JSC 27301D

Materials Control Plan For JSC Flight Hardware

Engineering Directorate

Structural Engineering Division

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National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center

PREFACE

This Materials Control Plan defines the implementation of the materials and processes (M&P) requirements for all new flight hardware developed by the NASA Johnson Space Center (JSC). Space Shuttle GFE, International Space Station GFE, and JSC-developed payload hardware are to be designed and manufactured in accordance with this plan. The plan describes the implementation of the M&P requirements in SSP 30233, Space Station Requirements for Materials and Processes and JPG 8080.5, JSC Design and Procedural Standards Manual.

This plan defines the responsibilities of the JSC Materials & Processes Branch and JSC contractors for flight hardware M&P requirements implementation and verification, and includes modifications of Space Shuttle and ISS requirements for flight hardware. The contents of this document are consistent with the tasks performed for the ISS as defined in SSP 41000, System Specification for the International Space Station Alpha Baseline.

This flight hardware Materials Control Plan shall be implemented on all new contracts for the procurement of JSC flight hardware, and shall be included in existing contracts through contract changes. This document is under the control of the JSC Structural Engineering Division (JSC Code ES), and any changes or revisions shall be approved by the same organization.

MATERIALS CONTROL PLAN FOR JSC FLIGHT HARDWARE

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REVISIONS		
VERSION	CHANGES	DATE
Baseline	Original version (Materials Control Plan for JSC Space station Government-Furnished Equipment)	3/96
A	Retitled and revised to address all JSC flight hardware; numerous minor technical revisions, including reference document updates	7/16/99
B	Added requirement for oxygen system hardware exposure to pressurized oxygen before flight (Section 5.1.4.1)	3/9/00
C	Added ISS alcohol usage control (VUAs); added requirements for precision-cleaned hardware; revised author; incorporated administrative changes for division reorganization; numerous minor technical revisions, including reference document updates	1/29/02
D	Clarified requirement on low earth orbit environment survivability (Section 5.3.7); added related requirement on external use of silver-plated fasteners (Section 5.6.5.2)	2/26/02

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APPENDICES

1.0 INTRODUCTION

This plan documents the methods by which the NASA Johnson Space Center (JSC) will implement materials and processes control for flight hardware developed by JSC. Flight hardware under JSC control shall be designed and fabricated in accordance with this plan. The plan does not apply to program hardware developed by a program contractor as contractor-furnished equipment (CFE).

This plan also implements for JSC flight hardware the Materials and Processes (M&P) requirements contained in JPG 8080.5, JSC Design and Procedural Standards Manual. In the event of a conflict between these two documents and this implementation plan, this plan shall take precedence.

This document shall be incorporated as a general materials control specification in end-item specifications for JSC flight hardware procurements. It shall be implemented on all new contracts for procurement of JSC flight hardware, and shall be included in existing contracts through contract changes.

Notes:

1. Although this plan addresses the detailed requirements in SSP 30233, Space Station Requirements for Materials and Processes, it applies to all manned space flight hardware developed by JSC, including Space Shuttle Government-Furnished Equipment (GFE) and JSC payloads.

2. This plan does not address fracture control. Fracture control for JSC flight hardware structures, including pressure vessels, is implemented in accordance with JSC 25863A, Fracture Control Plan for JSC Flight Hardware. However, the Materials and Fracture Control Certification generated to verify compliance with this plan (see Section 4.6) includes certification of compliance with fracture control requirements and any flight limitations determined by the fracture control analysis. The JSC Materials & Processes Branch monitors and reviews the fracture control program and evaluates the fracture control analysis.

1.1 SCOPE

This document defines the implementation of the materials and processes (M&P) requirements for all new flight hardware developed by the NASA Johnson Space Center (JSC), including International Space Station GFE, Space Shuttle GFE, and payload hardware. Ground Support Equipment (GSE) supplied as JSC-controlled hardware shall comply with this plan where GSE hardware can adversely affect flight hardware.

2.0 DOCUMENTS

The following documents include specifications, standards, handbooks, and other special publications. They are applicable to the extent specified herein. In the event of a conflict between these documents and this plan, this plan shall take precedence.

2.1 APPLICABLE DOCUMENTS

2.1.1 VOLUNTARY CONSENSUS STANDARDS

DOCUMENT NO.	TITLE
ASTM-E595-93	Total Mass Loss and Collected Volatile Condensable Materials From Outgassing In A Vacuum Environment
Reference	5.3.7
AWS C-3.3-1980	Design, Manufacture, and Inspection of Critical Brazed Components, Recommended Practices for
Reference	5.4.5
AWS C-3.4-1999	Torch Brazing
Reference	5.4.5
AWS C-3.5-1999	Induction Brazing
Reference	5.4.5
AWS C-3.6-1999	Furnace Brazing
Reference	5.4.5
AWS C-3.7-1999	Aluminum Brazing
Reference	5.3.5
SAE-AMS-H-6875	Heat Treatment Of Steel Raw Materials
Reference	5.2.2.1

SAE-AMS-STD-401	Sandwich Constructions and Core Materials; General Test Methods
Reference	5.6.2
SAE-AMS-STD-1595	Qualification Of Aircraft, Missile and Aerospace Fusion Welders
Reference	5.4.4
SAE-AMS-STD-2175	Castings, Classification and Inspection Of
Reference	5.4.2
SAE-AMS 2488	Anodic Treatment - Titanium & Titanium Alloys, Solution pH 13 or Higher
Reference	5.2.3.3
SAE-AMS 2491D	Surface Treatment, Polytetrafluoroethylene, Preparation for Bonding
Reference	5.7.7
SAE-AMS 2759C	Heat Treatment of Steel Parts, General Requirements
Reference	5.2.2.1
SAE-AMS 2759 9	Hydrogen Embrittlement Relief (Baking) of Steel Parts
Reference	5.2.2.1
SAE-AMS 2770E	Heat Treatment of Wrought Aluminum Alloy Parts
Reference	5.2.1
SAE-AMS 2772	Heat Treatment of Aluminum Alloy Raw Materials
Reference	5.2.1
SAE-AMS 2774	Heat Treatment, Wrought Nickel Alloy and Cobalt Alloy Parts
Reference	5.2.9.1
SAE-AMS-H-81200,	Heat Treatment of Titanium and Titanium Alloys.
Reference	5.2.3.1

SAE-AS7928	Terminals, Lug: Splices, Conductors: Crimp Style, Copper, General Specification For
Reference	5.7.9
IPC-CM-770D	Component Mounting Guidelines For Printed Boards.
Reference	5.7.6.2
IPC EIA-J-STD-001C	Requirements for soldered electrical and electronic assemblies
References	5.7.6.2, 5.7.8
IPC-2221	Generic Standard on Printed Board Design
Reference	5.7.5
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
Reference	5.7.5
IPC-6011	Generic Performance Specification for Printed Boards
Reference	5.7.5
IPC-6012A	Quality and Performance Specification for Rigid Printed Boards
Reference	5.7.5

2.1.2 MILITARY

DOCUMENT NO.	**TITLE**
MIL-H-81200B	Heat Treatment of Titanium and Titanium Alloys
Reference	5.2.3.1
MIL-HDBK-5H	Metallic Materials and Elements for Aerospace Vehicle Structures
Reference	4.5, 5.3.4
MIL-HDBK-17 1E,2D,3E	Polymer Matrix Composites
Reference	4.5

MIL-HDBK-6870	Inspection Program Requirements, Nondestructive for Aircraft and Missile Materials and Parts
Reference	5.5.1
MIL-PRF-31032	Printed Circuit Board Printed Wiring Board, General Specification for
Reference	5.6.5
MIL-HDBK-454A	General Guidelines for Electronic Equipment
Reference	5.3.9
MIL-STD-810F	Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
Reference	5.3.9
MIL-STD-889B	Dissimilar Metals
Reference	5.6.4

2.1.3 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

DOCUMENT NO.	**TITLE**
NASA-STD-6001 (formerly NHB-8060.1C)	Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion
References	5.1, 5.1.1, 5.1.2, 5.1.3, 5.1.4, 5.1.5
NSTS 1700.7B (including ISS Addendum)	Safety Policy and Requirements for Payloads Using the Space Transportation System
References	3.4, 5.1.3
NASA-TM-86556	Lubrication Handbook For the Space Industry, Part A: Solid Lubricants, Part B: Liquid Lubricants
Reference	5.3.5
NASA-STD-8739.4	Crimping, Interconnecting Cables, Harnesses, and Wiring
References	5.7.3, 5.7.9, 5.7.10

NASA-STD-8739.5	Fiber Optic Terminations, Cable Assemblies, and Installation
References	5.7.4
NASA-STD-8739.1	Workmanship Standard for Surface Mount Technology
References	5.7.6.1
NASA-STD-8739.2	Requirement for Conformal Coating and Staking of Printed Wiring Boards and Electronic Assemblies
References	5.7.6.1, 5.7.6.2
NASA-STD-8739.7	Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)
Reference	5.7.11

2.1.4 JOHNSON SPACE CENTER / SPACE STATION PROGRAM

DOCUMENT NO.	TITLE
JSC 20584	Spacecraft Maximum Allowable Concentrations for Airborne Contaminants
Reference	5.1.2
JSC 25863 (Latest revision)	Fracture Control Plan for JSC Flight Hardware
Reference	1.0
JPG 8080.5	JSC Design and Procedural Standards Manual
References	1.0 and 6.0
JPG 8500.4	Engineering Drawing System Manual: Drawing Format, Requirements, and Procedures
References	3.0, 4.2
SE-R-0006D	Space Shuttle Program Requirements for Materials and Processes
References	3.1.1, 3.4

SSP 30233F	Space Station Requirements for Materials and Processes
Reference	3.1.1
SSP 30234E	Instructions for Preparation of Failure Modes and Effects Analysis and Critical Items List for Space Station
References	3.2.1, 3.2.2
SSP 30426D	Space Station External Contamination Control Requirements
Reference	5.3.7
SSP 50431A	Space Station Program Requirements for Payloads
Reference	3.2.1

2.1.5 MARSHALL SPACE FLIGHT CENTER

DOCUMENT NO.	**TITLE**
MSFC-SPEC-250A	Protective Finishes for Space Vehicle Structures and Associated Flight Equipment, General Specification for
Reference	5.6.4
MSFC-SPEC-445A	Adhesive Bonding, Process and Inspection, Requirements for
Reference	5.4.3
MSFC-SPEC-504C	Welding, Aluminum Alloys
References	5.4.4.3, 5.4.4.5
MSFC-STD-3029 (formerly MSFC-SPEC-522B)	Guidelines for Selection of Metallic Materials for Stress-Corrosion-Cracking Resistance in Sodium Chloride Environments
Reference	5.6.3
MSFC-SPEC-560A	The Fusion Welding of Steels, Corrosion and Heat Resistant Alloys
Reference	5.4.4.4

MSFC-STD-557	Threaded Fasteners, 6 Al-4V Titanium Alloy, Usage Criteria for Spacecraft Applications
Reference	5.6.5
MSFC-SPEC-766	Specification: Fusion Welding Titanium and Titanium Alloys
Reference	5.4.4.5
MSFC-PROC-404A	Procedure: Gases Drying and Preservation, Cleanliness Level and Inspection Methods
Reference	5.1.4.1

2.1.6 JOHNSON SPACE CENTER MATERIALS AND PROCESSES BRANCH

PRC-0001	Manual Arc Welding of Aluminum Alloy Flight Hardware
Reference	5.4.4.3
PRC-0004	Manual Arc Welding of Titanium Alloy Flight Hardware, Process Specification for
Reference	5.4.4.5
PRC-0006	Manual Arc Welding of Steel and Nickel Alloy Flight Hardware
Reference	5.4.4.4
PRC-0008	Qualification of Manual Arc Welders, Process Specification for
Reference	5.4.4.5
PRC-1001	Adhesive Bonding
Reference	5.4.3
PRC-6001	Composite Laminate Prepreg. Parts, Process Specification for the Manufacture of
Reference	5.3.4
PRC-6002	Sandwich Structures, Process Specification for the Assembly of
Reference	5.3.4

