Mission Assurance Requirements For Magnetospheric MultiScale (MMS) Mission Instrument Suite

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Chapter 1. Overall Requirements

1.0 GENERAL

The purpose of this document is to concisely present the Safety and Mission Assurance (SMA) requirements necessary for the Magnetospheric MultiScale (MMS) Mission.

The SMA requirements for the MMS Mission are structured to accept the increased risk that is inherent in a predominately non-redundant system. A strong parts and materials program, robust reliability and quality programs for hardware and software, and significant reliance on the test program will be key factors in balancing requirements against program cost and complexity constraints. The developer has responsibility and control over development of the deliverable hardware, the integration and test program, and delivery to the MMS Project. The MMS Project Office will monitor the developer's activities to provide insight into their compliance with SMA requirements. Emphasis will be focused on those activities that contribute most to product reliability and integrity. The developer shall ensure the Mission Assurance Requirements are flowed down to all of their vendors who are producing hardware, software, and critical ground support equipment.

It should be noted that "developer" as specified in this document applies to the instrument-suite vendor. In addition, the instrument-suite vendor shall flowdown this document in its entirety to each of their instruments and their subcontractors.

The developer shall use this (MAR) in developing their SMA approach, and realistically addressing the costs associated with these tasks. The quality program shall be modeled after ANSI/ASQC Q9001-2000, "Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation, and Servicing".

The developer is encouraged to make maximum use of existing practices and procedures in developing and implementing the safety and mission assurance program. The developer may offer an alternate method of meeting the intent of a requirement when such a method is better aligned with the manner in which the total work is to be accomplished, subject to MMS Project approval. The developer shall describe the plans for maintaining adequate internal documentation for all safety, reliability and quality assurance activities and for providing the Project with essential deliverable documentation. Upon request, all developer documents utilized on MMS shall be available for MMS Project Office review.

1.1 DESCRIPTION OF OVERALL REQUIREMENTS

This document presents a concise statement of the MMS mission SMA requirements. The developer shall plan and implement an organized SMA program for flight hardware, software and ground support equipment as defined in this MAR appropriate to the nature of the particular deliverable hardware or software to be delivered. The developer shall support and participate with the MMS Project in validating and periodically reviewing the SMA program.

Managers of assurance activities shall have direct access to developer management independent of Project management, along with the functional freedom and authority to interact with all other elements of the Project. The developer shall direct issues requiring Project management attention through the MMS Contracting Officer's Technical Representative (COTR).

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 requirements.

1.3 SURVEILLANCE OF THE DEVELOPER

The work activities, operations, and documentation performed by the developer or their suppliers are subject to evaluation, review, audit, and inspection by government-designated representatives from the MMS Project, the Government Inspection Agency, or an independent assurance contractor. The MMS Project will delegate in-plant responsibilities and authority to those organizations via a letter of delegation, letter of assignment, or task assignment.

The developer shall grant access for NASA and NASA representatives to conduct an assessment or survey upon notice. The developer, upon request, shall provide government assurance representatives with documents, records, databases and equipment required to perform their assurance and safety activities. The developer shall also provide the government assurance representative(s) with an acceptable work area within developer facilities.

1.4 SAFETY AND MISSION ASSURANCE VERIFICATION

The developer shall submit their Quality Manual for MMS Project review and approval. The MMS Systems Assurance Manager (SAM) will periodically validate the developers' overall SMA program to inform the Project office of potential problems or concerns.

Chapter 2. Quality Management System

2.0 QUALITY MANAGEMENT SYSTEM

Each developer shall define and implement a quality system based on ANSI/ISO/ASQ Q9001:2000 or equivalent that properly encompasses MMS flight hardware, software, and ground support equipment. Each developer's Quality Manual, as required by this standard, shall be provided to the MMS Project Office.

2.1 SUPPLEMENTAL QUALITY MANAGEMENT SYSTEM REQUIREMENTS

The following requirements supplement ANSI/ISO/ASQ Q9001:2000:

2.1.1 Nonconformance Reporting and Corrective Action

Each developer shall have a system for identifying and reporting hardware and software nonconformances through a closed loop reporting system; ensuring that positive corrective action is implemented to preclude recurrence and verification of the adequacy of implemented corrective action by audit and test as appropriate. Each developer shall provide the MMS Project with documentation describing how nonconforming material is designated, controlled, and segregated from normal production flow. The document shall describe in detail the approval authority for accepting the disposition with government concurrence, and how the documentation is controlled, i.e. Material Review Boards (MRB).

The Nonconformance Reporting and Corrective Action (NRCA) process shall include:

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

2.1.1.1 Material Review Board

Each developer shall inform the MMS Project of MRB meeting schedules and agendas with sufficient advance notice (four hours minimum) to permit MMS Project participation. Each developer shall provide the MMS Project access to their MMS material discrepancy-reporting database. The MMS Project COTR reserves disapproval rights on MRB decisions.

2.1.1.2 Reporting of Failure

Each developer shall report hardware/software failures to the MMS Project beginning with the first "power on application" tests at the major box, subsystem, instrument, or spacecraft level of flight hardware/software; or the first operation of a mechanical item. Reporting shall continue through successful closure by the Failure Review Board (FRB).

Failures shall be reported to the MMS Project office within one business day of occurrence. Failure reports documenting the failure and investigation shall be supplied to the MMS Project COTR within 5 business days of the occurrence. Monthly, each developer shall provide to the MMS Project a list of all open failure reports and a separate list of the failure reports closed during the month.

The MMS Project reserves disapproval rights on failure report dispositions prior to Observatory or Instrument Integration and Test (I&T) and final approval of all failure report dispositions starting at the first instrument I&T with the spacecraft.

Each developer shall implement a process for Software NRCA that addresses reporting, analyzing, and correcting nonconformances throughout the development life cycle. Each developer's Quality Manual shall provide for a corrective action process that tracks every nonconformance to its final disposition. The NRCA process for a software product shall start no later than the establishment of a configuration management baseline that includes the product.

2.1.2 Control of Monitoring and Measuring Devices

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

2.1.3 Configuration Management

Each developer shall perform configuration management (CM) in support of the MMS Project. Each developer shall document the CM process in a separate document submitted to the MMS Project. The configuration of deliverable items shall be maintained throughout all phases of assembly and test. Configuration verification shall be performed and documented as assemblies are incorporated into higher-level assemblies and at major Project milestones (i.e. pre-environmental test, pre-ship, pre-launch, etc). The CM system shall have a change classification and impact assessment process that results in Class 1 changes being forwarded to the MMS Project for disposition. Class 1 changes are defined as major changes that affect mission requirements, system safety, cost, schedule, and external interfaces. All other changes are considered to be Class 2 changes.

Any flight item that is found to be non-compliant with the requirements of the contract Statement Of Work (SOW) or the MAR and is not reworked to be compliant, or is not replaced with a compliant item, shall be dispositioned via a waiver. The developer shall submit Class I waivers to the MMS Project office for final approval. Waivers that affect mission requirements, system safety, cost, schedule, and external interfaces are to be processed as Class I. All other waivers are processed as Class 2.

Software CM is further defined in Chapter 5 of this MAR.

2.2 GROUND SUPPORT EQUIPMENT

Mechanical and electrical Ground Support Equipment (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, especially calibration control and configuration management. Parts and materials selection and reporting requirements are excepted as long as deliverable flight item contamination requirements are not compromised. Problem reporting shall begin with the first use of deliverable flight items and shall continue for the duration of the Project.

2.3 REQUIREMENTS FLOW-DOWN

Each developer shall ensure flow-down of technical requirements to all suppliers and establish a process to verify compliance. Each developer's contracts review and purchasing processes shall indicate the process for documenting, communicating, and reviewing requirements with sub-tier suppliers to ensure requirements are met. These mission assurance requirements, in their entirety, shall be flowed down to all institutions, domestic or foreign, providing hardware/software/ground system for the MMS mission, regardless of the funding source of the institution. All quality manuals have to demonstrate how their standards map to and are equivalent to the requirements in this MAR.

Chapter 3. System Safety Requirements

3.0 GENERAL REQUIREMENTS

Each developer shall implement a system safety program in accordance with contractual and regulatory requirements. The system safety program shall be initiated in the concept phase of design and continue thoughout all phases of the mission as defined by the requirements documents in this Chapter. Each developer shall implement a program that provides for early identification and control of hazards during design, fabrication, test transportation, and ground activities.

Each developer shall plan and implement a system safety program that accomplishes the following:

a. Identifies and controls hazards to personnel, facilities, support equipment, and the flight system during all stages of Project development. The program shall address hazards in the flight hardware, associated software, ground support equipment, and support facilities;

b. Meets the system safety requirements of EWR 127-1 "Range Safety Requirements Eastern and Western Range" and KHB 1710.2D, "Kennedy Space Center Safety Practices Handbook" for launches from KSC;

c. Meets the baseline industrial safety requirements of the institution, EWR 127-1, and any special contractually imposed mission unique obligations.

