	METRIC (SI)/ENGLISH
NASA TECHNICAL STANDARD **Office of the NASA Chief Engineer**	**NASA-STD-7002B**
	Approved: 2018-06-06 **Superseding NASA-STD-7002A**

PAYLOAD TEST REQUIREMENTS

DOCUMENT HISTORY LOG

<table>
<tr><th>Status</th><th>Document Revision</th><th>Change Number</th><th>Approval Date</th><th>Description</th></tr>
<tr><td>Baseline</td><td></td><td></td><td>1996-07-10</td><td>Baseline Release</td></tr>
<tr><td>Revision</td><td>A</td><td></td><td>2004-09-10</td><td>General formatting and editorial changes.</td></tr>
<tr><td colspan="5">Added Distribution Statement and Document History Log.

Foreword: General revision for clarity. Added “NASA-STD-7002A supersedes NASA-STD-7002 and provides additional clarification of test conditions and durations for hardware operating in Low Earth Orbit.”

1.1 Added to 1st sentence: “for hardware operating in earth orbit.”

1.3 Added in 1st paragraph, 4th sentence: “Subject to approval by the assigned Technical Authority” before “individual”. Added in 2nd paragraph, next to last sentence: “and the assigned Technical Authority” after “the project manager”.

2.2.1: Corrected MIL-STD-461 title. Deleted MIL-STD-462, “Electromagnetic Interference Characteristics, Measurement of.” Replaced MIL-STD-1818, “Electromagnetic Effects for Systems” with MIL-STD-464, “Electromagnetic Environmental Effects Requirements for Systems.”

3. DEFINITIONS – Replaced “None” with:

3.1 Protoflight hardware: Flight Hardware of a new design; it is subject to a qualification test program that combines elements of prototype and flight acceptance verification; i.e., the application of design qualification test levels and flight acceptance test durations.

3.2 Prototype hardware: Hardware of a new design; it is subject to a design qualification test program, and is not intended for flight.

4.2.1: Added “for Space Transportation System (STS) payloads” in “The minimum probability level used to define the flight-limit level is P99.87/50 for Space Transportation System (STS) payloads,…” Added the following sentences: “For expendable launch vehicle (ELV) payloads, the minimum probability level used to define the flight-limit level is P97.72/50, which corresponds to 97.72 percent probability of not exceeding the level and is estimated with 50 percent confidence. This is equal to the mean plus 2 sigma for normal distributions.”

4.2.2: Added “and STS payloads” to paragraph heading. Added “for ELV payloads” in 4th sentence. Added the following sentences: “Sine vibration applies to STS payloads only if required to simulate sustained periodic environment from upper stages or apogee motors, etc. For STS payloads, the minimum probability level used to define the flight-limit level is P99.87/50. This is equal to the mean plus 3 sigma for normal distributions.”</td></tr>
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Status	Document Revision	Change Number	Approval Date	Description
Revision	A		2004-09-10	Continued

4.3.1 Added “predicted” in first sentence: “These tests shall demonstrate performance and survival under temperature conditions which exceed predicted flight temperature levels….” Added “the expected,” deleted “component temperature,” and changed “may” to “shall” in “If the expected flight variation is small, then component test temperature levels shall be established to provide a minimum temperature differential between test levels to adequately stress the component.”

Changed paragraph from “The number of cumulative cycles shall be no less than 10 with the test levels at maximum/minimum predicted temperature levels +/-10° Celsius (C) respectively, with a minimum temperature differential of 55°C for component level testing” to “The thermal vacuum tests shall include a number of cycles from nominal to maximum temperatures, to minimum, and then back to nominal with the test levels at temperatures of at least +/-10 Celsius (C) above/below the respective maximum/minimum predicted flight temperatures.” Added the following sentence and paragraph: “The number of cycles is to be determined by the user considering the type of mission profile and temperature margin employed.

For deep-space, interplanetary, or other non-earth orbiting missions, temperature exposure criteria must be developed on a mission-unique basis.”

4.3.2 Changed from “This test, normally performed at the subsystem and payload levels, shall be used to verify the analytical thermal model and provide confidence that the thermal control system can maintain components, subsystems, etc., within the specified operational temperature limits. The test data and the verified thermal analytical model shall be used to demonstrate the design margins in the thermal design” to “This test is normally performed at the subsystem and payload levels. The test data shall be used to demonstrate that the thermal control system can maintain components, subsystems, etc., within required temperature limits under simulated worst-case flight environments. The test shall also be used to verify analytical thermal models. The test data and the verified analytical thermal model shall demonstrate design margins in the thermal control system.”

Changed 2nd paragraph from “…The boundary conditions for evaluating the thermal design shall include, as a minimum, a worst-case hot and a worst-case cold scenario. The actual requirements, stabilization criteria, etc., shall be established in such a manner as to provide a conservative assessment of the thermal control system” to “…The test shall be designed to provide boundary conditions simulating a worst-case hot and a worst-case cold scenario. Other test requirements, such as stabilization criteria, shall be established to provide a conservative assessment of the thermal control system and ensure verification of the analytical thermal model.”

4.3.3: Added “without damaging the hardware” to “…Outgassing testing shall have sufficient margins to ensure a conservative contamination assessment without damaging the hardware.”

4.4: In 1st sentence changed “expected” to “predicted.” In 2nd paragraph, 4th sentence, deleted “MIL-STD-462” and replaced “MIL-STD-1818” with “MIL- STD-464”. In 7th sentence, replaced “MIL-

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<tr><th>Status</th><th>Document Revision</th><th>Change Number</th><th>Approval Date</th><th>Description</th></tr>
<tr><td>Revision</td><td>A</td><td></td><td>2004-09-10</td><td>Continued</td></tr>
<tr><td colspan="5">STD-1818” with “MIL-STD-464.” In 2nd paragraph, last sentence, added “approved by the Program Manager and the assigned Technical Authority” after “Waivers”.

4.5.2 Added “and thermal-cycling” in ”Additional CPTs shall be conducted during the hot and cold extremes of thermal-vacuum and thermal-cycling tests; …”

4.5.3: Changed “trouble-free” to “failure-free” in “Programs shall set a total hour “failure-free” performance requirement…” Added “or software” to “Major hardware or software changes during.…”

4.5.4 a: Changed “that encompass the entire chain of payload operations” to “End-to-end compatibility tests encompassing all payload operations.…” Added the following: “The software development schedule for delivery of fully qualified flight software shall be based on the end-to-end compatibility test need date, and not the launch date. This is to allow for compatibility testing of the flight hardware with the flight software in comprehensive performance tests.”

