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LANDSAT Data Continuity Mission
LDCM

LANDSAT DATA CONTINUITY MISSION

Spacecraft
Mission Assurance Requirements

Effective Date: January 04, 2013

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CONFIGURATION MANAGEMENT (CM) FOREWORD

This document is a Landsat Data Continuity Mission Project CM-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the Landsat Data Mission Continuity Configuration Management Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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1.0 OVERALL REQUIREMENTS

The Landsat Data Mission Continuity Mission (LDCM) will be a Category 2, Class B mission per NPR 8705.4 utilizing a bus from the Rapid Spacecraft Development Office (RSDO) catalogue with a System Safety and Mission Assurance (S&MA) Program that meets all of the requirements listed in this document.

1.1 DESCRIPTION OF OVERALL REQUIREMENTS

The S&MA Program documented herein is applicable to the bus/spacecraft/observatory and its associated contractors and as such is a contractual document. All "shall" statements are requirements which must be addressed. Any deviations or waivers to this document must be forwarded to the Goddard Space Flight Center (GSFC) Project Office for review and approval.

The following definitions are used throughout this document:

- Shall = required
- Should = recommended
- Will = planned; to be carried out

The contractor shall plan and implement an organized S&MA Program that encompasses:

a. All flight hardware, that is designed, built, and/or provided by the contractor or furnished by GSFC, from project initiation through launch and mission operations
b. The ground system (e.g., test equipment and simulators) that interfaces with flight equipment to the extent necessary to assure the integrity and safety of flight items including ground test equipment that interfaces with flight hardware or software
c. All software critical for mission success

The Government's assurance activity managers shall have direct access to contractor management independent of project management, with the functional freedom and authority to interact with all other elements of the project. Issues requiring project management attention shall be addressed with the contractor(s) through the Project Manager(s) and/or Contracting Officer Technical Representative(s) (COTR).

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

When hardware or software 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 contractor shall demonstrate how the hardware or software complies with these requirements and submit substantiating documentation in accordance with Contract Delivery Requirements List (CDRL) 74.

1.3 SURVEILLANCE OF THE CONTRACTOR

The work activities, operations, and documentation performed by the contractor and/or his suppliers are subject to evaluation, review, audit, and inspection by government-designated representatives from GSFC including employees from the GSFC Office of Systems Safety and Mission Assurance (OSSMA), the Government Inspection Agency (GIA) including those from the Defense Command Management Agency (DCMA), and/or an Independent Assurance Contractor (IAC) including those from the National Aeronautics and Space Administration (NASA) Contractor Assurance Supplier (NCAS). GSFC will delegate in-plant responsibilities and authority via a letter of delegation or the GSFC contract with the

IAC. Although the S&MA representatives report to the GSFC LDCM Chief Safety and Mission Assurance Officer (CSO), they represent, and act for, the GSFC LDCM project and its management.

The contractor and/or suppliers shall:

a. Grant access for NASA and/or NASA representatives to conduct an assessment/survey upon notice
b. Provide resources to assist with the assessment/survey with minimal disruption to work activities
c. Provide government assurance representatives with documents, records, and equipment required to perform their assurance and safety activities
d. Provide the government assurance representative(s) with an acceptable work area within contractor facilities.

As with any government contract, GSFC has the right to review/audit/inspect any and all related hardware or software at either the prime contractor's or any of his subcontractors' at any time while the contract is in place. (Also see Section 3.13 on Safety Assessments.)

1.4 CONTRACT DELIVERY REQUIREMENTS LIST (CDRL)

The CDRL identifies Descriptions of Required Data (DRDs) describing data deliverable to the GSFC Project Office. Note: These are also referred to as "data item descriptions" or "DID" in other GSFC contracts.

2.0 QUALITY MANAGEMENT SYSTEM

2.1 GENERAL

The contractor shall provide the Mission Assurance Implementation Plan (MAIP) and Quality Documentation in accordance with CDRL 75. The contractor may utilize as much of their existing documentation as appropriate to complete the requirements of CDRL 75. If the contractor (or their subcontractors or suppliers) elects to utilize in-house documentation that does not fully meet the requirements of this Mission Assurance Requirements (MAR) document, the contractor (etc.) shall either modify/amend their existing documentation or submit a program waiver (in accordance with CDRL 3) for GSFC Project Office concurrence. Once the MAIP is submitted, reviewed, and accepted by GSFC all changes require either a Configuration Change Request or a waiver (as appropriate), approved by the GSFC Project Office.

CDRL 75 shall consist of the following:

a. The LDCM MAIP shall cover all chapters of the MAR in the order that they appear in the MAR. It shall also include any plans/documents associated with the primary plans called-out in this document as part of CDRL 75.

b. A MAR Cross-Reference Matrix listing each MAR requirement including any/all related DRD requirements and cross-reference them to the internal contractor/subcontractor processes that meet this requirement. (All MAR and MAR-related DRDs shall be covered by this matrix.) The matrix shall include columns listing:

   1. The title and document number for the contractor’s processes, standards, procedures, etc. that enable the contractor to meet this MAIP requirement.
   2. A clear statement that the contractor “fully complies” with this requirement and a summary of corresponding evidence (i.e., A list of any commercial or Government programs that have successfully met this MAR requirement using the identical cited contractor/subcontractor processes, standards, procedures, etc., including any other pertinent information the contractor wishes to offer concerning the applicability of the process, etc.). Any significant process/etc. changes since the process/etc. was utilized will be noted.
   3. If the requirement is judged non-applicable or the contractor is unable to fully comply with a requirement, the associated rationale and any planned deviation from the MAR must be described to fully convey why the Government should grant a waiver to the MAR requirement for the contractor against this specific requirement.

c. First, second, and/or third party Quality Certificate(s) issued to verify their compliance to ANSI/ISO/ASQC Q9001:1994 or ANSI/ISO/ASQ Q9001:2000 or SAE AS9100. This documentation will ensure that the contractor has a Quality Management System (QMS) that is compliant with the minimum requirements of respective ANSI/ISO/ASQ quality system.

e. Subcontractor Assurance Verification Matrix demonstrates the flow-down of MAR requirements to suppliers and contractor verification of compliance to those requirements.

f. GOLD Rules Applicability, Compliance, and Waivers provides information on the contractor’s compliance with GSFC’s “GOLD Rules,” GSFC-STD-1000, “Rules for Design, Development, Verification, and Operation of Flight Systems.”

   1. The GOLD Rules Applicability Assessment shall identify each rule's applicability, relative to the LDCM Project. All identified and agreed upon non-applicable rules shall be implicitly waived as project requirements.

2. The GOLD Rules Compliance Assessment shall identify the project's compliance, relative to each applicable rule per Goddard Procedures and Guidelines (GPR) 8070.4, "Administration and Application of Goddard Rules for Design, Development, Verification and Operation of Flight Systems." Upon a determination of noncompliance to an applicable rule; the contractor shall modify its design for compliance or formally request a waiver for the existing design.

The contractor shall have a QMS that is compliant with the minimum requirements of ANSI/ISO/ASQC Q9001:1994 or ANSI/ISO/ASQ Q9001:2000 or SAE AS9100. The contractor's Quality Manual, if separate from the LDCM MAIP, will be available to Government personnel for review upon request. The documentation of that manual, as appropriate shall be applied to this contract and cited in the MAIP and the MAR Cross-Reference Matrix.

2.2 SUPPLEMENTAL QUALITY MANAGEMENT SYSTEM REQUIREMENTS

Some assurance related activities are not covered by International Organization for Standardization (ISO) requirements. These activities are identified in the following LDCM MAR sections and will supplement the ANSI/ISO/ASQC Q9001:1994 or ANSI/ISO/ASQ Q9001:2000 or SAE AS9100 requirements.

2.2.1 Control of Nonconforming Product

In accordance with CDRL 75, the contractor shall have a closed-loop system for identifying and reporting non-conformances, ensuring that corrective action is implemented to prevent recurrence. This system will be defined in the contractor's Nonconformance Reporting and Material Review Board (MRB) Plan. The system shall include:

a. Audit and test as applicable to verify adequacy of the corrective action implemented
b. A nonconformance review process, which consists of a preliminary review and a MRB
c. A requirement for the LDCM CSO's in-plant representative (e.g., DCMA) to review all MRB activity related to flight hardware or ground support equipment (GSE) that interfaces with flight hardware. The material/documentation will also be available for review by GSFC personnel upon request.

2.2.2 Preliminary Review

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

a. Scrapped - because the product is not usable for the intended purposes and cannot be economically reworked or repaired
b. Re-worked - to result in a characteristic that completely conforms to the standards or drawing requirements
c. Returned to supplier - for rework, repair or replacement.
d. Repaired using a standard repair process previously approved by the MRB and /or government Quality Assurance (QA) organization.

All nonconformances that are not classified to be in one of the above categories and thus be classified as "minor" shall be referred to MRB.

Note: Preliminary review does not negate the contractor's requirement to identify, segregate, document, and report and disposition nonconformances. All "minor" nonconformance reports shall be made available for review by the GSFC MRB representative(s). Other GSFC personnel will also have access upon request.

2.2.3 Material Review Board

Nonconformances not dispositioned by preliminary review, normally "critical" and "major" nonconformances, shall be referred to the MRB for disposition. The MRB composition and process shall be defined in the contractor's Nonconformance Reporting and MRB Plan. This shall include the:

a. Potential MRB dispositions including scrap, rework, return to supplier, repair by standard or non-standard repair procedures, use-as-is, or request for major waiver
b. The MRB membership and chairperson including duties. This includes Government participation and responsibilities
c. The process for calling a meeting, distributing meeting minutes/notes, and distributing and maintaining MRB records
d. Process for investigating nonconforming items in a timely manner in sufficient depth to determine the proper disposition to determine the cause and required corrective actions for the nonconformance.
e. MRB signature authorities

The LDCM Government representative(s) shall be invited to all MRB activities/meetings; however, the activities/meetings may take place without the presence of the Government representative(s) if necessary to maintain contractor schedules, The MRB chairperson shall submit all MRB dispositions/reports to the GSFC LDCM CSO or their designee in a timely manner for their approval. At this point, the contractor may continue to process their hardware at their own resources and schedule risk.

