NSTS 07700, Volume XIV,

Appendix 4

System Description and Design Data –

Structures and Mechanics

DESCRIPTION OF CHANGES TO

SYSTEM DESCRIPTION AND DESIGN DATA – STRUCTURES AND MECHANICS
NSTS 07700, VOLUME XIV, APPENDIX 4

CHANGE NO.	DESCRIPTION/AUTHORITY	DATE	PAGES AFFECTED
REV J	Complete revision; replaces and supersedes the structures and mechanics sections to Revision I of NSTS 07700, Volume XIV (reference CR D07700-014-004-001). The following CRs are included: D07700-014-004-002, D07700-014-004-003, D07700-014-004-004, D07700-014-004-005.	2/23/88	ALL
1	The following CRs are included: D07700-014-004-006, D07700-014-004-007, D07700-014-004-008, D07700-014-004-009, D07700-014-004-010.	6/14/89	Figure 1, 2-8, 5-3, 5-4, 5-5, 7-1, 7-3, 12-2
REV K	Complete revision (reference CR D07700-014-004-013). The following CRs are included: D07700-014-004-011, D07700-014-004-012.	2/22/94	ALL
	Reformat Word for Windows.	7/96	ALL
REV L	Complete revision (reference CR D07700-014-004-0014)	6/21/01	ALL

Preface

This document is designed to be used in conjunction with the series of documents illustrated in Figure 1. Information on structural/mechanical accommodations available in the orbiter payload bay and crew cabin is presented herein.

Specific agreements for structural/mechanical design must be specified in the individual payload integration plan (PIP).

Configuration control of this document will be accomplished through application of the procedures contained in Mission Integration Control Board Configuration Management Procedures, NSTS 18468.

Questions and recommendations concerning this document should be addressed to:

Manager, Space Shuttle Integration and Operations Office
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Signed by R. Dittemore for
Lawrence. G. Williams
Lawrence G. Williams
Manager
Space Shuttle Systems and Operations Integration

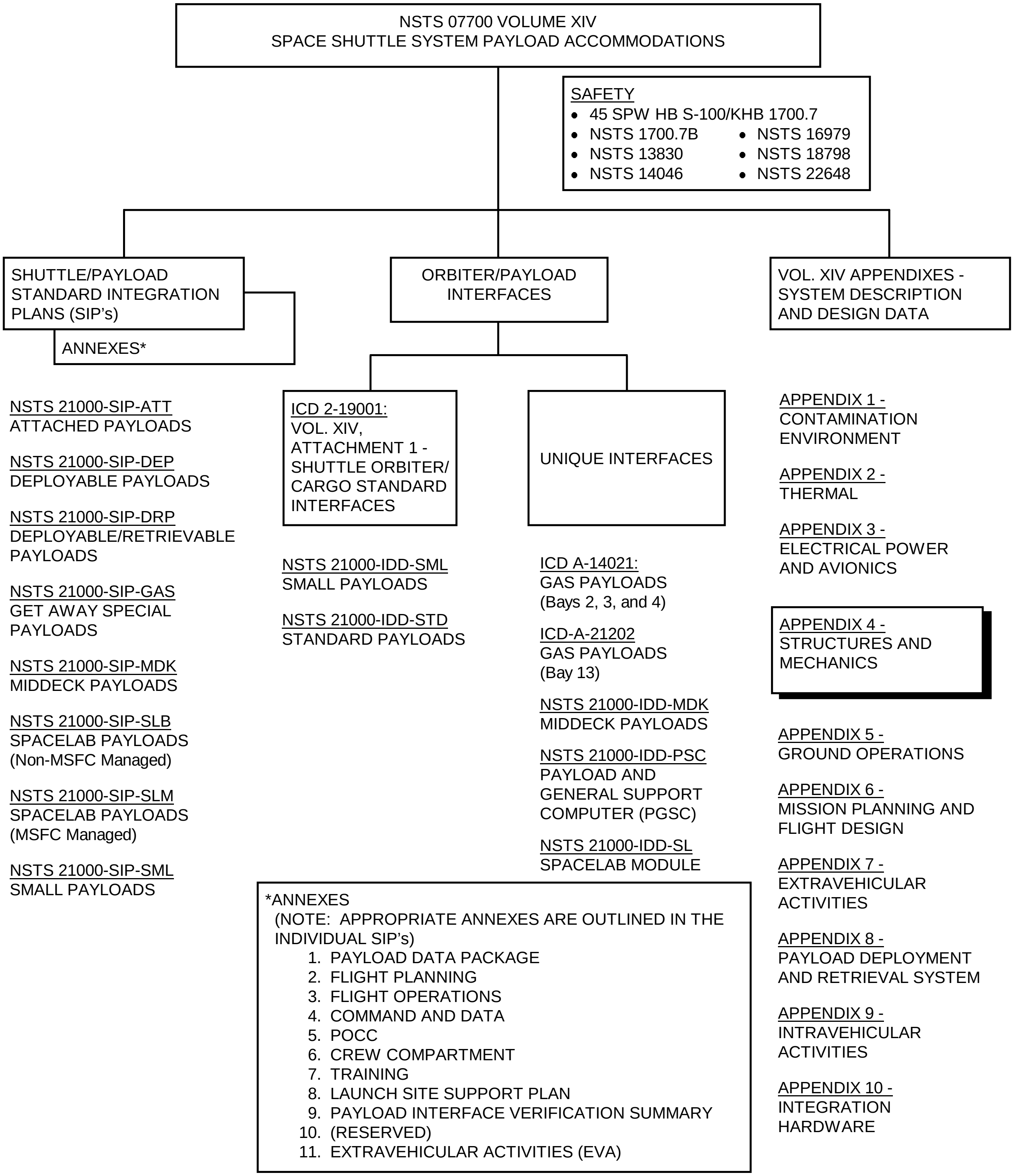

Figure 1.- Space Shuttle customer documentation tree.

Table of Contents

Tables

Figures

Introduction

1

1.1 General Information

This document 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 document is intended for use in conjunction with Shuttle Orbiter/Cargo Standard Interfaces , ICD 2-19001 or if the payload is a piece of Space Station hardware; then, use International Space Station Interface Definition Document, NSTS 21000-IDD-ISS.

This document identifies the structural/mechanical supports and deployment devices provided by the baseline orbiter for payloads, and establishes commonality for analytical approaches, analytical models, technical data, and definitions for integrated analysis by the Space Shuttle customer. The Space Shuttle system is shown in Figure 1-1. An overview of the payload design and analysis process is shown in Figure 1-2.

The orbiter provides structural support attachment points for payloads in the payload bay and the crew compartment. 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 the ICD 2-19001 or NSTS 21000-IDD-ISS document.

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 cargo elements are not attached directly to the orbiter, but to a cargo element 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 small payload carriers are supported by the orbiter sidewall. The orbiter crew cabin middeck area provides environmentally controlled payload locker storage.

The remote manipulator system (RMS) is available for payload deployment and retrieval. For more information, see System Description and Design Data – Payload Deployment and Retrieval System, NSTS 07700, Volume XIV, Appendix 8.

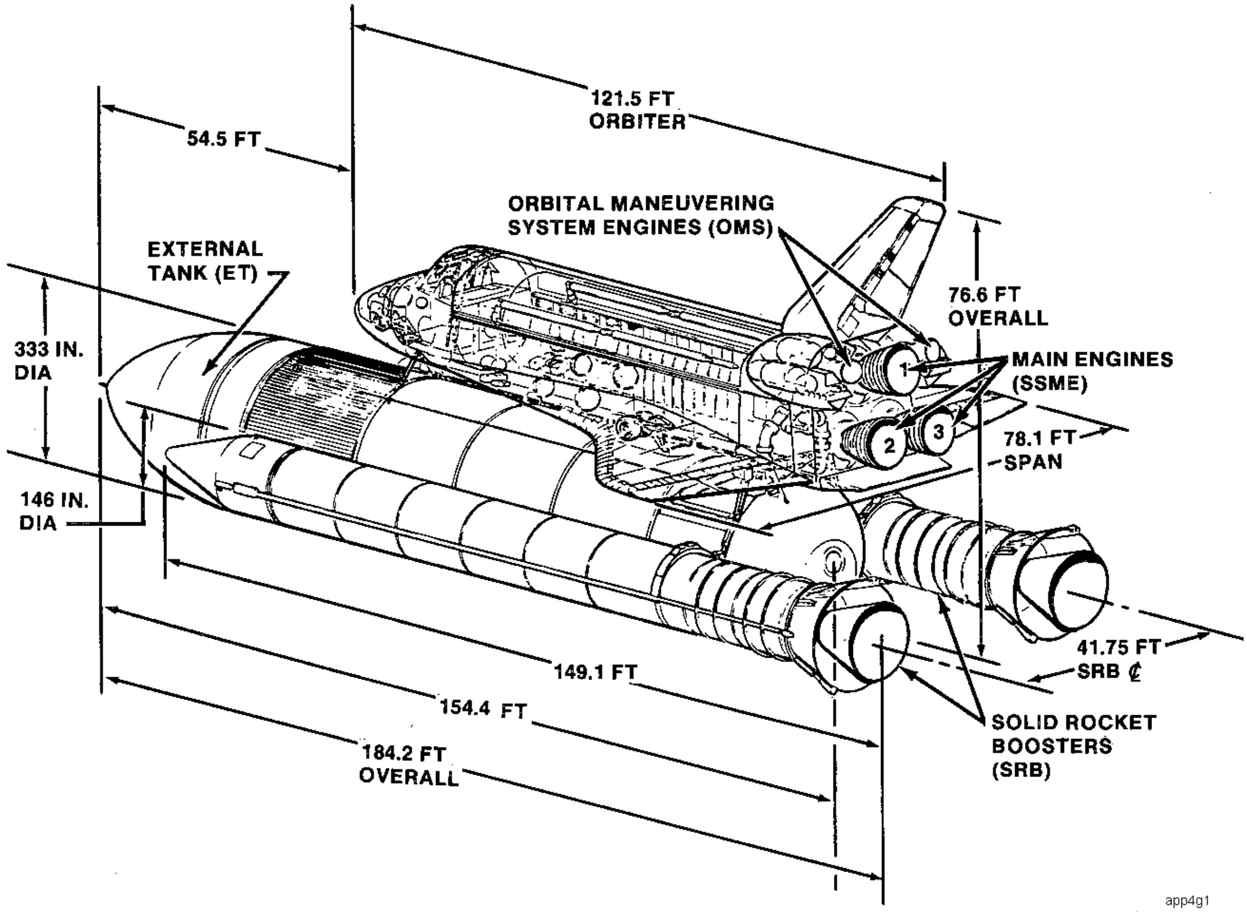

Figure 1-1.- Space Shuttle flight system.

1.2 Applicable Documentation

An essential element to achieving structural compatibility with the Space Shuttle Program (SSP) is the supporting reference documentation. This documentation provides the requirements for customer payload structural design and the planned missions. The documents listed in the bibliography provide background information for understanding Space Shuttle payload accommodations.

Any inconsistency between this document and the ICD 2-19001 or NSTS 21000-IDD-ISS shall be resolved by giving precedence to the ICD 2-19001 or NSTS 21000-IDD-ISS, except for payload safety requirements documents which take precedence.