4.5.4 b: Changed “from the early stages” to “To provide sufficient time for checkout of the Payload Operations Control Center, it is essential that users participate in mission simulations throughout all stages of the process.”</td></tr>
<tr><td>Revision</td><td>B</td><td></td><td>2018-06-06</td><td>Significant changes were made to this NASA Technical Standard. It is recommended that it be reviewed in its entirety before implementation.

Key changes were: Provides additional clarification of the test requirements for sinusoidal vibration, modal survey, and thermal vacuum testing. The references to perform testing per the appropriate NASA, military, and The American Institute of Aeronautics and Astronautics standards have been added to the requirements for strength, random and acoustic, shock, and EMI/EMC testing. A section has been added to discuss prototype testing as an alternate verification approach to the protoflight test program that is defined as the baseline for this NASA Technical Standard. Numbered all requirements, added a Requirements Compliance Matrix, and reformatted the document in compliance with the current template.</td></tr>
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FOREWORD

This NASA Technical Standard is published by the National Aeronautics and Space Administration (NASA) to provide uniform engineering and technical requirements for processes, procedures, practices, and methods that have been endorsed as standard for NASA programs and projects, including requirements for selection, application, and design criteria of an item.

This NASA Technical Standard is approved for use by NASA Headquarters and NASA Centers and Facilities, and applicable technical requirements may be cited in contract, program, and other Agency documents. It may also apply to the Jet Propulsion Laboratory (a Federally Funded Research and Development Center (FFRDC)), other contractors, recipients of grants and cooperative agreements, and parties to other agreements only to the extent specified or referenced in applicable contracts, grants, or agreements.

This NASA Technical Standard establishes a common set of standard test program requirements for NASA payloads.

The original version of NASA-STD-7002, released in 1996, was developed by the NASA Standard Payload Test Panel, which was assembled and chaired by the Goddard Space Flight Center. Members were nominated by Engineering Management Board representatives of the Centers. To provide additional technical expert guidance in the thermal-vacuum and electromagnetic interference (EMI)/electromagnetic compatibility (EMC) testing disciplines, the Panel established two corresponding subgroups. These subgroups were chaired by personnel from the Marshall Space Flight Center (MSFC) and the Glenn Research Center, respectively.

NASA-STD-7002B supersedes NASA-STD-7002A and provides additional clarification of the test requirements for sinusoidal vibration, modal survey, and thermal vacuum testing. The references to perform testing per the appropriate NASA, military, and The American Institute of Aeronautics and Astronautics (AIAA) standards have been added to the requirements for strength, random vibration and acoustics, shock, and EMI/EMC testing. A section has been added to discuss prototype testing as an alternate verification approach to the protoflight test program that is defined as the baseline for this NASA Technical Standard.

Requests for information should be submitted via "Feedback" at https://standards.nasa.gov. Requests for changes to this NASA Technical Standard should be submitted via MSFC Form 4657, Change Request for a NASA Engineering Standard.

Original signed by
Ralph R. Roe, Jr.
NASA Chief Engineer

06/06/2018
Approval Date

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PAYLOAD TEST REQUIREMENTS

1. SCOPE

1.1 Purpose

The purpose of this NASA Technical Standard is to provide an Agency-wide basis from which test programs are developed for NASA payloads. The document defines a standard set of flight hardware test requirements which provide the necessary verification of design adequacy and flight worthiness of NASA spacecraft. Compliance provides consistency across the Agency and its contractors, facilitating the sharing of hardware between Centers and programs. Compliance also provides a basis for establishing a baseline pedigree for the "qualification by similarity" evaluation process for "heritage" hardware without the need to consider the variability of test requirements.

This NASA Technical Standard includes selected environmental exposure tests for flight hardware. The NASA Technical Standard has been developed for payloads that will operate in Earth's orbit but may be tailored to include other operating environments. The tests included are generally regarded as the most critical and the ones having the highest cost and schedule impact. This NASA Technical Standard also includes functional demonstration tests necessary to validate the capability of the hardware to perform its intended function (with and without environmental exposure). This NASA Technical Standard specifies test levels, factors, margins, durations, and other parameters. In some cases, these specifics are expressed statistically or are referenced in other NASA standards.

1.2 Applicability

This NASA Technical Standard is approved for use by NASA Headquarters and NASA Centers and Facilities, and applicable technical requirements may be cited in contract, program, and other Agency documents. It may also apply to the Jet Propulsion Laboratory (a Federally Funded Research and Development Center (FFRDC)), other contractors, recipients of grants and cooperative agreements, and parties to other agreements only to the extent specified or referenced in applicable contracts, grants, or agreements.

This NASA Technical Standard applies to all NASA payload hardware developed in-house or under contract that is launched on expendable or reusable launch vehicles (both free-flyer and attached payloads). This NASA Technical Standard defines a baseline test program which is applicable to all NASA payload hardware regardless of mission risk classification as defined in NPR 8705.4, Risk Classification for NASA Payloads. However, the test program may be tailored based on mission success criteria and risk classification following the Center's defined risk philosophy and with approval from the delegated Technical Authority. The levels of assembly for which this NASA Technical Standard applies are the payload, modular subsystem (which includes large instruments), and component. Small instruments may be treated as components.

This NASA Technical Standard defines a baseline test program for NASA payload hardware. In general, no distinction has been made between “human-rated” and “robotic” missions. Human-rated flight systems may be subjected to additional verification and/or safety requirements that are consistent with the established risk levels for mission success and flight crew safety not covered by this NASA Technical Standard.

This NASA Technical Standard excludes payloads launched on sounding rockets, balloons, and aircraft, as well as the launch vehicle hardware itself. Also excluded from this NASA Technical Standard are tests that may be required below the component level of assembly such as material testing or electronic part screening.

This NASA Technical Standard is developed for the typical NASA protoflight payload wherein one payload is built and serves to qualify the design and is also the flight article. It also recognizes the need to define the mission-unique environment for each test discipline. This environmental definition ensures the tailoring of test requirements to the environmental envelope encountered during the payload’s total lifetime, considering phases such as ground handling, launch, and in-space operations.

The principal objective of the test program is to demonstrate the system’s ability to collect scientific data and perform specific remote operations rather than meet rigid general requirements. Certain environments and functions cannot reasonably be simulated on Earth because of factors such as size, zero-gravity limitations, and interface boundary conditions. Tailoring the test program, with supplemental analysis, is appropriate in such cases. This NASA Technical Standard is generally not retroactive from the approval date for hardware already under contract.

