PREFACE

The extension phase of the Orbital Service Module (OSM) Systems Analysis Study was conducted to further identify Power Extension Package (PEP) system concepts which would increase the electrical power and mission duration capabilities of the Shuttle Orbiter. Use of solar array power to supplement the Orbiter's fuel cell/cryogenic system will double the power available to payloads and more than triple the allowable mission duration, thus greatly improving the Orbiter's capability to support the payload needs of sortie missions (those in which the experiment remains in the Orbiter).

To establish the technical and programmatic basis for initiating hardware development, the PEP concept definition has been refined, and the performance capability and the mission utility of a reference design baseline have been examined in depth. Design requirements and support criteria specifications have been documented, and essential implementation plans have been prepared. Supporting trade studies and analyses have been completed.

The study report consists of 12 documents:

- Volume 1 Executive Summary
- Volume 2 PEP Preliminary Design Definition
- Volume 3 PEP Analysis and Tradeoffs
- Volume 4 PEP Functional Specification
- Volume 5 PEP Environmental Specification
- Volume 6 PEP Product Assurance
- Volume 7 PEP Logistics and Training Plan Requirement
- Volume 8 PEP Operations Support
- Volume 9 PEP Design, Development, and Test Plans
- Volume 10 PEP Project Plan
- Volume 11 PEP Cost, Schedules, and Work Breakdown Structure Dictionary
- Volume 12 PEP Data Item Descriptions
Questions regarding this study should be directed to:

Jerry Craig/Code EA4
Manager, Orbital Service Module Systems Analysis Study
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058, (713) 483-3751

D.C. Wensley, Study Manager, Orbital Service Module Systems Analysis Study
McDonnell Douglas Astronautics Company-Huntington Beach
Huntington Beach, California 92647, (714) 896-1886
FOREWORD

The Power Extension Package (PEP) is a solar electrical power generating system to be used on the Shuttle Orbiter to augment its power capability and to conserve fuel cell cryogenic supplies, thereby increasing power available for payloads and allowing increased mission duration. The Orbiter, supplemented by PEP, can provide up to 15 kW continuous power to the payloads for missions of up to 48 days duration.

When required for a sortie mission, PEP is easily installed within the Orbiter cargo bay as a mission-dependent kit. When the operating orbit is reached, the PEP solar array package is deployed from the Orbiter by the remote manipulator system (RMS). The solar array is then extended and oriented toward the sun, which it tracks using an integral sun sensor/gimbal system. The power generated by the array is carried by cables on the RMS back into the cargo bay, where it is processed and distributed by PEP to the Orbiter load busses. After the mission is completed, the array is retracted and restowed within the Orbiter for earth return.

The figure below shows the PEP system, which consists of two major assemblies -- the Array Deployment Assembly (ADA) and the Power Regulation and Control Assembly (PRCA) -- plus the necessary interface kit. It is nominally installed at the forward end of the Orbiter bay above the Spacelab tunnel, but can be located anywhere within the cargo bay if necessary. The ADA, which is deployed, consists of two lightweight, foldable solar array wings with their containment boxes and deployment masts, two diode assembly interconnect boxes, a sun tracker/control/instrumentation assembly, a two-axis gimbal/slip ring assembly, and the RMS grapple fixture. All these items are mounted to a support structure that interfaces with the Orbiter. The PRCA, which remains in the Orbiter cargo bay, consists of six pulse-width-modulated voltage regulators mounted to three cold plates, three shunt regulators to protect the Orbiter buses from overvoltage, and a power distribution and control box, all mounted to a support beam that interfaces with the Orbiter.

PEP is compatible with all currently defined missions and payloads and imposes minimal weight and volume penalties on these missions. It can be installed and removed as needed at the launch site within the normal Orbiter turnaround cycle.
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>DOCUMENTATION</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>NATURAL ENVIRONMENTS</td>
<td>3</td>
</tr>
<tr>
<td>3.1</td>
<td>Ground Natural Environments</td>
<td>3</td>
</tr>
<tr>
<td>3.2</td>
<td>Space Natural Environments</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>INDUCED ENVIRONMENT</td>
<td>11</td>
</tr>
<tr>
<td>4.1</td>
<td>Thermal Environment</td>
<td>11</td>
</tr>
<tr>
<td>4.2</td>
<td>Limit-Load Factors/Angular Accelerations</td>
<td>11</td>
</tr>
<tr>
<td>4.3</td>
<td>Acoustics</td>
<td>17</td>
</tr>
<tr>
<td>4.4</td>
<td>Vibration</td>
<td>17</td>
</tr>
<tr>
<td>4.5</td>
<td>On-Orbit Accelerations</td>
<td>17</td>
</tr>
<tr>
<td>4.6</td>
<td>Orbiter/Cargo Bay Particulates and Gases Environment</td>
<td>21</td>
</tr>
<tr>
<td>4.7</td>
<td>Electromagnetic Interference Environment</td>
<td>24</td>
</tr>
<tr>
<td>4.8</td>
<td>RCS Plume Environment</td>
<td>35</td>
</tr>
<tr>
<td>4.9</td>
<td>Relative Deflections</td>
<td>35</td>
</tr>
</tbody>
</table>
Section 1
INTRODUCTION

This specification establishes the natural and induced environments that the Power Extension Package (PEP) and GSE may be exposed to during ground operations and space operations with the Shuttle System. Space induced environments are applicable at the Orbiter attach point interface location. Attenuation or amplification of the environment by cradle or carrier structure between the Orbiter attachment and individual PEP components are not accounted for. The Orbiter provides an induced environment as benign or more benign than existing launch vehicles.