3.1 SYSTEM SAFETY IMPLEMENTATION PLAN

Each developer shall prepare a System Safety Implementation Plan (SSIP), that describes the systems safety implementation process for each flight mission which includes analysis, reduction, and/or elimination of hazards that may cause the following:

a. Loss of life or injury/illness to personnel;

b. Damage to or loss of equipment or property (including software);

c. Unexpected or collateral damage as a result of tests;

d. Failure of mission;

e. Loss of system availability;

f. Damage to the environment.

3.2 SAFETY PACKAGE

The spacecraft developer shall submit a Missile System Prelaunch Safety Package (MSPSP) consistent with the design maturity of the program at each of the phase C/D independent reviews, up to and including the Pre-shipment Review. It should be noted that all instrument and instrument-suite developers shall provide the necessary information to the spacecraft developer for completion of the MSPSP. The contents of the package shall be consistent with the requirements of the Eastern/Western Test Range requirements of EWR 127-1 and NASA safety KHB 1710.2D requirements.

Early in the design phase and continuing through the development effort, the spacecraft developer shall identify the ground operations hazards associated with the flight system, ground support equipment, and their interfaces. The MSPSP shall include, as a minimum, a detailed description of the payload design sufficient to support hazard analysis results, hazard analysis method, and other applicable safety related information. It may be necessary to conduct tests to determine if certain hazards exist. All hazards affecting personnel, launch vehicle hardware, or the spacecraft shall be identified. The analysis shall be updated as the hardware progresses through the stages of design, fabrication, and test. Operations that may require analyses include handling, transportation, functional tests, and environmental tests. The spacecraft developer shall submit the MSPSP for approval in accordance with the milestones required by the Eastern/Western Test Range safety regulation. A list of all hazardous/toxic materials and associated material safety data sheets shall be prepared and included in the final MSPSP.

3.3 SUPPORT FOR SAFETY WORKING GROUP MEETINGS

Each developer shall provide technical support to the MMS Project for safety working group meetings, Technical Interface Meetings, and technical reviews, when necessary.

3.4 ORBITAL DEBRIS ASSESSMENT

The spacecraft developer shall supply an Orbital Debris Assessment required to produce the assessment consistent with NSS 1740.14, Guidelines and Assessment Procedures for Limiting Orbital Debris. The spacecraft developer shall develop the debris assessment in accordance with the NASA policy NPD 8710.3. All instrument-suite developers shall provide the necessary information to the spacecraft developer for completion of the Orbital Debris Assessment.

3.5 SOFTWARE SAFETY ASSURANCE

Each developer shall conduct a software safety program to identify and mitigate safety-critical software products. If any software component is identified as safety-critical, each developer shall conduct a software safety program on that component in compliance with NASA-STD-8719.13A "NASA Software Safety Standard".

The software safety program shall ensure that:

1. Safety-related deficiencies in specifications and design are identified and corrected;
2. Software design incorporates positive measures to enhance the safety of the system;.
3. Software safety is included as an agenda item for formal reviews.

The software safety process shall include the following activities:

1. Determination of the safety criticality for each software component;
2. Analysis of the consistency, completeness, correctness, and testability of safety requirements;
3. Analysis of design and code to ensure implementation of safety-critical requirements;
4. Analysis of changes for safety impact.

3.6 SAFETY NONCOMPLIANCE/WAIVER REQUESTS

When a specific safety requirement cannot be met, the hardware developer shall submit an associated safety noncompliance/waiver request, which identifies the hazard and shows the rationale for approval of a noncompliance/waiver, as defined by applicable launch range requirements.

Chapter 4. Reliability Requirements

4.0 RELIABILITY REQUIREMENTS

Early in the design process each developer shall identify specific reliability concerns and the steps being taken to mitigate them. Reliability analyses of the design shall be conducted in accordance with the following sections. These analyses shall be reviewed with the MMS Project as they are developed and iterated, and reported in detail at the formal design reviews.

The Reliability program shall:

a. Use Probabilistic Risk Assessments (PRA) and Fault Tree Analyses (FTA) to assess, manage, and 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 stress applied to parts is not excessive;
d. Identify single point failure items, their effect on the attainment of mission objectives, and possible safety degradation;
e. Show that the reliability design meets mission design life requirements and is consistent among the systems, subsystems, and components;
f. Identify limited-life items and ensure that special precautions are taken to conserve their useful life for on-orbit operations;
g. Select significant engineering parameters for the performance of trend analysis to identify performance trends during pre-launch activities;
h. Ensure that the design permits easy replacement of parts and components and that redundant paths are easily monitored.

4.1 RELIABILITY ANALYSES

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

4.1.1 Failure Modes and Effects Analysis and Critical Items List

Each developer shall perform a Failure Modes and Effects Analysis (FMEA) early in the design phase to identify system design problems. As additional design information becomes available each developer shall refine the FMEA. 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 (e.g., launch, deployment, on-orbit operation, and retrieval) shall be addressed in the analysis.

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

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

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 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 instrument failure will prevent removal of power from the instrument). 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.

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 will be included on the CIL. The FMEA and CIL shall be submitted to the MMS Project in accordance with the contractual deliverable list. Results of the FMEA and the CIL shall be presented at all design reviews starting with the Preliminary Design Review. 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.

4.1.2 Probabilistic Risk Assessment And Fault Tree Analysis

Each developer shall use Probabilistic Risk Assessment (PRA) and Fault Tree Analysis (FTA) as part of the Project's risk management and reliability programs. Each developer shall include specific results in their Preliminary Design Review (PDR), Critical Design Review (CDR) and post-CDR reviews. The PRA and FTA shall be submitted to the MMS Project in accordance with the contractual deliverable list.

4.1.2.1 Fault Tree Analysis

Each developer shall perform FTAs that address both mission failures and degraded modes of operation. 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.

4.1.2.2 Probabilistic Risk Assessment (PRA)

Each developer shall perform PRAs that include an analysis of the probability (or frequency) of occurrence of a consequence of interest, and the magnitude of that consequence, including assessment and display of uncertainties. The PRA shall be implemented as part of the systems engineering process, based on comprehensive systems analysis with analytical support, and repeated periodically as the design matures and new data become available.

4.1.3 Parts Stress Analyses

Each developer shall perform stress analyses on Electrical, Electronic, and Electromechanical (EEE) parts and devices, as applied in circuits within each component for conformance with the derating policy of MIL-STD-975 and the GSFC PPL-21 (Preferred Parts List). 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 justification shall be included for all applications that do not meet the derating criteria.

4.1.4 Reliability Assessments and Predictions

When necessary/prudent or when agreed-upon with the MMS Project, each developer shall perform comparative numerical reliability assessments and/or reliability 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

Each 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 MMS Project for information in accordance with the contractual deliverable list. The results of any reliability assessment shall be reported at PDR and CDR. The presentations shall include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

4.2 RELIABILITY ANALYSIS OF TEST DATA

Each developer shall fully utilize test information during the normal test program to assess flight equipment reliability performance and identify potential or existing problem areas.

4.2.1 Trend Analyses

Each developer shall perform trend analyses 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). Each developer shall establish a system for 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 to the MMS Project upon request. 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.

4.2.2 Analysis of Test Results

Each developer shall analyze test information, trend data, and failure investigations to evaluate reliability implications. Identified problem areas shall be documented and directed to the attention of developer management for action. This information shall be included in the developer's monthly status reports to the MMS Project. 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.

4.3 LIMITED-LIFE ITEMS

Each developer shall identify and manage limited-life items. 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. The developer shall maintain a list of limited-life items 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 either (1) its fabrication or (2) installation into flight hardware, as appropriate, and ends when the orbital mission is completed.

The list of limited-life items should include selected structures, thermal control surfaces, instrument sensors, and electromechanical mechanisms. Atomic oxygen, solar radiation, shelf-life, extreme temperatures, thermal cycling, wear and fatigue should be used to identify limited-life thermal control surfaces and structure items. Mechanisms such as batteries, compressors, seals, bearings, valves, tape recorders, momentum wheels, gyros, actuators, and scan devices should be included when aging, wear, fatigue and lubricant degradation limit their life. 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. The use of an item whose expected life is less than its mission design life must be approved by the MMS Project by means of a program waiver.

4.4 CONTROL OF SUPPLIERS

Each developer shall ensure that system elements obtained from suppliers will meet the pertinent Project reliability requirements. All subcontracts shall include provisions for review and evaluation of the suppliers' reliability efforts by the prime developer at the prime developer's discretion, and by the MMS Project at its discretion.

