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STRUCTURAL DESIGN AND TEST FACTORS OF SAFETY FOR SPACEFLIGHT HARDWARE

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FOREWORD

This 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 standard is approved for use by NASA Headquarters and NASA Centers, including Component Facilities.

The material covered in this standard is based on the consensus judgment of a working group of structural engineers from all the NASA Centers. The group was empowered by the NASA Engineering Management Council (now the Engineering Management Board) to develop more uniform design and verification criteria to be applicable NASA wide. This activity was prompted by concerns expressed by industry and NASA program management that practices and requirements in this area vary widely among Centers, making the verification of structural adequacy difficult in cases involving multiple Centers and increasing costs to verify identical hardware under different criteria.

Revision A of this standard incorporates additional design and qualification requirements for pressure vessels, pressurized structure, pressurized components, and structural softgoods, along with updates to minimum design factors for joint separation of preloaded joints.

Requests for information, corrections, or additions to this standard should be submitted via "Feedback" in the NASA Technical Standards System at http://standards.nasa.gov.

Original Signed By

August 5, 2008

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Approval Date

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1. SCOPE

1.1 Purpose

The purpose of this standard is to establish NASA structural strength design and test factors, as well as service life factors to be used for spaceflight hardware development and verification. It is intended to reduce space project costs and schedules by enhancing the commonalty of use of hardware designs among NASA flight projects, Centers, and their contractors. While it is true that structural designs are sometimes governed by criteria other than strength, the criteria in this document are to be considered as minimum acceptable values unless adequate engineering risk assessment is provided which justifies the use of lower values.

1.2 Applicability

This standard recommends engineering practices for NASA programs and projects. It may be cited in contract, program, and other Agency documents as a technical requirement. Requirements are numbered and indicated by the word "shall." Explanatory text or guidance is indicated in italics beginning in section 4.

1.2.1 Tailoring of this standard for application to a specific program or project shall be formally documented as part of program/project requirements and approved by the assigned Technical Authority.

Determining the suitability of this standard and its provisions is the responsibility of program/project management and the performing organization. Project-specific tailoring may generate other project-specific requirements that are derivatives of this standard.

1.2.2 NASA programs and projects that do not meet the provisions of this document shall be assessed by the NASA Program Manager for the associated risk to the success of the planned NASA mission and approved by the assigned Technical Authority.

1.2.3 This document shall not supersede applicable laws and regulations unless a specific exemption has been obtained by the Office of the NASA Chief Engineer.

The criteria in this standard are applicable to payloads and launch vehicle structures (including propellant tanks and solid rocket motor (SRM) cases). These criteria apply to flight hardware that is utilized for NASA missions. The standard presents acceptable minimum factors of safety for use in analytical assessment and test verification of structural adequacy of the flight hardware. Designs must generally be verified by both structural strength analyses and tests.

1.2.4 The factors shall be multiplied by the limit stresses (including additive thermal stresses), and the products shall be verified not to exceed material allowable stresses (yield and ultimate) under the expected temperatures and other operating conditions.

Criteria are specified for design and test of flight articles when the actual flight hardware is tested (protoflight), and when qualification tests are conducted on a separate (prototype) article. In general, no distinction is made between “manned” and “unmanned” missions. Structures of manned flight systems may be subjected to additional verification and/or safety requirements (e.g., fracture control) that are consistent with the established risk levels for mission success and flight crew safety.

The requirements specifically excluded from this standard are design loads determination, fracture control, engines, rotating hardware, solid propellant, insulation, ground support equipment, and facilities. Also excluded are specific configuration factors, such as fitting factors, buckling knockdown factors, and load uncertainty factors.

1.3 Constraints and Preconditions

The criteria of this standard were developed in the context of structural and mechanical systems designs that are amenable to engineering analyses by current state-of-the-art methods and conforming to standard aerospace industry practices. More specifically, the designs are assumed to use materials having mechanical properties that are well characterized for the intended service environments and all design conditions. For reusable and multi-mission hardware, these criteria are applicable throughout the design service life and all of the missions.

