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National Aeronautics and Space Administration

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GENERAL FRACTURE CONTROL REQUIREMENTS FOR MANNED SPACEFLIGHT SYSTEMS

NASA TECHNICAL STANDARD

FOREWORD

This standard is approved for use by NASA Headquarters and all Field Centers and is intended to provide a common framework for consistent practices across NASA programs.

This standard establishes requirements for fracture control of all NASA manned spaceflight systems. NASA-STD-5003, "Fracture Control Requirements for Payloads Using the Space Shuttle," provides supplementary implementation information specifically for payloads using the space shuttle. It was developed by the NASA Fracture Control Methodology Panel to harmonize and provide a common framework for fracture control practices on NASA manned spaceflight programs.

It is the policy of NASA to produce flight systems with a high degree of reliability and safety. This is accomplished through good engineering practices in the design, analyses, inspections, testing, fabrication, and operation of flight structures. In keeping with this policy, all manned spaceflight systems shall be subjected to fracture control to preclude catastrophic failure.

Requests for information, corrections, or additions to this standard should be directed to ED22, Marshal Space Flight Center, AL 35812. Requests for general information concerning standards should be sent to NASA Technical Standards Program Office, ED41, MSFC, AL, 35812 (telephone 256-544-2448). This and other NASA standards may be viewed and downloaded, free-of-charge, from our NASA Technical Standards Homepage: http://standards.nasa.gov

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1. INTRODUCTION

It is the policy of NASA to produce flight systems with a high degree of reliability and safety. This is accomplished through good engineering practices in the design, analyses, inspections, testing, fabrication, and operation of flight structures. In keeping with this policy, all manned spaceflight systems shall be subjected to fracture control to preclude catastrophic failure.

1.1 Scope. This document establishes the fracture control requirements for all manned spaceflight systems and all payloads on manned spaceflight systems. NASA-STD-5003, "Fracture Control Requirements for Payloads Using the Space Shuttle," provides supplementary implementation information specifically for payloads using the space shuttle. These requirements are applicable to in-house activities as well as all related contractor and subcontractor efforts. These requirements are not imposed on systems other than manned spaceflight but may be tailored for use in specific cases where it is prudent to do so such as for personnel safety or when national assets are at risk.

1.2 Fracture Control Authority. The NASA Center responsible for the manned spaceflight system shall be responsible for approving the fracture control of flight hardware and for assuring compliance with the requirements of this document. In this document this Center will be referred to as the responsible fracture control authority.

1.3 Alternate Requirements. In the event that a particular requirement of this document cannot be met for a specific component, alternative requirements may be proposed to preclude catastrophic failure. These alternate requirements shall be approved by the responsible fracture control authority.

1.4 Other Requirements. Nothing in this document shall be construed as requiring the duplication of effort dictated by other contract provisions. Conversely, provisions stated herein shall not be interpreted to preclude compliance with requirements invoked by other provisions.

1.5 Prerogatives of the Government. All plans, data, and documentation generated under contract to NASA or its suppliers in fulfillment of these requirements are subject to examination, evaluation, and inspection by the procuring installation or its designated representatives.

2. FRACTURE CONTROL IMPLEMENTATION

2.1 Fracture Control Applicability. All flight hardware of a manned spaceflight system and its payloads shall be subjected to fracture control to preclude catastrophic failure. A catastrophic failure is an event that results in loss of life, serious personal injury, or loss of the manned spaceflight system.

2.2 Program Specific Fracture Control Requirements. The NASA Center responsible for a manned spaceflight system shall develop Program Specific Fracture Control Requirements (PSFCR) to prevent catastrophic failures during the service life of the spaceflight program hardware. The PSFCR shall meet the requirements of this document and define Program Specific submittals, schedules, and reviews.

2.3 Selection Process. All spaceflight hardware parts shall be examined to determine their fracture criticality classification. Parts are Fracture Critical if it is credible that cracks in the part could lead to a catastrophic failure. For composite materials, the term crack also includes delaminations, defects due to manufacturing, impact damage, and in-service damage. Specific criteria and methodology requirements for selection of Fracture Critical parts shall be specified in the PSFCR, which shall address all relevant categories which typically may include: primary load-carrying structure; pressure vessels; high energy rotating systems; pressurized and hazardous fluid systems; glass components; and potentially free-flying parts. Fracture Critical parts shall meet the damage tolerance requirements of Section 3.0. Parts designated as Non-Fracture Critical must clearly have non-catastrophic failure modes or else an evaluation must be performed to support the Non-Fracture Critical status. The responsible fracture control authority may establish general classifications wherein the hardware is deemed to possess a sufficiently low risk and is determined to be Non-Fracture Critical.

2.4 Fracture Control Documentation.

2.4.1 Fracture Control Plan. The organization with primary responsibility for hardware development shall provide a Fracture Control Plan. The plan shall be responsive to the PSFCR and provide detailed hardware specific fracture control methodology and procedures for the prevention of catastrophic failures associated with the propagation of cracks during fabrication, testing, handling, transportation, and operational life. The plan shall identify organizational elements and their responsibilities for activities required to implement the Fracture Control Plan, including reviews of design and structural integrity analyses, configuration control, and generation of required documentation such as the Fracture Control Summary Report described in Section 2.4.2, accessibility to the supporting data described in section 2.4.3, and special processing described in section 4.0.

2.4.2 Fracture Control Summary Report. To certify fracture control compliance, the organization with primary responsibility for the hardware development shall provide a Fracture Control Summary Report on the entire flight system for review and approval by the responsible fracture control authority or as specified in the PSFCR. The report shall include an accounting of all parts and the basis for determining acceptability.