All probable environments are systematically listed according to each ground and mission phase.
Section 2
DOCUMENTATION

The following documents form a part of this specification to the extent specified herein. In the event of conflict between this document and other documents involved herein, the contents of this specification shall govern.

JSC 07700, Volume X
Appendix 10.10
NASA TMX 64757
NASA TN D-4404
NASA TMS 53957
TMS 64668
JSC 07636
MIL-STD-810E

Natural Environment Design
Requirements
Terrestrial Environment (Climatic)
Criteria Guidelines for use in Aerospace Vehicle Development, 1973 Revision
An Analysis of Energetic Space Radiation and Dose Rates
Space Environment Criteria Guideline for Use in Space Vehicle Development
Natural Environment Design Requirements for the Sortie Module
Space Shuttle Program Lightning Protection Criteria Document
Environmental Test Methods
The following are the natural environmental conditions to which PEI equipment and GSE may be exposed during its useful lifetime and must be considered in the design. These conditions are expressed in terms of parameters which are generally defined at extreme levels.


If so desired, the PEI equipment may be protected during delivery to the launch and recovery operation by use of appropriate site facilities so that it is protected from the environment. Since a limited number of units are involved, relaxation of these requirements are allowable contingent upon an appropriate shipping or storage plan.

3.1 GROUND NATURAL ENVIRONMENTS

3.1.1 Transportation (Packaged)

The PEI system shall be capable of meeting the operating performance requirements specified herein after exposure to the following transportation conditions when packaged.

A. Air

1. Temperature
   Minus 65° to plus 150°F for 6 hours; 190°F maximum for 1 hour.

2. Pressure
   Maximum of 15.23 pounds per square inch absolute (psia) sea level, minimum of 3.28 psia (35,000 feet).
3. Humidity 0 to 100 percent relative humidity.

B. Ground
1. Temperature Minus 40°F to plus 122°F (ambient); plus 150°F for 6 hours; 190°F for one hour.
2. Pressure Maximum of 15.23 psia (sea level) minimum of 9.76 psia (10,000 feet).
3. Humidity 8 to 100 percent relative humidity.


3.1.2 Storage
The PEP system shall be capable of meeting the operating performance requirements specified herein after exposure to the following storage conditions. Environments specified are for Shuttle operational sites only.

A. Sheltered uncontrolled environment (packaged or unpackaged)
1. Temperature Minus 23°F to plus 150°F.
2. Humidity 8 to 100 percent relative humidity.
3. Pressure Maximum of 15.23 psia (sea level), minimum of 12.4 psia.
4. Ozone Surface maximum* 3 to 6 parts per million (ppm).
5. Fungus As specified in MIL-STD-810A.
6. Sand and dust As encountered in desert and ocean beach areas, equivalent to 140-mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 grams per cubic foot.

B. Unsheltered equipment (packaged)
1. Temperature Minus 23°F to plus 115°F.
2. Pressure Maximum of 15.23 psia (sea level), minimum of 12.4 psia.
3. Humidity 8 to 100 percent relative humidity.
4. Sand and dust Extreme design surface values as follows.

Sand particle diameter* inches 0.0031 to 0.039

*NOTE: 90 percent or more between 0.0031 and 0.012 inches.
Sandstorm suspended sand,
 pcf  1.2
Sandstorm wind speed,
 ft/sec  33
Sand particle hardness,
 Moh. scale  7 to 8
Dust particle  0.0000039 to
 diameter**  0.0031 inches
 inches
Dust storm wind
 speed ft/sec 33
Dust storm vertical Uniform to
distribution 656 ft.
Dust particle hardness,
 Moh. scale  7 to 8

5. Hail and snow

Design for extreme hail at surface
characteristics as follows:
Maximum hailstorm diameter,
 inches 2
Duration, minutes  ≤ 15
Fall velocity,
 ft/sec 100
Hailstorm density,
 pcf 50
Wind speed,
 ft/sec 33
Hail hardness,
 Moh. scale  2 to 4
Maximum depth,
 inches 2
Occurrence Once in 15 years
frequency

**NOTE: 9 percent or more between 0.0000039 and 0.0000079 inches.
Design extreme surface snow characteristics as follows:

6. Salt fog
Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 1.0 percent salt (NaCl) solution by weight for 30 days.

7. Rain
Maximum of 19 inches in 24 hour period including short period extremes of four inches for one hour.

8. Ozone
Surface maximum* 3 to 6 parts per hundred million (phm); 35,000 feet maximum 100 phm.

9. Solar radiation
Solar radiation of 377.6 British thermal unit (Btu)/ft² hour total normal incident.

10. Fungus
As specified in MIL-STD-810E.

3.1.3 Ground Handling Loads (Unpackaged)
The following are the ground handling loads for unpackaged hardware.

A. Handling shock - Bench handling shock as specified in MIL-STD-810, Method 516.1, Procedure V.

B. Design shock - As specified in MIL-STD-810, Method 516.1, Procedure I.

C. Acceleration (hoisting loads) - Land: 2 g vertical within a plus or minus cone angle of 20 degrees. Water: 2.67 g vertical within a plus or minus cone angle of 20 degrees.