1.3.1 Therefore, design considerations shall include material property degradation under the service environments.

1.3.2 Material allowables shall be chosen to minimize the probability of structural failure due to material variability.

1.3.3 Allowables shall be based on sufficient material tests to establish values on a statistical basis.

1.3.4 Further, the service environments and limit loads shall be well defined.

1.3.5 Aerospace standard manufacturing and process controls shall be used in hardware fabrication and handling.

1.3.6 Test hardware shall be representative of the flight configuration.

2. APPLICABLE DOCUMENTS

2.1 General

The documents listed in this section contain provisions that constitute requirements of this standard as cited in the text of section 4.

2.1.1 The latest issuances of cited documents shall apply unless specific versions are designated.

2.1.2 Non-use of specific versions as designated shall be approved by the responsible Technical Authority.

The applicable documents are accessible via the NASA Technical Standards System at http://standards.nasa.gov or may be obtained directly from the Standards Developing Organizations or other document distributors.

2.2 Government Documents

NSTS 22206, Table 3.2	Requirements for Preparation and Approval of Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL)

2.3 Non-Government Documents

ANSI/AIAA S-080	Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components
ANSI/AIAA S-081	Space Systems – Composite Overwrapped Pressure Vessels (COPVs)

2.4 Order of Precedence

This document establishes requirements for NASA structural strength design and test factors as well as service life factors to be used for spaceflight hardware development and verification but does not supersede nor waive established Agency requirements found in other documentation.

2.4.1 Conflicts between this standard and other requirements documents shall be resolved by the responsible Technical Authority.

3. ACRONYMS AND DEFINITIONS

3.1 Acronyms

%	Percent
AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
COPVs	Composite Overwrapped Pressure Vessels
MDP	Maximum Design Pressure
NA	Not Applicable
NASA	National Aeronautics and Space Administration
NSTS	National Space Transportation System
psi	pounds per square inch
psia	pounds per square inch absolute
SI	Systeme Internationale, or metric system of measurement
SRM	Solid Rocket Motor

3.2 Definitions

Acceptance Test: A test performed on each article of the flight hardware to verify workmanship, material quality, and structural integrity of the design. In the protoflight structural verification approach, acceptance, proof, and protoflight tests are synonymous.

Creep: Time-dependent permanent deformation under sustained load and environmental conditions.

Detrimental Yielding: Yielding that adversely affects the fit, form, function, or integrity of the structure.

Factors of Safety (Safety Factors): Multiplying factors to be applied to limit loads or stresses for purposes of analytical assessment (design factors) or test verification (test factors) of design adequacy in strength or stability.

Failure: Rupture, collapse, excessive deformation, or any other phenomenon resulting in the inability of a structure to sustain specified loads, pressures, and environments or to function as designed.

Fatigue: The cumulative irreversible damage incurred in materials caused by cyclic application of stresses and environments, resulting in degradation of load-carrying capability.

Glass: Composed of any of a large class of materials with highly variable mechanical and optical properties that solidify from the molten state without crystallization and is typically made by silicates fusing with boric oxide, aluminum oxide, or phosphorus pentoxide; generally hard, brittle, and transparent or translucent; an amorphous (non-crystalline) material that is isotropic and elastic.

Limit Load: The maximum anticipated load, or combination of loads that a structure may experience during its service life under all expected conditions of operation or use.

Maximum Design Pressure (MDP): The highest possible operating pressure considering maximum temperature, maximum relief pressure, maximum regulator pressure, and, where applicable, transient pressure excursions. MDP for Space Shuttle payloads is a two-failure tolerant pressure; i.e., it will accommodate any combination of two credible failures that will affect pressure during association with the Space Shuttle. MDP also accommodates the maximum temperature to be experienced in the event of an abort to a site without cooling facilities.

Pressure Vessel: A container designed primarily for storing pressurized gases or liquids and (1) contains stored energy of 19,309 Joules (14,240 foot-pounds) or greater, based on adiabatic expansion of the intended use media gas or bulk modulus expansion of the use media liquid; (2) experiences a limit pressure greater than 689.5 kiloPascal [kPa] absolute (100 psia); or (3) contains a pressurized fluid in excess of 103.4 kPa absolute (15 psia), which will create a safety hazard if released.

Pressurized Component: A line, fitting, valve, or other part designed to contain pressure and that (1) is not made of glass, (2) is not a pressure vessel, (3) is not a propellant tank, or (4) is not an SRM case.

Pressurized Structures: Structures designed to carry both internal pressure loads and vehicle structural loads. The main propellant tank of a launch vehicle is a typical example.

