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James Webb Space Telescope Project

Mission Assurance Requirements for the JWST Instruments

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Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

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JAMES WEBB SPACE TELESCOPE PROJECT

Mission Assurance Requirements
for the JWST Instruments

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DOCUMENT CHANGE RECORD Sheet: 1 of 1

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Basic	Released per JWST-CCR-000031	John Decker	4/11/2003
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WAIVERS AND DEVIATIONS RECORD

Waiver/Deviation #	CCR #	Date Approved	Section	Requirement	Description
JWST-DEV-000011	JWST-CCR-001676	11/2/2009	11.1	MAI-268	RFD for ETU decontamination heater derating deviation is applicable only to the the JWST Fine Guidance Sensor (FGS) Engineering Test Unit (ETU) being delivered to ISIM.
JWST-DEV-000012	JWST-CCR-001677	11/2/2009	11.1	MAI-268	RFD for ETU decontamination heater derating deviation is applicable only to the the JWST Fine Guidance Sensor (FGS) being delivered to ISIM.
JWST-WVR-000023	JWST-CCR-001776	3/24/2010	16.2	MAI-401	RFW Snaprings and Set Screws
JWST-WVR-000099	JWST-CCR-002188	2/14/2011	10.0 10.3.2.2	MAI-249 MAI-257	Waiver on the NIRCam Cernox Temperature Sensor Solder Joint Gold Content
JWST-WVR-000108	JWST-CCR-002252	5/4/2011	10.0	MAI-249	Solder slump and oxidation test

List of TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date

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1.0 OVERALL REQUIREMENTS

MAI-100 This document specifies the Mission Assurance Requirements (MAR) for the James Webb Space Telescope (JWST) instruments. JWST instrument partners include the European Space Agency (ESA), the Canadian Space Agency (CSA), the University of Arizona, and the Jet Propulsion Laboratory (JPL). All Instrument Providers will implement these requirements or equivalent requirements on the instruments they are providing to National Aeronautics and Space Administration (NASA). The Memorandum of Agreement (MOA) between Jet Propulsion Laboratory and GSFC (MOU-2002-520-203) will be implemented. ESA and CSA Instrument Providers may use their standard processes and procedures for spaceflight hardware and software but shall identify to NASA all processes and procedures that do not meet or exceed the requirements in this document.

MAI-101 The implementation of these requirements shall be documented in the providers' Performance/Quality Assurance Plan submitted to NASA (SA-01).

1.1 DESCRIPTION OF OVERALL REQUIREMENTS

The Instrument Provider is required to plan and implement an organized Systems Safety and Mission Assurance Program that encompasses:

1. All flight hardware, either designed/built/provided by the Instrument Provider or furnished by the Goddard Space Flight Center (GSFC), from project initiation through launch and mission operations.
2. The ground system that interfaces with flight equipment to the extent necessary to assure the integrity and safety of flight items.
3. All software critical for mission success.

MAI-102 The Performance/Quality Assurance Plan shall be submitted in accordance with Data Requirements Document (DRD SA-01).

MAI-103 Managers of the assurance activities shall have direct access to Instrument Provider management independent of project management, with the functional freedom and authority to interact with all other elements of the Project. Issues requiring project management attention shall be addressed with the Instrument Provider(s) through the Project Manager(s) and/or Contracting Officer's Technical Representative(s) (COTR) and/or Instrument Manager.

The Mission Assurance Program is applicable to the Project and its associated contractors.

1.2 USE OF MULTI-MISSION OR PREVIOUSLY DESIGNED, FABRICATED OR FLOWN HARDWARE

MAI-104 When hardware that was designed, fabricated, or flown on a previous project is considered to have demonstrated compliance with some or all of the requirements of this document such that certain tasks need not be repeated, the Instrument Provider shall demonstrate how the hardware complies with these requirements.

MAI-105 The Instrument Provider shall submit substantiating documentation in accordance with DRD SA-03.

1.3 SURVEILLANCE OF THE INSTRUMENT PROVIDER

The work activities, operations, and documentation performed by the Instrument Provider and/or his suppliers are subject to evaluation, review, audit, and inspection by government-designated representatives from GSFC, the Government Inspection Agency (GIA), or an independent assurance contractor (IAC). GSFC will delegate in-plant responsibilities and authority via a letter of delegation, or the GSFC contract with the IAC.

MAI-106 The Instrument Provider and/or suppliers shall grant access for NASA and/or NASA representatives to conduct an assessment/survey upon notice.

MAI-107 Resources shall be provided to assist with the assessment/ survey with minimal disruption to work activities.

MAI-108 The Instrument Provider, upon request, shall provide government assurance representatives with documents, records, and equipment required to perform their assurance and safety activities.

MAI-109 The Instrument Provider shall also provide the Government assurance representative(s) with an acceptable work area within Instrument Provider facilities.

1.4 APPLICABLE DOCUMENTS

To the extent referenced herein, the documents listed in Section 17 form a part of this document.

1.5 ACRONYMS AND ABBREVIATIONS AND DEFINITIONS

Appendix A defines acronyms and abbreviations and Appendix B defines the terms as applied in this document.

1.6 DATA REQUIREMENTS DOCUMENTS

Each instrument has its own applicable Data Requirements Document (DRD). The required DRDs for Mission Assurance are as listed in Section 17 of this document.

2.0 QUALITY MANAGEMENT SYSTEM

MAI-110 The Instrument Provider shall have a Quality Management System (QMS) that is compliant with the minimum requirements of paragraphs 4.10 through 4.14 and 4.17 of ANSI/ASQC Q9001-1994.

MAI-111 The Instrument Provider shall be compliant to ANSI/ASQC Q9001-2000 by December 2003. For accredited suppliers, certificates issued to ISO 9001:1994 will have a maximum validity of three (3) years from the publication date of ISO 9001:2000.

MAI-112 The Instrument Provider's Quality Assurance (QA) process shall be documented in their Systems Safety and Mission Assurance Plan (DRD-SA-01).

2.1 QUALITY ASSURANCE MANAGEMENT SYSTEM REQUIREMENTS AUGMENTATION

MAI-113 The following requirements augment identified portions of ANSI/ASQC Q9001-1994 and shall apply to the equivalent paragraphs of ANSI/ASQC Q9001-2000.

2.1.1 Augmentation to ANSI/ASQC Q9001-1994 Paragraph 4.13, Nonconformance Reporting

MAI-114 The Instrument Provider shall have a system for identifying and reporting hardware and software nonconformances through a closed loop reporting system; ensuring that positive corrective action is implemented to preclude recurrence and verification of the adequacy of implemented corrective action by audit and test as appropriate.

MAI-115 The system shall include a nonconformance review process and consisting of a Preliminary Review and a Material Review Board (MRB).

MAI-116 Nonconformances shall be reported in accordance with DRD SA-04.

2.1.1.1 Preliminary Review

The material review process shall be initiated with the identification and documentation of a nonconformance. A preliminary review shall be the initial step performed by Instrument Provider-appointed personnel to determine if the nonconformance is minor and can readily be processed using the following disposition actions:

a) scrapped, because the product is unusable for the intended purposes and cannot be economically reworked or repaired.

b) reworked (or retested), to result in a characteristic that completely conforms to the standards, procedures, or drawing requirements.

c) returned to supplier, for rework, repair or replacement.

d) repaired using a standard repair process previously approved by the MRB and /or Government QA organization.

e) referred to the MRB when the above actions do not apply to the nonconformance.

Note that Preliminary Review does not negate the requirement to identify, segregate, document, report and disposition nonconformances.

2.1.1.2 Material Review Board

MAI-119 Nonconformances not dispositioned by Preliminary Review shall be referred to the MRB for disposition. MRB dispositions will include: scrap, rework, return to supplier, repair by standard or non-standard repair procedures, use-as-is, or request for major waiver.

MAI-120 The MRB shall contain a core team with other disciplines brought in as necessary.

MAI-121 It shall be chaired by an Instrument Provider representative responsible for ensuring that the MRB actions are performed in compliance with this standard as implemented by Instrument Provider procedures.

MAI-122 The MRB shall consist of the appropriate functional and Project representatives that are needed to ensure timely determination, implementation and closeout of the recommended MRB disposition.

At Instrument Provider/supplier facilities, the NASA/Government representatives will participate in MRB activities as deemed appropriate by Government management.

MAI-123 The MRB process shall investigate, in a timely manner, each nonconforming item in sufficient depth to determine proper disposition.

MAI-124 For each reported nonconformance, there shall be an investigation and engineering analysis sufficient to determine cause and corrective actions for the nonconformance.

MAI-125 Written authorization shall be documented to disposition the nonconforming product.

2.1.1.3 Reporting of Nonconformances

MAI-126 Reporting of hardware and software nonconformances shall begin with the first power application at the start of end item acceptance testing or the first operation of a mechanical item; and continue through formal Government acceptance of the end item.

MAI-127 Nonconformances shall be reported in accordance with DRD SA-04.

2.1.2 Augmentation to ANSI/ASQC Q9001-1994 Paragraph 4.11, Calibration

MAI-128 Testing and Calibration Laboratories shall be compliant with the requirements of ISO 17025 – General Requirements for the Competence of Testing and Calibration Laboratories.

2.1.3 Augmentation to ANSI/ASQC Q9001-1994 Paragraph 4.6.3, Flow-Down

MAI-129 The Instrument Provider's QA program shall ensure the flow-down of all technical requirements to all major and critical suppliers and shall document and implement a process to verify compliance.

MAI-130 Specifically, contract review and purchasing processes shall indicate the process for documenting, communicating, and reviewing requirements with sub-tier suppliers to ensure requirements are met.

3.0 SYSTEM SAFETY

This section addresses the System Safety Requirements for the JWST instruments.

MAI-131 The System Safety Program shall be initiated in the concept phase of design and continue throughout all phases of the mission and GSFC will certify spacecraft safety compliance prior to the Mission Pre-Shipment Review (PSR).

MAI-132 The Instrument Provider's system safety program shall provide for the early identification and control of hazards to personnel, facilities, support equipment, and the instrument during all stages of Project development including design, fabrication, test, transportation and ground activities.

MAI-133 The program shall address hazards in the hardware, associated software, ground support equipment (GSE), operations, and support facilities, and conform to the safety review process requirements of NASA-STD-8719.8, "Expendable Launch Vehicle Payloads Safety Review Process Standard".

Top-level safety requirements documents for the JWST launch are:

1. NPR 8715.3, "NASA Safety Manual" which is the central Agency document containing procedures and guidelines that define the NASA Safety Program.

2. Ariane 5 User's Manual, March 2000 Edition, which contains the technical information necessary to assess compatibility of a spacecraft with the Ariane 5 launch vehicle, and the guidelines for preparation of all technical and operational documentation.

3. CSG-RS-10A-CN, "Centre Spatial Guyanais (CSG) Safety Regulations, Vol. 1: General Rules", which contains the rules to be applied on the Ariane Launch Base to protect persons, property, and the environment against potentially hazardous systems from the design stage through operations. It also defines the safety data submission requirements and format, and data submission schedule.

4. CSG-RS-21A-CN, "CSG Safety Regulations, Vol. 2 Pt. 1: Specific Rules: Ground Installations", which defines the principles and rules applicable to the design and operation of ground installations (actual ground installations and ground support equipment).

5. CSG-RS-22A-CN, "CSG Safety Regulations, Vol. 2 Pt. 2: Specific Rules: Spacecraft", which defines the principles and rules applicable to the design and operation of the spacecraft to be launched from the Ariane Launch Base.

6. ECSS-Q-40-02A, "European Cooperation for Space Standardization (ECSS) Space Product Assurance: Hazard Analysis", which defines the principles, process, implementation, and requirements of performing a hazard analysis.

7. ECSS-Q-40B, "ECSS Space Product Assurance: Safety", which defines the safety program and the technical safety requirements that are implemented in order to comply with the general ECSS safety policy. It is intended to protect flight and ground personnel, the launch

vehicle, associated payloads, ground support equipment, the general public, public and private property, and the environment from hazards associated with European space systems.

Additional references include:

1. EWR 127-1, "Eastern and Western Range Safety Requirements" which defines the Range Safety Program responsibilities and authorities and which delineates policies, processes, and approvals for all activities from the design concept through test, check-out, assembly, and the launch of launch vehicles and payloads to orbital insertion or impact from or onto the Eastern Range (ER) or the Western Range (WR). It also establishes minimum design, test, inspection, and data requirements for hazardous and safety critical launch vehicles, payloads, and GSE, systems, and materials for ER/WR users.

2. KHB 1710.2D, "Kennedy Space Center Safety Practices Handbook" which specifies and establishes safety policies and requirements essential during design, operation, and maintenance activities at the Kennedy Space Center (KSC) and other areas where KSC has jurisdiction.

3. GSFC document 5405-048-98, Mechanical Systems Center Safety Manual (as appropriate), which defines safety requirements for any testing performed at GSFC.

MAI-134 The Instrument Provider's system safety program shall meet the baseline industrial safety requirements of the institution, EWR 127-1, applicable Industry Standards to the extent practical to meet NASA and the Office of Safety and Health Administration (OSHA) design and operational needs, and any special contractually imposed mission unique obligations.

3.1 SYSTEM SAFETY PROGRAM PLAN

MAI-135 Each JWST Instrument Provider shall describe their safety program requirements and implementation procedures in either a stand-alone System Safety Plan or as a part of a Performance/Quality Assurance Plan.

MAI-136 The Instrument Provider shall describe in detail the tasks and activities of system safety management and engineering required to identify, evaluate, and eliminate hazards or control them to an acceptable risk level throughout the system life cycle.

MAI-137 GSFC Code 302 shall prepare a System Safety Program Plan (SSPP) specific to the Integrated Science Instrument Module (ISIM). The purpose of the SSPP is to provide a detailed description of the tasks and activities of safety management and safety engineering required to identify, evaluate, and eliminate or control hazards throughout the ISIM lifecycle. The SSPP provides the basis of understanding between the GSFC JWST Project Office, their contractors, and their customers as to how the safety effort will be accomplished to meet the technical and operational safety requirements for the JWST Program. The SSPP also delineates the safety plans and activities applicable to environmental testing at GSFC as well as the Glenn Research Center (GRC) Plum Brook Station. In addition, the SSPP provides overall guidance to the ISIM subcontractors and instrument manufacturers on the safety tasks, activities, and documentation required of them to support overall JWST System Safety Program. See Section 5.2.2 for software safety requirements.

3.2 PRELIMINARY HAZARD ANALYSIS

MAI-138 GSFC Code 302 shall perform a Preliminary Hazard Analysis (PHA).

MAI-139 Each JWST Instrument Provider shall provide inputs to support development of the PHA as requested. The PHA identifies safety concerns, provides an initial assessment of hazards, and identifies requisite hazard controls and follow-on actions. Based on the best available data, including mishap data from similar systems and other lessons learned, hazards associated with the proposed instrument design or function will be evaluated for hazard severity, hazard probability, and operational constraint. Safety provisions and alternatives needed to eliminate hazards or reduce their associated risk to an acceptable level will be included.

3.3 SAFETY ASSESSMENT REPORT

MAI-140 Each JWST Instrument Provider shall perform and document a Safety Assessment Report (SAR), SA-14, which is a comprehensive evaluation of the mishap risk of their instrument.

