NSTS 14046
Revision E

Payload Verification Requirements

Space Shuttle Program

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National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
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DESCRIPTION OF CHANGES TO

PAYLOAD VERIFICATION REQUIREMENTS

CHANGE NO.	DESCRIPTION/AUTHORITY	DATE	PAGES AFFECTED
--	Basic issue/B14046-1	08/--/80	All
REV A	General revision/B14046-2	07/16/82	All
1	Replace section 6.3/B14046-3	11/23/82	12
2	Change Paragraph 5.1.1.1/ B14046-4	04/03/84	6
3	Delete Annex 9 Part I requirements/B14046-5	09/14/84	1,4,5,10, 11,B-1,F-2
4	Update sections 3.3.1, 3.3.2, 3.3.3, 4.0, 5.2.1, 5.2.2, and 5.3.2/B14046-7	09/18/85	v,2,3,4,7, 8,9,9A
	This document is a continuation of the Payload Verification Requirements remaining after annex 9 Blank Book requirements were extracted to create NSTS 21000-A09		
REV B	General revision/R14046-008	03/08/89	All
1	Update table of contents, and section 5.1.3.1/A14046-010	04/06/90	iv,13,13A
2	Update table of contents and add section 5.1.5/R14046-011	04/20/90	iv,13A

DESCRIPTION OF CHANGES (CONTINUED)

PAYLOAD VERIFICATION REQUIREMENTS

CHANGE NO.	DESCRIPTION/AUTHORITY	DATE	PAGES AFFECTED
3	Update section 5.1.1.1/R14046-012	05/29/90	11,11A
4	Update table of contents and sections 5.3 and 5.3.2.1/ R14046-013	11/30/90	v,15,15A, 16
5	Update section 5.1.5/R14046-014	04/26/91	13A
6	Update sections 5.1.1, 5.1.1.2, 5.1.1.3, and 5.1.1.4/R14046-015	10/07/92	4,4A,11, 11A,11B, 11C,11D,12
	Errata to correct sections 5.1.1 and 5.1.1.2k	10/29/92	4,4A,11C
7	Update section 5.2/R14046-018	03/31/94	13A
REV C	Pagination revision to include global change of NSTS and STS to SSP and Space Shuttle respectively, also updates to sections 3.0, 3.1.1, 5.0, and 5.1.2.1/P14046-017	04/01/94	All
1	Update table of content and section 5.1.1.5/R14046-019A	07/08/94	iv,17,17A, 17B
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REV D	General revision/R14046-S060703	07/02/97	All
REV E	General revision/R14046-0021	03/03/00	All

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2	Update section 5.1.1/S061842	07/25/02	5,5A
3	Update table of contents and sections 4.0, 5.2.2, 5.3, and 5.3.1/R14046-0023	08/07/02	vi,4,35, 36,37,37A
4	Update section 5.1.1.9.3/ S061983	08/29/03	27,27A

Note: Date reflects latest approval dates of CR's received by PILS.

NSTS 14046

PAYLOAD VERIFICATION REQUIREMENTS

MARCH 3, 2000

Signed by C. Harold Lambert, Jr.,
dated 07/06/89

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FOREWORD

The Space Shuttle provides many interfaces and services to payloads. These interfaces and services are physical as well as functional and are defined in the following:

a. Interface Control Document (ICD) 2-19001, Shuttle Orbiter/Cargo Standard Interfaces

b. NSTS-21000-IDD-ISS, Shuttle Orbiter/International Space Station (ISS) Interface Definition Document

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

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

In order to maintain personnel safety and Orbiter integrity, and to ensure efficient use of flight and ground systems by all customers, the Space Shuttle Program (SSP) has established the minimum payload requirements for verifying the Payload-to-Shuttle design interfaces.

Payload verification is considered a primary step toward certification of that payload for flight. It is the responsibility of the customer to verify compatibility of payload physical and functional interfaces with the applicable interface agreements. The SSP, however, intends to provide the customer maximum flexibility in determining the manner or method to be used to accomplish this verification. All payload physical and functional compliance is expected to be accomplished prior to installation of the payload in the Orbiter payload bay. Similarly, the SSP is responsible for verifying Cargo Integration Test Equipment (CITE) and Orbiter payload-dependent interface compliance prior to payload installation. This document specifically addresses payload verification.

Any proposed changes to these requirements must be submitted on an SSP Change Request (CR) to the Program Requirements Control Board (PRCB) Secretary. The CR must include a complete description of the change and the rationale to justify its consideration. All such requests will be processed in accordance with NSTS 07700, Volume IV, and dispositioned by the Chair of the Integration Control Board, on a Space Shuttle PRCB Directive (PRCBD).

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1.0 INTRODUCTION

This document establishes the basic requirement for the Space Shuttle Program (SSP) payload verification program and the verification requirements to be documented in the Operations and Maintenance Requirements and Specifications Documents (OMRSD). Depending on cargo and mission classification, the Integration Plan (IP) may be referred to as an IP, a Payload Integration Plan (PIP), or a Mission Integration Plan (MIP). Hereafter in this document, the term “payload” will refer to any payload, cargo element, DTO, DSO, RME, and other technology demonstration activities.

2.0 APPLICABILITY

This document is applicable to all Space Shuttle payloads which will be installed in the Orbiter crew compartment or the payload bay and launched from the National Aeronautics and Space Administration (NASA) John F. Kennedy Space Center (KSC). Exceptions to these verification requirements must be negotiated with the SSP and documented in the appropriate payload IP. This document is also applicable to the SSP for all Orbiter or simulated Orbiter interfaces with a payload.

3.0 BASIC PRINCIPLES OF VERIFICATION PROGRAM

The SSP and the customer have mutual interest in both mission safety and mission success. The primary objective to be accomplished by the verification program is to assure that all payload hardware and software are compatible with the Space Shuttle. This is accomplished by tests, inspections, and/or analyses performed by both the customer and the SSP. For those systems that have catastrophic hazard potential, the verification program will be designed to confirm that the entire integrated flight system (payload and Orbiter) will perform as intended.

The SSP and the customer will conduct extensive tests and analyses of their respective systems prior to integration. Each party, having verified their respective systems, must then decide to what extent interface verification will be conducted. Interface verification testing will then be conducted at the launch site as mutually agreed to by the SSP and the customer. Detailed test procedures will be documented in payload-specific work authorizing documents such as Operations and Maintenance Instructions (OMIs). The OMIs will be written to implement the requirements specified in the OMRSD.

3.1 Payload Stand-alone Verification

Before entering the KSC launch processing flow, the customer must demonstrate compatibility with SSP requirements.

3.1.1 Customer Responsibility.- It is the customer's responsibility to: Satisfy SSP requirements in the design of the payload; perform appropriate tests, analyses and inspections necessary to verify that payload design features controlling hazards have the necessary redundancy/margins and that the design features are not compromised or degraded by exposure to the design environments; verify compliance with all requirements identified in the Orbiter-to-payload Interface Control Documents (ICDs); and develop and institute a verification program for payload systems having catastrophic hazard potential. This verification program will be designed to confirm that the entire integrated flight system (payload and Orbiter) will perform as intended. The individual elements of this program can be accomplished via inspection, analyses and test. The plan that defines this verification program will be submitted as part of the safety assessment reports for Phase I, II, and III Payload Safety Reviews as defined in NSTS 13830 and in SSP 30599 for International Space Station Program (ISSP) cargo elements. The Phase I safety assessment report must identify payload systems having catastrophic hazard potential and reflect the verification approach proposed to confirm intended system performance. The Phase II safety assessment report must contain a verification plan(s) which identifies the test and analytical efforts required to verify intended hardware performance for all systems, with operational hazard potential. The plan(s) must identify the basic content of the test and/or analysis effort along with a summary of the pass/fail criteria and simplified end-to-end schematics/diagrams depicting electrical, mechanical, fluid and software controlled interfaces with clear and consistent nomenclature. The Phase III safety assessment report shall summarize the results achieved by the verification activity and compare the results from all independent verification activities.

3.1.2 Customer Facilities.- These facilities are defined as those manufacturing, development, assembly, and test areas which are controlled by the payload organization and are primarily involved in individual payload or experiment development, test, and checkout. It is within these facilities that the majority of the payload side of the payload-to-Orbiter interfaces will be verified.

3.2 Interface Verification

After the customer has complied with SSP payload stand-alone verification requirements, government facilities are available to provide a simulated Orbiter interface for payload integration testing. The intended use of these facilities is to provide an opportunity to verify design and operational compatibility between the hardware and software prior to installation into the Orbiter. The SSP and the customer shall consider the complexity and criticality of the interfaces between the Orbiter and the payload to determine the benefits/value provided by utilizing these facilities for interface verification.

3.2.1 Lyndon B. Johnson Space Center Facilities.- The NASA Lyndon B. Johnson Space Center (JSC) has several facilities available which provide simulation of Space Shuttle payload and payload interfaces. These facilities can be of significant benefit to the SSP customer in early determination of payload-to-Orbiter interface compatibilities. Included in the JSC SSP verification facility capabilities are the Shuttle Avionics Integration Laboratory (SAIL), the Electronic Systems Test Laboratory (ESTL), the Manipulator Development Facility (MDF), and the Neutral Buoyancy Lab (NBL). The SAIL offers flight fidelity Space Shuttle avionics test capability (hardware and software); ESTL provides the Space Shuttle communications configuration for payload interfaces; the MDF can be used for interface verification of deployable and/or retrievable payloads requiring the Remote Manipulator System (RMS); and the NBL can be used to develop and test payload operations and hardware associated with Extravehicular Activity (EVA). These facilities are available to the SSP customer as a nonstandard service. Dedication of time and resources with respect to these facilities must be planned well in advance of payload delivery to the launch site to assure that problems encountered during testing can be solved prior to required launch readiness dates. Support requirements and schedules are identified in the respective IPs.

3.2.2 Launch Site Facilities.- The KSC Orbiter interface simulation facility and accommodations are described in Space Shuttle System Payload Accommodations, NSTS 07700, Volume XIV, Appendix 5.