PRC-6003	Trimming and Drilling of Composites, Process Specification for
Reference	5.3.4
PRC-6501	Ultrasonic Inspection of Composites, Process Specification for the
Reference	5.3.4
PRC-7001	Soldering of Electrical Components
Reference	5.7.8
PRC-7002	Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
References	5.7.6.1 and 5.7.6.2
PRC-7003	Electrical Cables, Wiring, and Harnesses
Reference	5.7.3
PRC-7005	Printed Circuit Boards and Assemblies
Reference	5.7.5
ES SOP-004.5	Control of Weld and Braze Filler Materials, Electrodes, and Fluxing Materials
Reference	5.4.4.2
ES SOP-007.5	Materials and Processes Drawing Approval
Reference	4.1.2, 4.6.1
ES SOP-007.6	Materials and Fracture Control Certification
Reference	4.6

2.2 REFERENCE DOCUMENTS

DOCUMENT NO.	TITLE
ASTM G63-99	Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service
Reference	5.1.4
ASTM G88-90	Standard Guide for Designing Systems for Oxygen Service
Reference	5.1.4
ASTM G94-92	Standard Guide for Evaluating Metals for Oxygen Service
Reference	5.1.4
NSTS 22648	Flammability Configuration Analysis for Spacecraft Applications
Reference	5.1.1
GSFC Supplement S-312-P003	Process Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses,
Reference	5.7.5

3.0 REQUIREMENTS IMPLEMENTATION RESPONSIBILITIES

Primary responsibilities for implementing the requirements in this plan are divided between the JSC Materials & Processes Branch and JSC contractors as outlined in this section. These and other responsibilities are discussed in further detail in other sections of this document. JSC contractors are divided into in-house contractors that design and fabricate flight hardware at JSC, using the JSC engineering drawing release system per JPG 8500.4, and outside contractors that design and fabricate flight hardware for JSC in accordance with a contractor drawing release system

3.1 "PLAN" AND "NON-PLAN" CONTRACTORS

The terms "plan" and "non-plan" JSC contractors are used only for the purposes of this plan, as follows:

3.1.1 "PLAN" CONTRACTOR

A "plan" flight hardware contractor is defined as a contractor that has a Materials Control Plan approved by the JSC Materials & Processes Branch as meeting the requirements of either this control plan or the applicable program materials and processes requirements document (such as JSC SE-R-0006 for Space Shuttle and SSP 30233 for ISS). Only a few major contractors are required by contract by the JSC Materials & Processes Branch to provide a Materials Control Plan. (Refer to Section 4.1 of this plan for information on Materials Control Plans.) Plan contractors (and not the JSC Materials & Processes Branch) are responsible for certifying their flight hardware for materials and processes to JSC requirements, unless otherwise specified in the Materials Control Plan and/or the contract.

3.1.2 "NON-PLAN" CONTRACTOR

A "non-plan" flight hardware contractor is defined as a contractor that neither has, nor is required by contract to develop, a Materials Control Plan approved by the JSC Materials & Processes Branch. Consequently, a non-plan contractor cannot provide final materials certification for JSC flight hardware. The JSC Materials & Processes Branch shall provide Materials and Fracture Control Certification for JSC flight hardware provided by non-plan contractors.

3.2 NEW FLIGHT HARDWARE

Basic M&P responsibilities for new flight hardware are summarized in this section. Recertification of existing Shuttle and payload flight hardware provided to support ISS is addressed in section 3.4 of this plan. Further details on these and other M&P responsibilities are discussed in other sections of this plan.

3.2.1 JSC PLAN CONTRACTOR FLIGHT HARDWARE

JSC plan contractor flight hardware refers to flight hardware developed for JSC by a contractor with an approved Materials Control Plan (per Section 3.1.1). The plan contractor shall perform the following basic M&P functions:

- provide drawing review and approval for M&P

- provide a Materials Identification and Usage List (MIUL) (or an electronic searchable parts list) for all Criticality category 1 flight hardware. (Criticality categories are defined in SSP 30234.) Criticality categories 1R, 1S, 1SR and 1P are not included.

  Notes:

  1. The MIUL is required for payload criticality 1 hardware only if the payload is Class A or Class B per SSP 50431, Space Station Program Requirements for Payloads

  2. For selected plan contractors, additional MIUL requirements may be specified in the contract.

- generate and approve Materials Usage Agreements (MUAs) and water-soluble Volatile Organic Compound Uasge Agreements (VUAs). However, final MUA/VUA approval shall be by the JSC Materials and Processes Branch.

- provide materials certification as specified in the Materials Control Plan and/or the contract.

3.2.2 JSC NON-PLAN CONTRACTOR FLIGHT HARDWARE (& FLIGHT HARDWARE DESIGNED BY JSC EMPLOYEES)

The above two types of flight hardware in the title are grouped together in this section because both types of flight hardware have M&P functions which shall be performed by the JSC Materials & Processes Branch, as shown below:

- provide drawing review and approval for M&P. This applies to drawings generated by JSC employees, and to most of the non-plan contractors who generate drawings in the "JSC engineering drawing system", with the following two exceptions:

  (a) A few non-plan contractors who generate flight hardware drawings in the JSC engineering drawing system have been selected by the JSC Materials & Processes Branch to sign their own JSC drawings for M&P (and also generate their own MIULs and MUAs).

  (b) The JSC Materials & Processes Branch does not approve contractor drawings generated per a contractor's own engineering drawing system, but does review such drawings to the extent necessary to insure compliance with M&P requirements.

- provide a Materials Identification and Usage List (MIUL) (or an electronic searchable parts list) for Criticality category 1 flight hardware.

Notes:

1. The MIUL is required for payload criticality 1 hardware only if the payload is Class A or Class B per SSP 50431, Space Station Program Requirements for Payloads
2. For selected plan contractors, additional MIUL requirements may be specified in the contract.

- provide assistance to flight hardware managers in the generation of Materials Usage Agreements (MUA)

- approve MUAs

- provide Materials and Fracture Control Certification

3.3 MATERIALS AND PROCESSES INTERCENTER AGREEMENTS

NASA Centers (or other space agencies) with reciprocal agreements for Materials and Processes with JSC shall generate MUAs and materials certifications on hardware that they manage or manufacture. These reciprocal or intercenter agreements involve acceptance of each other's materials certifications and MUAs. Currently, NASA Centers that have reciprocal agreements with JSC include Lewis Research Center, Marshall Space Flight Center, Jet Propulsion Laboratory, and Goddard Space Flight Center. Copies of these agreements can be obtained from the JSC Materials & Processes Branch.

3.4 SPACE SHUTTLE GFE FOR ISS

JSC Shuttle GFE for ISS include JSC GFE provided by the Space Shuttle Vehicle Engineering Office and the EVA Project Office to support the ISS, and JSC Shuttle Payload GFE provided by the responsible JSC payload organizations for the ISS. JSC Shuttle GFE hardware certified prior to the release of this document is certified by the JSC Materials & Processes Branch as meeting the requirements of SE-R-0006, Space Shuttle Program Requirements for Materials and Processes, and NSTS 1700.7, Safety Policy and Requirements for Payloads Using the Space Transportation System. For previously approved hardware built to SE-R-0006 and NSTS 1700.7 and supplied as GFE to the ISS Program, Materials Usage Agreements (including Materials Stowage Codes) shall be reviewed by the JSC Materials & Processes Branch, or plan contractor, as applicable, to verify compliance with this plan. If Shuttle GFE hardware is modified for ISS and the part number or dash number changes, or if the use environment or exposure will be more severe, a new Materials and Fracture Control Certification shall be issued by the JSC Materials & Processes Branch, or plan contractor, as applicable. Otherwise, acceptability shall be documented through Government Furnished Equipment Common Certification Change Directive issued by the GFE Common Hardware Assessment Panel (which includes a M&P representative) and a formal materials and fracture control recertification is not required.

4.0 GENERAL REQUIREMENTS

Material used in the fabrication of JSC flight hardware shall be selected by considering the operational requirements for the particular application and the design engineering properties of the candidate materials. The operational requirements shall include, but not be limited to, operational temperature limits, loads, contamination, life expectancy, and vehicle related induced and natural space environments. Properties to be considered in material selection include mechanical properties, fracture toughness, flammability and offgassing characteristics, corrosion, stress corrosion, thermal and mechanical fatigue properties, vacuum outgassing, fluids compatibility, fretting, galling, etc. Conditions that could contribute to deterioration of hardware in service shall receive special consideration.

4.1 MATERIALS CONTROL PLAN

The contractor shall provide a Materials Control Plan when specified in the contract data requirements. This plan, upon approval by the procuring activity will become the Materials and Processes implementation document used for verification. The plan shall describe how the contractor will implement the requirements in each section of this plan. Only a few major contractors are required by contract to provide a Materials Control Plan. All other JSC flight hardware contractors not required by their contract to provide a Materials Control Plan shall use this document as their Materials Control Plan instead of developing a separate contractor plan.

The materials control plan shall include the following:

4.1.1 COORDINATION, APPROVAL, AND TRACKING

A method of coordinating, approving, and tracking all engineering drawings, engineering orders, and other documentation that establishes or modifies materials and/or processes usage for M&P review.

4.1.2 APPROVAL SIGNATURE

A requirement that each engineering drawing, engineering order, etc., be approved and signed by the responsible Materials and Processes organization prior to release. For designs produced by automated Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) systems, an equivalent level of review and approval shall be defined. The M&P drawing approval process shall comply with ES SOP-007.5, Materials and Processes Drawing Approval.

For non-plan contractors, the JSC Materials & Processes Branch shall review drawings to the extent necessary to insure compliance to M&P requirements.

4.1.3 MATERIALS AND PROCESS DOCUMENTATION

A Materials Identification and Usage List (MIUL), or an electronic searchable parts list, (unless specified otherwise in the contract) shall be required for all Criticality 1 flight hardware, except as specified in section 3.2. The documentation system used shall be an integral part of the engineering configuration control/release system and be integrated (or integrable) into an automated data system. A copy of the stored data shall be provided to JSC in a form compatible for electronic searches for M&P purposes

Note: For non-plan contractors, the JSC Materials & Processes Branch must be notified by CDR of all Criticality 1 flight hardware for which it is responsible for providing the MIUL and Materials and Fracture Control Certification (as well as any changes "to or from" a Criticality 1 status which might occur after CDR).

The procedures and formats for documentation of materials and processes usage will depend upon specific hardware but shall cover the final design.

This system shall identify the following applicable information through an electronic searchable parts list or separate Materials Identification and Usage List (MIUL).

a. Associate contractor code number (assigned by the Prime Contractor)
b. Part number
c. Next assembly
d. NASA Material code
e. Material specification
f. Process specification
g. MUA number or rationale code

The NASA Materials and Processes Technical Information System (MAPTIS) database shall be consulted to obtain material codes & ratings for materials, standard and commercial parts and components. New material codes shall be assigned by NASA Marshall Space Flight Center (MSFC).

A procedure shall be established by the contractor to ensure that all vendor-designed, off-the-shelf, and vendor-furnished items are covered by the M&P requirements of this document. Where batch/lot testing is required, traceability of specific test reports for batch/lot used shall be provided.

Wire, cable, and exposed surfaces of connectors shall meet the requirements of this document and be reported on the MIUL. All other Standard and Nonstandard Electrical, Electronic, and Electromechanical (EEE) Parts shall be exempt from these requirements and reporting on the MIUL.

Materials used in hermetically sealed electronic containers and in ground support equipment are exempt from inclusion in the MIUL.

A periodic review by of plan contractors shall be conducted by the JSC Materials & Processes Branch to ensure compliance with Material and Processes requirements.

4.1.4 MATERIALS USAGE AGREEMENTS

Material Usage Agreements (MUA) shall be submitted for all materials not rated "A" or better in MAPTIS for the intended application or that do not meet other M&P requirements of this document. A tiered MUA system with three categories shall be used.