Verifiable requirement statements are designated by the acronym PTR (Payload Test Requirement), numbered, and indicated by the word “shall”; this NASA Technical Standard contains 67 requirements. Explanatory or guidance text is indicated in italics beginning in section 4. To facilitate requirements selection by NASA programs and projects, a Requirements Compliance Matrix is provided in Appendix A.

1.3 Tailoring

[PTR 1] Tailoring of this NASA Technical Standard for application to a specific program or project shall be formally documented, including rationale, as part of program or project requirements; approved by the delegated Technical Authority in accordance with NPR 7120.5, NASA Space Flight Program and Project Management Requirements; and maintained as a record.

2. APPLICABLE DOCUMENTS

2.1 General

The documents listed in this section contain provisions that constitute requirements of this NASA Technical Standard as cited in the text.

2.1.1 [PTR 2] The latest issuances of cited documents shall apply unless specific versions are designated.

2.1.2 [PTR 3] Non-use of specifically designated versions shall be approved by the delegated Technical Authority.

Applicable documents may be accessed at https://standards.nasa.gov or obtained directly from the Standards Developing Body or other document distributors. When not available from these sources, information for obtaining the document is provided.

References are provided in Appendix B.

2.2 Government Documents

Department of Defense

MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-464	Electromagnetic Environmental Effects Requirements for Systems

National Aeronautics and Space Administration (NASA)

NPR 7120.5	NASA Space Flight Program and Project Management Requirements
NASA-STD-5001	Structural Design and Test Factors of Safety for Spaceflight Hardware
NASA-STD-7001	Payload Vibroacoustic Test Criteria
NASA-STD-7003	Pyroshock Test Criteria

2.3 Non-Government Documents

AIAA

AIAA S-121	Electromagnetic Compatibility Requirements for Space Equipment and Systems

2.4 Order of Precedence

2.4.1 The requirements and standard practices established in this NASA Technical Standard do not supersede or waive existing requirements and standard practices found in other Agency documentation, or in applicable laws and regulations unless a specific exemption has been obtained by the Office of the NASA Chief Engineer.

2.4.2 [PTR 4] Conflicts between this NASA Technical Standard and other requirements documents shall be resolved by the delegated Technical Authority.

3. ACRONYMS, ABBREVIATIONS, SYMBOLS, AND DEFINITIONS

3.1. Acronyms, Abbreviations, and Symbols

°C	Degrees Celsius
°F	Degrees Fahrenheit
%	Percent
AIAA	The American Institute of Aeronautics and Astronautics
CLA	Coupled Loads Analysis
CPT	Comprehensive Performance Test
dB	Decibel
EID	Electrically Initiated Device
ELV	Expendable Launch Vehicle
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
FFRDC	Federally Funded Research and Development Center
Hz	Hertz
kg	Kilogram
lb	Pound
LISN	Line Impedance Simulation Network
MIL	Military
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NPR	NASA Procedural Requirements
PTR	Payload Test Requirement
RF	Radio frequency

SI	Système Internationale
STD	Standard

3.2 Definitions

Acceptance Test: A test performed to demonstrate that the flight hardware is acceptable for its intended use. It also serves as a quality control screen to detect manufacturing, material, or workmanship defects in the flight build and to demonstrate compliance with specified requirements. This type of test is performed on previously qualified hardware to flight limit levels and durations.

Component: A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronic box, transmitter, gyro package, actuator, motor, battery. The term unit may also be used to designate this level of assembly.

Flight Acceptance Test: See Acceptance Test.

Instrument: See Subsystem.

Payload: An integrated assemblage of subsystems designed to perform a specified mission in space. Other terms that may be used to designate this level of assembly are Satellite, Spacecraft, or Observatory.

Protoflight Hardware: Flight hardware of a new design that is qualified through a protoflight test program.

Protoflight Test: A test performed on flight hardware that demonstrates qualification for flight by combining elements of prototype and flight acceptance verification; i.e., the application of design qualification test levels and flight acceptance test durations.

Prototype Hardware: Hardware of a new design that is not intended for flight but is manufactured using the same drawings, materials, tooling, inspections methods, and personnel competency as will be used for the flight hardware; it is subject to a prototype test program.

Prototype Test: A test performed on prototype hardware to demonstrate that the design is qualified for flight. The test is intended to demonstrate that the test item will function within performance specifications after being exposed to levels which demonstrate margin over the expected flight environment. Test durations are defined to demonstrate fatigue-life capability against planned ground testing and exposure to the flight environment.

Qualification Test: A test intended to verify that the hardware meets design requirements and will function within performance specifications after being exposed to levels that demonstrate margin over the expected flight environment. Both prototype and protoflight tests are considered to be qualification tests.

Subsystem: A functional subdivision of a payload consisting of two or more components and may include interconnection items such as cables or tubing and the supporting structure to which they are mounted. Examples are structural, electrical power, attitude control, telemetry, thermal control, and propulsion subsystems. For the purposes of this document, an instrument (sensors and associated hardware) is considered a subsystem of the payload.

4. REQUIREMENTS

4.1 Payload Test Requirements Matrix (Protoflight Program)

[PTR 5] Payload verification testing shall be performed as defined in Table 1, Payload Test Requirements Matrix (Protoflight Program).

The tests shown in Table 1 are divided into four categories: mechanical, thermal, electro-magnetic interference (EMI), and functional tests. The requirements are defined for each of the three levels of assembly (component, modular subsystem/large instrument, and spacecraft/payload). Small spacecraft, typically those under 454 kilograms (kg) (1000 pounds (lb)), are usually fabricated from components (with the exception of the structure which may be a subsystem). Thus, only two levels of assembly are appropriate for this case. The matrix is appropriate for the NASA baseline spacecraft program, that is, a "protoflight" program.

