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NSTS 14046
Revision D

Payload Verification Requirements

Space Shuttle Program

July 1997

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

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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 require- ments/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 This document is a continuation of the Payload Verification Requirements remaining after annex 9 Blank Book requirements were extracted to create NSTS 21000-A09	09/18/85	v,2,3,4,7, 8,9,9A
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

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DESCRIPTION OF CHANGES (CONCLUDED)

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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
2	Update table of contents and section 7.0; add new section 5.1.6/R14046-020	12/06/94	iv,19,19A,19B,19C,25
REV D	General revision/R14046-S060703	07/02/97	All

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

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JULY 2, 1997

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 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, ISS 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.

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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.

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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

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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. 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 in the Orbiter, flight interface verification will be performed in accordance with SSP/customer agreements as specified in the payload-unique OMRSD.

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

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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 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 Structures.- All Orbiter payloads are required to be proven structurally safe and compatible with the Orbiter vehicle for all expected Shuttle flight environments. This process includes verification of payload structural strength and life integrity as well as strength verification for certain materials that may be contained within the payload. Special attention is given to the strength verification of beryllium, composites (including honeycomb structures), and glass and ceramic materials. The process also includes verification of structural bonding techniques, payload deformations under loading, interface load capability between the payload and the Orbiter, payload dynamic characteristics, and special verification for payloads that may be classified as habitable modules.

The payload organization must present a comprehensive Payload Structural Verification Plan that specifies how the strength and dynamic requirements given in the following paragraphs will be met. This plan is to be presented to the Structural/Mechanical Working Group (SMWG) for approval. The purpose of this plan is to establish an understanding between the payload organization and the SMWG on how the SSP payload structural requirements will be implemented and verified. This plan must clearly state the proposed method for verification of the structural design. It is required that the plan be submitted by the Phase 1 Safety Review, or by the Preliminary Design Review, whichever is earlier.

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5.1.1.1 Strength: 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). The payload structure must be capable of supporting limit loads from all critical load conditions without detrimental deformation and ultimate loads without failure.

The structure will be verified for ultimate loads by static test or a combination of static test and analysis. A test plan showing the proposed loading conditions, structural configuration to be tested, and method of test including load application and instrumentation shall be presented for SSP SMWG approval prior to testing. Compliance for structural strength integrity verification will be demonstrated by the preparation of a formal stress analysis for the payload and successful completion of any one of the following test options.

a. Static test a designated payload structural test article to demonstrate the minimum required factor of safety of 1.4. This option is applicable to all payloads where normal and accepted stress analyses techniques cannot be adequately addressed, and thereby cloud the integrity of the formal stress analysis.

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

c. Static test the payload flight structure or a designated test article to 1.1 times the design limit load. This test shall 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 preagreed critical payload elements and/or components will be required to be tested at ultimate load to verify their ultimate strength capability. This verification test may be conducted on dedicated test articles having the same configuration, materials, and workmanship. It will also be required to demonstrate prior experience in successful structural design

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and analysis projects, static math modeling techniques, structural testing, and success of structural designs from previous programs.

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 option will require prior approval by the SSP SMWG. Verification of the payload structure for strength integrity by analysis only is not considered to be a viable option without prior and written approval by the SSP SMWG.

In addition to the above static test options, payloads must identify the approach for life verification. The extent of fatigue and fracture analyses and testing must be identified.

There are several structural materials that require special consideration due to their inherent failure characteristics and/or manufacturing processes. In addition to the payload verification required above, structural strength verification for each of these materials is given in the following paragraphs.

a. Beryllium structures - SSP must review and approve the Structural Verification Plan for any beryllium structure which is to be flown on the Space Shuttle. Any deviation from the following criteria must be approved by the SSP SMWG.

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

   A formal component internal loads analysis shall be submitted for 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.

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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 SSP 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:

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

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

3. All fracture-critical beryllium parts must meet the fracture control requirements of NSTS l700.7B - Safety Policy and Requirements for Payloads Using the Space Transportation System.

The Structural Verification Plan for beryllium structures should comply with one of the following three options:

l. For two or more beryllium components 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 component, a verification test program must be implemented to demonstrate the component ultimate load carrying capability by statically testing one of the components to a minimum of 1.4 times the maximum limit load expected to be experienced during the Shuttle flight environment for the component. 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 tested flight hardware will be required to insure integrity of the structure prior to flight. The remaining flight articles shall be proof tested to the

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limit load expected to be experienced for the Shuttle environment. The 1.4 load test shall be corrected to account for actual thicknesses and material properties of the test article versus the minimum drawing thicknesses and minimum material properties used for the formal stress analysis.

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

Perform sufficient testing of design details to establish confidence that analytical predictions are correct for those areas of the beryllium component where the failure criteria are questionable.