Each developer shall tailor the reliability requirements of this document in hardware and software subcontracts for the Project and shall exercise necessary surveillance to ensure that suppliers' reliability efforts are consistent with overall system requirements. Each developer shall, as a result of this tailoring:

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

Chapter 5. Software Assurance Requirements

5.0 GENERAL REQUIREMENTS

Each developer shall define and implement a quality system based on ANSI/ISO/ASQ Q9001:2000 or equivalent that addresses software development and software assurance functions. The management program shall be described in a Software Development Plan which will be submitted to the MMS Project in accordance with the contractual deliverable list.

5.0.1 Management Review

Each developer's management process shall provide for a series of developer-presented formal reviews chaired by a government review panel. These reviews shall be chaired by the Systems Review Office, Code 301 at NASA/Goddard. However, if circumstances warrant it and the MMS Project and Code 301 office concurs, these Software Reviews may be combined with the formal Hardware Reviews. The formal review program shall consist of a Software Requirements Review (SRR), a Preliminary Design Review (PDR), a Critical Design Review (CDR), a Test Readiness Review (TRR), and an Acceptance Review. Each developer shall record minutes and action items during each review. Each developer shall respond to and follow through to closure actions assigned by the Project as a result of each review.

Records of reviews not required by the contract but conducted by the developer in accordance with the developer's Quality Management System, shall be available for review by the MMS Project upon request.

5.0.2 Peer Review

Each developer shall implement a program of engineering working-level reviews (peer reviews) 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.

5.1 SOFTWARE QUALITY ASSURANCE

Each developer shall plan, document and implement a software assurance program for software development activities. Each developer shall identify the Software Quality Manager responsible for Project software quality assurance. The software assurance 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. Assure timely and effective preventive action by identifying root causes of deficiencies and nonconformances.

5.1.1 Software Development Plan

Each developer shall document the software assurance processes to be applied to the software development effort in a Software Development Plan.

5.1.2 Process Monitoring

Each developer's quality assurance program shall ensure:

1. Standards and procedures for management, engineering and assurance activities are specified;
2. Management, engineering, and assurance personnel adhere to specified standards and procedures;
3. All plans (e.g., configuration management, risk management, etc.) are completed and implemented according to specified standards and procedures.

Each developer's quality assurance activities shall include:

1. Evaluation of specified standards and procedures;
2. Audits of management, engineering, and assurance processes;
3. Reviews of Project documentation including reports, schedules, and records;
4. Monitoring of formal inspections and formal reviews;
5. Monitoring/witnessing of formal and acceptance-level software testing.

5.2 SOFTWARE QUALITY ENGINEERING

Each developer shall implement a system for Software Quality Engineering (SQE) that ensures requirements for reliability, maintainability, usability and safety are built into the products produced at each phase of the software development life cycle.

The SQE program shall ensure that:

1. All quality requirements are defined in a manner that is measurable or otherwise verifiable;
2. Quality requirements are considered during design of the software;
3. The software is tested/measured to verify compliance with quality requirements.

The SQE program shall include the following activities:

1. Analysis, identification, and detailed definition of all quality requirements;
2. Quality engineering evaluations of standards, design, and code;
3. Collection and analysis of metric data pertaining to quality requirements.

5.2.1 Software Configuration Management

Each developer shall maintain a Software Configuration Management (SCM) system that provides control of changes to software products, beginning in the testing phase and continuing until government acceptance. SCM control shall be implemented in the development cycle no later than immediately prior to the first test for which test results must be reported to the MMS Project office.

Each developer shall ensure the configuration management system addresses baseline control, configuration identification, configuration control, configuration status accounting and configuration authentication. Each developer shall describe the SCM system in a Software Development Plan.

5.2.2 Status Reporting

Each developer shall include in the monthly status reports to the government information that identifies software development schedules, issues and action items.

5.3 SOFTWARE VERIFICATION AND VALIDATION

Each developer shall implement a Software Verification and Validation (V&V) program to ensure that software being developed or maintained satisfies functional and other requirements for each phase of the development.

5.3.1 Verification and Validation Activities

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.

5.3.2 Independent Verification and Validation

Each developer shall provide information requested by the MMS Project for the NASA Independent Verification and Validation (IV&V) effort. Wherever possible, each developer shall permit electronic access to the required information. Each developer shall allow NASA IV&V review and participation in development activities before final product delivery to NASA.

5.4 GOVERNMENT FURNISHED EQUIPMENT, EXISTING AND PURCHASED SOFTWARE AND FIRMWARE

If any developer is provided software as government-furnished equipment (GFE), or will use existing or purchased software and firmware, the developer shall ensure that the software and firmware meets the functional, performance, and interface requirements placed upon it. The developer shall ensure that the software and firmware meets applicable standards, including those for design, code, and documentation, or shall secure a MMS Project waiver to those standards. Any significant modification to any piece of the existing software shall be subject to the provisions of the developer's QMS and the provisions of this document. A significant modification is defined as the change of twenty percent of the lines of code in the software.

Chapter 6. Technical Review Requirements

6.0 GENERAL REQUIREMENTS

Each developer shall provide support for a formal review program chaired by GSFC that ensures that the MMS Mission Assurance review program:

1. Assures that the spacecraft, instrument(s) and supporting designs are consistent with the MMS Mission Requirements Document;
2. Assures that the characteristics of the systems are carefully examined to develop the best approach consistent with existing constraints and available resources;
3. Provides a means of periodic evaluation of the hardware, software, and ground support development;
4. Assures that end-item deliverables (systems and subsystems) meet the MMS requirements for performance.

Each developer shall provide the following formal system level reviews (Hardware and Software):

- System Requirement Review
- Preliminary Design Review;
- Critical Design Review;
- Pre-Environmental Review;
- Pre-Ship Review;

Each developer shall support the series of comprehensive system-level design reviews that are conducted by the GSFC Systems Review Office (SRO). The reviews cover all aspects of flight and ground hardware, software, and operations for which the developer has responsibility. For each specified system-level review conducted by the GSFC SRO, each developer shall:

a. Develop and organize material for oral presentation to the MMS government review team. “Draft” copies of the presentation material will be provided to the MMS Project 30 prior to the meeting. Copies of the “final” presentation material will be provided to the MMS Project 5 days prior to the meeting..

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 developer reviews at the component and subsystem level.

6.1 PHASE B REVIEWS

The System Review Team (SRT) shall include personnel experienced in subsystem design, systems engineering and integration, testing, and all other applicable disciplines. The SRO will chair these reviews. The review chairperson, in concert with the Mission Manager, and/or Principal Investigator (PI), appoints independent key technical experts as review team members. Phase B formally begins with the signed contract agreement for the mission and ends with formal confirmation for the mission by NASA headquarters following a Confirmation Review (CR). During Phase B the mission team shall hold a System Requirements Review (SRR) and Preliminary Design Review (PDR) prior to the CR.

System Requirement Review (SRR) – this review is keyed to the end of the definition study phase and shall evaluate the design approaches, hardware/software tradeoffs, software requirements and the operational concepts.

Preliminary Design Review (PDR) – This review occurs early in the design phase prior to manufacture of engineering hardware and the detail design of associated software. Where applicable, the developer shall include the results of test bedding, breadboard testing, and software prototyping. Long-lead procurements shall be discussed. Efforts to retire identified risk items shall be discussed. Efforts to retire identified risk items shall be discussed.

6.2 PHASE C/D REVIEWS

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. Each developer shall emphasize implementations of design approaches as well as test plans for flight systems including the results of engineering model testing.

Pre-Environmental Review (PER) – This review occurs prior to the start of environmental testing of the flight instrument. Each developer shall present the readiness of the flight hardware and software, and facilities for system level test and evaluate the environmental test plans.

Pre-Shipment Review (PSR) – This review shall take place prior to shipment of the instrument-suite to the observatory. Each developer shall present evidence to show that testing has been completed with no unacceptable open issues and will evaluate the readiness of the hardware and software for flight. Each developer shall address the testing on flight hardware and software, verification and documentation of the hardware and software configuration, identification of outstanding safety risks, disposition of waivers/deviations/open issues, compatibility of spacecraft and ground support equipment, and orbital operations plans

6.3 PEER REVIEWS

Engineering peer reviews of component and subsystem hardware/software chaired by each developer shall occur during all phases of the Project life cycle. These reviews are expected to be the most detailed of the MMS reviews. It is the intent of the peer reviews that participants generate a detailed understanding of the component and subsystem designs' ability to meet higher level system and mission requirements. Effective peer reviews will enable significant streamlining of the content of higher-level formal reviews. To promote continuity of the whole review program, each developer shall allow notify the MMS Project of the peer review schedule to allow participation by the GSFC Systems Review Office and the GSFC MMS Project technical experts at the peer review sessions. All peer reviews shall be completed prior to their formal Code 300 review.

6.4 REVIEW ACTION ITEM TRACKING

Each developer shall implement a system for tracking the status and resolution of Action Items initiated during peer and formal reviews, and the status of these Action Items shall be reported at the formal reviews. Action Items shall be assigned unique control numbers that identify the item under review and the review type. The numbering/tracking system shall be capable of differentiating Action Items of any specific system review from all other system reviews.