3.2.3 Additional Facilities.- Payload Processing Facilities (PPFs) and Hazardous Processing Facilities (HPFs) are available at the launch site. Use of these facilities is a nonstandard service. Activities which may be performed by SSP customers in PPFs and HPFs are described in K-STSM-14.1, Launch Site Accommodations Handbook.

4.0 FLOW OF VERIFICATION PROGRAM

The payload verification program requires preestablished commitments from both the customer and the SSP to minimize interruption to the Orbiter turnaround checkout and payload integration flow.

In order to obtain smooth and timely compliance with verification requirements, the significant activity leading to Space Shuttle Program launch shall proceed in the following manner:

a. The customer shall perform appropriate tests, analyses, and inspections necessary to verify compliance with ICDs or hazard controls and identify requirements for use of SSP facilities and support.

b. The SSP will verify compliance of the Orbiter simulation equipment to the ICD prior to payload testing.

c. Simulated payload-to-Orbiter interface verification will be performed in accordance with the NASA/customer agreements.

d. The SSP will verify the appropriate Space Shuttle interfaces prior to payload installations into the Orbiter. This verification is accomplished in accordance with the Operations and Maintenance Requirements and Specifications (OMRS).

e. SSP standard and payload-unique equipment and/or mission integration hardware and payload bay wiring is installed and verified per the payload premate OMRSD, File II, Vol. 4. A second set of customer-provided payload-unique equipment and/or mission integration hardware may be required to permit testing of the payload interfaces using an Orbiter interface simulation facility. Following installation of the payload/experiment into the Orbiter, flight interface verification will be performed in accordance with SSP/customer agreements as specified in the payload-unique OMRSD, File II, Vol’s 2 & 6.

f. Following Space Shuttle/payload interface verification, payload operations or servicing may be performed in parallel with SSP launch operation using minimal SSP services on a noninterference basis. Services for this activity will normally be limited to Orbiter main dc power, T-0 umbilical, purge air, and physical access.

If additional Space Shuttle services such as Orbiter avionics support are required, the customer requirements are to be submitted and documented in the IP.

5.0 VERIFICATION REQUIREMENTS

The primary objectives of the verification program are to verify by tests, inspection, and/or analysis that the Cargo Element (CE)/payload hardware and software are compatible with the Space Shuttle. Additionally, for those systems that have catastrophic hazard potential, the verification program must verify that the integrated system in-flight configuration will perform as intended.

5.1 Design Requirements and Customer Verification

5.1.1 Structural Requirements.- For the purpose of structural design, analysis and verification, a CE is defined as the entity that is installed in the Orbiter cargo bay and is either retained with Payload Retention Latch Assemblies (PRLAs) for across-the-bay-mounted structures or attached to the Orbiter sidewall for smaller structures. The term component refers to stand-alone experiments and equipment items that are part of a CE and are treated as an entity for the purposes of structural analysis (such as electronic boxes, batteries, electromechanical devices, payloads, etc.). Components also include Orbital Replacement Units (ORUs), stowage items, and Government Furnished Equipment (GFE). The CE developer has the overall responsibility for designing, developing, building, testing, verifying, operating, and ensuring the safety of the CE including all components that are mounted to it.

All CEs and components shall be proven structurally safe and compatible with the Orbiter vehicle for all expected flight environments (i.e., prelaunch, liftoff, ascent and descent quasi-static loading, Orbiter intact abort landing, nominal end-of-mission landing, contingency landing, postlanding, ferry flight, and on-orbit events such as Reaction Control System (RCS), Orbiter Maneuvering System (OMS), RMS and crew induced loads). This requirement encompasses verification of structural strength and life integrity as well as strength verification for certain materials that may be contained within the CE or component. Special attention is given to nonmetallics and brittle materials such as beryllium, ceramics, glass, and composite materials (including honeycomb structures). This requirement also applies to verification of structural bonding techniques, dynamic characteristics, deformations under loading, interface load capability between the CE and the Orbiter, and CEs that are classified as pressurized elements. Structural verification is intended to show that the CE structure and all of its components do not constitute a safety hazard to the Orbiter, its crew, and/or ground personnel. This process is not intended to verify functionality of the CE and its components, which is considered to be a CE developer responsibility.

It is strongly recommended that the CE/component developer consult with the Structures Working Group (SWG) early in the design phase. This recommendation is especially true for any CE/component that does not clearly satisfy all SSP requirements. Noncompliance with the verification requirements specified herein without prior consultation and written approval from the SWG is at the CE/component developer's risk. Early consultation will minimize the risk of the CE or component being disapproved for flight due to noncompliance with SSP requirements. If a CE/component developer does not know who their SWG contact is, the developer shall contact their Payload Integration Manager (PIM). The PIM, through Shuttle Cargo Integration, shall put the appropriate SWG person in contact with the CE/component developer.

It is recommended that structural qualification and other environmental testing be performed on prototype hardware. The use of prototypes eliminates the risk of damaging flight hardware. In addition, due to life and fatigue issues, proto-flight testing is generally not acceptable for hardware that will fly on more than three missions.

5.1.1.1 Loads, Factors of Safety and Stress Combinations: In cases where loads produced by different environments can occur simultaneously, these loads shall be combined in a rational manner to define the limit load for that flight event. For the SSV, the most common types of loads combinations are the transient loads with random vibration loads due to liftoff events and transient loads with thermally induced loads due to landing. Loads due to pressurization effects, venting and installation misalignments shall also be included.

When combining random loads (high frequency) and transient loads (low frequency) loads, several methods are acceptable to the SWG. Standard SWG acceptable methods for combining random with transients are addition and root sum square approaches per NASA-STD-5002. Other combination methods and supporting rationale shall require written approval of the SWG prior to implementation. Loads resulting from the low frequency transient and random vibration environments shall not be combined on a time consistent manner for CE/component design analysis purposes.

The minimum ultimate factor of safety for stresses due to combined loads (e.g., mechanical, pressure, and thermal) shall be determined in a rational manner and shall be equal to or greater than 1.4. The CE developer shall use the equations given below.

Additional details on the equations and the recommended process for combining loads is defined in Appendix P of NSTS 37329, Structural Integration Analyses Responsibility Definition for Space Shuttle Vehicle and Cargo Element Developers. Any deviation from these equations and processes shall be explained in the Structural Verification Plan and requires SWG written approval. Stresses induced into the structure by other loads (e.g., manufacturing, latching, torquing) shall be combined with appropriate factors of safety, but shall not be used as relieving stresses.

$$K_C = \frac{(K_1 S_E + K_2 S_P + K_3 S_T)}{\sum S} \qquad \text{Eqn. 1}$$

where the variables are defined in Table 5.1.1.1-1.

The following restrictions shall apply:

1. In circumstances where pressure stresses have a relieving or stabilizing effect on structural capability, the minimum guaranteed value of the relieving pressure shall be used to determine the stress relief. The stress relief factor of safety shall be 1.0 (i.e., $K_2 = 1.0$) when calculating K_C.

2. Thermal stresses shall be combined with mechanical and pressure stresses when additive but shall not be used for stress relief (i.e., set both S_T and $K_3 = 0.0$).

Table 5.1.1.1-1.- VARIABLE DEFINITION FOR EQN. 1

	Stresses		
Variable	Additive	Relieving	Description
K_1	*FS	1.0	Factor of Safety Associated with S_E
K_2	*FS	1.0	Factor of Safety Associated with S_P
K_3	*FS	0.0	Factor of Safety Associated with S_T
S_E			Stresses due to mechanical externally applied loads (e.g. inertial)
S_P	Stresses due to Maximum Design Pressure (MDP)	Minimum guaranteed pressure	MDP defined in NSTS 1700.7B
S_T			Stresses due to thermally induced loads (not included when relieving)
K_C			Safety Factor for Combined Loads – shall never be less than 1.4
ΣS			$S_E + S_P + S_T$; Assumed to be additive in the direction of primary stress

*FS is factor of safety being applied as approved by the SWG.

The worst case combined stresses depend upon the magnitude and direction of the component stresses. For case- and time-consistent conditions, both the maximum positive stress and the maximum negative stress shall be evaluated based on the following six possibilities:

1. S_E = Primary Positive (e.g., tensile) with associated pressure and thermal stresses.
2. S_E = Primary Negative (e.g., compression) with associated pressure and thermal stresses.
3. S_P = Primary Positive (e.g., tensile) with associated mechanical and thermal stresses.
4. S_P = Primary Negative (e.g., compression) with associated mechanical and thermal stresses.
5. S_T = Primary Positive (e.g., tensile) with associated pressure and mechanical stresses.
6. S_T = Primary Negative (e.g., compression) with associated pressure and mechanical stresses.

Alternatively, a max-on-max, non-case consistent, non-time consistent maximum positive and maximum negative stress conditions may be used to envelope all stress cases.

When stresses are derived from automated stress analysis systems (e.g., finite element models, post-processing programs), a method shall be available to demonstrate that proper signs and safety factors were used for each combined stress case.

5.1.1.2 Documentation Requirements: The CE/component developer shall develop and provide to the SWG a comprehensive Structural Verification Plan (SVP) that specifies how the design and verification requirements of this document will be met. The purpose of this plan is to establish an understanding and agreement between the CE/component developer and the SWG on how the SSP structural requirements will be implemented and verified. Random vibration and acoustic verification approaches including how the expected environments are defined and verified shall also be addressed in the SVP. The required content of an SVP can be found in Appendix K of NSTS 37329. The SVP shall be submitted directly to the SWG at or prior to the Preliminary Design Review (PDR) for SWG review and approval.

In addition to the SVP, the following documents shall be submitted, reviewed and approved in writing by the SWG before a CE/component will be certified as complying with the SSP structural verification requirements: modal test plan, model verification and correlation report, strength/static model verification test plan, strength test report and static model correlation report. Specialized documents, reports, etc., shall be delivered to the SWG for review and approval upon request.

