data generation computer. The SSCS ground version data subsystem contains the following equipment:

A. The Ground version onboard computer system performs I/O and processing functions of the DMS multiprocessor and GNC computer. These systems are able to execute onboard programs on a line-for-line coding basis in real time. This capability is achieved by use of hardware functionally duplicate computers or commercially available computers configured to allow interpretive simulation. Included in this subsystem are computer peripherals similar to
those available onboard the Space Station. Provision for interaction of these computers with the experiments multiprocessor is provided by allowing the experiment control simulator data bus to be attached to the SSCS data bus.

B. Data bus accepts and routes all data to and from the data terminals of the ground version Space Station data system. May be connected to the experiment control simulator data bus for joint simulations of the experiment control simulator and the Space Station command simulator.

C. Data terminals provide appropriate interfaces between the data bus and the simulated onboard data acquisition subsystems provided by the simulation data generation equipment. These data terminals are capable of receiving data from and outputting data to both the data bus and the simulated data acquisition subsystems.

3.1.6.2 Experiments Control Simulation Group

The experiments control simulation group (ECSG) provides the capability to train onboard experiments control personnel in the operation of selected experiments and the use of the onboard experiment multiprocessor, to train ground-based experiments control personnel at their consoles, and to check out onboard experiment multiprocessor software.

Effective working relationships and interfaces between Space Station and MMC personnel and between the ground-based principal investigators and their onboard counterparts are developed through use of the ECSG. This simulation equipment is separate from that used to train Space Station control personnel because of the conflicts in the requirements for training experiments control personnel, who perform their tasks during nominal flight conditions (major vehicle systems are functioning properly), and the requirements for training Space Station control personnel, who are most active during Space Station maneuvers, rendezvous, and docking of external vehicles and major Space Station subsystem malfunctions. The two groups of simulation equipment are, however, able to conduct joint interactive simulations for training in those activities which require teamwork between the onboard operational and experiment control personnel. These joint simulations can also be used to validate the software interactions of the
onboard experiment multiprocessor and the onboard DMS multiprocessor. The ECSG consists of the following elements.

A. Onboard experiment control trainee D/C equipment provides mockups of selected experiments control man/machine interfaces with appropriate display-driving and computer input equipment. Trainee D/C stations are provided for only those experiments which have a complex control interface, require a high level of training for motor skills, or require experience in real-time evaluation of experiment data.

B. ECSG simulation data generation equipment generates responsive simulation data to exercise trainees at experiment control area consoles and at Space Station experiments control mockups; generates visual effects; drives the ground version experiments multiprocessor; and serves as a common communication point among the two groups of trainees and the instructor personnel.

C. Simulation instructor D/C equipment provides a capability for simulation instructors to control the simulation exercise, control the generation of simulation data, and evaluate trainee performance.

D. Ground version Space Station experiment multiprocessor provides the capability to train Space Station experiment personnel in the operation of the Space Station experiment DMS and to check out Space Station experiments processing software in an interactive environment.

E. Experiments control group ground-based experiments control and monitoring personnel are trained at excess consoles provided in the experiments control area. The ECSG simulation data generation subsystem supplies simulation data to the communications processor and the MOCC as required to exercise trainees.

The experiments control simulation group consists of a duplicate or functional duplicate of the onboard experiment multiprocessor, a simulation data generation computer, visual and aural simulation equipment, trainee station mockups for those experiments requiring simulation training, a number of instructor consoles as required for the trainee station mockups, and an interface with the communications processor that is adequate for driving ground-based experiment console displays.
3.1.6.2.1 Onboard Experiments Control Trainee Display/Control Equipment

**Requirements**—Provide realistic interactive interfaces through which experiments personnel can be trained in the operation of onboard experiment subsystems.

**Functional Description**—Trainee D/C equipment is provided for those experiment systems using the Space Station DMS which have complex control interfaces, require a high level of motor skill, or require experience in real-time evaluation of scientific data or subsystem performance to ensure proper operation. The trainee D/C subsystem consists of the following equipment:

A. Trainee consoles contain a replica control interface with controls of the same arrangement, appearance, feel, and operation as the actual controls and displays of the same type and resolution onboard the Space Station. Controls and displays for the control activities to be simulated behave operationally and have realistic response time and damping characteristics.

B. Video display generation equipment converts computer word outputs to video having the same characteristics as those used by Space Station experimenters for display to trainees.

C. Video switching matrix is used to distribute video displays compatible with the onboard display techniques. This equipment is capable of distributing closed circuit TV and can be used in common by the simulation instructor D/C subsystem.

D. Display driving equipment drives trainee consoles indicators and digital displays.

E. Computer input multiplexer inputs trainee control entries into the simulation data generation computer.

**Physical Description**—Details of the onboard ECSG Space Station trainee D/C equipment are highly dependent on the types and numbers of onboard experiment control interfaces that are developed and that require simulation training.
3.1.6.2.2 Experiments Control Simulator Group Simulation Data Generation Equipment

**Requirements**—Provide simulation data to exercise trainees at Space Station experiment control mockups and experiments control room consoles, and in the use of the ground version Space Station experiment multiprocessor and MOCC real-time experiments software. Generate any visual effects required for experiment control training.

**Functional Description**—The simulation data generation equipment (SDGE) for the ECSG consists of the following elements:

A. The SDGC performs experiment system modeling, generates appropriate scientific data for input to the onboard experiment multiprocessor, maintains equations of motion and drives visual effect simulation equipment. It also drives the simulation instructor display/control equipment, performs simulation system diagnostics, generates simulation data tapes, and performs analyses of trainee performance. The SDGC for the ECSG is software-compatible with those for other simulation systems to allow common software modules to be used among the several systems and to allow initial software debug to be performed in any of several computers.

B. Interface equipment interfaces standard digital I/O equipment to the ground version experiment processor, the communications processor, and simulation visual drive equipment.

C. Visual simulation equipment generates external visual displays as required for training in specific experiment control operations. The visual display equipment for a given experiment display may be driven either by the simulation data generation computer or by direct analog control devices, depending on the response time required. Equipment such as modules with appropriate control, movie projectors, virtual imaging equipment, television equipment, and optical mixing equipment is included.

D. Data logging equipment records data required for analysis of trainee and simulation system performance. It consists of equipment such as digital magnetic tape transports, X-T recorders, X-Y recorders, event recorders, and voice recorders.
E. Instructional data playback equipment provides video, sound, and
digital data for familiarization and procedures training. This
equipment includes digital tape transports, film-to-TV display
generation equipment, and voice tape transports. The equipment
is capable of synchronized operation under the control of the SDGC.

Physical Description—The SDGE consists of a computer system with
appropriate peripherals, external visual display generation models, and
standard equipment racks housing interface equipment, analog control equip-
ment and a visual display drive electronics.

3.1.6.2.3 Experiments Control Simulator Group Simulation Instructor
Display/Control Equipment

Requirements—Provide appropriate displays and controls to allow simulation
instructor personnel to control simulation exercises and evaluate trainee
performance.

Functional Description—The simulation instructor D/C equipment provides
man/machine interfaces and equipment to permit communication between the
simulation instructors and the Space Station experiment control and experi-
ment control room trainees, SDGC, simulation data generation equipment,
and other simulation systems. This equipment uses elements in common
with that provided for the trainee D/C subsystems wherever possible to
reduce total system cost, and includes the following elements:

A. Consoles provide the man/machine interface at which simulation
activities will be directed. Controls and displays are available to
permit the following functions to be performed: simulation system
configuration, trainee performance monitoring, simulation reset,
step ahead, fast-time and freeze, simulated system control,
simulated system, sensor, telemetry faulting, trainee D/C sub-
system faulting, simulation data logging, data recording for simu-
lation reset, simulation equipment control, simulation equipment
fault isolation, and operation of instructional data playback
equipment.
Displays and controls are primarily of a generalized, readily reconfigurable nature to allow evolution of simulator capability without downtime for hardware modification.

B. Video display generation equipment converts computer language output from the SDGC to video for display to simulation instructors along with appropriate background information. This display equipment is compatible with that used for trainee displays to allow trainee repeater displays to be shown at any instructor CRT.

C. Video switching matrix is provided to distribute closed circuit TV and, if appropriate, to distribute simulation control displays and repeater trainee displays.

D. Computer input multiplexer encodes and transfers to the SDGC all simulation instructor computer entry switch actions.

E. Indicator and digital display driver event displays and digital displays that are unsuitable for CRT presentation are driven by this equipment.

F. Group displays are provided to display information required by all simulation instructors in common.

3.1.6.2.4 Experiments Control Simulator Group Ground Version Space Station Experiment Data Equipment

Requirements—Provide the capability to execute Space Station experiment software to train onboard experiments control personnel in checking out experiments software and validating experiments multiprocessor/DMS multiprocessor software compatibility.

Functional Description—The ground version Space Station experiments data equipment is able to accept experiment subsystem data, experiment subsystem control, and scientific data as would be supplied to the Space Station data bus data terminals, transmit the data on the data bus, perform all experiments multiprocessor processing and I/O functions in real time, and accept and route all computer-to-data-bus outputs. The capability to perform these functions is incorporated in the ECSG to enable trainees to acquire a detailed working knowledge of Space Station experiments multiprocessor control functions and software. The various small dedicated experiment
processors are for the most part modeled in software in the SDGC. Functional duplication of the experiments data subsystem is not attempted beyond the level of the data terminals; the functioning of RADU's and experiment subsystems is modeled in software in the ECSS simulation data generation computer. The ECSG ground version data subsystem contains the following equipment:

A. Ground version experiments multiprocessor performs all I/O and processing functions of the Space Station experiments multiprocessor on a line-for-line basis in real time. This capability is achieved by use of functionally duplicate computers or a commercially available computer system configured to allow interpretive simulation. Included in this subsystem are computer peripherals similar to those available onboard the Space Station. Provision for interaction of these computers with the Space Station DMS multiprocessor is provided by allowing the experiment control simulator data bus to be attached to the SSCS data bus.

B. Data bus accepts and routes all data to and from the data terminals of the ground version Space Station data system. It may be connected to the ECSG data bus for joint simulations of the experiments control simulator and the Space Station command simulator.

C. Data terminals provide appropriate interfaces between the data bus and the simulated onboard data acquisition units provided by the simulation data generation equipment. These data terminals are capable of receiving data from and outputting data to both the data bus and the simulated data acquisition subsystems.

3.1.6.3 Flight Operations Support Room Simulation Group

Requirements—Provide the capability to perform simulation training of flight operations support room personnel, check out real-time flight support software, and check out ground DMS systems.

Functional Description—The FOSR simulation group (FSG) primarily utilizes existing ground support systems and flight personnel training simulators to exercise FOSR personnel and MOCC software. A fully dedicated simulation
capability is not required for the FOSR because of the low level of continuing support that has been identified for the largely autonomous manned Space Station and the primarily repetitive nature of the tasks associated to FOSR personnel. The FOSR and MMC on-line simulations are conducted frequently before launch of the Space Station, as the initial MOCC software and ground DMS hardware are being validated, during initial ground personnel training, and while flight procedures are being developed. After launch of the Space Station, DMS hardware is continually checked out during operations and much of the FOSR activities will be amenable to on-the-job training. Thus, FOSR simulations fall off in frequency after Space Station launch and manning.

The need for periodically validating improved versions of the continually updated MOCC software in its actual operational environment and conducting a low level of simulation training of FOSR personnel is met by the limited FOSR simulation system defined here.

The FOSR simulation system is capable of several modes of simulation, as follows:

A. Full FOSR Joint Simulation—All FOSR personnel, the MOCC, and the communications processor are connected to one or more of the flight personnel simulators for fully interactive simulations utilizing exact flight support software. This mode is used for flight support software checkout and FOSR team training. A simulation supervisor within the FOSR controls the conduct of such joint simulations. A communications configuration officer in addition to the one participating in the simulation maintains contact with the Space Station and performs his communication task utilizing a second CPU in the MOCC.

B. Partial FOSR Joint Simulation—Selected FOSR personnel sit at excess FOSR consoles and participate in interactive simulations with personnel in the flight personnel simulators. The communications processor merges suitably tagged simulation data with actual downlinked data. The MOCC processes and displays these data to those excess consoles which have been designated as simulation consoles. This mode is used for individual or small group training and procedure development.
C. Partial FOSR Separate Simulation—Individuals sitting at excess FOSR consoles can request input of selected data from magnetic tapes by MOCC controllers, communications processor controllers, or the FOSR simulation supervisor. This mode is used for familiarization and procedures training.

Since the FOSR simulation system utilizes, for the most part, existing flight support and simulation systems, it levies on these systems a number of requirements, as follows:

A. FOSR
1. Additional consoles available in the FOSR for use in simulations while full on-line support is being performed at FOSR consoles.
2. Fully reconfigurable FOSR consoles so that any excess console may be used for training in any FOSR support function.
3. Consoles which may be individually driven by any MOCC CPU. A configuration control officer must remain in contact with the Space Station during Mode 1 simulations. He utilizes a CPU separate from that being used for simulations, since this CPU may be loaded with software that is not fully checked out and may be prone to failure. Therefore, any one of the FOSR consoles must be capable of being interfaced with any of the MOCC CPU's while the rest are conducting Mode 1 simulations.
4. A simulation supervisor console must be provided in the FOSR which will be capable of displaying information from both the FOSR and the crew training simulators.

B. MOCC
1. During selected simulations, the MOCC must be capable of accepting merged operational and simulation data and simultaneously performing processing of both operational and simulation data of the same types, driving both operational and simulation console displays, and generation of both operational and simulation commands.
2. The MOCC must be capable of performing simulations in one or more CPU's and simultaneously performing communications configuration for actual vehicles and the network switch actions in another CPU.
3. The MOCC must be able to perform FOSR simulation supervisor display/control processing within the same CPU that will be conducting simulations.

C. Communications Processor
1. The communications processor must be capable of receiving data from the training simulators, magnetic tapes, and operational data sources, merging it for use by FOSR operational and simulation and operational commands from the MOCC for routing to appropriate simulation and operational users.
2. The communications processor must be capable of performing communications configuration of actual network elements and required routing of actual data utilizing a CPU separate from the one(s) participating in simulations.

D. Data Modem Equipment
1. The data modem equipment interfacing the communications processor should be capable of recording downlinked systems data with appropriate timing during simulations for analysis after the termination of the simulation.

E. MSFN and DRSS
The MSFN and DRSS communications links between space vehicles and the MMC should operate essentially as "bent pipes"—transferring data to and from the Space Station in exactly the same form as originated in the Space Station or communications processor. If the data are altered in any way at intermediate points such as GSFC or DRSS ground terminals, the FOSR simulation system may require a dedicated computer system to make compatible the input/output of the communications processor and the training simulators.

F. Training Simulators
1. The training simulator simulation instructors acting as GSFC, MSFN sites, and DRSS ground terminals as seen by vehicle trainees must also be able to act as these stations, as will be seen by the FOSR.
2. The training simulators must generate MSFN tracking data in the same form as would be accepted by the communications processor.
3. Display/control communication from the training simulators to the FOSR to allow the FOSR simulation supervisor to maintain cognizance of simulator activity and to maintain control of the exercise.

4. The Space Station should be capable of operation for periods from 4 to 8 hours in length with only communications configuration support from the ground DMS while Mode 1 simulations will be in progress.

Physical Description—The FOSR simulation group consists almost entirely of subsystems utilized by other MMC systems. Therefore, the FOSR simulation group imposes few new physical requirements upon the center. The FOSR simulation supervisor console is one of the few new elements required. It should be a four-bay console with displays available from both the FOSR and the flight crew simulators who will participate in joint simulations. The console should be in an area that will be aurally isolated from the FOSR to allow voice coordination of simulation activity and will provide full visibility of the FOSR consoles. Subflooring should be available to allow cabling access.

3.1.7 Test Article GSE
Space Station Project system-level test articles requiring ground support are the functional model (FM) and the flight integration tool (FIT). This section defines the GSE associated with these items.

3.1.7.1 Functional Model
The functional model is a "breadboard" development fixture upon which are mounted various elements of the Space Station subsystems. The unit is utilized for development and integration of Space Station electrical subsystems, for Space Station/GSE interfaces, and for preliminary software development. The functional model is located at the Space Station engineering and manufacturing facility.

Equipment required to support the functional model consists of selected items of the Station GSE listed in Table 3-2. The development hardware required for the FM will be obtained from the development test hardware
Table 3-2  
FUNCTIONAL MODEL GSE

<table>
<thead>
<tr>
<th>Item</th>
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<tbody>
<tr>
<td>Integrated Checkout Equipment</td>
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<tr>
<td>Digital Data Terminal</td>
</tr>
<tr>
<td>Control and Display Console</td>
</tr>
<tr>
<td>RF Interface Unit</td>
</tr>
<tr>
<td>Communications Ground Station</td>
</tr>
<tr>
<td>Data Processing Unit</td>
</tr>
<tr>
<td>Magnetic Tape Recording Unit</td>
</tr>
<tr>
<td>Ground Power Source</td>
</tr>
<tr>
<td>Electrical Load Unit</td>
</tr>
<tr>
<td>Interface Simulation Group</td>
</tr>
<tr>
<td>Timing Reference Unit</td>
</tr>
<tr>
<td>Ground Measurement and Switching Unit</td>
</tr>
<tr>
<td>Metabolic Simulator</td>
</tr>
<tr>
<td>Electrical Distribution Group</td>
</tr>
</tbody>
</table>

each unit. No specific new hardware will be required to support the FM. Definitions of this GSE are contained in the Space Station GSE, Sections 3.1.1.1 and 3.1.3.3.

3.1.7.2 Flight Integration Tool

The flight integration tool (FIT) is structurally like the flight configuration Space Station. It contains a full complement of operational subsystem equipment except for certain items such as the solar array which cannot be installed due to physical and operational constraints. The unit (Figure 3-23) is used for final subsystem integration, design verification, software development, and for verification of the Space Station interfaces with the production ground checkout, servicing, and handling equipment at the manufacturing location. Following these initial activities, it is maintained as a training aid and as an integration fixture for subsystems, experiments, and modifications which are designed for on-orbit installation.

During the manufacturing site operations the FIT is supported by the Station GSE previously described in Subsection 3.1.1. There is no additional GSE required during this period.

Upon completion of the factory integration activities, the FIT is installed in a permanent facility in which it performs the continuing integration and mission support role. Long-term support is provided by selected items of flight vehicle GSE following launch of the Space Station. See subsection 2.1.2.2 in mission management for definition of functions and GSE required for support of the 10-year program.
3.2 EXPERIMENT SUPPORT OPERATIONS

GSE defined in this section includes that equipment required to support experiment and experiment module operations at KSC. The GSE includes that which is employed in the operations and checkout area and the Launch Site Biological Laboratory (LSBL), as well as that which is used elsewhere at the launch site. The definitions included in this section contain certain departures from the Phase B study and are a reflection of the results of the KSC study.

3.2.1 Attached Experiment GSE

Attached experiment GSE includes that required for the following experiments accommodated in attached modules:

A. FPE A-4A 0.9M Narrow Field UV Telescope
B. FPE A-4B 0.3M Wide Field UV Telescope
C. FPE A-4C Small UV Survey Telescope
D. FPE A-5B Gamma Ray Telescope
E. FPE A-6 IR Telescope
F. FPE P-2BB Wake, Plasma, Wave Particle, Elect. Beam
G. FPE P-3 Cosmic Ray Physics Lab
H. FPE ES-1 Earth Observation Facility
I. FPE ES-1AA Earth Observation Sequential
J. FPE ES-1G Minimum Payload (CORE)
K. FPE C/N-1 Communications/Navigation Facility
L. FPE C/N-1A Communications/Navigation Subgroup A
M. FPE C/N-1B Communications/Navigation Subgroup B
N. FPE T-3B Manned Work Platform
O. FPE LS-1B Minimal Life Science Research Facility
P. FPE LS-1C Intermediate Life Science Research Facility
Q. FPE LS-1D Dedicated Life Science Research Facility

The elements of attached experiment module GSE are described as follows:

3.2.1.1 Onboard Checkout Subsystem Electrical Test and Checkout Set

Requirements — The OCS is functionally exercised and verified in all modes, including self-check operations, at all testing locations.
**Functional Description**—The OCS test and checkout set simulates the Space Station OCS to the extent practicable, and provides ground checkout equipment interfaces, as necessary, to augment the simulated Space Station OCS. Control and display capability required by the mechanical test and checkout set coolant system is also provided.

The OCS electrical test and checkout set has the capability of supporting the OCS in system level component testing. This is the same equipment used at the experiment payload integration center (EPIC) to perform integration testing when the experiment is assembled in the flight carrier. The test set is capable of functionally checking all flight hardware in the OCS. The following equipment is included in this test set:

A. The GSE adapter provides a data bus interface between the GSE and the OCS. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS to the GSE. The GSE simulates command and control functions of the Space Station.

B. The control and display unit provides the control and displays required to interface with the OCS and GSE. This unit is portable and can be used within a module.

C. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for testing and checkout.

D. The electrical test set provides the following:
   1. Processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Electrical equipment to simulate impedances and stimuli; monitor voltages, temperatures, and currents; and display outputs on digital devices and an oscilloscope.
   3. Electrical power required to test the OCS.

**Physical Description**—The electrical test and checkout set for the OCS subsystem is installed in standard racks requiring subfloor cooling. These racks are interconnected by a cable assembly installed in subfloor cableways. The racks are pallet-mounted to facilitate handling when moving them to different locations for testing airborne hardware.
The test and checkout set is the same basic equipment used for testing the experiment packages after installation at the EPIC. The requirements for this testing are as follows:

A. All items listed in A through D above.
B. Docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

This GSE will be packaged in five 2 by 2 by 6-ft standard racks and a portable container for the cable assembly.

3.2.1.2 Atmosphere Control Subsystem Electrical Test and Checkout Set

Requirements—During subsystem manufacturing tests, subsystem/flight carrier integration tests, and prelaunch and checkout tests at the launch site, the electrical performance of the atmosphere control subsystem (ACS) is functionally verified to conform with specification requirements. The OCS is used for checkout and testing to the greatest extent possible. Other requirements for stimuli, functions, response, measurements, etc., are to be provided.

Functional Description—The atmosphere control subsystem electrical test and checkout set has the capability of supporting the OCS in system level component testing. GSE and test tooling required at each site provide stimuli, simulate loads and other functions, provide monitoring and recording, and supplement the OCS, as required, to functionally check out all flight hardware. The following listed equipment is included as GSE for this subsystem:

A. The OCS adapter provides a two-way hardware digital interface between the OCS and the GSE. This adapter furnishes special stimuli for controlling and calibrating airborne equipment and allows integrated system testing by combining flight and ground capabilities for checkout, mounting, and control.
B. The control and display simulator provides the control and display required to interface with the OCS and GSE for checkout of the subsystem.
C. The electrical test set simulates selected impedances and stimuli; monitors voltages, temperatures, servosystems, pressures, levels, etc.; processes and displays telemetry digital signals on charts, oscilloscopes, etc.; and processes other checkout functions as required.

D. The cable assembly contains all cabling with connectors necessary to interconnect the airborne equipment with the GSE for integration testing and checkout.

E. The power supply interfaces with the electrical power subsystem to furnish electrical power to the ACS for integration testing and checkout.

Physical Description—Electrical GSE for this subsystem is installed in standard racks requiring subfloor cooling. These racks are interconnected by a cable assembly installed in subfloor cableways. Racks are pallet-mounted to facilitate handling when moved to different locations for testing airborne hardware.

Electrical GSE required for the ACS is packaged as follows:
A. Three racks—2 by 2 by 4 ft.
B. One power supply—2 by 2 by 4 ft.
C. Three portable containers for cable assembly—1 by 1 by 4 ft.

3.2.1.3 Control and Display Subsystem Electrical Test and Checkout Set

Requirements—During subsystem manufacturing tests, subsystem/flight carrier integration tests, and prelaunch and checkout tests at the launch site, the electrical performance of the control and display subsystem is functionally verified to conform with specification requirements. The OCS is used for checkout and testing to the greatest extent possible. Other requirements for stimuli, functions, response, measurements, etc., are to be provided.

Functional Description—Electrical GSE for the control and display subsystem has the capability of supporting the OCS in system level component testing. GSE and test tooling required at each site provide stimuli, simulate
loads and other functions, provide monitoring and recording, and supplement the OCS as required to functionally check out all flight hardware. The following listed equipment is included as GSE for this subsystem:

A. The OCS adapter provides a two-way hardware digital interface between the OCS and the GSE. This adapter furnishes special stimuli for controlling and calibrating airborne equipment and allows integrated system testing by combining flight a ground capabilities for checkout, monitoring, and controls.

B. The control and display simulator provides the control and display required to interface with the OCS and GSE for checkout of the subsystem.

C. The electrical test set simulates selected impedances and stimuli; monitors voltages, temperatures, servosystems, pressure levels; etc.; processes and displays telemetry digital signals on charts, oscilloscopes, etc.; and processes other checkout functions as required.

D. The cable assembly contains all cabling with connectors necessary to interconnect the airborne equipment with the GSE for integration testing and checkout.

E. The power supply interfaces with the electrical power subsystem to furnish electrical power to the control and display subsystem for integration testing and checkout.

Physical Description—Electrical GSE for the control and display subsystem is installed in standard racks requiring subfloor cooling. These racks are interconnected by a cable assembly installed in subfloor cableways. Racks are pallet-mounted to facilitate handling when moved to different locations for testing of airborne hardware. Electrical GSE required for the control and display subsystem is packaged as follows:

A. Five racks—2 by 2 by 6 ft.

B. One power supply—2 by 2 by 4 ft.

C. Three portable containers for cable assembly—1 by 1 by 4 ft.
3.2.1.4 Guidance, Navigation, and Control Subsystem Electrical Test and Checkout Set

Requirements—During subsystem manufacturing tests, subsystem/flight carrier integration tests, and prelaunch and checkout tests at the launch site, the electrical performance of the guidance, navigation, and control subsystem is functionally verified to conform with specification requirements. The OCS is used for checkout and testing to the greatest extent possible. Other requirements for stimuli, functions, response, measurements, etc., are to be provided.

Functional Description—Electrical GSE for the guidance, navigation, and control subsystem has the capability of supporting the OCS in system level component testing. The GSE and test tooling required at each site provide stimuli, simulate loads and other functions, provide monitoring and recording, and supplement the OCS as required to functionally checkout all flight hardware. The following listed equipment is included as GSE for this subsystem:

A. The OCS adapter provides a two-way hardware digital interface between the OCS and the GSE. This adapter furnishes special stimuli for controlling and calibrating airborne equipment and allows integrated system testing by combining flight and ground capabilities for checkout, mounting, and control.

B. The control and display simulator provides the control and display required to interface with the OCS and the GSE for checkout of the subsystem.

C. The electrical test set simulates selected impedances and stimuli; monitors voltages, temperatures, servosystems, pressures, levels, etc.; processes and displays telemetry digital signals on charts, oscilloscopes, etc.; and processes other checkout functions as required.

D. The cable assembly contains all cabling with connectors necessary to interconnect the airborne equipment with the GSE for integration testing and checkout.
E. The power supply interfaces with the electrical power subsystem to furnish electrical power to the guidance, navigation, and control subsystem for integration testing and checkout.

**Physical Description**—Electrical GSE for this subsystem is installed in standard racks requiring subfloor cooling. These racks are interconnected by a cable assembly installed in subfloor cableways. Racks are pallet-mounted to facilitate handling when moved to different locations for testing airborne hardware. Electrical GSE required for this subsystem is packaged as follows:

A. Five racks—2 by 2 by 6 ft.
B. One power supply—2 by 2 by 4 ft.
C. Three portable containers for cable assembly—1 by 1 by 4 ft.