Table 1—Payload Test Requirements Matrix (Protoflight Program)

MECHANICAL TESTS	**COMPONENT**	**SUBSYSTEM/ INSTRUMENT**	**PAYLOAD/ SPACECRAFT**
Strength	**1**	**1**	**1**
Sinusoidal Sweep Vibration	**2 >**		
Random Vibration		**2,3**	**2 <454 kg**
Acoustics	**2 >**	**2,3 >**	
Shock (Mechanical and Pyro)			
A. Self-induced			
B. Externally induced	**2 >**	**2 >**	
Modal Survey			
Pressure Profile	**2**	**2**	**2**
Mechanical Function		>	
THERMAL TESTS			
Thermal Vacuum Thermal Cycle (4)			
Ambient Pressure Thermal Cycle (5)			
Thermal Balance		>	
Temperature-Humidity	**2**	**2**	**2**

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Bakeout (Contamination-Sensitive Applications)			
Leak Test for Sealed Components			
EMI/EMC TESTS			
Conducted Emissions		**7**	**6**
Radiated Emissions			
Conducted Susceptibility		**7**	**6**
Radiated Susceptibility			
FUNCTIONAL TESTS			
Electrical Interface			
Comprehensive Performance			
Failure-free Performance	>	>	
End-to-End Compatibility Tests & Mission			
Life Test Program (Critical Components)			
Mass Properties Verification			**1**
Alignment	>		

Required Test.
> Can be accomplished at a higher level of assembly.
1 May be accomplished by analysis.
2 Test if assessed to be sensitive to the environment.
3 An acoustic or random test is required at the subsystem/instrument level of assembly depending on sensitivity to the vibroacoustic environment.
4 If operation required in vacuum.
5 If operation required in pressurized environment.
6 For attached payloads or payloads that derive power from an off-board source such as payloads that receive power from a host vehicle.
7 At payload/spacecraft level and with concurrence from the delegated Technical Authority, conducted emissions and susceptibility testing may be replaced with power quality measurements, e.g., aggregate voltage ripple, turn-on/turn-off transients, etc. Such measurements have to be performed across a Line Impedance Simulation Network (LISN) that represents the spacecraft power bus source impedance at the point of distribution.

4.2 Mechanical Tests

4.2.1 Strength

Strength testing is intended to verify structural integrity requirements by exposing the hardware to the forces and stresses that simulate peak loading conditions with appropriate test margin.

4.2.1.1 [PTR 6] Strength testing shall be performed as specified in NASA-STD-5001, Structural Design and Test Factors of Safety for Spaceflight Hardware.

4.2.1.2 [PTR 7] The minimum probability and confidence levels shown in Table 2, Minimum Probability and Confidence Levels for Strength and Sinusoidal Vibration Tests, shall be used to define flight limit loads for strength testing.

Strength testing of pressurized structures, pressure vessels, and pressurized components for pressure loading is covered under NASA-STD-5001. The probability/confidence levels defined in Table 2 are not applicable to deterministic loading conditions such as pressure loads or thermally induced mechanical loads.

Table 2—Minimum Probability and Confidence Levels for Strength and Sinusoidal Vibration Tests

Payload Type	Minimum Probability and Confidence Level	Notes
Human Rated	99.87/50	99.87% probability of not exceeding level estimated with a 50% confidence. Equal to mean plus three-sigma level for a normal distribution.
Robotic	97.72/50	97.72% probability of not exceeding level estimated with a 50% confidence. Equal to mean plus two-sigma level for a normal distribution.

4.2.2 Sinusoidal Vibration

The sinusoidal vibration test is intended to simulate the low-frequency dynamic launch environment predicted by a coupled loads analysis (CLA) and should account for sustained sinusoidal environments when they are present in flight. The sinusoidal vibration test also satisfies requirements from the launch vehicle provider to demonstrate that the flight hardware can survive exposure to the low-frequency launch environment. The low-frequency launch environment is typically defined up to 100 hertz (Hz). The frequency range of the test should be defined to cover the significant flight events from the CLA.

4.2.2.1 [PTR 8] Sinusoidal vibration testing shall be performed to qualify hardware for the low-frequency launch environment.

In lieu of performing sinusoidal vibration testing, it is acceptable to demonstrate qualification for the low-frequency vibration environment during launch by using other types of input, including random vibration and transient, as long as these test inputs can be shown to envelope the expected environment with appropriate test margin and will satisfy requirements from the launch vehicle provider.

4.2.2.2 [PTR 9] Protoflight sinusoidal vibration testing shall be conducted at levels that are 1.25 times the flight-limit levels and at a sweep rate of 4 octaves per minute.

Other sweep rates may be used to more accurately replicate the duration of specific flight events.

4.2.2.3 [PTR 10] During testing, the hardware shall be configured both electrically and mechanically in the operational mode for liftoff.

4.2.2.4 [PTR 11] The minimum probability and confidence levels shown in Table 2 shall be used to define the flight-limit level for sinusoidal vibration testing.

4.2.3 Random Vibration and Acoustics

Random vibration and/or acoustic testing is performed to qualify the hardware for the expected mission environment and to provide workmanship screening for all electrical, electronic, and electromechanical components.

4.2.3.1 [PTR 12] Random vibration and acoustic testing shall be performed as specified in NASA-STD-7001, Payload Vibroacoustic Test Criteria.

Hardware should be assessed for sensitivity to the vibroacoustic environment to determine whether random, acoustic, or both types of tests should be performed.

4.2.3.2 [PTR 13] The minimum probability level used to define the flight limit level for random vibration and acoustics shall be $P_{95/50}$.

4.2.4 Shock (Mechanical and Pyro)

Shock testing is performed to verify that the hardware will function as intended after being exposed to the shock environment.

4.2.4.1 [PTR 14] Pyroshock testing shall be performed as specified in NASA-STD-7003, Pyroshock Test Criteria.

4.2.4.2 [PTR 15] The minimum probability level that shall be used to define the flight-limit shock level is $P_{95/50}$.

4.2.4.3 Self-Induced Shock

This shock occurs principally when pyrotechnic and pneumatic devices are actuated to release booms, solar arrays, protective covers, etc. Also, the impact of deployable devices as they reach their operational position at the "end of travel" is a possible source of significant shock.

[PTR 16] If hardware contains devices that produce a self-induced shock, it shall be exposed to each shock source twice, at a minimum.

4.2.4.4 Externally Induced Shock

This shock, both mechanical and pyro shock, originates from other subsystems, payloads, or launch vehicle operations.

4.2.4.4.1 [PTR 17] When the most severe shock is externally induced, a simulation of that shock shall be applied at the hardware interface.

Only testing for the dominant shock environment is required.

4.2.4.4.2 [PTR 18] When it is feasible to simulate the externally induced shock with a controllable shock-generating device, the qualification level shall be 1.4 times the flight-limit level at the hardware interface, applied once in each of three axes.

If it is not feasible to apply the shock with a controllable shock-generating device, the test may be conducted at the payload level by actuating the devices in the payload that produce the shocks external to the hardware to be tested. The shock-producing device has to be actuated a minimum of two times for this test.

4.2.5 Modal Survey

Modal survey testing is performed to ensure that the mathematical model is sufficiently accurate for load and deflection predictions.

[PTR 19] Modal survey testing shall be performed for all hardware that has significant modes in the frequency range of the launch vehicle CLA

Significant modes are typically defined as having modal effective mass of greater than 5% but low-mass modes that drive responses in critical areas based on the CLA results may also be considered as targets for a modal survey. The flight boundary conditions at the hardware interface and the stiffness of the underlying mounting structure should be considered when determining if a mode falls within the CLA frequency range.