In addition to the documents listed in Appendix K of NSTS 37329, a structural life assessment must be presented at the Verification Acceptance Review (VAR) if not provided earlier to the SWG. Structural life is defined as 4.0 times the service life loading environment to account for material data scatter. The type of data that shall be provided at the VAR can be found in Appendix J of NSTS 37329.

5.1.1.3 Across-the-Bay Cargo Element Verification Requirements: The across-the-bay CEs and components have specific requirements for verifying strength, fatigue, fracture, dynamics, random vibration, acoustics, deformation and interface loads.

All structure shall be verified for ultimate loads by static test or a combination of static test and analysis. The preparation of a formal stress analysis for the CE and its components and successful completion of any of the static test options listed in section 5.1.1.3.1 shall demonstrate compliance for structural strength integrity verification.

CE and component developers shall identify the approach for life verification. The extent of fatigue and fracture analyses and testing shall be identified. Details on SSP fracture requirements can be found in NASA-STD-5003, Fracture Control Requirements for Payloads Using the Space Shuttle. For International Space Station (ISS) items, refer to SSP 30558, Fracture Control Requirements for Space Station.

The CE developer shall provide a test-verified dynamic math model to the SSP for use in predicting flight loads and deflections that shall be used for the final structural verification of the CE and its components. Further details on required dynamic characterization are given in section 5.1.1.3.2. The SWG will review and approve the Model Verification and Correlation Report. The SWG will assess the math model to be used in the VLA based on the Model Verification and Correlation Report. If the math model correlation is judged to be inadequate, the SWG can require additional effort such as additional testing, additional analyses, and/or assign a model Uncertainty Factor (UF) that shall be applied to all results obtained from the use of the math model. The required contents of the model verification test plan and the model verification and correlation report can be found in Appendix K of NSTS 37329.

The CE/component structure shall be capable of withstanding all loads up to limit without violating the Orbiter cargo bay dynamic envelope or exceeding allowable trunnion travel limits, both of which are specified in the CE-unique ICD. Determination of deformation shall include contributions from applied loads, thermal loads, manufacturing tolerance, friction and other factors of significance. All critical conditions shall be considered. Compliance may be demonstrated by analysis, using uncertainty factors appropriate to model fidelity or as assigned by the SWG.

Space Shuttle/CE interface loads shall not exceed those specified in the CE-unique ICDs. Compliance may be demonstrated by analysis, using uncertainty factors appropriate to model fidelity or as assigned by the SWG.

Generic carriers used for across-the-bay CEs (such as Integrated Cargo Carrier (ICC), Multipurpose Logistics Module (MPLM), Spacelab Pallet, Mission Particular Experiment Support Structure (MPESS) and Spacehab module) may already have validated math models. CEs or components utilizing a generic carrier with test-verified math models may not require full-up strength and modal tests for subsequent flights of the carrier provided the carrier is used within the scope of the previous verification. All new components are required to comply with all structural verification requirements, and existing components shall be assessed to ensure that the prior verification activity is still applicable for the new configuration. The model verification process for generic carriers should attempt to cover future manifests to the best possible extent (multiple test cases). All generic carriers and generic components (e.g., racks, ORUs) shall have test-verified strength and dynamic math models.

If a CE, component, or Airborne Support Equipment (ASE) is deployed, extended or otherwise unstowed during flight but remains at least partially constrained in the payload bay, those configurations shall also be test-verified for strength and dynamic model correlation. Each unique configuration shall be described in the SVP along with a description as to how each configuration will be structurally verified. Alternate approaches for the on-orbit model correlation shall be coordinated with the SWG.

5.1.1.3.1 Strength Verification and Static Testing: Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by a factor of safety greater than or equal to 1.4). All structure shall be capable of sustaining limit loads from all flight events and load conditions without detrimental deformation. The structure shall also be capable of sustaining ultimate loads without failure.

A static test plan showing the proposed loading conditions, structural configuration to be tested, and method of test including load application and instrumentation shall be developed and provided to the SWG for approval. Grapple fixture interface stiffness verification shall also be included in the static test plan unless a sufficiently detailed analysis shows the CE/component fundamental frequency is significantly greater than the 0.2 Hz requirement for the CE or component attached to the RMS. This test plan shall be provided to the SWG at least two months prior to start of testing.

Verification of the CE/component structure for strength integrity by analysis only is not considered to be a viable option without prior written approval by the SWG. Current static test options (for metallic structures) are as follows.

a. Static test a designated structural test article to demonstrate the minimum required factor of a safety of 1.4 by testing to 1.4 times the limit load for all significant loading conditions. This option must be used by CEs or components where normal and accepted stress analysis techniques are not adequate to accurately define the state of stress in the structure. Because it is generally difficult to obtain 1.4 times the limit load in all parts of a complex structure, results from this test shall be used to verify the analytical static math model. This option may not be selected simply to avoid static math model correlation.

b. Static test the flight structure or a designated test article to 1.2 times design limit load. This test shall be used to verify the analytical static math model such that the design can then be verified for ultimate load capability by a detailed formal stress analysis. All analytical margins of safety shall be positive for minimum factor of safety of 1.4.

c. Static test the flight structure or a designated test article to 1.1 times the design limit load. This test shall be used to develop and verify the static analytical math model such that the design can then be verified for ultimate load capability by a detailed and formal stress analysis. The ultimate design factor of safety for the analysis shall be 1.4 or greater. In addition to the 1.1 limit load test, several pre-agreed-upon critical structural elements (e.g., beams, bulkheads, panels, etc.) and/or components may be required to be tested at ultimate load to verify their ultimate strength capability. These critical structural elements and/or components verification tests may be conducted on dedicated test articles having the same configuration, materials, and workmanship as the flight article. It shall also be required to demonstrate prior experience in successful structural design and analysis projects, static math modeling techniques, structural testing, and success of structural designs from previous programs. This option requires prior written approval of the SWG.

d. Other combinations of criteria and/or static testing, which are equivalent to those listed in paragraphs a, b, or c above, will be considered. This combination of criteria/testing option requires prior written approval by the SWG.

All static testing options will provide data that is used to develop a test verified strength math model. Guidelines for successful strength correlation are listed below.

1. Math model predictions for critical deflections shall be within 10 percent of the test data.

2. Math model predictions for critical stresses shall be within 20 percent of the test data.

3. If math model predictions are outside the above stated correlation criteria, the math model shall be updated until it meets the criteria and the analysis rerun.

4. If the math model predictions are within the correlation criteria but underpredict the test data, the stress analysis for flight load conditions shall be updated to reflect structural margins based on stresses that are adjusted according to he correlation results.

A stress analysis shall be performed for all metallic and non-metallic structural components in the primary load path. Structures are considered to be in the primary load path if the failure of that structure has the potential to jeopardize the crew, create a safety hazard (e.g., loose parts), or interfere with normal operations of other CEs, components or Orbiter systems. All hardware that transmits loads from one area of the structural assembly to another shall be considered to be in the primary load path.

The stress analysis shall use the minimum thickness of the part as designated by the hardware development program or the sponsoring NASA center. If the part has been manufactured, the actual thickness can be used directly in the stress analysis.

Margins of Safety shall be positive for all structures considering all combined loading conditions and Shuttle flight events.

The definition of Factor of Safety (FS) can be found in NASA-STD-5001 and Appendix P of NSTS 37329. FS that are generally accepted by the SWG are specified in NASA-STD-5001. All FS must be coordinated with the SWG prior to their use. Documentation of any modified FS that are approved by the SWG and supporting rationale will be provided to the SSP and Payload Safety Review Panel (PSRP) for concurrence.

There are no SSP published "analysis only" FS which would allow the CE an automatic "no test" option. This is because the use of a higher FS alone is not sufficient to account for structural uncertainties and possible math modeling errors that a test program is designed to uncover. However, a "no test" option can be negotiated with the SWG. Justification for using untested FS shall accompany the request for "analysis only" verification. Examples of possible justifications for the no test option that may be acceptable to the SWG can be found in NASA-STD-5001. Typically, the SWG will require additional analysis to ensure that potential errors in the analysis results in minor changes to the structural responses. The SWG will perform a thorough review of the CE developer plans for analysis and structural tests. With written approval from the SWG, the CE developer can then use the "analysis only" structural verification approach with the SWG approved FS.

5.1.1.3.2 Verification of Dynamic Characteristics: In general, loads and deformations used to verify structural strength and life integrity shall be calculated analytically using CE structural dynamic math models provided by the CE developer, along with Shuttle math models and forcing functions provided by the SSP. The CE developer is encouraged to conduct Coupled Loads Analyses (CLA) and quasi-static loads analyses to support the CE structural design process. The CLA results represent only the low-frequency dynamics portion of the loads. All applicable load conditions shall be considered (e.g., thermal, pressure, acoustic, random vibration). CLAs run to support the CE design process use CE math models of unknown validity because the analyses are generally performed prior to model verification. As a result, it is recommended that model UFs be applied to the results from the CLA. Typical UF values are specified in NSTS 37329, section 3.1. A mission-specific VLA is conducted by the SSP to predict the flight loads and deflections that shall be used for the final structural verification of the CE. The SWG may apply UFs to the VLA results if the CE models used in the VLA are not test-verified (also called uncorrelated), as judged by the SWG. The use of UFs does not allow the CE/component to forego math model verification. The SWG may, at its option, refuse to accept an uncorrelated model for use in the VLA if the potential errors introduced by the model are too large to be accounted for using linear analysis and UFs.

The purpose of the dynamic math model verification is to ensure that the loads and defections predicted in the VLA are appropriate for flight safety structural assessment. The VLA is conducted using modal transient analysis methodology and includes all modes up to 35 Hertz (Hz) of the combined Shuttle/CE model. Because some modes which are above 35 Hz in the CE model may drop below 35 Hz when combined with the Shuttle model, the recommended goal is to verify the CE modes (constrained at the Orbiter attach point interfaces) that significantly contribute to the coupled system response to at least 50 Hz (approximately 1.4 times the cut-off frequency of the loads analysis per NASA-STD-5002). Thus, the preferred model verification program is based on a modal survey test. The test shall be capable of providing sufficient data to verify the mode shapes, frequencies, and damping of the significant modes of the CE. The significant modes are those which are the primary contributors to Orbiter/CE interface loads and CE internal loads.