3.2.1.5 Thermal Control Subsystem Electrical Test and Checkout Set

**Requirements**—During subsystem manufacturing tests, subsystem/flight carrier integration tests, and prelaunch and checkout tests at the launch site, the electrical performance of the thermal control subsystem (TCS) is functionally verified to conform with specification requirements. The OCS is used for checkout and testing to the greatest extent possible. Other requirements for stimuli, functions, response, measurements, etc., are to be provided.

**Functional Description**—Electrical GSE for the thermal control subsystem has the capability of supporting the OCS in system level component testing. GSE and test tooling required at each site provide stimuli, simulate loads and other functions, provide monitoring and recording, and supplement the OCS as required to functionally check out all flight hardware. The following listed equipment is included as GSE for this subsystem:

A. The OCS adapter provides a two-way hardware digital interface between the OCS and GSE. This adapter furnishes special stimuli for controlling and calibrating airborne equipment and allows integrated system testing by combining flight and ground capabilities for checkout, mounting, and control.
B. The control and display simulator provides the control and display required to interface with the OCS and GSE for checkout of the subsystem.

C. The electrical test set simulates selected impedances and stimuli; monitors voltages, temperatures, servosystems, pressures, levels, etc.; processes and displays telemetry digital signals on charts, oscilloscopes, etc.; and processes other checkout functions as required.

D. The cable assembly contains all cabling with connectors necessary to interconnect the airborne equipment with the GSE for the purpose of integration testing and checkout.

E. The power supply interfaces with the electrical power subsystem to furnish electrical power to the TCS subsystem for integration testing and checkout.

Physical Description—Electrical GSE for the TCS subsystem is installed in standard racks requiring subfloor cooling. These racks are interconnected by a cable assembly installed in subfloor cableways. Racks are pallet-mounted to facilitate handling when moved to different locations for testing of airborne hardware. Electrical GSE required for this subsystem is packaged as follows:

A. Three racks—2 by 2 by 6 ft.
B. One power supply—2 by 2 by 4 ft.
C. Three portable containers for cable assembly—1 by 1 by 4 ft.

3.2.1.6 Communications and Data Management Subsystem Electrical Test and Checkout Set

Requirements—During subsystem manufacturing tests, subsystem/flight carrier integration tests, and prelaunch and checkout tests at the launch site, the electrical performance of the communications and data management (C&DM) subsystem is functionally verified to conform with specification requirements. The OCS is used for checkout and testing to the greatest extent possible. Other requirements for stimuli, functions, response, measurements, etc., are to be provided.
Functional Description—Electrical GSE for the C&DM subsystem has the capability of supporting the OCS in system level component testing. GSE and test tooling required at each site provide stimuli, simulate loads and other functions, provide monitoring and recording, and supplement the OCS as required to functionally check out all flight hardware. The following listed equipment is included as GSE for this subsystem.

A. The OCS adapter provides a two-way hardware digital interface between the OCS and GSE. This adapter furnishes special stimuli for controlling and calibrating airborne equipment and allows integrated system testing by combining flight and ground capabilities for checkout, mounting, and control.

B. The control and display simulator provides the control and display required to interface with the OCS and the GSE for checkout of the subsystem.

C. The electrical test set simulates selected impedances and stimuli; monitors voltages, temperatures, servosystems, pressures, levels, etc.; processes and displays telemetry digital signals on charts, oscillosopes, etc.; and processes other checkout functions as required.

D. The cable assembly contains all cabling with the connectors necessary to interconnect the airborne equipment with the GSE for integration testing and checkout.

E. The power supply interfaces with the electrical power subsystem to furnish electrical power to the C&DM subsystem for integration testing and checkout.

F. The RF interface unit (RFIU) contains S-band and UHF/UHF receivers, transmitters, and baseband separation/multiplexing equipment for interfacing with the vehicle RF systems. It provides separated voice and video signals to the communications ground station and receives voice, video, and commands from the ground station for transmission to the flight hardware.

G. The communications ground station provides the capability for generating video and audio test signals for uplink testing, for monitoring and analysis, and for downlink testing. It provides generated commands as required for checkout and provides for
checkout of intercommunications between the Space Station and the modules.

**Physical Description**—Electrical GSE for the C&DM subsystem is installed in standard racks requiring subfloor cooling. These racks are interconnected by a cable assembly installed in subfloor cableways. Racks are pallet-mounted to facilitate handling when moved to different locations for testing airborne hardware. Electrical GSE required for this subsystem is packaged as follows:

A. Seven racks—2 by 2 by 6 ft.
B. One power supply—2 by 2 by 4 ft.
C. Three portable containers for cable assembly—1 by 1 by 4 ft.
D. One ground station—TBD

3.2.1.7 Electrical Power Subsystem Electrical Test and Checkout Set

**Requirements**—During subsystem manufacturing tests, subsystem/flight carrier integration tests, and prelaunch and checkout tests at the launch site, the electrical performance of the electrical power subsystem is functionally verified to conform with specification requirements. The OCS is used for checkout and testing to the greatest extent possible. Other requirements for stimuli, functions, response, measurements, etc., are to be provided.

**Functional Description**—Electrical GSE for the electrical power subsystem has the capability of supporting the OCS in system level component testing. GSE and test tooling required at each site provide stimuli, simulate loads and other functions, provide monitoring and recording, and supplement the OCS as required to functionally check out all flight hardware. The following listed equipment is included as GSE for this subsystem:

A. The OCS adapter provides a two-way hardware digital interface between the OCS and GSE. This adapter furnishes special stimuli for controlling and calibrating airborne equipment and allows integrated system testing by combining flight and ground capabilities for checkout, mounting, and control.
B. The control and display simulator provides the control and display required to interface with the OCS and the GSE for checkout of the subsystem.

C. The electrical test set simulates selected impedances and stimuli; monitors voltages, temperatures, servosystems, pressures, levels; etc.; processes and displays telemetry digital signals on charts, oscilloscopes, etc.; and processes other checkout functions as required.

D. The cable assembly contains all cabling with connectors necessary to interconnect the airborne equipment with the GSE for the purpose of integration testing and checkout.

E. The power supply interfaces with the electrical power subsystem to furnish electrical power to the electrical power subsystem for integration testing and checkout.

F. The electrical load simulator provides load banks as required to simulate all subsystem loads for checkout out and testing this subsystem.

G. The electromagnetic interference (EMI) test set checks out EMI level for each subsystem.

**Physical Description—**Electrical GSE for the electrical power subsystem is installed in standard racks requiring subfloor cooling. These racks are interconnected by a cable assembly installed in subfloor cableways. Racks are pallet mounted to facilitate handling when moved to different locations for testing of airborne hardware. Electrical GSE required for this subsystem is packaged as follows:

A. Six racks—2 by 2 by 6 ft.
B. One power supply—2 by 2 by 4 ft.
C. Three portable containers for cable assembly—1 by 1 by 4 ft.

3.2.1.8 Onboard Checkout Subsystem Mechanical Test and Checkout Set

**Requirements—**During manufacturing, test, and checkout, the OCS equipment is protected from excessive temperatures due to internal power dissipation and external heat sources.
Functional Description—The OCS mechanical test and checkout set maintains the OCS equipment within the operating temperature limits during manufacture, test, and checkout operations, and prior to the time when the flight carrier thermal control subsystem can provide this function. The kit includes cold plates mechanically attached to each OCS equipment package, a coolant conditioning and pumping unit, hoses that connect between the pumping unit and the cold plates, and temperature-conditioned coolant fluid. The electrical functions required to control, monitor, and operate the kit are provided by the OCS electrical test and checkout kit.

Physical Description—The set is a portable unit mounted on wheels or casters with the dimensions of approximately 20 by 24 by 48 in., weighing approximately 400 lb.

3.2.1.9 Atmosphere Control Subsystem Mechanical Test and Checkout Set

Requirements—During manufacturing, test, and checkout, the atmosphere control subsystem (ACS) is checked to verify that its fabrication, assembly, and performance conform to the specification requirements.

Functional Description—The ACS mechanical test and checkout set simulates mechanical and fluid commodity interfaces provided by the Space Station ACS, thermal control subsystem, space suits, experiments, and men.

The Space Station ACS simulator verifies the mechanical interfaces between the Space Station ACS and the module ACS and provides the supply of conditioned gases (atmosphere, oxygen, and nitrogen) required by the module ACS.

The thermal control simulator verifies the mechanical interfaces between the thermal control subsystem and the module ACS at the air/fluid heat exchangers. The simulator also supplies the proper fluid flow to the heat exchangers during test and checkout.

The oxygen mask simulator verifies the mechanical disconnects and oxygen flow at the oxygen mask stations.
The experiment simulators verify the mechanical interfaces between the experiments and the module ACS and verify the conditioned atmosphere supplied to the experiments.

The man simulator varies the composition of the module atmosphere in order to verify the operation of the ACS atmosphere analyzer and other ACS monitor functions. The electrical functions required to control, monitor, and operate the ACS mechanical test and checkout set are provided by the ACS electrical test and checkout set.

One ACS mechanical test and checkout set is required at the vendor's facility and one set is required at the EPIC.

Physical Description—The set is made up of an enclosure 3 by 3 by 6 ft. plus flexible interconnecting hoses and interconnecting cables. The equipment is mounted on rigid steel pallets with provisions for lifting and transporting by overhead crane or fork lift. When installed, the equipment requires access to fresh air.

3.2.1.10 Guidance and Control Subsystem Mechanical Test and Checkout Set

Requirements—During manufacturing, test, and checkout, the guidance and control subsystem (G&C) is checked to verify that its fabrication, assembly, and performance conform to the specification requirements.

Functional Description—The G&C mechanical test and checkout set simulates mechanical interfaces with the G&C subsystem and checks the performance of mechanical functions controlled by the G&C subsystem. The G&C mechanical test and checkout set includes the following equipment:

A. The experiment simulators are used at the module manufacturer's facility to verify the mechanical interfaces with the G&C subsystem.

B. The target simulators are light sources or light reflectors to simulate the sun, stars, and earth horizon. The simulators are used as targets to functionally check the G&C sensors, gimbal drive mechanism, alignments, and attitude stabilization ability.
C. An angle measurement device measures the experiment pointing angles.

D. A two-axis support fixture is a yoke and cradle device to support the module and to allow the module to turn to a limited degree about two axes. The fixture is used to verify the ability of the G&C subsystem to control and stabilize the attitude of the pointing system.

Physical Description—The physical description of the items that comprise the G&C mechanical test and checkout set are listed in Table 3-3.

3.2.1.11 Thermal Control Subsystem Mechanical Test and Checkout Set

Requirements—During manufacturing, test, and checkout, the thermal control subsystem (TCS) is checked to verify that its fabrication, assembly, and performance conform to the specification requirements.

Functional Description—The set simulates mechanical interfaces with the thermal control subsystem and checks the performance of TCS mechanical functions. The TCS mechanical test and checkout set includes the following equipment:

A. The thermal properties test unit is used to verify the thermal properties of the coating on the wraparound radiator and test coupons. The unit consists of a portable emissometer and a portable reflectometer.

B. The ACS simulator is used to verify the mechanical interface at the ACS/TCS interfaces and to simulate the ACS air flow at the interfaces for verifying the TCS heat exchangers operational performance.

C. Cold plate load simulators mechanically interface with the TCS cold plates and simulate subsystem and experiment heat loads. The simulators are used to verify the performance of the TCS.

D. The TCS cleaning and loading unit is used to clean, flush, purge, and leak-check the TCS plumbing prior to loading coolant. The unit is also used to load and circulate the coolant in the TCS fluid loops.
### Table 3-3
GUIDANCE AND CONTROL SUBSYSTEM  
MECHANICAL TEST AND CHECKOUT SET COMPONENTS

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-4A Experiment Simulator</td>
<td>500</td>
<td>10 ft x 7 ft dia</td>
</tr>
<tr>
<td>A-4B Experiment Simulator</td>
<td>400</td>
<td>8.34 x 6 x 2.5</td>
</tr>
<tr>
<td>A-4C Experiment Simulator</td>
<td>250</td>
<td>6 x 4 x 2.5</td>
</tr>
<tr>
<td>A-5A Experiment Simulator</td>
<td>1000</td>
<td>27.8 x 13 dia</td>
</tr>
<tr>
<td>A-5B Experiment Simulator</td>
<td>300</td>
<td>6.96 x 13 dia</td>
</tr>
<tr>
<td>A-6 Experiment Simulator</td>
<td>250</td>
<td>9 x 5 dia</td>
</tr>
<tr>
<td>P-2BB Experiment Simulator</td>
<td>TBS</td>
<td>TBS</td>
</tr>
<tr>
<td>P-3 Experiment Simulator</td>
<td>1500</td>
<td>40 x 13.5 dia</td>
</tr>
<tr>
<td>ES-1 Experiment Simulator</td>
<td>600</td>
<td>10 x 7 x 14</td>
</tr>
<tr>
<td>ES-1AA Experiment Simulator</td>
<td>600</td>
<td>10 x 7 x 14</td>
</tr>
<tr>
<td>ES-1G Experiment Simulator</td>
<td>500</td>
<td>10 x 7 x 14</td>
</tr>
<tr>
<td>C/N-1 Experiment Simulator</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>C/N-1A Experiment Simulator</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>C/N-1B Experiment Simulator</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>T-3B Experiment Simulator</td>
<td>500</td>
<td>6 x 5 x 4</td>
</tr>
<tr>
<td>Sun simulator</td>
<td>10</td>
<td>2 by 2 by 1 ft</td>
</tr>
<tr>
<td>Star simulator</td>
<td>5</td>
<td>12 by 12 by 6 in.</td>
</tr>
<tr>
<td>Horizon simulator</td>
<td>100</td>
<td>20 by 20 ft by 1 in.</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

**Physical Description**—The physical description of the items that make up the TCS mechanical test and checkout set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Properties test unit</td>
<td>25</td>
<td>2 ft³</td>
</tr>
<tr>
<td>Atmosphere control subsystem simulator</td>
<td>200</td>
<td>10 ft³</td>
</tr>
<tr>
<td>Cold plate load simulators</td>
<td>200</td>
<td>10 ft³</td>
</tr>
<tr>
<td>TCS cleaning and loading unit</td>
<td>500</td>
<td>3 by 3 by 4 ft</td>
</tr>
</tbody>
</table>

335
Requirement—During manufacturing, test, and checkout, the communications and data management (C&DM) subsystem is checked to verify that is fabrication, assembly, and performance conform to the specification requirements.

Functional Description—The set simulates mechanical interfaces with the C&DM subsystem and provides mechanical functions necessary to verify the C&DM subsystem performance. The set includes the following equipment:

A. The film storage and processing equipment supports and verifies the performance of the C&DM film cameras.

B. The sensor stimulus unit provides mechanical calibration stimuli (pressure, temperature, fluid flow, motion displacement, light, force) to C&DM sensors to verify the D&DM data handling performance capability.

C. The cold plate simulators verify the mechanical interface between the C&DM assemblies and the thermal control subsystem cold plates. The cold plate simulators are also used with a coolant pumping unit during manufacturing tests as a heat sink for the C&DM assemblies before the thermal control subsystem can be used for this function.

D. The camera alignment unit aligns the TV monitor camera system with the experiment boresight.

Physical Description—The physical description of the items that make up the C&DM mechanical test and checkout set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film storage and processing equipment</td>
<td>380</td>
<td>125 ft³</td>
</tr>
<tr>
<td>Sensor stimulus unit</td>
<td>400</td>
<td>2.0 by 2.5 by 5.0 ft</td>
</tr>
<tr>
<td>Cold plate simulator with coolant conditioning unit</td>
<td>400</td>
<td>2.5 by 2.5 by 5.0 ft</td>
</tr>
<tr>
<td>Camera alignment unit</td>
<td>TBS</td>
<td>TBS</td>
</tr>
</tbody>
</table>
3.2.1.13 Electrical Power Subsystem Mechanical Test and Checkout Set

Requirements—During manufacturing, test, and checkout, the electrical power subsystem (EPS) is checked to verify that its fabrication, assembly, and performance conform to the specification requirements.

Functional Description—The set simulates mechanical interfaces with the electrical power subsystem and checks the performance of EPS mechanical functions. The EPS mechanical test and checkout set include the following equipment:

A. The Space Station docking ring simulator verifies the mechanical mating of the electrical interface between the module EPS and Space Station EPS.

B. The solar panel deployment and orientation checker verifies the mechanical functions of the solar panel deployment device and orientation mechanism. During this operation, the panels are supported in the 1-g environment by the EPS manufacturing handling kit.

C. The cold-plate simulator verifies the mechanical interface between the EPS and the thermal control subsystem. The cold plates are used with a coolant pumping unit to temperature-condition the EPS modules during manufacturing test.

Physical Description—The EPS mechanical test and checkout set includes the following equipment:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Station docking ring simulator</td>
<td>75</td>
<td>6 dia by 1</td>
</tr>
<tr>
<td>Solar panel deployment and orientation checker</td>
<td>TBS</td>
<td>TBS</td>
</tr>
<tr>
<td>Cold-plate simulator with coolant-conditioning unit</td>
<td>400</td>
<td>2.0 by 2.5 by 4.0</td>
</tr>
</tbody>
</table>
3.2.1.14 Structures Subsystem Mechanical Test and Checkout Set

**Requirements**—During manufacturing, test, and checkout, the structures subsystem is checked to verify that its fabrication, assembly, and performance conform to the specification requirements.

**Functional Description**—The set simulates mechanical interfaces with the structures subsystem and checks the performance of the structures subsystem mechanical functions. The set consists of the following items:

A. The Space Station docking simulator verifies the mechanical interface of the module docking ring.
B. Experiment simulators verify the mechanical interfaces between the experiments and the structures subsystem.
C. The pressure test unit pressurizes and leak-checks the sealed chambers in the module.
D. The ALS simulator verifies the mechanical interface between the module structure and the advanced logistics system.
E. The module cg and weight measurement device determines the center of gravity and weight of the module with all subsystems installed.
F. The module tumble and cleaning unit tumbles the module about its longitudinal axis and removes dirt and loose debris.

**Physical Description**—The physical description of the items that make up the structures subsystem mechanical test and checkout set are listed in Table 3-4.

3.2.1.15 Experiment Module Transportation Kit

**Requirements**—During transportation from the manufacturing facility to prelaunch and launch operations areas the experiment module is protected from shock, vibration, contamination, and excessive temperature and humidity. The requirement for three kits may increase if the baseline program flight plan or experiment accommodations mode change.

338
<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Station Docking Simulator</td>
<td>75</td>
<td>2 x 6 dia</td>
</tr>
<tr>
<td>A-1 Experiment Simulator</td>
<td>200</td>
<td>2 x 8.26 dia</td>
</tr>
<tr>
<td>A-2 Experiment Simulator</td>
<td>250</td>
<td>2 x 14 dia</td>
</tr>
<tr>
<td>A-2A Experiment Simulator</td>
<td>225</td>
<td>2 x 10.7 dia</td>
</tr>
<tr>
<td>A-3AA Experiment Simulator</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>A-3CC Experiment Simulator</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>A-4A Experiment Simulator</td>
<td>500</td>
<td>10 x 7 dia</td>
</tr>
<tr>
<td>A-4B Experiment Simulator</td>
<td>400</td>
<td>8.34 x 6 x 2.5</td>
</tr>
<tr>
<td>A-4C Experiment Simulator</td>
<td>250</td>
<td>6 x 4 x 2.5</td>
</tr>
<tr>
<td>A-5A Experiment Simulator</td>
<td>1,000</td>
<td>27.8 x 13 dia</td>
</tr>
<tr>
<td>A-5B Experiment Simulator</td>
<td>300</td>
<td>6.96 x 13 dia</td>
</tr>
<tr>
<td>A-6 Experiment Simulator</td>
<td>250</td>
<td>9 x 5 dia</td>
</tr>
<tr>
<td>P-2BB Experiment Simulator</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>P-3 Experiment Simulator</td>
<td>1,500</td>
<td>40 x 13.5 dia</td>
</tr>
<tr>
<td>ES-1 Experiment Simulator</td>
<td>600</td>
<td>10 x 7 x 14</td>
</tr>
<tr>
<td>ES-1AA Experiment Simulator</td>
<td>600</td>
<td>10 x 7 x 14</td>
</tr>
<tr>
<td>ES-1G Experiment Simulator</td>
<td>500</td>
<td>10 x 7 x 14</td>
</tr>
<tr>
<td>C/N-1 Experiment Simulator</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>C/N-1A Experiment Simulator</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>C/N-1B Experiment Simulator</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>T-2A Experiment Simulator</td>
<td>750</td>
<td>10 x 5.5 x 10.5</td>
</tr>
<tr>
<td>Item</td>
<td>Weight (lb)</td>
<td>Size (ft)</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------------</td>
<td>-----------</td>
</tr>
<tr>
<td>T-2BB Experiment Simulator</td>
<td>1,500</td>
<td>3 x 3 x 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 x 12 x 18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 x 12 x 10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 x 5 x 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 x 3 x 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x 2 x 3</td>
</tr>
<tr>
<td>T-3B Experiment Simulator</td>
<td>500</td>
<td>6 x 5 x 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 x 5 x 4</td>
</tr>
<tr>
<td>Pressure Test Unit</td>
<td>400</td>
<td>2 x 2 x 5</td>
</tr>
<tr>
<td>Advanced Logistics System</td>
<td>1,000</td>
<td>15 dia x 60</td>
</tr>
<tr>
<td>Module cg and weight measurement device</td>
<td>1,500</td>
<td>100 ft³</td>
</tr>
<tr>
<td>(2 support rings, 2 load cells, 2 cranes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

**Functional Description**—The transportation kit is required to contain and protect the experiment module during transportation from the manufacturing and acceptance test location to the EPIC. The kit is used for temporary storage at the EPIC before and after the experiment equipment is installed in the module. The kit is next used to transport the module with experiment equipment during operations at KSC. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment. The kit is compatible with experiment transportation kit components that may be used in conjunction with this equipment.

**Physical Description**—The kit is sized to accommodate an environmental control and monitoring system (500 lb and 10 ft³) and any of the items listed in Table 3-5.
Table 3-5
EQUIPMENT MODULE TRANSPORTATION KIT COMPONENTS

<table>
<thead>
<tr>
<th>Module and Experiment</th>
<th>Weight (lb)</th>
<th>Size (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>20,846</td>
<td>13.4 dia x 58</td>
</tr>
<tr>
<td>A-2</td>
<td>24,475</td>
<td>14 dia x 58</td>
</tr>
<tr>
<td>A-2A</td>
<td>17,400</td>
<td>12.7 dia x 48.8</td>
</tr>
<tr>
<td>A-3AA</td>
<td>18,930</td>
<td>13.4 dia x 58</td>
</tr>
<tr>
<td>A-3CC</td>
<td>13,298</td>
<td>13.4 dia x 58</td>
</tr>
<tr>
<td>A-4A</td>
<td>15,535</td>
<td>14 dia x 38.6</td>
</tr>
<tr>
<td>A-4B</td>
<td>14,900</td>
<td>14 dia x 38.6</td>
</tr>
<tr>
<td>A-4C</td>
<td>14,650</td>
<td>14 dia x 38.6</td>
</tr>
<tr>
<td>A-5A</td>
<td>17,170</td>
<td>14 dia x 44.2</td>
</tr>
<tr>
<td>A-5B</td>
<td>18,360</td>
<td>14 dia x 38.6</td>
</tr>
<tr>
<td>A-6</td>
<td>16,100</td>
<td>14 dia x 38.6</td>
</tr>
<tr>
<td>P-2BB</td>
<td>15,412</td>
<td>14 dia x 38.6</td>
</tr>
<tr>
<td>P-3</td>
<td>44,594</td>
<td>14 dia x 38.2</td>
</tr>
<tr>
<td>ES-1</td>
<td>19,512</td>
<td>14 dia x 43.5</td>
</tr>
<tr>
<td>ES-1AA</td>
<td>17,981</td>
<td>14 dia x 38.6</td>
</tr>
<tr>
<td>ES-1G</td>
<td>17,480</td>
<td>14 dia x 38.6</td>
</tr>
<tr>
<td>C/N-1</td>
<td>14,706</td>
<td>14 dia x 38.6</td>
</tr>
<tr>
<td>C/N-1A</td>
<td>14,488</td>
<td>14 dia x 38.6</td>
</tr>
</tbody>
</table>
Table 3-5
EQUIPMENT MODULE TRANSPORTATION KIT COMPONENTS (Continued)

<table>
<thead>
<tr>
<th>Module and Experiment</th>
<th>Weight (lb)</th>
<th>Size (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/N-1B</td>
<td>14,538</td>
<td>14 dia x 38.6</td>
</tr>
<tr>
<td>T-2A</td>
<td>19,550</td>
<td>14 dia x 37.5</td>
</tr>
<tr>
<td>T-2BB</td>
<td>23,091</td>
<td>14 dia x 37.5</td>
</tr>
<tr>
<td>T-3B</td>
<td>17,100</td>
<td>14 dia x 38.6</td>
</tr>
<tr>
<td>LS-1B</td>
<td>13,360</td>
<td>14 dia x 37.5</td>
</tr>
<tr>
<td>LS-1C</td>
<td>14,800</td>
<td>14 dia x 37.5</td>
</tr>
<tr>
<td>LS-1D</td>
<td>17,300</td>
<td>14 dia x 37.5</td>
</tr>
</tbody>
</table>

3.2.1.16 Electrical GSE

Electrical GSE is provided for the following experiments carried in attached modules:

- A. FPE A-4A 0.9M Narrow Field UV Telescope
- B. FPE A-4B 0.3M Wide Field UV Telescope
- C. FPE A-4C Small UV Survey Telescope
- D. FPE A-5B Gamma Ray Telescope
- E. FPE A-6 IR Telescope
- F. FPE P-2BB Wake, Plasma, Wave Particle, Elect. Beam
- G. FPE P-3 Cosmic Ray Physics Lab
- H. FPE ES-1 Earth Observation Facility
- I. FPE ES-1AA Earth Observation Sequential
- J. FPE ES-1G Minimum Payload (CORE)
- K. FPE C/N-1 Communications/Navigation Facility
- L. FPE C/N-1A Communications/Navigation Subgroup A
- M. FPE C/N-1B Communications/Navigation Subgroup B
- N. FPE T-3B Manned Work Platform
- O. FPE LS-1B Minimal Life Science Research Facility
- P. FPE LS-1C Intermediate Life Science Research Facility
- Q. FPE LS-1D Dedicated Life Science Research Facility

The elements of electrical GSE are described as follows.
Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extend possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

Functional Description—The electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage, except that GSE necessary for monitoring OCS status.

The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The optical interface simulator contains electrical and optical equipment for simulation and checkout of the equipment.
F. The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.

2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Process telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in six 2 by 2 by 6-ft standard racks and a portable container for the cable assembly.

3.2.1.16.2 A-4B 0.3m Wide Field UV Telescope Electrical Test and Checkout Kit

Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

Functional Description—The electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status.
The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module data management subsystem, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The optical interface contains electrical and optical equipment for simulation and checkout of the equipment.

F. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or display.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in six 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.
3.2.1.16.3 A-4C Small UV Survey Telescope Electrical Test and Checkout Kit

Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

Functional Description—The electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status.

The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module data management subsystem, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The optical interface contains electrical and optical equipment for simulation and checkout of the equipment.
F. The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.

2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Processes telemetry signals for strip charts, oscillographs, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in six 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3.2.1.16.4 A-5B Gamma Ray Telescope Electrical Test and Checkout Kit

Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

Functional Description—The electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status.
The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module data management subsystem, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The optical interface contains electrical and optical equipment for simulation and checkout of the equipment.

F. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in six 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.
Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

Functional Description—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OSC status.