Chapter 7. Design Verification Requirements

7.0 GENERAL REQUIREMENTS

Each developer shall conduct a system performance verification program covering the component through Instrument or Observatory levels. Each developer shall document the overall verification plan, implementation, and results to ensure that the spacecraft and instruments meet the specified mission requirements, and to provide traceability from mission requirements through launch and on-orbit capability. The program shall consist of a series of functional demonstrations, analytical investigations, physical property measurements, and environmental tests that simulate the environments encountered during handling and transportation, pre-launch, launch, and on-orbit. Each developer shall maintain as-run verification procedures, including all test and analysis data.

All flight hardware and software shall undergo qualification to demonstrate compliance with the requirements of this section. In addition, all other hardware (flight follow-on, spare and re-flight) shall undergo acceptance in accordance with the requirements of this section.

The Verification Program shall begin with functional testing at the component level of assembly. It shall continue through functional and environmental testing at the component, subsystem, instrument, spacecraft and observatory levels of assembly, supported by appropriate analysis. The program shall conclude with end-to-end testing of the entire operational hardware/software system at the observatory level including the instruments, the ground control center, and the appropriate network elements.

The GEVS-SE for STS & ELV Payloads, Subsystems, and Components shall be used to develop each instrument/instrument-suite verification program. The GEVS-SE document is available at http://arioch.gsfc.nasa.gov/302/verifhp.htm.

7.1 REQUIREMENTS VERIFICATION MATRIX

Each developer shall provide adequate documentation to demonstrate compliance with all performance requirements identified in the contract SOW. Each developer shall have a Requirements Verification Matrix or equivalent system that shows the flow-down of all requirements and the methods of verification. The Requirements Verification Matrix and supporting documentation shall provide the following information:

- Systems Performance Validation Plan flow-down;
- Basis for verification method (test, analysis, similarity, heritage, etc.);
- Dates accomplished with name and signature of person performing the action;
- Dates verified with name and signature of person verifying performance;
- Definition of specific environments for each requirement;
- Tracking of requirements verified against those planned;
- Detailed supporting documentation of compliance with each requirement.

7.2 ENVIRONMENTAL TEST PROGRAM

Each developer shall conduct an environmental test program for flight hardware sufficient to demonstrate design qualification, acceptance, and to test for workmanship. Spacecraft developer should provide environmental test levels to the instrument-suite developers. Functional testing shall be performed before, during, and after environmental tests, as appropriate. Each developer's environmental test plans shall define the specific parameters associated with the planned environmental tests. Each developer shall consider payload peculiarities and interactions with the launch vehicle in defining these environmental parameters. These special interactions include subjects like resonance de-tuning, EMI/EMC effects, pyrotechnic firing disturbances, etc. as applicable.

Each developer shall establish environmental test levels to encompass predictions based on launch vehicle information.

Prototype and protoflight hardware shall undergo appropriate qualification tests to demonstrate compliance with the design requirements. Flight, flight spare, follow-on, and re-flight hardware shall undergo flight-like acceptance test levels to verify acceptable assembly workmanship.

The following environmental exposures are required as a baseline for MMS Observatories and Instruments:

Components:

Sine Vibration, Random Vibration, Strength, EMI/EMC, Thermal Vacuum/Thermal Balance, Mass Properties, and Deployment shall be performed. Comprehensive Performance Tests (CPTs) shall be part of the verification program at these levels of assembly.

Observatory and Instrument Levels:

Strength (static or quasi-static), Low level (Pogo) Sine Vibration, Random Vibration, Acoustics, Mechanical Shock, EMI/EMC, Thermal Vacuum/Thermal Balance, Mass Properties, and Deployment shall be performed.

Repeated functional tests should be used to demonstrate the growing maturity of the instruments or spacecraft subsystems, perform trending analysis, and to baseline performance status before each environmental test. CPT demonstrations shall be performed to verify full mission hardware compliance, compatibility, and operability; and to perform trending analysis.

7.3 END-TO-END TEST

Prior to the PSRof the four MMS Observatories, each developer shall perform and/or participate in an end-to-end compatibility test to demonstrate the ground system capability to communicate with each observatory (up-link and down-link) via the ground to space network. 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. Observatory immunity to erroneous commands, autonomous safe-hold, and simulated anomaly recovery operations shall also be demonstrated.

7.4 DEMONSTRATION OF FAILURE-FREE OPERATION

At the conclusion of the instrument-suite verification program prior to delivery to the observatory, the MMS instrument-suite shall have demonstrated a period of 100 hours of consecutive failure-free operation in its simulated mission orbital environment. Prior to shipment to the launch site the MMS observatory (instrument-suite/spacecraft), shall have demonstrated a period of 200 hours of consecutive failure-free operation in its simulated mission orbital environment. The demonstration may be performed at the subsystem level when the time period of demonstration cannot be practically accomplished at the system level of assembly. Major hardware changes during or after the failure-free period will invalidate any previous demonstration. Note: These hours do not have to be consecutively powered, the instrument suite is allowed to power off and on to achieve this total.

CHAPTER 8. Workmanship Standards and Processes

8.0 GENERAL REQUIREMENTS

Each developer shall plan and implement a Workmanship Program to assure that all electronic packaging technologies, processes, and workmanship activities selected and applied meet mission objectives for quality and reliability.

8.1 APPLICABLE DOCUMENTS***

Conformal Coating and Staking: NASA-STD-8739.1, Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies;

Soldering – Flight, Surface Mount Technology: NASA-STD-8739.2, Surface Mount Technology;

Soldering – Flight, Manual (hand): NASA-STD-8739.3, Soldered Electrical Connections;

Soldering – Ground Systems: IPC/EIA J-STD-001C, Requirements for Soldered Electrical and Electronic Assemblies;

Electronic Assemblies – Ground Systems: IPC-A-610C, Acceptability of Electronic Assemblies;

Crimping, Wiring, and Harnessing: NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring;

Fiber Optics: NASA-STD-8739.5, Fiber Optic Terminations, Cable Assemblies, and Installation;

Electrostatic Discharge Control (ESD): ANSI/ESD S20.20-1999 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)

Printed Wiring Board (PWB) Design:

- IPC D-275 Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies
- IPC-2223, Sectional Design Standard for Flexible Printed Boards;

Printed Wiring Board Manufacture:

- IPC A-600, Acceptability of Printed Boards
- IPC-6011, Generic Performance Specification for Printed Boards
- IPC-6012, Qualification and Performance Specification for Rigid Printed Boards
  - Flight Applications – Supplemented with: GSFC/S312-P-003, Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses
- IPC-6013, Qualification and Performance Specification for Flexible Printed Boards.

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

8.2 DESIGN

8.2.1 Printed Wiring Boards

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

8.2.2 Assemblies

The design considerations listed in the NASA workmanship standards listed above should be incorporated to the extent practical.

8.2.3 Ground Systems That Interface With Space Flight Hardware

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

8.3 WORKMANSHIP REQUIREMENTS

8.3.1 Training and Certification

All personnel working on deliverable hardware shall be certified as having completed the required training, appropriate to their involvement, as defined in the above standards.

8.3.2 Flight and Harsh Environment Ground Systems Workmanship

8.3.2.1 Printed Wiring Boards

Printed Wiring Boards (PWBs) shall be manufactured in accordance with the Class 3 Requirements in the above referenced PWB manufacturing standards. Each developer shall provide printed wiring board (PWB) coupons to the MMS Project SAM, or to a GSFC-approved laboratory for evaluation. PWB coupon approval shall be obtained prior to population of flight PWBs. Each developer may have the coupons evaluated at an alternate laboratory if written approval is obtained from the MMS Project SAM in advance. If an approved alternate laboratory is used, delivery of the test reports to the MMS Project SAM is required.

8.3.2.2 Assemblies

Assemblies shall be fabricated using the appropriate workmanship standards listed above (i.e., NASA-STD-8739.3 for hand soldering; NASA-STD-8739.4 for crimping/cabling; NASA-STD-8739.5 for fiber optic termination and installation; etc.).

8.3.3 Ground Systems (non-flight) Workmanship

8.3.3.1 Printed Wiring Boards

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

8.3.3.2 Assemblies

Assemblies shall be fabricated using the Class 2 Requirements of J-STD-001C and IPC-A-610C, and ANSI/ESD S20.20-1999. If any conflicts between J-STD-001C and IPC-A-610C are encountered, the requirements in J-STD-001C shall take precedence.

8.3.4 Documentation

Each developer shall document the procedures and processes that will be used to implement the above referenced workmanship, design, and ESD control standards including any procedures or process requirements referenced-in via those standards.

Each developer may propose alternate standards. Proposals for use of alternate standards must be accompanied by objective data that documents mission safety or reliability will not be compromised. Each developer's use of alternate standards is limited to the MMS Project and is allowed only after they have been reviewed and approved by the MMS Project office.