The following paragraphs describe requirements placed upon the CE developer.

a. The CE developer shall submit a detailed dynamic math model verification test plan directly to the SWG for approval at least 2 months prior to testing.

b. The preferred test configuration to ensure verification of the dynamic characteristics of the Orbiter/CE interfaces is a fixed interface test with the test article constrained at the Orbiter attach point DOF. If additional interface DOFs are to be constrained in the test, the CE developer must provide pretest analysis that demonstrates that the test configuration does not overly constrain the CE, thereby preventing significant flight configuration modes from being measured. Free-free testing may be used but is not recommended. The proposal to perform free-free testing shall be identified to the SWG as early as possible and be fully described in the CE SVP. The use of free-free testing shall be coordinated with and approved in writing by the SWG prior to the start of testing. Free-free testing shall require additional analysis to show that the proposed test will capture the constrained, coupled system responses. Choosing alternate test boundary conditions may require verification of modes above 50 Hz.

c. The model verification test shall be conducted on flight or flight-like structure. The test article shall include all primary structures with significant dynamic characteristics below 50 Hz. Rigid mass simulators may be substituted for those components that have no significant modes active in the CE model below 50 Hz.

d. For components that have significant modes active in the CE model below 50 Hz, it may be necessary to verify the component model via a separate modal test. In this case, the component may be replaced with a mass simulator in the modal test of the CE provided it can be shown by pretest analysis that the stiffness of the component interface has negligible effect on the significant mode shapes of the CE below 50 Hz. If the component interface stiffness does influence the mode shapes of the CE, then the simulator shall correctly represent both the mass and the stiffness of the component. Every attempt shall be made to include flight-like interfaces between the component simulators and the CE.

e. If a separate component level modal test is conducted, the test shall be capable of providing sufficient data to verify the component/CE interface modes as well as all significant component modes active in the coupled CE model below 50 Hz. Component testing shall be performed up to 70 Hz (1.4 times the 50 Hz model upper bound per NASA-STD-5002). The preferred test configuration to verify the constrained interface modes is a fixed interface test. In addition, if an electrodynamic shaker-based vibration test is substituted for a fixed-base modal test, precautions shall be taken to prevent dynamic coupling of the component with its support structure and the shaker armature.

f. NASA-STD-5002 specifies the goals for the modal survey tests including checks for nonlinearities and correlation requirements such as auto-orthogonalities and cross-orthogonalities (see table 5.1.1.3.2-1). Standard methods such as measuring test article response to varying input force levels and reciprocity checks shall be used. Any nonlinearities shall be evaluated with respect to their significance in the CE load analyses. In the presence of significant nonlinearities, consideration shall be given to measuring the affected modes and frequencies under flight-like load levels. The presence of significant nonlinearities shall lead to the possibilities of tuning the math model to frequencies that produce the highest loads from coupled loads analyses. This activity shall be coordinated very closely with the SWG and requires their review and written approval.

g. Updates to the math model shall be made to achieve correlation of the model with the test data. The recommended method is to update/correct physical parameters of the model. If algorithms which adjust terms of the mass or stiffness matrix are used to enforce acceptable correlation of the mode shapes and frequencies, then the CE developer must address the effect of these adjustments on predicted loads and responses. For example, if changes have been made to the model which are not physically realizable, the CE developer must address the effects of these changes on the recovery matrices, such as load transformation matrices, developed from the model. Calculations such as effective modal mass, modal kinetic energy, strain energy, Modal Assurance Criteria (MAC), and two-dimensional modal deflection comparisons between analytical and test modes shall be used when appropriate to investigate correlation anomalies.

h. Evidence of successful test data acquisitions shall be demonstrated and provided in the Model Correlation and Verification Report. Prior to acceptance of the CE math model for use in the VLA, the report shall be submitted to the SWG for review and written approval. The report shall contain a complete summary of the verification test and the model correlation analysis, including a description of model updates. A summary of the VLA test-verified math model requirements by CE type is presented in table 5.1.1.3.2-2. Evidence that the model correlation has met the criteria contained in table 5.1.1.3.2-1 shall be presented. If the criteria cannot be met, then appropriate rationale shall be provided for the acceptability of the model. If the criteria are not met, the SWG may require additional analysis or additional testing to ensure that the CE dynamic math model is suitable for the VLA. If additional work does not result in a correlated math model, the SWG will apply an uncertainty factor to all results obtained from the use of the dynamic math model or reject the model altogether.

The SWG will consider alternative approaches for verification of the CE structural dynamic model.

Components carried inside modules are not necessarily dealt with as rigorously as a CE or component that is carried exposed in the Orbiter cargo bay.

i. For CE hardware that has less than 1-inch dynamic clearance, the SVP and other CE verification documents shall address the additional activities that will be performed to verify the clearances. See Appendix K and Appendix Q of NSTS 37329 for required details.

Table 5.1.1.3.2-1.- MODAL SURVEY AND MATH MODEL CORRELATION REQUIREMENTS

Para. 4.2.6 NASA-STD-5002	Model Verification Check	Model Correlation Requirement
a	Selection of significant modes (coordinate with Structures Working Group)	• Modes with modal effective mass (MEM) > 5 percent (total MEM for target modes below 50 Hz should be greater than 90 percent for X and Y translation, and greater than 75 percent for Z translation) • Modes which significantly contribute to Orbiter interface loads (based on influence coefficients) • Modes which contribute to CE internal loads or component interface loads (based on influence coefficients)
b	Boundary Conditions	Constrained in flight configuration; otherwise, additional testing and analysis shall be required to verify selection of significant modes for correlation to flight configuration modes
c	Identify nonlinearities	Vary input excitation levels and reciprocity checks; significant nonlinearities shall require additional testing
d	Frequencies: comparison of analytical and test	Within 5 percent for primary modes, within 10 percent for secondary modes
e	Mass representation/sensor placement auto-orthogonality	Diagonals close to 1.0; off-diagonals less than 0.1
f	Mode shapes : comparison of analytical and test both qualitatively and with cross-orthogonalities	Mode shape descriptions and deflection plot comparisons. Cross-orthogonality diagonals greater than 0.9; off-diagonals less than 0.1

Table 5.1.1.3.2-1.- MODAL SURVEY AND MATH MODEL CORRELATION REQUIREMENTS (Concluded)

Para. 4.2.6 NASA-STD-5002	Model Verification Check	Model Correlation Requirement
g	Modal damping	No requirement but should be measured for each significant mode during testing
i	1^{st} Frequency > model upper bound frequency (in fixed flight condition boundaries)	Resonant frequency testing to verify first frequency. Mode shape correlation not required.

Table 5.1.1.3.2-2.- ORBITER CARGO ELEMENT VERIFICATION LOADS ANALYSIS MATH MODEL REQUIREMENTS BY CE TYPE

CE Type	First Fundamental Frequency (Hz)	Model Verification Requirement	VLA Requirement	Additional Requirements
Across-the-Bay	Per ICD-2-19001 or NSTS-21000-IDD-ISS for flight control	Full modal test for significant modes and frequencies through 50 Hz	Correlated math model	Rigid mass simulators may be substituted for components with $F_1 > 50$ Hz
Sidewall	< 35	Full modal test for significant modes and frequencies through 50 Hz	Correlated math model	With SWG approval, vibration test may be substituted for full modal test.
	>= 35	Vibration test for fundamental frequency	Rigid body properties and fundamental frequency*	Loads and deflections per NSTS 21000-IDD-SML
Middeck, Not Locker Stowed	< 30	As specified by the SWG		SWG specified modifications to NSTS 21000-IDD-MDK weight, c.g., and load factors
	>= 30	Vibration test for fundamental frequency		Weight, c.g., and load factors per NSTS 21000-IDD-MDK

*Optionally, math model may be submitted if additional VLA results required by customer

5.1.1.4 Sidewall Mounted Cargo Elements Verification Requirements: Structural dynamic math model verification is not required for sidewall mounted CEs that comply with the minimum frequency requirement of 35 Hz with respect to the sidewall adapter. An SVP is required for all sidewall CEs. The fundamental frequency verification, whether by test or analysis (in cases where the structure is sufficiently simple) shall be submitted to the SWG for approval. Loads and deflections for sidewall-mounted CEs whose minimum frequency is greater than 35 Hz shall be calculated using the load factors specified in NSTS 21000-IDD-SML in lieu of a coupled loads analysis. Sidewall CEs that do not meet the minimum frequency requirement shall be required to provide a test-verified dynamic math model. Refer to section 5.1.1.3.2 for details concerning testing documentation and correlation requirements. Any sidewall CEs or components with grapple fixtures shall verify the first fundamental frequency is greater than 0.2 Hz when attached to the RMS.

5.1.1.5 Orbiter Middeck Payload Verification Requirements: Structural dynamic math model verification is not required for payloads that comply with the minimum frequency requirement of 30 Hz for nonlocker middeck payloads installed in the Orbiter. An SVP is required for all nonlocker middeck payloads. The fundamental frequency verification, whether by test or analysis (in cases where the structure is sufficiently simple) shall be submitted to the SWG for approval. Loads and deflections for nonlocker middeck payloads whose minimum frequency is greater than 30 Hz shall be calculated using the load factors specified in NSTS 21000-IDD-MDK. The SWG may require test-verified math models for nonlocker middeck payloads that do not meet the minimum frequency requirement. The SWG determination will be based on the information contained within the SVP and other information to be provided by the payload developer. If a test verified math model is required, refer to section 5.1.1.3.2 for details concerning testing documentation and correlation requirements. There are no model verification requirements for middeck payloads that are stowed inside lockers.