The following equipment is included as GSE or this experiment:

A. The GSE adapter provides a data bus interface between GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The optical interface simulator contains electrical and optical equipment for simulation and checkout of the equipment.
F. The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.

2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

G. The IR interference detector is composed of a small computer and other associated equipment capable of making a fast Fourier transform of an interferometer scan.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in six 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3.2.1.16.6 P-2BB Wake, Plasma, Wave Particle, Electron Beam Electrical Test and Checkout Kit

Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing will be conducted at the vendor's factory using the vendor's checkout equipment.
Functional Description—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage, except that GSE necessary for monitoring OCS status. The following requirement is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS through the module DMS to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS - and GSE - peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

**Physical Description**—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in five 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

**3.2.1.6.7 P-3 Cosmic Ray Physics Laboratory Electrical Test and Checkout Kit**

**Requirements**—System-level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed, using the OCS to the greatest extent possible. Ground checkout equipment is provided, as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

**Functional Description**—Electrical GSE is capable of supporting the OCS in performing experiment system level testing. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC, where the assembled module is installed in the orbiter. No GSE is required beyond this stage except the GSE necessary for monitoring the OCS status.

The following GSE equipment is used for this experiment:

A. The GSE adapter provides a data base interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the
OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS - and GSE - peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data-acquisition system.

2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cables requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in five 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.
Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

Functional Description—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS - and GSE - peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that;
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment from the Space Station.

3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

**Physical Description**—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in five 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

**3.2.1.16.9 ES-1AA Earth Observation Sequential Electrical Test and Checkout Kit**

**Requirements**—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

**Functional Description**—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

- **A.** The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.
B. The control and display unit provides the controls and displays required to interface with the OCS - and GSE - peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in five 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3.2.1.16.10 ES-1G Minimum Payload (CORE) Electrical Test and Checkout Kit

Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.
Functional Description—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS - and GSE - peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.
**Physical Description**—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in three 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3.2.1.16.11 C/N-1 Communications/Navigations Facility Electrical Test and Checkout Kit

**Requirements**—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

**Functional Description**—The electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS - and GSE - peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.
D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.

2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing locations. This GSE is packaged in five 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3. 2. 1. 16. 12 C/N-1A Communications/Navigations Subgroup A Electrical Test and Checkout Kit

Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

Functional Description—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC
where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS - and GSE -peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.
3.2.1.16.13 C/N-1B Communications/Navigations Subgroup B Electrical Test and Checkout Kit

Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground Checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

Functional Description—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring the control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port (Figure 2-9).

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provides stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Process telemetry signals for trip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This CSE is packaged in five 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3.2.1.16.14 T-3B Manned Work Platform Electrical Test and Checkout Kit

Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

Functional Description—The electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.
B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in four 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3.2.16.15 LS-1B Minimal Life Science Research Facility Electrical Test and Checkout Kit

Requirements—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used
to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

Functional Description—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.

2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and
provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

**Physical Description**—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in five 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3.2.16.16 LS-1C Intermediate Life Science Research Facility Electrical Test and Checkout Kit

**Requirements**—System level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing are conducted at the vendor's factory using the vendor's checkout equipment.

**Functional Description**—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS,
through the module DMS, to the GSE. The GSE simulates the command and control functions of the space station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.

2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in seven 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.
**Requirements**—System level integration tests and prelaunch functional tests fo the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

**Functional Description**—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with the experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. Electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

**Physical Description—**Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are palletmounted to facilitate handling when moved to a new testing location. This GSE is packaged in nine 2 by 2 by 6 standard racks and a portable container for the cable assembly.

3, 2, 1, 17 Mechanical/Structural GSE

Mechanical and structural GSE is provided for the following experiments carried in attached modules:

A. FPE A-4A 0.9M Narrow Field UV Telescope
B. FPE A-4B 0.3M Wide Field UV Telescope
C. FPE A-4C Small UV Survey Telescope
D. FPE A-5B Gamma Ray Telescope
E. FPE A-6 IR Telescope
F. FPE P-2BB Wake, Plasma, Wave Particle, Elect. Beam
G. FPE P-3 Cosmic Ray Physics Laboratory
H. FPE ES-1 Earth Observation Facility
I. FPE ES-1AA Earth Observation Sequential
J. FPE ES-1G Minimum Payload (CORE)
K. FPE C/N-1 Communications/Navigations Facility
L. FPE C/N-1A Communications/Navigations Subgroup A
M. FPE C/N-1B Communications/Navigations Subgroup B
N. FPE T-3B Manned Work Platform
O. FPE LS-1B Minimal Life Science Research Facility
P. FPE LS-1C Intermediate Life Science Research Facility
Q. FPE LS-1D Dedicated Life Science Research Facility
The elements of mechanical and structural GSE are described as follows:

3.2.1.17.1 FPE A-4A 0.9m Narrow Field UV Telescope Mechanical Test and Checkout Set

**Requirements**—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

**Functional Description**—A mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to verify the experiment/experiment-carrier mechanical interfaces and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The kit includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The target simulators are radiation sources that operate within the detection limits (size, intensity, wavelength) of experiment equipment. The simulators are used after the experiment is installed in the module to functionally check the experiment boresight alignment, pointing, stability, jitter, and attitude.

C. The angle measurement device measures and verifies the experiment pointing angles.

D. The two-axis support fixture is a yoke-and-cradle device required to support the experiment module and to allow the module to turn to a limited degree about two axes. The fixture is used to verify the ability of the system to maneuver, point, and stabilize on simulated targets.

E. The deployment measuring device measures operation of deployed devices such as sunshade, star-tracker cover, and mirror cover.

F. The vibration test fixture vibrates the module with the experiment installed to verify the integrity of the experiment mechanical interfaces and the experiment alignment.
G. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

H. The module tumble and cleaning unit tumbles the module about its longitudinal axis and removes dirt and loose debris.

**Physical Description**—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Deployment measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.1.17.2 FPE A-4B 0.3m Wide Field UV Telescope Mechanical Test and Checkout Set

**Requirements**—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

**Functional Description**—A mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to verify the experiment/experiment-carrier mechanical interfaces and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The kit includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.
B. The target simulators are radiation sources that operate within the detection limits (size, intensity, wavelength) of the experiment equipment. The simulators are used after the experiment is installed in the module to functionally check the experiment bore-sight alignment, pointing, stability, jitter, and attitude.

C. The angle measurement device measures and verifies the experiment pointing angles.

D. The two-axis support fixture is a yoke-and-cradle device required to support the experiment module and to allow the module to turn to a limited degree about two axes. The fixture is used to verify the ability of the system to maneuver, point, and stabilize on simulated targets.

E. The deployment measuring device measures operation of deployed devices such as sunshade, star-tracker cover, and mirror cover.

F. The vibration test fixture vibrates the module with the experiment installed to verify the integrity of the experiment mechanical interfaces and the experiment alignment.

G. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

H. **Physical Description**—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Deployment measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

Functional Description—A mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to verify the experiment/experiment-carrier mechanical interfaces and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The kit includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The target simulators are radiation sources that operate within the detection limits (size, intensity, wavelength) of the experiment equipment. The simulators are used after the experiment is installed in the module to functionally check the experiment bore-sight alignment, pointing, stability, jitter, and attitude.

C. The angle measurement device measures and verifies the experiment pointing angles.

D. The two-axis support fixture is a yoke-and-cradle device required to support the experiment module and to allow the module to turn to a limited degree about two axes. The fixture is used to verify the ability of the system to maneuver, point, and stabilize on simulated targets.

E. The deployment measuring device measures operation of deployed devices such as sunshade, star-tracker cover, and mirror cover.

F. The vibration test fixture vibrates the module with the experiment installed to verify the integrity of the experiment mechanical interfaces and the experiment alignment.

G. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.
H. The module tumble and cleaning unit tumbles the module about its longitudinal axis and removes dirt and loose debris.

Physical Description—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Deployment measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.1.17.4 FPE A-5B Gamma Ray Telescope Mechanical Test and Checkout Set

Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier, and service the experiment with dependables during ground operations and test exercises.

Functional Description—A mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to load experiment commodities, to verify the experiment/experiment-carrier interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The target simulators are radiation sources that operate within the detection limits (size, intensity, wavelength) of the experiment equipment. The simulators are used after the experiment is
installed in the module to functionally check the experiment bore-sight alignment, pointing, stability, jitter, and attitude.

C. The measurement device measures and verifies the experiment pointing angles.

D. The two-axis support fixture is a yoke-and-cradle device required to support the experiment module and allow the module to turn to a limited degree about two axes. The fixture is used to verify the ability of the system to maneuver, point, and stabilize on simulated targets.

E. The cryogenic loading unit loads cryogenics into the experiment cryostat.

F. The vibration test fixture vibrates the module with the experiment installed to verify the integrity of the experiment mechanical interfaces and the experiment alignment.

G. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

H. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

I. The argon/methane pressurization unit pressurizes the experiment spark chamber.

Physical Description—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Cryogenic Loading Unit</td>
<td>50</td>
<td>2 ft³</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Argon/methane pressurization unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
3.2.1.17.5 A-6 IR Telescope Mechanical Test and Checkout Set

Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

Functional Description—A mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to load experiment commodities, to verify the experiment/experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The deployment mechanism verification unit verifies the mechanical operation of the experiment deployment mechanism.

C. The target simulators are radiation sources that operate within the detection limits (size, intensity, wavelength) of the experiment equipment. The infrared sources are housed in a cryogenically cooled vacuum chamber. The simulators are used after the experiment is installed in the module to functionally check the experiment boresight alignment, pointing, stability, jitter, and attitude.

D. The angle measurement device measures and verify the experiment pointing angles.

E. The two-axis support fixture is a yoke-and-cradle device required to support the experiment module and allow the module to turn to a limited degree about two axes. The fixture is used to verify the ability of the system to maneuver, point, and stabilize on simulated targets.

F. The cryogenic loading units load liquid nitrogen and liquid helium into the experiment cryostat.

G. The vibration test fixture vibrates the module with the experiment installed to verify the integrity of the experiment mechanical interfaces and the experiment alignment.
H. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

I. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

**Physical Description**—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Deployment mechanism verification unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Cryogenic loading unit</td>
<td>500</td>
<td>52 ft³</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.1.17.6 P-2BB Wake, Plasma, Wave Particle, Electron Beam Mechanical Test and Checkout Set

**Requirements**—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

**Functional Description**—A mechanical test and checkout set is provided to check the experiment compliance with this requirement. The set is required at the EPIC to load experiment commodities, to verify the experiment/experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment mechanical functions before and after integration with the flight carrier. The set includes the following equipment.

A. The mechanical interface simulator verifies mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.
B. The deployment measuring device measures operation of deployed devices such as sensor booms, TV cameras, and spectrometer.
C. The GN$_2$ loading unit loads the gaseous nitrogen into the cold gas system.

Physical Description—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>150</td>
<td>10 ft$^3$</td>
</tr>
<tr>
<td>Deployment measuring device</td>
<td>20</td>
<td>2 ft$^3$</td>
</tr>
<tr>
<td>GN$_2$ loading unit</td>
<td>50</td>
<td>3 ft$^3$</td>
</tr>
</tbody>
</table>

3.2.1.17.7 P-3 Cosmic-Ray Physics Laboratory Mechanical Test and Checkout Set

Requirements—A cosmic-ray physics laboratory mechanical test and checkout set is used to determine whether the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier. The experiment is serviced with expendables during ground operations and test exercises.

Functional Description—The set is required at the EPIC to load experiment commodities, to verify the experiment and experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment before the experiment is installed in the flight carrier.
B. The liquid helium loading unit loads the experiment dewars.
C. The deployment mechanism verification unit verifies the operation of the detector deployment mechanism.
D. The liquid nitrogen loading unit loads liquid nitrogen into the experiment cryogenic system.
E. The vibration test fixture vibrates the module with the experiment installed to verify the integrity of the experiment mechanical interfaces.

F. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

G. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

H. The argon/methane servicing unit provides these gases to experiment tanks.

Physical Description—The physical description of the items in the set follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Liquid helium loading unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Deployment mechanism verification test</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Liquid nitrogen loading unit</td>
<td>50</td>
<td>2.0 ft³</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Argon/methane servicing unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.1.17.8 ES-1 Earth Observation Facility Mechanical Test and Checkout Set

Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

Functional Description—An Earth surveys mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to load experiment commodities, to verify
the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The target simulators are radiation sources and pattern screens operating within the detection limits (size, intensity, wavelength) of the experiment equipment. The simulators are used after the experiment is installed in the module to functionally check the experiment boresight alignment, field of view, focus, resolution, pointing angles, and line-of-sight orientation accuracy.

C. The angle measurement device measures and verifies the experiment pointing angle.

D. The deployment measurement device measures mechanical operation of the experiment deployment and scanning mechanism.

E. The LN$_2$ loading unit loads liquid nitrogen into the experiment cryostat.

**Physical Description**—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft$^3$</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft$^3$</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Deployment measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LN$_2$ loading unit</td>
<td>50</td>
<td>2 ft$^3$</td>
</tr>
</tbody>
</table>

3.2.1.17.9 ES-I.AA Earth Observation Sequential Mechanical Test and Checkout Set

**Requirements**—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.
**Functional Description**—An Earth surveys mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to load experiment commodities, to verify the experiment/experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment’s mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The target simulators are radiation sources and pattern screens operating within the detection limits (size, intensity, wavelength) of the experiment equipment. The simulators are used after the experiment is installed in the module to functionally check the experiment boresight alignment, field of view, focus, resolution, pointing angles, and line-of-sight orientation accuracy.

C. The angle measurement device measures and verifies the experiment pointing angle.

D. The deployment measurement device measures mechanical operation of the experiment deployment and scanning mechanism.

E. The LN$_2$ loading unit loads liquid nitrogen into the experiment cryostat.

**Physical Description**—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft$^3$</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft$^3$</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Deployment measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LN$_2$ loading unit</td>
<td>50</td>
<td>2 ft$^3$</td>
</tr>
</tbody>
</table>
3.2.1.17.10 ES-1G Minimum Payload (CORE) Mechanical Test and Checkout Set

Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

Functional Description—An Earth surveys mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to load experiment commodities, to verify the experiment/experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The target simulators are radiation sources and pattern screens operating within the detection limits (size, intensity, wavelength) of the experiment equipment. The simulators are used after the experiment boresight alignment, field of view, focus, resolution, pointing angles, and line-of-sight orientation accuracy.

C. The angle measurement device measures and verifies the experiment pointing angle.

D. The deployment measurement device measures mechanical operation of the experiment deployment and scanning mechanism.

E. The LN$_2$ loading unit loads liquid nitrogen in to the experiment cryostat.

Physical Description—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft$^3$</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft$^3$</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Deployment measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LN$_2$ loading unit</td>
<td>50</td>
<td>2 ft$^3$</td>
</tr>
</tbody>
</table>

381
3.2.1.17.11  C/N=1 Communications/Navigation Facility Mechanical Test and Checkout Set

**Requirements**—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

**Functional Description**—A mechanical test and checkout set is provided to check the experiment compliance with the above requirements. The set is required at the EPIC to verify the experiment/experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The deployment device verification unit verifies the mechanical operation of the experiment deployment mechanisms through the module airlocks.

C. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

D. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

**Physical Description**—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Deployment device verification unit</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
3.2.1.17.12 C/N-1A Communications/Navigation Subgroup A Mechanical Test and Checkout Set

Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

Functional Description—A mechanical test and checkout set is provided to check the experiment compliance with the above requirements. The set is required at the EPIC to verify the experiment/experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.
B. The deployment device verification unit verifies the mechanical operation of the experiment deployment mechanisms through the module airlocks.
C. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.
D. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

Physical Description—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Deployment device verification unit</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

383
3.2.1.17.13 C/N-1B Communications/Navigation Subgroup B Mechanical Test and Checkout Set

Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

Functional Description—A mechanical test and checkout set is provided to check the experiment compliance with the above requirements. The set is required at the EPIC to verify the experiment/experiment carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.
B. The deployment device verification unit verifies the mechanical operation of the experiment deployment mechanisms through the module airlocks.
C. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.
D. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

Physical Description—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Deployment device verification unit</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
3.2.1.17.14 T-3B Manned Work Platform Mechanical Test and Checkout Set

Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

Functional Description—A mechanical test and checkout set is provided to check the experiment compliance with the above requirements. The set is required at the EPIC to load experiment commodities, to verify the experiment/experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.
B. The deployment device verification unit verifies the mechanical operation of the experiment deployment mechanisms through the module airlocks.
C. The helium unit provides helium gas for leak checks.
D. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.
E. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.
F. The hydrazine loading unit provides for loading the experiment propellant tanks.

Physical Description—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Deployment device verification unit</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Helium loading unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Hydrazine loading unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier and service the experiment with expendables during ground operations and test exercises.

Functional Description—The mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to supply experiment commodities and services to verify the experiment/experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The Space Station simulator supplies the module with those commodities and services (electrical power, air, water) required to verify the operational performance of the integrated module and experiment.

C. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

D. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

E. The experiment EC/LS verification unit verifies the specimens' environmental factors such as atmosphere temperature, humidity, atmosphere pressure, atmosphere composition, light, and atmosphere flow rate.
Physical Description—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Space Station simulator</td>
<td>300</td>
<td>26 ft³</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Environmental control and life support verification unit</td>
<td>100</td>
<td>8 ft³</td>
</tr>
</tbody>
</table>

3.2.1.17.16 LS-1C Intermediate Life Science Research Facility
Mechanical Test and Checkout Set

Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier and service the experiment with expendables during ground operations and test exercises.

Functional Description—The mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to supply experiment commodities and services to verify the experiment/experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The Space Station simulator supplies the module with those commodities and services (electrical power, air, water) required to verify the operational performance of the integrated module and experiment.

C. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.
D. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

E. The experiment EC/LS verification unit verifies the specimens' environmental factors such as atmosphere temperature, humidity, atmosphere pressure, atmosphere composition, light, and atmosphere flow rate.

**Physical Description**—The physical description of the items in the set is as follows:

| Item                                           | Weight (lb) | Size (
| Mechanical interface simulator                | 600         | 75 ft³ |
| Space Station simulator                        | 300         | 26 ft³ |
| Module cg and weight measuring device          | TBD         | TBD    |
| Module tumble and cleaning unit                | TBD         | TBD    |
| Environmental control and life support verification unit | 100         | 8 ft³  |

3.2.1.17.17 LS-1D Dedicated Life Science Research Facility

**Mechanical Test and Checkout Set**

**Requirements**—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier and service the experiment with expendables during ground operations and test exercises.

**Functional Description**—A mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to supply experiment commodities and services to verify the experiment/experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.
B. The Space Station simulator supplies the module with those commodities and services (electrical power, air, water) required to verify the operational performance of the integrated module and experiment.

C. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

D. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

E. The experiment EC/LS verification unit verifies the specimen's environmental factors such as atmosphere temperature, humidity, atmosphere pressure, atmosphere composition, light, and atmosphere flow rate.

**Physical Description**—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Space Station simulator</td>
<td>300</td>
<td>26 ft³</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Environmental control and life support verification unit</td>
<td>100</td>
<td>8 ft³</td>
</tr>
</tbody>
</table>

3.2.1.18 Handling and Transport GSE

Handling and transport GSE is provided for the following experiments carried in attached modules:

A. FPE A-4A 0.9m Narrow Field UV Telescope
B. FPE A-4B 0.3m Wide Field UV Telescope
C. FPE A-4C Small UV Survey Telescope
D. FPE A-5B Gamma Ray Telescope
E. FPE A-6 IR Telescope
F. FPE P-2BB Wake, Plasma, Wave Particle, Elect. Beam
G. FPE P-3 Cosmic Ray Physics Lab
H. FPE ES-1 Earth Observation Facility
The elements of handling and transport GSE are described as follows:

3.2.1.18.1 A-4A 0.9m Narrow Field UV Telescope Transportation Kit

**Requirements** — During transportation from the manufacturing facility to the EPIC, the 0.9m narrow field UV telescope instrument is protected from shock, vibration, strain, contamination and excessive temperature and humidity.

**Functional Description** — The transportation kit is required to contain and protect the telescope and equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the telescope and equipment is installed in the flight carrier. The kit includes a handling fixture and protective enclosure, an environmental control system, and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the instrument during shipment.

**Physical Description** — The transportation kit is sized to accommodate the equipment for FPE A-4A identified in Experiments Requirements Summary (Green Book), Volumes I and II, Revision 1, April 28, 1971.
3.2.1.18.2 A-4B 0.3m Wide Field UV Telescope Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC, the 0.3m wide field UV telescope equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the telescope and equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the equipment is installed in the flight carrier. The kit includes a rigid handling fixture and protective enclosure, an environmental control system, and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the instrument during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE A-4B identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.1.18.3 A-4C Small UV Survey Telescope Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC, the small UV survey telescope equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the telescope and equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the equipment is installed in the flight carrier. The kit includes a rigid handling fixture and protective enclosure, an environmental control system, and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the instrument during shipment.
Physical Description — The kit is sized to accommodate one set of equipment composed of the following items:

<table>
<thead>
<tr>
<th>Assembly</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small UV Survey Telescope</td>
<td>750</td>
<td>6 x 4 x 2.5 ft</td>
</tr>
<tr>
<td>Control and display</td>
<td>17</td>
<td>12 x 18 x 10 in.</td>
</tr>
<tr>
<td>Two vaults with film and emulsion</td>
<td>150 each</td>
<td>22 x 28 x 30 in. each</td>
</tr>
</tbody>
</table>

3.2.1.18.4 A-5B Gamma Ray Telescope Transportation Kit

Requirements — During transportation from the manufacturing facility to the EPIC, the gamma ray telescope equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description — The transportation kit is required to contain and protect the gamma ray telescope equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the equipment is installed in the flight carrier. The kit includes a rigid handling fixture and protective enclosure, an environmental control system, a refrigerated shipping container for the gamma ray spectrometer crystal, and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the instrument during shipment. The refrigerated container for the spectrometer crystal may be used during shipment of the integrated module/FPE to the launch site.

Physical Description — The transportation kit is sized to accommodate the equipment for FPE A-5B identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.1.18.5 A-6 Infrared Telescope Transportation Kit

Requirements — During transportation from the manufacturing facility to the EPIC, the infrared telescope equipment is protected from shock, vibration, contamination, and excessive temperature and humidity.
Functional Description—The transportation kit is required to contain and protect the infrared telescope equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the infrared telescope equipment is installed in the flight carrier. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE A-6 identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.1.18.6 P-2BB Wake, Plasma, Wave Particle, Electron Beam Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC, the experiment equipment is protected from shock, vibration, strain, contamination and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the experiment equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the equipment is installed in the flight carrier. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE P-2 including FPE Subgroups P-2B, P-2C, P-2D, and P-2E identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.
3.2.1.18.7 P-3 Cosmic Ray Physics Laboratory Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC, the cosmic-ray physics laboratory equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the cosmic-ray physics laboratory equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the cosmic-ray physics laboratory equipment is installed in the flight carrier. The kit includes handling fixtures and protective enclosures; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment. Handling equipment for the 15,000-lb, 6-ft diameter ionization spectrograph is usable with normal facility equipment at the EPIC.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE P-3 identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.1.18.8 ES-1 Earth Observation Facilities Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC, the earth observation equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The kit is sized to accommodate the equipment for FPE ES-1, including ES-1G, ES-1AA (ES-1A thru ES-1F) and ES-1, identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

394
3.2.1.18.9 ES-1AA Earth Observation Sequential Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC, the earth observations equipment is protected from shock, vibration, strain, contamination and excessive temperature and humidity.

Functional Description—The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE ES-1, including ES-1G and ES-1A thru ES-1F, identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.1.18.10 ES-1G Minimum Payload (CORE) Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC, the minimum payload earth observation equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE ES-1, including only the ES-1G Minimum Payload (CORE), identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.
3.2.1.18.11 C/N-1 Communications/Navigation Facility Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC, Communications/Navigation facility equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the communications/navigational facility equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the equipment is installed in the flight carrier. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE C/N-1, including FPE Subgroups C/N-1A and C/N-1B, identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.1.18.12 C/N-1A Communications/Navigation Subgroup A Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC, the C/N Subgroup A equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the C/N Subgroup A equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the equipment is installed in the flight carrier. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.
Physical Description — The transportation kit is sized to accommodate the equipment for FPE C/N-1A identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.1.18.13 C/N-1B Communications/Navigational Subgroup B Transportation Kit

Requirement — During transportation from the manufacturing facility to the EPIC, the C/N Subgroup B equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description — The transportation kit is required to contain and protect the C/N Subgroup B equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the equipment is installed in the flight carrier. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description — The transportation kit is sized to accommodate the equipment for FPE C/N-1B identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.1.18.14 T-3B Manned Work Platform Transportation Kit

Requirements — During transportation from the manufacturing facility to the EPIC, the Manned Work Platform equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description — The transportation kit is required to contain and protect the Manned Work Platform equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the equipment is installed in the flight carrier. The kit includes a handling fixture and protective enclosure.
an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE T-3B identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

### 3.2.1.18.15 LS-1B Minimal Life Science Research Facility Transportation Kit

**Requirements**—During transportation from the manufacturing facility to the EPIC and from the specimen supply source to the launch site biological laboratory (LSBL), from the LSBL to the flight carrier, and from the return carrier vehicle to the LSBL; the equipment and specimens are protected from shock, vibration, contamination, and excessive temperature, pressure, and humidity; and are provided with food, nutrients, water, and fresh air.

**Functional Description**—The kit includes a handling fixture and protective enclosure; an environmental control system; a recording system to monitor environmental conditions, shock, vibration, temperature, atmospheric pressure, atmosphere composition and humidity; and apparatus to provide food, nutrients, water, and fresh air for the specimens. The enclosure provides isolation for each specimen, as necessary, and protection for specimen instrumentation. The above functions are also provided for the returned specimens during transportation from the return vehicle to the LSBL. Accommodations are required for preserving dead specimens.

**Physical Description**—The transportation kit is sized to accommodate the equipment (which may contain specimens as noted) for FPE LS-STB identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.
3.2.1.18.16 LS-1C Intermediate Life Science Research Facility Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC and from the specimen supply source to the launch site biological laboratory (LSBL), from the LSBL to the flight carrier, and from the return carrier vehicle to the LSBL; the equipment and specimens are protected from shock, vibration, contamination, and excessive temperature, pressure, and humidity; and are provided with food, water, and fresh air.

Functional Description—The kit includes a handling fixture and protective enclosure; an environmental control system; a recording system to monitor environmental conditions, shock, vibration, temperature, atmospheric pressure, atmosphere composition and humidity; and apparatus to provide food, water, and fresh air for the specimens. The enclosure provides isolation for each specimen, as necessary, and protection for specimen instrumentation. The above functions are also provided for the returned specimens during transportation from the return carrier vehicle to the LSBL. Accommodations are required for preserving dead specimens.

Physical Description—The transportation kit is sized to accommodate the equipment (which may contain specimens as noted) for FPE LS-STC identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.1.18.17 LS-1D Dedicated Life Science Research Facility Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC and from the specimen supply source to the launch site biological laboratory (LSBL), from the LSBL to the flight carrier, and from the return carrier vehicle to the LSBL; the equipment and specimens are protected from shock, vibration, contamination, and excessive temperature, pressure, and humidity; and are provided with food, nutrients, water, and fresh air.

399
Functional Description—The kit includes a handling fixture and protective enclosure; an environmental control system; a recording system to monitor environmental conditions, shock, vibration, temperature, atmospheric pressure, atmosphere composition and humidity; and apparatus to provide food, nutrients, water and fresh air for the specimens. The enclosure provides isolation for each specimen, as necessary, and protection for specimen instrumentation. The above functions are also provided for the returned specimens during transportation from the return carrier vehicle to the LSBL. Accommodations are required for preserving dead specimens.

