NASA TECHNICAL STANDARD

Office of the NASA Chief Engineer

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METRIC (SI)/ENGLISH

PAYLOAD TEST REQUIREMENTS

DRAFT 1—2023-03-07

This official draft has not been approved and is subject to modification.
DO NOT USE PRIOR TO APPROVAL

DOCUMENT HISTORY LOG

Status	Document Revision	Change Number	Approval Date	Description
Baseline			1996-07-10	Initial Release
Revision	A		2004-09-10	General formatting and editorial changes

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 <u>Protoflight hardware</u>: 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 <u>Prototype hardware</u>: 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."

Revision	A		2004-09-10	Continued

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."

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

Revision	A		2004-09-10	Continued

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" 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-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."

Revision	B		2018-06-06	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.
Revalidation	B	1	YYYY-MM-DD	Revalidated with Administrative/ Editorial Changes—This NASA Technical Standard was reviewed and only editorial changes resulted. Changed requirements PTR 1-4 to statements of fact and renumbered remaining requirements.

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.

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

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or the "Suggest a Change to this Standard" link on the Standard's Summary Page at https://standards.nasa.gov.

Original signed by　　　　　　　　　　　　　　　　　**06/06/2018**　　　　　　　
Ralph R. Roe, Jr.　　　　　　　　　　　　　　　　　　　　Approval Date
NASA Chief Engineer

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PAYLOAD TEST REQUIREMENTS

1. SCOPE

1.1 Purpose

~~The purpose of t~~This NASA Technical Standard ~~is to~~ provides 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 provides 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

1.2.1 ~~This 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. This language applies to the Jet Propulsion Laboratory (a Federally Funded Research and Development Center), other contractors, recipients of grants, cooperative agreements, or other agreements only to the extent specified or referenced in the 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,~~ ~~t~~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 NASA 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.

1.2.2   This 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. This language applies to the Jet Propulsion Laboratory (a Federally Funded Research and Development Center), other contractors, recipients of grants, cooperative agreements, or other agreements only to the extent specified or referenced in the applicable contracts, grants, or agreements.

1.2.3   References to "this Standard" refer to NASA-STD-7002B with Change 1; references to other documents state the specific document information.

1.2.4   Verifiable requirement statements are designated by the acronym "PTR" (Payload Test Requirement), numbered, and indicated by the word "shall." This Standard contains 6~~37~~ 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~~Identification Matrix is provided in Appendix A.

1.2.5   Explanatory or guidance text is indicated in italics beginning in section 4. The terms "may" or "can" denote discretionary privilege or permission, "should" denotes a good practice

and is recommended but not required, "will" denotes expected outcome, and "is/are" denotes descriptive material or a statement of fact.

1.3 Tailoring

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

2. APPLICABLE DOCUMENTS

2.1 General

2.1.1 Documents listed in this section contain provisions constituting requirements of this Standard as cited in the text. [PTR 2] Latest issuances of cited documents apply unless specific versions are designated. [PTR 3] Obtain approval from the delegated NASA Technical Authority to use a version other than as designated.

2.1.2 Applicable document may be a Accessed applicable documents at https://standards.nasa.gov or obtained documents directly from the Standards Developing Body, or other document distributors, information provided or linked, or by contacting the office of primary responsibility for this Standard.

Note: 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

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

American Institute of Aeronautics and Astronautics (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 Standard do not supersede or waive existing requirements and standard practices found in other Agency documentation.

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

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SI   Système Internationale or metric system of measurement
STD   Standard
STS   Space Transportation System

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, or 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 15] 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
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 NASA 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 26] 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 37] 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 48] 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 59] 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 610] During testing, the hardware **shall** be configured both electrically and mechanically in the operational mode for liftoff.

4.2.2.4 [PTR 711] 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 812] 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 913] 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 104] Pyroshock testing **shall** be performed as specified in NASA-STD-7003, Pyroshock Test Criteria.

4.2.4.2   [PTR 1~~5~~1] 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 1~~6~~2] 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 1~~7~~3] 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 1~~8~~4] 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. Actuate T~~t~~he 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 1~~9~~5] 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 1620] 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 1721] 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 1822] 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 1923] 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 204] The high- and low-energy tests **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 215] 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 226] 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 237] The test margin **shall** be sufficient to meet minimum workmanship requirements.

4.3.1.3 [PTR 248] 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 50 °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 248] 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 NASA Technical Authority.

For deep-space, interplanetary, or other non-Earth-orbiting missions, develop 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 259] 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 2630] The test **shall** be used to verify the accuracy of analytical thermal and power models.