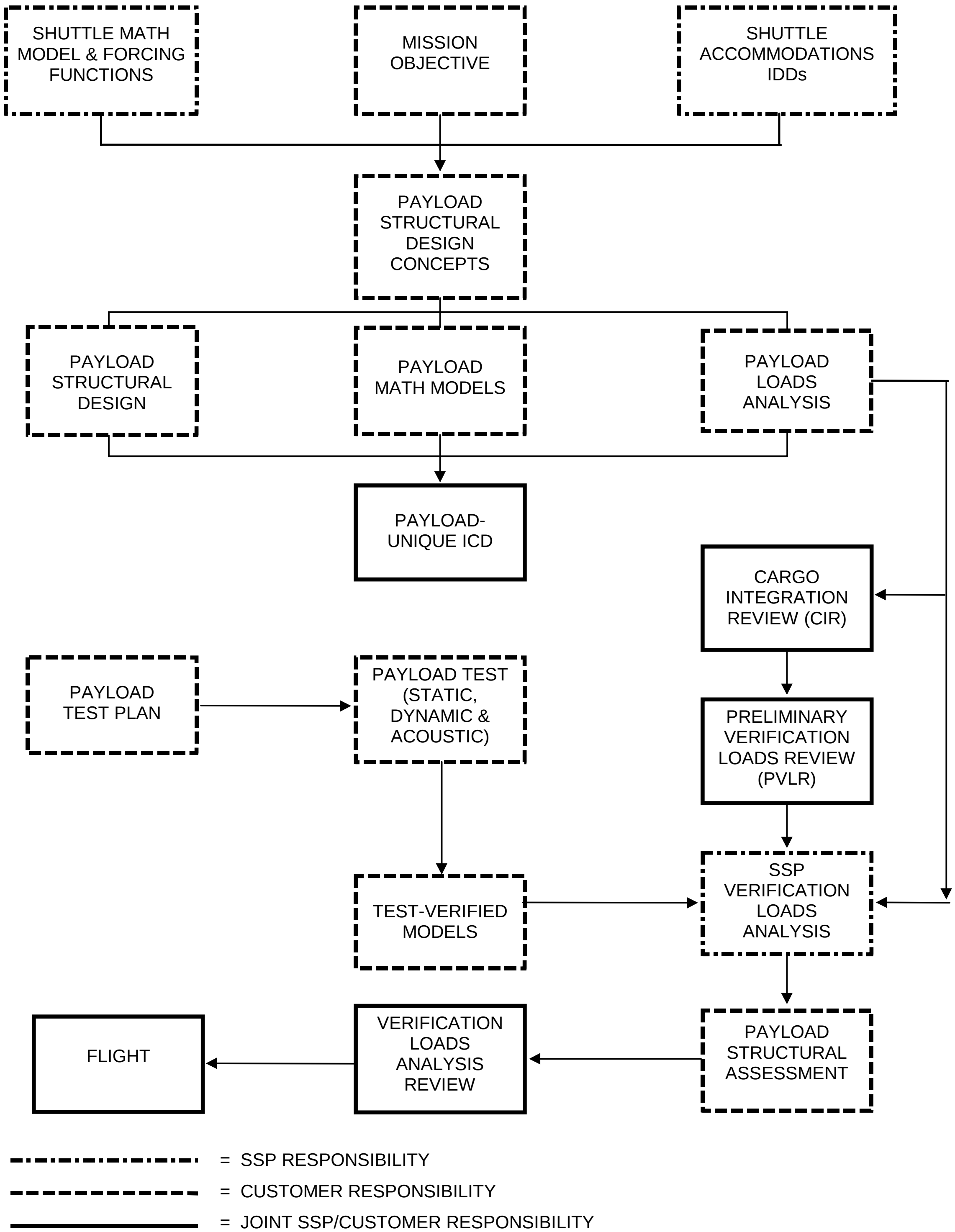

Figure 1-2.- Payload structural design and analysis process.

Mechanical and Physical Payload Interfaces

2

2.1 Payload Bay Envelope

A cylindrical envelope in the payload bay 15 feet in diameter extending from X_O 582 to X_O 1302 is provided for payload installation when the orbiter is configured without the airlock. When the payload bay is configured with the ISS external airlock and Orbiter Docking Structure (ODS), the payload envelope is 15 feet in diameter extending from X_O 704 to X_O 1302. The center of the envelope is at Y_O 0.0 and Z_O 400. The envelope is shown in Figure 2-1. It is the customer's responsibility to constrain the payload within this envelope for all flight phases, with the exception of orbiter interface hardware.

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_O 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 can extend beyond this dynamic envelope to mate with orbiter attachment fittings. Umbilicals that interface with the payload may also penetrate the dynamic envelope. Payload clearance loss with respect to the dynamic envelope should be calculated using the distorted orbiter centerline.

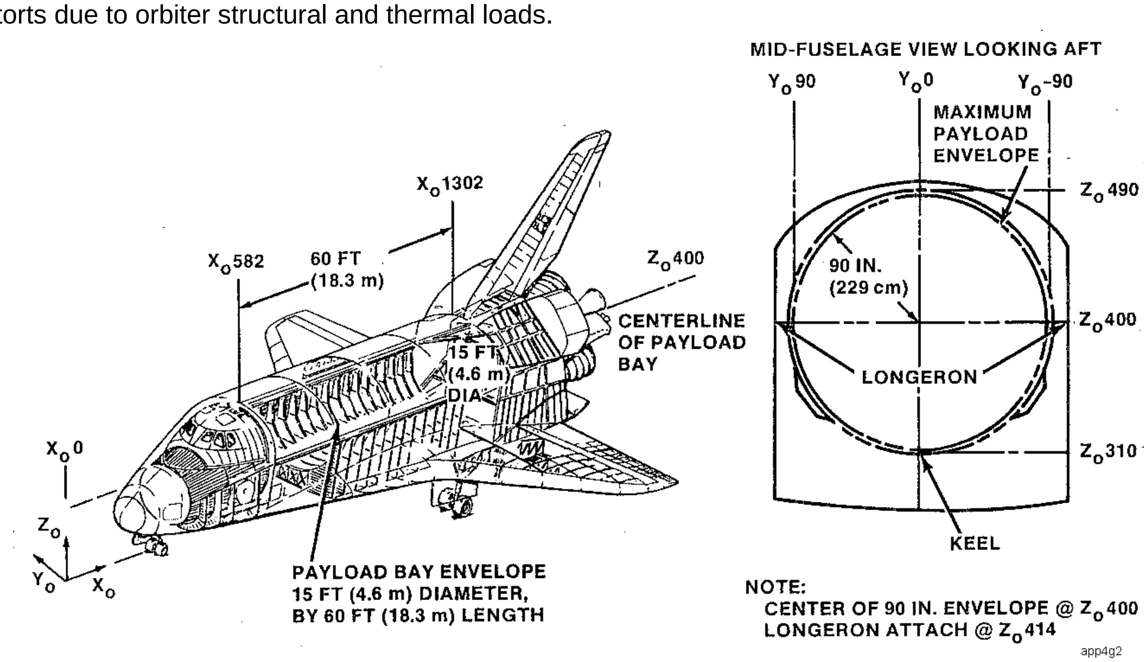

Figure 2-1.- Payload bay envelope.

Customers whose payloads exceed the 90-inch radius envelope for any flight phase shall either process a waiver to the interface control document (ICD) for a larger local envelope (after discussions with the SSP) or redesign the hardware to remain within the 90-inch radius envelope. Payload items that are statically within 3 inches (7.6 cm) of the 90-inch radius envelope shall be defined in the payload math models and used for clearance verification in the coupled loads analysis.

Customers must also consider potential interference caused by Space Shuttle mission kit and integration hardware intrusions into the 90-inch radius envelope. These include the Standard Interface Panels (SIP's), keel fittings aft of X_O1191, and certain camera mounts. In addition, the payload bay door centerline latches and passive radiators penetrate the payload envelope and are described in ICD 2-19001 or NSTS 21000-IDD-ISS.

2.2 Payload Attachment Provisions

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. All attach fittings are outside the 90-inch radius payload envelope. Longeron attachment locations are intended to react payload X_O and Z_O direction loading or Z_O direction loading only. Generally, the only Y_O 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_O loading with X_O and Z_O friction and rotation induced loads. In certain cases the keel can react X_O direction loading. Some common payload attachment arrangements are shown in Figure 2-2. Statically determinate and some indeterminate attachment schemes are acceptable.

Figure 2-3 shows a view of the payload bay looking aft from the starboard side. Longeron bridges for attaching the payload to the orbiter are visible on the port side. Only longeron and keel bridges required for a specific mission are installed.

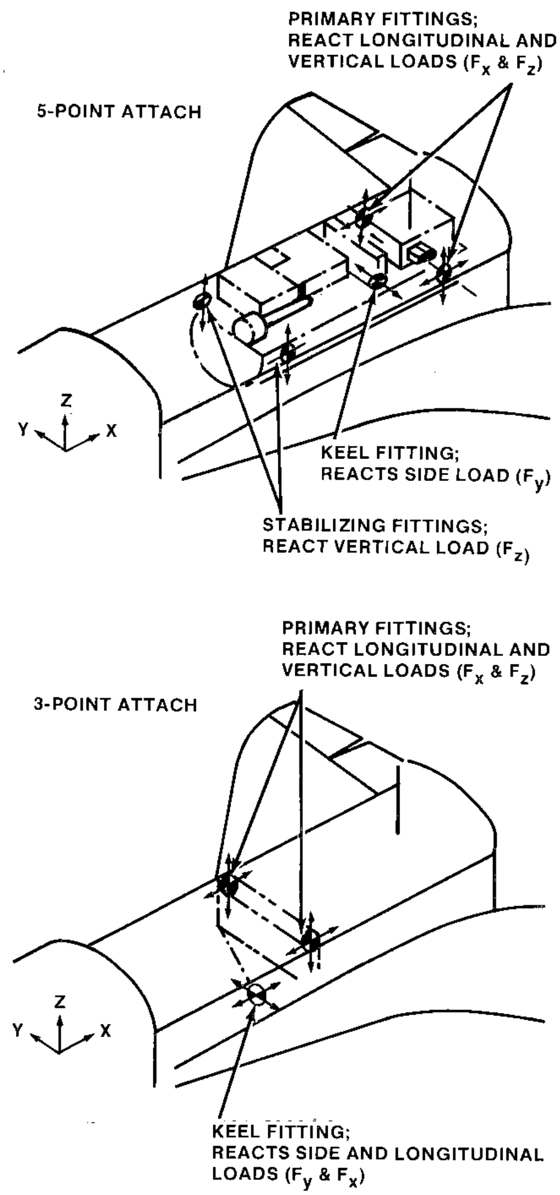

Figure 2-2.- 5-point and 3-point payload attachment methods.

Figure 2-4 is a view of the payload bay looking forward from the aft bulkhead. The keel bridge for a payload is visible in the lower center of the figure. Although payload attachment schemes are not limited to 5-point and 3-point systems, these descriptions provide examples of typical payload loads reactions.

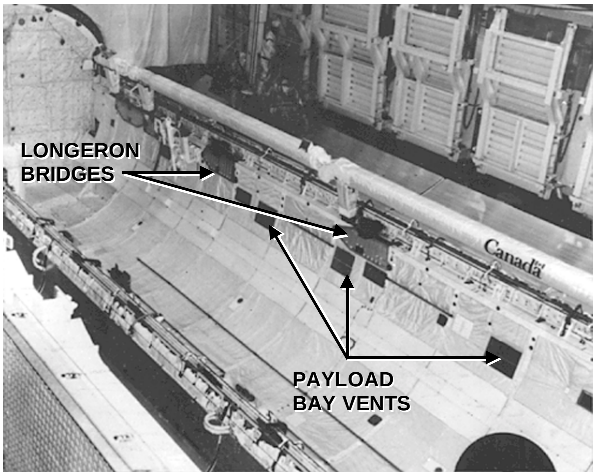

Figure 2-3.- Payload bay looking aft from the starboard side.

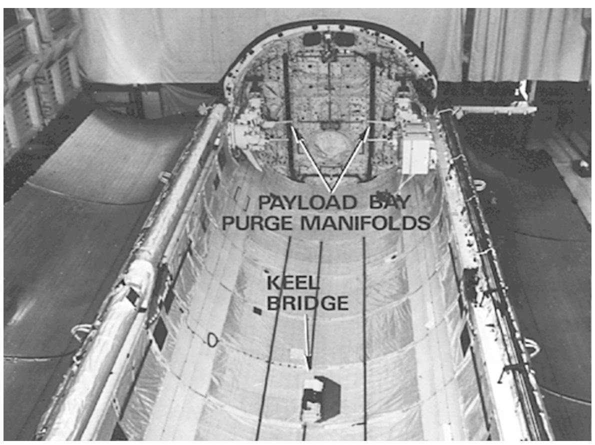

Figure 2-4.- Payload bay looking forward from aft bulkhead.

Cargo element 5-point installation. Figure 2-2 shows a 5-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.

Cargo element 3-point installation. Figure 2-2 also shows a 3-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.

2.3 Orbiter Attach Fittings for Payloads

Longeron attach fittings are mounted on bridges attached directly to the orbiter structure. Longeron attach fittings are available as passive (for nondeployable payloads) and active (for deployable payloads), as shown in Figure 2-5 and 2-6. Active latch assemblies consist of latch drive motors EVA latch drive capability, a differential gear box, payload alignment guides, and limit switches. The limit load capabilities for orbiter/payload attachment interfaces are specified in ICD 2-19001 and NSTS 21000-IDD-ISS. Both passive and active longeron attach fittings engage the longeron bridge with a tee and slot, which allows the fittings to slide in the X direction. When longeron attach fittings must support both X and Z loads, pins are installed between the fitting and the longeron bridge to prevent X motion. This attachment arrangement (when both X and Z loads are reacted) is referred to as a primary fitting. When the longeron latch remains free to slide in the X direction to accommodate payload and orbiter thermal expansion and structural deflection, it is referred to as a stabilizing fitting. The payload longeron attachment is a trunnion on the payload structure, which mates with the split bearing in the attach fitting housing on the orbiter longeron bridges.