Physical Description—The transportation kit is sized to accommodate the equipment (which may contain specimens as noted) for FPE LS-STD identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.2 Free-Flying Experiment GSE

Free-flying experiment GSE includes that required for the following experiments accommodated in free-flying modules:

A. FPE A-1 X-Ray Stellar Astronomy
B. FPE A-2 Advanced Stellar Astronomy
C. FPE A-2A Intermediate Stellar Astronomy
D. FPE A-3AA Advanced Solar Astronomy
E. FPE A-3CC ATM Follow-on
F. FPE A-5A X-Ray Telescope
G. FPE T-2A Long Term Cryo Storage
H. FPE T-2BB Short Term Cryos
Experiment Module GSE

The elements of free-flying experiment module GSE includes the following which were described in Subsection 3.2.1.

A. Onboard Checkout Subsystem Electrical Test and Checkout Set
B. Atmosphere Control Subsystem Electrical Test and Checkout Set
C. Control and Display Subsystem Electrical Test and Checkout Set
D. Guidance, Navigation, and Control Subsystem Electrical Test and Checkout Set
E. Thermal Control Subsystem Electrical Test and Checkout Set
F. Communications and Data Management System Electrical Test and Checkout Set
G. Electrical Power Subsystem Electrical Test and Checkout Set
H. Onboard Checkout Subsystem Mechanical Test and Checkout Set
I. Atmosphere Control Subsystem Mechanical Test and Checkout Set
J. Guidance and Control Subsystem Mechanical Test and Checkout Set
K. Thermal Control Subsystem Mechanical Test and Checkout Set
L. Communications and Data Management Subsystem Mechanical Test and Checkout Set
M. Electrical Power Subsystem Mechanical Test and Checkout Set
N. Structures Subsystem Mechanical Test and Checkout Set
O. Experiment Module Transportation Kit

In addition to the GSE described previously, the following elements of equipment are required for the free-flying experiment modules.
3. 2. 2. 1 Propulsion GSE

The elements of propulsion GSE are described as follows:

3. 2. 2. 1. 1 Propulsion Subsystem Electrical Test and Checkout Set

**Requirements**—During subsystem manufacturing tests, subsystem/flight carrier integration tests, and prelaunch and checkout tests at the launch site, the electrical performance of the propulsion subsystem is functionally verified to conform with specification requirements. The OCS is used for checkout and testing to the greatest extent possible. Other requirements for stimuli, functions, response, measurements, etc., are to be provided.

**Functional Description**—Electrical GSE for the propulsion subsystem has the capability of supporting the OCS in system level component testing. GSE and test tooling required at each site provide stimuli, simulate loads and other functions, provide monitoring and recording, and supplement the OCS as required to functionally checkout all flight hardware. The following listed equipment is included as GSE for this subsystem:

- **A.** The OCS adapter provides a two-way hardware digital interface between the OCS and the GSE. This adapter furnishes special stimuli for controlling and calibrating airborne equipment and allows integrated system testing by combining flight and ground capabilities for checkout, mounting, and control.

- **B.** The control and display simulator provides the control and display required to interface with the OCS and the GSE for checkout of the subsystem.

- **C.** The electrical test set simulates selected impedances and stimuli; monitors voltages, temperatures, servosystems, pressures, levels, etc.; processes and displays telemetry digital signals on charts, oscilloscopes, etc.; and processes other checkout functions as required.

- **D.** The cable assembly contains all cabling with connectors necessary to interconnect the airborne equipment with the GSE for integration testing and checkout.

- **E.** The power supply interfaces with the electrical power subsystem to furnish electrical power to the propulsion subsystem for integration testing and checkout.
Physical Description—Electrical GSE for the propulsion subsystem is installed in standard racks requiring subfloor cooling. These racks are interconnected by a cable assembly installed in subfloor cableways. Racks are pallet-mounted to facilitate handling when moved to different locations for testing airborne hardware. Electrical GSE required for this subsystem is packaged as follows:

A. Four racks—2 by 2 by 6 ft.
B. One power supply—2 by 2 by 4 ft.
C. Three portable containers for cable assembly—1 by 1 by 4 ft.

3.2.2.1.2 Propulsion Subsystem Mechanical Test and Checkout Set

Requirements—During manufacturing, test and checkout, and prelaunch operations, the propulsion subsystem is checked to verify that its fabrication, assembly, and performance conform to the specification requirements.

Functional Description—The set simulates mechanical interfaces with the propulsion subsystem and checks the performance of the propulsion subsystem mechanical functions. The set includes the following equipment:

A. Service and test interface simulators are used to verify the mechanical operation of the service, test and maintenance disconnects.
B. The pressure test unit is used to supply both nitrogen and helium pressure or a vacuum at the various disconnects in the propulsion subsystem for verifying the integrity of the distribution plumbing and component parts.
C. The leak detector is used to leak-check the distribution system connections, seals, and joints.
D. The thrust chamber manometer is used to verify the integrity of the thrust chamber valves.

Physical Description—The set is made up of an enclosure 2 by 2 by 5 ft plus flexible interconnecting hoses. The equipment is mounted on a rigid steel structure with wheels for moving about and provisions for lifting by an overhead crane or fork lift. The set weighs approximately 300 lb.
3.2.2.1.3 Propellant Servicing Equipment

Requirements — At the launch pad, the experiment module propulsion subsystem is loaded with liquid propellant and pressurization gas.

Functional Description — The propellant servicing equipment is required at the launch pad to store, condition, and load propellant and pressurization gas into the experiment module propulsion subsystem. The propellant (hydrazine) storage tank and a propellant temperature-conditioning unit are located in an isolated area near the launch pad. This fixed equipment provides a ready source of conditioned propellant whenever required. A portable propellant servicing unit (PSU) is loaded with propellant at the storage tank area and transported to the launch pad where the propellant is metered into the module through flex hoses. Prior to loading propellants, the PSU pulls a vacuum on the liquid side of the propellant tank expulsion bladder. After the propellants are loaded, the PSU pressurizes the dry side of the propellant tank expulsion bladder with GN₂. The GN₂ is supplied to the PSU through a flex hose connected to a facility GN₂ outlet. The above described loading functions at the launch pad are repeated for each propellant tank in the module.

Physical Description — The PSU is a portable unit mounted on wheels and contains a propellant tank, a propellant metering system, valves, pressure gauges, plumbing, flex hoses, vacuum pump, and controls. It is housed in an enclosure measuring approximately 4 by 4 by 5 ft and weighing about 600 lb.

3.2.2.2 Electrical GSE
Electrical GSE is provided for the following experiments carried in free-flying modules:

A. FPE A-1 X-Ray Stellar Astronomy
B. FPE A-2 Advanced Stellar Astronomy
C. FPE A-2A Intermediate Stellar Astronomy
D. FPE A-3AA Advanced Solar Astronomy
E. FPE A-3CC ATM Follow-on
The elements of electrical GSE are described as follows:

3.2.2.2.1 A-1 X-Ray Stellar Astronomy Electrical Test and Checkout Set

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed using the OCS to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance test is conducted at the vendor's factory, using the vendor's checkout equipment.

Functional Description—Electrical GSE is capable of supporting the OCS in performing experiment system level testing. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except for the GSE used in monitoring the OCS status.

The following GSE equipment is used for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is used only when the module is not accessible.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.
D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The optical interface simulator contains electrical and optical equipment for simulation and checkout of the equipment.

F. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data-acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Processes telemetry signals for strip charts, oscilloscopes, or other types of recorders or displays.

Physical Description—The electrical GSE for this experiment is composed of racks and cables requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in six 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.

3.2.2.2 A-2 Advanced Stellar Astronomy Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed, using the OCS to the greatest extent possible. Ground checkout equipment is provided, as necessary, to augment the OCS. Acceptance tests are conducted at the vendor's factory, using the vendor's checkout equipment.
Functional Description—Electrical GSE is capable of supporting the OCS in performing experiment system-level testing. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage, except the GSE necessary for monitoring OCS status.

The following GSE equipment is used for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is used only when the module is not accessible.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The optical interface simulator contains electrical and optical equipment for equipment simulation and checkout.

F. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout, based on the information collected by the OCS data-acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Processes telementry signals for strip charts, oscilloscopes, and other recorders or displays.
Physical Description—Electrical GSE for this experiment is composed of racks with cables requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in six 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.

3.2.2.2.3 A-2A Intermediate Stellar Astronomy Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed, using the OCS to the greatest extent possible. Ground checkout equipment is provided, as necessary, to augment the OCS. Acceptance tests are conducted at the vendor's factory, using the vendor's checkout equipment.

Functional Description—Electrical GSE is capable of supporting the OCS in performing experiment system-level testing. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage, except the GSE necessary for monitoring OCS status.

The following GSE equipment is used for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is used only when the module is not accessible.
C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The optical interface simulator contains electrical and optical equipment for equipment simulation and checkout.

F. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout, based on the information collected by the OCS data-acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Processes telemetry signals for strip charts, oscilloscopes, and other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cables requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in six 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.

3.2.2.2.4 A-3A Advanced Solar Astronomy Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed, using the OCS to the greatest extent possible. Ground checkout equipment is provided, as necessary, to augment the OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.
Functional Description—Electrical GSE has the capability of supporting the OCS in performing experiment system level testing. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage, except the GSE used in monitoring the OCS status.

The following GSE equipment is used for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module data management subsystem (DMS), to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is used only when the module is not accessible.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The optical interface simulator contains electrical and optical equipment for equipment simulation and checkout.

F. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

**Physical Description**—Electrical GSE for this experiment is composed of racks with cables requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in six 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.

3. 2. 2. 2. 5 A-3CC ATM Follow-on Electrical Test and Checkout Kit

**Requirements**—System-level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed, using the OCS to the greatest extent possible. Ground checkout equipment is provided, as necessary, to augment the OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

**Functional Description**—Electrical GSE has the capability of supporting the OCS in performing experiment system level testing. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage, except the GSE used in monitoring of the OCS status.

The following GSE equipment is used for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module data management subsystem (DMS), to the GSE. The GSE simulates the command and control functions of the Space Station.
B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is used only when the module is not accessible.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The optical interface simulator contains electrical and optical equipment for equipment simulation and checkout.

F. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cables requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in six 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.
3.2.2.6 A-5A X-Ray Telescope Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

Functional Description—The electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status.

The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module data management subsystem, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The optical interface contains electrical and optical equipment for simulation and checkout of the equipment.
F. The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.

2. Provides OCS ancillary equipment to simulate impedances; montiro voltages, temperatures, etc.; provides stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Processes telemetry signals for strip charts, oscilloscopes, other recorders or displays.

**Physical Description**—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. The GSE is packaged in six 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3.2.2.7 T-2A Long-Term Cryogenic Storage Electrical Test and Checkout Kit

**Requirements**—System-level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

**Functional Description**—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC...
where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in five 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.
T-2BB Short-Term Cryogenic Storage Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.

Functional Description—Electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the EPIC to perform integration testing when the experiment is assembled in the module. The GSE is then transported to the area at KSC where the assembled module is installed in the orbiter. No GSE is required beyond this stage except that GSE necessary for monitoring OCS status. The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The docking interface unit provides the capability for verifying the electrical interfaces at the experiment module interface with the Space Station docking port.

D. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in five 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3.2.2.3 Mechanical/Structural GSE

Mechanical and structural GSE is provided for the following experiments carried in free-flying modules:

A. FPE A-1 X-Ray Stellar Astronomy.
B. FPE A-2 Advanced Stellar Astronomy.
D. FPE A-3AA Advanced Solar Astronomy.
E. FPE A-3CC ATM Follow-on.
F. FPE A-5A X-Ray Telescope.
G. FPE T-2A Long Term Cryo Storage.
H. FPE T-2BB Short Term Cryos.

The elements of mechanical and structural GSE are described as follows:

3.2.2.3.1 A-1 X-Ray Stellar Astronomy Mechanical Test and Checkout Set

Requirements—A mechanical test and checkout set is used to determine whether the experiment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier. The experiment is serviced with expendables during ground operations and test exercises.
Functional Description—The set is required at the EPIC to load experiment commodities, to verify the experiment and experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. Appropriate portions of the set will be used in prelaunch and launch operations. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment before the experiment is installed in the flight carrier.

B. The target simulators are radiation sources that operate within the detection limits (size, intensity, and wavelength) of the experiment equipment. The simulators are used after the experiment is installed in the module to functionally check the experiment bore-sight alignment, pointing, stability, jitter, and attitude.

C. The angle measurement device measures and verifies the experiment pointing angles.

D. The two-axis support fixture is a yoke and cradle device required to support the experiment module and allow the module to turn about two axes to a limited degree. The fixture is used to verify the system's ability to maneuver, point, and stabilize on simulated targets.

E. The LN₂ loading unit loads liquid nitrogen in the experiment cryostat.

F. The vibration test fixture vibrates the module (with the experiment installed) to verify the integrity of the experiment mechanical interfaces and the experiment alignment.

G. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

H. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.
Physical Description—The physical description of the items in the set follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LN₂ loading unit</td>
<td>50</td>
<td>2 ft³</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.2.3.2 A-2 Advanced Stellar Astronomy Mechanical Test and Checkout Set

Requirements—A mechanical test and checkout set is used to determine whether the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

Functional Description—The set is required at the EPIC to verify the experiment and experiment-carrier mechanical interfaces and the operational performance of the experiment's mechanical functions after integration with the flight carrier. Appropriate portions of the set will be used in prelaunch and launch operations. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment before the experiment is installed in the flight carrier.

B. The target simulators are radiation sources that operate within the detection limits (size, intensity, and wavelength) of the experiment equipment. The simulators are used after the experiment is installed in the module to functionally check the experiment boresight alignment, pointing, stability, jitter, and attitude.
C. The angle measurement device measures and verifies the experiment pointing angles.

D. The two-axis support fixture is a yoke and cradle device required to support the experiment module and allow the module to turn about two axes to a limited degree. The fixture is used to verify the ability of the system to maneuver, point, and stabilize on simulated targets.

E. The deployment measuring device measures operation of deployed devices, such as telescope sunshade, star trackers, mirror coverings, and camera protective envelopes.

F. The vibration test fixture vibrates the module with the experiment installed to verify the integrity of the experiment mechanical interfaces and the experiment alignment.

G. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

H. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

**Physical Description** — The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Deployment measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
3.2.2.3.3 A-2A Intermediate Stellar Astronomy Mechanical Test and Checkout Set

Requirements—A mechanical test and checkout set is used to determine whether the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

Functional Description—The set is required at the EPIC to verify the experiment and experiment-carrier mechanical interfaces and the operational performance of the experiment's mechanical functions after integration with the flight carrier. Appropriate portions of the set will be used in prelaunch and launch operations. The set includes the following equipment.

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment before the experiment is installed in the flight carrier.

B. The target simulators are radiation sources that operate within the detection limits (size, intensity, and wavelength) of the experiment equipment. The simulators are used after the experiment is installed in the module to functionally check the experiment bore-sight alignment, pointing, stability, jitter, and attitude.

C. The angle measurement device measures and verifies the experiment pointing angles.

D. The two-axis support fixture is a yoke and cradle device required to support the experiment module and allow the module to turn about two axes to a limited degree. The fixture is used to verify the ability of the system to maneuver, point, and stabilize on simulated targets.

E. The deployment measuring device measures operation of deployed devices, such as telescope sunshade, star trackers, mirror coverings, and camera protective envelopes.

F. The vibration test fixture vibrates the module with the experiment installed to verify the integrity of the experiment mechanical interfaces and the experiment alignment.

G. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.
H. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

**Physical Description**—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
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</thead>
<tbody>
<tr>
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<td>75 ft³</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Deployment measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.2.3.4 A-3AA Advanced Solar Astronomy Mechanical Test and Checkout Set

**Requirement**—A mechanical test and checkout set is used to determine whether the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

**Functional Description**—The set is required at the EPIC to verify the experiment and experiment-carrier mechanical interfaces and the operational performance of the experiment's mechanical functions after integration with the flight carrier. Appropriate portions of the set will be used in prelaunch and launch operations. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment before the experiment is installed in the flight carrier.
B. The target simulators are radiation sources that operate within the detection limits (size, intensity, and wavelength) of the experiment equipment. The simulators are used after the experiment is installed in the module to functionally check the experiment boresight alignment, pointing, stability, jitter, and attitude.

C. The angle measurement device measures and verifies the experiment pointing angles.

D. The two-axis support fixture is a yoke and cradle device required to support the experiment module and allow the module to turn about two axes to a limited degree. The fixture is used to verify the ability of the system to maneuver, point, and stabilize on simulated targets.

E. The deployment measuring device measures operation of deployed devices, such as sun sensor, mirror covers, grating covers, and camera covers.

F. The vibration test fixture vibrates the module with the experiment installed to verify the integrity of the experiment mechanical interfaces and the experiment alignment.

G. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

H. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris.

Physical Description—The physical description of the items in the set follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Deployment measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
3.2.2.3.5 A-3CC ATM Follow-on Mechanical Test and Checkout Set

**Requirement**—A mechanical test and checkout set is used to determine whether the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

**Functional Description**—The set is required at the EPIC to verify the experiment and experiment-carrier mechanical interfaces and the operational performance of the experiment's mechanical functions after integration with the flight carrier. Appropriate portions of the set will be used in prelaunch and launch operations. The set includes the following equipment:

- **A.** The mechanical interface simulator verifies the mechanical interfaces with the experiment before the experiment is installed in the flight carrier.
- **B.** The target simulators are radiation sources that operate within the detection limits (size, intensity, and wavelength) of the experiment equipment. The simulators are used after the experiment is installed in the module to functionally check the experiment bore-sight alignment, pointing, stability, jitter, and attitude.
- **C.** The angle measurement device measures and verifies the experiment pointing angles.
- **D.** The two-axis support fixture is a yoke and cradle device required to support the experiment module and allow the module to turn about two axes to a limited degree. The fixture is used to verify the ability of the system to maneuver, point, and stabilize on simulated targets.
- **E.** The deployment measuring device measures operation of deployed devices, such as sun sensor, mirror covers, grating covers, and camera covers.
- **F.** The vibration test fixture vibrates the module with the experiment installed to verify the integrity of the experiment mechanical interfaces and the experiment alignment.
- **G.** The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.
- **H.** The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris.
Physical Description—The physical description of the items in the set follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Deployment measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.2.3.6 A-5A X-Ray Telescope Mechanical Test and Checkout Set

Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier, and service the experiment with dependables during ground operations and test exercises.

Functional Description—A mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to load experiment commodities, to verify the experiment/experiment-carrier interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. Appropriate portions of the set will be used in prelaunch and launch operations. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The target simulators are radiation sources that operate within the detection limits (size, intensity, wavelength) of the experiment equipment. The simulators are used after the experiment is installed in the module to functionally check the experiment bore-sight alignment, pointing, stability, jitter, and attitude.

C. The measurement device measures and verifies the experiment pointing angles.
D. The two-axis support fixture is a yoke-and-cradle device required to support the experiment module and allow the module to turn to a limited degree about two axes. The fixture is used to verify the ability of the system to maneuver, point, and stabilize on simulated targets.

E. The LN₂ loading unit loads liquid nitrogen into the experiment cryostat.

F. The vibration test fixture vibrates the module with the experiment installed to verify the integrity of the experiment mechanical interfaces and the experiment alignment.

G. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

H. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and loose debris in preparation for launch.

Physical Description—The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Target simulators</td>
<td>30</td>
<td>6 ft³</td>
</tr>
<tr>
<td>Angle measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Two-axis support fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LN₂ loading unit</td>
<td>50</td>
<td>2 ft³</td>
</tr>
<tr>
<td>Vibration test fixture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.2.3.7 T-2A Long-Term Cryogenic Storage Mechanical Test and Checkout Set

Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.
**Functional Description**—A mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to load experiment commodities, to verify the experiment/experiment-carrier mechanical interfaces, and to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. Appropriate portions of the set will be used in prelaunch and launch operations. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The fluid storage and transfer unit stores, conditions, and transfers liquid hydrogen to the experiment supply tanks. The unit is also required during experiment test and checkout operations to supply test fluids for verifying the integrity of the experiment plumbing and component parts. Existing hardware items are used to the maximum extent possible.

C. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

D. The Space Station simulator supplies Space Station commodities and services (electrical power, coolant, atmosphere) to the experiment module during integration tests and checkout.

E. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and debris in preparation for launch.

**Physical Description**—The physical description of the items in the set is as follows:

| Item                                       | Weight (lb) | Size  
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Fluid storage and transfer unit</td>
<td>3,000</td>
<td>500 ft³</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Space Station simulator</td>
<td>300</td>
<td>60 ft³</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
3.2.2.3.8 T-2BB Short-Term Cryogenic Storage Mechanical Test and Checkout Set

Requirements—Determine that the experiment equipment mechanical interfaces and mechanical performance meet the experiment specification requirements and are compatible with the experiment flight carrier.

Functional Description—A mechanical test and checkout set is provided to check the experiment compliance with the above requirement. The set is required at the EPIC to load experiment commodities, to verify the operational performance of the experiment's mechanical functions after integration with the flight carrier. Appropriate portions of the set will be used in prelaunch and launch operations. The set includes the following equipment:

A. The mechanical interface simulator verifies the mechanical interfaces with the experiment prior to installing the experiment in the flight carrier.

B. The fluid storage and transfer unit stores, conditions, and transfers six different experiment fluids to the flight carrier supply tanks and carry-on containers. The unit is also required during experiment test and checkout operations to supply test fluids for verifying the integrity of the experiment plumbing and component parts. Existing hardware items are used to the maximum extent possible.

C. The module cg and weight measuring device determines the center of gravity and weight of the module with the experiment installed.

D. The Space Station simulator supplies Space Station commodities and services (electrical power, coolant, atmosphere) to the experiment module during integration tests and checkout.

E. The module tumble and cleaning unit tumbles the module about its longitudinal axis to remove dirt and debris in preparation for launch.
Physical Description — The physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
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</thead>
<tbody>
<tr>
<td>Mechanical interface simulator</td>
<td>600</td>
<td>75 ft³</td>
</tr>
<tr>
<td>Fluid storage and transfer unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Module cg and weight measuring device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Space Station simulator</td>
<td>300</td>
<td>60 ft³</td>
</tr>
<tr>
<td>Module tumble and cleaning unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.2.4 Handling and Transport GSE

Handling and transport GSE is provided for the following experiments carried in free-flying modules:

A. FPE A-1 X-Ray Stellar Astronomy
B. FPE A-2 Advanced Stellar Astronomy
C. FPE A-2A Intermediate Stellar Astronomy
D. FPE A-3AA Advanced Solar Astronomy
E. FPE A-3CC ATM Follow-on
F. FPE A-5A X-Ray Telescope
G. FPE T-2A Long-Term Cryogenic Storage
H. FPE T-2BB Short-Term Cryogenic Storage

The elements of handling and transport GSE are described as follows:

3.2.2.4.1 A-1 X-Ray Stellar Astronomy Transportation Kit

Requirements — During transportation from the manufacturing facility to the EPIC, the x-ray telescope and associated experiment equipment are protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description — The transportation kit contains and protects the x-ray telescope and associated experiment equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is
also used for temporary storage at the EPIC until the telescope and associated experiment equipment are installed in the flight carrier. The kit includes a handling fixture and protective enclosure; an environmental control system; a refrigerated shipping container for x-ray polarimeter detector; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the instrument during shipment. The environmental control system provides an inert gas blanket. This portion of the kit and the refrigerated container for the x-ray polarimeter detector may be used during shipment of the integrated module and FPE to the launch site.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE A-1 identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.2.4.2 A-2 Advanced Stellar Astronomy Transportation Kit

Requirements—During transportation from the manufacturing facility to the EPIC, the stellar astronomy equipment is protected from shock vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the stellar astronomy equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the FPE equipment is installed in the flight carrier. The kit includes a rigis handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the module during shipment. The environmental control system provides an inert gas blanket. This portion of the kit may be used during shipment of the integrated module and FPE to the launch site.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE A-2 identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.
3.2.2.4.3 A-2A Intermediate Stellar Astronomy Transportation Kit

**Requirements**—During transportation from the manufacturing facility to the EPIC, the intermediate stellar astronomy equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

**Functional Description**—The transportation kit is required to contain and protect the intermediate stellar astronomy equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the FPE equipment is installed in the flight carrier. The kit includes a rigid handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the module during shipment. The environmental control system provides an inert gas blanket. This portion of the kit may be used during shipment of the integrated module and FPE to the launch site.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE A-2A identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.2.4.4 A-3AA Advanced Solar Astronomy Transportation Kit

**Requirements**—During transportation from the manufacturer's facility to the EPIC, the advanced solar astronomy equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

**Functional Description**—The transportation kit is required to contain and protect the advanced solar astronomy equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the telescope is installed in the flight carrier. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to
monitor environmental conditions, shock, vibration, and structural strain on selected parts of the instrument during shipment. The environmental control system provides an inert gas blanket. This portion of the kit may be used during shipment of the module-FPE to the launch site.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE A-3A and A-3B identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.2.4.5 A-3CC ATM Follow-on Transportation Kit

Requirements—During transportation from the manufacturer's facility to the EPIC, the ATM Follow-on equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the ATM Follow-on equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the telescope is installed in the flight carrier. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the instrument during shipment. The environmental control system provides an inert gas blanket. This portion of the kit may be used during shipment of the module-FPE to the launch site.

Physical Description—The transportation kit is sized to accommodate the following equipment:

<table>
<thead>
<tr>
<th>Assembly</th>
<th>Weight (lb)</th>
<th>Size (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photoheliograph</td>
<td>650</td>
<td>10 x 3 x 4</td>
</tr>
<tr>
<td>X-Ray Spectroheliograph</td>
<td>640</td>
<td>9.1 x 3 x 3.3</td>
</tr>
<tr>
<td>XUV Spectrometer</td>
<td>580</td>
<td>10 x 2.3 x 1.75</td>
</tr>
</tbody>
</table>
3.2.2.4.6 A-5A X-Ray Telescope Transportation Kit

Requirements — During transportation from the manufacturing facility to the EPIC, X-Ray Telescope equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description — The transportation kit is required to contain and protect the X-Ray Telescope equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the equipment is installed in the flight carrier. The kit includes a handling fixture and protective enclosure, an environmental control system, and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the instrument during shipment.

Physical Description — The transportation kit is sized to accommodate the equipment for FPE A-5A identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.2.4.7 T-2A Long-Term Cryogenic Storage Equipment Transportation Kit

Requirements — During transportation from the manufacturing facility to the EPIC, long-term cryogenic storage experiment equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description — The transportation kit is required to contain and protect the long term cryo storage experiment equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the experiment equipment is installed in the flight carrier. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration,
and structural strain on selected parts of the equipment during shipment. Liquid hydrogen to be used with this FPE is not provided with the equipment, so the kit need not accommodate this fluid.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE T-2A identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.2.4.8 T-2BB Short-Term Cryogenic Storage Equipment Transportation Kit

**Requirements**—During transportation from the manufacturing facility to the EPIC, short term cryogenic storage experiment equipment is protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

**Functional Description**—The transportation kit is required to contain and protect the short-term cryogenic storage experiment equipment during transportation from the manufacturing and acceptance test location to the EPIC. The kit is also used for temporary storage at the EPIC until the experiment equipment is installed in the flight carrier. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment. Fluids to be used with this FPE are not provided with the equipment, so the kit need not accommodate these materials.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPEs T-2B, T-2C, T-2D, and T-2E identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3 Integral or Carry-On Experiment GSE

With the Shuttle payload limit of 20,000 lb, all the following experiment hardware is carry-on. For any carry-on hardware identified to be launched integral with the GPL, the GSE is defined in this section.
Integral or carry-on GSE includes that required for experiments accommodated integral to the Modular Space Station or carried-on to the Station on-orbit.