Proof Test: A test performed on the flight hardware to verify workmanship, material quality, and structural integrity of the design. In the protoflight structural verification approach, proof, acceptance, and protoflight tests are synonymous.

Proof Test Factor: A multiplying factor to be applied to the limit load or MDP to define the proof test load or pressure.

Protoflight Test: A test performed on the flight hardware to verify workmanship, material quality, and structural integrity of the design. In the protoflight structural verification approach, protoflight, acceptance, and proof tests are synonymous.

Prototype Test: A test performed on a separate flight-like structural test article to verify structural integrity of the design. Prototype tests and qualification tests are synonymous.

Qualification Test: A test performed on a separate flight-like structural article of each type to verify structural integrity of the design. Qualification and prototype tests are synonymous.

Qualification Test Factor: A multiplying factor to be applied to the limit load or MDP to define the qualification test load or pressure.

Safety Critical: A classification for structures, components, procedures, etc., whose failure to perform as designed or produce the intended results would pose a threat of serious personal injury or loss of life.

Service Life: All significant loading cycles or events during the period beginning with manufacture of a component and ending with completion of its specified use. Testing, transportation, lift-off, ascent, on-orbit operations, descent, landing, and post-landing events are to be considered.

Service Life Factor (Life Factor): A multiplying factor to be applied to the maximum expected number of load cycles in the service life to determine the design adequacy in fatigue or fracture.

Structural Softgoods: Straps, fabrics, inflatable structures, gossamer structures, and others that carry structural loads upon launch or deployment.

Ultimate Design Load: The product of the ultimate factor of safety and the limit load.

Ultimate Strength: The maximum load or stress that a structure or material can withstand without incurring failure.

Yield Design Load: The product of the yield factor of safety and the limit load.

Yield Strength: The maximum load or stress that a structure or material can withstand without incurring detrimental yielding.

4. REQUIREMENTS

4.1 Selection Criteria for Factors of Safety

The appropriate design and test factors for a given mechanical or structural flight hardware element depend on several parameters such as the materials used, attachment methods (e.g., bonding), and the verification approach (prototype or protoflight). In applying the minimum factors of safety specified in this standard, it must be recognized that some structural and mechanical members and systems may be required to meet other more stringent and restrictive *performance requirements such as dimensional stability, pointing accuracy, stiffness/frequency constraints, or safety requirements (e.g., fracture control).*

4.1.1 Prototype versus Protoflight Approaches

The standard accepted practice for verification of launch vehicles is the prototype approach in which a separate, dedicated test structure, identical to the flight structure, is tested to demonstrate that the design meets the factor-of-safety requirements.

A widely used acceptable alternative for verification of spacecraft and science payloads is the protoflight approach, wherein the flight structure is tested to levels somewhat above limit stress (or load) but below yield strength.

a. In order to preclude detrimental yielding during protoflight strength verification testing, the yield factor of safety for protoflight structural design shall be higher than the test factor.

b. The protoflight test shall be followed by inspection and functionality assessment.

c. Consideration shall be given to development testing prior to committing to major test article configurations and especially prior to committing the flight article to protoflight test.

4.1.2 Test Verification Criteria

4.1.2.1 Test Methods

Strength verification tests fall into three basic categories: (1) tests to verify strength of the design (qualification, acceptance, or proof); (2) tests to verify strength models; and (3) tests to verify workmanship and material quality of flight articles (acceptance or proof).

Strength verification tests are normally static load tests covering all critical load conditions in the three orthogonal axes and, generally, can be classified as prototype or protoflight (see section 4.1.1).

a. The magnitude of the static test loads shall be equivalent to limit loads multiplied by the qualification, acceptance, or proof test factor.

In some cases, alternative test approaches (centrifuge, below resonance sine burst, saw tooth shock, etc.) are more effective in reproducing the critical load or environmental conditions and may be used in lieu of static testing if it can be demonstrated that the resulting loads in the test article are equivalent to or larger than the limit loads multiplied by the test factor.

Strength model verification tests are normally done as part of the strength verification.

b. Model verification shall be accomplished over the entire load range, especially if the test or the test article is nonlinear.

Strength model verification may not be required if the load path and the flight loads are straight forward and easy to understand.

c. Approval from the assigned Technical Authority shall be required.

d. The test article shall be adequately instrumented to provide sufficient test data for correlation with the strength model.