Figure 2-5 shows two longeron bridges with passive attach fittings installed. On the bridge to the left is a SIP for avionics and power. Figure 2-6 illustrates an active fitting for a deployable payload. This installation is a starboard side attach fitting. The power and avionics interface is the panel on the bridge to the left. Also shown between the retention fitting and the avionics SIP are the avionics and power disconnects. Refer to ICD 2-19001 or NSTS 21000-IDD-ISS for exact location of attach fittings and alignment guides (required for deployable payloads).

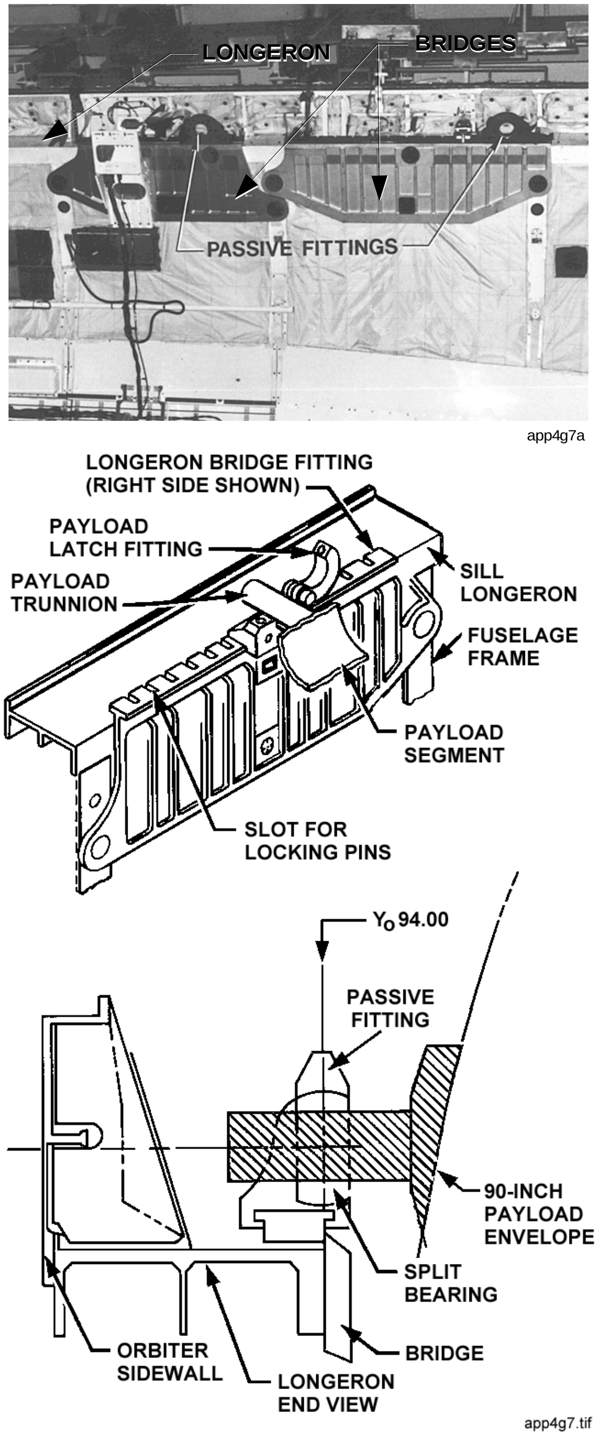

Figure 2-5.- Passive attach fitting and orbiter interface.

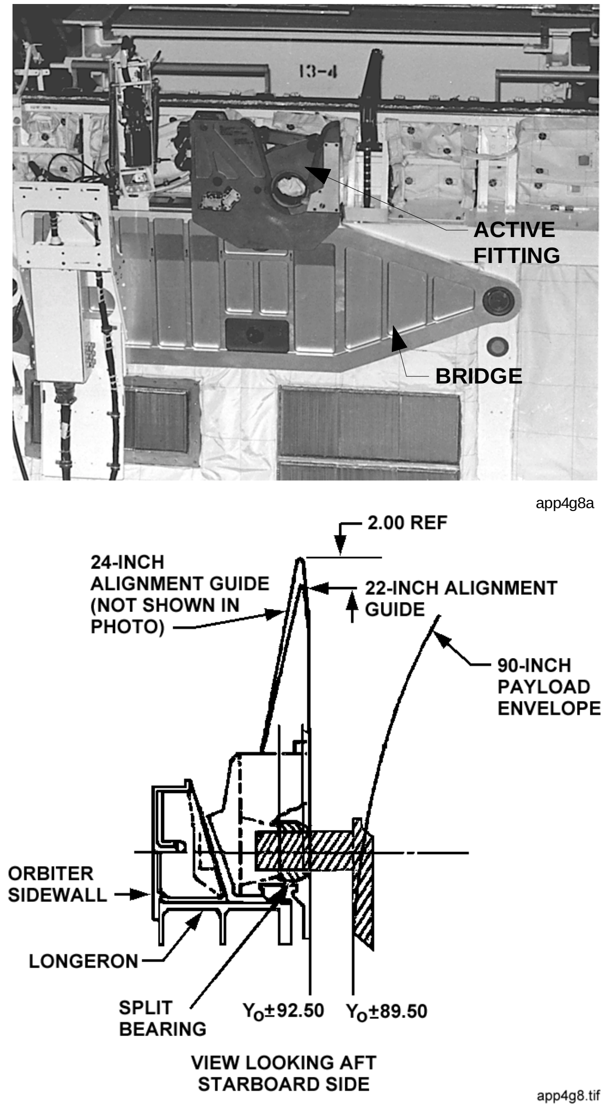

Figure 2-6.- Active attach fitting and orbiter interface.

NSTS 07700, Volume XIV, Appendix 8, includes a complete discussion of alignment guides. Orbiter keel retention latch fittings (Figure 2-7) are also mounted on bridges attached directly to the orbiter structure.

The limit load capabilities for orbiter/payload attachment interfaces are specified in ICD 2-19001 or NSTS 21000-IDD-ISS.

As shown in Figure 2-7, the keel retention latch also uses a tee-slot arrangement that is free to slide in the X direction. The fitting provides Y-axis payload restraint, but can also be pinned to provide X-axis payload restraint. The keel attach fitting is remotely opened and closed, allowing payload installation, deployment, and retrieval.

FORWARD

VIEW LOOKING DOWN AT ORBITER CENTERLINE
WITH KEEL FITTING IN CLOSED POSITION

app4g9

Figure 2-7.- Active keel fitting.

2.4 Payload to Orbiter Attachment

Payloads are supported in the payload bay on customer-supplied trunnions extending beyond the 90-inch radius envelope in the $\pm Y_O$ directions and in the negative Z_O direction at the payload bay bottom centerline (Figures 2-8 and 2-9). Details of the trunnion design are provided in ICD 2-19001 or NSTS 21000-IDD-ISS. 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.

The shoulder of the longeron trunnions is at Y_O ± 90 inches for nondeployable payloads and Y_O ± 89.5 inches for deployable payloads. This dimension provides a 3-inch clearance between the trunnion shoulder and the orbiter bridge and latch fittings for payload ground handling and installation. Requirements for the trunnion design based on separation of trunnions and location in the cargo bay are defined in ICD 2-19001 or NSTS 21000-IDD-ISS. The required longeron trunnion diameter is 3.245 inches.

The customer must provide a keel trunnion of the design defined in ICD 2-19001 or NSTS 21000-IDD-ISS. The SSP provides an active keel fitting to interface with the payload keel trunnion. The required keel trunnion diameter is 2.996 inches (ICD 2-19001).

Payload/cargo elements 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 3-point supported payloads. Ground support equipment (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/cargo element installation/ removal operations. For more information about payload ground handling, refer to System Description and Design Data – Ground Operations, NSTS 07700, Volume XIV, Appendix 5.

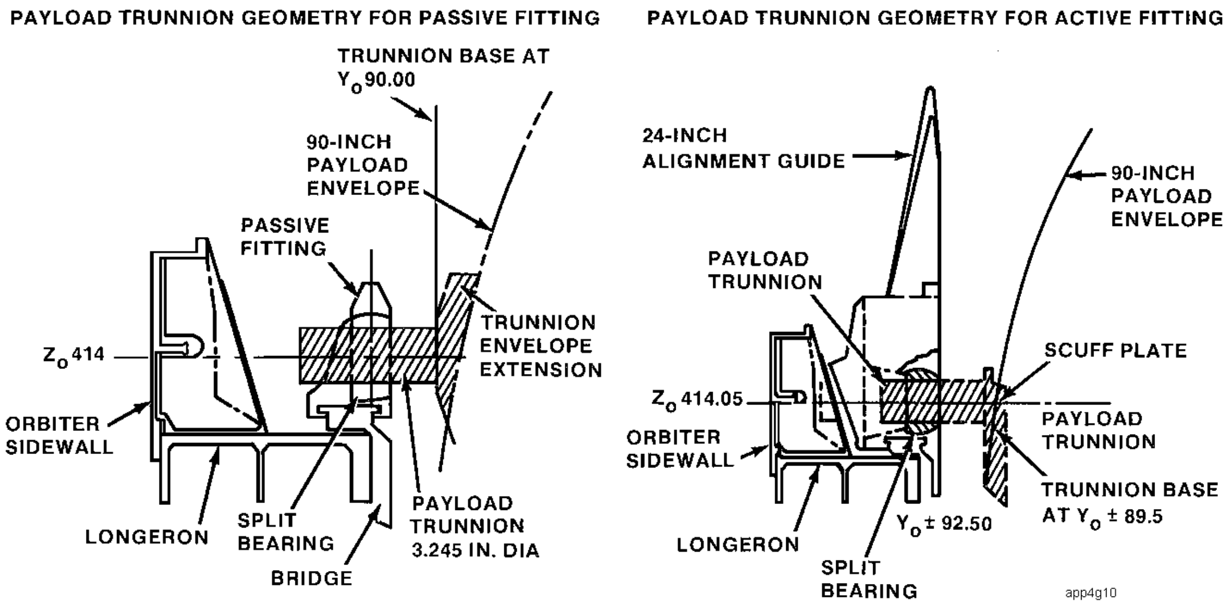

Figure 2-8.- Trunnion geometry for active and passive fittings.

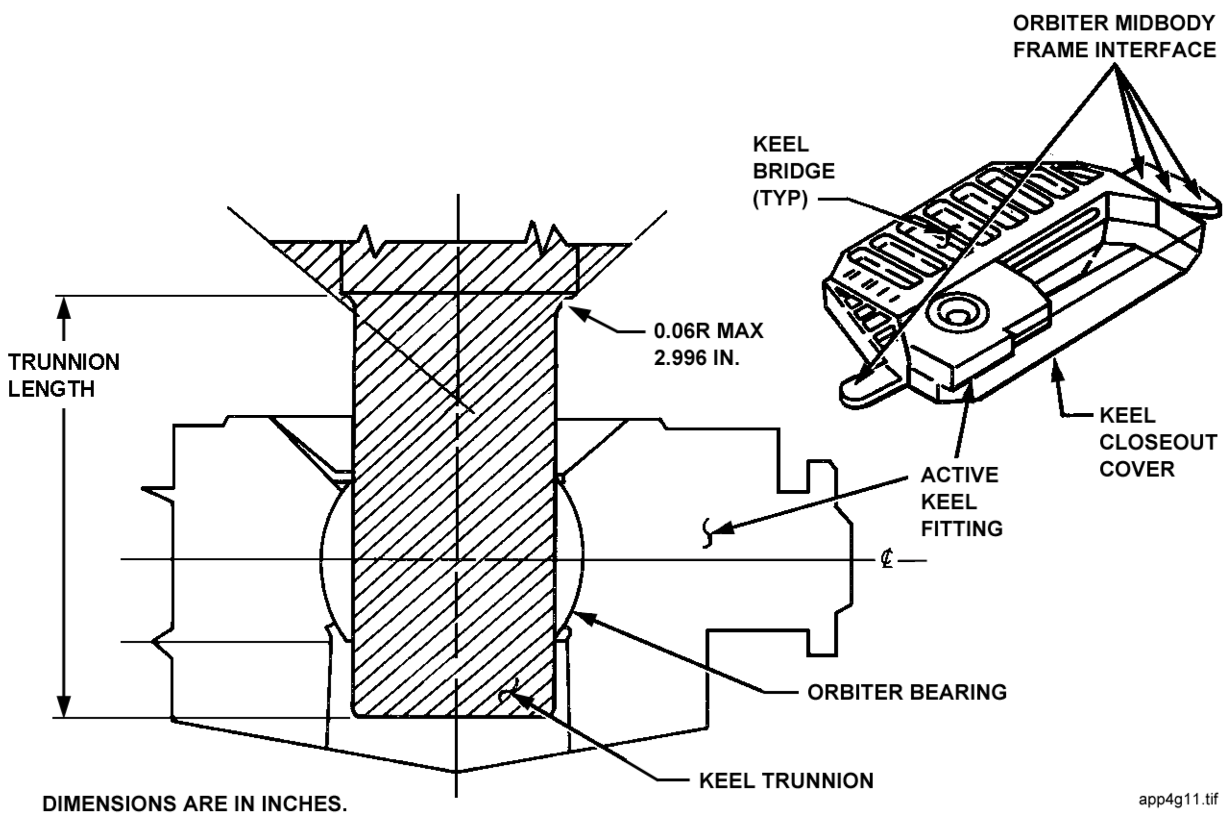

Figure 2-9.- Payload keel fitting and trunnion.

