



Procedures and Guidelines (PG)

DIRECTIVE NO. 541-PG-8072.1.2B
EFFECTIVE DATE: 08/06/2012
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COMPLIANCE IS MANDATORY

Responsible Office: 541 / Materials Engineering Branch

Title: Goddard Space Flight Center Fastener Integrity Requirements

PREFACE

P.1 PURPOSE

The purpose of this document is to define fastener integrity requirements for all fasteners used in flight hardware and for critical nuts and bolts used on ground support equipment, including all flight hardware to ground support equipment interfaces.

P.2 APPLICABILITY

This procedures and guidelines document outlines the acquisition, traceability, receiving inspection, and test requirements that shall be recommended by the Materials Engineering Branch personnel to Goddard Space Flight Center programs and projects to ensure fastener integrity. If this Procedures and Guidelines document is submitted for inclusion in contracts or program documents as a technical requirement or as a reference for guidance, the revision number or date of applicability must also be cited, as the controlled copy is subject to change under the Goddard Directives Management System.

P.3 AUTHORITY

GPR 8072.1 Process Control

P.4 REFERENCES

MSFC-STD-3029	Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments
NAM1312-108	Fastener Test Methods, Metric, Method 108, Tensile Strength
NASM1312-8	Fastener Test Methods, Method 8, Tensile Strength
FED-STD-H28/20	Screw-Thread Standards for Federal Services, Inspection Methods for Acceptability of UN, UNR, UNJ, M and MJ Screw Threads
230-WI-5340.2.1	Control of Non-Conforming Project Parts
541-WI-5330.1.15	Verification of Locking Torque and Breakaway Torque Values for Self-Locking Nuts, Plate nuts and Hi-Lok/Hi-Tigue Collars at Incoming Inspection

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541-WI-5330.1.16 Proof Testing of Flight Hardware Fasteners
547-PG-5330.1.1 Fastener Inspection Test Plan
GPR 4520.2 Receiving Inspection and Test

P.5 CANCELLATION

541-PG-8072.1.2A, Goddard Space Flight Center Fastener Integrity Requirements

P.6 SAFETY

N/A

P.7 TRAINING

N/A

P.8 RECORDS

N/A

P.9 MEASUREMENT/VERIFICATION

N/A

PROCEDURES

In this document, a requirement is identified by “shall,” a good practice by “should,” permission by “may” or “can,” expectation by “will,” and descriptive material by “is.”

1. General

1.1 Fastener Categories

The required practices for acquisition, control, and inspection of fasteners may vary depending on the criticality of the fastener. Fasteners shall be categorized as critical fasteners, controlled fasteners, or non-controlled fasteners. Refer to Appendix A, Definitions, for the distinction.

Critical fasteners are inspected and tested more rigorously than other fasteners and have more stringent requirements on supplier control because the consequences of failure of those fasteners are severe. Critical fasteners do not only occur in flight hardware; a fastener used in ground support equipment (GSE) in such a way that a single failure would pose a catastrophic hazard is also a critical fastener.

Any fastener used in flight hardware that is not used in a critical application is considered a controlled fastener. In addition, fasteners used to transfer load across a flight hardware-to-GSE interface are controlled fasteners.

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Non-controlled fasteners are any fasteners not otherwise categorized as critical or controlled. Non-controlled fasteners are outside the scope of this document.

1.2 Dimensions

In this document, fasteners are referred to by characteristic dimensions. In the case of bolts and nuts the dimension refers to the characteristic diameter or size designation for a standard thread. In the case of helical or cylindrical inserts the dimension refers to the size of the fastener that fits the insert after installation. In the case of shear pins, rivets, and shoulder bolts the dimension refers to the nominal diameter of the shank, that is, the portion subjected to direct shear. Fastener sizes are given herein in both metric and U.S. customary units. The applicable unit system shall be used without conversion.

2. Acquisition and Supplier Control

2.1 Material Selection

Metallic fastener materials for critical fasteners and controlled fasteners shall be selected from MSFC-STD-3029, Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments, Table I, Highly Resistant Materials.