MAI-141 This safety assessment will identify all safety features of the hardware and software, and system design, as well as procedural, hardware and software related hazards present in the system. It shall include:

- Safety criteria and methodology used to classify and rank hazards
- Results of hazard analyses and tests used to identify hazards in the system
- Hazard reports documenting the results of the safety program efforts
- List of hazardous materials generated or used in the system
- Conclusion with a signed statement that all identified hazards have been eliminated or controlled to an acceptable level
- Recommendations applicable to hazards at the interface of their system to the ISIM and Observatory systems.

This report is used by the ISIM safety engineer to evaluate the safety of the ISIM design with instruments, and ultimately is used by the JWST prime contractor to prepare the Safety Data Package as defined in CSG-RS-10A-CN, “Centre Spatial Guyanais (CSG) Safety Regulations, Vol. 1: General Rules”for submittal to the Launch Range.

3.4 GROUND OPERATIONS PROCEDURES

MAI-142 Each JWST Instrument Provider shall submit to the GSFC Project Office all ground operations procedures to be used at GSFC facilities, other integration facilities, or the launch site.

MAI-143 All hazardous operations as well as the procedures to control them shall be identified and highlighted.

MAI-144 All launch site procedures shall comply with the launch site and NASA safety regulations.

3.5 SAFETY NONCOMPLIANCE REQUESTS

MAI-145 When a specific safety requirement cannot be met, the JWST Instrument Provider shall submit an associated safety noncompliance request (SA-15) to the GSFC Project Office that identifies the hazard and shows the rationale for approval of a noncompliance, as defined in the requirements of EWR 127-1.

3.6 SUPPORT FOR SAFETY WORKING GROUP MEETINGS

MAI-146 Each JWST Instrument Provider shall provide technical support to the Project for safety working group meetings, technical interchange meetings (TIMs), and technical reviews, when necessary.

3.7 ORBITAL DEBRIS ASSESSMENT SUPPORTING DATA

MAI-147 Each JWST Instrument Provider shall provide applicable instrument information, as required, to support the GSFC development of the Orbital Debris Assessment, consistent with NPD 8710.3, Policy for Limiting Orbital Debris Generation and NSS 1740.14, Guidelines and Assessment Procedures for Limiting Orbital Debris.

4.0 RELIABILITY REQUIREMENTS

MAI-148 This chapter addresses the Reliability Requirements that shall be part of the Mission Assurance program for the JWST Project.

4.1 GENERAL REQUIREMENTS

MAI-149 The Instrument Provider shall plan and implement a reliability program that interacts effectively with other project disciplines, including systems engineering, hardware design, software reliability, and performance assurance.

MAI-150 The reliability plan shall be documented in DRD SA-01.

MAI-151 The program shall be tailored according to the risk level to:

a. Use Probabilistic Risk Assessment (PRA) to assess, manage, and, if necessary, quantitatively assess the need to reduce program risk.

b. Demonstrate that redundant functions, including alternative paths and work-arounds, are independent to the extent practicable.

c. Demonstrate that the electrical, mechanical, optical, and cryogenic stress applied to parts is not excessive.

d. Identify single failure items/points, their effect on the attainment of mission objectives, and possible safety degradation.

e. Show that the reliability design aligns with mission design life and is consistent among the systems, subsystems, and components.

f. Identify limited-life items and ensure that special precautions are taken to conserve their useful life for on-orbit operations.

g. Select significant engineering parameters for the performance of trend analysis to identify performance trends during pre-launch activities.

h. Ensure that the design permits easy replacement of parts and components and redundant paths are easily monitored.

4.2 RELIABILITY ANALYSES

MAI-152 Reliability analyses shall be performed concurrently with design so that identified problem areas can be addressed and correction action taken (if required) in a timely manner.

4.2.1 Failure Modes and Effects Analysis and Critical Items List

MAI-153 A Failure Modes and Effects Analysis (FMEA) shall be performed early in the design phase to identify system design problems (see DRD SE-09).

MAI-154 As additional design information becomes available the FMEA shall be refined.

MAI-155 Failure modes shall be assessed at the component interface level.

MAI-156 Each failure mode shall be assessed for the effect at that level of analysis, the next higher level and upward. The failure mode is assigned a severity category based on the most severe effect caused by a failure.

MAI-157 Mission phases (e.g., launch, deployment, on-orbit operation, and retrieval) shall be addressed in the analysis.

MAI-158 Severity categories shall be determined in accordance with Table 4-1:

Table 4-1. Severity Categories

Category	Severity Definition
1	Catastrophic Failure modes that could result in serious injury, loss of life (flight or ground personnel), or loss of launch vehicle.
1R	Failure modes of identical or equivalent redundant hardware items that, if all failed, could result in category 1 effects.
1S	Failure in a safety or hazard monitoring system that could cause the system to fail to detect a hazardous condition or fail to operate during such condition and lead to Severity Category 1 consequences.
2	Critical Failure modes that could result in loss of one or more mission objectives as defined by the GSFC project office.
2R	Failure modes of identical or equivalent redundant hardware items that could result in Category 2 effects if all failed.
3	Significant Failure modes that could cause degradation to mission objectives.
4	Minor Failure modes that could result in insignificant or no loss to mission objectives

MAI-159 FMEA analysis procedures and documentation shall be performed in accordance with documented procedures.

MAI-160 Failure modes resulting in Severity Categories 1, 1R, 1S or 2 shall be analyzed at a greater depth, to the single parts if necessary, to identify the cause of failure.

MAI-161 Results of the FMEA shall be used to evaluate the design relative to requirements (e.g., no single instrument failure will prevent removal of power from the instrument).

MAI-162 Identified discrepancies shall be evaluated by management and design groups for assessment of the need for corrective action.

MAI-163 The FMEA shall analyze redundancies to ensure that redundant paths are isolated or protected such that any single failure that causes the loss of a functional path will not affect the other functional path(s) or the capability to switch operation to that redundant path.

MAI-164 All failure modes that are assigned to Severity Categories 1, 1R, 1S, and 2, shall be itemized and maintained in the FMEA including a rationale for retaining these items.

MAI-165 Results of the FMEA shall be presented at all design reviews starting with the PDR.

MAI-166 The presentations shall include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

4.2.2 Fault Tree Analysis

MAI-167 Fault tree analyses (FTA) shall be performed that address both mission failures and degraded modes of operation. Beginning with each undesired state (mission failure or degraded mission), the fault tree will be expanded to include all credible combinations of events/faults and environments that could lead to that undesired state.

MAI-168 Both component hardware/software failures, external hardware/software failures, human factors shall be considered in the analysis.

The fault tree in itself is not a quantitative model, but can be combined with quantitative data as part of the PRA (See Section 4.10).

4.2.3 Parts Stress Analyses

MAI-169 Each application of electrical, electronic, and electromechanical (EEE) parts, shall be subjected to stress analyses for conformance with the applicable derating guidelines (DRD SA-09).

MAI-170 The analyses shall be performed at the most stressful values that result from specified performance and environmental requirements (e.g., temperature and voltage) on the assembly or component.

MAI-171 The analyses shall be performed in close coordination with the packaging reviews and thermal analyses and they will be required input data for component-level design reviews.

MAI-172 The presentations shall include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

4.2.4 Worst-Case Analyses

MAI-173 Worst-Case Analyses shall be performed on circuits where failure results in a severity category of 2 or higher question the flightworthiness of the design (DRD SA-10).

MAI-174 The most sensitive design parameters, including those that are subject to variations that could degrade performance, shall be subjected to the analysis.

MAI-175 Analyses and/or test to ensure flightworthiness shall demonstrate the adequacy of design margins in the electronic circuits, optics, electromechanical, and mechanical items.

MAI-176 This analysis (when performed) shall be made available at the Instrument Provider's facilities for Government review and the results presented at all design reviews starting with the Preliminary Design Review (PDR).

MAI-177 The presentations shall include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

MAI-178 The analyses shall consider all parameters set at worst case limits and worst case environmental stresses for the parameter or operation being evaluated. Depending on mission parameters and parts selection methods, part parameter values for the analysis will typically include: manufacturing variability, variability due to temperature, aging effects of environment, and variability due to cumulative radiation.

MAI-179 The analyses shall be updated in keeping with design changes and updates made available to the Government upon request.

4.2.5 Reliability Assessments

MAI-180 When necessary or when agreed-upon with GSFC, the Instrument Provider shall perform comparative numerical reliability assessments to:

a. Evaluate alternative design concepts, redundancy and cross-strapping approaches, and part substitutions
b. Identify the elements of the design which are the greatest detractors of system reliability
c. Identify those potential mission limiting elements and components that will require special attention in part selection, testing, environmental isolation, and/or special operations
d. Assist in evaluating the ability of the design to achieve the mission life requirement and other reliability goals and requirements as applicable
e. Evaluate the impact of proposed engineering change and waiver requests on reliability
f. Performa Probability of Success calculation in accordance with MIL-HDBK-338B, Electronic Reliability Design Handbook, or equivalent.

MAI-181 The Instrument Provider shall specify in their Systems Safety and Mission Assurance Plan how reliability assessments will be integrated with the design process and other assurance practices to maximize the probability of meeting mission success criteria.

MAI-182 The Instrument Provider shall describe how the reliability assessments will incorporate definitions of failure as well as alternate and degraded operating modes that clearly describe plausible acceptable and unacceptable levels of performance.

MAI-183 Degraded operating modes shall include failure conditions that could be alleviated or reduced significantly through the implementation of work-arounds via telemetry.

MAI-184 The Instrument Provider shall further describe in their Systems Safety and Mission Assurance Plan the level of detail of a model suitable for performing the intended functions enumerated above and make available for Government review.

MAI-185 The results of any reliability assessment shall be reported at PDR and the Critical Design Review (CDR).

MAI-186 The presentations shall include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

4.3 ANALYSIS OF TEST DATA

MAI-187 The Instrument Provider shall fully utilize test information during the normal test program to assess flight equipment reliability performance and identify potential or existing problem areas.

4.3.1 Trend Analyses

MAI-188 As part of the routine system assessment, the Instrument Provider shall assess all subsystems and components to determine measurable parameters that relate to performance stability.

MAI-189 Selected parameters shall be monitored for trends starting at component acceptance testing and continuing during the system integration and test phases.

MAI-190 The monitoring shall be accomplished within the normal test framework; i.e., during functional tests, environmental tests, etc.

MAI-191 The Instrument Provider shall establish a system for recording and analyzing the parameters as well as any changes from the nominal even if the levels are within specified limits.

MAI-192 Trend analysis data shall be reviewed with the operational personnel prior to launch.

MAI-193 A list of subsystem and components to be assessed and the parameters to be monitored and the trend analysis reports shall be maintained. (DRD SA-05).

4.3.2 Analysis of Test Results

MAI-194 The Instrument Provider shall analyze test information, trend data, and failure investigations to evaluate reliability implications and identified problem areas documented and directed to the attention of Instrument Provider management for action.

MAI-195 The results of the analyses shall be presented at design reviews and the presentations include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

4.4 LIMITED-LIFE ITEMS

MAI-196 Limited-life items shall be identified and managed by means of a Limited-Life Items list that will be submitted for approval (DRD SA-06).

MAI-197 The list shall present definitions, the impact on mission parameters, responsibilities, and a list of limited-life items, including data elements: expected life, required life, duty cycle, and rationale for selection. The useful life period starts with fabrication and ends with the completion of the final orbital mission.

MAI-198 The list of limited-life items shall include selected structures, thermal control surfaces, solar arrays, and electromechanical mechanisms.

MAI-199 Atomic oxygen, solar radiation, shelf-life, extreme temperatures, thermal cycling, electric fields in the Earth's geo tail, space debris, wear and fatigue shall be used to identify limited-life thermal control surfaces and structure items.

MAI-200 Mechanisms such as batteries, compressors, seals, bearings, valves, tape recorders, momentum wheels, gyros, actuators, and scan devices shall be included when aging, wear, fatigue and lubricant degradation limit their life.

MAI-201 Records shall be maintained that allows evaluation of the cumulative stress (time and/or cycles) for limited-life items starting when useful life is initiated and indicating the project activity that will stress the items. The use of an item whose expected life is less than its mission design life must be approved by GSFC by means of a program waiver.

4.5 PROBABILISTIC RISK ASSESSMENT

MAI-202 A PRA Planning Document shall be prepared that defines the approach to performing a PRA.

MAI-203 A PRA shall be performed in accordance with the Risk Management Plan (DRD PM-23) that provides a comprehensive, systematic and integrated approach to identifying undesirable events, the scenarios leading to those events beginning with the initiating event or events, the frequency or likelihood of those events and their consequences.

MAI-204 The assessment shall be used to assist in identifying pivotal events that may protect against, aggravate or mitigate the resulting consequences.

MAI-205 The PRA shall be comprehensive and balanced, and shall consider, as appropriate, all relevant critical factors, including safety of the public, pilots, NASA workforce, adverse impacts on the environment, high value equipment and property, national interests, security, etc.

MAI-206 The PRA implementation procedures shall reflect and incorporate the results of project risk analysis, including identification of hazards, risks, and recommended controls to manage risk.

5.0 SOFTWARE ASSURANCE REQUIREMENTS

5.1 GENERAL

MAI-207 For the purposes of Section 5.0, all references to the Instrument Provider shall include the prime software contractor, as well as any subcontractor tasked in the development process.

MAI-208 The Instrument Provider's QMS shall address software development and software assurance functions for all flight and ground system software. The QMS applies to software and firmware developed under this contract, including Government off-the-shelf (GOTS) software, modified off-the-shelf (MOTS) software, and commercial off-the-shelf (COTS) software.

5.2 SOFTWARE ASSURANCE

MAI-209 The Software Assurance function shall include Software Quality Assurance (SQA), Software Safety, Software Reliability, Verification and Validation (V&V), and Independent Verification and Validation (IV&V).

5.2.1 Software Quality Assurance

MAI-210 The Instrument Provider shall identify a person responsible for SQA implementation.

MAI-211 The Instrument Provider shall prepare and document their Software Quality Assurance Planning approach, documenting the SQA roles and responsibilities, surveillance activities (i.e., process and product audits), supplier control, records collection, maintenance and retention, and risk management.

MAI-212 Product assurance activities shall consist of tasks to assure:

1. Standards and procedures for management, software engineering and software assurance activities are defined.
2. All plans (e.g., CM, risk management, software development plan, etc.) required by the contract are completed and comply with contractual requirements.
3. Standards, design, and code are evaluated for quality and security issues.
4. All software requirements are documented and traceable from system requirements to design and test (i.e., a software requirements traceability matrix).
5. Software requirement verification status is updated and maintained via a software requirements verification matrix.
6. Formal and acceptance-level software tests are witnessed.
7. Software products and related documentation (e.g., Version Description Documents and User Guides) have the required content and satisfy their contractual requirements.
8. Reports, schedules and records are reviewed.
9. Assure that all software changes and patches conform and have been tested to software requirements.