2.5 Orbiter Payload Attachment Locations

The SSP provides orbiter attach points at 3.933-inch (10.0-cm) spacing between X_O 612.73 and X_O 1281.4. 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 2-10). Payload trunnion spacing must be compatible with the attach points defined in the ICD 2-19001 or NSTS 21000-IDD-ISS.

2.6 Attachment Point Location Tolerances

Orbiter longeron and keel attachment point location tolerances are defined in the ICD 2-19001 or NSTS 21000-IDD-ISS. These tolerances reflect the unloaded or zero-g condition, and include tolerances for the orbiter payload bay longerons and frames, bridge fittings, and retention hardware.

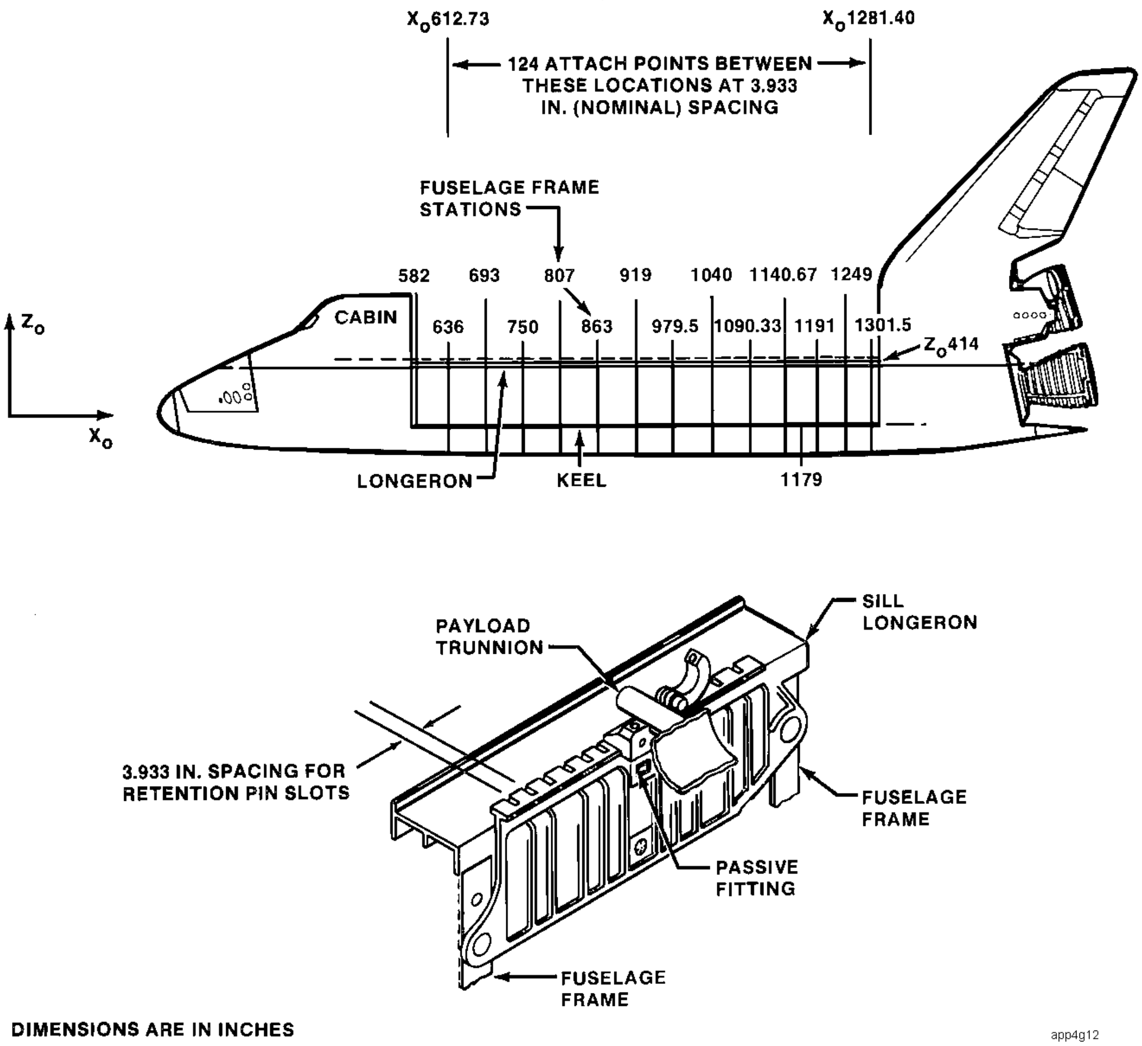

Figure 2-10.- Attach point spacing.

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 radius cargo 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.

Calculation of payload-to-orbiter interface forces required to align payload trunnions with attach fittings can be determined by the root sum square (RSS) of the orbiter and payload planarity errors caused by manufacturing tolerances in conjunction with the orbiter and payload stiffnesses and thermal distortions. Refer to ICD 2-19001 or NSTS 21000-IDD-ISS for details on the methodology for calculating planarity errors.

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 or NSTS 21000-IDD-ISS for details.

2.7 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 center-of-gravity (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 or NSTS 21000-IDD-ISS, while final c.g. calculations must be performed by SSP. Maximum orbiter liftoff weight is 256,000 pounds, and nominal end-of-mission (EOM) landing weight is 230,000 pounds.

Payload Design

3

Significant loading of payload structure occurs during various Space Shuttle mission events. Major mission events include liftoff, high-Q boost, solid rocket booster (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. Liftoff and landing are transient, dynamic events that usually produce the most severe payload structural loads environments. In addition, on-orbit events such as reaction control system (RCS) and/or orbital maneuvering system (OMS) firing, RMS berthing, docking, and crew induced loading can cause significant loading, particularly when the payload changes configuration in orbit. 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 Payload Integration Plan (PIP), Mission Integration Plan (MIP), or Integration Plan (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 ICD 2-19001 or NSTS 21000-IDD-ISS. For liftoff 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 as an optional service. 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 a verification loads analysis using test-verified payload math models for the specific cargo manifest. To support this analysis, the customer must supply the SSP with test-verified math model(s) that meet the requirements defined in NSTS 14046, Payload Verification Requirements. The verification loads analysis process, template, loads environments, and math model data requirements are given in Structural Integration Analyses Responsibility Definition for Space Shuttle Vehicle and Cargo Element Developers, NSTS 37329.

3.1 Payload Design Loads

The cargo limit-load factor and angular acceleration environments are defined in ICD 2-19001 or NSTS 21000-IDD-ISS for preliminary design of payloads and payload carriers. Cargo elements and secondary structure generally experience maximum accelerations at liftoff and landing. Coupled Space Shuttle/cargo element transient analyses are generally performed to determine cargo element design loads for liftoff and landing events. Ascent, on-orbit, and entry flight conditions are also design conditions.

Cargo load factor/angular acceleration is defined as the total externally applied force/moment on the cargo divided by the corresponding cargo weight/mass moment of inertia, and carries the sign of the externally applied force/moment in accordance with the orbiter coordinate system. The load factors/angular accelerations will be considered in all combinations for each flight condition. The load factors/angular accelerations are valid for any location in the payload bay.

Transient flight events correspond to conditions for which external forces are highly transient and produce significant dynamic response. Space Shuttle liftoff and landing are events of this type. The associated cargo responses depend on cargo geometry, stiffness, and mass characteristics. The transient load factors for liftoff and landing found in the ICD 2-19001 or NSTS 21000-IDD-ISS 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 loads 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.

Returnable and nonreturnable payload definitions and design criteria are defined in ICD 2-19001, NSTS 21000-IDD-ISS, and NSTS 37329. Landing loads for all payloads are considered to be design limit load conditions and require appropriate factors of safety.

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 flight crew 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 vernier reaction control system (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 or NSTS 21000-IDD-ISS. 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 ICD 2-19001 or NSTS 21000-IDD-ISS. 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 as a negotiated service.

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 ICD 2-19001 or NSTS 21000-IDD-ISS for preliminary loads analysis. The SSP can provide a detailed design and/or loads analysis of RCS plume impingement as an optional service.

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 or NSTS 21000-IDD-ISS.

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 or NSTS 21000-IDD-ISS. 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.

3.2 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 or NSTS 21000-IDD-ISS. 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 will 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. The acoustic environment in the payload bay is defined in sound pressure levels over the frequency range of 31.5 to 2500 Hz.

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 or NSTS 21000-IDD-ISS. 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, and orbiter main engines. The maximum allowable payload-induced shock at the orbiter/payload interface is also defined in the ICD 2-19001 or NSTS 21000-IDD-ISS.

3.3 Flight Control Interaction

The single/multiple payload frequency requirements cover both multiple and single payloads of both nominal and heavy weights. The requirements are based on the mass and modal characteristics of payloads and payload constraint systems. The minimum acceptable constrained frequencies are provided in the ICD 2-19001 or NSTS 21000-IDD-ISS. 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 payload bay doors closed. For frequency and stiffness requirements during RMS operations, see NSTS 07700, Volume XIV, Appendix 8.

These guidelines were developed by the SSP with an assumed structural damping of 1 percent of critical damping for the payload. Payloads which do not meet these flight control interaction criteria must be assessed by the SSP to determine if any flight-unique control system parameters will be required.

3.4 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. Specific factors of safety are defined in Structural Design and Test Factors of Safety for Spaceflight Hardware, NASA-STD-5001.

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

Small Payload Accommodations

4

Payloads that utilize Small Payload Accommodations (SPA) shall be designed in accordance with the requirements specified in Shuttle/Payload Interface Definition Document for Small Payload Accommodations, NSTS 21000-IDD-SML.

Small payloads are structurally attached to a side-mounted longeron beam such as an APC (Figure 4-1), an ICAPC, or an SPA GAS adapter beam.

4.1 Attachment/Installation

Sidewall-mounted adapter beams are attached to points on the payload bay longeron and frames, and utilize standard orbiter bridge mounting hardware. Adapter beams are supplied by the SSP and are positioned on the side of the payload bay (Figure 4-2). Payloads can be attached to the adapter beams utilizing the attach points identified in NSTS 21000-IDD-SML.