The three categories of MUAs are described below. MUA forms shall be used only for Category I and II MUAs. The standard JSC MUA form is shown in Appendix B.

4.1.4.1 Category I MUAs -- Category I MUAs are those that involve a materials process usage that could affect the safety of the crew, vehicle, or mission, or affect the mission success, but must be used for functional reasons. Category I flight hardware MUAs shall be approved by the hardware manager, the JSC Materials & Processes Branch Chief, and the applicable Program Office.

4.1.4.2 Category II MUAs -- Category II MUAs are those that involve a materials process usage that fails a screening of M&P requirements, and is not considered a hazard in its use configuration, but for which no Category III rationale code exists. Category II MUAs shall be approved by the hardware manager and the JSC Materials & Processes Branch Chief. (On selected MUAs, the Astronaut Office or Crew Training Office may also be required to concur.)

4.1.4.3 Category III MUAs (no MUA form is submitted) are those that involve materials or processes that do not comply with Section 5 of this document, but are acceptable in the use configuration, and the acceptance rationale is defined in a rationale code in Appendix C. Rationale codes for acceptability in configuration shall be used instead of an MUA form. The acceptance rationale is approved by the Materials and Fracture Control Certification. The rationale code shall be recorded in the backup information form for the JSC Materials and Fracture Control Certification, which is maintained by the JSC Materials & Processes Branch. (If an MIUL is required per Section 4.2.3, the rationale code shall also be reported in the MIUL, or electronic data system.)

4.1.5 VOLATILE ORGANIC COMPOUND USAGE AGREEMENTS

Volatile Organic Compound Usage Agreements (VUAs) shall be submitted for hardware containing the following water-soluble volatile organic compounds (Section 5.3.10):

> Methanol; ethanol; isopropyl alcohol; n-propyl alcohol; n-butyl alcohol; acetone; ethylene glycol; propylene glycol.

The restrictions on water-soluble volatile organic compounds apply only to hardware used in the ISS habitable environment and hardware used in the Space Shuttle orbiter while docked to ISS with the hatch open. VUAs are not required for hardware used in the orbiter at other times.

A tiered VUA system with two categories shall be used. VUA forms shall be used for both categories. The standard JSC VUA form is shown in Appendix B.

4.1.5.1 Category I VUAs -- Category I VUAs are those that involve water-soluble volatile organic compound usage that could affect the safety of the mission, crew, or vehicle or affect the mission success, but must be used for functional reasons. Category I flight hardware VUAs shall be approved by the hardware manager, the JSC Materials & Processes Branch Chief, and the responsible ISS program control board (Vehicle Control Board, GFE Control Board, Payloads Control Board, or equivalent).

4.1.5.2 Category II VUAs -- Category II VUAs are those that involve water-soluble volatile organic compound usage that is not considered a hazard to safety or mission success in its use application. Category II VUAs shall be approved by the hardware manager and the JSC Materials & Processes Branch Chief. Category II VUAs are permitted only for those applications that do not raise the gas-phase water-soluble volatile organic compound generation rate significantly above the background level that results from normal materials offgassing.

4.1.5.3 Volatile Organic Compound Usage Agreement Submittal -- Category I and II VUAs shall be submitted as appropriate for each usage of a water-soluble volatile organic compound that does not meet the requirements of this document. These VUAs shall be signed by a member of the contractor M&P organization and approved as indicated in the categories above. The information required on the VUA form shall be provided as specified in the contract data requirement for the category I and II MUAs and must include sufficient information to assess these usages. A typical VUA form is given in Appendix B page B-3.

The VUA shall be submitted separately from any MUA submitted for the same hardware. Documentation of a VUA in the applicable MIUL is not required.

4.2 PROCESS SPECIFICATIONS

All contractors are responsible for implementing the process requirements and specifications as required herein. Contractors are also responsible for flowing these requirements to their subcontractors and suppliers. Alternative specifications, which meet the technical intent expressed herein, may be used when identified in an approved materials control plan or approved through the MUA process.

JSC in-house hardware (designed and fabricated using the JSC engineering drawing release system per JPG 8500.4) shall be designed and fabricated in accordance with JSC internal process specifications approved by the Materials & Processes Branch. These specifications (designated PRC-xxxx) are available on the JSC JSC Structural Engineering Division web page at http://mmptdweb/home/ or the JSC Quality Management System web page at http://stic.jsc.nasa.gov/dbase/iso9000/docs/ES/master.htm.

4.3 CONTROLLING DOCUMENTS

All M&P shall be documented by standards and specifications to preclude unauthorized changes. Standards and specifications may be selected from government, industry, and company sources.

4.4 RAW MATERIALS CERTIFICATION AND TRACEABILITY

All parts or materials used in manufacturing JSC flight hardware shall be certified as to composition and properties as identified by the procuring document. Noncritical commercial off-the-shelf hardware is exempted from this requirement. Materials used in critical applications such as life-limited materials, safety and fracture critical parts shall be traceable through all critical processing steps and the end-item application.

4.5 MATERIAL DESIGN ALLOWABLES

Values for allowable mechanical properties of structural materials in their design environment shall be taken from MIL-HDBK-5, Metallic Materials And Elements For Aerospace Vehicle Structures; MIL-HDBK-17, Polymer Matrix Composites. When using MIL-HDBK-5, material "B" allowable values may be used in redundant structure in which the failure of a component would result in a safe redistribution of applied load-carrying members. MIL-HDBK-5, material "S" allowables may be used for materials in lieu of "A" and "B" allowables where batch lot acceptance testing is a procurement requirement. Where values for mechanical properties of new or existing materials or welds are not available, they shall be determined by analytical methods described in MIL-HDBK-5.

4.6 MATERIALS AND FRACTURE CONTROL CERTIFICATION PROCESS

Materials and Fracture Control Certification is required to document that hardware has been evaluated for compliance with ISS M&P requirements. The Materials and Fracture Control Certification process includes drawing review and approval, and issuance of a Materials and Fracture Control Certification. The Materials and Fracture Control Certification process shall comply with ES SOP-007.6, Materials and Fracture Control Certification.

A Materials and Fracture Control Certification shall be issued by the JSC Materials & Processes Branch, or plan contractor, as applicable, after satisfactory completion of required materials analysis and/or testing, drawing review, fracture control analysis, MUAs, and VUAs. The Materials and Fracture Control Certification shall identify any MUAs or VUAs applying to the hardware and the reason for each MUA (use of flammable materials, stress corrosion sensitive materials, etc.). The Materials and Fracture Control Certification shall also indicate the vehicle locations (environments) for which the hardware is approved, any flight limitations, and any coded stowage conditions agreed to. A backup information form to the JSC Materials and Fracture Control Certification contains additional details, and is maintained within the JSC Materials & Processes Branch. Use of this hardware in a different application (even in the same environment) may require different materials to be used and/or a new Materials and Fracture Control Certification. A copy of the JSC Materials & Processes Branch Materials and Fracture Control Certification form is shown in the Appendix.

Plan contractors may use their own form, with the following information shown as a minimum:

(a) Top assembly drawing number

(b) Applicable M&P requirements documents

(c) ISS location environment certified for

(d) Any MUAs or VUAs

(e) Any flight, EVA, or other limitations

4.6.1 M&P DRAWING APPROVAL

M&P approval is required for JSC flight hardware drawings, either by the JSC Materials & Processes Branch, or the plan contractor, as applicable. The M&P drawing approval process shall comply with ES SOP-007.5, Materials and Processes Drawing Approval. The JSC Materials & Processes Branch signature on drawings provides only "preliminary approval" for fabrication, pending the resolution of any open issues, such as toxicity, vacuum outgassing, or flammability testing, MUA approval, fracture control analysis, etc. (Contractors may choose to withhold their M&P signature until all materials issues have been resolved.) The JSC Materials & Processes Branch signature on drawings does "not" constitute Materials and Fracture Control Certification or final materials approval of the hardware. This is accomplished only through a formal Materials and Fracture Control Certification.

Note: The list of personnel approved to sign JSC Engineering Drawings for M&P is maintained and controlled by the JSC Materials & Processes Branch. In-house contractors and other personnel may be authorized by the Materials & Processes Branch to sign for M&P. Authorization will be in accordance with ES SOP-007.5.

4.6.2 CERTIFICATION OF NEW FLIGHT HARDWARE

For new flight hardware, a Materials and Fracture Control Certification issued by the JSC Materials & Processes Branch, or plan contractor, as applicable, shall include all top assembly part numbers and their dash numbers. Parts classified as subassemblies shall not be identified in the certification.

4.6.3 CERTIFICATION OF MODIFIED FLIGHT HARDWARE

JSC hardware that is modified by drawing change notices (DCNs) that do not change the top assembly dash number shall be approved by a Materials signature on the DCN; the Materials and Fracture Control Certification shall not be revised. When drawing changes result in the top assembly dash number being changed, a new Materials and Fracture Control Certification shall be issued.

When drawing changes result in the part number being changed or the dash number being rolled, but the changes have no effect on the rationale for MUAs applicable to the hardware, the revised part number may be redlined into the MUA, and the MUA will not be formally revised.

4.6.4 CERTIFICATION OF OFF-THE-SHELF (OTS) HARDWARE

The statement of work and/or procurement request for OTS hardware shall require identification of materials contained in off-the-shelf hardware, wherever practical and cost effective. When detailed materials information for OTS hardware is not available, OTS hardware shall be evaluated by sufficient analysis and/or testing in configuration as required to provide for Materials and Fracture Control Certification. Criticality 3 OTS hardware shall be evaluated only for compliance with M&P safety requirements (flammability, toxic offgassing, etc.) and for compatibility with the flight vehicle (normally limited to vacuum outgassing contamination).

5.0 DETAILED REQUIREMENTS

Deviations from the detailed requirements in this section require an approved MUA documenting the rationale for acceptability in the specific application.

Note: Materials and processes selection requires a tradeoff between the strengths and weaknesses of candidate materials. Materials and processes that deviate from the detailed requirements in this section are frequently the best overall choice for an application, provided that the deviations are acceptable in that application. In general, materials and processes that do not meet these detailed requirements are unacceptable for an application only if the deviations are unacceptable in that application.

5.1 FLAMMABILITY, OFFGASSING, AND COMPATIBILITY REQUIREMENTS

Materials shall meet the requirements of NASA-STD-6001, Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion as described below.

5.1.1 FLAMMABILITY CONTROL

Primary flammability control is based on using materials that are nonflammable or self-extinguishing when tested by NASA-STD-6001, Test 1; testing is not required for ceramics and metal oxides. Test 2 (Heat and Visible Smoke Release Rates) of NASA-STD-6001 is not required. If flammable materials must be used due to functionality, cost, or schedule impact, flammability control shall be based on separation of flammable materials in configuration to preclude fire propagation paths. The configuration analysis or test shall comply with the guidelines of NSTS 22648, Flammability Configuration Analysis for Spacecraft Applications.

Material flammability ratings and test data are given in the MAPTIS database. The thickness specified for flammability includes the minimum thickness in which the material was tested. Thinner materials may not have the same rating, and may need to be tested.

If flammable materials must be used, they should, if possible, be protected by covering with nonflammable materials, such as nonflammable tape, coatings, shrink tubing, and sleeving. Small flammable materials that are normally stowed in a locker or a nonflammable container may be acceptable, if the amount of time that they are left unstowed is sufficiently minimized, (refer to next section on stowed hardware). The absence of ignition sources is not normally sufficient justification in itself for accepting flammable materials, but may be used as supporting rationale for acceptance.