2.2 Critical Fastener Requirements

Critical fasteners shall be bolts or nuts M5 (size #10) or larger unless approval is granted by the PDL to use a smaller fastener in a specific critical fastener application. Critical fasteners shall be made to aerospace-quality specifications. Critical fasteners shall be the product of a manufacturer that has been approved by an on-site audit conducted by the requiring organization or accepted third party within two years prior to the fastener procurement. Accepted third party audits include Nadcap and ISO 9001 audits and equivalent audits performed by or for other NASA centers. Since manufacturers normally do not handle small lot size orders, fasteners are often procured through distributors. Critical fasteners may be procured through a distributor provided that the manufacturer and all subsequent distributors (or modifiers) have been approved by on-site audits conducted by the requiring organization or accepted third party within two years prior to the fastener procurement. A fastener supplied as a sub-component of a commercial off-the-shelf (COTS) hardware assembly may not be used if the fastener application is deemed critical. That is, COTS hardware assemblies shall not contain any fastener that would pose a catastrophic hazard by its failure.

An organization requiring critical fasteners shall indicate to the procuring organization that the fasteners are critical fasteners and must be procured to the requirements of the current version of 541-PG-8072.1.2.

2.3 Lot Homogeneity

All critical and controlled fasteners shall be procured as unmixed lots.

2.4 Material Test Reports

The following fasteners must be accompanied by the fastener manufacturer's material test report:

- a. all critical fasteners,
- b. controlled bolts, nuts, helical inserts, and cylindrical inserts size M5 (size #10) and larger, and
- c. controlled rivets and shear pins 5 mm (3/16") diameter and larger.

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2.5 Specialized Fasteners

The following products shall be evaluated by the procuring engineer and the purchaser's Materials and Processing activity to establish appropriate material, design, processing, and screening requirements: non-metallic fasteners, custom manufactured or modified fasteners, pyrotechnic fasteners, eyebolts, clevises, hooks, wire rope, turnbuckles, continuous threaded rod, and those fasteners not otherwise specified.

2.6 Threaded Product

The threads of externally threaded tension fasteners shall be produced by rolling unless approval is granted by the PDL.

3. Traceability

Traceability shall be accomplished by a set of documents by which a fastener is identified with the supplier, manufacturer, and raw material source. The documentation includes purchase orders and certificates of compliance. Traceability must show a chain of custody back from the last supplier, through all intermediate suppliers to the original manufacturer and raw material source. The traceability of the following fasteners shall be maintained into and including stores:

- a. all critical fasteners,
- b. controlled bolts, nuts, helical inserts, and cylindrical inserts size M5 (size #10) or larger, and
- c. controlled rivets and shear pins 5 mm (3/16") or larger.

It may not be possible to establish traceability back to the source material for fasteners under M5 (size #10) / 5mm (3/16"). If full traceability is not established for these fasteners, composition testing must be performed to verify that the fasteners are of the proper composition.

Traceability of critical fasteners shall be maintained into flight hardware or GSE. Traceability of non-critical fasteners may be maintained into flight hardware and GSE at each project's discretion. Storage of fasteners shall be controlled to ensure traceability.

4. Receiving Inspection and Test

All controlled fasteners and critical fasteners procured by GSFC shall be procured as directed by GPR 4520.2.

4.1 Inspection

All controlled fasteners and critical fasteners shall be subjected to inspection and testing per Table 2 to check conformity with the applicable specification requirements. The inspections and tests summarized in Table 2 should be conducted by an organization that is independent of the manufacturer and distributor. If the inspections and tests are performed by an organization that is not independent of the manufacturer and distributor, then the inspections and tests shall be witnessed by a qualified observer who is independent of the manufacturer and distributor. The following information supplements Table 2.

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4.1.1 Visual Inspection

A preliminary visual inspection to assure lot uniformity shall be performed at 1× on the entire fastener lot. Lots shall be unmixed.