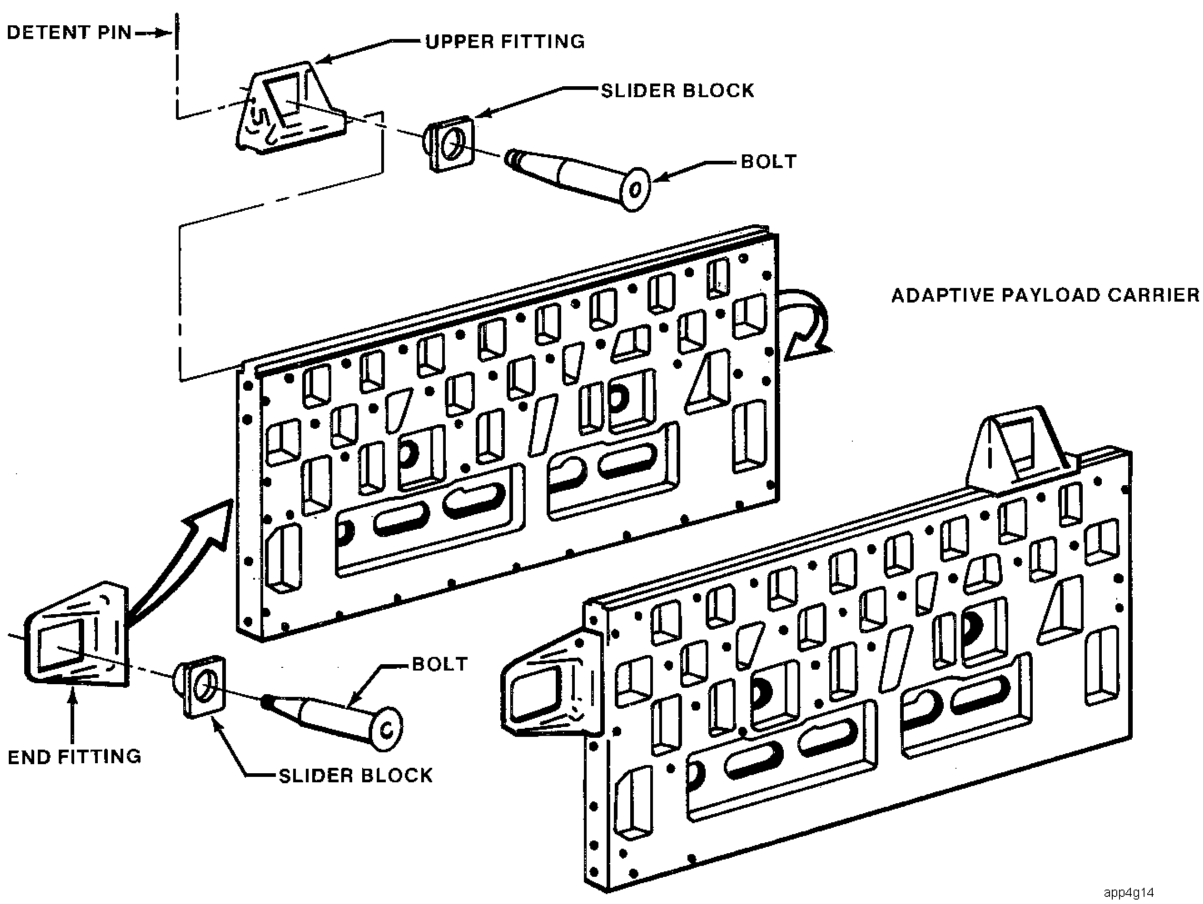

Figure 4-1.- Adaptive payload carrier (APC).

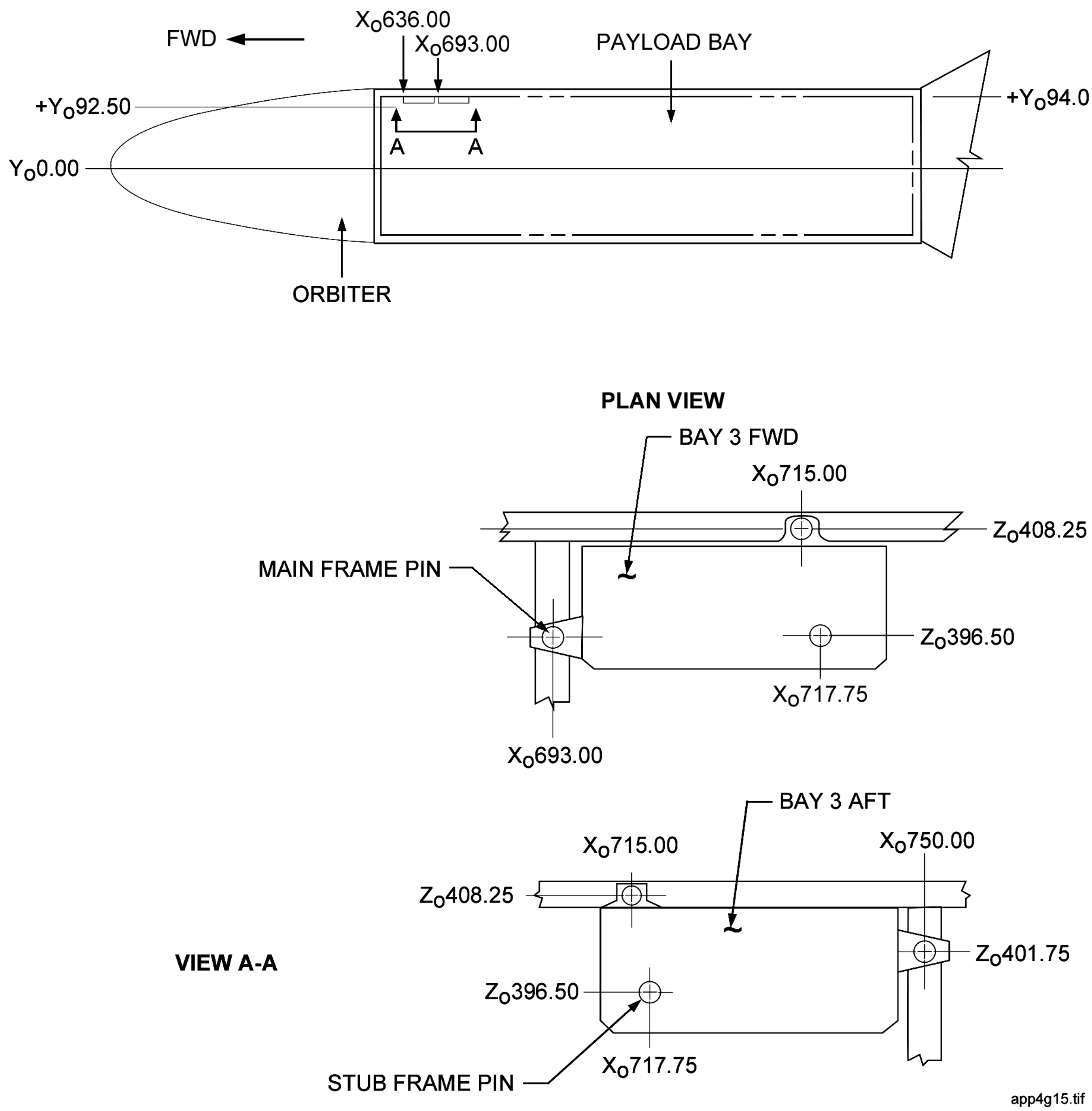

Figure 4-2.- Orbiter/ICAPC/APC attach point locations (typical for bay 3).

The APC can support payload weights up to approximately 300 pounds (136.1 kg) and the ICAPC can support payload weights up to approximately 500 pounds (226.8 kg).

Small payloads are structurally attached to the ICAPC beam in a manner similar to the APC. Payload attach hardware for the APC and ICAPC shall be supplied by the customer.

The SPA GAS adapter beam is a full-bay sidewall carrier attached to the main frame and sill longeron. Two canister payloads weighing approximately 350 pounds each or 700 pounds (317.5 kg) total can be attached to the SPA GAS adapter beam. There are a total of 32 attach locations that mount small payloads to the SPA GAS adapter beam.

SPA GAS limit load generic weight capabilities are defined in NSTS-21000-IDD-SML. These tables are to be used as a guide. Additional assessment is required for cases not listed in the tables and for weights approaching the limits.

4.2 Design Loads

The payload design loads discussed in section 3 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 3.

4.3 Vibration and Acoustic Loads

Liftoff/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 liftoff 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.

4.4 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.

Crew Compartment (Middeck) Payload Accommodations

5

Payloads that utilize orbiter crew compartment middeck accommodations should be designed to satisfy the requirements specified in Shuttle/ Payload Interface Definition Document for Middeck Accommodations, NSTS 21000-IDD-MDK. Accommodation of a payload in the middeck depends on payload size, the number of crew, and stowage volume required for crew equipment. Standard stowage lockers are provided for middeck payloads. Special adapter plates are available for experiments or payloads that do not fit in a standard stowage locker.

Middeck payload structural installation locations are shown in Figure 5-1. There are two typical locations for attaching payloads in the middeck area: (1) the aft wire tray structure of avionics bay 1 and avionics bay 2, and (2) the forward wire tray structure of avionics bay 3A.

Hardware, including bolts for attaching payloads, mounting plates, or panels, will be provided by the SSP for standard installation. For middeck payloads which require nonstandard attachment hardware, the customer must furnish appropriate flight-approved payload attachment hardware.

Middeck payloads that are removed from stowage lockers or adapter plates and attached to other crew compartment structure during on-orbit operations must show structural integrity for VRCS, PRCS, and OMS environments.

5.1 Standard Middeck Locker

The standard middeck locker and its inside dimensions are shown in Figure 5-2. Each locker provides 2 cubic feet (0.057 m^3) of stowage volume.

Locker structural provisions include SSP-provided large or small trays and foam inserts that can be placed in the trays to cushion stowed items. Tray dividers for equipment separation are also available. Elastic restraints, located in the trays, prevent equipment from floating out when the lockers are opened on orbit. Payloads that cannot be stowed in trays may be stowed directly in a locker. However, the payload must be surrounded by vibration-isolation foam and incorporate zero-g retention if on-orbit activities are required.

When a standard stowage locker is used and access to the experiment (for power, cooling, or crew attention) is necessary, a modified locker access door with three removable panels is available. Any or all panels may be removed without affecting the structural integrity of the locker.

For more information on middeck payloads, refer to NSTS 21000-IDD-MDK.

5.2 Special Middeck Stowage Provisions

Special stowage provisions are available for payloads that are not stowed in middeck lockers, including single and double adapter plates and payload mounting panels. Any payload that replaces a middeck locker must attach to an SSP-provided plate or panel; no payload may attach directly to the orbiter wire trays.

Experiments may be attached to a single adapter plate or payload mounting panel. The single adapter plate has a universal hole pattern for attaching payloads (Figure 5-3).

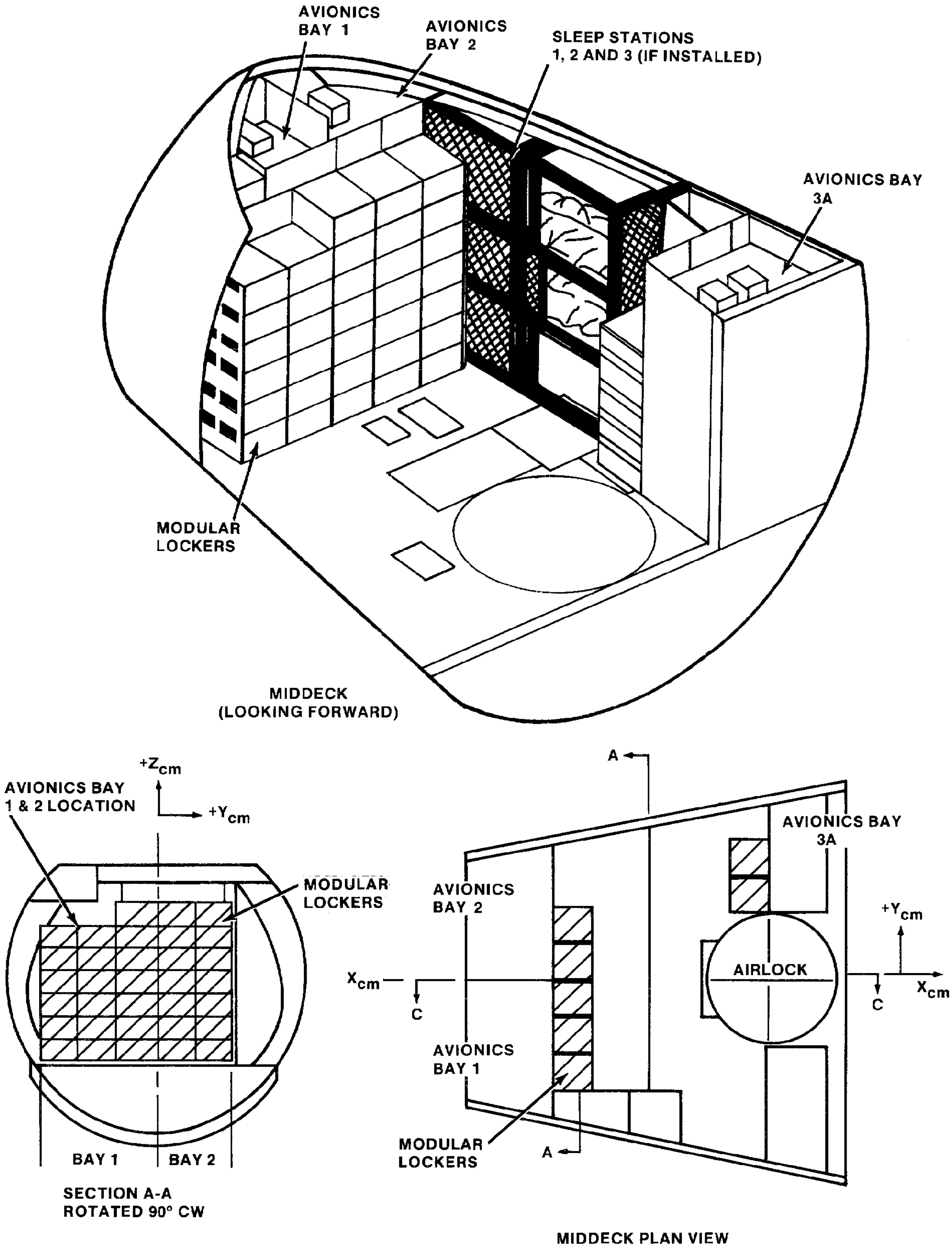

Figure 5-1.- Middeck payload structural locations.