3.1.4 Launch Site Operations Environment
This section describes the environments (atmosphere temperature, pressure, humidity, and contamination) to which PEP equipment may be subjected during integration, installation, and prelaunch checkout activities.

*NOTE: Total oxidant concentrations may infrequently reach 60 phm for periods of 1 to 3 hours during a 24-hour period.
4.1.4.1 Integration Operations

A. Operation and Checkout Building (O&C)
1. Temperature 77° ± 1°F (70° ± 5°F)
2. Humidity 50 ± 5% RH
3. Pressure 13.8 to 15.04 psia
4. Cleanliness Class 100 000

B. Orbiter Processing Facility (OPF) - The area assigned for payload processing and checkout will provide the following conditions:
1. Temperature 74 ± 1°C (75° ± 3°F)
2. Humidity 60% RH ± 5%
3. Pressure 12.4 to 15.23 psia
4. Cleanliness Purged with Class 100 000 air

4.1.4.2 Orbiter Cargo Bay

While the PIF flight unit is installed in the Orbiter cargo bay and the cargo bay doors are closed, the Orbiter cargo bay atmosphere will be controlled to provide the following conditions:

Air Purge - ground transport, VAR and OPF
1. Flow rate: 0 to 94 lcf/min.
2. Temperature: Selectable within the range of 60°-80°F controlled to ± 2°F of the desired setting.
3. Cleanliness: Nominally class 100 guaranteed class 5000 (HEPA filtered) air with 15 ppm or less hydrocarbons based on methane equivalent.
4. Humidity: Equal to or less than 50 percent relative humidity.

Prior to the cargo bay doors being closed, the cargo bay environment will be maintained by providing a facility purge of:
1. Temperature: 70 ± 5°F
2. Cleanliness: Nominally class 100 guaranteed class 5000 (HEPA filtered).
3. Humidity: 50 ± 5% RH

4.2 SPACE NATURAL ENVIRONMENTS

Space is normally considered to be altitudes greater than 58.0 n.m.a.,
(200,000 ft., 60 Km).
3.2.1 Pressure

$1 \times 10^{-10}$ Torr. $(1.3 \times 10^{-8} \text{ n/m}^2)$ shall be the design consideration. Other values are as follows:

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Max. P. Torr. $(\text{n/m}^2)$</th>
<th>Min. P. Torr. $(\text{n/m}^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 n.mi. (129.7 km)</td>
<td>$1.4 \times 10^{-5}$ ($1.87 \times 10^{-3}$)</td>
<td>$8 \times 10^{-6}$ ($0.63 \times 10^{-3}$)</td>
</tr>
<tr>
<td>100 n.mi. (186.5 km)</td>
<td>$2.2 \times 10^{-6}$ ($0.63 \times 10^{-3}$)</td>
<td>$4.7 \times 10^{-7}$ ($0.63 \times 10^{-3}$)</td>
</tr>
<tr>
<td>500 n.mi (926.5 km)</td>
<td>$2.2 \times 10^{-9}$ ($2.93 \times 10^{-8}$)</td>
<td>$4.7 \times 10^{-11}$ ($0.63 \times 10^{-8}$)</td>
</tr>
<tr>
<td>1200 n.mi. (2223.6 km)</td>
<td>Approx. $1 \times 10^{-11}$ ($0.13 \times 10^{-8}$)</td>
<td>Same as maximum</td>
</tr>
</tbody>
</table>

Highest pressure at orbital altitudes would be the maximum pressure at lowest orbital altitude 70 n.mi. (129.7 km) and lowest pressure at orbital altitudes would be the minimum pressure at the highest orbital altitude 1200 n.mi (2223.6 km).

3.2.2 Solar Radiation (Thermal)

Temperature extremes for items exposed to space environments cannot be categorically defined. When determining these extremes analytically, use the following data:

<table>
<thead>
<tr>
<th>Environmental Parameter</th>
<th>Design Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar radiation</td>
<td>443.7 Btu/ft$^2$/hr (1398.76 w/m$^2$)</td>
</tr>
<tr>
<td>Earth albedo</td>
<td>30 percent</td>
</tr>
<tr>
<td>Earth radiation</td>
<td>77 Btu/ft$/hr$ (242.74 w/m$^2$)</td>
</tr>
<tr>
<td>Space sink temperature</td>
<td>0$^\circ$ Rankin ($0^\circ$ Kelvin)</td>
</tr>
</tbody>
</table>

3.2.3 Solar Radiation Ionizing

The natural radiation environment in terrestrial space consists of (1) galactic cosmic radiation, (2) geomagnetically trapped radiation, and (3) solar flare particle events.

3.2.3.1 Galactic Cosmic Radiation (Mainly Protons)

Composition: 85% protons, 15% alpha particles, 2% heavier nuclei

Energy Range: $10^8$ to $10^{19}$ electron volts; predominant $10^9$ to $10^{13}$ electron volts.

Flux Outside Earth's Magnetic Field: 0.2 to 0.4 particles/CM$^2$/steradian/sec

Integrated Yearly Dose: Approximately 4 to 10 rads.
3.2.3.3 Geomagnetically Trapped Radiation (Proton, Electron)

Energy: Electron - Up to several MeV Proton - Up to several 100 MeV

Flux: Electron - Up to $10^8$ Electrons/cm$^2$/sec > 0.5 MeV Proton - Up to $10^5$

Protons/cm$^2$/sec > 30.0 MeV

See NASA TN D-4404 for specific mission radiation environments and resulting exposure/shielding relationships.