MAI-213 Process assurance activities shall consist of tasks to assure:

1. Management, software engineering, and assurance personnel comply with specified standards and procedures, consistent with the approved Instrument's Software Management Plan.
2. All plans (e.g., CM, risk management, software development plan, etc.) and procedures are implemented according to specified standards and procedures.
3. Contract requirements are passed down to any subcontractors, and that the subcontractor's software products satisfy the prime Instrument Provider's contractual requirements.
4. Peer reviews (e.g., code inspections) and management reviews are conducted and action items are tracked to closure.
5. A software problem reporting system and corrective action process is in place and provides the capability to document, search, and track software problems and anomalies.
6. The software is verified for compliance with quality requirements.
7. Metric data is collected and analyzed (e.g., analysis of open and closed software problem reports).

5.2.2 Software Safety

MAI-214 The Instrument Provider shall conduct a Software Safety program that is integrated with the overall software assurance and system safety program and is compliant with the software safety requirements of NASA-STD-8719.13.

MAI-215 The Instrument Provider shall be responsible for implementing the activities cited in the software safety program (i.e., analysis of consistency, completeness, correctness, testability, design and code to identified potential hazards, use of safety specific coding standards, testing of the software safety critical components on actual hardware, and analysis software changes).

Instrument Provider developed software will be integrated with GSFC developed software during the Science Instrument Application Acceptance Testing efforts. Software Safety will be a GSFC responsibility after the completion of the successful Science Instrument Application Acceptance Testing.

5.2.3 Software Reliability

MAI-216 The Instrument Provider shall conduct a Software Reliability program and document their Software Reliability program in the Management Plan or in the Flight Software Product Plan or in a separate Software Reliability Plan as appropriate.

MAI-217 The software reliability program shall be tailored to the appropriate level based upon criticality of the software to the mission, software safety criticality, software complexity, size, cost, consequence of failure, and other attributes. Items to be specifically addressed in the plan include monitor and control defect removal, and field performance.

MAI-218 As part of the software reliability program, the Instrument Provider shall collect, analyze, and track measures that are consistent with IEEE Standard 982.1-1988, IEEE Standard Dictionary of Measures to Produce Reliable Software.

Instrument Provider developed software will be integrated with GSFC developed software during the Science Instrument (SI) Application Acceptance Testing efforts. Software Reliability will be a GSFC responsibility after the completion of the successful Science Instrument Application Acceptance Testing.

5.2.4 Verification and Validation

MAI-219 The Instrument Provider shall implement a V&V program to ensure that software being developed or maintained satisfies functional and other requirements at each stage of the development process and that the final product meets customer requirements and expectations.

MAI-220 To assist in the V&V of software requirements, the Instrument Provider shall develop and maintain under configuration control a Software Requirements Verification Matrix that will be made available to NASA upon request. This matrix documents the flow-down of each requirement to the test case and test method used to verify compliance and the test results.

MAI-221 V&V activities shall be performed during each phase of the software lifecycle and shall include the following:

1. Analysis of system and software requirements allocation, verifiability, testability, completeness and consistency (including analysis of test requirements).
2. Interface analysis (requirements and design levels).
3. Design and code analysis including design completeness and correctness.
4. Walkthroughs or inspections.
5. Formal Reviews.
6. Documented test plans and procedures.
7. Test planning, execution, and reporting.

5.2.5 Independent Verification and Validation

MAI-222 The Instrument Provider shall provide all information required for the NASA IV&V effort to NASA IV&V personnel. This includes, but is not limited to, access to all software reviews and reports, Instrument Provider plans and procedures, software code, software design documentation, and software problem reporting data.

MAI-223 Wherever possible, the Instrument Provider shall permit electronic access to the required information or furnish soft copies of requested information to NASA IV&V personnel.

MAI-224 The Instrument Provider shall review and assess all NASA IV&V findings and recommendations and forward their assessment of these findings and recommendations to NASA IV&V personnel accordingly.

MAI-225 The Instrument Provider shall take necessary corrective action based upon their assessment and notify NASA IV&V personnel of this corrective action or notify NASA IV&V personnel of those instances where they decided not to take corrective action on specific IV&V findings and recommendations.

MAI-226 An Instrument Provider Point of Contract shall be assigned and available to NASA IV&V personnel for questions, clarification, and status meetings, as needed. Any modifications to the Memorandum of Agreement (MOA) between the NASA GSFC IV&V Facility (Code 180) and the NASA GSFC JWST Project Office will be communicated to the impacted Instrument Provider.

5.3 REVIEWS

5.3.1 Management Reviews

MAI-227 The Instrument Provider's management process shall provide for a series of Instrument Provider-presented formal reviews.

MAI-228 The Instrument Provider shall ensure that software safety is formally addressed as an agenda item at all reviews.

MAI-229 The Instrument Provider shall record and maintain minutes and action items from each review and respond to Request for Action (RFAs) and any action items assigned by the GSFC review panel and/or the project as a result of each review and provide a status of all action items and RFAs at subsequent formal reviews.

MAI-230 Records of reviews not required by the contract but conducted by the Instrument Provider in accordance with the Instrument Provider's QMS shall be available for review by GSFC upon request.

5.3.2 Peer Reviews

MAI-231 The Instrument Provider shall implement a program of engineering reviews (peer reviews) throughout the development lifecycle to identify and resolve concerns prior to formal, system level reviews.

MAI-232 Peer review teams shall be comprised of technical experts with significant practical experience relevant to the technology and requirements of the software to be reviewed and commensurate with the scope, complexity, and acceptable risk of the software system/product.

MAI-233 Topics that shall be addressed in the peer reviews include:

1. Design verification.
2. Coding standards and Style guides (e.g., C++ Coding Standard Flight Software Branch Code 582, Version 1.0, 12/11/03, 582-2003-004, JWST CC&DH FSW Development Guidelines, IFSW-STND-000003)
3. Code inspections (or walkthroughs).
4. Analyses and studies.
5. Software safety.
6. Risk assessment, resolution and contingency plans.
7. Procurements.
8. CM
9. Testability and test planning, including test anomalies and resolution.

MAI-234 Action items from peer reviews shall be recorded, maintained, and tracked throughout the development lifecycle.

5.4 SOFTWARE CONFIGURATION MANAGEMENT

MAI-235 The Instrument Provider shall develop, document and implement a Software Configuration Management (SCM) system that provides baseline management and control of software requirements, design, source code, data, and documentation.

MAI-236 As part of the SCM, the Instrument Provider shall employ a source code version control tool (e.g., ClearCase, Starbase, etc.) that allows Instrument Providers to check in/check out current or previous versions of a source file.

MAI-237 The Instrument Provider shall also use a requirements management tool (e.g., Dynamic Object-Oriented Requirements System [DOORS]) to manage the software requirements baseline.

MAI-238 As part of the SCM system, the Instrument Provider shall create and maintain a CCB to manage, assess and control all changes and in conjunction with the CCB, classify proposed software changes as defined by NASA Procedures and Guidelines, 400-PG-1410.2.1.

MAI-239 The Instrument Provider shall ensure that the overall SCM system addresses configuration identification, configuration control, configuration status accounting, and configuration authentication. Audits may include baseline audits, library control audits, physical configuration audits (PCAs), and functional configuration audits (FCAs).

MAI-240 The Instrument Provider shall describe and document their SCM system, and associated tools.

5.5 SOFTWARE PROBLEM REPORTING AND CORRECTIVE ACTION

MAI-241 The Instrument Provider shall implement a process for Software Problem Reporting and Corrective Action that addresses reporting, analyzing and correcting software nonconformances throughout the development lifecycle to its final disposition.

MAI-242 The Software Problem Reporting system and Corrective Action process shall include:

1. Nonconformance detection and reporting procedures.
2. Nonconformance tracking and management procedures.
3. Nonconformance impact assessment and corrective action procedures.
4. Interfaces to the CM process.

5.6 GOVERNMENT FURNISHED EQUIPEMENT, EXISTING, AND PURCHASED SOFTWARE

MAI-243 If the Instrument Provider will be provided software or firmware as Government-Furnished Equipment (GFE), or will use existing or purchased software or COTS, the Instrument Provider shall ensure that the software meets the functional, performance, and interface requirements placed upon it.

5.7 SOFTWARE PROBLEM REPORTING AND CORRECTIVE ACTION

MAI-244 SQA status shall be reported as a part of the monthly status reports provided to the Program/Project Office.

MAI-245 The status reports shall include the following software assurance highlights:

1. Organization and key personnel changes.
2. Assurance accomplishments and resulting metrics for activities such as, but not limited to, inspection and test, reviews, Instrument Provider/subcontractor surveys, and audits.
3. Trends in metrics data (e.g., total number of software problem reports, including the number of problem reports that were opened and closed in that reporting period).
4. Significant problems or issues that could affect cost, schedule and/or performance.
5. Plans for upcoming software assurance activities.

6.0 INSTRUMENT REVIEWS

6.1 GENERAL

This section describes the instrument review requirements for all of the JWST instruments. The GSFC Systems Review Office (SRO) will lead the Review Team with JWST Project Partner (ESA, CSA, JPL) co-chair(s) as appropriate.

6.2 REVIEWS

Typical reviews include the System Requirements Review (SRR), Preliminary Design Review (PDR), Critical Design Review (CDR), Test Readiness Review (TRR), Pre-Environmental Review (PER), and the Pre-Shipment Review (PSR). The content of the reviews is detailed in the applicable Instrument DRD.

7.0 RISK MANAGEMENT REQUIREMENTS

This section addresses the Risk Management requirements for the JWST Project.

7.1 GENERAL REQUIREMENTS

Risk Management is a requirement established by the Risk Management Procedures and Guidelines (NPG 8000.4) and NASA Program and Project Management Processes and Requirements (NPG 7120.5A). The development and implementation of the project-specific Risk Management Plan (DRD PM-23) will aid in performing risk assessment and risk management within the reliability and quality assurance activity. Risk Management applies to all software and hardware products and processes (flight and ground) to identify analyze, track, and control risks and well as plan risk mitigation actions.

MAI-246 The Instrument Provider shall:

a. Search for, locate, identify, and document reliability and quality risks before they become problems

b. Evaluate, classify, and prioritize all identified reliability and quality risks

c. Develop and implement risk mitigation strategies, actions, and tasks and assign appropriate resources

d. Track risk being mitigated; capture risk attributes and mitigation information by collecting data; establish performance metrics; and examine trends, deviations, and anomalies

e. Control risks by performing: risk close-out, re-planning, contingency planning, or continued tracking and execution of the current plan

f. Communicate and document (via the risk recording, reporting, and monitoring system) risk information to ensure it is conveyed between all levels of the project

g. Report on outstanding risk items at all management and design reviews. The GSFC JWST Project Office, the GSFC SRO (for design reviews only), and the Instrument Provider will agree on what level of detail is appropriate for each review.

h. Submit critical or primary risks to the JWST Risk Management Tool database.

MAI-247 All identified reliability and quality risks shall be documented and reported on in accordance with the James Webb Space Telescope Project Continuous Risk Management Plan (JWST-PLAN-000651). Risk status shall and be available to the Project for monthly review.

MAI-248 The status of risks shall also be provided in Technical Review Reports and be addressed with mitigation and acceptance strategies agreed upon at appropriate mission reviews.

NOTE: The GSFC Office of Systems Safety and Mission Assurance has developed training and processes to aid GSFC and NASA missions in implementing an effective Risk Management Program. This training and assistance is available upon request.

8.0 RESERVED

9.0 RESERVED

10.0 WORKMANSHIP STANDARDS

MAI-249 The Instrument Provider shall plan and implement a Workmanship Program to assure that all electronic packaging technologies, processes, and workmanship activities selected and applied meet mission objectives for quality and reliability. See Chapter 14 for additional information on electrostatic discharge (ESD) control. Any use of pure tin is prohibited. [See Waiver/Deviation Table.]

10.1 APPLICABLE DOCUMENTS*

- Conformal Coating and Staking: NASA-STD-8739.1, Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
- Soldering – Flight, Surface Mount Technology: NASA-STD-8739.2, Surface Mount Technology
- Soldering – Flight, Manual (hand): NASA-STD-8739.3, Soldered Electrical Connections
- Soldering – Ground Systems: IPC/EIA J-STD-001C, Requirements for Soldered Electrical and Electronic Assemblies
- Electronic Assemblies – Ground Systems: IPC-A-610C, Acceptability of Electronic Assemblies
- Crimping, Wiring, and Harnessing: NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring
- Fiber Optics: NASA-STD-8739.5, Fiber Optic Terminations, Cable Assemblies, and Installation
- Electrostatic Discharge Control (ESD): ANSI/ESD S20.20, Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
- Printed Wiring Board (PWB) Design:

– IPC D-275, Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies

– IPC-2223, Sectional Design Standard for Flexible Printed Boards

– GSFC S-312-P003, Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses

- PWB Manufacture:

– IPC A-600, Acceptability of Printed Boards

– IPC-6011, Generic Performance Specification for Printed Boards

– IPC-6012, Qualification and Performance Specification for Rigid Printed Boards

- Flight Applications – Supplemented with: GSFC/S312-P-003, Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses

– IPC-6013, Qualification and Performance Specification for Flexible Printed Boards

– GSFC S-312-P003, Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses

* current status and/or any application notes for these standards can be obtained at URL http://standards.nasa.gov

10.2 DESIGN

10.2.1 Printed Wiring Boards

MAI-250 The PWB manufacturing and acceptance requirements identified in this chapter are based on using PWBs designed in accordance with the PWB design standards referenced above. Space flight PWB designs shall not include features that prevent the finished boards from complying with the Class 3 Requirements of the appropriate manufacturing standard (e.g., specified plating thicknesses, internal annular ring dimensions, etc.).

10.2.2 Assemblies

MAI-251 The design considerations listed in the NASA workmanship standards listed above shall be incorporated.

10.2.3 Ground Systems that Interface with Space Flight Hardware

MAI-252 Ground system assemblies that interface directly with space flight hardware shall be designed and fabricated using space flight parts, materials, and processes for any portion of the assembly(ies) that mate with the flight hardware; or that will reside with the space flight hardware in environmental chambers or other test facilities that simulate a space flight environment (e.g., connectors, test cables, etc.).

10.3 WORKMANSHIP REQUIREMENTS

10.3.1 Training and Certification

MAI-253 All personnel working on JWST hardware shall be certified as having completed the required training, appropriate to their involvement, as defined in the above standards or in the Instrument Provider's quality manual and shall have evidence of completed certifications. This includes, but is not limited to, the aforementioned workmanship and ESD standards. At a minimum, certification includes successful completion of formal training in the appropriate discipline.

10.3.2 Flight and Harsh Environment Ground Systems Workmanship

10.3.2.1 Printed Wiring Boards

MAI-254 PWBs shall be manufactured in accordance with the Class 3 requirements in the above referenced IPC PWB manufacturing standards and GSFC/S312-P-003, "Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses".

MAI-255 The Instrument Provider shall provide PWB test coupons to the GSFC Materials Engineering Branch (MEB) or a GSFC/MEB approved laboratory for evaluation (see DRD SA-11) and obtain approval prior to population of flight PWBs.

MAI-256 Test coupons are not required for delivery to GSFC/MEB if the Instrument Provider has the test coupons evaluated by a laboratory that has been approved by the GSFC/MEB. However, they shall be retained and included as part of the Project's documentation/data deliverables package. The test reports for these test coupons will be submitted to GSFC per DRD SA-11.