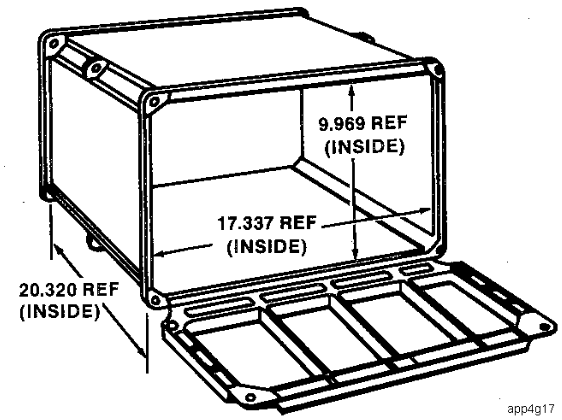

Figure 5-2.- Standard middeck modular locker.

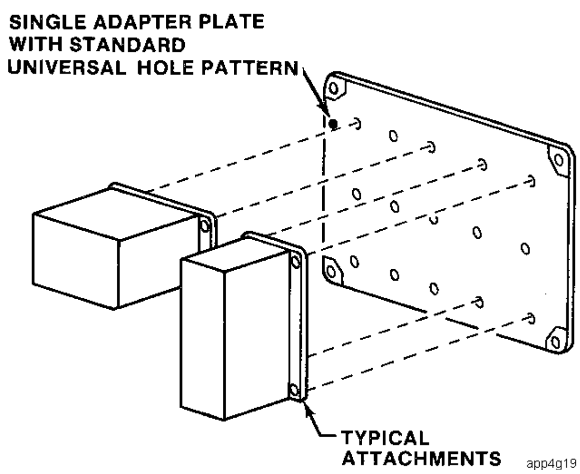

Figure 5-3.- Stowage and mounting provision - single adapter plate.

When a payload or experiment is larger than one middeck locker, a double adapter plate or two payload mounting panels may be used. The double adapter plate provides a universal hole pattern and attaches to either two single adapter plates or two payload mounting panels (Figure 5-4). A payload may attach directly to two payload mounting panels without using a double adapter plate (Figure 5-5). For more information about middeck payload mounting provisions, refer to NSTS-21000-IDD-MDK.

5.3 Middeck Accommodations Rack

The middeck accommodations rack (MAR) is designed to accommodate middeck experiments larger than double-locker replacements. The MAR (Figure 5-6) has an internal volume of approximately 15 cubic feet (0.42 m^3) and can accommodate payloads weighing up to 340 pounds (154 kg). The MAR is located on the port side of the middeck aft of the galley (Figure 5-7). It is adaptable to several payload/experiment configurations. Experiments in the MAR can be powered from the middeck utility panel or any middeck outlet. Experiments may be passively cooled by heat dissipation through the MAR/orbiter structure. Active cooling, up to 1000 watts, is available through the MAR cooling module, using the payload heat exchanger loop. For more information, see Shuttle Orbiter/MAR Cargo Element Interfaces, NSTS-21000-IDD-MAR.

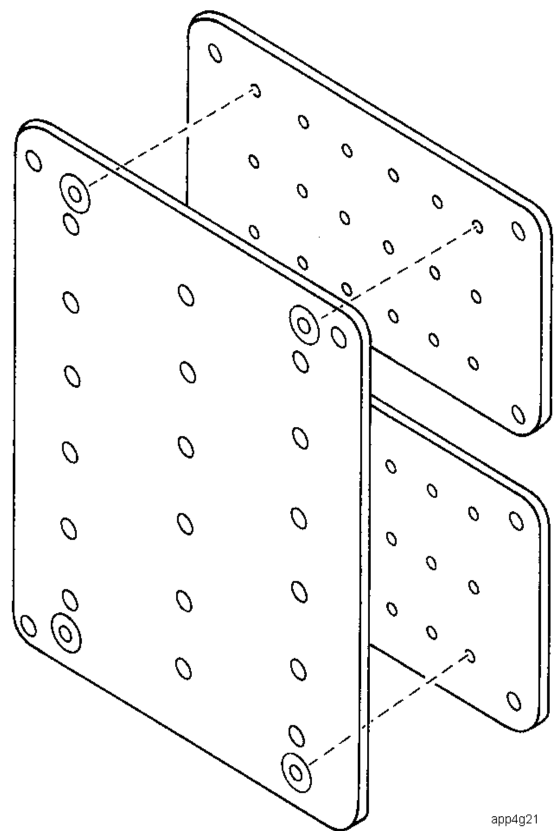

Figure 5-4.- Mounting provisions for double adapter plate.

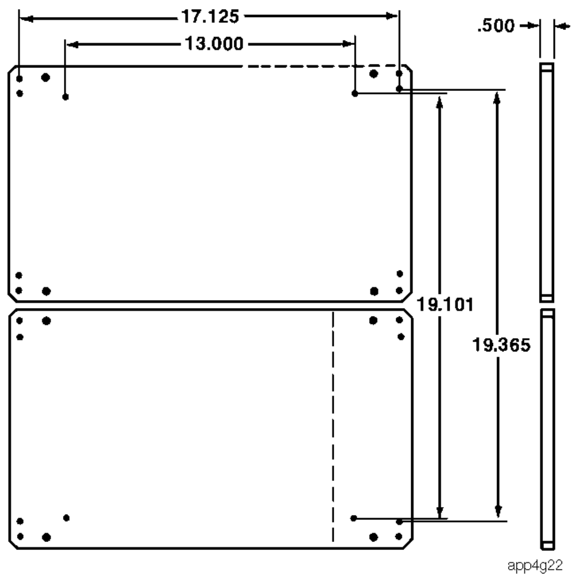

Figure 5-5.- Payload mounting panel installation.

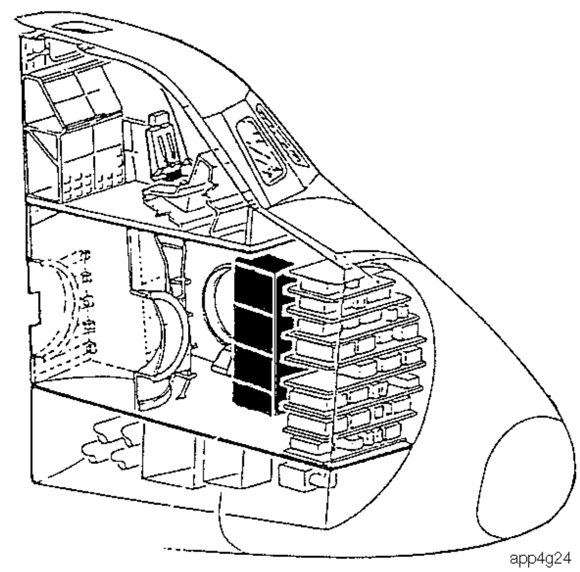

Figure 5-7.- MAR location in the middeck.

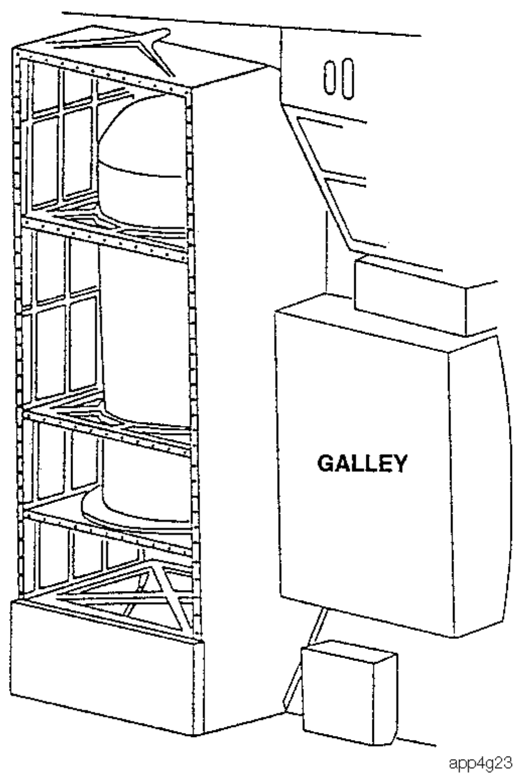

Figure 5-6.- MAR payload/experiment configuration.

Get-Away Special Payload Accommodations

6

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 6-1).

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.

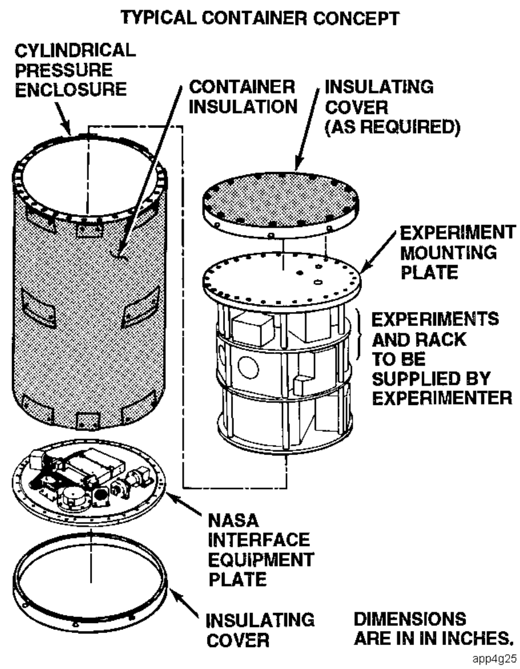

Figure 6-1.- GAS payload canister and typical payload.

Materials and Processes Applications

7

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 or NSTS 21000-IDD-ISS. 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 Lyndon B. Johnson Space Center (JSC).

Several organizations have intercenter agreements with JSC that address all M&P requirements in NSTS 1700.7B and ICD 2-19001 or NSTS 21000-IDD-ISS. 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.

7.1 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 SSP Safety Panel 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 FLAGRO.

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

7.2 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.

7.3 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 7-I.

TABLE 7-I.- 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

Figure 7-1 is a flammability analysis flowchart which can be used for any oxygen concentration listed in Table 7-I. For example, a payload in the payload bay can follow the flowchart and evaluate materials at 20.9 percent oxygen at 14.7 psia.

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 extravehicular activities (EVA). 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. Small material usages shall not be considered a propagation hazard.

Payloads or materials 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 Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion, NHB 8060.1.

7.4 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:

a. 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.

b. 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.

c. 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.