5.1.1.1 Stowed Flammable Hardware -- Control of flammability of materials may fall under the JSC Materials & Processes Branch stowage policies. The stowage policies are expressed as codes that describe different rationales concerning use of a non "A" rated flammable material. These codes are based on the size of flammable surface materials, and the limited amount of time these materials will be left unstowed outside of nonflammable stowage containers. Any stowage codes used are documented on the Materials and Fracture Control Certification. The codes are described in Appendix E:

5.1.1.2 Spacing of Hook and Loop Fasteners -- Hook and loop fasteners in habitable areas, whether applied on the ground or on orbit, shall not exceed the following restrictions:

(a) Maximum size - 4 square inches

(b) Maximum length - 4 inches

(c) Minimum separation - 2 inches

5.1.2 TOXIC OFFGASSING

All materials used in habitable flight compartments shall meet the offgassing requirements of NASA-STD-6001 using one of the following methodologies:

(a) Offgassing is tested as an assembled article

Summation of Toxic Hazard Index (T) values (total concentration in milligrams per cubic meter Spacecraft Maximum Allowable Concentration) of all offgassed constituent products must not exceed 0.5.

(b) Hardware components evaluated on a materials basis (individual materials used to make up components)

The summation of T values for each constituent material must be less than 0.5.

(c) More than one hardware component or assembly

If a single hardware component is tested or evaluated for toxicity, but more than one will be flown, the T value obtained for one unit times the number of flight units must be less than 0.5.

(d) Bulk materials and other materials not inside a container

All materials shall be evaluated individually using the ratings in the MAPTIS database. The maximum quantity and associated rating is specified for each material code.

Offgassing testing is not required for metallic materials or for ceramics and metal oxides. SMAC values shall be selected from JSC 20584, Spacecraft Maximum Allowable Concentrations for Airborne Contaminants. For compounds for which no SMAC values are found in JSC 20584, the values in MAPTIS may be used.

5.1.2.1 Personal Hygiene Kit (PHK) Materials -- Each astronaut is able to select basic generic off-the-shelf personal hygiene items, such as toothpaste, deodorant, makeup, etc. without an offgas test being required for each new item. The JSC Materials & Processes Branch, in conjunction with the JSC Medical Sciences Division Toxicology Group, consider that personal hygiene products sold in the United States (with exceptions cited below) do not present a significant toxic offgassing hazard in manned flight compartments.

Note: Personal Hygiene Kit items used on ISS or on the Space Shuttle orbiter while it is docked to ISS shall also comply with Section 5.3.10 . A VUA is required if any of the 8 controlled water-soluble volatile organic compounds are present.

Astronaut Personal Hygiene Kit items which meet the following conditions shall not normally require offgas testing:

(a) Products, which do not have an alcohol, ketone, or other solvent, listed as one of their first four ingredients. Exceptions to this shall be offgas tested.

(b) Unscented products are recommended, but are not mandatory.

(c) Aerosol and pump sprays are not allowed.

(d) Products manufactured in foreign countries and not sold in the U.S. shall be evaluated on a case by case basis.

(e) Any special non-generic items shall also be evaluated on a case by case basis.

5.1.3 FLUID COMPATIBILITY

Materials exposed to corrosive or hazardous fluids shall be evaluated or tested for compatibility and shall meet the fluid compatibility requirements of NSTS 1700.7B, paragraph 209.1a. As a minimum, materials compatibility with hazardous fluids other than oxygen shall be tested for 48 hours at the maximum system temperature or 160 (F (whichever is higher) per Test 15 of NASA-STD-6001. The NASA-STD-6001 test is appropriate only for short-term or intermittent fluid exposure; appropriate long-term tests shall be conducted for materials with long-term exposure to hazardous or corrosive fluids.

When materials can be exposed to hazardous fluids by a credible single barrier failure, an evaluation of test data and other information shall be conducted to demonstrate the acceptability of the configuration.

5.1.4 OXYGEN COMPATIBILITY

Liquid and gaseous oxygen systems containing flammable metallic materials shall be designed to eliminate all potential ignition sources. Materials compatibility with liquid and gaseous oxygen shall be evaluated and tested if required in accordance with NASA-STD-6001 Test 13 for mechanical impact, and Test 17 for upward flammability in GOX. When a material in an oxygen system fails either test at its maximum use pressure, a hazard analysis shall be conducted and the system safety rationale shall be documented in an approved MUA. Configurational testing shall be conducted as required to support the hazard analysis.

Fluid systems used to store and deliver gases with an oxygen concentration greater than 23 percent should be designed using ASTM Standard G88-90 "Standard Guide for Designing Systems for Oxygen Service" as a guideline. In addition, materials selection should consider the guidelines in ASTM G63-99,"Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service", and ASTM G94-92, "Standard Guide for Evaluating Metals for Oxygen Service".

Note: With a few exceptions, such as Monel alloys, common structural metallic materials are flammable in oxygen at modest pressures. However, most metals can be used safely in oxygen provided that the system is designed to eliminate potential ignition sources. Titanium alloys are extremely flammable and should be used only in exceptional circumstances and at very low pressures (never above 100 psia). Aluminum alloys are also highly flammable, but can be used for static components, such as pressure vessels, at pressures up to 3,000 psia; aluminum valves, regulators, etc. should not be used at pressures above 100 psia. Stainless steel and Inconel alloys are flammable at pressures above 500 psia, but, with careful design to eliminate ignition sources, can be used safety at pressures as high as 10,000 psia.

5.1.4.1 Oxygen Component Acceptance Test -- Oxygen system components shall undergo oxygen compatibility acceptance testing as noted in Table 5-1. This test ensures all oxygen system flight hardware is exposed to oxygen prior to launch and screens workmanship defects that could result in ignition of the component when pressurized with oxygen.

Oxygen system components shall be exposed to oxygen at maximum design pressure (MDP). Functional tests, other than leakage, shall be conducted while the component is pressurized with oxygen at MDP (functional tests include opening and closing a valve, connecting and disconnecting a quick disconnect, etc.). Cleanliness shall be maintained to the level specified in the component specification. Hydrocarbon detection analysis shall be performed as specified in MSFC-PROC-404 prior to the oxygen compatibility acceptance test for components exposed to non oxygen-compatible solvents as an assembly. Total hydrocarbon count shall not exceed 5 parts per million.

Each component shall be subjected to 10 oxygen pressurization cycles from ambient pressure (10 to 15 psia) to MDP within 100 milliseconds. The component shall be maintained at MDP for at least 30 seconds following each pressurization cycle. Each component shall be subjected to oxygen flow in both the forward and reverse flow directions, where reversible flow is within the operational capability of the component.

Visual inspection shall be performed after conduct of the oxygen compatibility acceptance test and shall be verified to the level specified in the component specification. If disassembly of the component occurs after the oxygen compatibility acceptance test, the test must be repeated. All functional and leak tests required in the component specification shall be conducted (or repeated) after the oxygen compatibility acceptance test.

Table 5–1. Oxygen Components Requiring Acceptance Testing

Component	Testing Required
Hard Line (rigid metal tubing)	
Metal Flex Hose	
Metal Flex Hose (>=3,000 psia)	X
Metal Fluid Fitting with all metal seals	
Self–Sealing Quick Disconnect	X
Valve	X
Pressure Relief Valve	X
Temperature Sensor	X
Pressure Sensor	X
Nonmetal Lining Flex Hose	X
Fluid Fitting with nonmetal seals	X
Pressure Regulator	X
Metal Pressure Vessels	

5.1.5 ELECTRICAL WIRE INSULATION MATERIALS

Electrical wire insulation materials shall be evaluated for flammability in accordance with NASA-STD-6001 Test 4. The optional overload test is not required.

Arc tracking shall be evaluated in accordance with NASA-STD-6001Test 18 or a generally accepted voluntary standard aerospace wiring arc tracking test. Testing is not required for polytetrafluoroethylene (PTFE), PTFE laminate, ethylene tetrafluoroethlyene (ETFE), or silicone insulated wires.

5.2 METALS

The following requirements are specific to metallic materials. Additional information regarding metallic materials can be found in MAPTIS.

5.2.1 ALUMINUM

In structural applications using aluminum, maximum use shall be made of those alloys, heat treatments, and coatings, which minimize susceptibility to general corrosion, pitting, intergranular and stress corrosion cracking. Aluminum alloys 2024-T6, 7079-T6, and 7178-T6 shall not be used in structural applications. The following alloys and heat treatments shall not be used in applications where the temperature exceeds 150 degrees Fahrenheit (66 degrees C): 5083-H32, 5083-H38, 5086-H34, 5086-H38, 5456-H32, and 5456-H38.

Heat treatment of aluminum alloy parts shall meet the requirements of SAE-AMS 2772, Heat Treatment of Aluminum Alloy Raw Materials, or SAE-AMS 2770, Heat Treatment of Wrought

Aluminum Alloy Parts. Heat treatments not included in SAE-AMS 2772 or SAE-AMS 2770 may be used if sufficient test data are available to conclusively demonstrate that the specific heat treatment improves the mechanical and/or physical properties.

5.2.2 STEEL

Carbon and low alloy steels heat-treated to strength levels at or above 180 ksi UTS shall not be used. Carbon and low alloy high strength steels greater than 180 ksi UTS used in ball bearings, springs, gears, or similar applications where primary loading is compressive, low tensile stresses or history of satisfactory performance may be used by Category III MUA.

5.2.2.1 Heat Treatment of Steels -- Steel parts shall be heat treated to meet the requirements of SAE-AMS-H-6875, Heat Treatment of Steel Raw Materials, or SAE-AMS 2759, Heat Treatment of Steel Parts, General Requirements. Heat treatments not included in SAE-AMS-H-6875 or SAE-AMS 2759 may be used if sufficient test data are available to conclusively demonstrate that the specific heat treatment improves the mechanical and/or physical properties. When acid cleaning baths or plating processes are used, the part shall be baked in accordance with SAE-AMS 2759/9, Hydrogen Embrittlement Relief (Baking) of Steel Parts, to alleviate potential hydrogen embrittlement problems.

5.2.2.2 Drilling and Grinding of High Strength Steel -- The drilling of holes, including beveling and spot facing, in martensitic steel hardened to 180 ksi UTS or above, shall be avoided. When such drilling, machining, reaming, or grinding is unavoidable, carbide-tipped tooling and other techniques necessary to avoid formation of untempered martensite shall be used. Micro-hardness and metallurgical examination of test specimens typical of the part shall be used to determine if martensite areas are formed as a result of drilling or grinding operations, or temper etch actual hardware in lieu of destructive test. The surface roughness of finished holes shall not be greater than 63 roughness-height-ratio, and the edges of the holes shall be deburred by a method, which has been demonstrated not to cause untempered martensite.

5.2.2.3 Corrosion Resistant Steel -- Unstabilized, austenitic steels shall not be used above 700 degrees Fahrenheit (371 degrees C). Welded assemblies shall be solution heat-treated and quenched after welding except for the stabilized or low carbon grades such as 321, 347, 316L, and 304L.

5.2.3 TITANIUM

Most titanium alloys have limited hardenability with section size and should not be used in section thicknesses that exceed their specified limits. The variation of mechanical properties with thickness as heat-treated shall be evaluated for all titanium alloys used. The surfaces of titanium parts shall be machined or chemically milled to eliminate all contaminated zones formed during processing.

Titanium shall not be used with Liquid Oxygen (LOX) or Gaseous Oxygen (GOX) at any pressure or with air at oxygen partial pressures above 5 psia (34.5 kPa).

5.2.3.1 Heat Treatment -- Heat treatment of titanium and titanium alloy parts shall meet the requirements of MIL-H-81200 or SAE-AMS-H-81200, Heat Treatment of Titanium and

Titanium Alloys. Heat treatments not included in MIL-H-81200 or SAE-AMS-H-81200 may be used if sufficient test data are available to conclusively demonstrate that the specific heat treatment improves the mechanical and/or physical properties.

5.2.3.2 Titanium Contamination -- Care shall be exercised to ensure that cleaning fluids and other chemicals used on titanium are not detrimental to performance. Surface contaminants which can induce stress corrosion, hydrogen embrittlement, or reduce fracture toughness include the following: hydrochloric acid, cadmium, silver, chlorinated cutting oils and solvents, methyl alcohol, fluorinated hydrocarbons, and components containing mercury.