10.3.2.2 Assemblies

MAI-257 Assemblies shall be fabricated using the appropriate workmanship standards listed above (i.e., NASA-STD-8739.3 for hand soldering; NASA-STD-8739.4 for crimping/cabling; NASA-STD-8739.5 for fiber optic termination and installation; etc.) and ANSI/ESD S20.20. [See Waiver/Deviation Table.]

10.3.3 Ground Systems (Non-Flight) Workmanship

10.3.3.1 Printed Wiring Boards

MAI-258 PWBs shall be manufactured in accordance with the Class 2 Requirements in the above referenced PWB manufacturing standards.

10.3.3.2 10.3.3.2 Assemblies

MAI-259 Assemblies shall be fabricated using the Class 2 Requirements of J-STD-001C and IPC-A-610C, and ANSI/ESD S20.20. If any conflicts between J-STD-001C and IPC-A-610C are encountered, the requirements in J-STD-001C take precedence.

10.3.4 Documentation

MAI-260 The Instrument Provider shall document the procedures and processes that will be used to implement the above referenced workmanship, design, and ESD control standards; including any procedures or process requirements referenced in via those standards.

Alternate standards may be proposed by the Instrument Provider. Proposals must be accompanied by objective data that documents mission safety or reliability will not be compromised. Their use is limited to the specific project and allowed only after they have been reviewed and approved by program management.

10.4 NEW OR ADVANCED PACKAGING TECHNOLOGIES

MAI-261 New and/or existing advanced packaging technologies (e.g., multi-chip modules (MCMs), stacked memories, chip on board, ball grid array (BGA), etc.) shall be reviewed and approved for the intended application through the PCB as defined in Section 11.3.

MAI-262 New and/or existing advanced technologies shall be part of the Parts Identification List (PIL) and Program Approved Parts List (PAPL) defined in Section 11.8.

10.5 HARDWARE HANDLING

MAI-263 The Instrument Provider shall use proper safety, ESD control and, where appropriate, cleanroom practices when handling flight hardware.

MAIl-264 The electrostatic charge generation and contamination potential of materials, processes, and equipment (e.g., cleaning equipment, packaging materials, purging, tent enclosures, etc.) shall be addressed.

11.0 PARTS REQUIREMENTS

This section addresses the Parts Requirements for the JWST Project.

11.1 GENERAL CRITERIA

MAI-265 The Instrument Provider shall plan and implement an EEE Parts Control Program to assure that all parts selected for use in flight hardware meet mission objectives for quality and reliability.

MAI-266 The program shall be in place to effectively support the design and selection processes for the duration of the contract.

MAI-267 The Instrument Provider shall control the selection, application, evaluation, and acceptance of all parts through a PCB, or another documented system of parts control that is approved by the JWST Project.

MAI-268 All parts shall be selected and processed in accordance with GSFC EEE-INST-002, "Instructions for EEE Parts Selection, Screening, and Qualification and Derating" for part quality level 1. [See Waiver/Deviation Table]

MAI-269 Exceptions for use of a lesser grade part with additional testing shall only be made on a case-by-case basis when a level 1 part is unavailable or because of Instrument-level cost or schedule impacts, and such exceptions require approval by the SI PCB. The JWST PCB will balance performance, cost, and schedule when making a decision on level 1 part exceptions.

MAI-270 The Instrument Provider shall prepare a Parts Control Plan (PCP) describing the approach and methodology for implementing the Parts Control Program. The PCP shall also define the Instrument Provider's criteria for parts selection and approval based on the guidelines of this section. See DRD SA-13.

11.2 JWST INSTRUMENT PROVIDER AND SUBCONTRACTOR PROJECT PARTS ENGINEERS

MAI-271 The Instrument Provider and each subcontractor shall designate one key individual to be their Project Parts Engineer (PPE), who has the prime responsibility for management of their EEE parts control program. This individual directs independent and unimpeded access to the GSFC PPEs and PCB.

MAI-272 Tasks typically performed by the Instrument Provider PPE and each subcontractor PPE shall include but are not limited to the following:

1. Work with design engineers, Radiation Engineers, Reliability Engineers and the GSFC PPE Team to perform part selection and control.
2. Provide PCB agenda, prepare PILs and provide supporting part information for part evaluation and approval by the PCB.
3. Coordinate PCB meetings, maintain minutes, develop and maintain the PAPL, develop and maintain As Designed Parts List (ADPL) and As Built Parts Lists (ABPL).
4. Perform Customer Source Inspections (CSI) and audits at supplier's facilities as necessary or as directed by the PCB.
5. Prepare part procurement, screening, qualification, and modification specifications, as required.
6. Disposition/track part nonconformances and part failure investigations
7. Track and report impact of ALERTS and advisories on flight hardware.
8. Participate in the Integrated Parts Procurement (IPP) efforts by notifying the GSFC PPE team of EEE part needs for long lead hybrids such as Direct Current (DC)-DC converters, Field Programmable Gate Arrays (FPGAs), and commonly used microcircuits.

11.3 PARTS CONTROL BOARD

MAI-273 The Instrument Provider shall establish a PCB or a similar documented system to facilitate the management, selection, standardization, and control of parts and associated documentation for the duration of the contract. The PCB is responsible for the review and approval of all EEE parts, for conformance to established criteria of Section 11.4 (including radiation effects), and for developing and maintaining a PAPL.

In addition, the PCB is responsible for providing assistance in all parts activities such as failure investigations, disposition of non-conformances, and problem resolutions.

MAI-274 PCB operating procedures shall be included as part of the PCP.

11.3.1 PCB Responsibilities

MAI-275 The PCB shall be responsible for:

- evaluation of EEE parts for conformance to established criteria and inclusion in the,
- review and approve EEE part derating as necessary for unique applications,
- define testing requirements,
- review non preferred applications (including radiation effects),
- track part failure investigations and nonconformances.

MAI-276 The GSFC Chief Safety and Mission Assurance Officer (CSO) shall have the final authority in PCB decisions. If there are any parts issues that cannot be resolved at the PCB level, the issues will be elevated to the GSFC Project Manager for disposition.

11.3.2 PCB Meetings and Notification

MAI-277 PCB meetings shall be convened on a regular basis or as needed. The JWST PPE will participate in all PCB meetings and be notified in advance of all upcoming meetings.

MAI-278 The Instrument Provider shall maintain meeting minutes or records to document all decisions made and provide a copy provided to GSFC within five business days of convening the meeting. GSFC will retain the right to overturn decisions involving nonconformances within ten days after receipt of meeting minutes.

MAI-279 The Instrument Provider PPE shall notify attendees at least five days in advance of all upcoming meetings. Notification shall as a minimum, include a proposed agenda and PIL of candidate parts (Refer to Section 11.8.1 of this document).

11.3.3 PCB Membership

MAI-280 As a minimum, the PCB membership shall consist of the Instrument Provider PPE, subcontractors PPE (as requested to support the Instrument Provider PPE), GSFC PPE and GSFC Project Radiation Engineer ([PRE], GSFC Code 561). The Instrument Provider PPE and GSFC JWST PPE participate in all PCB meetings. The CSO, or designee may attend as necessary. The GSFC JWST PPE and GSFC RE are permanent working and voting members of the PCB.

MAI-281 The Instrument Provider and subcontractors shall assure that the appropriate individuals with engineering knowledge and skills are represented as necessary at meetings, such as part commodity specialists, Radiation Engineers or the appropriate subsystem design engineer.

11.4 PART SELECTION AND PROCESSING

11.4.1 General

MAI-282 All part commodities identified in the GSFC Preferred Parts List (PPL 21) and NASA Part Selection List (NPSL) are considered EEE parts and shall be subjected to the requirements set forth in this section.

MAI-283 Custom or advanced technology devices such as custom hybrid microcircuits, detectors, Application Specific Integrated Circuits (ASIC), and MCM shall also be subject to parts control appropriate for the individual technology.

11.4.2 Selection

MAI-284 Parts selected from the GSFC EEE Parts Selection, Screening, Qualification and Derating (EEE-INST-002), or the NPSL for quality level 1 are preferred. All other EEE parts shall be selected, manufactured, processed, screened, and qualified, as a minimum, in the same manner as the nearest applicable quality level 2 device, but must be subjected to additional testing to bring them into level 1 compliance.

MAI-285 GSFC EEE-INST-002 shall be used as a guideline for any additional testing.

For those parts not readily available as quality level 1 but which are available at quality level 2, additional testing may be required by the JWST PCB on a case-by-case basis. The JWST PCB will balance performance, cost, and schedule when making a decision on any additional testing requirements for level 2 parts.

GSFC will be establishing an on-line Common Parts Selection List (CPSL) based upon EEE part needs that are in common between all JWST Instrument Providers. This catalog will offer access to negotiated inventories of screened EEE parts for the purpose of combining common parts needs into IPP. All JWST Instrument Providers are encouraged to participate.

11.4.3 Radiation Requirements for Part Selection

MAI-286 All parts shall be selected to perform their function in their intended application for a 2X mission radiation dose based on the James Webb Space Telescope Project Environmental Specification (SE-17), (JWST-SPEC-003149), The Radiation Environment for the James Webb Space Telescope (JWST-RPT-000453), and any associated analyses. The radiation environment consists of three main degradation effects that are critical for active part selection.

NOTE: In JWST-RPT-000453, potential radiation effects due to transfer orbit are not included. Radiation levels are based on a minimum equivalent shielding effectiveness of 0.100 inches (2.54mm) Aluminum.

The radiation environment consists of three main degradation effects that must be accounted for in active part selection. These effects and others may require individual part application analysis to be performed as necessary by the PRE.

MAI-287 The following items are general guidelines for radiation effects. If a discrepancy exists between this document and the JWST Radiation Specification (JWST-RQMT-000871), the Radiation Specification document shall govern. The PRE may take exceptions to these values and recommend additional testing on a case-by-case basis. Radiation Lot Acceptance Testing (RLAT) for active parts potentially susceptible to Radiation Effects shall be performed as directed by the PRE.

- **Total Ionizing Dose (TID)**, including Enhanced Low Dose Rate (ELDR) effects. Parts will be selected to ensure their adequate performance in the application up to a dose of 2x the expected mission dose. For a top level minimum shielding equivalent to 0.100 inches (2.54mm) aluminum, this corresponds to a Radiation Design Margin (RDM) of 2, for a total dose of 50 kilorads (Krads) (Silicon [Si]), or as otherwise specified by the PRE.

- **Displacement Damage.** Assuming shielding equivalent to 0.100 inches (2.54mm) aluminum, parts must be able to withstand a minimum fluence of 3 x 1011 Protons/cm2 (Si) at an equivalent energy level of 50 Mega Electron Volt (MeV) without degradation or as otherwise specified in the PRE. Using an RDM of 10X and 0.100 inches (2.54mm) Al equivalent shielding, for parts that can be demonstrated to withstand a fluence of 3 x 1012 Protons/centimeters squared (cm2) (Si) at an equivalent energy level of 50 MeV without degradation, no further application circuit analysis or flight lot testing is needed.

- **Single-Event Effects (SEE).** Parts must be assessed for the potential of Single Event Upset (SEU) or Single Event Transient (SET), which requires analysis of the circuit application on a case-by-case basis. Parts susceptible to Single Event Latchup (SEL) should be avoided.

NOTE: If performance demands the use of an SEL susceptible part, measures will be implemented to ensure that SEL induced damage (both prompt and latent) are mitigated and that the mission success is not compromised. These measures must be approved by PRE and PPE before the part can be added to the PAPL.

11.4.4 Custom or Advanced Technology Devices

MAI-288 Devices such as custom hybrid microcircuits, detectors, ASICs, and MCMs shall also be subject to parts control and include a design review appropriate for the individual technology. The design review will include element evaluation to assure each element's reliability, (review should include such items as burn-in, voltage conditioning, sample size, element derating, etc.), device construction and assembly process, including materials evaluation (for such items as contamination concerns, metals whisker concerns, and adequate material thermal matching Materials specialists may be consulted as necessary). A CSI may be required.

MAI-289 A procurement specification may be required for parts in this category based on the recommendation of the PPE. These specifications shall fully describe the item being procured and include physical, mechanical, electrical, and environmental test requirements and QA provisions necessary to control manufacture and acceptance. Screening requirements designated for the part can be included in the procurement specification. Test conditions, burn-in circuits, failure criteria, and lot rejection criteria will be included.

MAI-290 For lot acceptance or rejection, the Percentage of Defectives Allowable (PDA) in a screened lot shall be in accordance with that prescribed in the closest military part specification.

11.4.5 Plastic Encapsulated Microcircuits

MAI-291 The use of Plastic Encapsulated Microcircuits (PEMs) is discouraged. However, when use is necessary to achieve unique requirements that cannot be found in hermetic high reliability microcircuits, plastic encapsulated parts, must meet the requirements of NASA GSFC Supplement to GFSC, Instructions for Plastic Encapsulated Microcircuits (PEMs) Selection, Screening and Qualification (EEE-PEM-001). The PCB shall review the procurement specification for appropriate testing, and also review application, procurement and storage processes for the plastic encapsulated part(s) to assure that all aspects of the GSFC policy have been met. The PCB may grant preliminary approval when the GSFC requirements have been met. Final approval for the use of the PEMs will be acquired from the GSFC JWST Project Office.

11.4.6 Verification Testing

MAI-292 Re-performance of screening tests, which were performed by the manufacturer or authorized test house as required by military or procurement specification, is not required unless deemed necessary as indicated by failure history, Government Industry Data Exchange Program (GIDEP) Alerts, age or other reliability concerns. If required, testing shall be performed in accordance with GSFC EEE-INST-002 or as determined by the PCB.

11.4.7 Parts Approved on Prior Programs

MAI-293 "Grandfather approval" of parts previously approved by GSFC via a Nonstandard Parts Approval Request (NSPAR) or prior PCB activity shall not be permitted. (Preparation of NSPARs is not a requirement for JWST). However, existing approvals may be presented to the PCB as an aid to review candidate parts for approval.

MAI-294 Such candidate parts shall be evaluated by the PCB for compliance to current Program requirements by determining that:

- No changes have been made to the previously approved NSPAR, Source Control Drawing (SCD) or vendor list.
- All stipulations cited in the previous NSPAR approval have been implemented on the current flight lot, including performance of any additional testing.
- The previous program's parts quality level is identical to the current program.
- No new information has become available which would preclude the use of the previously approved part in a high reliability space flight application.

11.4.8 Parts Used in Off the Shelf Assemblies

MAI-295 Units or assemblies that are purchased as "off-the-shelf" hardware items shall be subjected to an evaluation of the parts used within them and be evaluated for screening compliance to GSFC EEE-INST-002, established reliability level, and include a radiation analysis. Units may be required to undergo modification for use of higher reliability parts or Radiation hardened parts. All parts are subject to PCB approval.

MAI-296 Modifications such as additional shielding for radiation effectiveness or replacing radiation soft parts for radiation hardened parts may be required and shall be subject to RE approval.

