NSTS 21492

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

Space Shuttle Program

Payload Bay Payload

User's Guide

BASIC

DECEMBER, 2000

NSTS 21492

SPACE SHUTTLE PROGRAM
PAYLOAD BAY PAYLOAD
USER'S GUIDE

December 4, 2000

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DESCRIPTION OF CHANGES TO

SPACE SHUTTLE PROGRAM
PAYLOAD BAY PAYLOAD USER'S GUIDE

CHANGE NO.	DESCRIPTION/AUTHORITY	DATE	PAGES AFFECTED
--	Basic issue/R21492-001	12/04/00	ALL
1	Update section 8.2.5.7, 8.2.7, 8.2.7.1, 8.4.1.3, and 8.4.2/R21492-0002	05/24/01	8-14, 8-15, 8-17
2	Update section 8.4.1.3 and appendix B/R21492-0003	10/17/02	vii, 8-17, 8-18, 8-19, 8-20, B-2

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Appendix

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INTRODUCTION

1.0

This document contains information on the Space Shuttle system required by payload customers during the design definition, integration and flight phases for payload bay payloads. Payloads or experiments that will be using the middeck accommodations should refer to the Space Shuttle Program (SSP) Middeck Payload User's Guide, NSTS TBD. The purpose of this document is to provide potential customers with information on Space Shuttle capability to deliver payloads into orbit and return them to Earth; on services provided to payload customers; and on the means by which payload customers can avail themselves of these services. Standard interface provisions between the Orbiter and payloads are also defined. With this information, payload planning and design studies can be undertaken incorporating known Shuttle capabilities and interface provisions.

Additionally, information is provided on the process employed by the SSP to integrate individual payloads into the Shuttle, and the process of manifesting multiple payloads and providing for their integration into a Shuttle mission or flight. Additional information with hyperlinks to program documentation can be found at the Space Shuttle Payload Information System (SSPIS) web site.

This document should be used in conjunction with the documents outlined in figure 1-1.

Payload customers must satisfy the specific safety requirements contained in the primary safety documents noted in figure 1-1.

The NSTS 07700 Volume XIV, Space Shuttle System Payload Accommodations is the top-level document in the SSP customer documentation tree. It defines the first level of requirements and establishes references to lower level requirement documents. All other documents in the tree are considered subordinate to the Volume XIV.

Standard Integration Plans (SIPs) also referred to as blank books, have been developed to serve as guides for preparation of the payload customer's Integration Plan (IP). When IP is used in this document, it includes the Payload Integration Plan (PIP), IP, Mission Integration Plan (MIP), and Carrier Integration Plan (CIP) documents. Blank book annexes are also available, as required; to facilitate definition of detailed integration requirements.

Attachment 1, Shuttle Orbiter/Cargo Standard Interfaces, ICD 2-19001 is the principal document defining Space Shuttle/payload interfaces. In addition, several standard Interface Definition Documents (IDDs) are provided to facilitate the customer's development of a payload-unique Interface Control Document (ICD).

When a prospective customer has negotiated a formal agreement (Launch Services Agreement (LSA), Joint Endeavor Agreement (JEA), or Memorandum of Understanding (MOU), etc.) with the Office of Space Flight, Space Shuttle Operations Utilization Division at National Aeronautics and Space Administration (NASA) Headquarters, a Payload Integration Manager (PIM) will be assigned at Lyndon B. Johnson Space Center (JSC), and a Launch Site Support Manager (LSSM) at John F. Kennedy Space Center (KSC). The PIM will coordinate with the JSC customer payload support group to provide the payload customer with required documentation.

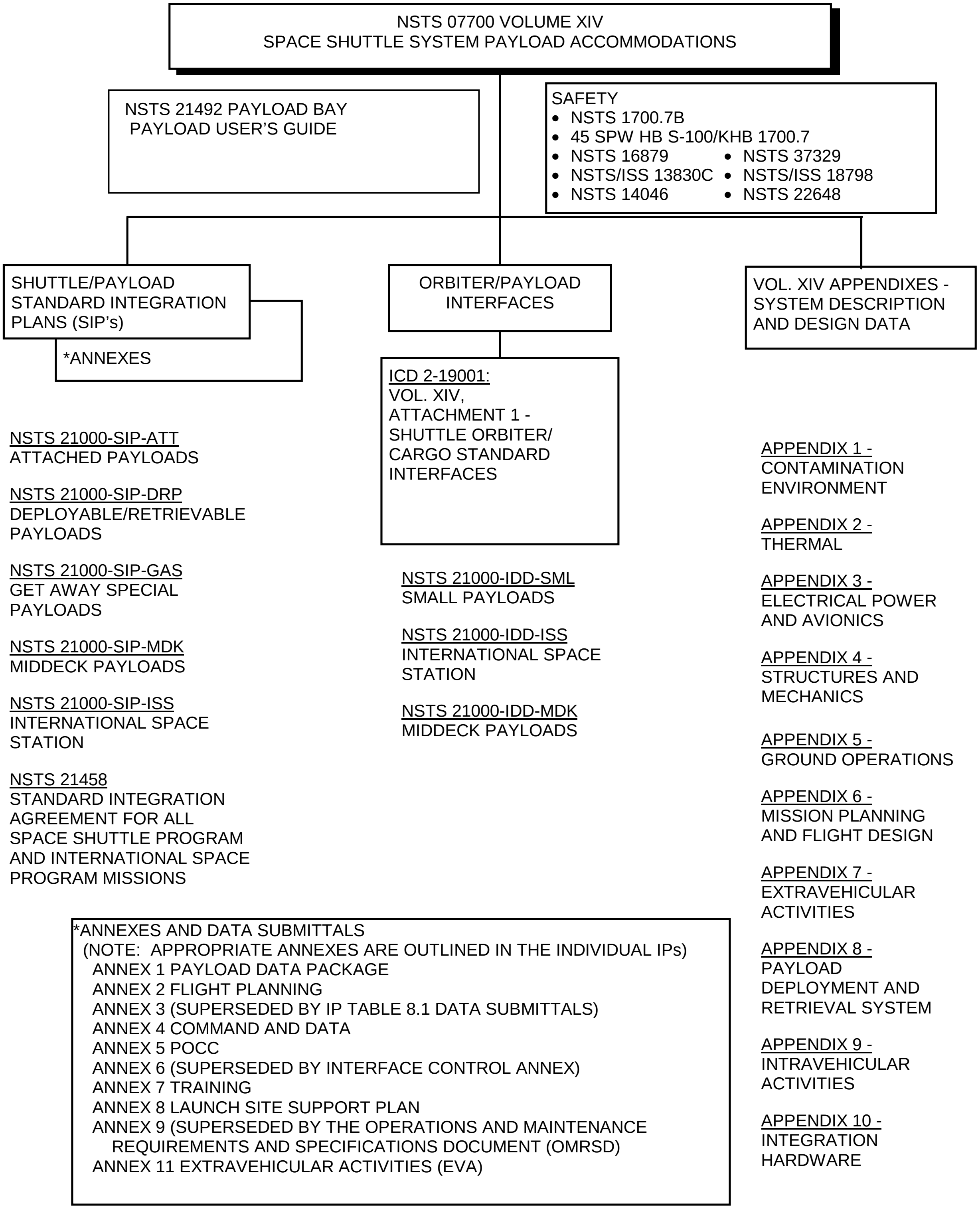


Figure 1-1. SSP customer documentation tree

SPACE SHUTTLE VEHICLE DESCRIPTION

2.0

2.1 SPACE SHUTTLE VEHICLE

The Space Shuttle vehicle is composed of the Orbiter, an External Tank (ET), and two Solid Rocket Boosters (SRBs). These elements are depicted in figure 2.1-1.

1. Orbiter - The Orbiter is comparable in size and weight to a modern commercial airliner. It has three main engines (commonly referred to as Space Shuttle Main Engines (SSMEs)) and two smaller Orbital Maneuvering System (OMS) engines mounted in the rear. Launch accelerations are limited to less than 3 g by use of the throttling capability of the SSMEs. In space, attitude control is affected by the Reaction Control System (RCS) engines.

   The Orbiter payload bay is approximately 60 feet long and 15 feet in diameter. If the Orbiter Docking System (ODS) is installed, the envelope for payload use is only 48 feet long. Normally, several compatible payloads share each flight; occasionally, however, a single payload requires the entire payload bay.

   The flightcrew normally consists of a commander, pilot, and three or more Mission Specialist (MS) astronauts. Payload Specialists (PSs) may be included to operate their experiments. The commander and pilot operate the Orbiter and manage Orbiter systems, while the MSs accomplish mission objectives and assist the commander and pilot with management of Orbiter systems. The commander, pilot, and MSs are selected by NASA on a career basis. One or more PSs may be added as required with approval from the SSP. Detailed responsibilities of MSs and PSs are tailored to meet the requirements of each mission; crew size is therefore a function of mission complexity and duration.

   Displays and controls for payload operations are located in the Aft Flight Deck (AFD), which is the upper level of the crew compartment. The middeck, located immediately below the flight deck, provides the crew living area and accommodations for middeck payloads.

2. ET - The ET provides the Orbiter main propulsion system with liquid hydrogen (fuel) and liquid oxygen (oxidizer). After cutoff of the SSMEs, the ET is jettisoned and breaks up in the atmosphere over remote ocean areas.

3. SRBs - Two SRBs are fired in parallel with the SSMEs to provide initial ascent thrust. The SRBs are recovered after each flight, refurbished, and reused.

SPACE SHUTTLE SYSTEM

OVERALL LENGTH	184.2 FT (56.1 m)
HEIGHT	76.6 FT (23.3 m)

EXTERNAL TANK

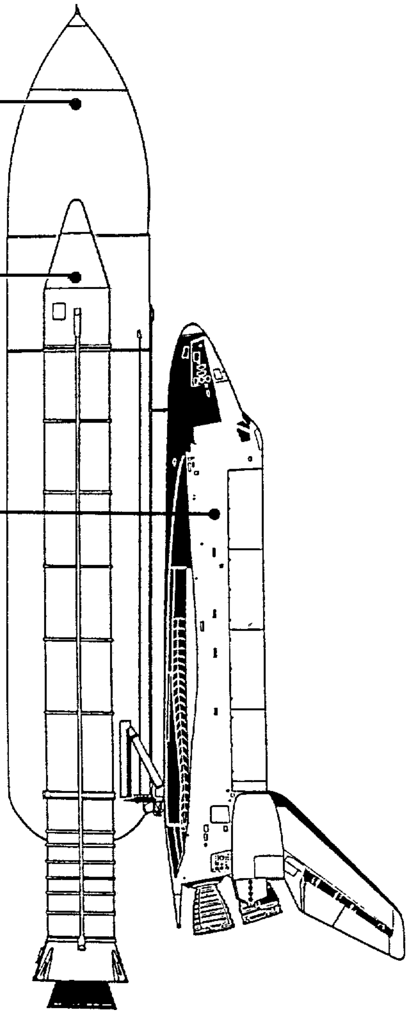
DIAMETER	27.8 FT (8.5 m)
LENGTH	154.4 FT (47.1 m)

SOLID ROCKET BOOSTER

DIAMETER	12.2 FT (3.7 m)
HEIGHT	149.1 FT (45.4 m)
THRUST (EACH)	
— LAUNCH	2,700,000 LB (12,010,140 N)

ORBITER

LENGTH	122.2 FT (37.2 m)
WINGSPAN	78.1 FT (23.8 m)
TAXI HEIGHT	~ 57 FT (~ 17 m)
PAYLOAD BAY	15 FT DIAM BY 60 FT LONG (4.6 m BY 18.3 m)
MAIN ENGINES (3)	
— VACUUM THRUST EACH	470,000 LB (2,090.7 kN)
OMS ENGINES (2)	
— VACUUM THRUST EACH	6,000 LB (26.7 kN)
RCS	
— 38 ENGINES	
VACUUM THRUST EACH	870 LB (3,869.9 N)
— 6 VERNIER ENGINES	
VACUUM THRUST EACH	25 LB (111.2 N)



OMS - *ORBITAL MANEUVERING SYSTEM*
RCS - *REACTION CONTROL SYSTEM*

Figure 2.1-1. Space Shuttle system

SPACE SHUTTLE PERFORMANCE CAPABILITY

3.0

The SSP provides launch services to a wide range of payloads, from small hand-held experiments to large laboratories and satellites. Besides the traditional launch services provided by expendable launch vehicles, the SSP can provide a variety of man-supported services in space, then return the vehicle, crew, equipment, and products to Earth.

The SSP is composed of the Space Shuttle vehicle, flight and ground hardware and software, and personnel required to operate the system. Ground systems include facilities for payload and Space Shuttle flight hardware processing, launch and landing, and crew training and mission operations.

3.1 TYPICAL SPACE SHUTTLE MISSION

Space Shuttle launches take place at KSC in Florida. Missions are launched from KSC with orbital inclinations of 28.45°, 39°, 51.6° or 57°.

As depicted in the Shuttle mission profile (figure 3.1-1), the Space Shuttle is launched with all three SSMEs operating in parallel with the SRBs. SRB separation occurs approximately 2 minutes after launch. After SRB separation, the Orbiter and ET continue ascent, using the three main engines with Main Engine Cutoff (MECO) occurring about 8 minutes after lift-off. Then the ET is separated from the Orbiter. After a short coasting period, the Orbiter OMS engines are fired for additional velocity necessary to achieve proper orbit.

Payload Bay Doors (PLBDs) are opened soon after orbit stabilization to allow the Orbiter space radiators to dissipate heat. Payload operations are then conducted by the crew from the payload station on the AFD. Upon completion of on-orbit operations, the PLBDs are closed and the Orbiter is configured for return to Earth.

Mission duration is dependent upon Space Shuttle capability and payload requirements. Typical mission duration is 5 to 7 days. However, under specific conditions, missions can be extended beyond 7 days. If requirements justify the need, an Extended Duration Orbiter (EDO) kit has been developed to support missions up to 16 days.

The Orbiter returns to Earth by firing the OMS engines to reduce velocity. After reentering Earth atmosphere, the Orbiter glides to an unpowered landing at KSC or alternate landing site such as Edwards Air Force Base (EAFB).

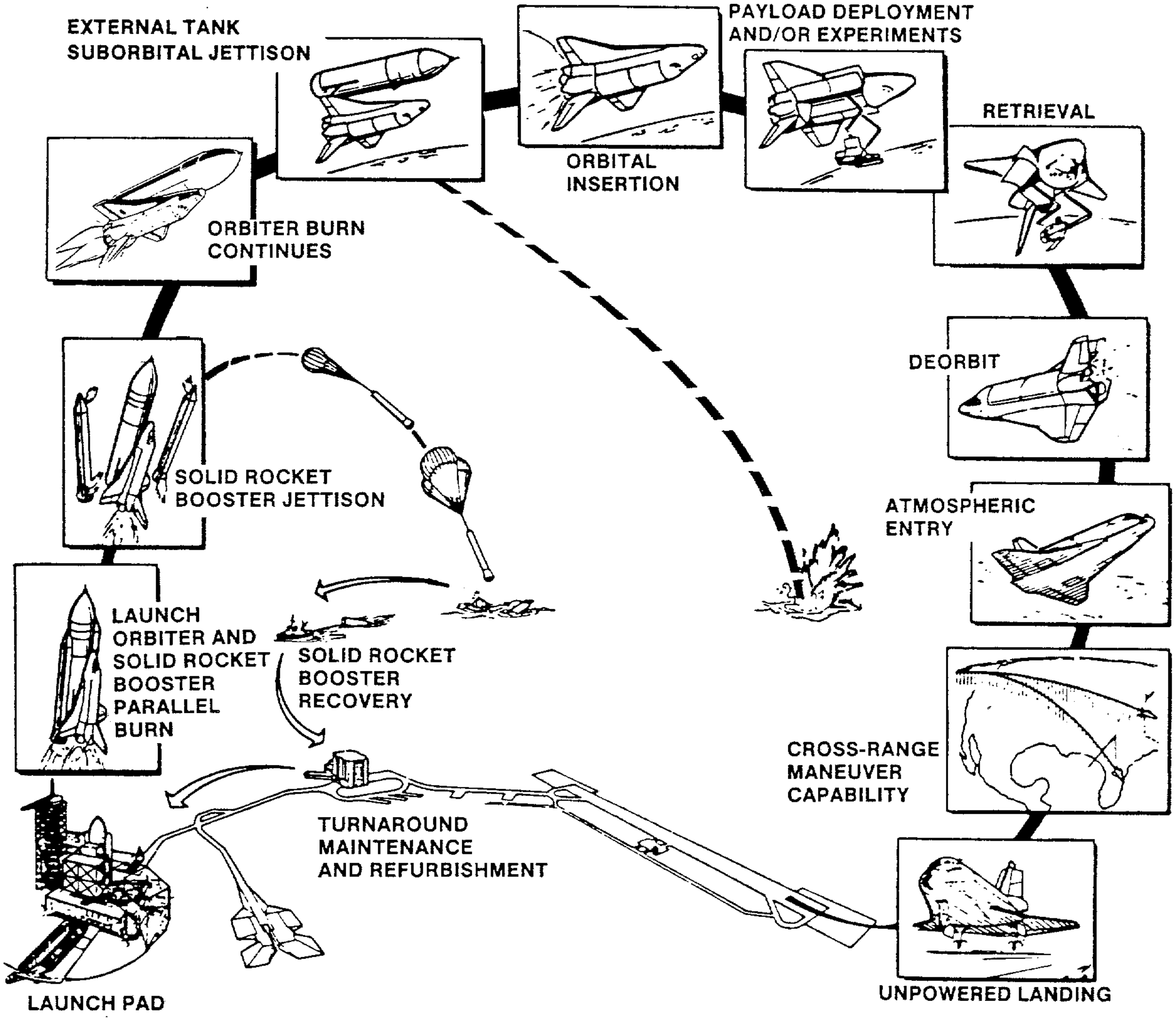


Figure 3.1-1. Mission phases (typical)

3.2 SPACE SHUTTLE CARGO CAPABILITY

The allowable launch cargo weight of no more than 56,000 pounds is influenced by various operational requirements that depend upon the type of mission. Allowable cargo weight is constrained by either ascent performance or landing weight limits, and is affected by such factors as orbital altitude and inclination, mission duration, crew size, and rendezvous requirements. If payload requirements exceed the capabilities described below, the customer should inform the PIM assigned to that particular payload.

The weight of the payload itself, including any carrier or booster, Airborne Support Equipment (ASE), and payload-unique integration hardware, is considered payload control weight. This includes PSs and associated personnel provisions (500 pounds per person). Payload control weight is specified in the IP, and specific agreements for any control weight deviations must be negotiated with the SSP.

GROUND AND FLIGHT ENVIRONMENTS

4.0

This section addresses the thermal, radiation and electromagnetic, contamination and cleanliness, and mechanical environments during off-line and on-line ground flow operations, flight events, postlanding, and ferry flight. Also included is a review of contamination conditions within and between various launch site facilities. The information provided will aid the Space Shuttle user in planning payload-to-Orbiter interfaces and the integration of design considerations for the environments described.

Payload integration and mission success are dependent on payload customer understanding of exposed from delivery to the launch site to postflight removal of the payload from the Orbiter. The SSP assists the customer in understanding the Space Shuttle by identifying facility and Orbiter cleanliness and operational controls, which determine the payload environment.

The payload bay is a cylindrical volume in the upper portion of the Orbiter midbody. Its dimensions vary slightly between static and dynamic conditions and the payload does not come in direct contact with the payload bay walls. The maximum payload dimensions by design are 720 inches (18.46 m) long by 180 inches (4.6 m) in diameter, or a volume of 10,600 cubic feet (306.6 m^3).

The payload bay is, with a few exceptions, a smooth surface with filtered vents, lights, and flush-mounted wire trays as shown in figure 4-1. The standard configuration displays a patchwork of thermal control blankets in the lower half of the payload bay, and when required a liner of tightly woven Teflon-coated Beta Cloth is installed in 6-foot widths over the blankets to form a barrier between the payload bay and the equipment bay in the lower part of the mid fuselage. The liner covers almost 1500 square feet of the payload bay’s 3300 square feet of surface area.

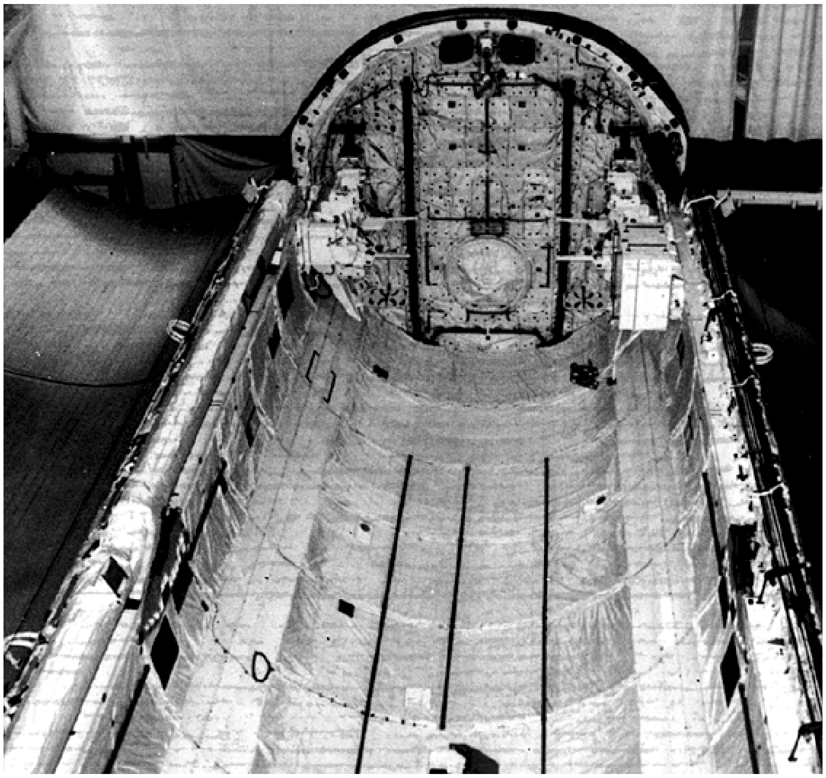


Figure 4-1. Payload bay looking forward

Without the liner installed (see figure 4-2), the lower part of the payload bay is covered with a continuous sheath of Beta Cloth and aluminized Kapton (polyimide) insulation blankets, painted metal wire tray covers, metal vent filters and recessed lighting fixtures. The liner is flown as standard equipment, but the Orbiter may be flown without the liner or with a partial liner. The vents that allow the payload bay to breathe with the external environment and the lower midbody contain filters. The filters are a double dutch twilled stainless steel weave with a glass bead rating of 40 micrometers (allowing passage of an 88 micrometer particle).

The payload bay is purged at the forward bulkhead with activated charcoal and High Efficiency Particle Air (HEPA)-filtered air. Filters are installed in the Orbiter Processing Facility (OPF) and Mobile Launch Platform (MLP) Engine Control System (ECS). No purge is available for Orbiter rollover to the Vehicle Assembly Building (VAB); this period can be as long as 100 hours.

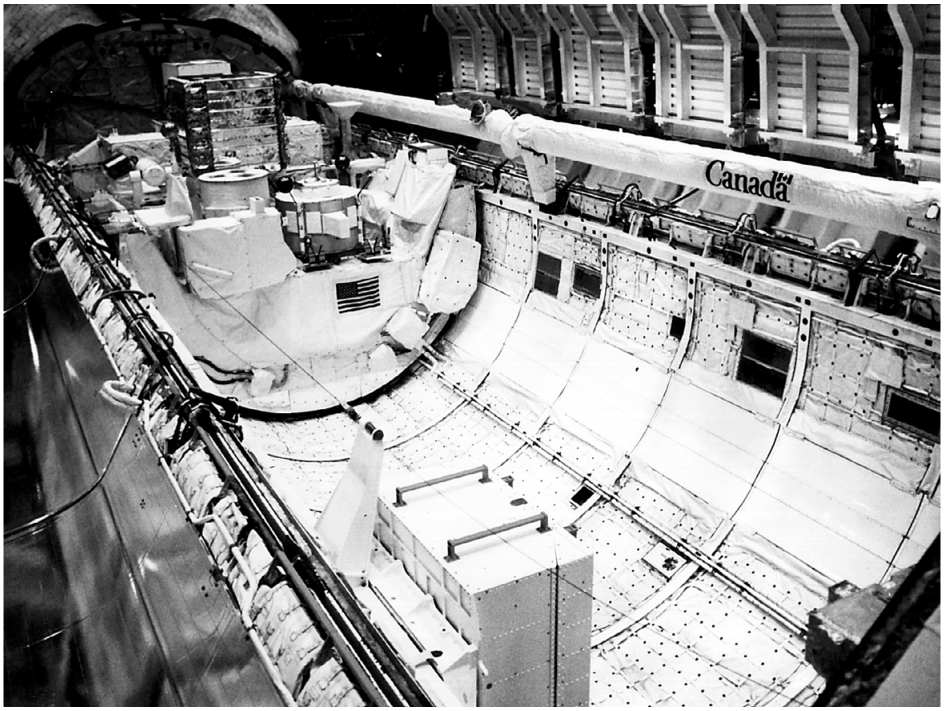


Figure 4-2. Payload bay looking aft

4.1 GROUND ENVIRONMENT

The payload will be subjected to natural and induced environments while on the ground including thermal, radiation and electromagnetic, contamination, structural loads, vibration, acoustic and shock as given in Shuttle Orbiter/Cargo Standard Interfaces, ICD 2-19001.

4.1.1 Thermal

The payload thermal environment while on the ground is a function of the Orbiter location, external ambient conditions and the payload bay purge. While in the OPF and VAB, the payload environment is generally controlled by the facility and by the purge. While on the pad and on the runway, the payload bay environment is influenced by the launch and landing site, time of year, time of day, and Orbiter payload bay purge gas parameters and availability.

4.1.1.1 Payload Bay Temperatures

Payload bay temperature ranges (figure 4.1.1.1-1) for prelaunch and postlanding given in Shuttle Orbiter/Cargo Standard Interfaces, ICD 2-19001. Actual temperatures are expected to fall between these extremes and depend upon payload design and thermal characteristics. During prelaunch when the PLBDs are closed, temperatures are relatively moderate.

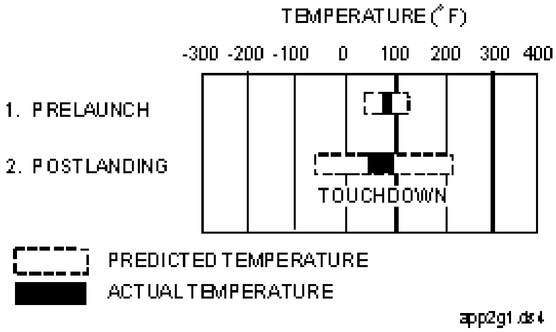


Figure 4.1.1.1-1. Ground payload bay temperatures

During postlanding, the temperature environment is influenced by the initial condition (that is, the preentry condition), entry heating and subsequent heat conduction inward, ground purge (if any), and weather conditions at the landing site. Generally, the maximum temperature occurs after landing as a result of heat soak-back through the Orbiter structure and air entering the payload bay through the vent doors.

4.1.1.2 Payload Bay Purge

The payload bay purge system supplies conditioned air or gaseous nitrogen (GN_2) to the payload bay with PLBDs closed during prelaunch operations, and with conditioned air during the postlanding period at primary and alternate landing sites. The principal function of the payload bay purge system is to inert the payload bay; the purge produces only limited thermal conditioning. The customer should consider additional services (such as spigot cooling with purge gas or active cooling using the payload heat exchanger) for payloads that require close temperature control and/or large heat rejection capacity.

Purge is to be provided to all payloads by mobile/facility equipment during closed PLBD operations except during:

1. Mobile Ground Support Equipment (GSE) facility/mobile GSE transfer
2. Towing
3. Orbiter mate/demate
4. Orbiter test or purge system Line Replaceable Unit (LRU) replacement/test
5. GSE periodic maintenance at the OPF, VAB, and pad

Purge can also be provided at ferry flight stopover sites as described in section 4.3.1.4.

The purge gas is conditioned air except during cryogenic servicing of the Orbiter power reactant storage and distribution subsystem and during final launch countdown before external tank cryogenic loading until launch (or detanking). During these times temperature conditioned GN_2 is provided for inerting purposes.

The purge gas inlet temperature can be set between 45° and 100° F at the pad, nominally controllable to ±5° F (under steady flow conditions, a tolerance of ±2° F with excursions to ±5° F for 1 hour over a period of 12 hours is negotiable for temperature-sensitive payloads).

The standard purge gas inlet temperature is set at 65° F and can vary from 60° to 70° F. The temperature control point is on the facility side (upstream of the Orbiter T-0 umbilical) and payload bay temperatures may vary depending on ambient conditions. Orbiter payload bay thermal analytical models (see section 6.4.1.3) include the capability to determine the payload bay environment, and integrated analyses can be performed to determine resulting payload thermal conditions if required.

Additional purge gas characteristics (including flow rates) are given in ICD 2-19001. For payloads sharing a mission, special flow rate consideration is required. The purge gas enters the payload bay at the forward bulkhead ($X_0$576) and exits at the aft bulkhead ($X_0$1307). Due to leakage through the PLBDs and flow to the lower midfuselage (the volume beneath the payload bay) through payload bay vents, the local flow rate may be less than the inlet flow rate. Additionally, three spigots are available to provide supplemental flow. Therefore, the local purge flow rate may vary considerably, especially for shared missions. Customers whose payloads share a flight must design for both the maximum and minimum flow rates specified in ICD 2-19001 since the location in the payload bay will be determined by the SSP.

Payload bay postlanding purge is normally provided at KSC or EAFB. Payload bay purge will be provided approximately 30 minutes after safety assessment completion. The payload bay purge shall not be used to satisfy the technical requirements contained in Safety Policy and Requirements for Payloads using the Space Transportation System, NSTS 1700.7B. Payload requirements for special postlanding services shall be negotiated with the SSP and documented in the IP. Emergency landing site environmental conditions are in ICD 2-19001.

4.1.1.3 Active Liquid Cooling

Active liquid cooling is available to payloads located in the payload bay. Cooling is accomplished by the payload heat exchanger, which is a component of the Orbiter Active Thermal Control System (ATCS). The payload heat load, together with loads from various Orbiter heat sources is absorbed into the ATCS Freon 21 coolant loops. Heat rejection from the ATCS is accomplished with the following sinks:

1. GSE heat exchanger during prelaunch

2. Radiators and ammonia boiler during postlanding

3. GSE heat exchanger approximately 45 minutes after wheel stop

The payload heat exchanger has two passages available to payloads. One is normally provided to payloads in the middeck, the other is provided to payloads in the payload bay. However, both passages can be provided for payloads located in the payload bay.

The supply temperature to the payload is a function of actual heat exchanger performance and should be determined using the effectiveness curves in ICD 2-19001. Dual use of the payload heat exchanger will reduce performance and the supply temperature will be determined by the SSP. The cooling capacity available at the payload heat exchanger varies as a function of mission phase. As indicated in ICD 2-19001, cooling during prelaunch and postlanding is limited to 5200 Btu/hr. For checkout purposes, the 29,000 Btu/hr capacity is available for limited periods during prelaunch; however, this requires special negotiation with the SSP and is not available during the final hours of the countdown.

The payload customer will provide a pump package with an accumulator, which controls coolant flow rate and pressure (180 psia maximum) on the payload side of the heat exchanger.

In addition to limiting the maximum operating pressure to 180 psia, the payload must also withstand 180 psia on the payload side of the heat exchanger if a leak develops in the heat exchanger between the payload side and the Orbiter side.

4.1.1.4 Prelaunch/Postlanding Spigot Cooling

Purge gas spigot cooling is available to supplement the standard payload bay purge during prelaunch and postlanding at primary and alternate landing sites. Three spigots are available and are capped unless required. Manifests for shared missions may include payloads using the spigots. The supplemental spigot flow is introduced into the payload bay as it exits the using payload.

If the spigots are used, the SSP will design and fabricate the ducting and support fixtures from the negotiated payload interface to one or more spigots. If all three spigots are used, the nominal flow rate is 50 pounds per minute from each spigot. If only one spigot is used, the maximum flow rate is 100 pounds per minute from that spigot. Since the spigot system is part of the payload bay purge system, the conditioned gas is the same as the purge supply. Therefore, the negotiated gas conditions and flow rates must be compatible with other payloads manifested for the flight.

4.1.1.5 Payload Active Cooling Kit

For payloads in the payload bay, a Payload Active Cooling Kit (PACK) is used to connect the payload to the Orbiter ATCS. The interconnecting plumbing between the PACK and the payload is furnished by the payload customer. The PACK interface is at a Standard Interface Panel (SIP). The SIP is located on the port side of the Orbiter at a longitudinal position specified in the payload-unique ICD. PACK installation is designed for a wet mate (quick disconnect) interface and accommodates both OPF horizontal and launch pad vertical installation of payloads. The interfacing quick disconnects will be furnished by the SSP.

For payload system analyses, the PACK leakage rates are 0.1 cc/hour for water and 0.2 cc/hour for Freon 114. The ground conditions assume an internal pressure of 60 psia and an external pressure of 14.7 psia.

4.1.2 Radiation and Electromagnetic

Launch and landing site environmental limits are described in the following documents:

1. Space Shuttle Launch Pad and Platform, ICD 2-0A002 - The section regarding Orbiter electrical and electronic requirements.
2. STS OPS Flight PRD Vol II Payload Annex 17 OSTA-3, JSC 16719, Volume I - The section regarding Radio Frequency (RF) impingement on the Orbiter.

Space Shuttle Launch Pad and Platform, ICD 2-0A002 limits radiated and conducted emissions of power circuits routed from GSE through the T-0 umbilical to installed equipment in the payload bay. This prevents coupling of interference to Orbiter or other payload circuits.

GSE circuits routed through the T-0 umbilical must meet the signal grounding and isolation requirements of ICD 2-0A002. This prevents compromising the Orbiter single-point grounding scheme concept, thus eliminating signal ground loops.

All payload T-0 circuits must meet the conducted and radiated emission requirements of the lower limits of ICD 2-19001, which are identical to Electromagnetic Interference Characteristics, Requirements for Space Shuttle Equipment, SL-E-0002.

4.1.3 Contamination and Cleanliness

This section addresses contamination environments during off-line and on-line ground flow operations, postlanding, and ferry flight. Also included is a review of contamination conditions within and between various launch site facilities. The information provided will aid the Space Shuttle user in planning payload-to-Orbiter interfaces and the integration of design considerations for the environments described.

Payload integration and mission success are dependent on payload customer understanding of contamination conditions to which a payload is exposed from delivery to the launch site to postflight removal of the payload from the Orbiter. The SSP assists the customer in understanding the Space Shuttle by identifying facility and Orbiter design practices and cleanliness and operational controls which determine the payload contamination environment.

4.1.3.1 Space Shuttle Contamination Environment

This section will delineate the pertinent contamination control requirements, and outline both, the outgassing requirements found in General Specification Vacuum Stability Requirements of Polymeric Material for Spacecraft Applications, SP-R-0022, and the payload bay cleanliness requirements of Contamination Control Requirements for the Space Shuttle Program, SN-C-0005.

The SP-R-0022 specification, referenced through General Specification NASA JSC Requirements for Materials and Processes, SE-R-0006, establishes outgassing requirements and test guidelines for polymeric materials in the payload bay and selected other areas of the Orbiter. Its objective is to control outgassing of materials so that contamination is not deposited on sensitive optics or thermal control surfaces.

The SN-C-005 specification addresses particulate and Nonvolatile Residue (NVR) levels for surfaces of the Space Shuttle during assembly and ground operations. It does not specify flight or facility contamination.

The approach utilized is similar to other NASA specifications; it primarily establishes a standard framework that guides requirements. This facilitates commonality of nomenclature among the hundreds of contractor and facility personnel. The precision cleanliness levels offered for selection by the contractors, for instance, are derived from the industry standard Product Cleanliness Levels and Contamination Control Program, MIL-STD-1246.

SN-C-0005 is also the source of the Orbiter external surface cleanliness levels: Standard, Sensitive and Highly Sensitive. One of these levels is established in negotiations between NASA and the payload customer, and is then specified in the applicable IP. When a request for other than Standard is made, these negotiations must be accompanied by a detailed analysis or data, which demonstrate the sensitivity of the payload. Mixed payloads must be compatible with the Standard cleanliness level. The individual payload customer must certify compliance with the specified level of cleanliness during ground processing. Table A.1 of SN-C-0005, which defines these alternate payload bay surface cleanliness levels, is included here as table 4.1.3.1-1. The Sensitive and Highly Sensitive cleanliness levels require a closer and more painstaking scrutiny and cleaning. Additionally, the Highly Sensitive cleaning incorporates extensive solvent wiping. The vast majority of payloads have performed successfully in a payload bay inspected to just the Standard cleanliness level.

Table 4.1.3.1-1. Visibly clean levels and inspection criteria

Table A.1
Visibly Clean (VC) Levels and Inspection Criteria
for the
Orbiter Payload (Cargo) Bay, Payload Canister, and Payloads*

Three levels of VC requirements are available for the Orbiter payload bay, payload canister and payloads during SSP Orbiter/payload integrated operations at launch and landing sites. VC Standard is the baseline referred to in contractual documentation. The VC definition in table I is applicable to this table with the understanding that incident light levels and inspection distances are specified herein.

VC level	Incident light level Note-1	Observation distance	Remarks
Standard	≥ 50 foot-candles	5 to 10 feet	Notes 2, 3, 5
Sensitive	≥ 50 foot-candles	2 to 4 feet	Notes 2, 3, 5
Highly Sensitive	≥ 100 foot-candles	6 to 18 inches	Notes 3, 4

*This table has been reprinted from Contamination Control Requirements for the Space Shuttle Program, SN-C-0005; therefore, the reference to table I is found in SN-C-0005.

NOTES:

1. One foot-candle (lumens per square foot) is equivalent to 10.76 lumens per square meter.
2. Cleaning is required if the surface in question does not meet VC under the specified incident light and observation distance conditions.
3. Exposed and accessible surfaces only.
4. Initial cleaning is mandatory; note 2 applies thereafter.
5. Areas of suspected contamination may be examined at distances closer than specified for final verification.

4.1.3.2 Ground Operations and Facilities Environments

All facilities and the payload canister have been categorized into one of five cleanliness classes based on the facility design, capability, and operational controls. The environmental requirements and operations and maintenance requirements for these five cleanliness classes are described in Launch Site Accommodations Handbook for Payloads, K-STSM-14.1. A copy of this document is available through the payload-assigned LSSM.

Payload owners are expected to comply with facility rules. Payloads must meet the cleanliness requirements for the mission as defined in the mission-unique IP and Operations and Maintenance Requirements and Specifications Document (OMRSD). Joint payload inspections will be made with launch site contamination control engineers to verify compliance. A variety of environmental data as described below are routinely collected in the launch site facilities.

4.1.3.2.1 Clean Work Area Environment

Payload facilities at KSC include the Spacecraft Assembly and Encapsulation Facility-2 (SAEF-2), the Vertical Processing Facility (VPF), the Payload Hazardous Servicing Facility (PHSF), the Multi-Purpose Processing Facility (MPPF), the Space Station Processing Facility (SSPF) and the Operations and Checkout (O&C) Building. The SSPF and O&C are also used as an integration facility where payloads are integrated for testing and installation into the payload canister. The OPF at Launch Complex (LC) 39 is the Space Shuttle facility used for horizontal installation of payloads into the Orbiter; the Payload Changeout Room (PCR) at the pad is used for vertical installations. Typical horizontal and vertical payload flows are shown in section 7. A summary of the clean work area environments are shown in table 4.1.3.2.1-1.

4.1.3.2.1.1 Airborne Particles

A hazard-proofed Environmental Monitoring Data System (EMDS) has been installed in the OPF and PCR facilities. This system continuously monitors airborne particles as well as the temperature and relative humidity.

Automated laser particle counters are used for particulate monitoring. Data are collected for two categories of particles: those larger than 0.5 micron and those larger than 5.0 microns.

4.1.3.2.1.2 Particle Fallout

Two methods are utilized to determine particle fallout. Particle fallout distributions can be obtained from depositions on 37mm filters for periods of 1 to 2 weeks by methods described in Sizing and Counting Airborne Particulate Contamination in Clean Rooms and Other Dust-Controlled Areas Designed for Electronic and Similar Applications, ASTM-F25. Size ranges are selected in accordance with MIL-STD-1246, and counts are converted to values averaged over 24 hours on a square foot surface. Particle fallout rate can also be determined from depositions on silicon wafers. Percent Area Coverage (PAC) is determined by automated instrumentation. Real-time particle fallout data collection is available and can be requested by the payload customer.

4.1.3.2.1.3 Volatile Hydrocarbons

Measurements have been made periodically, typically every 2 weeks, by collecting a grab sample in a facility and analyzing the sample using a flame ionization detector sensitive to hydrocarbons and organic solvents. The instrument is calibrated with methane, and data reported in parts per million (ppm) volume/ volume methane equivalent. Data seldom exceed or even approach the quoted limit of 15 ppm. Real-time hydrocarbon monitoring is available and can be requested by the payload customer.

Table 4.1.3.2.1-1. CWA environmental summary

	Airborne particle concentration (1)		Temp (°F) (4)	Relative humidity (%) (4)	Volatile hydrocarbons (ppm) (3)	Nonvolatile residue (mg/0.1 m^2/month)	Fallout particle distribution (2)	Differential pressure (H_2O)	Air changes per hour
	>0.5 µm	>5.0 µm							
OPF HB 1, 2, & 3 PLB areas	100,000	700	71±6	55 max	15 max	1.0 max	Level 750	0.02 min	4
SSPF	100,000	700	71±6	60 max	15 max	1.0 max	Level 750	0.02	4
O&C	100,000	700	71±6	60 max	15 max	1.0 max	Level 750	0.02	4
PCR (Pads A & B, all 5 levels)	100,000	700	71±6	55 max 30 min	15 max	1.0 max	Level 750	0.02 min	15
SAEF-2	100,000	700	71±6	60 max	15 max	1.0 max	Level 750	0.02	1.5

(1) Airborne particle counts are performed using optical instrumentation with He-Ne Laser as the powered light source. The data are expressed per Fed. Std. No. 209B criteria.

(2) Particle fallout rates are expressed per MIL-STD-1246 criteria. Level 750 is a goal and not a KSC requirement.

(3) Volatile hydrocarbons (HC) are expressed as methane equivalent.

(4) Refer to latest revision of Shuttle Facility/Orbiter Contamination Control Plan, KVT-PL-0025, Table 1.

(5) Program PRD or OMRSD may supersede these requirements.

(6) Recent Shuttle processing data is available upon request.

(7) Requirement goal per KSC Payload Facility Contamination Control Requirements Plan, K-STSM-14.2.1.

4.1.3.2.1.4 Nonvolatile Residue

NVR plates are analyzed by gravimetric technique. Real-time NVR data collection is available and can be requested by the payload customer.

4.1.3.2.1.5 Temperature and Humidity

Temperature data are monitored continuously in KSC facilities. Out-of-spec conditions are usually short-lived and associated with door openings during payload or canister arrivals and departures.

Humidity data are also collected continuously. Again, out-of-spec conditions are sometimes associated with door openings in facilities without airlocks. In some facilities during the winter months, readings lower than 30 percent relative humidity readings may occur for periods of several days during cold, dry weather.

4.1.3.2.1.6 Differential Pressure

The differential air pressure between the Clean Work Areas (CWAs) (higher pressure) and the area adjacent to the CWA (another room or the outside of the building) shall be monitored daily in most CWAs to verify that the air flow is from the inside to the outside of the area thus preventing an influx of contaminants. Low differential pressure transducers are the accepted method to monitor the room pressure for KSC CWAs.

4.1.3.2.1.7 Changes per Hour

To control contamination in the air, the KSC facilities are designed to allow the movement of a volume of air through a filtered system in a given period of time. If a CWA has four air changes per hour, it means that all of the air in the CWA will be replaced four times in a 1-hour period.

4.1.3.3 Payload Bay During Ground Processing

4.1.3.3.1 Payload Bay Environment

The Orbiter payload bay yields a unique environment for contamination control. With the PLBDs open, the payload bay becomes an integral part of the facility to which it is exposed. This factor stresses the importance of facility management and the need for meeting the specified cleanliness criteria designated for the Orbiter’s mission. There are three levels of cleanliness, as seen in table 4.1.3.1-1, which may be assigned to a mission.

4.1.3.3.2 Payload Bay Cleaning

In a generic flow, payload bay cleaning occurs in the OPF. Since every day payload bay operations in the OPF involve a high level of activity from both personnel and equipment, daily payload bay surface cleaning operations are performed if required. This operation involves vacuuming and solvent wipedown techniques performed by midbody technicians.

When a specific payload bay area is ready for closeout procedures, a preflight inspection is performed to verify a VC level. Subsequent to this inspection and prior to payload installation or PLBD closure for OPF rollout, a final cleanliness verification is performed.

For horizontally installed payload elements, the payload bay area, which becomes inaccessible subsequent to payload installation will be cleaned. Prior to PLBD closure in preparation for rollover, all accessible payload bay surfaces, including radiator panels, are inspected and cleaned to the mission-selected cleanliness level.

As feasible and/or at the payload customer’s request, an aft debris cover can be installed with optional witness plates on the X_o1307 bulkhead. This cover will effectively catch any debris during vertical orientation and rollout to the pad. The debris cover is not used for horizontally installed missions with no scheduled PLBD opening at the pad. It also serves as a barometer of cleaning effectiveness in the OPF. To further evaluate the payload bay environment after cleaning and until PLBD opening at the pad, an array of contamination monitors can be installed on the cover at the payload customer’s request.

4.1.3.3.3 Payload Bay Monitoring

For particle fallout rate analysis, 37mm gridded filter disks or silicon wafers are used. The disks are analyzed according to MIL-STD-1246 distribution and expressed as particles settled/ft^2/24 hours versus particle size. The wafer analysis is expressed in PAC.

For molecular contaminant measurement and analysis, 1-square-foot stainless steel plates are used and analyzed gravimetrically for total NVR.

4.1.3.4 Postlanding Conditions

A conditioned GSE purge will be provided to the payload bay after safety assessment completion. If landing occurs at an abort site, an emergency site, or the White Sands Space Harbor (WSSH), payload bay purge will not be available. After the Orbiter has been returned to the OPF, the payload and/or ASE are removed from the payload bay and transported to the appropriate area for deintegration and return to the customer.

At landing sites other than those above, the primary consideration is safety and an Orbiter forced to land at one of these sites might not include environmental protection for extended periods.

4.1.4 Mechanical

Ground processing mechanical loads are defined in ICD 2-19001. Loads can be found concerning prelaunch accelerations, towing and MLP loads, and contingency Orbiter rollback/rollout.

4.2 FLIGHT ENVIRONMENT

This section describes the environments seen by payload in the payload bay during the launch, on-orbit (PLBDs opened and closed), and entry phases of the mission.

4.2.1 Thermal

The thermal environment in flight with the PLBDs opened can vary considerably depending on the Orbiter attitude orientation, beta angle, and payload bay arrangement. The payload design must be compatible with these expected thermal environments or define its limitations.

4.2.1.1 Payload Bay Temperatures

Payload bay temperature ranges (figure 4.2.1.1-1) for various mission phases given in Shuttle Orbiter/Cargo Standard Interfaces, ICD 2-19001. Actual temperatures are expected to fall between these extremes and depend upon payload design, thermal characteristics, and flight conditions. During ascent when the PLBDs are closed, temperatures are relatively moderate. After the Orbiter reaches orbit and the PLBDs are opened, temperatures can vary considerably, depending on flight attitudes and the payload configuration.

The temperature ranges given in ICD 2-19001 and reproduced in figure 4.2.1.1-1 can be used to estimate the payload bay thermal environment to initiate the payload thermal design. Table 4.2.1.1-1 can be used for estimating the payload bay thermal environment on-orbit when the PLBDs are open. It gives analytical predictions of steady-state liner temperatures for various flight attitudes and beta angles. The influence of a payload in the bay on payload bay liner temperatures should be noted. The payload bay liner is assumed to be insulated and the cylindrical payload is assumed to be adiabatic.

Empty payload bay liner temperatures can be used in the thermal design for payload diameters up to 90 inches (for a payload whose centerline coincides with the longitudinal axis (X- axis) of the payload bay). For payload diameters between 90 and 120 inches, liner temperatures can be estimated by interpolating between the empty payload bay temperature and the temperature with cylindrical payload in the payload bay.

During entry and postlanding, the temperature environment is influenced by the initial condition (that is, the pre-entry condition), entry heating and subsequent heat conduction inward, ground purge (if any), and weather conditions at the landing site. Generally, the maximum temperature occurs after landing as a result of heat soak-back through the Orbiter structure and air entering the payload bay through the vent doors.

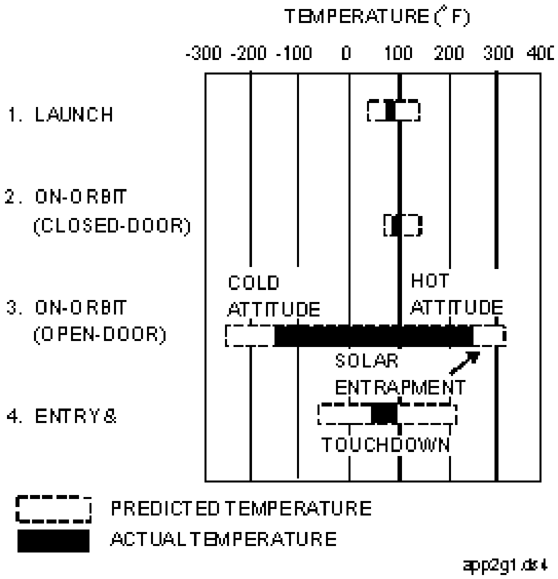
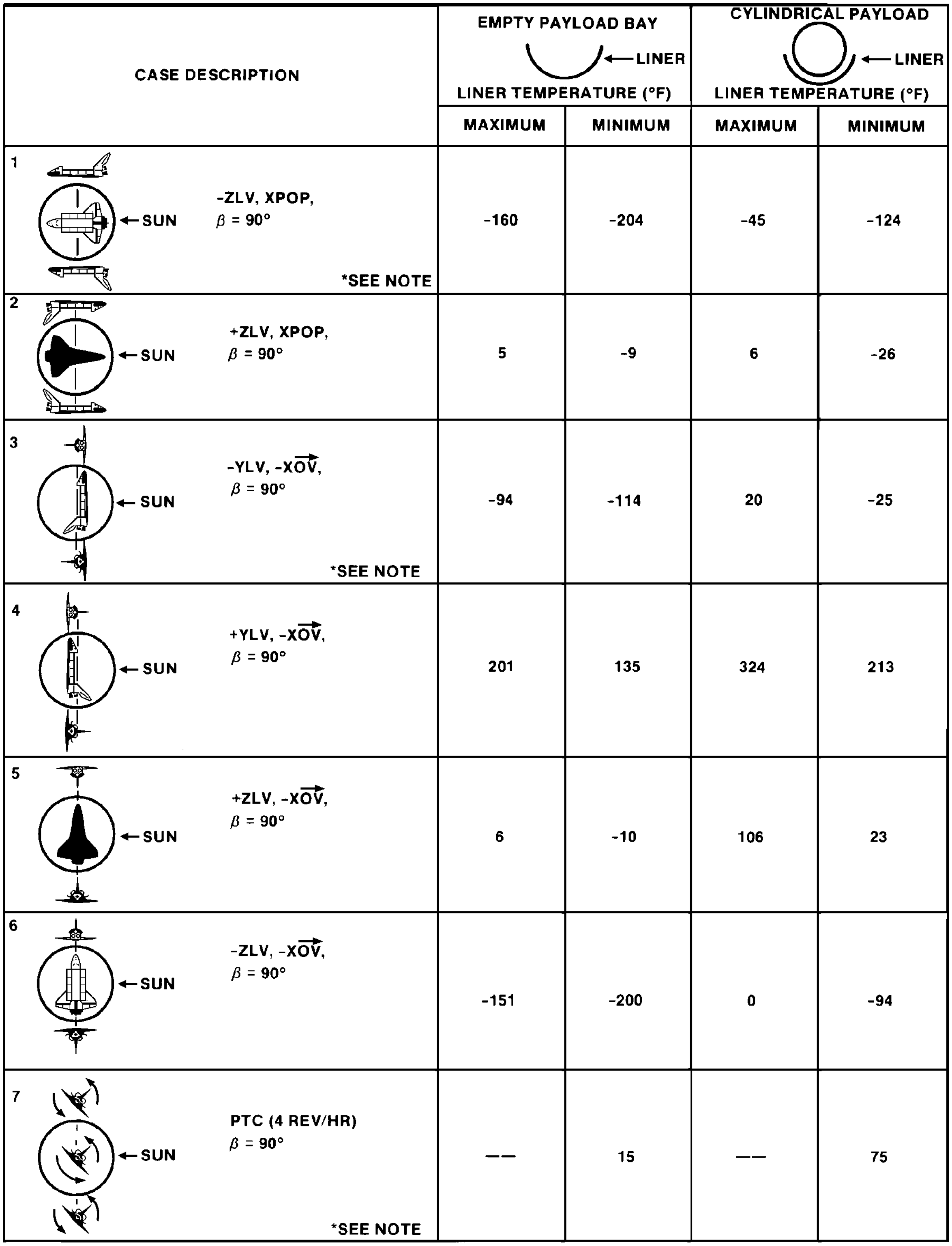


Figure 4.2.1.1-1. Flight payload bay temperatures

Table 4.2.1.1-1. Steady-state liner temperature for preliminary design application



CASE DESCRIPTION	EMPTY PAYLOAD BAY LINER LINER TEMPERATURE (°F)		CYLINDRICAL PAYLOAD LINER LINER TEMPERATURE (°F)	
	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
1 ← SUN -ZLV, XPOP, β = 90° *SEE NOTE	-160	-204	-45	-124
2 ← SUN +ZLV, XPOP, β = 90°	5	-9	6	-26
3 ← SUN -YLV, -$\overrightarrow{XOV}$, β = 90° *SEE NOTE	-94	-114	20	-25
4 ← SUN +YLV, -$\overrightarrow{XOV}$, β = 90°	201	135	324	213
5 ← SUN +ZLV, -$\overrightarrow{XOV}$, β = 90°	6	-10	106	23
6 ← SUN -ZLV, -$\overrightarrow{XOV}$, β = 90°	-151	-200	0	-94
7 ← SUN PTC (4 REV/HR) β = 90° *SEE NOTE	––	15	––	75

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Table 4.2.1.1-1. Continued

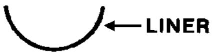
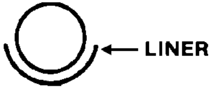
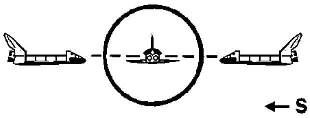
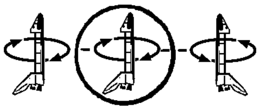
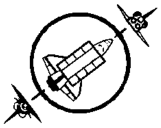
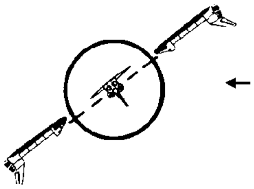
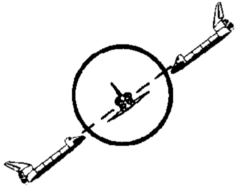
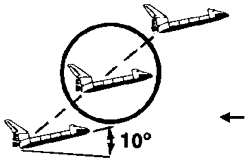
CASE DESCRIPTION	EMPTY PAYLOAD BAY  LINER TEMPERATURE (°F)		CYLINDRICAL PAYLOAD  LINER TEMPERATURE (°F)	
	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
8  $+ZLV, -\overrightarrow{XOV}$, $\beta = 0°$ ← SUN	40	30	60	40
9  $-XLV, +\overrightarrow{YOV}$, $\beta = 0°$ ← SUN	0	-10	13	-5
10  PTC (4 REV/HR) $\beta = 0°$ ← SUN	——	5	——	60
11  $-ZLV, -\overrightarrow{XOV}$, $\beta = 45°$ ← SUN *SEE NOTE	-61	-90	-20	-40
12  $-XLV, -\overrightarrow{YOV}$, $\beta = 60°$ ← SUN	117	86	130	92
13  $-XLV, +\overrightarrow{YOV}$, $\beta = 60°$ ← SUN *SEE NOTE	-28	-155	5	-30
14  -XSI NOSE UP 10° $\beta = 45°$ ← SUN *SEE NOTE	70	-92	-20	-45

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Table 4.2.1.1-1. Concluded

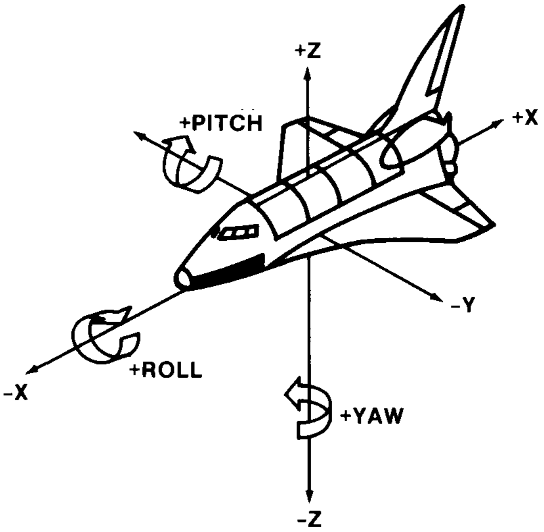
KEY TO TABLE 2-I

ORBITER AXIS:
+X = TAIL
-X = NOSE
+Y = RIGHT WING
-Y = LEFT WING
+Z = TOP (UP)
-Z = BOTTOM (DOWN)

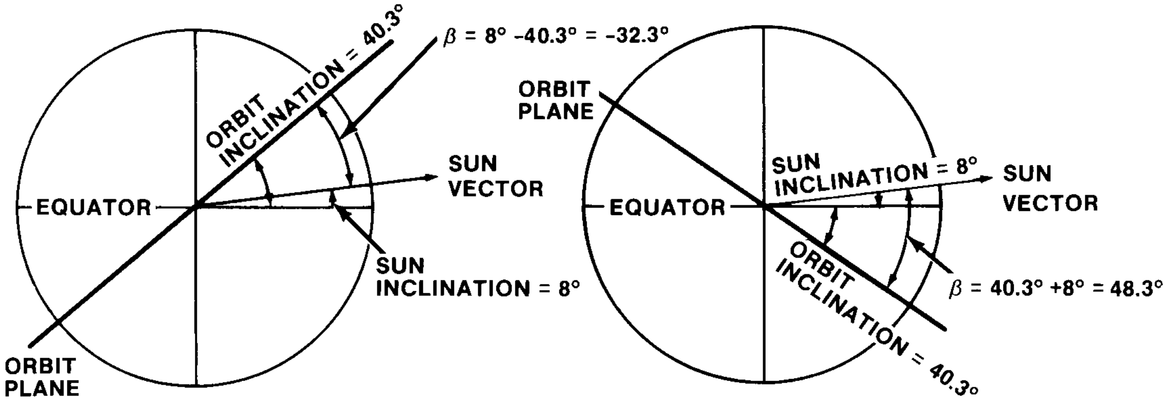
DIRECTION OF AXIS:
LH = LOCAL HORIZONTAL
LV = LOCAL VERTICAL
OV = ON VELOCITY VECTOR
POP = PERPENDICULAR TO ORBIT PLANE
SI = SOLAR INERTIAL

NOMENCLATURE:
ORBITER AXIS + DIRECTION OF AXIS

EXAMPLE:
+ZLV = TOP LOCAL VERTICAL
-YPOP = LEFT WING PERPENDICULAR TO ORBIT PLANE



DEFINITION OF BETA (β) ANGLE:



(a) MAXIMUM NEGATIVE β ANGLE CONDITION FOR A GIVEN ORBIT PLANE (ASCENDING/DESCENDING NODES PERPENDICULAR TO THE SUN VECTOR).

(b) MAXIMUM POSITIVE β ANGLE CONDITION FOR A GIVEN ORBIT PLANE (ASCENDING/DESCENDING NODES PERPENDICULAR TO THE SUN VECTOR).

*NOTE: FOR THIS CASE, LINER TEMPERATURE IS FOR INFORMATION ONLY; ORBITER TEMPERATURE LIMITS ARE EXCEEDED UNDER STEADY STATE CONDITIONS.

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4.2.1.2 Orbiter Attitude Hold Capabilities

The Orbiter attitude hold capabilities (attitude and attitude hold durations) in ICD 2-19001 have been established to preclude Orbiter temperature limit violations and to satisfy heat rejection requirements imposed by Orbiter systems, crew, and payloads heat rejection accommodations. These attitude hold capabilities are based on analyses, tests, and flight experience.

The attitude hold times in ICD 2-19001 vary from 5 to 160 hours and upon beta angle and payload bay orientation. These attitude hold capabilities are representative of Orbiter capability and considered suitable or applicable for most payload missions.

The Orbiter pre-entry thermal conditioning attitude and duration requirement is established during the mission based on real-time temperature measurements. The thermal conditioning duration may range from 0 to 12 hours (ICD 2-19001). For normal entry, the pre-entry thermal conditioning attitude and duration are selected for compatibility with both Orbiter and payload operational or refurbishment requirements. As stated in ICD 2-19001, if mutually compatible requirements cannot be established, pre-entry conditioning will be accomplished by Passive Thermal Control (PTC). For analysis purposes, PTC will be assumed to be the rotation of the Orbiter at 2 to 5 revolutions per hour about the Orbiter X-axis, with the orientation of this axis within ±20° of the perpendicular-to-the-Sun vector.

In the event of an anomaly, the SSP will observe the payload operational attitude constraints to the extent possible. If these constraints must be violated, payload safety constraints will be observed. Payload flight safety constraints and operational or refurbishment attitude hold constraints are established by the customer and defined in the IP and IP annexes.

4.2.1.2.1 Local Vertical/Local Horizontal

Local Vertical/Local Horizontal (LVLH), figure 4.2.1.2.1-1, is a reference frame used to describe the location and orientation of the Orbiter in orbit. An LVLH +Z axis vector points from the Orbiter's center of mass (c.m.) to the center of the Earth. The +Y axis points in the direction opposite to the Orbiter angular momentum vector. The +X axis lies in the orbit plane in the direction of the velocity vector, but is only identical to the velocity vector for perfectly circular orbits. When the Orbiter is in an LVLH attitude with Pitch, Yaw, and Roll (PYR) all equal to zero, the belly points to the center of the Earth (i.e., the open payload bay points away from the Earth) and the nose points in the direction of the velocity vector. LVLH is an Earth-relative reference frame. When the Orbiter is maintaining a fixed LVLH attitude, it will remain in the same Earth-facing orientation as it orbits.

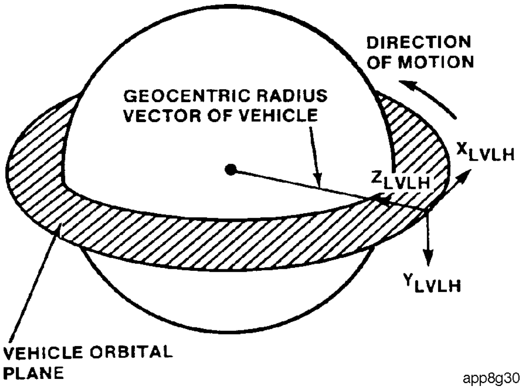


Figure 4.2.1.2.1-1. LVLH reference system

4.2.1.2.2 Inertial

An inertial reference frame describes the location and orientation of the Orbiter in space. It is fixed relative to the stars and has its axis origin at the center of the Earth. Various inertial reference frames exist, each defining the direction of the X, Y, and Z axes in relation to different star references.

4.2.1.3 Active Liquid Cooling

Active liquid cooling is available to payloads located in the payload bay. Cooling is accomplished by the payload heat exchanger, which is a component of the Orbiter ATCS. The payload heat load, together with loads from various orbiter heat sources is absorbed into the ATCS Freon 21 coolant loops (figure 5.4.1-1). Heat rejection from the ATCS is accomplished with the following sinks:

1. Flash evaporator during ascent and deorbit

2. Radiators supplemented by the flash evaporator while on-orbit

3. Radiators and ammonia boiler during descent

The payload heat exchanger has two passages available to payloads. One is normally provided to payloads in the middeck, the other is provided to payloads in the payload bay. However, both passages can be provided for payloads located in the payload bay. The supply temperature to the payload is a function of actual heat exchanger performance and should be determined using the effectiveness curves in ICD 2-19001. Dual use of the payload heat exchanger will reduce performance and the supply temperature will be determined by the SSP. The cooling capacity available at the payload heat exchanger varies as a function of mission phase. As indicated in ICD 2-19001, cooling during prelaunch, ascent, descent, and postlanding is limited to 5200 Btu/hour. The on-orbit maximum capacity is 29,000 Btu/hour after the PLBDs are opened. For checkout purposes, the 29,000 Btu/hour capacity is available for limited periods during prelaunch; however, this requires special negotiation with the SSP and is not available during the final hours of the countdown.

The payload customer will provide a pump package with an accumulator, which controls coolant flow rate, and pressure (180 psia maximum) on the payload side of the heat exchanger. In addition, the customer is responsible for freeze protection, filtration, and instrumentation. Freon 114 or water may be used in the payload bay; however, Freon 114 is recommended to avoid potential freezing problems.

In addition to limiting the maximum operating pressure to 180 psia, the payload must also withstand 180 psia on the payload side of the heat exchanger if a leak develops in the heat exchanger between the payload side and the Orbiter side.

4.2.1.4 Payload Active Cooling Kit

For payloads in the payload bay, a PACK is used to connect the payload to the Orbiter ATCS. The interconnecting plumbing between the PACK and the payload is furnished by the customer. The PACK interface is at a SIP. The SIP is located on the port side of the Orbiter at a longitudinal position specified in the payload-unique ICD.

4.2.1.5 PACK Leakage Rates

For payload system analyses, the PACK leakage rates are 0.2 cc/hour for water and 0.5 cc/hour for Freon 114. The on-orbit condition assumes an internal pressure of 100 psia and a vacuum outside the lines.

4.2.2 Radiation and Electromagnetic

4.2.2.1 Environments

Isolation requirements for electromagnetic radiated and conducted emissions and power/signal cable harnesses are defined in ICD 2-19001. This ICD describes the Orbiter-to-payload, payload-to-Orbiter, and payload-to-payload emissions, which constitute the electromagnetic environment. Electromagnetic Compatibility (EMC) is defined as the condition when telecommunications equipment collectively performs its designated functions in a common environment without unacceptable degradation from electromagnetic interference from other equipment or systems in the same environment.

4.2.2.2 Intentional Space Shuttle Radiated Emissions

Intentional Space Shuttle radiated emissions are described for the payload bay in ICD 2-19001 in a figure entitled “Maximum Field Intensities on Payload Envelope.” The Ku-band system has a software obscuration mask to preclude exposure of the standard payload envelope to the main beam. This provides a 9 V/m field intensity limit in the payload bay envelope. The obscuration mask for a volume outside the payload bay and over the cabin may be enlarged using a computer-controlled capability, which enables ground personnel or the crew to alter the mask parameters, by keyboard entry. This capability may be negotiated with the SSP. The larger the solid-angle coverage of the mask, the smaller the coverage of the Tracking and Data Relay Satellite System (TDRSS) communication link.

The Ku-band main beam field levels for the communication modes and radar modes are plotted in ICD 2-19001, and NSTS 21000-IDD-SML. Experimental evidence shows that some long-wave Infrared (IR) sensors are temporarily upset by exposure to Ku-band field intensities above 30 V/m. IR devices should be tested to determine upset thresholds if sensors will be used in or around of the Orbiter. Relative Orbiter antenna locations are shown in figure 4.2.2.2-1.

S-band fields in the hemisphere over the Orbiter cabin are shown in ICD 2-19001.

If the Space Shuttle Tactical Air Navigation (TACAN) system landing aid system (L-band), is activated on-orbit, and is a payload concern, the issue should be addressed during IP negotiations.

