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Global Precipitation Measurement (GPM)

Microwave Imager (GMI)

Mission Assurance Requirements

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Goddard Space Flight Center
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Document Control Information

This document is controlled by the Global Precipitation Measurement (GPM) Project. Changes require the approval of the GPM Project Manager. Submit proposed changes to the GPM Project Configuration Management Office. This document will be revised per 422-PG-1410.2.1, “GPM Project CM Procedure.”

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Global Precipitation Measurement (GPM)
Microwave Imager (GMI)
Mission Assurance Requirements (MAR)

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DOCUMENT CHANGE RECORD

Note: the Document Change Record will be generated per 422-PG-1410.2.1, "GPM Project CM Procedure" and will be included in the initial formal release of this document and with each revision.

CCR#	Class	Approved Date	Contract Mod#	CCR Title	Affected Sec/Tbl/ Fig
00011	1	10/01/03	N/A	Baseline GPM GMI Mission Assurance Requirements (MAR) Approval (Rev -)	All
00016	2	01/14/04	N/A	GMI MAR Section 6.2.4 Reference Document Update	6.2.4
00019	2	02/23/04	N/A	GMI MAR Administrative and Reference Document Updates	3.1, 3.2, 3.4, 3.10, 8.2.4, Appx – A
00023	1	04/27/04	N/A	GPM GMI MAR Updates (Re-instates workmanship rqmts)	10.2, 10.4.2, Appx-A

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1 OVERALL REQUIREMENTS

1.1 GENERAL REQUIREMENTS

This document presents the Goddard Space Flight Center (GSFC) Global Precipitation Measurement (GPM) Microwave Imager (GMI) Program Safety and Mission Assurance (SMA) requirements. The developer shall have an organized SMA program for flight hardware/software and ground support equipment (GSE) as defined in this document appropriate to the nature of the particular hardware or software to be delivered. The SMA program shall encompass all software critical for mission success and the GSE that interfaces with flight equipment to the extent necessary to ensure the integrity and safety of flight items.

Managers of the assurance activities shall have direct access to developer management independent of project management, with the functional freedom and authority to interact with all other elements of the project.

A Quality Manual that provides for control and traceability through all phases of the design, manufacturing, and testing of deliverable items shall be made available for review. If needed, supplemental plans or procedures describing how the requirements of this document will be accomplished shall be developed and made available for project review. The rationale for any planned noncompliance with a requirement shall be submitted to the GSFC GPM Project for approval.

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

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 developer shall demonstrate how the hardware complies with GPM requirements.

1.3 SURVEILLANCE OF THE DEVELOPER

The work activities, operations, and documentation performed by the developer or his suppliers are subject to evaluation, review, audit, and inspection by government-designated representatives from the GSFC GPM Project, the Government Inspection Agency (GIA), or an independent assurance contractor (IAC). In-plant responsibilities and authority to those agencies will be documented via a letter of delegation or contract with the IAC. The quality assurance (QA) representatives shall be provided documents, records, and equipment needed to perform their assurance and safety related surveillance activities, including a suitable in-plant work area (upon request).

1.4 REFERENCE DOCUMENTS

To the extent referenced herein, applicable portions of the documents listed in Appendix A form a part of this document.

1.5 ACRONYMS AND GLOSSARY

Appendix B defines acronyms as applied in this document.

Appendix C defines terms as applied in this document.

1.6 DELIVERABLE DOCUMENTATION

Data Item Descriptions (DIDs) referenced herein can be found in 422-30-00-003 “GMI Contract Data Requirements List (CDRL)”. The following definitions apply with respect to GPM GMI Contract Data Requirements List (CDRL):

Deliver for Approval:	Documents in this category require written GSFC GPM Project approval prior to use. Requirements for resubmission shall be as specified in the letter(s) of disapproval.
Deliver for Review:	Documents in this category require written GSFC GPM Project approval, but developer may continue with associated work while preparing a response to GSFC comments, unless directed to stop.
Deliver for Information:	Documents in this category require receipt by GSFC GPM Project for the purpose of determining current program status, progress, and future planning requirements. When project evaluations reveal inadequacies, the developer will be directed to correct the documents.

2 QUALITY ASSURANCE REQUIREMENTS

2.1 GENERAL REQUIREMENTS

A Quality Management System (QMS) that is compliant with the minimum requirements of ANSI/ISO/ASQ Q9001-2000 (or equivalent) shall be planned, documented, and implemented. Certificates issued to ANSI/ISO/ASQC-Q9001-1994 may be utilized through December 2003, and then ANSI/ISO/ASQ Q9001-2000 shall apply. International Organization for Standardization (ISO) certification is not mandatory. The developer Quality Manual shall be made available for the GSFC GPM Project review at the developer's facility.

2.2 SUPPLEMENTAL QMS REQUIREMENTS

Assurance related requirements not adequately covered by ANSI/ISO/ASQ Q9001-2000 are identified in the following sections.

2.2.1 Control of Nonconforming Product

Nonconforming Product is a condition of any hardware, software, material, or service in which one or more characteristics do not conform to the requirements. Nonconforming products fall into two categories--discrepancies and failures.

a. 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 (typically addressed via Material Review Board (MRB) process).
b. A failure is a departure from specification that is discovered in the functioning or operation of the hardware or software (typically addressed via Failure Review Board (FRB) process).

2.2.1.1 Nonconformance Reporting and Corrective Action (NRCA)

The developer shall have a system for:

a. Identifying and reporting nonconforming hardware and software through a closed loop reporting system
b. Controlling and segregating nonconforming material from normal production flow
c. Ensuring that positive corrective action is implemented to preclude recurrence
d. Verifying the adequacy of implemented corrective action by audit and test, as appropriate

2.2.1.1.1 Reporting of Discrepancies

A system for documenting and tracking the disposition of all discrepancies shall be implemented. The GSFC GPM Project shall be provided access to developer GPM material discrepancy data files.

2.2.1.1.2 Reporting of Failures

A system for documenting and tracking the disposition of all failures shall be implemented. The GSFC GPM Project shall be provided access to developer GPM failure data files and FRB meeting schedules and agenda. Failure reporting shall begin with the first “power on application” tests at the component level or the first operation of a mechanical item (refer to DID 37).

Failure reports shall be submitted to the GSFC GPM Project office for review. Failures shall be reported within one business day of occurrence. Written reports documenting the failure shall be provided within 5 business days. The developer shall submit a list of all open failure reports and a separate list of the failure reports closed during the month.

2.2.2 Control of Monitoring and Measuring Devices

Testing and Calibration Laboratories shall be compliant with the requirements of ANSI/ISO 17025 – General Requirements for the Competence of Testing and Calibration Laboratories.

2.2.3 Configuration Management

Contractors and internal elements not utilizing the GPM CM System shall prepare and use a CM System that provides for control of changes to hardware and software products (refer to DID 5). The CM system shall address baseline control, configuration identification, configuration control, configuration status accounting, and configuration authentication through reports to and audits by the GPM Project CMO.

Control of changes to software products shall begin in the testing phase and continue until delivery. Formal Software CM (SCM) control shall be implemented in the development cycle no later than first use with flight hardware. A SCM baseline shall be established after each formal software build.

Any flight item that is found to be noncompliant with the requirements of the contract SOW or this MAR and is not reworked to be compliant, or is not replaced with a compliant item, shall be presented for disposition via a waiver. Waivers will typically affect mission requirements, system safety, cost, schedule or external interfaces. Waivers shall be submitted to the GSFC GPM Project office for final approval.

2.2.4 Requirements Flow-Down

The developer shall ensure flow-down of this MAR and system technical requirements to all suppliers and establish a process to verify compliance. The contract review and purchasing processes shall indicate the process for documenting, communicating, and reviewing requirements with sub-tier suppliers to ensure requirements are met.

2.2.5 Ground Support Equipment (GSE)

The developer shall address safety and mission assurance for GSE. Mechanical and electrical GSE and associated software that directly interfaces with flight deliverable items shall be assembled and maintained to the same standards as the deliverable flight items (reference Sections 10.3.2 and 10.4.3).

2.2.6 Ground Data System (GDS)

GPM GDS hardware and software design, implementation, test, operations, and maintenance requirements will be specified via a separate MAR document. GDS applies to the Mission Operations System (MOS), the Precipitation Processing System (PPS), and the Ground Validation System (GVS).

2.2.7 Manufacturing, Assembly, and Test Documentation

A traveler system shall be established to plan and document all manufacturing, assembly, and test activities. Traveler steps may reference controlled procedures, processes and associated drawings.

3 SYSTEM SAFETY REQUIREMENTS

3.1 GENERAL REQUIREMENTS

The system safety program shall be initiated in the concept phase of design and continue throughout all phases of the mission. GSFC shall certify safety compliance in support of the Pre-Ship Review. The system safety program shall accomplish the following:

a. Provide for the early identification and control of hazards to personnel, facilities, support equipment, and the flight system during all stages of project development including design, development, fabrication, test, handling, storage, transportation and prelaunch activities. The program shall address hazards in the flight hardware, associated software, ground support equipment, operations, and support facilities, and shall conform to the safety review process requirements of NASDA-STD-14C "Launch Vehicle Payload Safety Requirements" and NASA-STD-8719.8, "Expendable Launch Vehicle Payloads Safety Review Process Standard". CCR 0019
b. Meets the system safety requirements of NASDA-STD-14C and EWR 127-1 "Range Safety Requirements Eastern and Western Range".
c. Meets the baseline industrial safety requirements of the institution, EWR 127-1, applicable Industry Standards to the extent practical to meet NASA, NASDA, and OSHA design and operational needs, and any special contractually imposed mission unique obligations. This should be documented in the contractor's Facility Health and Safety Plan.

3.2 SYSTEM SAFETY PROGRAM PLAN (SSPP)

CCR 0019

The SSPP will be prepared by NASA/GSFC.