8.4 NEW OR ADVANCED PACKAGING TECHNOLOGIES

New and/or existing advanced packaging technologies (e.g., multi-chip modules (MCMs), stacked memories, chip on board, ball grid array (BGA), etc.) shall be reviewed, approved by the Project Parts Control Board and included in the Project Approved Parts List (PAPL).

8.5 HARDWARE HANDLING

The handling of flight hardware shall be performed by designated personnel in accordance with approved procedures that address cleaning, handling, packaging, tent enclosures, shipping containers, bagging (e.g., antistatic film materials), and purging. Procedures for the control of contamination shall be implemented in all phases of assembly and test. All personnel working on flight hardware shall be certified as having completed the required certifications prior to handling any flight hardware. This includes, but is not limited to, the aforementioned workmanship, design and ESD awareness courses.

8.6 ELECTROSTATIC DISCHARGE CONTROL REQUIREMENTS

Each developer shall document and implement an ESD Control Program in accordance with ANSI/ESD S20.20-1999 suitable to protect the most sensitive components used in the Project. At a minimum, the ESD Control Program shall address training, protected work area procedures and verification schedules, packaging, facility maintenance, 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 S20.20-1999 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 developer's 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.

Chapter 9. Parts Requirements

9.0 ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS

Each developer shall plan and implement an Electrical, Electronic, and Electromechanical (EEE) Parts Control Program to assure that all parts selected for use in flight hardware meet mission objectives for quality and reliability.

Each developer shall have a Parts Control Program (PCP) describing the approach and methodology for implementing Parts Control on MMS. The PCP will also define each developer's criteria for parts selection and approval based on the guidelines of this section.

All part commodities identified in the NASA Parts Selection List are considered EEE parts and will be subjected to the requirements set forth in this section. 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.

9.0.1 Parts Control Board

Each developer shall establish a Parts Control Board (PCB) or a similar documented system to facilitate the management, selection, standardization, and control of parts and associated documentation for the duration of the contract. The PCB shall be responsible for the review and approval of all EEE parts for conformance to established criteria including radiation effects, and for developing and maintaining a Parts Identification List (PIL) and Project Approved Parts List (PAPL). In addition, the PCB shall be responsible for all parts activities such as failure investigations, disposition of non-conformances, and problem resolutions. PCB operating procedures shall be included as part of the PCP.

If there are any parts issues, which the developer and GSFC cannot resolve at the PCB level, then the GSFC Parts Engineer shall inform the System Assurance Manager (SAM) and the Project Manager of the issue and the associated risk. After this discussion, the GSFC Project Manager will decide whether to accept the risk and ask the developer to submit a waiver to document the issue, or to elevate the issue to the developer's management for resolution.

9.0.1.1 PCB Meetings

PCB meetings shall be convened on a regular basis or as needed. GSFC shall participate in PCB meetings and shall be notified ,and provided with an agenda in advance of all upcoming meetings (minimum 5 days notice). As a minimum, membership shall consist of the developer's Project Parts Engineer (PPE), the NASA System Assurance Manager (SAM) and NASA Project Parts Engineer. The PCB shall be chaired by the developer's PPE. GSFC shall have voting rights at the meetings in order to concur or veto decisions. . Each developer will maintain meeting minutes or records to document all decisions made and a copy provided to GSFC within five days of convening the meeting. PCB activities may be audited by GSFC on a periodic basis to assess conformance to the developer's PCP.

Developer or subcontractor PCB members who are presenting part approval requests to the PCB shall provide part approval documentation as necessary to describe testing, screening, application and derating. Preparation of Nonstandard Parts Approval Requests (NSPARs) is not required. Parts previously approved by GSFC for the developer or subcontractor(s) via a NSPAR or by other means may be submitted to the PCB as an aid in documenting a specific need or application but does not constitute automatic approval for use in the MMS Project application.

9.0.2 Parts Selection and Processing

All parts shall be selected and processed in accordance with the GSFC 311-INST-001, Revision B "Instructions for EEE Parts Selection, Screening and Qualification" for Quality Level 2. All application notes in 311-INST-001 will apply.

As an aid in selecting parts for MMS, the following items are listed from 311-INST-001 and are tailored to MMS needs. Parts selected and procured as specified below are considered acceptable by the MMS Project.

9.0.3 General

Parts listed in NASA Part Selection List (NPSL), GSFC Preferred Parts List (PPL), or the NASA Standard Electrical, Electronic, and Electromechanical (EEE) Parts List (MIL-STD-975) are considered acceptable by the MMS Project, provided all mission requirements (performance, de-rating, radiation, etc) are met. Where differences in requirements exist between the NSPL, PPL and MIL-STD-975, the NPSL shall take precedence. Parts should be procured in accordance with the appropriate specification designated for that part type, and shall be subjected to any required additional testing listed in 311-INST-001 prior to use.

9.0.3.1 Microcircuits and Hybrids

MIL-PRF-38535 - Class Q or better, MIL-M-38510 - Class B or better microcircuits procured from a Qualified Manufacturers' List (QML) supplier. Additional PIND testing is required for class B and Q devices.

MIL-PRF-38534, Class H or better hybrid microcircuits procured from a Qualified Manufacturers' List (QML) supplier. Additional PIND testing and DPA are required for class H devices.

Standard Military Drawing (SMD) - Class M microcircuits which are not listed as QML sourced in MIL-HDBK-103 and are procured from an authorized supplier as listed in the SMD. Class M microcircuits procured to SMD's shall be subjected to additional PIND testing and DPA. Parts procured from manufacturers without QML status shall be procured with lot specific or generic Group C Quality Conformance Inspection (QCI) data within one year of the lot date code of the parts being procured.

Microcircuits compliant with paragraph 1.2.1 of MIL-STD-883 and procured from manufacturers having QML status for parts of the same technology. Parts procured from manufacturers without QPL or QML status shall be procured with lot specific or generic Group C Quality Conformance Inspection (QCI) data within one year of the lot date code of the parts being procured. MIL-STD-883 compliant microcircuits shall be subjected to PIND testing. Pre-cap visual inspection or DPA is required.

Microcircuits and Hybrids processed to manufacturer's in-house high reliability flow, provided all screening tests listed in GSFC 311-INST-001 have been satisfied. The high reliability process flow should be formally documented by the manufacturer. Additional tests not included in the manufacturer's high reliability flow must be performed by the manufacturer, an independent test facility, or by the developer, unless waived by the PCB. Parts procured in this section shall be procured with lot specific or generic Group C Quality Conformance Inspection (QCI) data within one year of the lot date code of the parts being procured. If not included in the manufacturer's high reliability test flow, the parts shall be subjected to PIND testing. A DPA may also be required for vendors that do not have a history of supplying reliable flight product. Screening data is required with the order. Pre-cap visual inspection is recommended for hybrids.

9.0.3.2 Semiconductors

MIL-S-19500, JANTX, JANTXV and JANS semiconductors procured from a QPL listed supplier. Semiconductors procured to JANTXV level or better are preferred. Any JANTX and JANTXV semiconductor that has an internal cavity shall be subjected to PIND testing. For JANTX level devices, a DPA on samples shall be performed.

9.0.4 Passive Parts

Established Reliability (ER) passive components procured from a QPL listed supplier for the appropriate military specification. Only ER parts within the minimum and maximum value ranges specified in the NPSL shall be considered acceptable. Additional screening as required by GSFC 311-INST-001 shall be performed.

9.0.4.1 Specification Drawings, all commodities

Parts procured to a GSFC S-311 specification from a GSFC approved source.

9.0.4.2 Custom Devices

In addition to applicable requirements of 311-INST-001, custom microcircuits, hybrid microcircuits, MCM, ASIC, etc. planned for use by each developer shall be subjected to a design review. The review may be conducted as part of the PCB activity. The design review will 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. All custom devices shall be subjected to a pre-cap inspection by the developer, or a GSFC approved inspector.

9.0.4.2.1 Developer Controlled Drawings

A developer controlled drawing may be necessary for procurement of parts where additional testing is required. These specifications shall fully identify the item being procured and shall include physical configuration, materials, environmental, electrical, and quality assurance provisions necessary to control manufacture and acceptance. Drawings shall specify test conditions, failure criteria, and lot rejection criteria. For lot acceptance or rejection, the Percentage of Defectives Allowable (PDA) in a screened lot shall be in accordance with that required in the closest military part specification.

9.0.4.3 Off the Shelf Items

9.0.4.3.1 Plastic Encapsulated Microcircuits (PEMs)

The use of plastic microcircuits shall be restricted to applications where no similar high reliability hermetically sealed device exists. Each lot of plastic microcircuits shall be screened and qualified in accordance with GSFC 311-INST-001, Rev B.