5.2.3.3 Fretting of Titanium -- Titanium alloys are susceptible to the reduction of fatigue life by fretting at interfaces between titanium alloys or titanium and other metal parts; therefore, structural applications of titanium shall be designed to avoid fretting. Where fretting interfaces cannot be eliminated, the surfaces shall be protected by anodizing per AMS 2488, Anodic Treatment - Titanium & Titanium Alloys, Solution pH 13 or Higher, or by a tungsten carbide/cobalt hardcoat.

5.2.3.4 Titanium Welding -- Alloyed titanium shall be welded using alloy weld wire to avoid potential hydrogen embrittlement associated with the use of Commercially Pure (CP) wire in alloy welds. CP wire may be used in CP-to-CP alloy welds.

5.2.4 MAGNESIUM

Magnesium alloys shall not be used except in areas where minimal exposure to corrosive environments can be expected and protection systems can be maintained with ease and high reliability. Magnesium alloys shall not be used in the primary structure, or in other areas subject to wear, abuse, foreign object damage, abrasion, erosion, or at any location where fluid or moisture entrapment is possible.

5.2.5 BERYLLIUM

Beryllium shall not be used for primary structural applications. Beryllium is allowed as an alloying constituent up to a maximum of 4% (percent) by weight.

5.2.6 CADMIUM

Cadmium shall not be used in crew environments at temperatures above 100 degrees Centigrade or in vacuum environments where the temperature/pressure environment could cause contamination of optical surfaces or electrical devices.

5.2.7 MERCURY

Equipment containing mercury shall not be used where the mercury could come in contact with the spacecraft or space flight equipment during manufacturing, assembly, test, checkout, and flight. Well-protected lamps containing mercury, including those used in the fluorescent penetrant inspection of flight parts are exempt from this requirement.

5.2.8 REFRACTORY METALS
Since engineering data on refractory alloys are limited, especially under extreme environmental usage of spacecraft, appropriate tests shall be performed to characterize such materials for the intended application.

5.2.9 SUPERALLOYS (NICKEL-BASED AND COBALT-BASED)
High nickel content alloys are susceptible to sulfur embrittlement; therefore, any foreign material which could contain sulfur, such as oils, grease, and cutting lubricants, shall be removed by suitable means prior to heat treatment or high temperature service. Some of the precipitation-hardening superalloys are susceptible to alloying element depletion at the surface in a high temperature, oxidizing environment. This effect shall be carefully evaluated when a thin sheet is used, since a slight amount of depletion could involve a considerable proportion of the effective cross section of the material.

5.2.9.1 Heat Treatment of Nickel- and Cobalt-Based Alloys -- Heat treatment of nickel- and cobalt-based alloy parts shall meet the requirements of SAE-AMS 2774, Heat Treatment, Wrought Nickel Alloy and Cobalt Alloy Parts. Heat treatments not included in SAE-AMS 2774 may be used if sufficient test data are available to conclusively demonstrate that the specific heat treatment improves the mechanical and/or physical properties.

5.3 NONMETALLIC MATERIALS
The following requirements are specific to nonmetallic materials.

5.3.1 ELASTOMERIC MATERIALS
Elastomeric components shall have long-term resistance to aging, low temperature, ozone, heat aging, polymer reversion, working fluids, lubricants, and operating media. Elastomeric materials shall be cure dated for tracking purposes. RTV elastomeric materials that liberate acetic acid during cure shall not be used in electronic applications. In addition, any other use must be approved by the JSC Materials and Processes Branch.

5.3.2 POLYVINYL CHLORIDE
Use of polyvinyl chloride on flight hardware shall be limited to applications in pressurized areas where temperatures do not exceed 120 degrees Fahrenheit (49 degrees C). Polyvinyl chloride shall not be used in vacuum.

5.3.3 COMPOSITE MATERIALS
Defects resulting from the manufacturing process shall be assessed through the proper application of Nondestructive Evaluation (NDE) techniques. Appropriate NDE techniques selected from the available PRC-6500-series of JSC process specifications shall be used as appropriate. Other NDE specifications may be invoked in those cases where adequate JSC process specifications do not exist. A-basis or B-basis material property design allowables shall be developed per the methodology of MIL-HDBK-5 for use in the design and analysis of composite flight hardware.

5.3.4 LUBRICANTS

NASA-TM-86556, Lubrication Handbook For the Space Industry, Part A: Solid Lubricants, Part B: Liquid Lubricants, shall be used in the evaluation and selection of lubricants for space flight systems and components. Long life performance shall be considered in lubricant selection. Lubricants containing chloro-fluoro components shall not be used with aluminum or magnesium if shear stresses can be imposed.

5.3.5 LIMITED-LIFE ITEMS

Materials shall be selected to ensure maximum life and minimum maintenance. As a goal, all materials shall be selected to provide the full operational service life with no maintenance. Materials, which are not expected to meet the design life requirements but must be used for functional reasons shall be identified as limited-life items requiring maintainability.

5.3.6 VACUUM OUTGASSING

Nonmetallic materials which are exposed to space vacuum shall be tested using the technique of ASTM-E595, Total Mass Loss and Collected Volatile Condensable Materials From Outgassing In A Vacuum Environment, Test Method for, with acceptance criteria of <0.1 percent Collected Volatile Condensable Materials (CVCM) and <1.0 percent Total Mass Loss (TML). A TML greater than 1.0 percent is permitted if this mass loss has no effect on the functionality of the material itself and no effect the functionality of any materials, components, or systems that could be adversely affected by the subject mass loss. A hardware item (component, assembly, etc.) containing materials that fail the CVCM requirement and/or having unidentified materials, may be vacuum baked at a temperature of 125 (C until the outgassing rate, as measured by a quartz crystal microbalance at 25 (C, is less than 1 x 10-9 grams/square centimeter/second. When a vacuum-bake temperature of 125 (C could damage flight hardware, lower temperatures may be used with approval from the Materials and Processes Branch.

Additional, program-specific requirements may exist (such as SSP 30426), but are not addressed by the materials control program.

5.3.7 LOW EARTH ORBIT ENVIRONMENT SURVIVABILITY

Materials exposed in the low Earth orbit (LEO) environments shall be selected to perform in that environment for their intended life cycle exposure. The critical properties of the material (most commonly, but not limited to, mechanical and optical properties) shall survive exposure to the LEO environments of atomic oxygen, solar ultraviolet radiation, ionizing radiation, plasma, vacuum, thermal cycling and contamination. Noncritical properties may be allowed to degrade, provided such degradation does not result in release of particulate that would violate external contamination requirements or affect the functioning of other hardware (in particular, mechanisms). Meteoroids and orbital debris shall also be considered in the analysis of long term degradation.

An MUA shall be processed in accordance with section 4.1.4 for materials applications where critical or noncritical properties degrade during exposure to the LEO environment, but the hardware is deemed to have adequate life for the intended application. Contingency tools and materials that are normally protected from the environment and exposed only temporarily as a result of removal of the protective covering (blankets, shrouds, etc.) for maintenance or assembly operations are exempt from the MUA requirement.

5.3.8 MOISTURE AND FUNGUS RESISTANCE

Organic materials used in the pressurized environment shall be evaluated for fungus resistance prior to selection and qualification. Materials which are non-nutrient to fungi shall be used, as defined by MIL-STD-810, Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, Method 508, or as identified in MIL-HDBK-454, General Guidelines for Electronic Equipment, Requirement 4, Fungus-Inert Materials, Table 4-I, Group I, except when one of the following criteria is met.

1. Materials used in crew areas, where fungus would be visible and easily removed.
2. Materials used inside environmentally sealed containers with internal container humidity less than 60% RH at ambient conditions.
3. Materials used inside electrical boxes where the temperature is always greater than or equal to the ambient cabin temperature.
4. Materials with edge exposure only.
5. Materials normally stowed with no risk of condensation in stowage locations.
6. Materials used on non-critical off-the-shelf electrical/electronic hardware that is stowed and/or used in crew areas.
7. Fluorocarbon polymers (including ETFE) or silicones.
8. Crew clothing items.

When fungus-nutrient materials must be used, they shall be treated to prevent fungus growth. Materials not meeting this requirement shall be identified including any action required such as inspection, maintenance, or replacement periods. Fungus treatment shall not adversely affect unit performance or service life or constitute a health hazard to higher order life. Materials so treated shall be protected from environments that would be sufficient to leach out the protective agent.

5.3.9 WATER-SOLUBLE VOLATILE ORGANIC COMPOUNDS

The release of the following water-soluble volatile organic compounds into the ISS habitable environment is prohibited:

> Methanol; ethanol; isopropyl alcohol; n-propyl alcohol; n-butyl alcohol; acetone; ethylene glycol; propylene glycol.

This requirement applies to hardware used in the ISS habitable environment and hardware used in the Space Shuttle orbiter while docked to ISS with the hatch open. It does not apply to hardware used in the orbiter at other times.

A VUA must be processed in accordance with section 4.1.5 for all hardware containing such compounds, with the following exceptions:

- The release of these compounds by normal materials offgassing

- The water-soluble volatile organic compound is properly contained and released to the habitable environment only as a result of a single barrier failure (redundant containment is not required)
- All emergency surgery pack and drug subpack items are exempt

Note: Commercial personal hygiene items such as toothpaste and deodorant are acceptable if none of the 8 controlled water-soluble volatile organic compounds are listed as ingredients on the commercial container or packaging. Ethanol may be listed as "ethyl alcohol", "SD alcohol", or "Alcohol Denat."

5.4 PROCESSES

5.4.1 FORGING

Because mechanical properties are optimum in the direction of material flow during forging, forging techniques shall be used that produce an internal grain- flow pattern such that the direction of flow is essentially parallel to the principal stresses. The forging pattern shall be essentially free from re-entrant and sharply folded flow lines. After the forging technique, including degree of working, is established, the first production forging shall be sectioned to show the grain-flow patterns and to determine mechanical properties at control areas. The procedure shall be repeated after any change in the forging technique. The information gained from this effort shall be utilized to redesign the forging as necessary. Grain flow patterns shall not be determined for hand forgings. Where forgings are used in critical applications, trim ring or protrusion specimens shall be obtained for each forging and shall be tested for required minimum mechanical properties.

5.4.2 CASTINGS

Castings shall meet the requirements of SAE-AMS-STD-2175, Castings, Classification and Inspection of.

5.4.3 ADHESIVE BONDING

Structural adhesive bonding shall meet PRC-1001, Adhesive Bonding or MSFC-SPEC-445A, Adhesive Bonding, Process, and Inspection, Requirements for, with the exception of paragraph 3.1.1.1. Contractors are not required to submit for review either an operator certification plan or an adhesive control plan. Adhesives used for production parts will not be retested if within shelf life. Bonded primary structural joints shall demonstrate cohesive failure modes in shear.

5.4.4 WELDING

The design selection of parent materials and weld methods shall be based on consideration of the weldments, including adjacent heat affected zones, as they affect operational capability of the parts concerned. Welding procedures shall be selected to provide the required weld quality, minimum weld energy input, and protection of the heated metal from contamination. The suitability of the equipment, processes, welding supplies, and supplementary treatments selected shall be demonstrated through qualification testing of welded specimens representing the materials and joint configuration of production parts. As a minimum requirement, welding operators shall be qualified in accordance with SAE AMS-STD-1595, Qualification of Aircraft, Missile and Aerospace Fusion Welders, or PRC-0008, Qualification of Manual Arc Welders, Process Specification for. In addition, contractors shall provide the necessary training and qualification requirements to certify each operator and the applicable welding equipment for specific welding tasks.

5.4.4.1 Weld Repair -- At the discretion of the cognizant engineer, two additional welding operations may be performed on any one location, within a two inch length, to repair defects determined by inspection without JSC Discrepancy Report or Material Review Board (MRB) approval. Weld repair does not include the correction of dimensional deficiencies by weld buildup or "buttering" of parts in areas where the design did not provide a welded joint. All weld repairs shall be fully documented to facilitate procuring activity review. The weld repair process and inspection shall be qualified to the same level of assurance as the primary process specification drawing requirement using the same inspection technique that found the original defect and by all other methods of examination that were originally required for the affected area.