11.5 VALUE ADDED TESTING

The following value-added tests referenced in the Instructions for EEE Parts Selection, Screening, Qualification, and Derating (EEE-INST-002) are recommended for space applications to provide for enhanced reliability of parts and provide for increased subsystem reliability, by increasing the overall probability of mission success. All additional testing should be noted in the PAPL.

11.5.1 Particle Impact Noise Detection

MAI-297 All EEE devices with internal cavities (transistors, microcircuits, hybrids, relays and switches) shall be subjected to Particle Impact Noise Detection (PIND) screening, in accordance with the applicable specification.

MAI-433 Any device failing this screen shall not be used in any flight application, but may be retained for DPA.

11.5.2 Capacitors

11.5.2.1 Surge Current Screening for Tantalum Capacitors

MAI-298 All solid tantalum capacitors used in filtering applications shall be subjected to surge current screening. Chip capacitors (CWR06 types for example) as a minimum receive testing in accordance with MIL PRF 55365 (+25°C only). This testing can be performed at the manufacturer's facilities by adding an "A" suffix to the standard military part number.

MAI-299 Leaded devices (M39003/01 for example) shall receive testing in accordance with MIL PRF 39003/10.

11.5.2.2 Dielectric Screening for Ceramic Capacitors

MAI-300 Ceramic capacitors used in circuits at or below 10 volts (V) shall be rated at 100V or greater.

MAI-301 Each lot of capacitors rated below 100V, shall have samples subjected to Humidity Steady State Low Voltage testing (85°C and 85% relative humidity) in accordance with MIL PRF 123 (12 piece sample for each lot/date code).

MAI-302 Following humidity exposure, a Destructive Physical Analysis (DPA) shall be performed in accordance with MIL PRF 123 (sample size per GSFC S 311 M 70, for each lot/date code).

11.5.3 Screening for Magnetic Components

MAI-303 Magnetic devices (transformers and inductors) shall be assembled and screened to the requirements of MIL-STD-981 (Design, Manufacturing and Quality Standards for Custom Electromagnetic Devices for Space Applications) for Class S devices.

MAI-304 Burn-in screening shall be considered based on vendor history, performance stability requirements, device complexity, and application criticality.

Simple torroidal coils with one layer of windings may be exempted from burn in unless required by the core manufacturer to stabilize its properties, and such decisions require PCB documentation and approval.

11.6 PART ANALYSIS

11.6.1 Destructive Physical Analysis

MAI-305 A sample of each lot date code of microcircuits, hybrid microcircuits, and semiconductor devices may be subjected to a DPA based on PCB recommendation. All other parts may require a sample DPA if it is deemed necessary as indicated by failure history, GIDEP Alerts, or other reliability concerns. DPA tests, procedures, sample size and criteria shall be as specified in GSFC specification S 311 M 70, Destructive Physical Analysis.

MAI-306 Instrument Provider's procedures for DPA may be used in place of S 311 M 70 and shall be submitted with the PCP for concurrence prior to use. The PCB on a case-by-case basis will consider variation to the DPA sample size requirements, due to part complexity, availability or cost.

11.6.2 Failure Analysis

MAI-307 When a component part Failure Analysis (FA) is necessary to support a Failure Review Board (FRB), the Contractor shall prepare a part Failure Analysis Report.

MAI-308 The Instrument Provider PPE will submit the completed EEE part failure report with all supporting data, analyses, and photographs to the PCB for review and approval in order to assure proper documentation is presented for the FRB. The failure report form shall as a minimum, provide the following information:

- The failed part's identity (part name, part number, reference designator, manufacturer, manufacturing lot/date code, and part serial number if applicable), and symptoms by which the failure was identified (the conditions observed as opposed to those expected).
- The name of the unit or subsystem on which the failure occurred, the contract number, date of failure, the test phase, and the environment in which the test was being conducted.
- The results of the failure analyses conducted and the nature of the rework/retest /corrective action taken in response.

- An indication of whether the failure of the part or item in question constitutes a primary or a secondary (collateral) failure (caused by another failure in the circuit and not a failure on its own merit).

MAI-309 The completed failure report shall include copies of any supporting photographs, X-rays, metallurgical data, microprobe or spectrographic data, Scanning Electronic Microscope (SEM) photographs, pertinent variables (electrical and radiation) data, and Radiation data where it is deemed pertinent to the failure mechanism.

11.7 ADDITIONAL REQUIREMENTS

11.7.1 Parts Age Control

MAI-310 All active EEE parts procured with date codes five years from the date of manufacture to date of procurement shall be subjected to a re-screen and sample DPA per PCB recommendation. Parts taken from user inventory older than five years do not require re-screen, provided they have been properly stored.

MAI-311 Parts over 10 years from the date of manufacture to date of procurement are discouraged. Exceptions shall be reviewed on a case-by-case basis.

MAI-312 Parts stored in uncontrolled conditions where they may be exposed to the elements or sources of contamination shall not be used.

Alternate test plans may be used as approved by the PCB on a case-by-case basis.

11.7.2 Derating

MAI-313 All EEE parts shall be used in accordance with the derating guidelines of the EEE Parts Selection, Screening, Qualifications and Derating (EEE-INST-0002). The Instrument Provider's derating policy may be used in place of the PPL guidelines and be submitted with the Instrument Provider's PCP.

11.7.3 Traceability

MAI-314 The Instrument Provider shall utilize traceability database(s) that provide the capability to retrieve historical records of EEE parts from initial procurement and receipt through, storage, kiting, assembly, test, and final acceptance of the deliverable product.

MAI-315 Also, the database shall permit the traceability to the procurement document and shall provide for:

- Cross-referencing and traceability of part manufacturer and date code to the assembly traveler or production plan.
- The storage of the accumulated data records.

MAI-316 All flight EEE parts shall be traceable to the date code or manufacturer's inspection lot, wafer lot (where applicable) and be maintained throughout manufacturing for each deliverable item.

11.7.4 Alerts

MAI-317 The Instrument Provider shall be responsible for the review and disposition of all GIDEP Alerts for impact on parts proposed for flight use.

MAI-318 In addition, any NASA Alerts and Advisories provided to the Instrument Provider by GSFC shall be reviewed and dispositioned.

MAI-319 Alert applicability, impact, and corrective actions shall be documented and made available for GSFC review.

11.7.5 Prohibited Metals

MAI-320 Pure tin plating shall not be used in the construction and surface finish of EEE parts proposed for space hardware. Only alloys containing less than 97% tin are acceptable.

MAI-321 The use of pure cadmium or zinc is prohibited in the construction and surface finish of space hardware. All cadmium alloys or zinc alloys (e.g. brass) must be completely overplated with an approved metal. The GSFC Materials Branch shall be consulted as necessary.

11.8 PARTS LISTS

MAI-322 The Instrument Provider shall create and maintain a PAPL and a PIL for the duration of the program and submit the PAPL to GSFC in accordance with the appropriate instrument DRD. Parts must be approved for listing on the PAPL before initiation of procurement activity, unless otherwise approved by the PCB.

MAI-323 All submissions to the JWST Project shall include a computer compatible form (Microsoft Excel, Microsoft Access, etc. Consult GSFC Lead PPE for acceptable format).

11.8.1 Parts Identification List

MAI-324 The PIL shall list all parts proposed for use in flight hardware. The PIL is prepared from design team inputs or subcontractor inputs, to be used for presenting candidate parts to the PCB. The PIL includes as a minimum the following information: part number, part name or description, manufacturer, manufacturer's generic part number, drawing number, specifications, comments as necessary (to indicate problems, long lead times, additional testing imposed, application unique notes, etc.).

11.8.2 Program Approved Parts List

MAI-325 The PAPL shall be the only listing of approved parts for flight hardware, and as such may contain parts not actually in flight design.

MAI-326 Only parts that have been evaluated and approved by the PCB shall be listed in the PAPL. The PCB shall assure standardization and the maximum use of parts listed in the PAPL.

11.8.3 As-Designed Parts List

MAI-327 The Instrument Provider PPE shall establish an As-Designed Parts List (ADPL) as soon as practical after the preliminary release. The GSFC PPE will maintain a copy in the GSFC Code 562 Parts database, and will work with the design teams to keep the list(s) current.

11.8.4 As-Built Parts List

MAI-328 An ABPL shall also be prepared and submitted to the JWST Project by the Instrument Provider PPE. The ABPL is generally a final compilation of all parts as installed in flight equipment, with additional "as-installed" part information such as manufacturer name, Commercial and Government Entity (CAGE) code, Lot-Date Code, part serial number (if applicable), quantity used and box or board location. The manufacturer's plant specific CAGE code is preferred, but if unknown, the supplier's general CAGE code is sufficient

11.9 DATA REQUIREMENTS

11.9.1 General

MAI-329 Attributes summary data shall be kept available to the user for all testing performed.

MAI-330 Variable data (read and record) recorded for initial, interim and final electrical test points and shall be kept available to the user.

MAI-331 For flight part lots with samples subjected to RLAT, the summary radiation report that identifies parameter degradation behavior shall be provided to the PCB, and variables data acquired during radiation testing kept available to the user.

11.9.2 Retention of Data and Test Samples

MAI-332 All builders of flight hardware shall have a method in place for retention of data generated for parts tested and used in flight hardware.

MAI-333 The data shall be kept on file in order to facilitate future risk assessment and technical evaluation, as needed.

MAI-334 In addition, the Instrument Provider and subcontractors shall retain all part functional failures, all destructive and non-flight non-destructive test samples, which could be used for future validation of parts for performance under certain conditions not previously accounted for. PIND test failures may be submitted for DPA or radiation testing, but are not recommended for use in engineering models. Parts and data shall be retained for the useful life of the spacecraft, unless otherwise permitted by the PCB.

MAI-335 All historical quality records and those data required to support these records shall be retained for a period of 20 years, minimum, and shall be provided upon request by GSFC.

11.9.3 Photographic Requirements

MAI-336 A photographic record or electronic image of each electronic board, module or subassembly shall be kept on file for the duration of the useful life of the Observatory. The photographic requirements of the appropriate instrument DRD may be used.

MAI-337 The photograph or electronic image shall be of sufficient resolution to clearly show component placement, part marking, or details that are covered or obscured at subsequent levels of assembly and/or any other operation that renders subsequent inspection impractical.

MAI-338 The resolution shall also permit further enlargement of the image if required for analysis.

12.0 MATERIALS, PROCESSES, AND LUBRICATION REQUIREMENTS

This section addresses the Materials, Processes, and Lubrication Requirements for the JWST Project.

12.1 GENERAL REQUIREMENTS

MAI-339 The Instrument Provider shall implement a comprehensive materials and processes plan, as defined in DRD SA-01, beginning at the design stage of the hardware. Materials and lubrication approval by GSFC is required for each usage or application in space flight hardware.

12.2 MATERIALS SELECTION REQUIREMENTS

MAI-340 In order to anticipate and minimize materials problems during space hardware development and operation, the Instrument Provider shall, when selecting materials and lubricants, consider potential problem areas such as radiation effects, thermal cycling, stress corrosion cracking (SCC), galvanic corrosion, hydrogen embrittlement, lubrication, contamination of cooled surfaces, composite materials, atomic oxygen, useful life, vacuum outgassing, toxic offgassing, flammability and fracture toughness as well as the properties required by each material usage or application.

MAI-341 Materials selected shall meet the hazardous materials requirements, including flammability, toxicity and compatibility as specified in the Range Safety Requirements (EWR 127-1, Sections 3.10 and 3.12).

MAI-342 Materials selected shall meet the SCC requirements as defined in MSFC-STD-3029.

12.2.1 Non-Compliant Materials

MAI-343 A material that does not meet the requirements of 12.2, or meets the requirements of 12.2 but is used in an unconventional application, shall be considered a non-compliant material.

MAI-344 Materials that do not satisfy the contamination control planning as defined in the Instrument Provider's Contamination Control Plan (CCP) shall also be considered non-compliant.

The proposed use of a non-compliant material requires that a Materials Usage Agreement (MUA) and/or a Stress Corrosion Evaluation Form or Instrument Provider's equivalent forms (Figures 12-1 and 12-2), be submitted to GSFC for approval.

12.2.1.1 Materials Used in "Off-the-Shelf-Hardware”

MAI-345 "Off-the-shelf hardware" for which a detailed materials list is not available and where the included materials cannot be easily identified and/or changed shall be treated as non-compliant.

MAI-346 The Instrument Provider shall define on a MUA, what measures shall be used to ensure that all materials in the hardware are acceptable for use. Such measures might include any one or a combination of the following: hermetic sealing, vacuum bakeout, material changes for known non-compliant materials, etc. When a vacuum bakeout is the selected method, it must incorporate a quartz crystal microbalance (QCM) and cold finger to enable a determination of the duration and effectiveness of the bakeout as well as compliance with the satellite contamination plan and error budget.

12.2.2 Conventional Applications

Conventional applications or usage of materials is the use of compliant materials in a manner for which there is extensive satisfactory aerospace heritage.

<table>
<tr><td colspan="4">MATERIAL USAGE AGREEMENT</td><td colspan="5">USAGE AGREEMENT NO.:</td><td colspan="3">PAGE OF</td></tr>
<tr><td colspan="2">PROJECT:</td><td colspan="2">SUBSYSTEM:</td><td colspan="5">ORIGINATOR:</td><td colspan="3">ORGANIZATION:</td></tr>
<tr><td colspan="2">DETAIL DRAWING</td><td colspan="3">NOMENCLATURE</td><td colspan="3">USING ASSEMBLY</td><td colspan="4">NOMENCLATURE</td></tr>
<tr><td colspan="2"></td><td colspan="3"></td><td colspan="3"></td><td colspan="4"></td></tr>
<tr><td colspan="6">MATERIAL & SPECIFICATION</td><td colspan="6">MANUFACTURER & TRADE NAME</td></tr>
<tr><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td rowspan="2">USAGE</td><td rowspan="2">THICKNESS</td><td rowspan="2">WEIGHT</td><td rowspan="2">EXPOSED AREA</td><td colspan="8">ENVIRONMENT</td></tr>
<tr><td colspan="3">PRESSURE</td><td colspan="3">TEMPERATURE</td><td colspan="2">MEDIA</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="3"></td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td colspan="12">APPLICATION:</td></tr>
<tr><td colspan="12">RATIONALE:</td></tr>
<tr><td colspan="4">ORIGINATOR:</td><td colspan="5">PROJECT MANAGER:</td><td colspan="3">DATE:</td></tr>
</table>

Figure 12-1. Material Usage Agreement Form

STRESS CORROSION EVALUATION FORM

1. Part Number ______________________________
2. Part Name ______________________________
3. Next Assembly Number ______________________________
4. Manufacturer ______________________________
5. Material ______________________________
6. Heat Treatment ______________________________
7. Size and Form ______________________________
9. Sustained Tensile Stresses-Magnitude and Direction
   a. Process Residual ______________________________
   b. Assembly ______________________________
   c. Design, Static ______________________________
10. Special Processing ______________________________
11. Weldments
   a. Alloy Form, Temper of Parent Metal ______________
   b. Filler Alloy, if none, indicate ______________
   c. Welding Process ______________________________
   d. Weld Bead Removed - Yes ( ), No ( ) ______________
   e. Post-Weld Thermal Treatment ______________
   f. Post-Weld Stress Relief ______________________
   11. Environment ______________________________
   12. Protective Finish ______________________________
   13. Function of Part ______________________________

   ____
   14. Effect of Failure ______________________________

   ____
   15. Evaluation of Stress Corrosion Susceptibility __________

   ____
   16. Remarks: ______________________________

____

Figure 12-2. Stress Corrosion Evaluation Form

12.2.3 Non-Conventional Applications

MAI-347 The proposed use of a compliant material for an application for which there is limited satisfactory aerospace usage shall be considered a non-conventional application.