The GSFC LDCM CSO or their designee may justify non-concurring with the MRB disposition/ report if the MRB disposition will put the LDCM spacecraft's safety, quality, reliability, mission objective, or mission life at risk. The contractor's MRB shall subsequently re-evaluate their disposition until the GSFC Project Office/CSO/COTR agrees that the MRB's disposition will not put the LDCM program at risk and approves that disposition.

The Nonconformance Reporting and MRB Plan shall be delivered to the GSFC Project Office as part of the MAIP, CDRL 75. MRB actions and meeting reports are due to the GSFC Project Office in accordance with CDRL 30.

2.2.4 Reporting of Failures

The contractor shall have a closed-loop system for identifying and reporting failures to ensure that corrective action is implemented to prevent recurrence. This reporting system (including the review and disposition of failures) shall be defined in detail in the contractor's Failure Reporting and Failure Review Board (FRB) Plan. This shall include:

a. Potential FRB dispositions including request for major waiver as defined by the contractor
b. The FRB membership and chairperson including duties - this includes any Government participation and responsibilities, Government participation will include a requirement for the LDCM CSO's in-plant representative (e.g., DCMA) to review all failure reports and FRB activity related to flight hardware or GSE that interfaces with flight hardware. The material/documentation will also be available for review by GSFC personnel upon request.
c. The process for calling a meeting, distributing meeting minutes/notes, and distributing and maintaining FRB and Failure Report records
d. Process for investigating failures in a timely manner in sufficient depth to determine the proper disposition to determine the cause and required corrective actions for the failure
e. FRB signature authorities

Reporting must begin by the first application of power at the start of end-item acceptance testing or by the first operation of a mechanical item. Reporting shall continue through formal acceptance by the GSFC LDCM Project Office. Failures shall be reported to the GSFC Project Office within 24 hours in accordance with CDRL 30.

The LDCM Government representative(s) shall be invited to all FRB activities/meetings; however, the activities/meetings may take place without the presence of the Government representative(s) if necessary to maintain contractor schedules, The FRB chairperson shall submit all FRB dispositions/reports to the GSFC LDCM CSO or their designee in a timely manner for their approval. At this point, the contractor may continue to process their hardware at their own resources and schedule risk.

The GSFC LDCM CSO or their designee may justify non-concurring with the FRB disposition/ report if the FRB disposition will put the LDCM spacecraft's safety, quality, reliability, mission objective, or mission life at risk. The contractor's FRB shall subsequently re-evaluate their disposition until the GSFC Project Office/CSO/COTR agrees that the FRB's disposition will not put the LDCM program at risk and approves that disposition.

The Failure Reporting and FRB Plan shall be delivered to the GSFC Project Office as part of the MAIP, CDRL 75. Failure reports and FRB reports are due to the GSFC Project Office in accordance with CDRL 30.

2.2.5 Control of Monitoring and Measuring Devices

The contractor shall comply with the requirements of Section 7.6 of ANSI/ISO/ASQ Q9001 "Quality Management Systems" regarding the control of monitoring and measuring devices. Testing and calibration laboratories used by contractors shall be compliant with the calibration laboratory competency requirements identified in ANSI/NCSL Z540.1- 1994 (R2002), and accredited to ANSI/ISO/IEC 17025:2000.

Contractors shall maintain calibration on all test and measuring equipment and safety instruments associated with the following functions:

a. Acceptance testing (determining that a part, component, or system meets specifications)
b. Inspection, maintenance, or calibration
c. Flight hardware qualification
d. Measurement of processes where test equipment accuracy is essential for the safety of personnel or the public
e. Telecommunication, transmission, and test equipment where exact signal interfaces and circuit confirmations are essential to mission success
f. Development, testing, and special applications where the specifications, end products, data, or instruments are used in hazardous and critical applications

Contractors shall limit the use of non-calibrated instruments to applications where substantiated accuracy is not required, or for "indication only" purposes in non-hazardous, non-critical applications.

2.2.6 Flow-Down

The contractor's/supplier's S&MA programs shall ensure flow-down of requirements to all suppliers including a process to verify compliance. Specifically, contract review and purchasing processes shall indicate the processes for documenting, communicating, and reviewing requirements with sub-tier suppliers to ensure requirements are met. These processes shall be defined in the contractor's Quality Manual. Examples include, but are not limited to the following: Technical, safety, parts and materials, reliability, hardware and software quality assurance, NASA Advisories, and Government Industry Data Exchange Program (GIDEP) (Alerts, Safe-Alerts, Problem Advisories, and Agency Action Notices).

The contractor shall prepare and update as necessary a requirements verification matrix showing how these requirements will be met by all suppliers in accordance with CDRL 75. The final version of this document will show how the requirements were met for by each supplier.

2.3 PHOTOGRAPHIC DOCUMENTATION

The contractor shall provide photographic documentation of all flight printed wiring assemblies, subsystem and system level boxes and structures, wiring harness routing in accordance with CDRL 6. These photographs shall accompany the hardware along with the data package to the next higher level of assembly through integration and testing. This documentation shall be available to Government personnel upon request prior to its delivery to the GSFC Project Office. It will be provided to the GSFC Project Office as part of the S&MA Data Package in accordance with CDRL 42

2.4 SAFETY AND MISSION ASSURANCE POLICY

Contractors shall ensure that appropriate review processes are in place at their level to certify the safety and operational readiness of flight hardware/software, mission-critical support equipment, hazardous facilities/operations, and high-energy ground-based systems. Not withstanding any other requirements contractors shall direct the suspension of any operation that presents an immediate and unacceptable danger to personnel, property, or mission operations.

2.5 SAFETY AND MISSION ASSURANCE MONTHLY STATUS REPORTING

The contractor Mission Assurance Manager shall provide monthly status reports to the LDCM CSO as part of their Monthly Status Review/Report to the GSFC Project Office in accordance with CDRL 1. The S&MA Monthly Status Report will discuss the following for each S&MA discipline:

a. Open/recently closed issues
b. Open/recently closed risks
c. Assurance accomplishments and resulting assurance metrics for activities such as, but not limited to, inspection and test, reviews, contractor/subcontractor surveys, and audits
d. Subcontractor assurance accomplishments, including items listed above
e. Upcoming assurance activities
f. Significant problems or issues that could affect cost, schedule and/or performance
g. Alert/Advisory status
h. Safety Hazard status
i. Lessons Learned
j. Major S&MA organization or staffing changes.

This S&MA information may be included as integrated information in the various sections of the contractor's Monthly Status Report/Review or it may be a separate section of the report/review.

In addition to the written monthly report/review, the contractor's Mission Assurance Manager shall hold a weekly teleconference with the GSFC LDCM CSO at a mutually agreed-upon day and time. The Safety Working Group and/or Reliability Working Group meetings may be held as part of these teleconferences. (See sections 3.8 and 4.2 respectively.) These teleconferences may include S&MA subject matter experts from the Government, contractor, and suppliers as required by current issues/activities. Teleconferences may be rescheduled or cancelled by mutual agreement. Face-to-face S&MA Working Group Meetings may be scheduled; however, (excluding emergency situations) they will be splinter meetings associated with audits, surveys, design reviews, status reviews, etc. where special travel will not be required.

3.0 SYSTEM SAFETY REQUIREMENTS

System safety is concerned with the application of systems engineering and systems management to the process of hazard, safety and risk analysis.

3.1 GENERAL REQUIREMENTS

The spacecraft contractor (including Government Furnished Equipment [GFE] instruments, subcontractors and suppliers) shall implement a system safety program for flight hardware, GSE, associated software, and support facilities in accordance with NPR 8715.3, "NASA General Safety Program Requirements," the requirements imposed by the GSFC OSSMA, and the appropriate launch service provider/launch range safety representative. The contractor's system safety program shall be initiated in the concept phase of design and continue through prelaunch and launch as defined by the applicable requirements documents listed in Section 3.1.1 below, and be based on a process of continuous risk assessment.

GSFC will certify safety compliance in support of the Pre-Shipment Review (PSR), and again at the Mission Readiness Review (MRR). The system safety program shall accomplish the following:

a. Provide for the early identification and control of hazards to personnel, facilities, support equipment, and the flight system during all stages of project development including design, development, fabrication, test, handling, storage, transportation, and pre-launch activities
b. Address hazards in the flight hardware, associated software, GSE, operations, and support facilities
c. Conform to the safety review process requirements of NPR 8715.7 (5/30/2008 Release), "Expendable Launch Vehicle Payload Safety Program"
d. Meet the system safety requirements of the Air Force Space Command (AFSPC) 91-710, "Range User Requirements Manual"
e. Meet the baseline industrial safety requirements of the institution, AFSPC 91-710 applicable Industry Standards to the extent practical to meet NASA and Office of Safety and Health Administration (OSHA) design and operational needs and any special contractually imposed mission unique obligations. This will be documented in the contractor's Facility Health and Safety Plan per CDRL 75.

Specific safety requirements shall include the following:

a. If a system failure may lead to a catastrophic hazard, the system shall have three (3) inhibits (dual fault tolerant). A catastrophic hazard is defined as:
    1. A hazard that could result in a mishap causing fatal injury to personnel and/or loss of one or more major elements of the flight vehicle or ground facility
    2. A condition that may cause death or permanently disabling injury, major system or facility destruction on the ground or vehicle during the mission.
b. If a system failure may lead to a critical hazard, the system shall have two (2) inhibits (single fault tolerant). A critical hazard is defined as a condition that may cause severe injury or occupational illness, or major property damage to facilities, systems, or flight hardware.
c. Hazards which cannot be controlled by failure tolerance (e.g., structures, pressure vessels, etc.) are called "Design for Minimum Risk" areas of design and have separate detailed safety requirements that they must meet. Hazard controls related to these areas are extremely critical and warrant careful attention to the details of verification of compliance on the part of the contractor.