3.2.3.1 Electrical GSE

Electrical GSE is provided for the following integral or carry-on experiments:

A. P-1A Atmospheric and Magneto Science
B. P-1B Cometary Physics
C. P-1C Meteoroid Science
D. P-1D Thick Material Meteoroid Penetration
E. P-1E Small Astronomy Telescopes
F. P-2A Wake Measurements from Station and Booms
G. P-3C Plastic/Nuclear Emulsions
H. P-4A Airlock and Boom Experiments
I. P-4B Flame Chemistry and Laser Experiments
J. P-4C Test Chamber Experiments
K. MS-3A Crystal Growth, Biological and Physical Processes
L. MS-3B Crystal Growth from Vapor
M. MS-3C Controlled Density Materials
N. MS-3D Liquid and Glass Processing
O. MS-3E Supercooling and Homogenous Nucleation
P. T-1A Contamination Experimental Package
Q. T-1B Contamination Monitor Package
R. T-3A Astronaut Maneuver Unit
S. T-4A Long Duration System Tests
T. T-4B Medium Duration Tests
U. T-4C Short Duration Tests
V. T-5A Initial Flight Teleoperator
W. T-5B Functional Teleoperator
X. T-5C Ground Control Teleoperator
Y. LS-1A Minimal Medical Research Facility.
The elements of electrical GSE are described as follows:

3.2.3.1.1 P-1A Atmospheric and Magneto Science Electrical Test and Checkout Kit

**Requirements**—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station OCS is simulated to the extent practical, and ground checkout equipment (including ACE) is provided, as necessary, to augment the simulated OCS. Acceptance tests are conducted at the vendor's factory, using the vendor's checkout equipment.

**Functional Description**—Electrical GSE has the capability of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the KSC support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the Flight Integration Tool (FIT) area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The following equipment is included as GSE for this experiment:

A. The OCS adapter provides for simulating the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data acquisition units, stimuli generators, and data terminals.

B. The GSE adapter provides a data bus interface between the OCS adapter and the remaining GSE. This interface allows integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE. The GSE simulates the command and control functions of the Space Station.

C. The control and display unit provides the controls and displays required to interface with the OCS-and GSE-peculiar functions associated with this experiment. This unit is portable and can be removed from the GSE mounting.
D. The camera alignment device is used to verify that the camera plan and tilt mechanisms are calibrated and operating properly.

E. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

F. The target simulator simulates different sizes, types, and intensities of light sources required for checkout.

G. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the data acquisition equipment.
   2. Provides OCS ancillary equipment to simulate impedances; monitors voltages, temperatures, etc; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

The GSE is packaged in six 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.

3.2.3.1.2 P-1B Cometary Physics Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station is simulated to the extent practical, and ground checkout equipment provided, as necessary, to augment the simulated OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

Functional Description—Electrical GSE has the capability of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the KSE support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the FIT area to perform
integration testing. The GSE is then used at the Shuttle orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The following equipment is included as GSE for this experiment:

A. The OCS adapter provides for simulating the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data acquisition units, stimuli generators, and data terminals.

B. The GSE adapter provides a data bus interface between the OCS adapter and the remaining GSE. This interface allows integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE. The GSE simulates the command and control functions of the Space Station.

C. The control and display unit provides the controls and displays required to interface with the OCS-and GSE-peculiar functions associated with this experiment. This unit is portable and can be removed from the GSE mounting.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the data acquisition equipment.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in six 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.
3. 2. 3. 1. 3 P-1C Meteoroid Science Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station OCS is simulated to the extent practical, and ground checkout equipment is provided, as necessary, to augment the simulated OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

Functional Description—Electrical GSE is capable of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the KSE support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter Maintenance Area to support critical systems reverification tests. No GSE is required beyond this stage.

The following GSE is provided for this experiment:

A. The OCS adapter provides for simulating the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data-acquisition units, stimuli generators, and data terminals.

B. The GSE adapter provides a data bus interface between the OCS adapter and the remaining GSE. This interface will allow integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE. The GSE simulates the command and control functions of the Space Station.

C. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.
E. The optical interface simulator contains electrical and optical equipment for simulation and checkout of the equipment.

F. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the data-acquisition equipment.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in six 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.

3.2.3.1.4 P-1D Thick Material Meteoroid Penetration Electrical Test and Checkout Kit

Requirements—Equipment for this experiment is launched integral with the GPL Module. Electrical GSE is not required. Preflight checkout and integration verification will be performed by OCS and module GSE.

3.2.3.1.5 P-1E Small Astronomy Telescopes Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed. The OCS is used to the greatest extent possible. Ground checkout equipment is provided as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory using the vendor's checkout equipment.
Functional Description—The electrical GSE has the capability of supporting the OCS in performing system level testing of the experiment. This equipment is used at the KSC support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter Maintenance Area to support critical systems reverification tests. No GSE is required beyond this stage.

The following equipment is included as GSE for this experiment:

A. The GSE adapter provides a data bus interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE. The GSE simulates the command and control functions of the Space Station.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The cable assembly contains all cabling with connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

D. The optical interface simulator contains electrical and optical equipment for simulation and checkout of the equipment.

E. The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.

2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Process telemetry signals for strip charts, oscilloscopes, or other recorders or displays.
Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in six 2 by 2 by 6-ft standard racks and a portable container for the cable assembly.

3.2.3.1.6 P-2A Wake Measurements from Station and Booms Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station is simulated to the extent practical, and ground checkout equipment provided, as necessary, to augment the simulated OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

Functional Description—Electrical GSE has the capability of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the KSC support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The following equipment is included as GSE for this experiment:

A. The OCS adapter provides for simulating the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data acquisition units, stimuli generators, and data terminals.

B. The GSE adapter provides a data bus interface between the OCS adapter and the remaining GSE. This interface allows integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE. The GSE simulates the command and control functions of the Space Station.

C. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be removed from the GSE mounting.
D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the data acquisition equipment.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

**Physical Description**—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

The GSE is packaged in six 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.

3.2.3.1.7 P-3C Plastic/Nuclear Emulsions Electrical Test and Checkout Kit

**Requirements**—System-level integration tests and prelaunch functional tests of the flight hardware for this experiment are performed, using the OCS to the greatest extent possible. Ground checkout equipment is provided, as necessary to augment the OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

**Functional Description**—Electrical GSE is capable of supporting the OCS in performing experiment system level testing. This equipment is used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.
The following GSE equipment is used for this experiment:

A. The GSE adapter provides a data base interface between the GSE and the module. This interface allows integrated system testing by completing the checkout monitoring and control loop from the OCS, through the module DMS, to the GSE.

B. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be used within the module.

C. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

D. The electrical test set contains electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data-acquisition system.

2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Processes telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of a rack with cables requiring subfloor cooling and subfloor cableways. This rack is pallet-mounted to facilitate handling when moved to a new testing location.

The GSE is packaged in one 2- by 2- by 6-ft standard rack and a portable container for the cable assembly.
3.2.3.1.8 P-4A Airlock and Boom Experiments Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station is simulated to the extent practical, and ground checkout equipment provided, as necessary, to augment the simulated OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

Functional Description—Electrical GSE has the capability of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The following equipment is included as GSE for this experiment:

A. The OCS adapter provides for simulating the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data acquisition units, stimuli generators, and data terminals.

B. The GSE adapter provides a data bus interface between the OCS adapter and the remaining GSE. This interface allows integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE.

C. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be removed from the GSE mounting.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Process telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

**Physical Description**—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in two 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3.2.3.1.9 Flame Chemistry and Laser Experiments Electrical Test and Checkout Kit

**Requirements**—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station is simulated to the extent practical, and ground checkout equipment provided, as necessary, to augment the simulated OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

**Functional Description**—Electrical GSE has the capability of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The following equipment is included as GSE for this experiment:

A. The OCS adapter provides for simulating the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data acquisition units, stimuli generators, and data terminals.
B. The GSE adapter provides a data bus interface between the OCS adapter and the remaining GSE. This interface allows integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE.

C. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions as associated with this experiment. This unit is portable and can be removed from the GSE mounting.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.
   3. Process telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in two 2 by 2 by 6 ft standard racks and a portable container for the cable assembly.

3.2.3.1.10 P-4C Test Chamber Experiments Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station is simulated to the extent practical, and ground checkout equipment provided,
as necessary, to augment the simulated OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

Functional Description—Electrical GSE has the capability of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The following equipment is included as GSE for this experiment:

A. The OCS adapter provides for simulating the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data acquisition units, stimuli generators, and data terminals.

B. The GSE adapter provides a data bus interface between the OCS adapter and the remaining GSE. This interface allows integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE. The GSE simulates the command and control functions of the Space Station.

C. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be removed from the GSE mounting.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the OCS data acquisition system.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; provide stimuli; and provide other functions beyond the range of the OCS and
normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

3. Process telemetry signals for strip charts, oscilloscopes, or other recorders or displays.

Physical Description—Electrical GSE for this experiment is composed of racks with cabling requiring subfloor cooling subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in two 2 by 2 by 6 ft. standard racks and a portable container for the cable assembly.

3.2.3.1.11 MS-3A Crystal Growth, Biological and Physical Processes

3.2.3.1.12 MS-3B Crystal Growth from Vapor

3.2.3.1.13 MS-3B Controlled Density Materials

3.2.3.1.14 MS-3D Liquid and Glass Processing

3.2.3.1.15 MS-3E Supercooling and Homogeneous Nucleation Electrical Test and Checkout Kit

Requirements—Prelaunch functional tests of the flight hardware at KSC are not required for the equipment of these FPE Subgroups. Verification with the FIT includes installation of equipment packages in the module and connection of electrical cabling. Electrical checkout will not be performed, hence electrical test and checkout kits are not required.
Requirements—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station OCS is simulated to the extent practical, and ground checkout equipment is provided, as necessary, to augment the simulated OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

Functional Description—Electrical GSE is capable of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the KSC support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter Maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The following GSE is provided for this experiment:

A. The OCS adapter provides for simulating the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data-acquisition units, stimuli generators, and data terminals.

B. The GSE adapter provides a data bus interface between the OCS adapter and the remaining GSE. This interface allows integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE.

C. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.
E. The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the data-acquisition equipment.

2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

Physical Description—Electrical GSE for this experiment is composed of racks with cables requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in two 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.

3.2.3.1.17 T-1B Contamination Monitor Package Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station OCS is simulated to the extent practical, and ground checkout equipment is provided, as necessary, to augment the simulated OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

Functional Description—Electrical GSE is capable of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the KSC support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter Maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.
The following GSE is provided for this experiment:

A. The OCS adapter provides for simulating the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data-acquisition units, stimuli generators, and data terminals.

B. The GSE adapter provides a data bus interface between the OCS adapter and the remaining GSE. This interface allows integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE.

C. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the data-acquisition equipment.
   2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

Physical Description—Electrical GSE for this experiment is composed of racks with cables requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location. This GSE is packaged in two 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.
3.2.3.1.18 T-3A Astronaut Maneuver Unit Electrical Test and Checkout Kit

**Requirements**—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station OCS is simulated to the extent practical, and ground checkout equipment is provided, as necessary, to augment the simulated OCS. Acceptance testing is conducted at the vendor's factory, using vendor's checkout equipment.

**Functional Description**—Electrical GSE is capable of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The following GSE is provided for this experiment:

A. The OCS adapter provides for simulating of the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data-acquisition units, stimuli generators, and data terminals.

B. The GSE adapter provides a data bus interface between the OCS Adapter and the remaining GSE. This interface allows integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE.

C. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be removed from the GSE mounting.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:
   1. Provides the processor capabilities required to complete checkout based on the information collected by the data-acquisition equipment.
2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

Physical Description—Electrical GSE for this experiment is composed of racks with cables requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in three 2-by-2-by 6-ft standard racks and a portable container for the cable assembly.

3.2.3.1.19 T-4A Long Duration System Tests and T-4B Medium-Duration Tests Electrical Test and Checkout Kit

Requirements—Equipment for these experiments is launched integral with the GPL Module. Electrical GSE is not required. Preflight checkout and integration verification will be performed by OCS and module GSE.

3.2.3.1.20 T-4C Short-Duration Tests Electrical Test and Checkout Kit

Requirements—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station OCS is simulated to the extent practical, and ground checkout equipment is provided, as necessary, to augment the simulated OCS. Acceptance testing is conducted at the vendor's factory, using the vendor's checkout equipment.

Functional Description—Electrical GSE is capable of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.
The following equipment is included as GSE for this experiment:

A. The OCS adapter provides for simulating the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data acquisition units, stimuli generators, and data terminals.

B. The GSE adapter provides a data bus interface between the OCS adapter and the remaining GSE. This interface allows integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE.

C. The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be removed from the GSE mounting.

D. The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

E. The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout, based on the information collected by the data acquisition equipment.

2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc.; and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

Physical Description—Electrical GSE for this experiment is composed of racks with cables requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in two 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.
3.2.3.1.21 T-5A Initial Flight Teleoperator Electrical Test and Checkout Kit

**Requirements**—System-level integration tests and prelaunch functional tests of the flight hardware are performed for this experiment. The Space Station OCS is simulated to the extent practical, and ground checkout equipment is provided, as necessary, to augment the simulated OCS. Acceptance testing is conducted at the vendor's factory, using vendor's checkout equipment.

**Functional Description**—Electrical GSE is capable of simulating the OCS in performing system-level testing of the experiment. This equipment is used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The following GSE is provided for this experiment:

**A.** The OCS adapter provides for simulating of the Space Station OCS interface with the experiment hardware. This includes ground equipment versions of the remote data-acquisition units, stimuli generators, and data terminals.

**B.** The GSE adapter provides a data bus interface between the OCS Adapter and the remaining GSE. This interface allows integrated system testing by completing the checkout monitoring and control loop from the simulated OCS to the remaining GSE.

**C.** The control and display unit provides the controls and displays required to interface with the OCS- and GSE-peculiar functions associated with this experiment. This unit is portable and can be removed from the GSE mounting.

**D.** The cable assembly contains all cables and connectors necessary to interconnect the onboard equipment with the electrical GSE for required integration testing and checkout.

**E.** The electrical test set contains electrical equipment that:

1. Provides the processor capabilities required to complete checkout based on the information collected by the data-acquisition equipment.
2. Provides OCS ancillary equipment to simulate impedances; monitor voltages, temperatures, etc. and provide stimuli and other functions beyond the range of the OCS and normally provided on orbit by OCS ancillary equipment furnished from the Space Station.

Physical Description—Electrical GSE for this experiment is composed of racks with cables requiring subfloor cooling and subfloor cableways. These racks are pallet-mounted to facilitate handling when moved to a new testing location.

This GSE is packaged in two 2- by 2- by 6-ft standard racks and a portable container for the cable assembly.

3.2.3.1.22 T-5B Functional Teleoperator Electrical Test and Checkout Kit

Requirements—No integration or prelaunch electrical tests are required for this experiment. The equipment is passive. Accordingly, no electrical GSE is required.

3.2.3.1.23 T-5C Ground Control Teleoperator Electrical Test and Checkout Kit

Requirements—No flight equipment, except that used in T-5A and T-5B experiments, is required for this FPE. Accordingly, no electrical GSE is required.

3.2.3.1.24 LS-1A Minimal Medical Research Facility Electrical Test and Checkout Kit

Requirements—Equipment for this experiment is launched integral with the Space Station Module. Electrical GSE is not required. Preflight checkout and integration verification will be performed by OCS and module GSE.
3.2.3.2 Mechanical/Structural GSE

Mechanical and structural GSE is provided for the following integral or carry-on experiments:

A. P-1A Atmosphere and Magneto Science
B. P-1B Cometary Physics
C. P-1C Meteoroid Science
D. P-1D Thick Material Meteoroid Penetration
E. P-1E Small Astronomy Telescopes
F. P-2A Wake Measurements from Station and Booms
G. P-3C Plastic/Nuclear Emulsions
H. P-4A Airlock and Boom Experiments
I. P-4B Flame Chemistry and Laser Experiments
J. P-4C Test Chamber Experiments
K. MS-3A Crystal Growth, Biological and Physical Processes
L. MS-3B Crystal Growth from Vapor
M. MS-3C Controlled Density Materials
N. MS-3D Liquid and Glass Processing
O. MS-3E Supercooling and Homogeneous Nucleation
P. T-1A Contamination Experimental Package
Q. T-1B Contamination Monitor Package
R. T-3A Astronaut Maneuver Unit
S. T-4A Long Duration System Tests
T. T-4B Medium Duration Tests
U. T-4C Short Duration Tests
V. T-5A Initial Flight Teleoperator
W. T-5B Functional Teleoperator
X. T-5C Ground Control Teleoperator
Y. LS-1A Minimal Medical Research Facility

The elements of mechanical and structural GSE are described as follows:

3.2.3.2.1 P-1A Atmospheric and Magneto Science Mechanical Test and Checkout Set

Requirements—At atmospheric and magneto science mechanical test and checkout set is provided to verify that the experiment equipment mechanical
performance meets the experiment specification requirements and is compatible with the experiment flight carrier.

**Functional Description**—The mechanical test and checkout set is required at the KSC support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the Flight Integration Tool (FIT) area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems verification tests. No GSE is required beyond this stage.

The set includes the following equipment:

A. The deployment boom measurement device measures and verifies the boom deployment, extension, and orientation mechanisms.

B. The camera target simulators are light sources and screen patterns operating within the detection limits (size, intensity, and wavelength) of the photometer system. The simulators are used to functionally check the experiment focus, alignment, pointing, stability, jitter, and attitude.

**Physical Description**—A physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deployment boom</td>
<td>100</td>
<td>15</td>
</tr>
<tr>
<td>measurement device</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camera target simulators</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2.3.2.2 P-1B Cometary Physics, Mechanical Test and Checkout Set

**Requirements**—A cometary physics mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier. The experiment is serviced with expendables during ground operations and test exercises.

**Functional Description**—The mechanical test and checkout set is required at the KSC support laboratories and facilities for experiment support, checkout,
and calibration. It is then used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems verification tests. No GSE is required beyond this stage.

The set includes the following equipment:

A. The boom mechanism verification unit verifies the operation of the deployment and orientation mechanisms for the scanning grating spectrometer, the NH$_3$ release device, and the ICN release device.
B. The commodities servicing unit stores, conditions, transfers, and loads the expendables into the experiment canisters.

**Physical Description**—A physical description of the set is as follows:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Weight</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom mechanism verification unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Commodities servicing unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.3.2.3 P-1C Meteoroid Science Mechanical Test and Checkout Set

**Requirements**—A meteoroid science mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier.

**Functional Description**—The mechanical test and checkout set is required at the KSC support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems re-verification tests. No GSE is required beyond this stage.

The set includes the following equipment:

The exposure verification unit verifies the pointing of the gimbal device and the external mounting of the recoverable panel assembly.
Physical Description — The physical description of the equipment is as follows:

<table>
<thead>
<tr>
<th>Exposure verification unit</th>
<th>Weight</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.3.2.4 P-1D Thick Material Meteoroid Penetration Mechanical Test and Checkout Set

Requirements — Equipment for this experiment is launched integral with the GPL Module. Mechanical GSE is not required. Preflight checkout and integration verification will be performed by OCS and module GSE.

3.2.3.2.5 P-1E Small Astronomy Telescopes Mechanical Test and Checkout Set

Requirements — A mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier.

Functional Description — The mechanical test and checkout set is required at the KSC support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The set includes the following equipment:
The deployment boom measurement device measures and verifies the boom deployment, extension, and orientation mechanisms.

Physical Description — A physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Deployment boom measurement device</th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>15</td>
</tr>
</tbody>
</table>
3. 2. 3. 2. 6 P-2A Wake Measurements From Station and Booms
Mechanical Test and Checkout Set

Requirements — A mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier.

Functional Description — The mechanical test and checkout set is required at the KSC support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the FIT area to perform integration testing. The GSE is then used at the Shuttle/Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage. The set includes the following equipment:

The deployment boom measurement device measures and verifies the boom deployment, extension, and orientation mechanisms.

Physical Description — A physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>15</td>
</tr>
</tbody>
</table>

3. 2. 3. 2. 7 P-3C Plastic/Nuclear Emulsions Mechanical Test and Checkout Set

Requirements — A mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier.

Functional Description — The mechanical test and checkout set is required at the FIT area to perform integration testing. No GSE is required beyond this stage. The set includes the following equipment:

The operating measurement device verifies insertion and extension of experiment mechanisms.

Physical Description — A physical description of the set is as follows:

<table>
<thead>
<tr>
<th>Weight</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
3.2.3.2.8 P-4A Airlock and Boom Experiments Mechanical Test and Checkout Set

**Requirements**—A mechanical test and checkout set is provided to verify the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier.

**Functional Description**—The mechanical test and checkout set is required at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The set includes the following equipment:

A. The deployment boom measurement device measures and verifies the boom deployment, extension, and orientation mechanisms.

B. The camera target simulators are light sources and screen patterns operating within the detection limits (size, intensity, and wavelength) of the photometer system. The simulators are used to functionally check the experiment focus, alignment, pointing, stability, jitter, and attitude.

C. The commodities servicing unit stores, conditions, transfers, and loads the expendables into the experiment canisters.

**Physical Description**—A physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deployment boom measurement device</td>
<td>100</td>
<td>15</td>
</tr>
<tr>
<td>Camera target simulators</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>Commodities servicing unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.3.2.9 P-4B Flame Chemistry and Laser Experiments Mechanical Test and Checkout Set

**Requirements**—A mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier.
**Functional Description**—The mechanical test and checkout set is required at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The set includes the following equipment:

A. The deployment boom measurement device measures and verifies the boom deployment, extension, and orientation mechanisms.

B. The camera target simulators are light sources and screen patterns operating within the detection limits (size, intensity, and wavelength) of the photometer system. The simulators are used to functionally check the experiment focus, alignment, pointing, stability, jitter and attitude.

C. The commodities servicing unit stores, conditions, transfers, and loads the expendables into the experiment canisters.

**Physical Description**—A physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deployment boom measurement device</td>
<td>100</td>
<td>15</td>
</tr>
<tr>
<td>Camera target simulators</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>Commodities servicing unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.3.2.10 P-4C Test Chamber Experiments Mechanical Test and Checkout Set

**Requirements**—A mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier.

**Functional Description**—The mechanical test and checkout set is required at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.
The set includes the following equipment:
The commodities servicing unit stores, conditions, transfers, and loads the expendables into the experiment canisters.

**Physical Description**—The commodities servicing unit weights TBD lb and has a volume of TBD cu ft. It accommodates liquid helium, nitrogen gas, water, freon, xenon, and SF\(_6\) or CO\(_2\).

MS-3A Crystal Growth, Biological and Physical Processes
MS-3B Crystal Growth from Vapor
MS-3C Controlled Density Materials
MS-3D Liquid and Glass Processings
MS-3E Supercooling and Homogeneous Nucleation Mechanical Test and Checkout Set

**Requirements**—Prelaunch functional tests of the flight hardware at KSC are not required for the equipment of these FPE Subgroups. Verification with the FIT includes installation of equipment packages in the module and connection of electrical cobling. Mechanical checkout will not be performed, hence mechanical test and checkout sets are not required.

### 3.2.3.2.11 T-1A Contamination Experimental Package Mechanical Test and Checkout Set

**Requirements**—A mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier.

**Functional Description**—The mechanical test and checkout set is required at the KSC support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.
The set includes the following equipment:

A. The deployment boom measurement device measures and verifies the boom deployment, extension, and orientation mechanisms.
B. The nitrogen gas servicing unit provides a dry nitrogen blanket for selected components.

Physical Description—A physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deployment boom measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Nitrogen gas servicing unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.3.2.12 T-1B Contamination Monitor Package Mechanical Test and Checkout Set

Requirements—A mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier.

Functional Description—The mechanical test and checkout set is required at the KSC support laboratories and facilities for experiment support, checkout, and calibration. It is then used at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The set includes the following equipment:

A. The deployment boom measurement device measures and verifies the boom deployment, extension, and orientation mechanisms.
B. The nitrogen gas servicing unit provides a dry nitrogen blanket for selected components.

Physical Description—A physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deployment boom measurement device</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Nitrogen gas servicing unit</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
3.2.3.2.13 T-3A Astronaut Maneuver Unit Mechanical Test and Checkout Set

Requirements—A mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier.

Functional Description—The mechanical test and checkout set is required at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverifyification tests. No GSE is required beyond this stage.

The set includes the following equipment:

A. The gaseous oxygen servicing unit provides gaseous oxygen pressurizing the experiment gas tank.

Physical Description—A physical description of the set is as follows:

<table>
<thead>
<tr>
<th>Gaseous oxygen servicing unit</th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

3.2.3.2.14 T-4A Long-Duration Systems Test

3.2.3.2.15 T-4B Medium-Duration Tests Mechanical Test and Checkout Kit

Requirements—Equipment for these experiments is launched integral with the GPL Module. Mechanical GSE is not required. Preflight checkout and integration verification will be performed by OCS and module GSE.

3.2.3.2.16 T-4C Short-Duration Tests Mechanical Test and Checkout Set

Requirements—A mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets experiment specification requirements and is compatible with the experiment flight carrier.
Functional Description—The mechanical test and checkout set is required at the FIT area to perform integration testing. The GSE is then used at the Shuttle Orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The set includes the following equipment:

A. The deployment boom measurement device measures and verifies the boom deployment, extension, and orientation mechanisms.
B. The commodities servicing unit stores, conditions, transfers, and loads the expendables into the experiment tanks.
C. The test components verification unit verifies the mechanical operation of components, parts and items to be further tested in space.
D. The leak detector unit verifies the integrity of the experiment fluid systems.

Physical Description—A physical description of the items in the set is as follows:

<table>
<thead>
<tr>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deployment boom measurement device</td>
<td>100</td>
</tr>
<tr>
<td>Commodities servicing unit</td>
<td>TBD</td>
</tr>
<tr>
<td>Test components verification unit</td>
<td>100</td>
</tr>
<tr>
<td>Leak detector unit</td>
<td>50</td>
</tr>
</tbody>
</table>

3.2.3.2.17 T.5A Initial Flight Teleoperator Mechanical Test and Checkout Set

Requirements—A mechanical test and checkout set is provided to verify that the experiment equipment mechanical performance meets the experiment specification requirements and is compatible with the experiment flight carrier.

Functional Description—The mechanical test and checkout set is required at the FIT area to perform integration testing. The GSE is then used at the
Shuttle orbiter maintenance area to support critical systems reverification tests. No GSE is required beyond this stage.

The set includes the following equipment:

A. The gaseous nitrogen loading unit provides gaseous nitrogen to the experiment tanks.
B. The leak detector unit verifies the integrity of the experiment fluid systems.

**Physical Description**—A physical description of the items in the set are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaseous nitrogen loading unit</td>
<td>100</td>
<td>15</td>
</tr>
<tr>
<td>Leak detector unit</td>
<td>50</td>
<td>1</td>
</tr>
</tbody>
</table>

3.2.3.2.18 T-5B Functional Teleoperator Mechanical Test and Checkout Set

**Requirements**—Integration tests include installation of passive experiment equipment in the FIT. No mechanical GSE is required.

3.2.3.2.19 T-5C Ground Control Teloperator Mechanical Test and Checkout Set

**Requirements**—No flight equipment, except that used in T-5A and T-5B experiments, is required for this FPE. Accordingly, no mechanical GSE is required.