2.4.3 Supporting Data. The organization with primary responsibility for the hardware development shall keep documents supporting the Fracture Control Summary Report for the life of the hardware where return from orbit or re-flight is anticipated. These documents shall be available for audit by the responsible fracture control authority and it's agents as identified in the PSFCR. The documents required to support the acceptability of a Fracture Critical part shall include a report of damage tolerance analyses or tests and a record of Non-Destructive Evaluation (NDE) inspection or proof-test. A documented description of the load spectrum and material properties used in the analysis shall be included in the report. The record of NDE inspection shall include the date of inspection, identification of the part inspected, type of inspection, and the name of the inspector. If specialized NDE is used, additional data to ensure acceptability and traceability of the process shall be required in the inspection report. Supporting data also includes relevant structural integrity documentation such as detailed design and assembly drawings, specifications, stress reports, materials data and certifications, quality assurance and conformance inspection reports.

3. DAMAGE TOLERANCE REQUIREMENTS

A damage-tolerant part is one that possesses the ability to resist failure due to the presence of cracks during its entire service life multiplied by the required service-life factor. The service-life factor for all NASA spaceflight hardware on manned systems shall be four (4). Damage tolerance evaluations shall be performed on all Fracture Critical parts to demonstrate their damage tolerance capabilities. Damage tolerance evaluations shall be done by damage tolerance analyses (also referred to as safe-life fracture mechanics analyses) or tests. Evaluations shall assume cracks to exist in the most critical locations and orientations in the part based on flaw screening capability performed per Section 4.2. For materials such as composites, which may sustain hidden impact damage, the level of damage assumed in the evaluation shall be representative of the credible damage threat after inspection and prior to flight service.

Load spectra used in damage tolerant evaluations shall meet the requirements in Section 3.1. Any benefits of crack growth retardation shall not be considered in crack-growth analysis without approval of the responsible fracture control authority.

Damage tolerance analyses shall meet the requirements of Section 3.2. Damage tolerance testing shall be used whenever fracture mechanics analysis methodologies are not applicable, and shall meet the requirements of Section 3.3. Damage tolerance testing is also an acceptable alternative to analyses when the test plan is approved by the responsible fracture control authority.

3.1 Load Spectrum Requirements. A load spectrum shall be developed for each Fracture Critical part so that a damage tolerance assessment can be made. The part's load spectrum shall include the load level, the number of cycles, and duration for each significant load source during the hardware service life. Effects of residual stresses shall be considered. The damage tolerance assessment shall be made using this load spectrum and the material properties corresponding to the environment of each event within the spectrum.

3.2 Analysis Requirements. Analysis methods and computer programs used for damage tolerance evaluations shall be subject to the acceptance of the responsible fracture control authority.

Fracture mechanics material properties used for damage tolerance analysis shall be chosen to provide conservative but realistic results. When the data sources are particularly sparse, specific tests shall be conducted or conservative estimates of the crack growth rate shall be used and documented. All material properties shall correspond to the actual environments that are to be encountered in service, the particular material specification, processing, and product form.

3.3 Test Requirements. Damage tolerance testing shall be performed in the operational environment on specimens representative of the structural design, thickness of the part, and initial defect sizes located at critical locations. If testing in the operational environment is not feasible, the test level shall be adjusted to account for the effects of the operational environment on the material properties. Tests shall demonstrate the same capabilities as required by analyses.

For components where neither damage tolerance analysis nor damage tolerance testing are appropriate, such as for some composite material failure modes, proof testing of each flight hardware item may be used to establish similar confidence in a part's damage tolerance, provided it is approved by the responsible fracture control authority. Proof test factors shall be the larger of those required to establish damage tolerance or strength and workmanship requirements.

4. SPECIAL PROCESSING FOR FRACTURE CRITICAL PARTS

4.1 Traceability. Traceability of materials, design changes and analyses, manufacturing processes, inspections, environmental exposure, and load history shall be maintained on all Fracture Critical parts throughout the hardware development, manufacturing, testing, and flight. Specific procedures to ensure traceability, which shall be summarized in the fracture control plan, shall be established by the primary organization responsible for developing the hardware. Engineering documentation shall identify Fracture Critical Parts and specify the appropriate inspection or crack-screening method to be used on the part.

4.2 Non-destructive Evaluation (NDE). All Fracture Critical Parts shall be subjected to NDE or proof testing to screen internal and external cracks. Prior approval is required from the responsible fracture control authority when a proof test is used as the crack-screening technique. Hardware that is proof tested as part of its acceptance (i.e., not screening for specific cracks) shall receive post-proof test NDE at critical welds and other critical sections.

All NDE shall be accomplished with a 90 percent probability of detection and a 95 percent confidence level for the crack size assumed in damage tolerance evaluations. Etching of parts prior to penetrant inspection is required on mechanically disturbed metallic surfaces.

4.3 Detected Cracks. A specific damage tolerance assessment shall be performed to justify the use of any Fracture Critical part with detected cracks. The use of such a Fracture Critical part must have prior approval of the responsible fracture control authority. The analyses and rationale for acceptance of detected cracks shall be included in the Fracture Control Summary Report. The assessment shall be made using conservative assumptions regarding the actual maximum crack size, material properties, and all internal and external loads. Additional requirements including larger factors on crack size, life, and/or fracture than normally used for damage tolerance assessment may be imposed by the responsible fracture control authority.