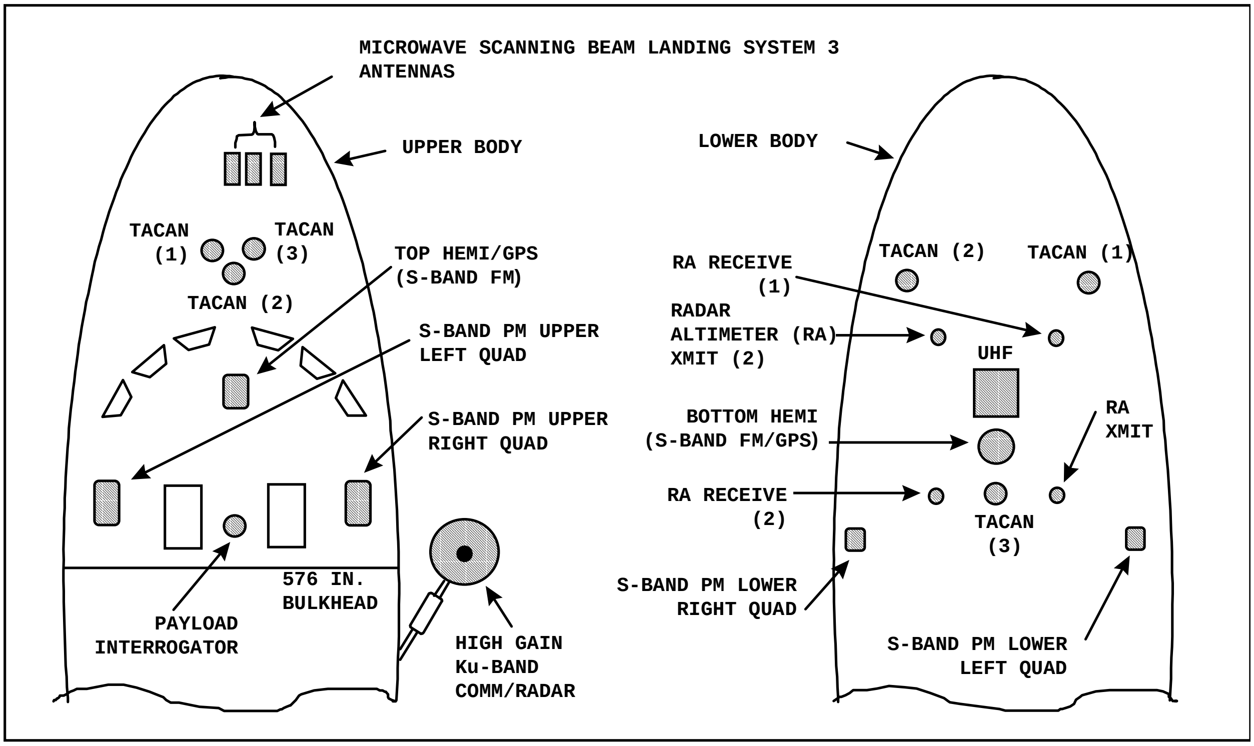


Figure 4.2.2.2-1. Orbiter antennas

4.2.2.3 Unintentional Space Shuttle Radiated Emissions

Payloads may be exposed to unintentional radiated emissions under normal operating modes. These emissions are described in the Space Shuttle-produced payload bay radiated broadband emissions curve and narrowband curve in ICD 2-19001, which are envelopes covering peak emissions. Alternating Current (ac) and direct current (dc) magnetic fields are also described in ICD 2-19001.

4.2.2.4 Laser Systems Requirements

Space Shuttle payloads may be scanned and/or illuminated by a laser. Space Shuttle payloads may also utilize lasers. The guidelines below are presented to eliminate the potential for pilot and crew eye and skin damage from direct or indirect (reflection, refraction, etc.) laser beam illumination.

Payloads must be designed to limit laser illumination to below the specified Maximum Permissible Exposure (MPE) levels. Operational restrictions may be imposed to meet intended laser and laser systems safety requirements. For example, with the use of Class 3b and 4 laser/laser systems on the Orbiter, the distance from any laser beam emission point to the crew compartment windows, and EVAs must be greater than the American National Standards Institute (ANSI) Z136.1-1993 specified Nominal Ocular Hazard Distance (NOHD). The NOHD is determined from the particular laser characteristics. If the distance requirement cannot be met, it may be necessary to restrict the lasers ability to point in directions which would either directly or indirectly illuminate the crew compartment windows and EVAs. Any such restrictions should be specified in the IP.

4.2.3 Contamination and Cleanliness

This section addresses contamination environments during flight events. The information provided will aid the Space Shuttle user in planning payload-to-Orbiter interfaces and the integration of design considerations for the environments described.

Payload integration and mission success are dependent on payload customer understanding of contamination conditions to which a payload is exposed from delivery to the launch site to postflight removal of the payload from the Orbiter. The SSP, assists the customer in understanding the Space Shuttle by identifying facility and orbiter design practices and cleanliness and operational controls which determine the payload contamination environment.

4.2.3.1 Ascent Conditions

4.2.3.1.1 Ascent Environment

The launch and ascent phase of the flight produces a significant dynamic environment. Particles present in the payload bay at launch can become excited because of energy provided by the vibro acoustic environment. This environment is particularly energetic during SRB firing and ingestion of aeronoise through the payload bay vents (transonic phase). Excited particles can be transported from their original locations to other surfaces due to venting of the payload bay through vents in the lower walls and acceleration of the Orbiter. Thus, a redistribution of particles may occur during launch and ascent.

There are three ports on each side of the payload bay as shown in figure 4.2.3.1.1-1. Each vent contains a filter to inhibit entry of particulates into the payload bay (40 micrometers glass bead rating, 88 micrometers longest particle dimension). ICD 2-19001 shows vent locations and sizes.

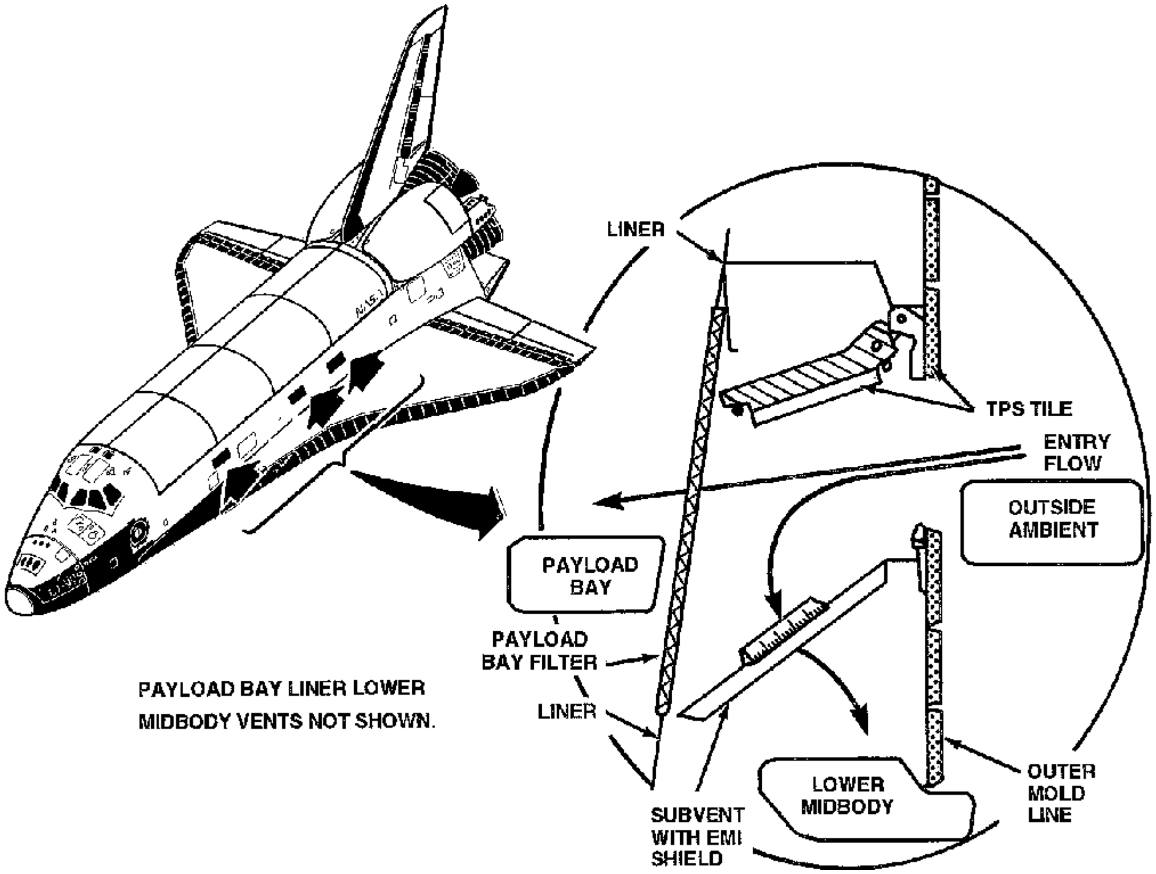


Figure 4.2.3.1.1-1. Side wall vents

4.2.3.1.2 Data Collection and Results

Particulate data have been collected by the cascade impactor flown as part of the Induced Environment Contamination Monitor (IECM). The IECM is a set of 10 instruments designed to acquire information on the payload bay environment. The results can be found in Update of Induced Environment Contamination Monitor Results, AIAA-83-2582-CP, in Space Shuttle Contamination Measurements from Flight STS-1 through STS-4, J. Spacecraft, Vol. 21, No. 3, May-June 1984, and in SS-2, -3, -4 Induced Environment Contamination Monitor (IECM) Summary Report, NASA TM-82524. The preliminary results from Spacelab-1 can be found in Induced Environment Contamination Monitor-Preliminary Results from the Spacelab 1 Flight, NASA TM-86461.

A summary of the data collected by this instrument is shown in table 4.2.3.1.2-1. The data indicate that maximum particle counts usually occur within 1 minute after launch and decay thereafter. Results of the measurements taken on the Spacelab-1 mission indicate that there was insufficient particle deposition for detection.

Gases were collected by the IECM air sampler during ascent for postflight analysis. Table 4.2.3.1.2-2 summarizes the results of these analyses. The quantity of volatile hydrocarbons present was very low and no Hydrogen Chloride (HCl), which would be present because of solid rocket plumes, was found.

The humidity monitor measured less than 1 percent relative humidity, reflecting the environment provided by the dry nitrogen gas purge prior to launch. Dewpoint was below the hygrometer's lower measurement limit of -6.7° C.

Temperature-controlled Quartz Crystal Microbalances (TQCMs) were used to measure mass deposition during ascent. Levels near 100 ng/cm^2(10A) were detected within the first minute after lift-off. These depositions rapidly dissipated, often below prelaunch levels.

Optical (253.7 nm) transmittance losses of 1 to 2 percent were detected. This loss occurred during the time period from last ground measurement to first on-orbit measurement.

Overall, the ascent contamination environment does not appear to be too severe. Typically, contaminants will build up for the first minute after launch when the dynamic environment is most severe, and decay to low levels thereafter.

Table 4.2.3.1.2-1. Ascent particle measurement summary

Particle size µm	Flight results from three missions (µg/m3)
> 5	30 10 Nonfunctional
1 to 5	500 10 400
0.3 to 1	250 10 150

Table 4.2.3.1.2-2. Ascent air sample summary

Species	Detection method	Flight results
Volatile hydrocarbons*	Concentration on absorbent; postflight GC/MS analysis	50 ppm by weight 10 ppm by volume
Reaction HCL	Reaction with silver oxide/hydroxide surfaces	None detected to ppm sensitivity

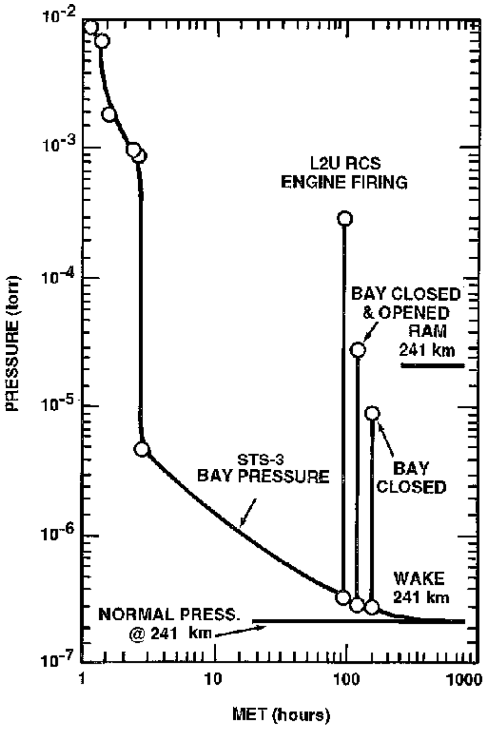
* Covers C_9 to C_{24} range and uses $\simeq C_{12}$ as average molecular weight to obtain ppm by volume

4.2.3.2 On-orbit Conditions

4.2.3.2.1 Pressure

The pressure in the payload bay drops rapidly after the bay doors are opened on-orbit. After an initial rapid drop, the pressure decays to near space ambient levels. The pressure decay occurs slowly because of gas densities resulting from outgassing, leakage, and other contaminant sources. Figure 4.2.3.2.1-1 shows payload bay pressure decay versus Mission Elapsed Time (MET).

Certain events, such as thruster firings and PLBD closing can increase the payload bay pressure by several orders of magnitude as shown in figure 4.2.3.2.1-1. Pressure effects because of thruster firings depend on thrusters used, length of time fired, and Orbiter attitude, and are typically not as great as the special L2U-RCS test case shown where three engines fired for as long as 100 seconds. Pressures returned to near pretest levels within 5 minutes of termination. Rotating the payload bay from the wake to the ram orientation can also increase the pressure significantly, as shown in figure 4.2.3.2.1-1. When the payload bay is in the direction of the velocity vector, the ramming ambient pressure in the payload bay is about two orders of magnitude higher than if no ramming occurred for altitudes in the range of 54 nautical miles (n. mi.)***.***



STS-3 PRESSURE AND STS BASELINE EMPTY BAY PRESSURE WITH OPEN AND CLOSED DOORS AT 20°C

Figure 4.2.3.2.1-1. Baseline payload bay pressure

4.2.3.2.2 Particles and Gases Data Collection and Analysis

The Space Shuttle Orbiter provides a unique environment for study and measurement without the restrictions imposed by the Earth’s atmosphere; however, the Orbiter has its own environment, which can affect on-orbit measurements. It is important to understand this environment so that potential effects on payloads may be determined and appropriate actions taken.

Table 4.2.3.2.2-1 lists contamination requirements and goals developed for the Orbiter from the Contamination Requirements Definition Group (CRDG) report, and the Particles and Gases Contamination Panel (PGCP).

The primary contamination measurements taken aboard the Orbiter to date were acquired by the IECM, which provided most of the data presented. Missions flown with a virtually empty payload bay generally represent the environment of the Orbiter. Missions flown with a full payload bay may produce a more severe environment due to payload contributions.

NASA has developed the Shuttle/Payload Contamination Evaluation (SPACE-II) model to predict on-orbit induced molecular contamination levels. SPACE-II can predict direct flux and deposition, return flux (from ambient and self-scattering) and deposition, and molecular column density. Contamination sources considered by the model include early desorption, nonmetallic materials outgassing, thrusters, water dumps and vents, and crew cabin leakage.

Table 4.2.3.2.2-1. Summary of contamination specification and measurement requirements on-orbit

Contamination specification

Molecular column density less than:
10^{12} molecules/cm^2 for H_2O
10^{11} molecules/cm^2 for $H_2O + CO_2$
10^{13} molecules/cm^2 for $N_2 + O_2$
10^{10} molecules/cm^2 for all other species

Scattered/emission light background less than:

m_v = 20th magnitude star per square arc second in the ultraviolet region

$3.5\mathrm{X}10^{-11}$W/m^2/sr/nm,$\lambda = 155$ nm	
$1.9\mathrm{X}10^{-11}$W/m^2/sr/nm,$\lambda = 191$ nm	
$1.3\mathrm{X}10^{-11}$W/m^2/sr/nm,$\lambda = 246$ nm	In
$5.9\mathrm{X}10^{-11}$W/m^2/sr/nm,$\lambda = 298$ nm	ultraviolet
$1.0\mathrm{X}10^{-10}$W/m^2/sr/nm,$\lambda = 332$ nm	and visible
$2.5\mathrm{X}10^{-10}$W/m^2/sr/nm,$\lambda = 425$ nm	at 90°
$2.0\mathrm{X}10^{-10}$W/m^2/sr/nm,$\lambda = 550$ nm	Sun angle
$1.0\mathrm{X}10^{-10}$W/m^2/sr/nm,$\lambda = 1000$ nm	
10^{-11}W/m^2/m^2/nm, $\lambda \geq 30$ µm	
10^{-10}W/m^2/sr/nm, $\lambda < 30$ µm	

Table 4.2.3.2.2-1. Concluded

Fewer than one particle larger than -5 µm per orbit in 1.5×10^{-5} sr field of view within 5 km

Molecular return flux (RF) such that:

- RF $<10^{12}$ molecules/cm^2/s for H_2O
- Deposition $< 10^{-7}$ g/cm^2/s for H_2O
  0.1 sr on 300 K surface at 400 km altitude
- Deposition $< 10^{-5}$ g/cm^2/30 days
  2π sr on 300 K surface
- Deposition $< 10^{-5}$ g/cm^2/30 days
  0.1 sr on 20 K surface at 400 km altitude
- Degradation of optics < 1%

SPACE-II utilizes geometric math models and surface viewfactors developed from the Thermal Radiation Analysis System (TRASYS) program. TRASYS uses simple shapes (e.g., rectangles and cylinders) to define complex configurations, then calculates mass transport factors (the percentage of mass emitted by a Lambertian source that will impinge upon another surface) and geometrical relationships for all the surfaces. Mass transport factors are used by SPACE-II to calculate contaminant transport for Lambertian sources, such as early desorption and nonmetallic materials outgassing, and to determine the effects of surface shadowing and reflection. SPACE-II uses the geometrical relationships in the mathematical expressions utilized for such sources as thrusters and vents.

Mass transport data files for the Orbiter and Spacelab configurations have been precalculated and are available as permanent data files. Modifications or other configurations can be developed using TRASYS. Thermal data (used to determine material mass loss rates and deposition rates) for a hot and a cold thermal profile and mass loss rates normalized to 100° C are also available for the Orbiter and Spacelab configuration. Data for other configurations can be easily developed.

Contamination analyses using SPACE-II can be performed by NASA as a nonstandard service. Once SPACE-II predicts molecular contamination levels, the levels must be checked against payload sensitivities to determine any effects. Design or operational changes may then be made to minimize the effects.

4.2.3.3 On-orbit Contamination Sources and Effects

4.2.3.3.1 General

In this section, the Space Shuttle sources of contamination are described. Data are provided on the location and characteristics of each source, including the constituents, mass rate, typical operation, and molecular velocity. Information is also included on decay rates for the contaminants and their deposition potential for the payload bay.

Figure 4.2.3.3.1-1 and table 4.2.3.3.1-1 show the major Orbiter contamination source characteristics.

Table 4.2.3.3.1-1. Major on-orbit contaminant source summary

Source	Duration/ frequency	Flowrate	Constituents	Velocity	Size parameter
Cabin atmosphere leakage	Continuous	3.18 kg/day; design limit may be considerably lower	See table 4.2.3.3.1-2	$129\sqrt{\frac{T}{M}}$ m / sec M = Molecular wt T = Ambient temp, °K	Average molecular wt = 29
Evaporator(2) water dump	As required	13.6 kg/hr total 1.8 lb/min	Water	1012 m/sec	Molecular wt = 18
RCS engines	As required	1419.8g/ sec/engine	See table 4.2.3.3.4-1	3505 m/sec	Molecular
Vernier RCS engines	As required	40.8g/ sec/engine	See table 4.2.3.3.4-1	3505 m/sec	Molecular
Early desorption/ offgassing	Estimated decay $e = t/\tau$ t = time/(hr) τ = 18 hr		Water light gases volatiles (see table 4.2.3.3.5-1)	$129\sqrt{\frac{T}{M}}$ m / sec T = Surface temp °K M = Molecular wt	Average molecular wt = 18
Outgassing	Continuous	Dependent on materials, temperature, and time on-orbit	Hydrocarbon chain fragments, RTVs, etc.	$129\sqrt{\frac{T}{M}}$ m / sec T = Surface temp °K M = Molecular wt	Average molecular wt = 100

4.2.3.3.2 Leakage

Atmospheric gases may leak through seals in pressurized spacecraft volumes. Orbiter leakage locations are considered to be concentrated at the forward payload bay bulkhead as shown in figure 4.2.3.3.1-1. Orbiter leakage characteristics and constituents are listed in tables 4.2.3.3.1-1 and 4.2.3.3.2-1, respectively. Pressurized payloads may also leak into the payload bay. The quantity and species of the contaminants depends on the specific payload configuration.

Orbiter leakage results in a continuous contamination source emanating from the forward bulkhead. Pressurized payload leakage will also result in a continuous source concentrated around the pressurized volume. Transport of the gases is Lambertian or diffuse in nature, indicating that the gases will disperse with a cosine distribution. Contaminants will travel in a direct Line-of-Sight (LOS) to other parts of the payload bay to be deposited or reflected to other payload bay surfaces. Contaminants may also travel out of the payload bay envelope and be diffused into the environment or returned into the payload bay because of scattering with the ambient environment.

Table 4.2.3.3.2-1. Contaminant species and mole fractions for crew cabin leakage

Contaminant species	Mole fraction
H_2O	0.016
N_2	0.758
CO_2	0.007
O_2	0.219

4.2.3.3.3 Water Dumps/Vents

During orbital operations, dumping of potable water occurs on a thermal demand basis. Normally, all excess fuel cell water is automatically used by the Flash Evaporator System (FES) to reject heat. Location of water vents and FES are shown in figure 4.2.3.3.1-1. The characteristics of this source are listed in table 4.2.3.3.1-1. The FES operates in 200 millisecond pulses and an on-off pulsing frequency variable between 0 and 4 Hertz. The specific frequency is determined by the heat rejection requirements. The water vent operates as required and is normally scheduled to be compatible with payload requirements.

The water vents and the flash evaporator do not eject waste water directly into the payload bay; however, water dumps can produce numerous ice particles. Typically, the ice particle population decays quickly (15 to 20 minutes) and the effluent can be directed so that recontact with the Orbiter is precluded.

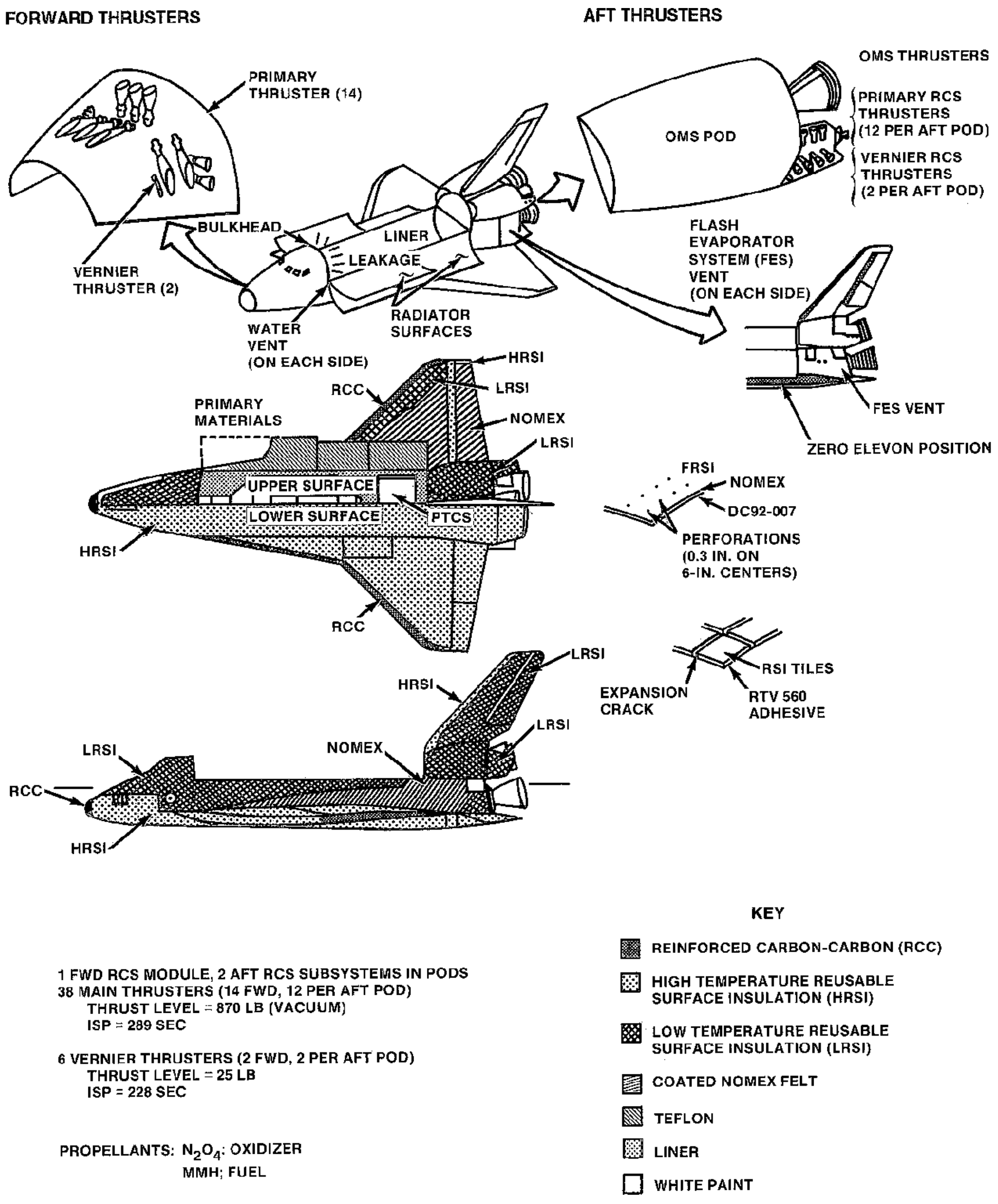


Figure 4.2.3.3.1-1. Space Shuttle contamination sources

4.2.3.3.4 Thrusters

The thrusters used by the Orbiter to control on-orbit maneuvers are the 870-pound RCS thrusters and the 25-pound Vernier Reaction Control System (VRCS) thrusters. The RCS thrusters are used for major vehicle PYR and translation maneuvers. The VRCS thrusters are utilized for fine corrections. Both systems use hypergolics with Monomethyl Hydrazine (MMH) as the fuel and nitrogen tetroxide (N_2O_4) as the oxidizer. One forward thruster module is in the nose and two aft thruster subsystems are in the pods, as shown in figure 4.2.3.3.1-1. There are no upward firing VRCS thrusters.

Characteristics of the thrusters are listed in table 4.2.3.3.1-1. Contaminant characteristics change as the effluents expand through the nozzle and disperse through space. Average plume constituents after the plume has expanded from the thrusters are listed in table 4.2.3.3.4-1. The RCS thrusters operate as required for Orbiter maneuvers with pulsing or steady-state burns lasting nominally from 80 milliseconds to 150 seconds. The VRCS thrusters also operate on an as-required basis with 80 millisecond pulses at 12.5 Hertz maximum frequency.

Table 4.2.3.3.4-1. Average contaminant species and mole fractions for RCS and VRCS thrusters

Contaminant species	Mole fraction
H_2O	0.328
N_2	0.306
CO_2	0.036
O_2	0.0004
CO	0.134
H_2	0.17
H	0.015
$MMH\text{-}NO_3$*	0.002

*Represents a group of unreacted and partially reacted thruster fuel products

The thrusters have been oriented to eliminate firing or reflection directly into the payload bay. Thruster contaminants can only be transported into the payload bay because of ambient interactions and backscatter of the plume. Instruments in the payload bay may have LOS through transient contaminant above the payload bay envelope caused by upward firing thrusters. Because of their velocity, thruster effluents will typically dissipate within a second after thruster firing. Satellites launched from or captured by the Space Shuttle may be unavoidably impinged upon by thruster effluents. Figure 4.2.3.3.4-1 shows plume contours for the forward/aft and upward-firing RCS engines.

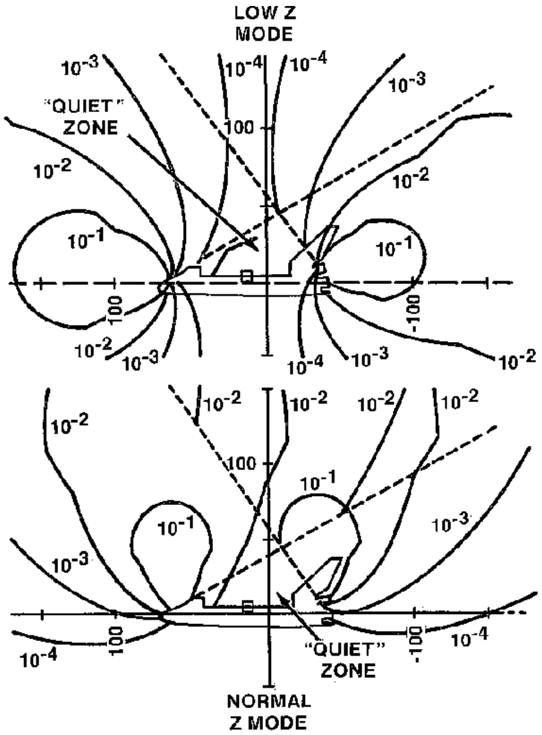


Figure 4.2.3.3.4-1. Forward/aft and upward firing thruster plumes

4.2.3.3.5 Early Desorption of Molecular Weight Materials

On Earth, nonmetallic materials on the Orbiter and payloads will adsorb gases present in the atmosphere. The gases will consequently desorb from the surfaces upon exposure to space vacuum after launch. This is a short-term process known as early desorption. The characteristics of this contamination source are listed in tables 4.2.3.3.1-1 and 4.2.3.3.5-1. Contaminant characteristics depend upon prelaunch conditions. For instance, rain showers while the Orbiter is on the pad will increase the amount of water absorbed.

Table 4.2.3.3.5-1. Average contaminant species and mole fractions for early desorption/offgassing products

Contaminant species	Mole fraction
H_2O	0.57
N_2	0.23
CO_2	0.12
O_2	0.08

Early desorption occurs from all materials so that contaminants are either produced from or have a direct path to almost all surfaces in the payload bay. Fortunately, early desorption is a short-term contaminant source having an exponential decay rate with a time constant of about 18 hours. After approximately 1 day on-orbit, contaminant levels will have dropped to minimal amounts.

4.2.3.3.6 Outgassing

Gases are released when materials are exposed to the vacuum environment of space. This process, known as outgassing, is caused by the bulk mass loss of the material resulting in the release of fairly large chain fragments (with an average molecular weight of 100 atomic mass units [amu]).

Outgassing source characteristics are listed in table 4.2.3.3.1-1. The rate at which a material outgasses and the molecules outgassed depend on the characteristics of the particular material. Outgassing allowables for materials used in the midbody and selected other areas of the Orbiter are controlled as discussed in section 4.1.3.1.

Outgassing allowables for a payload are controlled by the payload-unique ICD with the payload provider. The locations of the major exterior Orbiter materials are shown in figure 4.2.3.3.1-1.

The best way to minimize outgassing is selection of materials with the lowest possible outgassing rates. Vacuum chamber exposure, particularly thermovacuum exposure, can decrease the outgassing rate of unacceptable materials to render them acceptable. However, because of the time involved, proper material selection is the best alternative and should always be used in the design of new hardware. Materials on an Orbiter that has flown a number of missions will have a lower outgassing rate than similar materials with less vacuum exposure, thereby reducing the overall rate of contaminant production.

4.2.3.3.7 Particle Production

Materials used in the payload bay are selected with minimum particle sloughing as a consideration. The Passive Optical Sample Array (POSA) on STS-1 and the Passive Sample Arrays (PSAs) on subsequent flights indicated that surface fallout was in the range of 10^3 particles per square centimeter. About 30 percent of these were in the 2 to 4 micrometers range, with the overwhelming majority below 10 micrometers. About 3 percent were above 24 micrometers.

Optical tests were performed on passive sample array optical materials as well as payloads that contain sensors and optics sensitive to film and particle contamination. These tests have not demonstrated significant degradation of performance attributable to induced contamination from the Orbiter. The degradation of performance is in the range of 1 to 2 percent.

4.2.3.3.8 Macrodebris

There is photographic evidence of loose objects in the payload bay at PLBD opening. These are most likely lost residuals of vehicle manufacture, rework, or repair. These could be a washer, a screw, a snip of spot tie material, a flake of cut insulation material, etc. These objects generally exit the payload bay and are rarely seen after 15 hours of

MET. There has not been an incident as a result of macrodebris and few objects have been noted in recent flights.

4.2.3.3.9 Flux Deposition and Effects

Flux of contaminant molecules to a surface can occur in two ways: either directly from another surface, or due to contaminant molecules from a surface interacting with ambient or other molecules and being scattered to a surface. These processes are commonly known as direct flux and return flux, respectively. Deposition of contaminants on a surface is a complex phenomenon and depends on surface temperature, sublimation rates, contaminant type, surface type, etc. However, only high molecular weight gases, such as outgassing products and unburned thruster fuel, will deposit on typical surfaces. All gases can deposit on cryogenically-cooled surfaces, if the temperature is low enough.

Analysis of results from the PSA and the Optical Effects Module flown as part of the IECM show no significant evidence of molecular film deposition. TQCM measurements from the IECM on three flights are listed in table 4.2.3.3.9-1. As shown in this table, mass accumulation depends greatly upon the orientation of the sensor. The differences in mass accumulation rates detected during the missions are probably due to several factors including payload complements and vehicle attitude.

Results from the Spacelab-1 mission indicate significantly greater mass accumulation, probably due to the large payload, location of sensors, and unacceptable materials.

Large rapid increases in mass accumulation can result from particular mission events. Figure 4.2.3.3.9-1 shows the mass accumulation recorded during an abnormally extensive planned RCS test firing. This effect is caused primarily by the return flux, since no thrusters fire into the bay, and will depend on vehicle attitude relative to the velocity vector.

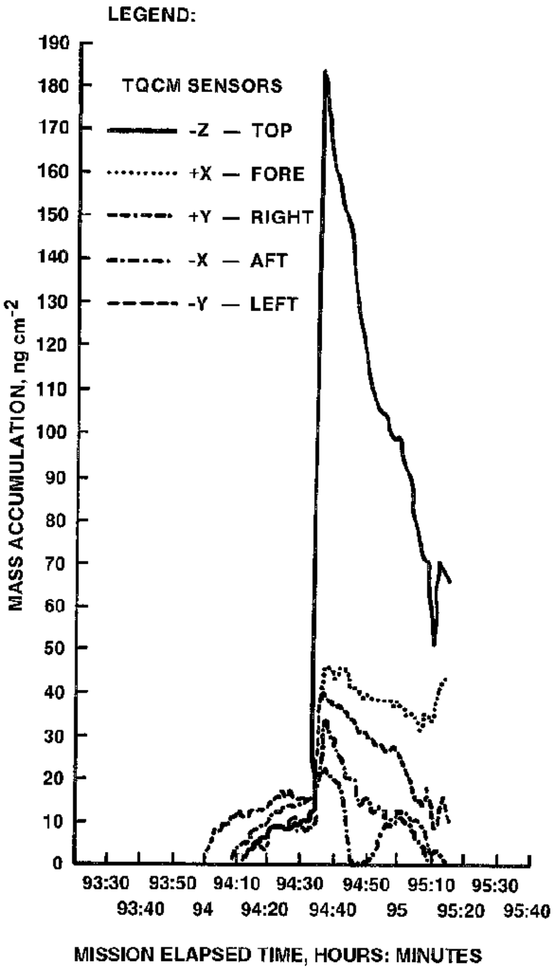


Figure 4.2.3.3.9-1. Mass accumulation during an L2U engine firing

Cryogenically-cooled Quartz Crystal Microbalance (CQCM) measurements from three missions are listed in table 4.2.3.3.9-2. The CQCM has a nearly 2π sr view to space. The temperature of the CQCM is not controlled but determined by the spacecraft attitude and varied from -101° to 35° C. During the initial hours of each mission, the CQCM indicated mass losses, then a gradual increase throughout the on-orbit period.

Molecular return flux was determined from on-orbit measurements using a 2 to 150 amu quadrupole mass spectrometer. The gases observed by the mass spectrometer have been generally those with molecular weights below 50 amu. The mass spectrometer was configured to spend half its time on mass 18 since water is a significant contaminant. Table 4.2.3.3.9-3 lists the return flux determined for water.

Table 4.2.3.3.9-1. TQCM average mass accumulation rates (ng/cm^2/hr) with minimum and maximum rates detected during three missions

		Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
STS-2	30*	5	11	70	25	33	45	-15	-2	10	9	21	44		Inoperative	
	*	2	9	15	24	35	52	-8	-2	8	10	15	21			
	0	-4	13	25	44	57	74	3	22	35	18	27	34			
	-30	-3	20	30	31	78	191	-41	40	155	70	130	218			
	-60															
STS-3	30	5	12	17	10	32	70	-20	0	2	-10	16		15	5	20
	0	5	38	125	20	60	105	0	19	50	-10	28	80	5	22	35
	-30	0	14	60	5	44	65	-5	9	20	5	16	25	0	11	25
	-60	5	38	175	50	75	105	10	21	35	10	32	75	0	14	25
STS-4	30	5	6	10	-25	-2	5	-5	3	20	-25	1	15	0	5	10
	0	-5	9	50	0	12	50	0	9	20	-5	4	20	0	6	20
	-30	-15	22	90	-20	11	115	0	19	50	-15	3	25	-10	4	10
	-60	0	19	40	-25	9	55	-20	3	30	-15	17	95	-20	14	45

*		
*	-X	Aft (toward Shuttle tail)
	+X	Forward
	-Y	Left
	+Y	Right
	-Z	Out of payload bay

** Large first 30° C collection period excursions on STS-2 omitted (-347 to +126 ng/cm^2/hr)

Measurements taken to date indicate deposition is typically within the range of the requirements and goals listed in table 4.2.3.3.1-1 for quiescent periods. Contamination levels from certain events, such as thruster firings, exceed the limits in table 4.2.3.3.9-3 momentarily.

Direct and return flux and deposition resulting from Orbiter and payload contaminant sources can be calculated using SPACE-II. Predictions to date have agreed well with flight measurements. Once the contamination levels have been predicted, the levels must be compared with the sensitivity of the instrument to determine any potential problems, which may require design or operational changes.

Table 4.2.3.3.9-2. CQCM on-orbit mass accumulation summary for three missions

	Mass accumulation rate (ng/cm^2/hr)	**Total accumulation (ng/cm^2)**	**Accumulation period (hr)**
STS-2	5	246	49.3
STS-3	2	376	188
STS-4	-1	-162	162

Table 4.2.3.3.9-3. Return flux for water for three missions

	Return flux (molecules/cm^2/sr/sec)	
	Initial *	Final
STS-2	1.3×10^{14}	1.8×10^{13}
STS-3	9.8×10^{11}	2.6×10^{11}
STS-4	2.1×10^{14}	6.6×10^{12}

*Except for RCS firings and PLBD closing.

4.2.3.3.10 Column Density

Column density is the density of gaseous molecules integrated over a LOS and can be expressed as either mass or number of molecules per square centimeter. This quantity has never been directly measured on-orbit, but has been calculated using SPACE-II, based upon return flux measurements. Column densities calculated for water are listed in table 4.2.3.3.10-1.

The requirement for water column density is less than 1×10^{12} molecules/cm^2. This requirement was met on one of the flights but was exceeded on the other two. The high water column density subsequently decayed and was found generally acceptable after 48 hours. The high concentrations are thought to be due to water vapor from the tiles of the thermal protection system which were exposed to rain prior to launch. It is expected that these excessive initial desorption rates will not recur on later flights because of improved waterproofing techniques for the Orbiter thermal protection system.

Column densities for other gases will have to be measured more directly using optical instruments. Densities for such sources as outgassing and early desorption have been predicted using SPACE-II and fall within the requirements and goals listed in table 4.2.3.3.1-1for quiescent periods.

If an instrument is sensitive to these levels of contamination a more complete analysis can be performed as an non-standard service using SPACE-II. SPACE-II can predict column densities from all Orbiter or payload contamination sources. These levels must then be compared with the sensitivity of the instrument. The payload designer is advised that potential problems arising from this analysis may require solutions involving design or operational timeline changes.

Table 4.2.3.3.10-1. Calculated column densities for water for three missions

	Column density (molecules/cm^2)	
	Initial *	Final
STS-2	2.0×10^{13}	2.7×10^{12}
STS-3	1.5×10^{11}	4.0×10^{10}
STS-4	3.2×10^{13}	1.0×10^{12}

*Except for RCS firings and PLBD closing.

4.2.3.3.11 Particle Density Effects

The particulate environment of the Orbiter is of concern because particles, which were present prior to launch or generated by Orbiter activities, may deposit on sensitive surfaces or obscure the Field-of-View (FOV) of an instrument. Currently, flight data have been limited to photographic images of particles in the vicinity of the payload bay.

Particle images and counts have been made by the camera photometer flown as part of the IECM. Useful images can only be made from this instrument when the Orbiter is sunlit and the camera and the payload bay face a dark stellar or terrestrial background. This instrument can detect particles as small as 25 µm within 20 meters of the Orbiter. Larger particles can be detected at greater distances.

The camera photometer has been used on various flights to gain flight particulate data. Figure 4.2.3.3.11-1 shows the average time history, as a function of the percentage of the total number of frames that could show contamination for particle detection. Figure 4.2.3.3.11-2 is a similar plot for the Spacelab-1 mission. In all cases, high levels of particulates were observed early in the flight. The origin of these particles is unknown, but it is felt that they are caused by the release and redistribution of particles that were present on the surfaces prior to launch. These particles generally are swept away from the Orbiter because of atmospheric drag effects. Particle levels drop to low levels within the first 15 to 20 hours on-orbit with a general decay for the first 48 hours. Figure 4.2.3.3.11-2 shows a high particulate level after 48 hours perhaps because of the complexity of the Spacelab-1 payload as compared to the earlier flights.

Water dumps have produced large quantities of particles exceeding 100 counts per frame. Protection of sensitive surfaces may be required for the first 15 minutes after water dumps with normal operation resumed within 25 minutes. Particle releases have not been detected from operation of the FES.

In general, particulate levels early in the mission could affect equipment (such as star tracker) performance if particles occur in the FOV. However, after 15 to 17 hours on-orbit background brightness levels in the visible spectrum are not detectable except during water dumps. A telescope with a 1° FOV would detect particles at an average of one particle (equivalent diameter greater than 25 µm) every two orbits. Degradation of optical samples on the IECM has generally been too small to provide useful particle effects data.

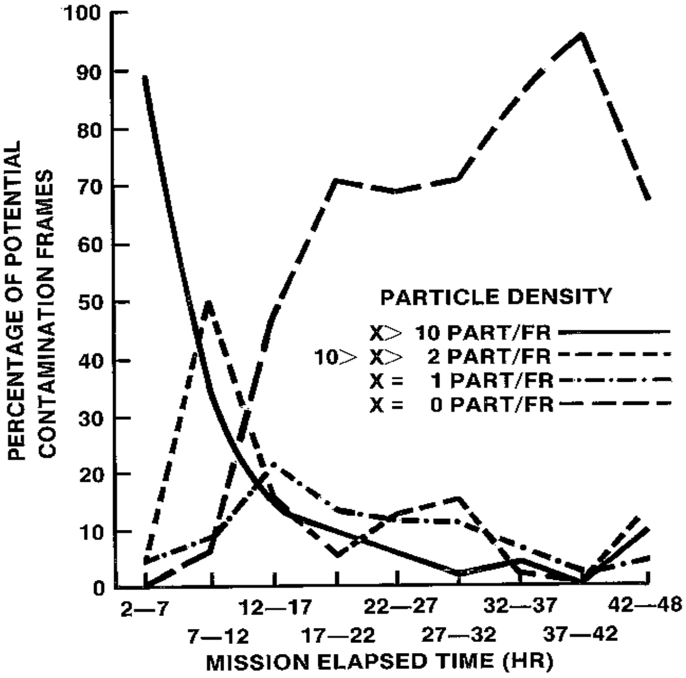


Figure 4.2.3.3.11-1. Particle densities

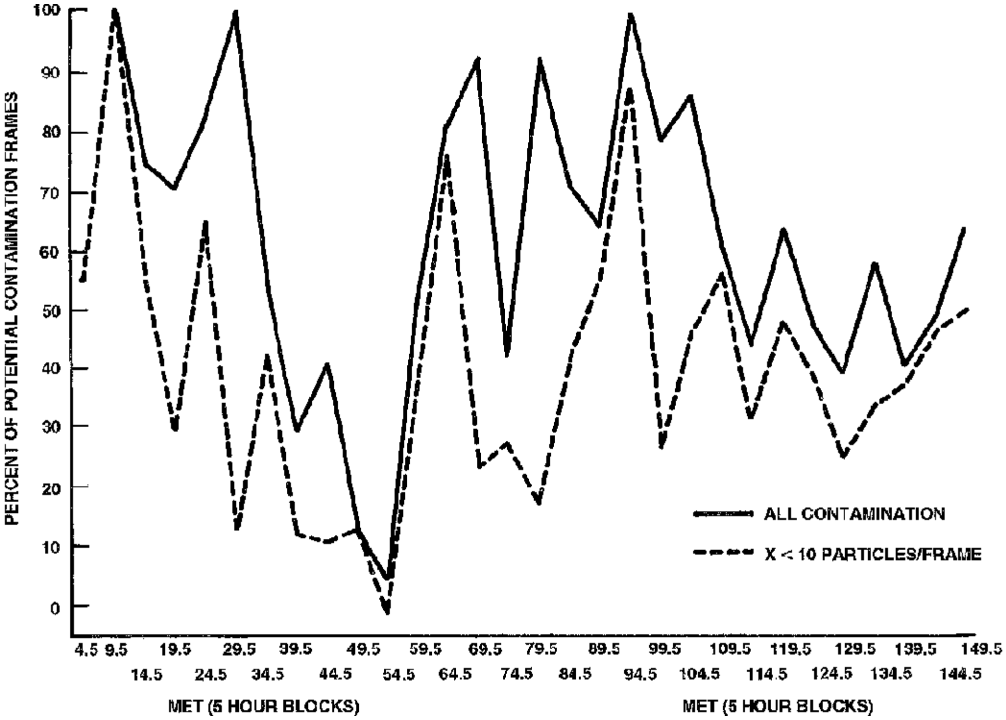


Figure 4.2.3.3.11-2. Particle densities for the Spacelab-1 mission

4.2.3.3.12 Particle Protection Techniques

If it is determined that an experiment may be sensitive to the particle levels expected, protection techniques may be appropriate. Some useful techniques include:

1. Shrouds (removed shortly before launch)
2. Special cleaning and inspection procedures for the payload and payload bay (Sensitive and Highly Sensitive classifications per, SN-C-0005)
3. Active covers (openable, or openable and closable on-orbit)
4. Experiments scheduled to avoid contamination events; *e.g.*, scheduled late in mission, during unilluminated times, or during engine/vent suppression
5. Experiments designed to tolerate a certain amount of degradation

The first two protection techniques for flight particle protection are actually ground activities. The techniques are included here because ground activities establish part of the particle reservoir for flight, and the effects of ground particles are usually most critical during orbital phases. Covering the critical surface itself can minimize the background level at the time of launch. The second technique serves to decrease the total payload bay particle population, and is more effective at controlling launch particles.

Active covers give experimenters the greatest control over experiment surface cleanliness. However, the use of such a device may greatly complicate hardware and operation design, particularly if crew or ground activation is required. The mechanism also provides another possible failure point if the cover does not deploy.

Experiment scheduling is probably the most effective technique for dealing with orbital particles crossing FOV. Some experiments, however, may not have the flexibility to select operation times. Also, the camera-photometer data of the Spacelab-1 mission does not show a steady decrease in particles with mission time. It is possible that this will also be the case in other Spacelab missions, with a large number of experiments located in the payload bay. The length of time that engines and vents may be inhibited is limited, which also interferes with a scheduling approach to particle protection.

The final approach listed for protection from orbital particles is to include greater tolerances in the design of hardware elements. For example, if degradation of a thermal control surface caused by particles is anticipated, the surface could be sized to allow it to meet its requirements even in a degraded state.

4.2.3.3.13 Space Glow

A diffuse near-field glow phenomenon has been observed above spacecraft surfaces subjected to the impact of atmospheric species as the spacecraft travels through the low-Earth orbital atmosphere. This phenomenon results from interactions between the ambient atmosphere and the spacecraft surfaces, or in some instances between the ambient environment and the induced environment generated by the spacecraft. Although sufficient data does not exist to fully understand the phenomenon, a number of theories have been proposed which could account for the glow. These include: (1) gas phase collisions (during quiescent periods, thruster firings and water dumps), (2) surface-aided chemiluminescence reactions with adsorbates on Orbiter surfaces, and (3) surface bulk reactions with the atomic oxygen environment leading to material loss or compositional changes. The following data are the best available to describe the effects of this phenomenon.

1. The glow has been spectrally measured in the Ultraviolet (UV), visible, and infrared. Emissions due to electronically excited molecular nitrogen have been observed in the UV. A broad continuum is present in the visible region due to nitrogen dioxide. In the IR, emissions are observed from 0.7 - 5.3 µm and are attributable primarily to nitric oxide, ionized nitric oxide, and hydroxyl.

2. The glow intensity is dependent upon the surface orientation to the velocity vector; however, the relationship is not directly cosine and in the infrared exhibits a cosine squared dependency.

3. The glow intensity viewed normal to the surface on STS-9 was calculated as 3. 88 R/A. (R = Rayleigh (1R = 10^6 photons/cm^2-sec)). The glow intensity normalized for normal incidence of the velocity vector gives an equivalent intensity of 4.3 R/A.

4. The glow intensity of STS-41D at 6300A normalized to the NASA data resulted in an intensity of 9.7 R/A. IR measurements from STS-39 and STS-62 show quiescent glow emission intensities on the order of 10^{-9} W/cm^2 sr µm (Noise Equivalent Spectral Radiance) and that during thruster firings the intensities are enhanced by a factor of 10 with resultant changes in the spectral distributions.

5. The exponential folding distance of the glow above spacecraft surfaces appears to be 20 centimeters.

6. Within the altitude regimes of the Orbiter, the glow intensity varies as a function of the atomic oxygen density.

7. Glow intensity has been observed to depend on the type of material and, therefore, on some material property. The spatial extent, however, appears to be the same for all materials. Glow intensities relative to different materials are shown in table 4.2.3.3.13-1.

Table 4.2.3.3.13-1. Material glow values

Material	Glow Value (1=least, 9=most)
M_gF_2 (Magnesium fluoride)	8
Z306 (Polyurethane coating)	6
Z302 Overcoated with silicon	9
Z302 (Polyurethane coating)	7
Polyethylene	1
401-C10 (Black polyester)	2
Carbon cloth	4
Chemical conversion film	5
Anodized aluminum	3

8. The difference in glow intensity above various materials is not proportional to material erosion. For example, some organic materials, such as black Chemglaze paint, glowed the brightest, yet suffered no detectable mass loss on-orbit.

   By contrast, polyethylene, which is one of the most reactive materials, glowed the least.

9. Emissivity characteristics of the material samples along with the thermal capacitance may produce variations in the glow intensity. Cooler surfaces appear to produce a more intense glow, as shown in figure 4.2.3.3.13-1.

10. During STS-39, nitric oxide gas was released into the payload bay while the Orbiter was in a bay-to-ram attitude. At the start of the release the visible glow was significantly enhanced. At the end of the gas release the glow intensity decreased with two different decay times. A fast decay was attributable to gas phase interactions while a slower decay time was due to surface mediated

reactions. During STS-62, molecular nitrogen was released into the payload bay while the Orbiter was in a bay-to-ram attitude. The nitrogen release extinguished the existing quiescent glow on all nearby surfaces. When the gas was turned off the glow came back. This was observed in the visible and IR.

Numerous experiments are planned so that the glow process may be understood and approaches developed to minimize its effects.

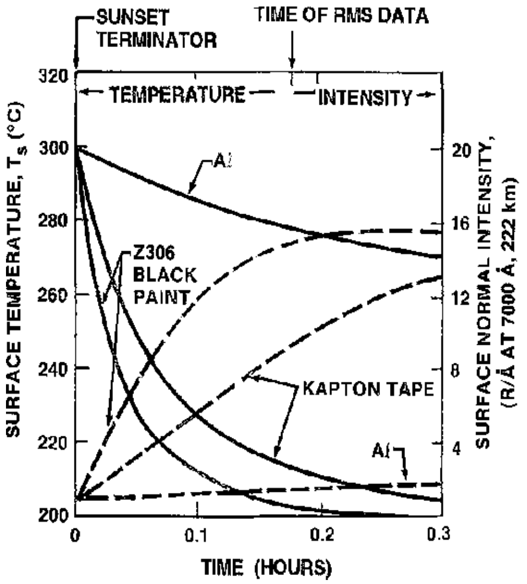


Figure 4.2.3.3.13-1. Vehicle glow as a function of material temperature

A short-term effect is also produced by operation of the Orbiter's attitude control thrusters. The effluent clouds produced during thruster operations contain abundant amounts of H_2O, N_2, CO, and H_2 and minor amounts of CO_2, O_2, H, and MMH-NO_3. It is suspected that visible glow emissions arise as atomic oxygen within the atmosphere atom exchanges with N_2 molecules to form vibrationally excited NO and N within the thruster cloud. This glow is widespread and can fill most of the sky. It is strongest in the red region of the emission spectrum. Although they are very bright, these thruster glow effects last only for a few seconds.

4.2.3.3.14 Atomic Oxygen Surface Interactions

As the Orbiter travels in low Earth orbit, it undergoes energetic collisions with the ambient atmosphere. These collisions have resulted in rapid oxidation and surface recession of a number of materials exposed to the ambient environment. Observations have shown a loss of surface gloss, an apparent aging of painted surfaces, and film thickness degradation. Atomic oxygen, produced by photo-disassociation of molecular oxygen in the upper atmosphere, is the predominant species in low Earth orbit and has been proposed as the cause of the material recession process. In addition to being highly chemically reactive, the atomic oxygen atoms have a high kinetic energy (> 5 eV) relative to the spacecraft as a result of its orbital velocity and can have a flux as high as

10^{15} atoms/cm^2-sec. This can result in thickness losses for organic compounds as high as 6 µm/day during periods of high solar activity at moderate altitudes.

The quantity of erosion depends upon the atomic oxygen fluence and the reaction efficiency of the particular material. Atomic oxygen fluence is the flux of atomic oxygen atoms intercepting the surface integrated over the time in which the surface is exposed to the ambient velocity vector. The flux depends upon the atomic oxygen density which, in turn, depends on such things as vehicle altitude, orbital inclination, attitude, and solar/ geomagnetic activity. Reaction efficiency, a quantitative factor for reaction characterization, is derived by normalizing the material thickness loss to the atomic oxygen fluence and is given in units of cm^3/atom. The reaction efficiency of a material depends on its particular chemical structure and consequently must be determined individually for each material.

A number of material samples have been flown aboard the Orbiter in an attempt to understand the erosion process and to quantify its effects on various materials. The general conclusions drawn from these experiments are:

1. Unfilled organic materials containing only C, H, O, N, and S react with approximately the same reaction efficiency ($2\text{-}4 \times 10^{-24}$ cm^3/atom).

2. Prefluorinated carbon-based polymers and silicones have lower reaction efficiencies by a factor of 10 or more than organics.

3. Filled or composite materials have reaction efficiencies that are strongly dependent upon the characteristics of the fillers.

4. Metals, except for silver, carbon, and osmium, do not show macroscopic changes. Microscopic changes, however, have been observed and should be investigated for systems very sensitive to surface properties. Silver and osmium react rapidly and are generally considered unacceptable for use in uncoated applications.

5. Magnesium fluoride and oxides in various forms show good stability.

Table 4.2.3.3.14-1 lists reaction efficiencies derived for a number of typical spacecraft materials.

Table 4.2.3.3.14-1. Reaction efficiencies of selected materials with atomic oxygen in low earth orbit

Material	Reaction efficiency (cm^3/atom)
Kapton	3×10^{-24}
Mylar	3.4
Tedlar	3.2
Polyethylene	3.7
Polysulfone	2.4
Graphite/epoxy	
1034C	2.1
5208/T300	2.6
Epoxy	1.7
Polystyrene	1.7
Polybenzimidazole	1.5
25% Polysiloxane/45% polyimide	0.3
Polyester 7% polysilane/93% polyimide	0.6
Polyester	Heavily attacked
Polyester with antioxidant	Heavily attacked
Silicones	
RTV-560	0.2*
DC6-1104	0.2*
T-650	0.2*
DC1-2577	0.2*
Black paint Z306	0.3-0.4*
White paint A276	0.3-0.4*
Black paint Z302	2.03*
Perfluorinated polymers	
Teflon, TFE	EO .05
Teflon, FEP	EO .05
Carbon (various forms)	0.9-1.7
Silver (various forms)	Heavily attacked
Osmium	0.026

*Units of mg/cm^2. Loss is assumed to occur in early part of exposure; therefore, no assessment of efficiency can be made.

4.2.3.4 Descent Conditions

Deceleration and repressurization of the payload bay during descent can disperse particles concentrated on the vent filters and located on surfaces throughout the bay. As during ascent, particulate measurement during descent has been limited to the measurements made by the cascade impactor on the IECM and has been inconclusive. Table 4.2.3.4-1 lists the particle measurements for three missions. The data indicate that the particulate environment during descent should have minimal impact on payloads.

Gas samples were collected by the IECM air sampler for postflight analysis. Table 4.2.3.4-2 summarizes the results of these analyses. The quantity of volatile hydrocarbons detected was very low.

Nitrogen compounds, caused by RCS and Auxiliary Propulsion Unit (APU) exhaust product ingestion into the payload bay, were not detected.

Relative humidity during descent ranged from 15 to 25 percent. Air temperature in the payload bay was 10° to 20° C.

TQCMs were used to measure deposition during descent. Levels on most of the sensors rose steadily to a worst case of approximately 370 ng/cm^2 for a +X sensor. Deposition depended upon sensor location and axis. The -Y sensors decreased in weight during descent.

Table 4.2.3.4-1. Descent particle measurement summary

Particle size µm	**Flight results ($\mu g/m^3$)**
>5	10
	10
	20
1 to 5	250
	10
	10
0.3 to 1	125
	10
	NF*

*NF - Nonfunctional

Optical (253 nm) transmittance losses of one percent were detected. Unfortunately, this loss covered not only descent but also landing, ferry flight, and deintegration, a period of about four weeks.

Table 4.2.3.4-2. Descent air sample summary

Species	Detection method	Flight results
Reactives NO, NO_2, NH_3	Reaction with rutheniumtrichloride surfaces	None detected to ppm sensitivity
Volatile hydrocarbons*	Concentration on absorbent; postflight GC/MS analysis	20 ppm by weight 4 ppm by volume

*Covers C_9 to C_{24} range and uses $\simeq C_{12}$ as average molecular weight to obtain ppm by volume

4.2.4 Mechanical

Significant loading of payload structure occurs during various Space Shuttle mission events. Major mission events include lift-off, high-Q boost, SRB staging, main engine cutoff, entry, and landing. Other events requiring consideration include on-orbit and cargo handling loads. Sources of loading during these events include transient dynamics, random vibration, acoustics, quasi-static accelerations, thermal displacements, pressure, preloading, and pyroshock. Lift-off and landing are transient, dynamic events that usually produce the most severe payload structural loads environments. In addition, on-orbit events such as RCS and/or OMS firing, RMS berthing, docking, and crew-induced loading can cause significant loading, particularly when the payload changes configuration in orbit. The mechanical environmental loads for the payload may be found in the ICD 2-19001 or NSTS 21000-IDD-ISS.

4.2.4.1 Structural Loads

The structural loads factors should include effects from quasi-static flight events, transient flight events, lift-off loads, landing loads, and emergency control. Preliminary design loads are specified in ICD 2-19001.

4.2.4.2 Vibration Loads

Payload structure must be certified to vibration criteria that are based on the ICD 2-19001 environments to be considered safe to fly on the Space Shuttle. The payload will need to take into account random vibrations through the mechanical and electrical interfaces and modal frequencies as appropriate.

4.2.4.3 Acoustic Loads

The acoustic levels in the payload bay represent the minimum levels to which a payload must be certified to be considered safe to fly on the Shuttle. The acoustic levels during entry and landing are significantly below the ascent levels and are usually not considered. Ascent acoustic levels for specific payload local zones/surfaces are dependent on payload geometry, surface areas and acoustic absorption. The acoustic environment in the payload bay is defined in sound pressure levels over the frequency range of 31.5 to 2500 Hz.

4.2.4.4 Shock Loads

The payload-generated pyrotechnic shock detected on the trunnion at the payload-to-Orbiter interface and from other sources are detailed in ICD 2-19001.

4.3 FERRY FLIGHT ENVIRONMENT

When the Orbiter uses any landing site other than KSC, the payload generally remains in the payload bay and returns to the launch site via ferry flight. This is accomplished by hoisting the Orbiter up in an open-air mate/demate device outside the hangar and attaching it to a Boeing 747 Shuttle Carrier Aircraft (SCA) that is rolled in beneath the Orbiter. The SCA provides electrical power to the Orbiter during the ferry flight. However, environmental conditions in the payload bay are not controlled. If a payload is still in the bay, it experiences the ambient environment in multiple cycles depending upon the ferry route.

4.3.1 Thermal

When a Space Shuttle flight ends at EAFB, payloads usually remains aboard the Orbiter, which is ferried from EAFB to the launch site on SCA. Payloads and ASE should be designed for compatibility with ferry flight thermal environments.

During ferry flight operations, payloads in the payload bay are exposed to ambient conditions that are not controlled or monitored. Payloads are normally not powered, heated, or cooled. Customers should specify any unique payload requirements in the IP, IP Annex 8, and OMRSD.

4.3.1.1 Payload Bay Temperatures

Payload bay temperature ranges (figure 4.3.1.1-1) for ferry flight given in ICD 2-19001, apply to many payloads and mission conditions. Actual temperatures are expected to fall between these extremes and depend upon payload design and thermal characteristics.

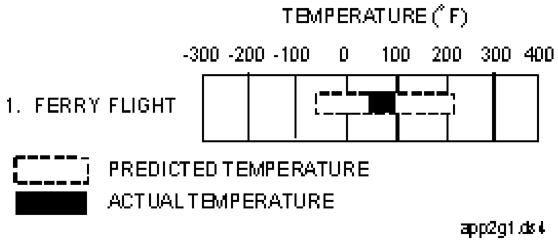


Figure 4.3.1.1-1. Ferry flight payload bay temperatures

During ferry flight, the temperature environment is influenced by the ground purge (if any) and weather conditions.

4.3.1.2 Payload Bay Purge

Purge at ferry flight stopover sites can be provided by request (see section 4.3.1.4).

4.3.1.3 Flight Phase Thermal Environment

The maximum duration of any flight segment is approximately 4 hours during which time the payload bay environment is not controlled. Based on measurements recorded during several ferry flights, payload bay temperatures vary from about +35° to +86° F.

Although the payload bay thermal environment is not controlled during flight, as a nonstandard service the payload temperature may be biased at takeoff within a reasonable range by conditioned air supplied to the Orbiter payload bay via the Orbiter purge system while the Orbiter and SCA are on the ground. Ground purge during ferry flight is discussed further in Section 4.3.1.4.

4.3.1.4 Ground Phase Thermal Environment

The interval on the ground at selected Air Force bases or NASA facilities varies from a few hours to more than 24 hours, and the payload bay temperature may vary from about +10° to +125° F as the result of diurnal and seasonal variations.

During stops en route, conditioned air can be furnished to payloads in the payload bay. If conditioned air is required, the requirement must be specified in the IP, IP Annex 8 and OMRSD. The specific temperature range and flow rate are negotiated with the SSP.

When determining conditioned air requirements, the customer should consider possible payload and payload bay temperatures at touchdown, minimum duration of ground services available between flights, the influence of ground environments, and payload bay surface temperatures.

4.3.1.5 Payloads with Active Cooling Systems

For payloads that use water cooling, it is necessary to prevent the water from freezing in the cooling system during ferry flight.

The customer should specify electrical power requirements in the IP and IP Annexes 2 and 8 and the OMRSD.

For payload bay payloads that utilize water cooling, freezing protection will be provided using methods described in sections 4.1.1.4 and 4.1.1.5.

4.3.2 Contamination and Cleanliness

During a ferry flight to KSC from EAFB, the POSA flown during the mission remained exposed. To allow differentiation of contaminants collected subsequently on the ferry flight, two samples were added at Dryden Flight Research Center (DFRC) at EAFB. Contamination collected on these two samples could be subtracted from the contamination on the corresponding positioned samples that had been exposed during the whole flight (from KSC and return to KSC) to yield a particle distribution that could be attributed just to the ascent/on-orbit/descent part of the flight. The specimens were electrets of Tetrafluoroethylene (TFE) Teflon, one facing up (-Z) and one facing down (+Z) into the bay. In each case, the positively charged side of these organic magnets faced out. The particle distributions of each is graphed in figure 4.3.2-1.

Chemical elements in the contaminants were predominantly aluminum; the upfacing specimen had some silver and the downfacing specimen had some calcium. The trace amount of contamination is not considered significant.

Similar tests using the PSA were conducted on three separate missions. Ferry flight samples were optical-grade wafers inserted through a small access door in the forward part of the payload bay at the landing site. A summary of these results compared to KSC (OPF) and flight samples is shown in figure 4.3.2-2. Note that the values shown for the flight are a net value after the ferry flight distributions were subtracted from the gross amounts; i.e., the flight samples were exposed continuously until they were removed at KSC.

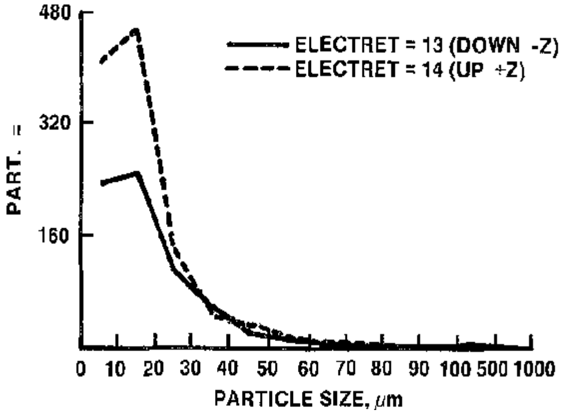


Figure 4.3.2-1. Particle distribution on electrets of POSA ferry flight

The measured optical change in the ferry flight samples was so low as to be in the realm of measurement uncertainty, and could be attributed to the deposited particulate. This indicates that film formation or nonvolatile residue was very low, much like what has been found at KSC in the OPF and PCR facilities.

4.3.3 Mechanical

The mechanical environmental loads for the payload may be found in ICD 2-19001 and SMD-90-1635.

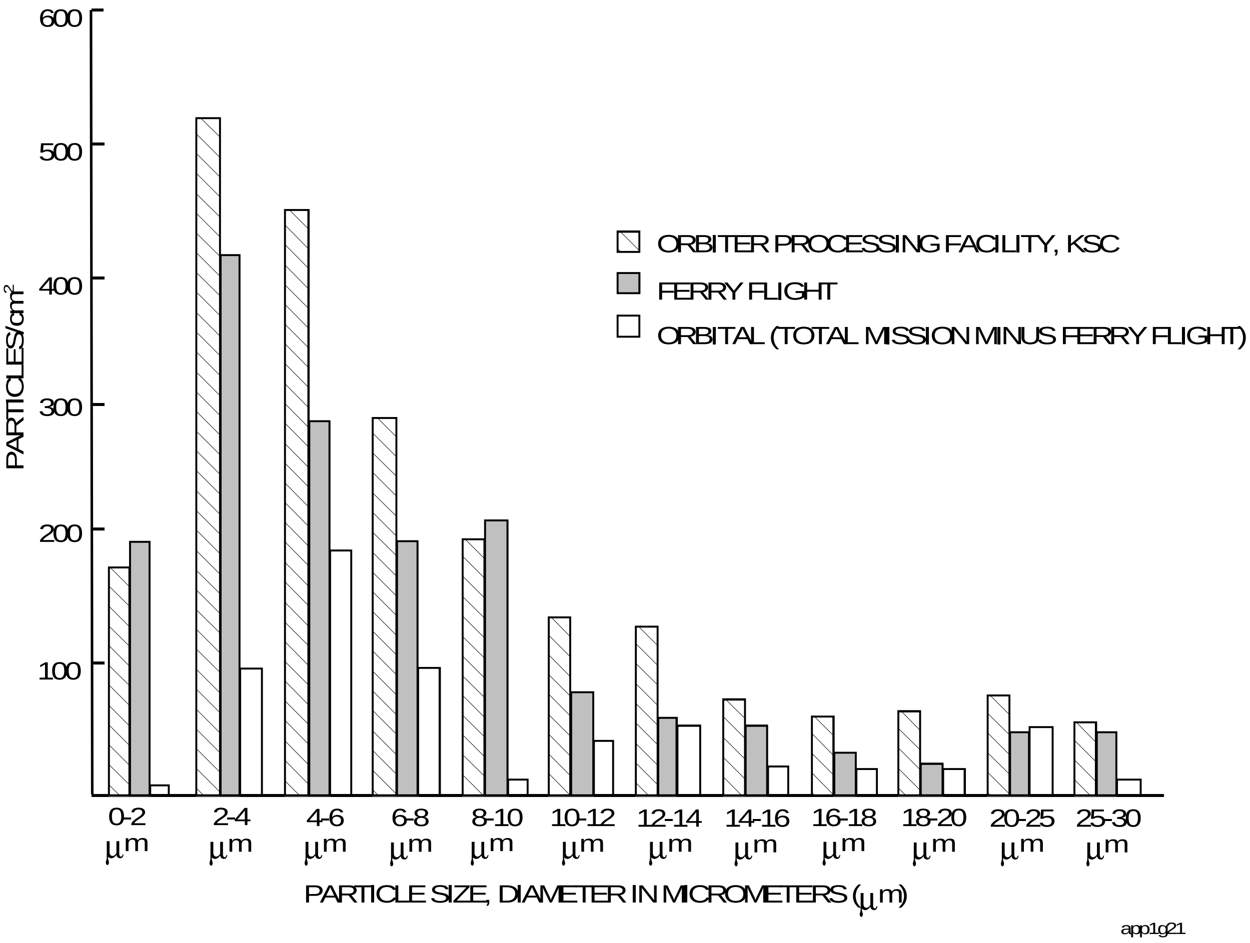


Figure 4.3.2-2. PSA particle distributions

SPACE SHUTTLE PAYLOAD INTERFACES

5.0

5.1 MECHANICAL INTERFACES

5.1.1 Introduction

5.1.1.1 General Information

The Orbiter provides structural support attachment points for payloads in the payload bay. Small payloads can be accommodated on special carriers located along the payload bay sidewall or on across-the-bay payload carriers. The available payload bay envelope is defined in ICD 2-19001.