5.4.4.2 Weld Filler Metal -- Weld wire filler materials shall meet the requirements of ES SOP-004.5, Control of Weld and Braze Filler Materials, Electrodes, and Fluxing Materials. In addition, qualitative analysis or nondestructive testing shall be conducted on each nickel base filler rod or immediately before and after each segment of rolled nickel base weld wire used to assure that the correct filler metal is used on each specific critical part.

5.4.4.3 Aluminum Welding -- The welding of aluminum alloys shall meet the requirements of PRC-0001, Manual Arc Welding of Aluminum Alloy Flight Hardware, or MSFC-SPEC-504, Welding, Aluminum Alloys.

5.4.4.4 Welding of Steel Alloys -- Welding of steel alloys shall meet the requirements of PRC-0006, Manual Arc Welding of Steel and Nickel Alloy Flight Hardware, or MSFC-SPEC-560, Welding, Steels, Corrosion and Heat Resistant Alloys.

5.4.4.5 Welding of Titanium Alloys -- Welding of Titanium alloys shall meet the requirements of JSC PRC-0004, Manual Arc Welding of Titanium Alloy Flight Hardware, or MSFC-SPEC-766, Specification: Fusion Welding Titanium and Titanium Alloys.

5.4.4.6 Low Stress Welds and Structures -- Weldments meeting all conditions below are suitable for reduced qualification and inspection before flight:

1) Not listed as criticality 1 on the Critical Items List
2) Having no site on the weld above 4,000 psi uniaxial stress;
3) Made from materials with KQ FTY > 0.5 in .5 at the design thickness;
4) Using a process specification and procedure specified in the contractor Materials Control Plan.

American Welding Society (AWS) code requirements, AWS welder certification, and AWS Weld Process Specifications (WPS) may be used for low stress welds in place of the applicable JSC process specification and MSFC-SPEC-504. Pressure testing is an acceptable alternate to penetrant and radiographic tests for these low stress welds. Partial penetration butt and corner welds are acceptable for design. Low stress welds shall be identified on drawings.

5.4.5 BRAZING

Brazing shall be conducted in accordance with AWS C-3.3, Design, Manufacture, and Inspection of Critical Brazed Components, Recommended Practices for. Brazing of aluminum alloys shall meet the requirements of AWS C-3.7, Aluminum Brazing. Torch, induction, and furnace brazing shall meet the requirements of AWS C-3.4, AWS C-3.5 and AWS C-3.6, respectively. Subsequent fusion-welding operations in the vicinity of brazed joints or other operations involving high temperatures that might affect the brazed joint shall be prohibited unless it can be demonstrated that the fixturing, processes, methods, and/or procedures employed will preclude degradation of the braze joint. Brazed joints shall be designed for shear loading and shall not be relied upon for strength in tension for structural parts.

5.4.6 STRUCTURAL SOLDERING

Soldering shall not be used for structural applications.

5.4.7 ELECTRICAL DISCHARGE MACHINING

The electrical discharge machining (EDM) process shall be controlled to limit the depth of the oxide layer, the recast layer, and the heat-affected zone. The EDM oxide layer, when present, shall be removed from the surface. In addition, the recast layer and the heat-affected zone shall be removed from bearing, wear, fatigue or fracture critical surfaces, and from crack or notch sensitive materials. The recast layer and heat-affected zone may be left on a part if an engineering evaluation shows that they are not of consequence to the required performance of the part. EDM schedules shall be qualified to determine the maximum thickness of the EDM layers when the depth of EDM-affected material must be known for removal or analysis."

5.4.8 PRECISION CLEAN HARDWARE

Precision clean hardware shall be cleaned and packaged in accordance with JPG 5322.1. The following additional requirements apply to ensure such hardware is maintained clean during assembly and operation.

5.4.8.1 Assembly, Cleaning, Flushing, and Testing Fluids --The assembly, cleaning, flushing, and testing fluid surface cleanliness requirement is the same as the surface cleanliness level required by the operational system this fluid is to be used within. Residual cleaning, flushing, and testing fluids shall be removed prior to charging with the operating fluid (removal by flushing with the operating fluid is permitted when appropriate). Positive verification is required only when specified.

5.4.8.2 Personnel Training -- A certification-training course shall be established and required for anyone working around precision-cleaned hardware. The focus of the course shall be on awareness, and shall require a minimum 1-hour of instruction time. As a minimum, the course content shall include definition of precision cleanliness, problems that have occurred with precision-cleaned hardware, the best practices for maintaining cleanliness, and specific controls identified at the site where work will be performed.

5.4.8.3 Welding Precision-Cleaned Hardware (Including Tube Preparation) -- Whenever precision-cleaned hardware must be maintained clean during welding into an assembly, the welding operation shall be performed in a dedicated Class 100,000 Clean Work Area (CWA). This may require temporary tents over the weld area and/or local monitors located in the area of welding to ensure the Class 100,000 environment is being met. Portable particle counters shall be located as close as possible to the work area, so as to monitor local contaminants during tube preparation and welding. Tools used in weld preparation and welding (such as cutter, weld head, files) shall be visibly cleaned per JPG 5322.1 and maintained clean (e.g. bagged when not in use).

For hardware that cannot be subsequently precision-cleaned, a proven method for protecting against system contamination during tube preparation shall be implemented. One such method is the use of a physical barrier, such as plugs. The installation and removal of plugs shall be tracked by a reliable method and independently verified. Prior to plug removal the exposed internal surfaces of the tube shall be cleaned using a swab wetted with an approved solvent, and positive backpressure shall be maintained as the plug is removed.

Tube cutters shall use a sharp blade, changed frequently. Cutting shall be performed with minimal cutter pressure to aid in preventing particle generation. Vacuum shall be used during tube facing operations to remove particulate. Whenever possible, facing operations shall be performed away from the weld assembly area, to reduce particulate contamination of the welding work area. Tube facing shall be performed without the use of cutting oils, other fluids, lubricants or coolants. Abrasives, including sandpaper or abrasive pads, shall not be used inside tubes or when unprotected internal surfaces are exposed. After each tube preparation, and prior to welding, a high-velocity gas purge shall be performed. The purge gas velocity shall be the maximum attainable using a 90-psig source. Purge gas used during facing and welding shall meet the hydrocarbon, moisture, and particulate controls of the applicable welding specification or for the system under assembly (whichever is the more stringent). The purge gas shall be supplied through precision-cleaned low-nonvolatile residue (NVR)/particulate tubing such as polyethylene, nylon, Teflon, or ethyl vinyl acetate. Standard grade Tygon is not acceptable for use.

When welding O2 systems, regulators used during purging operations shall have O2 compatible grease, purge tubing shall be verified to be O2 compatible, and bagging materials used to store O2 tubes, hoses, components and welded assemblies shall be cleaned to the same level of cleanliness as the O2 hardware and verified to be O2 compatible.

5.4.8.4 Ground Support Equipment (GSE) Interfaces -- GSE supply interface final filters interfacing with precision-cleaned flight fluid systems shall be located as close to the flight hardware interface as possible. Interface filters are required on outlet lines if it is determined that some operations, such as servicing or deservicing fluids, could permit flow in a reverse direction. Interfacing GSE shall be cleaned to at least the cleanliness level of the flight hardware. GSE fluid hardware (such as hoses, servicing units) shall be handled with the same cleanliness procedures as flight hardware.

5.4.8.5 Convoluted Flex Hoses -- Convoluted metal flex hoses shall receive special attention to cleaning. All detail flex hoses shall be verified as precision-clean in a vertical orientation. For flex hose tube diameters equal to or greater than one inch, verification of precision cleanliness shall be performed by sampling a rinse fluid applied internally through use of a high-pressure nozzle to the entire length of the flex hose. For flex hose tube diameters less than one inch, the use of a high-pressure nozzle is preferred, but verification may be performed by flushing a rinse fluid through the entire length of the flex hose with flex hose agitation. Precision cleaning shall be considered successful when the verification rinse fluid indicates compliance with the flex hose engineering drawing cleanliness requirement.

5.4.8.6 Maintaining System Cleanliness -- Hardware (including GSE) that has not been precision-cleaned shall not be brought into the vicinity of precision-cleaned flight hardware (for fit checks etc.) without protection to the flight hardware (i.e., wrapped in approved packaging material).

Clean room bags shall always be used to transport cleaned hardware (including GSE), even short distances when outside of the clean room environment. Precision-cleaned hardware shall be exposed only in a particulate controlled environment, including the use of flow benches providing a Class 100,000 CWA or better, when conducting hardware inspections. Clean room gloves shall be used during all handling of precision-cleaned flight hardware and GSE. Any inspection tools that are to be exposed to precision-cleaned fluid systems hardware (borescopes, etc.) shall be visibly cleaned and maintained clean. Solvents used for such cleaning shall be filtered to 10 microns or better prior to use.

All precision cleaned open tubes and lines must be protected, i.e. wrapped or bagged with approved materials, as soon as possible after fabrication, until final installation. All precision-cleaned fluid systems configured for flight shall have integrity seals installed. Precision cleaned hardware that has been welded shall remain capped (non-particle generating caps, or wrapped and taped) at the ends during x-ray operations to avoid potential contamination of hardware.

5.4.8.7 Sampling For Residual Solvents Incompatible With Fluid Systems -- When isopropyl alcohol (IPA) is used for cleaning, flushing, or testing of gaseous oxygen systems, the residual concentration of IPA solvent must be verified as within acceptable limits prior to the introduction of flight fluids. After purging with an inert gas, a 24 hour "lock-up" of the component or assembly is required to assure that enough time is provided for contaminant solvent to volatilize, thus achieving concentration equilibrium so that gas sampling will provide an accurate reflection of the residual solvent concentration. The solvent concentration in "lock-up" gas samples shall not exceed 18 ppm when measured as methane.

When water is used for cleaning, flushing, or testing of systems that use ammonia (NH3) as the operating fluid, the residual concentration of water must be verified as within acceptable limits prior to the introduction of flight fluids. After purging with a dry gas, a 24 hour "lock-up" of the component or assembly is required to assure that enough time is provided for contaminant water to volatilize, thus achieving concentration equilibrium so that gas sampling will provide an accurate reflection of the residual water concentration. The water concentration in "lock-up" gas samples shall not exceed a dew point of –50 °C (-58 °F).

5.5 MATERIAL NONDESTRUCTIVE INSPECTION

5.5.1 NDE PLAN

The Nondestructive Evaluation (NDE) activities associated with aerospace hardware shall meet the intent of MIL-HDBK-6870, Inspection Program Requirements, Nondestructive for Aircraft and Missile Materials and Parts.

5.5.2 NDE ETCHING

All fracture critical parts shall be NDE etched prior to dye penetrant inspection unless otherwise specified by the Materials and Processes Branch.

Note: All machined or otherwise mechanically disturbed surfaces which are to be penetrant inspected must be adequately etched to assure removal of smeared, masking material prior to penetrant application on fracture critical parts.

5.6 SPECIAL MATERIALS REQUIREMENTS

5.6.1 RESIDUAL STRESSES

Residual tensile stresses are induced into manufactured parts as a result of forging, machining, heat-treating, welding, or special metal-removal processes. Residual stresses shall be controlled or minimized during the fabrication sequence by special treatments such as annealing and stress relieving. These stresses may be harmful in structural applications when the part is subjected to fatigue loading, operation stresses, or corrosive environments. Therefore, every available effort shall be made to eliminate or minimize residual tensile stresses from finished structural parts.

5.6.2 SANDWICH ASSEMBLIES

Sandwich assemblies shall be designed to prevent the entrance and entrapment of water vapor or other contaminants into the core structure. Honeycomb sandwich assemblies that will be subjected to heating shall use a metallic or glass reinforced core to minimize the absorption of moisture. Sandwich assemblies can utilize perforated and moisture-absorbing cores provided they are protected during assembly and pre-launch activities. Test methods for sandwich constructions and core materials shall meet the requirements of SAE-AMS-STD-401 , Sandwich Constructions and Core Materials; General Test Methods.