Workmanship tests may be static or dynamic load tests. Dynamic tests may be sinusoidal vibration, random vibration, or acoustic. Test loads should be equivalent to or slightly higher than the limit loads.

e. Each propellant tank and each SRM case shall be proof pressure tested.

4.1.2.2 Test versus Design Factors of Safety

When using the prototype structural verification approach, the minimum ultimate design factors can be the same as the required qualification test factors for both metallic and composite/bonded structures.

a. Metallic structures shall be verified to have no detrimental yielding at yield design load before testing to full qualification load levels.

b. When using the protoflight structural verification approach, design factors larger than the required acceptance or proof test factors shall be used to prevent detrimental yielding of the metallic or damage to the composite/bonded flight structure during test.

4.1.2.3 Test versus No-test Options

Structural designs generally should be verified by analysis and by either prototype or protoflight strength testing. For metallic structures only, it may be permissible to verify structural integrity by analysis alone without strength testing.

a. Analysis shall be provided with an acceptable engineering rationale for the “no-test” option.

Increasing the design factors of safety does not by itself justify this “no-test” approach. Some examples of criteria on which to base such an approach are as follows:

- *The structural design is simple (e.g., statically determinate) with easily determined load paths; it has been thoroughly analyzed for all critical load* *conditions; and there is a high confidence in the magnitude of all significant loading events.*

- *The structure is similar in overall configuration, design detail, and critical load conditions to a previous structure that was successfully test verified, with good correlation of test results to analytical predictions.*

Development and/or component tests have been successfully completed on critical, difficult-to-analyze elements of the structure. Good analytical model correlation to test results has been demonstrated.

Projects which propose to use the "no-test" approach generally must use larger factors of safety.

b. In order to use the "no-test" approach, project-specific criteria and rationale shall be developed for review and approval by the assigned Technical Authority.

4.1.3 Probabilistic Methods

Design factors of safety and test factors are intended to compensate conservatively for uncertainties in the strength analysis. Current standard NASA structural verification criteria are deterministic, and experience has shown these deterministic criteria to be adequate. The probabilistic method uses knowledge (or assumptions) of the statistical variability of the design variables to select design criteria for achieving an overall success confidence level.

Any proposed use of probabilistic criteria to supplement deterministic factors of safety shall be approved by the assigned Technical Authority on an individual-case basis.

4.2 Design and Test Factors of Safety

a. The design factors of safety and test factors of this standard are the minimum required values for NASA spaceflight structures and shall be applied to both mechanical and additive thermal stresses.

b. Applications of these factors to the development and verification of a structure shall be accepted by the assigned Technical Authority only when all of the constraints and preconditions specified in section 1.3 are met.

Higher factors than those listed here may be required for proof testing if the proof test is to be used for fracture control flaw screening.

c. If pressure or temperature has a relieving or stabilizing effect on the mode of failure, then for analysis or test of that failure mode, the unfactored stresses induced by temperature or the minimum expected pressure shall be used in conjunction with the ultimate (factored) stresses from all other loads.

d. Otherwise, the design and test factors shall be applied equally to MDP and other stresses.

Factors of safety on yield are not specified for composite/bonded structures, glass, and bonds for structural glass.

e. These hardware items shall be designed to preclude any detrimental permanent deformation or functional degradation of the flight system under the limit loads and, for programs employing the protoflight verification approach, the acceptance or proof test loads.

4.2.1 Metallic Structures

Spaceflight metallic structures can be developed using either the prototype or the protoflight approach.

The minimum design and test factors of safety for metallic structures, excluding fasteners, shall be as specified in table 1.

Table 1—Minimum Design and Test Factors for Metallic Structures

Verification Approach	Ultimate Design Factor	Yield Design Factor	Qualification Test Factor	Acceptance or Proof Test Factor
Prototype	1.4	1.0*	1.4	NA or 1.05**
Protoflight	1.4	1.25	NA	1.2***

NOTES:

* Structure must be assessed to prevent detrimental yielding during flight, acceptance, or proof testing.

** Propellant tanks and SRM cases only.

*** Protoflight level testing is required for the first article of a multiple article build. A workmanship level test is required for all subsequent copies of the first article. The workmanship test shall be approved by the responsible Technical Authority.