Payloads and payload carriers that are located across the bay are supported in the payload bay on payload trunnions. These payload trunnions mate with Orbiter attach fittings located on the longerons on both sides of the payload bay, and on the keel located at the bottom centerline of the payload bay. Bridges distribute attach fitting loads to the Orbiter structure. These structural accommodations are available for nondeployable, deployable, and retrievable payloads.

In some cases payloads are not attached directly to the Orbiter, but to a payload carrier. The carrier, in turn, is attached to the Orbiter. Sidewall payload elements may be mounted on bridge-like structures such as the Adaptive Payload Carrier (APC), Increased Capability Adaptive Payload Carrier (ICAPC), and Get-Away Special (GAS) adapter beam. These payload carriers are supported by the Orbiter sidewall.

The Remote Manipulator System (RMS) is available for payload deployment and retrieval. For more information, see section 8.5.

5.1.1.2 Coordinate Systems

Several different coordinate systems are used to define payload locations during integration, installation and mission operations. The most commonly used systems are the Orbiter Coordinate System (OCS) and the Payload Axis System (PAS). Each of these systems is discussed below.

5.1.1.2.1 Orbiter Coordinate System (Orbiter Structural Reference System)

The OCS, also referred to as the Orbiter Structural Reference System (OSRS), figure 5.1.1.2.1-1, originates 236 inches (6 m) forward of the nose and 400 inches (10.2 m) below the centerline of the Orbiter. The +X axis points toward the Orbiter’s tail, the +Y axis points toward the starboard wing, and the +Z axis points “up” to complete the right-handed coordinate system. Payload manifest location coordinates (X_o, Y_o, and Z_o) are given in this system.

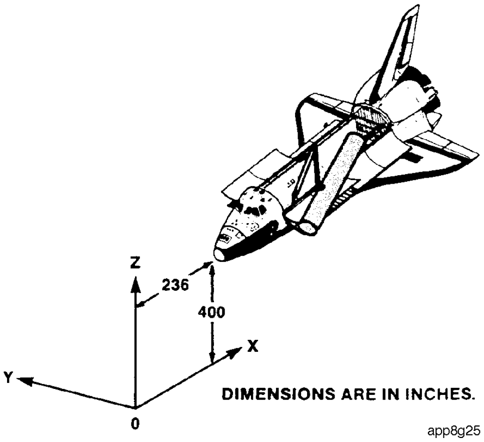


Figure 5.1.1.2.1-1. Orbiter coordinate system

5.1.1.2.2 Payload Axis System

The PAS is defined by the payload designer and is used as the spacecraft's reference system just as the Orbiter coordinate system is used to define Shuttle stations. The PAS must be a right-handed, orthogonal coordinate system for ease of transposing into the other right-handed, orthogonal coordinate systems used by the Orbiter and Orbiter systems. The PAS is usually chosen so that its axes are parallel or orthogonal to those of the Orbiter coordinate system when the payload is berthed. The origin is usually located at or near the payload's geometric center or the c.m. The PAS is also known as spacecraft coordinate system, payload coordinate system, and mass property coordinate system. Dimensional drawings of the payload which clearly define the PAS origin location and the axes orientation with respect to the payload structure are required. These drawings are used to help visualize the payload structure as well as generate analytical and simulation models. The drawings should include physical dimensions of the major structural components and their connection points.

5.1.2 Mechanical and Physical Payload Interfaces

5.1.2.1 Payload Bay Envelope

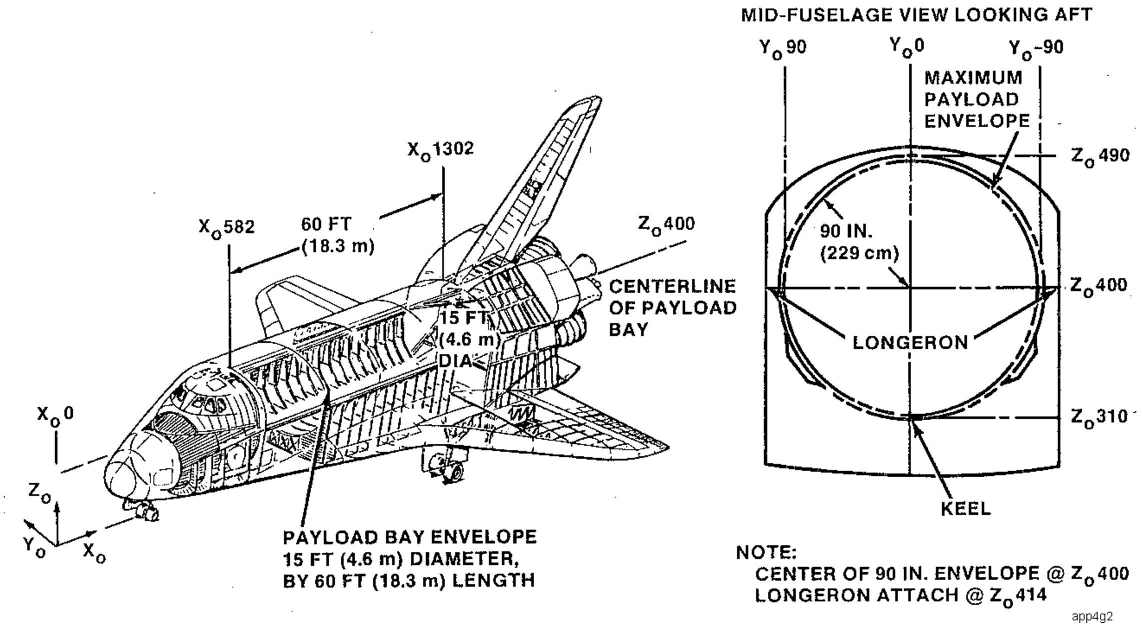
A cylindrical envelope in the payload bay 15 feet in diameter (90-inch radius) and 49.8 feet long (60 feet for Orbiter without ODS) is available for payload accommodation as shown in figure 5.1.2.1-1. It is the payload customer's responsibility to constrain the payload within this envelope, with the exception of Orbiter interface hardware. The available payload bay envelope is defined in Shuttle Orbiter/Cargo Standard Interfaces, ICD 2-19001. Typically, a 3-inch thermal/dynamic clearance between the payload and the Orbiter is requirement.

During Space Shuttle flight events the payload bay distorts due to Orbiter structural and thermal loads. The resulting Orbiter and payload thermal and dynamic envelope is a

90-inch radius (15-foot diameter) circle at each Orbiter X_0 station, with the center of the circular envelope located at the distorted Orbiter centerline. The effects of payload manufacturing and Orbiter installation tolerances should be included when calculating payload clearance losses with respect to the 90-inch envelope.

Payload attachment fittings and umbilicals that interface with the payload can extend beyond this dynamic envelope to mate with Orbiter attachment fittings. Payload clearance loss with respect to the dynamic envelope should be calculated using the distorted Orbiter centerline.

Customers must also consider potential interference caused by Space Shuttle mission kit and integration hardware intrusions into the 90-inch envelope. These include the SIPs, keel fittings aft of $X_0$1191, and certain camera mounts. In addition, the PLBD centerline latches and passive radiators penetrate the payload envelope. These intrusions are specified in ICD 2-19001.



NOTE:
CENTER OF 90 IN. ENVELOPE @ Z_O400
LONGERON ATTACH @ Z_O414

Figure 5.1.2.1-1. Payload bay envelope

5.1.2.2 Orbiter Attachment Locations

The SSP provides structural support attachment points for various types of payloads in the payload bay. Payload supports are located along both sides of the payload bay at the longerons and along the bottom centerline of the bay at the keel. The attach points are located between X_0 612.73 and X_0 1281.4 at 3.933-inch (10.0-cm) intervals. This spacing is defined by the retention fitting pin locations on the Orbiter bridge fittings, which span the approximate 5-foot distance between Orbiter frames (figure 5.1.2.2-1). Payload trunnion spacing must be compatible with these attach points as defined in ICD 2-19001.

All attach fittings are outside the 90-inch radius payload envelope. Longeron attachment locations are intended to react payload X_0 and Z_0 direction loading or Z_0 direction loading only. Generally, the only Y_0 direction loading on the longeron will be induced friction loads and loading caused by payload attachment trunnion rotation relative to the Orbiter sidewall. Keel attachment locations are intended to react payload Y_0 loading with X_0 and Z_0 friction and rotation induced loads. In certain cases the keel can react X_0 direction loading. Only longeron and keel bridges required for a specific mission are installed.

Common payload five-point and three-point attachment arrangements are shown in figure 5.1.2.2-2. Statically determinate and some indeterminate attachment schemes are acceptable.

Figure 5.1.2.2-2 shows a five-point statically indeterminate installation. Two opposite longeron primary fittings will react both longitudinal X and vertical Z loads. Two opposite longeron stabilizing fittings will carry only Z loads since they are free to slide in the longitudinal direction. The stabilizing fittings may be either forward or aft of the primary fittings. The keel fitting reacts only Y loads and is free to slide in the longitudinal direction. If a five-point (or more) latch system is chosen and a latch fails, it will not be possible to determine the loads applied to the remaining latches during entry. Under worst-case circumstances, it may be necessary to leave the payload in orbit rather than land with it.

Figure 5.1.2.2-2 also shows a three-point statically determinate installation. Two opposite longeron primary fittings will react both longitudinal X and vertical Z loads. The keel fitting will react both X and Y loads; locking pins are installed so the keel will accept longitudinal loads. This support system is generally used for lightweight payloads.

Although payload attachment schemes are not limited to five-point and three-point systems, these descriptions provide examples of typical payload loads reactions that are used for most payloads.

Attachment point location manufacturing tolerances reflecting the unloaded or zero-g condition, and including tolerances for the Orbiter payload bay longerons and frames, bridge fittings, and retention hardware are defined in ICD 2-19001. They also encompass the effects of hysteresis, which may be of the same or lesser magnitude. Calculation of payload-to-Orbiter clearances, including clearance loss with respect to the 90-inch payload envelope, should consider these tolerances. Gravity effects, Orbiter thermal distortions, and external loading will produce structural deformation that affects attachment point locations relative to each other.

Loads for redundantly attached payloads caused by tolerances at the payload-to-Orbiter interface will result in a preload. This preload shall be added to the flight loads (dynamic loads plus Orbiter thermally induced loads plus payload thermally induced loads, as appropriate) and assessed against Orbiter interface load capability and payload capability. Refer to ICD 2-19001 for details.

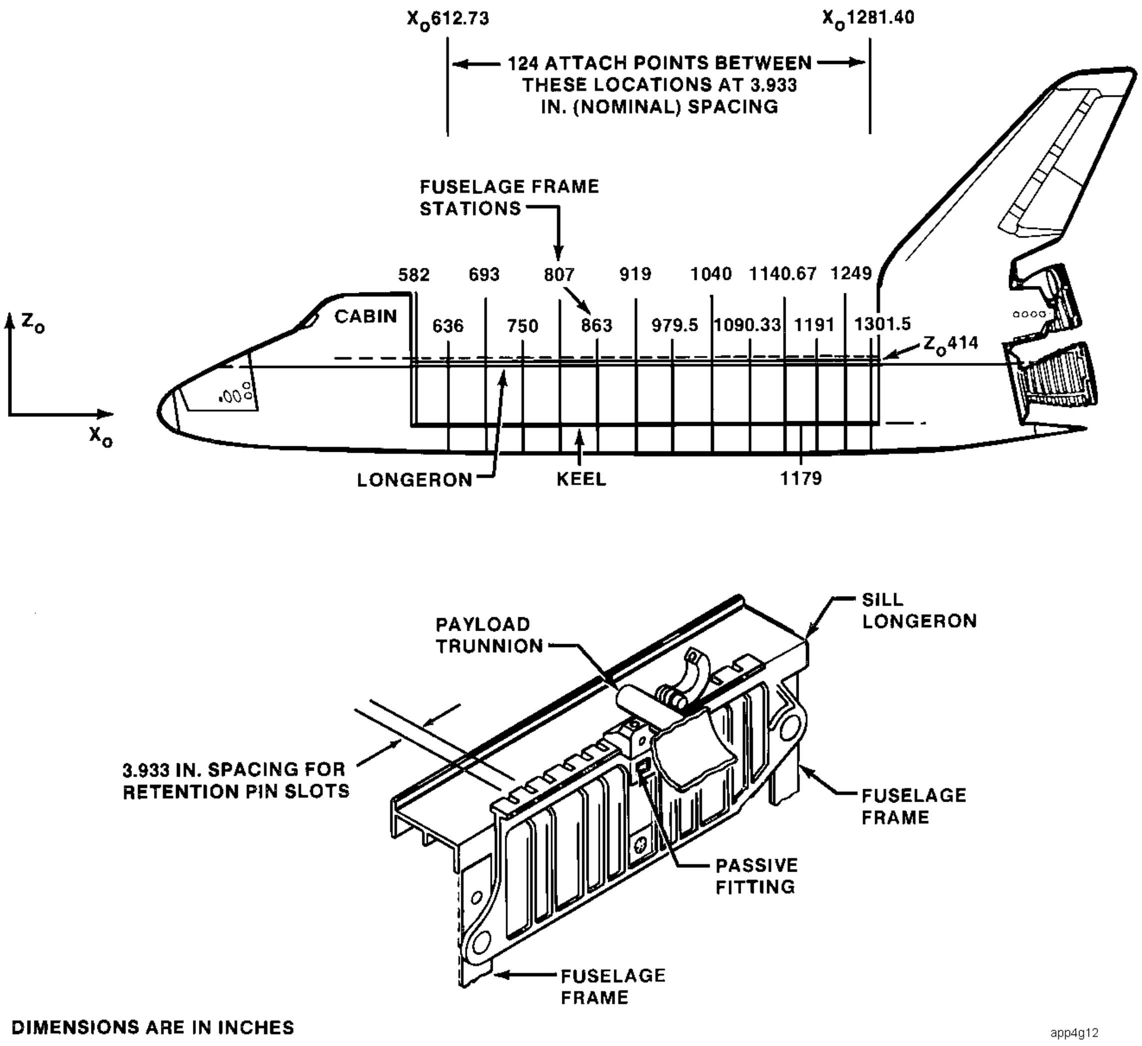


Figure 5.1.2.2-1. Orbiter longeron fittings

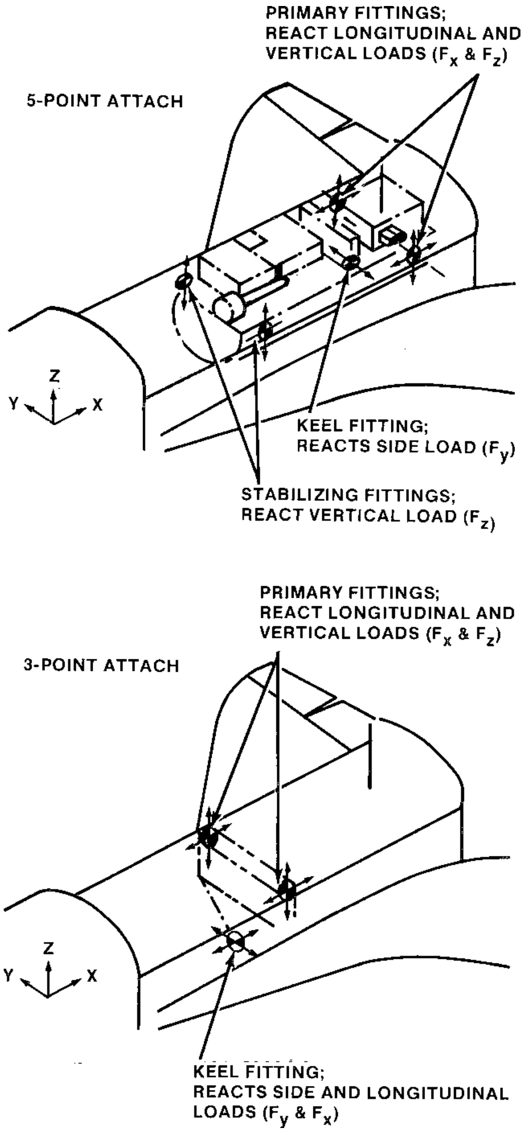


Figure 5.1.2.2-2. 5-point and 3-point payload attachment methods

5.1.2.3 Attachment Provisions for Payloads

Two types of Payload Retention Latch Assemblies (PRLA) are provided by the SSP to secure trunnions of deployable and nondeployable payloads to the Orbiter structure: longeron latches and keel latches. PRLAs react loads through the Orbiter structure in the X-X, Z-Z, and combined X-Z directions.

5.1.2.3.1 Longeron attach fittings

Longeron PRLAs are mounted on bridges attached directly to the Orbiter structure and are designed to restrain payloads weighing up to 65,000 pounds (29,484 kg). Longeron attach fittings are available as passive (for nondeployable payloads) and active (for deployable payloads), as shown in figure 5.1.2.3.1-1. Passive latches are fixed, nonelectrical structures, which cannot be controlled from the crew cabin. Active latch assemblies are electromechanical devices which each employ two three-phase reversible induction motors and the necessary gearing to drive a latch through a differential. Payload latch selection is made by NASA, and is determined by payload weight and c.g., total payload bay mix, and latch availability. All longeron latches currently in use have an Extravehicular Activity (EVA) manual override mechanism, which bypasses the drive train to allow manual operation of the latch.

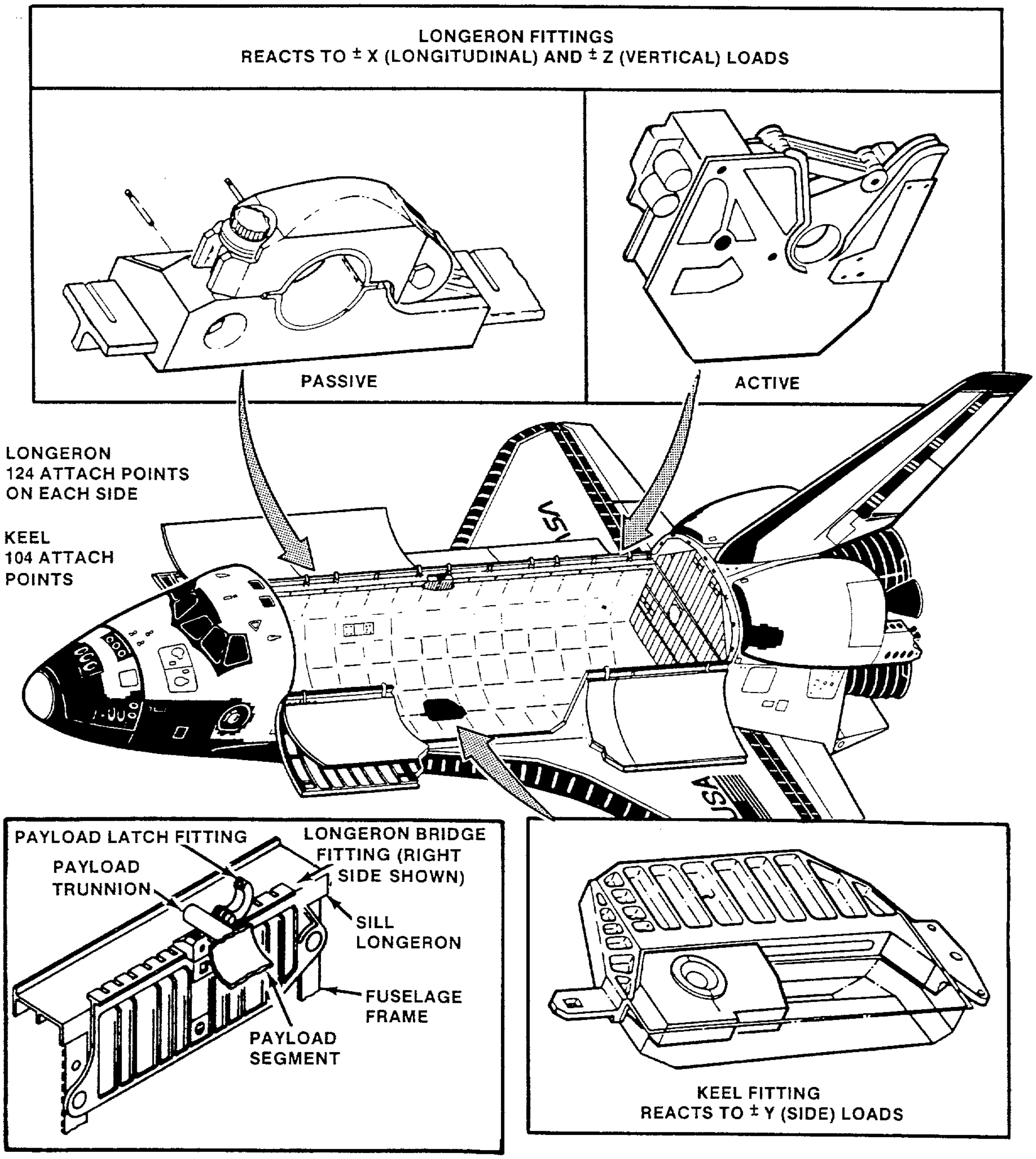


Figure 5.1.2.3.1-1. Attach fittings for payload

5.1.2.3.2 Keel attach fittings

Keel latches (figure 5.1.2.3.1-1) secure nondeployable and deployable payload keel trunnions to the Orbiter structure or payload cradle, and feature a trunnion-in-place switch. The keel attach fitting is remotely opened and closed, allowing payload installation, deployment, and retrieval. Keel latches mount to a standard keel bridge fitting and also use a tee-slot arrangement that is free to slide in the X direction.

5.1.2.3.3 Trunnions

Payloads are supported in the payload bay on payload customer-supplied trunnions extending beyond the 90-inch envelope in the $\pm Y_O$ directions and in the negative Z_0 direction at the payload bay bottom centerline (figures 5.1.2.3.3-1 and 5.1.2.3.3-2). Details of trunnion design are provided in ICD 2-19001. Payload trunnions are designed to be free to slide axially through split self-aligning bearings contained in Orbiter attach fittings which, in turn, are supported on bridges at the sides of the payload bay (longerons) and the bottom of the payload bay (keel). The chrome-plated trunnion/bearing surfaces are the interfaces, which transmit loads between the Orbiter and the payload. Maximum and minimum longeron trunnion lengths will be limited by Orbiter structure and by combined deflections of the Orbiter and the payload. To prevent excessive deflections in the Y direction from contacting the Orbiter, the payload designer/manufacturer will incorporate scuff plates described later.

A minimum longeron trunnion spacing of 27.53 inches is necessary to allow vertical installation and removal of the payload. The required trunnion diameter is 3.245 inches for longeron trunnions and 2.996 inches for keel trunnions. Payloads should be capable of being installed and removed with the Orbiter in either a horizontal or vertical attitude. Since SSP ground facilities do not attach to the keel fitting during installation, a ground handling trunnion is required for three-point supported payloads. GSE end caps on longeron trunnions are available for horizontal payload ground handling operations. A clearance envelope at the longeron trunnion interface will be provided for vertical payload installation/removal operations. For more information about payload ground handling, refer to section 7.

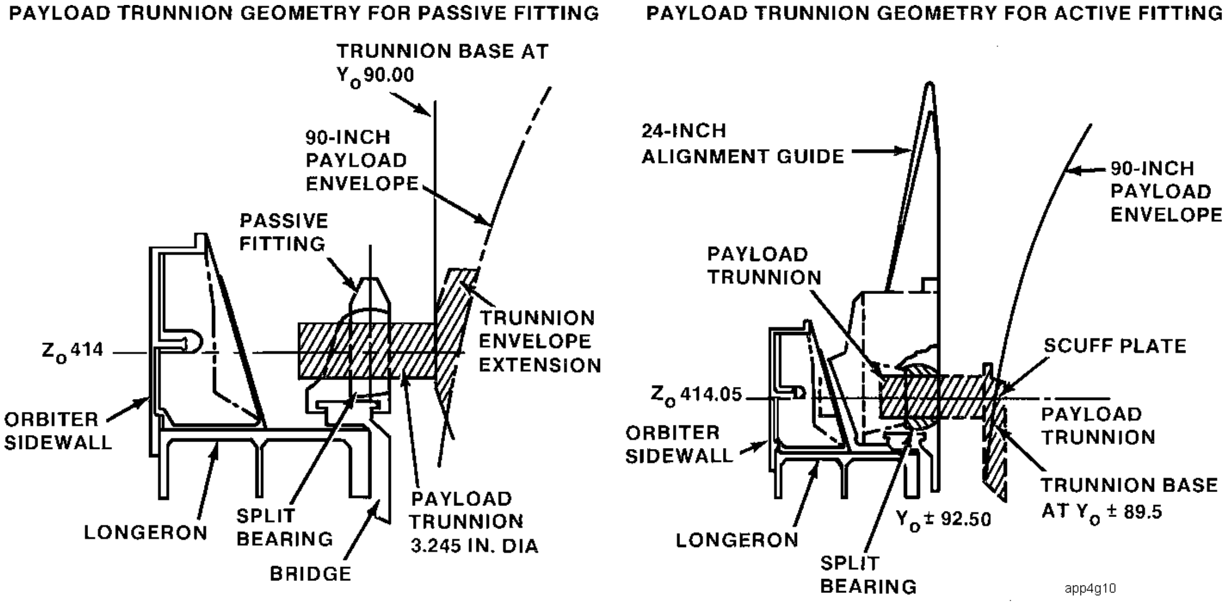


Figure 5.1.2.3.3-1. Trunnion geometry for active and passive fittings

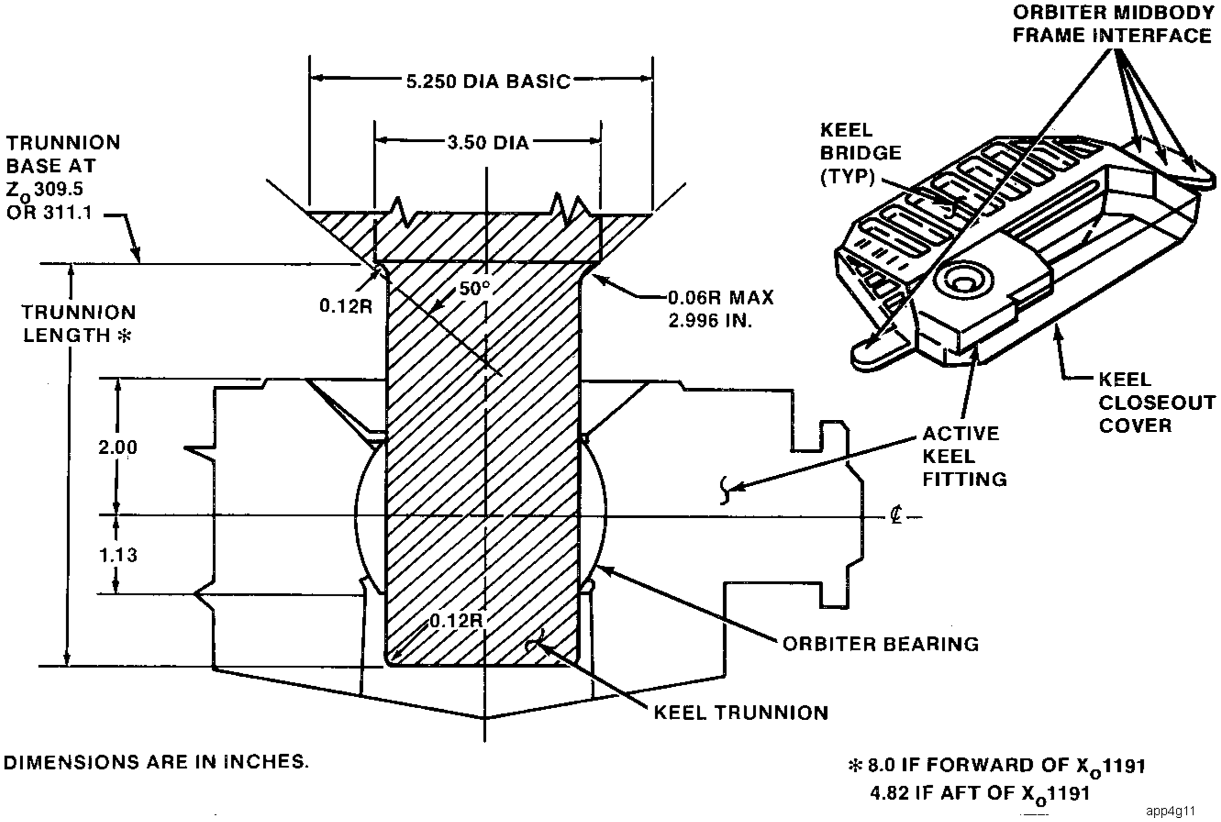


Figure 5.1.2.3.3-2. Payload keel fitting and trunnion

5.1.3 Sidewall Mounted Payload Accommodations

The SSP provides longeron-mounted beams for payloads that attach to the Orbiter sidewall. These include the APC, an ICAPC, or a Small Payload Accommodations (SPA) GAS adapter beam. See figure 5.1.3-1. Payloads that use sidewall mounting accommodations will be designed in accordance with the requirements specified in Shuttle/Payload Interface Definition Document for Small Payload Accommodations, NSTS 21000-IDD-SML.

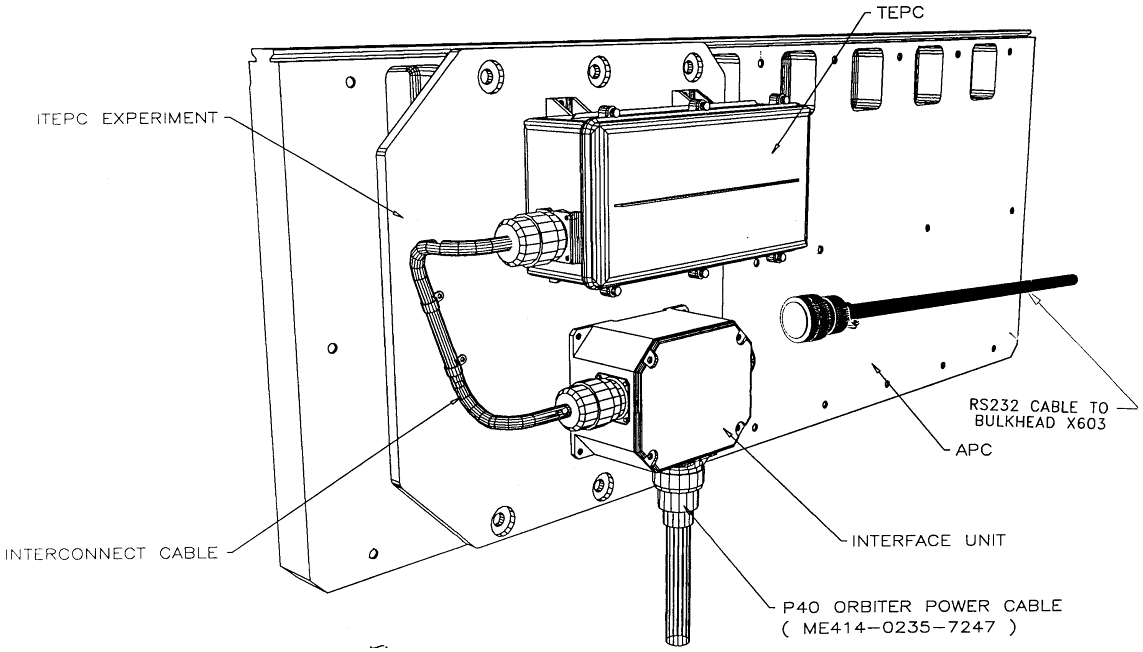


Figure 5.1.3-1. Typical payload - APC

5.1.3.1 Attachment/Installation

Sidewall-mounted adapter beams are attached to points on the payload bay longeron and frames, and use standard Orbiter bridge mounting hardware. Payloads can be attached to the adapter beams using the attach points identified in NSTS 21000-IDD-SML.

APCs and ICAPCs are aluminum partial bay sidewall carriers, which attach to the mainframe, stub frame, and sill longeron on the port or starboard side of the payload bay.

The APC is an aluminum plate designed to carry an equally distributed 300-pound (maximum) payload with its center of gravity (c.g.) not exceeding 6 inches from the APC inboard face. A 12-American Wire Gauge (AWG) grounding point is provided on the port APC and a 0-AWG on the starboard APC.

The ICAPC is designed to carry an equally distributed 500-pound (maximum) payload with its c.g. not exceeding 6 inches from the ICAPC. The ICAPC has ground attach points for 12-, 4-, and 0-AWG electrical bond jumpers.

The SPA GAS adapter beam is a full bay sidewall-mounted carrier with attachments to the main frames and sill longeron. The GAS adapter beam-to-payload interface provides 32 attachment inserts with precision close-fit bushings capable of transferring shear loads through the front cover plate, and is configured for shear plate accommodation for GAS canister applications. The GAS adapter beam can generally accommodate payloads of up to 700 pounds in bays 2 through 8 starboard, and bay 13 both port and starboard. The maximum weight capacity varies by location. The beams each have the capacity for mounting up to two GAS can payloads.

Information regarding attachment hardware and drill templates for sidewall carriers can be obtained from the SSP Cargo Engineering Office.

5.1.3.2 Get-Away Special Payload Accommodations

Standard GAS containers are provided in two volumes: 5 cubic feet (0.14 m^3) and 2.5 cubic feet (0.07 m^3). Payloads weighing up to 100 pounds (45.4 kg) can be housed in the 2.5-cubic foot containers, and payloads up to 200 pounds (90.7 kg) can be housed in the 5-cubic foot containers (figure 5.1.3.2-1).

The Goddard Space Flight Center (GSFC) is the integrator for GAS experiments. For design requirements, Get-Away Special (GAS) Small Self-contained Payloads, Experimenter Handbook, should be obtained from GSFC.

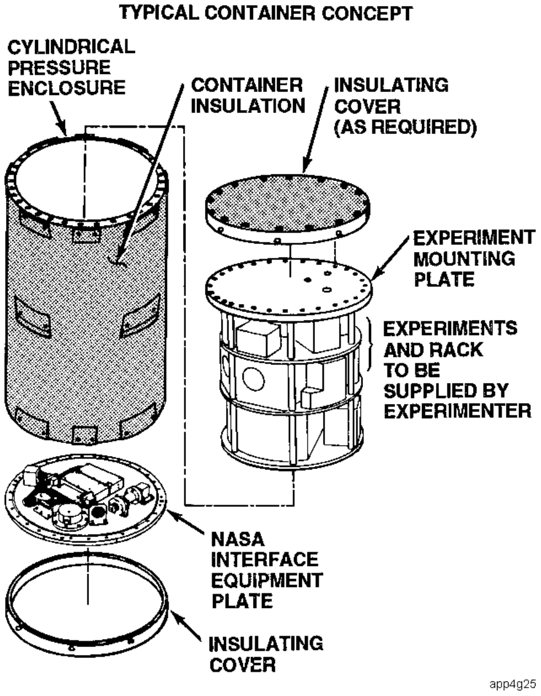


Figure 5.1.3.2-1. GAS payload canister and typical payload

5.2 ELECTRICAL POWER INTERFACES

5.2.1 Electrical Power for Payloads

The Orbiter Electrical Power Distribution System (EPDS) is a multiple source system consisting of three independent fuel cell power plants, which consume hydrogen and oxygen to generate electrical energy, and produces water as a byproduct.

Primary payload dc power is available at a payload-dedicated SIP mounted adjacent to the payload on the starboard side of the payload bay. Additional dc power can be provided for safety-related requirements from auxiliary buses. In the AFD, a limited amount of ac and dc electrical power can be provided at the Mission Station Distribution Panel (MSDP) and the Payload Station Distribution Panel (PSDP). DC power (only) can be provided at the On-orbit Station Distribution Panel (OOSDP).

DC power can be supplied from the aft end of the payload bay at station X_0 1203. AC power can be provided at station X_0 603 (starboard) and, for short-term use, from outlets located at each of the sill longeron payload retention system interfaces, 12 port and 12 starboard. Interface requirements, specific capabilities, and characteristics of the Orbiter EPDS are defined in Shuttle Orbiter/Cargo Standard Interfaces, ICD 2-19001.

5.2.1.1 Power Availability

Twenty-eight-volt (V) DC electrical power is available to payloads during all mission phases, but usage is restricted during periods when Orbiter demand is high. Maximum continuous power is the power at that level drawn by a payload when operating in its highest power consuming mode for periods of time generally longer than the peak power operating time limits as defined in ICD 2-19001. Peaks of less than 1 second are considered to be transients. Peak power consumption is limited in duration because of Orbiter thermal considerations and fuel cell limitations. During ascent and descent approximately 2600 W is available for payloads. This power must be shared by all payloads in the payload bay. During orbital operations, approximately 7 kilowatts (kW) is available to in the payload bay. This power also must be shared by all payloads. The on-orbit power allocation can be provided to payloads during ground operations before PLBD closure for payload checkout. After PLBD closure at the launch site, limited power can be provided. Actual power availability is dependent on vehicle and mission complement.

Voltage levels defined at the Orbiter/payload interface depend upon fuel cell output, payload power usage, payload bay temperature, and cable length. Minimum voltage levels are defined in ICD 2-19001. Customers with payloads requiring voltage levels outside this range should consider dc-to-dc converters.

Situations may occur when the Orbiter can provide only very limited power to payloads (e.g., during loss of Orbiter cooling or after a fuel cell failure). Power will be temporarily provided to the payload for payload safing. After payload safing, power may be cut off.

5.2.1.2 124 V Direct Current Power

One hundred twenty-four V DC power is only available when the Assembly Power Converter Units (APCUs) are installed in the payload bay. This power is available only during orbit operations, and is not available during ascent or entry. Interface requirements, specific capabilities, and characteristics of the Orbiter APCUs are defined in Shuttle/International Space Station Interface Definition Document, NSTS 21000-IDD-ISS and APCU ICD-A-21321.

5.2.1.3 Aft Bus Power

The Orbiter can provide payload dc electrical power from two outlets located at the aft fuselage in the payload bay. On/off control is available from an AFD panel. These 4-AWG buses are each fused at 80 amperes (A), and each can provide power up to 1500 W during ground operations and on-orbit or up to 1000 W for other mission phases as an alternative source, except during ascent when aft payload power is not typically available. These power sources exhibit reduced interface voltage at the payload caused by longer cable runs, and power quality degradation caused by an increase in hydraulic circulation pump transient noise on the aft buses.

5.2.1.4 Auxiliary Direct Current Power

Auxiliary power is available for payloads requiring a second power source for safety critical operations. Orbiter main buses A and B are the two sources of auxiliary dc power (28 Vdc nominal). Each can provide a maximum of 400 W for payload use, 200 W of which may be used in the AFD. Power may be drawn from either one or both simultaneously. The auxiliary buses may be tied together if diode isolated for must-work situations, however the total power is limited to 400 W.

5.2.1.5 Alternating Current

Three-phase, 400-Hz, 115-V ac electrical power (four wire, wye) is available for payloads except during prelaunch and ascent. Space Shuttle vehicle requirements preclude payload allocation during these mission phases. Orbiter ac buses 2 and 3 are the two sources of ac power. Each is protected on the Orbiter side of the interface by a 3-amp, three-phase circuit breaker (derated to 2.85 amps). During on-orbit operations, each bus can provide 690 VA maximum continuous and 1000 VA peak. AC power is available at the AFD and/or at the starboard SIP in the payload bay. Because of Space Shuttle vehicle ac power demands, payloads are limited to a total of 1380 VA maximum continuous (2000 VA peak) during orbital and ground operations (time-shared with Space Shuttle). During descent and postlanding, payloads are limited to 350 VA maximum continuous, 420 VA peak.

5.2.2 Payload Wiring and Harnesses

The Standard Mixed Cargo Harnesses (SMCHs) interconnect the payload with the standard Orbiter avionics. Services are provided by cables terminated at SIPs on the starboard and port side of the payload bay (figure 5.2.2-1). Additional SMCH cables are also available to interface the port SIP to GSE through the Orbiter T-0 umbilical. The T-0 umbilical, connecting the Orbiter to the ground facility, is disconnected at Space Shuttle lift-off.

The nominal Orbiter/payload avionics interface is the SIP, although other methods may be acceptable. One method is to use SSP-provided jumper cables instead of interface cables to interconnect the SIP and the payload. The payload has a connector panel mounted where the exiting cables would be clamped. Another approach acceptable only for fixed-position cable interfaces also uses a payload-mounted connector panel, but the Orbiter cables are routed directly to the panel rather than terminating at a SIP. It is the payload customer’s responsibility to provide the cables between the SIP and their payload interface.

Besides the standard interfaces to customer-provided GSE, up to six 12-AWG, HO-classified circuits through the T-0 umbilical can be provided to the payload at the starboard Orbiter/payload interface. For these circuits, KSC also provides large-gauge wiring to reduce the voltage drop between GSE and the payload. Each of the six circuits can deliver up to 33 amperes of dc power to the payload. If these circuits are not used by any payload manifested, the KSC large-gauge wiring distribution system can be substituted for the higher resistance facility circuits which connect to three specific HO circuits of the 12 circuits interfacing with the payload of the port SIP connector J102.

0-AWG and 4-AWG wiring are used to distribute primary DC power and aft power to payloads. Other wire sizes are possible using unique integration hardware as described in the following sections.

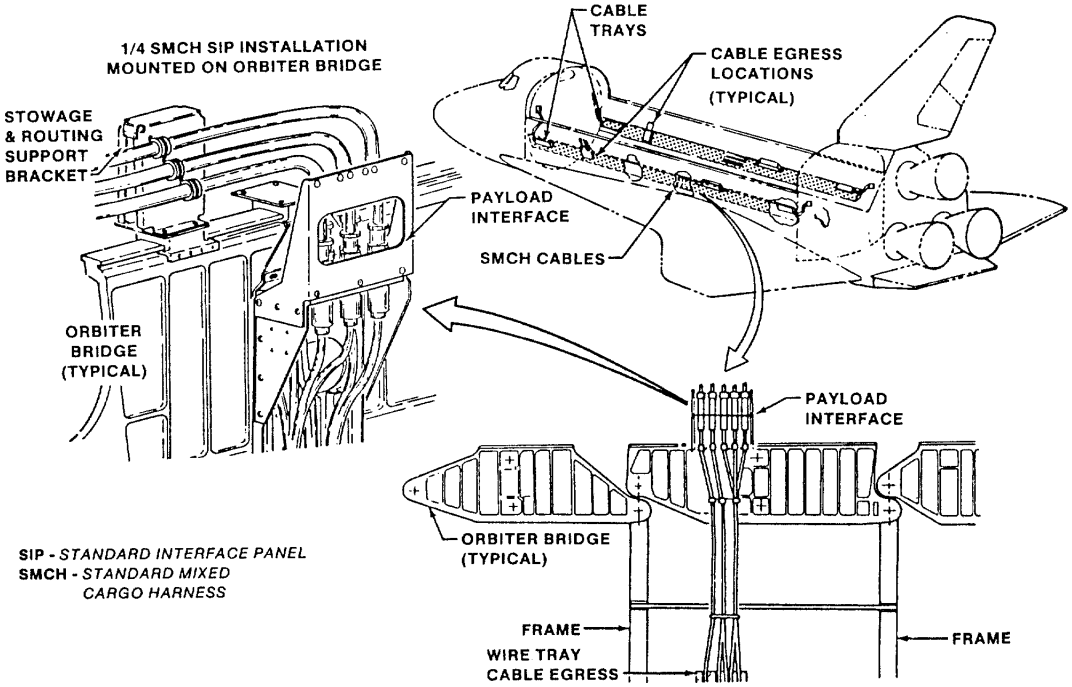


Figure 5.2.2-1. Standard interface panel

5.2.2.1 Remotely Operated Electrical Umbilical System

The Remotely Operated Electrical Umbilical (ROEU) system provides power and data interfaces between the Orbiter and a payload. The umbilical can be mated and demated on command from the AFD. The ROEU is designed to accommodate up to one quarter-SMCH services for deployable payloads. The ROEU accommodates Orbiter/payload relative motion as well as a minimal amount of Orbiter/payload misalignment during the mate/demate process.

The ROEU retracts to clear the payload during deployment and features minimal intrusion into the payload envelope.

Although there is dual redundancy in the drive motors, an EVA backup mate/demate capability also exists.

The ROEU mounts on the port or starboard bridge rail parallel to the Xo axis in the demated stowed position. The mate/demate operation will be commanded from the AFD using payload retention latch control logic.

A complete description of the ROEU is available in the JSC document JSC 23004, Remotely Operated Electrical Umbilical User's Manual.

The primary components of the ROEU system are the Orbiter Disconnect Mechanism (ODM) and the Payload Disconnect Assembly (PDA). The ODM mounts on an Orbiter bridge rail on either the port or starboard side of the payload bay. The ODM consists of an arm drive mechanism and an ODA.

As shown in figure 5.2.3-1, the one-quarter SMCH connects to the stationary end of the ODM and the PDA connects to the opposite end at the ODA.

The ODA and PDA comprise the two halves of the electrical services connection. The ODA contains the disconnect plug with socket contacts, while the PDA contains a receptacle with pin contacts. The PDA is provided to the payload customer for mounting on the payload.

The PDA is mounted on the payload using a mounting assembly. The mounting assembly provides for an X_0 displacement of ± 1.50 inches maximum (1.0 inches for payload use, 0.5 inches for system use). This displacement accommodation is placed on the PDA rather than the Orbiter positioning mechanism to minimize intrusion of the ODM into the payload envelope. An interface cable runs between the PDA and the payload. The number of wires in the interface cable varies as requested by the payload customer. The PDA is sized to accommodate 25 size 20 AWG pins, 15 size 8 AWG pins, and 6 size 12 AWG pins. The cable is wired to the PDA receptacle on one end of the cable. The other end of the cable is terminated by the payload customer. The payload interface cable shall be routed by the payload customer to provide cable stress relief at the PDA displacement accommodation assembly. The cable routing shall provide maximum restraining force of 15 pounds when the displacement accommodation assembly traverses its full travel of ± 1.50 inches. Any ROEU interface panels required for interfacing with the payload are provided by the payload customer and controlled by the applicable ICD.

Control and status monitoring of the electrical mate/demate process is accomplished through the payload retention control panel in the AFD. Power and command/data circuits routed to the payload via the ROEU will be procedurally deadfaced by the customer prior to mating or demating of the ROEU.

The ROEU accommodates a lateral displacement of the ODA/PDA electrical interface along the Y_0 axis by +3 inches, -2.75 inches. No spring force is applied to the payload after full mate and latch verification has occurred and the Orbiter arm drive mechanism is at its intermediate relaxed position.

The force capability of the electrical latch mechanism for mating and demating is a minimum of 400 pounds. This force is produced by the dual drive motors through the gear train assembly and the latch mechanism. The forces will be reacted within the Orbiter deployment mechanism and payload disconnect assembly and will not be imparted to the payload.

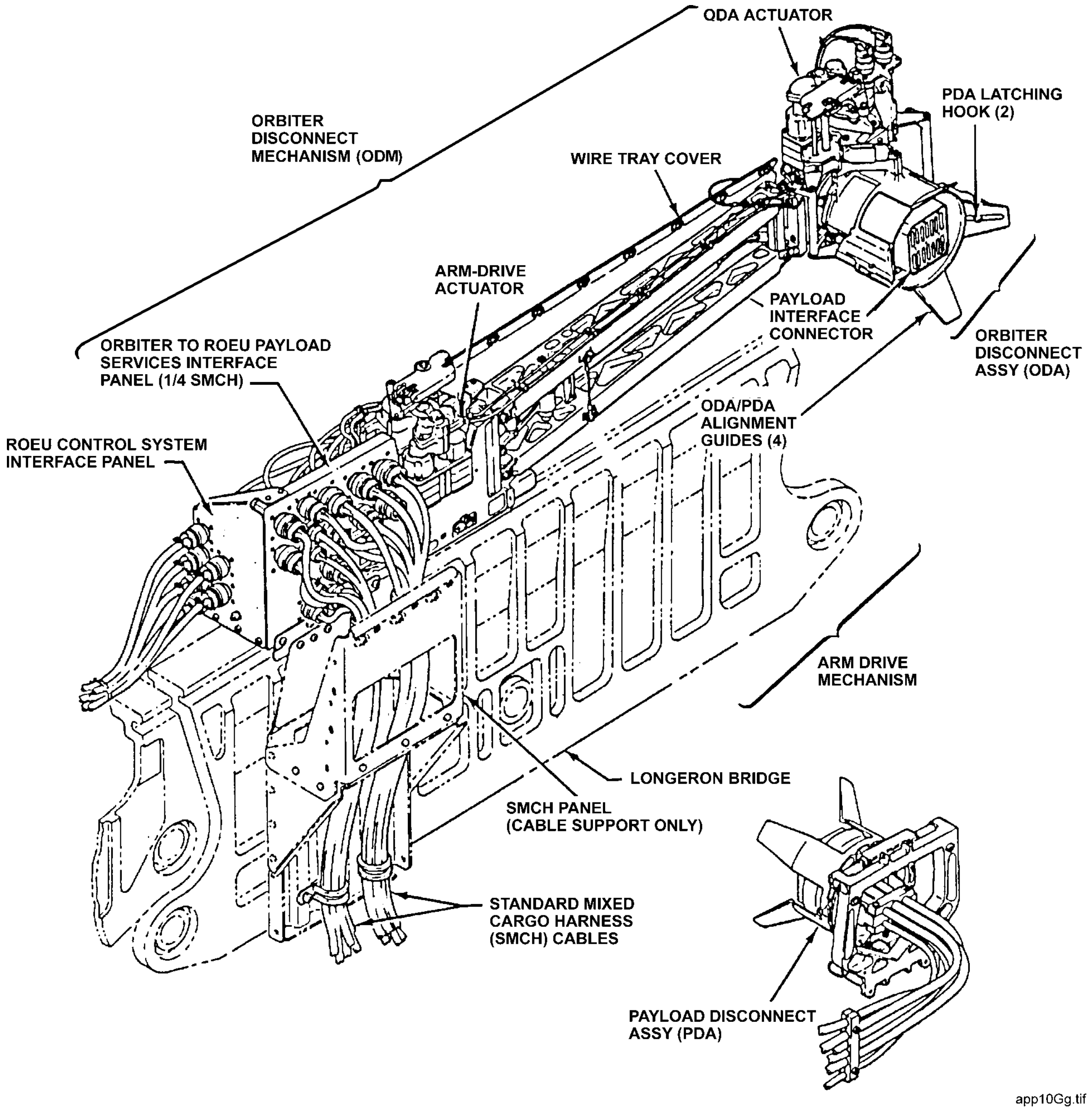


Figure 5.2.3-1. Typical ROEU mounted on a bridge rail (demated position), port side installation

5.2.2.2 Payload Power Switching Unit (PPSU)

The Payload Power Switching Unit (PPSU) is designed to provide the capability for command, data feedback, via Standard Switch Panel and distribution of 0 AWG and 4 AWG 28 V dc power. The PPSU provides two each 8 AWG outputs per system A and system B.

The system is designed to mount on either the port or starboard wire tray at any location defined for the wire tray foldback cover. In addition, an adapter plate has been designed which allows mounting of the PPSU on an APC at any applicable payload bay location.

The PPSU and typical payload bay installation are shown in figure 5.2.2.2-1.

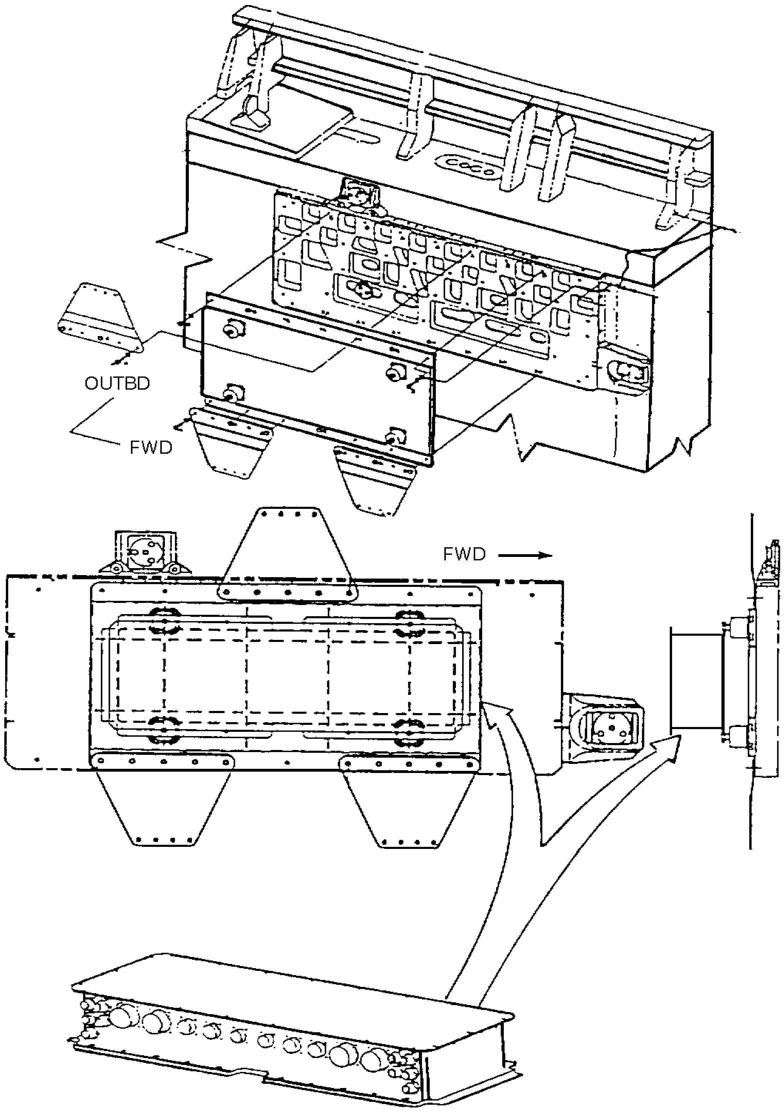


Figure 5.2.2.2-1. PPSU typical installation of APC

5.2.2.3 Station Power Distribution Unit

The Station Power Distribution Unit (SPDU) is designed to distribute 124 V DC APCU power to downstream loads in the payload bay. The SPDU has two input connectors with 8 AWG pins. Each connector is powered by a separate APCU. The SPDU has two EVA compatible (NZGL type) output connectors. Each SPDU output connector provides four fused (7.5 A), derated to 3.75 A, 16-gauge pins and four corresponding 16-gauge return pins. The SPDU output connectors also support a fault bond between the Orbiter and the payloads. See figure 5.2.2.3-1 for an SPDU wiring schematic.

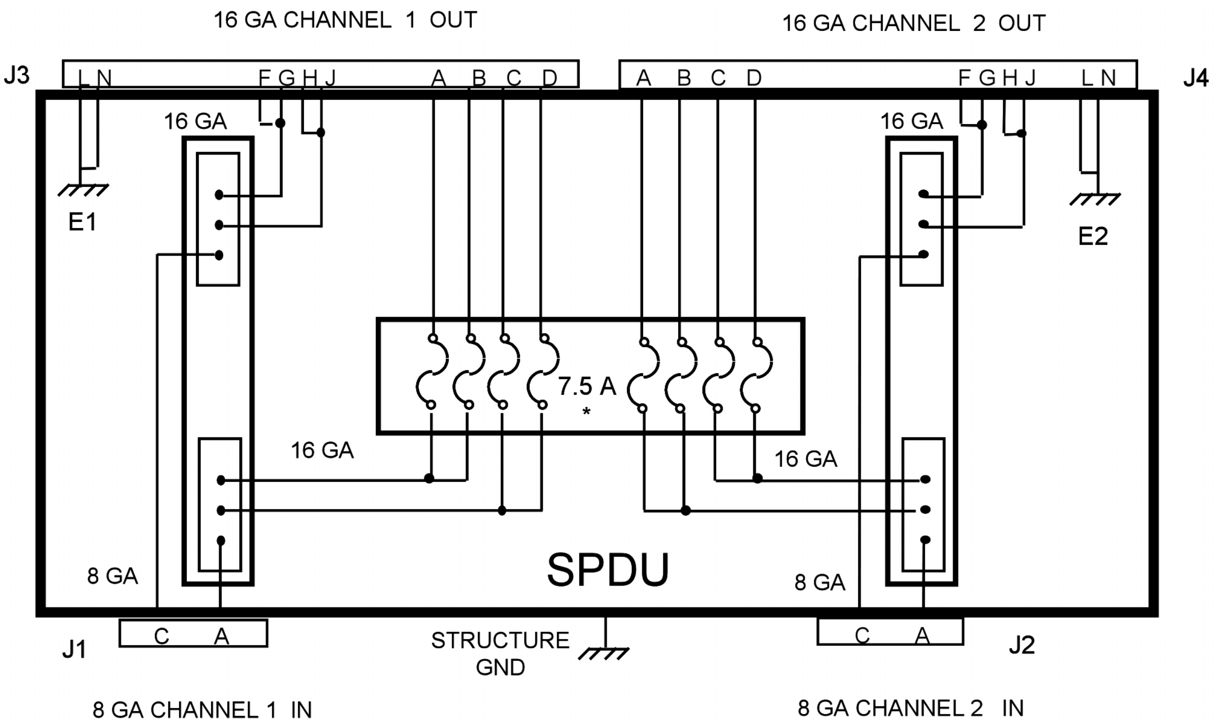


Figure 5.2.2.3-1. Station power distribution unit

5.2.2.4 Power Accommodation Terminal

The Power Accommodation Terminal (PAT) is a power distribution device that accepts Orbiter dc power from either main dc (0 AWG) or aft dc power (4 AWG) and provides four 8 AWG outputs for payload use. The PAT is designed to fit on the payload bay wire tray and it can mount on either port or the starboard side of the bay. A simplified schematic of the PAT is shown in figure 5.2.2.4-1.

The PAT has been certified for use with the Orbiter APCU-provided 124 V dc power. The PAT accepts power from the APCU via one of the four 8-AWG connectors, and can distribute it to users via the other connectors.

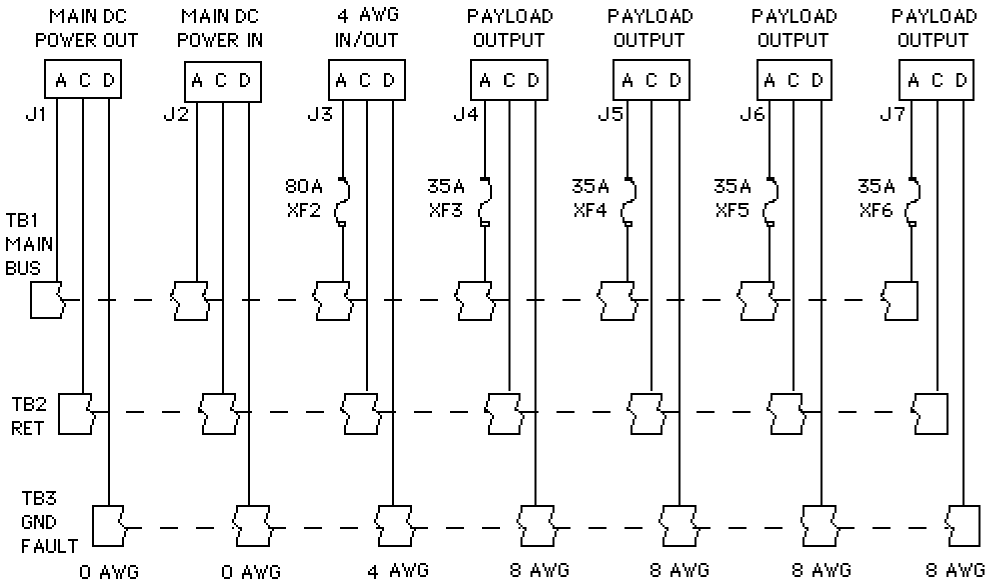


Figure 5.2.2.4-1. Simplified schematic of the PAT

5.2.2.5 Small Payload Accommodation Terminal

The Small Payload Accommodation Terminal (SPAT) is a power and signal distribution assembly provided for integration of small payloads. A summary of the SPAT electrical interfaces is shown in figure 5.2.2.5-1. The SPAT box accepts a 0-AWG power input and provides 35 A fused 8-AWG power outputs for use by small payloads. Electrical control and data signals are passed through the box between Orbiter systems and small payloads through connector J7/J8 (RF) or J9/J10 (HO).

A unique display and control panel is provided to support operation of small payloads. This panel is intended to be installed in either the A6A2 or A7A2 positions at the on-orbit station.

The SPAT is installed in the payload bay and provides uplink to small payloads via the payload signal processor or directly from the Ku-band signal processor, downlink via the

Payload Data Interleaver (PDI), timing via the Orbiter timing buffer, power via the main dc distribution assembly, and switching via the SPA unique switch panel.

The SPAT is designed to fit on the payload bay wire tray in place of two wire tray covers. Mounting fasteners of the same type are used to secure the closeout covers to the wire tray.

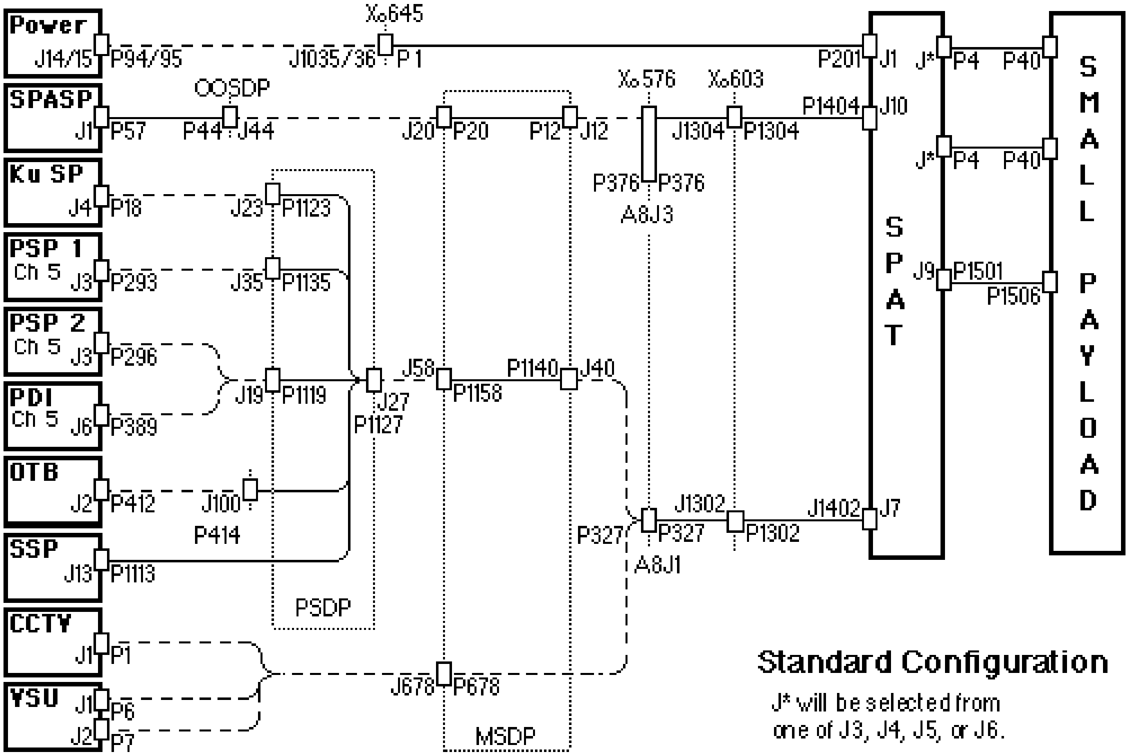


Figure 5.2.2.5-1. SPAT electrical interfaces

5.3 COMMAND AND DATA INTERFACES

5.3.1 Air-to-Ground Communication Systems

During orbital operations, the Space Shuttle provides payload command and data capability via the Space Network (SN) which consists of S-band ground tracking sites and the TDRSS (see figure 5.3.1-1).

5.3.1.1 Space Network Ground Stations

The SN consists, in part, of a worldwide system of S-band ground tracking stations. Ground tracking stations provide augmented support of S-band telemetry, commanding, and voice outside the Tracking and Data Relay Satellite (TDRS) coverage zone. The TDRSS network supports all orbital operations.

Ground site functions include receiving and recording of all telemetry, real-time transmission of 64- or 128-kbps real-time operational telemetry to the MCC, and conversion of voice to analog signals for transmission to the MCC. Voice from the MCC is digitized, encrypted, and time-division-multiplexed with command data for the uplink.

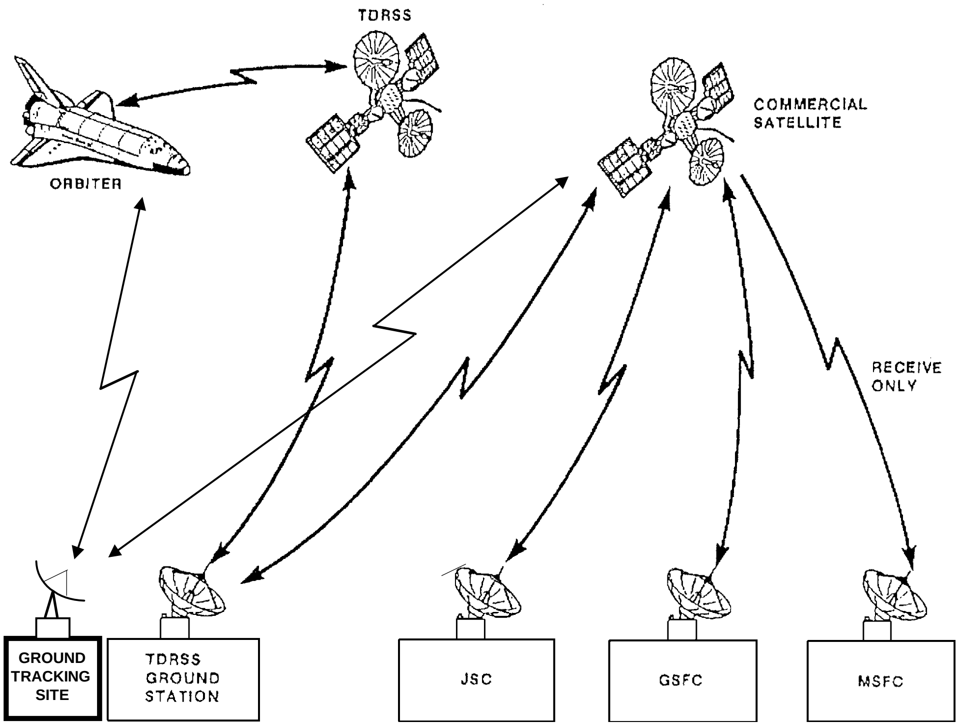


Figure 5.3.1-1. Flow diagram of ground communications

5.3.1.2 Tracking and Data Relay Satellite System

The TDRSS consists of geosynchronous operational satellites separated by 130 orbital degrees (figure 5.3.1.2-1) and a ground station at White Sands, New Mexico. The TDRSS system provides PM interfaces to the Orbiter Ku-band system and the S-band PM system. At flight altitudes of 161 to 322 km, the TDRSS typically provides communications for near-continuous coverage compared with ground tracking station communications contact of 7 to 30 percent of continuous coverage. TDRSS ground station data is routed via commercial satellite to ground stations located at JSC, GSFC, and Marshall Space Flight Center (MSFC).

Real-time and playback telemetry, digital voice data and video can be transmitted to ground. TDRSS also provides uplink capabilities for commanding, voice, and other services on a link available basis.