3.1.1 Mission-related Safety Requirements Documentation

In the event of conflict, duplication, or overlap, the most stringent safety requirement takes precedence.

3.1.1.1 Expendable Launch Vehicle (ELV) Eastern Test Range (ETR) or Western Test Range (WTR) Missions

The contractor shall comply with the following launch range safety documentation:

a. AFSPCMAN 91-710, "Range Safety User Requirements"
b. KNPR 1710.2, "Kennedy Space Center Safety Practices Procedural Requirements"
c. NPR 8715.3, "NASA General Program Safety Requirements"
d. Facility-specific Safety Requirements, as applicable
e. NSS 1740.12, "Safety Standard for Explosives, Propellants, and Pyrotechnics"
f. NASA-STD 8719.14 (8/28/2007 Release), "Process for Limiting Orbital Debris"

3.1.1.2 Payload Integration Facility Requirements

Contractors performing integration and test (I&T) activities shall comply with all applicable installation safety requirements as well as the following NASA safety requirements:

NASA STD 8719.9, Lifting Devices and Equipment

NASA STD 8719.17, Ground-Based Pressure Vessels and Pressurized Systems

Contractors shall provide procedures that apply to operations within facilities other than GSFC I&T facilities when requested.

3.2 SYSTEM SAFETY DELIVERABLES

The contractor shall not forward any safety deliverable to the Launch Range or to Launch Range Safety until it has been reviewed and accepted by the LDCM Safety Team and subsequently approved by the LDCM Project Office.

3.2.1 System Safety Program Plan

The contractor shall prepare a System Safety Program Plan (SSPP) as part of the MAIP in accordance with CDRL 75 which describes in detail, tasks and activities of system safety management and system safety engineering required to identify, evaluate, eliminate, and control hazards or reduce the associated risk to a level acceptable throughout the system life cycle. The approved plan provides the formal basis of understanding between the contractor and GSFC Project Office on how the System Safety Program will be conducted to meet NASA and range safety requirements including general and specific provisions.

3.2.2 Safety Requirements Compliance Checklist

The contractor shall develop a Safety Requirements Compliance Checklist in accordance CDRL 49 to demonstrate that the payload is in compliance with all safety requirements (or that Failure Reports/ waivers have been submitted to and approved by the GSFC Project Office and the launch site safety representative). Safety compliance will be granted via a GSFC Code 321 Safety Certification Letter to the GSFC LDCM Project Manager only after verification that all applicable safety requirements have been met.

3.2.3 Safety Analysis

3.2.3.1 Preliminary Hazard Analysis

The contractor shall perform and document a Preliminary Hazard Analysis (PHA) in accordance with CDRL 49 to identify safety critical areas, to provide an initial assessment of hazards, to identify requisite hazard controls and follow-on actions, and to obtain an initial risk assessment of a concept or system.

3.2.3.2 Subsystem Hazard Analysis

In accordance with 49, the Subsystem Hazard Analysis (SSHA) will verify subsystem compliance with safety requirements contained in subsystem specifications and other applicable documents, to identify previously unidentified hazards associated with the design of subsystems (including component failure modes, critical human error inputs, and hazards resulting from functional relationships between components and equipment comprising each subsystem), and to recommend actions necessary to eliminate identified hazards or control their associated risk to acceptable levels. The SSHA will identify all components and equipment that could result in a hazard whose design does not satisfy contractual safety requirements.

The SSHA will include GFE, non-developmental items, and software. Areas to consider are performance, performance degradation, functional failures, timing errors, design errors or defects, or inadvertent functioning. The human should be considered a component within a subsystem, receiving both inputs and initiating outputs, during the conduct of this analysis. Results shall be documented in the Spacecraft/Observatory Missile System Pre-Launch Safety Data Package (MSPSP). (See Section 3.4 for more information on the MSPSP.)

3.2.3.3 System Hazard Analysis

In accordance with 49, the System Hazard Analysis (SHA) verifies system compliance with safety requirements contained in system specifications and other applicable documents to identify previously unidentified hazards associated with the subsystem interfaces and system functional faults, to assess the risk associated with the total system design (including software, and specifically that of the subsystem interfaces), and to recommend actions necessary to eliminate identified hazards and/or control their associated risk to acceptable levels. Results shall be documented in the Spacecraft/Observatory MSPSP. (See Section 3.4 for more information on the MSPSP.)

3.2.3.4 Operations Hazards Analyses

The contractor shall prepare an Operations Hazard Analysis (OHA) in accordance with CDRL 41 which describes the hardware and test equipment operations, demonstrates that the planned I&T activities are compatible with the facility safety requirements, and demonstrates that any inherent hazards associated with those activities is mitigated to an acceptable level.

The contractor's system safety program shall:

a. Review the organization's test and handling procedures for I&T prior to receiving the hardware at the I&T facility
b. Review and approve all in-process procedures and travelers that involve safety related items
c. Approve hazardous procedures and travelers generated during I&T activities (including real-time changes to documents)
d. Witness hazardous operations

3.2.3.5 Operating and Support Hazard Analysis

In accordance with CDRL 49, the Operating and Support Hazard Analysis (O&SHA) shall evaluate activities for hazards or risks introduced into the system during pre-launch processing and evaluate the adequacy of operational and support procedures used to eliminate, control, or abate identified hazards or risks. The O&SHA results shall be documented in the MSPSP. (See Section 3.4 for more information on the MSPSP.)

The spacecraft contractor/observatory integrator shall perform and document an O&SHA to examine procedurally controlled activities at the launch site or processing facilities in order to identify and evaluate hazards resulting from the implementation of operations or tasks performed by persons, considering the following criteria:

a. The planned system configuration and/or state at each phase of activity
b. The facility interfaces
c. The planned environments
d. The supporting tools or other equipment including software controlled automatic test equipment, specified for use; operational and/or task sequence, concurrent task effects and limitations; biotechnological factors; and regulatory or contractually specified personnel safety and health requirements
e. The potential for unplanned events including hazards introduced by human errors

The human will be considered an element of the total system, receiving both inputs and initiating outputs during the conduct of this analysis.

3.2.3.6 Software Safety

Hazards caused by software will be identified as a part of the nominal hazard analysis process and their controls will be verified prior to acceptance. Hazard analysis recommendations typically require the software contractor to demonstrate that adequate inhibits and/or controls are incorporated to eliminate or mitigate hazards to an acceptable level. Additional independent assessment may be required as dictated by the hazard probability and severity. Section 5.2 describes the LDCM spacecraft/observatory software safety activities required to meet NASA guidelines. Section 5.2.1 describes the Software Safety Plan which will be included in the System Safety Program Plan, CDRL 75.

3.3 MISSILE SYSTEM PRELAUNCH SAFETY PACKAGE

The spacecraft contractor/observatory integrator shall prepare and submit three (3) progressive iterations of the MSPSP in accordance with CDRL 49 to GSFC Project Office prior to submittal to the launch range. The contractor shall:

a. Work with GSFC Project personnel early in the project life cycle to tailor (as appropriate) safety requirements deemed not applicable to the payload and then coordinate these with the launch range
b. Identify hazards associated with the flight system, GSE, and their interfaces that affect personnel, launch vehicle hardware, or the spacecraft starting early in the design phase and continuing throughout the development effort
c. Utilize Safety Assessment Reports (SARs) from the instrument and subsystem contractors as inputs to the MSPSP
d. Demonstrate compliance with safety requirements and certify to GSFC Project Office and the launch range, through this MSPSP, that all safety requirements have been met

3.4 VERIFICATION TRACKING LOG

The spacecraft contractor/observatory integrator shall establish a "closed loop" process for tracking all hazards to acceptable closure through the use of a Verification Tracking Log (VTL) in accordance with CDRL 49. The VTL will be delivered with the final MSPSP and updated regularly as requested until all items are closed. Individual VTL items must be closed with appropriate documentation verifying the stated hazard control has been implemented, and individual closures must be complete prior to the first operational use/restraint.

3.5 GROUND OPERATIONS PROCEDURES

In accordance with 16, the contractor shall submit all hazardous ground operations procedures to be used at GSFC facilities or the launch site. All hazardous operations, as well as the procedures to control them, shall be identified and highlighted. All launch site procedures shall comply with the launch site and NASA safety regulations. The GSFC Project Office will approve all hazardous procedures before their submittal to the launch range to ensure they comply with the launch site and NASA safety regulations.

3.6 SAFETY WAIVERS

When a specific NASA safety requirement cannot be met, the contractor shall submit an associated safety waiver or exception, in accordance with NASA Procedural Requirement (NPR) 8715.3 and CDRL 3, which identifies the hazard and shows the rationale for approval. All requests for waivers or exceptions will be accompanied by documentation as to why the requirement cannot be met, what risks are involved, alternative means to reduce the hazard or risk, the duration of the variance, and comments from any affected employees or their representatives if the waiver/exception affects personnel safety.

3.7 SUPPORT FOR SAFETY MEETINGS

Technical support shall be provided to the Project for Safety Working Group (SWG) meetings, Technical Interface Meetings (TIMs), and technical reviews, as required. The SWG will meet as necessary to review procedures and analyses that contain or examine safety critical functions, or as convened by GSFC Project to discuss any situations that may arise with respect to overall project safety. For proposal purposes, the contractor should assume that SWG meetings will normally be held as a sidebar to other reviews and meetings to minimize travel.