4.2.2 Fasteners and Preloaded Joints

a. The minimum design and test factors for fasteners shall be as specified in table 2.

b. The strength of fasteners used in preloaded joints shall be assessed at zero and maximum preload.

c. For the zero preload case, the factor of safety shall be applied to the induced fastener load.

For the maximum preload case, the factor of safety need only be applied to the additional fastener load induced beyond the preload.

d. Unless specifically designed to separate, all joints shall maintain the factor of safety in table 2 against separation.

e. Minimum preload shall be used in the separation assessment.

f. For prototype hardware, fasteners shall be designed to preclude any detrimental permanent deformation or functional degradation under the limit loads.

g. For protoflight hardware, fasteners shall be designed to preclude any detrimental permanent deformation or functional degradation under the acceptance or proof test loads.

h. Additional guidance and/or project-specific criteria and rationale shall be reviewed and approved by the assigned Technical Authority.

Table 2—Minimum Design and Test Factors for Fasteners and Preloaded Joints**

Verification Approach	Design Factors			Test Factors	
	Ultimate Strength	Joint Separation		Qualification	Acceptance or Proof
		Safety Critical*	Other		
Prototype	1.4	1.4	1.2	1.4	NA
Protoflight	1.4	1.4	1.2	NA	1.2

NOTE:

* Joints where structural failure could cause a catastrophic event. Examples of a catastrophic event include, but are not limited to, loss of life, disabling injury, or loss of a major national asset such as the Space Shuttle or Space Station.

** Factors of safety on yield are not specified for fasteners.

4.2.3 Composite/Bonded Structures

Composite/bonded structures, including bonded metallic and/or nonmetallic sandwich structure and excluding glass, developed for NASA spaceflight missions shall, as a minimum, use the design and test factors specified in table 3.

Each flight article under the composite/bonded prototype approach requires acceptance or proof testing unless the requirements of section 4.1.2.3 or 4.4 are met.

Table 3—Minimum Design and Test Factors for Composite/Bonded Structures

Verification Approach	Geometry of Structure	Ultimate Design Factor	Qualification Test Factor	Acceptance or Proof Test Factor
Prototype	Discontinuities**	2.0*	1.4	1.05
	Uniform Material	1.4	1.4	1.05
Protoflight	Discontinuities**	2.0*	NA	1.2
	Uniform Material	1.5	NA	1.2

NOTE:
* Factor applies to concentrated stresses. For nonsafety-critical applications, this factor may be reduced to 1.4 for prototype structures and 1.5 for protoflight structures.
** Discontinuities are defined as an interruption in the physical structure or configuration of the part. These include, but are not limited to, holes, delaminations, and debonds.

4.2.4 Glass

Because of its brittle nature and susceptibility to moisture-assisted crack growth, glass poses a special challenge for those designing and analyzing glass structures. The strength of glass found in the literature can be misleading and is almost never applicable to NASA applications. Knowledge of the glass fracture toughness, crack growth characteristics, and environment are required to fully understand the ability of a piece of glass to withstand a given stress for the required time. Fracture toughness and crack growth rates are basic material properties of glass that must be used in conjunction with environmental exposure to determine the adequacy of a piece of glass. The environmental exposure has four components:

- *Stress.*
- *Time.*
- *Moisture.*
- *Flaws/cracks.*

Glass structures are always imperfect and contain flaws either from manufacturing or use. So, for glass structures such as windows that must carry pressure loads for extended times, fracture mechanics principals are required to assess strength.

4.2.4.1 A more traditional strength approach is possible for glass structures such as mirrors and lenses used in science instruments provided very conservative strength allowables for the glass are used; however, the responsible NASA Center's approval of the allowable and approach shall be obtained before implementing this option.

These options include, but are not limited to the following:

1. *Determining the glass allowable through a Weibull distribution.*
2. *Proof testing the actual article and using this proof test value as the ultimate strength.*
3. *Using a "low" initial ultimate strength allowable of 1000 psi.*
4. *Using a test verified threshold stress for the particular type of glass chosen.*

It should be noted that the traditional strength approach does not waive any fracture control requirements and that fracture-critical pieces of glass would still require a fracture mechanics assessment. Also, it should be noted that the proof tests specified in this document are workmanship tests; fracture mechanics considerations may drive the project to a higher proof test factor.