3.2.3.2.20 LS-1A Minimal Medical Research Facility Mechanical Test and Checkout Set

**Requirements**—Equipment for this experiment is launched integral with the Space Station Module. Mechanical GSE is not required. Preflight checkout and integration verification will be performed by OCS and module GSE.
3.2.3.3 Handling and Transport GSE

Handling and transport GSE is provided for the following integral or carry-on experiments:

A. P-1A  Atmospheric and Magneto Science
B. P-1B  Cometary Physics
C. P-1C  Meteoroid Science
D. P-1D  Thick Material Meteoroid Penetration
E. P-1E  Small Astronomy Telescopes
F. P-2A  Wake Measurements from Station and Booms
G. P-3C  Plastic/Nuclear Emulsions
H. P-4A  Airlock and Boom Experiments
I. P-4B  Flame Chemistry and Laser Experiments
J. P-4C  Test Chamber Experiments
K. MS-3A  Crystal Growth, Biological and Physical Processes
L. MS-3B  Crystal Growth from Vapor
M. MS-3C  Controlled Density Materials
N. MS-3D  Liquid and Glass Processing
O. MS-3E  Supercooling and Homogeneous Nucleation
P. T-1A  Contamination Experimental Package
Q. T-1B  Contamination Monitor Package
R. T-3A  Astronaut Maneuver Unit
S. T-4A  Long Duration System Tests
T. T-4B  Medium Duration Tests
U. T-4C  Short Duration Tests
V. T-5A  Initial Flight Teleoperator
W. T-5B  Functional Teleoperator
X. T-5C  Ground Control Teleoperator
Y. LS-1A  Minimal Medical Research Facility

The elements of handling and transport GSE are described as follows.
3.2.3.3.1 P-1A Atmospheric and Magneto Science Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the atmospheric and magneto science equipment during transportation from the manufacturing and acceptance test location to the launch site receiving laboratory, area, or facility. It may then be used for support of storage and checkout functions. The kit is then used during transit to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter Maintenance area. No transportation kit GSE is required beyond this stage. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE P-1A identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

P-1B Cometary Physics Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the cometary physics equipment during transportation from the
manufacturing and acceptance test location to the launch site receiving laboratory, area, or facility. It may then be used for support of storage and checkout functions. The kit is then used during transit to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage. The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE P-1B identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.3.2 P-1C Meteoroid Science Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the meteoroid science equipment during transportation from the manufacturing and acceptance test location to the launch site receiving laboratory, area, or facility. It may then be used for support of storage and checkout functions. The kit is then used during transit to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental
conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE P-1C identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.3.3 P-1D Thick Material Meteoroid Penetration Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the thick material meteoroid penetration equipment during transportation from the manufacturing and acceptance test location to the launch site receiving laboratory, area, or facility. It may then be used for support of storage and checkout functions. The kit is then used during transit to the facility for integration into the GPL module. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE P-1D identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

P-1E Small Astronomy Telescopes Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must
be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

**Functional Description**—The transportation kit is required to contain and protect the small astronomy telescopes equipment during transportation from the manufacturing and acceptance test location to the launch site receiving laboratory, area, or facility. It may then be used for support of storage and checkout functions. The kit is then used during transit to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE P-1E identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.3.4 P-2A Wake Measurements from Station and Booms Transportation Kit

**Requirements**—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

**Functional Description**—The transportation kit is required to contain and protect the wake measurements from station and booms equipment during transportation from the manufacturing and acceptance test location to the launch site receiving laboratory, area, or facility. It may then be used for support of storage and checkout functions. The kit is then used during transit to the FIT area. After operations with the FIT, applicable portions
of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE P-2A identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.3.5 P-3C Plastic/Nuclear Emulsions Transportation Kit

**Requirements**—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

**Functional Description**—The transportation kit is required to contain and protect the plastic/nuclear emulsion equipment during transportation from the manufacturing and acceptance test location to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE P-3C identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.
3.2.3.6 P-4A Airlock and Boom Experiments Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the airlock and boom experiments equipment during transportation from the manufacturing and acceptance test location to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE P-4A identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.7 P-4B Flame Chemistry and Laser Experiments Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the flame chemistry and laser experiments equipment during transportation from the manufacturing and acceptance test location to the FIT area.
After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation Kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description — The transportation kit is sized to accommodate the equipment for FPE P-4B identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.3.8 P-4C Test Chamber Experiments Transportation Kit

Requirements — During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description — The transportation kit is required to contain and protect the test chamber experiments equipment during transportation from the manufacturing and acceptance test location to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description — The transportation kit is sized to accommodate the equipment for FPE P-4C identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.
3.2.3.9 MS-3A Crystal Growth Biological and Physical Processes
Transportation Kit

Requirements—During transportation from the manufacturing facility to the
launch site and between launch site facilities, the experiment equipment must
be protected from shock, vibration, strain, contamination, and excessive
temperature and humidity.

Functional Description—The transportation kit is required to contain and
protect the crystal growth, biological and physical processes equipment
during transportation from the manufacturing and acceptance test location
to the FIT area. After operations with the FIT, applicable portions of the
transportation GSE are used during transfer to the Shuttle Orbiter mainten-
ance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental
control system; and a recording system to monitor environmental conditions,
shock, vibration, and structural strain on selected parts of the equipment
during shipment.

Physical Description—The transportation kit is sized to accommodate the
equipment for FPE MS-3A identified in Experiments Requirements Summary
(Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.10 MS-3B Crystal Growth from Vapor Transportation Kit

Requirements—During transportation from the manufacturing facility to the
launch site and between launch site facilities, the experiment equipment must
be protected from shock, vibration, strain, contamination, and excessive
temperature and humidity.

Functional Description—The transportation kit is required to contain and
protect the crystal growth from vapor equipment during transportation from
the manufacturing and acceptance test location to the FIT area. After
operations with the FIT, applicable portions of the transportation GSE are
used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shocks, vibration, and structural strain on selected parts of the equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE MS-3B identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.3.11 MS-3C Controlled Density Materials Transportation Kit

**Requirements**—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

**Functional Description**—The transportation kit is required to contain and protect the controlled density materials equipment during transportation from the manufacturing and acceptance test location to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE MS-3C identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.
3.2.3.3.12 MS-3D Liquid and Glass Processing Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the liquid and glass processing equipment during transportation from the manufacturing and acceptance test location to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE MS-3D identified in Experiments Requirements Summary (Green-Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.3.13 MS-3E Supercooling and Homogeneous Nucleation Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the supercooling and homogeneous nucleation equipment during transportation from the manufacturing and acceptance test location to the FIT area. After operations with the FIT, applicable portions of the
transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE MS-3E identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

**3.2.3.3.14 T-1A Contamination Experimental Package Transportation Kit**

**Requirements**—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

**Functional Description**—The transportation kit is required to contain and protect the contamination experimental package equipment during transportation from the manufacturing and acceptance test location to the launch site receiving laboratory, area, or facility. It may then be used for support of storage and checkout functions. The kit is then used during transit to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE T-1A identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.
3.2.3.3.15 T-1B Contamination Monitor Package Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the contamination monitor package equipment during transportation from the manufacturing and acceptance test location to the launch site receiving laboratory, area, or facility. It may then be used for support of storage and checkout functions. The kit is then used during transit to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE T-1B identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.3.16 T-3A Astronaut Maneuver Unit Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the astronaut maneuver unit equipment during transportation from the manufacturing and acceptance test location to the FIT area. After
operations with the FIT, applicable portions of the transportation GSE are
used during transfer to the Shuttle Orbiter maintenance area. No trans-
portation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environ-
mental control system; and a recording system to monitor environmental
conditions, shock, vibration, and structural strain on selected parts of the
equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the
equipment for FPE T-3A identified in Experiments Requirements Summary
(Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.3.17 T-4A Long-Duration System Tests Transportation Kit

**Requirements**—During transportation from the manufacturing facility to the
launch site and between launch site facilities, the experiment equipment must
be protected from shock, vibration, strain, contamination, and excessive
temperature and humidity.

**Functional Description**—The transportation kit is required to contain and
protect the long duration system tests equipment during transportation from
the manufacturing and acceptance test location to the launch site receiving
laboratory, area, or facility. It may then be used for support of storage and
checkout functions. The kit is then used during transit to the area for
integration into the GPL module. No transportation kit GSE is required
beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental
control system; and a recording system to monitor environmental conditions,
shock, vibration, and structural strain on selected parts of the equipment
during shipment.

**Physical Description**—The transportation kit is sized to accommodate the
equipment for FPE T-4A identified in Experiments Requirements Summary
(Green Book) Volumes I and II, Revision 1, April 28, 1971.
3.2.3.3.18 T-4B Medium-Duration Tests Transportation Kit

**Requirements**—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

**Functional Description**—The transportation kit is required to contain and protect the medium duration tests equipment during transportation from the manufacturing and acceptance test location to the launch site receiving laboratory, area, or facility. It may then be used for support of storage and checkout functions. The kit is then used during transit to the area for integration into the GPL module. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosures; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE T-4B identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.3.19 T-4C Short-Duration Tests Transportation Kit

**Requirements**—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

**Functional Description**—The transportation kit is required to contain and protect the short duration tests equipment during transportation from the manufacturing and acceptance test location to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during...
transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE T-4C identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.3.20 T-5A Initial Flight Teleoperator Transportation Kit

**Requirements**—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

**Functional Description**—The transportation kit is required to contain and protect the initial flight teleoperator equipment during transportation from the manufacturing and acceptance test location to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

**Physical Description**—The transportation kit is sized to accommodate the equipment for FPE T-5A identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.
3. 2. 3. 3. 21 T-5B Functional Teleoperator Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.

Functional Description—The transportation kit is required to contain and protect the functional teleoperator equipment during transportation from the manufacturing and acceptance test location to the FIT area. After operations with the FIT, applicable portions of the transportation GSE are used during transfer to the Shuttle Orbiter maintenance area. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description—The transportation kit is sized to accommodate the equipment for FPE T-5B identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3. 2. 3. 3. 22 T-5C Ground Control Teleoperator Transportation Kit

Requirements—No flight equipment except that used in T-5A and T-5B experiments, is required for this FPE. Accordingly, no transportation GSE is required.

3. 2. 3. 3. 23 LS-1A Minimal Medical Research Facility Transportation Kit

Requirements—During transportation from the manufacturing facility to the launch site and between launch site facilities, the experiment equipment must be protected from shock, vibration, strain, contamination, and excessive temperature and humidity.
Functional Description — The transportation kit is required to contain and protect the minimal medical research facilities equipment during transportation from the manufacturing and acceptance test location to the launch site receiving laboratory, area, or facility. It may then be used for support of storage and checkout functions. The kit is then used during transit to the area for integration into the GPL module. No transportation kit GSE is required beyond this stage.

The kit includes a handling fixture and protective enclosure; an environmental control system; and a recording system to monitor environmental conditions, shock, vibration, and structural strain on selected parts of the equipment during shipment.

Physical Description — The transportation kit is sized to accommodate the equipment for FPE LS-STA identified in Experiments Requirements Summary (Green Book) Volumes I and II, Revision 1, April 28, 1971.

3.2.4 Supporting Laboratory Equipment
This section identifies the GSE required for the following laboratory and support functions:

A. Experiment Payload Integration Center Optical Laboratory.
B. Experiment Payload Integration Center Electronics Laboratory.
C. Experiment Payload Integration Center Analysis Laboratory.
D. Experiment Payload Integration Center Cleaning Laboratory.
E. Experiment Payload Integration Center Machine Shop.
F. Launch Site Biological Laboratory.
G. Experiment Handling and Access Kit.

3.2.4.1 Experiment Payload Integration Center Optical Laboratory GSE

Requirements — Components and subassemblies of optical experiments require alignment, calibration, and functional verification after receipt at the EPIC. This requirement applies to new, modified, redesigned, and refurbished equipment.
Functional Description—Optical laboratory instruments and equipment are required to perform the following:

A. Detector verification.
B. Target calibration.
C. Film calibration.
D. Optical alignment check.
E. Pointing systems check.

Equipment for accomplishing these functions must be housed in suitable buildings providing environmental control for the laboratory instruments and for the FPE's. Common commercial electrical power service is required. Handling and storage/equipment for cryogenics is also required.

Physical Description—The laboratory will contain one each of the items listed in Table 3-6.

Table 3-6
EXPERIMENT PAYLOAD INTEGRATION CENTER
OPTICAL LABORATORY GSE

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film developing apparatus</td>
<td>200</td>
<td>3.0 by 4.0 by 8.0 ft</td>
</tr>
<tr>
<td>(tanks, distilled water, temperature controlled fluid, trays, pans, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photometric sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Visible</td>
<td>10</td>
<td>12 by 8.0 by 6.0 in.</td>
</tr>
<tr>
<td>B. Infrared black body</td>
<td>25</td>
<td>1 by 1 by 2 ft</td>
</tr>
<tr>
<td>C. Ultraviolet</td>
<td>80</td>
<td>6 by 6 in. by 3 ft</td>
</tr>
<tr>
<td>D. X-ray</td>
<td>40</td>
<td>1 by 1 by 3 ft</td>
</tr>
<tr>
<td>Vacuum chamber</td>
<td>200,000</td>
<td>20 ft dia by 80 ft</td>
</tr>
<tr>
<td>Precision sensiometric film</td>
<td>100</td>
<td>3 by 4 by 4 ft</td>
</tr>
<tr>
<td>Densitometer</td>
<td>75</td>
<td>2 by 2 by 1.5 ft</td>
</tr>
</tbody>
</table>
Table 3-6
EXPERIMENT PAYLOAD INTEGRATION CENTER
OPTICAL LABORATORY GSE (Continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photometer detectors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Visible</td>
<td>35</td>
<td>12 by 8.0 by 8.0 in.</td>
</tr>
<tr>
<td>B. Ultraviolet</td>
<td>35</td>
<td>12 by 8 by 8 in.</td>
</tr>
<tr>
<td>C. Near infrared</td>
<td>35</td>
<td>12 by 8 by 8 in.</td>
</tr>
<tr>
<td>X-ray detectors</td>
<td>10</td>
<td>6 by 6 by 3 in.</td>
</tr>
<tr>
<td>Proportional counter</td>
<td>10</td>
<td>6 by 6 by 3 in.</td>
</tr>
<tr>
<td>Pulse height analyzer</td>
<td>50</td>
<td>2 by 1 by 2 ft</td>
</tr>
<tr>
<td>Scaler</td>
<td>30</td>
<td>24 ft by 6 by 18 in.</td>
</tr>
<tr>
<td>Gamma-ray source</td>
<td>500</td>
<td>2 by 2 by 2 ft</td>
</tr>
<tr>
<td>Cryogenically cooled IR detector chamber</td>
<td>40</td>
<td>18 by 18 by 36 in.</td>
</tr>
<tr>
<td>Radiometer</td>
<td>25</td>
<td>24 by 12 by 18 in.</td>
</tr>
<tr>
<td>Spectrometer with attachments</td>
<td>300</td>
<td>4 by 4 by 3 ft</td>
</tr>
<tr>
<td>Optical bench</td>
<td>8,000</td>
<td>3 by 4 by 15 ft</td>
</tr>
<tr>
<td>Collimator mirror</td>
<td>35</td>
<td>40 by 40 by 8 in.</td>
</tr>
<tr>
<td>He-Ne laser source</td>
<td>20</td>
<td>12 by 8 by 8 in.</td>
</tr>
<tr>
<td>Prisms and mirror</td>
<td>25</td>
<td>1.0 by 2 by 1 in.</td>
</tr>
<tr>
<td>Modulation transfer function measuring apparatus</td>
<td>150</td>
<td>10 by 2 by 2 ft</td>
</tr>
<tr>
<td>Resolution chart set</td>
<td>25</td>
<td>2 by 2 by TBD</td>
</tr>
<tr>
<td>Ellipsometer</td>
<td>40</td>
<td>4 by 2 by 2 ft</td>
</tr>
<tr>
<td>Precision turntable</td>
<td>12,000</td>
<td>12 ft dia by 4 ft</td>
</tr>
<tr>
<td>Theodolite</td>
<td>35</td>
<td>2 by 2 by 2 ft</td>
</tr>
<tr>
<td>Isodensitracer</td>
<td>250</td>
<td>3 by 3 by 3 ft</td>
</tr>
<tr>
<td>Microdensitometer</td>
<td>500</td>
<td>3 by 4 by 6 ft</td>
</tr>
<tr>
<td>Monochromator</td>
<td>500</td>
<td>3 by 4 by 6 ft</td>
</tr>
</tbody>
</table>
3.2.4.2 **Experiment Payload Integration Center Electronics Laboratory GSE**

**Requirements**—Calibration, maintenance, and functional verification of electronics equipment are performed at the EPIC.

**Functional Description**—An electronic laboratory is required at the EPIC to perform calibration, maintenance, modification, and functional verification of new, modified, redesigned, and refurbished electronic equipment used in the Space Station program experiments.

**Physical Description**—The electronics laboratory GSE consists of furniture, test instruments, electronic components, hand tools and materials listed in Table 3-7.

<table>
<thead>
<tr>
<th>Table 3-7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXPERIMENT PAYLOAD INTEGRATION CENTER ELECTRONICS LABORATORY GSE</strong></td>
</tr>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>Furniture:</td>
</tr>
<tr>
<td>Work benches</td>
</tr>
<tr>
<td>Storage cabinets</td>
</tr>
<tr>
<td>Tables</td>
</tr>
<tr>
<td>Dollies</td>
</tr>
<tr>
<td>Test instruments:</td>
</tr>
<tr>
<td>Oscilloscopes</td>
</tr>
<tr>
<td>Generators</td>
</tr>
<tr>
<td>V-O-A meters</td>
</tr>
<tr>
<td>Power meters</td>
</tr>
<tr>
<td>Strip chart recorders</td>
</tr>
<tr>
<td>Bridges</td>
</tr>
<tr>
<td>Standards</td>
</tr>
<tr>
<td>Analyzers</td>
</tr>
<tr>
<td>Attenuators</td>
</tr>
<tr>
<td>Amplifiers</td>
</tr>
<tr>
<td>Counters and scalers</td>
</tr>
<tr>
<td>Stroboscopes</td>
</tr>
<tr>
<td>Power equipment:</td>
</tr>
<tr>
<td>Power supplies</td>
</tr>
<tr>
<td>Regulators</td>
</tr>
<tr>
<td>Autotransformers</td>
</tr>
<tr>
<td>Motor controllers</td>
</tr>
</tbody>
</table>
Table 3-7
EXPERIMENT PAYLOAD INTEGRATION CENTER
ELECTRONICS LABORATORY GSE (Continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistors</td>
<td>200</td>
<td>10</td>
</tr>
<tr>
<td>Capacitors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inductors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid state devices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical connectors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miscellaneous electrical hardware</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand Tools:</td>
<td>200</td>
<td>10</td>
</tr>
<tr>
<td>Pliers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screw drivers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soldering irons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wire strippers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bench vise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrenches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hammers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saws</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Files</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miscellaneous tools</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials:</td>
<td>200</td>
<td>10</td>
</tr>
<tr>
<td>Solder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tape</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulation materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miscellaneous supplies</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2.4.3 Experiment Payload Integration Center Analysis Laboratory GSE

Requirements—Materials and equipment used in the Space Station program are analyzed at the EPIC.

Functional Description—An analysis laboratory is required at the EPIC to perform both quantitative and qualitative analyses on any solid, liquid, or gas used in the Space Station program experiments. The laboratory is also required to analyze any equipment failures that occur in the Space Station hardware.
Physical Description—The analysis laboratory GSE consists of furniture, chemical analysis equipment, electronic test equipment, and physical-property test equipment. The laboratory GSE consists of the following items:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furniture</td>
<td>1,000</td>
<td>500</td>
</tr>
<tr>
<td>Chemical analysis equipment and supplies</td>
<td>2,000</td>
<td>500</td>
</tr>
<tr>
<td>Electronic test equipment</td>
<td>2,000</td>
<td>100</td>
</tr>
<tr>
<td>Physical properties test equipment</td>
<td>1,000</td>
<td>50</td>
</tr>
</tbody>
</table>

3.2.4.4 Experiment Payload Integration Center Cleaning Laboratory GSE

Requirements—Fluid systems components are required, cleaned and pressure tested at the EPIC.

Functional Description—A laboratory is required at the EPIC to purge, leak-detect, repair, proof pressure test, and clean FPE's and module fluid systems. The laboratory is required to handle cryogenic and combustible fluids at pressures from vacuum to high pressure. System equipment that must interface the laboratory may be welded or use screw fittings.

Physical Description—The cleaning laboratory GSE consists of furniture, fluid test equipment, detection equipment, cryogen, and other fluid handling equipment; and electronic, mechanical, and hydraulic tools as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furniture</td>
<td>1,000</td>
<td>500</td>
</tr>
<tr>
<td>Fluid test equipment</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Leak detectors</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Fluid handling equipment</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Special tools</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
3.2.4.5 Experiment Payload Integration Center Machine Shop GSE

Requirements—Machine shop functions are performed at EPIC, as required to support the Space Station program.

Functional Description—A machine shop is required at the EPIC to perform any machine shop operation (cut, drill, ream, shape, trim, counterbore, bend, grind, polish, thread, weld, etc.) on metallic and machinable materials as may be required for installation, modification, maintenance, or new fabrication of hardware used in the Space Station program.

Physical Description—Machine shop GSE consists of the furniture, shop machines, power tools, hand tools, expendable commodities, and supplies listed in Table 3-8.

3.2.4.6 Launch Site Biological Laboratory GSE

Requirements—During the time the biological specimens are located at the launch site, the specimens are housed, protected, and maintained in a controlled environment. A means is also provided to evaluate the effects of space environments on the biological specimens and for conducting experiment activities similar to the on-orbit experiment operations.

Functional Description—The LSBL is provided for specimen storage, care, feeding, and examination before and after the specimens are exposed to space flight. Control experiment operations routines are conducted as required for comparison of results with on-orbit experiments. The specimen storage area is supplied with a controlled and monitored environment (temperature, humidity, atmosphere pressure, and atmosphere composition) compatible with the specimen requirements. Food, water, fresh air, and light are provided for the specimens. The biological laboratory is also used to test, examine, and analyze biological data. Laboratory equipment duplicates the Space Station biological laboratory equipment.

Physical Description—The LSBL contains the items listed in Table 3-9.
<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Furniture:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work benches</td>
<td>2,000</td>
<td>1,500</td>
</tr>
<tr>
<td>Storage cabinets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dollies</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Shop machines:</strong></td>
<td>100,000</td>
<td>2,000</td>
</tr>
<tr>
<td>Lathes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milling machines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shapers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drill presses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheet metal brake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grinders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power saws</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power shear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power punch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power press</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crane or hoist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welders</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power hand tools:</strong></td>
<td>200</td>
<td>6</td>
</tr>
<tr>
<td>Drills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grinders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polishers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saws</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hand tools:</strong></td>
<td>200</td>
<td>5</td>
</tr>
<tr>
<td>Hammers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrenches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pliers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Files</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scales</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gauges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saws</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bench vise</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Expendable commodities</strong></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Compressed Air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lubricants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coolants</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3-9
LAUNCH SITE BIOLOGICAL LABORATORY GSE

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio centrifuge</td>
<td>800</td>
<td>5 by 20-ft dia</td>
</tr>
<tr>
<td>Laminar flow table</td>
<td>400</td>
<td>54 by 54 by 30 in.</td>
</tr>
<tr>
<td>Freezer</td>
<td>70</td>
<td>5 ft³</td>
</tr>
<tr>
<td>Environmental control and life-support equipment</td>
<td>1,100</td>
<td>27 ft³</td>
</tr>
<tr>
<td>Waste management equipment</td>
<td>100</td>
<td>16 ft³</td>
</tr>
<tr>
<td>Gas monitor equipment</td>
<td>162</td>
<td>13 ft³</td>
</tr>
<tr>
<td>Instrument bench</td>
<td>100</td>
<td>30 ft by 48 by 96 in.</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>65</td>
<td>5 ft³</td>
</tr>
<tr>
<td>Chemical storage cabinet</td>
<td>80</td>
<td>10 ft³</td>
</tr>
<tr>
<td>Ultrasonic cleaner</td>
<td>100</td>
<td>5 ft³</td>
</tr>
<tr>
<td>Mass determination device</td>
<td>50</td>
<td>2 ft³</td>
</tr>
<tr>
<td>Microscope</td>
<td>35</td>
<td>1.7 ft³</td>
</tr>
<tr>
<td>Dissecting microscope</td>
<td>15</td>
<td>1.2 ft³</td>
</tr>
<tr>
<td>Cameras</td>
<td>50</td>
<td>1.0 ft³</td>
</tr>
<tr>
<td>Gas chromatograph</td>
<td>85</td>
<td>2.25 ft³</td>
</tr>
<tr>
<td>Mass spectograph</td>
<td>45</td>
<td>1.5 ft³</td>
</tr>
<tr>
<td>Refractometer</td>
<td>25</td>
<td>0.5 ft³</td>
</tr>
<tr>
<td>Spectrophotometer</td>
<td>95</td>
<td>2.0 ft³</td>
</tr>
<tr>
<td>Polarograph</td>
<td>110</td>
<td>4.5 ft³</td>
</tr>
<tr>
<td>Colorimeter</td>
<td>55</td>
<td>1.5 ft³</td>
</tr>
<tr>
<td>Oven</td>
<td>75</td>
<td>1.5 ft³</td>
</tr>
<tr>
<td>Muffle furnace</td>
<td>75</td>
<td>1.5 ft³</td>
</tr>
<tr>
<td>Lyophilizer</td>
<td>25</td>
<td>1.0 ft³</td>
</tr>
<tr>
<td>Autoclave</td>
<td>25</td>
<td>3.5 ft³</td>
</tr>
<tr>
<td>Refrigerated centrifuge</td>
<td>200</td>
<td>9.0 ft³</td>
</tr>
<tr>
<td>Radiation shielding</td>
<td>300</td>
<td>0.4 ft³</td>
</tr>
<tr>
<td>Oscillograph</td>
<td>20</td>
<td>2.5 ft³</td>
</tr>
<tr>
<td>Potentiometric recorder</td>
<td>60</td>
<td>2.0 ft³</td>
</tr>
<tr>
<td>Respirometer</td>
<td>45</td>
<td>8.0 ft³</td>
</tr>
</tbody>
</table>
Table 3-9
LAUNCH SITE BIOLOGICAL LABORATORY GSE (Continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data console</td>
<td>2,800</td>
<td>70 ft³</td>
</tr>
<tr>
<td>Six reentry capsules</td>
<td>400</td>
<td>20 ft³</td>
</tr>
<tr>
<td>Staining kit</td>
<td>2</td>
<td>0.5 ft³</td>
</tr>
<tr>
<td>Microbiology kit</td>
<td>2</td>
<td>0.5 ft³</td>
</tr>
<tr>
<td>Histology kit</td>
<td>2</td>
<td>0.5 ft³</td>
</tr>
<tr>
<td>Storage structure for LS-1A racks</td>
<td>100</td>
<td>55 by 60 by 24 in.</td>
</tr>
<tr>
<td>Storage structure for LS-1B racks</td>
<td>300</td>
<td>160 by 74 by 24 in.</td>
</tr>
<tr>
<td>Storage structure for LS-1C plant growth chamber</td>
<td>100</td>
<td>58 by 72 by 14 in.</td>
</tr>
<tr>
<td>Storage structure for LS-1D racks</td>
<td>100</td>
<td>55 by 60 by 24 in.</td>
</tr>
</tbody>
</table>

3.2.4.7 Experiment Handling and Access Kit

Requirements—The experiment equipment is installed in the flight carrier, with personnel access provided to the experiment equipment.