3.3 SAFETY ASSESSMENT REPORT

The developers shall perform and document a comprehensive evaluation of the mishap risk of their system. This safety assessment (refer to DID 38) shall identify all safety features of the hardware, software, and system design, as well as procedural related hazards present in the system. It shall include:

a. Safety criteria and methodology used to classify and rank hazards
b. Results of hazard analyses and tests used to identify hazards in the system
c. Hazard reports documenting the results of the safety program efforts
d. List of hazardous materials generated or used in the system
e. Conclusion with a signed statement that all identified hazards have been eliminated or controlled to an acceptable level
f. Recommendations applicable to hazards at the interface of their system
g. List of safety noncompliances and associated rationale for acceptance

This report is used to prepare the Safety Data Package (SDP) for submittal to the launch range.

3.4 SAFETY DATA PACKAGE

The SDP will be prepared by NASA/GSFC. CCR 0019

3.5 GROUND OPERATIONS PROCEDURES

All ground operations procedures to be used at GSFC facilities, other integration facilities, or the launch site shall be submitted to the GSFC GPM Project Office (refer to DID 39). All hazardous operations as well as the procedures to control them shall be identified and highlighted. All launch site procedures shall comply with the launch site and NASA safety regulations.

3.6 SAFETY NONCOMPLIANCE REQUESTS

When a specific safety requirement cannot be met, an associated safety noncompliance request shall be submitted to the GSFC GPM Project Office that identifies the hazard and shows the rationale for approval of a noncompliance, as defined in the requirements of EWR 127-1 (refer to DID 40).

3.7 SUPPORT FOR SAFETY WORKING GROUP MEETINGS

Technical support shall be provided to the Project for safety working group meetings, Technical Interface Meetings (TIM), and technical reviews, when necessary.

3.8 ORBITAL DEBRIS ASSESSMENT

Information required to produce the assessment consistent with NPD 8710.3, Policy for Limiting Orbital Debris Generation and NSS 1740.14, Guidelines and Assessment Procedures for Limiting Orbital Debris shall be provided to the GPM Project on request.

3.9 SOFTWARE SAFETY

A software safety program to identify and mitigate safety-critical software products shall be conducted in accordance with NASA-STD-8719.13A, “NASA Software Safety Standard". The developer approach to software safety shall be documented in the Safety Assessment Report.

The software safety program shall ensure that:

a. Safety-related deficiencies in specifications and design are identified and corrected
b. Software design incorporates positive measures to enhance the safety of the system

Hazards caused by software shall be identified as a part of the nominal hazard analysis process, and their controls shall be verified prior to acceptance. This verification of software hazard controls shall be coordinated with the software development group, and shall include the following activities:

a. Determination of the safety criticality for each software component
b. Analysis of the consistency, completeness, correctness, and testability of safety requirements

c. Analysis of design and code as required to ensure implementation of safety-critical requirements
d. Analysis of changes for safety impact

3.10 SAFETY COMPLIANCE

The Safety Compliance Certification will be prepared by NASA/GSFC. CCR 0019

4 RELIABILITY REQUIREMENTS

4.1 GENERAL REQUIREMENTS

A reliability program applicable to the development of all software and hardware products and processes shall be planned and implemented. The reliability program shall be tailored in order to:

a. Use Probability 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 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 prelaunch activities.
h. Ensure that the design permits easy replacement of parts and components and that redundant paths are easily monitored.

4.2 RELIABILITY PLAN

The developer shall prepare and maintain a Reliability Program Plan for the GPM Project applicable to the system level for which they are responsible. The plan shall address the GMI approach for the reliability activities and associated risk management functions, identify the reliability tasks to be performed, describe how reliability assessments will be integrated with the design, and discuss the scheduling of these tasks relative to the GPM Project milestones.

The Reliability Plan shall be made available at the developer's facility for the GPM Project review.

4.3 PROBABILISTIC RISK ASSESSMENT

The developer shall perform comparative numerical reliability assessments and/or predictions 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

The developer shall describe in their assessments the level of detail of a model suitable for performing the intended functions enumerated above. The assessments and updates shall be submitted to the GSFC GPM Project for information in accordance with DID 42. The results of any reliability assessment shall be reported at applicable PDRs and CDRs. 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.

4.4 RELIABILITY ANALYSES

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

4.4.1 Failure Modes and Effects Analysis and Critical Items List

A Failure Modes and Effects Analysis (FMEA) shall be performed early in the design phase to identify system design problems and associated critical items list (CIL) (refer to DID 41). As additional design information becomes available, the FMEA shall be refined.

Failure modes shall be assessed at the component interface level. Each failure mode shall be assessed for the effect at that level of analysis, the next higher level, and upward. The failure mode shall be assigned a severity category based on the most severe effect caused by a failure. Mission phases (launch, deployment, on-orbit operation) shall be addressed in the analysis.

Severity categories shall be determined in accordance with Table 4-1.

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

Results of the FMEA shall be used to evaluate the design relative to requirements (e.g., no single subsystem failure will prevent removal of power from the subsystem). Identified discrepancies shall be evaluated by management and design groups for assessment of the need for corrective action.

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.

Table 4-1
Severity Categories

Category	Severity	Description
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 could result in category 1 effects if all failed.
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

All failure modes that are assigned to Severity Categories 1, 1R, 1S, and 2, shall be itemized on a Critical Items List (CIL) and maintained with the FMEA report. Rationale for retaining the items shall be included on the CIL. The FMEA and CIL shall be held at the developer's facility for GSFC GPM Project review and/or audit. Results of the FMEA and the CIL shall be presented at all design reviews starting with the PDR. 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.

4.4.2 Fault Tree Analysis

Fault Tree Analyses (FTAs) that address both mission failures and degraded modes of operation shall be performed and retained for GPM Project review upon request. Beginning with each undesired state (mission failure or degraded mission), the fault tree shall be expanded to include all credible combinations of events/faults and environments that could lead to that undesired state. Component hardware/software failures, external hardware/software failures, and human factors shall be considered in the analysis. The fault tree itself is not a quantitative model, but becomes a quantitative assessment when combined with quantitative data as part of the PRA.

4.4.3 Parts Stress Analyses

Stress analyses shall be performed on Electrical, Electronic, and Electromechanical (EEE) parts and devices, as applied in circuits within each component for conformance with the de-rating policy of the EEE-INST-002. The analyses shall be performed at the most stressful part-level parameter values that can result from the specified performance and environmental requirements on the assembly or component. The analyses shall be performed in close coordination with the packaging reviews and shall be required input data for component-level design reviews. The analyses shall be documented and maintained at the developer's facility for the GSFC GPM Project review.

4.4.4 Worst-Case Analyses

Worst-case analyses shall be performed for critical parameters that are subject to variations that could degrade performance, where failure results in a severity category of 2 or higher, and provides data that question the flightworthiness of the design (refer to Table 4-1). Analyses or test or both shall demonstrate adequacy of margins in the design of electronic circuits, optics, electromechanical and mechanical items (mechanisms). The analyses shall consider all parameters set at worst-case limits and worst-case environmental stresses for the parameter or operation being evaluated. The analyses shall be updated in keeping with design changes. The analyses and updates shall be presented at applicable design reviews.

4.4.5 Software Reliability

A software reliability program shall be implemented addressing the tolerance of minor defects and the complete removal of critical defects. The software reliability program shall monitor and control defect removal, field performance, and include a model to predict the bug removal rate or number of bugs remaining based on testing, running time, or bug count. The software reliability model may be:

a. Time domain (related to the number of bugs at a given time during development)
b. Data domain (estimated by running the program for a subset of input data)
c. Axiomatic (based on laws/rules applied during the programming process)
d. Based other methods resulting from input data sets, logic paths, etc.

The developer shall document actions to verify that the software design and software engineering techniques improve the duration or probability of failure free performance and ensure repeatability of the software.

4.5 RELIABILITY ANALYSIS OF TEST DATA

Information acquired during the normal test program shall be fully utilized to assess flight equipment reliability performance and identify potential or existing problem areas.

4.5.1 Trend Analyses

Trend analyses shall be performed to the component level to track measurable parameters that relate to performance stability. Selected parameters shall be monitored for trends starting at component acceptance testing and continuing during the system integration and test phases. The monitoring shall be accomplished within the normal test framework (i.e., during functional tests, environmental tests, etc). A system shall be established for tracking total operational time and recording and analyzing the parameters, as well as any changes from the first observed value, even if the levels are within specified limits. A list of parameters to be monitored and the trend analysis reports shall be available for the GSFC GPM Project review at the developer's facility. Trend analysis data shall be reviewed with the mission operational personnel prior to launch, and the mission operational personnel shall continue recording trends throughout mission life for early detection of possible mission failure tendencies.

4.5.2 Analysis of Test Results

Test information, trend data, and failure investigations shall be analyzed to evaluate reliability implications. Identified problem areas shall be documented and directed to the attention of project management for action. This information shall be included in status reports to the GSFC GPM Project or it may be a separate monthly report. The results of the analyses shall be presented at design reviews. 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.

4.6 LIMITED-LIFE ITEMS

A Limited-Life Plan shall be prepared and implemented to identify and manage limited-life items. The Limited-Life Plan may be combined with the Reliability Plan and/or the Risk Management Plan, or maintained as a separate document. Limited-life items include all hardware that is subject to degradation because of age, operating time, or cycles such that their expected useful life is less than twice the required life when fabrication, test, storage, and mission operation are combined. Any items to be used, when the expected life is less than the mission design life, shall be approved by the GSFC GPM Project via a waiver.

The contractor shall maintain a list of limited-life items (refer to DID 43), which shall include the following data elements: item, expected life, required life, duty cycle, rationale for selection and effect on mission parameters. An item’s useful life period begins with fabrication and ends when the orbital mission is completed.

Records shall be maintained that allow 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 stresses the items. Refer to GEVS Section 2.3.5 and 2.4.5.1 for guidance.