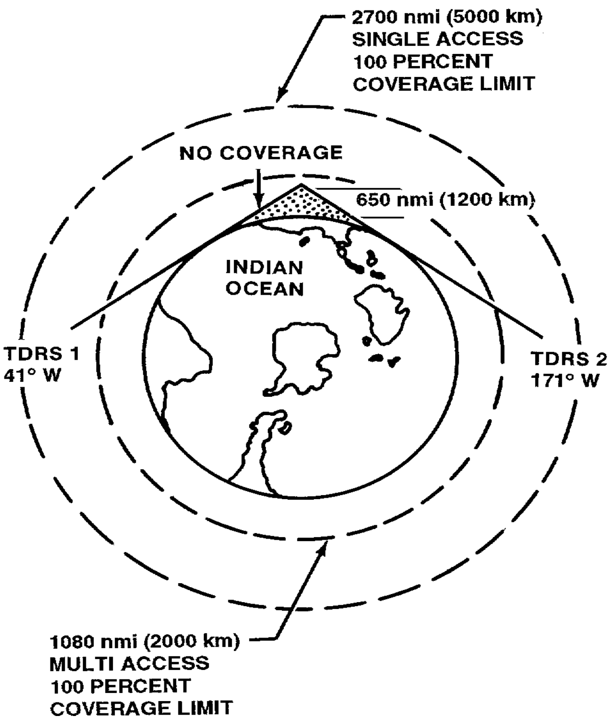


Figure 5.3.1.2-1. Coverage capability of TDRSS

5.3.2 Command Services for Payloads

A payload may require Orbiter and ground communications. The Orbiter contains versatile payload-oriented avionics hardware and software, and provides communications links to various ground stations.

The Orbiter avionics system supports the following:

1. Payload command interfaces
2. Transfer and/or relay of command data from the SN and TDRSS to attached and detached payloads

Payload commands to either attached or detached payloads may be uplinked from the ground or initiated onboard. Onboard commands are initiated from the Orbiter General Purpose Computer (GPC) and the Payload General Support Computer (PGSC). Uplink commands are initiated from the Mission Control Center (MCC) or a Payload Operations Control Center (POCC), and transmitted by the MCC. Payload command flow is shown in figure 5.3.2-1. Additionally, onboard commands can be initiated from the standard switch panel to an attached payload.

Uplink commands from the operational uplink are transmitted from the ground to the Orbiter through the S-band PM link or the Ku-band link. These links must be time shared between payload and Orbiter system requirements. Commands are processed through the Orbiter data system and sent to attached or detached payloads.

Command data are encoded to 8 kbps and multiplexed with digital voice information for a total uplink of 32 kbps (one 24 kbps digital voice channel used during S-band operations through the TDRSS) or 72 kbps (two 32 kbps digital voice channels used during S-band operations direct with ground or Ku-band operations through TDRSS). All uplink commands include a destination. The following uplink command types can be processed by the Orbiter and transferred to the payload:

1. Single-stage commands are processed by the Systems Management (SM) GPC as soon as complete data is received in the two-stage buffer. Unlike two-stage commands, the execute flag is appended to the payload command for single-stage commands. There is no downlist verification of command contents before transmission.

2. Two-stage commands are uplinked as a load command and a separate execute command. The load is stored in the two-stage buffer, then downlisted (at 1.04 Hz) to the ground for validation. If the load is ascertained to be correct, an execute command is sent. The load is transferred to its destination within 2 seconds of receiving the execute command.

3. Stored program commands (SPCs) are a subset of two-stage commands which allow the execution time to be specified within the command. The GPC software processes the SPCs as is done for two-stage commands, but instead of executing the SPCs upon the reception of an execute command, the commands are stored until the time specified with the command matches the current monitor time. At such time, the command is executed. SPCs are used only for setting or resetting system discretes. A limit of 25 commands can be stored in the GPC.

4. Time-Executed Commands (TECs), like SPCs, are executed at specified times, TECs send serial commands to a payload through a payload MDM (PF01) Serial Input/Output (SIO) channel, a customer-provided bus terminal unit SIO channel, or Payload Signal Processor (PSP). A maximum of 25 TECs can be stored in the GPC at one time and TECs may be replaced by uplink commands. A maximum of 64 sixteen-bit words is allowed for each TEC (excluding the Greenwich mean time (g.m.t.) of execution) if the destination is the PSP; 32 sixteen-bit words maximum is allowed if the destination is a payload through a nonstandard-service SIO channel of a payload MDM. The maximum rate of TEC execution is one TEC per second.

Prelaunch services are limited as follows:

1. Before PLBD closing, on-orbit SM payload software is provided for payload interface verification testing.

2. GPC applications software (called vehicle utility) allows the ground to communicate with payloads utilizing the Launch Data Bus (LDB) interface. This is a limited optional capability which allows the ground to send individual requests to the Orbiter GPC for execution. The ground can specify that a resulting response will be transmitted from the LDB. Interfaces supported for commands are payload Multiplexer/Demultiplexers (MDMs), and payload data buses.

Commands during ascent and descent are limited to MCC-initiated uplink discretes only (no crew-initiated commands). Interfaces supported for commands are payload MDMs, and payload bus terminal units attached to payload data buses.

Payload command characteristics, rates and structure are defined in ICD 2-19001 and the Shuttle Orbiter/Small Payload Accommodation Interface Document, NSTS-21000-IDD-SML. Detailed requirements for commands sent to the payload will be defined in the Command and Data Annex, (IP Annex 4).

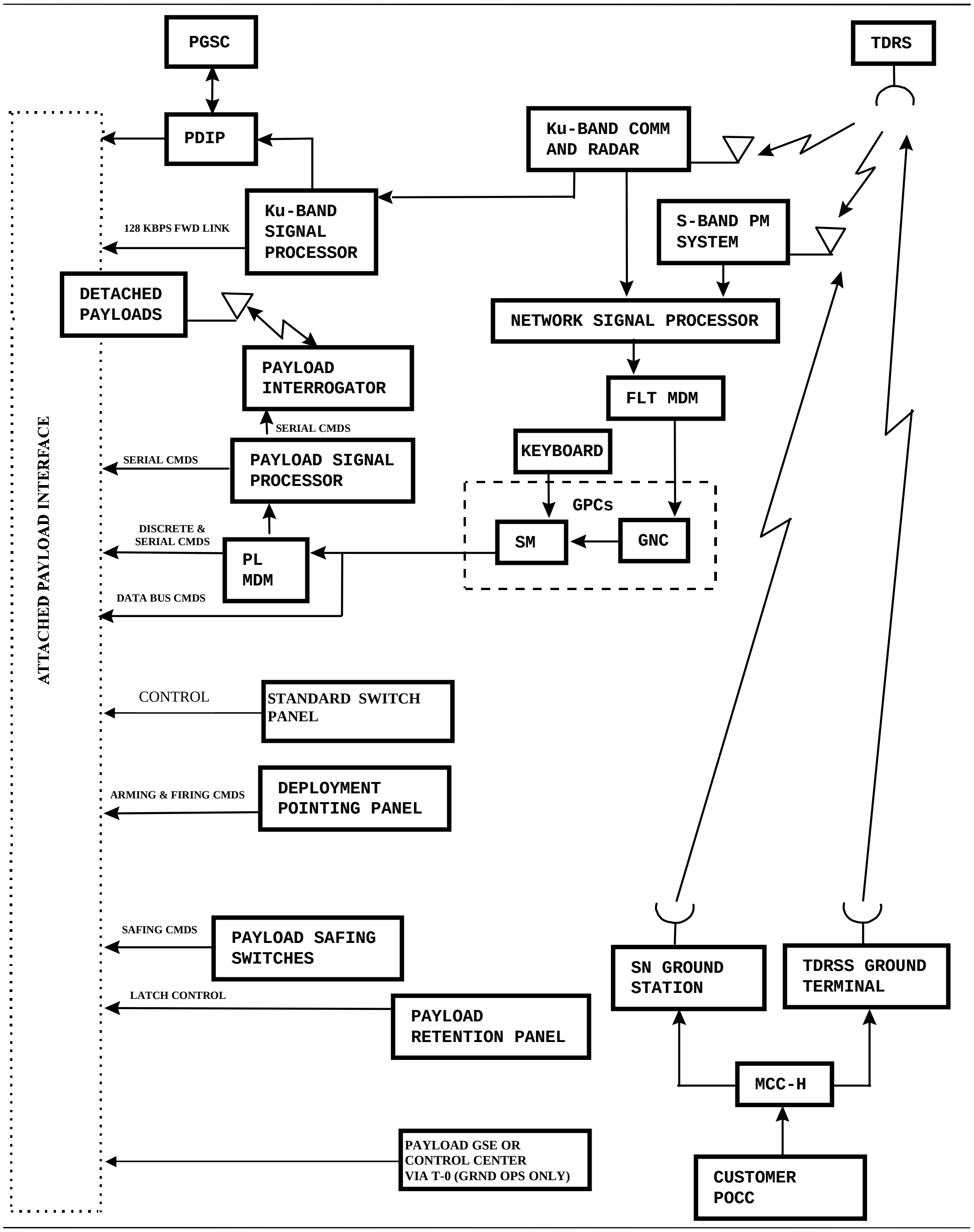


Figure 5.3.2-1. Command services data flow

5.3.2.1 Hardwired Commands from the Standard Switch Panel

Switch closure and/or 28 V dc commands are provided from the standard switch panel at the payload station on the AFD. Overlay panels identify specific payload functions (reference figure 5.3.2.1-1).

There are two standard switch panels for shared use by all payloads. Each has two identical half sections. Each standard switch panel half section provides 12 switches for payload use. Switch configurations characteristics and voltage levels are defined in ICD 2-19001.

If a customer elects to provide the excitation voltage to switches on the standard switch panel, each circuit shall be current-limited on the payload side to the equivalent of a 5-amp fuse or less.

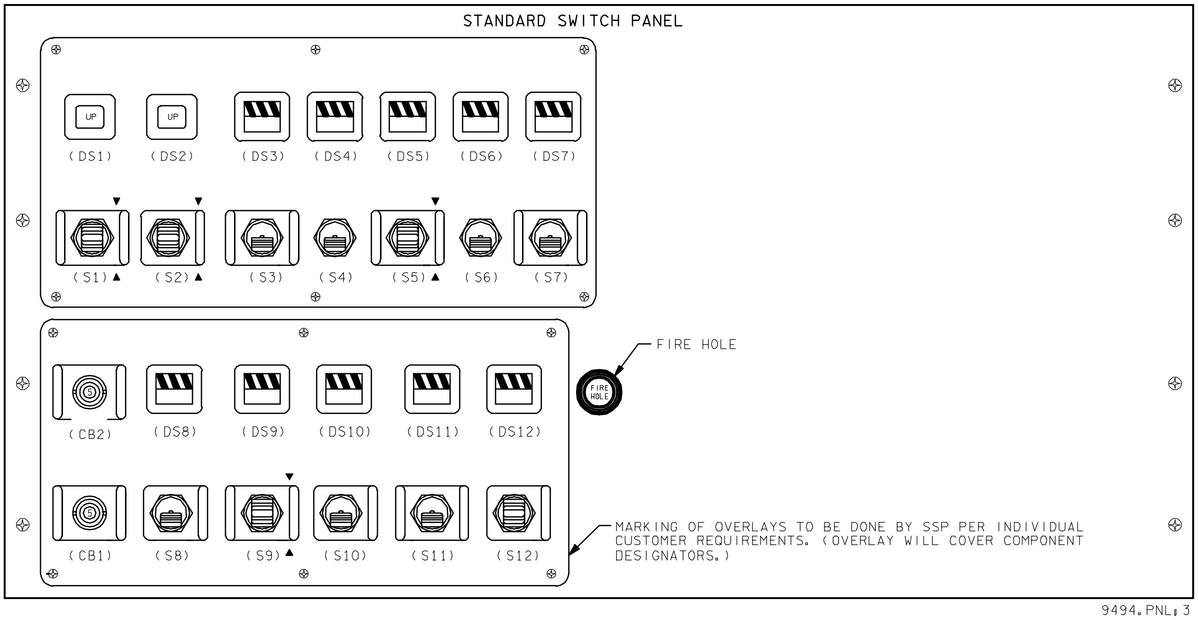


Figure 5.3.2.1-1. Sample standard switch panel

5.3.2.2 Payload Hardwired Multiplexer/Demultiplexer Commands

The Orbiter payload MDMs act as data acquisition, distribution, and signal conditioning units. MDMs accept serial digital information from the SM GPC through the GPC data bus system and convert or format this information into analog, discrete, or serial digital form for transfer to Space Shuttle subsystems and payloads.

Discrete commands are provided at the payload wiring interface by an Orbiter MDM. Commands are controlled by the Orbiter GPC in response to keyboard entries from the flightcrew or by commands from the MCC. Output signals are discrete, high-level signals (0 to 28 V dc) and discrete, low-level signals (0 to 5 V dc).

Characteristics of the MDMs are described in ICD 2-19001. Reference Shuttle Orbiter Failure Modes and Fault Tolerances for Interface Services, NSTS 16979 for further details.

5.3.2.3 Commands Using the Payload Signal Processor

Serial digital commands to attached payloads are available through one of two PSPs. These commands can be initiated onboard using the Orbiter GPC, at the MCC, or at the POCC through the MCC. MCC can forward payload commands initiated at the POCC. Nine specific burst data rates up to 2 kilobits per second (kbps) and three Nonreturn-to-Zero (NRZ) data codes are available. The allowable data rates are 2000, 1000, 500, 250, 125, 125/2, 125/4, 125/8, or 125/16 bps and are defined in Shuttle Orbiter/Cargo Standard Interfaces, ICD 2-19001. Use of the PSP must be time-shared with the Orbiter. The customer must supply the command data in hexadecimal form before the mission.

5.3.2.4 Commands Using the Payload Interrogator

The Payload Interrogator (PI) supplies an S-band RF link to command payloads, which are compatible with the SN and Deep Space Network (DSN). Command signals from the PSP through the PI are on a 16-kilohertz (kHz) subcarrier which is Phase Shift Key (PSK) modulated by the baseband command signal. Nine specific burst data rates up to 2000 kbps and three NRZ data codes are available.

The PI can simultaneously transmit commands to and receive telemetry from a DSN- and SN-compatible transponder-equipped payload. The PI can operate on any single set of frequencies (one transmit, one receive) selected from the 831 NASA payload transmit/receive frequency sets (808 SN sets plus 23 DSN sets). The transmit-to-receive frequency ratio is 221/240. The PI also provides four receive-only and six transmit-only channels. The transmit/receive frequency channel allocations are listed in ICD 2-19001.

The receiver can automatically acquire, lock on to, and phase track modulated and unmodulated payload RF signals in the 2200 to 2300.875-Mhz frequency band. The receiver will automatically acquire phase-modulated RF signals at any assigned frequencies listed in ICD 2-19001 plus or minus (±80 kHz). The sweep generator of the phase lock loop is automatically inhibited when a valid carrier lock is achieved.

Use of the PI must be time shared on-orbit. Priority use of the PI will be given to the payload undergoing deployment. Payload selection is accomplished by switching frequencies.

5.3.2.5 Software for Onboard-Initiated Single Commands

The standard onboard command processing capability can initiate single commands through the SM GPC. These commands can be issued to a payload data bus, the Orbiter payload MDM, or the PSP (for attached or detached payloads).

5.3.2.6 T-0 Umbilical Commands

During prelaunch ground operations, T-0 umbilical cabling may be used for commands originating in payload GSE or a local payload control center. Launch-critical commands through the T-0 umbilical must be adequately redundant.

5.3.2.7 Uplink Commands through the Ku-band Forward Link

The Orbiter 128 kbps uplink command capability can provide command data to payloads but must also be time shared to support the Orbiter. The PGSC interfaces via Payload Data Interface Panel (PDIP) with the Ku-band 128 kbps forward link, allowing transfer of computer files between a ground based computer and a PGSC onboard the Orbiter.

5.3.2.8 Deployment Pointing Panel

Payload deployment and payload manual pointing capabilities are available using the Deployment Pointing Panel (DPP) in the AFD and a manual pointing controller which operates with the DPP. The DPP has two toggle switches and a rotary switch which can arm and fire any one of nine separate pyrotechnic devices, see figure 5.3.2.8-1. It also provides the signal conditioning and output selection for payload pointing signals originated in the Manual Pointing Controller (MPC) which connects to the DPP.

The pyrotechnic initiation functions of the DPP are typically used for payload deployment when the payload has a cradle that remains in the payload bay. The panel provides separately switchable 28-V dc Arm and Fire discretes to the payload.

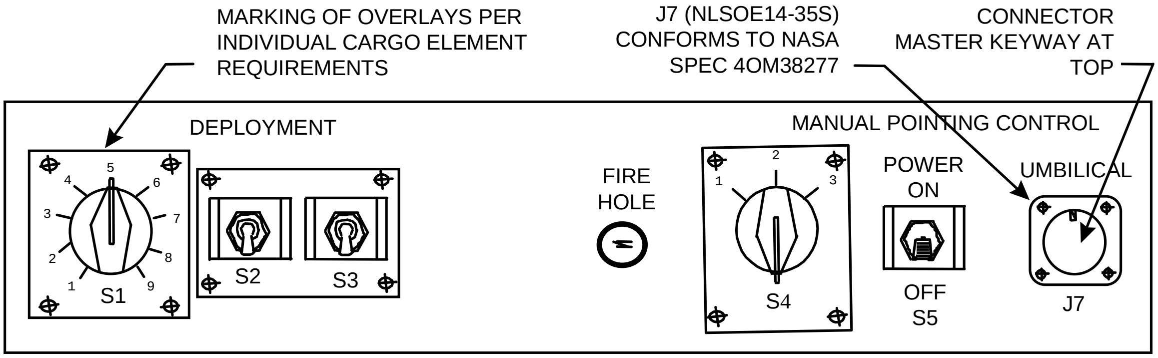


Figure 5.3.2.8-1. Deployment pointing panel front panel layout

5.3.2.9 Payload Safing Switches

Five safing switches are allocated for active payloads which may require safing in the event of a malfunction. These payload safing switches are located on the center console between the Space Shuttle commander and pilot (panel C3A5). Each switch can send a payload-provided signal back to the payload. The customer must provide excitation voltage current limiting to the equivalent of a 5-A fuse or less. This function can be used with the caution and warning alerts discussed in paragraph 5.3.3.9.

5.3.2.10 Ku-band Signal Processor

The Ku-band communication system is a combined system with the rendezvous radar. The system cannot be used in both the radar and communication modes at the same time. Ku-band service is not available when the PLBDs are closed. Ku-band Signal Processor (KUSP) data flow is shown in figure 5.3.2-1.

The KUSP provides a 128-kbps forward link channel for payload use, which must be time-shared with the Orbiter. The forward data link is in NRZ-L format accompanied by a clock. Characteristics of the data and clock signals are defined in ICD 2-19001.

For mixed user flights, where some payloads are susceptible to Ku-band electromagnetic interference, deployment operations will be coordinated to preclude incompatible operations.

The KUSP can be accessed by a PGSC to allow two way transfer of computer files with a ground based computer.

5.3.2.11 Payload and General Support Computer

The SSP can provide a PGSC to support in-flight payload operations. The PGSC is a laptop computer that can communicate with payloads in the payload bay using recognized standards. The SSP can provide the required cables necessary to interface to the Orbiter. The PGSC has different configurations depending on the service required. The PGSC supports several communication standards such as RS-232C, RS-422A, Ethernet. For more detailed information, see Shuttle/Payload Interface Definition Document for the Payload and General Support Computer (PGSC), NSTS 21000-IDD-760XD.

5.3.2.12 Small Payload Accommodations Switch Panel

The Small Payload Accommodations Switch Panel (SPASP) has six switch closures for payload use. These functions, which are hardwired to the payload, can be used on-orbit by the crew during active payload operations. Overlay panels identify specific payload functions. SPASP interface requirements and characteristics are defined in NSTS 21000-IDD-SML.

5.3.3 Data Processing and Display Services for Payloads

Payload data processing and monitoring are available onboard the Orbiter, at MCC, and at the POCC. Payload telemetry is forwarded by the Orbiter communication systems to the MCC and the POCC. Telemetry service data flow is shown in figure 5.3.3-1.

For data acquisition, the Orbiter can accept analog, discrete, serial digital, and Pulse Code Modulation (PCM) data from attached and detached payloads and process it for telemetry, recording, and/or display.

Payload telemetry data can be transmitted to the ground by the Orbiter S-band Phase Modulation (PM) link or Ku-band link. When a communication link to a ground station or

TDRSS is unavailable, some payload data can be recorded on the Modular Memory Unit (MMU) recorder for playback at a later time.

Communication between the Space Shuttle and a detached payload is provided via an S-band duplex RF link.

Interfaces supported for data acquisition are Payload Data Interleaver (PDI)/Pulse Code Modulation Master Unit (PCMMU), payload MDMs, and payloads attached to payload data buses.

Details of Orbiter capability to support payload data are defined in ICD 2-19001 and the Shuttle Orbiter/Small Payload Accommodation Interface document, NSTS-21000-IDD-SML. Detailed requirements for data accessed from the payload will be defined in the Command and Data Annex, (IP Annex 4).

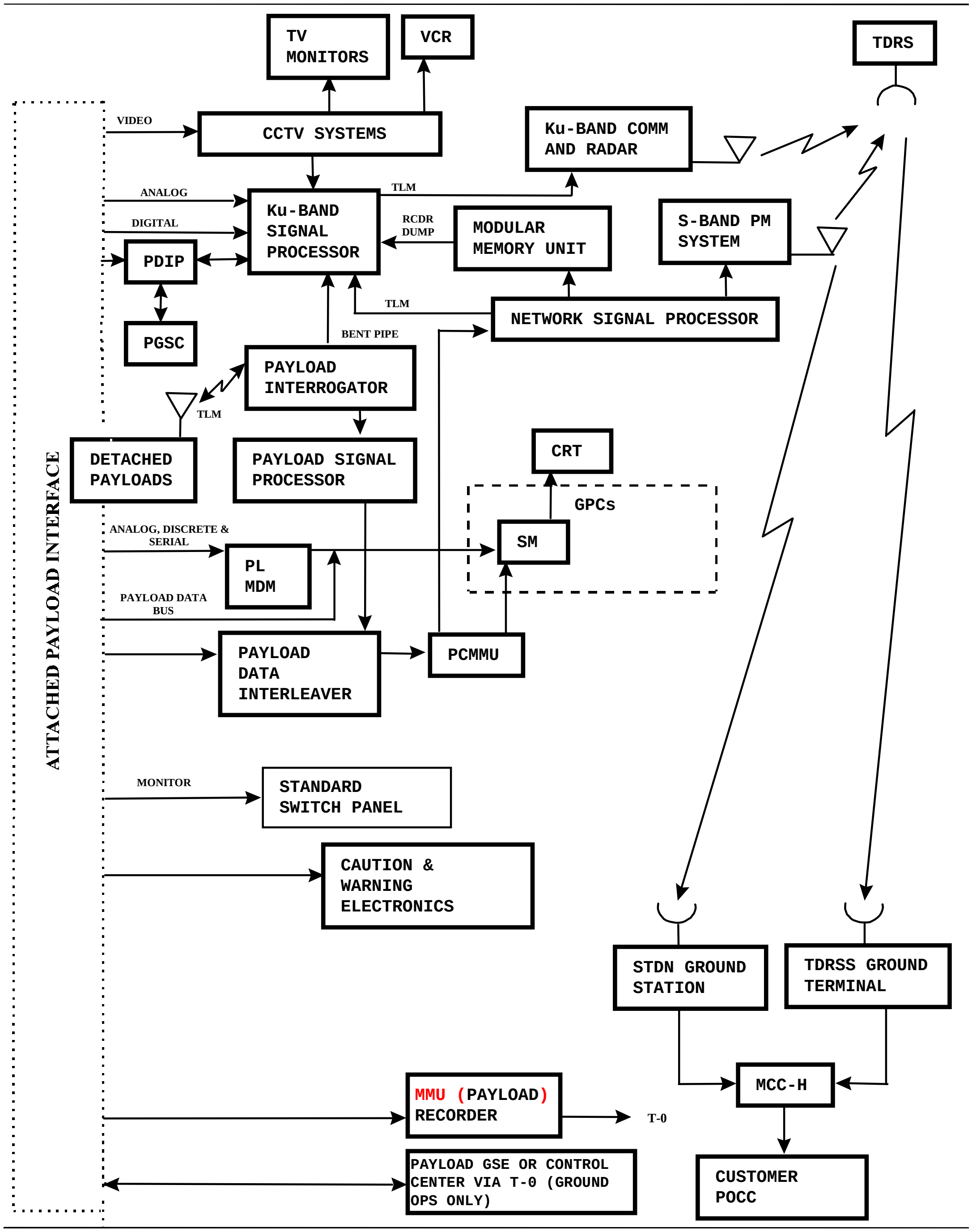


Figure 5.3.3-1. Telemetry services data flow

5.3.3.1 Hardwired Displays from the Standard Switch Panel

There are two standard switch panels for payload use (see figure 5.3.2.1-1). Each has two identical half sections. Each standard switch panel half section provides 12 status indicators (talkbacks) driven by nominal 28-V inputs, which enable the crew to monitor payload status and operation. Ten of the 28 V dc talkbacks are discrete, two-position status indicators and two are 3-position status indicators. These indicators are normally only used during active crew control of payload operations and are not monitored during crew sleep periods. Characteristics of and access to these indicators are given in ICD 2-19001.

5.3.3.2 Hardwired Data and Displays from the Orbiter Multiplexer/Demultiplexer

The MDM can receive discrete low level signals (0 to 5 V dc), discrete high level signals (0 to 28 V dc) and analog differential signals (-5 to +5 V dc) for onboard data processing or transmission to ground stations.

Analog and discrete payload signals received by the Orbiter MDM can be monitored onboard, at the MCC, and at the POCC. These signals may be limit sensed by the Orbiter GPC so that crewmembers are visually or audibly notified when predetermined limits or conditions are exceeded.

5.3.3.3 Data and Displays through the Payload Data Interleaver

Compatible payload telemetry data can be input to the PDI for onboard display and/or forwarding to the MCC and/or the POCC.

The Orbiter software can process 8-bit analog and discrete parameters from payload data. The Orbiter PDI operates in two decommutation modes, block mode and format synchronization mode. Allowable telemetry codes are NRZ-L, -S, or -M, and biphase-L, -S, or -M.

During ascent and descent, payload downlink telemetry allocation will be limited to 6 kbps for all payloads. On-orbit, telemetry allocation will be limited to 64 kpbs for all payloads. Orbiter time tag and status will be included. Usage of bandwith for individual payloads must be negotiated with the SSP.

Onboard processing capability (8-bit words) is also available to provide display and limit sensing for flightcrew monitoring and payload operation.

5.3.3.4 Data and Displays through the Payload Interrogator

Data from detached payloads is received by the PI/PSP. The Orbiter can process data from the PI/PSP through the PDI for crew display or transmission to ground stations, where it can be forwarded to a POCC. The PI/PSP receives the RF carrier and detects a pulse code modulated/PSK 1.024-megahertz (Mhz) subcarrier. Data is sent to the PSP where the PSK subcarrier is demodulated. After bit and frame synchronization, the PSP transfers telemetry data to the PDI. Payload data can be received at one of five specific rates up to 16 kbps. NRZ and biphase data codes are available. Direct transmission to the ground is available through the Ku-band system.

The PI/PSP may forward a maximum of 16 kbps of telemetry data to the PDI. Use of the PI must be time shared on-orbit. Priority use of the PI will be given to the payload undergoing deployment. Payload selection is accomplished by switching frequencies.

5.3.3.5 Data and Displays Through the Payload and General Support Computer

The PGSC interfaces with the payload for the following data processing and monitoring functions:

1. Two-way transfer of data files between a ground-based computer and a PGSC onboard the Orbiter. The PGSC OCA port connects to the PDIP for access to the Ku-band.
2. Access to the Orbiter Downlink (OD) telemetry via the PCMMU port. Specific PCMMU data may be de-commutated by the PGSC WinDECOM software and routed via packetized data to other PGSCs.
3. Two-way transfer of video teleconferencing sessions between a ground-based computer and a PGSC onboard the Orbiter.

Refer to section 5.3.2.11 for additional PGSC information.

5.3.3.6 Software for Onboard Data Processing

Onboard data processing for discrete or analog parameters is provided by the Orbiter GPC. Data may be acquired by the PDI or Orbiter payload MDM. Data is displayed to the crew and transmitted to the MCC, and/or forwarded to a POCC.

5.3.3.7 Ku-band Signal Processor

The Orbiter KUSP provides direct wideband analog and digital data input channels on a time-shared basis during orbital operations. The KUSP provides return link channels for transmitting payload wideband analog and digital data to the ground. The KUSP also provides bent-pipe capability for relaying detached payload telemetry to the ground.

Only a single input to channels 2 and 3 of the Ku-band is available to all payloads. For mixed user flights, where some payloads are susceptible to Ku-band Electromagnetic Interference (EMI), deployment operations will be coordinated to preclude incompatible operations. Refer to table 5.3.3.7-1 for KUSP downlink modes.

The KUSP can be accessed by a PGSC to allow two-way transfer of computer files with a ground-based computer.

Table 5.3.3.7-1. KUSP downlink modes

Mode 1 QPSK PM	Channel 2 (Select one)	• PI (narrowband bent pipe from detached payload) • Payload digital output, 16 kbps to 2 Mbps, NRZ-L, -M, or -S, or 16 kbps to 1.024 Mbps, biphase-L, -M, or -S • Operational data (MMU dump) • Payload data MMU dump
	Channel 3	• Payload digital output, 2 to 50 Mbps with clock, NRZ-L, -M, or -S
Mode 2 FM	Channel 2	• Same as mode 1
	Channel 3 (Select one)	• Television (TV) • Payload digital output, 16 kbps to 4 Mbps, NRZ-L, -M, or -S • Payload analog output, dc to 4.5 Mhz • PI (wideband bent pipe from detached payload)

5.3.3.8 Timing

Timing signals are provided by the Orbiter Master Timing Unit (MTU) for payload use. The MTU can send frequency and time code outputs through redundant crystal oscillators, frequency divider circuits, and GMT/MET accumulators. Characteristics of these timing signals are defined in ICD 2-19001.

5.3.3.9 Caution and Warning

The Orbiter provides audio and visual indications of system malfunctions. There are various ways for the crew to identify malfunctions, from simple parameter monitoring to audiovisual alerts. Audio and visual alerts should only be used when crew intervention is required. The two classes of crew alert available to payload are class 2 and class 3. The class 2 alert, or Caution and Warning (C&W) alarm, is used when immediate crew action is required. The class 3 alert, known as a payload or SM alert, is less urgent than the class 2. Crew action or intervention are not immediately required. Payload designers should eliminate failure modes requiring use of these alerts, especially during ascent and descent. Other crew interfaces are recommended for status advisories which may have safety implications but do not require urgent crew action. A functional diagram of the C&W system is shown in figure 5.3.3.9-1.

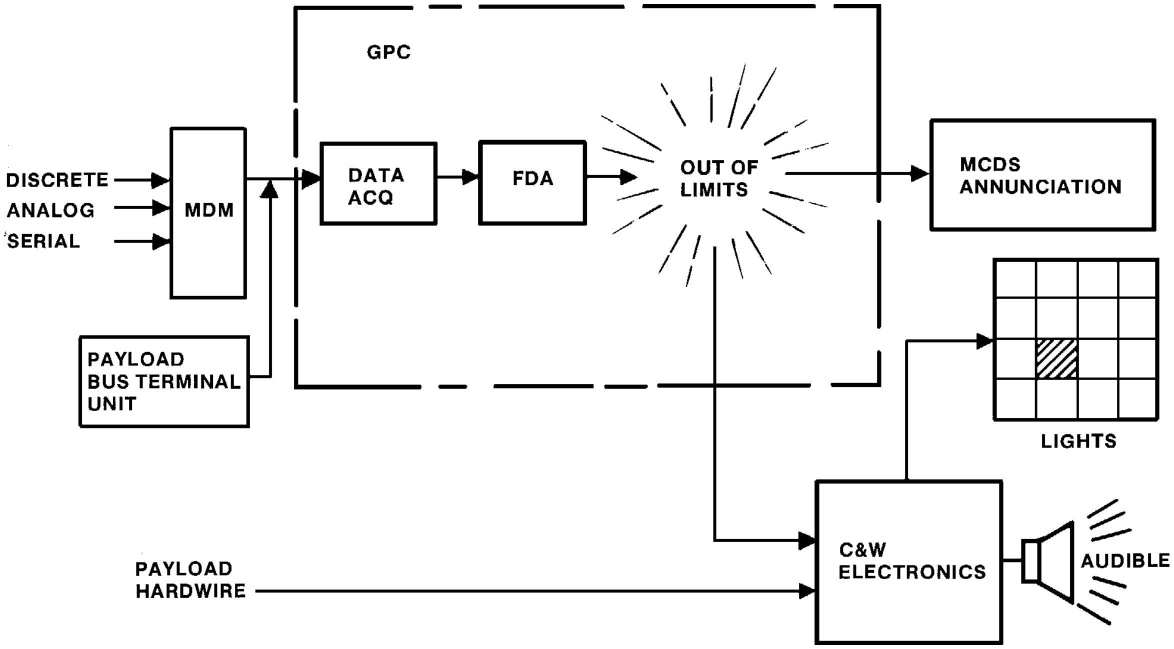


Figure 5.3.3.9-1. Functional diagram, C&W system

5.3.3.10 Payload Recording

The Orbiter MMU provides the capability to record biphase level digital data. A typical data rate for the MMU is 60 kbps (60 minutes recording time). Other data rates may be negotiated with the SSP in the IP.

5.3.3.11 Video

The Orbiter has an onboard Closed Circuit Television (CCTV) system capable of downlinking one 4.2 MHz video channel. Two onboard color monitors are located in the AFD. Video recording and playback services are available.

5.3.3.12 Payload Multiplexer/Demultiplexer Data Processing

While the payload is in orbit and attached to the Orbiter, payload data may be acquired by the SM GPC from the payload MDM. Allowable data types are discretes, signed and unsigned eight-bit analogs, sign plus magnitude eight-bit analogs, and signed ten-bit analogs. Data received will be processed for display and/or Fault Detection Annunciation (FDA) and downlisted by the GPC through the PCMMU to the ground.

The Payload MDMs receive payload data and convert and format it into serial digital words for transfer to the SM GPC. MDM characteristics are described in ICD 2-19001. Reference Shuttle Orbiter Failure Modes and Fault Tolerances for Interface Services, NSTS 16979 for further details.

5.3.3.13 GPC Processing Of Payload Data

While the payload is on-orbit and attached to the Orbiter, data may be acquired by the SM GPC from the payload connected to the GPC data bus. The bus terminal unit must be compatible with the payload data bus characteristics and GPC software. The data bus code is biphase-L with a 1.0-Mbps burst rate on a half-duplex system. Bit rate tolerance is 0.1 percent. Allowable data types are signed or unsigned 8-bit analogs, sign plus magnitude 8-bit analogs, 10-bit signed analogs, and discretes.

5.3.3.14 Audio Central Control Network

The Audio Central Control Network (ACCN) provides duplex voice communication, paging and warning to attached manned payloads. A limited subset of the above can be monitored during on-orbit phases of flight. The ACCN provides the following analog channels:

- Air to Ground 1
- Air to Ground 2
- Intercom A
- Intercom B
- Air to Air
- Page

5.3.3.15 T-0 Umbilical Data

The T-0 umbilical can supply data from the payload to payload GSE or the POCC during prelaunch ground operations.

5.3.3.16 Small Payload Accommodations Switch Panel

The SPASP has six status indicators (talkbacks) for payload use. These functions, which are hardwired to the payload, can be used on-orbit by the crew during active payload operations. Overlay panels identify specific payload functions. SPASP interface requirements and characteristics are defined in NSTS 21000-IDD-SML.

5.4 FLUIDS INTERFACES

5.4.1 Payload Active Cooling Kit

PACK integration hardware consists of Quick Disconnects (QDs), fluid lines, supports, insulation blankets, and brackets necessary to provide an interface for payloads requiring active cooling, such as: Materials Science Laboratory, Electrophoresis Operations in Space, Spacelab Pallet System, and others. See figure 5.4.1-1. The PACK connects the payload to the Orbiter active thermal control system via the Orbiter to payload heat exchanger.

The payload interface with the PACK is mounted on a SIP at the sill level of the Orbiter. See figure 5.4.1-2. The SIP is located on the port side of the Orbiter at a longitudinal position specified in the payload-unique ICD. The Orbiter side PACK hardware connects to the Orbiter X_o 636 heat exchanger interface panel. The pump to move the cooling fluid and the interconnecting plumbing between the SIP and the payload is furnished by the customer. The acceptable cooling fluids are Freon 114, water, and GN_2.

The PACK installation is designed for a wet mate QD interface and accommodates launch pad vertical installation of payloads. Interfacing QDs are furnished by the SSP.

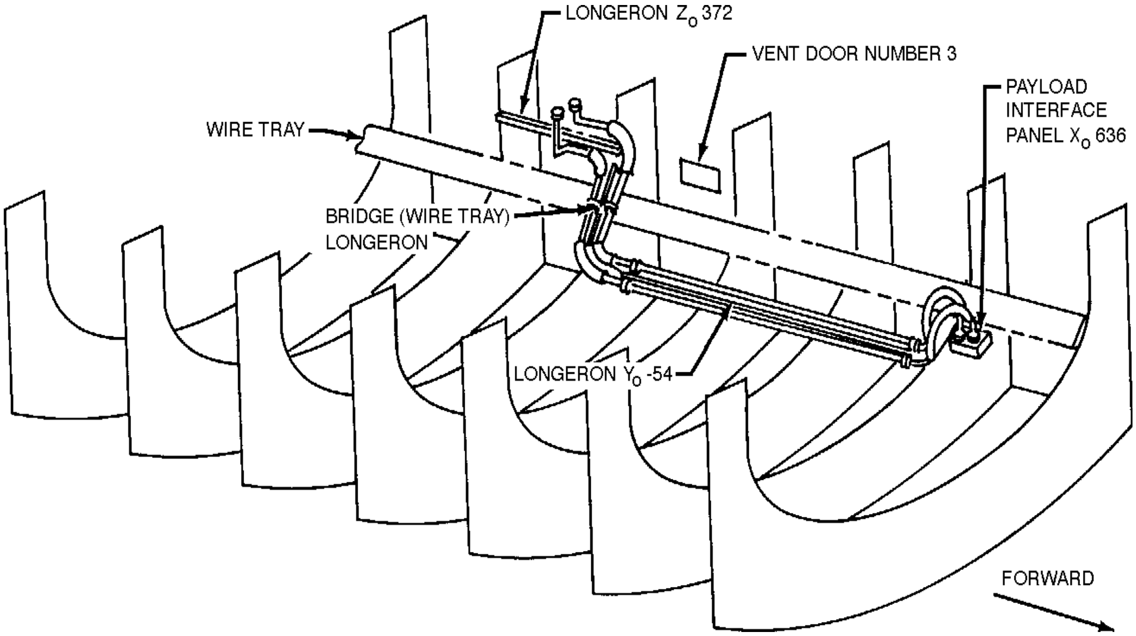


Figure 5.4.1-1. Typical PACK installation

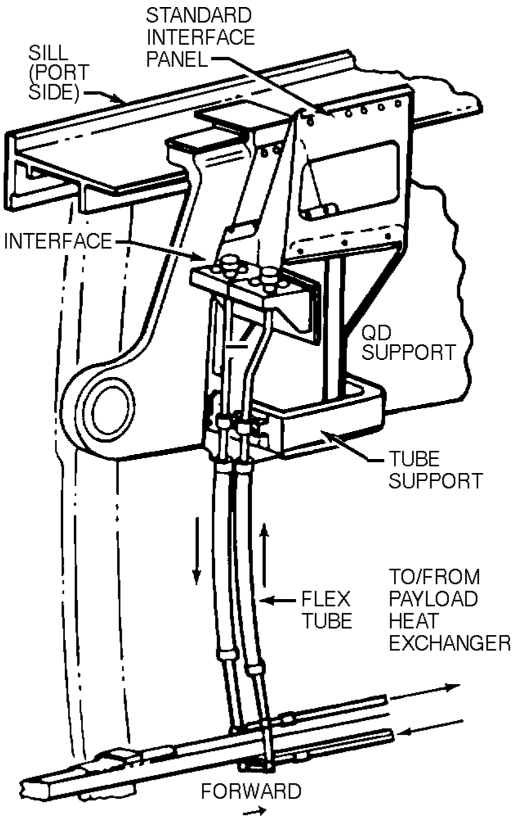


Figure 5.4.1-2. PACK-to-payload interface

SPACE SHUTTLE PAYLOAD DESIGN AND VERIFICATION REQUIREMENTS

6.0

6.1 STRUCTURES AND LOADS DESIGN AND VERIFICATION REQUIREMENTS

6.1.1 Introduction

6.1.1.1 General Information

This section establishes commonality for analytical approaches, analytical models, technical data, and definitions for integrated structural analysis by the Space Shuttle customer. An overview of the payload design and analysis process is shown in Figure 6.1.1.1-1.

This section provides payload designers with useful data regarding Space Shuttle-to-payload structural/mechanical accommodations and interfaces. Technical information is provided to Space Shuttle customers to aid in the design of payloads to achieve structural and mechanical compatibility with the Orbiter and the planned mission. This section is intended for use in conjunction with Shuttle Orbiter/Cargo Standard Interfaces, ICD 2-19001, Payload Verification Requirements, NSTS 14046, and Structural Integration Analyses Responsibility Definition for Space Shuttle Vehicle and Cargo Element Developers, NSTS 37329.

6.1.1.2 Total Cargo Mass Properties

The Orbiter must remain aerodynamically stable during certain phases of the mission. To ensure that the aerodynamic stability is maintained, the total cargo c.g., regardless of location (within the cargo bay, crew module etc.) shall be constrained. Preliminary design information on mass properties are defined in ICD 2-19001, while final c.g. calculations must be performed by the SSP. Maximum Orbiter lift-off weight is 256,000 pounds, and nominal End-of-Mission (EOM) landing weight is 230,000 pounds.

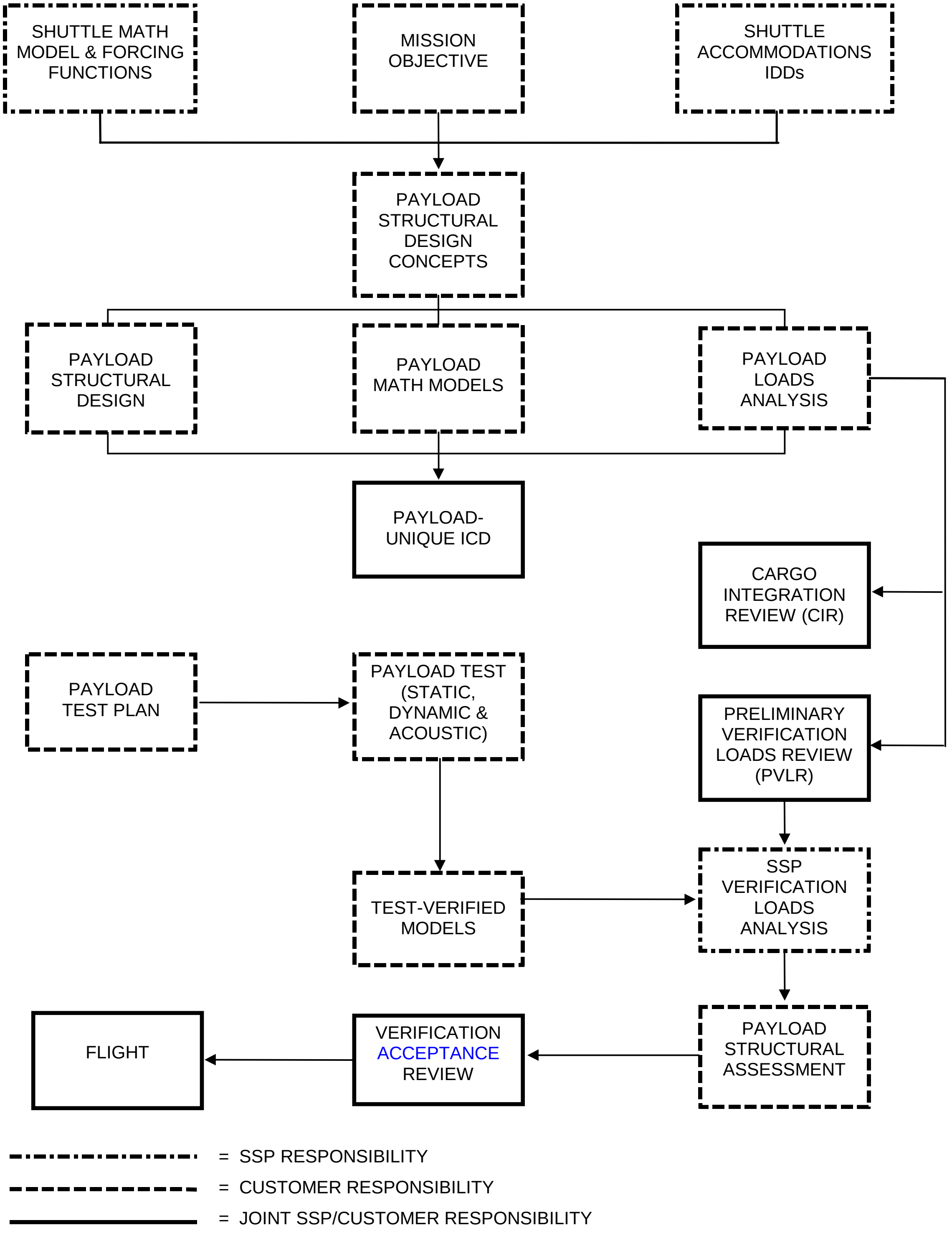


Figure 6.1.1.1-1. Payload structural design and analysis process

6.1.2 Payload Design

Payload loads analyses shall be performed during payload design and verification to ensure the structural integrity of the payload and structural compatibility with the Space Shuttle. These analyses must account for the application of conservative loading environments and loading combinations.

SSP and customer structural analysis responsibilities are documented in the IP. The SSP provides Space Shuttle dynamic and quasi-static math models and environments to support payload design activities. Preliminary design loads environments for typical payloads are provided in the form of accelerations or net load factors defined in the ICD 2-19001. For lift-off and landing, design and verification transient loads are usually determined through a coupled loads analysis of the Space Shuttle and payload.

During payload design, one or more design loads analyses are usually performed to provide payload design loads data. Payload design loads analyses can be performed by the SSP for the customer on request. Final payload design loads analysis, Space Shuttle interface loads, and clearance data must be provided to the SSP to support the Cargo Compatibility Review (CCR) and Cargo Integration Review (CIR).

To maintain manifest flexibility, payloads should be designed to accommodate the broadest range of payload bay locations possible (subject to Orbiter hardware limitations). As a minimum, the design loads analysis should be performed for the most forward and most aft possible manifest locations. Design loads analyses for small payloads can be performed for a cargo configuration consisting of several duplicate payload models attached in various payload bay locations. A typical across-the-bay payload design loads analysis configuration might consist of payload models mounted in forward, mid, and aft locations in the payload bay.

Prior to flight, the SSP conducts verification loads analyses using test-verified payload math models for the specific cargo manifest. To support these analysis, the customer must supply the SSP with test-verified math models that meet the requirements defined in NSTS 14046. The SSP Structures Working Group (SWG) verifies for the SSP that the test-verified math models meet the requirements of NSTS 14046. The verification loads analysis process, schedule, loads environments, and math model data requirements are given in NSTS 37329.

6.1.2.1 Payload Design Loads

The cargo limit-load factor and angular acceleration environments are defined in ICD 2-19001 for preliminary design of payloads and payload carriers. Cargo elements and secondary structure generally experience maximum accelerations at lift-off and landing. Coupled Space Shuttle/cargo element transient analyses are generally performed to determine cargo element design loads for lift-off and landing events. Ascent, on-orbit, and entry flight conditions are also design conditions.

Transient flight events correspond to conditions for which external forces are highly transient and produce significant dynamic response. Space Shuttle lift-off and landing are events of this type. The associated cargo responses depend on cargo geometry, stiffness, and mass characteristics. The transient load factors for lift-off and landing found in the ICD 2-19001 are preliminary design guidelines and are superseded by coupled loads analysis. On-orbit loads associated with docking, berthing, RCS jet plume impingement, and crew induced may also produce significant transient loading on deployed appendages and assembled space structures.

The load factors/angular accelerations associated with quasi-static flight events are generated by external forces that change slowly with time; i.e., vehicle dynamic responses are negligible. Consequently, coupled transient dynamic analyses are not normally required for these quasi-static flight events. Instead, a coupled static analysis of the various quasi-static flight events will be used for determining deflections and cargo interface forces. For quasi-static flight events, statically determinate payloads can calculate interface loads directly from the load factors without a coupled Space Shuttle/payload quasi-static analysis.

In addition to returnable or nonreturnable design landing conditions, the payload must be designed for emergency landing conditions. These emergency landing load factors are treated as ultimate load conditions in the same manner as crash requirements for aircraft. Payload equipment inside the Orbiter crew compartment must be designed to preclude hazards to the flightcrew after emergency landing. Payload attachment structures (including fittings and fasteners) must be designed to accommodate emergency landing loads.

During normal Orbiter attitude control and translational maneuvers, RCS jet thrusting produces payload accelerations. In particular, design loads can be significant for payloads which change configuration in orbit. Due to the limitations of the VRCS, payload structure must be designed to withstand Primary Reaction Control System (PRCS) loads during normal Orbiter attitude control and translational maneuvers. PRCS design limit-load factors for attitude control and rotational maneuvers are given in the ICD 2-19001. These limit-load factors include flexible body amplification effects of the payload and Orbiter. For unique configurations, coupled dynamic loads analyses may be required to verify cargo element loads and deflections. In the event that PRCS loads are not acceptable, the use of alternate (ALT) PRCS may result in a significant reduction of PRCS loads but must be negotiated with the SSP.

The maximum limit-load factors and angular accelerations exerted on the cargo during OMS engine burns are defined in the IDD. The maximum values include the effects of OMS engine thrust overshoot, misalignment, and dynamic magnification of payload and Orbiter structures. RCS jet firing during OMS engine burns must be accounted for when calculating OMS maneuver loads. The SSP can provide detailed design and/or verification loads analyses for RCS jet firing and/or OMS engine burns on request.

RCS plume impingement produces significant loading during payload deployment and/or proximity operations including payloads which change configuration in orbit. RCS plume impingement characteristics are provided in the IDD for preliminary loads analysis. The SSP can provide a detailed design and/or loads analysis of RCS plume impingement on request.

With the exception of emergency landing loads, all payload-to-Orbiter interface forces must not exceed the Orbiter attach point limit-load capability. The Orbiter load capability equations are provided in the ICD 2-19001.

Friction loads are present at the longeron and keel trunnion interfaces. These friction loads occur in the nonrestrained degrees of freedom of each payload point (i.e., the sliding interface). Friction loads are calculated statically by multiplying a friction coefficient times the normal load. The friction coefficient is a function of temperature and normal load and is defined in ICD 2-19001. In all cases, the payload must be capable of sustaining the friction load plus any other induced loads (e.g., bearing rotation) with a positive margin of safety.

6.1.2.2 Vibration and Acoustic Loads

Payloads must be designed to be compatible with the payload bay acoustic environment, based on the overall spatial average of sound pressure levels in the payload bay. Acoustic levels in an empty payload bay are defined in the ICD 2-19001. These values represent the minimum levels to which a payload will be certified safe for Space Shuttle flights. Acoustic levels during entry and landing are significantly lower than ascent levels and can be assumed negligible. Acoustic levels for specific payloads depend on payload geometry, surface area, and acoustic absorption characteristics, and will differ from those of the empty payload bay.

Based upon Space Shuttle flight data, the random vibration environments predicted for the payload bay main longeron trunnion fitting and keel trunnion fitting are defined in the ICD 2-19001. Random vibration environments are defined at the Orbiter/payload trunnion interfaces in the 20 to 2000 Hz frequency range. The vibration environment at payload attach points is produced by external acoustics, structure-borne vibrations produced by the Solid Rocket Motors (SRMs), and Orbiter main engines.

The maximum allowable payload-induced shock at the Orbiter/payload interface is also defined in the ICD 2-19001.

6.1.2.3 Flight Control Interaction

To preclude possible interaction with the Space Shuttle flight control system during ascent and entry, the payload minimum structural frequency is defined as a function of payload weight. This payload structural frequency is defined by the lowest structural mode of the payload when fixed at the restrained Orbiter/payload attach degrees of freedom. The frequency restrictions are applicable to all flight control regimes (ascent, on-orbit, and descent) with payloads in their stowed positions and the PLBDs closed.

The minimum acceptable constrained frequencies are provided in the ICD 2-19001. If the payload is deployable, additional constraints on the minimum frequency are imposed for use of the RMS. These constraints are provided in ICD 2-19001.

6.1.2.4 Payload Factors of Safety

The structural design of all mounting hardware, bracketry (or any other structure that could be affected by flight loads), and pressurized lines or fittings must ensure an ultimate factor of safety. Factors of safety for structural design are addressed in NSTS 1700.7B and NASA STD-5001.

Structural strength verification is best accomplished by static test. Options for strength verification are described in NSTS 14046.

6.1.3 Small Payloads Accommodations

6.1.3.1 Design Loads

The payload design loads discussed in section 6.1.2.1 also apply to small payloads; however, small sidewall-mounted payloads (with a minimum frequency of 35 Hz with respect to the adapter beam interface) have a simplified set of load factors for use in design analyses. These limit load factors are defined in NSTS 21000-IDD-SML. These load factors will encompass all Space Shuttle flight events. Angular acceleration load factors are about the payload c.g. Sidewall-mounted payloads with frequencies below 35 Hz generally need to base their design on coupled loads analysis as discussed in section 6.1.2.1.

6.1.3.2 Vibration and Acoustic Loads

Lift-off/ascent acoustic levels in an empty payload bay (as defined in NSTS 21000-IDD-SML) are the minimum for which a payload will be certified safe for flight on the Space Shuttle. Acoustic levels during entry and landing are significantly lower than ascent levels and will be assumed to be negligible.

Random vibration environments associated with Space Shuttle lift-off are specified for longeron/adapter-mounted cargo elements. Random vibration environments for hardware mounted on the payload bay sidewall through an adapter are provided in the NSTS 21000-IDD-SML.

6.1.3.3 Interface Load Constraints

Structural interface load limitations for longeron/adapter-mounted small payloads are governed by the weight and c.g. of the payload, the adapter beam and mounting provisions, and the Orbiter longeron and frame structural capabilities. These limitations will differ for each of the unique adapter applications. The structural interface loads between a payload and an adapter beam cannot exceed the structural capabilities of the beam as defined in NSTS 21000-IDD-SML. Individual assessment of interface loads may be required for each application.

6.1.4 Materials and Processes Applications

The guidelines in this section are intended to identify general approaches to meeting the requirements for Materials and Processes (M&P) defined in Safety Policy and

Requirements for Payloads Using the Space Transportation System, NSTS 1700.7B, and ICD 2-19001. The following M&P disciplines are addressed: fracture control, flammability, stress corrosion, fluid compatibility, toxicity (offgassing), and external contamination (vacuum outgassing). Additional information can be obtained by contacting the Materials and Processes Technology Branch of the Manufacturing, Materials, and Process Technology Division at JSC.

Several organizations have intercenter agreements with JSC that address all M&P requirements in NSTS 1700.7B and ICD 2-19001. In such cases, the customer should reference the payload M&P organization materials certification in all hazard reports to which it applies. The SSP will accept the hazard report without further review.

6.1.4.1 Fracture Control/Pressure Vessels

All fracture-critical components (including all pressure vessels) should be designed to prevent catastrophic failure from crack-like defects. Fracture control should begin with design and continue through manufacturing and testing to completion of the payload's association with the Space Shuttle. A fracture control plan defining payload compliance with fracture control requirements should be submitted to the Payload Safety Review Panel (PSRP) for approval as soon as possible. If there are unique fracture control considerations for a particular payload or part, they should be fully addressed in the fracture control plan. Proper implementation of fracture control, in accordance with the approved plan, should be given high priority by the manufacturer. The safe life of a fracture-critical component can be determined by fracture mechanics analysis using a computational program such as NASA Flaw Growth (FLAGRO).

Fracture control requirements are delineated in NASA-STD-5003, Fracture Control Requirements for Payloads Using the Space Shuttle.

6.1.4.2 Stress Corrosion

The use of metals resistant to stress corrosion shall be emphasized during the design of a payload. A noncompliance report may be required if the use of a susceptible alloy results in a controlled risk to the Space Shuttle. For methods to reduce susceptibility to stress corrosion, customers should consult Design Criteria for Controlling Stress Corrosion Cracking, MSFC SPEC-522.

6.1.4.3 Flammability

Flammability assessment guidelines are contained in Flammability Configuration Analysis for Spacecraft Applications, NSTS 22648. This document includes methodology for flammability hazard analyses. Payloads should be evaluated for flammability hazards at the atmospheres listed in table 6.1.4.3-1.

Table 6.1.4.3-1. Flammability hazards

Location	Worst case atmosphere
Orbiter cabin/Spacehab	30% oxygen/10.2 psia
MPLM/ISS	24.1% oxygen/14.7 psia
Payload bay	20.9% oxygen/14.7 psia
Other regions	Worst case environment

In the payload bay, materials with a maximum dimension of 12 inches or less need not be considered unless a succession of such parts form a propagation path. For materials greater than 12 inches, nonflammable materials should be used. If flammable materials are used, a fire hazard assessment is required and must be documented in the hazard report.

Materials used inside the Orbiter crew cabin must be evaluated at 10.2 psia and 30 percent oxygen because of the prebreathe requirement for EVAs. This also applies to missions without a scheduled EVA, because of the possibility of contingency EVAs.

Components used only during launch or reentry inside the cabin can be evaluated at 25.9 percent oxygen which is the maximum O_2 concentration under normal operations.

Components stowed in middeck lockers without electrical power and not removed during the mission are acceptable without further analysis. Components in lockers with electrical power must be evaluated to assure that if a fire started, it would be contained inside the locker. Payloads that contain flammable materials and are stowed in a locker except while in use are acceptable, provided the dimensions of the flammable materials are small and the duration of use exposure is short.

Individual material test data are included in Material Selection List for Space Hardware Systems, MSFC HDBK-527 (JSC 09604) and the electronic NASA Materials and Processes Technical Information System (MAPTIS) database (accessible by Telnet or at http://map1.msfc.nasa.gov/). Materials not listed in the test data handbook or in MAPTIS should be tested in accordance with the procedures in NASA-STD-6001.

6.1.4.4 Fluid Compatibility

Fluid system compatibility refers to the interaction of materials with the liquid or gaseous fluids to which they are exposed. Compatibility problems generally fall into one of the following categories:

1. Material degradation – Includes phenomena such as chemical attack, corrosion, galvanic corrosion, stress corrosion, hydrogen embrittlement, and crack growth acceleration with metallic materials and embrittlement, softening, abnormal swelling, and leaching of plasticizers with nonmetallic materials. Material degradation is a concern only if it adversely affects safety.

2. Ignition – Ignition of flammable fluids or materials that are flammable in an oxidizing fluid; in rare cases, materials may become shock-sensitive explosives in contact with nitrogen tetroxide or liquid oxygen.

3. Catalytic decomposition – Decomposition of hydrazine fuels is catalyzed by many metallic and nonmetallic materials and can change the fluid purity or result in runaway self-heating, possibly leading to a thermal explosion.

MSFC HDBK-527 (JSC 09604) and MAPTIS contain materials ratings for compatibility with hydrazine fuels, nitrogen tetroxide, liquid and gaseous oxygen, and gaseous hydrogen. These ratings were obtained using test procedures specified in NHB 8060.1. Compatibility of materials with other fluids should be assessed if materials degradation can create a hazard such as leakage of toxic species.

All polymeric materials and many metallic materials are flammable in gaseous oxygen at relatively low pressures (most aluminum and some steel alloys are flammable below 100 psia); the hazard is somewhat reduced in liquid oxygen because of its low temperature. When flammable materials are used in oxygen systems, a system-level evaluation must be conducted to demonstrate that ignition cannot occur; configurational testing may sometimes be necessary. Potential ignition sources include rapid pressurization, frictional heating, particle impact, sources of electrical energy, and single barrier failures.

The materials compatibility ratings for hydrazine fuels in MSFC HDBK-527 (JSC 09604) and MAPTIS are applicable for systems with a maximum operating temperature of 160° F or lower. If the system can operate at temperatures higher than 160° F, additional analyses must be conducted to demonstrate that catalytic decomposition reactions cannot produce runaway self-heating. If necessary, accelerated rate calorimeter testing can be conducted for the customer by NASA to verify compatibility at temperatures above 160° F.

6.1.4.5 Offgassing and Outgassing

This section provides guidelines to assist the customer in meeting the offgassing requirements specified in NSTS 1700.7B, and the outgassing requirements in section 4.0. The assessments performed by the customer depend, in part, on where in the Orbiter the payload is flown. If the materials in question are never exposed to a vacuum environment, assessment of vacuum induced outgassing is not required; if the payload is never inside a manned compartment, toxic offgassing does not require assessment. Payloads exposed to both environments require both assessments. Outgassing requirements are intended to control payload cross-contamination; therefore, application of the SSP requirements to dedicated missions can be significantly relaxed. Only large outgassing sources which may significantly interfere with Orbiter performance or maintenance must be addressed for dedicated missions.

6.1.4.5.1 Offgassing Analysis (Toxicity)

Payload hardware flown in the manned compartments of the Space Shuttle must meet the toxic offgassing requirements in NHB 8060.1. The standard offgassing test in NHB 8060.1 consists of collecting gaseous emissions for 72 hours at 120° F (or the maximum use temperature) and analyzing samples to determine the identity and quantity of each gas emitted. The acceptability of hardware is determined by comparing the concentration of each offgassed product with its Spacecraft Maximum Allowable Concentration (SMAC); SMAC values are listed in Spacecraft Maximum Allowable Concentrations for Airborne Contaminants, JSC 20584 and in MAPTIS. The offgassing data should comply with the following acceptance criteria:

1. Offgassing tested as assembled article – Summation of Toxic Hazard Index (T) values of all offgassed constituent products (total concentration in milligrams per cubic meter/SMAC) must not exceed 0.5.
2. Hardware components evaluated on a materials basis (individual materials used to make up components) – The summation of T values for each constituent material must be less than 0.5.
3. More than one hardware component or assembly – If a single hardware component is tested or evaluated for toxicity, but more than one will be flown, the T values obtained for one unit times the number of flight units must be less than 0.5.
4. Bulk materials and other materials not inside a container – All materials will be evaluated individually using the ratings in MSFC HDBK-527 (JSC 09604) or MAPTIS. The maximum quantity and associated rating is specified for each material code. The material or design organization responsible for the hardware must track the amount of each material being used to ensure the maximum quantity is not exceeded.

If the offgassing data do not comply with the criteria above, they should be submitted to a NASA toxicologist for assessment.

6.1.4.5.2 Payload Bay Vacuum Outgassing Analysis

Outgassing requirements specify that the materials must have low concentrations of Volatile Condensable Material (VCM) to preclude payload cross-contamination and contamination of sensitive Orbiter systems (such as radiators and cameras) by outgassing materials. For equipment that does not meet outgassing requirements, the customer may decide to vacuum bake the entire unit at the maximum use temperature for a period of time sufficient to reduce the rate of outgassing. Payload acceptance testing which may include significant conditioning by thermal vacuum exposure may qualify as providing sufficient bakeout for use.

Additional requirements may be imposed on payloads manifested with primary payloads (such as the Hubble Space Telescope (HST) servicing missions) where the primary payload is highly sensitive to contamination.

6.1.4.6 Beryllium Applications

Beryllium is recognized as a material with low ductility and potential for premature brittle failures in all forms. In particular, cross-rolled sheets have a very low tolerance to out-of-plane displacements. The amount of out-of-plane displacement considered acceptable has not been adequately quantified, and the failure mode is not well understood. Out-of-plane displacements are produced by point loads, local constraints, or incipient buckling.

Detailed requirements for use of beryllium on SSP payload critical structures are contained in Interpretations of STS Payload Safety Requirements, JSC 18798 and NSTS 14046.

Special attention should be given to protecting parts from damage during assembly and transportation, and removal of mechanically disturbed surfaces by etching.

6.1.4.7 Composite Material Applications

Composite materials provide considerable flexibility in selecting material properties required for a specific application, and significant weight savings usually result from their use. This flexibility requires custom manufacturing of the composite and therefore, leads to concerns about quality of the parts produced and the adequacy of the property data base.

Use of composite material systems for critical structures associated with SSP payloads will require experience with building-like designs, specific experience with application of the material process specifications using trained personnel, correlation of process specifications to material property allowables, and appropriate nondestructive testing of parts. If an experience base does not exist, acceptance testing of the composite structure to a minimum of 1.2 times the design limit load should be conducted. Even under the latter condition controlled manufacturing processes must be used. Special attention should be given to protecting critical composite parts from damage during assembly and transportation. All standard repair procedures should be certified prior to use on payload structures. See NSTS 14046 for verification requirements.

6.1.5 Structural Interface Verification Requirements

To provide personnel safety, Space Shuttle integrity, and efficient use of flight and ground systems by all users, payload requirements have been established for verifying payload-to-Orbiter structural interfaces. The customer must verify the compatibility of the payload physical and functional interfaces with applicable interface agreements. The customer has flexibility in determining the method for accomplishing this verification which must be completed prior to payload bay installation. Application of the structural interface verification requirements is defined in Payload Verification Requirements, NSTS 14046 and NSTS 37329.

6.1.5.1 Payload Structural Verification

The objectives of the structural verification program are to verify (by tests, inspections, and analyses) that payload structural hardware is compatible with the Space Shuttle. Payload structural verification includes all verification activities performed at customer facilities, followed by launch site verification testing. Safety requirements applicable to all Space Shuttle payloads, ASE, and GSE are described in NSTS 1700.7B. These include requirements for verification of hardware functions identified as potentially hazardous. Verification of hazardous functions must be implemented and reported through the established safety review process.

Prior to flight on the Space Shuttle, all payload structures will be demonstrated safe for flight. Payload models submitted to support the structural verification effort must be in accordance with NSTS 37329 and NSTS 14046. The payload structural verification analysis process for payload bay payloads progresses in the following manner:

1. IP **–** The IP is the contractual document that begins the loads analysis process. It specifies implementation of the loads analysis and the schedule of activities to accomplish the loads analysis.

2. Model test verification **–** Working with the Structures Working Group at JSC, the structural test plan, tests, and test reports are reviewed and approved. The static and dynamic structural models are reviewed for adequate correlation with test results. Refer to NSTS 14046 for additional verification information.

3. Preliminary Verification Loads Review (PVLR) **–** The PVLR is held a few months prior to model delivery. It is conducted and chaired by the SSP so that analysis participants can discuss the process, the condition of the payload models, how data will be transmitted, and the schedule of activities leading to the Verification Acceptance Review (VAR).

4. Payload model delivery **–** All models, whether the payload is across-the-bay or sidewall, primary or secondary, are delivered to the SSP by the payload customer. This delivery begins the verification loads analysis cycle. The models are checked to ensure that they are complete and ready for coupling. The schedule for delivery of the models is defined at the PVLR and revised as required by the SSP.

5. Loads data dump **–** As a result of the verification loads analysis, loads and displacement data are transmitted to payload customers for analysis of individual payloads.

6. Loads Report **–** The formal report documenting the SSP portion of verification loads analysis is released by the SSP.

7. Verification Acceptance Review **–** A meeting of analysis participants is again conducted and chaired by the SSP. Its purpose is to discuss and approve the results of the verification loads analysis (e.g., all margins of safety are positive and the payload is safe for flight as defined in NSTS 14046). This meeting completes

the verification analysis process and provides results for the Flight Readiness Review (FRR).

6.1.5.2 Shuttle/Payload Structural Interface Verification

The payload and Orbiter will be checked out independently before structural mating by the payload customer and the SSP, respectively. This limits the postmate checkout by the SSP to verifying the functional interfaces between those elements. Verification of interfaces before payload installation will normally be specified for the Orbiter in Operations and Maintenance Requirements and Specifications Document (OMRSD), NSTS 08171. The Orbiter interfaces for the payload will be verified by the SSP, primarily during checkout, but in some cases by analyses and/or inspection as well as maintenance.

6.2 AVIONICS DESIGN AND VERIFICATION REQUIREMENTS

6.2.1 Introduction

6.2.2 Payload Electrical Design, Experience, and Usage

6.2.2.1 Activation and Deactivation

The crew must be able to manually interrupt all power supplied to a payload, except for a maximum total current of one amp. In addition, in order to minimize payload cargo-produced transients, a payload can have no more than 500 W of latched-on power. This means that if a payload's power source is inadvertently interrupted, there shall be no more than a 500 W load on the payload bus during power restoration.

6.2.2.2 Circuit Protection

The customer is required to provide circuit protection on the payload side of the interface for wiring located inside manned modules, for safety circuits and, in some cases, to protect Orbiter wiring. Properly selected circuit protection devices are defined as those which will not allow wiring to exceed the wire manufacturer's recommended operating temperature limits for wire insulation during any possible circuit loading or fault condition under worst-case environmental conditions.