Requirements for modal survey testing and mathematical model verification are specified in NASA-STD-5002, Load Analyses of Spacecraft and Payloads.

4.2.6 Pressure Profile

A pressure profile qualification test may be required if analysis does not indicate a positive margin at loads equal to those induced by the maximum expected pressure differential during launch.

4.2.6.1 [PTR 20] If a pressure profile test is required, the limit-pressure profile shall be derived from the predicted pressure-time profile for the nominal trajectory of the particular mission.

4.2.6.2 [PTR 21] The pressure profile test shall be performed using the test factor for loads as specified in NASA-STD-5001.

4.2.7 Mechanical Function

4.2.7.1 [PTR 22] A mechanical function test of all deployable appendages and mechanical devices shall be conducted under the nominal conditions expected during flight.

4.2.7.2 [PTR 23] A high-energy test and a low-energy test shall also be conducted to prove positive margins of strength and function.

4.2.7.3 [PTR 24] The high- and low-energy test shall demonstrate margins beyond the nominal flight conditions by considering adverse interaction of potential extremes of parameters such as temperature, friction, spring forces, stiffness of electrical cabling or thermal insulation, and spin rate.

4.2.7.4 [PTR 25] Mechanical function tests of all deployable appendages and mechanical devices shall be conducted to demonstrate the hardware will meet performance requirements before and after environmental test exposure.

Unless the design of the device dictates otherwise, mechanical functional tests conducted to demonstrate the hardware meets performance requirements after environmental test exposure may be performed in ambient laboratory conditions.

4.3 Thermal Tests

4.3.1 Thermal Vacuum and Ambient Pressure Thermal Cycle

Thermal vacuum and thermal cycle tests are intended to demonstrate performance and survival under temperature conditions which exceed predicted flight temperature levels and act as an environmental stress screen to stimulate latent defects to minimize infant mortality failures.

Hardware that is operated in a vacuum should undergo thermal vacuum testing at a vacuum level that is sufficient to prevent natural convection. Ambient pressure thermal cycling may be substituted for thermal-vacuum temperature cycling if it can be shown by comprehensive analysis that the temperature levels and gradients are as severe in air as in vacuum.

4.3.1.1 [PTR 26] The temperature levels for thermal vacuum and thermal cycle tests shall be based on worst-case, high- and low-temperature extremes, with added margins.

4.3.1.2 [PTR 27] The test margin shall be sufficient to meet minimum workmanship requirements.

4.3.1.3 [PTR 28] The thermal vacuum test shall include a number of cycles from nominal to maximum temperatures, to minimum, and then back to nominal, with the test levels at temperatures of at least 10 °C (18 °F) above/below the maximum expected temperature range for flight.

The maximum expected temperature range is the maximum and minimum temperatures defined by analysis or by operational requirement and does not include thermal uncertainty. The minimum 10 °C test margin specified in [PTR 28] includes 5 °C of thermal uncertainty beyond the maximum expected temperature range and 5 °C margin for a protoflight test. If the maximum expected flight temperature range is small, the component test range may be increased to provide the minimum temperature differential necessary to adequately stress the component.

The parameters of the thermal test profile, including number of cycles, ramp rate, plateau temperatures, and the duration of each cycle, are to be determined by the user following his/her Center's specific verification philosophy or based on guidance from the delegated Technical Authority.

For deep-space, interplanetary, or other non-Earth-orbiting missions, temperature exposure criteria has to be developed on a mission-unique basis.

4.3.2 Thermal Balance

This test is normally performed at the subsystem and payload levels in a vacuum. Test conditions and durations are dependent upon the test article's configuration, design, and mission requirements.

4.3.2.1 [PTR 29] The test data shall be used to demonstrate that the thermal control system can maintain components, subsystems, etc., within required temperature limits under simulated worst-case flight environments.

4.3.2.2 [PTR 30] The test shall be used to verify the accuracy of analytical thermal and power models.

4.3.2.3 [PTR 31] The test data and verified analytical thermal model shall be used to demonstrate design margins in the thermal control system.

4.3.2.4 [PTR 32] At a minimum, the test shall be designed to provide boundary conditions simulating a worst-case hot and a worst-case cold prediction.

4.3.2.5 [PTR 33] Other test requirements such as stabilization criteria shall be established to provide a conservative assessment of the thermal control system and ensure verification of the analytical thermal model.

4.3.3 Bakeout

4.3.3.1 [PTR 34] Components or higher levels of assembly which pose a contamination threat to contamination-sensitive hardware shall be thermal-vacuum baked to achieve an acceptable level of molecular outgassing, as defined in a contamination control plan.

4.3.3.2 [PTR 35] Outgassing testing shall have sufficient margins to ensure a conservative contamination assessment without damaging the hardware.

4.3.4 Leak Test for Sealed Components

[PTR 36] Leak rates shall be determined prior to stress-inducing environmental tests and periodically during subsequent testing.

4.4 EMI/EMC Tests

4.4.1 [PTR 37] The EMI/EMC test program shall ensure that the total payload/vehicle system performs its intended functions when operating in the predicted electromagnetic environment.

A structured EMI/EMC program should be defined early in the design phase and require a definition of the mission environment, including all phases of the mission, and an appropriate mix of component, subsystem, and payload qualification tests dependent on the complexity and sensitivity of the payload.

4.4.2 [PTR 38] MIL-STD-461, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment; MIL-STD-464, Electromagnetic Environmental Effects Requirements for Systems; AIAA S-121, Electromagnetic Compatibility Requirements for Space Equipment and Systems; or NASA mission-specific specifications shall be used for setting test levels and defining consistent test procedures.

MIL-STD-461 specifies the limit values used for qualification of electronic hardware. MIL-STD-461 also specifies the test methods to be used to perform the measurements. Earlier test methods may be specified where appropriate (e.g., CE03 for current measurement for conducted emissions in lieu of CE102 for voltage measurement). AIAA S-121 is an EMC specification for the space systems industry that is derived in large part from MIL-STD-461 and MIL-STD-464. MIL-STD-464 provides the basis for the development of EMI/EMC performance requirements.

All specifications permit the use of tailoring as needed.

4.4.3 [PTR 39] The test regime shall be composed of a variety of conducted and radiated emissions, as well as susceptibility tests needed to satisfy mission requirements.