4.7 CONTROL OF SUB-DEVELOPERS AND SUPPLIERS

System elements obtained from sub-developers and suppliers shall meet the project reliability requirements. All subcontracts shall include provisions for review and evaluation of the sub-developer and supplier reliability efforts at the prime developer’s discretion, and by the GSFC GPM Project office discretion.

Reliability requirements shall be tailored in hardware and software subcontracts for the project and shall exercise necessary surveillance to ensure that sub-developer and supplier reliability efforts are consistent with overall system requirements. As a result of this tailoring, the developer shall:

- Incorporate quantitative reliability requirements in subcontracted equipment specifications
- Ensure that sub-developers have reliability programs that are compatible with the overall program
- Review sub-developer assessments and analyses for accuracy and correctness of approach
- Review sub-developer test plans, procedures, and reports for correctness of approach and test details
- Attend and participate in sub-developer design reviews
- Ensure that sub-developers comply with the applicable system reliability requirements during the project operational phase

5 SOFTWARE ASSURANCE REQUIREMENTS

5.1 GENERAL REQUIREMENTS

A Software Development and Management Plan (SDMP) shall be prepared that addresses software development and software assurance functions in compliance with ANSI/ISO/ASQ 9001-2000, or equivalent (refer to DID 12). The SDMP shall be applied to software and firmware developed for the GPM Project.

5.2 SOFTWARE TECHNICAL REVIEWS

Software systems reviews shall be integrated with the technical reviews defined in Section 8.2. A program of software engineering working-level peer reviews shall be implemented (refer to Section 8.3) throughout the development life cycle to identify and resolve concerns prior to formal system level reviews. Topics that shall be addressed in the peer reviews include:

1. Design verification
2. Coding
3. Analyses and studies
4. Safety
5. Risk assessment, resolution and contingency plans
6. Procurements
7. Configuration management
8. Testability and test planning (including test anomalies and resolution)

5.3 SOFTWARE QUALITY ASSURANCE (SQA)

A SQA plan shall be prepared that describes how the software development activities will be planned, implemented, and documented. The SQA Plan can be part of the SDMP. The SQA program shall:

1. Ensure that assurance requirements are documented and satisfied throughout all phases of the development life cycle
2. Detect actual or potential conditions that could degrade quality, including deficiencies and system incompatibilities, and provide a process to ensure corrective action is taken and completed
3. Ensure timely and effective preventive action by identifying root causes of deficiencies and nonconformance
4. Ensure standards and procedures for management, engineering and assurance activities are specified and compliance by management and engineering personnel is verified

5.4 SOFTWARE VERIFICATION AND VALIDATION

A Software Performance Verification Matrix shall be prepared and maintained as a part of the System Performance Verification Matrix, or a separate document, that shows the flow-down of each software system performance requirement and the verification process (refer to Section 9.2.1.1). V&V activities shall be performed during each phase of the software life cycle and shall include the following:

1. Analysis of system and software requirements allocation, verifiability, testability, completeness, and consistency (including analysis of test requirements)
2. Design and code analysis including design completeness and correctness
3. Interface analysis (requirements and design levels)
4. Formal Inspections
5. Formal Reviews (phase transition reviews)
6. Test planning, performance, and reporting

Access to information shall be provided when requested by the GSFC GPM Project for the NASA Independent Verification and Validation (IV&V) effort. Wherever possible, electronic access shall be permitted.

5.5 SAFETY ASSURANCE

If any component is identified as safety critical, the developer shall conduct a software safety program on that component that complies with NASA-STD-8719.13A “NASA Software Safety Standard". Refer to Section 3.10 for additional software safety requirements.

5.6 GFE, EXISTING AND PURCHASED SOFTWARE/FIRMWARE (SW/FW)

If the developer is provided SW/FW as government-furnished equipment (GFE), or will use existing or purchased SW/FW; the developer shall ensure that the SW/FW meets the functional, performance, and interface requirements placed upon it. This SW/FW shall meet all applicable standards, including those for design, code, and documentation; or a waiver to those standards shall be submitted for GSFC GPM Project approval. Any significant modification to any piece of the existing SW/FW will be subject to all of the provisions of the developer’s SQA plan and the provisions of this MAR. The definition of a significant modification is a change of 20% of the lines of code in the SW/FW.

6 PARTS REQUIREMENTS

6.1 GENERAL REQUIREMENTS

An Electrical, Electronic, and Electromechanical (EEE) Parts Control Program shall be planned and implemented to ensure that all parts selected for use in flight hardware meet mission objectives for quality and reliability for a Quality Level 2 Mission.

A Parts Control Plan (PCP) shall be prepared as a part of the M&PCP, or a separate document, describing the approach and methodology for implementing the Parts Control Program. The PCP shall define the criteria for parts selection and approval based on the guidelines in this chapter. The PCP shall be made available for the GPM Project review at the developer's facility.

6.2 ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS

The NASA Parts Selection List (NPSL) has been developed to serve as a parts selection tool for design engineers and parts engineers supporting NASA space flight programs. The NPSL provides a detailed listing of EEE part types that the NASA EEE Parts Assurance Group (NEPAG) recommends for NASA flight projects based on evaluations, risk assessments and quality levels. In general, the parts listed in the NPSL:

- Have established procurement specifications
- Have available source(s) of supply
- Are capable of meeting a wide range of application needs
- Have been assessed for quality, reliability, and risk and found to meet the criteria for listing

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

6.2.1 Quality Level

The GMI parts reliability requirement is Quality Level 2. This was determined in accordance with EEE-INST-002. This document provides detailed instructions for the selection and testing of electronic parts to be used in GSFC space flight programs depending on mission requirements. The NPSL may be used as a vehicle for parts selection to the specified quality levels.

6.2.2 Parts Control Board

A Parts Control Board (PCB) shall be established. The PCB shall manage and control usage of EEE parts for the GPM project. The PCB shall approve all parts to be used to ensure that the mission requirements have been met. The PCB shall meet regularly to concur, resolve, and document any issues necessary for compliance. The PCB shall be responsible for developing and maintaining a GPM Project Approved Parts List (PAPL) including responsibility for all parts activities such as failure investigations, disposition of nonconformances, and problem resolutions.

The PCB operating procedures shall be included as part of the PCP. The GSFC GPM Project parts engineer shall be a voting member of all GPM PCBs. Meeting minutes or records shall be maintained to document all decisions made and a copy provided to the GSFC GPM Project Systems Assurance Manager (SAM) within five working days of convening the meeting. These minutes shall be placed into the project parts database. The project SAM retains the right to overturn decisions involving nonconformance within ten days after receipt of meeting minutes.

6.2.3 Parts Selection and Processing

All parts shall be selected and processed in accordance with the EEE-INST-002 "Instructions for EEE Parts Selection, Screening, Qualification and De-rating". All application notes in EEE-INST-002 shall apply. Parts shall be procured to Quality Level 2 as defined in EEE-INST-002 unless otherwise justified and approved by the PCB in accordance with the reliability program. These requirements shall then become the established criteria for parts selection, testing, and approval for the duration of the project, and shall be documented in the PCP. Parts selected from the NASA Parts Selection List are considered to have met all criteria of EEE-INST-002 for the appropriate parts quality level, and may be approved by the PCB provided all mission application requirements (performance, de-rating, radiation, etc.) are met. If the parts to be used on the Engineering Development Unit (EDU) are procured by methods 1 through 4 of EEE-INST-002, full paperwork and documentation (i.e. pedigree) are not required.

6.2.3.1 Custom Devices

In addition to applicable requirements of EEE-INST-002, custom microcircuits, hybrid microcircuits, MCM, ASIC, etc. planned for use shall be subjected to a design review. The review may be conducted as part of the PCB activity. The design review shall address, at a minimum, de-rating of elements, method used to assure each element reliability, assembly process and materials, and method for assuring adequate thermal matching of materials.

6.2.4 De-rating

All EEE parts shall be used in accordance with the de-rating guidelines of the EEE-INST-002. The developer's de-rating policy may be used in place of the EEE-INST-002 guidelines and shall be submitted with the PCP. Documentation on parts de-rating analyses shall be maintained and available for GSFC GPM Project review. **CCR 000016**

6.2.5 Radiation Hardness

All parts shall be selected to meet their intended application in the predicted mission radiation environment. The radiation environment consists of two separate effects, those of total ionizing dose and single-event effects. Analyses for each part with respect to both effects shall be documented. The possibility of displacement damage shall also be considered for parts susceptible to these effects.

6.2.6 Verification Testing

Verification of screening or qualification tests by re-testing is not required unless deemed necessary as indicated by failure history, Government-Industry Data Exchange

Program (GIDEP) Alerts, or other reliability concerns. If required, testing shall be in accordance with EEE-INST-002 as determined by the PCB. The developer, however, shall be responsible for the performance of supplier audits, surveys, source inspections, witnessing of tests, and/or data review to verify conformance to established requirements.

6.2.7 Destructive Physical Analysis (DPA)

A Destructive Physical analysis (DPA) shall be required for a sample of components identified based on failure history, construction concerns, vendor information, recent GIDEP alerts or advisories, or other reliability concerns. The DPA should be performed upon receipt of parts or prior to kitting.

A sample of each lot date code of microcircuits, hybrid microcircuits, and semiconductor devices shall be subjected to a DPA. DPA tests, procedures, sample size and criteria shall be as specified in GSFC specification S-311-M-70, Destructive Physical Analysis. Developer's procedures for DPA may be used in place of S-311-M-70 and shall be submitted with the PCP. Variation to the DPA sample size requirements, due to part complexity, availability, or cost, shall be determined and approved by the PCB on a case-by-case basis. In lieu of performing the required DPAs, the developer may provide the required number of DPA samples to GSFC for DPA. This shall be accomplished on a case-by-case basis through mutual agreement by the developer and GSFC.