Payload electrical power distribution circuitry shall be designed so that electrical faults will not damage Orbiter wiring or present a hazard to the Orbiter or crew. Circuit protection devices and wire sizes shall be selected in accordance with Interpretation of NSTS/ISS Payload Safety Requirements, NSTS 18798, and NASA Technical Memorandum 102179 and incorporated into the payload design in each of the following cases:

1. When Orbiter wiring is to be energized from a payload power bus

2. When payload power distribution wiring is located within a crew habitable volume

3. When payload redundant safety critical power is derived from a single approved Orbiter source
4. When energized payload power distribution circuits are routed through wire bundles containing circuits which, if energized, would potentially bypass or remove more than one inhibit to a hazardous function

Case 2. does not apply to power distribution circuitry inside payload electronics boxes; all other cases apply.

6.2.2.3 Bussing of Power Lines

When two wires are tied together at both ends (bused) to carry more current than either is rated for, both wires must be appropriately fused (or equivalent) at the power source end. When three or more wires are bused, each must be appropriately fused (or equivalent) at both ends or the fusing at the power source end must protect the smallest bused wire. For example, a power run of five 12-gauge wires, bused at both ends, would require either one 20-A fuse feeding the input end of the wires or 10, 20-A fuses, one at each end of each wire. See figure 6.2.2.3-1. The reason for the fusing requirement at both ends is as follows: if only one end were fused, a smart short (discussed in paragraph 6.2.3.2.9) in a single wire would cause it to be powered by the combined fuses of the remaining wires through the bused connection at the unfused end.

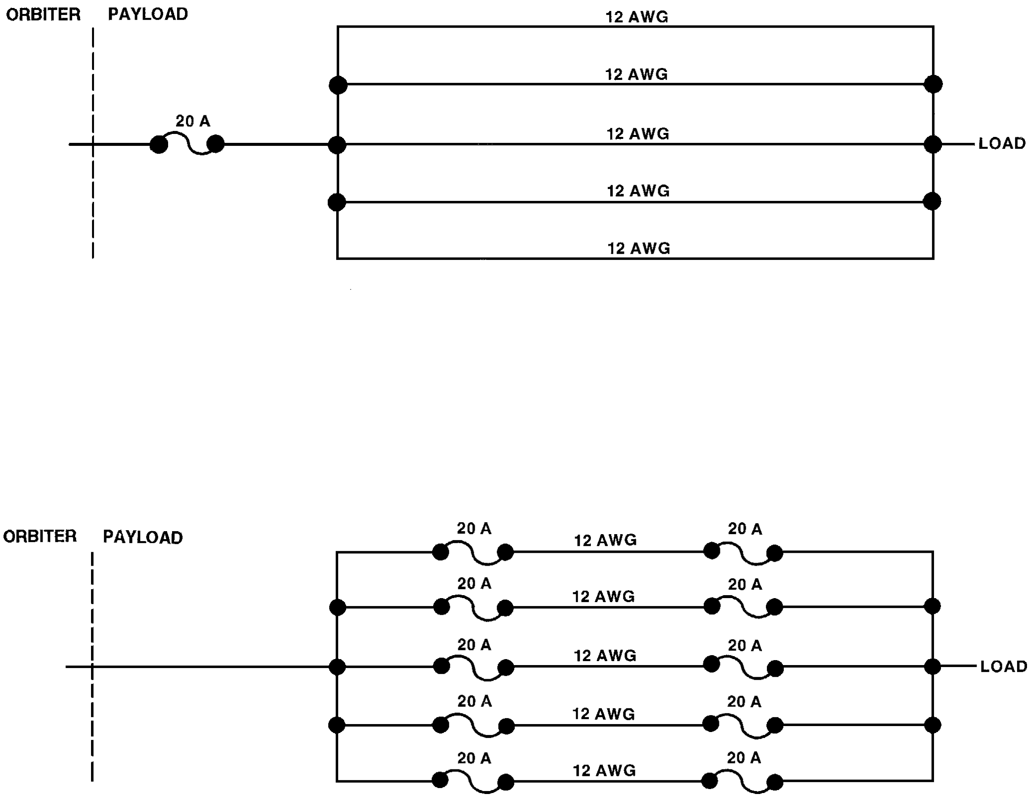


Figure 6.2.2.3-1. Fusing example of multiple-wire power bus

6.2.2.4 Connector Deadfacing

To prevent electrical shorts or arcs during ground operations, current flow through any connector pins while mating or demating a connector is not allowed. Crew mating and demating of powered connectors is defined in NSTS/ISS 18798.

6.2.2.5 Pyrotechnic Initiation

Pyrotechnic initiators are generally used to free deployable payloads. Such initiators shall be current limited to a maximum of 10 A each, when a PPSU is utilized with a total maximum current of 80 A per initiation (grouped). This restriction is necessary to limit voltage transients on the Orbiter bus. The crew or a timer must be provided with the capability to shut off all power to an initiator after it has been fired within 10 seconds. Typical reduction in the main dc power bus interface voltage at the SIP due to pyrotechnic initiation within the payload is shown in figure 6.2.2.5-1.

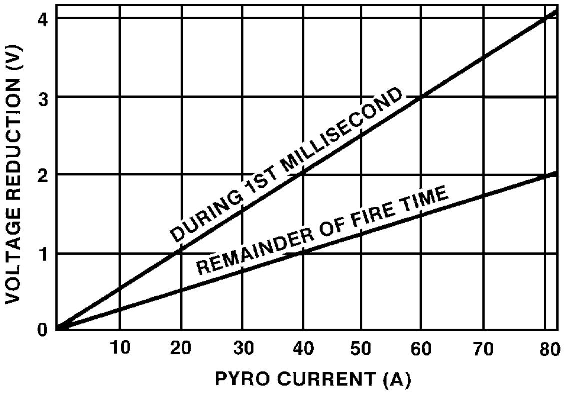


Figure 6.2.2.5-1. Voltage reduction due to pyrotechnic fusing

6.2.2.6 Transients and Ripple

Orbiter-produced transients and ripple resulting from load switching are subject to the limitations defined in ICD 2-19001, which delineates the maximum transients and ripple to the payload expected from Orbiter sources.

6.2.2.7 Experience and Usage

Although certain standard power amounts are allocated to a payload, actual power available to a payload at a given time depends on many variables, including payload manifest, mission duration, unique mission attitude requirements (e.g., cold facing), payload power feeder allocation, and Orbiter power requirements.

6.2.2.7.1 On-orbit Power Time Sharing

On mixed payload flights, time sharing of peak power levels between payloads may be necessary, depending on payload requirements in a mission manifest.

Longer mission durations reduce the total energy available to payloads since the Orbiter consumes more power and energy than payloads. Contingency power and energy requirements must be reserved for the Orbiter and the remaining payloads. For example, if a deployable payload cannot be deployed, additional power/energy is required to ensure payload survival. Payload energy requirements shall include energy to account for 2 additional days on-orbit due to inclement weather, if power is required. These energy requirements shall also include payload power requirements postlanding.

Special attitude requirements, especially cold-facing, require more Orbiter and payload heater power, which reduces power available for payload operations. Hot-facing attitudes tend to increase the power feeder resistance and reduce power transfer capability to high power payloads; this is usually not a detriment to mixed payloads.

The single-section 0-gauge feeder can conduct the standard power allocation and maintain an interface voltage of 26.4 V (at 1750 W) at the payload. Higher payload power requirements may require additional power feeds to provide usable interface voltages or enable high power to transfer. A single-section payload can occasionally utilize a second SMCH power feeder, but this requires a unique negotiation with the SSP and usually produces manifesting constraints.

6.2.2.7.2 T-0 Umbilical Considerations

The T-minus zero (T-0) umbilical can maintain a trickle charge to payload batteries independent of Orbiter bus power when PLBDs are open or closed. For payloads requiring primary charging of batteries after installation in the Orbiter, the SSP recommends using the Orbiter primary payload bus feed over the use of a drag-on power cable, due to the requirement that the PLBDs must be open when drag-on cables are used. During ground operations a maximum peak power of 3 kW is allowed for payload use from the Orbiter primary payload bus feed. Although no Orbiter avionics are connected to the payload T-0 umbilicals, the EMC wire classifications and requirements are still applicable because of the length of wire runs where the Orbiter and payload T-0 harnesses are bundled together in the Orbiter tail section. Any EMI from payload harnesses could interfere with critical monitoring of Orbiter health and status prior to launch.

6.2.2.7.3 Batteries

If the payload automatically transfers to internal power upon loss of Orbiter power, the capability to transfer the payload back to Orbiter power after it is restored must be provided by the customer. The crew must be able to isolate the payload from Orbiter power and, preferably, power it down during management of Orbiter emergencies. See Safety Policy and Requirements for Payloads Using the Space Transportation System, NSTS 1700.7B. Batteries should be designed to support ground operations constraints according to System Description and Design Data - Ground Operations, NSTS 07700, Volume XIV, Appendix 5.

6.2.2.8 Test and Verification

Before payload installation, verification of Orbiter flight readiness is performed by the SSP, and verification of the payload flight readiness is performed by the customer.

Payload mission kit wiring is installed in the Orbiter to provide necessary interfaces for the payloads. Functional testing is conducted at the payload interface to verify that the Orbiter is ready to accept the payload. Design verification testing of Orbiter subsystems will already have been completed.

A payload undergoes receiving inspection at the launch site and may require additional stand-alone testing. Payload Cargo Interface Test Equipment (CITE) is employed for preinstallation verification that a payload will interface properly with the Orbiter. Test and verification requirements are defined in Payload Verification Requirements, NSTS 14046.

After installation of a payload in the Orbiter, an interface verification test is performed to verify all payload interfaces with Orbiter flight hardware and software. When required by the customer, an End-To-End (ETE) test is conducted through the ground network, including the POCC, as an additional service. For an ETE test of telemetry data flow only, a PCMMU data tape (produced during interface verification testing) will be used for Mission Control Center - Houston (MCC-H)/POCC interface validation.

6.2.3 Payload Wiring and Harnesses

T-0 access cables were designed and installed to meet specific Orbiter EMC criteria (HO, ML, and RF) as defined in ICD 2-19001. The customer must comply with these criteria when using these circuits to avoid interference with Orbiter functions routed in adjacent cables. RF-classified circuits are typically used for functions such as payload/GSE, uplink, and downlink communication independent of Orbiter processing. ML-classified circuits provide an interface for low-level (5-V dc) payload/GSE discrete and analog signals, and HO-classified circuits generally provide limited dc ground power for payload heaters, battery charging, etc., and for high-level (28-V dc) command and response signals.

Electrical interface implementation requirements are specified in ICD 2-19001. The SIPs are installed just forward of the payload structure. The SMCH harness is then routed up the sidewall and connected to the bottom side of the feedthrough connectors mounted in the SIP. Customer-provided extender cables (which are tied out of the way during payload installation into the Orbiter) are routed to the sill longeron and down to the SIP and mated with the top side of the feedthrough connectors mounted in the SIP. The payload extender cables should be clamped down as near as possible to the forward part of the payload structure, and should exit from the structure in the $-X_0$ or forward direction. The extender cables, will be clamped as appropriate while extending along the sill longeron (maximum 18-inch span) and, at the top of the SIP.

Because of the stiffness of the 0-AWG dc power cables, the bend radius is extremely large and must be considered when designing payload cable routing and departure points. Improper placement of the harnesses as they exit the payload structure can produce an excessive amount of unsupported cable length.

6.2.3.1 Interface Connectors

ICD 2-19001 lists the specifications for those connectors that have been certified for use in the SSP. Customers may also use connectors which carry the vendor part numbers shown in tables 6.2.3.1-1, 6.2.3.1-2, 6.2.3.1-3, and 6.2.3.1-4.

Table 6.2.3.1-1. Specification 40M38277 connector correlation data

40M38277	BENDIX	ITT
NLS0E16-35S	10-475305-35S	KJ3E16N35SN16
NLS0T12-35S	10-475413-35S	KJ3T12N35SN16
NLS0T16-35SA	10-475415-35SA	KJ3T16N35SA16
NLS0T16-35SB	10-475415-35SB	KJ3T16N35SB16
NLS0T20-35S	10-475417-35S	KJ3T20N35SN16
NLS0T20-35SA	10-475417-35SA	KJ3T20N35SA16
NLS0T20-35SB	10-475417-35SB	KJ3T20N35SB16
NLS6GT10-35P	10-475432-35P	KJG6T10N35PM16
NLS6GT10-35S	10-475432-35S	KJG6T10N35SN16
NLS6GT10-35PA	10-475432-35PA	KJG6T10N35PA16
NLS6GT12-35P	10-475433-35P	KJG6T12N35PN16
NLS6GT12-35S	10-475433-35S	KJG6T12N35SN16
NLS6GT12-35PA	10-475433-35PA	KJG6T12N35PA16
NLS6GT14-35P	10-475434-35P	KJG6T14N35PN16
NLS6GT14-35S	10-475434-35S	KJG6T14N35SN16
NLS6GT14-35PB	10-475434-35PB	KJG6T14N35PB16
NLS6GT14-35PC	10-475434-35PC	KJG6T14N35PC16
NLS6GT16-35P	10-475435-35P	KJG6T16N35PN16
NLS6GT16-35S	10-475435-35S	KJG6T16N35SN16
NLS6GT16-35PA	10-475435-35PA	KJG6T16N35PA16
NLS6GT16-35PB	10-475435-35PB	KJG6T16N35PB16
NLS6GT16-35PC	10-475435-35PC	KJG6T16N35PC16
NLS6GT16-35PD	10-475435-35PD	KJG6T16N35PD16
NLS6GT18-35P	10-475436-35P	KJG6T18N35PN16
NLS6GT18-35S	10-475436-35S	KJG6T18N35SN16
NLS6GT20-35P	10-475437-35P	KJG6T20N35PN16
NLS6GT20-35S	10-475437-35S	KJG6T20N35SN16
NLS6GT20-35PA	10-475437-35PA	KJG6T20N35PA16
NLS6GT20-35PB	10-475437-35PB	KJG6T20N35PB16
NLS6GT20-35SA	10-475437-35SA	KJG6T20N35SA16
NLS6GT20-35SB	10-475437-35SB	KJG6T20N35SB16
NLS6GT20-35SC	10-475437-35SC	KJG6T20N35SC16
NLS6GT20-35SD	10-475437-35SD	KJG6T20N35SD16
NLS6GT22-35P	10-475438-35P	KJG6T22N35PN16
NLS6GT22-35S	10-475438-35S	KJG6T22N35SN16
NLS6GT22-35SA	10-475438-35SA	KJG6T22N35SA16
NLS6GT22-35SB	10-475438-35SB	KJG6T22N35SB16

Table 6.2.3.1-2. Specification 40M39569 connector correlation data

40M39569	DEUTSCH	ITT CANNON
NB6GE12-10PNT2	38180-12-32PN-1A	PV6B12S32PN16
NB6GE12-10PWT2	38180-12-32PW-1A	PV6B12S32PW16
NB6GE12-10PNT3	-------------------------	PV6B12S32PN16
NB6GE12-10PWT3	-------------------------	PV6B12S32PW16
NB6GE14-4PNT2	28180-14-4PN-1A	PV6B14S4PN16
NB6GE14-4PNT	38180-14-4PN-1A	PV6B14S4PN16
NB6GE14-19PNT3	-------------------------	PV6B14S19PN16
NB6GE14-19SNT3	-------------------------	PV6B14S19SN16
NB6GE18-8PNT2	38180-18-8PN-1A	PV6B18S8PN16
NB6GE18-PNT3	------------------------	PV6B18S8PN16
NB6GE18-32PNT3	------------------------	PV6B18S32PN16
NB6GE18-32SNT3	------------------------	PV6B18S32SN16
NB6GE22-55PNT2	38180-22-55PN-1A	PV6B22S55PN16
NBOE10-6SNT3	------------------------	PV6B10B6SN16
NBOE14-19SNT3	------------------------	PV6B14B19SN16
NBOE18-8SNT3	------------------------	PV6B18B8SN16
NBOE18-32SNT3	------------------------	PV6B18B32SN16

Table 6.2.3.1-3. Rockwell MC and ME specification connector correlation data

MC414-0614-0011 = SEALECTRO CORP. 50-607-0359-89

ME414-0234-7222 = ITT CANNON* CVA0R36-5S-16
ME414-0235-7101 = ITT CANNON* CVA6R20-24P-16
ME414-0235-7226 = ITT CANNON* CVA6R36-5P-16
ME414-0235-7229 = ITT CANNON* CVA6R36-5S-16
ME414-0235-7244 = ITT CANNON* CVA6R32-17P-16
ME414-0250-0306 = ITT CANNON* 053147-0056

* also time elect. west

Table 6.2.3.1-4. Specification 40M39569 connector correlation data

40M39569	MIL SPEC
NB0E14-12PNT2	MS3470L14-12P
NB0E12-10PNT2	MS3470L12-10P
NB0E14-4PNT	MS3470L14-4P

6.2.3.2 Design Requirements

Payloads must demonstrate that they meet the intent of the design and safety requirements of the SSP. All integrated agreements related to payload safety must be documented in the IP and Unique ICD.

NSTS 1700.7, Payload Safety Policy and Requirements contains technical and system safety requirements applicable to Space Shuttle payloads (including payload-provided ground and flight support systems) during ground and flight operations. General responsibilities are identified in chapter 1 while the technical requirements and overall philosophy are identified in chapter 2 and specific program requirements are identified in chapter 3. Interpretations of some specific safety requirements are documented in NSTS 18798, Interpretations of NSTS/ISS Payload Safety Requirements.

The SSP payload ground safety policy for ground processing for both prior to lift-off and during postlanding activities are identified in KHB 1700.7. This document identifies safety requirements which are unique to ground operations and GSE design.

The Payload Safety Review and Data Submittal Requirements, NSTS/ISS 13830 defines the process and data submittal requirements for implementing the payload safety process. Section 5 provides an overview of how the safety reviews are to be conducted. Section 6 explains the process and section 7 identifies the required data submittals. This document also contains a section on variations to the process for multiple payload cargo, reflown and series payloads. If the payload cannot meet the requirement, a Noncompliance Reports (NCR) process is described in section 10.

6.2.3.2.1 Orbiter Services

The Space Shuttle provides many interfaces and services to the payloads and these interfaces and services are defined and made available in the following documents:

1. Interface Control Document (ICD) 2-19001, Shuttle Orbiter/Cargo Standard Interfaces
2. NSTS-21000-IDD-ISS, Shuttle Orbiter/International Space Station (ISS) Interface Definition Document
3. NSTS-21000-IDD-SML, Shuttle/Payload Interface Definition Document for Small Payload Accommodations
4. NSTS-21000-IDD-MDK, Shuttle/Payload Interface Definition Document for Middeck Accommodations

6.2.3.2.2 Fault Tolerance

Payloads utilizing Orbiter services to control a hazard must recognize the inherent failure modes and fault tolerance as described in NSTS 16979 and only use those services in a manner which provide the required independence if Orbiter services redundancy is required.

Hazards associated with the interactions among mixed payloads, and between payloads and the Space Shuttle is the responsibility of SSP. These hazards are documented through the Generic Integrated Cargo Hazard Assessment, NSTS 21111 process. The mission-specific hazards are controlled by established group responsibilities through the Certification of Flight Readiness (CoFR) process documented in Requirements and Procedures for Certification of Flight Readiness, NSTS 07118.

Prime safety considerations utilizing integrated circuit design for control hazard must apply the NSTS 1700.7 requirements across the complete ETE design. Those controls need to provide adequate fault tolerance. For payloads using Orbiter services to provide hazard control, the payload avionics system (including the Orbiter service) must include design considerations, which provide independence of controls. This independence ensures that no common cause credible failure can remove more that one control.

For integrated hazards, each supporting control circuit must be well understood in terms of functional need to support safety. Some hazards are related to a must-work function while others are related to preventing premature activity from occurring. The functional safety need of the proposed hazard control method must have verifiable independence.

6.2.3.2.3 Payload Safety Process

To provide required integration data, the payload is required to generate specific documentation aimed at supporting the payload safety requirements. The payload is required to identify all potential payload hazards and report on them during the phase safety reviews. Whenever a branch of the controls of the hazard are partially obtained from the Orbiter services, additional information must be provided in both the safety data package and in the NSTS 07700 program documentation.

Safety Critical End-to-End Safety Critical Schematics – The payload must provide unique drawings which match the words provided in the hazard report, identifying each of the active safety critical components (both Orbiter and payload) and the specific Orbiter interface. This drawing has to be developed as the hazard control rationale is developed. Its interfaces must agree with and be attached to the appropriate hazard report. The drawing must be provided and maintained as part of the payload-provided As-Built End-to-End Electromechanical safety critical drawings as specified in the IP Annex 1.

Hazard Event Table – Additionally, the payload must create and maintain hazard events tables. These tables identify each of the safety critical interfaces related to the hazard. These tables must also be maintained to remain consistent with the End-to-End Electromechanical schematics and also attached to the individual hazard reports. These tables must be accumulated and formatted consistent with NSTS 07700 Vol. XIV, Section 13, Hazard Events Table and provided in the payload-unique ICD.

6.2.3.2.4 General Electrical Systems Requirements

Electrical power distribution circuitry shall be designed to include circuit protection devices to protect against circuit damage normally associated with an electrical fault when such a fault could result in damage to the Orbiter or present a hazard to the crew by direct or propagated effects. The payload is provided with an option which requires them to prove that they have created postmate functional verifications demonstrating that no shorts between any adjacent connector pins (both Orbiter and payload) or from pins to connector shell do not exist.

If a payload can demonstrate that such a test can be created and performed, then bent pins will be considered noncredible. If a conclusive verification test cannot be created, then the payload is provided with an option to create a design which will assure that any pin if bent prior to or during connector (Orbiter and/or payload) mating cannot invalidate more than one hazard inhibiting feature.

Traditionally payloads cannot base their design on these type safety requirements, payloads elect to:

1. Minimize the circuits running through their connectors to those which are functionally used therefore all pins within those connectors are verifiable during a postmate testing.
2. The Orbiter performs a bent pin analysis utilizing the payload-provided ICD Hazard Events Table. The analysis identifies testing requirements for adjacent unused circuits to eliminate credible bent pin safety concerns within the Orbiter.
3. The payload provides a pin selection design configuration of the last payload to Orbiter interface connector such that required independent circuits are separated such that a single bent pin would not invalidate both hazard controls.

6.2.3.2.5 Safety Critical Power

The power circuits and sources fall into two major areas of concern to safety, those which provide the capability to perform a the task which otherwise would create a hazard, and those electrical circuits and sources which provide energy to activate the safety control devices and safety monitors.

Relative to cargo integration, a significant amount of the details contained in this document relates to standardizing the interfaces so that safety aspects of the integrated design can be assured to be controlled. When SSP services are to be utilized to control payload hazards, the integrated system must meet the failure tolerance and redundancy requirements. Normally, each Orbiter service can be considered independent from another. However, certain services have common cause failures precluding their use as redundant functions. Some services have been extensively evaluated and may be considered as equivalent to single fault tolerant if specific conditions are met.

Safety Critical Circuit

Any circuit which controls a hazard as documented in the payload hazard report and the loss of that control feature would reduce the hazard failure tolerance by one. In addition, payloads are required to monitor a specific documented set of inhibits and/or have monitoring capability to make operational decisions effecting the fault tolerance as documented in the hazard report. All of these circuits must be documented in the payload hazard report and are defined as safety critical. For all safety critical circuits which cross the Orbiter to payload interface, the payload must include compatible information as required in the IP Annex 1, Safety Critical End-to-End Electromechanical simplified schematics and the payload-unique ICD Hazard Events Table.

6.2.3.2.6 Conditional Single Fault Tolerant Services

GPC Data Bus Couplers – Orbiter-provided services such as the redundant data bus couplers will affect the Orbiter capability of controlling the PLBDs. These redundant services are provided on the port and starboard sides of the Orbiter. If the payload elects to use these services and not keep them independent, a failure of one system may adversely affect the other requiring an EVA be performed to close the doors. Payloads using these services must maintain independence and document these services in the payload-unique ICD section 13 Hazard Events table, and with proper application the two buses are single fault tolerant.

ACCU – Orbiter provides manned payloads with access to the Orbiter redundant ACCN Interfaces which can provide communications, paging, and aural C&W. These services are critical in the ability of the Orbiter to communicate in both the air-to-air and air-to-ground environments. Since these services are critical and instrumental in providing control for numerous hazards, these redundant services must remain independent.

6.2.3.2.7 Orbiter Services Fault Tolerant

NSTS 16979 is dedicated to documenting failure modes and fault tolerances for interface services. These analyses and certification require that very specific criteria be followed. These exceptions allow specific services to be used and considered as being equivalent to either single fault tolerance or in some combinations equivalent to two fault tolerant.

0 AWG Feeder – Under very specific conditions, a single Orbiter 0 gauge may provide the equivalence of single-fault tolerance power supply for payload must-work-type hazards. Before attempting to use this service as single-fault tolerance the payload must agree to all of the conditions documented in the 0 gauge portion of section 4 of NSTS 16979.

AUX Power Feeder – Also, under very specific conditions the two AUX gauge services may be considered single-fault tolerant.

Aft DC Buses – Restricted to being considered zero-fault tolerant.

Cabin Payload Buses – Restricted to being considered zero-fault tolerant.

AC Buses – Restricted to being considered zero- fault tolerant.

T-0 Wire Pairs – Each wire pair is independent of all other pairs. The wires contained within a pair can only be considered as providing zero-fault tolerance.

Standard Switch Panel (SSP) Switches – Under very specific conditions a single SSP switch may provide through it multiple contacts the equivalence of single-fault tolerance must-work capability. This capability is not available if independent power is not available and cannot be applied to multiple inhibits. Also, the payload cannot rely on EVA for a third leg of the hazard control.

Deployment Pointing Panel – The payload design must provide for a ground return inhibit. The select, arm and deploy switches are all considered equivalent to providing single-fault tolerant redundancy services if cabled up to appropriately.

Flight Deck Safing Switches – All safing switches are independent. Like other Orbiter-type, multipole toggle switches, a single switch can be considered as providing an equivalent of single-fault tolerance must-work applications if the appropriate design features required in NSTS 16979 are met and specific testing and the exclusion of an EVA control is provided.

Payload Retention/Latch Assembly System (A6A1) – Payloads utilizing the ac PRLA system must evaluate the complete circuitry carefully. Individual latch/release switches are independent of each other if the redundant feature of System 1 and System 2 are maintained. The payload must provide another level of protection such that the failure of these redundant Orbiter services does not result in an immediate hazard. Where this system is a portion of the payload's two-fault tolerance system, the payload must provide design features to demonstrate compliance.

Payload Signal Processor (PSP) – Circuits of PSP No. 1 or PSP No. 2 are considered zero-fault tolerant; however, circuits of PSP No. 1 and PSP No. 2 will provide single-fault tolerance.

MDM Discrete Output High – All combination of Discrete Output Highs (DOHs) of PF1 circuits must be consider zero-fault tolerant, and likewise all circuits of DOHs of PF2 must be considered zero-fault tolerant; however, in combination they are independent and can provide for single-fault tolerance.

MDM Discrete Output Low – All combination of Discrete Output Lows (DOLs) of PF1 circuits must be consider zero-fault tolerant, and likewise all circuits of DOLs of PF2 must be considered zero-fault tolerant; however, in combination they are independent and can provide for single-fault tolerance.

MDM SIO – All combination of SIOs of PF1 circuits must be consider zero-fault tolerant, and likewise all circuits of SIOs of PF2 must be considered zero-fault tolerant; however, in combination they are independent and can provide for single-fault tolerance.

6.2.3.2.8 Verification of Hazard Controls

As the payload is integrated into the Shuttle, as a minimum, payloads must provide verification as identified in NSTS 14046 to maintain personnel safety, Orbiter integrity and safe use of flight and ground systems.

6.2.3.2.9 Smart Shorts of Power Lines

The SSP requires customers to analyze power distribution systems for the impact of a failure that is smart enough to stress the current limiter (fuses, circuit breakers, resistors) to the maximum possible current level prior to trip. (This phenomenon is called a smart short.) The customer should assume that the power line under analysis provides nominal loads to all load paths except for the largest fuse/current limiter and is sustaining a smart short. Each power line or distribution segment must be safe under this smart combined load as well as a smart short.

6.3 ELECTROMAGNETIC COMPATIBILITY DESIGN AND VERIFICATION REQUIREMENTS

6.3.1 Electromagnetic Compatibility Tailoring

Space Shuttle payloads may be exposed to a complex spectrum of RF emissions. The guidelines below are presented to maximize payload EMC and minimize RF discrepancies; their benefits include enhanced payload manifesting opportunities, improved operational flexibility, and more efficient utilization of Shuttle on-orbit communications capabilities.

The Shuttle-generated electromagnetic environment and the worst-case RF emissions radiated from payloads in the payload bay are defined in ICD 2-19001. Payloads should be designed to limit payload emissions to these field strength levels and tolerate emissions at the same levels from other sources. Any performance deviations waivers are documented in the payload-unique ICD.

Operational restrictions are sometimes imposed on Orbiter transmitters. For example, the Orbiter S-band network transponder requires low-frequency operation if a payload uses the high end of the S-band spectrum, and vice versa. Any such restrictions will be specified in the IP.

Payload RF susceptibility threshold levels provided to the SSP must not be overly conservative. Because of the known field strength of the electromagnetic environment in and around the payload bay, the SSP recommends that payload customers with RF-sensitive equipment conduct a full-scale EMC program tailored to the expected environment. Ideally, this should include tests or detailed analyses to determine the true threshold levels of payload susceptibility. Payloads should be qualified to no less than the exposure levels described in the payload-to-payload field strength versus frequency curve in ICD 2-19001.

If required, payload suppliers must demonstrate a radiated susceptibility safety margin. For example, if Electromagnetic Compatibility Requirements, Systems, MIL-E-6051, is imposed on the supplier, then a 6 dB safety margin is required, and qualification testing should be conducted at field strength levels of 6 dB greater than the environment. The payload customer and the SSP should exchange information on unique intentional or unintentional emissions early in the conceptual phase of payload development. This information should be updated periodically during the integration process.

6.3.2 Conducted Emissions

Ripple and transient limits for payloads are provided in ICD 2-19001.

6.3.2.1 Ripple

Payload-generated ripple is evaluated by comparing test results with the ICD 2-19001 limits mentioned above. If exceedances occur, averages are compared against a chart depicting Orbiter avionics emissions and susceptibilities. If no conflict is apparent, the overlimit ripple current in decibels above a microampere (dBµA), root-mean-square, is converted to peak-to-peak ripple voltage. The ripple current is multiplied by Orbiter dc bus impedance at the overlimit frequency; the product is multiplied by a factor of 2.82 (9-dB increase). This peak-to-peak voltage is then compared to the ripple voltage requirements to determine if a waiver is justified. However, no deviation is allowed for any overlimit ripple between 700 Hz and 3.5 kHz, due to the nature of the conducted emission limit curve and the Orbiter dc power source impedance versus frequency curve.

6.3.2.2 Transients

Payload-generated transient and spike excursion limits vary as a function of the time duration. Note that the allowable voltage excursion is severely reduced after 0.00005 seconds as defined in ICD 2-19001. During transient and ripple generation tests, a bank of batteries simulates the load characteristics of the Orbiter fuel cells as a power source more accurately than a regulated power supply. Quite often, over-limit transients are generated by the commercial power supply regulator response characteristics and not the equipment under test. The oscilloscope’s time sweep should be fast enough for accurate determination of rise and fall times and amplitudes from the recorded data.

6.3.3 Payload-Radiated Emissions

Intentional and unintentional emissions limits are described in ICD 2-19001. If overlimit intentional radiations from a payload cannot be waived, a hazard assessment is conducted by the SSP to determine if there are enough inhibits to preclude radiation in the payload bay. For critical hazards, there must be two inhibits (one-fault tolerance). For catastrophic hazards, there must be three inhibits (two-fault tolerance). See NSTS 1700.7B, for definitions and more detail. Of particular interest are paragraphs which apply to nonionizing radiation.

The following guidelines are used for reviewing waiver requests when radiation limits are exceeded:

1. If the radiated field emanates from a directional antenna located above Z_0 410 inches and the antenna boresight is up and out of the bay without obstructions, a waiver is usually granted.

2. If the overlimit condition is slight and the payload-to-Orbiter impingement in the $-Z_0$ direction is predominantly aft of X_0 900 inches, a waiver is usually granted.

3. Waivers are not granted if analysis or test indicates that the overlimit fields transmitted through the cabin rear windows (No. 9 and No. 10) result in high field intensities in the cabin.

4. Waivers are not granted based on:

    a. An assumed payload bay location in a mixed cargo manifest

    b. An assumed payload activation and deployment sequence

    c. An assumed mix of particular cargo elements

6.3.4 Broadband Electric Field Emissions

The only concern for broadband emissions is whether any overlimit segment of the spectrum from 14 kHz to 10 gigahertz (GHz) falls into the 60 dB passband of any Orbiter receiver or payload receiver.

6.3.5 Narrowband Electric Field Emissions

There are two concerns for overlimit narrowband emissions:

1. Any overlimit frequency spur falling into the 60 dB passband of any Orbiter receiver or payload receiver

2. Any overlimit spur amplitude exceeding the susceptibility level of any Orbiter avionics element.

6.3.6 Alternating Current Magnetic Fields

If the magnetic field at any frequency from 30 Hz to 2 kHz exceeds the limits defined in ICD 2-19001, a waiver may be granted depending on geometric relationships to Orbiter equipment and other cargo elements.

6.3.7 Cargo Susceptibility

Cargo susceptibility requirements are a contractual issue between the payload supplier and the customer and outside the scope of ICD documentation except for safety matters. However, payload suppliers and customers are advised that payloads should be EMC-qualified for the environment (radiated and conducted) generated by the Orbiter and other cargo elements in a mixed cargo manifest. Cargo susceptibility thresholds should be higher than the environment plus any safety margin requirements. The practice of testing to environmental levels and then requesting that the Space Shuttle and cargo elements reduce emissions to accommodate contracted safety margins is not acceptable.

6.3.8 Interface Cable Classifications and Routing

Orbiter interface cables are assigned EMC classifications by the type of signal carried. Coupled interference between wire bundles is prevented by providing minimum edge-to-edge separation between wire bundles of different EMC classifications. See ICD 2-19001.

6.3.8.1 Orbiter Wire Treatment, Bundling Electromagnetic Compatibility Classification and Separation

The Orbiter wiring scheme (including SMCH cabling) is based on the requirements of ICD 2-19001. Strict adherence to these requirements has resulted in no identified Orbiter EMI anomalies on Space Shuttle flights.

6.3.8.2 Payload Requirements

Payload circuits must meet EMC signal classifications at Orbiter/payload interfaces.

In some instances, payload cable bundles are routed with Orbiter cables. To preclude coupling of interference into Orbiter circuits, payload signals shall be routed in wire bundles of the proper EMC classification.

6.3.9 Electroexplosive Devices

Payload Electroexplosive Device (EED) circuit shields must be continuous from the current initiating source to the EED case. EED connectors must have RF-conductive backshells with provisions for 360° circumferential termination. All EED components and circuitry must meet the requirements of Space Shuttle System Pyrotechnic Specification, NSTS 08060, or NSTS 1700.7B. Due to the potential hazard to flight safety presented by pyrotechnics, EED circuits must be certified to have a 20 dB safety margin by test or analysis.

6.3.10 Electromagnetic Compatibility Services

6.3.10.1 Electromagnetic Compatibility Assessments

Early incorporation of EMC solutions to interface conflicts within a payload design is strongly recommended. EMC assessments include:

1. RF beat frequency analysis
2. Payload bay allowable field strength assessment
3. Cabin allowable field strength assessment
4. Payload-conducted emission test data assessment
5. Payload unintentional broadband and narrowband radiated emissions
6. Grounding and bonding issues, including:
    a. RF potentials
    b. Fault currents

c. Electrostatic discharge

d. Ground loops

e. Shielding techniques

f. Wire and cable routing

7. A review of all payload-unique ICD preliminary interface revision notices

6.3.10.2 Beat Frequency and Field Strength Analysis

The Electromagnetic Compatibility Frequency Analysis (EMCFA) computer program analyzes possible interference between transmitters and receivers, determines direct and intermodulation product interference, and computes the amplitude of the interference.

Interference frequencies may be coupled into receivers in two ways. In the first case, undesired signals mix with other signals in the receiver mixing stage and cause interference. The undesired signals combine in the receiver mixer, generating a number of new frequencies. If the unwanted signals generated in the mixer are within the Intermediate Frequency (IF) passband and have sufficient amplitude, they are accepted by the IF amplifier as desired signals. In the second case, interference results from the mixing of two or more transmitted frequencies incident on a nonlinear element external to the receiver antenna. When more than one signal is incident on a nonlinear junction, sums and differences of the original signals’ fundamentals and harmonics are generated and the phenomenon is known as intermodulation. These intermodulated signals can be radiated by the junction and coupled into the receiver antennas. These signals may cause receiver interference when the signals contain frequencies that fall within the receiver passband.

6.3.10.2.1 Payload Transmitter, Receiver, and Antenna Data Input

Payloads with RF transmitter and/or receiver systems must provide the data outlined in NSTS 21288, even if system activation is not planned until after separation from the Orbiter. In this case, data provided will be used to assess the payload receiver damage threat from the activated Orbiter and other payload transmitters.

6.3.10.2.2 Launch and Landing Radio Frequency Environment

All fixed transmitters in the vicinity of the launch pad and landing runway with a measured peak field strength of more than 1 V/m are included in the EMCFA computer analysis. Mobile, airborne, and shipboard transmitters are not included in the analysis. Although there are numerous variables and uncertainties associated with international airspace and waters, the potential threat from these uncontrollable mobile transmitters is small, considering the low probability of close approaches to the launch site and the attenuation provided by the Orbiter.

6.3.10.2.3 Data Processing and Review

The EMCFA program conducts a worst-case analysis. Calculated interferences are tabulated and plotted if the interferences are within the 60-dB passband of any receiver and down to 30 dB below maximum sensitivity. The raw printout has to be analyzed to discard impossible signal combinations and duplications. The remainder with some potential RF Interference (RFI) is recalculated manually and analyzed in greater detail.

6.3.10.2.4 Interpayload Field Strength Exposure Matrix

Payload transmitter field strengths are predicted at different Orbiter and payload locations and are assessed to preclude overexposure of the Orbiter and payloads. Payloads and Orbiter payload bay avionics are considered vulnerable regardless of their activation status. Worst-case LOS field strengths are calculated, and non-problems are culled by inspection. A detailed EMI prediction can be performed on the rest.

6.3.10.2.5 Payload Ground Radiation Constraints

Customers should inform the SSP of payload RF susceptibility if it could be detrimental to the Orbiter, crew, or other payloads. The required customer-provided information is outlined in NSTS 21288.

6.3.10.2.6 Launch Complex Combined Magnetic Field Survey

Payloads containing ultrasensitive magnetic devices may incur calibration shifts when exposed to the combined Space Shuttle and launch complex residual magnetism and the local geomagnetic field for many days at the launch site. If a magnetic survey is necessary at a launch site to determine the combined magnetic triad, the requirement should be specified in the PIP and PIP Annex 8, Launch Site Support Plan. Details should be addressed with the launch site support manager.

6.3.10.2.7 Payload Hazard Report Reviews for Safety

All payload hazard reports involving EMC issues are reviewed for disposition. EMC issues include the following:

1. Intentional or inadvertent payload transmitter emissions in the payload bay that constitute critical or catastrophic hazards; transmitter inhibits to preclude turn-on are reviewed for adequacy

2. EED (pyrotechnic initiator) types and usage

3. EED sensitivity levels to Electrostatic Discharges (ESDs) resulting in premature firings that constitute catastrophic hazards

4. EED sensitivity levels to nonionizing radiation that constitute catastrophic hazards

5. Lightning protection to avoid catastrophic hazards, per Lightning Protection Criteria Document, NSTS 07636

6. Payload-generated ESD that triggers explosive atmospheres or ignites flammable atmospheres in the payload bay
7. Intentional or inadvertent payload laser or laser systems radiation in the payload bay that constitutes potential hazards for flightcrews (such as distraction, disruption, disorientation, and incapacitation), or presents an electrical shock, fire damage hazard to the Orbiter

Safety policy and requirements are stated in NSTS 1700.7B, and implementation procedures in Implementation Procedure for STS Payloads System Safety Requirements, NSTS 13830.

6.3.10.3 Payload Electromagnetic Compatibility Test Reports

EMC testing formally demonstrates EMC compliance with ICD-2-19001 requirements. Payloads must be compatible with the Shuttle-produced EMI environment and must not generate conducted and radiated emissions exceeding cargo-allowed EMI environment limits. Although conducted emissions testing isn't normally required for cabin payloads with self-contained power supplies, customers should perform this testing if the crew might need to connect the payload to Orbiter facility power due to a power-related problem (e.g., drained batteries or other reasons).

6.3.10.3.1 Waivers

If a payload exhibits EMC noncompliances and poses no threat to the Orbiter, the customer may request a waiver to the requirements. Desirable safety margins required for issuing a waiver are 6 dB for conducted emissions, 12 dB for radiated emissions, and 20 dB for ordnance as compared to sensitivity levels of other payloads and Space Shuttle avionics.

6.3.10.4 Electrostatic Discharge

ESD involves differential charging among cargo elements and the Orbiter. Differential charging occurs when different elements are charged to different negative potentials. The primary charging mechanism of concern is triboelectrification, or charging caused by materials with different dielectric constants rubbing or sliding in contact and then parting. Charging is also caused by liquid flow through piping, commencing at 1 meter per second. High-velocity air flow on a surface, where the air has a heavy concentration of particulates, is another triboelectrification process. Particulates may be dust and hydrometeors such as rain, snow, hail, sleet, or fog. Charging commences at flows greater than 5 meters per second (assuming mass flow rates at standard conditions) and is greatly affected by humidity.

The voltage required to break down air is a function of pressure and distance between elements with a minimum of 350 V at 170,000 feet, as described by the air Paschen curve. At 340,000 feet and above, where the pressure is below 0.0001 torr, breakdown voltage is independent of residual gas pressure. It depends on surface shape and materials as well as distance between elements. The breakdown voltage of the air mixture at Low Earth Orbit (LEO) between cargo/Orbiter elements is over 100,000 V/cm. Therefore, arching in nonenclosed volumes at LEO is not a threat.

The major ESD concern for the Orbiter is triggering an explosion of hydrogen gas that might inadvertently leak into the payload bay during launch, Return to Launch Site (RTLS), Abort Once Around (AOA), or normal landing from residuals in the aft equipment bay plumbing. Hydrogen leakage into an enclosure of air at one atmosphere is typically triggered by an arc of 200 microjoules (μJ). An ideal mixture could trigger at 17 μJ. Stoichometric mixtures of pure hydrogen and pure oxygen could be triggered by an arc of 1.2 μJ energy at one atmosphere.

6.3.10.4.1 Static Bonding

NSTS 37330 requires structure resistance to ground of less than 1Ω for static charging prevention (class S).

Class S bonding in NSTS 37330 refers to all isolated conducting items (except antennas) that have any linear dimension greater than 3 inches; are subject to frictional charging (triboelectrification) by a credible charging mechanism, carry fluids in motion at rates greater than 1 meter per second; or are external to the vehicle and not in a sealed enclosure.

The linear dimension rule of 3 inches is somewhat misleading. Surface area and shape is a more accurate concept (sharp points and edges versus rounded surfaces). The minimum surface area of concern, hence its capacitance, is a variable depending on the interaction between two rubbing, sliding, or touching and parting surfaces plus the following parameters for materials:

1. Conductivity
2. Dielectric constants
3. Insulator material thicknesses
4. Environmental (gas) temperature, pressure, and humidity
5. Energy required to generate an arc discharge capable of triggering an explosion or starting a fire if the environmental gas is flammable or explosive

The static charge bleed resistors on the isolated RMS grapple fixture, installed on deployable payloads, are two 10,000 Ω resistors in parallel, or 5000 Ω to Orbiter's RMS end-effector structure. The relaxation time, (the time to drain the charge differential between the RMS and payload) is five resistance times capacitance (RC) time constants

$\tau = Rg \text{ x } C$
or 99.3 percent of the charge.

6.3.10.4.2 Arc Discharges Triggering Explosive Gases

In an explosive gas environment, at one atmosphere, the chances of explosion exist due to an arc discharge if the following conditions are present:

1. Arc energy (joules) exceeds the trigger threshold for that gas mixture
2. Charged conductor (single) RC time constant is greater than one millisecond, allowing for significant charge buildup

Ground capacitance of typical objects:

Low:	needle point	1 pf
	hand tool	10 pf
	human	150 to 250 pf
High:	auto	500 pf
	isolated railroad tank car	1000 pf

Structural capacitance above 1000 pf is rare. Exceptions are capacitors and thermal blankets.

More energetic arc discharges can occur if an object's capacitance is large, but more charge is required to build high voltages.

A discharge derived from a charged conductor produces a more serious hazard in a flammable or explosive atmosphere than one derived from a charged insulator, the charging in coulombs being equal. A single spark from a conductor generally discharges most of the total charge.

6.3.10.4.3 Thermal Blankets

The following should be used for thermal blankets:

All metallized surfaces in Multilayer Insulation (MLI) blankets shall be electrically grounded to structure. Metallized multilayer surfaces should be electrically grounded to each other by ground tabs at the blanket edges. Each tab should be made from a 2.5-cm-wide strip of 0.005-cm-thick aluminum foil. The strip should be accordion folded and interleaved between the blanket layers to give a 2.5- by 2.5-cm contact area with all metallized surfaces and the blanket front and back surfaces.

Redundant grounding tabs on all blankets are required as a minimum. Tabs should be located on blanket edges and spaced to minimize the maximum distance form any point on the blanket to the nearest tab. Extra tabs may be needed on odd-shaped blankets to meet one additional condition: any point on a blanket should be within one meter of a ground tab.

The following practices should be observed during blanket design, fabrication, handling, installation, and inspection:

1. Verify layer-to-layer blanket grounding during fabrication.
2. After installation, verify that there is less than 10 Ω dc resistance between blanket and structure.
3. Close blanket edges (cover, fold in, or tape) to prevent direct irradiation of inner layers.
4. Do not use crinkled, wrinkled, or creased metallized film material.
5. Handle blankets carefully to avoid creasing of the film or degrading the ground tabs.
6. If the blanket exterior is conductive (paint, indium tin oxide) make sure it contacts the ground tab.

6.3.10.4.4 Purge Air

Prelaunch purge air is filtered to HEPA class 5000. During entry and descent, atmospheric air is filtered through 35-micron filters. Charging effects of clean air impinging on spacecraft surface are minimal.

6.3.10.4.5 Articulating Joints

Static bonding across threaded bolts is unreliable and unacceptable. If structure must be grounded across an articulating joint or hinge, a ground strap as short as possible shall carry the ground across the joint. Reliance on bearings as a ground is unacceptable.

6.3.10.4.6 Temporary Structures

Erectable type structures assembled on-orbit for temporary use have less stringent bonding requirements than permanent structures. The dc impedance of disassembled components to structure when stowed in a grounded enclosure is the primary concern during launch and landing. Specific bonding requirements should be negotiated with the SSP.

6.3.10.4.7 Beta Cloth

When the outermost layer of thermal blanket is made of beta cloth for protection against solar UV emissions and for abrasion, a Vapor-Deposited Aluminum (VDA) backlayer or conductive wire grid woven into the fabric is usually unnecessary. Exceptions are when payloads carry dangerous liquid fuels or there is a credible charging mechanism to the beta cloth surface. Specific designs should be negotiated with the SSP.

6.3.10.5 Lightning

Payloads are provided direct lightning strike protection by enclosing Orbiter structure. However, payloads are potentially exposed to lightning induced transients from a nearby or direct lightning strike to the Orbiter. The lightning induced transients may damage or upset payload electrical/electronic equipment without deliberate lightning protection. The exposure is reduced significantly by lightning protection features of the Orbiter and operational restrictions implemented to avoid being struck by lightning. The Orbiter is protected on the launch pad by a catenary wire system which prevents direct attachment of lightning to the vehicle. The Launch Commit Criteria is designed to avoid launch in atmospheric conditions favorable to lightning conditions. Landing criteria tend to minimize landing in inclement weather conditions (such as high turbulence and precipitation) which may accompany lightning. As such, the exposure of payloads to lightning effects is considered possible but remote. As a reference protection guide, only critical Orbiter electrical/electronic equipment are designed and protected against lightning induced transients. The defined lightning environment and methodology to be used for lightning protection design and assessment is given in NSTS 07636, Revision G.

6.3.10.6 Electromagnetic Compatibility Provisions

6.3.10.6.1 Bridge and Trunnion Latches

The sill trunnion latch fibriloid liners provide up to 1 megohm (MΩ) of isolation between the payload trunnion and latch.

6.3.10.6.2 Keel Latch

Keel latches have a fibriloid liner providing up to 1 MΩ of isolation. At the request of the payload contractor, two beryllium-copper tabs (fingers) may be installed in the keel latch to provide a static ground (1 ohm) for the payload. This provision may be required for retrievable payloads, and must be incorporated in the payload-unique ICD.

6.3.10.6.3 Adaptive Payload Carrier

APCs are aluminum mounting plates installed on the sides of the payload bay near the sill longeron. APCs are used for installing small payloads in the payload bay. A ground wire in the 28-V dc power cable provides a fault ground for payloads mounted on APCs; however, the ground wire does not provide a sufficiently low impedance path to ground for RF energy as required by NSTS 37330.

The SSP will furnish a RF jumper to bond the payload mounting plate to the APC with less than 1.25 mΩ resistance. The APC-to-structure bond resistance will also be less than 1.25 mΩ. This gives the payload a low impedance RF bond path with a resistance of less than 2.5 mΩ to Orbiter structure.

The payload contractor is responsible for bonding the equipment mounted on the payload mounting plate in accordance with NSTS 37330.

6.3.10.6.4 Standard Mixed Cargo Harness

The SMCH standard 200-A, 28-V dc power service for major payloads provides a 0-gauge wire for electrical bonding of the payload to Orbiter structure. The 0-gauge ground wire is 8 feet long on the Orbiter side of the interface and an estimated 8.5 feet in length on the payload side. Since a 16.5-foot ground wire has substantial impedance at megahertz frequencies, this factor should be considered in evaluating payload RF bonds.

6.3.10.6.5 Additional Bonding Jumpers

Special RF bonding jumpers up to 30 inches long that will provide less than 2.5mΩ of resistance at the payload/Orbiter interface are available. Customers should identify the attach points for these jumpers in the unique ICD. The requirement for unique bonding jumpers should be negotiated with the SSP.

6.3.10.6.6 Special Cables

Customers requiring special cables for EMI protection should negotiate procurement of such cables with the SSP and incorporate the requirement into the payload-unique ICD.

6.3.10.6.7 Get-Away Special Electromagnetic Compatibility

The standard GAS canister protects the Orbiter from GAS experiments emissions. GAS canisters are EMC certified by GSFC, but canisters with any nonstandard opening or feedthrough must be retested for EMC by GSFC.

6.3.10.7 Laser and Laser Systems

The nature of the lasers and their concentrated energy can create the potential for permanent eye injury and/or skin damage to crew and Mission Specialists of the Shuttle Orbiter if operated closer than the NOHD. In addition, when laser emissions are projected or reflected into airspace they can be intercepted by other spacecraft, including payloads, EVAs and the International Space Station (ISS). Unplanned exposure from spectral or diffuse reflections may also cause crew distractions and/or create temporary vision impairments such as glare, flash-blindness, and afterimage beyond the NOHD. As a result, safeguards must be established to ensure that pilots and crews are not exposed to unsafe levels of laser exposure that could interfere with lift-off, landing, or on-orbit operations. Therefore, a laser safety assessment shall be conducted on all proposals for laser and/or laser systems to ensure there are no hazardous effects during launch/landing and on-orbit activities.

Considerations for Laser Assessments:

1. Does any payload contain devices that emit laser radiation? If so, are there laser emissions that exceed Orbiter or payload laser sensitivity levels?

2. Does the MPE at any wavelength between 180 nanometers and 1 millimeter exceed the MPE limits in ICD 2-19001?

3. Are there constraints built into the laser design to limit or prevent lateral and elevation movement of a laser platform if required?

4. Are there any diffuse/specular reflections from surfaces in the immediate area of the laser? If so, what are they and where are they located? Identify any potential hazards.

5. Evaluate the intended laser usage in the laser environment.

6. Identify the accepted fault tolerance of the laser per its classification and verify that the appropriate controls are in place for the potential hazards.

7. Identify any potential hazardous laser beam path(s) or zone(s).

8. Identify the type of laser and whether it is pulsed or Continuous Wave (CW).

6.3.10.7.1 Laser MPE from Payloads

The Laser MPE is described in ICD 2-19001. The following guidelines are used to review a waiver request when the MPE limits would be violated:

1. If the violations in the MPE are from a laser source located above $Z_0$410 inches and whose laser beam boresight is pointing up and out of the bay without obstructions, a waiver is usually granted if devices are incorporated to preclude laser beam from intercepting the crew compartment rear windows. Examples of such devices are positive mechanical stops on the azimuth and elevation traverse, or an integrated electrical beam control system to control with high-precision the laser pointing capability.

2. If the over-limit condition is slight and the distance of the laser to Orbiter impingement in the $-Z_0$ direction, is predominantly aft of $X_0$900 inches, and it is farther than the required NOHD in the crew compartment after correction factor due to the transmittance factor of the Orbiter window, then a waiver is usually granted. The transmittance factors for the Orbiter windows are given in ICD 2-19001.

3. Waivers are not granted if analysis or test indicates that the maximum irradiance through the cabin rear windows (windows 9 and 10) exceed the MPE.

4. Each request of waiver shall be analyzed to determine the hazards and assess the risk of the proposed waiver of a requirement, or a specified method or process. The change in the risk involved in accepting the waiver shall be identified. When the level of safety of the system will be reduced by waiver of the requirement, method, or process, technical justifications must be fully included.

Laser and laser systems hazard safety requirements are also defined in ICD 2-19001. The requirements follow the ANSI Standard, ANSI Z136.1-2000, American National Standard for Safe Use of Lasers. The standard provides guidance and defines control measures (for each of four laser classifications) which protect the pilot and crew from unsafe laser exposure.

6.4 THERMAL ANALYSIS DESIGN AND VERIFICATION REQUIREMENTS

6.4.1 Thermal Design and Analysis Requirements

The payload customer is responsible for payload thermal design consistent with SSP requirements and for providing data to the SSP for use in conducting the compatibility assessment. Payload thermal math models shall be provided to the SSP for use in conducting a thermal verification analysis/assessment. The payload customer is also responsible for providing payload thermal data for the payload documentation.

The SSP role in the thermal integration process includes providing the documentation on Space Shuttle thermal requirements and accommodations. The SSP will supply Orbiter thermal math models for payload thermal design analysis. The SSP will conduct a compatibility assessment prior to the CIR. The SSP will conduct a verification thermal analysis/assessment to ensure payload compatibility with the flight design.

6.4.1.1 Payload Thermal Design Summary

In addition to the design considerations for achieving payload mission objectives, special considerations for Space Shuttle safety and mission compatibility are required.

The customer is responsible for investigating the effects of potential anomalies to preclude thermal limit violations which could endanger the crew or compromise the flight during any mission phase. Two payload thermal design considerations must be addressed: design requirements for contingency operations and analyses defining limitations during contingency operations.

1. Contingency Design Requirements

   a. Payloads must be designed for thermal compatibility with abort during any mission phase.

   b. During powered ascent, abort can occur as either RTLS or abort to an alternate landing site such as a Transatlantic Abort Landing (TAL) site. On-orbit aborts can occur before or after PLBD opening. Prior to door opening, AOA represents minimum orbit time, while maximum time depends on orbit inclination. The PLBDs are normally opened 1 to 1¼ hours after lift-off; however, customers must design for a maximum of 3 hours. If the doors are not opened by 3 hours after lift-off, an abort will be declared and landing will occur by lift-off plus 6.5 hours for 28.5° inclination missions or 11.5 hours for 57° inclination. Following the 3-hour abort time, special Orbiter contingency operations may be necessary which require curtailment of standard payload services (i.e., power, cooling, etc.). Following PLBD opening, aborts can occur at any time; therefore, payloads must be compatible with an abort from the worst hot or cold condition possible for that particular mission.

   c. Payloads must be designed to present no hazards to the Orbiter for flights ending at emergency landing sites (i.e., where ground services (such as payload bay purge or active cooling) are not available).

   d. Payloads using Orbiter-provided heat rejection must be designed to present no hazards to the Orbiter for reduced or lost heat rejection.

   e. Payloads using Orbiter-provided electrical energy for thermal control must not present a hazard in the event of loss of power.

   f. Payloads must not present a hazard in the event of a failed open Orbiter payload bay vent door or a failed on payload bay floodlight.

2. Contingency Analyses Defining Limitations

   Data must be provided to the SSP to support contingency planning.

   a. Long-term (off nominal) exposure to worst hot or cold mission environments must be analyzed and temperature limits affecting safety must be identified.

   b. For deployable/retrievable payloads, limitations associated with delay in the deployment sequence or restow of erectable spacecraft (if applicable) and delayed deployment must be identified and thermal recovery periods defined.

Additional contingencies due to payload-peculiar characteristics as well as the contingencies noted above will be defined and documented in the applicable IP and IP annex.

Payload operational constraints associated with implementation of payload objectives should be established by conducting appropriate thermal analyses of the payload design.

6.4.1.1.1 Shared Payloads

Payloads which share flights with other payloads and utilize the standard accommodations (defined in ICD 2-19001) must incorporate into the payload design a minimum thermal capability common to all users of a particular flight. To ensure this mixed cargo compatibility, the SSP has defined on-orbit Orbiter attitude requirements with which (as a minimum) all payloads sharing a flight must be compatible. All mixed payloads must accommodate a selected attitude continuously; (i.e., an attitude which can be maintained without interruption). For missions with beta angles (beta angle and Orbiter coordinate axis system are defined in table 4.2.1.1-1) less than 60°, the selected attitude is with the Orbiter payload bay continuously facing the Earth (+ZLV). For beta angles greater than 60°, the selected attitude is specified as the Orbiter X-axis perpendicular to the solar vector operations within 20° and rolling about the X-axis at a rate of two to five revolutions per hour. This attitude is called PTC. The continuous attitude will be maintained during crew sleep periods as well as long duration coast periods, such as between deployment opportunities for deployable spacecraft. Short-term deviations from the continuous attitude are required to allow for deployment of deployable spacecraft. As a minimum, all mixed payloads must be able to incur 30 minutes of Orbiter + Z-axis directed toward the Sun, as well as 90 minutes of + Z-axis directed toward deep space. Thermal recovery from the short-term solar or deep-space attitudes will be made in the applicable continuous attitudes; (i.e., +ZLV or PTC).

The Orbiter has considerably greater attitude capability than has generally been required of mixed payloads. For this reason, on mixed payload missions, deployable payload ASE (equipment remaining in the payload bay after deployment) is required to have attitude capability equivalent to that of the Orbiter. ASE that does not constrain Orbiter attitudes allows manifesting of deployable-type payloads with nondeployable types, performing deployments early in the flight, and retaining the capability to accommodate attitudes required for nondeployable payloads. Requirements for nondeployable payloads are generally more demanding than for deployable payloads. Similarly, nondeployable payloads must have, as a minimum, the capability to accommodate the mixed payload criteria without constraining deployable payloads.

For mixed cargo missions, the SSP is responsible for determining payload location in the payload bay and the order of deployment of deployable payloads. Payload thermal design must incorporate these considerations. If a payload is sensitive to being located near a bulkhead or large payload, this must be addressed in the design. Similarly, thermal design for deployable payloads must not assume first-day deployment. Attention to these considerations will maximize manifesting opportunities.

6.4.1.1.2 Dedicated Payloads

For dedicated payload missions (i.e., nonmixed payloads) specific attitude constraints consistent with the Orbiter attitude hold capability defined in ICD 2-19001 are generally acceptable; however, analysis must provide sufficient data to plan for contingencies. Specific thermal attitude constraints will be agreed to and documented in the IP and included in mission attitude timeline planning. The nominal mission profile then will be used by the SSP for the integrated mission verification analyses.

6.4.1.2 Integrated Thermal Analysis Considerations

The payload thermal control design process must include an integrated thermal analysis to ensure that the design meets expected mission objectives and defines payload-unique thermal requirements for IP and ICD inputs. Integrated analysis can be an iterative process where the initial effort is directed toward defining payload thermal control design. Subsequent analyses, after the payload design matures, should establish payload-unique requirements, particularly in orbit.

An integrated analysis may consist of several separate analyses, depending on the thermal interfaces of a particular payload. The following separate analyses should be performed:

1. Payload/Orbiter interface analysis for payloads and ASE in the payload bay
2. Payload bay floodlight interface analysis for payloads in the payload bay
3. Failed payload bay vent door analysis
4. Heat rejection analysis for payloads using the payload heat exchanger
5. Heat rejection analysis for payloads using the spigot system

6. Ferry flight interface analysis for payloads and ASE in the payload bay, middeck, or AFD
7. Payload/grapple fixture/end effector interface analysis for payloads using the RMS

The integrated analysis for payloads and ASE in the payload bay or payloads deployed from the payload bay is relatively complex. This procedure requires using suitable payload and Orbiter math models and using computer programs capable of analyzing them.

Design timelines for these conditions must be defined. The Orbiter geometric and thermal math models used for the integrated analysis are available from the SSP.

Generally, Integrated Thermal Math Models (ITMMs) and analysis cases are tailored specifically for a payload, its mission conditions, and the objective of the analysis. For example, if the integrated analysis is performed primarily to support payload thermal control design, a detailed payload thermal model is used with the simplest interface models to represent the Orbiter and other adjoining payloads in the payload bay. These and other considerations that minimize the cost of integrated thermal analysis are discussed in subsequent sections.

6.4.1.2.1 On-orbit Attitudes and Constraints Analysis

The Orbiter’s attitude/duration constraints for thermal compatibility are defined in the ICD 2-19001. These payload constraints are determined by integrated analysis. Worst hot and worst cold attitudes are examined, as well as operational and nonoperational payload attitudes. The worst hot and cold attitudes normally are +ZSI (top Sun inertial) and +XSI (tail Sun inertial), respectively. A colder attitude would be +X Sun orbital rate (tail-to-Sun, one revolution per orbit about the X-axis), so that the payload bay is always facing deep space. Some other attitude may be locally coldest or hottest in special circumstances (e.g., unusual payload geometry or physical properties).

Among other factors, the beta angle influences the thermal severity of these and other attitudes. Generally, the shortest time required to exceed the operating and nonoperating temperature limits of critical components is used to define constraints. Of course, if these constraints violate Orbiter constraints the latter must prevail.

In addition to the time to exceed a temperature limit, the time to recover from a limiting temperature to a nominal condition (e.g., to +ZLV, payload bay facing Earth) is also of interest. This time establishes the waiting period before commencing another hot or cold attitude excursion. Depending on whether a hot or cold extreme has been reached, the recovery attitude is generally +ZLV, PTC, +XSI, or +ZSI. The designation PTC (passive thermal control) is assumed for analysis purposes to be rotation of the Orbiter about its X-axis at two to five revolutions per hour with the X-axis within 20° of perpendicular to the Sun vector. This is sometimes called the barbecue mode.

The Orbiter attitudes referred to above are depicted in section 8. Note that other Orbiter orientations could also satisfy these attitude designations. The direction of at least one other Orbiter axis is needed to uniquely define the attitudes shown.

6.4.1.2.2 Prelaunch, Ascent, Entry, and Postlanding Analysis

These mission phases are of particular interest for AOA and contingency landing site conditions and for cryogenic and high-heat-generating payload components for which thermal compatibility with the closed-door Orbiter must be determined. Variables that must be considered are launch and landing site, time of year, time of day, and Orbiter payload bay purge gas parameters and availability.

6.4.1.2.3 Payload Bay Floodlight Analysis

Payload surfaces or elements located near payload bay floodlights should be analyzed to determine if a temperature violation could result (from floodlight operation). If a temperature violation could occur and a suitable redesign is not feasible or practical, the floodlight operational constraint should be specified in the IP and analysis results supplied to the SSP for evaluation and planning.

To conduct the analysis, the payload bay floodlight locations and thermal characteristics, in ICD 2-19001, should be used; they are adequate for most cases. In special situations that require a more detailed analysis, the SSP can provide a floodlight thermal math model.

The payload should not be designed to utilize payload bay floodlights for thermal control.

A single failure in floodlight circuitry could cause a floodlight to fail on. The payload must be designed to be safe with any floodlight failed on.

6.4.1.2.4 Failed-Open Vent Door Analysis

The temperature, mass flow rate of repressurizing air entering the payload bay, and payload bay pressure during entry in ICD 2-19001, are the maximum or worst conditions that occur at or near the payload bay vents. Thermally sensitive payload surfaces that may be located near a payload bay vent should be analyzed to determine the impact of exposure to hot entry air after the vent doors are opened. As shown in the ICD, the entry air temperature declines rapidly from approximately 400° F (low density air) at vent door opening to 100° F in approximately 60 seconds.

Normally, payload bay vent doors are closed at the start of entry and do not open until after peak aerodynamic heating has occurred. However, customers must conduct thermal assessments to confirm that no hazards are presented to either the payload or its integration hardware if one or more vent doors should fail in the open position and remain open during reentry. The methodology for performing these assessments is presented in ICD 2-19001.

6.4.1.2.5 Inadvertent Release of Fluids

As a minimum, payloads must provide additional data if a payload fluid containment system fails to meet the established safety requirements. An integrated evaluation has to be performed if an inadvertent payload vent/leak is credible. Flammability and cargo bay over-pressurization must be evaluated after the payload has exhausted its ability to meet the no venting allowed during ascent and return requirements meant for even those contingency cases where credible failure were required for the event to occur.

6.4.1.3 Payload Thermal Math Models

Among the first details to be considered by a thermal analyst in preparing a payload Thermal Math Model (TMM) are those associated with its eventual inclusion in an Orbiter TMM. The resulting ITMM is required for an integrated analysis to confirm payload thermal compatibility with the Orbiter and its mission environment. Specific payload TMM criteria and guidelines have been established in Criteria/Guidelines for Payload Thermal Math Models for Integration Analysis, JSC 14686, to assist the thermal analyst in this process. These requirements ensure consistent and adequate TMM and supporting data for economical and reliable analysis and compatibility with SSP standard services. Among these requirements are payload TMM size restrictions (i.e., number of nodes, conductors, external surfaces), minimum allowable stable calculation time interval, payload/Orbiter interface considerations, and adequate documentation.

A complementary payload Geometric Math Model (GMM) is required for each TMM for combining with an Orbiter GMM to produce an integrated IGMM. The IGMM is used to calculate radiation interchange factors and orbital heat rates for external surfaces. Payload math model documentation should be referenced in the payload-unique ICD.

6.4.1.4 Orbiter Thermal Math Models

Several Orbiter midsection/payload bay TMMs are available for use in integrated thermal analyses and are authorized in the appropriate IDD or ICD. These models are listed in table 6.4.1.4-1 in order of decreasing detail, with major differences noted.

Each Orbiter TMM is constructed to allow for renodalization of its payload bay liner and wire tray nodes (or zones). This provides additional and/or better distribution of nodes to attain the desired accuracy for both the liner/wire trays and an included payload TMM. Renodalization of the payload bay liner should be considered when the Sun’s rays shine directly into the payload bay parallel to the Orbiter Z-axis. The TMM references also describe how to add the optional payload retention fittings and RMS.

Input data for constant and diurnal prelaunch and postlanding environments consist of ambient air and surrounding boundary temperatures and solar heat rates for various conditions at the Eastern Test Range (ETR). These data are included in the closed-door TMM documents, ES3-77-3, and ES3-76-7, and ES3-77-1.

While simpler Orbiter models may suffice for most applications, the capabilities and limitations of ES3-76-7 and ES3-77-1 should be understood before the models are used.

Table 6.4.1.4-1. Available thermal math models

Orbiter TMM	Modeling of payload bay liner and outward through Orbiter sides and bottom	Wire trays, frames, and aft fuselage	External Orbiter heat loads and radiation interchange	References
390 Node	Detailed	Included	Directly applied (must be calculated)	ES3-76-1 ES3-77-3
136-Node	Less detailed than 390 node	May be added	Directly applied (must be calculated)	ES3-76-7 ES3-77-1

6.5 CREW HABITABLE MODULE DESIGN SPECIFICATIONS

6.5.1 General

This section details specifications for design of crew habitable module interfaces and accommodations. These requirements are directed toward design of habitable modules and man/machine interfaces for crew operation in a microgravity environment.

Hardware must be designed to operate under the conditions described in this appendix and meet flammability, offgassing, and other safety requirements specified in NSTS 1700.7B. Consult NSTS 07700, Volume XIV (and its appendixes), ICD 2-19001, and NSTS 21000-IDD-MDK for complete design requirements.