3.8 ORBITAL DEBRIS ASSESSMENT

Program/Project Managers shall ensure the implementation of orbital debris mitigation measures for all mission hardware in Earth orbit, as defined in NPR 8715.6A "NASA Procedural Requirements for Limiting Orbital Debris," and NASA-STD 8719.14 (8/28/2007 Release), "Process for Limiting Orbital Debris." Each instrument or subsystem contractor shall aid the spacecraft contractor and/or GSFC in completing an orbital debris assessment (ODA) in accordance with CDRL 48 of the instrument/subsystem by:

a. Designing for end-of-mission disposal
b. Developing an end-of-mission plan
c. Addressing potential orbital debris generation in their ODA from the following:
    1. Normal operations
    2. Stored energy sources in instruments (pressure vessel, dewar, etc.)
    3. Accidental explosions
    4. Intentional breakups
    5. On-orbit collisions with objects during mission operations
    6. Disposal of space systems after mission completion

7. Energy sources that can be passivated at end of life
8. Structural components impacting the Earth following post-mission disposal by atmospheric reentry

The contractor can use ODA Software that is available for download from the NASA Orbital Debris Program Office at URL: http://sn-callisto.jsc.nasa.gov

3.9 LAUNCH SITE SAFETY SUPPORT

The contractor shall provide and coordinate manpower requirements necessary for safety support of all operations at the launch site. Range safety is not responsible for project safety support at the launch ranges. Safety support of hazardous I&T operations performed at the launch site will be planned and budgeted for by the project and contractor, as appropriate.

3.10 MISHAP REPORTING AND INVESTIGATION

In accordance with CDRL 47, the contractor shall participate in NASA's mishap reporting and investigation process. Any mishaps, incidents, hazards, and/or close calls shall be reported to NASA via their Incident Reporting Information System (IRIS) or equivalent form, per NPR 8621.1, "NASA Procedures and Guidelines for Mishap Reporting, Investigating, and Recordkeeping." All accidents, mission or test failures, or other mishaps shall be promptly investigated to determine the dominant root cause.

3.11 MISCELLANEOUS SUBMITTALS FOR RANGE USE

The following list of forms is required by range safety and shall be submitted through GSFC Safety in accordance with CDRL 49.

a. Material Selection List for Plastic Films, Foams, and Adhesive Tapes – (http://rtreport.ksc.nasa.gov/techreports/95report/msf/ms10.html).
b. Radiation forms/analysis – KHB 1860.1 (Kennedy Space Center [KSC] Ionizing Radiation Protection Program) and KHB 1860.2 (KSC Non-Ionizing Radiation Protection Program)
c. Process Waste Questionnaire (PWQ) (KSC Only)
d. Environmental Impact Statement (EIS) (KSC Only)

3.12 SAFETY ASSESSMENTS

Contractors shall provide full support (management and technical) to GSFC Safety Assessments/Audit Teams which include, but is not limited to planning and scheduling, management participation in briefings (in-briefings, daily briefings, out-briefings, etc.), providing escorts as required or requested, responding to findings and observations with corrective actions within 30 days of receipt, and supporting follow-up assessments as determined necessary by the GSFC Project Office. The Assessment/Audit Team will make every effort to minimize their impact to on-going work schedules. The Assessment/ Audit teams will generally consist of 2 or 3 people who are experts in the safety field. These Assessments/Audits may be conducted independently or combined with others reviews of the contractor's activities.

4.0 RELIABILITY AND PROBABILISTIC RISK ASSESSMENT REQUIREMENTS

A Reliability and Probabilistic Risk Assessment (PRA) program, applicable to all system elements, shall be implemented as specified herein and as referenced in NPR 8705.4 Risk Classification for NASA Payloads, "Class B," requirements to ensure that:

a. A PRA is used to assess, manage, and quantitatively assess the need to reduce program technical risks.
b. Redundant functions, including alternative paths and work-arounds, are shown to be independent to the extent practicable.
c. Stresses applied to parts are not excessive.
d. Performance margins for electrical/electronic circuits are demonstrated, and are shown to be commensurate with mission lifetime requirements under worst case conditions.
e. Single failure items/points, their effect on the attainment of mission objectives, and possible safety degradation are clearly identified and addressed.
f. The reliability design aligns with mission design life and is consistent among the systems, subsystems, and components.
g. Limited-life items are clearly identified and special precautions are taken to conserve their useful life for on-orbit operations as needed to meet mission requirements,
h. Significant engineering parameters are selected for trend analysis to identify/monitor performance trends during integration and test activities.
i. The design permits easy replacement of parts and components during ground testing and redundant paths are easily monitored.

An individual to serve as the point of contact for Reliability and Probabilistic Risk Assessment activities shall be identified by contractor(s) to support, report on, and assess progress toward achieving the applicable requirements of this chapter including identification of areas for improvement.

4.1 RELIABILITY PROGRAM PLAN

The contractor shall provide a documented Reliability Program Plan (PPR) that describes the planned approach for the project reliability activities in accordance with CDRL 75. The contractor's plan will ensure that the Reliability and Maintainability (R&M) design and operational functions and performance requirements are an integral part of the design and development process, beginning early in the project lifecycle, and that the reliability functions interact effectively with other project activities including systems engineering, hardware design, safety, quality, logistics (including maintenance), availability, life-cycle cost, configuration management, and other activity critical to mission success.

The contractor shall establish and document a system maintenance concept and include it in the plan early in the system development lifecycle and ensure that compatibility is sustained among system design, maintenance planning, and logistics support activities throughout the project lifecycle. As part of the system maintenance concept, the contractor will establish and maintain logistics support capability to sustain delivered hardware and software systems, consistent with the intended mission requirements and plans. In addition, the contractor will maintain a list of mission critical facilities and equipment along with the accompanying rationale for the critical designation.

4.2 RELIABILITY WORKING GROUP PARTICIPATION

The contractor shall provide technical support to the Project for Reliability Working Group (RWG) meetings and technical reviews, as required. The RWG meets as necessary, and as convened by the project personnel, to review reliability and PRA requirements and analyses, to assist in resolving reliability and risk related issues and concerns, and to discuss any situations that may arise with respect to overall mission reliability. For proposal purposes, the contractor should assume that RWG meetings will be held as a sidebar to other reviews and meetings to minimize travel.

4.3 RELIABILITY ANALYSES AND PROBABILISTIC RISK ASSESSMENT ACTIVITIES

The contractor performs/supports reliability and risk analyses concurrently with design activities to optimize system configurations and to identify and promptly correct potential problems. The contractor shall present results of the analyses at all design reviews starting with the Spacecraft System Requirements Review (SSRR) and include comments on how the analysis was used to perform design and operational trade-offs and how the results were taken into consideration when making design or risk management decision.

4.3.1 Probabilistic Risk Assessment

In accordance with CDRL 75, the contractor shall generate a Probabilistic Risk Assessment Plan (PRAP) that will describe the project's approach for the probabilistic risk assessment activities, including a Limited-Scope PRA performed by the contractor commensurate with a Class B Mission as defined in NPR 8705.4, NPR 8705.5 and NPR 8715.3. A Limited-Scope PRA is performed with the same general rigor as a Full-Scope PRA but focuses on mission-related end-states of decision-making interest instead of all applicable end-states.

Potential candidates for PRA analysis may be identified at systems meetings, working group meetings, from hazard analyses, instrument and observatory Failure Modes and Effects Analyses (FMEAs), I&T problem reports, etc. The contractor will submit PRA analysis candidates to the GSFC Project Office. The purpose for each PRA analysis will be clearly stated; i.e., what specific risk scenarios, decisions, or trade studies the analysis will be used to support.

The contractor shall support and implement PRA procedures to reflect and incorporate the results of project risk analysis including the identification of hazards, risks, and recommended controls to manage risk, as necessary. In addition, the contractor shall update design, operating, and implementation plans to reflect insights gained from PRA analysis and use the insights to reinforce or modify existing relevant management decisions or to generate new management decisions.

PRA Analysis information and reports shall be provided to the GSFC Project Office in accordance with CDRL 35.

4.3.2 Failure Modes and Effects Analysis (FMEA), Critical Items List (CIL), and Critical Items Control Plan (CICP)

In accordance with CDRL 36, the contractor shall perform, a FMEA, develop a CIL, and document a corresponding CICP and. deliver the same to the GSFC Project Office. Activities begin early in the design phase to identify potential failure modes and the effect of those failures on related systems or the mission. The FMEA is then updated throughout the lifecycle of the system or mission to reflect current configuration(s).

The FMEA assesses failure modes at the component interface level for all spacecraft components, all experimental interfaces (i.e., instruments), and all interfaces to GSE and/or simulators that will interface with spaceflight hardware. The effect at that level of analysis, the next higher level, and upward will be evaluated. A severity category is assigned to each failure mode based on the most severe effect caused by a failure. The FMEA addresses specific mission phases (e.g., launch, deployment, and on-orbit operation) in the analysis.

The severity category designations are shown in Table 4-1 below:

Table 4-1. Severity Categories

Category	Severity Description
1	Catastrophic Failure modes that could result in serious injury, loss of life (flight or ground personnel), or loss of launch vehicle.
1R	Failure modes of identical or equivalent redundant hardware items that could result in Category 1 effects if all failed.
1S	Failure in a safety or hazard monitoring system that could cause the system to fail to detect a hazardous condition or fail to operate during such condition and lead to 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.

The contractor uses the results of the FMEA to evaluate the design against requirements and to ensure that any identified discrepancies are evaluated by project or mission management to determine the need for corrective action. The FMEA is also used to ensure that redundant paths are isolated or protected so that any single failure causing loss of a functional path will not affect other functional paths or the capability to switch to a redundant path. The contractor shall analyze failure modes resulting in severity categories 1, 1R, 1S or 2 down to the piece part level for electronics, down to the mechanism or electro-mechanical level for mechanical systems, and down to the functional level for software.