6.2.8 Failure Analysis

Failure analyses, performed by experienced personnel, shall be required to support the nonconformance reporting system. The failure analysis laboratory (in-house or out-of-house) shall be equipped to analyze parts to the extent necessary to ensure an understanding of the failure mode and cause. The failure analyses shall be available to GSFC GPM Project for review upon request.

6.2.9 Parts Age Control

A parts age control process shall be developed. Prior to use, the PCB shall determine the required additional screening or lot sample testing based on the part type, complexity, expected failure mechanisms, and available data.

Parts drawn from controlled storage after 5 years from the date of the last full screen shall be subjected to a full 100 percent re-screen and sample DPA. Alternative test plans may be used as determined and approved by the PCB on a case-by-case basis. Parts over 10 years from the date of the last full screen or stored in other than controlled conditions where they are exposed to the elements or sources of contamination shall be submitted to the PCB for approval prior to use.

6.3 PARTS LISTS

Plans shall be prepared for generating and formatting a Project Approved Parts List (PAPL) and As-Built Parts Lists (ABPL). A PAPL and/or a Parts Identification List (PIL) shall be created and maintained for the duration of the project (refer to DID 44). The PAPL and PIL may be incorporated into one list, which shall be submitted to GSFC

GPM Project as a PIL, provided clear distinctions are made as to parts approval status and whether parts are planned for use in flight hardware.

6.3.1 Project Approved Parts List

The PAPL shall be the only source of approved parts for project flight hardware, but may contain parts not actually in flight designs. Only parts that have been evaluated and approved by the PCB shall be listed in the PAPL. Parts must be approved for listing on the PAPL before initiation of procurement activity. The criteria for PAPL listing shall be based on EEE-INST-002 and as specified herein. The PCB will ensure standardization and the maximum use of parts listed in the PAPL. The PAPL and all subsequent revisions shall be available for GSFC GPM Project review upon request.

6.3.2 Parts Identification List

As opposed to the PAPL, the PIL shall list all parts planned for use in flight hardware regardless of their approval status. The initial PIL and subsequent updates shall be submitted to GSFC in accordance with the contract delivery requirements. The developer shall provide the process as to how the PIL will be shared with GSFC's parts organizations.

6.3.3 As-Built Parts List

As opposed to the PAPL and PIL, an ABPL shall be prepared and submitted to GSFC in accordance with the contract delivery requirements. The ABPL identifies parts actually used in flight hardware with additional as-built information, such as parts manufacturers, lot date code and locations (circuit designations) where the parts are used in the hardware.

6.3.4 Parts List Information

Each parts list shall be a composite of the parts selections for each circuit design in the component, including EEE parts. As a minimum, each list shall contain the following information:

a. Part number
b. Description
c. Next assembly
d. Trace ID
e. Quantity issued/used
f. Serial Number
g. Order Type
h. P.O. Number
i. Name or Commercial and Government Entity (CAGE) Code of the part manufacturer
j. Manufacturing lot date code
k. Vendor ID
l. System used
m. Part specification control drawing number
n. Common designator or generic number
o. Drawing number of component to which the list pertains

6.4 GIDEP ALERTS AND PROBLEM ADVISORIES

The developer shall participate in the Government/Industry Data Exchange Program (GIDEP). Copies of documentation relevant to the GPM hardware that are sent to GIDEP shall be provided to the GSFC GPM Project SAM.

The developer shall review and disposition all GIDEP Alerts for impact on flight equipment. New parts procurements and parts pulled from storage shall be continuously checked for impact. Parts pulled from inventory for flight shall have the alert history checked for the period dating back to the date code marked on the parts. In addition, the developer shall review and disposition any NASA Alerts and Advisories. Alert applicability, impact, and corrective actions shall be documented and status provided to the GSFC GPM Project on a monthly basis. In the event of a conflict between GIDEP alerts and NASA Advisories, the NASA Advisory shall govern.

Sufficient records shall be maintained to determine applicability of any GIDEP alerts related to parts and materials selected or used for GPM.

7 MATERIALS, PROCESSES, AND LUBRICATION REQUIREMENTS

7.1 GENERAL REQUIREMENTS

A comprehensive Materials and Processes Control Program (M&PCP) shall be planned and implemented beginning at the design stage of the hardware to help ensure the success and safety of the GPM mission by the appropriate selection, processing, inspection, and testing of the materials and lubricants for use in flight hardware. The M&PCP Plan shall be made available for the GPM Project review at the developer's facility. The GSFC GPM Project Materials Assurance Engineer (MAE) review and approval is required for each material and lubrication usage or application in GPM flight hardware.

7.2 MATERIALS SELECTION REQUIREMENTS

In order to anticipate and minimize materials problems during space hardware development and operation, the developer shall, when selecting materials and lubricants, consider potential problem areas such as radiation effects, thermal cycling, stress corrosion cracking, galvanic corrosion, hydrogen embrittlement, lubrication, contamination, 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.

7.2.1 Material Identification List (MIL)

The contractor shall maintain a Materials Identification List (MIL) of all materials planned for use in flight hardware, regardless of their approval status (refer to DID 45). The initial MIL and subsequent updates shall be submitted to GSFC GPM Project in accordance with the contract delivery requirements. An As-Built Materials List (ABML) shall also be prepared and submitted to GSFC GPM Project in accordance with the contract delivery requirements. The ABML identifies materials and lubricants actually used in flight hardware with additional as-built information such as materials manufacturers and lot date codes.

The MIL shall include a Polymeric Materials and Composites Usage List, an Inorganic Materials and Composites Usage List, a Lubrication Usage List, and a Materials Process Utilization List.

7.2.2 Compliant Materials

Compliant materials shall be used in the fabrication of flight hardware to the extent practicable. In order to be compliant, a material must be used in a conventional application and meet the applicable selection criteria identified in Table 7.1. A compliant material does not require a Materials Usage Agreement (MUA).

Table 7-1
Material Selection Criteria

Type Launch	Payload Location	Flammability and Toxic Offgassing	Vacuum Outgassing	Stress Corrosion Cracking (SCC)
ELV	All	Note 1	Note 2	Note 3

NOTES:
1. Hazardous materials requirements, including flammability, toxicity and compatibility as specified in Eastern and Western Range 127-1 Range Safety Requirements, Sections 3.10 and 3.12.
2. Vacuum Outgassing requirements as defined in Section 7.2.6.2.
3. Stress corrosion cracking requirements as defined in MSFC-SPEC-522.

7.2.3 Noncompliant Materials

A material that does not meet the requirements of the applicable selection criteria of Table 7.1, or meets the requirements of Table 7.1 but is used in an unconventional application, shall be considered to be a noncompliant material. The proposed use of a noncompliant material requires that a Materials Usage Agreement (Figure 7-1) and/or a Stress Corrosion Evaluation Form (Figure 7-2) or developer's equivalent form, be submitted for review and approval by the GSFC GPM Project MAE.

7.2.3.1 Materials Used in “Off-the-Shelf-Hardware”

"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 noncompliant. A MUA shall be prepared and submitted to define what measures will 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 bake-out, material changes for known noncompliant materials, etc. When a vacuum bake-out is the selected method, it shall incorporate a quartz crystal microbalance (QCM) and cold finger to enable a determination of the duration and effectiveness of the bake-out as well as compliance with the GPM Project contamination plan and error budget.

7.2.4 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.

7.2.5 Non-conventional Applications

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. 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.

7.2.6 Polymeric Materials

A polymeric materials and composites usage list (Figure 7-3), or equivalent, shall be prepared and submitted as a part of the MIL for MAE review and approval. Material acceptability shall be determined on the basis of flammability, toxic offgassing, vacuum outgassing, and all other materials properties relative to the application requirements and usage environment.

7.2.6.1 Flammability and Toxic Offgassing

Material flammability and toxic offgassing shall be determined in accordance with the test methods described in NASA-STD-6001. ELV payload materials shall meet the requirements of Eastern and Western Range 127-1 Range Safety Requirements, Sections 3.10 and 3.12.

7.2.6.2 Vacuum Outgassing

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, the GSFC GPM Project may require lot testing of any material for which lot variation is suspected. In such cases, material approval is contingent upon the lot testing results. Only materials 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.

7.2.6.3 Shelf-Life-Controlled Materials

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 with expired date code requires a demonstration, by means of appropriate tests, that the properties of the materials have not been compromised for their intended use; such materials shall be approved by the GSFC GPM Project by means of a waiver. When a limited-life piece part is installed in a subassembly, the subassembly item shall be included in the Limited-Life Items List (refer to Section 4.6).

7.2.7 Inorganic Materials

An inorganic materials and composites usage list (Figure 7-4), or equivalent, shall be prepared and submitted as a part of the MIL for MAE review and approval. In addition, the developer may be requested to submit supporting applications data. The criteria specified in MSFC-SPEC-522 shall be used to determine that metallic materials meet the stress corrosion cracking (SCC) criteria. An MUA (Figure 7-1) and SCC evaluation (Figure 7-2) shall be submitted for GSFC GPM Project MAE review and approval for each material usage that does not comply with the MSFC-SPEC-522 SCC requirements.

7.2.7.1 Fasteners

The developer shall comply with the procurement documentation and test requirements for flight hardware and critical ground support equipment fasteners outlined in 541-PG-8072.1.2, Goddard Space Flight Center Fastener Integrity Requirements (formerly GSFC S-313-100). For a copy of 541-PG-8072.1.2, use the following hyperlink --- http://gdms.gsfc.nasa.gov/gdms/plsql/masterlist.menu. Material test reports for fastener lots shall be submitted to the GSFC GPM Project MAE for review upon request.

Fasteners made of plain carbon or low alloy steel shall be protected from corrosion. When plating is specified, it shall be compatible with the space environment. On steels harder than RC 33, plating shall be applied by a process which is not embrittling to the steel.