3.2.3.3 Solar Particle Events

Composition: Protons and alpha particles

Occurrence: Sporadically and lasting for several days

Particle Event Model (free space): See Section 2.4.3 of NASA TN 64627

Protons: $N_p(>T) = \begin{cases} 7.25 \times 10^{11}T^{-1.2} & \text{1 MeV} \leq T \leq 10 \text{ MeV} \\ 3.54 \times 10^{11}e^{-F(T)/73} & \text{10 MeV} \leq 30 \text{ MeV} \\ 2.64 \times 10^{11}e^{-F(T)/73} & T > 30 \text{ MeV} \end{cases}$

Alphas: $N(>T) = \begin{cases} 7.07 \times 10^{12}T^{-2.14} & T \geq 30 \text{ MeV} \end{cases}$

Where $N_p(>T), N(>T) =$ Protons/cm$^2$, Alphas/cm$^2$ with energy $>T$ in MeV

$F(T) =$ Particle magnetic rigidity in mV given by

$F(T) = 1.7Z_e T (T+2M_eC^2)$

$Z_e =$ is particle charge in units of electron charge; i.e., $Z_e = 1$ for Protons and 2 for Alphas

$M_e C^2 =$ 938 MeV for Protons, 3728 MeV for Alphas

For near-earth orbital altitudes, the above free-space event model must be modified since the earth's magnetic field deflects some of the low-energy particles that would enter the atmosphere at low latitudes to the poles. While in near earth polar exposure from solar particle events will be approximately 30% of that of free space. Relative exposure decreases rapidly with decreasing orbital inclination.

3.2.4 Meteoroids

The meteoroid model encompasses particles of cometary origin in the mass range between $1 \times 10^{-11}$ grams for sporadic meteoroids and $1 \times 10^{-15}$ grams for stream meteoroids.
Average total environment:

Particle density \(0.5\mu/cm^3\)

Particle velocity \(20\text{km/sec}\)

(1) \(\text{For } 10^{-6} \leq m \leq 10^6 \text{ Io}_{10} N_t = 14.37 - 1.213 \log_{10} m\)

(2) \(\text{For } 10^{-12} \leq m \leq 10^{-6} \text{ Io}_{10} N_t = 14.339 - 1.584 \log_{10} m - 0.063 (\log_{10} m)^2\)

\(N_t + \) no. particles/m²/sec of mass \(m\) or greater

\(m\) = mass in grams

Defocusing factor for earth, and if applicable, shielding factor are to be applied.
The following induced environment exists in the payload bay.

4.1 THERMAL ENVIRONMENT

4.1.1 Payload Bay Wall Temperature
The temperature range at the payload bay walls are defined in Table 4.1-1. The maximum temperature for the radiator when the doors are closed shall be 184°F.

Table 4.1-1. Payload Bay Wall Temperature

<table>
<thead>
<tr>
<th>Condition</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Prelaunch</td>
<td>+40°F (4.4°C)</td>
<td>+120°F (48.9°C)</td>
</tr>
<tr>
<td>2. Launch</td>
<td>+40°F (4.4°C)</td>
<td>+150°F (65.6°C)</td>
</tr>
<tr>
<td>3. On-orbit (doors open)</td>
<td>-250°F (-156.7°C)</td>
<td>+200°F (93.3°C)</td>
</tr>
<tr>
<td>4. Entry and post-landing</td>
<td>-50°F (-45.6°C)</td>
<td>+200°F (93.3°C)</td>
</tr>
</tbody>
</table>

Conditions 1 and 2 are for an assumed adiabatic payload.

Condition 3 is for an assumed empty cargo bay.

Condition 4 is for an assumed adiabatic payload. The maximum temperature is for an assumed initial 70°F cargo bay wall temperature. The minimum temperature is for an assumed initial -250°F cargo bay wall temperature. Local areas around the vents may reach 225°F for duration of less than 2 minutes after vents are opened.

4.1.2 Entry Air Inlet Temperature
For design purposes, the worst case temperature of air entering the payload bay during entry shall be assumed to be as defined in Figure 4.1-1.

4.2 LIMIT-LOAD FACTORS/ANGULAR ACCELERATIONS
The load factors/angular accelerations specified in Tables 4.2-1, 2, and 3 are appropriate for preliminary design of PEP primary structure and for determination of preliminary Orbiter/PEP interface loads as the guiding criteria only.
Figure 4.1-1. Air Temperature Entering the Payload Bay During Entry – Max Air Temperature Case

The center-of-rotation for angular accelerations is at the PEP element center-of-gravity. The load factors/angular accelerations for emergency landing condition are defined in Paragraph 4.2.3.