Itemized failure modes assigned to "severity categories" 1, 1R, 1S, and 2 (from Table 4-1 above) shall be placed on a CIL. Specific controls used to mitigate risks associated with each critical item shall be identified and documented. The CICP requires specific, traceable, and verifiable procedures be introduced into the design, manufacturing, and test phases of the program to control and reduce the likelihood that critical items will fail on-orbit. The CICP also provides retention rationale for each critical item that describes justification for retaining the potential failure in the design. Retention rationale consists of design features, test, inspection, heritage and flight history, operational considerations, workarounds, etc. that reduce the likelihood of the failure occurring and reduce the potential consequences if the failure occurs.

4.3.3 Fault Tree Analysis

In accordance with CDRL 36, the contractor shall perform fault tree analyses that address both mission failures and degraded modes of operation. Beginning with each undesired state (mission failure or degraded mission), the fault tree expands to include all credible combinations of events, faults, and environments that could lead to the undesired state. Component hardware and software failures, external hardware and software failures, and human factors are considered in the analysis.

4.3.4 Parts Stress Analyses

In accordance with CDRL 36, the contractor shall subject each application of electrical, electronic, and electromechanical (EEE) parts to stress analyses for conformance with the applicable derating guidelines as agreed upon with the GSFC Project Office. The analyses shall be performed at the most stressful values that result from specified performance and environmental requirements (e.g., temperature and voltage) on the assembly or component.

4.3.5 Worst Case Analysis

In accordance with CDRL 36, the contractor shall perform a Worst Case Analysis (WCA) on circuits where failure results in a "severity category" (from Table 4-1 above) of 1, 1S, 1R, 2, or 2R and provides data that questions the flightworthiness of the design. The WCA will analyze the most sensitive design parameters including those that are subject to variations that could degrade performance. The adequacy of design margins in the electronic circuits, optics, electromechanical, and mechanical items may be demonstrated by analyses, test, or both to ensure flightworthiness.

The analyses consider all parameters set at worst case limits and worst case environmental stresses for the parameter or operation being evaluated. Depending on mission parameters and parts selection methods, part parameter values for the analyses will typically include:

a. Manufacturing variability
b. Variability due to temperature
c. Aging effects of environment
d. Variability due to cumulative radiation

4.3.6 Reliability Assessments and Predictions

The contractor shall perform comparative numerical reliability assessments and/or reliability predictions including Spacecraft Reliability Model Analysis and Reports as applicable (e.g., to support trade studies particularly before the Preliminary Design Review [PDR]) in accordance with CDRL 36 to:

a. Evaluate alternative design concepts, redundancy, and cross-strapping approaches, and part substitutions
b. Identify the elements of the design that are the greatest detractors of system reliability
c. Identify 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, other reliability goals, and requirements as applicable
e. Evaluate the impact of proposed engineering change and waiver requests on reliability

4.3.7 Trend Analyses

As part of routine system assessment, the contractor assesses all subsystems and components to determine measurable parameters that relate to performance stability. Selected parameters are monitored for trends starting at component acceptance testing and continuing during the system I&T phases. The monitoring will be accomplished within the normal test framework; i.e., during functional tests and environmental tests. The contractor establishes a system for recording and analyzing the parameters as well as any changes from the nominal (even if the levels are within specified limits). Trend analysis data is reviewed with operational personnel prior to launch and operational personnel continue recording trends throughout the system's mission life. A list of subsystem and components to be assessed, parameters to be monitored, and trend analysis reports shall be maintained and submitted in accordance with the Statement of Work (SOW) or the Reliability Program Plan (RPP) in accordance with CDRL 42. The contractor presents the list of parameters to be monitored at the Critical Design Review (CDR) while the trend analysis reports are presented at the Pre-Environmental Review (PER) and the Flight Readiness Review (FRR).

4.3.8 Analysis of Test Results

The contractor 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 contractor management for action. This information shall be available to GSFC Office personnel for review upon request.

4.4 LIMITED-LIFE ITEMS

The contractor shall provide the GSFC Project Office with a plan to identify and manage limited-life items in accordance with CDRL 36. Additionally, the S&MA Data Package, which shall include an as-built Limited Life List, shall be delivered in accordance with CDRL 42. In the plan, the contractor defines the impact on mission parameters, identifies the responsibilities for mitigating the impact of limited-life items, and provides a list of limited-life items including selected structures, thermal control surfaces, solar arrays and electro-mechanical mechanisms including data elements as follows:

a. Expected life
b. Required life
c. Duty cycle
d. Rationale for selection

The useful life period starts with fabrication and ends with the completion of the final orbital mission.

Atomic oxygen, solar radiation, shelf-life, extreme temperatures, thermal cycling, wear and fatigue are all factors 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 will be included when aging, wear, fatigue, and lubricant degradation limit their life. Records shall be maintained that allow evaluation of cumulative stress (e.g., 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 will be approved by the GSFC Project Office by means of a program waiver in accordance with CDRL 3.

4.5 CONTROL OF SUBCONTRACTORS AND SUPPLIERS

Contractors shall ensure that system elements obtained from subcontractors and suppliers meet project reliability requirements. All subcontracts shall include provisions for review and evaluation of the subcontractors' and suppliers' reliability efforts by the prime contractor at the prime contractor's discretion and by GSFC at its discretion. The contractor shall tailor the reliability requirements of this document in hardware and software subcontracts for the project. The contractor exercises necessary surveillance to ensure that subcontractor and supplier reliability efforts meet overall system requirements.

The contractor ensures that the tailored requirements:

a. Incorporate quantitative reliability requirements in subcontracted equipment specifications
b. Assure that subcontractors have reliability programs that are compatible with the overall program
c. Review subcontractor assessments and analyses for accuracy and correctness of approach
d. Review subcontractor test plans, procedures, and reports for correctness of approach and test details
e. Attend and participate in subcontractor design reviews
f. Ensure that subcontractors, during the project operational phase, comply with the applicable system reliability requirements

4.6 RELIABILITY AND MAINTAINABILITY OF GOVERNMENT-FURNISHED EQUIPMENT

When the overall system includes components or other elements furnished by the Government, the contractor shall identify and request adequate reliability data on the items from the GSFC Project Office.

The data will be used for performing the reliability analyses. When examination of the data or testing by the contractor indicates that the reliability of GFE is inconsistent with the reliability requirements of the overall system, the contractor shall formally and promptly notify the GSFC Project Office.

5.0 SOFTWARE ASSURANCE REQUIREMENTS

5.1 GENERAL

LDCM software contractors for systems that are designed, developed, and/or implemented shall implement and document, as part of their QMS, a software assurance program that is consistent with the philosophy that assurance activities must be integral throughout the software planning and development process. In accordance with CDRL 75, a Software Assurance Plan (SAP) specific to work designed, developed, and/or implemented for LDCM shall be provided by each software contractor. The SAP shall identify the heritage code and discuss the assurance plan for new and modified code.

5.1.1 Software Assurance

In addition to requirements outlined in this document, contractors shall comply with:

a. NPR 7150.2, NASA Software Engineering Requirements
b. NASA-STD-8719.13, NASA Software Safety Standard
c. NASA-STD-8739.8, NASA Standard for Software Assurance

The contractor shall identify a person responsible for directing and managing the Software Assurance Program; e.g., a software assurance manager. The contractor shall ensure that all personnel involved with software covered by this document receives appropriate training and are qualified. The contractor shall also verify that the assessment program meets all NASA, GSFC, and contract requirements. Any Safety critical software shall be identified by the contractor as part of a software classification assessment. The contractor must certify all safety critical software for its intended use.

As part of the Software Assurance Program the following plans, documents, and reports shall be provided by the contractor to GSFC for all software and firmware developed for programs/projects developed or implemented through GSFC, including Government off-the-shelf (GOTS) software, modified off-the-shelf (MOTS) software, and commercial off-the-shelf (COTS) software (as required by the contract or the SOW). For the purposes of this contract, software shall be treated as a subsystem; hence, the software document shall be part of a higher level document due to the project. For example, the Software Assurance Plan shall be part of the MAIP, CDRL 75, and the Software Safety Plan shall be part of the System Safety Project Plan, CDRL 75.

a. Software Assurance Plan
b. Software Management Plan
c. Software Safety Plan
d. Software Requirements Specifications
e. Software Requirements Traceability Matrix
f. Software Requirements Verification Matrix
g. Software Configuration Management Plan
h. Software Monthly Status Reports
i. Version Description Documents and User Guides

The SAP shall be prepared in accordance with CDRL 75 and the Institute of Electrical and Electronics Engineers (IEEE) Standard 730, "Software Quality Assurance Plans." It shall include information on what contractor documentation includes each of the above plans, specifications, matrices, reports, documents, and guides.

The Software Management Plan, shall document software roles and responsibilities, software development processes and procedures, software reviews, software tools, resources, schedules, and deliverables throughout the development life cycle. In addition, the Software Management Plan shall address the safe termination of operations, decommissioning, and retirement of the system for which the software is designed.

5.1.2 Software Quality

As part of the overall Software Assurance Program, contractors shall implement Software Quality program activities to assure the quality of the software products and processes. These activities include planning, analysis, tracking, controlling, and implementation of process and product assurance activities throughout the procurement and development life cycle.

The following software assurance activities shall be considered as part of the software quality assurance planning and scoping activities that determine the software components to be analyzed:

a. Standards and procedures for management, software engineering, and software assurance activities are well defined and implemented.
b. All plans (e.g., Configuration Management, Risk Management, and Software Management Plan) required by the contract are documented, comply with applicable standards and contractual requirements, are mutually consistent, and are executed.
c. Standards, design, and code are evaluated for quality issues.
d. All software requirements are defined, documented, and traceable throughout all project lifecycle phases (i.e., from system requirements through design, code, and test) in a software requirements bi-directional traceability matrix.
e. Software requirement verification status is updated and maintained via a software requirements verification matrix.
f. Formal and acceptance-level software tests are witnessed to assure satisfactory completion and maintenance of test artifacts.
g. Software products and related documentation (e.g., Version Description Documents and User Guides) have the required content and satisfy their contractual requirements.
h. Project documentation including plans, procedures, reports, schedules, and records are reviewed for impact to the quality of the product.
i. Software quality metrics are captured, analyzed, and trended to ensure the quality and safety of the software products.
j. Management, software engineering, and assurance personnel adhere to specified standards and procedures and comply with contractual requirements.
k. All plans (e.g., Configuration Management and Software Management) and procedures are implemented according to specified standards and procedures.
l. Contract requirements are passed-down to any/all subcontractors and that the subcontractor's software products satisfy the prime contractor's contractual requirements.
m. Engineering peer reviews (e.g., design walkthroughs and code inspections) and software milestone reviews are conducted and action items are tracked to closure.
n. A software problem reporting system and corrective action process is in place and provides the capability to document, search, and track software problems and anomalies.
o. The software is tested to verify compliance with functional and performance requirements.
p. Software safety processes and procedures are followed.
q. Software assurance processes are in place for maintenance of software.