MAI-348 Under these circumstances, GSFC and the Instrument Provider may agree for the Instrument Provider to provide any/all the information required in a Materials Usage Agreement (MUA) so that GSFC may fully understand the application. In that case, the material usage shall be verified for the desired application on the basis of test, similarity, analyses, inspection, existing data, or a combination of those methods.

12.2.4 Polymeric Materials

MAI-349 The Instrument Provider shall prepare and submit a Polymeric Materials and Composites Usage List (Figure 12-3) or the Instrument Provider's equivalent to GSFC for review/approval.

12.2.4.1 Flammability and Toxic Offgassing

MAI-350 Material flammability and toxic offgassing shall be determined in accordance with the test methods described in NASA-STD-6001.

12.2.4.2 Vacuum Outgassing

MAI-351 Material vacuum outgassing shall be determined in accordance with ASTM E-595. In general, a material is qualified on a product-by-product basis. However, GSFC may require lot testing of any material for which lot variation is suspected. In such cases, material approval is contingent upon lot testing.

MAI-352 Only materials that have a total mass loss (TML) less than 1.00% and a collected volatile condensable mass (CVCM) less than 0.10% shall be approved for use in a vacuum environment unless application considerations listed on a MUA dictate otherwise.

12.2.4.3 Shelf-Life-Controlled Materials

MAI-353 Polymeric materials that have a limited shelf-life shall be controlled by a process that identifies the start date (manufacturer's processing, shipment date, or date of receipt, etc.), the storage conditions associated with a specified shelf-life, and expiration date. Materials such as o-rings, rubber seals, tape, uncured polymers, lubricated bearings and paints shall be included. The use of materials whose date code has expired requires that the Instrument Provider demonstrate, by means of appropriate tests, that the properties of the materials have not been compromised for their intended use. Such materials must be approved by GSFC. This may be accomplished by means of a waiver. When a limited-life piece part is installed in a subassembly, its usage must be approved by GSFC. This may be accomplished by including the subassembly item in the Limited-Life Plan.

12.2.5 Inorganic Materials

MAI-354 The Instrument Provider shall prepare and document an Inorganic Materials and Composites Usage List (Figure 12-4) or the Instrument Provider's equivalent and submitted to GSFC for review and approval.

POLYMERIC MATERIALS AND COMPOSITES USAGE LIST

SPACECRAFT ____________ SYSTEM/EXPERIMENT ____________ GSFC T/O ____________

INSTRUMENT PROVIDER/CONTRACTOR ____________ ADDRESS ____________

PREPARED BY ____________ PHONE ____________ DATE PREPARED ____________

GSFC MATERIALS EVALUATOR ____________ PHONE ____________ DATE RECEIVED ____________ DATE EVALUATED ____________

Area, cm^2	Vol., cc	Wt., gm
1 0-1	A 0-1	a 0-1
2 2-100	B 2-50	b 2-50
3 101-1000	C 51-500	c 51-500
4 >1000	D >500	d >500

ITEM NO.	MATERIAL IDENTIFICATION(2)	MIX FORMULA(3)	CURE(4)	AMOUNT CODE	EXPECTED ENVIRONMENT(5)	REASON FOR SELECTION(6)	OUTGASSING VALUES	
							TML	CVCM

NOTES

1. List all polymeric materials and composites applications utilized in the system except lubricants which should be listed on polymeric and composite materials usage list.

2. Give the name of the material, identifying number and manufacturer. Example: Epoxy, Epon 828, E. V. Roberts and Associates

3. Provide proportions and name of resin, hardener (catalyst), filler, etc. Example: 828/V140/Silflake 135 as 5/5/38 by weight

4. Provide cure cycle details. Example: 8 hrs. at room temperature + 2 hrs. at 150C

5. Provide the details of the environment that the material will experience as a finished S/C component, both in ground test and in space. List all materials with the same environment in a group. Example: T/V : -20C/+60C, 2 weeks, 10E-5 torr, ultraviolet radiation (UV)
   Storage: up to 1 year at room temperature
   Space: -10C/+20C, 2 years, 150 mile altitude, UV, electron, proton, atomic oxygen

6. Provide any special reason why the materials was selected. If for a particular property, please give the property.
   Example: Cost, availability, room temperature curing or low thermal expansion.

Figure 12-3. Polymeric Materials and Composites Usage List

INORGANIC MATERIALS AND COMPOSITES USAGE LIST

SPACECRAFT ______ SYSTEM/EXPERIMENT ______ GSFC T/O ______
INSTRUMENT PROVIDER/CONTRACTOR ______ ADDRESS ______
PREPARED BY ______ PHONE ______ DATE PREPARED ______
GSFC MATERIALS EVALUATOR ______ PHONE ______ DATE RECEIVED ______ DATE EVALUATED ______

ITEM NO.	MATERIAL IDENTIFICATION(2)	CONDITION(3)	APPLICATION(4) OR OTHER SPEC. NO.	EXPECTED ENVIRONMENT(5)	S.C.C. TABLE NO.	MUA NO.	NDE METHOD

NOTES:
1. List all inorganic materials (metals, ceramics, glasses, liquids, and metal/ceramic composites) except bearing and lubrication materials that should be listed on Form 18-59C.
2. Give materials name, identifying number manufacturer.
   Example: a. Aluminum 6061-T6
   b. Electroless nickel plate, Enplate Ni 410, Enthone, Inc.
   c. Fused silica, Corning 7940, Corning Class Works
3. Give details of the finished condition of the material, heat treat designation (hardness or strength), surface finish and coating, cold worked state, welding, brazing, etc.
   Example: a. Heat treated to Rockwell C 60 hardness, gold electroplated, brazed.
   B. Surface coated with vapor deposited aluminum and magnesium fluoride
   c. Cold worked to full hare condition, TIG welded and electroless nickel plated.
4. Give details of where on the spacecraft the material will be used (component) and its function.
   Example: Electronics box structure in attitude control system, not hermetically sealed.
5. Give the details of the environment that the material will experience as a finished S/C component, both in ground test and in space. Exclude vibration environment. List all materials with the same environment in a group.
   Example: T/V: -20C/+60C, 2 weeks, 10E-5 torr, Ultraviolet radiation (UV)
   Storage: up to 1 year at room temperature
   Space: -10C/+20C, 2 years, 150 miles altitude, UV, electron, proton, Atomic Oxygen

Figure 12-4. Inorganic Materials and Composites Usage List

MAI-355 In addition, the Instrument Provider may be requested to submit supporting applications data. The criteria specified in MSFC-STD-3029 shall be used to determine that metallic materials meet the stress corrosion cracking criteria.

MAI-356 An MUA shall be submitted for each material usage that does not comply with the MSFC-STD-3029 SCC requirements. Additionally, for GSFC to approve usage of individual materials, a stress corrosion evaluation form, as discussed in Section 12.2.1, or an equivalent Instrument Provider form or any/all of the information contained in the Stress Corrosion Evaluation form may be required by GSFC from the Instrument Provider. Nondestructive evaluation requirements are contained in the Space Transportation System (STS) fracture control requirements.

12.2.5.1 Fasteners

MAI-357 As part of the parts and materials list approval process, GSFC will approve all flight fasteners. Towards this end, the Instrument Provider shall provide all information required by GSFC to ensure its ability to concur with the flightworthiness of JWST flight fasteners.

MAI-358 The Instrument Provider shall comply with the procurement documentation and test requirements for flight hardware and critical GSE fasteners contained in GSFC 541-PG-8072.1.2, Goddard Space Flight Center Fastener Integrity Requirements.

MAI-359 The Instrument Provider shall prepare a Fastener Control Plan and Material test reports for fastener lots and make available for review by GSFC.

MAI-360 Fasteners made of plain carbon or low alloy steel shall be protected from corrosion.

MAI-361 When plating is specified, it shall be compatible with the space environment.

MAI-362 On steels harder than RC 33, plating shall be applied by a process that is not embrittling to the steel.

12.2.6 Lubrication

MAI-363 The Instrument Provider shall prepare and document a Lubrication Usage List (Figure 12-5) or the Instrument Provider's equivalent (DRD SA-06) and submitted to GSFC for approval. The Instrument Provider may be requested to submit supporting applications data.

MAI-364 Lubricants shall be selected for use with materials on the basis of valid test results that confirm the suitability of the composition and the performance characteristics for each specific application, including compatibility with the anticipated environment and contamination effects.

MAI-365 All lubricated mechanisms shall be qualified by life testing in accord with the life test plan or heritage of an identical mechanism used in identical applications.

12.3 PROCESS SELECTION REQUIREMENTS

MAI-366 The Instrument Provider shall prepare and document a Material Process Utilization List (Figure 12-6) or the Instrument Provider's equivalent (DRD SA-06) and submitted to GSFC for approval.

MAI-367 A copy of any process shall be submitted for review upon request.

MAI-368 Manufacturing processes (e.g., lubrication, heat treatment, welding, and chemical or metallic coatings) shall be carefully selected to prevent any unacceptable material property changes that could cause adverse effects of materials applications.

12.4 PROCUREMENT REQUIREMENTS

12.4.1 Purchased Raw Materials

MAI-369 Raw materials purchased by the Instrument Provider shall be accompanied by the results of nondestructive, chemical and physical tests, or a Certificate of Compliance. This information need only be provided to GSFC when there is a direct question concerning the material's flightworthiness.

12.4.2 Raw Materials Used in Purchased Products

MAI-370 The Instrument Provider shall require that their suppliers meet the requirements of Section 12.4.1 of this document and provide, upon request, the results of acceptance tests and analyses performed on raw materials.

LUBRICATION USAGE LIST

SPACECRAFT ____________ SYSTEM/EXPERIMENT ____________ GSFC T/O ____________

DEVELOPED/CONTRACTOR ____________ ADDRESS ____________

PREPARED BY ____________ PHONE ____________ DATE PREPARED ____________

GSFC MATERIALS EVALUATOR ____________ PHONE ____________ DATE RECEIVED ____________ DATE EVALUATED ____________

ITEM NO.	COMPONENT TYPE, SIZE MATERIAL[1]	COMPONENT MANUFACTURER & MFR. IDENTIFICATION	PROPOSED LUBRICATION SYSTEM & AMT. OF LUBRICANT	TYPE & NO. OF WEAR CYCLES[2]	SPEED, TEMP., ATM. OF OPERATION[3]	TYPE OF LOADS & AMT.	OTHER DETAILS[5]

NOTES

(1) BB = ball bearing, SB = sleeve bearing, G = gear, SS = sliding surfaces, SEC = sliding electrical contacts. Give generic identification of materials used for the component, e.g., 440C steel, PTFE.

(2) CUR = continuous unidirectional rotation, CO = continuous oscillation, IR = intermittent rotation, IO = intermittent oscillation, SO = small oscillation, (<30°), LO = large oscillation (>30°), CS = continuous sliding, IS = intermittent sliding.
No. of wear cycles: A($1\text{-}10^2$), B($10^2\text{-}10^4$), C($10^4\text{-}10^6$), D($>10^6$)

(3) Speed: RPM = revs./min., OPM = oscillations/min., VS = variable speed
CPM = cm/min. (sliding applications)
Temp. of operation, max. & min., °C
Atmosphere: vacuum, air, gas, sealed or unsealed & pressure

(4) Type of loads: A = axial, R = radial, T = tangential (gear load). Give amount of load.

(5) If BB, give type and material of ball cage and number of shields and specified ball groove and ball finishes. If G, give surface treatment and hardness. If SB, give dia. of bore and width. If torque available is limited, give approx. value.

GSFC 18-59C 3/78

Figure 12-5. Lubrication Usage List

MATERIALS PROCESS UTILIZATION LIST

SPACECRAFT ______________________ SYSTEM/EXPERIMENT ______________________ GSFC T/O __________

INSTRUMENT PROVIDER/CONTRACTOR ______________________ ADDRESS ______________________

PREPARED BY ______________________ PHONE ______________________ DATE PREPARED __________

GSFC MATERIALS EVALUATOR ______________________ PHONE __________ DATE RECEIVED __________ DATE EVALUATED __________

ITEM NO.	PROCESS TYPE[(1)]	CONTRACTOR SPEC. NO.[(2)]	MIL., ASTM., FED. OR OTHER SPEC. NO.	DESCRIPTION OF MAT'L PROCESSED[(3)]	SPACECRAFT/EXP. APPLICATION[(4)]

NOTES

(1) Give generic name of process, e.g., anodizing (sulfuric acid).

(2) If process if proprietary, please state so.

(3) Identify the type and condition of the material subjected to the process.
E.g., 6061-T6

(4) Identify the component or structure of which the materials are being processed.
E.g., Antenna dish

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Figure 12-6. Materials Process Utilization List

13.0 CONTAMINATION CONTROL REQUIREMENTS

This section addresses the Contamination Control Requirements for the JWST Project.

13.1 GENERAL

MAI-371 The Instrument Provider shall plan and implement a contamination control program applicable to the hardware.

MAI-372 The program shall establish the specific cleanliness requirements and delineate the approaches in a CCP (DRD SA-02).

13.2 CONTAMINATION CONTROL PLAN

MAI-373 The Instrument Provider shall prepare a CCP that describes the procedures that will be followed to control contamination.

MAI-374 The CCP shall define a contamination allowance for performance degradation of contamination sensitive hardware such that, even in the degraded state, the hardware shall meet its mission objectives.

MAI-375 The CCP shall establish the implementation and describe the methods that will be used to measure and maintain the levels of cleanliness required during each of the various phases of the hardware's lifetime.

MAI-376 In general, all mission hardware shall be compatible with the most contamination-sensitive components.

13.3 MATERIAL OUTGASSING

MAI-377 All materials shall be screened in accordance with NASA Reference Publication 1124, Outgassing Data for Selecting Spacecraft Materials.

MAI-378 Individual material outgassing data shall be established based on each component's operating conditions and shall be reviewed by GSFC prior to selection.

13.4 THERMAL VACUUM BAKEOUT

MAI-379 The Instrument Provider shall perform thermal vacuum bakeouts of all hardware.

MAI-380 Exceptions to this shall be identified in the CCP (DRD SA-02). The parameters of such bakeouts (e.g., temperature, duration, outgassing requirements, and pressure) must be individualized depending on materials used, the fabrication environment, and the established contamination allowance.

MAI-381 Contamination shall be measured with a temperature controlled quartz microbalance (TQCM).

MAI-382 Contamination control plates shall be placed in the chamber during bakeout to measure and identify outgassed materials.

MAI-383 Results shall be documented and available for GSFC review.

13.5 HARDWARE HANDLING

MAI-384 The Instrument Provider shall practice cleanroom standards in handling hardware.