Test demonstrate a minimum buckling margin of safety of 10 percent (based on 1.4 times the component limit load for Shuttle environment) for structures subjected to buckling loads.

2. For beryllium components that are one-of-a-kind, and no dedicated test article has been instituded, 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 experienced 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 or other payloads, this special testing criteria for beryllium will not be required.

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4. Other combinations of criteria and/or testing, which are equivalent to those above, will be considered. This option will require prior approval from the SSP SMWG and must be documented in a structural verification plan.

b. Composites structures - SSP must review and approve the Structural Verification Plan for any composite load carrying structure which is to be flown on the Space Shuttle. Any deviation from the following verification criteria must be approved by the SSP SMWG.

1. All load carrying composite structures shall be acceptance tested to 1.2 times the maximum limit load expected, and must be conducted on the flight article.

   It is preferred that the acceptance test be conducted at the component level; however, it may be performed on an assembly if the test loads that are induced into the composite article duplicate the required testing value of 1.2 times its Shuttle environment limit load in both magnitude and direction.

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 agreement by the SSP SMWG. Data to be presented for evaluation must 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-l7 allowables, manufacturers

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minimum guaranteed allowables, or must be developed for specific manufacturing processes using a statistically valid data base that has prior approval by the SSP SMWG.

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 and approved by the sponsoring organization.

5. All fracture critical composite structures must meet the fracture control requirements of NSTS l700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System.

c. Ceramics and glass structures - SSP must review and approve the Structural Certification Plan for any ceramic and/or glass load carrying structure which is to be flown on the Space Shuttle. Any deviation from the following design and verification criteria must be approved by the SSP SMWG.

1. Ceramic and glass structure (any component which must sustain stress and is not contained sufficiently, so that failed parts are a threat to the Orbiter, crew, or other payloads) shall be designed to have an end-of - life factor of safety of 1.4 or greater. Since moisture contributes to flaw growth in many ceramics, flaw growth calculations will be based on the total design life, with a life scatter factor of 4, and with average flaw growth properties derived for 100 percent moisture. The proof stress will be based on KlC nominal plus one sigma. The fracture mechanics analysis for predicting life will be based on KlC nominal minus three sigma.

2. Accurate, confident predictions of the magnitude and location of maximum tensile stress in the ceramic or glass structural component are imperative in properly verifying the structure. Confidence can be assured by the use of detailed analyses and tests of the component. Tests to verify stress predictions may be waived if the stress predictions are historically accurate for the configuration considered. Confirmation of this judgment should be obtained from the SSP SMWG prior to this no-test option.

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

4. A proof test of flight hardware will be conducted to screen manufacturing flaws larger than those assumed in the fracture mechanics analysis to assess a particular design for the required factor of safety and life. Proof tests will be conducted in environments which do not promote flaw growth in the flight hardware. The proof test plan and results will be made available for review upon request of the SSP SMWG.

5. An alternative to the proof tests required by paragraph 4 above is included for special cases. 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 should be submitted to the SSP SMWG in lieu of test results.

d. Structural bonding - The payload customer shall certify that the bonding materials and processes used for the structural certification hardware are the same bonding materials and processes used for the flight hardware. The payload customer shall assure that the chemical composition, processing, and mechanical properties used for both the certification hardware and the flight hardware are the same. Compliance of this requirement shall be a written statement signed by the payload customer stating that the above requirement has been met and submitted as the part of the structural verification at the verification analysis review held in the L-4 months timeframe.

5.1.1.2 Dynamic Characteristics:

a. In general, loads and deformations used to verify structural strength and life integrity shall be calculated analytically using cargo element structural dynamic math models provided by the payload developer, along with Shuttle math models and forcing functions provided by the SSP. The payload developer is encouraged to conduct coupled loads analyses to support

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the payload design process. A mission-specific Verification Loads Analysis (VLA) is conducted by the SSP to predict the flight loads and deflections which shall be used for the final structural verification of the cargo element.

b. Cargo element math models intended for use in the VLA shall be verified by test. The purpose of the model verification is to ensure that the loads and deflections predicted in the

VLA will be adequate for structural assessment for flight safety. The VLA is conducted using modal transient analysis methodology and includes all modes up to 35 Hz of the combined Shuttle/cargo element model. Because some modes which are above 35 Hz in the cargo element model may drop below 35 Hz when combined with the Shuttle model, a recommended goal is to verify the cargo element modes (constrained at the Orbiter attach point interfaces) up to 50 Hz. 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 cargo element. The significant modes are those which are the primary contributors to Orbiter/payload interface loads and payload internal loads.