9.0.4.3.2 Units and sub-assemblies

Function of units or assemblies that are purchased as "off the shelf" hardware items shall be analyzed for mission criticality. When loss of off the shelf units does not compromise mission success, on a case by case basis, these units may be considered exempt from the parts control requirements of this section, subject to approval of the program office and the parts control board. However, additional unit level testing such as thermal cycling or thermal vacuum testing, may be directed by the PCB or project in lieu of additional part level screening.

When failure of such units represents significant compromise to mission success, an analysis of the parts used within the units shall be performed. The parts shall be evaluated for screening compliance to GSFC 311-INST-001, established reliability level, and include a radiation analysis. A reliability analysis for proper derating, etc, is documented in Chapter 4 of this MAR. Pending the results of this investigation, units may be required to undergo modification for use of higher reliability parts, or Rad hard parts. All upgrade parts shall be subject to PCB approval.

Modifications such as additional shielding for radiation effectiveness or replacing radiation soft parts for Rad-Hard parts, may be recommended and may be performed at the user's facility.

9.0.4.4 Screening and Testing

All parts used in the spacecraft and instruments shall be screened in accordance with GSFC 311-INST-001, “Instructions for EEE Parts Selection, Screening, and Qualification”, for Parts Quality Level 2. Many standard items chosen from the NPSL, GSFC PPL-21 or MIL-STD-975 may be used as is without further screening. However, when these standard items are selected and their normal screening does not meet the screening requirements of 311-INST-001, additional screening must be performed to bring them up to compliance with 311-INST-001 prior to use. Items not covered by the NPSL, GSFC PPL or 311-INST-001, (ex: switches, heaters, crystals) shall be screened in accordance with the nearest applicable GSFC or military specification.

9.0.4.4.1 Parts Data and Test Sample Retention

The developer shall have a method in place for retention of data generated for parts tested and used in flight hardware, in order to facilitate future risk assessment and technical evaluation, as needed. In addition, the developer shall retain all part functional failures, all destructive and non-flight non-destructive test samples, which could be used for future validation of parts for performance under certain conditions not previously accounted for.

PIND test failures do not require retention and may be submitted for DPA, radiation testing or used in engineering models. Parts and data shall be retained for the useful life of the spacecraft, unless otherwise approved by the PCB.

9.0.4.4.2 Verification Testing

9.0.4.4.2.1 Re-testing

When deemed necessary by age, failure history, GIDEP Alerts, or other reliability concerns, verification of performance by re-testing may be required. If required, testing shall be as determined by the PCB, based on the guidelines of GSFC 311-INST-001.

9.0.4.4.2.2 Plastic Encapsulated Microcircuits (PEMs)

Each lot of plastic microcircuits shall be screened and qualified in accordance with GSFC 311-INST-001, Rev B.

9.0.4.4.2.3 Field Programmable (non-erasable) devices

For field programmable devices such as fuse linked PROMS, burn-in and final electricals shall be performed after programming. Burn in shall be performed for 160 hours at 125°C.

9.0.4.4.2.4 Magnetics

Magnetic devices (transformers and inductors) shall be assembled and screened to the requirements of MIL-STD-981 (Design, Manufacturing and Quality Standards for Custom Electromagnetic Devices for Space Applications) for class B devices. Burn-in screening shall be considered based on vendor history, performance stability requirements, device complexity, and application criticality.

9.0.4.4.2.5 Capacitors

Ceramics For 50V rated ceramic capacitors used in application voltages less than 10V DC, Steady State Humidity Low Voltage testing on 12 samples is required in accordance with MIL-PRF-123, group B inspection.

Tantalums For Tantalum capacitors, 100% surge current testing is required in accordance with the procedures in MIL-PRF-39003/10 for leaded capacitors or MIL-PRF-55365/4 for chip capacitors.

9.0.4.4.2.6 Microcircuits, Hybrids, Crystal Oscillators and Semiconductor Devices

For non-QML microcircuits and crystal oscillators, class H or equivalent hybrid microcircuits, and devices which did not receive customer internal visual inspection, a Destructive Physical Analysis (DPA) is required on samples of each lot date code. A DPA is also required for semiconductor devices that did not receive precap visual inspection. For small procurements, small lot sampling per 311-M-70 may be used.

9.0.4.4.2.7 Relays

For relays that were not subjected to small particle (millipore) cleaning and internal visual inspection (specified in the purchase order), a DPA shall be performed.

9.0.4.4.2.8 Other parts

Other part types may require a sample DPA as part of normal testing, or as dictated by failure from additional testing, or deemed necessary by failure history, GIDEP Alerts, or other reliability concerns.

9.0.4.4.3 Particle Impact Noise Detection (PIND)

All devices with internal cavities shall be subjected to 100% PIND screening, in accordance with MIL-STD-883 or MIL-STD-750 as applicable. Any device failing this screen shall not be used in any flight application.

9.0.5 De-rating

All EEE parts shall be used in accordance with the de-rating guidelines of the NASA Preferred Parts List (PPL-21), Appendix B. Each developer's de-rating policy may be used in place of the NASA Parts Selection List guidelines. However, each developer's de-rating policy shall be submitted to the PCB for approval prior to use. Each developer shall maintain documentation on parts de-rating analysis and shall make it available for GSFC review.

9.0.6 Radiation Hardness

All parts shall be selected to meet their intended application in the predicted mission radiation environment. The radiation environment causes two separate effects, those of total ionizing dose (including "low-dose") and single-event effects. Each developer shall document the analysis for each part with respect to both effects. The developer should also document the radiation analysis of displacement damage for parts susceptible to this effect.

9.0.7 Verification Testing

Verification of screening or qualification tests by re-testing is not required unless deemed necessary as indicated by failure history, GIDEP Alerts, or other reliability concerns. If required, testing shall be in accordance with 311-INST-001 as determined by the PCB. Each 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.7

9.0.8 Destructive Physical Analysis

A sample of each lot date code of microcircuits, hybrid microcircuits,relays, filters, oscillators, and semiconductor devices shall be subjected to a Destructive Physical Analysis (DPA). All other parts may require a sample DPA if it is deemed necessary as indicated by failure history, GIDEP Alerts, or other reliability concerns. DPA tests, procedures, sample size and criteria shall be as specified in GSFC specification S-311-M-70, Destructive Physical Analysis. Developer's procedures for DPA may be used in place of S-311-M-70 and shall be submitted to the PCB prior to use. 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.

9.0.9 Parts Age Control

9.0.9.1 Parts Drawn From Controlled Storage

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 and stored in other than controlled conditions where they are exposed to the elements or sources of contamination shall not be used. Variation of the part age control requirement, due to availability or cost shall be determined and approved by the PCB on a case-by-case basis.

9.0.10 Traceability Control for Parts

The developer shall maintain traceability records for all parts through incoming receiving inspection to board installation. Replacement control traceability shall also be kept for all removed parts, in order to allow for feedback on circuit performance as necessary. Records shall be kept on file for the useful life of the spacecraft.

9.0.10.1 Part serial numbers.

When serialized parts are used in flight hardware, part serial number shall be traceable to board installation location by circuit designator. (Ex: DRAM P/N 23456-7, S/N 101, installed on board 34567-501, S/N 201, microcircuit designator U10).

9.0.10.2 Parts Lists

Each developer shall develop and maintain Parts Identification List (PIL) for the duration of the Project. This list shall include all parts planned for use in flight hardware irrespective of their approval status. The developer shall submit this list to PCB for review. The PCB shall assure standardization of parts listed in the PIL for use across various systems and sub-systems.

Each developer shall maintain a Program Approved Parts List (PAPL). Only parts that have been evaluated nd approved by the PCB shall be listed in the PAPL. The PAPL shall be the only source of approved parts for flight hardware. All PAPL submissions to the MMS project shall include a computer compatible form.

An As-Built Parts List (ABPL) shall also be prepared and submitted to GSFC in accordance with the contract delivery requirements. The ABPL is generally the final PIL with additional information, such as parts manufacturers,lot date code etc.

Each parts list shall be a composite of the parts selections for each assembly and sub-assembly at circuit card level . As a minimum, each list shall contain the following information:

(a) Part number;

(b) Description;

(c) Next assembly;

(d) Quantity issued/used;

(e) Manufacturing lot date code;

(f) Vendor Name or CAGE Code;

(g) Part specification control drawing number;

(h) Common designator or generic number;

(i) TID and SEE Radiation Information on Active Devices (Semiconductors and Mircocircuits)

9.1 ALERTS

Each developer shall be responsible for review and disposition of Government Industry Data Exchange Program (GIDEP) Alerts for applicability to the parts proposed for use. In addition, any NASA Alerts and Advisories provided to the developer by GSFC shall be reviewed and dispositioned. Alert applicability, impact, and corrective actions shall be documented and be made available for GSFC review within 30 days. See Section 12 of this document for additional requirements on GIDEP Alerts. In the event of a conflict between GIDEP Alerts & NASA Advisory, the NASA Advisory shall govern.