PEP load factor/angular acceleration is defined as the total externally applied force/moment on the PEP or PEP component divided by the corresponding total or component weight/mass moment of inertia and carries the sign of the externally applied force/moment in accordance with the Orbiter coordinate system. (See Figure 4.2-1.)
Table 4.2-1 Cargo Limit-Load Factors/Angular Accelerations For Preliminary Design (Quasi-Steady Flight Events)

<table>
<thead>
<tr>
<th>FLIGHT EVENT</th>
<th>LOAD FACTOR g</th>
<th>ANGULAR ACCELERATION RAD/SEC ²</th>
<th>CARGO WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nx</td>
<td>Ny</td>
<td>Nz</td>
</tr>
<tr>
<td>ASCENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIGH-Q BOOST ENVELOPE</td>
<td>-1.9</td>
<td>±0.40</td>
<td>-0.50</td>
</tr>
<tr>
<td>INTEGRATED VEHICLE BOOST MAX Nx</td>
<td>-2.9</td>
<td>±0.06</td>
<td>-0.10</td>
</tr>
<tr>
<td>ORBITER BOOST MAX Nx</td>
<td>-3.17</td>
<td>0.0</td>
<td>-0.60</td>
</tr>
<tr>
<td>POST SRB STAGING</td>
<td>-1.10</td>
<td>±0.12</td>
<td>-0.59</td>
</tr>
<tr>
<td>DESCENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAEM: PITCH MANEUVER</td>
<td>0.15</td>
<td>0</td>
<td>2.50</td>
</tr>
<tr>
<td>-</td>
<td>0.25</td>
<td>0</td>
<td>2.50</td>
</tr>
<tr>
<td>-</td>
<td>0.97</td>
<td>0</td>
<td>-1.00</td>
</tr>
<tr>
<td>TAEM: ROLL MANEUVER</td>
<td>0.65</td>
<td>±0.12</td>
<td>1.98</td>
</tr>
<tr>
<td>TAEM: YAW MANEUVER</td>
<td>0.90</td>
<td>±1.25</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>0.03</td>
<td>±1.24</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Table 4.2-2 Cargo Limit-Load Factors/Angular Accelerations For Preliminary Design (Transient Flight Events)

<table>
<thead>
<tr>
<th>FLIGHT EVENT</th>
<th>LOAD FACTOR g</th>
<th>ACCELERATION RAD/SEC²</th>
<th>CARGO WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NX</td>
<td>NY</td>
<td>NZ</td>
</tr>
<tr>
<td>ASCENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIFT-OFF</td>
<td>-0.2</td>
<td>1.0</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>-3.2</td>
<td>-1.0</td>
<td>-2.5</td>
</tr>
<tr>
<td>DESCENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LANDING</td>
<td>1.8</td>
<td>±1.0</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>-2.0</td>
<td>±1.0</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

Table 4.2-3 Emergency Landing Design Load Factors

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>LOAD FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>65 Klb (29484 kg) Up</td>
<td>32 Klb (14515 kg) Down</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Load Factor</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Landing (Outside Crew Compartment)</td>
<td>+4.5</td>
<td>-1.5</td>
<td>+4.5</td>
</tr>
<tr>
<td></td>
<td>+1.50</td>
<td>-1.50</td>
<td>-2.0</td>
</tr>
</tbody>
</table>

Sign convention follows that of the Orbiter coordinate system in Figure 4.2-1.

Emergency landing load factors are ultimate. The longitudinal load factors are directed in all aftward azimuths within a cone of 20 degrees half-angle. The specified load factors shall operate separately.
Figure 4.2-1. Sign Convention for Cargo Limit-Load Factors/Angular Accelerations

These load factors/angular accelerations are valid for any location in the bay. The load factors/angular accelerations result from the response of the Shuttle vehicle structure, including cargo, to external forces corresponding to both quasi-static and transient flight events. These external forces are generated by the thrust, aerodynamics, wind shear, prelaunch restraints, entry maneuvers, landing gear impact, etc.

Accelerations at specific points within the PEP will depend upon PEP design characteristics and mounting methods. Portions of the PEP that are cantilevered from their support points, or that have substantial internal flexibility, may experience higher accelerations than those reflected in the tables.

The load factors/angular accelerations shall be considered in all combinations for each event.
4.2.1 Quasi-Steady Flight Events

The load factors/angular accelerations associated with the quasi-steady flight events are generated by external forces which change slowly with time and for which the vehicle elastic responses are relatively small. Consequently, coupled transient dynamic analyses are not normally required. However, for PEP with redundant Orbiter interfaces, a coupled static analysis of the various quasi-static flight events shall be used for determining deflections and PEP interface forces. Shuttle model and deflection data to analyze quasi-static flight events shall be included in the payload-unique ICD.

Load factors and angular accelerations are specified in Table 4.2-1 for quasi-steady flight events during ascent and descent, for up to a maximum of 65,000 lb. (29,484 kg) lift-off cargo and up to maximum of 32,000 lb. (14,515 kg) landed cargo. These conditions are normal design conditions for the Orbiter structure.

4.2.2 Transient Flight Events

The transient flight events correspond to conditions for which the external forces are highly transient in nature and significant elastic response occurs. Shuttle lift-off and landing are events of this type. The associated PEP responses depend on the PEP geometry, stiffness, and mass characteristics. Consequently, design values of PEP/Shuttle interface forces and PEP design loads shall be determined by coupled transient analysis. However, typical load factors for the transient events are given in Table 4.2-2.

The load conditions in Table 4.2-2 are for an ascent cargo weight of up to a maximum of 65,000 lb. (29,484 kg) lift-off cargo and up to a maximum of 32,000 lb. (14,515 kg) landing cargo. The maximum symmetric design landing sink speed is 9.6 fps (2.93 mps).

4.2.3 Emergency Landing Load Factors

The Orbiter vehicle design considers safe crew egress following emergency landing or water ditching. Hence, the mounting structures for equipment and crew provisions vessels shall be designed to load factors equal to or greater than those shown in Table 4.2-2. Equipment inside the Orbiter crew compartment shall be designed to preclude hazards to the flight personnel after the application of the emergency landing loads defined in the table. The attachment
structures (including fittings and fasteners) must be designed for emergency landing loads. The attachment structure equipment where failures could result in injury to personnel or prevent egress from the emergency landed vehicle must be designed for this requirement. Equipment design shall consider provisions to maximize the probability of safe crew egress following an emergency landing.