Both steady-state and transient environments should be considered when developing the EMI/EMC test program. Mission-unique environmental requirements such as intentional *transmitters and receivers, ground handling and space-charging electrostatic discharge, and lightning-induced effects in the prelaunch mode must also be considered.*

4.4.4 [PTR 40] Tests at the developmental level shall result in one of the following:

a. Test passage,
b. Redesign and retest of the offending circuitry, or
c. Submission of waiver(s) for non-compliance(s) if needed for subsequent flight hardware.

4.4.5 [PTR 41] Waivers approved by the Program Manager and the assigned Technical Authority may be invoked for tests at the qualification level, but they shall be evaluated to ensure that program/mission-level EMI safety margins are maintained.

4.4.6 EMI Safety Margin Requirements

Safety margin requirements may be demonstrated by test, analysis, or a combination thereof.

4.4.6.1 [PTR 42] Safety critical circuits shall demonstrate safety margins of not less than 6 decibels (dB).

Additional margin may be required if verification is performed by analysis only.

4.4.6.2 [PTR 43] Electrically Initiated Device (EID) interfaces shall demonstrate a minimum safety margin of 20 dB radio frequency (RF) level referenced to direct current no-fire level.

Lower margins may be used as approved by the delegated Technical Authority.

An EID is a single unit, device, or subassembly that uses electrical energy to produce a non-reversible explosive, pyrotechnic, thermal, or mechanical output.

4.4.6.3 [PTR 44] EID interfaces shall demonstrate a minimum safety margin of 12 dB RF level referenced to RF no-fire level.

4.5 Functional Tests

4.5.1 Electrical Interface

4.5.1.1 [PTR 45] Before the integration of an assembly into the next higher hardware assembly level, electrical interface tests shall be performed to verify that all interface signals are within acceptable limits of applicable performance specifications.

4.5.1.2 [PTR 46] Prior to mating with other hardware, electrical harnessing shall be tested to verify proper characteristics such as routing of electrical signals, impedance, isolation, and overall workmanship.

4.5.2 Comprehensive Performance

4.5.2.1 [PTR 47] A comprehensive performance test (CPT) demonstrating that hardware and software meet performance requirements within allowable tolerances shall be conducted on each hardware element after each stage of assembly (component, subsystem, and payload).

4.5.2.2 [PTR 48] Additional CPTs shall be conducted during the hot and cold extremes of thermal-vacuum and thermal-cycling tests, at the conclusion of the environmental test sequence, and at other times prescribed in the verification plan.

CPTs conducted during the hot and cold extremes should take into consideration demonstrating start-up performance at the thermal plateaus and functional testing at cycle transitions.

4.5.2.3 [PTR 49] At the payload level, the CPT shall demonstrate that, with the application of known stimuli, the payload will produce the expected responses.

4.5.2.4 [PTR 50] At lower levels of assembly, the test shall demonstrate that, when provided with appropriate inputs, internal performance is satisfactory and outputs are within acceptable limits.

4.5.2.5 [PTR 51] Redundant circuit performance and critical-fault protection shall be verified.

4.5.3 Failure-Free Performance

4.5.3.1 [PTR 52] Programs shall set a total hour "failure-free" performance requirement tailored to hardware classification, criticality, and mission-reliability goals.

4.5.3.2 [PTR 53] At the conclusion of the performance verification program, payloads shall have demonstrated this failure-free performance.

Subsystem testing may be included. Failure-free operation during the thermal-vacuum test exposure may also be included.

4.5.3.3 [PTR 54] Major hardware or software changes during or after verification shall require re-verification of the affected items.

4.5.4 End-to-End Compatibility Tests and Mission Simulations

4.5.4.1 Compatibility Tests

4.5.4.1.1 [PTR 55] End-to-end compatibility tests encompassing all payload operations occurring during all mission modes shall be conducted to ensure the system will fulfill mission requirements.

4.5.4.1.2 [PTR 56] The mission environment shall be simulated as realistically as possible.

4.5.4.1.3 [PTR 57] The instruments shall receive stimuli similar to that to be received during the mission.

4.5.4.1.4 [PTR 58] The radio frequency links, ground-station operations, and software functions shall be exercised.

Acceptable simulation facilities may be used for the test of portions of the operational systems.

4.5.4.1.5 [PTR 59] The software development schedule for delivery of fully qualified flight software shall be based on the end-to-end compatibility test need date and not the launch date.

This allows for compatibility testing of the flight hardware with the flight software in comprehensive performance tests.

4.5.4.2 Mission Simulations

4.5.4.2.1 [PTR 60] After compatibility between the network and the user facility has been verified, data flow tests shall be performed that exercise the total system.

4.5.4.2.2 [PTR 61] Once the data flow paths have been verified, mission simulations shall be enacted to validate nominal and contingency mission operating procedures and to provide for operator training.

To provide sufficient time for checkout of the Payload Operations Control Center, it is essential that users participate in mission simulations throughout all stages of the process.

4.5.5 Life Test Program

4.5.5.1 [PTR 62] A life test program on a dedicated article shall be implemented for critical mechanical and electrical elements that have limited lifetimes.

Such elements include mechanical items that move or rotate repetitively and electrical items such as motors, batteries, solar arrays, and lamps having usefulness limited to a specified time or number of cycles.

4.5.5.2 [PTR 63] The verification plan shall address the life test programs by specifying the elements that require such testing and by describing the test hardware and methods that will be used.

4.5.6 Mass Properties Verification

4.5.6.1 [PTR 64] Hardware mass property requirements (weight, center of gravity, moments of inertia, balance) are mission-dependent and shall be determined on a case-by-case basis.

4.5.6.2 [PTR 65] The mass properties program shall include an analytical assessment of the payload's ability to comply with the mission requirements, supplemented as necessary by measurement.

4.5.7 Alignment

4.5.7.1 [PTR 66] Critical optical and mechanical alignments shall be verified to meet performance requirements before and after environmental test exposure.

4.5.7.2 [PTR 67] Critical optical and mechanical alignments necessary to meet on-orbit performance requirements shall be verified during thermal vacuum testing.

4.6 Protoflight vs. Prototype Test Approaches

This NASA Technical Standard defines the baseline test approach for NASA payloads as a protoflight test program in which the flight hardware is tested to demonstrate design qualification and also to verify the workmanship and material quality of the flight build.

An acceptable alternate approach to protoflight testing is the prototype test program. Prototype testing is also referred to as a qualification/flight acceptance verification approach. In a prototype test program, a dedicated non-flight test article of the same quality as the flight build is tested to demonstrate design qualification. Prototype testing is performed at increased durations and/or levels over a protoflight test to demonstrate margin against predicted failure modes of the hardware. Prototype test durations are defined to demonstrate fatigue-life capability against planned ground testing and exposure to the flight environment. Under a prototype test program, the flight hardware is tested to levels and durations that are representative of the flight environment to demonstrate acceptability for flight.