Chapter 10. Materials, Processes and Lubication Requirements

10.0 GENERAL REQUIREMENTS

Each developer shall implement a comprehensive Materials and Processes Program beginning at the design stage of the hardware. The program shall help ensure the success and safety of the mission by the appropriate selection, processing, inspection, and testing of the materials, processing and lubricants employed to meet the operational requirements for the MMS Project. Materials and lubrication assurance approval is required for each usage or application in space-flight hardware. Materials selection shall be in accordance with the specific Project performance requirements and as defined below.

10.1 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 of cooled surfaces, composite materials, atomic oxygen, useful life, vacuum outgassing, toxicity, flammability and fracture toughness, as well as the properties required by each material usage or application.

10.1.1 Materials Identification List

Each developer shall maintain a Materials Identification List (MIL) of all materials planned for use in flight hardware, regardless of their approval status. The initial MIL and subsequent updates shall be submitted to GSFC in accordance with the contract delivery requirements. An As-Built Materials List (ABML) shall also be prepared and submitted to GSFC in accordance with the contract delivery requirements. The ABML is generally the final MIL with additional as-built information such as materials manufacturers.

The MIL shall include information for Polymeric Materials and Composites Usage, Inorganic Materials and Composites Usage, Lubrication Usage, and Material Process Utilization. Reference lists are provided in this document as a guide for all developer's (Figures 10-3 through 10-6). The MIL can be submitted as one list as long as it contains all the appropriate information referenced in the attached figures. These lists shall be reviewed and approved by the GSFC Materials Assurance Engineer (MAE) assigned to MMS.

10.1.2 Compliant Materials

Each developer shall use compliant materials 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 following applicable selection criteria:

– 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 and NASA-STD-6001;

– Vacuum Outgassing requirements as defined in paragraph 10.1.3;

– Stress corrosion cracking requirements as defined in MSFC-SPEC-522.

10.1.3 Vacuum Outgassing

Material vacuum outgassing shall be determined in accordance with ASTM E595. In general, a material is qualified on a product-by-product basis. However, GSFC may require lot testing of any material for which lot variation is suspected. In such cases, material approval is contingent upon lot testing. Only materials that have a total mass loss (TML) less than 1.00% and a collected volatile condensable mass (CVCM) less than 0.10% shall be approved for use in a vacuum environment. A waiver shall be submitted to the MMS Project for materials planned to be used which do not meet the CVCM and/or TML requirement.

10.1.4 Non-compliant Materials

A material that does not meet the requirements of the applicable selection criteria above (see 10.1.2), or meets the requirements above but is used in an unconventional application, shall be considered to be a non-compliant material. The proposed use of a non-compliant material requires a waiver to be submitted to the MMS Project. This waiver can take the form of Materials Usage Agreement (Figure 10-1) and/or a Stress Corrosion Evaluation Form (Figure 10-2). If a developer prefers, they can use their own equivalent form for proposed usage of a non-compliant material.

10.1.4.1 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 non-compliant. The developer shall submit a waiver to the MMS Project defining 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 non-compliant 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 satellite contamination plan and error budget.

10.1.5 Conventional Applications (Definition)

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

10.1.6 Non-conventional Applications (Definition)

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 will be verified for the desired application on the basis of test, similarity, analyses, inspection, existing data, or a combination of those methods.

10.1.7 Polymeric Materials

Each developer shall include polymeric materials and composites on the MIL. Material acceptability shall be determined on the basis of flammability, toxicity, vacuum outgassing and all other materials properties relative to the application requirements and usage environment.

10.1.8 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 exp ired date code requires that the developer demonstrate 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 GSFC 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.

10.1.9 Inorganic Materials

Each developer shall include inorganic materials and composites on the MIL. In addition, each 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. A wavier shall be submitted to the MMS Project for each material usage that does not comply with the MSFC-SPEC-522 SCC requirements (Reference Figure 10-1 and 10-2 as a guide).

10.1.9.1 Fasteners

Each developer shall comply with the procurement documentation and test requirements for flight hardware and critical ground support equipment fasteners contained in GSFC S-313-100, Goddard Space Flight Center Fastener Integrity Requirements (also known as 541-PG-8072.1.2). Material test reports for fastener lots shall be submitted for information.

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 that is not embrittling to the steel.

10.1.10 Lubrication

Each developer shall prepare and document a lubrication usage list as part of the MIL. In addition, each developer may be requested to submit supporting applications data.

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 in accord with the life test plan or heritage of an identical mechanism used in identical applications.

10.2 PROCESS SELECTION REQUIREMENTS

Each developer shall prepare and document a material process utilization list as part of the MIL. A copy of any process shall be submitted for review upon request. Manufacturing processes (e.g., lubrication, heat treatment, welding, chemical or metallic coatings), shall be carefully selected to prevent any unacceptable material property changes that could cause adverse effects of materials applications.

10.3 PROCUREMENT REQUIREMENTS

10.3.1 Purchased Raw Materials

Raw materials purchased by each developer shall be accompanied by the results of nondestructive, chemical and physical tests, or a Certificate of Compliance.

10.3.2 Raw Materials Used in Purchased Products

Each developer shall require that the supplier meet the requirements of 10.3.1 and provide on request the results of acceptance tests and analyses performed on raw materials.

10.4 GIDEP ALERTS

See Section 12 of this document for GIDEP Alert requirements.

<table>
<tr><td colspan="3">MATERIAL USAGE AGREEMENT (MUA)</td><td colspan="3">USAGE AGREEMENT NO.:</td><td>PAGE OF</td></tr>
<tr><td>PROJECT:</td><td colspan="2">SUBSYSTEM:</td><td colspan="3">ORIGINATOR:</td><td>ORGANIZATION :</td></tr>
<tr><td>DETAIL DRAWING</td><td colspan="2">NOMENCLATURE</td><td colspan="2">USING ASSEMBLY</td><td colspan="2">NOMENCLATURE</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="4">MATERIAL & SPECIFICATION</td><td colspan="3">MANUFACTURER & TRADE NAME</td></tr>
<tr><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td>USAGE</td><td>THICKNESS</td><td>WEIGHT</td><td>EXPOSED AREA</td><td colspan="3">ENVIRONMENT</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td>PRESSURE</td><td>TEMPERATURE</td><td>MEDIA</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="7">APPLICATION:</td></tr>
<tr><td colspan="7">RATIONALE:</td></tr>
<tr><td colspan="3">ORIGINATOR:</td><td colspan="3">PROJECT MANAGER:</td><td>DATE:</td></tr>
</table>

FIGURE 10-1 Material Usage Agreement

FIGURE 10-2: 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: ____

POLYMERIC MATERIALS AND COMPOSITES USAGE LIST

SPACECRAFT ____________________ SYSTEM/EXPERIMENT ____________________ GSFC T/O ____________________

DEVELOPER/DEVELOPER ____________________ 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 10-3 POLYMERIC MATERIALS AND COMPOSITES USAGE LIST

INORGANIC MATERIALS AND COMPOSITES USAGE LIST

SPACECRAFT ______________________ SYSTEM/EXPERIMENT ______________________ GSFC T/O ______________

DEVELOPER/DEVELOPER ______________________ 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 10-4 INORGANIC MATERIALS AND COMPOSITES USAGE LIST

LUBRICATION USAGE LIST

SPACECRAFT________________________ SYSTEM/EXPERIMENT________________________ GSFC T/O __________

DEVELOPED/DEVELOPER________________________ 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 10-5 LUBRICATION USAGE LIST

MATERIALS PROCESS UTILIZATION LIST

SPACECRAFT ____________________ SYSTEM/EXPERIMENT ____________________ GSFC T/O ____________________

DEVELOPER/DEVELOPER____________________ ADDRESS ____________________

PREPARED BY ____________________ PHONE____________________ DATE PREPARED ____________________

GSFC MATERIALS EVALUATOR ____________________ PHONE____________________ DATE RECEIVED____________________ DATE EVALUATED ____________________

ITEM NO.	PROCESS TYPE(1)	DEVELOPER 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 10-6 MATERIALS PROCESS UTILIZATION LIST

Chapter 11. Contamination Control Requirements

11.0 GENERAL REQUIREMENTS

Each developer shall plan and implement a contamination control program for MMS hardware. Each developer shall establish the specific cleanliness requirements and delineate the approaches to meet the requirements in a Contamination Control Plan (CCP) deliverable to the MMS 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.

11.1 CONTAMINATION CONTROL PROGRAM

Each developer shall have a Contamination Control Program (CCP) that addresses the procedures that will be followed to control contamination. The CCP shall establish implementation and methods that will be used to measure and maintain the levels of cleanliness required during each of the various phases of the item's lifetime. In general, all mission hardware should be compatible with the most contamination-sensitive components. 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. Each develop shall support the MMS project in the generation of a project contamination control plan by providing support for the generation of requirements, details of instruments and I & T plans and procedures.