Visual inspection for finish and other characteristics required by a procurement specification shall be performed at 10× minimum magnification on a sampling basis. Visual inspection is non-destructive.

4.1.2 Dimensional Inspection

Dimensional inspection shall include verifying any dimension with limits specified in the procurement documentation or applicable fastener specification documents. Thread dimensional inspection shall be performed on the threaded products specified in Table 2, except helical wire inserts, to System 21 of FED-STD-H28/20 (go and no go ring or plug thread gages).

Dimensional inspection of non-threaded products and helical inserts specified in Table 2 shall consist of measurements to determine that diameter and length conform to specification requirements.

Dimensional inspection shall be performed on a sampling basis for controlled fasteners and on a lot basis (100%) for critical fasteners. Dimensional inspection is non-destructive.

4.1.3 Tensile Test

Tensile testing shall be performed per a standard test method. The test method identification shall be included with the test results. Tensile test methods specified in an applicable fastener specification shall be preferred, but alternate standard test methods are acceptable. Tensile testing at GSFC not performed per the fastener specification should be performed per the latest revision of NASM1312-8 Tensile Strength or NAM1312-108 Metric Tensile Strength. When bolts or screws are too short to perform the tensile test (when the length is less than 4 times the diameter), perform hardness testing.

Tensile testing shall be performed on sampling basis. Tensile testing is a destructive test.

4.1.4 Hardness Test

The purpose of hardness testing is to verify that the hardware is of the proper strength when an established relationship exists between measured hardness and strength or when a fastener specification gives acceptable hardness limits. When a hardness test is required for a bolt or screw, it should be performed on the thread end.

Hardness testing shall be performed on a lot basis (100%) for critical fasteners and on a sampling basis in all other cases. Hardness testing performed on the thread end of bolts is non-destructive. Hardness testing performed on the face of a nut is destructive.

4.1.5 Non-Destructive Evaluation

Critical bolts and screws shall be inspected using a non-destructive evaluation (NDE) method to ensure that surface flaws equal to or greater than the critical size established by fracture and crack growth analysis are not present. Acceptable NDE methods include dye penetrant, eddy current, and magnetic particle inspections.

When required, NDE shall be performed on a lot basis (100%).

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4.1.6 Proof Test

Proof testing may be performed in lieu of hardness and NDE testing. The purpose of proof testing in this context is to demonstrate that the fastener is free of structural defects. The proof test load applied to an externally threaded fastener establishes the largest flaw that may be present in the loaded portion of the fastener. In the case of fracture critical fasteners in programs subject to fracture control requirements it may not be possible to apply a proof load large enough to detect the critical flaw size for crack growth analysis without causing general yielding of the fastener. NDE is required in those cases.

Proof testing performed at GSFC shall conform to the current version of 541-WI-5330.1.16 Proof Testing of Flight Hardware Fasteners. Proof testing performed by other organizations shall substantially conform to 541-WI-5330.1.16 (in the method of load determination, loading rate, and pre- and post-test inspections).

Proof testing is performed on a lot basis (100%) and is non-destructive if acceptable results are achieved.

4.1.7 Composition

The elemental composition of critical fasteners shall be determined by spectroscopic or other analytical methods. The measured composition shall conform to the composition limits specified in the fastener documentation. The measured composition shall be consistent with the reported source lot composition.

Composition testing is performed on a sampling basis. Composition testing may be performed on destructively tested samples (e.g., broken tensile test specimens). Composition testing may be destructive or non-destructive depending on the method used.

4.1.8 Locking and Breakaway Torques

Locking torque and breakaway torque shall be verified on samples of 5 mm (size #10) and larger self-locking nuts, plate nuts, and Hi-Lok®/Hi-Tigue® collars. Locking torque and breakaway torque testing is not required for non-locking product. Values shall comply with the applicable product specification. Nuts, plate nuts, and Hi-Lok®/Hi-Tigue® collars shall be subjected to one installation and removal cycle only and shall not be subjected to bake out nor be seated prior to or during the test. Locking and breakaway torque verification at GSFC shall be performed in accordance with 541-WI-5330.1.15.