5.2 SOFTWARE SAFETY

The contractor shall conduct a software safety program that is integrated with the overall software assurance and systems safety program (See Chapter 3.) and is compliant with the software safety requirements levied upon the contractor by the GSFC Project Office. That software safety program shall contain the following elements: 1) planning, 2) safety-critical software determination, 3) hazard analyses, 4) validation and verification, and 5) tracking.

5.2.1 Planning

In accordance with CDRL 75, the contractor shall prepare a Software Safety Plan that contains all of the following elements:

a. The activities to be carried out, the schedule on which they will be implemented, the personnel who will carry out the activities, the methodologies to be used, and the products that will result
b. The mechanism by which safety-critical requirements will be generated, implemented, tracked, and verified
c. Procedures for ensuring prompt follow-up and satisfactory resolution of software safety concerns and recommendations
d. How the software safety activities and schedule will be synchronized with related program/ project activities and the software and system lifecycles
e. The number and relative schedule of software safety assurance audits to be conducted
f. The assignment of responsibility for monitoring the system during systems operation and the procedures to be followed when those monitoring the system feel that the safety of the system, environment, or personnel may be threatened
g. Training requirements for project software safety roles
h. The change approval and configuration management process, including the change and approval process, for the software safety-related portions of all project documents
i. A matrix between NASA-STD-8719.13 and this Software Safety Plan to demonstrate how the Plan meets the requirements of NASA-STD-8917.13.

5.2.2 Safety-Critical Software Determination

The contractor shall evaluate the software for its contribution to the safety of the system. Software is safety-critical if it meets at least one of the following criteria:

a. Resides in a safety-critical system (as determined by a hazard analysis) AND at least one of the following is true:
   i. Causes or contributes to a hazard
   ii. Provides control or mitigation for hazards
   iii. Controls safety-critical functions
   iv. Processes safety-critical commands or data
   v. Detects and reports or takes corrective action if the system reaches a specific hazardous state
   vi. Mitigates damage if a hazard occurs
   vii. Resides on the same system (processor) as safety-critical software
b. Processes data or analyzes trends that lead directly to safety decisions; e.g., determining when to turn power to a wind tunnel off to prevent system destruction
c. Provides full or partial verification or validation of safety-critical systems including hardware or software subsystems

The contractor shall document all analyses used to determine software safety critical items. This information shall be made available to the GSFC Project Office upon request.

5.2.3 Hazard Analyses

The contractor shall perform safety analyses (e.g., PHA, subsystem hazard analyses, FMEA, and/or Fault Tree Analysis [FTA]) to identify hazards, assess risks, and determine design features and requirements to prevent, mitigate, or control failures and faults. The contractor shall use those safety analyses to ensure that:

a. Hazards associated with a specific requirement, design concept and/or operation for a software's contribution to hazard causes, controls, or mitigations are identified.
b. Hazard controls that require software implementation are identified.
c. Safety design features and methods (e.g., inhibits, failure detection and recovery, interlocks, assertions, and partitions) that the contractor will use to implement the software safety requirements are identified.
d. Software safety requirements derived from safety analyses are clearly identified, documented, tracked, and controlled throughout the lifecycle.
e. Software safety analyses are coordinated with the overall system safety analyses.

The contractor shall:

a. Record the results of the safety analyses in the appropriate documentation.
b. Assure that the software safety requirements during the design phase provide adequate response to potential failures and are adequate for their function. Areas to consider will include, but are not limited to, limit ranges; relationship logic for interdependent limits; out-of-sequence event protection; timing problems; sensor or actuator failures; voting logic; hazardous command processing requirements; Fault Detection, Isolation, and Recovery (FDIR); switchover logic for failure tolerance; and the ability to reach and maintain a safe state if so required.
c. Identify and document safety-critical events, commands, data, and constraints including modes or states where those events, commands, data, and constraints are not safety-critical.
d. Assure that safety-critical off-the-shelf software (e.g., COTS, GOTS, MOTS, etc.) and reused software undergo safety analysis. The safety analysis shall consider the software's ability to meet required safety functions, extra functionality, and interfaces to developed code.
e. Assure that all project tools that could potentially impact safety-critical software are identified. Tools may include CASE products, compilers, editors, fault tree generators, simulators, emulators, and test environments for hardware and software.

5.2.4 Software Safety Validation and Verification

The contractor shall perform Verification and Validation (V&V) activities as follows:

a. Create a tracing system that maps the relationships between software safety requirements and system hazards and traces the flow down of software safety requirements to design, implementation, and test.
b. Identify all software safety requirements as safety-critical and assure that those requirements have been flowed down to system specifications.
c. Verify that all software safety requirements, design features, and methods have been correctly implemented into the design and code.
d. Verify all functional software safety requirements and safety-critical software elements through testing.
e. The contractor shall assure that testing:

i. Includes unit level tests and component level tests that incorporate software safety testing. The contractor shall make the documentation related to these tests available to the GSFC Project Office upon request.
ii. Verifies that system hazards related to software have been eliminated or controlled to an acceptable level of risk
iii. Demonstrates that the software maintains the system in a safe state and does not compromise any safety controls or processes
iv. Verifies the correct and safe operation of the system under system load, stress, and off-nominal conditions and configurations
v. Uses safety analyses, such as PHAs, subsystem hazard analyses, FMEAs, FTAs to determine which failures to test for, and the level of failure combinations to include (e.g., both a software and a hardware failure or multiple concurrent hardware failures)
vi. Verifies the correct and safe operation of the system in the presence of failures and faults including software, hardware, input, timing, memory corruption, communication, and other failures
vii. Verifies correct and safe operation in conjunction with system hardware and operator inputs

f. Verify that the software design and implementation do not compromise any safety controls or processes; that any additional hazard, hazard cause, or hazard contribution is documented; and that the design maintains the system in a safe state during all modes of operation.
g. Document the results of V&V activities including any new hazards identified during verification and improperly implemented requirements.

5.2.5 Software Safety Tracking

The contractor shall:

a. Assure that its problem tracking system traces identified safety-critical software problems back to the system-level hazard involved
b. Coordinate the software problem tracking system with system level hazard tracking
c. Evaluate software changes, including those that result from problem or discrepancy resolution, for potential safety impact including the creation of new hazard contributions and impacts, modification of existing hazard controls or mitigations, or detrimental effect on safety-critical software or hardware
d. When applicable, assure that operational documentation including user manuals and procedures describe all safety related commands, data, input sequences, options, and other items necessary for the safe operation of the system

In cases, where the contractor/subcontractor cannot meet the MAR's full software safety requirements, the contractor shall document the variances in a deviation/waiver package. The contractor will furnish this deviation/waiver package to the GSFC Project Office in accordance with CDRL 3.

5.3 SOFTWARE TRACKING

The contractor's software assurance program shall include level, time between discovery and fault removal, and the number documenting, monitoring, analyzing, and tracking software metrics during each stage of development and across development and operational phases. Examples include fault counts by severity of defects per lines of code. The contractor shall also perform trend analysis on the software defects and make the analysis results available for root cause analysis or lessons learned. This information shall be made available to the GSFC Project Office upon request.

5.4 VERIFICATION AND VALIDATION

The contractor shall plan and implement a V&V program to ensure that software being developed or maintained satisfies functional, performance, and other requirements at each stage of the development process and that each phase of the development process yields the right product. To assist in the V&V of software requirements, the contractor will develop and maintain (under configuration control) a Software Requirements Verification Matrix. This matrix will document the flow-down of each requirement to the test case and test method used to verify compliance and the test results. The matrix will be made available to the GSFC Project Office upon request.

V&V activities are performed during each phase of the development process. V&V activities shall include the following:

a. Analysis of system and software requirements allocation, verifiability, testability, completeness, and consistency
b. Design and code walkthroughs and/or inspections; i.e., engineering peer reviews
c. Formal reviews
d. Documented test plans and procedures
e. Test planning, execution, and reporting
f. Witness tests and/or review test results

5.5 INDEPENDENT VERIFICATION AND VALIDATION

The contractor shall provide all information required for the Independent Verification and Validation (IV&V) effort to NASA IV&V Facility personnel upon request and as funded by NASA Headquarters (HQ). This shall include, but is not limited to, access to all software reviews and reports, contractor plans and procedures, software code, software design documentation, and software problem reporting data. Wherever possible, the contractor shall permit electronic access to the required information or furnish soft copies of requested information to NASA IV&V personnel.

The contractor shall review and assess all NASA IV&V findings and recommendations. The contractor will forward their assessment of these findings and recommendations to NASA IV&V personnel accordingly. The contractor will take necessary corrective action based upon their assessment and notify NASA IV&V personnel of this corrective action. The contractor will also notify NASA IV&V personnel of those instances where they chose not to take corrective action. A contractor Point of Contact will be assigned and available to NASA IV&V personnel, as required, for questions, clarification, and status meetings.