It is not expected that the verification flow defined in this NASA Technical Standard will be significantly different if a prototype test approach is followed. However, if a prototype test program is derived based on this NASA Technical Standard, the overall approach, including *test levels and durations, needs to be reviewed by the delegated Technical Authority to ensure that all the goals of a successful verification program will be met.*

APPENDIX A

REQUIREMENTS COMPLIANCE MATRIX

Due to the complexity and uniqueness of space flight, it is unlikely that all of the requirements in a NASA technical standard will apply. The Requirements Compliance Matrix below contains this NASA Technical Standard's technical authority requirements and may be used by programs and projects to indicate requirements that are applicable or not applicable to help minimize costs. Enter "Yes" in the "Applicable" column if the requirement is applicable to the program or project or "No" if the requirement is not applicable to the program or project. The "Comments" column may be used to provide specific instructions on how to apply the requirement or to specify proposed tailoring.

NASA-STD-XXXXR				
Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
1.3	Tailoring	[PTR 1] Tailoring of this NASA Technical Standard for application to a specific program or project shall be formally documented, including rationale, as part of program or project requirements; approved by the delegated Technical Authority in accordance with NPR 7120.5, NASA Space Flight Program and Project Management Requirements; and maintained as a record.		
2.1.1	Applicable Documents, General	[PTR 2] The latest issuances of cited documents shall apply unless specific versions are designated.		
2.1.2	Applicable Documents, General	[PTR 3] Non-use of specifically designated versions shall be approved by the delegated Technical Authority.		
2.4.2	Order of Precedence	[PTR 4] Conflicts between this NASA Technical Standard and other requirements documents shall be resolved by the delegated Technical Authority.		
4.1	Payload Test Requirements Matrix (Protoflight Program)	[PTR 5] Payload verification testing shall be performed as defined in Table 1, Payload Test Requirements Matrix (Protoflight Program).		

Table 1—Payload Test Requirements Matrix (Protoflight Program)

MECHANICAL TESTS	COMPONENT	SUBSYSTEM/ INSTRUMENT	PAYLOAD/ SPACECRAFT
Strength	1	1	1
Sinusoidal Sweep Vibration	2 >		
Random Vibration		2,3	2 <454 kg
Acoustics	2 >	2,3 >	
Shock (Mechanical and Pyro)			
A. Self-induced			
B. Externally induced	2 >	2 >	
Modal Survey			
Pressure Profile	2	2	2
Mechanical Function		>	
THERMAL TESTS			
Thermal Vacuum Thermal Cycle (4)			
Ambient Pressure Thermal (5)			
Thermal Balance		>	
Temperature-Humidity	2	2	2
Bakeout (Contamination-Sensitive Applications)			
Leak Test for Sealed Components			
EMI/EMC TESTS			
Conducted Emissions		7	6
Radiated Emissions			
Conducted Susceptibility		7	6
Radiated Susceptibility			
FUNCTIONAL TESTS			
Electrical Interface			
Comprehensive Performance			
Failure-free Performance	>	>	
End-to-End Compatibility Tests & Mission Simulations			

Life Test Program (Critical Components)			
Mass Properties Verification			**1**
Alignment	>		

[shaded box] Required Test.

> Can be accomplished at a higher level of assembly.

1 May be accomplished by analysis.

2 Test if assessed to be sensitive to the environment.

3 An acoustic or random test is required at the subsystem/instrument level of assembly depending on sensitivity to the vibroacoustic environment.

4 If operation required in vacuum.

5 If operation required in pressurized environment.

6 For attached payloads or payloads that derive power from an off-board source such as payloads that receive power from a host vehicle.

7 At payload/spacecraft level and with concurrence from the delegated Technical Authority, conducted emissions and susceptibility testing may be replaced with power quality measurements, e.g., aggregate voltage ripple, turn-on/turn-off transients, etc. Such measurements have to be performed across a Line Impedance Simulation Network (LISN) that represents the spacecraft power bus source impedance at the point of distribution.

4.2.1.1	Mechanical Tests, Strength	[PTR 6] Strength testing shall be performed as specified in NASA-STD-5001, Structural Design and Test Factors of Safety for Spaceflight Hardware.		
4.2.1.2	Mechanical Tests, Strength	[PTR 7] The minimum probability and confidence levels shown in Table 2, Minimum Probability and Confidence Levels for Strength and Sinusoidal Vibration Tests, shall be used to define flight limit loads for strength testing.		

Table 2—Minimum Probability and Confidence Levels for Strength and Sinusoidal Vibration Tests

Payload Type	Minimum Probability and Confidence Level	Notes
Human Rated	99.87/50	99.87% probability of not exceeding level estimated with a 50% confidence. Equal to mean plus three-sigma level for a normal distribution.
Robotic	97.72/50	97.72% probability of not exceeding level estimated with a 50% confidence. Equal to mean

<table>
<tr><td></td><td></td><td><table><tr><td></td><td></td><td>plus two-sigma level for a normal distribution.</td></tr></table></td><td></td><td></td></tr>
<tr><td>4.2.2.1</td><td>Sinusoidal Vibration</td><td>[PTR 8] Sinusoidal vibration testing shall be performed to qualify hardware for the low-frequency launch environment.</td><td></td><td></td></tr>
<tr><td>4.2.2.2</td><td>Sinusoidal Vibration</td><td>[PTR 9] Protoflight sinusoidal vibration testing shall be conducted at levels that are 1.25 times the flight-limit levels and at a sweep rate of 4 octaves per minute.</td><td></td><td></td></tr>
<tr><td>4.2.2.3</td><td>Sinusoidal Vibration</td><td>[PTR 10] During testing, the hardware shall be configured both electrically and mechanically in the operational mode for liftoff.</td><td></td><td></td></tr>
<tr><td>4.2.2.4</td><td>Sinusoidal Vibration</td><td>[PTR 11] The minimum probability and confidence levels shown in Table 2 shall be used to define the flight-limit level for sinusoidal vibration testing.