MAI-385 The contamination potential of material and equipment used in cleaning, handling, packaging, tent enclosures, shipping containers, bagging (e.g., anti-static film materials), and purging shall be described in detail for each subsystem or component at each phase of assembly, integration, test, and launch.

14.0 ELECTROSTATIC DISCHARGE CONTROL

MAI-386 The Instrument Provider shall document and implement an ESD Control Program to assure that all manufacturing, inspection, testing, and other processes will not compromise mission objectives for quality and reliability due to ESD events.

14.1 APPLICABLE DOCUMENTS*

- Electrostatic Discharge Control (ESD): ANSI/ESD S20.20, Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

* current status and/or any application notes for these standards can be obtained at URL http://standards.nasa.gov

14.2 ELECTROSTATIC DISCHARGE CONTROL REQUIREMENTS

MAI-387 The Instrument Provider shall document and implement an ESD Control Program in accordance with ANSI/ESD S20.20 suitable to protect the most sensitive component involved in the project.

MAI-388 At a minimum, the ESD Control Program shall address training, protected work area procedures and verification schedules, packaging, facility maintenance, storage, and shipping.

MAI-389 All personnel who manufacture, inspect, test, otherwise process or handle electronic hardware, or require unescorted access into ESD protected areas shall be certified as having completed the required training, appropriate to their involvement, as defined in ANSI/ESD S20.20 or in the Instrument Provider's quality manual prior to handling any electronic hardware.

MAI-390 Electronic hardware shall be manufactured, inspected, tested, or otherwise processed only at designated ESD protective work areas.

MAI-391 These work areas shall be verified on a regular schedule as identified in the Instrument Provider's ESD Control Program.

MAI-392 Electronic hardware shall be properly packaged in ESD protective packaging at all times when not actively being manufactured, inspected, tested, or otherwise processed.

Alternate standards may be proposed by the Instrument Provider. Their use is limited to the specific project and are allowed only after they have been reviewed and approved by the GSFC.

15.0 GOVERNMENT-INDUSTRY DATA EXCHANGE ALERTS AND PROBLEM ADVISORIES

15.1 GOVERNMENT-INDUSTRY DATA EXCHANGE PROGRAM PARTICIPATION

MAI-393 The Instrument Provider shall participate in the GIDEP in accordance with the requirements of the GIDEP S0300-BT-PRO-010 and S0300-BU-GYD-010, available from the GIDEP Operations Center, PO Box 8000, Corona, California 91718-8000.

MAI-394 The Instrument Provider shall review all GIDEP ALERTS, GIDEP SAFE-ALERTS, GIDEP Problem Advisories, GIDEP Agency Action Notices, and NASA Advisories to determine if they affect the Instrument Provider's products produced for NASA.

MAI-395 For GIDEP ALERTS, GIDEP SAFE-ALERTS, GIDEP Problem Advisories, GIDEP Agency Action Notices, and NASA Advisories that are determined to affect the program, the Instrument Provider shall take action to eliminate or mitigate any negative effect to an acceptable level.

MAI-396 The Instrument Provider shall generate the appropriate failure experience data report(s) (GIDEP ALERT, GIDEP S AFE-ALERT, GIDEP Problem Advisory) in accordance with the requirements of GIDEP S0300-BT-PRO-010 and S0300-BU-GYD-010 whenever failed or nonconforming items, available to other buyers, are discovered during the course of the program.

16.0 JWST MECHANISM REQUIREMENTS

MAI-397 The mechanism requirements listed below shall be verified and documented.

16.1 MECHANICAL CLEARANCES

MAI-398 Clearances between mechanism components in relative motion to each other during operation, except for bearings, hinges, and similar items shall be:

Radial	0.25 mm	(0.01 inch) minimum
Axial	0.375 mm	(0.015 inch) minimum

MAI-399 External clearances between mechanisms with relative motion to other parts of the assembly such as blankets, harnesses, and covers shall not be less than 0.5 mm and their location shall employ positive means of support to ensure no interference with the operation of the mechanism.

MAI-400 The above listed clearances refer to both static and dynamic conditions and shall be determined using worst-case environments.

16.2 FASTENERS

MAI-401 All fasteners shall have positive thread locking features. Snaprings, cotter pins or set screws shall not be used to secure components. [See Waiver/Deviation Table]

16.3 COMPONENT MOUNTING

MAI-402 Except in the case of non-metallic interfaces, friction shall not be relied upon to affix components where their alignment is essential to the performance of the component and where the joint is used for the transfer of force or torque during a mechanism operation.

MAI-403 Where practical, keying or pinning shall be employed.

MAI-404 Shear strength of pins used in either torque or force transmission shall be such that they will be able to accommodate these quantities under worst-case conditions including possible large impact loads.

MAI-405 If the use of adhesives is planned, proper adhesive selection for the operating environment, surface preparation, bond line thickness, and component configuration shall be made and indicate positive margins with an ultimate factor of safety (FS) of 1.5 with analysis.

MAI-406 All bonded interfaces shall be strength test verified.

16.4 BEARINGS

MAI-407 The values shown below in Section 16.5 assume the use of 440C steel. If other bearing materials are used, the allowable load shall be calculated based on using appropriate reduction factors for aerospace applications.

MAI-408 Justification for use of these reduction factors shall be included with the analysis.

MAI-409 Further, the values shown in Section 16.5 shall be calculated under worst-case environmental conditions.

16.5 BEARING PRELOAD

MAI-410 Bearing preloads shall be determined considering all anticipated loads and environments such as launch, pyro shock, mechanical fit and tolerances, and temperature under fully assembled conditions.

MAI-411 For the application where quiet running is required, such as instrument bearings, the mean Hertzian stresses shall be limited to:

Exposure to yield loads:	2.31E9 N/sq. m	(335,000 psi)
Operational loads:	6.89E8 N/sq. m	(100,000 psi)

MAI-412 For non-quiet running, such as deployment systems, the stresses shall be limited to:

Exposure to yield loads:	2.41E9 N/sq. m	(350,000 psi)
Operational loads:	1.03E9 N/sq. m	(150,000 psi)

MAI-413 Deployment impact load stress shall not exceed the yield limits stated above.

MAI-414 Furthermore, the bearing stress patch ellipse shall not be truncated under any load condition.

16.6 BEARING LIFE

MAI-415 Justification for use of these reduction factors Section 16.4 shall be included with the analysis.

MAI-416 Bearing fatigue life calculation shall be based on a survival probability of 99.95 percent when subjected to maximum time varying loads under worst-case environmental conditions.

16.7 BEARING LUBRICATION

MAI-417 The selection of lubricant for use in critical moving mechanical assemblies shall be based upon development tests of the lubricant that demonstrate its ability to provide adequate lubrication under all specified operating conditions over the design lifetime.

MAI-418 Since life testing cannot typically provide proof of lubricant availability based on evaporation over the required life of the mechanism, an analysis shall be performed to show that there is an adequate amount of lubricant in the system (not including degradation) for the duration of the mechanism life with a margin greater than 10.

MAI-419 Lubricant availability analyses based on degradation rates shall be proven through life testing.

MAI-420 If solid lubrications are used, particular attention shall be given to the method of application and subsequent handling of the components and assemblies to avoid exposure to moisture or humidity.

16.8 TORQUE AND FORCE MARGINS

MAI-421 Adequate torque or force margins shall be provided to assure reliable mechanism operation over the life of the mission.

MAI-422 The peak torque available at the motor shaft shall not be less than 7.06E-3 N-m (1 oz-in).

MAI-423 Margins shall be determined using worst-case conditions and shall include all flight drive electronics effects and limitations.

MAI-424 Torque margins shall be test verified at unit qualification or acceptance level testing.

MAI-425 The minimum available driving torque for the mechanism shall be determined based on the factor of safety (FS) listed below.

MAI-426 The Torque Margin (TM) shall be greater than zero and shall be calculated using the following formula:

$$TM = \{T_{avail} / (FS_k \, \Sigma T_{known} + FS_v \, \Sigma T_{variable})\} - 1$$

Where:

Driving Torques:

T_{avail} = the minimum torque or force available from the mechanism at worst-case environmental conditions at any time in its life. If motors are used in the system, T_{avail} will be determined at the output of the motor, not including gear heads or gear trains at its output based on minimum supplied motor voltage and current. Tavail also applies to other actuators such as springs, pyrotechnics, solenoids, heat actuated devices, pin pullers, and segmented nut release devices.

Resistive Torques:

ΣT_{known} = sum of the fixed torques or forces that are known and quantifiable such as accelerated inertias ($T=I\alpha$) and not influenced by friction, temperature, life, etc. A constant FS is applied to the calculated torque.

$\Sigma T_{variable}$ = sum of the torques or forces that may vary over environmental conditions and life such as static or dynamic friction, alignment effects, latching forces, wire harness loads, damper drag, variations in lubricant viscosity, including degradation or depletion of lubricant over life.

Program Phase	Known Torque Factor of Safety (FS_k)	Variable Torque Factor of Safety (FS_v)
Preliminary Design Review	2.00	4.0
Critical Design Review	1.50	3.0
Acceptance / Qualification Test	1.50	3.0

16.9 MECHANISM LIFE TESTING

MAI-427 A life test shall be conducted at the worst-case predicted environments to at least 2 times the required operational.

MAI-428 Mechanism life test results to date shall be presented at the CDR.

MAI-429 Life tests of mechanisms that have a large number of operating cycles with lubricants that do not allow for increase in operating speed shall be started at the earliest possible time so the test results can be incorporated in the design of the flight unit.

MAI-430 Furthermore, the on-orbit deployment performance of deployable mechanisms such as communication antennas and their drive systems, solar arrays and their drive systems, telescope articulating appendages, etc. shall be verified and documented in ground testing to show required margins and repeatability.

16.10 GEAR ANALYSIS

MAI-431 All mechanisms utilizing gear trains shall have an analysis performed to show positive margin for contact stresses and fatigue based on the worst-case loading conditions and appropriate safety factors.

MAI-432 Justification for use of these safety factors shall be included with the analysis.

17.0 APPLICABLE DOCUMENTS

DOCUMENT	DOCUMENT TITLE
ANSI/ASQC Q9001-1994	Model for Quality Assurance in Design, Development, Production, Installation, and Servicing
ANSI/ASQOC Q9000-3	Quality Management and Quality Assurance Standards
ANSI/IPC-A-600	Acceptance Criteria for Printed Wiring Boards
ANSI/IPC-D-275	Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies
ANSI/IPC-6018, Rev A	Microwave End Product Board Inspection and Test
ANSI/IPC-6011	Generic Performance Specification for Printed Boards
ANSI/IPC-6012	Qualification and Performance Specification for Rigid Printed Boards
ASTM E-595	Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVCM) from Outgassing in a Vacuum
CSG-RS-10A-CN	Centre Spatial Guyanais (CSG) Safety Regulations, Vol. 1: General Rules
CSG-RS-21A-CN	CSG Safety Regulations, Vol. 2 Pt. 1: Specific Rules: Ground Installations
CSG-RS-22A-CN	CSG Safety Regulations, Vol. 2 Pt. 2: Specific Rules: Spacecraft
ECSS-Q-40B	ECSS Space Product Assurance: Safety
EEE-INST-002	Instruction for EEE Parts Selection, Screening, Qualification and Derating
EWR 127-1	Eastern and Western Range Safety Requirements 127-1
GSFC PPL	Goddard Space Flight Center Preferred Parts List
GSFC S-312-P003	Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses
IEEE Std 610.12	IEEE Standard Glossary of Software Engineering Terminology
IEEE Std 730	Software Quality Assurance Plan
IEEE 730	Software Quality Assurance Plans
IEEE 982.1	Standard Dictionary of Measures to Produce Reliable Software

JWST-PLAN-000651	James Webb Space Telescope Project Continuous Risk Management Plan
JWST-RQMT-000739	James Webb Space Telescope Project Integrated Science Instrument Module Near-Infrared Camera Data Requirements Document
JWST-RQMT-002090	Near-Infrared Spectrograph and Mid-Infrared Instrument (European Consortium-Provided Elements) Data Requirements Document
JWST-RQMT-002626	ISIM Goddard-Provided Components Data Requirements Document
JWT-RQMT-002628	Fine Guidance Sensor Data Requirements Document
JWST-RQMT-002882	Mid-Infrared Instrument (JPL-Provided Elements) Data Requirements Document
JWST-SPEC-003149	James Webb Space Telescope Project Environmental Specification (SE-17)
KHB 1710.2D	Kennedy Space Center Safety Practices Handbook
MIL-HDBK-338B	Electronic Reliability Design Handbook
MIL-PRF-123	Capacitors, Fixed, Ceramic Dielectric, Temperature Stable and General Purpose, High Reliability
MIL-PRF-39003	Capacitors, Fixed, Tantalum, Electrolytic (Solid Electrolyte), Polarized, Established Reliability
MIL-PRF-55365	Capacitors, Fixed, Electrolyte (Tantalum), Chip, Tantalum Nonestablished Reliability, Established Reliability, General Specifications For
MIL-STD-756B	Reliability Modeling and Prediction
MIL-STD 1629A	Procedures for Performing a Failure Mode Effects and Criticality Analysis
MSFC CR 5320.9	Payload and Experiment Failure Mode Effects Analysis and Critical Items List Ground Rules
MSFC-HDBK-527	Material Selection List for Space Hardware Systems
MSFC-STD-3029	Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments
NASA Reference Publication (RP) 1124	Outgassing Data for Selecting Spacecraft Materials
NASA RP-1161	Evaluation of Multi-layer Printed Wiring Boards by Metallographic Techniques

NASA-STD-6001	Flammability, Odor, Off-Gassing and Compatibility Requirements & Test Procedures for Materials that Support Combustion
NASA-STD-8719.8	Expendable Launch Vehicle Payloads Safety Review Process Standard
NPG 7120.5A	NASA Program and Project Management Processes and Requirements
NPG 8000.4	Risk Management Procedures and Guidelines
NPR 8715.3	NASA Safety Manual
NSS 1740.13	Software Safety Standard
NSS 1740.14	Guidelines and Assessment Procedures for Limiting Orbital Debris
S0300-BT-PRO-010	GIDEP Operations Manual
S0300-BU-GYD-010	Government-Industry Data Exchange Program (GIDEP) Requirements Guide
P-302-720	Performing a Failure Mode and Effects Analysis
S-311-M-70	Specification for Destructive Physical Analysis
302-PG-7120.2.1	Systems Safety Support to GSFC Missions
541-PG-8072.1.2	Goddard Space Flight Center Fastener Integrity Requirements
5405-048-98	Mechanical Systems Center Safety Manual
NONE	Ariane 5 Users Manual