NASA-STD-3000 is the reference document for the human-to-equipment interface for payloads flown in man-tended facilities and for the facility itself. It provides extensive information on biomechanics, human resources and performance, architectural considerations, and design guidance for equipment, controls, and restraints.

6.5.2 Prototype and Mockup Hardware Evaluations

All payload hardware requiring a crew interface must undergo early iterative evaluations using customer-supplied mockups or prototypes. The majority of these evaluations will be conducted in a 1-gravity (g) environment, and may use the Orbiter full fuselage trainer or crew compartment trainer as an engineering test bed for fit and function checks. Use of these 1-g facilities for hardware evaluations is a standard service. Prototypes and mockups should be evaluated before engineering designs are finalized to prevent costly changes. Prototype hardware can often be adapted to support subsequent crew training.

Complicated or unique hardware may require evaluation in a neutral buoyancy facility such as the Neutral Buoyancy Lab (NBL). For information on the NBL, refer to Neutral Buoyancy Lab General Operating Procedures, JSC 26990.

6.5.3 Mobility Aids and Crew Restraints

Crew restraint provisions (e.g., handholds and handrails) shall be provided by the customer along translation paths and in planned work areas to prevent drifting and allow initiation and termination of movement. Such devices shall not restrict minimum translation path diameter. Restraints are also to be used in areas where force may be applied by a crewmember to prevent reactionary motion which would degrade task performance.

When properly designed and located, handholds and handrails serve as convenient locations for temporary restraint of loose equipment, and may be utilized to protect payload components from inadvertent damage by the crew. Some structural components may double as translation or mobility aids if suitably identified. Handrails must be painted yellow for rapid identification by the crew. Payload designers should consult the SSP for recommended handhold and handrail locations.

Proper restraint of crewmembers and equipment at the worksite is mandatory to ensure maximum capability. Adequate restraint allows two-handed operations and is a factor in preventing crew fatigue. Use of restraint provisions is an essential part of basic training.

Use of handholds and handrails may be adequate for low force, brief tasks such as inspection, monitoring, and switch activation. Foot restraints have proven the most effective restraint system for Intravehicular Activity (IVA) functions that require force application, precise positioning, and/or long periods of time at a particular workstation.

NASA-STD-3000 contains guidelines for designing mobility aids and crew restraints.

6.5.4 Crew and Equipment Safety

Payload designs shall meet the requirements of NSTS 1700.7B, protecting the crew from electrical, fluid, radiation, mechanical, chemical, and other hazards. Hazards and controls shall be identified through the SSP safety review process.

A fire protection system and module atmosphere venting capability shall be provided as part of the customer-supplied habitable module, in accord with the requirements of NSTS 1700.7B.

A major safety concern in IVA design is the compatibility of payload systems and structures with the crewmember. Payload equipment, structures along translation routes, worksite provisions, and items requiring crewmember contact must be designed to preclude sharp edges and protrusions or be covered to protect the crewmember. Rounding and curling criteria relative to sharp edges and protrusions are illustrated in figure 6.5.4-1. Sharp edge inspections shall be performed on all components.

Customer payloads that include sharp objects (such as syringes) must give special consideration to configuration, containment, storage, materials, and procedures. Customers shall submit hazard controls through the SSP safety review process.

6.5.5 Color Coding and Labeling Design Requirements

Indicator lights shall conform to Human Engineering Design Criteria for Military Systems, Equipment, and Facilities, MIL-STD-1472D. Hazards shall be physically identified by markings, labeling, and coloring as follows.

6.5.5.1 Color Coding

Only one hue within a color category (e.g., reds, greens) shall be used in a given coding scheme, and that color shall always be associated with a single meaning. No more than nine colors, including white and black, shall be used in a coding system. Color coding shall not be used as a primary method of identification where lighting is insufficient in quantity or spectral characteristics.

The following colors (as specified in Colors, Federal Standard 595) shall be utilized for the purposes indicated.

1. Red No. 21105 (or No. 11302) - Emergency, warning, and master alarm lights; safety controls; critical controls requiring rapid identification for emergency shutdown; control panel outline of a functionally critical emergency nature. (Under ambient red lighting, use orange-yellow and black striping)
2. Yellow No. 33538 - Caution; emergency exits; safety controls associated with emergencies of a less critical nature
3. Yellow No. 33538 with black No. 37038 stripe - Immediate access; exit releases
4. Orange No. 32246 - Hazardous moving parts; machinery; start switches, etc.
5. Green No. 14187 - Important and frequently operated controls with no urgent or emergency implications
6. Green No. 14260 (sage) - First aid and survival
7. Blue No. 25102 (or No. 15177) - Advisory (not recommended for general use)
8. Purple No. 37142 (magenta) - Radiation hazard

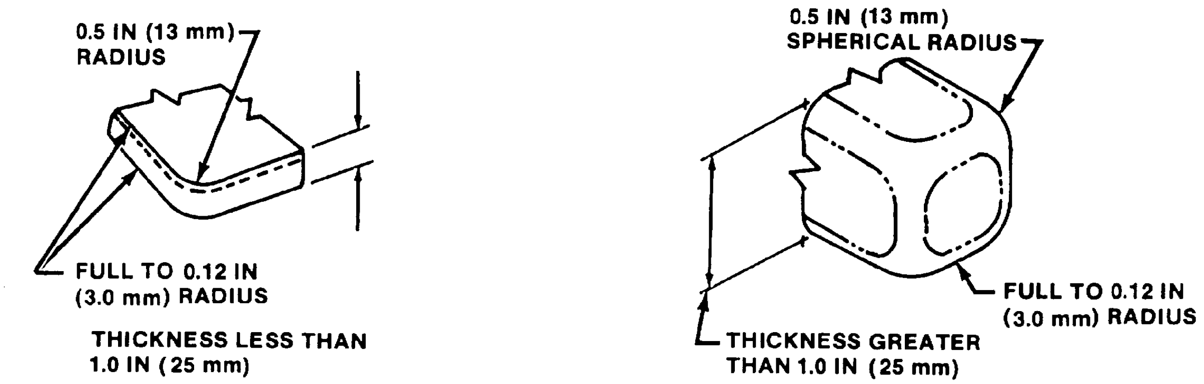
To avoid confusion by color-deficient observers, do not use the color green if the color scheme uses more than six colors. If six or fewer colors including green No. 14260 and yellow are used, yellow No. 23655 shall be substituted for No. 33583. Use of red and green within the same color coding system should be avoided.

A) REQUIREMENTS FOR ROUNDING EXPOSED EDGES 0.25 IN (6.4 mm) THICK OR THICKER

B) REQUIREMENTS FOR ROUNDING EXPOSED EDGES 0.12 TO 0.25 IN (3.0 TO 6.4 mm) THICK

C) REQUIREMENTS FOR ROUNDING EXPOSED EDGES LESS THAN 0.12 IN (3.0 mm) THICK

D) REQUIREMENTS FOR CURLING OF SHEETS LESS THAN 0.25 IN (3.5 mm) THICK



E) REQUIREMENTS FOR ROUNDING OF CORNERS LESS THAN 0.1 IN (25 mm) THICK

F) REQUIREMENTS FOR ROUNDING OF CORNERS GREATER THAN 0.1 IN (25 mm) THICK

app9g3

Figure 6.5.4-1. Rounding and curling criteria

6.5.5.2 Caution and Warning Labeling

Caution and warning labels are required to identify potentially undesirable conditions.

1. Caution and warning labels shall identify the type of hazard and the action that would prevent its occurrence.
2. Caution markings shall be located in a position that permits sufficient opportunity for the crew to avoid the hazard, and shall be large enough to be clearly legible from all normal viewing distances.

3. All immediate action controls, buttons, and small handles or levers requiring immediate access shall have panel backgrounds colored as specified in paragraph 6.5.5.1. Large handles or levers shall be colored on the handle or lever itself.
4. Emergency use items (e.g., repair kits, emergency lighting, fire extinguishers, etc.) shall display a unique marking (EMERGENCY USE) surrounded by diagonal yellow and black stripes either on the item or adjacent to it. Emergency use items within a stowage container shall have diagonal striping on the door of the container, and titles of the emergency items shall be listed on the label instead of the words EMERGENCY USE.
5. Warning stripes shall be alternating yellow No. 33538 and black No. 37038 as described in Federal Standard 595, beginning and ending with yellow. Black stripes shall not be less than 0.065 inches (1.6 mm) wide. Yellow stripes shall be at least twice the width of the black stripes. Striping shall be applied at a 45° angle rotated clockwise from the vertical.
6. Payloads containing a liquid, gas, or dust that has the potential of escaping into the habitable volume shall have a label as defined in paragraph 6.5.5.3 to allow immediate response in the event of a toxic/irritant spill.

NASA-STD-3000 contains guidelines for letter size, spacing, and preferred font styles.

6.5.5.3 Toxic Labeling Standard

Decals will be utilized for identifying toxic hazard potential as defined in table 6.5.5.3-1. Colors and numbers are required for immediate crew response to substance spills.

These decals can be easily distinguished from the color coding requirements in paragraph 6.5.5.2. The Payload Integration Manager (PIM) can assist the customer in ordering required decals for the payload, based on the recommendation of the JSC toxicologist and JSC PSRP.

6.5.6 Transfer Requirements

Factors such as package geometry, size, mass, transfer clearance envelope, and positioning requirements should be considered before transporting replacement modules or servicing equipment from launch stowage locations to the servicing worksite. Transfer aids shall not pose a safety hazard to crewmembers; no other specific criteria exist for the design of these payload-peculiar aids. Items such as large and small trash bags, specialized bags, and tool caddies are available from the SSP and may be used to transfer equipment of various sizes (reference NSTS 21000-IDD-MDK, Shuttle/Payload Interface Definition Document for Middeck Accommodations).

Table 6.5.5.3-1. Toxic labeling

Color/ level	State	Flammability	Systemic/ internal damage	Irritancy	Criticality level	Summary of hazard level
Red 4	Gas, volatile liquid, or fumes that are not containable by a cleanup crew. The ARS will be used to decontaminate. The 5-micron surgical masks will not protect the crew. Either quick don masks or SEBS is required.	May be capable of producing flammable vapors or fine mist in sufficient quantity to produce a hazard.	Appreciable effects on coordination, perception, memory, etc., or potential for long term (delayed) serious injury (e.g., cancer), or may result in internal tissue damage.	Moderate to severe irritation with potential for long-term crew performance decrement (for eye only hazards, there must be a risk of permanent eye damage). Note: Will require therapy.	Catastrophic	Catastrophic hazard (capable of causing disabling injury) not containable by a cleanup crew, with potential for systemic toxicity, moderate to severe irritation, tissue damage, or production of flammable vapors. Surgical masks will not, combined with goggles and gloves, protect the crew. Either quick don masks or SEBS required while the ARS decontaminates. No provision for severe skin irritation or absorption. Example: Metal vapor like mercuric iodide.
Orange 3	Either a solid or nonvolatile liquid which can be contained by a cleanup crew and disposed of. Surgical masks and gloves will not protect the crew. Either quick don masks or SEBS and gloves required.	Capable of producing flammable vapors or fine mist in sufficient quantity to produce a hazard.	Appreciable effects on coordination, perception, memory, etc., or potential for long-term (delayed) serious injury (e.g., cancer), or may result in internal tissue damage.	Irritation may accompany systemic toxicity concerns, however, irritancy alone does not cause a level 3.	Catastrophic	Catastrophic hazard (capable of causing disabling injury) containable by a cleanup crew with potential for systemic toxicity, or capable of producing flammable vapors, or causing internal tissue damage. The 5-micron surgical masks, gloves, and goggles are not sufficient to protect the crew. Either quick don masks or SEBS required by all crewmembers. Only the cleanup crew will be required to wear gloves. Example: Acetonitryle.

Table 6.5.5.3-1. Concluded

Color/ level	State	Flammability	Systemic/ internal damage	Irritancy	Criticality level	Summary of hazard level
Yellow 2	Either a solid or nonvolatile liquid which can be contained by a cleanup crew and disposed of. Crew protected by 5-micron surgical masks, gloves, and goggles.	May be capable of producing flammable solids or liquids (but not vapors) in sufficient quantity to produce a hazard.	None	Moderate to severe irritation with potential for long-term crew performance decrement (for eye-only hazards, there must be a risk of permanent eye damage). Note: Will require therapy.	Catastrophic	Catastrophic hazard (capable of causing disabling injury) but containable by a cleanup crew. No systemic toxicity concerns or tissue damage (other than eye); 5-micron surgical masks, goggles, and gloves will protect the crew. Quick don masks and SEBS not required. Since the substance is a severe irritant or could cause eye damage, the crew must wear surgical masks, goggles, and gloves. No provision for severe skin irritation or absorption. Example: Sodium hydroxide with very high pH (>12).
Blue 1	May or may not be containable. Crew protected by surgical masks and goggles.	Very low flammability potential. Substance has a high flash point and low vapor pressure.	Minimal effects. No potential for lasting internal tissue damage or injury.	Slight to moderate irritation that lasts more than 30 minutes. If an eye-only hazard, can affect visual acuity for more than 30 minutes. Note: Will require therapy.	Critical	Critical hazard (capable of causing nondisabling injury) and may or may not be containable by a cleanup crew. Crew must be protected by surgical masks and goggles. With level 1 hazards, it is assumed that the crew needs therapy if exposed. Therefore, all crewmembers in the area must wear protective gear to avoid contact. Example: Solutions like 15 % sodium chloride.
Green 0	May or may not be containable.	None	None	Slight irritation that lasts less than 30 minutes and does not require therapy. Effects resolved within 30 minutes without therapy.	None	Not a health or fire hazard. May or may not be containable. If not, report to MCC. Example: Silicon oil or weak hypertonic solutions.

6.5.7 Atmosphere

Customer-provided habitable modules must ensure a safe and habitable atmosphere compatible with that of the Orbiter, and must establish acceptable preflight offgassing levels as described in NSTS 1700.7B.

The payload system shall provide for adequate atmospheric interchange with the Orbiter and proper circulation and temperature/humidity conditioning within the payload. The Orbiter Environmental Control and Life Support System (ECLSS) will provide carbon dioxide removal, oxygen replenishment, and total pressure control.

The payload shall have a scrubber and filtration system to adequately cleanse the expected payload atmosphere. Trace gas contaminant levels shall not exceed concentrations specified for spacecraft in Spacecraft Maximum Allowable Contaminant Concentrations for Space Transportation Systems Applications, JSC 20584. Any consumables required for repressurization after venting of the module atmosphere shall also be supplied by the customer. Rehabitation of a customer-supplied module may be permitted by the SSP, following problem resolution, purging, repressurization, and reverification of the module atmosphere. Reverification shall be accomplished as defined in NSTS 1700.7B.

6.5.7.1 Prelaunch

Attached modules which have been closed out prior to launch minus 96 hours require atmospheric purging in the form of scrubbing, filtering, or other provisions prior to on-orbit ingress. Extended launch holds will result in an additional purge. Purge duration and hold capability will vary according to payload configuration and purge method. This requirement will be documented in the NSTS 08171, Operations, Maintenance, and Requirements Specifications Document (OMRSD).

6.5.7.2 Module Transfer Tunnel

The module transfer tunnel described above may be used with the tunnel adaptor to provide passage and atmosphere circulation between the module and the Orbiter Atmosphere Revitalization System (ARS). Airflow is generated by an Orbiter fan, which pumps air into the tunnel air ducting . A backflow of air is induced into the tunnel from the module to the Orbiter. This air exchange is essential to replenishment of oxygen, nitrogen and CO_2 and humidity control in the module during on-orbit flight phases while the module is attached to the Orbiter with hatches open.

6.5.8 Habitability

General guidelines for radiation levels, thermal stability, visibility, acoustics, and vibration are described in this subsection.

The size of the airlock, tunnel adapter, and associated hatches limits the external dimensions of packages that can be transferred.

Payload components which are operationally sensitive or susceptible to inadvertent damage or contamination by an IVA crewmember shall be guarded or otherwise protected or located in work areas away from IVA workstations and translation paths.

6.5.8.1 Ionizing Radiation

Table 6.5.8.1-1 defines dose limits which may not be exceeded. The SSP shall provide dosimeters for measuring radiation exposure. Space Shuttle flights are nominally constrained to 30-day exposure limits, which are conservatively set to preclude any mission impact. NASA-STD-3000 describes the space radiation environment and example design solutions.

Table 6.5.8.1-1. Ionizing radiation exposure limits from space flight

Constraints in rem*	Depth (5 cm)	Eye (0.3 cm)	Skin (0.01 cm)
30 days	25 rem	100 rem	150 rem
Annual	50 rem	200 rem	300 rem
Career	100-400** rem	400 rem	600 rem

*rem = Radiation absorbed dose, in rads, multiplied by a quality factor, Q, to account for the relative biological effectiveness of different types of radiation. For planning purposes, Q = 1.2.

**The career depth dose equivalent limit is based upon a maximum 3% lifetime risk of career mortality. The total dose equivalent yielding this risk depends on sex and age at start of exposure. The career dose equivalent is approximately equal to: Male - 200 + 7.5 (age minus 30) rem, up to 400 rem maximum. Female - 200 + 7.5 (age minus 38) rem, up to 400 rem maximum.

Note: Space Shuttle crew radiation exposure limits were recommended to NASA by the National Council on Radiation Protection and Measurement in 1987 and are expected to be legally adopted as the supplementary standard for compliance with Supplementary Standards, 29 CFR 1960.18. Space Shuttle flights are nominally constrained to 30-day exposure limits, which are conservatively set to preclude any mission impact.

6.5.8.2 Nonionizing Radiation

RF protection guidelines published by the ANSI contain criteria adopted by NASA to ensure safe RF/microwave exposure limits for the IVA crew.

Equipment tolerance of nonionizing radiation is a more limiting factor for payload designers than crew tolerance. ICD 2-19001 defines allowable limits of intentional and unintentional electric field strength in the Orbiter crew compartment.

6.5.8.3 Thermal

Crew protection from exposure to high or low surface temperature extremes is required in accordance with NSTS 1700.7B.

For habitable modules, the instrumentation necessary for monitoring module temperature, partial pressure of CO_2, relative humidity or dew point, and cabin fan flow rate parameters shall be provided by the customer.

6.5.8.4 Visibility and Lighting

Lighting requirements to ensure sufficient illumination and provide redundancy consistent with emergency egress are specified in NSTS 1700.7B.

NASA-STD-3000 provides design guidelines for illumination levels, light distribution, glare, brightness, dark adaptation, etc.

6.5.8.5 Acoustics

Noise generation shall be controlled so that acoustic energy will not injure personnel, interfere with communications, induce fatigue, or contribute to degradation of overall man/machine effectiveness.

Maximum noise levels in customer-supplied habitable modules during manned operations shall not exceed the limits defined in NSTS 1700.7B.

Individual payload elements in the Orbiter middeck acoustic environment shall not exceed limits defined in NSTS 21000-IDD-MDK.

6.5.8.6 Vibration

Vibration shall be controlled to guard against crew injury and interference with task performance. Equipment shall be designed and mounted to minimize vibration at crew stations, and shall be compatible with all Orbiter environments.

6.5.9 Crew Command, Control, and Display

Indicator lights shall conform to MIL-STD-1472D. Controls should be designed for barehanded operations unless gloved operations are specifically designated as a requirement. Controls should be designed to minimize susceptibility to accidental movement. Design of critical controls whose inadvertent operation could cause damage to equipment or personnel shall adhere to the requirements established in NASA-STD-3000.

NASA-STD-3000 provides design guidance for knobs, switches, input devices, and display systems.

6.5.10 Access Doors and Drawers

Doors and drawers providing IVA access should incorporate integral locking and unlocking mechanisms suitable for one-handed operation, a hold-open mechanism, a handhold for crewmember position control when opening and closing, and visual means for verifying proper closing and latching.

6.5.11 Windows

Windows shall be provided in the customer-supplied crew module only when necessary for essential mission operations. Consult NSTS 1700.7B. Design verification shall be in accordance with Payload Verification Requirements, NSTS 14046.

6.5.12 Pressure Hull

Pressure hull design for customer-supplied habitable modules shall comply with requirements defined in NSTS 1700.7B, and structural verification shall be in accordance with NSTS 14046.

6.5.13 Hatches

Hatches for habitable modules shall be no smaller than the Orbiter airlock hatch. NSTS 1700.7B contains additional hatch design requirements.

The airlock and tunnel adaptor employ a universal D-shaped hatch. Each hatch has a clear passageway 40 inches (101.6 cm) in diameter, and one flat side which reduces the minimum dimension of the hatch opening to 36 inches (91.4 cm). The hinge geometry is designed to maintain compatibility with pressure seals and position the hatch open without obstructing the passage. The latch mechanism is designed to produce sufficient force on the seals to maintain compartment integrity during thermal or structural deflections.

All required interfaces (communications, power, cooling, TV, telemetry, and ventilation) between the Orbiter and a customer-provided module must be achievable without EVA.

6.5.14 Translation Paths

The customer shall provide a minimum translation path for the crewmember of 32 inches (81 cm) diameter for moving between crew habitable modules through interconnecting tunnel structures.

KSC GROUND OPERATIONS

7.0

KSC is the launch site and the primary landing site for the Space Shuttle. Located at Merritt Island, Florida, KSC is responsible for implementing activities associated with preparing the Space Shuttle and its payloads for launch, landing, and postflight services.

KSC is responsible for payload processing and support at the launch site. Each customer is assigned an LSSM to serve as a single point of contact between the customer and KSC for all launch site support and payload processing activities. The LSSM is responsible for development of the Launch Site Support Plan (LSSP) which will be used to document the customer’s processing requirements.

7.1 PLANNING

The LSSM or the Launch Site Support Engineer (LSSE) at KSC are the initial points of contact for KSC operations. The LSSM/LSSE will explain the generic requirements and guidelines that the customer must adhere to while processing hardware at KSC. The customer will interact with the KSC organizations to define the ground processing requirements specific to their payload. The LSSE will define these requirements in the LSSP, which is a joint customer and KSC support agreement. The LSSP serves as Annex 8 of the IP.

Requirements for KSC processing are derived through discussion and negotiations during Ground Operations Working Group (GOWG) meetings, usually the first meetings held with the customer at KSC. After firm working relationships have been established between the customer and the launch processing support elements, the function of the planning meeting begins to transform into smaller Technical Interchange Meetings (TIMs) with more specialized agendas that are focused on specific topics.

A payload can be processed in either a vertical or horizontal orientation and may be processed in one or more of the different payload processing facilities available at KSC. The facility provided to support off-line processing will be dependent upon the size and type of payload, as well as the capabilities required during off-line processing. Additional factors determining facility selection include payload orientation, the need to perform hazardous operations, and facility availability. Possible processing flows for a payload are illustrated in figure 7.1-1.

Certain KSC facilities are designated for payload processing. An overview of all these facilities is presented in K-STSM-14.1, Launch Site Accommodations Handbook and more detailed information is provided in Facility Handbooks for each facility. There is also a Standard Interface Drawing (SID) for each of these facilities. Facility environmental standards are addressed in section 4.1.3. Modifications to these facilities can be made if the request for and approval of modifications are received in a timely manner.

Technical and operational requirements for a given mission may consist of assembly, testing, inspection, servicing, and time/life cycle requirements. These requirements are conveyed to KSC for implementation through the Operations and Maintenance Requirements and Specifications (OMRS) system. KSC participates in the requirements definition and development to ensure the launch and landing site's capability to satisfy those requirements. Upon satisfactory completion of these processing activities, KSC provides requirements closure status to the originator(s) of those requirements.

The end of the planning process and the start of the implementation phase is marked by the Ground Operations Review (GOR). The GOR is held approximately 30 days prior to the primary payload hardware arrival at KSC. The purpose is to verify KSC facilities, services, and personnel are ready to receive and process the flight hardware, and the customer is ready to ship the flight hardware and support the processing. The customer is expected to present status including a summary and a readiness statement at the GOR.

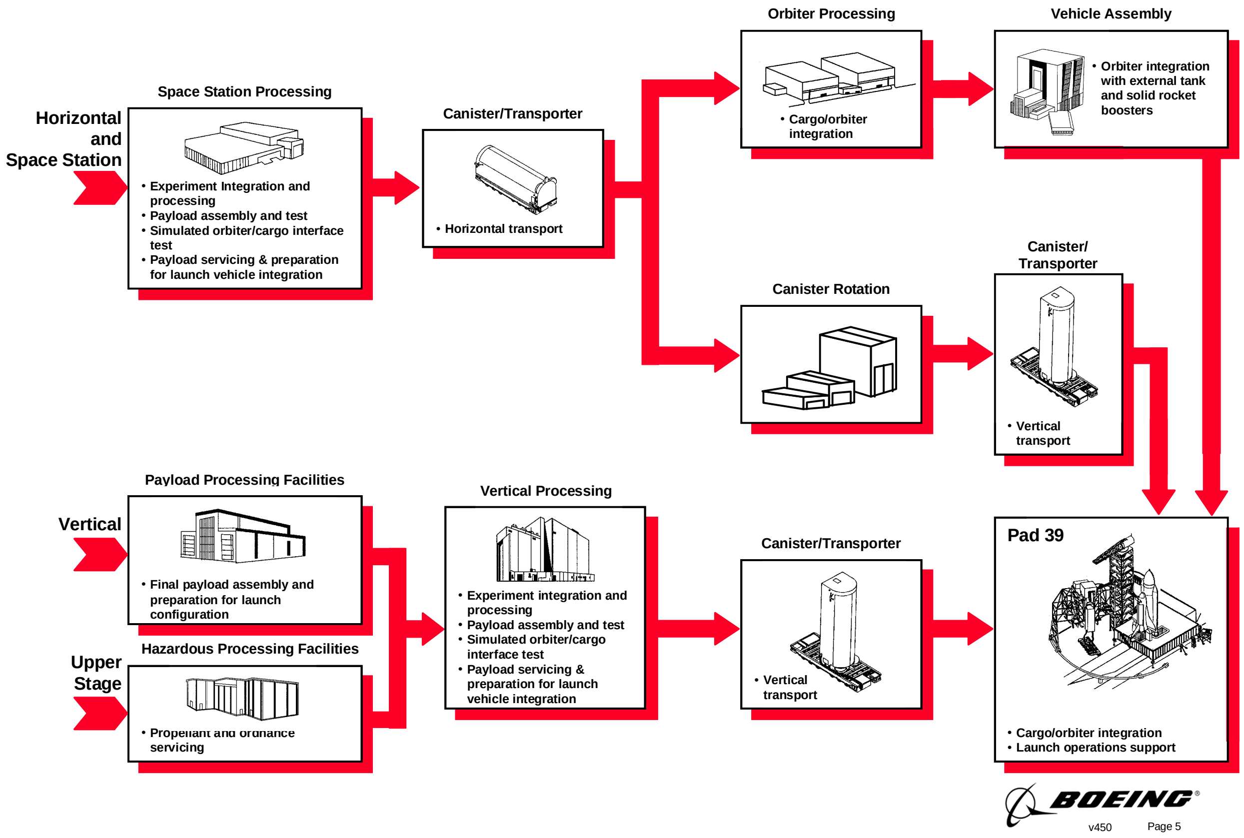


Figure 7.1-1. Launch site payload processing flows

7.2 OFF-LINE PROCESSING

The payload is considered off-line before custody is formally transferred from the payload customer to NASA-KSC for final launch site processing and integration with the Space Shuttle.

The payload customer has responsibility for off-line integration of their payload, including postshipment processing before turnover to KSC.

7.2.1 Arrival at KSC

All shipments must be coordinated with the KSC representative prior to shipment. The KSC representative will coordinate applicable delivery and property transfer activities with the applicable KSC transportation office.

Any KSC support required to offload the shipment will be scheduled and coordinated by the KSC representative. All items will be placed in the integration area, unless otherwise specified by the customer.

If any off-site storage of shipping containers is required, arrangements must be completed by the customer and coordinated with the KSC representative before shipment of hardware/GSE to KSC.

7.2.2 Off-line Processing in Facilities

The O&C Building, the SSPF, and Hangar L contain laboratory and shop areas to support payload ground processing activities. Use of these laboratories and shops and their services must be requested and scheduled. The laboratories typically accommodate smaller payloads and individual experiments.

Other facilities on KSC are designated as Payload Processing Facilities (PPF). These include separate facilities such as the PHSF, the VPF, the MPPF and the Spacecraft Assembly and Encapsulation Facility (SAEF-2) as well as designated space in the processing areas of the O&C Building and the SSPF. All facilities capabilities are detailed in individual Facility Handbooks, and are summarized in the Launch Site Accommodations Handbook, K-STS-14.1.

The payload customer has responsibility for off-line integration of their payload, including postshipment processing before turnover to KSC. Following offloading of element hardware and GSE into the processing area, the defined off-line integration activities will be performed by the payload customer. Typical activities can include, performing postdelivery verification testing, and performing other off-line operations, if required.

During development of the LSSP, the customer will define the support required for preintegration activities. KSC is responsible for providing and scheduling the agreed-upon support services. KSC support to customer operations is normally provided for one shift per day, 5 days per week, with additional shifts scheduled as required to meet customer requirements and launch schedules.

7.3 ON-LINE PROCESSING

The payload is considered on-line when custody is formally transferred from the payload customer to NASA-KSC for final launch site processing and integration with the Space Shuttle.

7.3.1 KSC Services

The following is a summary of some of the services available to the payload customer:

Facility chilled water is available. GN_2, GHe and compressed air are provided by pneumatics panels and compressed air stations.

A clean vent system is provided for use by experiments to vent clean gases. A dirty vent system is provided for vacuum pumps, cooling servicers, and other systems to vent contaminating gases.

A facility vacuum system is available for housekeeping activities during payload processing.

An automated monitoring system continuously monitors particulates, temperature, and humidity. This system is augmented by periodic testing of air samples and testing of witness plates located throughout the facility.

The hypergol vent and drain system is available to support contingency operations requiring the removal of fuel from a spacecraft/upper stage.

A payload Environmental Control System (ECS) can provide localized cooling to a payload.

7.3.2 Pre-Orbiter Installation

The following processing activities are typical examples of tasks performed during this stage:

1. Experiment integration and processing
2. Payload assembly and test
3. Simulated Orbiter/payload test
4. Payload servicing & preparation for Shuttle integration
5. Weight and c.g. determination
6. Transport to the Orbiter (OPF or pad)

7.3.2.1 Cargo Integration Test Equipment

During integrated testing, problems may be discovered within the payload or the customer support GSE that can be repaired or rectified prior to Orbiter installation.

Discrepancies in the procedures used or operations performed are identified earlier and can be modified and re-tested prior to the Pad flow. A better understanding of the payload and customer GSE's operational limits can be made using the CITE hardware. Discovery and identification of problems early in the processing flow make modifications easier to make without an impact to the major milestone schedule.

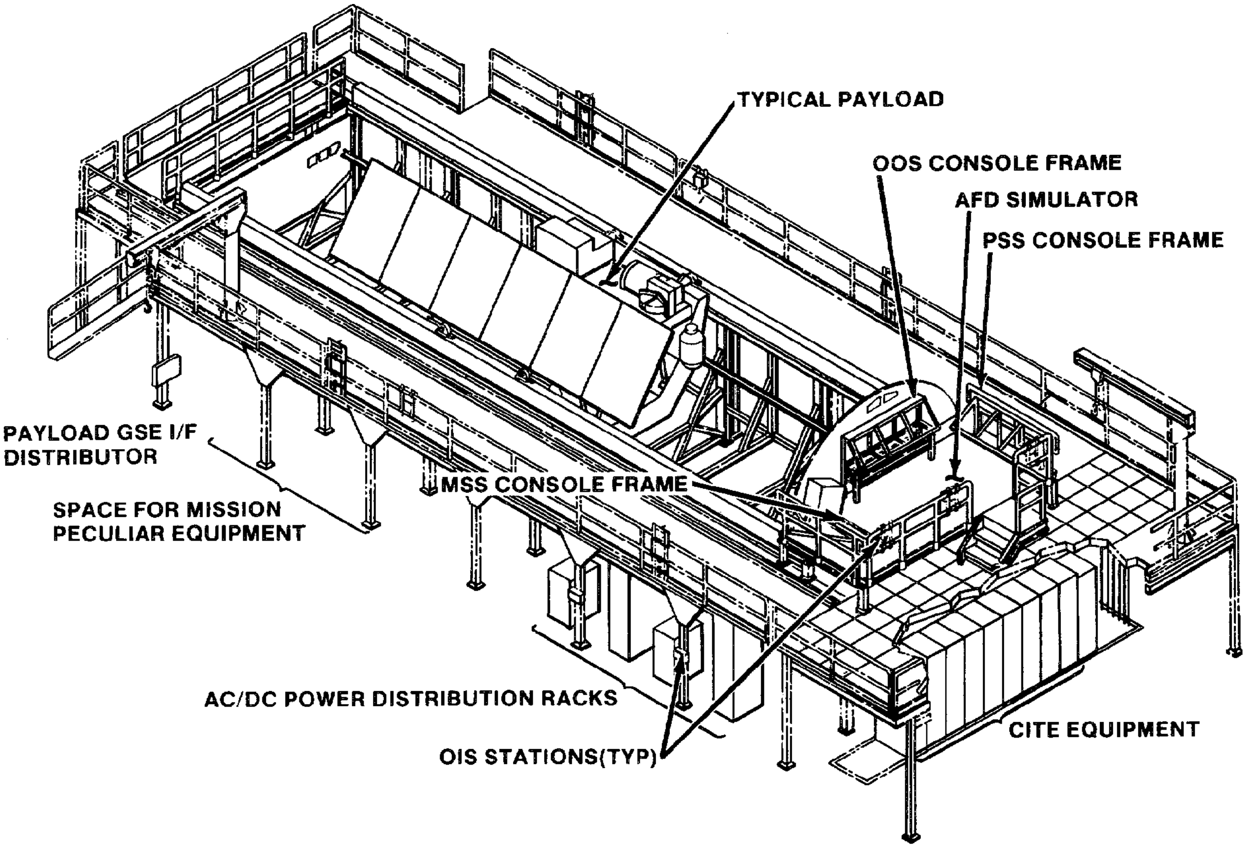
There are two CITE facilities. The horizontal CITE resides in the SSPF, and the vertical CITE is in the VPF. The SSPF is utilized if the payload under test is nonhazardous and does not have the stringent cleanliness requirements. The VPF is utilized if the payload under text is Hazardous (contains toxic propellant, explosives, etc.) or requires a Class 100,000 Clean Room environment.

The CITE stand simulates Orbiter accommodations for payload interfaces, and is used to verify compatibility between payloads and simulated Orbiter mechanical, electrical, and electronic interfaces. (ref. figure 7.3.2.1-1) A network communications ETE test with the POCC is provided when required by the payload.

CITE testing includes an Interface Verification Test (IVT), a mission sequence test (if appropriate), required payload element tests, and operations to validate planned online prelaunch and postflight operations, including emergency, contingency, and scrub/turnaround procedures.

Mechanical equipment in the CITE stand includes items such as an AFD structure, a forward Orbiter bulkhead assembly, an aft bulkhead, Orbiter-simulated cable trays, and a midbody assembly. The workstand deck provides basic access to the payload in the CITE stand.

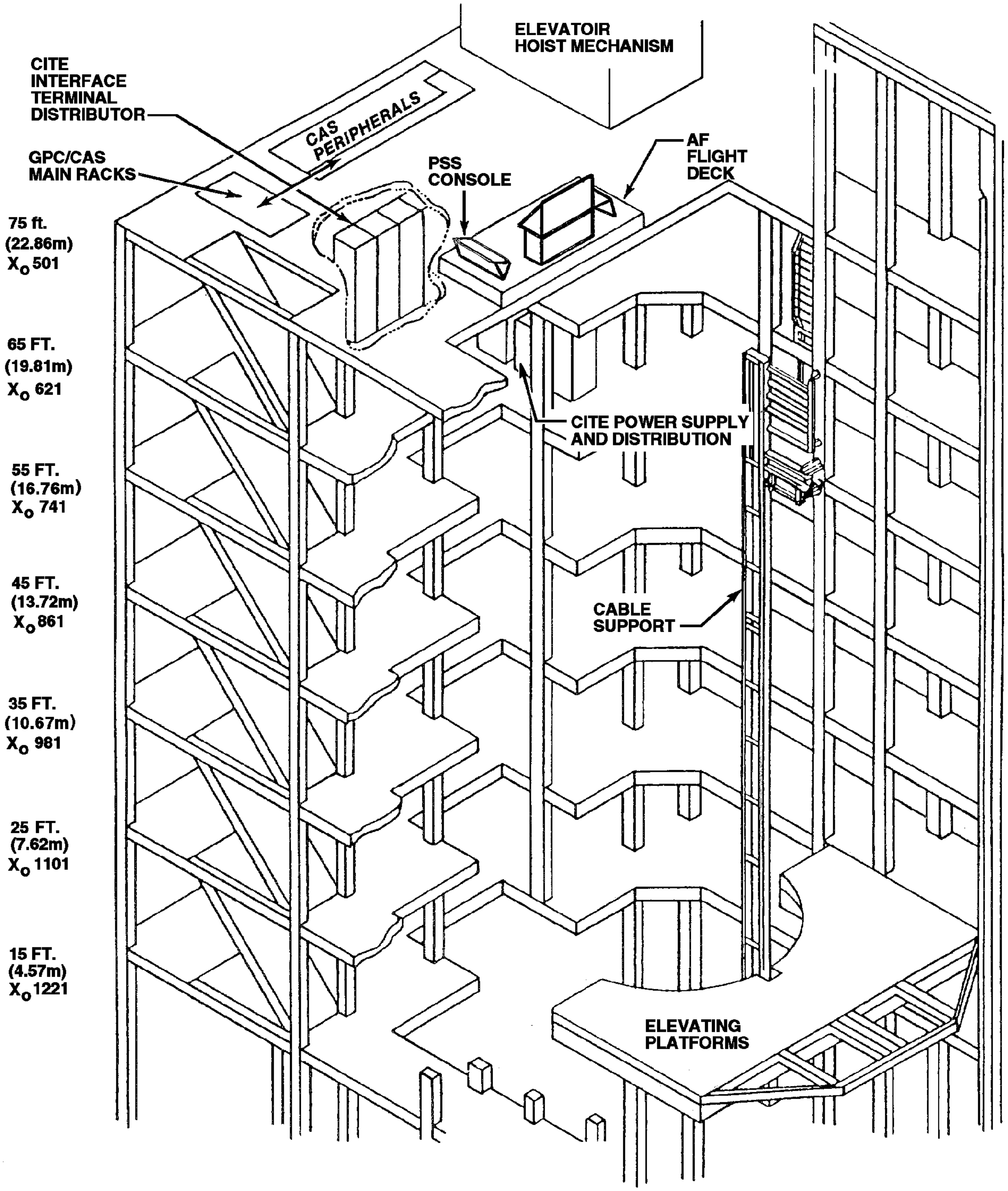
The CITE configuration in the SSPF is shown in figure 7.3.2.1-1. The VPF CITE stand is shown in figure 7.3.2.1-2.



AFD - AFT FLIGHT DECK
CITE - CARGO INTEGRATION TEST EQUIPMENT
GSE - GROUND SUPPORT EQUIPMENT
I/F - INTERFACE

MSS - MISSION SPECIALIST STATION
OIS - OPERATIONAL INTERCOMMUNICATION SYSTEM
OOS - ON-ORBIT STATION
PSS - PAYLOAD SPECIALIST STATION

Figure 7.3.2.1-1. Horizontal CITE stand, view B from the starboard side



GPC - GENERAL PURPOSE COMPUTER
CAS - CITE AUGMENTATION SYSTEM

CITE - CARGO INTEGRATION TEST EQUIPMENT
PSS - PAYLOAD SPECIALIST STATION

Figure 7.3.2.1-2. Vertical CITE stand equipment location

7.3.2.1.1 SSPF CITE

The SSPF is located at the eastern end of the KSC Industrial Area. The SSPF High Bay measures 105 x 437 feet with a ceiling height of 61.5 feet. The High Bay is divided into eight sections called footprints. Footprints 1, 3, 5 and 7 are on the South side (West to East), and footprints 2, 4, 6 and 8 are on the North side (going from West to East).

Each footprint is electrically equipped with eight 120/208 V 60 A, six 120/208 V 100 A and two 480 V 100 A services. In addition, power carts can be provided to supply 120 V 30 A or standard household services.

Footprint 2 is the home location for the Launch Package Integration Stand (LPIS), AFD Stand and T-0 Stand. The LPIS is the mechanical and electrical simulator of the Orbiter payload bay. The payload will be placed in the LPIS at the location determined by its launch configuration.

The AFD Stand is comprised of two floors. The upper floor houses the CITE simulation of the Orbiter’s AFD station. This includes the standard switch panels, Multifunction Cathode Ray Tube (CRT) Display System (MCDS) display and other mission-unique assemblies. The lower floor contains the Interface Terminal Distributor Racks. These racks contain the Orbiter’s Avionics boxes; i.e., PI, PDI, PCMMU, MDM, and PSP.

The T-0 stand simulates the Orbiter T-0 system and can simulate the launch pad’s T-0 avionics system. The stand contains Hardware Interface Modules (HIMs) and GSE to simulate power losses in the pad T-0 system. Both the T-0 and AFD Stands are mobile and can be utilized by both the LPIS and CEWS stands.

After a payload is placed in the CEWS or LPIS, the customer may perform servicing or final assembly and/or configuration in preparation of CITE testing. In addition, validation testing may proceed between the customer’s GSE and the CITE T-0, RF and landline systems.

The IVT may be followed by Mission Sequence Testing (MST) or a network communications ETE test.

Following the successful completion of the IVT, the CITE interfaces are disconnected and the payload customer prepares the payload for transport to the OPF or launch pad. Closeout activities must be performed on areas that will not be accessible once the payload is in the Orbiter’s payload bay.

7.3.2.1.2 VPF CITE

The VPF is located at the southern end of the KSC Industrial Area. The VPF High Bay measures 75 x 150 feet with a ceiling height of 105 feet. There are two Test cells, East and West, so accommodations may be made to house more than on mission at a time. However, only one mission can actively undergo VPF CITE IVTs at any time.

The payload customer may use the High Bay floor for final assembly, payload servicing or off-line standalone testing. In addition, validation testing may proceed between the payload customer's GSE and the CITE T-0, RF or landline systems.

Following the off-line phase, the payload is ready to be placed into the Test Cell. Following installation, electrical interfaces are configured, as they would be in the Orbiter in preparation of the IFT. The CITE system uses flight-equivalent avionics boxes and cabling to perform testing. The 55-foot level contains the power supplies for CITE and the retention system test panels.

The 65-foot level contains the Orbiter's avionics boxes; i.e., MTU, PCMMU, PDI, PI, MDM, and PSP, and the patch panels needed for testing. The 75-foot level houses the AFD with the SSPs and MCDS interface. The IVT may be followed by MST or a network communications ETE test.

7.3.3 Payload Installation

Payload canisters are provided at KSC to transport and install payloads horizontally and vertically. The capability and accommodations of the canisters are defined in the Launch Site Accommodations Handbook, K-STSM-14.1. Figure 7.3.3-1 shows an overview of a canister. Canisters can be rotated from horizontal to vertical and vice versa in the Canister Rotation Facility (CRF) when required.

7.3.3.1 Horizontal Installation

Installation activities in the OPF start with lifting the payload strongback from the payload strongback transporter and end with payload mechanical, fluids, and electrical systems connected to the Orbiter. Specific tasks include the following:

1. Opening payload canister doors
2. Attaching payload strongback to payload
3. Hoisting payload from canister
4. Mechanically installing payload into Orbiter
5. Removal of strongback and canister
6. Initiation of payload bay purge
7. Connecting electrical, fluid, and gas interfaces
8. Removal of trunnion endcaps (GSE), when used

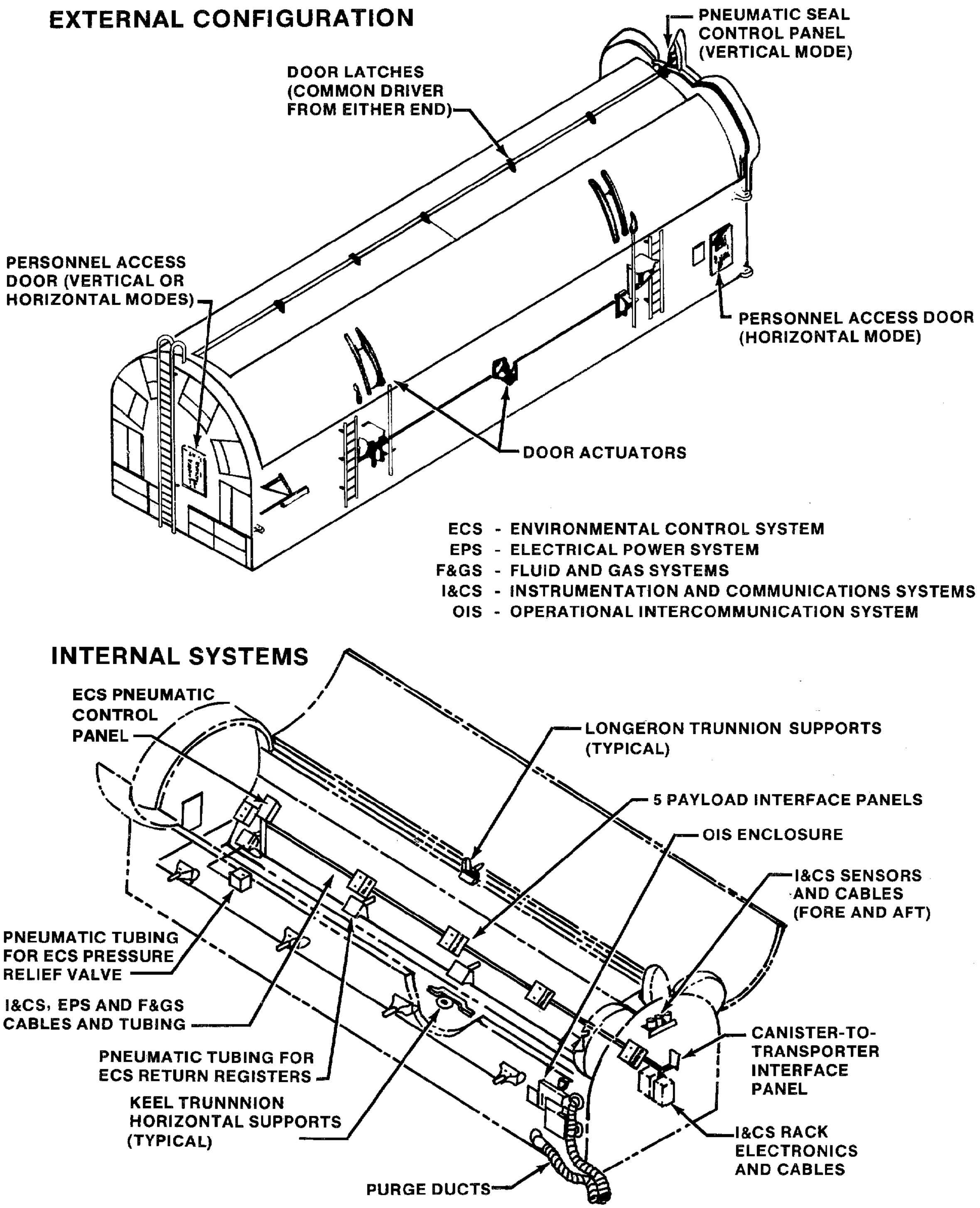


Figure 7.3.3-1. Payload canister

7.3.3.2 Vertical Installation

Installation of the payload into the RSS/PCR normally occurs before Shuttle transfer to the launch pad. Once the Space Shuttle vehicle is positioned on the pad, the RSS is moved into position to enclose the Orbiter payload bay, and environmental seals are established. The space between the closed Orbiter and RSS/PCR doors is purged with clean air, and the PCR and PLBDs are opened.

This function includes, but is not limited to, the following:

1. Extension of PGHM into the payload bay
2. Mechanical connection of Orbiter/payload interface
3. Electrical preconnect checks followed by connection of Orbiter/payload interface
4. Fluid connection of Orbiter/payload interface
5. Removal of trunnion endcaps (GSE), when used
6. Repositioning and connection of GSE as required
7. Sharp edge inspection of payloads

7.3.4 Post-Orbiter Installation

7.3.4.1 Interface Verification Test

The IVT is performed following completion of payload installation. It is the single test which verifies proper interface connections between the Orbiter and payload. This will be performed for each flow per requirements defined in NSTS 08171, OMRSD. This test will be accomplished using launch site integrated Operations and Maintenance Instructions (OMIs), TPSs, and Taps, which verify Orbiter/payload interfaces. The necessary Orbiter and payload systems (such as power, ECLSS, instrumentation, data processing and software, D&Cs, and the GPC will be activated to support the test. Selected data required from the Orbiter will be provided to the payload and selected data transmitted from the payload to the Orbiter will be verified. Orbiter/payload IVT includes the following:

Copper path primary and secondary power and command and data circuits, RF interfaces, fluid and gas services when applicable, pyro firing circuits, T-0 umbilical services, and Orbiter-payload retention hardware when applicable.

7.3.4.2 Payload Ordnance/Servicing

Final payload and Orbiter payload bay ordnance connections will be accomplished as late as possible, but prior to PLBD closure. Access required for late payload servicing will be provided. Payload servicing may include, but is not limited to, the following:

1. Topping-off expendable commodities
2. Battery charging or installation
3. Special nuclear material installation

4. Limited-life hardware
5. Payload closeout

7.4 LAUNCH COMMIT CRITERIA

Payload Launch Commit Criteria (LCC) will be developed by all customers in accordance with the following requirements and constraints. Any LCC that exceed groundrules or constraints specified herein will be negotiated with the SSP as exceptions and documented in the IP.

LCC Documentation Requirements:

1. All payload parameters utilized for safety monitoring during the count and criteria used for calling safety-related holds
2. Specific actions and payload commanding initiated by the customer after pad clearing which, if unsuccessful, could cause a launch hold
3. Orbiter payload interface services (i.e., PDI, power, etc.) and ground operations support decisions (i.e., POCC, communications lines, aircraft, etc.) which represent GO/NO-GO decisions

The approved LCC requirements will be documented in the Shuttle Launch Commit Criteria and Background Document, NSTS 16007. It is the customer's responsibility to document and maintain all criteria and payload parameter monitoring required at the customer's POCC/facility.

Groundrules/Constraints:

1. Payload safety holds may be called until L-31 seconds. NSTS 16007 will identify parameter limits and loss of inhibits used as a basis for the safety hold.
2. All mission success and safety LCC must be monitored via ground display and must not rely on flightcrew monitoring.
3. All customer-initiated holds will be verbal. No payload parameters will be permitted in the ground launch system.
4. The customer is required to immediately notify the SSP whenever a payload launch concern arises.
5. Mission success-related launch holds may be called only by primary payloads. Any function whose failure results in a mission-success hold must be monitored such that no single failure will result in a loss of visibility into the status of that function. Any exception to this requirement must be negotiated and identified in the IP.
6. For a confirmed loss of a total function that would cause the loss of primary mission objectives, the customer may call a hold until L-31 seconds of the countdown.

7. For payloads with mission times consistent with Shuttle flight length, the customer may call a hold up until T-9 minutes of the countdown for a confirmed loss of redundancy of a flight function which would affect primary mission objectives. If a specific redundant system failure would jeopardize a majority of primary mission objectives, an exception may be considered by the SSP for holds until L-31 seconds. Any exception will be negotiated in the IP and documented in the customer’s internal LCC documentation.

8. For payloads with long-term (multi-year) primary mission objectives that are at risk due to a confirmed loss of redundancy of a flight function when this redundancy is critical to mission lifetime, the customer may call a hold in the countdown until L-31 seconds. The fact that a payload will have LCC calls until 31 seconds will be negotiated in the IP, and the specific requirements will be documented in the customer’s internal LCC documentation.

7.5 POSTFLIGHT OPERATIONS

7.5.1 General

Postflight operations include activities accomplished from the time the Orbiter performs a nominal EOM or an intact abort landing, until it is returned to an OPF. These operations include runway support of crew, Orbiter, and payloads; Orbiter safing, deservicing, and preparation for ferry to KSC; payload support/removal when required; Orbiter ferry to KSC; and postmission payload activities.

7.5.2 Landing Site Support

Landing site support will vary depending on landing site selected; i.e., primary or alternate EOM, etc. KSC will be the primary landing site unless a mission-specific exception to land at EAFB is approved by the SSP. Under nominal conditions, payload purge and ECLSS coolant will be applied to the Orbiter. Payload requirements for postlanding services shall be negotiated with the SSP and documented in the IP and detailed in the LSSP.

7.5.3 Payload Bay Early Access

The Orbiter vehicle provides physical access to the payload bay through the crew compartment and airlock hatches to satisfy crew habitable module and similar payloads early access requirements. These access requirements must be identified in the IP. Payload bay physical access requirements for a given mission must also be further defined in NSTS 08171, OMRSD, unique to that mission. Any special provisions required (e.g., special access platforms) will be supplied by the payload customer.

7.5.4 Ferry Flight Operations

If the Space Shuttle lands at a landing site other than KSC, it must be ferried to KSC. The Orbiter is attached to SCA and the Orbiter is ferried to KSC. During the ferry flight, the SCA will maintain an altitude and flight duration to ensure a minimum payload bay temperature of 35° F and minimum pressure of 8.0 psia. At designated overnight stops, a payload bay purge may be applied. After arrival at KSC, the Orbiter is removed from the SCA at the MDD and towed to the OPF.

FLIGHT OPERATIONS

8.0

This section was written to assist the customer with mission planning and flight design. Mission planning and flight design is the preparation of trajectory, attitude consumables profile, and crew timeline for a specific flight. Flight design and crew activities requirements are defined in IP Annex 2, Flight Planning.

IP Annex 2 is comprised of three parts. Part I contains agreements between the customer and the SSP on matters which relate to payload electrical power, energy, cooling, and Orbiter support equipment usage. Part II includes an outline of the customer’s crew-related activities, attitude and pointing requirements, contamination constraints, photographic and Television (TV) events, and extravehicular activities for inclusion in the Flight Plan. Part III deals with trajectory design and deployment target considerations.

8.1 CREW ACTIVITY PLANNING

8.1.1 Crew Time

Mission planning for payload activities involves a variety of considerations for all mission phases. The phases of ascent and entry provide no opportunity for crew actions associated with payloads. Since no crew-initiated nominal operations take place during these phases, there are no general operational considerations that add to the requirements stated in other documents. Because of this, this section will deal only with the phases of postinsertion, on-orbit, and deorbit preparation.

No definitive statement can be made regarding crew availability for any mission until preliminary mission plans are developed. However, the constraints used in developing the crew timelines are documented in the Shuttle Crew Scheduling Constraints, NSTS 37326. Some factors affecting the planning of crew work schedules are summarized below.

The principal considerations which drive crew schedules are Shuttle operational activity, crew physiological factors, and payload requirements. The amount of crew time available for payload operations on any given day depends on total mission duration, which may affect crew day length. Reasonable crew circadian shifts are implemented to accommodate the required deorbit opportunities. The number of crewmembers assigned and the needs of other shared payload components will also determine crew availability. Mission duration and the size of the crew are established by the SSP.

For typical single-shift operations, crew time is allocated for crew sleep and meals. Additionally, dedicated time is provided for pre- and postsleep Orbiter configuration and crew personal hygiene, as well as daily periods of exercise for all NASA crewmembers. This results in 7.5 hours per day available for crew interaction with payloads. Launch day duration is reduced by the crew prelaunch awake time. Postinsertion activities further reduce crew availability on launch day. Similarly, at the end of a mission, activities such as cabin stowage and deorbit preparation also reduce crew time for payload operations. Details of these considerations are included in NSTS 37326.

Another staffing option for Space Shuttle missions involves the use of two teams of crewmembers operating on opposing shifts. This is referred to as two-shift ops. This variation is available only in unique situations negotiated on a case-by-case basis with the SSP. Use of this approach may result in additional constraints on payload activities (due to a sleeping crew team) as well as a reduced number of crewmembers available on each shift.

8.1.2 How the Integrated Mission Timeline Is Built

The process utilized to transform the customer’s IP, IP Annex, and Payload Operations Working Group (POWG) mission planning information into an integrated timeline is described below. Each mission or payload manifest presents unique planning situations and may vary from this general description.

8.1.2.1 Early Mission Development

The planning process for the Shuttle mission begins after the mission manifest has been established. The payload requirements specified in the IP and its Annexes are evaluated to establish key mission drivers such as deployment opportunities or time-constrained events. These are in turn evaluated against SSP constraints, trajectory requirements, and the needs of other shared payload partners. Variations of the trajectory and the mission activities are iterated until a flight profile is developed which meets all mission objectives and provides the highest probability of mission success. Since this is the first integrated timeline produced for a given mission manifest, the resulting mission plan will be assessed internally by the SSP, and then jointly by the SSP and the customers at the CIR. This mission timeline (including changes resulting from the CIR) will then be published as the preliminary Flight Plan.

8.1.2.2 Detailed Timeline Development

For the postinsertion and deorbit prep mission phases, timeline constraints on payload operations dictate that little payload activity occur. The on-orbit phase is the most flexible for payload operations. Payload timelines are managed within a POWG.

This working group includes operational representatives from the customer, the Mission Operations Directorate (MOD), and the SSP. The members of the group will meet several times between the request for launch services and the actual launch. In these meetings, several iterations of procedures and timelines will be worked in order to optimize the use of time on-orbit and the probability for mission success.

As payload requirements are developed further through use of the Annexes, the Payload Operations Workbook (POW) and POWGs, a more detailed iteration of the trajectory will also be developed. It will incorporate further refinements of requirements, changes resulting from new data or a new launch date, and improved knowledge of mission events (a byproduct of the initial planning cycle). Potential conflicts among the payloads are worked to provide an acceptable mission timeline.

This planning cycle leads to publication of the Flight Operations Review (FOR) edition of the Flight Plan which reflects the details of the mission timeline and includes all the payload requirements to be satisfied on the mission. The basic editions of all other Flight Data File (FDF) articles are also published in order to support the FOR. After a 1-month review time, the FOR edition Flight Plan and FDF products will be reviewed with the customer at the FOR. Any discrepancies between customer requirements and the mission plans are identified and actions taken to resolve the conflict. After the FOR, the basic edition of the Flight Plan and updated versions of the FDF are published. After this publication, the Flight Plan (and all other FDF articles) is placed under configuration control. Subsequent changes to the Flight Plan or FDF require submittal of the details of the change and rationale justifying incorporation. This change must then be approved by the Crew Procedures Control Board (CPCB), which consists of representatives of the various disciplines involved in the mission.

8.1.2.3 Final Mission Timelines

After the basic Flight Plan is published, only mandatory changes will be made to the mission timelines and procedures. Stability of these products is crucial for crew and flight controller training with near flight-ready data, as well as for use as the basis for detailed consumables projections and final mission planning. This last iteration of the timeline, the final Flight Plan, also incorporates the latest and most accurate iteration of the trajectory and any changes which may result from lessons learned in integrated simulations and procedure validations.

Changes from the basic to the final Flight Plan should be small refinements resulting in the flight-ready version of the mission timeline rather than late changes to customer requirements. Due to the highly integrated nature of the timeline for multiple payloads, such changes would require massive revisions of the timeline and affect the planning of the other payloads on the mission. This cannot be accommodated close to flight.

The final Flight Plan is published about 6 weeks prior to launch and is the primary product for integrated training. All procedures and timelines undergo a final validation review before certification for flight. After review by the flightcrew and about 10 days before launch, the flight copies of the FDF are shipped to KSC.

8.1.2.4 Customer Participation

Each payload customer’s IP and Annexes, as well as inputs made at the POWGs, are factored into a mission timeline for the entire payload complement. The customer is involved in these key functions: The CIR, from which the preliminary Flight Plan is produced; meetings of the POWG, which manages procedures and timelines leading to the basic Flight Plan; and the FOR, at which the basic FDF products are formally reviewed.

8.1.3 Flight Activity Planning and Flight Operations Integration

8.1.3.1 Flight Plan

The SSP will be responsible for all crew activity planning and will develop an integrated Space Shuttle/payload Flight Plan to support the flight. The plan will be developed using customer-supplied payload crew activity requirements.

8.1.3.1.1 Data Submittal Requirements for Flight Operations Integration

The customer is responsible for development and verification of the payload data submittals as specified below. The customer is to provide this data to the Lead Payload Officer beginning at L-12. Details on these data submittals are available in JSC-27508.

1. Customer Flight Control Team (FCT) and Launch OPS Team/Customer Support
2. Formal letter specifying MCC/JSC POCC/CSR support facility requirements signed by customer
3. Keyset/loop requirements
4. Flight rules and payload facility LCC
5. Joint Operations Interface Procedure (JOIP) procedures
6. Operations support timeline
7. Nominal, backup, and contingency procedures
8. Payload switch configuration requirements (ascent/entry/postlanding)
9. Malfunction procedures
10. In-flight Maintenance (IFM) procedures
11. Hazardous, MOC, Prelaunch commands
12. Formal letter listing all operational hazard controls jointly signed between payload organization and DO5
13. Unique payload data collection requirements
14. PGSC/microcomputer requirements & user’s guide

The customer is also required to provide schematics/diagrams to support the following processes:

1. Cargo Systems Manuals

2. Flightcrew procedures development

Specific diagram/schematic requirements and delivery dates will be defined in the IP and/or coordinated with the Lead Payload Officer or designated representative.

8.1.4 Intravehicular Activity

8.1.4.1 Introduction

8.1.4.1.1 General

The SSP offers a variety of services to payload customers in addition to transportation to and from orbit. These services include IVA performed during planned on-orbit payload operations. Crew-related payload activities during ascent and descent mission phases are very limited and must be specifically negotiated with the SSP.

SSP IVA provisions, manned systems, and IFM requirements apply to payloads flown in the Orbiter middeck, payloads flown in a crew habitable module, and to the module itself. A crew habitable module is defined as a module certified as a man-rated facility to be inhabited while docked with the Orbiter, during which the crewmember will be in a shirtsleeve environment. Reference section 6.5, Crew Habitable Module Design Specifications.

Commercially developed payloads may use Man-Systems Integration Standards, NASA-STD-3000, as a guideline for achieving design goals consistent with Space Shuttle operations and efficient, productive, safe crew interfaces within the Space Shuttle flight environment. NASA-STD-3000 also includes supporting data for design requirements, other design considerations, and design solution examples.

8.1.4.1.2 Definition and Constraints of Intravehicular Activities

IVA includes crew activities that occur within the Orbiter crew compartment or a customer-provided pressurized module such as an attached pressurized module in the payload bay or a free flying module docked with the Orbiter.

IVA operations include module activation/deactivation, on-orbit operations, and monitoring while hatches are open allowing free access to the Orbiter. Nominal operations include IVA activity planned prior to launch and included in the nominal mission timeline. This includes performance of normal procedures such as unpacking, assembly, powering up, etc.

Off-nominal operations include performance of backup, malfunction, contingency, or emergency procedures that do not involve hardware modification or repair.

IFM includes repair activities conducted by the crew within a pressurized vessel or payload module to keep the payload to return it to operability. IFM normally involves removal of payload panels, mating and demating of electrical connectors, or replacement of Line Replaceable Units (LRUs).

The following general constraints apply to payload design for IVA:

During crew operations, hatches which either separate module elements or separate a module element from the Orbiter must remain open in accordance with NSTS 1700.7B.

Payloads that require crew operations must size access corridors and work areas to allow crewmembers to perform the required tasks safely and with adequate mobility.

Customer-supplied modules will be sealed off from the Orbiter prior to EVA prebreathe activities; crewmembers may not inhabit the module during EVA.

To ensure that payload configuration for safe Orbiter entry is accomplished in approximately the same time interval as the Orbiter can be prepared for contingency return, the following design provisions for rapid safing are required. Neither payload configuration nor payload operations will inhibit a rapid return of the crewmember to the Orbiter crew compartment from any location in the module. Safing shall be accomplished as rapidly as possible, and must be compatible with closing the PLBDs within 20 minutes and deorbit OMS firing within 30 minutes. Provisions to meet these time constraints shall be at least single-fault tolerant. Provisions for total safing shall remain two-fault tolerant. See NSTS 1700.7B for fault tolerance definitions.

The availability of crew time during a mission is determined by numerous factors. The constraints used to develop crew timelines are defined in Shuttle Crew Scheduling Constraints, JSC 37326. The principal considerations that drive crew schedules are Orbiter operational activity, crew physiological factors, and payload requirements. Mission duration and number of crewmembers are determined by the SSP.

8.2 FLIGHT DESIGN

8.2.1 Launch Window

Payload operating constraints or objectives that may influence the Shuttle launch window should be identified early. Typical factors that may affect launch window are payload injection constraints, specified orbital timing or lighting, astronomical sightings, or rendezvous requirements. Customers will be expected to quantify the constraints that influence launch window in the IP and its Flight Planning Annex (Annex 2).

Each customer should provide the largest possible launch window of up to 3 hours in duration to allow manifesting options. This type of window, consistent with Orbiter preferred lighting constraints, guarantees the greatest likelihood of launch success. A payload’s launch window constraints will be combined with those of other payloads, if any, and the normal operating constraints of the Orbiter itself, to produce a composite window for each planned mission.

8.2.2 Deployment and Separation

Payload deployment is that phase of a flight when the payload is released from the Orbiter by some means (RMS, spring ejection system, etc.) and a separation rate is induced to ensure a continually opening rate. The separation rate may be the result of a payload ejection system, an Orbiter translation, or a combination. The net result is that the Orbiter leaves the vicinity of the payload and does not remain to conduct proximity operations.

For more information on payload deployment and separation, refer to section 8.5. Mission timeline deployment constraints are documented in the Shuttle Crew Scheduling Constraints, NSTS 37326. Orbiter control system, visibility, and separation requirements are documented in STS Operational Flight Design Standard Groundrules and Constraints, NSTS 21075. Payload deployment constraints on the Orbiter (for example, Right-Ascension-of-Ascending-Node (RAAN) and lighting constraints) are specified in IP Annex 2, Part III. All of these constraints are used to compute the launch window as well as to determine deployment opportunities (for example, longitude bands).

8.2.2.1 Attitude and Pointing

The attitude of the Orbiter at payload deployment is a function of payload requirements and Orbiter operations procedures. Payload pointing requirements are most compatible with Orbiter operational requirements if they allow the Orbiter to be in a +ZVV (orbiter belly along the positive velocity vector) attitude at deployment. Deployment in a direction other than +ZVV may result in a more complicated separation procedure and could increase the potential level of contamination and disturbance due to Orbiter thruster activity; however, other deploy attitudes are acceptable.

Release in either inertial or LVLH is generally acceptable. An LVLH release generally provides a greater deploy window opportunity. Payloads with small clearances from other structures will be analyzed on an individual basis; release in an inertial attitude hold to maximize clearance may be required.

Another payload concern during deployment is the accuracy with which the payload can be pointed. Several sources of misalignment must be taken into account such as:

1. Orbiter Inertial Measurement Unit (IMU) misalignment,

2. Orbiter Digital Automatic Pilot (DAP) deadbands, and

3. Deployment system misalignment and pointing accuracies.

Despite these sources of error, RMS deploys can generally meet pointing accuracies within 5° of the desired attitude, and ejection type deploys, within 1°.

8.2.2.2 Tip-Off Rates

The customer should design the payload to be compatible with tip-off rates which might be experienced during deployment. These rates come from such sources as:

1. Orbiter DAP deadbands - The payload should be compatible with primary as well as VRCS.

2. Deployment system - The payload should be compatible with tip-off rates for both nominal and off-nominal deployment.

The payload Attitude Control System (ACS) should be capable of overcoming these induced tip-off rates and should be capable of reorienting to its desired attitude after achieving a safe separation distance.

8.2.2.3 Appendage Deployment

Some payloads have appendages (solar arrays, antennas, etc.) which must be deployed at or near payload release. The longer a payload can delay appendage deployment during the separation, the less Orbiter thruster plume impingement will affect the stability of the payload and the contamination of its appendage surfaces. Payloads which are ejected from the Orbiter generally must delay appendage deployment until separated some distance; hence, they avoid the increased impingement effects.

There is a trade-off for payloads released by RMS-type systems, however. The payload can deploy appendages while on the release system and accomplish much of its payload checkout while captured by the Orbiter. Malfunctions may be easier to accommodate in this way; however, the price is increased impingement and increased design loads due to the larger surface areas at separation.

Operation of any appendage whose failure to deploy would result in the Space Shuttle taking contingency measures should be designed to be performed while the vehicle is grappled. The primary advantages of operating this way are that the RMS is available to point the payload, and rendezvous and re-grapple, which are very Orbiter propellant consumptive and which risk higher contamination of the payload by Orbiter jet firings, can be avoided.

Manual appendage deployment by unscheduled EVA is possible, but is not a preferred backup for failed appendage deployment operations. Customers requiring an unscheduled EVA capability must design their operations to be compatible with the constraints placed on payload-related EVA. (Refer to section 8.6.)