Functional Description—The kit is required at the EPIC and at the launch pad to assist ground personnel to install experiment equipment in the flight carrier. The kit includes the following equipment:

A. The experiment handling equipment lifts, holds, translates, and positions the experiment equipment when the experiment is removed from the transportation kit enclosure and installed in flight carrier.

B. The personnel access equipment provides ground personnel access to the experiment equipment for installation, ground test, checkout operations, and ground maintenance of the experiment in flight carrier.

Physical Description—

A. The experiment handling equipment includes cranes, slings, dollies, fork lifts, and unique fixtures designed as required to protect and handle all experiment hardware that cannot be hand carried.

B. The personnel access equipment includes such items as ladders, stairs, elevators, walkways, handrails, and work platforms. These items are specifically designed for each flight carrier.
Space Station program facilities include the total facilities required for manufacture and test, prelaunch and launch, mission operations support, and logistics support of the Space Station, experiments, logistics system spacecraft, and their launch vehicles. Mission operations and logistics support facilities are used throughout the Space Station's 10-year life.

Space Station prelaunch and launch facilities are used to support the ISS module launches and two GSS launches five years later. The launch facilities are provided by the shuttle.

4.1 SPACE STATION PROJECT
Space Station Project facilities include those required for manufacture and test, prelaunch and launch, flight operations support, and logistics support of the Space Station flight hardware, its development fixtures, spares, GSE, and software.

4.1.1 Manufacture and Test
Manufacture and test facilities include those required for development, qualification, manufacture, and acceptance testing of the Space Station flight hardware, its simulators and development fixtures, spares, GSE, and software. Manufacturing and test facilities consist of three major categories: those which accommodate prime test articles and the static test vehicle (STV) during development and qualification testing; those which accommodate development and qualification testing of components and subsystems; and those required for basic component fabrication, assembly of components into subsystems and subassemblies, final integration of subsystems and subassemblies into an assembly or system, and formal acceptance testing. Facilities for these three categories provide the capability for multiple functions to be performed under one roof using the same tooling, GSE, and
other test equipment where practicable; i.e., singularly integrated facilities provide for both development and qualification testing of the FIT; module final assembly and ISS station acceptance testing are accomplished in the same building, using the same holding fixtures and access platforms, etc.

4.1.1.1 Development Facilities

Requirements—Development testing will be accomplished on select unique and critical items of hardware and software in those instances where developed test data is nonexistent on similar items from which the necessary experience could be gained or where the situation warrants. Special environments and test facilities are necessary to support development testing.

Functional Description—Development facilities will provide the means for design, test, and analysis of select critical components, subassemblies, subsystems, and software of the Space Station. Test results will be instrumental in establishment of hardware design, establishment of software programs to verify analysis, or to confirm margins. Major test articles involved in development testing for which facilities are to be provided include the functional model and the Flight Integration Tool (FIT). The functional model is the prime tool for electrical subsystem level hardware and computer program development. The functional model incorporates development test hardware to the greatest degree possible but does not include a primary flight-type structure.

The FIT is an almost complete flight configuration Space Station module used for development and verification of subsystems operation and for verification of installation and interfaces of integral experiments, i.e., the solar array will be replaced by a ground power supply. After Space Station launch, the FIT becomes a qualified, ground-based flight article through continuous modification in accord with changes to the orbiting Space Station. In addition to major test articles, facilities are provided for development testing accomplished on select components, subsystems, integrated subsystems, and operations as follows.
A. Environmental Control and Life Support (EC/LS) Subsystem.
   1. Urine, wash water, and condensate water recovery assemblies.
   2. Water electrolysis modules.
   3. Integrated atmosphere temperature control, atmosphere ventilation, and heat transport circuits.
   4. EC/LS subsystem integrated in a simulation of the core module.

B. Propulsion/Reaction Control Subsystem (P/RCS).
   1. Integrated low-thrust resistojet system with the EC/LS subsystem.
   2. Resistojet thrustors.
   3. Resistojet subsystems and assemblies—test firings of thrustor modules under simulated altitude conditions, subsystem level nonfiring thermal vacuum, and development testing of loading, resupply, decontamination, and repair concepts.
   4. High-thrust subsystem hot-firing, including development test of loading, resupply, decontamination, and repair concepts.

C. Guidance/Navigation and Control Subsystems.
   1. Drag accelerometer.
   2. Digital computer, interface equipment, and software development and integration.
   3. Electro-optical instrument design and structural alignment.
   5. Control moment gyros.
   6. Development of control moment gyros installation location, access, maintenance procedures, and fault isolation.
   7. Dynamic analysis and simulation of Space Station and control system in artificial and zero gravity.

D. Data Management Subsystem (DMS).
   1. Development of hardware, software, and interfaces, including hardware characteristic establishment to allow development of the entire data bus concept.
   2. Subsystem simulation and modeling to develop such characteristics as queue lengths, time delays, and data rates.
   3. Development of distribution system.
4. Development of optical or special processing techniques.
5. Display and control equipment.

E. Onboard Checkout Subsystem (OCS).
1. Development and integration of onboard checkout subsystem, subsystem under test, GSE, procedures, data management subsystem, and attendant software.
2. Compatibility development testing with the functional model to yield integrated subsystem checkout software and software required for acceptance testing, prelaunch checkout, mission operation, and experiment integration.

F. Communications Subsystem.
1. High-gain antenna system.
2. Development of high reliability components—Ku band transmitters.

G. Electrical Power Subsystem.
2. Solar Array deployment mechanism.

H. Structural Mechanical Subsystem.
1. Structural/mechanical redundant force analysis and mass properties management through computer programs.
2. Dynamic seals, lubrication, and integrated meteoroid shield/radiation/insulation.
3. Docking mechanisms and separation concepts.

I. Crew Habitability and Protection Subsystem—TBD.

J. General Purpose Laboratory (GPL) Equipment Subsystem—Development will be the responsibility of the particular experiment requiring support of the GPL.

K. GSE—GSE development will be accomplished primarily through the functional model and, to a lesser extent, through the FIT.

Physical Description—Sizing of development facilities, hook heights, environments, etc., will be predicated on the physical characteristics and subsystems of Space Station modules and the operations conducted thereon as described under the functional description. Individually producible Space Station major assemblies are as follows
A. Power/Subsystems Module.
B. Crew/Operations Module.
C. General-Purpose Laboratory.

4.1.1.2 Qualification Test Facilities

Requirements—Qualification testing is performed on select critical production hardware or developed computer programs of the Space Station to verify that design/performance specifications have been met. Special environments and test facilities are necessary to support qualification testing.

Functional Description—Qualification facilities provide floor space and environment required by personnel, equipment, and operations for verifying that selected Space Station production hardware or developed computer programs operate as designed under simulated conditions. The major test article used during qualification testing is the FIT. After initial development testing, the FIT is used in integrated qualification of subsystems, system, and software, including electromagnetic interference (EMI).

The functional model is used in qualification-testing of data management and onboard checkout systems along with associated computer programs.

Physical Description—For the major part, facilities necessary for qualification-testing are the same used during development-testing of the functional model and FIT. On completion of development tests, much of the same installations and equipment are used to a great extent in support of qualification-testing. On completion of qualification and verification activities, the FIT is located at (TBD) for continuing use throughout the 10-year program. (Location undetermined - in study. Possible locations are discussed in Subsection 2.1.2.3.) In all cases, sizing of these facilities, hook heights, environments, etc., will be sufficient to accommodate individually producible Space Station major assemblies.

4.1.1.3 Manufacturing and Acceptance Testing Facilities

Requirements—Manufacture and accept Space Station hardware and software. Prepare for shipment to the utilization site.
Functional Description—Facilities required to support manufacturing of the Space Station include those needed for component fabrication, assembly of components into subsystems and subassemblies, and final integration of the subsystems and subassemblies into an assembly or system. These facilities fulfill the requirement for acceptance testing in most cases.

Physical Description—Manufacturing facilities are selected from those existing, where possible. Requirements for these facilities are based on existing techniques, procedures, and capabilities. Selection of facilities and modifications thereto will be predicated on fabrication of three Space Station structures built to flight article production specifications and will include the Static Test Vehicle, FIT, and Operational Vehicle (OV). The OV will be the only item which contains all flight configuration subsystems. The FIT will contain select subsystems necessary to accomplish its intended purpose with missing subsystems, components, and interfaces simulated through use of substitutes. The STV will be the specimen for structural testing.

Acceptance test provisions are integrated within the manufacturing capability where possible and practicable to avoid duplication of "large assembly" facilities and to reduce handling operations.

Sizing of these facilities will be sufficient to accommodate individually producible Space Station modules, one of which is 14 ft in diameter x 59 ft long and two of which are 14 ft in diameter x 45 ft long.

4.1.2 Launch Operations
Launch operations will be conducted from the Shuttle launch which is currently identified as Kennedy Space Center (KSC), Figure 4-1. The modules will arrive at KSC orbit-ready from the factory and thus will require only pre-flight servicing prior to installation in the Shuttle orbiter. The modules will arrive at the Shuttle landing strip in a Super Guppy after which they will be transported over existing roadways to the Shuttle maintenance area for preflight servicing. After nonhazardous servicing, the module will be installed in the Shuttle orbiter cargo bay and will then become an integral
part of the Shuttle operational flow. The prelaunch and launch operations
are described in Section 2.1.5. Related activation and transportation
operations are covered in Sections 2.1.3 and 2.1.4.

4.1.2.1 Landing Strip and Roads

Requirements—Transport Space Station modules individually to the launch
site for launch site operations.

Functional Description—After the Super Guppy landing on the Shuttle landing
strip, the modules will be unloaded and transported on existing KSC roads
to the Shuttle maintenance area.

Physical Description—The Super Guppy will land on the Shuttle landing strip
and taxi to a point as close to the Shuttle maintenance area to minimize the
distance of ground transportation. The module and trailer will be towed
from the plane by a prime mover and towed slowly over existing prepared
surfaces or roads to the Shuttle maintenance area where the prime mover
will be decoupled and removed.

4.1.2.2 Shuttle Maintenance Area

Requirements—Perform preflight servicing of the modules prior to installa-
tion in the Shuttle orbiter cargo bay.

Functional Description—An area in the Shuttle maintenance area will be used
to remove the protective cover, inspect the environmental recording equip-
ment for adverse transportation environments, check existing pressures on
systems pressurized at the factory to confirm no leaks and remove gauges.
The power module requires battery installation with the aid of a portable
airlock. This is the only module that requires interior access. Nonhazard-
ous servicing will be performed after which the module is lifted and installed
in the Shuttle orbiter cargo bay where interfaces are verified.
Physical Description — The servicing operations will require (TBD) sq ft of floor area for the module and its supporting servicing equipment. A crane with a hook height of (TBD) will be required to lift the module from its servicing location and move it to a position over the Shuttle orbiter cargo bay for horizontal loading.

4.1.2.3 Launch Umbilical Tower

Requirements — Provide for electrical and fluid equipment and umbilical interfaces.

Functional Description — The LUT is modified to support the Shuttle launch vehicle operations. In addition to the Shuttle configuration, certain items of integrated checkout equipment, electrical and mechanical GSE are installed on the LUT or employed therefrom.

Physical Description — The Space Station module is in the Shuttle orbiter cargo bay when the Shuttle is on the LUT. The Space Station umbilicals will be installed on the Shuttle provided swing arms which provide access-to-access ports in the Shuttle skin.

4.1.2.4 Launch Pad

Requirements — Conduct Shuttle countdown and launch operations. Provide for Space Station propellant loading and high-pressure gas servicing.

Functional Description — The launch pad provides the structural/mechanical/electrical interfaces for physically supporting the LUT/Shuttle and payload. The pad has provisions for and supports propellant loading and high-pressure gas servicing for the Space Station modules.

Physical Description — Existing high-pressure gas facilities are adequate. A chilled water supply is provided for the ground coolant thermoconditioning system to be located on the LUT.
A ground-level hardstand area is provided for installation of a hydrazine storage tank and dump tank. The tanks are skid-mounted and connected by hard piping through control and transfer equipment to LUT interfaces. Provisions are made for \( \text{H}_2 \) purging of the hydrazine system and venting, drainage and disposal of hydrazine.

4.1.2.5 Central Instrumentation Facility

Requirements—Instrumentation and data reduction support may be required during prelaunch and launch operations.

Functional Description—The CIF can provide instrumentation and data reduction support for the Space Station during launch pad operations.

Physical Description—The control and monitor GSE is installed in the launch control center (LCC) through a cable interface. An RF link is established with the Space Station on the launch pad. Data reduction capability exists in the present facility.

4.1.2.6 Manned Spaceflight Operations Building

Requirements—Support Space Station contingency checkout and other prelaunch and launch activities.

Functional Description—The MSOB provides support for contingency checkout. Functions may include testing and recertification of components, subsystems equipment, and other hardware which requires the use of a controlled environment or other specialized facility.

Physical Description—MSOB-clean environment, altitude simulation, and adaptable test facilities are employed during any contingency Space Station support activities.

4.1.2.7 KSC General Support Facilities

General support facilities and capabilities required for Space Station support are identified in Table 4-1.
Table 4-1

KSC GENERAL SUPPORT FACILITIES

<table>
<thead>
<tr>
<th>Administrative</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices</td>
<td>Mechanical GSE maintenance area</td>
</tr>
<tr>
<td>Conference and briefing rooms</td>
<td>Electrical GSE maintenance area</td>
</tr>
<tr>
<td>Supplies storage</td>
<td>Machine shop</td>
</tr>
<tr>
<td>Safe storage facilities</td>
<td>Fluids laboratory (hydraulic test)</td>
</tr>
<tr>
<td>Waste repositories and disposal</td>
<td>Cryogenic laboratory</td>
</tr>
<tr>
<td>Mail services</td>
<td>LO₂-clean area</td>
</tr>
<tr>
<td>Packaging and packing</td>
<td>Calibration and standards laboratory</td>
</tr>
<tr>
<td>Reproduction facilities</td>
<td>Chemical analysis laboratory</td>
</tr>
<tr>
<td>Badge and lock</td>
<td>Communications equipment maintenance area</td>
</tr>
<tr>
<td>Parking facilities</td>
<td>Electronics laboratory (breadboard/mockup)</td>
</tr>
<tr>
<td>Technical library</td>
<td>X-ray laboratory (radiographic)</td>
</tr>
<tr>
<td>Telephone, datafax, and TWX leased lines</td>
<td>Welding shop</td>
</tr>
<tr>
<td>Fire protection</td>
<td>Vacuum test area</td>
</tr>
<tr>
<td>Safety surveillance and equipment</td>
<td>Telemetry systems maintenance area</td>
</tr>
<tr>
<td>Security guards and control</td>
<td>Screen room</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>Photographic laboratory</td>
</tr>
<tr>
<td>First aid/emergency treatment</td>
<td>Optical laboratory</td>
</tr>
<tr>
<td>Warehouse</td>
<td>Materials Laboratory</td>
</tr>
<tr>
<td></td>
<td>Acoustics laboratory</td>
</tr>
<tr>
<td></td>
<td>Clean benches</td>
</tr>
<tr>
<td></td>
<td>Computers</td>
</tr>
<tr>
<td></td>
<td>Hypergolic analysis</td>
</tr>
<tr>
<td></td>
<td>Gas analysis</td>
</tr>
<tr>
<td></td>
<td>Meteorological forecast</td>
</tr>
</tbody>
</table>

507
4.1.3 Logistics Module
KSC facilities required for support of Logistics Module ground operations include those necessary for housing the Logistics Module itself during checkout, maintenance, and loading/unloading operations; those required for storage and for performing lengthy modifications; electrical equipment, servicing equipment, access and handling equipment, and transportation equipment; and those from which Logistics Module checkout operations are conducted.

Requirements—Conduct initial receiving inspection, checkout, and loading and unloading of the Logistics Module. Reaccomplish those functions on a continuing basis along with Logistics Module maintenance and storage for a period of 10 years.

Functional Description—The VAB Low Bay shall be modified to provide the means for accommodating the Logistics Module. As shown in Figure 4-2, the two southeastern uncompleted S-II checkout areas are to be used for

![Figure 4-2. Logistics Module Maintenance, Checkout, and Loading](image-url)
horizontal checkout, maintenance, and loading. The Logistics Modules will move down the VAB transfer aisle on their transporters after being off loaded from the Shuttle orbiter. They will be positioned in the modified S-II areas where they will be turned around for the next flight. Uncompleted S-IVB checkout areas opposite the S-II areas are to be used as the storage or extensive maintenance/modification area. Test control is to be maintained from the test control area in the support areas behind the Low Bay. A logistics staging area will be on the first floor adjacent to the Logistics Module checkout area.

**Physical Description**—Two Logistics Module checkout positions are to be provided in the low bay. They are to permit horizontal installation of the Logistics Modules and have sufficient area for installation of servicing and electrical equipment, ground handling equipment, test umbilicals, access equipment, and loading equipment. Electrical and fluids support is to be provided with exception of propulsion system requirements. Two additional positions are to be provided on the opposite side of the low bay with essentially the same provisions except that they will not have an automatic checkout capability.

Automatic checkout equipment is installed in the existing test control area on the third floor behind the Logistics Module checkout areas. Cables interconnect the two areas. The logistics staging area is on the ground floor underneath the test control area and is adjacent to the checkout area.

The existing low bay environment is adequate for Logistics Module operations. If special particulate or oil/volatile control of the atmosphere is required, it will be provided through portable protective enclosures and other GSE.

4.1.4 **Mission Support**
Mission support facilities include those provided to support orbital flight operations; mission analysis and planning, direct real-time logistics advice
and consultation for the Space Station and mission management activities; and direct real-time support for experiment operations. Also, facilities must be provided for logistics cargo storage and handling, the flight integration tool (if located at KSC) flight crew training, and crew accommodations. This support continues throughout the Space Station's 10-year life. All the facilities described in this section are assumed to be at KSC, however, some, including the mission operations support center could be located at MSC. The exceptions are the cargo portion of logistics operations which should be at the launch site and the FIT which could be at the launch site or an alternate location.

4.1.4.1 Mission Operations Support Center*

The Mission operations support center (MOSC) centrally coordinates and integrates all ground activities required for support of Space Station flight operations on a continuing basis for 10 years.

The MOSC contains and supports operation of electronic equipment, consoles, maintenance shops, and offices. Centralized control is provided for integration of flight operations, mission analysis and planning, direct logistics advice and consultation for Space Station and mission management activities, and direct real-time experiment operations support. A design reference library consisting of microfilm and information stored in data banks is also located in the MOSC.

Functional requirements are further defined in Subsections 2.5 and 3.1.5.

The MSOB and CIF provide the space, electrical power, lighting, environment, and communications necessary for the functions of the MOSC. Facilities consist of a control center; attendant support areas for flight operations, mission analysis and planning, logistics support, and experiment support; and other equipment installation areas, offices, briefing or conference rooms, maintenance shops, and administrative and technical services and support.

*Could be located at MSC as an alternate.
Support areas for flight operations, mission analysis and planning, logistics, operations, and experiment operations are further defined as follows:

4.1.4.1.1 Flight Operations Support

Requirements—Support Space Station flight operations communications configuration control, telemetry, ground tracking data processing, Space Station system status parameters processing, uplink data processing, and information presentation.

Functional Description—Flight Operations Support (FOS) is part of the MOSC. It includes GSE installation areas for the mission operations computer complex (MOCC), the communications processor (CP), the necessary communications interface equipment, and flight operations support display/control equipment.

Physical Description—Equipment installation areas are provided for MOCC, CP, and communications interface equipment in the CIF as follows:

A. Mission Operations Computer Complex
   The MOCC consists of processing units, storage devices, I/O data channels, and associated peripheral devices. The MOCC is housed in an area having special air-conditioning provisions and underfloor cable routing. MOCC floor space requirements are TBD.

B. Communications Processor
   TBD sq ft of floor space provides the necessary room for various equipments comprising the CP. Provisions are made for underfloor cabling and air-conditioning.

C. Communications Interface Equipment
   TBD sq ft of floor space provides the necessary room for communications interface equipment. Provisions are made for underfloor cabling and air conditioning.

FOS display/control equipment is installed in the FOS control center in the MOSC which is located in the MSOB. This D/CE consists of 10 consoles as required by the FOS team.
Remaining FOS equipment is contained in equipment racks and is located in support areas adjacent to the control center. This equipment requires air-conditioning and underfloor cable routing provisions.

The FOS support area is located in adjacent rooms or floors to minimize interface problems. Subfloor space with easy access is required for cable routing, cooling air distribution, and utilities installation. Proper grounding and RFI protection is provided for subsystems instrumentation. Security and access control is provided.

4.1.4.1.2 Mission Analysis and Planning Support

Requirements—Centrally accommodate the mission analysis and planning team in its development of preliminary reference mission design, mission operations plans, and planning in support of actual mission operations.

Functional Description—Mission analysis and planning support (MAPS) is part of the MOSC. It includes GSE installation areas for mission analysis and planning team in performance of its analysis and planning tasks.

Physical Description—The MAPS area will have provisions for routing cables between the mission analysis and planning display terminals and the MOCC. The MAPS area is located adjacent to the FOS area as near to the MOCC as practical to minimize operational and equipment interface problems. The MAPS consists of offices and conference rooms requiring TBD sq ft of floor space.

4.1.4.1.3 Logistics Support

Requirements—Centrally control and manage logistics activities for the Space Station throughout its 10-year life.

Functional Description—Logistics support is part of the MOSC. The logistics support area maintains centralized surveillance, control, and management over Space Station logistics support elements. These elements include inventory control, material, maintenance, transportation, configuration
control, and personnel management. Logistics support provides consultation, instructions, and other data for the Space Station through the MOSC.

Physical Description—The logistics support area is located in the MSOB adjacent to the FOS area and consists of offices, administrative/technical services and support, briefing and conference rooms, data center, and a control center sufficient for managing and supporting the activities required by the logistics elements. Primary and secondary voice communications interconnect this facility with other elements of the MOSC. Other communications and data links are established between this facility, inventory control facilities and the FIT area. Critical communications and data systems have emergency power backup.

4.1.4.1.4 Experiment Support

Requirements—Centrally accommodate activities required for experiment operational support and data collection; real-time experiments data preprocessing; experiments monitoring, planning and coordination; and real-time experiments data analysis.

Functional Description—Experiment Support is part of the MOSC. It includes GSE installation areas for experiment support display/control equipment, and accommodates personnel in performance of their experiment support tasks. The experiment support area consists of an experiment control room (ECR), experiment analysis laboratories (EAL's), and launch site biological laboratory (LSBL).

Physical Description—The experiment support area is located in the MSOB adjacent to the FOS area. The ECR has an area of approximately 2,000 sq ft suitable for housing consoles and group displays. The EAL's comprise a large area (TBD) of easily partitioned and reconfigurable equipment space surrounded by a large number (TBD) of offices for the PI's and staff. The LSBL has an area of approximately 2,500 sq ft and imposes several unique facilities requirements (TBD), including that for an independent air-conditioning system. The experiment support area shall be located as near as practical to the MOCC to minimize equipment interface problems.
4.1.4.2 Crew Accommodations Complex

The crew accommodations complex could be located at MSC with the mission operations support center.

Requirements—Centrally accommodate flight crew personnel and other key personnel in final preparations for flight. Accommodate flight crew personnel just returned from orbit undergoing debriefing and observation.

Functional Description—The crew accommodations complex (CAC) performs the following functions throughout the Space Station 10-year orbital lifetime.

A. Live-in accommodations and separate isolation for two groups of crew personnel each in final preparation for space flight and 2 supporting personnel assigned to each group.
B. Physical restriction of final-preparation flight crew members in their interpersonal contacts with medically unscreened individuals.
C. Debriefing and observation of flight crew personnel just returned from space flight for a period of two weeks.
D. Continuation of flight crew training.
E. Continuation of flight crew physical fitness.
F. Dining and dietary management for flight crew and support personnel.
G. Recreational facilities for flight crew personnel in final preparation for space flight.
H. Medical and laboratory services for flight crew personnel.

Physical Description—The MSOB provides the space, electrical power, lighting, environment, and communications necessary for accomplishing the functions required of the CAC. The CAC is designed for live-in accommodations of two flight crew personnel for both the Space Station and logistics vehicle and two supporting personnel. These facilities have a high degree of self-sufficiency during periods of isolation prior to flight. The CAC consists

**Could be located at MSC with Mission Operations Support Center.
of living quarters, sanitary, dining, physical-conditioning, medical, and flight suit donning facilities. Other provisions are as follows:

A. Provisions for a 24-hour attendant.
B. Physiological training room containing space flight simulation equipment, flight suits, practice donning areas, etc.
C. Assembly room equipped with movie, slide, viewgraph, and opaque projectors and screens. The room also contains dais and speaker provisions.
D. Library.
E. Conference and meeting rooms.
F. Offices for the CAC manager and operations engineer.
G. Area for the CAC receptionist/secretary.
H. Medical room and laboratory containing areas for physical checkup and storage and maintenance of physical records.
I. Supply and storage rooms.

4.1.4.3 Flight Crew Training Facilities**
The flight crew training facilities could be located at MSC with the mission operations center.

Requirements—Train flight crew and ground crew personnel in Space Station flight and ground equipment operations and maintenance. Accommodate personnel, part-task trainers, and other equipment required for training activity.

Functional Description—Crew training facilities provide floor space and the environment for conducting flight and ground crew training. Activities conducted in the facilities include classroom instruction, training on part-task trainers, establishing training programs and curriculum, student administration, and maintaining and controlling equipment necessary for training. Crew training facilities provides space and environment for the space station command simulator (SSCS), experiments control simulator group (ECSG), and the flight operations support room simulation group (FSG).

**Could be located at MSC with Mission Operations Support Center.
Physical Description—Crew training facilities consist primarily of the existing Flight Crew Training Building for installation of part-task simulators/trainers and the MSOB where classroom training and administrative activities are conducted.

Subsystems within a given simulation system are located in rooms or on floor adjacent to the simulators in the Flight Crew Training Building to minimize interface problems. The SSCS and ECSG ground version data systems utilize immediately adjacent areas to allow data-bus interaction of these two equipment groups.

Facilities provide for electronic equipment, consoles, and maintenance shops. They have subfloor space with easy access for cable routing, cooling air distribution, and utilities installation. Equipment grounding and RFI protection are provided for instrumentation.

4.1.4.4 Ground Network

The ground network to be provided by NASA is required to support the Space Station program.

4.1.4.5 Inventory Control Facilities

Requirements—Centrally control and manage activities required for resupply of the Space Station throughout its 10-year orbital life.

Functional Description—The inventory control facilities maintain centralized control over specialized activities dealing with Space Station inventory resupply. Functions include determining the logistics vehicle cargo constituents, procurement, control of inventory item quality, preparation of the resupply cargo for flight, and loading resupply cargo in the logistics or crew cargo modules, also included are unloading logistics or crew cargo modules returned from flight and disposition of that cargo. Resupplies are defined as consumables, expendable, experiments, and spares.

Physical Description—The Supply Shipping and Receiving Building is used as the bulk resupplies cargo storage and preparation-for-shipment capability.
Included in these two functions are areas which support procurement, quality control, resupplies test and evaluation, shipping and receiving, packaging, and storage for both Space Station and experiment cargo. Cold storage and certain environmentally controlled areas are provided. Communications and data links are established with the logistics support area in the MSOB. Emergency power provided for cold storage and environmentally controlled areas and for other critical communications and data systems. The MSOB provides offices and support areas where procurement is coordinated and the cargo operations are monitored and controlled. A logistics staging area is located in the VAB low bay behind the logistics module maintenance, checkout, and loading area. In this area, the resupply cargo intended for next flight is collected, test loaded, and loaded on the logistics module.