5.6 REVIEWS

5.6.1 Software Reviews

The contractor shall adhere to the review criteria provided by the GSFC Systems Review Office including addressing software at all formal system-level reviews. See Chapter 8 of this document and see the SOW. The contractor shall record and maintain minutes and action items from each review. The contractor shall respond to Request for Actions (RFAs) and any action items assigned by the review panel and/or the project as a result of each review and provide a status of all action items and RFAs at subsequent software or system-level reviews.

5.6.2 Engineering Peer Reviews

The contractor is responsible for implementing a program of engineering peer reviews (e.g., design walkthroughs or code inspections) throughout the software development lifecycle to identify and resolve concerns prior to formal system/subsystem level reviews. Peer review teams are comprised of technical experts with significant practical experience relevant to the technology and requirements of the software to be reviewed. These reviews shall be commensurate with the scope, complexity, and acceptable risk of the software system/product.

Action items or RFAs from engineering peer reviews shall be recorded, maintained, and tracked throughout the development lifecycle.

5.7 SOFTWARE CONFIGURATION MANAGEMENT

The contractor shall develop, maintain, manage, and implement a Software Configuration Management (SCM) system that provides baseline management and control of software requirements, design, source code, data, and documentation. The SCM system shall be applied to all deliverables and designated non-deliverable software products. The contractor shall document the SCM system, and associated tools in the Software Configuration Management Plan as noted in Section 5.1.1 above. The plan shall address configuration identification, configuration control, configuration status accounting, and configuration audits and reviews. The SCM should be included as part of contractor's overall project CM Plan.

As part of SCM, the contractor will employ a source code version control tool (e.g., ClearCase or Starbase) that allows the contractor to check-in/check-out current or previous versions of a source file. The contractor will also use a requirements management tool (e.g., the Dynamic Object Oriented Requirement System [DOORS]) to manage the software requirements baseline. The contractor will document and implement a process for Software Problem Reporting and Corrective Action that addresses reporting, analyzing, and tracking software non-conformances throughout the development lifecycle. Software Problem Reporting should be included as part of contractor's overall project failure reporting system.

5.8 GFE, EXISTING, AND PURCHASED SOFTWARE

If the contractor will be provided software or firmware as GFE or will use existing or purchased software or COTS; the contractor shall ensure that the software meets the functional, performance, and interface requirements placed upon it. The contractor shall ensure that the software meets applicable standards including those for design, code, and documentation or secure a GSFC Project Office waiver to those standards in accordance with CDRL 3.

5.9 SOFTWARE ASSURANCE STATUS REPORTING

As part of the Project Monthly Status Reports, the contractor shall include the items listed in Section 2.5 of this document (as applicable) and trends in software quality metric data; e.g., total number of software problem reports, including the number of problem reports that were opened and closed in that reporting period.

5.10 NASA SURVEILLANCE OF SOFTWARE DEVELOPMENT

The contractor shall allow GSFC Project Office representatives and/or their designates/assignees the following insight/oversight surveillance activities (in addition to other activities as required) throughout the entire software development lifecycle:

a. Access to their software problem reporting system remotely from GSFC. If remote access is not permitted, hard copies shall be provided to the GSFC Project Office
b. Access to the software documentation to perform their job; e.g., software management plans, software assurance plans, configuration management plans, and design documentation
c. Review of the results and corrective action from process and product audits
d. Attendance at any/all engineering peer reviews (e.g., code inspections) that NASA representatives deem appropriate

e. Submission of RFAs or action items for contractor consideration
f. Review of the status of all RFAs and action items as well as their resolution
g. Access to the database for tracking requirements verification

6.0 GROUND DATA SYSTEMS ASSURANCE REQUIREMENTS

The LDCM Project has separate Ground System MAR(s) to cover mission operation requirements and activities. However, this MAR documents requirements for the spacecraft contractor/subcontractors as it pertains to test equipment and ground support equipment.

7.0 RISK MANAGEMENT

7.1 GENERAL

Risk management is a process that assists informed decision making through the systematic identification, analysis, planning, tracking, controlling, documentation, and reporting of risks. NASA uses risk as an expression of a possible loss or negative mission impact stated in terms of the likelihood that a project will experience an undesired event and the consequences, impact, or severity of that undesired event will it occur. Risk Management (RM) is a continuous, iterative process aimed at managing issues, concerns, and causes of undesired events in order to prevent them from impacting mission success. Continuous Risk Management (CRM) begins in the project formulation phase with an initial risk identification and development of a Risk Management Plan (RMP) and continues through the implementation phase with the disposition and tracking of existing and new risks.

Risk management shall be fully integrated into planning, preparation, and execution of programs and projects. Project managers are responsible for the implementation of risk management methods and techniques throughout the project lifecycle.

7.2 RISK MANAGEMENT PLAN

The contractor shall document the project-specific implementation of the CRM process in a RMP in accordance with CDRL 75. Preparation of the RMP is a requirement established by NPR 7120.5, Program and Project Management Requirements," and includes the content shown in NPR 8000.4, "Risk Management Procedural Requirements." The plan shall include risks associated with hardware and software (e.g., technical challenges, new technology qualification, reliability, etc.), COTS, system safety, performance, threats, vulnerabilities, cost and schedule (i.e., programmatic risks). The plan shall identify which tools and techniques will be used to manage these risks.

7.3 RISK LIST

The contractor shall maintain a Risk List throughout the project life cycle along with programmatic impacts. This list will indicate which risks have the highest probability, which have the highest consequences, and which risks represent the greatest risk to mission success. The list will also identify actions being taken to address each specific risk. The Risk List shall be configuration controlled.

7.4 REPORTING

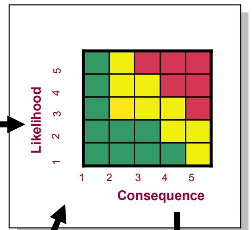
All identified risks will be documented and reported in accordance with the project's RMP. Identified risk areas will be addressed at project status reviews and at Integrated Independent Reviews. Risk status will be available to all members of the project team for review. As a minimum the risk list, the top ten risks, mitigation approaches, and any other relevant data shall be presented at all major reviews. Although not all risks will be fully mitigated, all risks shall be addressed with mitigation and acceptance strategies agreed upon at appropriate mission reviews. As a minimum, risks shall be reported for their impact in the following areas:

a. Performance or Technical
b. Safety
c. Cost
d. Schedule

Risks shall be reported at reviews and in reports using GSFC's five by five (5X5) matrix and related definitions as defined below:

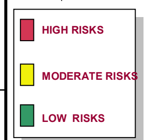
GSFC Recommended 5x5 Risk Scorecard

Likelihood Bins	Safety (Likelihood of safety event occurrences)	Technical (Estimated Likelihood of not meeting mission technical performance requirements)	Cost/Schedule (Estimated Likelihood of not meeting allocated Cost/Schedule requirement or margin)
5 Very High	($P_S > 10^{-1}$)	($P_T > 50\%$)	($P_{CS} > 75\%$)
4 High	($10^{-2} < P_S < 10^{-1}$)	($25\% < P_T < 50\%$)	($50\% < P_{CS} \leq 75\%$)
3 Moderate	($10^{-3} < P_S < 10^{-2}$)	($15\% < P_T < 25\%$)	($25\% < P_{CS} \leq 50\%$)
2 Low	($10^{-6} < P_S < 10^{-3}$)	($2\% < P_T < 15\%$)	($10\% < P_{CS} \leq 25\%$)
1 Very Low	($P_S < 10^{-6}$)	($0.1\% < P_T < 2\%$)	($P_{CS} \leq 10\%$)



Consequence Categories

Risk Type	1 Very Low	2 Low	3 Moderate	4 High	5 Very High
Safety	Negligible or No impact.	Could cause the need for only minor first aid treatment .	May cause minor injury or occupational illness or minor property damage.	May cause severe injury or occupational illness or major property damage.	May cause death or permanently disabling injury or destruction of property.
Technical	No impact to full mission success criteria	Minor impact to full mission success criteria	Moderate impact to full mission success criteria. Minimum mission success criteria is achievable with margin	Major impact to full mission success criteria. Minimum mission success criteria is achievable	Minimum mission success criteria is not achievable
Schedule	Negligible or no schedule impact	Minor impact to schedule milestones; accommodates within reserves; no impact to critical path	Impact to schedule milestones; accommodates within reserves; moderate impact to critical path	Major impact to schedule milestones; major impact to critical path	Cannot meet schedule and program milestones
Cost	<2% increase over allocated and negligible impact on reserve	Between 2% and 5% increase over allocated and can handle with reserve	Between 5% and 7% increase over allocated and can not handle with reserve	Between 7% and 10% increase over allocated, and/or exceeds proper reserves	>10% increase over allocated, and/or can't handle with reserves



Risk 5X5 Instructions

Purpose: The Risk 5x5 is a qualitative tool used for executive level management reporting and independent assessment to communicate individual and composite risk in the context of mission success. This tool is not intended for rigorous risk assessment needs and should be used in conjunction with other analytical tools and risk analysis techniques for a complete understanding of any risk insight which may have implications over mission successes. Users should concentrate on and assess all the consequences of risk.

Likelihood Scale Explained (Estimated likelihood value P should be based on analytic techniques whenever possible.)

Safety: Use this scale specifically for safety related risk. The 5 groups of likelihood bins come directly from the NASA Safety Manual NPR8715.3. The specified probability ranges (or likelihood bins) are the likelihood that an identified hazardous event will occur. These types of events should result directly in safety impacts, either as a mishap, an incident or accident based on assessments of such factors as location, exposure in terms of cycles or hours of operation, and affected population.

Technical: This scale of likelihood bins are used for ranking technical type of risks, which are measured using different scales from safety risks. A technical risk issue or event is primarily measured based on the likelihood of occurrence of such an event in terms of not meeting required minimum technical performances of a mission, or drifting from a specified design and performance margin. Percentage values are used here to better indicate likelihood of any events of technical risk impact.