5.1.1.6 Pressurized Volume Payload and Component Verification Requirements: Structural dynamic math model verification is not required for items that comply with the minimum frequency requirement of 35 Hz, that are located in non-Orbiter pressurized volumes, and that are contained in locker or locker-type structures. SVP requirements for pressurized payloads and components vary among different modules. Math model verification plans and requirements for ISS pressurized payloads that do not meet the minimum frequency requirements can be found in SSP 52005. All payloads/components in pressurized modules shall use the appropriate load factors from the respective ICD/Interface Requirements Document (IRD) for load and deflection calculations.

5.1.1.7 Vibroacoustic Verification Requirements: Verification of the CE structure's ability to safely withstand the applicable random vibration and acoustic environments shall be demonstrated by test, analysis and/or similarity. The approach for verification shall be identified in the SVP. Random vibration tests shall be conducted for nonfracture critical fasteners without positive locks, structural adhesive bond joints, all components whose function is critical to safety and high frequency items which cannot be analyzed.

5.1.1.8 Crew Habitable Module Specific Verification Requirements: All crew habitable modules, as defined in NSTS 1700.7B paragraph 220, shall be designed to withstand the worst-case loading condition resulting from either pressure alone or combined loads. These conditions are to be considered as separate loading conditions, and crew habitable module designs shall be compatible with both. Crew habitable module designs shall comply with all of the following requirements.

a. All crew habitable modules shall be designed to the ultimate pressure condition for both the maximum positive and maximum negative pressure differential. Ultimate pressure is equal to 2.0 times limit pressure where limit pressure is equal to the Maximum Design Pressure (MDP) as defined in paragraph 208.4 of NSTS 1700.7 or SSP 50021 for ISSP CEs.

b. All crew habitable modules shall be proof-tested to a minimum of 1.5 times limit pressure (i.e., MDP) and leak checked after proof testing. The proof test data shall be used to verify the analytical math model such that the design can then be verified for ultimate pressure loads by analysis. Either test or analysis may be used to verify the maximum negative pressure differential condition.

c. All crew habitable modules, in addition to satisfying the ultimate pressure conditions, shall be analyzed and comply with the combined loading conditions of section 5.1.1.1.

5.1.1.9 Material Verification Requirements: The following paragraphs describe the design, analysis, test and flight qualification requirements for beryllium, composites, adhesively bonded, ceramic and glass structures because they require different treatment and safety considerations than conventional metallic parts and structures due to their inherent failure characteristics and/or manufacturing processes. In addition to the verification requirements that are specified above, additional structural strength verification requirements for each of these materials are define in the following paragraphs. Thus, these materials must not only comply with the verification requirements specified for metallic structures (as describe in the preceding paragraphs of this document), but must also comply with the material specific verification requirements provided in the following paragraphs. More detailed explanation of these requirements may be obtained by contacting the SWG.

The SWG must review and approve the SVP for any special material listed in this section that is to be flown on the Space Shuttle Vehicle (SSV). The SWG must approve any deviation from the criteria listed for each material below.

5.1.1.9.1 Beryllium: All beryllium structures must be reported to the SWG by CE/component identification, part identification (drawing number), and beryllium alloy. The only beryllium alloys exempt from this review are those where beryllium is a minor constituent (less than 4 percent) constituent, such as copper-beryllium, nickel-beryllium alloys, and the beryllium oxide ceramics. Drawings of the part as well as drawings and sketches of the CE/component shall be submitted to aid in identifying the beryllium part location and its function. It is highly desirable that the SWG review these documents with the cognizant CE/component structures personnel for purposes of establishing an expedient disposition of the part for verification.

A formal internal loads analysis shall be submitted for SWG review that includes appropriate boundary conditions, external load application locations, bounded static and dynamic loads used for the design, distortions and forces that affect the short transverse (through the thickness) direction stresses, and thermal loads.

A formal stress analysis shall be submitted for review using the maximum design loads for the Shuttle flight environment. The formal stress analysis shall be in sufficient detail as to address the effects of elastic stress concentrations, tolerances, and displacements that may occur in the short transverse direction of the beryllium material.

For all beryllium structures, manufacturing and material processes are subject to SWG approval and must assure appropriate quality control and material processing to control residual stresses, surface imperfections, and mechanical properties. The following requirements must be included in the appropriate process specifications:

a. Machined/mechanically disturbed surfaces of a structural beryllium part must be chemically milled to ensure removal of surface damage.

b. All beryllium parts must be penetrant-inspected for crack-like flaws with a high sensitivity fluorescent penetrant per MIL-STD-6866.

c. All fracture-critical beryllium parts must meet the fracture control requirements of NASA-STD-5003.

The SVP for beryllium structures shall comply with one of the following four options:

1. For two or more beryllium parts utilizing the same design and geometrical configuration, which are produced by the same manufacturer using identical materials and process specifications for the production of each part, a verification test program must be implemented. This test program shall demonstrate the part ultimate load carrying capability by statically testing one of the parts to a minimum of 1.4 times the maximum limit load expected to be experienced during the Shuttle flight environment for the part. This test may be performed on a dedicated test article if the article is made by the same manufacturer using the same material and process specifications as the flight hardware. Otherwise, one of the flight articles must be used. There shall be no failures. A detailed inspection of the tested hardware shall be performed to insure the integrity of the structure prior to flight. The remaining flight articles shall be proof-tested to the limit load expected to be experienced for the Shuttle environment. The 1.4 times limit load test shall be corrected to account for actual thickness and material properties of the test article versus the minimum drawing thickness and minimum material properties used for the formal stress analysis.

The test article used for the 1.4 times limit load test must include all possible sources of out-of-plane loading that may occur from the assembly of the beryllium part or installation of the beryllium part into the spacecraft. This includes the effects of attachments and out-of-plane loading from clamp-up, fastener torque, etc.

For those areas of the beryllium part where the failure criteria are questionable, sufficient testing of design details shall be performed to establish confidence that the analytical predictions are correct.

For structures that are subjected to buckling loads, testing shall be performed to demonstrate a minimum buckling margin of safety of 10 percent (based on 1.4 times the part limit load for Shuttle environment).

2. For beryllium parts that are one-of-a-kind, and no dedicated test article has been instituted, a comprehensive ultimate load test must be implemented in which the flight article is subjected to a minimum loading of 1.4 times the maximum limit load that will be experience for the Shuttle flight environment. The rigors of this test are the same as those given in option 1. In addition, a complete and detailed structural inspection of the tested structure shall be performed to insure integrity of the structure prior to flight.

3. If containment of unconstrained pieces resulting from failed beryllium parts is inherent in the design, and it can be adequately shown that the failed parts are not a threat to the safety of the Orbiter, its crew, or other CEs, this special testing criteria for beryllium will not be required. Any failure in the primary load path is automatically judged to be a threat to the safety of the Orbiter.

4. Other combinations of criteria and/or testing, which are equivalent to those above may be acceptable to the SWG. This option requires prior approval by the SWG and must be documented in the structural verification plan.

5.1.1.9.2 Composites: A composite material is defined as a nonhomogeneous material created by the synthetic assembly of two or more materials. Sandwich panels (such as those with honeycomb) are included in this definition although the various materials making up the honeycomb might be the same, all aluminum for example. Composite structures do not have material characteristics and processes that are well defined and standardized. In most standard methods of structural analysis, it is assumed the material is homogeneous and isotropic although it is neither. Further, the strength of composite structures is a function of the composite lay-up process and these processes are not standardized. The existing composites, whose strength has to be determined by test, do not have sufficient documentation on the lay-up processes used to enable determination of data applicable to similar structures using similar processes.

Composites or nonmetallic structural elements in the primary load path (as defined in section 5.1.1.3.1) are always classified as safety critical and shall be subjected to stress analysis to determine safety margins. The developer shall conduct tests and analyses on the materials and parts to provide a statistically valid data set for an “A” Basis Allowable (or equivalent). Once the “A” Basis Allowable (or equivalent) has been established, a stress analysis using these criteria shall be performed for the part.

The verification criteria are as follows.

1. Testing shall be conducted in accordance with NASA-STD-5003, section 4.2.3.5.d.(1).

2. Acceptance testing as required in paragraph 1 above may be exempt if it can be shown that the manufacturer of the composite component has extensive experience and a successful history of manufacturing a like design, has proven application of the process specifications and trained personnel, and has proven successful nondestructive testing techniques to validate the quality and integrity of the finished article. This exemption must have prior written agreement by the SWG. Data to be presented for evaluation shall include adequate information to verify the manufacturing experience as well as detailing process controls, analysis methods, material properties, and nondestructive testing capabilities.

3. Manufacturers of composite structures shall use only manufacturing processes and controls (coupon tests, sampling techniques, etc.) that are consistent with established aerospace industry practices for composite structures. As a minimum, these manufacturing processes and controls shall provide adequate technical assurance to show that the as-built flight articles satisfy design and analysis assumptions and are representative of the verification test article. Material design properties must comply with MIL-HDBK-17 allowables and manufacturers minimum guaranteed allowables, or must be developed for specific manufacturing processes using a statistically valid database that has prior approval by the SWG.

4. A comprehensive plan for the prevention of inadvertent damage to manufactured composite structural components that may result from handling, transportation, storage, or final assembly shall be prepared by the CE or component developer and approved by the SWG.

5. All fracture critical composite structures must meet the fracture control requirements of NASA-STD-5003 or SSP 30558 for ISSP hardware.

5.1.1.9.3 Ceramics and Glass Structures: Uncontained ceramic and glass parts are always safety critical when located in a habitable area because of the inherent hazard to the crew. Therefore, glass in a habitable area must be shown safe from breakage or proven contained. Uncontained glass outside a habitable area is subject to the same scrutiny as other structural parts and shall be screened by the CE developer based on its hazard potential. All uncontained glass parts weighing

0.25 pounds or more outside a habitable area shall be deemed as being safety critical and subject to fracture control. *The most critical load for a glass or ceramic part may occur during handling, e.g., installation or removal from glass protective devices and/or experiment facilities. The CE developer must determine which environments to include for CE functionality; however, for CE safety verification all loads must be considered.*

The verification criteria are as follows:

1. Ceramic and glass parts, which cannot demonstrate containment (per NASA-STD-5003), shall meet end-of-life requirements as documented in NASA-STD-5003, paragraph 4.2.3.6.2.a.