5.6.3 STRESS CORROSION CRACKING

MSFC-STD-3029, Guidelines for Selection of Metallic Materials for Stress-Corrosion-Cracking Resistance in Sodium Chloride Environments (formerly MSFC-SPEC-522, Design Criteria For Controlling Stress Corrosion Cracking) shall be used to select metallic materials to control stress corrosion cracking.

5.6.4 CORROSION PREVENTION AND CONTROL

All parts, assemblies, and equipment, including spares, shall be finished to provide protection from corrosion in accordance with the requirements of MSFC-SPEC-250, Protective Finishes

For Space Vehicle Structures and Associated Flight Equipment, General Specification for. Corrosion evaluation shall show the possible effects of fluid release resulting from the failure or permeation of barriers. Corrosion control of galvanic couples shall be in accordance with MIL-STD-889, Dissimilar Metals. For hardware in the mild corrosive environment of standard habitable spacecraft volumes, the following changes may be made:

- The requirements of MIL-STD-889 may be relaxed with corrosion resistant aluminum alloys.

- Exposed aluminum surfaces may have anodic coatings instead of organic coatings specified in MSFC-SPEC-250.

- Conversion coatings may be used as the sole corrosion protection for 5000 and 6000 series corrosion resistant aluminum alloys. They not acceptable as the sole corrosion protection for 2000 and 7000 series aluminum alloys.

5.6.4.1 Steel -- Where exposed to atmosphere or corrosive environments, all parts, including fasteners made from low alloy, high strength steels, shall be suitably protected. Where plating is used, it shall be applied by a process that has been proven to be non-embrittling to the high strength steel and shall be compatible with the space environment.

5.6.4.2 Sealing -- All mechanical joints and seams located in exterior or internal corrosive environments, including structures under fairings, shall be faying-surface sealed. Sealants used shall be covered by a published specification and shall have acceptable ratings. Sealants not covered by a published specification or without acceptable ratings shall be subject to review and approval by the JSC Materials & Processes Branch. Removable panels and access doors in exterior or interior corrosive environments shall be sealed either by mechanical seals or by separable, faying-surface sealing.

5.6.5 FASTENER INSTALLATION

Self-locking fastener reuse shall be allowed when the running torque prior to clamp up remains between the maximum self-locking torque and the minimum breakaway torque. Wet installation of fasteners is not required except in applications where condensation or aqueous corrosive environments exist. The installation of titanium fasteners and associated parts shall meet the requirements of MSFC-STD-557, Threaded Fasteners, 6Al-4V Titanium Alloy, Usage Criteria for Spacecraft Applications.

5.6.5.1 Locking Requirements for Fasteners Used in Safety Critical Applications -- Each bolt, screw, nut, pin, or other fastener used in a safety critical application shall incorporate two separate verifiable locking features. Preload may be used as one of the features combined with a conventional aerospace secondary locking feature that is positive locking and vibration rated. Joints that are subject to rotation in operation shall use at least one non-friction locking device. Other retention methods, including non-positive and non-verifiable locking techniques such as liquid locking compounds, shall not be used without approval from the JSC Materials and Processes Branch. Installation procedures shall require functional verification of locking features, such as measurement of running (self-locking) torque or visual inspection of lock wire integrity. Preload torques and running torques shall be specified on the drawings.

5.6.5.2 Silver-Plated Fasteners – Silver reacts rapidly with atomic oxygen to generate a loose, friable, black oxide that can cause contamination and affect the operation of mechanisms. Silver-plated fasteners shall not be used in external applications where the silver plating is directly exposed to atomic oxygen.

5.7 MATERIALS AND PROCESSES FOR ELECTRICAL COMPONENTS

5.7.1 ELECTRICAL BONDING AND GROUNDING

Parts and materials used in electrical bonding and grounding shall meet the requirements of this document.

5.7.2 USE OF SILVER

Silver is prohibited as a plating on printed wiring boards, terminal boards and bus bars.

5.7.3 WIRE/CABLE ASSEMBLIES

The following shall be assembled or installed to meet the requirements of PRC-7003, Electrical Cables, Wiring, and Harnesses, or NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring.

1. Electrical connectors,
2. Interconnecting cables, harness, and wiring
3. Solders Sleeves.

5.7.4 FIBER OPTICS

Fabrication controls and processes for joining of fiber optic cable assemblies shall comply with NASA-STD-8739.5, Fiber Optic Terminations, Cable Assemblies, and Installation with the exception that process controls may be used in lieu of inspection under magnification.

5.7.5 PRINTED WIRING BOARDS

Printed wiring boards shall be designed in accordance with IPC-2221, Generic Standard on Printed Board Design and IPC-2222, Sectional Design Standard for Rigid Organic Printed Boards. Fabrication controls and processes used in rigid printed wiring boards shall meet the requirements of PRC-7005, Printed Circuit Boards and Assemblies, or IPC-6011, Generic Performance Specification for Printed Boards, and IPC-6012, Quality and Performance Specification for Rigid Printed Boards. The supplemental information in GSFC Supplement S-312-P003, Process Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses, should also be considered

5.7.6 PRINTED WIRING ASSEMBLIES

Electrical circuitry shall be designed and fabricated to prevent the production of unwanted current paths by debris or foreign materials floating in the spacecraft microgravity environment.

5.7.6.1 Staking/Conformal Coating -- Fabrication controls and processes used in staking and conformal coating of printed wiring boards and electronic assemblies shall meet the requirements of PRC-7002, Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies, or NASA-STD-8739.1, Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Assemblies

5.7.6.2 Other Processes -- Other processes used for printed wiring assemblies shall meet the requirements in IPC EIA-J-STD-001C, Requirements for Soldered Electrical and Electronic Assemblies, and PRC-7002, Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies, or NASA-STD-8739.1, Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Assemblies. Component mounting shall be consistent with IPC-CM-770D, Component Mounting Guidelines For Printed Boards.

5.7.7 ETCHING FLUOROCARBONS

The etching of fluorocarbons shall meet the requirements of SAE-AMS 2491, Surface Treatment, Polytetrafluoroethylene, Preparation for Bonding.

5.7.8 ELECTRICAL SOLDERING

Fabrication controls and processes used in soldering of electrical connections shall meet the requirements of PRC-7001, Soldering of Electrical Components; NASA-STD-8739.3, Soldered Electrical Connections; or IPC EIA-J-STD-001C, Requirements for Soldered Electrical and Electronic Assemblies. Surface mount devices shall be soldered according to the requirements of NASA-STD-8739.2, Workmanship Standard for Surface Mount Technology, or IPC EIA-J-STD-001C .

5.7.9 ELECTRICAL CRIMPING

Crimping of electrical terminations shall meet the requirements of NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring. However, terminal lugs, splices, and two-piece shield termination rings shall meet the tensile strength and electrical requirements of SAE-AS7928.

5.7.10 ELECTRICAL WIRE WRAPPED CONNECTIONS

Wire wrapping shall meet the requirements of NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring. Wire wrapping shall not be used, except for in Ground Support Equipment.

5.7.11 ELECTROSTATIC DISCHARGE CONTROL

Electrostatic discharge sensitive parts, assemblies, and equipment shall be controlled in accordance with the requirements of NASA-STD-8739.7, Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices).

6.0 TECHNICAL IMPLEMENTATION OF JPG 8080.5 M&P REQUIREMENTS FOR GFE (DESIGN PRACTICES)

The M&P requirements in JPG 8080.5 are superseded by this plan and are implemented by compliance with this plan.

7.0 REVIEWS

The JSC Materials & Processes Branch shall be notified of the program requirements review (PRR), preliminary design review (PDR), critical design review (CDR), and flight readiness review (FRR) for all JSC GFE hardware. M&P representatives will participate in these reviews, and any other reviews containing M&P issues on request. All pertinent documents and data shall be presented before or in the design reviews, including engineering drawings, drawing trees, MIULs, MUAs, and M&P specifications.

APPENDIX A ABBREVIATIONS AND ACRONYMS

ASTM	American Society for Testing and Materials
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CDR	Critical Design Review
CIL	Critical Items List
CP	Commercially Pure
CVCM	Collected Volatile Condensable Materials
DR	Data Requirement
EDM	Electrical Discharge Machining
EPA	Environmental Protection Agency
ETFE	Ethylene Tetrafluoroethylene
GOX	Gaseous Oxygen
GSE	Ground Support Equipment
HDBK	Handbook
IP	International Partner
JSC	Johnson Space Center
kPa	Kilopascals
ksi	Kilopounds per Square Inch
LOX	Liquid Oxygen
M&P	Materials and Processes
MCP	Materials Control Plan
MCR	Materials Control Requirement
MIL	Military
MIUL	Material Identification Usage List
mm	Millimeter
MRB	Materials Review Board
MSFC	Marshall Space Flight Center
MUA	Material Usage Agreement

NASA	National Aeronautics and Space Administration
NDE	Nondestructive Evaluation
NDI	Nondestructive Inspection
NDT	Nondestructive Test
NHB	NASA Handbook
NSTS	National Space Transportation System
OSF	Office of Space Flight
OSHA	Occupational Safety and Health Administration
PDR	Preliminary Design Review
PG	Product Group
psia	Pounds per Square Inch Absolute
PTFE	Polytetrafluoroethylene
RTV	Room Temperature Vulcanizing (rubber)
SE	Support Equipment
SMAC	Spacecraft Maximum Allowable Concentration
SPEC	Specification
SSQ	Space Station Quality
STD	Standard
TBS	To Be Specified
TML	Total Mass Loss
UTS	Ultimate Tensile Strength
UV	Ultraviolet

APPENDIX B DEFINITIONS

Corrosive Environment - Solid, liquid, or gaseous environment that deteriorates the materials by reaction with the environment. Cleanrooms and vacuum are normally considered noncorrosive.

Primary structure - Principle or main structure that sustains the significant applied loads or provides main load paths for distributing reactions to applied loads and which if it fails creates a catastrophic hazard.

Safety critical hardware - Hardware that, if it fails, creates a catastrophic hazard.

Structural - Primary load bearing structure.

Structural adhesive bond - Structural joint using adhesive bonds for the purpose of transferring structural load between structures.

Structure - All components and assemblies designed to sustain loads or pressures, provide stiffness and stability, or support or containment.

APPENDIX C

JSC MATERIALS AND FRACTURE CONTROL CERTIFICATION FORM

JSC MATERIALS AND FRACTURE CONTROL CERTIFICATION

PROJECT/SUBSYSTEM MANAGER:	REF: MATL - -
HARDWARE NAME:	PART NUMBER:

APPLICABLE REQUIREMENTS:

Materials Requirements:

- ☐ NSTS 1700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System
- ☐ SE-R-0006D, Space Shuttle System Requirements for Materials and Processes
- ☐ SSP 30233F, Space Station Requirements for Materials and Processes
- ☐ JSC 27301C, Materials Control Plan for JSC Flight Hardware
- ☐ Other:

Fracture Control Requirements:

- ☐ NASA-STD-5003, Fracture Control Requirements for Payloads Using the Space Shuttle
- ☐ SSP 3055 C, Fracture Control Requirements for Space Station
- ☐ SSP 52005B, ISS Payload Flight Equipment Requirements and Guidelines for Safety-Critical Structures

- ☐ Flammability
- ☐ Toxicity
- ☐ Stress Corrosion Cracking
- ☐ Fracture Control
- ☐ Aging
- ☐ Atomic Oxygen/Ultraviolet
- ☐ Thermal Vacuum Stability
- ☐ Fluid Compatibility:
- ☐ Microbiological Resistance
- ☐ Other:

LOCATION:

- ☐ Orbiter Crew Cabin
- ☐ Spacehab
- ☐ Orbiter Payload Bay
- ☐ Soyuz
- ☐ Progress
- ☐ MPLM
- ☐ Space Station: ☐ Internal ☐ External
- ☐ Other:

MATERIALS USAGE AGREEMENTS (MUA's):

- ☐ No MUA's
- ☐ MUA

Deviation:

LIMITATIONS: ☐ No Limitations

- ☐ Materials:
- ☐ Fracture Control:

This material certification is consistent with any existing Materials and Processes and Fracture Control Intercenter Agreements with MSFC, GSFC, JPL, and LeRC.