4.1.4.6 Flight Integration Tool Installation Area
The flight integration tool installation area could be located at site other than KSC. The location deferred should be determined by the bidding contractor for cost effectiveness.

Requirements—Maintain the Space Station orbital configuration using flight-type hardware and software through means of the ground-based FIT. Provide the capability for conducting hardware form and fit analysis, troubleshooting analysis, and experiment integration without the aid of extensive simulation equipment other than the FIT Space Station hardware and software.

Functional Description—The FIT installation area contains and supports the operation of electronic equipment, maintenance shops, and offices. It provides space and environment for the FIT and necessary attendant equipment to support total simulation of the Space Station configuration.

Physical Description—The MSOB provides space, electrical power, lighting, environment, and communications for installation of the FIT and attendant equipment. Adjacent areas are made available for offices, conference rooms, and maintenance shops. They have subfloor space with easy access for cable routing, cooling air distribution, and utilities installation. Proper grounding and radio frequency interference (RFI) protection is provided for instrumentation.
4.2 EXPERIMENT SUPPORT

Figure 4-3 shows the overall experiment and experiment module flow through the experiment/experiment module support facilities. Note that this sequence includes both KSC and off-site facilities.

The module-manufacturing facility provides for the fabrication, assembly, and test of both attached and free-flying modules. In addition, this facility provides the capability to support module development and qualification testing.

Subsequent to module acceptance testing, the flight article is transported to the experiment payload integration center (EPIC) for the installation of the experiment program functional program elements (FPE's). Flight readiness is established at the EPIC and the facility also serves as a modification and refurbishment center for those modules returned from orbit and scheduled for reuse.

Experiments are fabricated and assembled at their respective manufacturing facilities and transported to the EPIC for integration into experiment modules or to the logistics module loading area for loading on a logistics module. In either case, the loaded experiment module or logistics module is then transported to the shuttle orbiter maintenance area for installation in the orbiter. This installation occurs approximately 4 days prior to launch with the orbiter in the horizontal position.

The module moves to the launch pad with the orbiter for completion of launch preparations, installation of consumables and time-sensitive experiments, and proceeding with the launch countdown. The launch site provides the landing facility for orbiter return flights and the associated offloading of experiment program equipment returning from orbit.

The specimens required for the life science experiments require a special facility at the launch site. This facility serves to isolate the specimens and provide specimen life support, and serves as a 1-g ground control or reference for the orbiting experiments.
Figure 4–3. Experiments and Experiment Modules Flow Through Facilities
Illustrations of a concept for the experiment support complex are shown in Figures 4-4 and 4-5.

4.2.1 Experiment Payload Integration Center

Requirements—Integrate the module and experiment program FPE's. Support module and experiment receiving inspection, storage, reverification of critical module subsystems, and the installation of nonhazardous and non-time-sensitive consumables. Provide laboratories necessary to support module/experiment integration activities and to accommodate module/experiment modification and refurbishment as required.

Functional Description—The experiment payload integration center (EPIC) supports the module/experiment activity functions as shown in Figure 4-6.

Physical Description—The EPIC provides a high-bay work area of approximately 15,000 sq ft to accomplish the integration functions shown in Figure 4-6. Personnel access to the high-bay area is isolated from the supporting shops and laboratories. A connecting facility provides office and administrative facilities for a maximum of 200 people, as well as shipping/receiving and material storage areas. Supporting shops and laboratories are an integral part of this facility. Characteristics of these shops and laboratories are as follows:

A. The optical laboratory provides a capability for photometric calibration, functional verifications, modifications, and repair/adjustment of optical instruments and the detectors associated with large optical trains. The laboratory has a film-processing capability and provisions for film storage.

B. The analytical laboratory provides the capability and equipment for sampling and analyzing the purity of liquids and gases. This laboratory also provides the capability for the analysis of materials to determine the characteristics of materials and materials compatibility.
Figure 4-6. Experiment Payload Integration Center Operation
C. The electronics laboratory provides the capability for the calibration, modification, and repair of electronic subassemblies and components.

D. The cleaning laboratory provides the capability for the repair, cleaning, and pressure-testing of fluid-systems components.

E. The machine shop provides a facility subsystem to support module and experiment modification and repair and the fabrication of piece parts as required.

The physical characteristics of the EPIC are summarized in Table 4-2. The EPIC will be located to prevent duplication of experiment module facilities and to take advantage of existing facilities and capabilities which can be converted for its use.

4.2.2 Operations and Checkout Area

Requirements—Support experiment module and FPE receiving inspection, storage, reverification of critical module subsystems, and the installation of nonhazardous and on-time-sensitive consumables. Provide laboratories necessary to support module/experiment operations activities and checkout.

Functional Description—The receiving inspection, storage, checkout, and servicing of FPE’s and experiment modules during prelaunch operations will be performed in areas at the launch site providing suitable housing and cleanliness control. These areas must be located appropriately with respect to interfacing logistics modules and the FIT area.

Physical Description—A high bay area is required to provide space and environment necessary for module and large experiment operations and checkout as they are received from the integration area. Personnel access to the high-bay area should be isolated from the supporting shops and laboratories. Office and administrative facilities should be provided for a maximum of 200 people, as well as shipping and receiving and material storage.
<table>
<thead>
<tr>
<th>Facility Characteristics</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-bay area</td>
<td>15,000 square feet</td>
</tr>
<tr>
<td>Crane Hook height</td>
<td>75 feet</td>
</tr>
<tr>
<td>Crane capacity</td>
<td>50 tons</td>
</tr>
<tr>
<td>Air-conditioning</td>
<td>75 ± 3°C at 45 ± 5% RH</td>
</tr>
<tr>
<td>Lighting</td>
<td>100 footcandles</td>
</tr>
<tr>
<td>Electrical power</td>
<td>120/208 vac, 3 , 60 Hz</td>
</tr>
<tr>
<td>Electrical loading</td>
<td>75 kva plus lighting</td>
</tr>
<tr>
<td>Grounding</td>
<td>Single point isolated from structural steel and equipment</td>
</tr>
<tr>
<td>Cleanliness</td>
<td>Air-conditioning filters compatible with class 100,000. Level controlled by operational procedures. Portable class 10,000 tents available</td>
</tr>
<tr>
<td>Personnel entrance to high bay</td>
<td>Change room and airlock</td>
</tr>
<tr>
<td>Communications</td>
<td>Telephone and public address</td>
</tr>
<tr>
<td>Administrative/office area (low-bay area)</td>
<td>Accommodate 200 personnel (maximum)</td>
</tr>
<tr>
<td>Supporting labs/shops (low-bay area)</td>
<td>Optical lab, machine shop, electronics lab, analytical lab, cleaning lab</td>
</tr>
<tr>
<td>Commodities</td>
<td>Shop air at 200 psig, GN₂</td>
</tr>
</tbody>
</table>
areas. Supporting shops and laboratories should be an integral part of the operations and checkout area. Characteristics of these shops and laboratories are as follows:

A. The optical laboratory provides a capability for photometric calibration, functional verifications, modifications, and repair/adjustment of optical instruments and the detectors associated with large optical trains. The laboratory has a film-processing capability and provisions for film storage.

B. The analytical laboratory provides the capability and equipment for sampling and analyzing the purity of liquids and gases. This laboratory also provides the capability for the analysis of materials to determine the characteristics of materials and materials compatibility.

C. The electronics laboratory provides the capability for the calibration, modification, and repair of electronic subassemblies and components.

D. The cleaning laboratory provides the capability for the repair, cleaning, and pressure-testing of fluid-systems components.

E. The machine shop provides a facility subsystem to support module and experiment modification and repair and the fabrication of piece parts as required.

Physical characteristics of the operations and checkout area are summarized in Table 4-3.

4.2.3 Launch Site Biological Laboratory (LSBL)

Requirements — Provide for the storage, care, feeding, and flight preparation of space biology experiment specimens.

Functional Description — The LSBL provides for physical and biological examinations of specimens as well as performance evaluations in order to establish baseline characteristics and determine flight readiness. In addition,
<table>
<thead>
<tr>
<th>Facility Characteristics</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-bay area</td>
<td>15,000 square feet</td>
</tr>
<tr>
<td>Crane hook height</td>
<td>75 feet</td>
</tr>
<tr>
<td>Crane capacity</td>
<td>50 tons</td>
</tr>
<tr>
<td>Air-conditioning</td>
<td>75 ±3°F at 45 ± 5 percent RH</td>
</tr>
<tr>
<td>Lighting</td>
<td>100 footcandles</td>
</tr>
<tr>
<td>Electrical power</td>
<td>120/208 vac, 3Φ, 60 Hz</td>
</tr>
<tr>
<td>Electrical loading</td>
<td>75 kva plus lighting</td>
</tr>
<tr>
<td>Grounding</td>
<td>Single point isolated from structural steel and equipment</td>
</tr>
</tbody>
</table>
transducers and other flight instrumentation are installed/implanted at this facility. The LSBL also serves as the 1-g ground control facility which supports the on-orbit experiment activity.

Physical Description—This is a new requirement at the launch site. The facility has the following physical characteristics:

A. Experiment accommodations (cage racks, instrumentation, etc.) duplicate the orbital accommodations.

B. The facility is divided into contaminated and noncontaminated areas. The contaminated areas are further subdivided in accordance with the degree of contamination.

C. Slightly less than 50 percent of the roofed floor space consists of working space for laboratories, and slightly over 50 percent is utilized for offices, change room, storage, airlocks, etc.

D. Separate air-handling systems are provided for the cage racks, laboratories, and office areas.

E. Construction materials, surface finishes, and design features are selected for ease and effectiveness of decontamination and to provide effective barriers.

F. Facility design accommodates the objective of being capable to change the size, shape, and purpose of rooms and their installed equipment.

G. The main noncontaminated area includes some or all of the following: reception area, change rooms, main office, executive office, conference rooms, lunch room, receiving and storage, cage cleaning, walk-in refrigerator, and photo-processing laboratory.

H. Standby electrical power is provided.

I. Incinerator facilities are provided.

J. Barriers such as airlocks, sterilizers, disinfectant showers, and ultraviolet installations are provided between contaminated and noncontaminated areas.

4.2.4 Flight Integration Tool (FIT) Area

Requirements—Provide for installation, mechanical fit check, electrical hook-up, and critical functional checkout of carry-on FPE's. Provide for
docking electrical verification for experiment modules. Provide for docking mechanical verification through interface tools (no hard mechanical dock to FIT) for experiment modules.

**Functional Description**—Floor space with low-bay ceiling height and cleanliness control must be provided adjacent to the Modular Space Station FIT. The area must accommodate GSE, handling, and access equipment as well as FPEs and experiment modules. Flight modules will not be maintained in place at the FIT, but suitable tools will provide interface functions during flight operations after checkout with the FIT is completed for the flight article.

**Physical Description**—Low-bay floor space surrounding the Modular Space Station FIT must be adequate to accommodate a 15-ft-dia by 60-ft-long experiment module with supporting handling, access, and operating equipment. Access to the FIT must be feasible with the module being checked in place. More than one module need not be verified simultaneously with the FIT, but space must be provided at the appropriate docking port for tools to simulate the FIT-to-module interfaces during flight operations.

4.2.5 **Shuttle Orbiter Maintenance Area**

**Requirements**—Provide for installation of experiment modules, or logistics modules with integrated experiments, into the shuttle orbiter.

**Functional Description**—Existing cranes and floor area of a selected KSC facility will be used in conjunction with experiment and experiment module electrical, mechanical and transportation GSE to perform integration into shuttle orbiter.

**Physical Description**—The Shuttle orbiter maintenance area must provide for installation of 15-ft dia by 60-ft long experiment modules in an orbiter in horizontal position. Facility cranes, power, and housing will be used with experiment and experiment module GSE, handling, and access equipment.
Provision is required for accommodating special cleanliness equipment for experiments or the experiment modules but the area need not provide these clean-room capabilities.

4.2.6 Mission Operations Support

Requirements—Support experiment and experiment module prelaunch, launch, on-orbit and return operations by providing for monitoring selected functions.

Functional Description—Mission operations support requires the provision of suitable areas for housing the GSE and display equipment necessary to monitor experiments and experiment modules. This function is required throughout all mission phases to coordinate KSC operations in support of overall mission operations. Real-time coordination is necessary during Shuttle orbiter landings to return experiments and data.

Physical Description—Experiment and experiment module operations support at KSC will be compatible with the provisions made for the support of the Modular Space Station operations. Control and display panels with appropriate GSE will provide the capability for remote monitoring, control, and checkout of experiments and experiment modules. This equipment will display the parameters necessary to support range safety requirements and to provide an output interface to safely control operations consoles. Provision will be made for coordination with transient principal investigators of experiment data for assessment of results and control. These capabilities will be required throughout all phases of the continuing mission.
Appendix A

ALTERNATIVE LAUNCH SITE OPERATIONS FLOW

The modularization of the Space Station, the integration techniques required to ensure compatible modules on-orbit, the need to reduce operational costs, and the use of the Shuttle as a launch vehicle lead to an orbit-ready vehicle-from-the-factory concept that is a departure from prelaunch and launch operations concepts of past programs. The prelaunch and launch operations required of an orbit-ready philosophy are described in the basic text of this report. However, if an unavoidable requirement for checkout of selected module subsystems is identified in the development phase of the program, it may be necessary to make exceptions to the ship-and-shoot rule. The following paragraphs outline an approach that could be used that would minimize GSE and operational requirements, yet allow some checkout to be performed. The chief difference in facility requirements is that an area such as the MSOB high bay would be required instead of performing operations in the Shuttle maintenance area. A typical flow of operations is shown in Figure A-1

A.1 DETAILED PRELAUNCH OPERATIONS

The following paragraphs describe the detailed prelaunch operations accomplished at the launch site. These operations are defined as the module operations prior to interfacing with the Shuttle. Hence, the descriptions trace the operations from arrival of the modules at the launch site through moving the module to the Shuttle orbiter maintenance area for loading.

A.1.1 Receive and Off-load Module; Inspect and Verify Configuration

These two operations are closely related. The modules will be shipped to KSC by air and will arrive at the Shuttle landing runway. The CKAFS runway would be used as backup of a Shuttle landing or other interfering activity
Figure A-1. Typical Module Alternative Operational Flow
preventing use of the Shuttle runway. The modules will be removed from the aircraft and towed over the KSC roads on a transporter to the checkout area (the MSOB high bay or equivalent). Covers will be removed, the module will be opened, internal access equipment will be installed, and the module will be inspected. Fluid systems will be pressurized with inert fluids (to a nonhazardous pressure) at the factory and the pressures will be measured as part of inspection to determine if there has been any leakage.

The inspection team will not be allowed to enter the module until all safety precautions have been implemented and escape routes established. A buddy system will be used for personnel onboard in closed compartments. Both end ports will be opened and through ventilation established before entry. Emergency breathing, communications, and lighting equipment will be provided before entering isolated compartments of a module. In general, however, module size and layout will be such that personnel will never be more than about 7 m (23 ft) from an exit port maximum (the GPL), and normally less that 3 m (11 ft) for the other modules. Each module has at least two exit ports (the GPL, again) and usually five (the others).

It is planned that inspection and subsequent checkout will be accomplished in the MSOB checkout area as it is fully equipped for spacecraft checkout as it presently exists, has adjacently located supporting ships, laboratories, and offices; has a controlled clean environment that will allow module ventilation without special filtering of the air; and has adequate floor space to allow simultaneous operations of several types (e.g., FIT if located at KSC, RAM's, and Space Station).

A.1.2 Selected Module Subsystem Tests

As stated in the section on test philosophy, a goal of the overall test program is to reduce duplication of testing. Thus, if integration of the flight modules (see Subsection 2.1.2 for the discussion of integration) is accomplished prior to delivery of the modules to KSC, prelaunch test activities can be relatively simple and of limited scope when compared with past and present programs. Selected tests could be performed to verify that propellants
and high-pressure fluids can be safely loaded (e.g., valves operate, quantity and pressure readouts function, and there is no leakage); that functions crossing the module-Shuttle interface will not endanger the Shuttle or cause Shuttle malfunctions; that turning on subsystems on orbit will not result in a mishap comprising safe return of the Shuttle; that subsystems that must be on for launch can be turned on; that power distribution and circuit protection subsystems are operable; and that communications can be established with the module. These tests would be different for each type of module, since each module will carry a different complement of subsystems. Specific tests required for each module cannot be defined at this time, although the general type of test for each module is indicated in Table A-1.

This activity would include connection and verification of the GSE used to perform the testing. GSE requirements for the different modules will differ. The Power Subsystems Module will contain a flight computer. Thus, it will have the capability to command, control, and monitor performance of all onboard subsystems. However, the Power Module will have no built-in control and display capability to allow personnel to interface with the computer and control checkout. It will be possible to provide this interface in two ways; (1) by use of a portable control and display unit, a piece of flight equipment (Figure A-2) that plugs into the data bus — this will be the method used by the activation crew on orbit and if used for check out allows crew participation, or (2) by RF uplink commands through the communications system as would be accomplished during unmanned periods on orbit. (This method will automatically check communications capabilities at the same time).

The first method is preferred since it will require less sophisticated GSE to verify communications and will be available regardless. Other GSE required will consist of (1) module handling and access equipment, (2) fluid system servicing equipment, (3) battery handling equipment, and (4) a power supply, since solar arrays will not be operable and battery life will be limited.
<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Power Module</th>
<th>Crew Module</th>
<th>GPS Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guidance, Navigation and Control</td>
<td>Rate, gyro operation (continuous) Horison sensor turn-on and operation Reaction control electronics turn-on and operation</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Communications</td>
<td>RF communication on, instrument and receive verification</td>
<td>Verify antenna deployment commands</td>
<td>Intercom operational check</td>
</tr>
<tr>
<td>EC/LS</td>
<td>Air temperature control on, functional check</td>
<td>Same as for Power Module</td>
<td>Same as for Power Module</td>
</tr>
<tr>
<td></td>
<td>Coolant (H₂O and freon) circulation pump operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td>Emergency lighting operational check</td>
<td>Same as for Power Module</td>
<td>Same as for Power Module</td>
</tr>
<tr>
<td></td>
<td>Use external and internal lighting as required for other checks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Thrust Propulsion</td>
<td>Leak-check plumbing and tanks</td>
<td>Leak-check plumbing</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Operational checks of valve operation sequencing</td>
<td>Operational checks of valve opera-</td>
<td>N/A</td>
</tr>
<tr>
<td>Data Management</td>
<td>Self-check routines</td>
<td>and sequencing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use as required to control and check other subsystems</td>
<td>Use data bus as required to control and check other subsystems</td>
<td>Self-check routines</td>
</tr>
<tr>
<td>Power</td>
<td>Power distribution conversion and switching checks</td>
<td>Operational checks of control and display console</td>
<td>Use as required to control and check other subsystems</td>
</tr>
<tr>
<td></td>
<td>Control signals to solar array drive motors</td>
<td>Power distribution, conversion and switching checks</td>
<td>Same as for Crew Module</td>
</tr>
<tr>
<td>Docking</td>
<td>Docking mechanism deployment and retraction operational checks</td>
<td>Same as for Power Module</td>
<td>Same as for Power Module</td>
</tr>
<tr>
<td>Crew Systems</td>
<td>N/A</td>
<td>None</td>
<td>N/A</td>
</tr>
<tr>
<td>Experiments</td>
<td>N/A</td>
<td>N/A</td>
<td>None</td>
</tr>
</tbody>
</table>
Crew/Operations Module GSE requirements will be quite different from a control and test execution standpoint. The Crew/Operations Module will contain the primary control and display consoles for interfacing with the onboard computer, but no computer. Several viable alternatives are possible. A computer could be provided as GSE. Existing KSC computers could be used, (e.g., ACE, with suitable buffers and software), or mission control computers could be used. A separate complete set of software compatible with the existing computers would have to be developed and a buffer-data bus interface unit would have to be designed and built if existing computers were used. If a new computer were used, it could be selected to be compatible with the onboard data system and could use flight software thereby requiring no additional software development. A large computer would not be required, since most subsystems on the Crew/Operations Module are inactive during checkout and launch.

Mission control will have the capability to issue commands and monitor performance directly, given a communications link and data bus adapter, as a
result of similar capabilities required for the unmanned periods of orbital operation. The Crew/Operations Module has no communications (except high-gain antennas which connect to the Power/Subsystems Module). Therefore, if mission control capabilities were used, it would be necessary to provide a communications link (no problem if mission control is located at KSC) and equipment to adapt it directly to the Crew/Operations Module data bus instead of going through the onboard computer and data bus controller. Use of a compatible GSE computer or the mission control computers appears to be more desirable than existing computers as new software would not have to be developed. Hardware requirements would be about the same in each case. Other equipment (handling, access, etc.) would be common to the Power/Subsystems Module. There is also another alternative; the GPL module has a flight computer in it and could be connected to the Crew/Operations Module to provide full control capability. The GPL module would have to be shipped to KSC at the same time as the Crew/Operations Module in this case and would require duplicate GSE to support it and the Crew Module during simultaneous operation.

A flight computer, as mentioned above, will be in the GPL module. In addition, it will have onboard control and display capabilities. These will normally be used for experiment operations on orbit but will also be serviceable as a backup to the station controls and displays in the Crew Module. Hence, the GPL can be operated independently during checkout given power, servicing, and access equipment common the Power and Crew Modules.

A.1.3 Flight Servicing of Modules

All subsystems requiring servicing will be serviced at this time except for propellant and high-pressure subsystems which will be serviced on-pad. Any carry-on equipment not previously installed, batteries, and cargo or loose experiment equipment launched with the module would be loaded and secured in the module at this time. However, due to Shuttle payload weight limitations, no such items except batteries for the Power Module have been identified. Battery installation will be relatively easy, since the batteries will be designed for routine replacement on-orbit (Figure A-3).
A. 1.4 Move Module to Shuttle Maintenance Area
All GSE will be disconnected from the module except any portable monitoring equipment and power packs necessary to measure pressures, the status of which must be tracked throughout the remaining operations. The module, mounted on its transporter in a horizontal position, will then be covered to protect it from the outside environment, and towed from the checkout area (MSOB) to the Shuttle orbiter maintenance area. (VAB high bays will not be used for Shuttle stacking.)

A. 1.5 Install Ordnance
No ordnance items have been defined for any module. However, if tie-down releases, latches, and deployment mechanism final designs require ordnance, the ordnance will be installed prior to loading the module into the orbiter.

A. 2 DETAILED LAUNCH OPERATIONS
Launch operations will be the same as described in Subsection 2.1.5.2.
Appendix B

SHUTTLE-PAYLOAD GROUND OPERATIONS INTERFACE

Shuttle payloads will cover a broad spectrum of configurations and types. Obviously, all possible payloads cannot be analyzed with respect to configurations and associated ground operations to determine operational requirements affecting system design at the present time.

Of particular importance in the analysis of payload operations is the smooth and efficient phasing of payload operations into the Shuttle operational flow which will hopefully adhere to the ground rule of a "clean" Shuttle interface. A clean operational interface with the Shuttle implies installing payloads in the Shuttle, verifying the interface, and launching without compromising the Shuttle 10-day turnaround time and without modifying or altering the basic Shuttle orbiter configuration.

B.1 SHUTTLE OPERATIONS INTERFACE

Shuttle operations timelines, Figure B-1 shows approximately 12 hours during the fifth day of the 10-day turnaround cycle for installation of a payload module, and closing of the cargo bay doors. (MDC E0189, Space Shuttle Program Phase B Systems Study Data Book, Volume 1, 23 April 1970, Revised 20 May 1971 for more detail.) This may or may not be adequate time to install and verify installation of payloads with a complex Shuttle interface. Potential inadequacy of the time available is evident from the following considerations.

First, control of the payloads may be from within the Shuttle passenger compartment. This will require control and display equipment (at least the man-machine interface equipment) to be located in the passenger compartment with supporting equipment and the payloads in the cargo bay, separated from the control and display equipment by a pressure shell. Obviously, standard
control and display equipment which can be used with any payload and remain installed in the Shuttle on a semipermanent basis is desirable to reduce the time required for and the problems associated with installing new equipment in the Shuttle. Even with standard equipment, however, it would be necessary to exchange software programs to convert the standard equipment for use with the current payload.

Proper implementation of the software by the Shuttle flight equipment, compatibility of interfaces, and the integrated operation of the flight equipment, software, and payload (which will have not operated together before installation of the payload in the Shuttle) will have to be verified. This could be a complicated, time-consuming process, especially as each new payload and software package will be an unknown quantity. Any new system never previously used under operational conditions in conjunction with operational equipment is likely to exhibit previously undetected idiosyncrasies, and incompatibilities with interfacing equipment that must be worked out and corrected before the interfacing systems can function correctly together.

Second, all payloads will have critical safety parameters and limits displayed in the cockpit. The same type of problems will exist as described above, although not to the same degree.

Further, it is unlikely that it will be possible to completely control all payloads from within the Shuttle using a standard control and display console in the passenger compartment, considering the wide variety of payloads possible, although the majority of functions can probably be implemented with the standard equipment. In this case, where standard equipment is not sufficient, it is desirable from an operational viewpoint to be able to mount any special-purpose equipment on standard mounting brackets or racks and to connect the equipment to the payload in the cargo bay by means of standard, Shuttle-furnished, pressure shell feedthrough connectors. The problem of verifying integrated operation and implementation of the control and display functions is compounded by the problems of ensuring proper fit within the passenger area of the orbiter.
Table B-1 summarizes the Shuttle-payload integration problem, assuming a clean operational interface.

B.2 SHUTTLE-PAYLOAD OPERATIONS INTERFACE VERIFICATION
To ensure meeting Shuttle turnaround schedules, it will be necessary to verify the integrated operation and compatibility of experiment hardware, software, and Shuttle equipment before installing the experiment payload in the Shuttle in order to ensure a high degree of confidence that no problems will exist after installation. This will require an integration device that is a physical replica of Shuttle structures and equipment that may directly interface with payload equipment, such as the passenger compartment interior pressure shell (where experiment functions feed through), cargo bay interior including docking and deployment mechanism. The integration device must also be a functional replica of interfacing flight systems, e.g., the standard control and display equipment, power control, attitude and rate reference data (unless they interface through the standard equipment), cockpit caution and warning system, or pressure shell feed-through connectors. Subsystems and equipment in the integration device would be duplicates of the flight subsystem maintained under the same change control.

Table B-1
SHUTTLE-PAYLOAD INTEGRATION

<table>
<thead>
<tr>
<th>Elements to be Integrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard payload control and display flight equipment</td>
</tr>
<tr>
<td>Standard software</td>
</tr>
<tr>
<td>Special payload software</td>
</tr>
<tr>
<td>Payload</td>
</tr>
<tr>
<td>Shuttle cockpit caution and warning</td>
</tr>
<tr>
<td>Shuttle subsystems</td>
</tr>
<tr>
<td>Special-purpose payload control and display flight equipment</td>
</tr>
<tr>
<td>Cargo bay</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 to 12 hours (assuming integration must be completed before securing cargo doors for flight)</td>
</tr>
</tbody>
</table>
Location of this integration device should be centralized at a Shuttle payload preflight integration facility, since all payloads will require access to it and since it would be too large and complicated to ship to various payload manufacturers' facilities. An artist conception of the device is shown in Figure B-2.

There are two alternatives to providing a Shuttle-payload integration device: (1) increase Shuttle turnaround time to accommodate the integration function using the actual flight equipment, or (2) accomplish experiment integration in parallel with Shuttle operations after installation. The first alternative is obviously undesirable since numerous incompatibilities between payload and Shuttle may be encountered, making prediction of integration duration and accompanying launch delays difficult, if not impossible. An additional 20 hours could be gained with the second alternative provided there would be no interference between Shuttle and payload operations and assuming no payload access would be required, both of which are doubtful. Also, the extra time might not be sufficient.