11.1.1 Contamination Control Verification Process

Each developer shall implement a contamination control verification process. The verification process shall be performed in order to allow the:

a. Determination of contamination sensitivity;

b. Determination of a contamination allowance;

c. Determination of a contamination budget;

11.2 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 MMS Project for review.

11.3 THERMAL VACUUM BAKEOUT

The developer shall perform thermal vacuum bakeouts of all hardware 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 MMS 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. 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.

Chapter 12. GIDEP Alerts and Problem Advisories

12.0 GENERAL REQUIREMENTS

The MMS developer's shall participate in the Government/Industry Data Exchange Program (GIDEP). The developer shall transmit additional copies of documentation sent to GIDEP relevant to the MMS hardware to the NASA/GSFC Systems Assurance Manager (SAM) and to the:

Alert Coordinator

Code 300NASA Goddard Space Flight Center

Greenbelt, MD 20771

12.1 GIDEP ALERT RESPONSE

Each developer shall review and disposition all Government Industry Data Exchange Program (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, each developer shall review and disposition any NASA Alerts and Advisories provided to the developer by the MMS Project. Alert applicability, impact, and corrective actions shall be documented and status provided to the MMS Project on a monthly basis.

In the event of a conflict between GIDEP alerts and NASA Advisories, the NASA Advisory shall govern.

The developer shall ensure that either (1) their subs are participating in the GIDEP Program, or (2) the developer's subs are providing their parts/materials lists to the developer for GIDEP/NASA Advisory search review. All feedback shall be provided to the MMS SAM and the Alert Coordinator identified above.

12.2 DOCUMENTATION

Each developer shall keep parts and materials selection and usage records sufficient to determine applicability of any Government Industry Data Exchange Program (GIDEP) alerts related to materials used for MMS.

Chapter 13. Risk Management Requirements

13.0 GENERAL REQUIREMENTS

All identified Reliability and Quality risks shall be documented and reported on in accordance with the Project's Risk Management Plan. Although not all risks will be fully mitigated, all risks shall be addressed and mitigation and acceptance strategies will be agreed on in accordance with the Project Risk Management Plan and at appropriate mission reviews.

The developer/contractor shall develop and implement a Risk Management Plan to aid in performing risk assessment and risk management. Risk Management applies to all software and hardware products and processes (flight and ground) in order to identify, analyze, plan mitigation actions, track, control, and communicate risks.

The developer shall:

a. Implement a continuous program to capture, acknowledge, and document reliability and quality risks before they become problems

b. Analyze identified risks to estimate the probability of occurrence, severity of impact, timeframe when mitigation actions are needed, and classify into sets of related risks and prioritize.

c. Develop plans to implement risk mitigation strategies and actions and assign appropriate resources

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

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

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

g. Provide a "Top 10" risk list monthly from Phase B onward

h. Report on outstanding risk items at all management and design reviews.

13.1 RISK MANAGEMENT PLAN

The developer shall develop a Risk Management Plan for the instrument/instrument-suite for which they are responsible. The plan shall be developed in compliance with NPG 7120.5A, "NASA Program and Project Management Processes and Requirements" and the guidelines described in NPG 8000.4, "Risk Management Procedures and Guidelines". The plan shall include risks associated with hardware (technical challenges, new technology qualification, etc.), software, system safety, performance, and programmatic risks (cost and schedule). The plan shall identify the tools and techniques to be used to manage risks. The risk areas that are identified shall be addressed at peer reviews and at government reviews. The developer's plan shall address the risk areas to ensure adequate mitigation steps are in place.

Chapter 14. Applicable Documents List

DOCUMENT	DOCUMENT TITLE
ANSI/ASQ Q9001-2000	Model for Quality Assurance in Design, Development, Production, Installation, and Servicing
ANSI/IPC-A-600	Acceptance Criteria for Printed Wiring Boards
ANSI/J STD 001	Requirements for Soldered Electrical and Electronic Assemblies (not allowed for space flight hardware)
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 Safety Requirements
GEVS-SE	General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components
GSFC 311-INST-001	Instructions for EEE Parts Selection, Screening, and Qualification
GSFC PPL-21	Goddard Space Flight Center Preferred Parts List
GSFC S-312-P003	Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses
GSFC S-313-100	Goddard Space Flight Center Fastener Integrity Requirements
IPC D275	Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies
IPC-2223	Sectional Design Standard for Flexible Printed Boards

IPC A-600	Acceptability of Printed Boards
IPC-6011	Generic Performance Specification for Printed Boards
IPC-6012	Qualification and Performance Specification for Rigid Printed Boards Flight Applications – Supplemented with: GSFC/S312-P-003, Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses
IPC-6013	Qualification and Performance Specification for Flexible Printed Boards
ISO 17025	General Requirements for the Competence of Testing and Calibration Laboratories
KHB 1710.2D	Kennedy Space Center Safety Practices Handbook
MIL-STD 1629A	Procedures for Performing a Failure Mode Effects and Criticality Analysis
MSFC-HDBK-527	Material Selection List for Space Hardware Systems
MSFC-SPEC-522	Design Criteria for Controlling Stress Corrosion Cracking
NASA Reference Publication (RP) 1124	Outgassing Data for Selecting Spacecraft Materials
NASA RP-1161	Evaluation of Multi-layer Printed Wiring Boards by Metallographic Techniques
NASA-STD-6001	Flammability, Odor, Off-gassing and Compatibility Requirements & Test Procedures for Materials in Environments That Support Combustion
NASA-STD-8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronics Assemblies (Replaces NAS 5300.4(3J-1))

NASA-STD-8739.2	NASA Workmanship Standard for Surface Mount Technology (Replaces NAS 5300.4(3M))
NASA-STD-8739.3	Requirements for Soldered Electrical Connections Replaces NHB 5300.4(3A-2)
NASA-STD-8739.4	Requirements for Crimping Inter-connecting Cables, Harnesses, and Wiring (Replaces NHB5300.4(3G))
NASA-STD-8739.5	Fiber Optics Termination Standard
ANSI/ESD S20.20-1999	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)
NASA-STD-8719.13A	NASA Software Safety Standard
NSS 1740.14	Guidelines and Assessment Procedures for Limiting Orbital Debris
S-311-M-70	Specification for Destructive Physical Analysis

Chapter 15. Acronyms

ACRONYMS

ABPL	As-Built Parts List
ABML	As-Built Materials List
ANSI	American National Standards Institute
ASIC	Application Specific Integrated Circuits
ASQ	American Society for Quality
BB	Ball Bearing
BOL	Beginning of Life
CCB	Configuration Control Board
CCP	Contamination Control Plan
CDR	Critical Design Review
CIL	Critical Items List
CM	Configuration Management
CR	Confirmation Review
COTR	Contracting Officer's Technical Representative
CPT	Comprehensive Performance Test
CVCM	Collected Volatile Condensable Mass
DoD	Department of Defense
DPA	Destructive Physical Analysis
EEE	Electrical, Electronic, and Electromechanical
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FMEA	Failure Modes and Effects Analysis
FOR	Flight Operations Review
FRB	Failure Review Board
FTA	Fault Tree Analysis
GEVS	General Environmental Verification Specification
GEVS-SE	General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components
GFE	Government-Furnished Equipment
GIDEP	Government Industry Data Exchange Program
GSE	Ground Support Equipment

GSFC	Goddard Space Flight Center
I&T	Integration and Test
ISO	International Standards Organization
IV&V	Independent Verification and Validation
LRR	Launch Readiness Review
MMS	Magnetospheric Multiscale Mission
MAR	Mission Assurance Requirements
MCM	Multi-Chip Module
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
NASA	National Aeronautics and Space Administration
NHB	NASA Handbook
NRCA	Nonconformance Reporting and Corrective Action
NSTS	National Space Transportation System
OSSMA	Office of Systems Safety and Mission Assurance
PAIP	Performance Assurance Implementation Plan
PAPL	Project Approved Parts List
PCB	Parts Control Board
PCP	Parts Control Plan
PDR	Preliminary Design Review
PER	Pre-Environmental Review
PIL	Parts Identification List
PIND	Particle Impact Noise Detection
PPL	Preferred Parts List
PRA	Probabilistic Risk Assessment
PSR	Pre-Shipment Review
PWB	Printed Wiring Board
QCM	Quartz Crystal Microbalance
QMS	Quality Management System
SAM	Systems Assurance Manager
SB	Sleeve Bearing
SCC	Stress Corrosion Cracking

SCM	Software Configuration Management
SCR	System Concept Review
SOW	Statement of Work
SQMS	Software Quality Management System
SMA	Safety and Mission Assurance
SRO	Systems Review Office
SRR	Software Requirements Review
STS	Space Transportation System (Shuttle)
TML	Total Mass Loss
TRR	Test Readiness Review
V&V	Verification and Validation