4.3 ACOUSTICS

The spatially averaged acoustic levels in an empty payload bay shall not exceed those defined in Table 4.3-1. The acoustic levels during orbit, entry and landing are significantly below the ascent levels and shall be assumed to be negligible.

Acoustic levels for specific payload bay equipment are dependent on geometry, surface area and acoustic absorption characteristics and will differ from those of the empty payload bay.

4.4 VIBRATION

The random vibration environments predicted for the unloaded mid-fuselage main longeron payload trunnion fitting and the unloaded mid-fuselage keel trunnion fitting are shown, respectively, in Figures 4.4-1 and 4.4-2. These empty payload bay environments will be reduced by the presence of equipment. The unloaded attach point vibration environments may be adjusted to account for the presence of a payload by use of the 3-step procedure exemplified in Appendix I, Paragraph I.4 of ICD 2-19001, Shuttle Orbiter/Cargo Standard Interfaces, Revision F.

4.5 ON-ORBIT ACCELERATIONS

During normal Orbiter attitude keeping activities, thrusting of the Orbiter RCS shall cause slight accelerations to be exerted on STS element equipment depending on the location with respect to the center-of-rotation.

RCS and vernier thrust values shall be as defined in Table 4.5-1. All three angular accelerations may occur simultaneously and the linear acceleration at any point in the STS element system shall be calculated based on the distance from the vehicle center-of-rotation. This location shall vary to some extent with the particular payload weight distribution but shall be in the vicinity of Xo 1080, Yo 0, and Zo 400, for typical missions.
Table 4.3.1 Orbiter Cargo Bay Internal Acoustic Noise

<table>
<thead>
<tr>
<th>1/3 Octave Band Center Frequency (Hz)</th>
<th>Sound Pressure Level (dB) ref. $2 \times 10^{-5} \text{N/m}^2$ Lift-Off 5 Seconds/Mission</th>
<th>Sound Pressure Level (dB) ref. $2 \times 10^{-5} \text{N/m}^2$ Aeronoise 5 Seconds/Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.5</td>
<td>122.0</td>
<td>112.0</td>
</tr>
<tr>
<td>40.0</td>
<td>124.0</td>
<td>114.0</td>
</tr>
<tr>
<td>50.0</td>
<td>126.0</td>
<td>116.0</td>
</tr>
<tr>
<td>63.0</td>
<td>127.5</td>
<td>118.0</td>
</tr>
<tr>
<td>80.0</td>
<td>129.5</td>
<td>120.0</td>
</tr>
<tr>
<td>100.0</td>
<td>130.5</td>
<td>122.0</td>
</tr>
<tr>
<td>125.0</td>
<td>132.0</td>
<td>124.0</td>
</tr>
<tr>
<td>160.0</td>
<td>133.0</td>
<td>125.0</td>
</tr>
<tr>
<td>200.0</td>
<td>133.5</td>
<td>126.5</td>
</tr>
<tr>
<td>250.0</td>
<td>134.0</td>
<td>127.0</td>
</tr>
<tr>
<td>320.0</td>
<td>134.5</td>
<td>127.0</td>
</tr>
<tr>
<td>400.0</td>
<td>134.5</td>
<td>127.0</td>
</tr>
<tr>
<td>500.0</td>
<td>134.0</td>
<td>127.0</td>
</tr>
<tr>
<td>630.0</td>
<td>133.5</td>
<td>125.0</td>
</tr>
<tr>
<td>800.0</td>
<td>133.0</td>
<td>123.0</td>
</tr>
<tr>
<td>1,000.0</td>
<td>132.0</td>
<td>119.0</td>
</tr>
<tr>
<td>1,250.0</td>
<td>131.5</td>
<td>118.0</td>
</tr>
<tr>
<td>1,600.0</td>
<td>130.0</td>
<td>117.0</td>
</tr>
<tr>
<td>2,000.0</td>
<td>129.0</td>
<td>115.0</td>
</tr>
<tr>
<td>2,500.0</td>
<td>128.0</td>
<td>113.0</td>
</tr>
<tr>
<td>3,200.0</td>
<td>126.5</td>
<td>111.0</td>
</tr>
<tr>
<td>4,000.0</td>
<td>125.0</td>
<td>109.0</td>
</tr>
<tr>
<td>5,000.0</td>
<td>124.0</td>
<td>107.0</td>
</tr>
<tr>
<td>6,300.0</td>
<td>122.5</td>
<td>105.0</td>
</tr>
<tr>
<td>8,000.0</td>
<td>121.0</td>
<td>102.0</td>
</tr>
<tr>
<td>10,000.0</td>
<td>120.0</td>
<td>101.0</td>
</tr>
</tbody>
</table>

*OAL* | 145.0 | 137.0

*Development testing to confirm the internal payload bay acoustic environment has been completed with potential reductions in acoustic levels for portions of the spectra. Additional confirmation of payload bay acoustic levels and changes to the 145 dB OA environment are not expected before first Orbital flight; however, if specific hardware development problems are encountered which can be affected by incorporation of the development test results, the JSC Space Shuttle Program Office is to be contacted for additional consultation.
Figure 4.4-1. Unloaded Main Longeron Trunnion Fitting Vibration.
Figure 4.4-2. Unloaded Keel Trunnion Fitting Vibration
Table 4.5-1. ORBITER RCS MAXIMUM ACCELERATION LEVELS