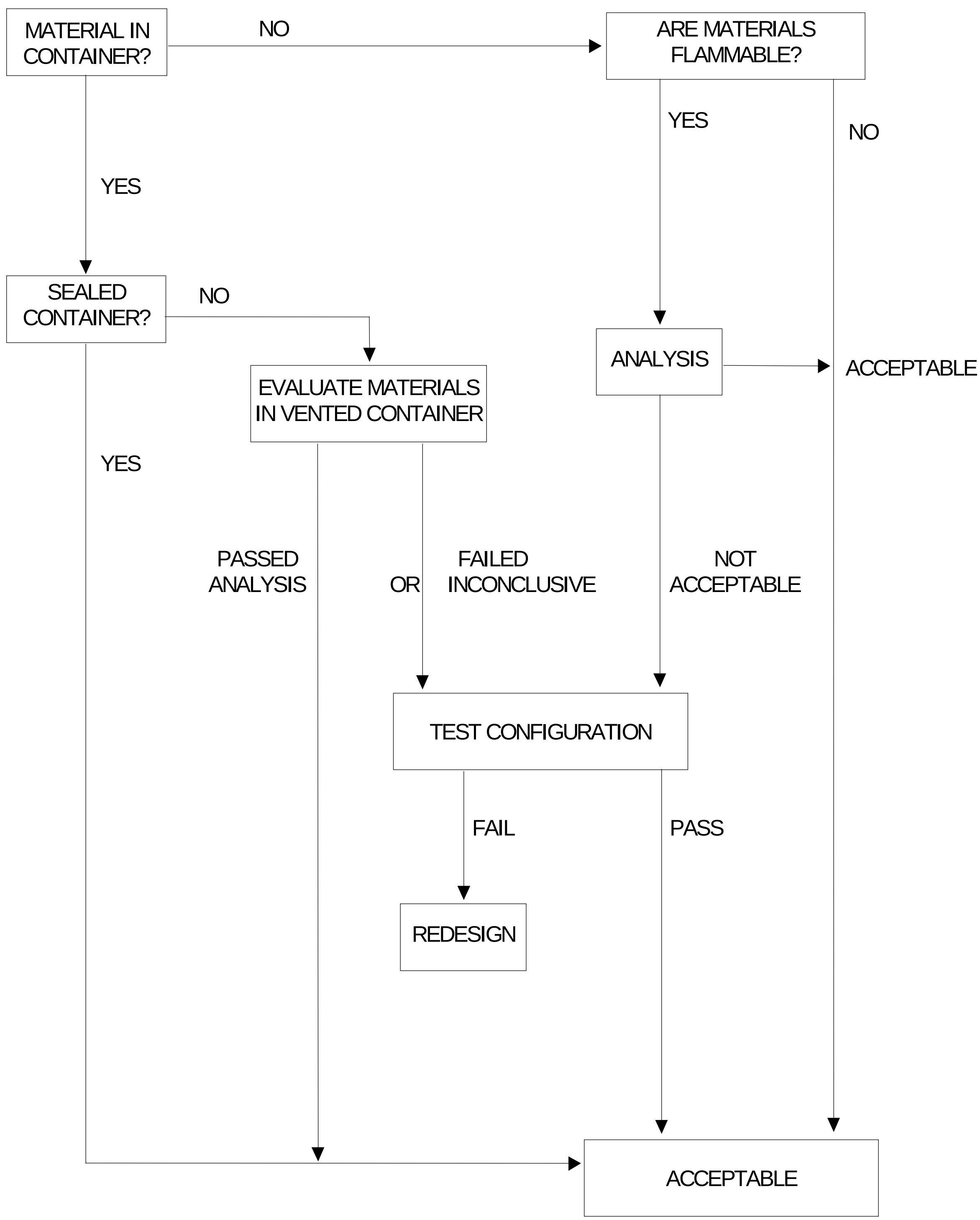

Figure 7-1.- Materials flammability logic chart.

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 degrees F or lower. If the system can operate at temperatures higher than 160 degrees 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 degrees F.

7.5 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 NSTS 07700, Volume XIV, Appendix 1. 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.

7.5.1 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 degrees F (or the maximum use temperature) and analyzing samples to determine the identity and quantity of each gas emitted. Such testing can be conducted for the customer by NASA. Figure 7-2 is a flow diagram of the offgassing assessment process.

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:

a. 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.

b. 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.

c. 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.

d. 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.

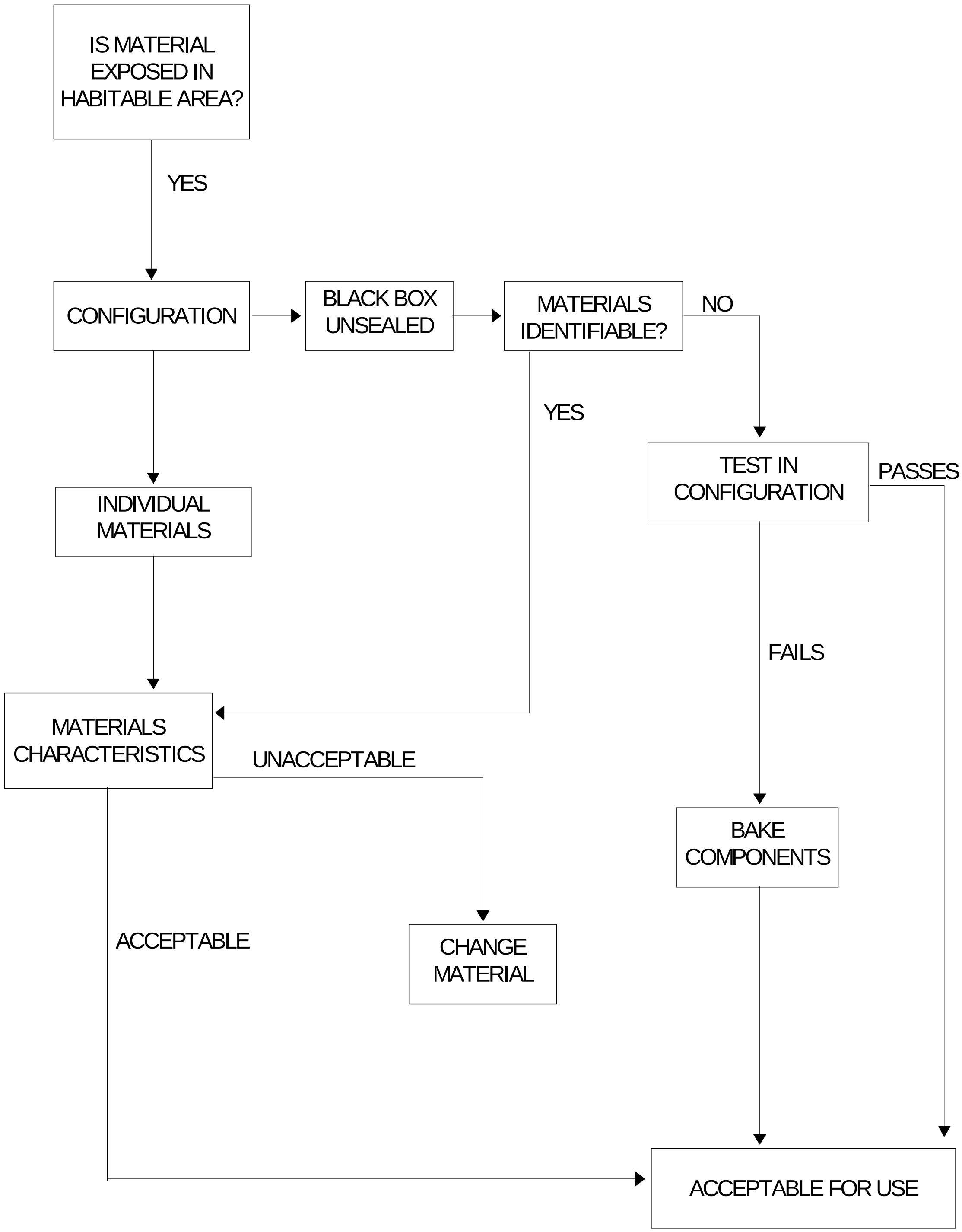

Figure 7-2.- Toxic offgassing evaluation logic for all manned compartment payloads.

7.5.2 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. General guidelines for materials evaluation are given in the outgassing flow diagram (Figure 7-3). In the figure, a dedicated mission refers to a payload which occupies the entire payload bay. 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 servicing missions) where the primary payload is highly sensitive to contamination.

7.6 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.

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

7.7 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.

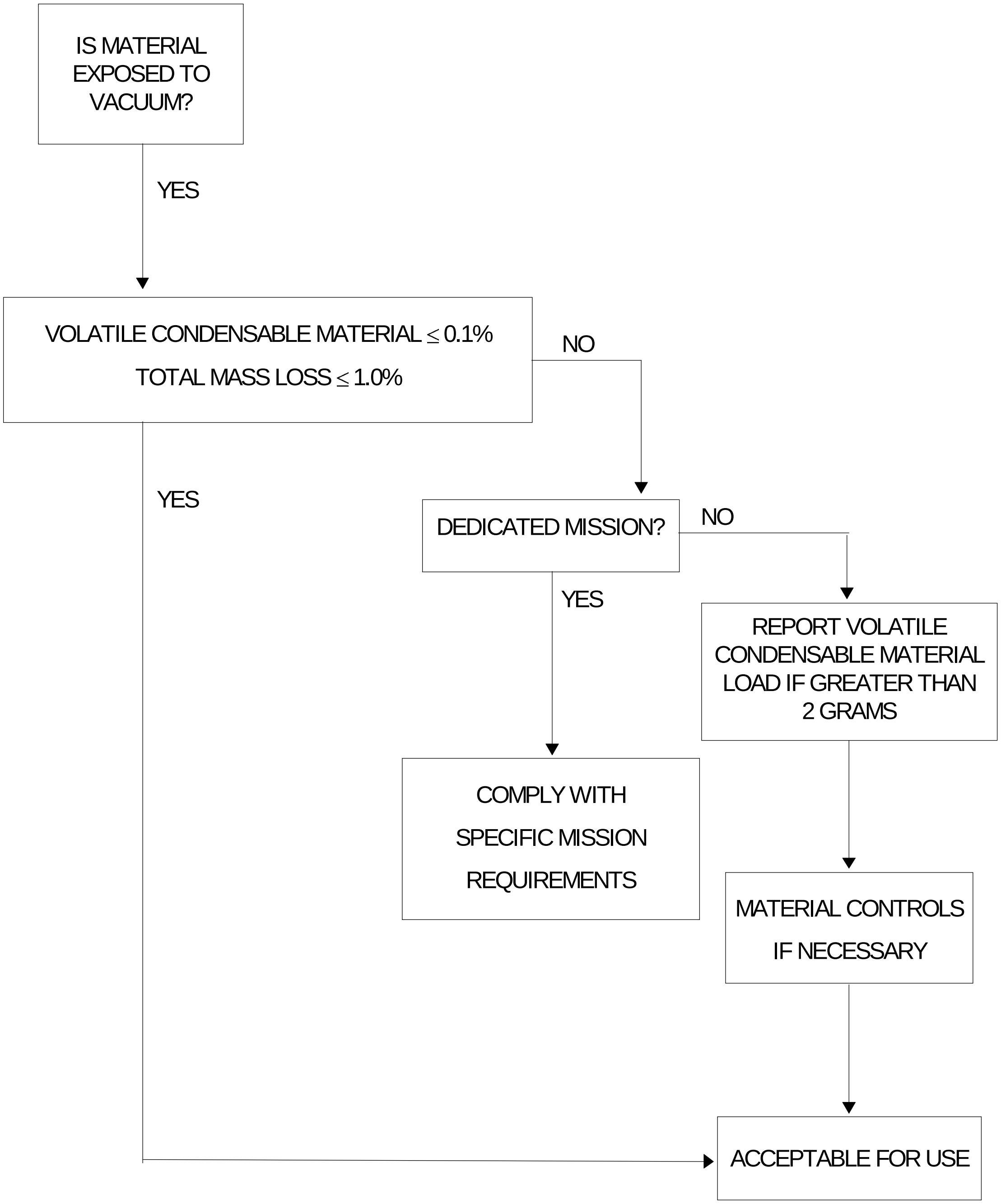

Figure 7-3.- Outgassing flow diagram.

Structural Interface Verification Requirements

8

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 for each flight is defined in NSTS 14046.

8.1 Payload Structural Verification

The objectives of the structural interface verification program are to verify (by tests, inspections, and analyses) that payload structural hardware is compatible with the Space Shuttle. Payload structural interface verification includes all interface verification activities performed at customer facilities, followed by launch site verification testing. Safety requirements applicable to all Space Shuttle payloads, airborne support equipment (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. The payload structural interface verification analysis process for payload bay payloads progresses in the following manner:

Integration Plan (IP) can be either a Payload integration plan (PIP), a Mission integration plan (MIP), or an Integration Plan. 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.

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 certification information.

Preliminary Verification Loads Review (PVLR). The PVLR is held a few months prior to model delivery. It is conducted 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).

Payload model delivery. All models, whether the payload is across-the-bay or sidewall, primary or secondary, are delivered to the SSP by the customer. This delivery begins the verification loads analysis cycle. The model is checked to ensure that it is complete and ready for coupling.

Loads data dump. As a result of the coupled loads analysis, loads and displacement data are transmitted to customers for analysis of individual payloads.

Loads Report. The formal report documenting the verification loads analysis is released.

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).