APPROVALS

Fracture Control Manager	Date	GFE Materials Control Manager	Date

APPENDIX D

JSC MATERIALS USAGE AGREEMENT FORM

and

JSC VOLATILE USAGE AGREEMENT FORM

JSC MATERIALS USAGE AGREEMENT	MUA NUMBER	REV.	PAGE 1 OF
	USER MUA NUMBER		

TITLE:	CATEGORY:	EFFECTIVITY:

TYPE OF DEVIATION:	REQUIREMENT DEVIATED:		
☐ MATERIAL ☐ EQUIPMENT	☐ FLAMMABILITY	☐ TVS	☐ SCC
(NO. PER VEHICLE:)	☐ OFFGASSING	☐ O_2 COMPATIBILITY	☐ OTHER

EQUIPMENT	PART NUMBER	MANUFACTURER

MATERIAL	TRADE NAME	SPECIFICATION	MANUFACTURER

THICK (in.)	WEIGHT (lbs.)	AREA (in^2)	LOCATION	ENVIRONMENT		
				TEMPERATURE (°F)	PRESS (PSIA)	MEDIA
			☐ HABITABLE ☐ NONHABITABLE			

APPLICATION (use second sheet if required)

RATIONALE (use second sheet if required)

APPROVALS

ORIGINATOR/ORGANIZATION	DATE	JSC MATERIALS AND PROCESSES TECHNOLOGY BRANCH	DATE
PROJECT MANAGER	DATE	PROGRAM MANAGER	DATE

VOLATILE ORGANIC COMPOUND USAGE AGREEMENT	USAGE AGREEMENT NO.	REV.	PAGE 1 OF

TITLE:	CATEGORY:	EFFECTIVITY:

EQUIPMENT	PART NUMBER	MANUFACTURER

MATERIAL	TRADE NAME	SPECIFICATION	MANUFACTURER

VOC(s) RELEASED	VOC WEIGHT	VOC RELEASE RATE (MG/DAY)

APPLICATION (use second sheet if required)

RATIONALE (use second sheet if required)

APPROVALS			
ORIGINATOR/ORGANI ATION	DATE	JSC MATERIALS AND PROCESSES BRANCH	DATE
PROJECT MANAGER	DATE	ECLSS AIT (Category 1 only)	DATE
CONTROL BOARD (Category 1 only)	DATE	ALCOHOL MANAGER (Category 1 only)	DATE

APPENDIX E

CATEGORY III MUA RATIONALE CODES

FLAMMABILITY RATIONALE CODES

CODE	RATIONALE
101	APPROVED MATERIALS USAGE AGREEMENT (MUA) CATEGORY I.
102	APPROVED MATERIALS USAGE AGREEMENT (MUA) CATEGORY II.
103	MATERIALS PASSED REQUIREMENTS WHEN TESTED IN CONFIGURATION.
104	UNEXPOSED, OVERCOATED OR SANDWICHED BETWEEN NON-FLAMMABLE MATERIAL AND NO IGNITION SOURCE OR PROPAGATION PATH.
105	MINOR USAGE (LESS THAN 0.1 LB. AND 2 SQ-IN SURFACE AREA); NO PROPAGATION PATH OR IGNITION SOURCE.
106	MATERIAL IS USED IN HERMETICALLY SEALED CONTAINER.
107	PASSES TEST NO. 8 OF NHB 8060.1, FLAMMABILITY TEST FOR MATERIALS IN VENTED CONTAINERS, BY TEST OR ANALYSIS.
108	OFF THE SHELF EQUIPMENT HAVING MATERIAL ACCEPTABLE IN CONFIGURATION; NO IGNITION SOURCE OR PROPAGATION PATH.
109	MATERIAL NOT EXPOSED; TOTALLY IMMERSED IN FLUID; EVALUATED FOR FLUID COMPATIBILITY ONLY.
110	MATERIAL IS ACCEPTABLE WHEN USED ON A METAL SUBSTRATE THAT PROVIDES A GOOD HEAT SINK. MATERIAL CONSIDERED NONCOMBUSTIBLE IN THIS CONFIGURATION BY TEST OR ANALYSIS.
111	MATERIAL NOT MAPTIS A-RATED FOR FLAM IS SANDWICHED BETWEEN NON-FLAMMABLE MATERIALS WITH EDGES ONLY EXPOSED AND IS MORE THAN 2 IN. FROM AN IGNITION SOURCE OR MORE THAN 12 IN. FROM OTHER MATERIALS NOT A-RATED.
112	MATERIAL NOT MAPTIS A-RATED FOR FLAM IS UNEXPOSED OR IS OVERCOATED WITH A NON-FLAMMABLE MATERIAL.
113	MATERIAL(NOT MORE THAN 0.010 IN. THICKNESS) NOT MAPTIS A-RATED FOR FLAM IS SPRAYED OR BONDED TO A METALLIC SURFACE >0.062 IN. THICK
114	MATERIAL NOT MAPTIS A-RATED FOR FLAM IS USED IN "SMALL AMOUNTS" AND IS MORE THAN 2 IN. FROM AN IGNITION SOURCE OR MORE THAN 12 IN. FROM OTHER MATERIALS NOT A-RATED FOR FLAM. "SMALL AMOUNTS" FOR FLAM MAY BE QUANTIFIED AS FOLLOWS: TOTAL WEIGHT ≤0.1 LB. AND ≤2.0 SQ. IN. SURFACE AREA.

TOXICITY (OFFGASSING) RATIONALE CODES

CODE	RATIONALE
201	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY I.
202	MEETS TOX REQUIREMENTS WITH PERFORMED CURE.
203	T VALUE FOR MATERIAL/COMPONENT IN USAGE WEIGHT IS LESS THAN 0.5 IN EACH 118 CUBIC METER VOLUME.
204	MATERIALS USAGE IN HERMETICALLY SEALED CONTAINER

FLUID SYSTEM COMPATIBILITY RATIONALE CODES

CODE	RATIONALE
301	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY I.
302	PASSES REQUIREMENTS IN CONFIGURATION.
303	MAPTIS "B" RATED MATERIAL PASSED BATCH LOT TEST.
304	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY II.

THERMAL VACUUM STABILITY RATIONALE CODES

CODE	RATIONALE
401	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY I.
402	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY II.
403	MAPTIS "C" RATED MATERIAL; EXPOSED AREA IS NOT MORE THAN 2 SQ-IN. AND NOT NEAR A CRITICAL SURFACE.
404	MAPTIS "X" RATED MATERIAL; EXPOSED AREA IS LESS THAN 1/4 SQ-IN.
405	UNEXPOSED, OVERCOATED OR ENCAPSULATED WITH APPROVED MATERIAL.
406	MAPTIS "B" RATED MATERIAL CURED TO MEET THE REQUIREMENTS OF A MAPTIS "A" RATING.
407	MEETS TVS REQUIREMENTS IN CONFIGURATION.
408	MATERIALS USAGE IN HERMETICALLY SEALED CONTAINER
409	MATERIAL NOT A-RATED FOR TVS IS ENCLOSED IN A SEALED CONTAINER (I.E., DESIGNED WITH A LEAKAGE RATE OF ≤0.0001 STANDARD CC/SEC. WITH ATMOSPHERE PRESSURE DIFFERENTIAL - REF. MSFC-PROC-1301, SECTION 1.3)

STRESS CORROSION CRACKING RATIONALE CODES

CODE	RATIONALE
501	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY I.
502	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY II.
503	MAXIMUM TENSILE STRESS LESS THAN 50% OF YEILD STRENGTH FOR PART ON ELECTRICAL/ELECTRONIC ASSEMBLIES.
504	MARTENSITIC OR PH STAINLESS STEELS USED IN BALL BEARING, RACE OR OTHER APPLICATIONS WHERE THE PRIMARY LOADING IS COMPRESSIVE AND/OR SHEAR.
505	METAL NOT MAPTIS A-RATED FOR SCC IS NOT EXPOSED TO A CORROSIVE ENVIRONMENT AFTER FINAL ASSEMBLY THROUGH TO END ITEM USE.
506	CARBON & LOW ALLOY HIGH STRENGTH STEELS GREATER THAN 180 KSI USED IN BALL BEARINGS, SPRINGS, OR SIMILAR APPLICATIONS WHERE PRIMARY LOADING IS COMPRESSIVE, LOW TENSILE STRESSES, OR HISTORY OF SATISFACTORY PERFORMANCE.

CORROSION RATIONALE CODES

CODE	RATIONALE
601	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY I.
602	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY II.
603	ADEQUATELY FINISHED FOR CORROSION PROTECTION.
604	ACCEPTABLE IN USE ENVIRONMENT
606	ELECTRICAL GROUNDING REQUIRED, CLADDING PLUS CONVERSION COATING ADEQUATE.
607	THERMAL CONDUCTANCE AND ELECTRICAL BONDING REQUIREMENTS PRECLUDE PAINTING. CONVERSION COATING IS ADEQUATE (FOR ALUMINUM ONLY).
608	FINISHED ON A HIGHER ASSEMBLY.
609	LAMINATED SHIM-MINIMUM EXPOSURE OF CORROSION RESISTANT MATERIAL.
610	SURFACE OF A METAL NOT MAPTIS A-RATED FOR CORR IS TREATED OR COATED IN A MANNER WHICH MEETS OR EXCEEDS THE REQUIREMENTS OF MSFC-SPEC-250A. ACTUAL SURFACE TREATMENT SHALL BE LISTED.
611	METAL NOT MAPTIS A-RATED FOR CORR IS NOT EXPOSED TO A CORROSIVE ENVIRONMENT AFTER FINAL ASSEMBLY THROUGH TO END ITEM USE.
612	WELDING OF TITANIUM ALLOY-TO-ALLOY OR CP-TO-ALLOY USING CP FILLER METAL IN MIXED ALLOY WELDS WHERE HYDROGEN EMBRITTLEMENT IS NOT PREDICTED IN SERVICE.

GENERAL CODES

CODE	RATIONALE
701	MATERIAL RATINGS IN MAPTIS ARE USED FOR ACCEPTANCE IN PLACE OF MSFC-HDBK-527/JSC 09604. (DATE OF MAPTIS RATING USAGE TO BE DOCUMENTED).
702	GENERIC MATERIALS CONTROLLED BY MIL-SPEC OR INDUSTRY SPECIFICATION USING MAPTIS AVERAGES FOR RATINGS OR TEST RESULTS. MATERIAL CODES FOR GENERIC MATERIAL SHALL BE USED.
703	MIL-SPEC OR INDUSTRY SPEC ALLOWING SEVERAL MATERIAL OPTIONS WHERE ALL OPTIONS HAVE ACCEPTABLE RATINGS
704	MATERIALS CONTROLLED BY OTHER NASA SPECIFICATION ACCEPTED BY M&P

FLAMMABILITY STOWAGE RATIONALE CODES

CODE	RATIONALE
S01	MAXIMUM DIMENSION 10 INCHES, AND UNSTOWED LESS THAN 1 DAY/WEEK
S02	UNSTOWED LESS THAN 1 HOUR/DAY
S03	CONTINGENCY USE ONLY
S04	MAXIMUM DIMENSION LESS THAN 6 INCHES, AND ALWAYS STOWED WHEN NOT IN ACTUAL USE
S05	USED ONLY WHEN COVERED BY CREW CLOTHING
S06	EXPOSED SURFACE AREA LESS THAN 1 SQUARE FOOT, AND ALWAYS WORN BY CREW WHEN UNSTOWED.