4.3.2.3 [PTR27 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 2832] 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 2933] 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 304] 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 315] 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 326] 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 337] 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 348] 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 359] 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 3640] 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 3741] Waivers approved by the Program Manager and the assigned delegated NASA 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 3842] 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 3943] 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 NASA 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 404] 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 4~~1~~5] 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 4~~2~~6] 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 4~~3~~7] 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 4~~4~~8] 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 4~~5~~9] 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 4~~65~~0] 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 4~~75~~1] Redundant circuit performance and critical-fault protection **shall** be verified.

4.5.3   Failure-Free Performance

4.5.3.1 ___[PTR 4~~85~~2] Programs **shall** set a total hour "failure-free" performance requirement tailored to hardware classification, criticality, and mission-reliability goals.

4.5.3.2 ___[PTR 4~~95~~3] 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 504] 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 515] 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 526] The mission environment **shall** be simulated as realistically as possible.

4.5.4.1.3 [PTR 537] The instruments **shall** receive stimuli similar to that to be received during the mission.

4.5.4.1.4 [PTR 548] 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 559] 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 560] 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 5761] 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 5862] 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 5963] 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 604] 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 615] 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 626] Critical optical and mechanical alignments **shall** be verified to meet performance requirements before and after environmental test exposure.

4.5.7.2 ___[PTR 637] 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, i~~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 NASA Technical Authority to ensure that all the goals of a successful verification program will be met.

APPENDIX A: REQUIREMENTS IDENTIFICATION MATRIX

A.1   PURPOSE

Due to the complexity and uniqueness of space flight, it is unlikely that all the requirements in a Standard will apply. Table 3, Requirements Identification Matrix, contains this Standard's technical authority requirements and may be used by programs and projects to indicate requirements that are applicable or not applicable. 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, specify proposed tailoring, or provide an explanation/justification when not applicable.

Table 3—Requirements Identification Matrix

NASA-STD-7002B with Change 1				
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.	1.3	Tailoring
2.1.1	Applicable Documents, General	[PTR 2] The latest issuances of cited documents shall apply unless specific versions are designated.	2.1.1	Applicable Documents, General
2.1.2	Applicable Documents, General	[PTR 3] Non-use of specifically designated versions shall be approved by the delegated Technical Authority.	2.1.2	Applicable Documents, General
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.	2.4.2	Order of Precedence
4.1	Payload Test Requirements Matrix (Protoflight Program)	[PTR 15] Payload verification testing shall be performed as defined in Table 1, Payload Test Requirements Matrix (Protoflight Program).	4.1	Payload Test Requirements Matrix (Protoflight Program)
	Table 1—Payload Test Requirements Matrix (Protoflight Program)			
	MECHANICAL TESTS		**COMPONENT**	**SUBSYSTEM/ INSTRUMENT**	**PAYLOAD/ SPACECRAFT**

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Section	Description	Requirement in this Standard		Applicable (Enter Yes or No)	Comments
		NASA-STD-7002B with Change 1			
	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) **3**				
	Ambient Pressure Thermal (5) Cycle **4**				
	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				

Section	Description	Requirement in this Standard	Applicable (Enter Yes or No)	Comments

NASA-STD-7002B with Change 1

	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.

| 4.2.1.1 | Mechanical Tests, Strength | [PTR 26] 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 37] 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

Section	Description	Requirement in this Standard	Applicable (Enter Yes or No)	Comments
		NASA-STD-7002B with Change 1		

NASA-STD-7002B with Change 1

Payload Type	Minimum Probability and Confidence Level	Notes
		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.

Section	Description	Requirement in this Standard
4.2.2.1	Sinusoidal Vibration	[PTR 48] Sinusoidal vibration testing shall be performed to qualify hardware for the low-frequency launch environment.
4.2.2.2	Sinusoidal Vibration	[PTR 59] 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.
4.2.2.3	Sinusoidal Vibration	[PTR 610] During testing, the hardware shall be configured both electrically and mechanically in the operational mode for liftoff.
4.2.2.4	Sinusoidal Vibration	[PTR 711] 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

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.

Section	Description	Requirement in this Standard
4.2.3.1	Random Vibration and Acoustics	[PTR 812] Random vibration and acoustic testing shall be performed as specified in NASA-STD-7001, Payload Vibroacoustic Test Criteria.

		NASA-STD-7002B with Change 1		
Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
4.2.3.2	Random Vibration and Acoustics	[PTR 193] The minimum probability level used to define the flight limit level for random vibration and acoustics shall be $P_{95/50}$.		
4.2.4.1	Shock (Mechanical and Pyro)	[PTR 104] Pyroshock testing shall be performed as specified in NASA-STD-7003, Pyroshock Test Criteria.		
4.2.4.2	Shock (Mechanical and Pyro)	[PTR 115] 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	[PTR 126] If hardware contains devices that produce a self-induced shock, it shall be exposed to each shock source twice, at a minimum.		
4.2.4.4.1	Externally Induced Shock	[PTR 137] 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 148] 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 159] 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 1620] 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 1721] 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 1822] 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 1923] 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 204] 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 215] 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.		