8.2 Shuttle/Payload Structural Interface Verification

The payload and orbiter will be checked out independently before structural mating by the 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 cargo will be verified by the SSP, primarily during checkout, but in some cases by analyses and/or inspection as well as maintenance. The SSP checkout and verification of payload structural interfaces on the orbiter will meet the same criteria governing other orbiter interfaces. After payload installation in the orbiter, structural interface verification checkouts and inspections will be used to determine a “go” condition. These payload verification requirements are documented in OMRSD file II, Volume II. Payload submittals for OMRSD file II, Volume II are entered into the NSTS 08171, OMRSD system for review and approval. These requirements are employed by launch site organizations to prepare detailed test procedures. Documentation (certification of compliance) by the SSP of satisfactory completion of each mechanical interface verification is necessary to formally satisfy payload and Space Shuttle interface requirements and identify compliance with interface control documentation. NSTS 08171 is the single authoritative source for technical test and checkout requirements which must be satisfied to ensure flight and ground readiness to support Space Shuttle and cargo prelaunch, launch, and turnaround operations. Further information about ground operations is found in NSTS 07700, Volume XIV, Appendix 5.

Acronyms and Abbreviations

9

ALT	alternate
APC	adaptive payload carrier
ASE	airborne support equipment
CCR	Cargo Compatibility Review
c.g.	center of gravity
CIR	Cargo Integration Review
EOM	end of mission
EVA	extravehicular activity
F	Fahrenheit
FRR	Flight Readiness Review
GAS	Get-Away Special
GSE	ground support equipment
GSFC	Goddard Space Flight Center
Hz	hertz
ICAPC	increased capability adaptive payload carrier
ICD	interface control document
IDD	interface definition document
IP	integration plan
JSC	Lyndon B. Johnson Space Center
kg	kilogram(s)
M&P	materials and processes
MAPTIS	Materials and Processes Technical Information System
MAR	middeck accommodations rack
MDM	manipulator deployment mechanism
MEOP	maximum expected operating pressure
MIP	Mission Integration Plan
MSFC	George C. Marshall Space Flight Center
MUA	material usage agreement
MWLL	middleweight longeron latch
NASA	National Aeronautics and Space Administration
NDI	nondestructive inspection
ODS	Orbiter Docking System
OMRSD	Operations and Maintenance Requirements and Specifications Document (NSTS 08171)
OMS	orbital maneuvering system
PAT	payload accommodation terminal
PIP	payload integration plan
PRCS	primary reaction control system
psia	pounds per square inch absolute
PVLR	Preverification Loads Review
RCS	reaction control system
RMS	remote manipulator system
RSS	root sum square
RTG	radioisotope thermal generator
SIP	standard interface panel
SMAC	Spacecraft Maximum Allowable Concentration
SPA	small payload accommodations
SRB	solid rocket booster
SSP	Space Shuttle Program
THI	Toxic Hazard Index
VAR	Verification Acceptance Review
VCM	volatile condensable material
VRCS	vernier reaction control system

Glossary

10

Aft flight deck:
That portion of the crew compartment upper deck dedicated to orbital operations, including the payload station, mission station, and on-orbit station.

Airborne support equipment (ASE):
Refers to cargo element-supplied onboard equipment items and systems required for operation of specific cargo elements during flight. As used in this document, this term is synonymous with payload support equipment, aerospace support equipment, and space support equipment.

Angular acceleration:
The total moment from all external forces acting on a payload about a given principal axis of the payload divided by the payload inertia about that axis.

Berthing:
The process of using the RMS to softly bring together an orbital element and the orbiter; for example, positioning a payload on the repair/ maintenance support fixture in the payload bay.

Cargo:
The total complement of cargo elements (one or more), including support equipment, carried on any one flight. In other words, everything contained in the orbiter payload bay plus other equipment, hardware, and consumables located elsewhere in the orbiter that are user unique and not carried onboard as part of the basic orbiter.

Cargo element:
The total complement of specific instruments, space equipment, support hardware, and consumables carried in the orbiter (but not included as part of the basic orbiter cargo element support) to accomplish a discrete activity in space. A cargo element is functionally independent of other cargo elements within a cargo.

Cargo element customer:
Owner/operator of any Space Shuttle cargo element.

Cargo element-provided:
Provided by the cargo element supplier, whether a private or government agency. This category includes items supplied by a sponsoring government agency as an adjunct to a specific cargo element.

Commonality:
The shared usage of technical or programmatic items among Space Shuttle system elements. Element requirements may permit common usage either in identical or similar configurations.

Contamination:
Particles or molecules that may deposit on a payload surface or inhibit/affect field of view.

Coupled loads:
Loads determined by transient analysis of the combined Space Shuttle and payload system, subjected to external forces during events such as liftoff and landing.

Deployable payload:
A payload planned for deployment from the Space Shuttle and only returned under a mission abort condition.

Deployment:
The process of removing an orbital element from a stowed or berthed position in the payload bay and releasing it to a position free of the orbiter.

Emergency:
Any condition that can result in crew injury or threat to life and requires immediate corrective action, including predetermined crew response.

Experiment:
An instrument or group of instruments and associated support equipment used to conduct research or to perform useful tasks in space.

Extravehicular activity (EVA):
Crew activities conducted outside the spacecraft pressure hull or within the payload bay with the payload bay doors open.

Fail safe:
A design philosophy under which a structure is designed with sufficient residual strength or adequate fracture arrest capability to sustain limit loads in a damaged condition.

Flaw:
A local discontinuity in a material, such as a crack, scratch, notch, or void.

Flight:
That portion of a mission encompassing the period from launch to landing or launch to termination of the active life of a spacecraft. The term Space Shuttle "flight" means a single Space Shuttle round trip—launch, orbital activity, and return. (One flight might deliver more than one payload. More than one flight might be required to accomplish one mission.)

Fracture control:
The application of design methodology, manufacturing technology, inspection techniques, and operating procedures to prevent structural failure due to the initiation or propagation of flaws during the service life of a structural member.

Fracture mechanics:
An engineering concept used to predict flaw growth and fracture behavior of materials and structures containing flaws or crack-like defects.

Ground support equipment (GSE):
Refers to those cargo element-supplied items and systems required for servicing, testing, handling, transporting, or protecting specific cargo elements during preflight or postflight operations.

Instrument:
A mechanical, optical, electrical, or electronic device for conducting experiments or performing useful tasks in space. Instruments observe, sense, or process materials and data, or manipulate other devices used for observation, sensing, and processing of data or materials – for example, camera, laser, telescope, furnace, etc.

Launch pad:
The area from which the Space Shuttle is launched. The stacked Space Shuttle undergoes final prelaunch checkout and countdown at the launch pad.

Limit load:
The expected load during any Space Shuttle flight event.

Load factor:
The sum of all external forces acting on a payload in any one axis divided by the payload weight.

Margin-of-safety:
A ratio of the excess strength to the required strength minus 1.

$$MS = \frac{AS}{ALS \times SF} - 1$$

where
AS = allowable stress
ALS = applied limit stress (or load)
MS = margin of safety
SF = safety factor

Mathematical model:
A finite element representation of a structure in the mathematical representation of mass and stiffness, or vibration mode shapes and frequencies.

Maximum expected operating pressure (MEOP):
The maximum expected operating pressure in a pressure vessel throughout its entire operating period.

Merging:
Coupling of two or more structural dynamic math models. Each model may be in the form of mass and stiffness or mode shapes and frequencies.

Mission:
A coherent set of investigations or operations in space to achieve program goals – for example, to measure the detailed structure of the Sun's chromosphere or survey mineral resources of North America.

Mixed cargo:
Term used when more than one cargo element is carried in the orbiter payload bay. These cargo elements are generally under the cognizance and control of more than one user or discipline, and no overall mission manager has been designated. Mixed cargoes include all associated user-provided ASE required to operate the cargo elements in space.

SSP-provided:
Provided by NASA or one of its contractors to supplement the basic orbiter. This category does not include items supplied by a sponsoring government agency as an adjunct to a specific cargo element.

Orbiter Processing Facility (OPF):
The building at KSC with two bays where the orbiter undergoes postflight inspection, maintenance, and premate checkout prior to payload installation.

Outgassing:
Molecular outflow from a material due to its surrounding environment.

Payload:
As used in this document, payload is synonymous with cargo element.

Payload carrier:
A special class of cargo element support equipment attached in the payload bay to provide support to, and/or deliver, one or more cargo elements to accomplish objectives assigned to the cargo elements. Carriers are identified as habitable modules, such as Spacelab, and attached but uninhabitable modules, such as pallets, free flyers, satellites, and propulsive stages.

Prelaunch:
Time period when the Space Shuttle vehicle is situated on the launch pad being prepared for launch, and lasting until the start of the liftoff sequence.

Pressure vessel:
For Shuttle applications, any structure which (1) contains stored energy of more than 0.01 pound of TNT equivalent, (2) will experience a design pressure greater than 100 psi, or (3) contains a gas or liquid which will create a hazard if released.

Primary structure:
The primary load path into the orbiter for all payload hardware.

Random vibration:
A structural response associated with excitation of a random nature from sources such as rocket engine thrust, acoustics, *etc*.

Retrieval:
Utilization of the RMS and/or other handling aids to return a captured orbital element to a stowed or berthed position. No orbital element is considered retrieved until it is fully stowed for safe return or berthed for repair/ maintenance tasks.

Returnable payload:
A payload planned for return from orbit by the Space Shuttle, whether on the mission on which it is launched, or on subsequent missions.

Safe life:
A design philosophy that ensures crack propagation to failure will not occur in the expected operational environment during the specified service life of the structure or between inspection intervals.

Safety factor:
A factor which is multiplied by the limit load to produce ultimate load.

Service life:
The interval beginning with manufacture of the structure and ending with completion of its specified missions.

Stowing:
The process of placing a cargo element or cargo element component in a retained position in the orbiter for ascent or return from orbit.

Stress corrosion:
Cracking caused by the simultaneous presence of tensile stress and a corrosive environment.

Ultimate load:
Safety factor times limit load.

Vehicle Assembly Building (VAB):
Building at KSC with four high bays for vertical storage of ETs and stacking of Space Shuttle elements onto the mobile launch platform.

Warning:
Any existing or impending condition or malfunction of a system that would adversely affect crew safety or compromise primary mission objectives. Immediate action by the crew is required.

Wire:
A single metallic conductor of solid, stranded, or woven construction designed to carry current in an electrical circuit. The wire may be bare or insulated, but does not have a metallic covering, sheath, or shield.

Wire harness:
One or more wires or cables and their terminations, mechanically held together, routed, and installed as a unit.

Wiring:
Wire and cable, including terminations.

Bibliography

11

Documents Referenced in this Appendix

1. NSTS 07700, Volume IV, Configuration Management Requirements

2. ICD 2-19001, Shuttle Orbiter/Cargo Standard Interfaces

3. NSTS 07700, Volume XIV, Appendix 1, System Description and Design Data – Contamination Environment

4. NSTS 07700, Volume XIV, Appendix 5, System Description and Design Data – Ground Operations

5. NSTS 07700, Volume XIV, Appendix 8, System Description and Design Data – Payload Deployment and Retrieval System

6. NSTS 08171, Operations and Maintenance Requirements and Specifications Document (OMRSD)

7. NSTS 14046, Payload Verification Requirements

8. NSTS 18798, Interpretations of STS Payload Safety Requirements

9. JSC 20584, Spacecraft Maximum Allowable Concentrations for Airborne Contaminants

10. NSTS 21000-IDD-MDK, Shuttle/Payload Interface Document for Middeck Accommodations

11. NSTS 21000-IDD-SML, Shuttle/Payload Interface Definition Document for Small Payload Accommodations

12. NSTS 21000-IDD-ISS, Shuttle/Payload Interface Definition Document for International Space Station

13. NSTS 21000-IDD-MAR, Shuttle Orbiter/MAR Cargo Elements Interfaces

14. NSTS 22648, Flammability Configuration Analysis for Spacecraft Applications

15. NSTS 37329, Structural Integration Analysis Responsibility Definition for Space Shuttle Vehicle and Cargo Element Developers

16. MSFC HDBK-527 (JSC 09604), Material Selection List for Space Hardware Systems

17. MSFC SPEC-522, Design Criteria for Controlling Stress Corrosion Cracking

18. Get-Away Special (GAS) Small Self-Contained Payloads, Experimenter Handbook

19. NASA-STD-5001, Structural Design and Test Factors of Safety for Space Flight Hardware

20. NASA-STD-5003, Facture Control Requirements for Payloads using the Space Shuttle

21. NHB 8060.1, Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion

22. NSTS 1700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System