7.2.8 Lubrication

A lubrication usage list (Figure 7.5), or equivalent, shall be prepared and submitted as a part of the MIL for MAE review and approval. Also, supporting applications data shall be submitted, upon request.

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.

All lubricated mechanisms shall be qualified by life testing; or heritage of an identical mechanism used in identical applications (refer to DID 46). Evidence of qualification must be provided for GSFC GPM Project MAE review.

7.3 PROCESS SELECTION REQUIREMENTS

A material process utilization list (Figure 7-6), or equivalent, shall be prepared and submitted as a part of the MIL for MAE review and approval. A copy of any process shall be submitted to the MAE for review upon request. 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.

7.4 PROCUREMENT REQUIREMENTS

7.4.1 Purchased Raw Materials

The results of nondestructive chemical and physical tests; or a Certificate of Compliance (COC) shall accompany raw materials. This information need only be provided to the GSFC GPM Project when there is a direct question concerning the material's flightworthiness.

7.4.2 Raw Materials Used in Purchased Products

The developer shall require that their suppliers meet the requirements of Section 7.4.1 of this document and provide copies of the results of acceptance tests and analyses performed on raw material; or the COCs, upon request of the GSFC GPM Project.

MATERIAL USAGE AGREEMENT	USAGE AGREEMENT NO.:	PAGE OF

PROJECT:	SUBSYSTEM:	ORIGINATOR:	ORGANIZATION:

DETAIL DRAWING	NOMENCLATURE	USING ASSEMBLY	NOMENCLATURE

MATERIAL & SPECIFICATION	MANUFACTURER & TRADE NAME

USAGE	THICKNESS	WEIGHT	EXPOSED AREA	ENVIRONMENT		
				PRESSURE	TEMPERATURE	MEDIA

APPLICATION:

RATIONALE:

ORIGINATOR:	PROJECT MANAGER:	DATE:

Figure 7-1. MUA

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 ____________________
8. Sustained Tensile Stresses-Magnitude and Direction
   a. Process Residual ____________________
   b. Assembly ____________________
   c. Design, Static ____________________
9. Special Processing ____________________
10. 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 7-2. Stress Corrosion Evaluation Form

POLYMERIC MATERIALS AND COMPOSITES USAGE LIST

SPACECRAFT______ SYSTEM/EXPERIMENT ______ GSFC T/O ______

DEVELOPER/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 7-3. Polymeric Materials and Composites Usage List

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INORGANIC MATERIALS AND COMPOSITES USAGE LIST

SPACECRAFT________ SYSTEM/EXPERIMENT ________ GSFC T/O ________

DEVELOPER/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 7-4. Inorganic Materials and Composites Usage List

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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(1-10^2), B(10^2-10^4), C(10^4-10^6), 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.

Figure 7-5. Lubrication Usage List

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MATERIALS PROCESS UTILIZATION LIST

SPACECRAFT ____________ SYSTEM/EXPERIMENT ____________ GSFC T/O ____________

DEVELOPER/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

Figure 7-6. Materials Process Utilization List

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8 TECHNICAL REVIEW REQUIREMENTS

8.1 GENERAL REQUIREMENTS

The developer shall support a series of comprehensive system-level technical reviews that are conducted by the GSFC Office of Systems Safety and Mission Assurance (OSSMA) Systems Review Office (SRO). These reviews cover all aspects of flight and ground hardware, software, and operations for which the developer has responsibility. In addition, each developer shall conduct a Peer Review program of planned, scheduled and documented component and subsystem reviews of all aspects of their area of responsibility. In addition, each developer shall conduct a program of peer reviews at the component and subsystem level.

For each specified system-level review conducted by the GSFC SRO, the developer shall:

a. Develop and organize material for oral presentation to the GSFC GPM review team. Copies of the presentation material shall be available at each review.
b. Support splinter review meetings resulting from the major review.
c. Produce written responses to recommendations and action items resulting from the review.
d. Summarize, as appropriate, the results of the peer reviews at the component and subsystem level.

8.2 SYSTEM REVIEW PROGRAM

8.2.1 System Review Team (SRT)

The Chief of the SRO, or designated representative, will chair (or co-chair) all formal system level reviews and appoint key SRT members with technical expertise in subsystem design, systems engineering and integration, testing, and all other applicable disciplines, as review team members.

Personnel outside the GSFC may be invited as members or co-chairperson of the SRT if it is felt their expertise will enhance the SRT.

8.2.2 Spacecraft System Review Requirements

The spacecraft systems personnel shall present the following formal system reviews. Instrument systems personnel shall attend and participate in these reviews to the extent required by the GPM Project.

a. System Requirements Review (SRR)-- Not Applicable
b. Preliminary Design Review (PDR)--This review occurs early in the design phase but prior to manufacture of engineering hardware and the detail design of associated software (refer to DID 48). Where applicable, it shall include the results of test bedding, breadboard testing, and software prototyping. It shall also include the status of the progress in complying with the launch range safety requirements. At PDR, all of the hazards associated with the flight hardware shall have been identified and documented. Reentry considerations shall also be reviewed at PDR.

c. Critical Design Review (CDR)--This review occurs after the design has been completed but prior to the start of manufacturing flight components or the coding of software (refer to DID 49). It shall emphasize implementations of design approaches as well as test plans for flight systems including the results of engineering model testing. The status of the controls for the safety hazards identified at the PDR and the status of all presentations to the launch range shall be addressed. Reentry considerations shall also be reviewed at CDR.
d. Mission Operations Review (MOR)-- Not Applicable
e. Pre-Environmental Review (PER)--This review occurs prior to the start of environmental testing of the protoflight or flight system (refer to DID 50). The primary purpose of this review is to establish the readiness of the system for test and evaluate the environmental test plans.
f. Pre-Shipment Review (PSR)--This review shall take place prior to shipment of the instrument for integration with the spacecraft (refer to DID 51). The PSR shall concentrate on system performance during qualification or acceptance testing. Additional presentation agenda required at PSR include, the status of the safety items listed in the validation tracking log, the status of deliverable documents to the launch range, and any subsequent launch range issues or approvals needed prior to sending flight hardware to the range.
g. Flight Operations Review (FOR)-- Not Applicable
h. Launch Readiness Review (LRR)-- Not Applicable

8.2.3 Science Instrument System Review Requirements

The System Review Program for each instrument shall consist of PDR, CDR, PER, and PSR (as defined in Section 8.2.2). Spacecraft systems personnel shall attend and participate in these reviews to the extent required by the GPM Project.

8.2.4 Ground System Review Requirements

Ground Systems personnel shall attend and participate in these reviews to the extent required by the GPM Project. CCR 0019

8.2.5 System Safety Review Requirements

The safety aspects of the systems being reviewed are a normal consideration in the system evaluations conducted by the SRO. At each appropriate review, the developer shall demonstrate understanding of and compliance with the applicable launch range requirements, list any known noncompliance, and provide justification for any expected waiver conditions. In addition, the GPM Project will present the results of any safety reviews held with the Launch Test Range.

8.2.6 Formal System Review Schedule

The formal system reviews will be conducted on a schedule determined by the Chief, SRO, after consultation with the GSFC GPM Project Manager.

8.3 COMPONENT/SUBSYSTEM REVIEW REQUIREMENTS

A program of peer reviews at the component and subsystem levels shall be planned and implemented. Peer reviews shall occur during all phases of the project life cycle and should include a PDR and a CDR. In addition, packaging reviews shall be conducted on all electrical and electromechanical components in the flight system.

The peer reviews shall evaluate the ability of the component or subsystem to successfully perform its function under operating and environmental conditions during both testing and flight. The results of parts stress analyses and component packaging reviews, including the results of associated tests and analyses, shall be addressed at the peer reviews. Electrical interconnection harness design and assembly requirements shall be addressed.

The packaging reviews shall specifically address the following:

a. Placement, mounting, and interconnection of EEE parts on circuit boards or substrates.
b. Structural support and thermal accommodation of the boards and substrates and their interconnections in the component design.
c. Provisions for protection of the parts and ease of inspection.

Peer reviews, chaired by the developer, shall be conducted by personnel who are not directly responsible for design of the hardware under review. To promote continuity of the whole review program and allow for participation of the GSFC GPM and SRO, the peer review schedule shall be provided to the GSFC GPM Project. The results of the reviews shall be documented and the documents shall be made available for GSFC GPM Project review at the developer's facility.

9 DESIGN VERIFICATION REQUIREMENTS

9.1 GENERAL REQUIREMENTS

A verification program shall be conducted to ensure that the systems meet the specified mission requirements. The program shall consist of functional demonstrations, analytical investigations, physical measurements and tests that simulate all expected environments. Adequate verification documentation shall be provided including a verification plan and matrix, environmental test matrix and verification procedures.

The Verification Program begins with functional testing of assemblies. It continues through functional and environmental testing supported by appropriate analysis, at the component, subsystem and instrument levels of assembly. The program concludes with end-to-end testing of the entire operational system, including the instrument and the appropriate Ground Data System elements.

The General Environmental Verification Specification (GEVS) for ELV Payloads, Subsystems, and Components shall be used as a baseline guide for developing the verification program. For a copy of the GEVS document, use the following hyperlink --- http://arioch.gsfc.nasa.gov/302/verifhp.htm. Alternative methods are acceptable provided that the net result demonstrates compliance with the intent of the requirements.

9.2 DOCUMENTATION REQUIREMENTS

9.2.1 System Performance Verification Plan

A System Performance Verification Plan shall be prepared and implemented (reference GEVS Section 2.1 and DID 27). The plan shall define the tasks and methods required to verify the ability of the system to meet each specified mission requirement (structural, thermal, optical, electrical, guidance/control, RF/telemetry, science, mission operational, etc.), including records documenting compliance. Limitations in the ability to verify any performance requirement shall be addressed, including the addition of supplemental tests and/or analyses that will be performed and a risk assessment of the inability to fully verify the requirement.