c. The preferred test configuration to ensure verification of the dynamic characteristics of the cargo element/Orbiter interfaces is a fixed interface test with the test article constrained at the Orbiter attach point Degrees of Freedom (DOF). If additional interface DOF are to be constrained in the test, the payload developer must provide pretest analysis which demonstrates that the test configuration does not overly constrain the cargo element, thereby preventing significant flight configuration modes from being measured.

d. The model verification test shall be conducted on flight or flightlike structure. The test article shall include all primary structure and all secondary structure with significant dynamic characteristics below 50 Hz. Rigid mass simulators may be substituted for those components which have no significant modes active in the cargo element model below 50 Hz.

e. For components which have significant modes active in the cargo element model below 50 Hz, it may be necessary to verify the component model via a separate modal test. In

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this case, the component may be replaced with a mass simulator in the modal test of the primary structure 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 primary structure below 50 Hz. If the component interface stiffness does influence the mode shapes of the primary structure, then the simulator must 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 primary structure.

f. If a separate component level modal test is conducted, the test shall be capable of providing sufficient data to verify the component/primary structure interface modes as well as all significant component modes active in the coupled cargo element model below 50 Hz. 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.

g. The model verification test shall include appropriate techniques to evaluate nonlinearities in the flight hardware. Standard methods such as measuring test article response to varying input force levels and reciprocity checks shall be used. Nonlinearities shall be evaluated with respect to their significance in cargo element loads analyses. In the presence of significant nonlinearities, consideration shall be given to measuring the affected modes and frequencies under flightlike load levels.

h. Evidence of successful test data acquisition shall be demonstrated and provided in the verification test/correlation report. Evidence of an accurate mass representation of the test article shall be demonstrated with auto-orthogonality checks using the analytical mass matrix and the mass normalized test mode shapes. The goal for such a calculation is for all off-diagonal terms in the resulting matrix to be less than 0.1.

i. Model verification shall be accomplished by comparison of the measured and predicted mode shapes and frequencies. If necessary, updates to the math model shall be made to achieve correlation of the model with the test data. It is

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preferable 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 payload 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 payload developer must address the effects of these changes on the recovery matrices, such as load transformation matrices, developed from the model.

j. Evidence of successful correlation between verification test data and the test article math model shall consist of frequency and mode shape comparisons. The goal for frequency correlation is less than ± 5 percent differences on the significant modes and less than ± 10 percent on higher order modes. Mode shape correlation shall be demonstrated qualitatively with mode shape descriptions and mode shape deflection plot comparisons. More importantly, quantitative mode shape comparisons shall be provided via cross-orthogonality checks using the test modes, the analytical modes, and the analytical mass matrix. The goal for the cross-orthogonality check is diagonal terms greater than 0.9 and off-diagonal terms less than 0.1 for modes critical to Orbiter/payload interface loads and payload internal loads. In addition, 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.

k. As part of the Payload Structural Verification Plan discussed in paragraph 5.1.1, the payload developer must address the overall approach to verification of the cargo element structural dynamic math model.

l. The payload developer is required to submit a detailed model verification test plan to the SMWG for approval. The test plan shall include complete descriptions of the test article and test setup, test article boundary conditions, instrumentation, and excitation methods, levels and locations. The plans for linearity verification, or nonlinearity investigation, shall be defined. An analytical assessment of the instrumentation number and location shall be provided, usually in the form of a cross-orthogonality check between a full model of the test article and one which has been reduced to the test instrumentation DOF. The test

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plan shall also include descriptions and plots of the target modes. If the test article is to be supported by a rig which couples with the test article in the frequency range of the test, evidence of a verified test rig model shall be provided along with an analysis of the coupled rig/test article modes. Finally, the test plan shall summarize the derivation of the test article math model which will be used for correlation to the test data. The model verification test plan shall be submitted by the Phase II Safety Review or 2 months prior to testing, whichever is earlier.

m. Prior to acceptance of the cargo element math model for use in the VLA, a model verification report shall be submitted to the SMWG for approval. The report shall contain a complete summary of the verification test and the model correlation analysis. Evidence that the model correlation has met the criteria contained in this section shall be presented. If the criteria cannot be met, then appropriate rationale must be provided for the acceptability of the model.

n. Alternative approaches for verification of the cargo element structural dynamic model will be considered by the SMWG.

o. Model verification is not required for the types of payloads discussed in the following subparagraphs. Test-verified structural dynamic math models of these payloads are not required; however, the minimum frequency shall be verified by test. If the payload structure is sufficiently simple to model, then the minimum frequency may be verified by analysis using a suitably detailed finite element model. The fundamental frequency verification, whether by test or analysis, shall be submitted to the SMWG for approval.