8.2.2.4 Payload Attitude Control And Translation

The payload is prohibited from firing Hot Gas and Solid Rocket thrusters for a period of time that is adequate for the Orbiter to achieve a safe separation distance from the deployed payload.

Momentum systems can generally be activated prior to release depending on momentum system size and deployment system capability.

8.2.2.5 Plume Impingement

Plume impingement on the payload due to Orbiter jet activity during the separation phase can be a major payload concern. Impingement concerns are centered around disturbance of the payload due to plume forces, and contamination due to deposition of Orbiter combustion products. In an effort to minimize these effects, there are several options available to preclude jet activity or to direct the plume away from the payload as much as possible.

8.2.3 Rendezvous Mission Techniques

Rendezvous flights can be divided into two categories: ground-up rendezvous, where the payload is already on-orbit at Space Shuttle launch, and deploy-retrieve, where the payload is deployed and retrieved on the same mission. Payloads which require the full, undivided resources of the Space Shuttle will probably require a dedicated flight. Rendezvous flight design on a dedicated mission is tailored to the needs of that particular spacecraft and may include many of the techniques mentioned in this section. However, a more desirable method to utilize the Space Shuttle is to accomplish the rendezvous on a shared payload mission. This complicates the flight design somewhat due to the need to meet the rendezvous and shared payload constraints. The desire to minimize the impact of including a rendezvous on a shared payload flight led to the development of the standard retrieval policy. This policy defines different classes of payloads depending on their capabilities and mission desires.

Ground-up rendezvous options for shared payload flights can generally be split into two payload classes: active and passive. Each class has certain characteristics which provide differing amounts of launch window, manifesting opportunities, and flight design flexibility. Payloads which fall under neither class are termed limited active and provide varying amounts of flexibility depending on the payload.

All payloads, regardless of class are required to meet some requirements. The payload must be compatible with Space Shuttle payload bay volume, weight and c.g. constraints. If the flight is shared with another payload, the needs of the other payload must also be considered. The spacecraft must be capable of achieving a safe retrieval-ready mode prior to grapple. This includes having an acceptable value for Orbiter/spacecraft differential drag. After rendezvous and grapple, up to 3 hours will be dedicated to payload berthing/support. The subsequent crew work period may be purchased as a nonstandard service for additional time.

Proximity operations are independent of the type of rendezvous technique used and are described in section 8.5.

8.2.3.1 Active Payloads

An active payload is defined as one that has the capability to achieve a large phase window, to adjust its down range position, plane, and altitude during the weeks before the launch of the rendezvous mission, and to quickly adjust its position and altitude after the Space Shuttle launch. The target spacecraft will usually perform most of the phasing necessary to meet the launch window requirements of the Space Shuttle revisit flight. This technique defines an area in space into which the target descends called the control box. The control box technique requires the target spacecraft to have navigation and guidance that will achieve the task of inserting the target spacecraft into the control box. After the target spacecraft is positioned in the control box, it ceases all translational motion while the Space Shuttle performs the rendezvous as the active vehicle.

8.2.3.2 Passive Payloads

A passive payload is defined as one that has no capability to adjust its altitude or orbital plane either before or after the Space Shuttle launch. Most spacecraft in this class are deployed and retrieved on the same Space Shuttle flight. The target spacecraft must be deployed within Space Shuttle operational altitudes and retrieved from an inclination of 28.5°, regardless of the method of deployment. Rendezvous with this class of spacecraft requires smaller launch windows and generally higher on-orbit propellant expenditure by the Space Shuttle.

8.2.3.3 Limited Active Payloads

Most spacecraft are not purely active or purely passive and are termed limited active payloads. This group is not really a payload class but covers vehicles from the nearly active to the nearly passive. Limited active spacecraft have some ability to alter their altitude and/or RAAN profile. It is desirable for a spacecraft to be as close to fully active as possible. Rendezvous techniques for limited active spacecraft are often a combination of those used for active and passive spacecraft and are determined on a case-by-case basis.

8.2.4 Rendezvous Operations

A rendezvous involves a multi-orbit, multi-impulse maneuver sequence ending in a manual approach phase. (See section 8.2.5, Proximity Operations Phases.) The Space Shuttle rendezvous operations which affect the payload involve the use of the Space Shuttle onboard sensors. The rendezvous radar is also discussed in section 8.3, along with other Space Shuttle onboard sensors.

8.2.4.1 Star Tracker Rendezvous Navigation

To support required star tracker rendezvous navigation, the payload must be capable of being tracked by the Orbiter to a range of 250 n. mi. from orbital noon to orbital sunset. This requirement can be satisfied by providing payload surface reflectivity characteristics and an attitude timeline that allow continuous payload visibility to the

Orbiter star tracker in reflected sunlight (equivalent brightness of a third magnitude star) for a minimum of 30 minutes per orbit revolution. Failure to meet this long-range tracking requirement will result in specialized mission planning with attendant delta costs and/or degraded probability of mission success.

8.2.4.2 Radar Rendezvous Navigation

Radar rendezvous navigation requires a payload to have an attitude-independent effective radar cross section of at least 1.0 square meter. This allows the rendezvous radar to assure lock-on to the payload outside a range of 10 n. mi., and to remain locked on until a range of 100 feet. Payloads with an effective cross section of less than 1.0 square meter are incompatible with current rendezvous techniques. The radar is capable of updating navigation data while the payload is within 27 n. mi., provided radar lock-on has occurred. It is beneficial in terms of controlling trajectory dispersions and increasing the probability of mission success for radar lock-on to occur as soon as possible after the range has closed to within 27 n. mi. For radar lock-on at 27 n. mi., the effective radar cross section needs to be approximately 53 square meters.

8.2.5 Proximity Operations

Proximity operations are flight operations during which active man-in-the-loop trajectory management tasks are conducted in the vicinity of a free-flying target. They are most often postrendezvous activities, but they can also be postdeployment activities (for example, inspection flyaround). During proximity operations, the relative position and rates are sufficiently small and stable so that the Orbiter does not need to maneuver to maintain proximity. Proximity operations can include final approach to, flyarounds of, stationkeeping with, and capture/dock of a payload. Proximity operations will include an Orbiter separation maneuver after payload deployment. The flying techniques used during proximity operations are manual and as such are highly crew-intensive. During proximity operations, through-the-window visual acquisition is required.

8.2.5.1 Proximity Operations Phases

8.2.5.1.1 Approaches

The approach to a free-flying target begins in the manual or terminal phase of the rendezvous. This phase serves as a transition between rendezvous operations and proximity operations. The final approach starts from a range of approximately 600 feet. The final approach brings the Orbiter to within a distance of about 35 feet from the payload where a final braking maneuver is performed and the RMS can capture the payload.

8.2.5.1.2 Final Approach Techniques

The Orbiter is capable of an approach for close-in stationkeeping with and/or RMS grapple of a payload stabilized in either an LVLH reference frame or in an inertial reference frame. The inertial approach is often used for inertially stabilized payloads.

This approach is generally only slightly more propellant expensive than the +RBAR approach.

The preferred final approach method is the LVLH +RBAR approach. This approach is preferred because it uses only a small amount of Orbiter propellant and offers the least plume impingement on the payload. Approaches along other LVLH directions (+VBAR, -RBAR, etc.) can also be used. The Orbiter first performs a flyaround from the +RBAR to that approach axis and then executes the final approach.

8.2.5.1.3 Stationkeeping

During stationkeeping, the Orbiter maintains a constant position relative to the target. Short-range stationkeeping is performed at around 35 feet to allow the RMS to grapple the payload. Long-range stationkeeping is performed at 100 to 2000 feet. It allows the Orbiter to stand by close to the payload to assist in payload communication and/or viewing during extended periods of payload checkouts. Long-range stationkeeping is generally performed on the target’s +VBAR.

8.2.5.1.4 Flyarounds

During flyarounds, the Orbiter translates around the target in the LVLH frame. This is usually performed to properly orient the payload to facilitate viewing of, approach to, or grapple of the payload. The flyaround can be performed at short ranges (35 feet) or long ranges (up to 500 feet). Short-range flyarounds are limited to payloads small enough to comfortably avoid a collision danger during the flyarounds. It is highly desirable to keep long-range flyarounds in the target’s orbit plane due to the significantly higher propellant cost of an out-of-plane flyaround.

8.2.5.1.5 Proximity Operations Separations

Proximity operations separations are designed to provide some separation between the payload and the Orbiter, but to stay within the proximity operations regime (as defined in section 8.1.3) in order to accomplish payload goals such as communications support. These separations are different from nominal separations in that nominal separations are designed to terminate proximity operations. These separations are usually performed to provide postdeploy inspection/photography. They usually involve stationkeeping or flying around the payload one or more times before final separation.

8.2.5.2 Sensors

Several sensors are used by the Orbiter crew during proximity operations to determine relative range and range rate, as well as rates perpendicular to the LOS. These include Rendezvous Radar (RR), the Trajectory Control Sensor (TCS), Hand-Held Lidar (HHL), the Crew Optical Alignment Sight (COAS), and CCTV.

The RR is essential for accurately determining range to the target and range rate. It used from the beginning of the final approach down to a range of 100 feet where it breaks lock.

The TCS is a laser sensor that provides the same data in proximity operations as the RR. The TCS is more accurate and can provide data into very close range but requires reflectors to be placed on the payload.

The HHL is a hand-held laser device that is manually pointed toward the payload and provides range and range rate data. It is generally used as a backup sensor to the RR or TCS.

The COAS is used as an alignment aid for the crew for early detection and correction of rates perpendicular to the LOS to the target. It is an illuminated sight with a reticle pattern to measure a payload's angle from the Orbiter's Z axis (overhead window). It may also be used as a visual backup aid to determine range by measuring subtended angle and deriving a very rough measure of range rate.

The TV cameras are generally used for alignment and piloting cues. They can also be used to determine range by triangulation within 200 feet and, again, offer a rough calculation of range rate.

8.2.5.3 Viewing/Visibility Requirements

The payload must be visible during all proximity operations. In addition, the payload shape and orientation must be clearly discernible to the crew at a range of 1000 feet and less. Normally the proximity operations are designed such that the payload is in sunlight until close range.

If nighttime operations are performed, there are several options available to satisfy the visibility requirements. These options include the Orbiter docking light, a 1,000,000 candlepower spotlight, reflectors, or running lights. The customer should check their lighting scheme with the SSP.

8.2.5.4 Plume Impingement

Due to the nature of the Orbiter activities during proximity operations, it is impossible to completely preclude the impingement of Orbiter thruster exhaust on some surfaces of the payload. However, some precautions can be exercised which tend to minimize the effects of impingement. One is the use of the +RBAR approach which results in almost no plume impingement. For other operations, the PRCS thrusters can be used, when permissible, for attitude control and translation in the low-Z mode. This mode can be selected depending on the relative geometry at the time of thruster activity.

Impingement on the payload may be of concern for two reasons: the plume exerts forces on the payload that may damage it or disturb its attitude, and the products of combustion may strike the payload's surface and contaminate it.

8.2.5.5 Retrieval Operations

Retrieval operations are a specialized subset of proximity operations. An RMS retrieval occurs as the Orbiter is stationkeeping at a range of 35 feet. A nominal retrieval attitude must be attained by the target spacecraft prior to the Orbiter's arrival on the payload's

+RBAR and must be maintained until just prior to grapple. The target must be put in free drift mode just prior to grapple.

8.2.5.6 Payload Appendage Stowage

Payload appendages such as solar arrays, antennas, etc., not only can make it more difficult for the Orbiter to safely approach to a grapple position, but also can make the payload more sensitive to plume impingement torques from PRCS jet firings during proximity operations. All appendages that would adversely affect the Orbiter's ability to approach and stationkeep with the payload should be stowed prior to the Orbiter's arrival on the +RBAR.

8.2.5.7 Payload Attitude Control System Activation/Deactivation

The payload Attitude Control System (ACS) must conform to the following: Hot gas thrusters must be safed at a range dependent on thruster size.

Often, cold gas thrusters and momentum wheels can be left on until just prior to grapple; however, the customer must negotiate these inhibits with the SSP. More information is available in section 5.5 and in Safety Policy and Requirements for Payloads Using the Space Transportation System (STS), NSTS 1700.7 (current issue).

8.2.6 Pointing Capability for Non-RMS Deployable Payloads

The Space Shuttle is capable of pointing the Orbiter structural interface with a payload to within 1° of the required inertial attitude when using the VRCS. The angular rate at deployment shall be no greater than 0.01 degrees/second/axis for vernier control, or 0.2 degrees/second/axis for primary control.

8.2.7 Navigation Accuracy and Tracking Requirements

On-orbit navigation is currently based on data from the ground tracking stations of the SN and the TDRSS. The main advantage of the TDRSS is increased Orbiter visibility. This allows the collection and processing of navigation data and the state vector uplink to occur much closer in time to the event (for example, maneuver or payload state vector initialization) to be supported than is possible with only the ground tracking stations.

8.2.7.1 Navigation Accuracies - General Information

Navigation accuracies are dependant on many factors. The following statements apply to navigational accuracies for both RMS and ejectable payloads:

1. Accurate navigation can be achieved no earlier than 4½ hours after lift-off. This time refers to the end of the tracking arc and does not include the time required to process the data and uplink the vector.
2. Velocities created by the deployment of the payload will increase errors in the navigation.

3. The navigation data gathering/processing/uplink interval is up to 7 hours for ground tracking stations and 5 hours and 15 minutes for TDRSS.

8.2.7.2 Navigation Accuracies - Factors

The navigation accuracy depends on unanticipated disturbances to the orbit. Many factors can increase errors in the navigation. Some of these factors are listed below:

1. Orbiter attitude change maneuvers using either primary or VRCS
2. Attitude hold using the PRCS
3. Vents, dumps, purges, or other thrusting
4. Atmospheric drag uncertainties (for orbits at 150-n. mi. or lower)
5. Time since the last state vector update

8.3 TRAINING REQUIREMENTS

8.3.1 Training Responsibilities

The SSP and the payload customer will jointly identify the training objectives including critical training objectives that are required to be successfully completed by the flightcrew and support personnel. Critical payload training objectives are those that are required for mission safety and payload mission success.

The customer is responsible for providing the necessary lessons to sufficiently train the flightcrew to support their operational roles and responsibilities directly associated with operating the payload experiment and/or experiment software that is provided by the customer.

8.3.2 Familiarization Training

The customer shall provide a payload familiarization briefing at JSC to the flightcrew members, flight controllers, support personnel, and instructors. This briefing will be conducted according to guidelines established in the Payload Familiarization Briefing Guidelines, SFOCFL2121. If requested, the customer will provide a payload familiarization briefing to the mission processing team at the launch site when the hardware arrives.

8.3.3 Simulations

A series of simulation will be conducted to insure that crew and flight controller are trained on nominal and contingency procedures.

The payload customer will provide a representative who is familiar with the technical details of the payload and the payload interfaces with the Orbiter and who can assist with the implementation of the payload training requirements, agreements, and who can support simulations and the presimulation scripting process.

The SSP will determine to what extent and fidelity the Shuttle Simulator will model the payload and its interfaces with the Orbiter. The customer will provide this information either in IP Annex 1 or directly to SSP.

8.4 MISSION SUPPORT

8.4.1 Communications and Control

Payloads requiring extensive communications with the ground for operations should include Space Shuttle compatibility as a mode of their communications system. This capability will yield significant mission planning and flight design flexibility over any other communications mode.

8.4.1.1 Orbiter/Payload Communication System Compatibility

The Orbiter provides a dedicated payload communications system capable of interfacing with a payload via hard line or RF. For free-flying payloads, the Orbiter PI may be employed in either of two modes, standard or bent-pipe, depending on the characteristics of the payload transmitter. The standard mode is described in more technical detail in section 5.2.

The standard mode provides the advantage of not competing with the Orbiter for TDRSS coverage and will in most cases eliminate any special attitude requirements for communications. Ku-band bent-pipe mode allows the payload to transmit to the ground at higher data rates, but this mode also places much greater restrictions on Orbiter operations. Bent-pipe Orbiter data relay should be restricted to accommodating noncritical data (such as science data or recorder dumps) and engineering data streams the rates of which are above the limit for the standard mode. The operational impacts of using the bent-pipe mode are significant due to:

1. The single string nature of the Ku-band system
2. The additional attitude requirements to provide a LOS for the Ku-band antenna to a TDRSS
3. Potential sensitivity of the payload, or other shared payload, to Ku-band radiation
4. Inability to display payload data on MCDS

Where payloads require direct communications with the TDRSS, these communications scenarios should be limited to short periods of time, such as during initial activation or, if the payload is deployable, just prior to release. This will limit the impacts to the thermal timelines of the other payload elements on the same flight, since TDRS pointing is generally a deep-space attitude. Those payloads requiring RF checks with a SN ground station or customer ground site will normally have these activities scheduled early enough in the mission so as not to constrain selection of deployment opportunities.

8.4.1.2 Onboard Payload Data Processing

The only circumstances where the customer is required by the SSP to provide crew access to payload telemetry parameters is for safety-critical payload subsystems. Any additional requirements for such services will usually develop as the customer designs the joint Space Shuttle/payload operations scenario. While in many cases Orbiter access to payload telemetry is not required, it can contribute significantly to the potential for mission success in many operations scenarios. This data can include spacecraft predeploy checkout parameters, GO/NO-GO RMS release data, and payload-to-Orbiter interface indicators.

Once the customer has determined that he will use onboard data processing, SSP personnel will work with the customer and flightcrew in developing the crew display requirements in concert with refinement of the payload operating procedures. The SSP will also work with the customer to define adequate crew training requirements.

Indirectly related to onboard data processing is the use of the standard switch panel for payload command and control. The customer should be aware that the status of switches and talkbacks are not available in the Orbiter downlink. More details about the standard switch panel can be found in section 5.2.

8.4.1.3 Ground Commanding

Any time-critical commanding required to perform any operation critical to the health of the payload may be more adequately provided from the Orbiter AFD. This has the distinct advantage of not relying on the availability of the forward link from the ground. In addition, the flightcrew has the best visual advantage for observing activities like solar array or antenna deployments. If time-critical commanding is to be performed from the AFD, the proper telemetry parameters should be provided for verification. Significant command traffic is best accomplished by the POCC. Control of POCC-generated hazardous commands to their payload, whether transmitted through the Orbiter system or directly to the payload via ground site, must follow the SSP guidelines set forth in Safety Policy and Requirements for Payloads Using the Space Transportation System (STS), NSTS 1700.7 (current issue) and in NSTS 21063, POCC Capabilities Document Payload Support Capabilities Description: MCC, JSC POCC, Remote POCC Interface. As a backup for loss of the POCC-to-JSC command capability, the Mission Control Center-Houston (MCC-H) can store important commands in the Generic Command Server (GCS).

8.4.2 Mission Control Center-Houston

The MCC-H at JSC provides facilities for flight control and data systems monitoring and control during Space Shuttle flights. The MCC-H is supported by the SN and TDRSS (figure 8.4.2-1), which provide flows of telemetry, trajectory, command, video, and voice data. Three major systems within MCC-H receive, route, process, display, and control data flows. These systems are the Communications Interface System (CIS), the Space Shuttle Data Processing Complex (DPC), and the display and control system (DCS).

Payload data from the PDI is available in the MCC-H; however, customer requirements must be identified in IP Annex 4.

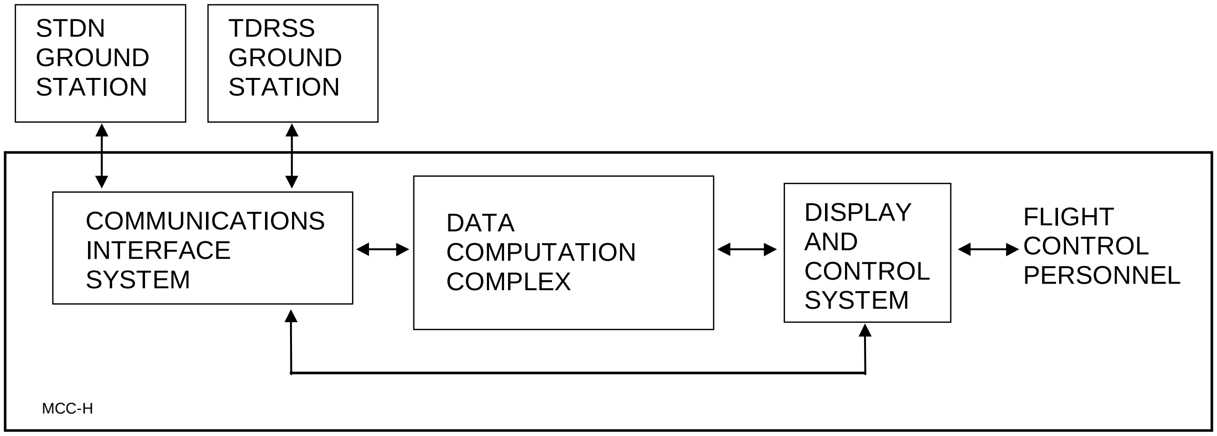


Figure 8.4.2-1. MCC-H

8.4.2.1 Communications Interface System

The CIS provides voice and data communications within the MCC-H, and voice, data, and video interfaces between MCC-H and external sources.

8.4.2.2 Data Computation Complex

The Data Computation Complex (DCC) supports MCC-H display and control computation, peripherals, and switching functions; it also provides real time command, control, and telemetry processing.

The DCC consists of the following major hardware components:

1. A multibus interface for multiple bidirectional data transfer between the DCC and elements of the CIS
2. The Shuttle data processing complex of switchable computer systems
3. The configuration and switching equipment subsystem for receiving command requests from and sending display data to the DCS

8.4.2.3 Display and Control System

Computer-generated display data can be requested and monitored using the DCS. The DCS will detect, encode, and transmit operator requests and generate displays in response. The MCC-H TV system provides reception, recording, color conversion, display, and public distribution of certain downlinked Shuttle video.

8.4.3 Payload Operations Control Centers

There are three NASA POCCs that maybe used: JSC, MSFC, and GSFC. The MCC-H can interface with customer-provided remote POCCs.

8.4.3.1 Telemetry

Payload data interleaved in the Orbiter operational telemetry downlink is routed to the MCC-H which processes the data, extracts the payload data, formats it for output, and transmits it along with standard base Orbiter data to the remote POCCs. Ephemeris data, command acceptance pattern data, and ground-systems data can be transmitted to remote POCCs with telemetry data.

Some payloads may, if compatible, transmit directly to TDRSS. These data streams are routed directly from the TDRSS ground site to the appropriate remote POCC.

8.4.3.2 Commands

When payloads are attached to the Orbiter or operating detached from the Orbiter through the PI link, commands from remote POCCs are routed to the MCC-H for verification, conversion into Orbiter command format, and uplinking to the payload through the Orbiter systems. The MCC-H will provide a nearly transparent path through the Orbiter to the payload but will maintain control over potentially hazardous commands. The MCC-H will perform message-error checks and provide command verifications to POCCs.

8.4.3.3 Remote Payload Operation Control Center Interfaces

POCC Capabilities Document Payload Support Capabilities Description; MCC, JSC POCC, Remote POCC Interface, NSTS 21063-POC-CAP, describes the customer mission operations support and interface capabilities in the MCC-H, JSC POCC, and customer remote POCC.

8.5 PAYLOAD DEPLOYMENT AND RETRIEVAL SYSTEM

This section gives the SSP community an overview of the Payload Deployment and Retrieval System (PDRS) capabilities and constraints that will affect the design and operation of a particular payload. NSTS 07700, Volume XIV, Appendix 8 contains details of the system overview and the constraints applied to the integration and operation of the payload and the PDRS. Actual mission design involving PDRS operations will be performed by the SSP working with the customer. Shuttle Orbiter/Cargo Standard Interfaces, ICD 2-19001, contains the constraints applied to the Orbiter-to-payload interface. International Space Station Interface Definition Document, NSTS 21000-IDD-ISS, contains the constraints applied to the Space Station-to-payload interface.

Payload and mission design information must be available to the PDRS/Orbiter community far enough in advance of launch to ensure adequate time for planning, nominal and off-nominal analyses, simulation model development, software development and approval, procedures development and verification, and crew and flight controller training.

8.5.1 PDRS Description

The PDRS consists of those SSP-provided systems which are devoted to payload deployment, retrieval, special handling operations, and other Orbiter servicing. Other Orbiter systems, not considered a part of the PDRS, are required to support the payload deployment and retrieval activities.

The primary components of the PDRS include the following:

1. RMS
2. PRLAs
3. Grapple Fixtures (GFs)
4. Targets
5. CCTV System

8.5.1.1 Remote Manipulator System

The RMS is anthropomorphic and can be used to repair satellites, service satellites, assist in EVA, and perform other special tasks. An upper and a lower arm boom driven by two joints at the shoulder and one joint at the elbow provide mainly translational capability. Three joints form the wrist and provide mainly attitude pointing. Six-joint arm motion is coordinated by an onboard computer from operator inputs or preflight-generated automatic point tables. Individual joint control is effected by the operator either through the computer system or through one of two hardwired systems.

The RMS is 50 feet 3 inches (15.32 m) in length and is located on the port side of the vehicle. It is stowed outside the payload dynamic envelope and its weight of 966 pounds (438 kg) is chargeable to the Orbiter. An overview of the arm is shown in figure 8.5.1.1-1.

The connection between the arm and the payload GF is the End Effector (EE), refer to figures 8.5.1.1-1 and 8.5.1.1-2. The EE provides capture and release of payloads, and it is equipped with an electrical connector that is capable of providing 16 command, data, or power (+28 V dc) lines to the payload. Special hardware interfaces to the EE are identified in ICD 2-19001.

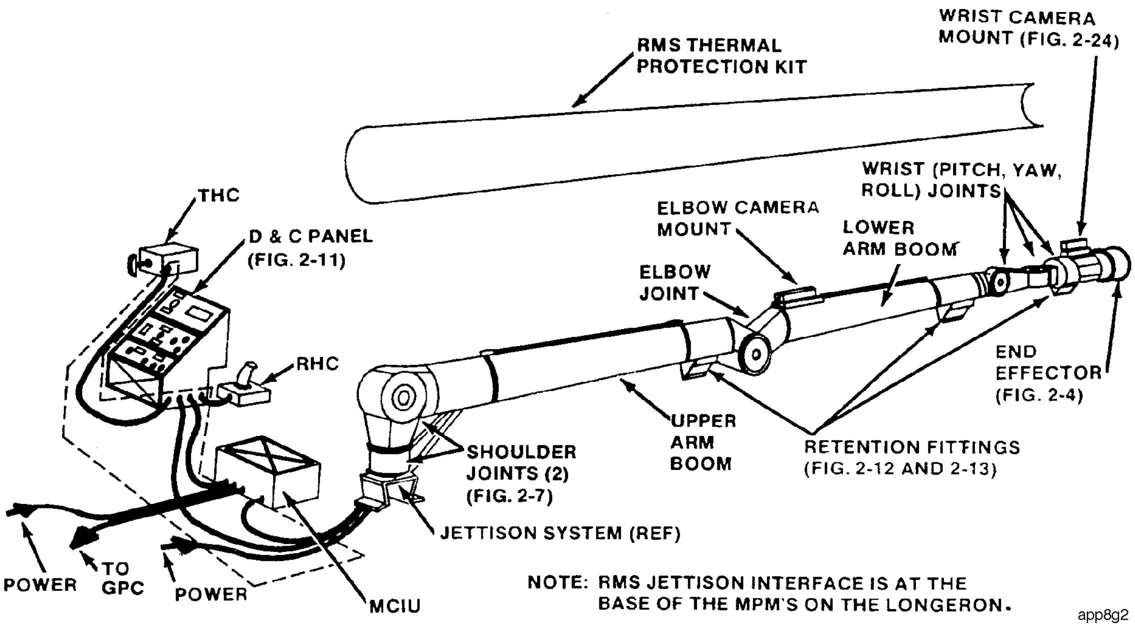


Figure 8.5.1.1-1. RMS

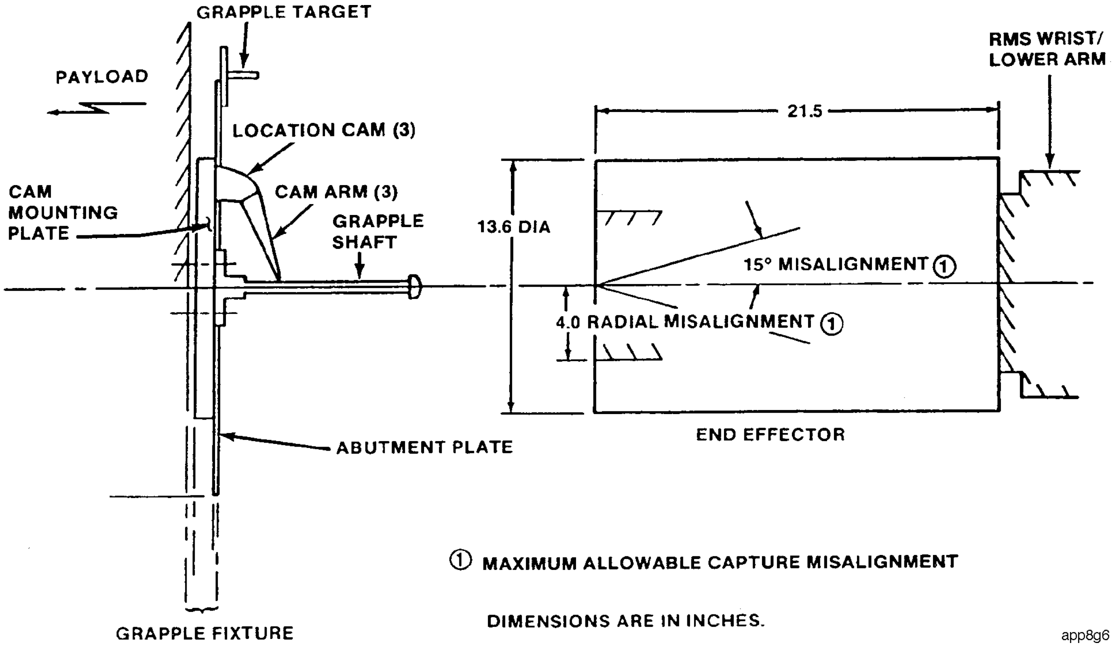


Figure 8.5.1.1-2. RMS standard EE and GF envelope

8.5.1.2 Payload Retention Latch Assembly

Two types of retention latches secure deployable and nondeployable payloads in the payload bay: longeron latches and keel latches. These latches are provided by the SSP. Special retention latches may be supplied by the customer, but must comply with

Shuttle Orbiter/Cargo Standard Interfaces, ICD 2-19001, which is the controlling document for SSP-supplied hardware.

The types of payload attachments, standard cargo bay locations, and the necessary payload interfaces are discussed in more detail in section 5.1.

8.5.1.3 Grapple Fixture

GFs are provided by the SSP (as Government Furnished Equipment (GFE)) to customers who plan for their payload to be deployed/retrieved. These mechanisms are installed on the payload by the payload customer according to ICD 2-19001 and they provide the primary connection between the RMS EE and the payload, see figure 8.5.1.3-1.

There are two types of GFs. They are the Flight Releasable Grapple Fixture (FRGF) and the Electrical Flight Grapple Fixture (EFGF). A GF includes a camera GF target.

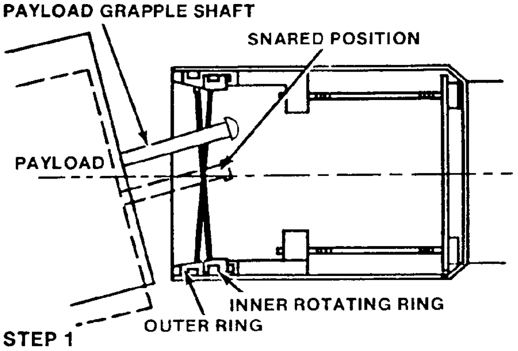
The FRGF provides a mechanical interface between the EE and a payload. The EFGF provides a mechanical and electrical interface between the EE and the payload. The EFGF uses a movable grapple shaft to extend and retract an electrical connector.

A GF target, figure 8.5.1.3-2, is used in conjunction with the wrist CCTV to align the EE to the GF during payload capture.

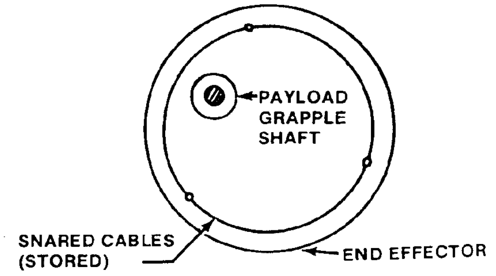
8.5.1.4 Targets

Camera targets must be placed on the payload when visual alignment cues are required in conjunction with CCTVs. The standard target is a payload GF target (without the GF). If a keel camera view is required for payload alignment, a corresponding target must be installed on the payload; likewise, if ASE docking is required, a corresponding target may be required and will be located in relation to the trunnions, as depicted in figure 8.5.1.4-1.

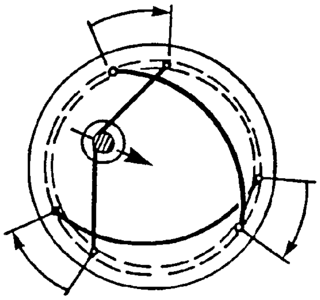
The payload customer must work with the SSP to determine the best set of visual cues necessary for payload operations.



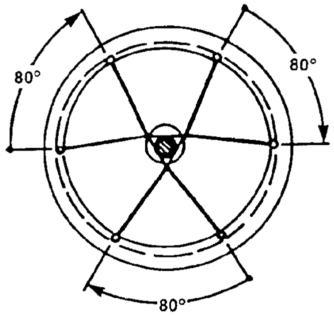
STEP 1
WITH RING IN FORWARD POSITION, SNARE CABLES ARE STORED. PAYLOAD GRAPPLE SHAFT ENTERS OPEN END OF EFFECTOR.



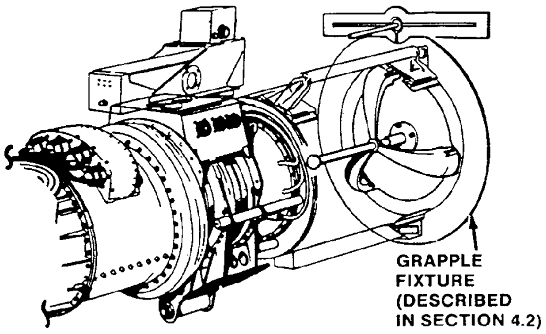
STEP 2
PAYLOAD GRAPPLE SHAFT IS INSIDE OPEN END OF END EFFECTOR.



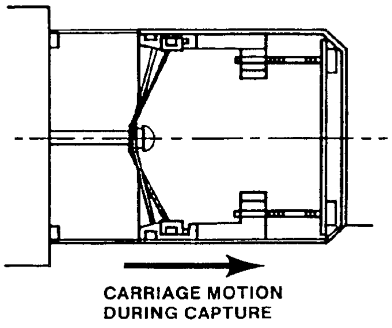
STEP 3
END EFFECTOR RING BEGINS TO ROTATE. THE SNARE CABLES BEGIN TO CLOSE ONTO PAYLOAD GRAPPLE SHAFT.



STEP 4
END EFFECTOR RING IS FULLY ROTATED. SNARE CABLES HAVE CLOSED ON PAYLOAD GRAPPLE SHAFT, CENTERING IT, AND CAPTURING PAYLOAD.



EE/GRAPPLE FIXTURE IN FULL CONTACT AND KEYED ORIENTATION.



STEP 5
BALL SCREW AND NUT OPERATION WITHDRAWS CARRIAGE WHICH PULLS PAYLOAD INTO FULL CONTACT AND KEYED ORIENTATION. FURTHER OPERATION TENSIONS SNARE CABLES RIGIDIZING THE CONTACT.

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Figure 8.5.1.3-1. Snare/EE capture and rigidize sequence

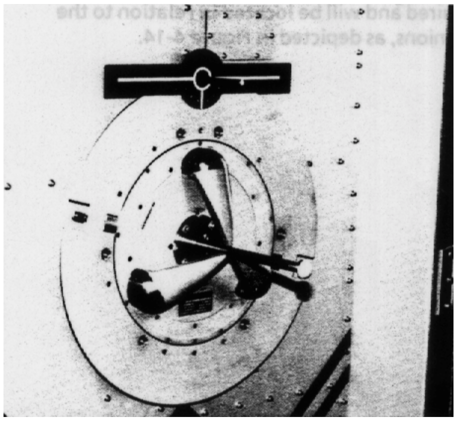

Figure 8.5.1.3-2. GF target

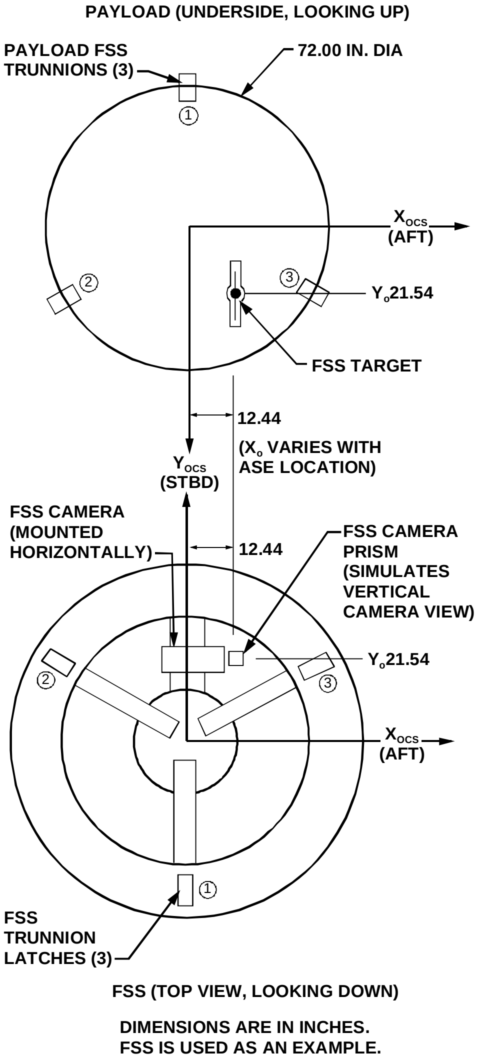

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Figure 8.5.1.4-1. Example of standard payload/ASE camera-target relationship

8.5.1.5 CCTV

CCTV cameras are strategically located to provide visual cues to monitor the RMS/payload motion. They are located in the payload bay, on payload support structures, and on the RMS to augment the operator’s window views. Lights in the bay and on the RMS provide illumination as required.

8.5.2 Payload Design Considerations

Payloads must have sufficient clearance from other payloads and Orbiter equipment in the Space Shuttle Cargo Bay. Orbiters OV-103, OV-104 and OV-105 contain an external airlock which protrudes 8 feet, 5 inches into the Bay. A payload must consider hardware, operational and manifesting properties in their design process.

8.5.2.1 Hardware Considerations

Hardware considerations that payload designers must take into account include:

1. Weight and mass properties are limited, and an analysis will be required to confirm RMS and Orbiter capabilities.
2. Visual cues to aid the operator during berthing, deploying, and proximity operations.
3. Dimensions must be compatible with the Orbiter and other payloads.
4. Payloads must be protected from contact with other payloads.
5. GF location and integration on the payload must be located within RMS reach capabilities and in an area easily accessible to an EVA crewmember.
6. Structural vibration frequencies of a payload and its GF interface.
7. Payload flexibility and thermal distortions must allow compliance during latching.
8. Payload-unique berthing/latching systems.
9. Berthing guides and scuff plates used to constrain payload motion.
10. EMI from the Orbiter.

8.5.2.2 Operational Considerations

Operational considerations that payload designers must take into account include:

1. Lighting availability to take advantage of daylight operations
2. Payload deployment flight control and accuracies

3. Payload capture flight control and accuracies
4. Flight rules document the operational guidelines and constraints as agreed to by the payload customer and the operations community

8.5.2.3 Manifesting Considerations

Manifesting considerations that payload designers must take into account include:

1. Proximity to neighboring Orbiter structure and payloads
2. Compatibility with neighboring Orbiter structures and payloads
3. Scheduling compatibility with the mission

8.5.3 Payload Retention Panel

Operation of Orbiter-deployable retention fittings or customer-supplied devices through the Orbiter retention system electrical subsystem requires a patch harness in the Orbiter. The harness will connect up to five selected sets of two electrical receptacles at payload bay longeron or keel fitting locations, to selector switch positions on the payload retention panel (A6A1 - on-orbit station). See figure 8.5.3-1. The switches on this panel are as follows:

1. Payload select switch - A five-position rotary switch governing which set of latches or payloads are operated and allows the operator to monitor latch status. The switch has three payload select positions and two monitor positions. When a payload select position is chosen, the operator can control up to five latches and monitor all the talkbacks associated with that position. The monitor position allows the operator to monitor every latch during any mission phase, and functions as an inhibit to prevent latch operation or inadvertent payload deployment. To obtain total payload status, the operator must call up the payload retention CRT display with the payload select switch in the monitor position.
2. Retention latch select switch - Five latch switches, each of which is a three-position switch (release, off, and latch), commanding two motors to open or close the motors' particular latch. The same 5 switches can operate as many as 15 latches. Five latches can be operated per payload select switch position, although the number of latches is determined by the size of the payload. Latch switch assignments are flight dependent.
3. Payload retention latch talkbacks - Each retention latch is associated with two talkbacks, a release/latch indication, and a payload ready-for-latch (trunnion-in-place) indication, for a total of 10 talkbacks. When a payload is selected, the talkback indications correspond only to the selected payload. The release/latch talkback has three indications: release (latch open), barberpole (latch transit), and latch (latch closed). The ready-for-latch talkback has two indications: gray when a payload is present and/or latched, and barberpole when payload is deployed. If power is not on, both system talkbacks will show barberpole.

4. Payload retention logic power - Two retention system switches which power the midmotor control assembly logic. Both logic power switches must be on to drive both motors on each latch simultaneously. Only system 1 drives both talkbacks.

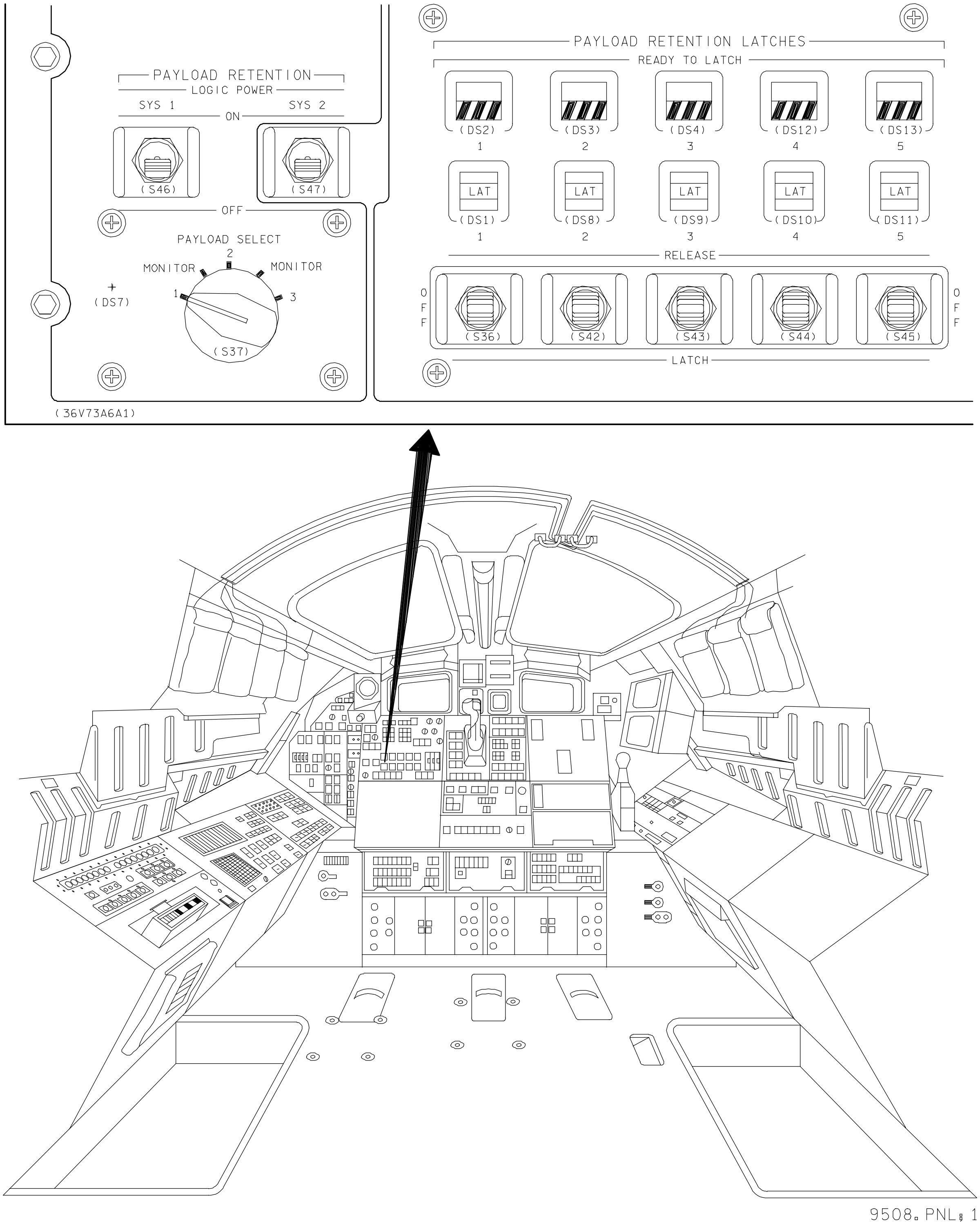

Figure 8.5.3-1. Payload retention panel

8.6 EXTRAVEHICULAR ACTIVITY

8.6.1 Extravehicular Activity Provisions, Capabilities, and Constraints

The SSP offers numerous services to payloads in addition to providing transportation to and from orbit and supplying an orbital operations platform. One such service is the capability to conduct Extravehicular Activity (EVA) for both payload and Orbiter operations.

EVA includes all activities performed external to the Orbiter cabin by crewmembers in their Extravehicular Mobility Units (EMUs).

8.6.1.1 Categories of Extravehicular Activity

There are three basic classes of EVA:

Scheduled EVA - EVA planned prior to launch and included in the nominal mission timeline

Unscheduled EVA - EVA not included in the nominal scheduled mission activities but which may be required to achieve payload operation success

Contingency EVA - EVA required for the safe return of the Orbiter and crew

The following tasks are selected to represent the wide range of EVA applications for payload support.

1. Providing backup capability to raise, lower, or jettison a satellite or experiment
2. Capture of an on-orbit satellite and berthing it to the Orbiter
3. On-orbit satellite repair and servicing
4. Structural assembly techniques
5. Inspection and photography of payloads
6. Installation, removal, and transfer of film cassettes, material samples, and instrumentation
7. Operation of equipment, including standard or special tools, cameras, and cleaning devices
8. Connection, disconnection, and stowage of fluid and electrical umbilicals when safed
9. Replacement and inspection of modular equipment and instrumentation on the payload or spacecraft

10. Remedial repair and repositioning of antennas, solar arrays, experiment covers and mechanisms

11. Conducting experiments

12. Transfer of cargo

8.6.1.2 SSP EVA Provisions

Shuttle EVA provisions and some basic carry-on equipment required for EVA are baselined for each Shuttle mission. This basic SSP accommodation satisfies program requirements to provide one, two-crewmember EVA on every flight for Orbiter contingencies. For payload activities, consumables and expendables can be provided for a maximum of five, two-crewmember EVAs, with a duration of 6 hours per EVA. Various types of EVA equipment have already been developed by SSP to provide a wide range of EVA capabilities but are not normally carried on each flight. Although most items of equipment were developed to satisfy specific needs, the full range of applications has yet to be determined. A more detailed description of SSP EVA hardware is provided in EVA Catalog Tools and Equipment, JSC 20466.

The customer may request, in the IP, items not normally baselined for a mission. These items would be payload chargeable based on their weight and/or volume. In the interest of minimizing cost, standardization, and simplified crew training, customers should use the existing tool inventory to satisfy their requirements since it greatly simplifies tool stowage and mission integration.

8.6.1.2.1 Extravehicular Mobility Unit

The EMU is an independent anthropomorphic system that provides environmental protection, mobility, life support, and communications for the Shuttle crewmember to perform EVA in Earth orbit. Two EMUs are included in each baseline Orbiter mission. Additional EMUs can be provided to satisfy specific mission requirements. Ancillary equipment that complements the pressure-suited crewmember’s capabilities include tethers, mini workstations, helmet-mounted lights, and cuff checklist.

8.6.1.3 Nonstandard SSP EVA Provisions

Various types of EVA equipment have already been developed by the SSP to provide a wide range of EVA capabilities but are not normally carried on each flight. Although most items of equipment were developed to satisfy specific needs, the full range of applications has yet to be determined. A more detailed description of SSP EVA hardware is provided in EVA Catalog Tools and Equipment, JSC 20466.

8.6.1.3.1 Manipulator Foot Restraint

The Manipulator Foot Restraint (MFR) is attached to the RMS EE and provides restrained access to EVA worksites within the operational reach of the RMS and MFR. The MFR is mounted on an APC, which is attached to the Orbiter longeron. As a portable workstation, the MFR provides for tool stowage and transfer of hardware from stowage sites to worksites.

The MFR is certified for the following load carrying capabilities and RMS velocities. The tables are based on the MFR carrying a 486-pound (220-kg) suited crewmember. Table 8.6.1.3.1-1 assumes a 500-pound (225-kg) payload is attached with the center of mass (c.m.) of the payload no more than 12 inches (30.5 cm) from the centerline of the stanchion.

Table 8.6.1.3.1-1. RMS velocities for MFR with payload attached

	Translation	Rotation
Vernier	0.25 ft/sec (0.076 m/sec)	0.59 deg/sec
Coarse	0.44 ft/sec (0.134 m/sec)	1.49 deg/sec

The crewmember should not apply more than 100 pound-force (460 N) to the MFR structure. The foot restraint is designed for a ±140-pound-force (640-N) load applied by each foot.

The RMS-applied constrained motion load limit is a force of 300 pound-force (1380 N) applied to the MFR on the foot-restraint-to-GF structure. The 300-pound-force limit is an ultimate load limit, and the MFR will not fail in any manner which would separate the crewmember from the RMS. The EVA crewmember’s space suit is limited to this same load. The RMS position must be chosen to limit the constrained loads to less than 300 pound-force. NASA uses the family of curves in the design process that defines the allowable RMS positions.

8.6.1.3.2 EVA Tools

Many EVA tasks on previous space missions have been accomplished using off-the-shelf industrial or consumer tools with modifications to enhance thermal performance or handling/gripping or tethering. EVA experience shows a properly restrained crewmember can perform the same manipulative operations on-orbit that can be performed on Earth. Therefore, given adequate interface designs (i.e., payloads designed for EVA servicing), a moderate complement of hand tools may satisfy payload servicing requirements. If special tools are required, the user can develop mission-specific EVA tools. However, these tools must meet SSP requirements and the design of EVA tools should closely follow the design criteria in paragraph 8.6.2.2.7. Previously developed and certified tools are shown in EVA Catalog Tools and Equipment, JSC 20466.

8.6.1.3.3 Tool Stowage Options

Orbiter EVA tools are stowed in the Provisions Stowage Assembly (PSA) and the Tool Stowage Assembly (TSA). The PSA consists of a pair of tool boxes mounted in the bottom forward end of the payload bay, external to the 15-foot (4.6-m) diameter, for tool and equipment stowage.

The port TSA contains the standard tools and equipment necessary to support Orbiter EVA tasks. The starboard TSA can be flown to provide additional stowage space. Limited space is available to stow payload-unique EVA support equipment. The stowage, weight, and volume will be agreed to by the customer and the SSP in the integration process. For additional information on EVA tools, refer to EVA Catalog Tools and Equipment, JSC 20466

8.6.1.4 Task Design

When considering the design of an EVA task, the customer should consider the constraints and the specifications in Paragraph 8.6.2 of this document as minimum requirements. The designer should use the proven hardware in EVA Catalog Tools and Equipment, JSC 20466, to enhance mission-success probability and minimize cost development efforts and crew training requirements. EVA worksites must provide adequate access to mechanisms, sufficient lighting, good crewmember restraints, reasonable force requirements, and hazard avoidance.

An early joint customer/SSP evaluation of the proposed EVA scenario is highly recommended to review EVA hardware interfaces, safety, training requirements, procedures, flight planning, and flight operations. Every EVA task must be evaluated on its own merits, and this initial review activity brings together all the elements necessary to ensure a successful design effort. As a result of the joint review, the customer is ready to proceed with the payload design, applying the specific EVA design criteria, and also with preparation of the IP EVA Annex.

There are three major benefits to be derived by the customer from the joint review. First, the customer can exercise contacts with the personnel who will be participating in the collective process of integrating the payload with the SSP and can benefit from their general EVA experience and lessons learned from other payload integration activities. Additionally, any trade-offs to be considered in selecting different approaches or even choosing to utilize EVA can be more clearly quantified. Finally, and as a result of the preceding benefits, the customer can design with reasonable confidence knowing that all payload and SSP requirements are being satisfied and that the chances are minimized for any critical discrepancies to go undetected before the remaining formal reviews are accomplished, or hardware is manufactured.

Safety

Safety Policy and Requirements for Payloads Using the Space Transportation System (STS), NSTS 1700.7B, states that a payload or payload ASE which violates the Orbiter PLBD closure envelope constitutes a safety hazard. Failure modes include failures of drive mechanisms, electrical failures, and structural failures. The hazard of preventing door closure must be controlled by independent primary and backup methods, and this combination must be two-failure tolerant. Payloads may be designed such that EVA may be used to provide the third method to safe the payload and/or to assure mission success.

8.6.1.5 EVA Mission Integration

The SSP payload integration process is used to define and document all payload EVA requirements. Determination of these requirements is accomplished during the development of the IP with the payload organizations. The EVA scenario and interface requirements are documented in the IP EVA Annex (Annex 11). For payload designers, incorporation of these man-machine interfaces constitutes a unique requirement for customer/SSP interaction during payload development. Keys to successful integration of EVA capability are consideration of EVA requirements at the earliest stages of payload design and concurrent establishment of an effective formal design review activity with the SSP involving both engineering and operational personnel with EVA experience.

8.6.1.5.1 Sequence of Integration Activities

The typical sequence of payload integration activities is included in Space Shuttle System Payload Accommodations, NSTS 07700, Volume XIV. A simplified diagram is shown in figure 8.6.1.5.1-1. Scheduled EVA requirements are usually identified early in the design concept development from the payload preliminary operational scenario, whereas unscheduled EVA requirements are often identified later as the SSP fail-operational/fail-safe criteria are applied to the maturing payload design. In either case, an analysis of the EVA task must then be conducted, beginning with identifying the specific task requirements and then applying the information contained in this document regarding translation, access, restraint, and safety to develop an end-to-end EVA scenario. Some feedback into the design effort will occur at this point, and modifications to the basic payload design may be required.

If unique EVA hardware is provided by the customer, the SSP prefers two sets of flight-certified hardware and requires one set of training hardware.

8.6.1.5.2 EVA Task Development

The NBL is used extensively in the development of EVA tasks and the associated hardware. Complicated and unique hardware requires early iterative evaluations involving pressure-suited exercises in a neutral buoyancy facility with customer-supplied mockups. These evaluations should take place before engineering designs are finalized to prevent costly changes. Prototype hardware can often be upgraded to support subsequent crew training. Mockup high fidelity is usually required only along the EVA translation paths and at the EVA worksites. For more information on the NBL, refer to Neutral Buoyancy Laboratory General Operating Procedures, DX12-0001.

Development of EVA procedures to be included in the mission FDF consists of several basic steps. Derived from the EVA requirements is a set of procedures which describe those actions required to accomplish the EVA task. Well before the system design is complete, a series of techniques is developed. These techniques are based on both a general knowledge of EVA capabilities and the current status of the payload design. As the design matures to a firm configuration, the techniques are refined and mature into the final EVA system procedures for this payload.

The SSP is solely responsible for final procedures development into the level of detail required for the FDF. Procedural checklists are formatted into FDF standard books, cue cards, and decals as required. Each element of the flight procedures is validated by testing to determine suitability for flightcrew training and on-orbit use. When complexity and criticality demand, the use of flight or developmental hardware, high-fidelity training articles, or mission simulators may be required and will be reflected in the IP. Training-type hardware or a desk top evaluation on the flight hardware may also satisfy this requirement.

Crew Activity Planning and Crew Training

To support the SSP crew activity planning, a listing of the payload events and flight conditions required for an EVA is documented in the IP Flight Planning Annex (Annex 2). The conduct of crew training for EVA is the responsibility of the SSP. The SSP EVA training provides crewmembers qualified to perform EVA tasks.

Like the design effort itself, payload training requirements are heavily dependent on the complexity and criticality of the given EVA task. Training requirements are minimized for simple tasks which are well within the recognized crewmember capabilities and constraints in the pressure-suited, zero-g environment. If the task is safety critical and therefore requires a very high probability for success, if there is small margin for error with regard to avoidance of hazards, or if the sequence of events is time critical with regard to either the task accomplishment or EMU endurance, unique training may be required.

Payload-specific EVA training is performed by the SSP using training articles provided by the customer with a level of fidelity of direct EVA interfaces appropriate to the complexity and criticality of the task.

Real-Time Support

It is the SSP’s responsibility to carry out the mission’s EVA requirements. Real-time ground support is also provided as required, and may include expertise from the customer organization. EVA tasks and decisions should be independent of ground support in the event of lost communications.

The payload operations support concept, FCT structure, responsibilities, and JOIPs are developed and negotiated between the SSP and the customer during the IP annex process. These are documented in the in data submittals per the Payload Operations Workbook, JSC 27508.

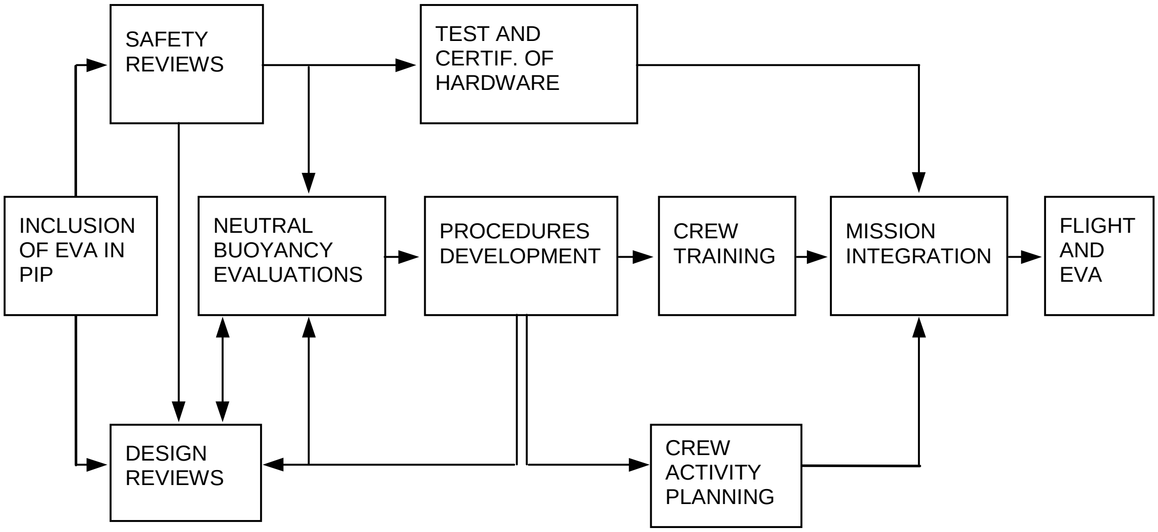

Figure 8.6.1.5.1-1. EVA mission integration

8.6.2 EVA Design Requirements

8.6.2.1 Introduction and Definitions

This section contains details of the specifications for designing EVA interfaces and accommodations. The guidelines and constraints presented in this document are primarily concerned with safety, design of EVA support equipment, and man-machine interfaces for crew operation in the zero-g environment.

EVA hardware should be designed to operate under the conditions listed in section 4 of this document. EVA hardware must also meet the flammability and off-gassing requirements specified in Shuttle/ Payload Interface Definition Document for Middeck Payload Accommodations, NSTS 21000-IDD-MDK.

EVA operational considerations and design requirements relating to the Space Station and future manned space vehicle activities can be found in Man/Systems Integration Standards (MSIS), NASA-STD-3000.

8.6.2.2 Design Requirements and Constraints

In considering an EVA mission from airlock egress through task completion and return to the cabin, payload designers should address the following:

1. Airlock-to-payload access corridor
2. Translation aids to worksites
3. Crew and equipment safety
4. Cargo transfer requirements

5. Restraint provisions at worksites
6. FOV and lighting requirements
7. Working volume requirements
8. EVA glove interfaces
9. EVA tool compatibility with the task and space environment
10. Scheduling constraints

The following general EVA guidelines and constraints apply to payload EVA design:

1. No scheduled EVA should be planned to be performed prior to flight day 4 (approximately 72 hours Mission Elapsed Time (MET)).

   No unscheduled or scheduled EVA should be performed on flight day 1 (approximately 24 hours MET) or on the day before entry.

   The payload should be designed to accommodate an unscheduled EVA no earlier than flight day 3 (approximately 48 hours MET).

   Furthermore,

   a. A payload should be designed such that once a failure that leads to an EVA has been discovered, 25 hours is allotted for EVA preparation prior to starting actual EVA maintenance on the failed component.
   b. If the above case occurs on launch day, then approximately 44 hours is required between failure discovery and start of EVA maintenance.
2. The EVA operations are performed by two EVA trained crewmembers, and a rest day should be allowed between EVAs.
3. Scheduled EVA periods should not exceed one 6-hour duration per day excluding the time required for EVA preparation and post-EVA activities.
4. The EVA may be conducted during both light and dark periods. Airlock egress and ingress may also be performed during either period.
5. The EVA is not constrained to ground communication periods.
6. Payloads requiring EVA operations should size access corridors and work areas to allow the EVA crewmember to perform the required EVA tasks safely and with adequate mobility (minimum of a 48-inch diameter cylinder).
7. Payload and support mechanism design must not inhibit unobstructed EVA access to potential Orbiter contingency work areas in the payload bay. The centerline and

bulkhead latches must be accessible in the entry (doors closed) configuration. This may be in contradiction to the allowable payload envelope.

8. Neither payload configuration nor EVA payload operations will inhibit a rapid return of the EVA crewmember to the airlock hatch from any location in the payload bay. PLBD closure should be possible within 20 minutes following an EVA-terminating contingency to support the contingency return requirement defined in Safety Policy and Requirements for Payloads Using the Space Transportation System (STS), NSTS 1700.7B. This will allow approximately 20 minutes to accomplish payload safing (stowage/jettison) as required.

9. For those payloads requiring an EVA to allow payload operations, the payload bay will always be left in a configuration which allows PLBD closure in the event of emergency return.

10. EVA support equipment, loose payload components, and umbilicals will be firmly secured or tethered at all times during EVA operations to prevent loss, damage, or entanglement.

11. The size of the airlock, tunnel adapter, and associated hatches limits the external dimensions of packages that can be transferred to or from payloads to 18 inches (457 mm) x 18 inches (457 mm) x 50 inches (1270 mm) for pressure suited operations. Package sizes exceeding these dimensions will be evaluated on an individual basis.

12. Payload components will be capable of withstanding inadvertent EVA contact (125 pounds over a 0.5-inch diameter). Payload components susceptible to inadvertent physical damage or contamination by an EVA crewmember should be guarded or otherwise protected. .

13. EVA crewmembers will not operate in, on, or near free flying satellites or payloads which have an excessive rate of rotation about any axis. The maximum acceptable rotation rate will be determined on a case-by-case basis.

14. Payload hatches for habitable payload volumes will be no smaller than the Orbiter airlock hatch. If the Orbiter cabin is the primary pressure source for a payload volume, the Orbiter-to-payload interface hatch will open toward the Orbiter cabin. Hatches shall be designed with redundant pressure seals and an observation port. Hatches will be designed so that a pressure-suited crewmember can dismantle a failed locking mechanism, equalize the pressure, and open the hatch from either side. The tools required to dismantle the mechanism will be located on both sides of the hatch. Pressure equalization valves, gauges, and relief valves are also required but the exact specifications may vary for different applications.

8.6.2.2.1 Airlock to Payload Access Corridor

1. Additional clearance between payloads on mixed cargoes may be imposed to provide access corridors on the payload requiring a planned EVA. Payload customers will provide access to the EVA work area and to the components requiring service. EVA crew transfer corridors and work areas will be compatible with overall dimensions and mobility volume requirements of the space-suited crewmember and any hardware being transferred.
2. Payload customers will provide a minimum translation corridor for EMU-suited crewmembers. The corridor is a 40-inch (1.02-m) diameter circle for straight-line translation through hatches and tunnel-like structures. A translation path requiring the EVA crewmember to use mobility aids (e.g., handholds, payload structures) should not be less than 43 inches (1.09 m) in diameter to avoid crewmember contact between EMU hardware and vehicle/payload structures (figure 8.6.2.2.1-1). Additional volume may be required when other than straight-line translation is needed.
3. Payloads will not obstruct egress from the Orbiter airlock. A 48-inch (1.22-m) diameter clear envelope is required for airlock egress and outer hatch operation. Variations to these guidelines can be evaluated on an individual basis. Other Orbiter configurations using the airlock, tunnel adapter, or docking module also require special evaluation.

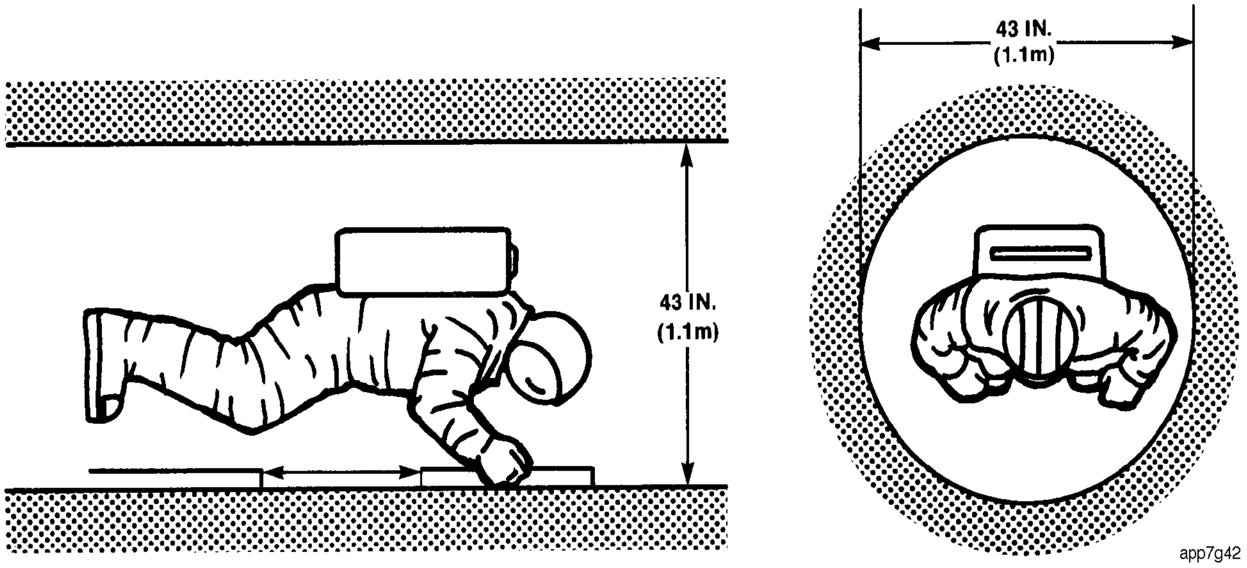

Figure 8.6.2.2.1-1. Envelope for handrail-assisted translation

8.6.2.2.2 EVA Worksite Provisions

Crew translation provisions (e.g., handholds, handrails, mobility aids) in the payload planned work area will be provided by the payload customer if task requirements exceed those provided by the Orbiter-attached payload bay handrails.

All payload handrails and handholds must meet the standardization requirements given in table 8.6.2.2.2-1.

A foot restraint platform can be attached directly to the payload structure, or PFR sockets may be mounted on the payload to accept the Orbiter PFR. Reference EVA Catalog Tools and Equipment, JSC 20466, for details. The payload PFR socket will be capable of ultimate design load of 140 pounds in tension and shear and torsion equal to 1800 inch/pound minimum (reference figure 8.6.2.2.2-1).