The plan shall address how compliance with each specification requirement will be verified. If verification relies on the results of measurements and/or analyses performed at lower (or other) levels of assembly, this dependence shall be described.

For each analysis activity, the plan shall include objectives, a description of the mathematical model, assumptions on which the models will be based, required output, criteria for assessing the acceptability of the results, the interaction with related test activity, if any, and requirements for reports. Analysis results shall take into account tolerance build-ups in the parameters being used.

9.2.1.1 System Performance Verification Matrix

Documentation to demonstrate compliance with each system performance requirement shall be provided. A matrix, or equivalent system, shall be prepared and maintained that shows the flow-down of each performance requirement and the verification process. The matrix shall be iterated as verification is completed, kept current, and the status made available upon request. The matrix shall be included in the system review data packages showing the current verification status.

9.2.1.2 Performance Verification Procedures

For each performance verification test activity conducted at the component, subsystem, and instrument levels (or other appropriate levels) of assembly, procedures shall be prepared for verifying compliance with each system performance requirement. These procedures shall identify the verification article configuration and provide detailed instructions for accomplishing and documenting the verification activity. As-run copies of these procedures shall be archived for reference via a user-friendly retrieval process.

Verification test procedures shall contain details such as instrumentation monitoring, facility control sequences, test article functions, test parameters, pass/fail criteria, quality control checkpoints, data collection, and reporting requirements. The procedures shall also address safety and contamination control provisions.

9.2.1.3 Performance Verification Reports

Upon completion of each system performance verification activity, a report shall be prepared to summarize the findings and results (refer to DID 28). This report may be attached to the applicable as-run procedures or archived as a separate document. The combined matrix, as-run procedure records, and summary reports shall be developed and maintained "real-time" throughout the program; thereby demonstrating compliance with the applicable system performance requirements prior to delivery of hardware/ software to the next higher level of assembly.

9.2.2 Environmental Verification Plan

An Environmental Verification Plan (EVP) shall be prepared as part of the system performance verification plan, or as a separate document, to prescribe the tests and analyses which will collectively demonstrate that the hardware and software comply with the environmental verification requirements. The EVP shall provide the overall approach to accomplishing the environmental verification program. For each test, it shall include the level of assembly, the configuration of the item, objectives, facilities, instrumentation, safety considerations, contamination control, test phases and profiles, necessary functional operations, personnel responsibilities, and requirement for procedures and reports. It shall also define a rationale for retest determination that does not invalidate previous verification activities. When appropriate, the interaction of the test and analysis activity shall be described.

Limitations in the environmental verification program that preclude the verification by test of any system requirement shall be documented. Alternative tests and analyses shall be evaluated and implemented as appropriate, and an assessment of the project risk shall be included in the System Performance Verification Plan.

The preliminary plan shall provide sufficient verification philosophy and detail to allow assessment of the program. For example, for the environmental test portion of the verification, it is not sufficient to state that the GEVS requirements will be met. A program philosophy must be included. Examples of program philosophy are:

- All components shall be subjected to random vibration.
- Random vibration shall be performed at the subsystem level of assembly rather than at the component level.
- All instruments shall be subjected to acoustics tests and 3-axis sine and random vibration.
- All components shall be subjected to EMC tests.
- All flight hardware shall see 8-thermal-vacuum cycles prior to integration on the spacecraft.

9.2.2.1 Environmental Verification Specification

As part of the Performance Verification Plan, or as a separate document, an environmental verification specification shall be prepared that defines the specific environmental parameters that each system element is subjected to either by test or analysis in order to demonstrate its ability to meet the mission performance requirements. Such things as payload peculiarities and interaction with the launch vehicle shall be taken into account.

9.2.2.2 Environmental Test Matrix

As an adjunct to the system Environmental Verification Plan, a matrix, or equivalent system, shall be prepared and maintained that identifies all environmental tests that will be performed on each component, subsystem, and instrument clearly showing each environmental exposure and test article level of assembly. For an example of an environmental test matrix, refer to GEVS Figure 2.1-1. The purpose is to provide a ready reference to the contents of the environmental test program in order to prevent the deletion of a portion thereof without an alternative means of accomplishing the objectives. All flight hardware, spares and prototypes (when appropriate) shall be included in the matrix. The matrix shall be iterated as performance is completed, kept current, and the status made available upon request. The matrix shall be prepared in conjunction with the initial environmental verification plan and shall be updated as the project matures. This matrix may be combined with the Performance Verification Matrix on a common database. The matrix shall be included in the system review data packages showing the current status.

9.3 ELECTRICAL FUNCTIONAL TEST REQUIREMENTS

9.3.1 Electrical Interface Tests

As a part of the integration of a component or subsystem into the next higher level of assembly, electrical tests (reference GEVS Section 2.3.1) shall be performed to verify the interface configuration (power, grounds, commands, telemetry, signals, timing, etc,). Prior to mating with other hardware, electrical harnessing shall be tested to verify the wire routing, isolation, impedance, and overall workmanship. The following parameters shall be verified as a minimum:

- Accuracy (signals on correct pins and nowhere else)
- Inputs and outputs (unloaded and loaded)
- Specified range (high/low extremes as well as nominal)
- Range impacts (how range extremes of one signal affect related signals)

9.3.2 Aliveness Tests

An aliveness test may be performed to verify that the instrument and its major components are functioning.

9.3.3 Comprehensive Performance Tests (CPTs)

Appropriate CPTs shall be conducted at the subsystem and instrument levels of assembly (reference GEVS Section 2.3.2). The CPT shall be a detailed demonstration that the hardware and software meet their performance requirements within allowable tolerances. The CPT shall demonstrate the operation of redundant circuitry and satisfactory performance in all operational modes. CPTs shall demonstrate that, with the application of known stimuli and appropriate inputs, the test article will produce the expected responses and outputs within acceptable limits. The initial CPT shall serve as a baseline against which the results of all later CPT's can be readily compared.

9.3.4 Limited Performance Tests (LPTs)

Appropriate LPTs shall be conducted at the subsystem and instrument levels of assembly when CPTs are not warranted to demonstrate that the functional capability has not been degraded (reference GEVS Section 2.3.3). The LPT shall be a demonstration that the hardware and software meet their performance requirements within allowable tolerances. The LPT shall demonstrate the operation of redundant circuitry and satisfactory performance in selected operational modes. LPTs shall demonstrate that, with the application of known stimuli and appropriate inputs, the test article will produce the expected responses and outputs within acceptable limits. The initial LPT shall serve as a baseline against which the results of all later LPTs can be readily compared.

9.3.5 End-to-End Performance Tests

Prior to the Observatory PSR, an end-to-end compatibility test shall be performed to demonstrate the ground system capability to communicate with the Observatory (up-link and down-link) via the ground to space network (reference GEVS Section 2.8). Simulated normal orbital mission scenarios encompassing launch, systems turn-on, housekeeping, command/control, and stabilization/pointing shall be demonstrated, including the collecting, processing, and archiving of science data. The Observatory immunity to erroneous commands, autonomous safe-hold, and simulated anomaly recovery operations shall also be demonstrated.

9.3.6 Performance Operating Time and Failure-Free Performance Testing

At the conclusion of the performance verification program, the GMI Instrument shall have demonstrated failure-free performance testing for a minimum of 300 hours of operation. Failure-free operation during the GMI thermal-vacuum test exposure may be included.

9.4 STRUCTURAL, MECHANICAL, AND THERMAL REQUIREMENTS

Compliance with the specified structural and mechanical requirements shall be demonstrated through a series of interdependent test and analysis activities (reference

GEVS Section 2.4). These demonstrations shall verify design and specified factors of safety as well as ensure instrument interface compatibility, acceptable workmanship, and material integrity. Safety requirements shall be accomplished in conjunction with these demonstrations.

The design shall be sufficiently modularized to permit realistic environmental exposures at the component and subsystem level. Each subsystem shall be verified for each of the applicable requirements identified. It is the developer's responsibility to document a meaningful set of design verification activities that best demonstrates compliance with the systems performance requirements.

When planning the tests and analyses, the developer shall consider all expected environments, including the following:

- Structural loads (reference GEVS Section 2.4.1)
- Mass properties (reference GEVS Section 2.4.7)
- Mechanical mechanism functions (reference GEVS Section 2.4.5)
- Vibration (acoustics, 3-axis sine sweep and random) (reference GEVS Sections 2.4.2, 2.4.3)
- Mechanical shock (self induced, externally induced) (reference GEVS Section 2.4.4)
- Thermal balance (reference GEVS Section 2.6.3)
- Thermal vacuum (min cycles - 8 @ instrument/subsystem) (reference GEVS Section 2.6)

9.5 ELECTROMAGNETIC COMPATIBILITY (EMC) REQUIREMENTS

The electromagnetic characteristics of hardware shall be designed in accordance with the systems performance requirements (reference GEVS Section 2.5) so that:

a. The instrument and its subsystems and components do not generate electromagnetic interference that could adversely affect its own subsystems and components or the safety and operation of the launch vehicle or the launch site.
b. The instrument and its subsystems and components are not susceptible to emissions that could adversely affect their safety and performance. This applies whether the emissions are self-generated or derived from other sources or whether they are intentional or unintentional.

10 WORKMANSHIP STANDARDS

10.1 GENERAL REQUIREMENTS

An Electronic Packaging and Processes Program shall be planned and implemented to assure that all electronic packaging technologies, processes, and workmanship activities selected and applied meet mission objectives for quality and reliability.