<table>
<thead>
<tr>
<th>System</th>
<th>Max Translational * Accelerations Ft/Sec²</th>
<th>Max Rotational * Accelerations Deg/sec²</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCS (870 lbs)</td>
<td>0.6 0.5 0.7 1.3 1.1</td>
<td>1.2 1.4 1.5 0.0</td>
</tr>
<tr>
<td>Verniers (25 lbs)</td>
<td>0.0 0.0 0.007 0.0 0.008</td>
<td>0.04 0.03 0.02 0.02</td>
</tr>
</tbody>
</table>

*Assumes 170 Klb Orbiter and 32 Klb payload. 65 Klb payload (TBD).

4.6 ORBITER/CARGO BAY PARTICULATES AND GASES ENVIRONMENT

4.6.1 Purge Gas in the Cargo Bay

4.6.1.1 Lift-Off Through Orbit Insertion
Purge gas shall be residue remaining from purge prior to lift-off. Nominal cargo bay pressure decay shall be assumed to be that shown in Figure 4.6-1.

4.6.1.2 Entry and Descent
Atmospheric air filtered through 35-micron glass-bead-rating filters shall be used to repressurize the cargo bay. Nominal cargo bay repressurization shall be assumed to be that shown in Figure 4.6-2.

4.6.2 Contamination
Payload bay contamination will be minimal by selection of materials with low outgassing characteristics. Material selection criteria of 1 percent, or less, total mass loss and 0.1 percent, or less, Volatile Condensible Material (VCM) as defined in NASA/JSC Specification SP-R-0022, or its equivalent, shall be used.

Contamination outside the bay will be to a level which shall limit contamination to cargo, payload bay, Orbiter windows, optical surfaces and Orbiter thermal protection system. Dump design shall be time-selectable in order to program occurrences to be compatible with other mission operations.
Figure 4.6-1: Orbiter Cargo Bay Internal Pressure Histories During Ascent.
Figure 4.6-2 Orbiter Cargo Bay Internal Pressure* Histories During Entry

*Assumes uniform pressure within the cargo bay.
4.7 ELECTROMAGNETIC INTERFERENCE ENVIRONMENT

4.7.1 Shuttle-Produced Interference Environment
The Shuttle-produced conducted and radiated interference is limited to the
levels indicated in Paragraphs 4.7.1.1 and 4.7.1.2.

4.7.1.1 Conducted Interference
The conducted interference produced by the Shuttle applicable to all DC and AC
interfaces shall be limited as follows:
A. In-Flight DC Power Bus Ripple: The in-flight DC power bus ripple at
the interface shall not exceed:
1. ±0.9 volts peak-to-peak narrowband (30 Hz to 7 KHz) falling 10 dB
per decade to 0.28 volts peak-to-peak to 70 KHz, thereafter remaining constant
to 400 MHz.

2. ±0.8 volts peak broadband in the frequency band from 30 Hz to 7
KHz and ±0.3 volts peak in the frequency band from 7 KHz to 400 MHz.

3. Under the conditions of a passive payload (resistive simulation
of load), the ripple on the power supplied will not be greater than 0.8 volts
peak-to-peak broadband (DC to 50 MHz): no discrete frequency will exceed 0.4
volts peak-to-peak. This condition applies at the modbody power interface
only.

4. For the dedicated fuel cell operation, the Shuttle-generated ripple
at the interface will not exceed 100 millivolts peak-to-peak (30 Hz to 10
MHz).

B. In-Flight DC Power Bus Transients: In-flight power bus transients
shall not exceed the impulse equivalent of 300 X 10^{-6} volt seconds above or
below normal line voltage. Peak transients will be limited to ±50 volts mea-
sured line-to-line and between positive line and structure and will be limited
to ±30 volts when measured between return line and structure. Rise and fall
times shall not be less than 1 microsecond.

C. Common-Mode Voltage: The common-mode voltage between electrical
Spacelab/Orbiter bonding interfaces in the payload bay and the aft flight deck
shall not exceed:
1. 0.3 volts peak-to-peak when measured in the time domain with an
instrument bandwidth of at least 50 MHz. This is inclusive of a DC component
which may exist in vehicle structural members.

MCDONNELL DOUGLAS
2. 0.15 volts peak-to-peak for any discrete frequency between 30 Hz and 50 MHz.

3. $50 \times 10^{-6}$ voltseconds maximum transient excursions with rise and fall times not less than 1 microsecond; the peak shall not exceed 5 volts.

The common mode voltage values given above are defined as the voltage drop across two points of the Orbiter structure.

Note: The trunnion and keel attach fittings will be electrically isolated by Orbiter design.

4.7.1.2 Radiated Interference

The Shuttle-produced radiated fields environment shall be limited as follows:

A. AC magnetic fields shall be limited to less than 140 dB above 1 picotesla (30 Hz to 1 KHz), falling 40 dB per decade to 50 KHz. The DC field shall be less than 170 dB above 1 picotesla. The above are worst case values for locations near the Orbiter power buses at Yo = $+79$, Zo = 349, $X_0 =$ any value in the payload bay.