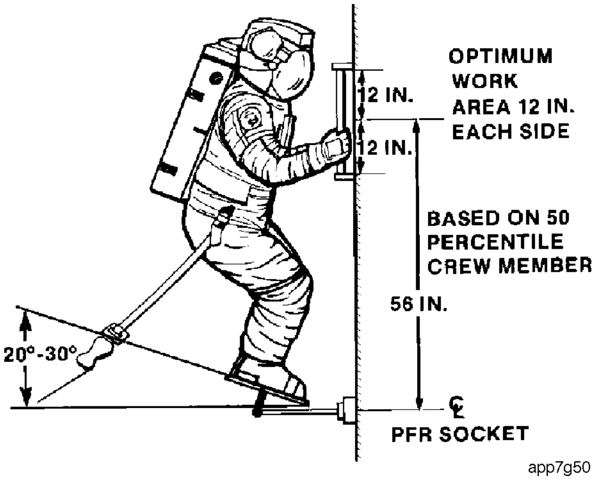

Figure 8.6.2.2.2-1. PFR location example

Table 8.6.2.2.2-1. Handhold and handrail general design characteristics

Design parameter	Design requirement/remarks
Cross section	(TBD)
Length	The minimum grip length of handholds/handrails for EVA is 6.0 inches (15.24 cm).
Mounting clearance	The minimum clearance distance between the lower surface of the handrail/handhold and the mounting surface is 2.25 inches (5.72 cm).
Spacing for translation	For extravehicular translation, handholds/handrails shall not be separated more than 36 inches (92 cm). Maximum spacing of 24.0 inches (61 cm) is preferred.
Spacing for worksites	Handhold/handrail spacing shall not exceed 18.0 inches (45.8 cm) above or below the shoulder or 24.0 inches (61.0 cm) to the left or right of the body centerline when working in a foot restrained position.
Loading	Extravehicular handholds/handrails shall be designed to a minimum crewmember-induced zero-g design load of 220 pounds (832 N) in any direction.
Tether attachment	EVA handrails/handholds will accommodate safety tether hooks at a spacing not to exceed 36 inches (92 cm), preferred 24 inches (61 cm).
Tether attachment loading	Extravehicular handhold/handrail stand-off tether points shall be designed to a limit load of 574 pounds (2553 N) in any direction.
General location	EVA handholds and handrails should be located to provide crewmember protection from thermal, electrical, pyrotechnic, radiological, and electromagnetic equipment. Potentially dangerous equipment shall not be located within 24.0 inches (60.96 cm) of the translation route or worksite . Thermal control shall be compatible with temperature specifications of the assembly (PGA). Handholds used as ingress aids for foot restraints should be vertically oriented with respect to the foot restraint platform and should extend from 36 inches (92 cm) to 48 inches (122 cm) above it.
Lighting	EVA handholds/handrails shall be illuminated in accordance with SC-L-0002.
Material	Handholds and handrails shall be fabricated from metals. Other rigid, semirigid, or nonmetallic materials also may be used but must not be susceptible to brittle fracture.
Grasp surface	Handholds and handrails shall have no sharp edges or protrusions injurious to the crewmember, EMU, or equipment.
Color	Lettering or numbering systems may be used to assist in rapid identification. Color shall be yellow from FED-STD-595A and minimize specular reflections.

Payload equipment exposed to EVA crewmembers will be capable of withstanding inadvertent contact of 125 pounds over a 0.5-inch diameter. Payload equipment or surfaces sensitive to inadvertent physical damage by an EVA crewmember should be protected.

When properly designed and located, handrails and handholds (refer to figure 8.6.2.2.2-2) may also provide location protection to payload components from damage by the crewmember as well as convenient locations for temporary restraint of loose equipment. Some structural components that meet the requirements of table 8.6.2.2.2-1 may double as translation or mobility aids if the structural components are suitably identified. Payload handrails must be painted yellow so that the crew can readily identify places to hold on. Handrails not rated per the loads in table 8.6.2.2.2-1 will not be yellow. Payload designers should consult with the SSP for recommended handrail/handhold locations.

(TBD)

Figure 8.6.2.2.2-2. Handhold/handrail example

The Remote Manipulator System (RMS) with MFR may also provide remote access to detached payloads, but it is preferred that the RMS with MFR be used only with attached payloads. The RMS reach envelope with the MFR and EVA crewmember attached is constrained to arm geometries which will not allow damage from EVA force inputs. Designers considering MFR operations should consult with SSP RMS personnel early in the design process.

8.6.2.2.3 Crew and Equipment Safety

1. Payload designs will conform to Safety Policy and Requirements for Payloads Using the Space Transportation System (STS), NSTS 1700.7B.
2. Payload designs will protect the crew from electrical, electronic, fluid, radiation, mechanical, chemical, propellant, and other hazards including inadvertent actuation of stored energy devices and pyrotechnics. Hazards shall be identified in accordance with Functional Requirement for Markings, Labeling and Color, Manned Spacecraft and Related Flight Crew Equipment, SC-M-0003.
3. No single failure or operator error will result in damage to the Orbiter or result in crew injury.
4. No two failures and/or operator errors will result in loss of life or prevent the safe return of the Orbiter vehicle.
5. Payload equipment, structures along translation routes, worksite provisions, and each equipment item requiring an EVA interface will be designed to preclude sharp edges and protrusions or will be covered in such a manner as to protect the crewmember and his critical support equipment. The criteria relative to sharp edges and protrusions are provided in tables 8.6.2.2.3-1a and b and figure 8.6.2.2.3-1. Sharp-edge inspections shall be performed on all payloads. Sharp edges may sometimes be eliminated by applying a space-compatible tape to cover the surface.
6. Payload customers should be aware of the following environmental concerns:
   a. Payloads sensitive to EVA equipment effluent discharge should be provided with inherent self-protective features, provided with protectors to be installed by the EVA crewmember, or have defined EVA crewmember operational constraints.

The EMU sublimates approximately 1.4 pounds/hour (0.64 kg/m) of water. The EMU specification leakage rate is 50 standard cubic centimeters (SCC) per minute of oxygen. During EVA this leakage will include small amounts of CO_2, water vapor, and trace gases.

b. The EMU radiates 4 V/m at a distance of 1 meter in the Ultrahigh Frequency (UHF) band (259.7 to 296.8 megahertz) when transmitting voice . Maximum field strength occurs directly behind the EMU (for UHF) and above the helmet (S-band). The EMU-light discharge (10 foot candles (108 lux)) should be considered for light-sensitive payloads.

Table 8.6.2.2.3-1a. Edge, corner, and protrusion criteria-edge and in-plane corner RADII[*]

Application	Radius				Remarks	Figure 8.6.2.2.3-1 Referenced
	Outer		Inner			
	in.	mm	in.	mm		
(a) Openings, panels, covers (corner radii in plane of panel)	0.25	6.4	0.12	3.0	Preferred	
	0.12	3.0	0.06	10.5	Minimum	
(b) Exposed corners:	0.50	13.0	–	–	Minimum	(a)
(c) Exposed edges: (1) 0.08 in. (2.0 mm) thick or greater	0.04	1.0	–	–		(b)
(2) 0.02 to 0.08 in. (0.5 to 2.0 mm) thick	Full Radius		–	–		(c)
(3) less than 0.02 in. (0.5 mm) thick	Rolled or Curled					(d)
(d) Flanges, latches, controls, hinges, and other small hardware operated by the pressurized-gloved hand	0.04	1.0	–	–	Minimum required to prevent glove snagging	–
(e) Small protrusions (less than approximately 3/16 in. (4.8 mm)) on toggle switches, circuit breakers, connectors, latches, and other manipulative devices	0.04	1.0	–	–	Absolute minimum unless protruding corner is greater than 120°	

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[*] A 45° chamfer by 0.06 inches (1.5 mm) (minimum) with smooth broken edges is also acceptable in place of a corner radius. The width of chamfer should be selected to approximate the radius corner described above.

Table 8.6.2.2.3-1b. Edge, corner, and protrusion criteria - protrusions and outside corners

Application	Criteria/remarks
Latching devices	All latching devices shall be covered in a manner that does not allow gaps or overhangs that can catch fabrics or pressure suit appendages, or shall be designed in a manner to preclude the catching of fabrics and pressure suit appendages. All surfaces and edges shall be smooth, rounded, and free of burrs.
Lap joints in sheet metal and mismatching of adjacent surfaces	All surfaces shall be mated within 0.03 inches (0.8 mm) of flat surface at edges, or shall be butted or recessed. All exposed edges must be smooth and radiused 0.06 inches (1.5 mm) minimum, chamfered 45°, or shall be covered with an appropriate material to protect EVA gloves.
Sheet metal structure, box and cabinet three-plane intersecting corners	Spherical welded or formed radii shall be required unless corners are protected with covers.
Screwheads, bolts, nuts, and nut plates, excess threads and rivets that can be contacted by crewmember	All screwheads and boltheads shall face the outside of the structure, if possible. Where nuts, nut plates, and threads are exposed, the nuts, nut plates and threads shall be covered in a secure manner. Recessed heads or the use of recessed washers is recommended. Overall height of heads shall be within 0.125 inches (3.2 mm) or covered unless more than seven head diameters apart from center to center. Height of roundhead or ovalhead screws is not limited. Screwheads or boltheads more than 0.25 inches (6.4 mm) deep must be recessed or be covered with a fairing, except those intended to be EVA crew interfaces. Rivet heads shall face out on all areas accessible to crewmember and shall protrude no more than 0.06 inches (1.5 mm) unless spaced more than 3.5 head diameters from center to center. In all exposed areas where unset ends of rivets extend more than 0.12 inches (3.1 mm), or 0.50 inches (12.7 mm) of unset and diameter if more than 0.12 inches (3.1 mm), a fairing shall be installed over them. This applies to explosive, blind, or pull rivets, etc. Unset ends of rivets must have edges chamfered 45° or ground off to a minimum radius of 0.06 inches (1.5 mm). A maximum gap of 0.02 inches (0.5 mm) shall be allowed only between one side of a fastener head and its mating surface. Burrs must be prevented or eliminated. Use of Allen heads is preferred. Torque-set, slotted, or Phillips head screws must be covered with tape or other protective materials or be individually deburred before flight.

(a) REQUIREMENTS FOR ROUNDING OF CORNERS

(b) REQUIREMENTS OF EXPOSED EDGES 0.08 IN. (2.0mm) THICK OR THICKER

(c) REQUIREMENTS FOR ROUNDING OF EXPOSED EDGES 0.02 TO 0.080 IN. THICK (0.5 TO 2.0mm)

(d) REQUIREMENTS FOR CURLING OF SHEETS LESS THAN 0.02 IN. (0.5mm) THICK

app7g46

Figure 8.6.2.2.3-1. Exposed corner and edge requirements

8.6.2.2.4 Cargo Transfer Requirements

Not all cargo transfer requirements may be satisfied by the RMS or by manual means. Factors such as package geometry, size, mass, transfer clearance envelope, or positioning requirements may render those means unsuitable for transporting replacement modules or servicing equipment from their launch stowage locations to the servicing worksite. No specific criteria exist for the design of payload-peculiar transfer aids.

Specialized SSP transfer requirements may be satisfied by items described in EVA Catalog Tools and Equipment, JSC 20466. Items such as the large and small trash bags, specialized transfer bags, and tool caddies may be used to transfer various sized equipment

All equipment transported or handled during EVA will be tetherable. Any tools or equipment detached from the vehicle structure will be tethered to the crewmember, the vehicle, or the payload whenever the tools or equipment are not securely stowed or installed. Even though EMU waist and wrist tethers can satisfy tethering requirements during translation, a tether and a hook integral to the object or its transfer container also satisfies temporary stowage requirements at the worksite or along the translation route.

The size of tether points (refer to figure 8.6.2.2.4-1) is driven by the dimensions of the three EVA tether hook types already in the SSP EVA inventory. Only two-dimensional requirements exist for tether points: the size of the opening (driven by cross-section dimension of large waist tether hook) and the cross-section dimension of the tether point (driven by maximum opening of small wrist/waist tether hook). The strength requirements for a tether point depend on its intended use. Tether points integral with restraint, mobility, translation aids, and at workstations shall be as strong as the waist tether and safety tether restraint system (574-pound (2.6-kN) limit load in any direction).

Tether points on small, lightweight tools shall be strong enough to withstand crew-induced handling limit loads of approximately 30 pounds (135 N). Experience has shown that heavier tools need tether theirweight.points with strengths approximately equal to their weight.

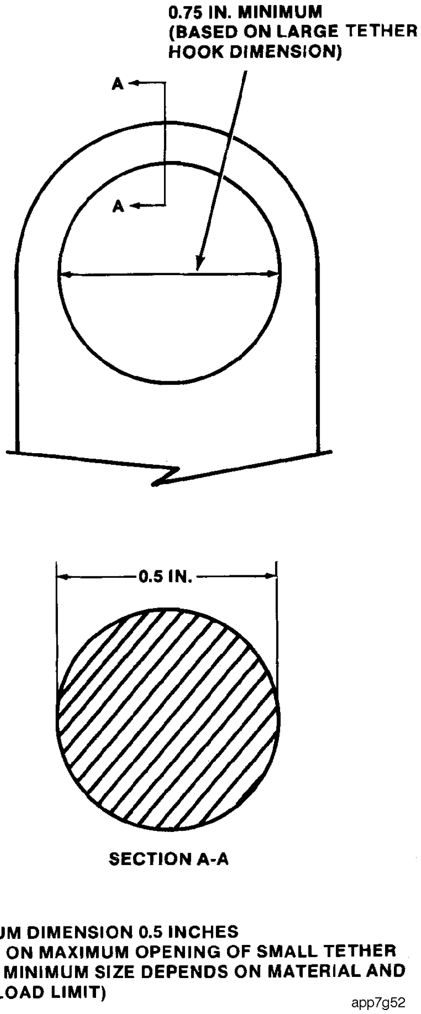


Figure 8.6.2.2.4-1. Tether point requirements

8.6.2.2.5 Working Volume Requirements

EVA tasks involving extensive body and arm manipulation need a working envelope of 4 feet (1.2 m) minimum (figure 8.6.2.2.5-1); the exact size is dependent on the EMU dimensions and the type of task to be performed. Access volume is not necessarily equivalent to required working volume; the latter also includes the factors of reach and force applications as well as the crewmember’s ability to see the task area. Adequate working volume therefore cannot always be specified and must be evaluated on a case-by-case basis.

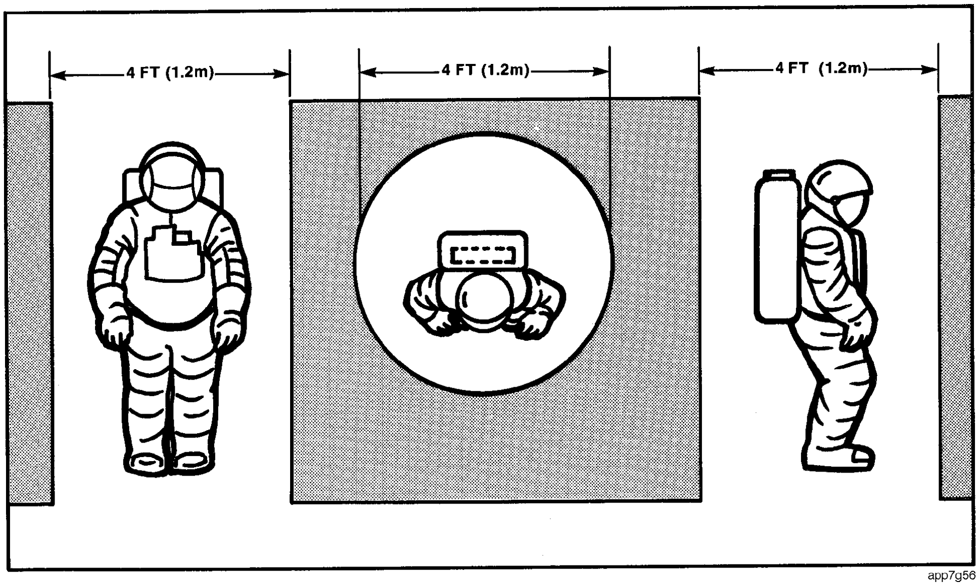


Figure 8.6.2.2.5-1. Recommended working volume for manipulative EVA tasks

8.6.2.2.6 Glove Interface

For payload servicing operations that require reaching into an aperture, designers should position the equipment as close to the exterior surface as the design permits while allowing sufficient volume for access by the EVA glove and for crewmember viewing. The 8-inch (0.20-m) minimum aperture must be increased for operation of valves, connectors, and latches requiring torquing motions or heavy force application. Tool extensions may be used to avoid the need for the large glove access envelope if adequate visibility is provided.

In designing payload interfaces for gloved-hand operations, compatibility of grasp surfaces must be considered. Conformal or oval handles are easier to grasp than cylindrical shapes; nonskid surfaces are preferred. Integral ribs or splines improve glove-gripping capability. Knurled surfaces which may cause glove abrasion should be avoided. Generally, items to be held or manipulated should be less than 2 inches in diameter.

8.6.2.2.7 EVA Tool Design

Although the basic selection or design of EVA tools is entirely dependent on the nature of the task, several features are common to all successful EVA tool designs. These features are as follows:

1. One-handed operation
2. Simplicity in operation

3. Grip size suitable for use with a pressurized EVA glove
4. Provisions for launch, entry, and temporary in-flight stowage
5. Provisions for tethering while in use that satisfy zero-g tool management requirements
6. Safety features to protect the EVA crewmember from inherent hazards

Since the functional design of the tool can vary greatly, no attempt is made here to provide more definitive specifications. Figure 8.6.2.2.7-1 illustrates the recommended standard EVA tool grip dimensions.

7. EVA tool design should concentrate on gross motor motions. The mobility in the upper body of the EMU lends itself to arm movements from either the shoulder or the elbow. Fine motor activity, particularly motions involving the gloved hand and fingers, should be avoided. If required, however, forces should be less than 5 pounds (22.5 N) force, or 40 inch-ounces (0.28 n.m) torque. Examples of motions which are very suitable to EVA are the cycling of a lever (ratcheting a drivescrew) and rotating a rotary actuator (airlock hatch). The likelihood of success of an EVA depends heavily on the workload of the crewmember, and using gross motor skills with relatively low loads is the place to begin; these tasks should require an actuation force of less than 20 pounds (89 N). Fastener torques above 25 foot-pounds (34 n.m) should be avoided. Two hands should never be required for successful tool installation and operation, as all EVA operations are considerably easier when using one hand for additional restraint or position management.

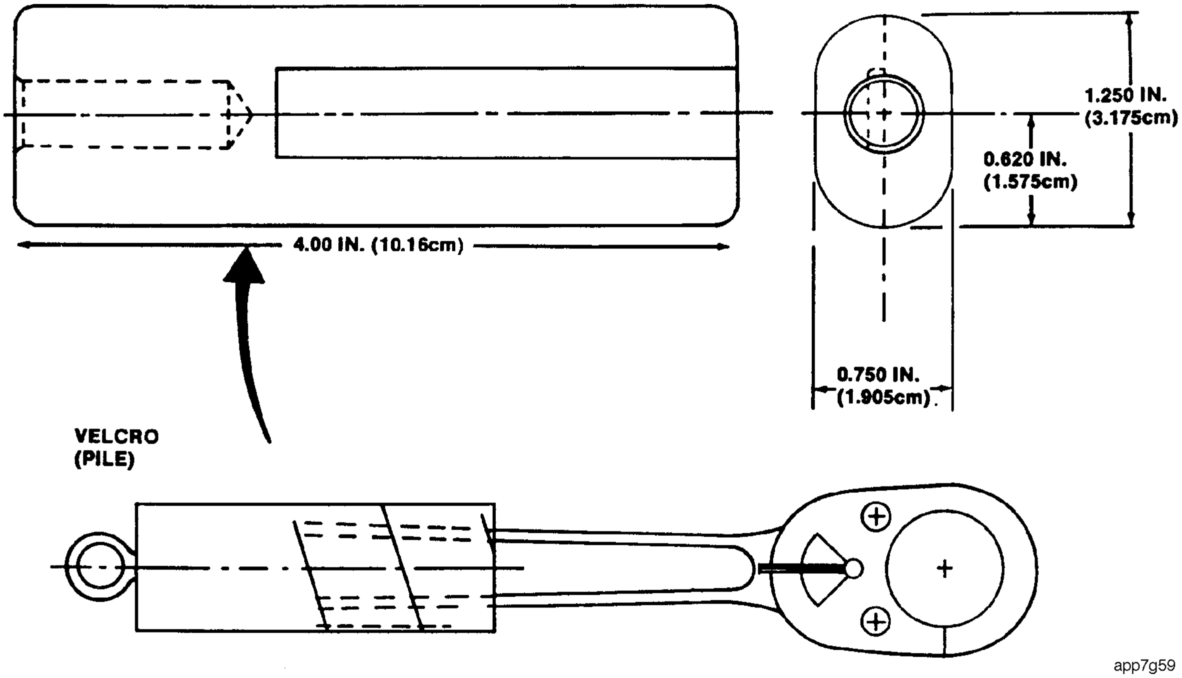


Figure 8.6.2.2.7-1. Recommended EVA tool grip dimensions

8. Power tools must meet the same design requirements as other hand tools regarding operability. Using power tools to accomplish repetitive manual tasks such as disengaging captive fasteners on replaceable modules or operating mechanical drive systems offers enormous returns in reduced crewmember time and effort, and ease of operation.

9. Limited space is available in Orbiter middeck lockers for hand tools. Locker dimensions are 17.312 x 9.950 x 20.320 inches (43.97 cm x 25.3 cm x 51.61 cm). Foam cushions cut to size provide restraint and impact/vibration protection.

10. If possible, an EVA compatible handle should be incorporated into the mechanism design, or the required tools should be mounted near the worksite on payload hardware to minimize integration problems.

11. EVA tools should have no lubricant or should use a lubricant which meets the environmental requirements. Dow-Corning 321R Molycote Spray is an example of a proven lubricant for use on EVA tools. Graphite lubricant should not be used on EVA tools.

12. EVA tools should be designed and tested to the operating and stowage environments listed in System Description and Design Data - Thermal, NSTS 07700, Volume XIV, Appendix 2, for thermal properties.

13. Additional considerations are:

    a. Avoid lift-to-dot snaps for glove operated fasteners

    b. Avoid tape

    c. Use covers on sharp edge tools for protection when tool is not in use

14. Other means to secure loose equipment during EVA include velcro and zippers.

15. Tethering provisions during hardware transfer can be accomplished by using existing SSP EVA provisions such as:

    a. Tool caddies

    b. Tool boards

    c. Retractable tethers

    d. Bayonet fittings

    e. Drop-proof tethering system

8.6.2.2.8 Knobs, Switches, Actuators, and Fasteners

1. Knobs, switches, lever and rotary actuators, and connector mate/demate devices should be designed to accommodate low-force, gross motor activity and provide positive stops and/or visual feedback to verify operation and prevent inadvertent selections. Ideally, simple or infrequently used devices should be designed to require force levels that can be satisfied without special restraint systems. Bump guards should be considered to prevent inadvertent actuation of these devices.
2. Examples of EVA compatible electrical connectors are shown in figure 8.6.2.2.8-1 (a)-(c).

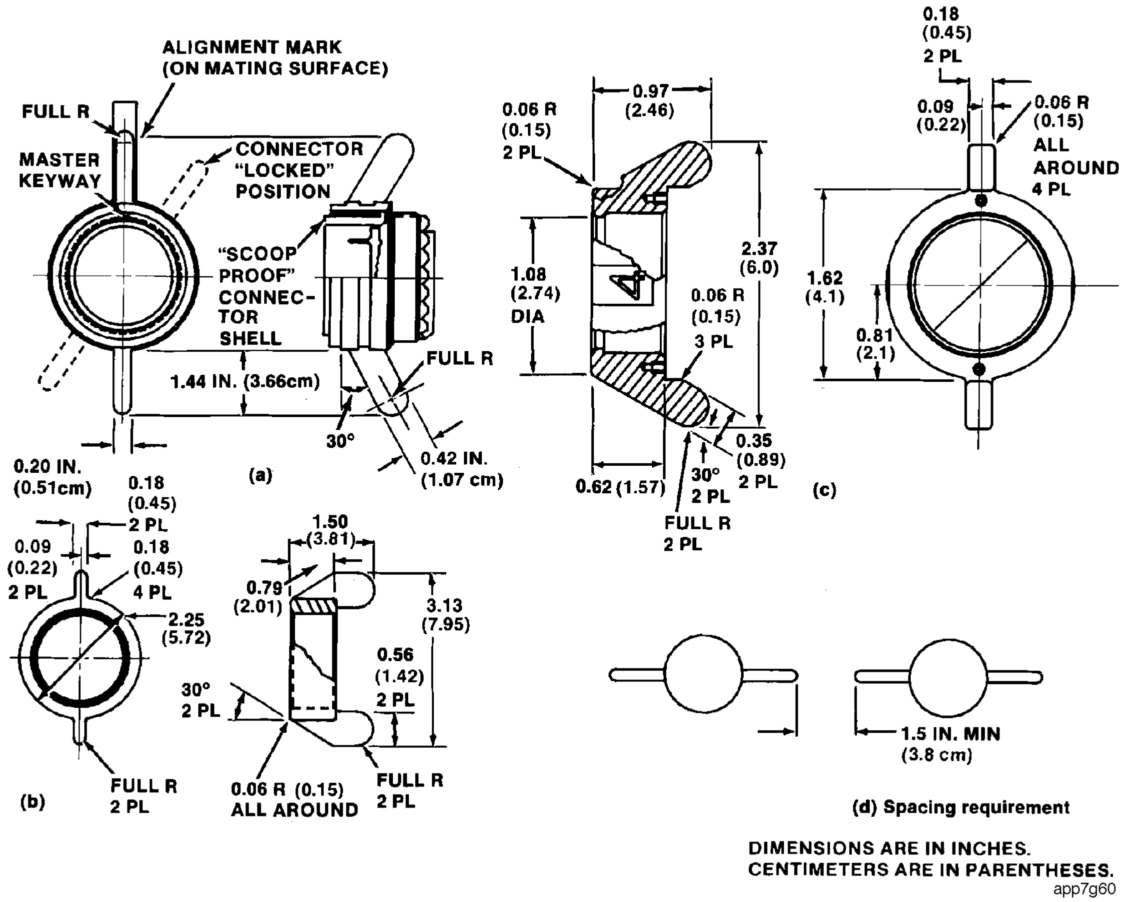


Figure 8.6.2.2.8-1. Connector examples (a-c) and connector spacing requirement (d)

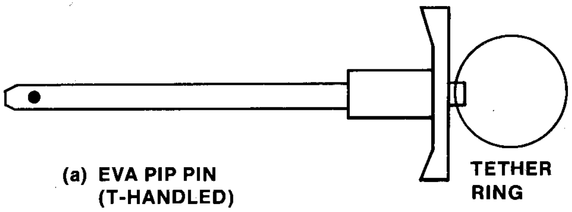
Overall dimensions vary with the design and performance requirements of the particular connector.

3. Connectors must be spaced for access as shown in figure 8.6.2.2.8-1 (d).
4. Alignment marks are needed for master key positioning.

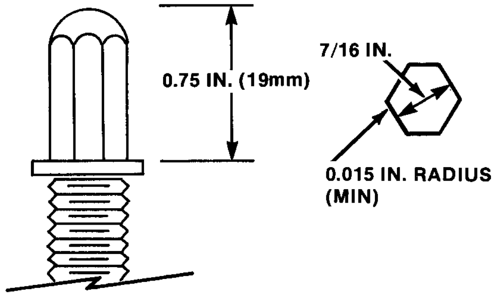
5. Ratchet wrench driven bolts should have a minimum running torque of 24 inch-ounces (0.17 N.m) to operate the ratchet mechanism of the wrench.

6. Pip pin fasteners have been used successfully on previous SSP EVA missions. T-handled pip pins designed to be captured when released are the easiest to operate (see figure 8.6.2.2.8-1(a)). Pip pins should be sized to be compatible with gloved-hand operation.

7. Screwdriver-type fasteners such as Phillips, torq-set, or slotted require an axial force for tool grip and operation. Consequently, the screwdrivers used for these types of fasteners tend to back out and slip. Allen head bolts and double-height hex head bolts are ideal (see figure 8.6.2.2.8-1(b-c)). All fasteners should be captive.



(a) EVA PIP PIN (T-HANDLED)



(b) RECOMMENDED EVA BOLT HEAD-
7/16 IN. DOUBLE HEIGHT HEX

(c) RECOMMENDED EVA BOLT
5/32 IN. ALLEN HEAD

app7g61

Figure 8.6.2.2.9-1. EVA pip pin and EVA bolt heads

8.6.2.2.9 Access Doors and Panels

Doors and panels to provide EVA access to payload enclosures should incorporate integral locking/unlocking mechanisms suitable for one-handed operation, incorporate some type of hold-open device, be complemented by a suitably placed handhold for crewmember position maintenance when opening and closing, and incorporate some means of visually verifying proper closing/latching.

CARGO INTEGRATION

9.0

9.1 OVERVIEW

The process of preparing for each Shuttle mission includes the manifesting of a compatible payload mix, and the installation of those payloads into the payload bay. The payload integration process varies in both length and activities performed depending on numerous factors: the complexity of the payload complement, horizontal vs. vertical installation, reflight of primary payload, etc.

The process and timeline presented in figure 9.1-1 represents a typical flow starting with the earliest stages of planning and design, and continuing through launch. The time scale is delineated in months before launch, or L minus months. Each of the bars symbolize a major component of the activities performed in the payload integration process, and the triangles denote major milestones encountered along the way.

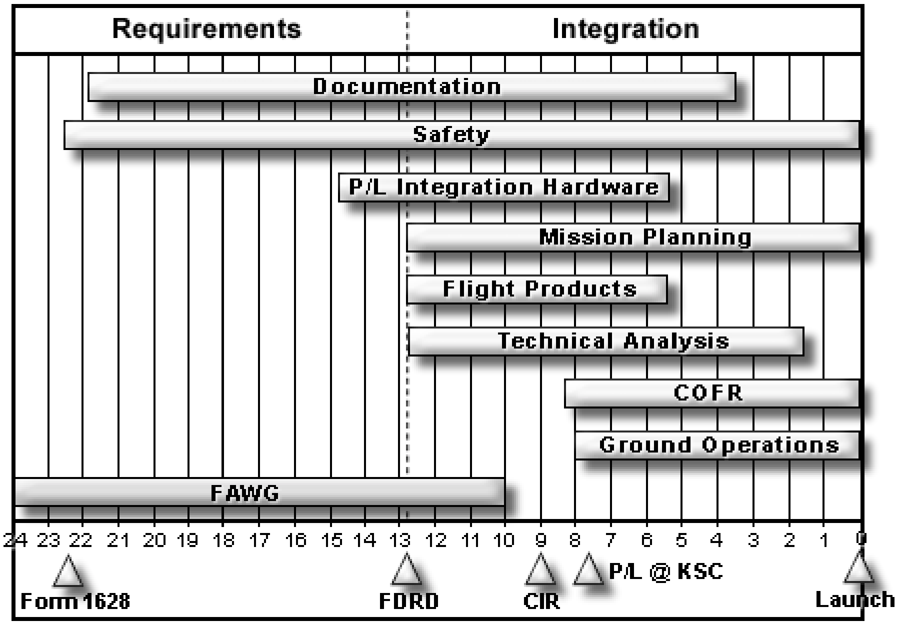


Figure 9.1-1. Process and timeline flow

9.2 FLIGHT ASSIGNMENT AND SCHEDULING

Assignment of a mix of payloads to the manifest for a specific mission is accomplished by analyzing a list of available payloads.

Payloads in the list are prioritized according to a number of factors, including: what is the payloads classification (standard, deployable/retrievable, small, middeck), importance of the mission objectives (i.e., what kind of science will the payload gather), and is there a restrictive launch window when the payload must fly. A detailed assessment is performed to determine the compatibility of various payloads that could possibly be manifested together. Numerous options for potential additions to the manifest are presented to the Flight Assignment Working Group (FAWG) where recommendations are made on which payloads will fly when.

In general, large complex payloads must submit a request for flight approximately 2 years before launch, with official addition to the manifest occurring as late as 12 months prior to launch. Less complex payloads may enter into the process much later, with manifesting happening as late as 9 months before launch. A Flight Production Schedule is developed for each mission, laying out a unique timeline for the major activities that must occur to prepare for flight.

9.3 DOCUMENTATION

A series of documents are prepared for each payload detailing the physical characteristics and operational requirements of the payload, services to be provided to the payload, and defining the interfaces between the payload and the Shuttle’s Orbiter. These documents are signed by both the payload customer and the Space Shuttle Program Office, serving as the technical agreement and contract between the payload owner and the Shuttle Program.

Each of these documents is based on a generic template or blank book that provides the structure for the document and guidelines for preparing payload-specific information.

The documents prepared for each payload include:

1. IP - Following acceptance of the payload, the payload integration process begins with development of an IP. The purpose of the IP is to:

   a. Define SSP and customer responsibilities.

   b. Define the technical baseline for implementation.

   c. Establish guidelines and constraints for integration and planning.

   d. Define integration tasks to be accomplished.

   e. Establish interface verification requirements.

   IPs are based on one of six available SIPs. The SIPs provide the template and guidelines for development of an IP. The PIM will work with the Payload Customer to determine which SIP is applicable:

   (1) NSTS 21000-SIP-ATT - Attached Payloads

   (2) NSTS 21000-SIP-DRP - Deployable/Retrievable - Type Payloads

    (3) NSTS 21000-SIP-GAS - Get-Away Special Payloads
    (4) NSTS 21000-SIP-MDK - Middeck-Type Payloads
    (5) NSTS 21000-SIP-MIP - Mission Integration Plan - International Space Station Missions
    (6) NSTS 21000-SIP-NDD - Nonstandard DSO/DTO Integration Plan
    (7) NSTS 21458 - Standard Integration Agreement for all Space Shuttle Program and International Space Program Missions

2. Annexes to the IP - A collection of standalone annexes that define the next level of detail in specific technical areas.
    a. Annex 1 - The Payload Data Package Annex contains payload configuration drawings (including payload mechanical, electrical power, command interface drawings, and safety critical circuits), mass properties data, and payload physical function data. The IP Annex 1 is developed from the NSTS 21000-A01 blank book.
    b. Annex 2, Part 1 - The Flight Planning Annex Electrical Power, Energy, and Cooling Requirements Annex is used by the SSP to determine the power, energy, and cooling requirements for the integrated mission profile and to ensure this profile is compatible with the system operating limits and constraints. The IP Annex 2, Part I is developed from the NSTS 21000-A02 blank book.
    c. Annex 2, Part 2 - The Flight Planning Annex, Flight Activity Planning Annex contains specifications of flight activity requirements for support of payload operations. The IP Annex 2, Part II is developed from the NSTS 21000-A02 blank book.
    d. Annex 2, Part 3 - The Flight Planning Trajectory Design Annex supplies data to support analysis and implementation of constraints imposed by the payload on the Orbiter flight design. The IP Annex 2, Part III is developed from the NSTS 21000-A02 blank book.
    e. Annex 4 - The Command and Data Annex identifies individual commands required to operate the payload, measurements of payload status and health, and measurements for accomplishing payload objectives. It also provides necessary information for processing and interpreting data. The IP Annex 4 is developed from the NSTS 21000-A04 blank book.
    f. Annex 5 - The Payload Operations Control Center (POCC) Annex defines customer requirements levied on the SSP for POCC, remote POCC, and communications resources. The IP Annex 5 is developed from the NSTS 21000-A05 blank book.

   g. Annex 7 -The Training Annex describes customer provided training of Space Shuttle personnel and POCC team training requirements, determines integrated simulation requirements, establishes training sequence flow, and provides payload training schedules. The IP Annex 7 is developed from the NSTS 21000-A07 blank book.

   h. Annex 8 - The LSSP Annex defines payload processing flow at the launch site, customer launch and landing site nominal and contingency support (e.g., scrub/ turnaround, intact abort) requirements, and specifies launch site facilities and resources to meet customer requirements. The IP Annex 8 is developed by the KSC LSSM through communications with the payload customer.

   i. Annex 11 - The EVA Annex defines specific design configuration for each hardware-to-hardware and hardware-to-crew interface associated with EVA support of a particular payload, including scheduled, unscheduled, and contingency EVAs. The IP Annex 11 is developed from the NSTS 21000-A011 blank book.

3. ICD - Defines the interfaces (e.g. mechanical attachments and electrical connections) between the payload and the Orbiter for payloads installed in the payload bay. An IDD has been developed for each type of payload (standard, small, and ISS) to facilitate preparation of the ICD. A dedicated payload will employ ICD-2-19001. The ICD is developed from the ICD-2-19001, CORE ICD using one of the IDDs.

4. Interface Control Annex (ICA) - The Orbiter Crew Compartment ICA identifies customer-supplied equipment stowed or installed in the crew compartment and defines requirements affecting stowage, installation, handling, or crew use and proposed stowage/ installation of payload materials. The document includes display and control and standard switch panel nomenclature requirements. The ICA is developed from the NSTS 21000-ICA blank book. The middeck interface requirements and environment are shown in the NSTS 21000-IDD-MDK.

5. OMRS - The Operations and Maintenance Requirements and Specifications Document (OMRSD) File II Volume 2 (for payloads) and File II Volume 6 (for DTO-DSO-RME-HTD experiments) identifies project level verification agreements, payload-to-Space Shuttle ICD interfaces to be verified, and the verification method and location. Requirements are generated using the guidelines set forth in the NSTS 08171 File I, Introduction to OMRSD.

6. Time-Critical Ground Handling Requirements (TGHR) - The TGHR table identifies mission-unique requirements for the time-critical ground handling integration of Space Shuttle Middeck-mounted Payloads and Shuttle Experiments. TGHR tables are generated using the guidelines set forth in the TGHR Table Ground Rules.

9.4 SAFETY

The SSP has implemented a rigorous payload safety process to ensure safe payload-related operations both during ground handling and in space. The primary objectives of the payload safety review process are to identify the potential hazards applicable to a payload (including its flight support hardware, ground support equipment, and ground operations), and to assure that the hazard controls and verification of those controls are adequate and in compliance with safety requirements. Compliance with safety requirements is assessed using a phased safety review process (phases 0, I, II, and III).

The payload customer is required to identify all potential payload hazards and report on them during the phase safety reviews. The appropriate data submittals are made in a Safety Data Package delivered prior to each Phase review. For more information on the Safety requirements and processes, see section 10.

9.5 PAYLOAD INTEGRATION HARDWARE

The Space Shuttle is designed to support its payloads in many ways. Much of the hardware required to integrate payloads on the Shuttle exists and is ready to use. Many aids for carrying, handling, and manipulating payloads have been developed and are already qualified for use with the Shuttle. Since testing and qualification of support devices can be time-consuming and costly, payload designers who can adapt their payload to these existing aids will save considerable time and money.

In the event that a payload has unique requirements that are not supported by the existing hardware inventory, custom hardware is developed to satisfy the need. The most commonly built integration hardware includes custom wire harnesses providing unique electrical connections, and special mounting and/or attach hardware.

9.6 MISSION PLANNING AND OPERATIONS

The Flight Operations team conducts astronaut and flight controller training, flight design, mission planning and execution, and maintenance and operations for the MCC at the JSC in Houston, Texas.

9.6.1 Mission Design and Planning

Flight planning and trajectory design are the processes by which payload objectives are matched with Shuttle operating capabilities to design a mission. Flight controllers create a detailed set of mission guidelines known as the FDF, including a master timeline called the Flight Plan developed by the Flight Planners. The Flight Plan defines all activities performed by the crew and flight controllers as well as vehicle orientation and payload operations. The Flight Data File also includes key technical reference and procedural manuals.

The objective of trajectory design is to accurately determine the trajectory required to rendezvous with orbiting objects such as the ISS and the HST, determining the amount of oxygen, hydrogen and propellant that are required, as well as defining the specifications for vehicle flight software and ground support software.

Throughout the design process, the plan and its components are repeatedly checked to ensure that they meet the payload customer requirements while still satisfying all Shuttle or Space Station operating constraints.

9.6.2 Astronaut and Flight Controller Training

Training teams are responsible for preparing the astronauts for their missions in space and for preparing the flight controllers to perform their duties on the ground for each flight of the Space Shuttle.

Training begins the moment the astronauts or flight controllers arrive at the JSC. It includes basic training to develop and maintain knowledge and skills, followed by mission-specific training to prepare for their assigned flight. Training evolves in complexity from classroom lessons and workbooks to computer-based training, stand-alone simulator training, and finally integrated team simulations in the weeks before a mission.

Lessons range from tasks as simple as sending a fax from space to more complex activities like grappling, securing, repairing, and releasing a satellite. The job of the instructors is to ensure that the Shuttle crew and the flight controllers in the MCC are well prepared for any situation, both planned and unplanned, that may arise during the course of their mission.

9.7 ENGINEERING FLIGHT PRODUCTS

The development of engineering flight products begins when the payload complement for a given Shuttle mission is defined in the Flight Definition and Requirements Document (FDRD). The engineering produced by the SSP for each mission includes the Cargo Arrangement Drawing that depicts the placement of payloads within the payload bay, Wiring Schematics and Diagrams, and Payload Installation Drawings. The Cargo Arrangement Drawings and Wiring Schematics and Diagrams are delivered as an Engineering Data Package that is reviewed by the appropriate community (including the payload customer, the designers, and the implementers) at the CIR. The Payload Installation Drawings are delivered at Final Reconfiguration Engineering Drawings (FRED), which occurs after CIR.

The design that is defined in these engineering drawings is translated into detailed Work Instructions that are used by the technicians at the KSC to perform the vehicle modifications and payload installations.

9.8 TECHNICAL ANALYSIS

Computerized mathematical modeling is used to perform analysis on various aspects of the configuration and operations of each Shuttle mission to verify that design and planning are adequate to ensure safety and mission success.

Types of analyses performed include:

1. Structural assessment,

2. Thermal assessment, and
3. Electromagnetic Compatibility Analysis

The payload customer is required to deliver data or models to support each of these analyses, such as:

1. Payload design loads analysis
2. Payload thermal math model
3. Payload radio frequency characteristic data

9.9 CERTIFICATION OF FLIGHT READINESS

The SSP has established a series of milestone reviews and a FRR to incrementally review and status progress towards readiness for flight. Each of the SSP elements and projects certify that their organizations have satisfactorily completed their respective portions of the effort required to safely support each flight at these reviews. The reviews of particular interest to the payload community are:

Payload Readiness Review (PRR) - The PRR occurs prior to payload transfer to the OPF (horizontally installed payloads) or Launch Pad (vertically installed payloads) for integration into the Orbiter. This review certifies that the payload is ready for integration into the Orbiter and ensures readiness of necessary integration hardware and engineering. Payload customer representatives may be required to develop and present briefings to address topics related to readiness for payload/Orbiter integration, including safety and quality readiness.

FRR - The FRR, held approximately 2 weeks prior to launch, is a comprehensive review of all activities/elements necessary for the safe and successful conduct of all operations from prelaunch through postlanding and recovery operations. The readiness of the Space Shuttle vehicle, flightcrew, and payloads is determined at this review. A signed CoFR endorsement certifies that all have successfully completed their Flight Preparation Processes.

9.10 GROUND PROCESSING

Once the payload arrives at the KSC, most of the handling is done by the payload processing group prior to installation into the Orbiter, and by the Shuttle processing group during and after installation. The payload team continues to perform servicing and closeout after payload installation into the Orbiter.

9.10.1 Payload Processing

Space Shuttle payload processing is performed in parallel with vehicle processing so that fully integrated and tested payloads are ready for installation in the Orbiter at the appropriate time to support the launch schedule. A complete array of world class processing facilities, services, ground support equipment, and operations are offered to payloads for prelaunch preparations.

Payload processing includes:

1. Initial receiving and checkout of flight hardware and payload-provided support equipment
2. Preparation and staging
3. Integration of payload elements that are shipped separately
4. Fit checks and interface testing
5. Functional testing
6. Transportation between facilities

9.10.2 Shuttle Processing

The Shuttle processing team is responsible for taking the Space Shuttle (Orbiter, external tank and SRBs) through a planned sequence of comprehensive testing, maintenance, and verifications to make it ready for the next mission. This process, including installation of payloads in the Orbiter’s payload bay and middeck, usually takes about 3 months. Once installed, power, command, and monitoring of the payloads are performed via the Orbiters onboard systems.

Launch countdown operations are controlled from the Launch Control Center (LCC) where numerous parameters are monitored on consoles to verify that everything is working properly and it is safe to launch.

Up to four missions can be processed at one time, with the four Orbiters - Columbia, Discovery, Atlantis and Endeavor - at various stages in the Flow.

9.11 MAJOR MILESTONES

There are many milestones associated with the integration and operations of payloads flying on the Space Shuttle. Below are a set of important major milestones to be noted by a payload customer.

9.11.1 Form 1628 Submittal

The payload integration process officially begins with the submission of a Request for Flight Assignment form (NASA Form 1628). The request form is submitted by the payload customer and signed by a sponsoring organization at NASA Headquarters. The form requires information such as size of the payload, requested launch date, and orbital parameters so that planners can begin the process that will culminate in the payload being placed on the manifest for a Shuttle mission.

The approved Form 1628 is distributed for evaluation by various organizations that play a role in the integration process. The purpose of conducting the evaluation is to determine acceptability as a Shuttle payload and to identify to the customer, as well as NASA Headquarters, any issues/areas that could complicate or facilitate the payload integration process so they may be addressed prior to Shuttle flight assignment. The evaluation process results in a formal response memorandum to NASA Headquarters that documents positive observations as well as concerns and suggested resolutions.

9.11.2 Flight Definition and Requirements Directive

The FDRD milestone represents the point in the flow when the chosen payload complement for a specific mission is officially manifested for flight by incorporation into the FDRD, NSTS 07700, Volume III. The addition of a mission to the official manifest initiates many of the activities performed in the integration process, including development of engineering and other flight related products. FDRD can be thought of as the crossover between the requirements definition and the integration phases of mission preparation.

9.11.3 Flight Operations Review

The FOR is a multi-day meeting where the payload customer participates in the review of the flight operations documentation. The purpose of the FOR is to determine the status of the Space Shuttle flight operations implementation and to ensure that the training, MCC, POCC, and operational documentation will be ready to support payload flight operations and the final phases of crew and flight operations support personnel training.

9.11.4 Cargo Integration Review

The CIR is typically a 4-day meeting where the payload customer participates in reviews of engineering drawings, flight operation plans, and various other products to verify compatibility with requirements. The review verifies fidelity of the cargo manifest and ensures compatibility of the NASA provided hardware and software with the payload. Cargo bay secondary and middeck payloads may be added to the manifest at the CIR. Satisfactory completion of CIR is authorization to proceed with generation of flight products.

9.11.5 Payload Arrival at KSC

This milestone represent the point in the flow where the payload hardware is delivered to the KSC. The Payload hardware may be shipped from the payload customer’s facility to KSC via land, sea or air transportation.

Payload processing generally begins with a receiving inspection at a KSC PPF. Additional processing that may occur in the PPF includes component or subsystem assembly, such as:

1. Mating to an upper stage that may boost the payload to a higher Orbit, or out into the solar system for exploration,
2. Installation onto a payload carrier, (that may be provided by NASA or by the Payload Customer), and
3. Integration with other components.

Shuttle payloads undergo final checkout, interface verification, and launch preparation at the KSC. Facilities used and services provided are based on the requirements of each payload, and may vary significantly from payload to payload.

9.11.6 Launch

As the countdown proceeds towards launch, the launch control team monitors numerous parameters to ensure that all systems are operating properly, and it is safe to launch. Each payload customer must develop countdown monitoring requirements called LCC that defines:

1. All payload parameters utilized for safety monitoring during the count and criteria used for calling safety-related holds
2. Specific actions and payload commanding initiated by the customer after pad clearing which, if unsuccessful, could cause a launch hold
3. Orbiter payload interface services and ground operations support decisions which represent GO/NO-GO decisions

Launch operations are considered complete and flight operations begin as the Shuttle clears the launch tower.

SAFETY

10.0

10.1 OVERVIEW

The SSP has implemented a rigorous payload safety process to ensure safe payload-related operations both during ground handling and in space. The primary objectives of the payload safety review process are to identify the potential hazards applicable to a payload (including its flight support hardware, ground support equipment, and ground operations), and to assure that the hazard controls and verification of those controls are adequate and in compliance with safety requirements.

The payload customer is required to identify all potential payload hazards and report on them during the phase safety reviews. Data submittals are made in a Safety Data Package (SDP) delivered to JSC and KSC. Safety reviews are scheduled approximately 45 days after the payload customer supplies an acceptable SDP. Payload Safety process (NSTS/ISS 13830) and technical requirements (NSTS 1700.7B, NSTS 1700.7B ISS Addendum, and 45 SPW HB S-1000/KHB 1700.7B) are located on the PSRP public domain web site.

10.2 GROUND SAFETY

The objective of the ground safety review process is to review the payload, GSE and operations for adequate safety implementation during the ground operations at the KSC. The Ground Safety Review Panel (GSRP) was established to accomplish the following:

1. Assure that payload customer interpretation of the safety requirements is consistent with NASA payload safety policy.
2. Conduct safety reviews as appropriate during the development of the payload, associated GSE and related operations.
3. Evaluate hazard analyses and Noncompliance Reports (NCRs).
4. Negotiate the resolution of safety issues involving design and operations to ensure compliance with all applicable safety requirements.
5. Assess the verification approach that confirms intended system performance.

Compliance with safety requirements is assessed using a phased safety review process (phases 0, I, II, and III).

10.3 FLIGHT SAFETY

The objective of the flight safety process is to review the payload and operations for adequate safety implementation during the in-flight operations. The PSRP was established to accomplish the following:

1. Assure that payload customer interpretation of the safety requirements is consistent with NASA payload safety policy.
2. Conduct safety reviews as appropriate during the development of the payload and related operations.
3. Evaluate hazard analyses and NCRs.
4. Negotiate the resolution of safety issues involving design and operations to ensure compliance with all applicable safety requirements.
5. Assess the verification approach that confirms intended system performance.

Compliance with safety requirements is assessed using a phased safety review process (phases 0, I, II, and III).

10.4 PHASED SAFETY REVIEWS

10.4.1 Phase 0 Safety Review

The optional phase 0 safety review is provided as a service to the payload customer. The objectives of the meeting are to:

1. Assist the payload customer in identifying hazards, hazard causes, and applicable safety requirements early in the development of the payload.
2. Adequately describe the hazard potential.
3. Answer questions regarding the interpretation of the safety requirements or the implementation procedures of this document.
4. Provide guidance to the payload customer for preparing the safety data required for subsequent safety reviews.

The Phase 0 review is held during the concept phase or at the start of the payload design.

10.4.2 Phase 1 Safety Review

The purpose of the phase I safety review is to obtain PSRP/GSRP approval of the updated safety analysis that reflects the preliminary design and operations scenario of the payload. At this point, the payload customer presents a refined safety analysis that identifies all hazards and hazard causes inherent in the preliminary design; evaluates all hazards for means of eliminating, reducing, or controlling the risk; and establishes preliminary safety verification and on-orbit verification/reverification methods. The payload customer provides a preliminary identification of the payload interfaces and of the hazards presented by these interfaces.

The Phase I review is held near the payload Preliminary Design Review.

10.4.3 Phase 2 Safety Review

The purpose of the phase II safety review is to obtain PRSP/GSRP approval of the updated SDP that reflects the Critical Design Review (CDR) level design and operations scenario of the payload. The phase II safety analysis identifies all hazards and hazard causes; defines and documents implementation of a means for eliminating, reducing, or controlling the risks; and documents finalized, specific safety verification and on-orbit verification/reverification methods (test plans, analysis, and inspection requirements, etc.). Payload interfaces, mission and ground operations, procedures, and timelines that were not addressed during the phase I safety review are assessed for safety hazards. The payload interfaces to be assessed include those between the Shuttle and the payload and among the various components that make up the payload (the spacecraft, upper stages, space platforms, pallets, experiments, ASE, ancillary flight equipment, GSE, KSC Facilities, GFE, etc.). Newly identified hazards are documented in additional hazard reports. For this review, the payload customer should provide the estimated KSC on-dock arrival date.

The Phase II review is near the payload Critical Design.

10.4.4 Phase 3 Safety Review

The purpose of the phase III safety review is to obtain PSRP/GSRP approval of the SDP and safety compliance data that reflects the safety verification findings. The focus of this review is to assess safety verification testing and analysis results. If verifications critical for establishing the acceptability of the fundamental design of the payload for safety are not completed prior to the phase III review, then subsequent reviews may be required prior to hazard report approval.

All safety verifications that are still incomplete at Phase III must be closed on the hazard report and transferred to the flight safety Verification Tracking Log (VTL) for further tracking. This log will allow the PSRP/GSRP Chairman to sign the hazard reports, indicating completion of the safety analysis, but with the understanding that approval for flight will be withheld until all flight verification activity is completed.

The Phase III review is associated with completion of payload safety verifications and/or the start of ground processing.

10.5 HAZARDOUS MATERIALS

For all hardware carried inside the crew compartment or any habitable volume, the payload customer is responsible for certifying that controls of hazardous material are consistent with the methods/designs approved by the SSP PSRP. The JSC Toxicologist will develop and manage the Hazardous Materials Summary Table (HMST) from the customer-supplied list as required for the SSP review. The customer will verify that:

1. Materials that are planned to be loaded are listed on the HMST
2. The materials loaded are on the approved planned loading list

The hazardous material requirements and process are documented in JSC 27472, Requirements for Submission of Test Sample Materials for Shuttle Payload Safety Evaluations.

Following the Flight Safety Phase III Review, the JSC Toxicologist will provide the customer with the preliminary HMST. The customer will return the HMST with the signed Verification 1 form which represents the final loading plan.

It is SSP policy to limit changes to the HMST to only allow deletions and/or reductions of concentration of the materials between Verification 1 and Verification 2.

Following SSP approval, corrections will be incorporated into the final HMST at L-2 months and provided to the customer. Since loading will occur at various times, the customer will return Verification 2 forms and the as-loaded HMST when material loading actually occurs. Review and concurrence of the as-loaded list by the JSC Toxicologist will constitute the as-loaded list of materials for use by the flight team.

ACRONYMS AND ABBREVIATIONS

APPENDIX A

A	ampere(s)
ac	alternating current
ACCN	Audio Central Control Network
ACS	Attitude Control System
AFD	Aft Flight Deck
ANSI	American National Standards Institute
AOA	Abort-Once-Around
APC	Adaptive Payload Carrier
APCU	Assembly Power Converter Unit
APU	Auxiliary Power Unit
ARS	Atmosphere Revitalization System
ASE	Airborne Support Equipment
ATCS	Active Thermal Control System
AUX	Auxiliary
AWG	American Wire Gauge

C&W or C/W	Caution and Warning
c.g.	center of gravity
c.m	center of mass
CCR	Cargo Compatibility Review
CCTV	Closed Circuit Television
CDR	Critical Design Review
CIP	Cargo Integration Plan
CIR	Cargo Integration Review
CIS	Communication Interface System
CITE	Cargo Interface Test Equipment
cm	centimeter(s)
COAS	Crew Optical Alignment Sight
CoFR	Certificate of Flight Readiness
CPCB	Crew Procedures Control Board
CQCM	Cryogenically-cooled Quartz Crystal Microbalance
CRDG	Contamination Requirements Definition Group
CRF	Canister Rotation Facility
CRT	Cathode Ray Tube
CWA	Controlled Work Area

D&C	Display and Control
DAP	Digital Automatic Pilot
dB	decibel(s)
dBμA	decibel(s) above a microampere
dBμV	decibel(s) above a microvolt

dc	direct current
DCC	Data Computation Complex
DFRC	Dryden Flight Research Center
DOH	Discrete Output High
DOL	Discrete Output Low
DPC	Data Processing Complex
DPP	Deployment Pointing Panel
DPS	Data Processing Subsystem
DSN	Deep Space Network
EAFB	Edwards Air Force Base
ECLSS	Environmental Control and Life Support System
ECS	Environmental Control System
EDO	Extended Duration Orbiter
EE	End Effector
EED	Electro-Explosive Device
EFGF	Electrical Flight Grapple Fixture
EMC	Electromagnetic Compatibility
EMCFA	Electromagnetic Compatibility Frequency Analysis
EMDS	Environmental Monitoring Data System
EMI	Electromagnetic Interference
EMU	Extravehicular Mobility Unit
EPDS	Electrical Power Distribution System
ET	External Tank
ETE	End to End
ETR	Eastern Test Range
EVA	Extravehicular Activity
FAWG	Flight Assignment Working Group
FCT	Flight Control Team
FDRD	Flight Definition and Requirements Document
FES	Flash Evaporator System
F*n*	fuse *n*
FOR	Flight Operations Review
FOV	Field of View
FRED	Final Reconfiguration Engineering Drawings
FRGF	Flight Releasable Grapple Figure
FRR	Flight Readiness Review
GAS	Get-Away Special
GCS	Generic Command Server
GF	Grapple Fixture
GFE	Government Furnished Equipment
GHz	gigahertz
GMM	Geometric Math Model
GOR	Ground Operations Review
GOWG	Ground Operations Working Group

GPC	General Purpose Computer
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GSRP	Ground Safety Review Panel
HCl	Hydrogen Chloride
HEPA	High Efficiency Particulate Air
HHL	Hand-Held Lidar
HIM	Hardware Interface Module
HMST	Hazardous Materials Summary Table
HO	medium strength ($6V < E \leq 40V$) signal
hr	hour
HST	Hubble Space Telescope
HYD	hydraulic
Hz	hertz
ICAPC	Increased Capability Adaptive Payload Carrier
ICD	Interface Control Document
IDD	Interface Definition Document
IECM	Induced Environmental Contamination Monitor
IF	Intermediate Frequency
IFM	In-flight Maintenance
IGMM	Integrated Geometric Math Model
IMU	Inertial Measurement Unit
IP	Integration Plan
IR	Infrared
ISS	International Space Station
ITMM	Integrated Thermal Math Model
IVT	Interface Verification Test
JEA	Joint Endeavor Agreement
JOIP	Joint Operations Interface Procedure
JSC	Lyndon B. Johnson Space Center
kbps	kilobit(s) per second
kHz	kilohertz
km	kilometer(s)
KSC	John F. Kennedy Space Center
KUSP	Ku-band Signal Processor
kW	kilowatt(s)
kWh	kilowatthour(s)
L-	Launch minus
LC	Launch Complex
LCC	Launch Commit Criteria
LDB	Launch Data Bus
LEO	Low Earth Orbit

LOS	Line of Sight
LPIS	Launch Package Integration Stand
LRU	Line Replaceable Unit
LSA	Launch Services Agreement
LSSE	Launch Site Support Engineer
LSSM	Launch Site Support Manager
LSSP	Launch Site Support Plan
LVLH	Local Vertical/Local Horizontal

m	meter
MΩ	megaohm(s)
mΩ	milliohm(s)
m/sec	meter(s) per second
MAPTIS	Materials and Processes Technical Information System
MAX	maximum
Mbps	megabits per second
MCC	Mission Control Center
MCC-H	Mission Control Center-Houston
MCDS	Multifunction CRT Display System
MDA	Main dc Distribution Assembly
MDM	Multiplexer/Demultiplexer
MECO	Main Engine Cutoff
MET	Mission Elapsed Time
MFR	Manipulator Foot Restraint
MHz	megahertz
MIP	Mission Integration Plan
ML	low strength ($100\ \text{mV} < E \leq 6\text{V}$) signal
MLI	multilayer insulation
MLP	Mobile Launch Platform
MMH	Monomethyl Hydrazine
MMU	Modular Memory Unit
MOD	Mission Operations Directorate
MOU	Memorandum of Understanding
MPE	Maximum Permissible Exposure
MPPF	Multipurpose Processing Facility
MS	Mission Specialist
MSDP	Mission Station Distribution Panel
MSFC	George C. Marshall Space Flight Center
MST	Mission Sequence Testing
MTU	master timing unit

n. mi.	nautical mile(s)
NASA	National Aeronautics and Space Administration
NBL	Neutral Buoyancy Lab
NCR	Noncompliance Reports
No.	number
NOHD	Nominal Ocular Hazard Distance

NRZ	nonreturn-to-zero
NRZ-L	nonreturn-to-zero-level
NVR	Nonvolatile Residue
O&C	Operations and Checkout
OCS	Orbiter Coordinate System
OD	Orbiter Downlink
ODM	Orbiter Disconnect Mechanism
ODS	Orbiter Docking System
OMI	Operations and Maintenance Instruction
OMRS	Operations Maintenance Requirements and Specifications
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	Orbital Maneuvering System
OOSDP	on-orbit station distribution panel
OPF	Orbiter Processing Facility
ORB	Orbiter
OSRC	Orbiter Structural Reference System
PAC	Percent Area Coverage
PACK	Payload Active Cooling Kit
PAS	Payload Axis System
PAT	power accommodation terminal
PCM	pulse code modulation
PCMMU	pulse code modulation master unit
PCR	Payload Changeout Room
PCS	Payload Checkout System
PDA	Payload Disconnect Assembly
PDI	payload data interleaver
PDIP	Payload Data Interface Panel
PDRS	Payload Deployment and Retrieval System
Pf	picofarad(s)
PGCP	Particles and Glass Contamination Panel
PGSC	Payload and General Support Computer
PHSF	Payload Hazardous Servicing Facility
PI	payload interrogator
PIM	Payload Integration Manager
PIP	Payload Integration Plan
PLBD	Payload Bay Door
P*n*	cable connector *n*
POCC	payload operations control center
POSA	Passive Optical Sample Array
POW	Payload Operations Workbook
POWG	Payload Operations Working Group
PPF	Payload Processing Facility
ppm	parts per million
PPSU	Payload Power Switching Unit

PRCS	Primary Reaction Control System
PRLA	Payload Retention Latch Assembly
PS	Payload Specialist
PSA	Passive Sample Array
PSA	Provisions Stowage Assembly
PSDP	payload station distribution panel
PSK	phase shift key(ed)
PSP	payload signal processor
PSRP	Payload Safety Review Panel
PTC	Passive Thermal Control
PVLR	Preliminary Verifications Loads Review
PYR	Pitch, Yaw, Roll
QPSK	quadrature phase shift keyed
RAAN	Right Ascension of Ascension Node
RC	resistance times capacitance
RCS	reaction control system
RF	radio frequency
RFI	Radio Frequency Interference
Rg	resistance to structure ground
RMS	remote manipulator system
ROEU	remotely operated electrical umbilical
RR	Rendezvous Radar
RTLS	Return to Launch Site
SAEF	Spacecraft Assembly and Encapsulation Facility
SCA	Shuttle Carrier Aircraft
SCC	standard cubic centimeters
SDP	Safety Data Package
sec	second
SID	Standard Interface Drawing
SIP	Standard Integration Plan
	Standard Interface Panel
SM	systems management
SMAC	Spacecraft Maximum Allowable Concentrations for Airborne Contaminants
SMCH	Standard Mixed Cargo Harness
SN	Space Network
SPA	Small Payload Accommodations
SPACE	Shuttle/Payload Contamination Evaluation
SPASP	Small Payload Accommodations Switch Panel
SPAT	Small Payload Accommodations Terminal
SPC	Stored Program Command
SPDU	Station Power Distribution Unit
SRB	Solid Rocket Booster
SRMS	Shuttle Remote Manipulator System

SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
SSPF	Space Station Processing Facility
SSPIS	Space Shuttle Payload Information System
STDN	Spaceflight Tracking and Data Network
SWG	Structures Working Group
TACAN	Tactical Air Command and Navigation System
TAL	Transatlantic Abort Landing
TCS	Trajectory Control Sensor
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TFE	Tetraflourethylene
TMM	Thermal Math Model
TQCM	Temperature-controlled Quartz Crystal Microbalances
TRASYS	Thermal Radiation Analysis System
TSA	Tool Stowage Assembly
TV	Television
UHF	Ultrahigh Frequency
UV	ultraviolet
V	Volt(s), voltage
V dc	Volt(s) direct current
V/cm	Volt(s) per centimeter
V/m	Volt(s) per meter
VA	Volt-ampere(s)
VAB	Vehicle Assembly Building
V ac	volt(s) alternating current
VAR	Verification Acceptance Review
VC	Visibly Clean
VCM	Volatile Condensable Material
VDA	Vacuum Deposited Aluminum
Vol.	volume
VPF	Vertical Processing Facility
VRCS	Vernier Reaction Control System
VTL	Verification Tracking Log
W	watt
WSSH	White Sands Space Harbor

REFERENCE DOCUMENTS

APPENDIX B

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2. 45 SPW HB S-100/KHB 1700.7, Space Transportation System Payload Ground Safety Handbook
3. AIAA-83-2582-CP, Update of Induced Environment Contamination Monitor Results
4. ANSI Z136.1-2000, American National Standard for Safe Use of Lasers
5. ASTM-F25, Sizing and Counting Airborne Particulate Contamination in Clean Rooms and Other Dust-Controlled Areas Designed for Electronic and Similar Applications
6. ICD 2-0A002, Space Shuttle Launch Pad and Platform
7. ICD 2-19001, Shuttle Orbiter/Cargo Standard Interfaces
8. J. Spacecraft Volume 21, No. 3, Space Shuttle Contamination Measurements from Flight STS-1 through STS-4
9. JSC 14686, Criteria/Guidelines for Payload Thermal Math Models for Integration Analysis
10. JSC 16719, STS OPS Flight PRD Vol II Payloads Annex 17 OSTA-3
11. DX12-0001 Neutral Buoyancy Laboratory General Operating Procedures
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13. JSC 20584, Spacecraft Maximum Allowable Concentrations for Airborne Contaminants
14. JSC 26990, Neutral Buoyancy Lab General Operating Procedures
15. JSC 27472, Requirements for Submission of test Sample Materials for Shuttle Payload Safety Evaluations
16. JSC 37326, Shuttle Crew Scheduling Constraints
17. K-STSM-14.1, Launch Site Accommodations Handbook for Payloads

18. K-STSM-14.2.1, KSC Payload Facility contamination Control Requirements
19. KVT-PL-0025, Shuttle Facility/Orbiter Contamination Control Plan
20. MIL-E-6051, Electromagnetic Compatibility Requirements Systems
21. MIL-STD-1246, Product Cleanliness Levels and Contamination Control Program
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25. NASA TM-82524, SS-2, -3, -4, Induced Environment Contamination Monitor (IECM) Summary Report
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27. NASA-STD-3000, Man Systems Integration Standards
28. NSTS 07636, Lighting Protection Criteria Document
29. NSTS 08060, Space Shuttle System Pyrotechnic Specification
30. NSTS 08171, Operations and Maintenance Requirements and Specifications Document (OMRSD)
31. NSTS 13830, Implementation Procedure for NSTS Payloads System Safety Requirements
32. NSTS 14046, Payload Verification Requirements
33. NSTS 16007, Shuttle launch Commit Criteria and Background Document
34. NSTS 16979, Shuttle Orbiter Failure Modes and Fault Tolerances for Interface Services
35. NSTS 1700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System
36. NSTS 18798, Interpretations of NSTS Payload Safety Requirements
37. Item deleted
38. NSTS 21000-A01, Payload Data Package Annex

39. NSTS 21000-A011, Extravehicular Activity Annex

40. NSTS 21000-A02, Data Requirements for the Flight Planning Annex

41. NSTS 21000-A04, Command and Data Annex Annex 4

42. NSTS 21000-A08, Launch Site Support Plan Annex 8

43. NSTS 21000-IDD-760XD, Shuttle/Payload Interface Definition Document for the Payload and General Support Computer (PGSC)

44. NSTS 21000-IDD-ISS, Shuttle/International Space Station Interface Definition Document

45. NSTS 21000-IDD-MDK, Shuttle/Payload Interface Definition Document for Middeck Accommodations

46. NSTS 21000-IDD-SML, Shuttle/Payload Interface Definition Document for Small Payload Accommodations

47. NSTS 21000-SIP-ATT, Shuttle/Payload Standard Integration Plan for Attached Payloads

48. NSTS 21000-SIP-DRP, Shuttle/Payload Standard Integration Plan Deployable/Retrievable – Type Payload

49. NSTS 21000-SIP-GAS, Shuttle/Payload Standard Integration Plan for Get Away Special Payloads

50. NSTS 21000-SIP-MDK, Shuttle/Payload Standard Integration Plan for Middeck-Type Payloads

51. NSTS 21000-SIP-MIP, Shuttle/Launch Package Standard Integration Plan for International Space Station Missions

52. NSTS 21000-SIP-NDD, Standard Integration Plan for the Nonstandard Development Test Objective/Detailed Supplementary Objective or Risk Mitigation Experiment

53. NSTS 21063-POC-CAP, POCC Capabilities Document Payload Support Capabilities Description: MCC, JSC POCC, Remote POCC Interface

54. NSTS 21075, STS Operational Flight Design Standard Groundrules and Constraints

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61. SP-R-0022, General Specification Vacuum Stability Requirements of Polymeric Material for Spacecraft
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70. NSTS 07700, Volume XIV, Space Shuttle Payload Accommodations
71. NSTS 21288, Required Data/Guidelines For Payload/Shuttle Electromagnetic Compatibility Analysis
72. NSTS 37330, Bonding, Electrical, and Lightning Specifications
73. JSC 27508, Payload Operations Workbook
74. SFOC FL2121, Payload Familiarization Breifing Guidelines
75. NSTS 21000-A05, Payload Operations Control Center Annex

76. NSTS 21000-A07, Traning Annex

77. NSTS 07700, Volume III, FDRD