Locking and breakaway torque testing is performed on a sampling basis. Locking and breakaway torque testing is non-destructive for self-locking nuts and plate nuts, but consumes one cycle of the locking feature's life. The life of locking features, in install-remove cycles, shall be established by: specification, historical data, or test. Locking and breakaway torque testing is destructive for Hi-Lok®/Hi-Tigue® collars, which are designed for a single installation.

4.2 Sampling

A random sample from a lot of fasteners shall be tested to verify that the fasteners meet applicable requirements. The same sample may be used for all non-destructive tests. Fasteners tested non-destructively may be returned to the lot at the completion of screening tests. Destructive tests may be performed on fasteners selected randomly from the non-destructive test sample. In addition, multiple destructive tests may be performed on a single sample so long as the property being tested has not been

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altered by previous tests. E.g., chemical composition testing may be performed on the remains of tensile tested fasteners.

The sample size shall be as shown in Table 1. The intent of sampling is to detect cases in which entire lots are mis-identified or in which a large portion of the lot is non-conforming. The sample sizes below lack the statistical rigor to reliably detect small non-conforming rates.

Table 1
 Sample Sizes for Testing Performed on a Sampling Basis

Lot Size	Destructive Test	Non-Destructive Test or Inspection
Through 25	2	2
26 – 50	2	3
51 – 150	3	4
151 – 500	4	5
501 – 1200	5	5
1201 +	5	8

4.3 Acceptance

In all cases, the acceptance criterion is zero non-conforming parts in the set tested, either the random sample drawn from a fastener lot in the case of attributes tested on a sampling basis or the entire lot in the case of 100% inspection as indicated in Table 2 (following page).

5. Quality Assurance Provisions

5.1 Non-conforming Fasteners

Non-conforming fasteners shall be handled per the developer's non-conforming product control procedures (230-WI-5340.2.1 at GSFC). Non-conforming product disposition may be other than scrap or return to vendor. A single non-conforming fastener in a lot shall cause the entire lot to be deemed non-conforming.

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Table 2
Inspection and Test Requirements

Fastener Type	Traceability	Material Test Reports	Visual	Dimensional	Tensile	Hardness	NDE	Proof Test	Composition	Locking/Breakaway Torques
Bolt – Critical	×	×	× ¹	100%	×	100%	100%	Opt. ²	×	
Bolt – Controlled M5 (#10) or Larger	×	×	× ¹	×	× ³					
Bolt – Controlled Smaller than M5 (#10)	× ⁴		× ¹	×					Opt. ⁴	
Nut – Critical	×	×	× ¹	100%	× ⁵			100%	×	× ⁶
Nut – Controlled M5 (#10) or Larger	×	×	× ¹	×	× ⁵					× ⁶
Nut – Controlled Smaller than M5 (#10)	× ⁴		× ¹	×					Opt. ⁴	
Insert M5 (#10) or Larger	×	×	× ¹	×						
Insert Smaller than M5 (#10)	× ⁴		× ¹	×					Opt. ⁴	
Rivet or Shear Pin 5mm (3/16”) or Larger	×	×	× ¹	×		× ⁷				
Rivet or Shear Pin Smaller than 5mm (3/16”)	× ⁴		× ¹	×					Opt. ⁴	
Setscrew	× ⁴		× ¹	×					Opt. ⁴	

Notes to Table 2:

1. Visual inspection includes 100% inspection at 1× and sampling inspection at 10× minimum. See 4.1.1.
2. Proof Testing is not required, but may be performed on a 100% basis as a substitute for hardness and NDE if it can be established that proof testing will detect a critical flaw size consistent with crack growth analysis for that fastener application.
3. Hardness testing may be performed in lieu of tensile testing for bolts too short to tensile test. See 4.1.4.
4. Full traceability may not be available for fasteners under size M5 (#10). Full traceability should be established if possible. If not possible, composition testing shall be performed to verify the material.
5. Hardness testing may be performed in lieu of tensile testing. See 4.1.4.
6. Locking / Breakaway Torque testing is required only for product having a locking feature.
7. Hardness testing requirement is waived for rivets and shear pins smaller than 6.4 mm (1/4”).