2. Accurate, confident predictions of the magnitude and location of maximum tensile stress in the ceramic or glass structural part are imperative in properly verifying the structure. Confidence can be assured by the use of detailed analyses and tests of the part, *and by careful consideration of all design and operational environments*. Tests to verify stress predictions may be waived if the stress predictions are historically accurate for the configuration considered. Confirmation of this judgment shall be obtained from the SWG prior to using this no test option.

3. A fracture mechanics analysis shall be completed which demonstrates that the part will have the required factor of safety and life. The fracture mechanics analysis and stress analysis shall be made available for review upon request of the SWG.

4. Acceptance proof testing will follow the requirements of NASA-STD-5003, paragraph 4.2.3.6.2b. The proof test plan and results shall be provided to the SWG. All test plans shall be submitted to the SWG for review and approval at least two months prior to the start of testing.

5. If a fracture mechanics analysis predicts critical flaws which are much greater than the constraints of the analysis, or if stresses are very low with respect to test verified allowables and a factor of safety of 5.0 or greater can be shown, a proof-test is not required. The appropriate analysis shall be submitted to the SWG in lieu of test results.

5.1.1.9.4 Structural Bonding: Structural bonds shall meet all requirements specified for safety critical composite structures as well as the requirements of the following paragraphs.

The CE/component developer shall certify that the bonding materials and processes (e.g., chemical composition, processing, mechanical properties) used for the structural certification (qualification) hardware are the same bonding materials and processes used for the flight hardware. The CE/component developer shall assure that the chemical composition, processing, and mechanical properties used for both the certification hardware and the flight hardware are the same. Compliance with this requirement shall be submitted to the SWG.

Thermal effects on bonds and bonding materials shall be considered. Thermal effects on the bonding material properties over time can affect the allowable stress of the bond, as well as the thermal effects on the bond at the time of load application (which is of primary importance since bond strength may decrease sharply with elevated temperatures). Some bonding liquefies at temperatures encountered in space or even at cargo bay temperatures during landing. Therefore, proof tests shall be performed to confirm load capability at the temperature extremes corresponding to the maximum load conditions (temperatures occurring at the time the load is applied).

5.1.2 Thermal.- Payload thermal and geometric math models are required to be developed and submitted by the customer. The models should be simplified to the extent practical; however, they must accurately represent the payload thermal response. The payload model will be integrated by the Space Shuttle with an Orbiter cargo bay model and used for the following two integrated mission verification analyses:

a. Mission conditions (attitude/times) used for mission verification analyses will be as specified in the appropriate IP.

b. Results of the integrated thermal analyses will be reviewed and approved by a joint Space Shuttle/customer working group.

All payload thermal hazard control functions which use SSP hardware shall be verified by modifying the math model and performing an analysis.

5.1.3 Avionics.-

5.1.3.1 General Requirements: The customer shall comply, and demonstrate compliance upon request with the avionics portions of the payload-unique ICD including all power wiring, Electromagnetic Compatibility (EMC), command and data interfaces. Verification of this compliance shall be performed by testing prior to Orbiter installation, using the flight, or flight-equivalent, payload hardware. EMC is the exception to these test requirements, as compliance can be demonstrated by test or analysis as appropriate. EMC data are to be submitted by the customer as defined in NSTS 21288, Required Data/Guidelines for Payload/Shuttle Electromagnetic Compatibility Analysis. The customer must perform the following types of testing on the actual payload flight equipment in the flight configuration. These are:

a. Power interface testing - The actual power drawn by the payload, measured on each power interface at the highest load condition for that power interface.

b. Connector interface testing - Every payload/Orbiter interface connector shall be tested to assure connector/pin compatibility with the payload ICD.

c. Control function testing - All control functions which use SSP hardware and/or software interfaces for command and/or monitoring shall be verified by test prior to installation in the Orbiter.

d. Hazardous systems - For those systems that have catastrophic hazard potential, testing shall demonstrate that the entire integrated flight system (payload and Orbiter) will perform as intended. In those cases where proper function of the end item is confirmed using Ground Support Equipment (GSE) or analyses, the GSE or analyses will be developed and configured by the end item developer or a group independent from the rest of the system based on the specifications of the end item.

e. Mission sequence testing - Any payload having hazard potential shall be subjected to a mission sequence test which replicates all mission events (planned and contingency), which could pose safety threat to the Orbiter or crew. The mission events may be time compressed if necessary and the payload systems must be monitored to verify planned events occur on time and the unwanted (hazardous) events do not occur at the unexpected times. Mission sequence testing shall be completed prior to installation in the Orbiter.

In addition, all customer-provided dc cables and wire harnesses to be installed and/or removed by SSP personnel within the Orbiter cabin are required to successfully pass an insulation resistance/high potential test prior to each mission.

The test voltage shall be 1500 V dc, ± 75 V. The test voltage dwell time shall be a minimum of 2 sec but shall not exceed 2 min. Leakage current shall be less than 0.5 ma. The test voltage shall be applied between the following points:

a. Between each conductor and all other conductors in the same harness assembly

b. Between each conductor terminating in a connector and the connector shell

c. Between each conductor (except shield ground wires) and each shield in the same wire harness assembly

d. Between each contact and all other contacts in the same connector and between each contact and the connector shell

e. Between each conductor in installed harnesses and ground, except conductors that are grounded in accordance with applicable engineering drawings or wire list

f. Between each conductor in a harness enclosed in metallic conduit or metallic braid and the conduit or braid

5.1.3.2 Safety Requirements: In addition to the requirements stated in 5.1.3.1 above, the customer shall test the payload flight equipment to ensure that all safety-critical items identified in the payload-unique ICD are in compliance with the ICD and NSTS 1700.7B or SSP 50021 for ISSP cargo elements.

5.1.4 Materials.- Material properties to be used in the structural analysis shall be obtained from MIL-HNBK-5, ML-HNBK-17, or equivalent handbooks. Material "A" or equivalent values shall be used in all applications where failure of a single load path could result in a loss of structural integrity in primary structure. Material "B" values may be used in redundant structure in which the failure of a component would result in a safe redistribution of applied loads into the remaining intact load-carrying structure. When conforming to MIL-HDBK-5, material "S" allowables may be used for material in lieu of "A" or "B" allowables where lot acceptance testing is a procurement specification requirement and approved by the SSP.

All material usage must be verified in accordance with applicable requirements in the CE-specific ICDs, this document, and NSTS 1700.7B or SSP 50021 for ISSP cargo elements. Verification will be demonstrated and documented through the implementation procedure defined in NSTS 13830 or SSP 30599 for ISSP cargo elements.

5.1.5 ICD Dimensions.- For all cargo bay installed CEs, the developer shall verify the as-built versus ICD dimensions for departure point locations and lengths, for all CE-to-Orbiter interfacing electrical cables and fluid lines. The as-built (actual) measurements will be made during final cable or fluid line installation and are to be documented in developer documents and verified by the developer Quality organization. Where exceedances occur, adjustment shall be made to the CE/component such that the ICD requirements are met. The final results are to be documented as above and submitted in Annex 1 to the IP, and are to be presented as a review item during the Cargo Integration Review (CIR). If the cables or fluid lines have not been installed or if actual final measurements have not been completed by the time of the CIR, the CE/component developer should be prepared to discuss, during the CIR, the planned closure of the required measurement data submittal, including date(s).

For all CEs and payloads with structure at or greater than a static radius of 87 inches (reference $Y_o = 0.0$, $Z_o = 400$) or within 3 inches of any Orbiter protrusions into the 90-inch cargo bay thermal and dynamic envelope, the developer shall verify the physical location of that structure and document in the CE unique ICD. This data will also be included in the Computer Aided Design (CAD) models that shall be provided to the SSP per the requirements specified in Appendix G of NSTS 37329.

5.1.6 Safety-critical Mechanical Systems.- A safety-critical mechanical systems verification approach shall comply with the provisions identified in paragraph 3.1.1 of this document. Verification that mechanical systems meet or exceed the requirements specified in Interpretation of NSTS Payload Safety Requirements NSTS 18798 (letter number JSC TA-94-041 Safety Critical Mechanical Systems) will be accomplished with adequate analysis and/or proper testing, and comprehensive inspection. The payload customer shall present a comprehensive plan that describes the verification approach to the Space Shuttle/Payloads Mechanical Systems Working Group (MSWG) for review and approval.

The purpose of this plan is to establish an understanding between the payload customer and the MSWG on how the SSP payload mechanical systems requirements will be implemented and verified. All elements that are required to be under fracture control must also meet fracture control requirements in addition to the following verification requirements.

The functionality and design of mechanical systems will be discussed with the MSWG during formal Technical Interchange Meetings (TIMs). A TIM will be conducted prior to each Payload Safety Phase review as required. During the TIM prior to the Phase 0/1 Review, the customer will discuss system features that fulfill design requirements, concept philosophy, and environmental conditions. Assumptions concerning design and requirements will also be discussed at this time. A summary of preliminary analyses, and preliminary test plans for functional, run-in, acceptance, qualification, and life cycle tests should also be provided. At succeeding TIMs, the customer should summarize additional analysis and test (force margins, structural margins, stress, etc.) results and/or test plans. In addition, the payload should respond to action items assigned at previous TIMs. Requested data will be used by the MSWG to assure that the mechanical systems have fulfilled all safety requirements. The following paragraphs describe the verification process for mechanical systems.

5.1.6.1 Strength: All strength requirements specified in paragraph 5.1.1 of this document shall apply to mechanical system structural components. Mechanical systems (mechanisms) which possess an over-center device at the end of travel are considered structure at the end of travel positions. The proper rigging to ensure that a mechanism reaches the over-center positions shall be documented and inspected per paragraph 5.1.6.3 of this document. Test or analysis shall verify that the over-center feature will not release during combined environmental loading.