Table 2—Minimum Probability and Confidence Levels for Strength and Sinusoidal Vibration Tests<table><tr><th>Payload Type</th><th>Minimum Probability and Confidence Level</th><th>Notes</th></tr><tr><td>Human Rated</td><td>99.87/50</td><td>99.87% probability of not exceeding level estimated with a 50% confidence. Equal to mean plus three-sigma level for a normal distribution.</td></tr><tr><td>Robotic</td><td>97.72/50</td><td>97.72% probability of not exceeding level estimated with a 50% confidence. Equal to mean plus two-sigma level for a normal distribution.</td></tr></table></td><td></td><td></td></tr>
<tr><td>4.2.3.1</td><td>Random Vibration and Acoustics</td><td>[PTR 12] Random vibration and acoustic testing shall be performed as specified in NASA-STD-7001, Payload Vibroacoustic Test Criteria.</td><td></td><td></td></tr>
<tr><td>4.2.3.2</td><td>Random Vibration and Acoustics</td><td>[PTR 13] The minimum probability level used to define the flight limit level for random vibration and acoustics shall be $P_{95/50}$.</td><td></td><td></td></tr>
<tr><td>4.2.4.1</td><td>Shock (Mechanical and Pyro)</td><td>[PTR 14] Pyroshock testing shall be performed as specified in NASA-STD-7003, Pyroshock Test Criteria.</td><td></td><td></td></tr>
<tr><td>4.2.4.2</td><td>Shock (Mechanical and Pyro)</td><td>[PTR 15] The minimum probability level that shall be used to define the flight-limit shock level is $P_{95/50}$.</td><td></td><td></td></tr>
<tr><td>4.2.4.3</td><td>Self-Induced Shock</td><td>[PTR 16] If hardware contains devices that produce a self-induced shock, it shall be exposed to each shock source twice, at a minimum.</td><td></td><td></td></tr>
</table>

4.2.4.4.1	Externally Induced Shock	[PTR 17] When the most severe shock is externally induced, a simulation of that shock shall be applied at the hardware interface.		
4.2.4.4.2	Externally Induced Shock	[PTR 18] When it is feasible to simulate the externally induced shock with a controllable shock-generating device, the qualification level shall be 1.4 times the flight-limit level at the hardware interface, applied once in each of three axes.		
4.2.5	Modal Survey	[PTR 19] Modal survey testing shall be performed for all hardware that has significant modes in the frequency range of the launch vehicle CLA.		
4.2.6.1	Pressure Profile	[PTR 20] If a pressure profile test is required, the limit-pressure profile shall be derived from the predicted pressure-time profile for the nominal trajectory of the particular mission.		
4.2.6.2	Pressure Profile	[PTR 21] The pressure profile test shall be performed using the test factor for loads as specified in NASA-STD-5001.		
4.2.7.1	Mechanical Function	[PTR 22] A mechanical function test of all deployable appendages and mechanical devices shall be conducted under the nominal conditions expected during flight.		
4.2.7.2	Mechanical Function	[PTR 23] A high-energy test and a low-energy test shall also be conducted to prove positive margins of strength and function.		
4.2.7.3	Mechanical Function	[PTR 24] The high- and low-energy test shall demonstrate margins beyond the nominal flight conditions by considering adverse interaction of potential extremes of parameters such as temperature, friction, spring forces, stiffness of electrical cabling or thermal insulation, and spin rate.		
4.2.7.4	Mechanical Function	[PTR 25] Mechanical function tests of all deployable appendages and mechanical devices shall be conducted to demonstrate the hardware will meet performance requirements before and after environmental test exposure.		
4.3.1.1	Thermal Vacuum and Ambient Pressure Thermal Cycle	[PTR 26] The temperature levels for thermal vacuum and thermal cycle tests shall be based on worst-case, high- and low-temperature extremes, with added margins.		
4.3.1.2	Thermal Vacuum and Ambient Pressure Thermal Cycle	[PTR 27] The test margin shall be sufficient to meet minimum workmanship requirements.		
4.3.1.3	Thermal Vacuum and Ambient Pressure Thermal Cycle	[PTR 28] The thermal vacuum test shall include a number of cycles from nominal to maximum temperatures, to minimum, and then back to nominal, with the test levels at temperatures of at least 10 °C (18 °F) above/below the maximum expected temperature range for flight.		

4.3.2.1	Thermal Balance	[PTR 29] The test data shall be used to demonstrate that the thermal control system can maintain components, subsystems, etc., within required temperature limits under simulated worst-case flight environments.		
4.3.2.2	Thermal Balance	[PTR 30] The test shall be used to verify the accuracy of analytical thermal and power models.		
4.3.2.3	Thermal Balance	[PTR 31] The test data and verified analytical thermal model shall be used to demonstrate design margins in the thermal control system.		
4.3.2.4	Thermal Balance	[PTR 32] At a minimum, the test shall be designed to provide boundary conditions simulating a worst-case hot and a worst-case cold prediction.		
4.3.2.5	Thermal Balance	[PTR 33] Other test requirements such as stabilization criteria shall be established to provide a conservative assessment of the thermal control system and ensure verification of the analytical thermal model.		
4.3.3.1	Bakeout	[PTR 34] Components or higher levels of assembly which pose a contamination threat to contamination-sensitive hardware shall be thermal-vacuum baked to achieve an acceptable level of molecular outgassing, as defined in a contamination control plan.		
4.3.3.2	Bakeout	[PTR 35] Outgassing testing shall have sufficient margins to ensure a conservative contamination assessment without damaging the hardware.		
4.3.4	Leak Test for Sealed Components	[PTR 36] Leak rates shall be determined prior to stress-inducing environmental tests and periodically during subsequent testing.		
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4.4.5	EMI/EMC Tests	[PTR 41] Waivers approved by the Program Manager and the assigned Technical Authority may be invoked for tests at the qualification level, but they shall be evaluated to ensure that program/mission-level EMI safety margins are maintained.		
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4.4.6.2	EMI Safety Margin Requirements	[PTR 43] Electrically Initiated Device (EID) interfaces shall demonstrate a minimum safety margin of 20 dB radio-frequency (RF) level referenced to direct current no-fire level.		
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4.5.5.2	Life Test Program	[PTR 63] The verification plan shall address the life test programs by specifying the elements that require such testing and by describing the test hardware and methods that will be used.		

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4.5.6.2	Mass Properties Verification	[PTR 65] The mass properties program shall include an analytical assessment of the payload's ability to comply with the mission requirements, supplemented as necessary by measurement.		
4.5.7.1	Alignment	[PTR 66] Critical optical and mechanical alignments shall be verified to meet performance requirements before and after environmental test exposure.		
4.5.7.2	Alignment	[PTR 67] Critical optical and mechanical alignments necessary to meet on-orbit performance requirements shall be verified during thermal vacuum testing.		

APPENDIX B

REFERENCES

B.1 Purpose

This Appendix provides reference material relative to this NASA Technical Standard.

B.2 Reference Documents

NPR 8705.4, Risk Classification for NASA Payloads

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