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Appendix A – Definitions

- A.1. Bolt: within this document includes tensile and shear bolts, shoulder bolts, screws, HiLoks, HiTigues, and lockbolts.
- A.2. Catastrophic Hazard: a condition in which a failure can result in disabling or fatal personnel injury, the loss of a spacecraft or launch vehicle, or failure of a system to meet mission objectives.
- A.3. Critical Fastener: a fastener, including fasteners used in ground support equipment, used in such a way that failure of that single fastener would present a Catastrophic Hazard. This includes, but is not limited to, single point failure fasteners and safe life fasteners.
- A.4. Controlled Fastener: a fastener used on a spacecraft, flight instrument, or interface between ground support equipment and flight hardware in such a way that failure of the fastener would not present a Catastrophic Hazard. This includes, but is not limited to, redundant load path fasteners and fail safe fasteners.
- A.5. Distributor: a commercial enterprise that stocks the products of multiple manufacturers for re-sale.
- A.6. Fastener: an installable component used to transfer load across an interface. This includes, but is not limited to, bolts, screws, nuts, anchor nuts, rivets, shear pins, helical wire inserts, cylindrical inserts, and setscrews.
- A.7. Material Test Report: one or more documents provided by a fastener supplier that certifies information required by an applicable fastener specification, procurement specification, or procurement agreement. The information typically includes fastener lot number, manufacturing date, lot quantity, raw material heat number, chemical composition and mechanical and metallurgical test results.
- A.8. Non-Controlled Fastener: fasteners not covered by this document. This includes fasteners used in ground support equipment (GSE) that neither directly interface with flight hardware nor are classified as critical fasteners.
- A.9. Nut: within this document includes plate nuts and anchor nuts.
- A.10. Product Design Lead (PDL): the manager or leader with overall responsibility for managing the design activity for a given product.
- A.11. Proof Test: a test conducted by a single load application to demonstrate the structural integrity of a fastener.
- A.12. Tension Fastener: a fastener that is loaded primarily in tension along its axis and relies on tension preload to maintain joint integrity.
- A.13. Traceability: the ability to identify the entire chain of transfer of a lot of fasteners back through all intermediate suppliers, the fastener manufacturer, and raw material source (e.g., wire or rod). Traceability shall ensure that the fastener is distinguished by lot number and that the fastener can be positively associated with test reports demonstrating that the fastener meets any applicable procurement specification.

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Appendix B – Acronyms

COTS	Commercial off-the-Shelf
GSE	Ground Support Equipment
ISO	International Standards Organization
Nadcap	National Aerospace and Defense Contractors Accreditation Program
NDE	Non-Destructive Evaluation
PDL	Product Design Lead

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CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
Baseline	06/05/2001	Initial Release
A	12/07/2006	<p>[Entire Document] Changed formatting to conform to the version of GPR 1410.1 applicable at the time of release. This includes re-numbering of sections from the baseline revision.</p> <p>P.10 Changed definition of fastener categories.</p> <p>4.1.7 Added composition testing requirement for critical fasteners.</p> <p>4.2 Altered sampling numbers; now no longer manufacturer-dependent.</p> <p>[Section N/A] Removed Approved Manufacturers List and requirement for approved manufacturer supplier for critical fasteners; added requirement for on-site audit of manufacturer / distributor for critical fasteners.</p>
B		<p>[Entire Document] Reformatted to PG template dated 11/09. Minor editorial clarifications not affecting the substance of any requirements were made throughout the document.</p> <p>P.4 Remove reference to GPR 8719, Certification and Recertification of Lifting Devices and Equipment.</p>

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