5.1.6.2 Testing: The functionality of mechanisms shall be verified, where practicable, through a series of tests which shall include acceptance, qualification, run-in, and design life verification tests. The environmental conditions of each test shall encompass all worst-case environments and be defined in an applicable test plan. A summary of these plans and any available results should be submitted prior to the Phase II Safety Review and include information such as environmental conditions, test setup, and test results. Final test results confirming verification shall be provided prior to the Phase III Safety Review. Qualification and design life testing shall be performed on a qualification test article, where practicable. If the flight article is used in the qualification and design life verification testing, a refurbishment plan shall be submitted. However, if these tests are projected to cause degradation of the flight article, then the payload customer shall present a plan describing the verification approach in lieu of the qualification and design life verification tests on the flight article. The verification approach shall be reviewed and approved by the MSWG.

Functional tests shall be performed before and after exposure to each of the previously mentioned tests to determine whether damage or degradation in performance has occurred. Functional tests shall be structured to demonstrate that the mechanical system is capable of operating in such a manner that all performance requirements are satisfied. The functional tests are usually conducted at room ambient condition, with the initial functional test serving as a baseline against which subsequent performance is compared. However, when a mechanical system is designed to operate in extreme heat or cold, or in other environmental extremes, the functional test shall be conducted in the worst-case environment that demonstrates performance. All command functions should be exercised during functional tests.

5.1.6.2.1 Run-in Test: The primary purpose of the run-in test is to detect material and workmanship defects which occur early in the component life. A secondary purpose is to wear-in parts of the mechanical system until it performs in a consistent and controlled manner. A run-in test should be performed on each mechanical system before it is subjected to acceptance testing, unless it can be shown that this procedure would be detrimental to performance and/or would result in reduced system reliability.

The run-in test conditions should be representative of the operational loads, speed, and environment. However, operation of the assembly at ambient conditions may be conducted if the test objectives can be met and the ambient environment will not degrade performance and/or reliability or cause unacceptable changes to occur within the equipment such as the generation of excessive debris.

5.1.6.2.2 Acceptance: Each flight mechanical system shall be subjected to acceptance testing to demonstrate the ability to achieve performance requirements and to identify any material and workmanship defects. All command functions shall be exercised during acceptance testing.

5.1.6.2.3 Qualification Testing: Qualification testing shall be conducted to verify satisfactory performance at the design environmental conditions and to verify that all design requirements have been met. Satisfactory completion of these tests is required for flight certification or qualification. Following the testing and the pursuant functional test, the assemblies shall be completely disassembled and inspected for possible damage. If no qualification test article is available, refer to paragraph 5.1.6.2 of this document.

5.1.6.2.4 Design Life Verification Tests: The design life verification test are intended to evaluate lubricant suitability, release and deployment life cycle margins, wear life and avoidance of fatigue. These tests shall be conducted to simulate operational use within the range of the worst predicted operational environments. The test article shall be subjected to tests which demonstrate the capability to perform the full operational cycle. In cases where there is no qualification test article available, refer to paragraph 5.1.6.2 of this document.

The mechanical systems used for life test shall be identical with the flight items except for those changes necessary for incorporation of test instrumentation. The design life test article shall be operated as expected in flight in accordance with the predicted duty cycle. All mechanical systems shall be tested to at least four times the number of duty cycles expected in operational use, plus four times the number of duty cycles expected during component and vehicle functional and environmental tests. Hard stops shall be tested using worst-case conditions by intentionally running the mechanical system into the hard stops, where practicable. If this test cannot be performed, an analysis must be conducted to show positive margins with a minimum factor of safety of 2.0. The stops shall be tested to at least four times the number of duty cycles expected in operational use, plus four times the number of duty cycles expected during component and vehicle functional and environmental tests. After design life testing and the pursuant functional test, the test article shall be disassembled and inspected for anomalous conditions. The critical areas of parts subject to fatigue failure shall be inspected to determine if failure has occurred.

5.1.6.3 Inspection: Documentation of rigging and installation procedures shall be provided to ensure that all mechanical systems are properly installed and rigged. This documentation shall provide signature spaces for approval by trained and certified personnel of safety-critical procedures.

5.2 Payload Interface with Simulated Orbiter Interfaces

When interface testing with an Orbiter interface simulator is to be performed, it must be completed satisfactorily prior to interface testing with the Orbiter.

5.2.1 Cargo Integration Test Equipment.- The utilization of CITE for payload testing shall be mutually agreed to on a case by case basis by the SSP and the customer and documented in the IP. Processing of repetitive payload configurations will be evaluated by the SSP and the customer to determine if CITE testing should be continued. Examples of considerations that enter into this evaluation are interface complexity, payload design changes, Orbiter design changes, flight software changes, extent of flight software involvement (number of formats, commands, measurement), and new test requirements.

5.2.2 Specific Requirements.- Payload test requirements to be implemented and performed by the SSP shall be documented in the appropriate OMRSD files and subfiles (i.e., File II Vol's. 2 & 6, File VII, File VIII and File X).

5.2.3 Data Flow Verification Test.- The SSP will provide as a standard service payload telemetry verification via a payload Data Flow Verification Test (DFVT) from Mission Control Center (MCC) to the Payload Operations Control Center (POCC). The purpose of this test is to demonstrate the Space Shuttle and payload network's ability to deinterleave and transmit a payload's telemetry to the POCC. This test will utilize an Orbiter simulator (CITE) or Orbiter telemetry tape obtained during the first payload to CITE or payload to Orbiter Interface Verification Test (IVT). The tape shall contain a payload's primary on-orbit telemetry configuration. Detailed DFVT requirements will be documented in IP Annex 5.

5.3 Payload Interface with Orbiter

The customer shall specify in the OMRSD those integrated Space Shuttle/Payload Interface Verification Operations that will be performed at the launch site. All payload-to-Orbiter interface verification requirements are to be identified and submitted by the customer in the OMRSD. Those interfaces that cannot be verified prior to flight shall be documented as an untested interface in the OMRSD with supporting rationale.

Requirements regarding commands, responses, and pass-fail criteria will be defined and agreed upon with the customer. Customer verification shall be completed prior to integrated operations in the Orbiter. Satisfactory completion of command and data tests is a prerequisite to any End-to-End (ETE) tests. Payload and Shuttle experiment test requirements to be implemented and performed by the SSP shall be documented in the appropriate OMRSD files (i.e., File II Vol's. 2, 4, & 6).

The following constraints apply:

a. When Orbiter software is utilized by the payload, the applicable mission phase software (latest version) will be used to support interface testing.

b. All Orbiter-to-payload interfaces must be verified during postmate IVT. The rules governing payload postmate requirements are defined in NSTS 08171, File I. These postmate requirements may include some or all of the following:

1. Electrical, fluid and/or mechanical interface verification.

2. Interfaces used to control payload hazards and safety critical functions.

3. Cargo Integration Test Equipment (CITE) interface verification.

4. T-O interface/verification.

5. End-to-end testing.

In addition to the postmate interface verification the following requirements may be performed in accordance with the OMRS to process a payload for launch:

1. The Shuttle general payload interface requirements levied per the P01 file on a payload or mission-unique basis.

2. Any services that are invoked or terminated during launch countdown or launch delay operations.

3. Any payload requirements that increase or impact SSP resources and/or scheduling, other than the need for low power, T-0 service and standard physical access.

If it is necessary as the only means to verify an interface which impacts mission or payload success, a limited functional test may be performed.

Verification requires test methods that produce quantitative data that will ensure operation of the service in flight. When verification of an Orbiter-to-payload interface requires special design provisions for testing, these provisions shall be provided as part of the payload design, or as a nonstandard service if required on the Orbiter side of the interface. Pass/fail criteria shall be defined for verification of each interface service and documented in the OMRSD.

c. IVTs will be conducted in the Orbiter by the SSP. These tests will verify all payload-to-Orbiter interfaces. Exceptions to this requirement will be negotiated with the SSP on a case-by-case basis and documented in the OMRSD with supporting rationale.

For those Orbiter electrical interfaces that mate to elements already on-orbit or cargo elements that provide a feed-through of this service to another element, testing will be performed which will be of sufficient fidelity to confirm connector pin compatibility as well as signal characteristics compatibility.

For those Orbiter physical interfaces that are not mated until on-orbit, a verification program will be implemented to ensure physical compatibility.

5.3.1 Baseline Processing Flow.- The baseline processing flow for payload services interfaces which require reconfiguration of the Orbiter, including any customer-provided unique equipment and/or mission interface hardware, for a specific flight configuration, will be accomplished and verified in the Orbiter Processing Facility (OPF). This will be accomplished in parallel with payload processing in the CITE or equivalent to minimize Orbiter turnaround processing. The cargo elements are then mated to the Orbiter in the OPF or at the launch pad in the Payload Changeout Room (PCR) for integrated checkout. The SSP-provided GSE will be utilized to perform payload services interface verification at the payload cabling interface for SSP-provided cabling and Aft Flight Deck (AFD) equipment. This GSE is capable of verification of the standard payload avionics services as defined in Space Shuttle System Payload Accommodations, NSTS 07700, Volume XIV, Appendix 5. Unique payload assignment of services or customer-provided equipment will require customer-provided GSE and/or customer-funded special patch harnesses for the SSP GSE.

Once the hardware for an interface has been installed in the Orbiter, the requirements for verifying that interface before payload installation will be specified in the OMRS documents for the Orbiter. The payload premate requirements, File II, Vol. 4, test Orbiter interfaces and services to be used by the payload. The OMRS files are the single authoritative source for technical requirements which must be satisfied to assure the flight and ground readiness to support Space Shuttle and payload prelaunch, launch, and turnaround operations. These requirements and specifications will be periodically reviewed with the intent of refining requirements to minimize operations for repetitive payloads.

5.3.2 Orbiter Interface Verification Approach.- Before mating the Orbiter interfaces to the payload, a certain amount of verification of both the Orbiter hardware and software which support the payload will be done. The Orbiter interfaces for the payload will be verified primarily by checkout testing but in some cases may be done by analyses and/or inspection as well as maintenance. The checkout and verification of payload services interfaces on the Orbiter will be done to the same criteria governing the other Orbiter interfaces.