For human-rated windows, refer to JSC-62550, Strength Design and Verification Criteria for Glass, Ceramics, and Windows in Human Spaceflight Applications.

4.2.4.2 The minimum design and test factors for pressurized and nonpressurized glass shall be as specified in table 4.

4.2.4.3 Structural integrity of all pressurized glass shall be verified by both analysis and testing.

Nonpressurized glass may be verified by analysis only with an ultimate minimum design safety factor of 5.0.

4.2.4.4 Protoflight tests of glass shall be configured to simulate flight-like boundary conditions and loading.

Prototype verification option is not available for glass.

4.2.4.5 For glass protoflight testing, the total time during unload shall be as short as possible, and the whole test done in an inert environment to minimize flaw growth.

Care should also be taken to configure protoflight hardware to prevent overloading any bonded joints during testing.

Table 4—Minimum Design and Test Factors of Safety for Glass

Verification Approach	Loading Condition	Ultimate Design Factor	Qualification Test Factor	Acceptance or Proof Test Factor
Protoflight Test	Nonpressurized	3.0	NA	1.2
	Pressurized	3.0	NA	2.0
Analysis Only	Nonpressurized	5.0	NA	NA

4.2.5 Bonds for Structural Glass

For human-rated windows, refer to JSC-62550.

4.2.5.1 Bonds for structural glass shall be qualification tested on a separate article.

4.2.5.2 Each flight article shall be proof tested in its bonded assembly.

4.2.5.3 The design and test factors shall be as specified in table 5.

Table 5—Minimum Design and Test Factors for Structural Glass Bonds

Ultimate Design Factor	Qualification Test Factor	Acceptance or Proof Test Factor
3.0	NA	3.0

4.2.6 Pressure Vessels, Pressurized Structures, and Pressurized Components

Pressure vessels and pressurized components shall be designed and qualified per the requirements of ANSI/AIAA S-080, Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressurized Components (metals); and ANSI/AIAA S-081, Space Systems – Composite Overwrapped Pressure Vessels (COPVs) (composites).

Pressurized structures are covered by this document. All relevant load combinations are applicable.

4.2.7 Factors of Safety for Softgood Structures

4.2.7.1 Static strength of all structural softgoods shall be test verified.

4.2.7.2 The minimum design and test factors of safety for structural softgoods shall be as specified in table 6.

Table 6 – Minimum Design and Test Factors for Structural Softgoods

Hardware Criticality Classification*	Ultimate Design Factor	Qualification Test Factor	Acceptance or Proof Test Factor
1 or 2	4.0	4.0	1.2
3	2.0	2.0	1.2

*Hardware Criticality is defined in NSTS 22206, table 3.2:

1 – Loss of life or vehicle
2 – Loss of mission or next failure of any redundant item could cause loss of life/vehicle
3 –All others

4.3 Fatigue and Creep

For NASA spaceflight structures made of well-characterized materials and with sufficient load cycle data that accounts for all in-service environments, a minimum service life factor of 4.0 shall be applied to the service life for fatigue and creep-life assessments.

For structures made of materials that are not well characterized or those that may have complex failure modes, such as composite structures, an additional factor and testing may be required by the assigned Technical Authority at the responsible NASA Center.

4.4 Alternate Approaches

4.4.1 In the event a particular factor of safety requirement of this standard cannot be met for a specific spaceflight structure or hardware component, an alternative or modified approach shall be proposed to verify the strength adequacy of the design.

4.4.2 A written risk assessment that justifies the use of the alternate approach shall be prepared by the organization with primary responsibility for the development of the structure or component.

4.4.3 The risk assessment shall be submitted to the assigned Technical Authority for approval prior to the implementation of the alternative approach.

4.4.4 If the lower factors of safety are approved by the assigned Technical Authority, a waiver shall be written that documents the rationale for this one-time exception.

4.4.5 This waiver shall not be used as a precedent for future mission applications.

5. GUIDANCE

5.1 Reference Documents

JSC 62550	Strength Design and Verification Criteria for Glass, Ceramics, and Windows in Human Spaceflight Applications

5.2 Key Word Listing

Acceptance test
Factors of safety
Proof test
Protoflight test
Prototype test verification
Qualification test
Spaceflight hardware
Standard
Structural design criteria
Test factors