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Section	Description	Requirement in this Standard	Applicable (Enter Yes or No)	Comments
		NASA-STD-7002B with Change 1		
4.3.1.1	Thermal Vacuum and Ambient Pressure Thermal Cycle	[PTR 226] 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 237] The test margin shall be sufficient to meet minimum workmanship requirements.		
4.3.1.3	Thermal Vacuum and Ambient Pressure Thermal Cycle	[PTR 248] 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 259] 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 2630] The test shall be used to verify the accuracy of analytical thermal and power models.		
4.3.2.3	Thermal Balance	[PTR 2731] 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 2832] 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 2933] 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 304] 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 315] 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 326] Leak rates shall be determined prior to stress-inducing environmental tests and periodically during subsequent testing.		
4.4.1	EMI/EMC Tests	[PTR 337] The EMI/EMC test program shall ensure that the total payload/vehicle system performs its intended functions when operating in the predicted electromagnetic environment.		

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		NASA-STD-7002B with Change 1		
Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
4.4.2	EMI/EMC Tests	[PTR 348] 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.		
4.4.3	EMI/EMC Tests	[PTR 359] The test regime shall be composed of a variety of conducted and radiated emissions, as well as susceptibility tests needed to satisfy mission requirements.		
4.4.4	EMI/EMC Tests	[PTR 3640] 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	EMI/EMC Tests	[PTR 3741] Waivers approved by the Program Manager and the ~~assigned~~ delegated 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.		
4.4.6.1	EMI Safety Margin Requirements	[PTR 3842] Safety critical circuits shall demonstrate safety margins of not less than 6 decibels (dB).		
4.4.6.2	EMI Safety Margin Requirements	[PTR 3943] 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.		
4.4.6.3	EMI Safety Margin Requirements	[PTR 404] EID interfaces shall demonstrate a minimum safety margin of 12 dB RF level referenced to RF no-fire level.		
		4.5 Functional Tests		
4.5.1.1	Electrical Interface	[PTR 415] 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	Electrical Interface	[PTR 426] 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.		

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		NASA-STD-7002B with Change 1		
Section	**Description**	**Requirement in this Standard**	**Applicable (Enter Yes or No)**	**Comments**
4.5.2.1	Comprehensive Performance	[PTR 437] 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	Comprehensive Performance	[PTR 448] 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.		
4.5.2.3	Comprehensive Performance	[PTR 459] 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	Comprehensive Performance	[PTR 4650] 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	Comprehensive Performance	[PTR 4751] Redundant circuit performance and critical-fault protection shall be verified.		
4.5.3.1	Failure-Free Performance	[PTR 4852] Programs shall set a total hour "failure-free" performance requirement tailored to hardware classification, criticality, and mission-reliability goals.		
4.5.3.2	Failure-Free Performance	[PTR 4953] At the conclusion of the performance verification program, payloads shall have demonstrated this failure-free performance.		
4.5.3.3	Failure-Free Performance	[PTR 504] Major hardware or software changes during or after verification shall require re-verification of the affected items.		
4.5.4.1.1	Compatibility Tests	[PTR 515] 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	Compatibility Tests	[PTR 526] The mission environment shall be simulated as realistically as possible.		
4.5.4.1.3	Compatibility Tests	[PTR 537] The instruments shall receive stimuli similar to that to be received during the mission.		
4.5.4.1.4	Compatibility Tests	[PTR 548] The radio frequency links, ground-station operations, and software functions shall be exercised.		
4.5.4.1.5	Compatibility Tests	[PTR 559] 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.		
4.5.4.2.1	Mission Simulations	[PTR 560] After compatibility between the network and the user facility has been verified, data flow tests shall be performed that exercise the total system.		

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Section	Description	Requirement in this Standard	Applicable (Enter Yes or No)	Comments
NASA-STD-7002B with Change 1				
4.5.4.2.2	Mission Simulations	[PTR 5761] 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.		
4.5.5.1	Life Test Program	[PTR 5862] A life test program on a dedicated article shall be implemented for critical mechanical and electrical elements that have limited lifetimes.		
4.5.5.2	Life Test Program	[PTR 5963] 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.		
4.5.6.1	Mass Properties Verification	[PTR 604] 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	Mass Properties Verification	[PTR 615] 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 626] Critical optical and mechanical alignments shall be verified to meet performance requirements before and after environmental test exposure.		
4.5.7.2	Alignment	[PTR 637] 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 information of a general or explanatory nature but does not contain requirements. The latest issuances of reference documents apply unless specific versions are designated. Access reference documents at https://standards.nasa.gov or obtain documents directly from the Standards Developing Body, other document distributors, information provided or linked, or by contacting the office of primary responsibility designee for this Standard.

B.2 REFERENCE DOCUMENTS

NPR 8705.4, Risk Classification for NASA Payloads

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