5.3.2.1 Checkout: The general philosophy for the SSP program is to check out the payloads, the Orbiter, and the ground system independently before mating to another element and to limit the postmate checkout to verification of proper interface performance.

5.3.2.2 Inspection: The following applies to interface hardware which has been previously installed and utilized.

a. Preflight inspection - These will apply to all the Orbiter systems and will include the full range of vehicle closeout inspection, shakedown inspections, and walkaround inspections. Those inspections will contribute to the readiness verifications required for mating to carriers/payloads.

b. Orbiter postflight inspection - These will be performed selectively on portions of the Orbiter interface to identify potential damage or degradation resulting from previous flights or payload removal. In certain instances, inspection can be used to verify the presence or absence of hardware functional failure modes. The postflight inspection may include both visual and other Nondestructive Evaluation (NDE) inspection techniques. The postflight inspection is considered to be a part of the planned maintenance function.

c. Orbiter special inspections - These inspections will be performed on a conditional basis. Such inspections may be performed to identify physical damage resulting from off-nominal conditions occurring during flight or ground operations. They may also be required to support fault isolation or to determine the extent of physical damage after failure of a normally scheduled checkout or inspection.

5.3.2.3 Postflight Anomaly Analyses: Flight data analyses will be performed during and after each flight to determine the condition of the Orbiter and the payload. For this purpose, flight data will be considered to include the flightcrew's observations, telemetered data, and onboard recorded data. Equipment malfunctions and flight performance anomalies identified through analysis of the flight data will provide requirements for unplanned maintenance. Equally important, however, will be the verifications of proper performance that can be made through analysis of the flight data. In many cases, such verifications can serve as a readiness verification for the next flight.

5.3.2.4 Maintenance: Interface reverification will be performed after hardware removal and replacement.

5.3.2.5 Software: The Orbiter flight software will comprise a link in many of the Orbiter/payload functional paths. The Software Production Facility (SPF) at JSC is utilized by the software developer to extensively verify any new software. The approach to verification of software/payload compatibility is the use of the flight software with the payload elements for the CITE integrated testing to perform the payload-specified functions. Normal functional cases only will be performed, and no off-normal stress cases will be tested.

For payload elements that do not utilize CITE, the approach to verification of software/payload compatibility will be satisfied by the use of an SSP-provided Orbiter software emulator and flight software.

5.3.3 Payload End-to-End Testing.- ETE testing is performed as a nonstandard service. ETE testing is designed to demonstrate satisfactory commanding with telemetry response between the payload and the POCC via the Space Shuttle and customer-provided system. These tests will be conducted in accordance with the customer IP. ETE interface verification is defined in general terms in table A-3 of NSTS TBS.

ETE test requirements will be jointly defined by the SSP and customer and documented in the specific OMRSD to each payload.

5.3.3.1 Prerequisite Testing: Prior to conducting the ETE tests, the following tests shall be successfully completed:

a. All payload subsystem checkout tests (by payload)

b. Orbiter and support systems verified by launch site

c. Ground facility validation tests (NASA Goddard Space Flight Center (GSFC), DOD, POCC, JSC)

d. Network validation tests (JSC)

e. Launch site standard services IVTs

5.3.3.2 Constraints: The following ETE test constraints apply:

a. SSP systems (flight and ground) which process the payload command and related data stream will be required to be in primary flight configuration for ETE tests.

b. The SSP system and networks elements which provide only a relay of command or data streams are not required for ETE tests but may be included at the option of the SSP.

c. ETE tests will not be required to check out generic Orbiter support capability (such as OPS recorder and state vector transfer).

d. ETE tests will not be used to verify command or telemetry data bases.

5.3.3.3 Time Limitations: ETE test requirements and procedures shall be developed to minimize utilization of SSP facilities. In order to minimize test time, the following guidelines shall be maintained:

a. Only a limited set of required commands will be used to verify each command interface for each payload. Total command library contents will not be verified as part of the ETE test. Only those telemetry formats necessary for command verification will be utilized. The customer will be responsible for providing verification of command responses. Command verification utilizing payload telemetry will be limited to sufficient time for a response recognition.

b. Multiple ground network stations will not be required; e.g., Merritt Island Launch (MIL), Ponce de Leon (PDL), Eastern Vehicle Checkout Facility (EVCF), or Western Vehicle Checkout Facility (WVCF).

c. Test sequences will not be performed on redundant Orbiter/ground system (PCMMU 1 and 2, etc.).

d. ETE testing will not be used to satisfy mission sequence or simulation testing requirements.

e. The ETE tests will not include payload/spacecraft subsystem test (buildup testing).

f. Direct payload/POCC network configuration will be used where possible to satisfy the customer's requirements for ETE testing.

5.3.4 Orbiter Services for Nonstandard Payload Operations.- The customer shall identify all nonstandard payload operations that require Orbiter services. The requirement for such payload testing shall be established in the IP and shall be documented in the OMRSD.

6.0 DOCUMENTATION REQUIREMENTS

6.1 Payload Verification Requirements - OMRSD

NSTS To Be Supplied (TBS) shall be used by the customer to prepare OMRSD verification requirements inputs if specified by the IP. The OMRSD requirements shall be submitted to the SSP in accordance with the IP schedules.

6.2 Certification of Safety Compliance

Customer certification of safety compliance with payload verification requirements will be provided through customer submittal of the Flight Safety Verification tracking log as required in NSTS 1700.7B or SSP 50021 for ISSP cargo elements and described in NSTS 13830 or SSP 30599 for ISSP cargo elements.

6.3 Change Control

All changes to this document will be in accordance with NSTS 07700, Volume IV, Configuration Management Requirements.

7.0 APPLICABLE DOCUMENTS

a. K-STSM-14.1, Launch Site Accommodations Handbook

b. MIL-HDBK-17, Vol I - Polymers Matrix Composite, Vol 2 - Plastics for Aerospace Vehicles Transparent Glazing Materials

c. MIL-STD-6866, Inspection Liquid Penetrant

d. NSTS 07700, Volume XIV, Appendices 1-10, Space Shuttle System Payload Accommodations

e. NSTS 13830, Implementation Program for STS System Safety Requirements

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

g. NSTS 07700, Volume IV, Configuration Management Requirements

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

i. NSTS 18798, Interpretations of NSTS Payload Safety Requirements

j. NSTS-21000-IDD-ISS, Shuttle Orbiter/International Space Station (ISS) Interface Definition Document

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

l. SSP 50021, Space Station Safety Requirements

m. SSP 30599, ISS Safety Review Process

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

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

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

q. NASA-STD-5001, Structural Design and Test Factors of Safety for Spaceflight Hardware

r. NASA-STD-5002, Load Analyses of Spacecraft and Payloads

s. NASA-STD-5003, Fracture Control Requirements for Payloads using the Space Shuttle

t. NASA-STD-7001, Payload Vibroacoustic Test Criteria

u. SSP 30558, Fracture Control Requirements for Space Station

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

APPENDIX A

ACRONYMS AND ABBREVIATIONS

AFD	Aft Flight Deck
ASE	Airborne Support Equipment
CAD	Computer Aided Design
CDR	Critical Design Review
CE	Cargo Element
CIR	Cargo Integration Review
CITE	Cargo Integration Test Equipment
CLA	Coupled Loads Analysis
CR	Change Request
DFVT	Data Flow Verification Test
DOF	Degree of Freedom
EMC	Electromagnetic Compatibility
ESTL	Electronic Systems Test Laboratory
ETE	End-to-End
EVA	Extravehicular Activity
EVCF	Eastern Vehicle Checkout Facility
FS	Factor of Safety
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HPF	Hazardous Processing Facility
Hz	Hertz
ICC	Integrated Cargo Carrier
ICD	Interface Control Document
IP	Integration Plan
IRD	Interface Requirements Document
ISS	International Space Station
ISSP	International Space Station Program
IVT	Interface Verification Test
JSC	Lyndon B. Johnson Space Center
KSC	John F. Kennedy Space Center
MAC	Modal Assurance Criteria
MCC	Mission Control Center
MDF	Manipulator Development Facility
MDP	Maximum Design Pressure

MEM	Modal Effective Mass
MIL	Merritt Island Launch
MIP	Mission Integration Plan
MPESS	Mission Peculiar Experiment Support Structure
MPLM	Multi-Purpose Logistics Module
MSWG	Mechanical Systems Working Group
NASA	National Aeronautics and Space Administration
NBL	Neutral Buoyancy Lab
NDE	Nondestructive Evaluation
NSTS	National Space Transportation System
OMIs	Operations and Maintenance Instructions
OMRS	Operations and Maintenance Requirements and Specifications
OMS	Orbital Maneuvering System
OMSRD	Operations and Maintenance Requirements and Specifications Document
OPF	Orbiter Processing Facility
ORU	Orbital Replacement Unit
PCMMU	Pulse Code Modulation Master Unit
PDL	Ponce de Leon (ground network station)
PDR	Preliminary Design Review
PIM	Payload Integration Manager
PIP	Payload Integration Plan
POCC	Payload Operations Control Center
PPF	Payload Processing Facility
PRCB	Program Requirements Control Board
PRCBD	PRCB Directive
PRLA	Payload Retention Latch Assembly
PSRP	Payloads Safety Review Panel
RCS	Reaction Control System
RMS	Remote Manipulator System
SAIL	Shuttle Avionics Integration Laboratory
SPF	Software Production Facility
SSP	Space Shuttle Program
SSP	Space Station Program (when used in conjunction with a document number)
SSV	Space Shuttle Vehicle
SVP	Structural Verification Plan
SWG	Structures Working Group

TBS	To Be Supplied
TIM	Technical Interchange Meeting
UF	Structural math model Uncertainty Factor
VAR	Verification Acceptance Review
VLA	Verification Loads Analysis
WVCF	Western Vehicle Checkout Facility

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