   1. Middeck payloads which are not stowed in lockers are required to have a minimum fundamental frequency greater than 30 Hz when constrained at the Orbiter attach points. Loads and deflections for these payloads shall be calculated using the load factors specified in NSTS 21000-IDD-MDK.

   2. Loads and deflections for sidewall-mounted payloads whose minimum frequency when constrained at the adapter beam interface is greater than 35 Hz shall be calculated using the load factors specified in NSTS 21000-IDD-SML.

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5.1.1.3 Deformation: The payload structure shall be capable of withstanding all loads up to limit without violating the Orbiter payload bay dynamic envelope or exceeding allowable trunnion travel limits, both of which are specified in the payload-unique ICD. Determination of deformation shall include contributions from applied loads, thermal loads, manufacturing tolerance, and other factors of significance. All critical conditions shall be considered. Compliance may be demonstrated by analysis.

5.1.1.4 Interface Load Compatibility: Space Shuttle/payload interface loads shall not exceed those specified in the payload-unique ICDs. Compliance may be demonstrated by analysis.

5.1.1.5 Habitable Modules: All habitable modules shall be designed to withstand the worst-case loading condition resulting from either pressure alone (as defined in paragraph 5.1.1.5a) or combined loads (as defined in paragraph 5.1.1.5c). These conditions are to be considered as separate loading conditions and the habitable module designs shall be compatible with both. Habitable module designs shall meet all of the following requirements:

a. All 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 NSTS 1700.7B or SSP 50021 for ISSP cargo elements.

b. All 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. The maximum negative pressure differential condition may be verified by either test or analysis.

c. All habitable modules, in addition to satisfying the ultimate pressure conditions (i.e., paragraph 5.1.1.5a), shall be analyzed and meet the following combined loading conditions. The minimum ultimate factor of safety for stresses due to combined loads (e.g., mechanical, pressure, and thermal)

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shall be determined in a rational manner using the equations given below. In no case shall the safety factor for combined stresses (i.e., K_C) be less than 1.40.

$$\sum S = S_E + S_P + S_T$$

where

$\sum S$ = The summation of the component stresses and is assumed to be additive in the direction of the primary stress

S_E = Stresses due to mechanical externally applied loads (e.g., inertial)

S_P = Stresses due to MDP, as defined in NSTS 1700.7B, when the term is additive to $\sum S$; stresses from minimum guaranteed pressure when the term provides relief to $\sum S$

S_T = Stresses due to thermally induced loads which are used only as additive stresses (thermal stresses shall not be combined when relieving)

and

$$K_C = \frac{(K_1 S_E + K_2 S_P + K_3 S_T)}{\sum S}$$

where

K_C = Safety Factor for Combined Loads
K_1 = 1.4 when the term is additive to ($\sum S$)
K_1 = 1.0 when the term provides relief to ($\sum S$)
K_2 = 1.5 when the term is additive to ($\sum S$)
K_2 = 1.0 when the term provides relief to ($\sum S$)
K_3 = 1.4 when the term is additive to ($\sum S$)
K_3 = 0.0 when the term provides relief to ($\sum S$)

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.

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

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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, noncase consistent, nontime 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, postprocessing programs), a method must be available to demonstrate that proper signs and safety factors were used for each combined stress case.

The following restrictions shall be applied for stress combinations. 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. 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).

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

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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.

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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

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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.- All material usage must be verified in accordance with applicable requirements in the payload-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.- The customer, for all payload bay-installed payloads, shall verify the as-built versus ICD dimensions for departure point locations and lengths, for all payload-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 customer documents and verified by the customer Quality organization. Where exceedances occur, adjustment shall be made on the payload side 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 payload customer should be prepared to discuss, during the CIR, the planned closure of the required measurement data submittal, including date(s).

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.

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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

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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 environmental 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.

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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

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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 2 Vol’s. 2 & 6, File 7, and File 8).

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

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verification requirements are to be identified and submitted by the customer in the OMRSD. Those interfaces that cannot be verified prior to flight shall also be documented 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 payload nonstandard service End-to-End (ETE) tests. Payload test requirements to be implemented and performed by the SSP shall be documented in the appropriate OMRSD files (i.e., File 2 Vol's. 2 & 6, File 7, File 8).

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. This includes those interfaces which are redundant (i.e., electrical, mechanical, fluids, etc.) and those interfaces used to control and monitor payload hazards and safety critical functions.

   Verification requires test methods that produce quantitative data which 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

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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 the launch pad for integrated checkout. The SSP-provided Ground Support Equipment (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 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 reducing requirements and broadening tolerances 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

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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

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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

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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).

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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 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

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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

g. NSTS 07700, Volume IV, Configuration Management Requirements

h. NSTS TBS, Payload Verification Requirements - 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