10.2 APPLICABLE DOCUMENTS

The NASA preferred standards identified in the NASA technical standards program in the NASA Online Directives Information System (NODIS) shall be used. For copies of referenced documents, use the following hyperlink --- http://standards.nasa.gov/

- Conformal Coating and Staking: NASA-STD-8739.1, "Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies". CCR 0023
- Soldering – Flight, Surface Mounting Technology: NASA-STD-8739.2, "Surface Mount Technology".
- Soldering – Flight, Manual (hand): NASA-STD-8739.3, "Soldered Electrical Connections".
- Soldering – Ground Systems: Association Connecting Electronics Industries (IPC)/Electronics Industry Alliance (EIA) J-STD-001C, "Requirements for Soldered Electrical and Electronic Assemblies" (Class 2).
- 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".
- ESD Control: ANSI/ESD S20.20, "Protection of Electrical and Electronic Parts, Assemblies and Equipment" (excluding electrically initiated explosive devices).
- Printed Wiring Board (PWB) Design:
  - IPC-2221, "Generic Standard on Printed Board Design".
  - IPC-2222, "Sectional Design Standard for Rigid Organic Printed Boards".
  - IPC-2223, "Sectional Design Standard for Flexible Printed Boards".
- PWB Manufacture:
  - IPC A-600F, "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".

– IPC-6018, “Microwave End Product Board Inspection and Test”

Alternate workmanship standards may be used when approved by the GSFC GPM Project. The developer shall submit the alternate standard (identifying the differences between the alternate standard and the required standard) for GSFC GPM Project approval prior to use.

10.3 DESIGN

10.3.1 Printed Wiring Boards (PWB)

The PWB manufacturing and acceptance requirements identified in this chapter are based on using PWBs designed in accordance with the PWB design standards referenced in Section 10.2. 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 thickness, internal annular ring dimensions, etc.).

10.3.2 Ground Support Equipment (GSE)

GSE 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 assemblies (connectors, test cables, etc.) that:

- Mate with the flight hardware
- Will reside with the space flight hardware in environmental chambers or other test facilities that simulate a space flight environment

10.4 WORKMANSHIP REQUIREMENTS

10.4.1 Training and Certification

All personnel working on flight hardware (and applicable GSE) shall be certified as having completed the required training, appropriate to their involvement, as defined in the standards referenced in Section 10.2. This includes, but is not limited to, the aforementioned workmanship and ESD standards.

10.4.2 Flight Workmanship

Assemblies shall be fabricated in accordance with NASA-STD-8739.1, “Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies”, NASA-STD-8739.2, “Surface Mount Technology”, NASA-STD-8739.3, “Soldered Electrical Connections”, NASA-STD-8739.4 “Crimping, Interconnecting Cables, Harnesses, and Wiring”, NASA-STD-8739.5 “Fiber Optic Terminations, Cable Assemblies, and Installation”, and ANSI/ESD S20.20 “Protection of Electrical and Electronic Parts, Assemblies and Equipment” CCR 0023

PWBs shall be manufactured in accordance with the Class 3 requirements in the IPC PWB manufacturing standards and GSFC/S312-P-003, “Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses” referenced in Section 10.2. PWB test coupons shall be provided to the GSFC Materials Engineering Branch (MEB) or a GSFC/MEB approved laboratory for evaluation (refer to

DID 47). Approval shall be obtained prior to population of flight PWBs. Test coupons and test reports evaluated by a GSFC/MEB approved laboratory are required for delivery to GSFC/MEB.

10.4.3 GSE (non-flight) Workmanship

PWBs shall be manufactured in accordance with the Class 2 requirements in the IPC PWB manufacturing standards referenced in Section 10.2. Assemblies shall be fabricated using the Class 2 requirements of J-STD-001C, 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 shall take precedence. These requirements are not applicable to COTS products.

10.5 ESD REQUIREMENTS

An ESD Control Program, compliant with ANSI/ESD S20.20, Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding electrically initiated explosive devices), shall be documented and implemented. The program shall protect the most sensitive parts involved in the project and ensure that all manufacturing, inspection, testing, and other processes will not compromise mission objectives for quality and reliability due to ESD events. At a minimum, the ESD Control Program shall address training, protected work area procedures and verification schedules, packaging, facility maintenance, handling, storage, and shipping.

All personnel who manufacture, inspect, test, otherwise process 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 prior to handling any electronic hardware.

Electronic hardware shall be manufactured, inspected, tested, or otherwise processed only at designated ESD protective work areas. These work areas shall be verified on a regular schedule as identified in the ESD Control Program.

Electronic hardware shall be properly packaged in ESD protective packaging at all times when not actively being manufactured, inspected, tested, or otherwise processed. Materials selected for packaging or protecting ESD sensitive devices shall not leach chemicals, leave residues, or otherwise contaminate parts or assemblies.

10.6 NEW/ADVANCED PACKAGING TECHNOLOGIES

New and/or advanced packaging technologies (multi-chip modules (MCMs), stacked memories, chip on board, etc.) that have not previously been used in space flight applications shall be reviewed and approved through the Parts Control Board (PCB) as defined in Chapter 6. When appropriate, a detailed Technology Validation Assessment Plan (TVAP) may be developed for each new technology. A TVAP identifies the evaluations and data necessary for acceptance of the new/advanced technology for reliable use and conformance to project requirements.

New/advanced technologies will be part of the Parts Identification List (PIL) and Project Approved Parts List (PAPL) defined in Section 6.3 of this document.

11 RISK MANAGEMENT REQUIREMENTS

11.1 GENERAL REQUIREMENTS

A Continuous Risk Management (CRM) program applicable to the development of all software and hardware products and processes (flight and ground) shall be planned and implemented.

The developer shall:

a. Identify, document, evaluate, classify, and prioritize reliability risks before they become problems
b. Develop and implement risk mitigation strategies, actions, and tasks and assign appropriate resources
c. Track risk being mitigated; capture risk attributes and mitigation information by collecting data; establish performance metrics; and examine trends, deviations, and anomalies
d. Control risks by performing: risk close-out, re-planning, contingency planning, or continued tracking and execution of the current plan
e. Communicate and document (via the risk recording, reporting, and monitoring system) risk information to ensure it is conveyed between all levels of the project
f. Report on outstanding risk items at all management and design reviews.

11.2 RISK MANAGEMENT PLAN

A Risk Management Plan shall be prepared for the GPM Project (refer to DID 6) applicable to the system level for which they are responsible. The plan shall include risks associated with hardware (technical challenges, new technology qualification, etc.), software, COTS, system safety, performance, and programmatic risks (cost and schedule). The plan shall identify which tools and techniques will be used to manage risks. The risk areas that are identified shall be addressed at peer reviews (component, subsystem) and SRO reviews (instrument). The developer's surveillance plan (refer to Section 1.3) shall address the risk areas to ensure adequate mitigation steps are in place. Although not all risks will be fully mitigated, all risks shall be addressed with mitigation and acceptance strategies agreed upon at appropriate mission reviews.

12 CONTAMINATION CONTROL REQUIREMENTS

12.1 GENERAL REQUIREMENTS

A contamination control program shall be planned and implemented for GPM hardware. Specific cleanliness requirements shall be established and the approaches to meet the requirements shall be delineated in a Contamination Control Plan (CCP) deliverable to the GSFC GPM Project for concurrence.

Contamination includes all materials of molecular and particulate nature whose presence degrades hardware performance. The source of the contaminant materials may be the hardware itself, the test facilities, and the environments to which the hardware is exposed.

12.2 CONTAMINATION CONTROL PLAN

A CCP shall be prepared that describes the procedures that will be followed to control contamination (refer to DID 31). The CCP shall define a contamination allowance for performance degradation of contamination sensitive hardware such that, even in the degraded state, the hardware will meet its mission objectives. 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. In general, all mission hardware should be compatible with the most contamination-sensitive components.

12.3 MATERIAL OUTGASSING

All materials shall be screened in accordance with NASA Reference Publication 1124, Outgassing Data for Selecting Spacecraft Materials. Individual material outgassing data shall be established based on each component's operating conditions. Established material outgassing data shall be verified and shall be provided to the GSFC GPM Project for review.

12.4 THERMAL VACUUM BAKEOUT

Thermal vacuum bakeouts of all hardware shall be performed as required to protect contamination-sensitive components. 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. Thermal vacuum bakeout results shall be verified and shall be provided to the GSFC GPM Project for review.

A quartz crystal microbalance (QCM), or temperature controlled quartz crystal microbalance (TQCM), and cold finger shall be incorporated during all thermal vacuum bakeouts at the instrument level. These devices shall provide additional information to enable a determination of the duration and effectiveness of the thermal vacuum bakeout as well as compliance with the CCP.

12.5 HARDWARE HANDLING

The developer shall practice cleanroom standards in handling hardware. 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.