Appendix A. Abbreviations and Acronyms

Acronym/ Abbreviation	DEFINITION
ABPL	As-Built Parts List
ADPL	As-Designed Parts List
ANSI	American National Standards Institute
AR	Acceptance Review
ASE	Airborne Support Equipment
ASIC	Application Specific Integrated Circuits
ASQC	American Society for Quality Control
ASIC	Application Specific Integrated Circuits
ASTM	American Society for Testing and Materials
BGA	Ball grid array
C	Centigrade
CAGE	Commercial and Government Entity
CC&DH	Core Command and Data Handling
CCB	Configuration Control Board
CCP	Contamination Control Plan
CDR	Critical Design Review
cm^2	Centimeters squared
CND	Could-Not-Duplicates
COTR	Contracting Officer's Technical Representative
COTS	Commercial off-the-shelf
CPT	Comprehensive Performance Test
CSA	Canadian Space Agency
CSI	Customer Source Inspection
CSO	Chief Safety and Mission Assurance Officer
CVCM	Collected Volatile Condensable Mass
DOORS	Direct Object-Oriented Requirements System
DPA	Destructive Physical Analysis
DRD	Data Requirements Document
EEE	Electrical, Electronic, and Electromechanical
EIA	Electronics Industry Association
ELDR	Enhanced Low Dose Rate
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPIMS	Electronics Parts Information Management Systems
ER	Eastern Range
ESA	European Space Agency
ESD	Electrostatic Discharge
ETU	Engineering Test Unit

Acronym/ Abbreviation	DEFINITION
EWR	Eastern and Western Range
FCA	Functional Configuration Audit
FMEA	Failure Modes and Effects Analysis
FSW	Flight Software
FTA	Fault Tree Analyses
GFE	Government-Furnished Equipment
GIA	Government Inspection Agency
GIDEP	Government Industry Data Exchange Program
GOTS	Government off-the-shelf
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HDBK	handbook
IAC	Independent Assurance Contractor
ICD	Interface Control Document
IDT	Instrument Development Team
IEEE	Institute of Electrical and Electronics Engineers
IFSW	ISIM Flight Software
In.	Inch(es)
IPC	Institute for Printed Circuits
ISIM	Integrated Science Instrument Module
ISO	International Standards Organization
IV&V	Independent Verification and Validation
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
JWST	James Webb Space Telescope
KHB	Kennedy Space Center Handbook
KSC	Kennedy Space Center
Krad	Kilorad
MAR	Mission Assurance Requirements
Mb	Megabyte
MCM	Multi-Chip Module
MEB	Materials Engineering Branch
MeV	Mega Electron Volts
MIL	Military
Mils or mm	millimeter
MISRA	Motor Industry Software Reliability Association
MOA	Memorandum of Agreement
MOTS	Modified off-the-shelf
MOU	Memorandum of Understanding
MRB	Material Review Board
MSFC	Marshall Space Flight Center

Acronym/ Abbreviation	DEFINITION
MUA	Materials Usage Agreement
NASA	National Aeronautics and Space Administration
NHB	NASA Handbook
NPD	NASA Policy Directive
NPG	NASA Procedures and Guidelines
NPSL	NASA Part Selection List
NSPAR	Nonstandard Parts Approval request
NSS	NASA Safety Standard
OSHA	Office of Safety and Health Administration
PAPL	Project Approved Parts List
PCA	Physical Configuration Audit
PCB	Parts Control Board
PCP	Parts Control Plan
PDA	Percentage of Defectives Allowable
PDR	Preliminary Design Review
PEM	Plastic Encapsulated Microcircuits
PER	Pre-Environmental Review
PHA	Preliminary Hazard Analysis
PIL	Parts Identification List
PIND	Particle Impact Noise Detection
PM	Project Management
PPE	Project Parts Engineer
PPL	Preferred Parts List
PRA	Probabilistic Risk Assessment
PSR	Pre-Shipment Review
PWB	Printed Wiring Board
QA	Quality Assurance
QCM	Quartz Crystal Microbalance
QMS	Quality Management System
RDM	Radiation Design Margin
RE	Radiation Engineer
RFA	Request for Action
RP	Reference Publication
RPT	Report
RQMT	Requirement
SA	Systems Assurance
SAR	Safety Assessment Report
SCD	Source Control Drawing
SCM	Software Configuration Management
SEE	Single Event Effects
SEL	Single Event Latchup

Acronym/ Abbreviation	DEFINITION
SET	Single Event Transient
SEU	Single Event Upset
Si	Silicon
SPEC	Specification
SQA	Software Quality Assurance
SRO	Systems Review Office
SRR	Software Requirements Review, System Requirements Review
STD	Standard
STS	Space Transportation System
TID	Total Ionizing Dose
TIMs	Technical Interchange Meetings
TML	Total Mass Loss
TRR	Test Readiness Review
URL	Uniform Resource Locator
V&V	Verification and Validation

Appendix B. Definitions

The following definitions apply within the context of this document:

Acceptance Tests: The validation process that demonstrates that hardware is acceptable for flight. It also serves as a quality control screen to detect deficiencies and, normally, to provide the basis for delivery of an item under terms of a contract.

Audit: A review of the Instrument Provider's, contractor's or subcontractor's documentation or hardware to verify that it complies with project requirements.

Collected Volatile Condensable Material (CVCM): The quantity of outgassed matter from a test specimen that condenses on a collector maintained at a specific constant temperature for a specified time.

Configuration: The functional and physical characteristics of the payload and all its integral parts, assemblies and systems that are capable of fulfilling the fit, form and functional requirements defined by performance specifications and engineering drawings.

Configuration Control: The systematic evaluation, coordination, and formal approval/disapproval of proposed changes and implementation of all approved changes to the design and production of an item the configuration of which has been formally approved by the Instrument Provider or by the purchaser, or both.

Configuration Management: The systematic control and evaluation of all changes to baseline documentation and subsequent changes to that documentation which define the original scope of effort to be accomplished (contract and reference documentation) and the systematic control, identification, status accounting and verification of all configuration items.

Contamination: The presence of materials of molecular or particulate nature which degrade the performance of hardware.

Derating: The reduction of the applied load (or rating) of a device to improve reliability or to permit operation at high ambient temperatures.

Design Specification: Generic designation for a specification that describes functional and physical requirements for an article, usually at the component level or higher levels of assembly. In its initial form, the design specification is a statement of functional requirements with only general coverage of physical and test requirements. The design specification evolves through the project life cycle to reflect progressive refinements in performance, design, configuration, and test requirements. In many projects the end-item specifications serve all the purposes of design specifications for the contract end-items. Design specifications provide the basis for technical and engineering management control.

Designated Representative: An individual (such as a NASA plant representative), firm (such as assessment contractor), Department of Defense (DOD) plant representative, or other government representative designated and authorized by NASA to perform a specific function for NASA. As related to the Instrument Provider's effort, this may include evaluation, assessment, design review, participation, and review/approval of certain documents or actions.

Destructive Physical Analysis (DPA): An internal destructive examination of a finished part or device to assess design, workmanship, assembly, and any other processing associated with fabrication of the part.

Discrepancy: See Nonconformance.

Design Qualification Tests: Tests intended to demonstrate that the test item will function within performance specifications under simulated conditions more severe than those expected from ground handling, launch, and orbital operations. Their purpose is to uncover deficiencies in design and method of manufacture. They are not intended to exceed design safety margins or to introduce unrealistic modes of failure. The design qualification tests may be to either "prototype" or "protoflight" test levels.

Discrepancy: See Nonconformance

Electromagnetic Compatibility (EMC): The condition that prevails when various electronic devices are performing their functions according to design in a common electromagnetic environment.

Electromagnetic Interference (EMI): Electromagnetic energy which interrupts, obstructs, or otherwise degrades or limits the effective performance of electrical equipment.

Electromagnetic Susceptibility: Undesired response by a component, subsystem, or system to conducted or radiated electromagnetic emissions.

End-to-End Tests: Tests performed on the integrated ground and flight system, including all elements of the payload, its control, stimulation, communications, and data processing to demonstrate that the entire system is operating in a manner to fulfill all mission requirements and objectives.

Failure: A departure from specification that is discovered in the functioning or operation of the hardware or software. See nonconformance.

Failure Modes and Effects Analysis (FMEA): A procedure by which each credible failure mode of each item from a low indenture level to the highest is analyzed to determine the effects on the system and to classify each potential failure mode in accordance with the severity of its effect.

Flight Acceptance: See Acceptance Tests.

Fracture Control Program: A systematic project activity to ensure that a payload intended for flight has sufficient structural integrity as to present no critical or catastrophic hazard. Also to ensure quality of performance in the structural area for any payload (spacecraft) project. Central to the program is fracture control analysis, which includes the concepts of fail-safe and safe-life, defined as follows:

a. **Fail-safe:** Ensures that a structural element, because of structural redundancy, will not cause collapse of the remaining structure or have any detrimental effects on mission performance.

b. **Safe-life:** Ensures that the largest flaw that could remain undetected after non-destructive examination would not grow to failure during the mission.

Functional Tests: The operation of a unit in accordance with a defined operational procedure to determine whether performance is within the specified requirements.

Hardware: As used in this document, there are two major categories of hardware as follows:

a. **Prototype Hardware:** Hardware of a new design; it is subject to a design qualification test program; it is not intended for flight.
b. **Flight Hardware:** Hardware to be used operationally in space. It includes the following subsets:

   (1) **Protoflight Hardware:** Flight hardware of a new design; it is subject to a qualification test program that combines elements of prototype and flight acceptance validation; that is, the application of design qualification test levels and duration of flight acceptance tests.

   (2) **Follow-On Hardware:** Flight hardware built in accordance with a design that has been qualified either as prototype or as protoflight hardware; follow-on hardware is subject to a flight acceptance test program.

   (3) **Spare Hardware:** Hardware the design of which has been proven in a design qualification test program; it is subject to a flight acceptance test program and is used to replace flight hardware that is no longer acceptable for flight.

   (4) **Re-flight Hardware:** Flight hardware that has been used operationally in space and is to be reused in the same way; the validation program to which it is subject depends on its past performance, current status, and the upcoming mission.

Inspection: The process of measuring, examining, gauging, or otherwise comparing an article or service with specified requirements.

Limit Level: The maximum expected flight.

Limited Life Items: Spaceflight hardware (1) that has an expected failure-free life that is less than the projected mission life, when considering cumulative ground operation, storage and on-orbit operation, (2) limited shelf life material used to fabricate flight hardware.

Margin: The amount by which hardware capability exceeds mission requirements

Material Review Board (MRB): The formal Instrument Provider board established for the purpose of reviewing, evaluating, and disposing of specific nonconforming materials, supplies or services, and for ensuring the implementation and accomplishment of corrective action to preclude recurrence.

Monitor: To keep track of the progress of a performance assurance activity; the monitor need not be present at the scene during the entire course of the activity, but he will review resulting data or other associated documentation (see Witness).

Nonconformance: A condition of any hardware, software, material, or service in which one or more characteristics do not conform to requirements. As applied in quality assurance, nonconformances fall into two categories--discrepancies and failures. A discrepancy is a departure from specification that is detected during inspection or process control testing, etc., while the hardware or software is not functioning or operating. A failure is a departure from specification that is discovered in the functioning or operation of the hardware or software.

Nonconformance, critical. A nonconformance that judgment and experience indicate is likely to result in hazardous or unsafe conditions for individuals using, maintaining, or depending upon the supplies or services; or is likely to prevent performance of a vital agency mission.

Nonconformance, major. A nonconformance, other than critical, that is likely to result in failure, or to materially reduce the usability of the supplies or services for their intended purpose.

Nonconformance, minor. A nonconformance that is not likely to materially reduce the usability of the supplies or services for their intended purpose, or is a departure from established standards having little bearing on the effective use or operation of the supplies or services.

Offgassing: The emanation of volatile matter of any kind from materials into a manned pressurized volume.

Outgassing: The emanation of volatile materials under vacuum conditions resulting in a mass loss and/or material condensation on nearby surfaces.

Performance Validation: Determination by test, analysis, or a combination of the two that the payload element can operate as intended in a particular mission; this includes being satisfied that the design of the payload or element has been qualified and that the particular item has been accepted as true to the design and ready for flight operations.

Protoflight Testing: See Hardware.

Prototype Testing: See Hardware.

Qualification: See Design Qualification Tests.

Redundancy (of design): The use of more than one independent means of accomplishing a given function.

Repair: A corrective maintenance action performed as a result of a failure so as to restore an item to operate within specified limits.

Rework: Return for completion of operations (complete to drawing). The article shall be reprocessed to conform to the original specifications or drawings.

Shall: Designates a mandatory requirement. Any deviations from the mandatory requirements require the approval of the NASA Contracting Officer.

Similarity, Validation by: A procedure of comparing an item to a similar one that has been verified. Configuration, test data, application, and environment shall be evaluated. It should be determined that design-differences are insignificant, environmental stress will not be greater in the new application, and that manufacturer and manufacturing methods are the same.

Single Point Failure: A single element of hardware the failure of which would result in loss of mission objectives, hardware, or crew, as defined for the specific application or project for which a single point failure analysis is performed.

Temperature Cycle: A transition from some initial temperature condition to temperature stabilization at one extreme and then to temperature stabilization at the opposite extreme and returning to the initial temperature condition.

Temperature Stabilization: The condition that exists when the rate of change of temperatures has decreased to the point where the test item may be expected to remain within the specified test tolerance for the necessary duration or where further change is considered acceptable.

Thermal Balance Test: A test conducted to verify the adequacy of the thermal model, the adequacy of the thermal design, and the capability of the thermal control system to maintain thermal conditions within established mission limits.

Thermal-Vacuum Test: A test conducted to demonstrate the capability of the test item to operate satisfactorily in vacuum at temperatures based on those expected for the mission. The test, including the gradient shifts induced by cycling between temperature extremes, can also uncover latent defects in design, parts, and workmanship.

Torque Margin: Torque margin is equal to the torque ratio minus one.

Torque Ratio: Torque ratio is a measure of the degree to which the torque available to accomplish a mechanical function exceeds the torque required.

Total Mass Loss (TML): Total mass of material outgassed from a specimen that is maintained at a specified constant temperature and operating pressure for a specified time.

Validation: See Performance Validation.

Vibroacoustics: An environment induced by high-intensity acoustic noise associated with various segments of the flight profile; it manifests itself throughout the payload in the form of directly transmitted acoustic excitation and as structure-borne random vibration.

Waiver: A written authorization to accept an item that is found to depart from specific requirements, either during the manufacturing process or after having been submitted for Government inspection or acceptance but nevertheless is considered "acceptable as is", or after repair by an approved method.

Waiver, Critical Waiver: consists of acceptance of an item having a nonconformance with contract or configuration documentation involving safety.

Waiver, Major Waiver: consists of acceptance of an item having a nonconformance with contract or configuration documentation involving a) performance, b) interchangeability, reliability, survivability or maintainability, c) effective use or operation, d) weight or e) appearance.

Waiver, Minor Waiver: consists of acceptance of an item having a nonconformance with contract or configuration documentation which does not involve any of the factors listed in the above definition for a major waiver.

Workmanship Tests: Tests performed during the environmental validation program to verify adequate workmanship in the construction of a test item. It is often necessary to impose stresses beyond those predicted for the mission in order to uncover defects. Thus random vibration tests are conducted specifically to detect bad solder joints, loose or missing fasteners, improperly mounted parts, etc. Cycling between temperature extremes during thermal-vacuum testing and the presence of electromagnetic interference during EMC testing can also reveal the lack of proper construction and adequate workmanship.

Witness: A personal, on-the-scene observation of a performance assurance activity with the purpose of verifying compliance with project requirements (see Monitor).