The above values of magnetic flux density are reduced in accordance with the following equation for separation from the power buses in the Y-Z plane.

$$\text{dB (reduction)} = 20 \log_{10} \left( \frac{57 R^2}{P} \right)$$

where $P$ (meters) = radial separation in the Y-Z plane from the nearest port or starboard power bus described by the above location coordinates.

For locations within 2.5 meters of the 576 to 1307 $X_0$ locations, the value of $R$ in the equation should be the separation from the $X_0 = 576$ or $X_0 = 1307$ locations in meters.

B. Electric fields along the payload bay centerline are defined in Figures 4.7-1 and 4.7-2 for unintentional emissions.

C. The electric field strengths produced by Orbiter-installed transmitters (defined in Figure 4.7-3) are worst case values in upper (+Z) quadrant of the payload envelope with doors open. Reduced levels can generally be expected in the lower levels of the payload bay.
Figure 4.7-1. Shuttle-Produced Payload Bay Radiated Broadband Emissions

D. The electric field strengths produced by Orbiter-installed transmitters external to the bay are as follows:

<table>
<thead>
<tr>
<th>Antenna</th>
<th>Transmitter power (W)</th>
<th>Spherical coverage (%)</th>
<th>Field strength (V/M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ku Band (Comm)</td>
<td>50</td>
<td>1.6</td>
<td>2181/R</td>
</tr>
<tr>
<td>Ku Band (Radar)</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>S Band Quad</td>
<td>100</td>
<td>72</td>
<td>42/R</td>
</tr>
<tr>
<td>S Band Hemi</td>
<td>10</td>
<td>40-50</td>
<td>6.9/R</td>
</tr>
<tr>
<td>S Band P/I</td>
<td>5</td>
<td>TBD</td>
<td>5.29/R</td>
</tr>
<tr>
<td>UHF (EVA)</td>
<td>0.25</td>
<td>85</td>
<td>0.27/R</td>
</tr>
</tbody>
</table>

where R is the distance in meters between the antenna and object in the electric field.
4.7.2 Cargo-Produced Interference Environment

4.7.2.1 Cargo-Produced Conducted Noise

The cargo-generated conducted emission limits, applicable to all DC and AC power interfaces, shall be limited to the following:

A. DC Power:

1. The power line conducted emissions shall be limited to the levels indicated in Figure 4.7-4. These levels may be exceeded when operating from a dedicated fuel cell provided the radiated emissions limits of Paragraph 4.7.2.2 below are met; however, the Shuttle power bus ripple voltages shall not be applicable.
2. The cargo-generated spikes produced on DC power lines by switching or other operations shall not exceed the limits defined in Figure 4.7-5 for normal operation and Figure 4.7-6 for abnormal operation when fed from a source impedance within the limits defined in Figures 4.7-7 and 4.7-8. Rise and fall times shall be greater than 1.0 microsecond.

B. AC Power:

1. The AC-power-line-conducted emissions of the Cargo AFC equipment shall not exceed the limits defined in Figure 4.7-5.
Figure 4.7.6. Envelope of Cargo Allowed Spikes on DC Power Busses for Normal Electrical System Operation
2. AC power-bus transient spikes generated by the Cargo AFD equipment shall not exceed the limits defined in Figure 4.7-9 for both normal and abnormal operations when fed from a source impedance not greater than 10 ohms. Peak spikes below 10 microseconds duration, for normal electric system operations, shall be limited to 60 volts superimposed on the 400 Hz sine wave. Rise and fall times shall be greater than 1.0 microseconds.

4.7.2.2 Cargo-Produced Radiated Fields
The cargo-produced radiated fields shall be limited as follows:
A. The generated AC magnetic fields (applies at a distance of 1 meter from any payload equipment) shall not exceed 130 dB above 1 picotesla (50 Hz to 2 KHz) falling 40 dB per decade to 50 KHz.
B. The radiated electric fields shall not exceed the levels defined in Figures 4.7-10 and 4.7-11 except that the broadband emissions for cargo equipment in the payload bay shall be limited to 70 dB above 1 microvolt/meter/MHz in the frequency range of 1770 MHz to 2300 MHz. Narrowband emissions shall be limited to 25 dB above 1 microvolt/meter from 1770 MHz to 2300 MHz, excluding any payload intentional transmitters.
C. Allowable levels of radiation from payload transmitter antenna systems are shown in Figure 4.7-12. These levels are established with respect to levels incident on Orbiter equipment and should not be construed to limit radiation at higher levels with a directional antenna through open payload bay doors.
D. Electrostatic discharges shall not occur within the payload bay other than those isolated from the AFD and payload bay gaseous environment (hydrogen-oxygen mixture) and shielded by the cargo to satisfy the requirements of Subparagraphs A and B above.

4.7.3 Ground Radar-Produced Radiated Interference
Electric field intensities of 22V/M maximum in the Radar Band of the electromagnetic spectrum are indicated to exist.

4.8 RCS PLUME ENVIRONMENT
TBD

4.9 RELATIVE DEFORMATIONS
TBD
Figure 4.7-10. Cargo Allowable Radiated Broadband Emissions
Figure 4.7-12. Allowable Field Strength From Cargo Transmitters

*WAIVER REQUIRED TO NASA HQS. DOCUMENT "SAFETY POLICY & REQUIREMENTS FOR PAYLOADS USING THE SHUTTLE TRANSPORTATION SYSTEM (STS)" RADIATION UP TO THESE LEVELS IS ALLOWED.