Appendix A REFERENCE DOCUMENTS LIST

DOCUMENT	DOCUMENT TITLE
ANSI/ESD S20.20	ESD Association Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding electrically initiated explosive devices)
ANSI/IPC-D-275	Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies
ANSI/ISO/ASQ Q9001-2000	American National Standard Quality Management System Requirements
ANSI/ISO/ASQC Q9001-1994	American National Standard Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation, and Servicing
ANSI/ISO/ASQC-Q10013	Guidelines for Developing Quality Manuals
ANSI/ISO-17025	General Requirements for the Competence of Testing and Calibration Laboratories
ASTM E-595	Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVCM) from Outgassing in a Vacuum Environment
EWR 127-1	Eastern and Western Range Policies and Procedures
GEVS	General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components, rev A, dated June 1996
EEE-INST-002	Instructions for EEE Parts Selection, Screening, Qualification and De-rating
GSFC S312-P-003	Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses
IEEE STD 730	IEEE Standard for Software Quality Assurance Plans
IPC-A-600	Acceptability of Printed Wiring Boards
IPC-A-610C	Acceptability of Electronic Assemblies
IPC/EIA J-STD-001C	Requirements for Soldered Electrical and Electronic Assemblies (Ground Systems) CCR 0023
IPC-2221	Generic Standard on Printed Board Design
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
IPC-2223	Sectional Design Standard for Flexible Printed Boards

IPC-6011	Generic Performance Specifications for Printed Boards
IPC-6012	Qualification and Performance Specification for Rigid Printed Boards
IPC-6013	Qualification and Performance Specification for Flexible Printed Boards
IPC-6018	"Microwave End Product Board Inspection and Test"
MIL-HDBK-217	Reliability Prediction of Electronic Equipment
MIL-STD 1629A	Procedures for Performing a Failure Mode Effects and Criticality Analysis
MIL-STD-756B	Reliability Modeling and Prediction
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-SPEC-522	Design Criteria for Controlling Stress Corrosion Cracking
NASA 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 Requirement and Test Procedures for Materials in Environments that Support Combustion
NASA-STD-8719.8	Expendable Launch Vehicle Payload Safety Review Process Standard
NASA-STD-8719.13A	Software Safety NASA Technical Standard (replaces NSS1740.13)
NASA-STD-8729.1	Planning, Developing, and Managing an Effective Reliability and Maintainability (R&M) Program
NASA-STD-8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
NASA-STD-8739.2	Workmanship Standard for Surface Mount Technology
NASA-STD-8739.3	Workmanship Standard for Soldered Electrical Connections
NASA-STD-8739.4	Workmanship Standard for Crimping, Interconnecting Cables, Harnesses and Wiring
NASA-STD-8739.5	Workmanship Standard for Fiber Optic Terminations, Cable Assemblies and Installation
NASDA-STD-14C	Launch Vehicle Payload Safety Requirements
NPD 8700.1	NASA Policy for Safety and Mission Success

CCR 0019 & 0023

CCR 0019

NPD 8710.3	NASA Policy for Limiting Orbital Debris Generation	CCR 0019
NPSL	NASA Parts Selection List (http://www.nepp.nasa.gov)	
NSS 1740.14	Guidelines and Assessment Procedures for Limiting Orbital Debris	
NUREG-0492	Fault Tree Handbook	
RADC-TR-85-229	Reliability Predictions for Spacecraft	
S-311-M-70	Specification for Destructive Physical Analysis	
541-PG-8072.1.2	Goddard Space Flight Center Fastener Integrity Requirements (formerly GSFC S-313-100)	
422-30-00-003	Global Precipitation Measurement (GPM) Microwave Imager (GMI) Contract Data Requirements List (CDRL)	

Appendix B ACRONYMS

ABML	As-Built Materials List
ABPL	As-Built Parts List
ADML	As-Designed Materials List
ADPL	As-Designed Parts List
ANSI	American National Standards Institute
ASQC	American Society for Quality Control
ASIC	Application Specific Integrated Circuits
ASTM	American Society for Testing of Materials
CAGE	Commercial and Government Entity
CCP	Contamination Control Plan
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CIL	Critical Items List
CM	Configuration Management
COC	Certificate of Compliance
COTS	Commercial Off-the-Shelf
CPT	Comprehensive Performance Test
CRM	Continuous Risk Management
CVCM	Collected Volatile Condensable Mass
DID	Data Item Description
DOD	Department of Defense
DPA	Destructive Physical Analysis
EDU	Engineering Development Unit
EEE	Electrical, Electronic, and Electromechanical
EIA	Electronics Industry Alliance
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
EVP	Environmental Verification Plan
EWR	Eastern and Western Test Ranges
FMEA	Failure Modes and Effects Analysis
FOR	Flight Operations Review
FRB	Failure Review Board
FTA	Fault Tree Analysis
GDS	Ground Data Systems
GEVS	General Environmental Verification Specification
GFE	Government-Furnished Equipment
GIA	Government Inspection Agency
GIDEP	Government Industry Data Exchange Program
GMI	GPM Microwave Imager
GPM	Global Precipitation Measurement

GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
I&T	Integration and Test
IAC	Independent Assurance Contractor
ICD	Interface Control Document
IPC	Institute for Interconnecting and Packaging Electronic Circuits
ISO	International Organization for Standardization
IV&V	Independent Verification and Validation
KHB	Kennedy Space Center Handbook
LPT	Limited Performance Test
LRR	Launch Readiness Review
M&PCB	Materials and Processes Control Board
M&PCP	Materials and Processes Control Program
MAE	Materials Assurance Engineer
MAR	Mission Assurance Requirements
MCM	Multi-Chip Module
MEB	Materials Engineering Branch
MIL	Materials Identification List
MOR	Mission Operations Review
MRB	Material Review Board
MSFC	Marshall Space Flight Center
MUA	Materials Usage Agreement
NAS	NASA Assurance Standard
NASCOM	NASA Communications Network
NASDA	National Space Development Agency of Japan
NDE	Non-Destructive Examination
NEPAG	NASA EEE Parts Assurance Group
NHB	NASA Handbook
NPD	NASA Policy Directive
NPSL	NASA Parts Selection List
NRCA	Nonconformance Reporting and Corrective Action
NSPAR	Nonstandard Parts Approval Request
NSS	NASA Safety Standard
OSHA	Occupational Safety and Health Administration
OSSMA	GSFC Office of Systems Safety and Mission Assurance
PAPL	Project Approved Parts List
PCB	Parts Control Board
PCP	Parts Control Plan
PDL	Product Design Lead
PDR	Preliminary Design Review
PER	Pre-Environmental Review
PFR	Problem/Failure Report
PI	Principal Investigator
PIL	Parts Identification List
POCC	Payload Operations Control Center

PRA	Probabilistic Risk Assessment
PSM	Project Safety Manager
PSR	Pre-Shipment Review
PWB	Printed Wiring Board
QA	Quality Assurance
QCM	Quartz Crystal Microbalance
SAM	Systems Assurance Manager
SCC	Stress Corrosion Cracking
SCM	Software Configuration Management
SCR	System Concept Review
SDMP	Software Development and Management Plan
SDP	Safety Data Package
SI	Science Instrument
SMA	Safety and Mission Assurance
SOW	Statement of Work
SQA	Software Quality Assurance
SQMS	Software Quality Management System
SRO	Systems Review Office
SRR	System Requirements Review
SRT	Systems Review Team
SSPP	System Safety Program Plan
TIM	Technical Interface Meeting
TML	Total Mass Loss
TQCM	Temperature Controlled Quartz Crystal Microbalance
V&V	Verification and Validation
VTL	Payload Safety Verification Tracking Log

Appendix C 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.

Assembly: Refer to Level of Assembly.

Audit: A review of the developers, 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.

Component: Refer to Level of Assembly.

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 contractor 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 that degrade the performance of hardware.

De-rating: 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 contractor'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.

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.

Developer: Any entity (federal or contractor) that provides goods or services to the project.

Discrepancy: Refer to 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 that 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. Refer to nonconformance.

Failure Free Hours of Operation: The number of consecutive hours of operation without failure the hardware and/or software (as appropriate) accumulated without an operating problem or anomaly since the last major hardware/software change (as appropriate), problem, or anomaly. Hours may be accumulated over various stages of hardware integration. (Refer to Section 9.3.6.)

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: Refer to 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 which is subjected 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.

Instrument: Refer to Level of Assembly.

Level of Assembly: The environmental test requirements of GEVS generally start at the component or unit level assembly and continue hardware/software build through the system level (referred to in GEVS as the payload or spacecraft level). The assurance program includes the part level. Validation testing may also include testing at the assembly and subassembly levels of assembly; for test record keeping these levels are combined into a "subassembly" level. The validation program continues through launch, and on-orbit performance. The following levels of assembly are used for describing test and analysis configurations:

a. Part: A hardware element that is not normally subject to further subdivision or disassembly without destruction of design use. Examples include resistor, integrated circuit, relay, connector, bolt, and gaskets.

b. Subassembly: A subdivision of an assembly. Examples are wire harness and loaded printed circuit boards
c. Assembly: A functional subdivision of a component consisting of parts or subassemblies that perform functions necessary for the operation of the component as a whole. Examples are a power amplifier and gyroscope.
d. Component or Unit: A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronic box, transmitter, gyro package, actuator, motor, battery. For the purposes of this document, "component" and "unit" are used interchangeably.
e. Subsystem: A functional subdivision of a payload consisting of two or more components. Examples are structural, attitude control, electrical power, and communication subsystems. Also included as subsystems of the payload are the science instruments or experiments.
f. Instrument: A spacecraft subsystem consisting of sensors and associated hardware for making measurements or observations in space. For the purposes of this document, an instrument is considered a subsystem (of the spacecraft).
g. Observatory: Refer to Payload. A payload" or "spacecraft" with the science instruments installed. For the purposes of this document, "payload" and "spacecraft" are used interchangeably. Other terms used to designate this level of assembly are laboratory, spacecraft, and satellite.
h. Payload: An integrated assemblage of modules, subsystems, etc., designed to perform a specified mission in space. For the purposes of this document, "payload" and "spacecraft" are used interchangeably. Other terms used to designate this level of assembly are laboratory, observatory, and satellite.
i. Spacecraft: Refer to Payload. For the purposes of this document, "payload" and "spacecraft" are used interchangeably. Other terms used to designate this level of assembly are laboratory, observatory, and satellite.

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

Module: Refer to Level of Assembly.

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 (refer to 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, nonconformance falls 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.

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.

Part: Refer to Level of Assembly.

Payload: Refer to Level of Assembly.

Performance Operating Time/Hours: The number of hours or amount of time that the hardware or software (as appropriated) was operated at any level of assembly or at a particular level of assembly as defined.

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: Refer to Hardware.

Prototype Testing: Refer to Hardware.

Qualification: Refer to 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 op within specified limits.

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

Section: Refer to Level of Assembly.

Similarity, Validation By: A procedure of comparing an item to a similar one that has been verified. Configuration, test data, application, and environment should 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.

Spacecraft: Refer to Level of Assembly.

Subassembly: Refer to Level of Assembly.

Subsystem: Refer to Level of Assembly.

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.

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.

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 (refer to Monitor).