Cost/Schedule: This scale of likelihood bins are used for ranking any programmatic type of risks, such as Cost and Schedule. These risks are measured similarly as technical risks except using a slightly different likelihood scale. A Cost or Schedule risk issue or event is primarily measured based on the likelihood of occurrence of any such events in terms of not meeting program budget constraints or schedule requirement. Percentage values are used here to better indicate likelihood of any events of Cost/Schedule risk impact.

Consequences Scale Explained

Safety: Use this consequence scale to ranking the severity levels of safety related risk consequences which result directly from occurrence of any hazardous events that have safety impact only.

Technical: Use this consequence scale to ranking the severity levels of technical or mission performance related risk consequences which result directly from occurrence of any technical or mission operational events that have direct risk impact on meeting technical requirement or suffer from degraded design/operating margin or mission performances.

Cost/Schedule: Use this consequence scale to ranking the severity levels of programmatic type of risks, such as Cost/Schedule related consequences, which result directly from occurrence of any events (either technical or programmatic) that have direct risk impact on established Cost/Schedule requirement or degraded program performance etc.

High risk – Generally unacceptable and needs concurrence of center leadership or PMC attention

Moderate risk – Generally acceptable and needs concurrence PMC

Low risk – No need for center or PMC management attention

8.0 INTEGRATED INDEPENDENT REVIEW REQUIREMENTS

Independent Assessments/Reviews will be conducted by the GSFC on all systems and projects designed, developed and/or implemented through the GSFC. These independent assessments will be conducted above the project management level for the purpose of reviewing plans and performance at key decisions points in the lifecycle to provide input to decision authorities in making a determination for the authorization for continuation of the effort and progression to the next stage of the project.

The contractor and all subcontractors will cooperate and assist in a comprehensive set of independent assessments to the fullest extent necessary to obtain an accurate status of the project and its prospects for mission success. In addition, each contractor/subcontractor shall conduct a program of planned, scheduled, and documented engineering peer reviews covering all aspects of its area of responsibility.

8.1 GENERAL REQUIREMENTS

Specific activities are required of the contractor/subcontractors for each review conducted by the GSFC Systems Review Office (SRO/Code 301) or other Government independent authorities. In accordance with CDRL 7, the contractor shall:

a. Develop and organize material for oral presentation to the Government review team. Copies of the presentation material will be made available (preferably electronic copies) at least 5 days before the various reviews.
b. Support splinter meetings resulting from the review
c. Produce timely written responses to recommendations and action items resulting from the review
d. Summarize, as appropriate, the results of the engineering peer reviews conducted by the contractor and present this summary to the GSFC Project Office as requested

8.2 REFERENCES

The contractor shall support a review program as delineated in the following GSFC and NASA document(s).

- GPR 8700.4 Integrated Independent Reviews
- GPR 8700.6 Engineering Peer Reviews
- GSFC-STD-1000 Rules for the Design, Development, Verification, and Operation of Flight Systems
- NPR 7120.5 NASA Space Flight Program and Project Management Requirements

8.3 SPACECRAFT REVIEWS

Reviews required for the LDCM Spacecraft/Observatory are specified in the Observatory SOW in accordance with CDRL 7.

8.4 PEER REVIEWS

The contractor shall implement a program of peer reviews at the component and subsystem levels. The program will, at a minimum, consist of a PDR and a CDR. In addition, packaging reviews shall be conducted on all electrical and electromechanical components in the flight system.

The PDR and CDR will evaluate the ability of the component or subsystem to perform nominally under operating and environmental conditions during both testing and flight. The results of parts stress analyses and component packaging reviews, including the results of associated tests and analyses, will be discussed at the component PDRs and CDRs.

The packaging reviews will specifically address the following:

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

The contractor peer reviews shall be conducted by personnel who are not directly responsible for design of the hardware under review. GSFC Project Office and SRO personnel shall be invited to attend the peer reviews with ten (10) working days notification.

The peer reviews shall have RFA items recorded, reviewed, and assigned to appropriate personnel at the end of the reviews. The contractor team shall submit written responses to recommendations and action items resulting from the reviews to GSFC in a timely manner upon request.

9.0 DESIGN VERIFICATION REQUIREMENTS

9.1 GENERAL

The contractor shall conduct a Verification Program to ensure that the flight system meets the specified mission requirements. The program shall consist of functional demonstrations, analytical investigations, physical measurements, and tests that simulate all expected environments.

The Design Verification Requirements are contained in the LDCM Environmental Verification Requirements (LEVR) Document and the Observatory SOW.

9.2 DOCUMENTATION REQUIREMENTS

The CDRL requirements applicable to design verification are included in the Observatory SOW.

9.3 PERFORMANCE OPERATING TIME AND FAILURE-FREE PERFORMANCE TESTING

LDCM Spacecraft/Observatory performance operating time and failure-free performance testing shall meet the requirements specified in the LEVR, GSFC 427-03-05.

9.4 RADIATION ANALYSIS

The contractor shall perform a radiation analysis that documents compliance with all radiation requirements as well as demonstrating that radiation-induced errors and failure modes do not prevent hardware from meeting mission requirements. At a minimum, this analysis shall include documentation/rationale on which part radiation qualification is based, worst-case analyses of error/failure consequences, test reports, and other information needed to analyze independently claims of compliance with requirements. This documentation shall be made available to Government personnel upon request.

10.0 WORKMANSHIP STANDARDS

10.1 GENERAL

The contractor shall plan and implement a Workmanship Program to assure that all electronic packaging technologies, processes, and workmanship activities selected and applied meet mission objectives for quality and reliability. (See Chapter 14 for information on Electrostatic Discharge [ESD] control.) The workmanship program documentation, including the Workmanship Implementation Plan, must be submitted to the GSFC Project Office in accordance with CDRL 75 prior to the start of any electronics fabrication and assembly. If the contractor (or their subcontractors or suppliers) currently utilize in-house workmanship requirements that do not fully include the workmanship requirements imposed by this MAR, the contractor (etc.) shall be required to:

a. Adopt the workmanship requirements detailed in this document for the LDCM project including those contained in the applicable documents listed below
b. Modify their requirements for the LDCM project to meet the workmanship requirements detailed in this document including those contained in the applicable documents listed below
c. Request a waiver to use their workmanship requirement(s) for the LDCM project based on both:
   1. The history of its/their successful use on NASA RSDO or non-RSDO programs in recent years. This shall include a list the program(s), the years/dates of use, and any modifications to the requirement documents since it/they was/were used for the cited program(s).
   2. A detailed list of each individual technical requirement in each workmanship document for which the contractor is seeking a waiver and the justification for relief from that requirement. Each justification shall address quality and reliability impact and risk mitigation.

10.2 APPLICABLE DOCUMENTS

The current status and/or any application notes for the NASA standards can be found at http://workmanship.nasa.gov/. The most current version of these standards shall be used for new procurements. However, if a specific revision is listed for a referenced standard, only that revision is approved for use, unless otherwise approved by the GSFC Project Office. All requirements contained in the NASA Standards and other documentation referenced below shall be considered requirements of this document as if they were repeated in detail herein.

General Workmanship:

NASA-STD-8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
NASA-STD-8739.2	Surface Mount Technology
NASA-STD-8739.3	Soldered Electrical Connections
NASA-STD-8739.4	Crimping, Interconnecting Cables, Harnesses, and Wiring
NASA-STD-8739.5	Fiber Optic Terminations, Cable Assemblies, and Installation
ANSI/ESD S20.20	Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding electrically initiated explosive devices)

Printed Wiring Board (PWB) Design:

IPC-2221	Generic Standard on Printed Board Design
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
IPC-2223	Sectional Design Standard for Flexible Printed Boards

PWB Manufacture:

IPC A-600	Acceptability of Printed Boards
IPC-6011	Generic Performance Specification for Printed Boards
IPC-6012B	Qualification and Performance Specification for Rigid Printed Boards *Flight Applications – Supplemented with: IPC 6012B Performance Specification Sheet for Space and Military Avionics
IPC-6013	Qualification and Performance Specification for Flexible Printed Boards
IPC-6018	Microwave End Product Board Inspection and Test

10.3 WORKMANSHIP REQUIREMENTS

10.3.1 Training and Certification

All personnel working on/with flight hardware shall be certified in accordance with the requirements defined in the above workmanship standards which include training as an operator, inspector or in-house instructor (as appropriate). ESD training will be in accordance with the contractor's internal ESD implementation plan which will be traceable to ANSI/ESD S20.20. (See Section 14.3.) Recertification is also conducted in accordance with the requirements defined in the above workmanship standards. The contractor and subcontractors shall maintain records of operator, inspector, and in-house instructor certifications and make these records available for Government review upon request.

10.3.2 Flight and Harsh Environment Ground Systems Workmanship

10.3.2.1 Printed Wiring Boards

PWBs shall be manufactured in accordance with Class 3 requirements of IPC PWB manufacturing standards and the Class 3/A of the IPC 6012B. For rigid PWBs, in the event of a conflict, the requirements specified in the IPC 6012B take precedence over all other specifications. The contractor shall provide PWB test coupons to the GSFC Materials Engineering Branch (MEB) or a GSFC/MEB approved laboratory for evaluation. All Coupons shall be traceable to the flight boards that they represent. Coupon acceptance shall be obtained prior to population of flight PWBs. Test coupons and test reports are not required for delivery to GSFC/MEB if the contractor has the test coupons evaluated by a laboratory that has been approved by the GSFC/MEB; however, they shall be retained and included as part of the S&MA Data Package in accordance with CDRL 42. Prior to their delivery to the GSFC Project Office, they shall be available for Government review.

If the contractor/subcontractor's schedule will not allow them to wait for GSFC/Laboratory PWB coupon approval prior to populating the flight PWBs, they may proceed with the population with the following understandings:

a. The contractor/subcontractor is doing so at their own financial risk without the Government's approval and will not be compensated for any losses in resources, schedule, etc.
b. The contractor/subcontractor must have the consent of their own PMCB and Parts Control Board (PCB) to move forward with this action.
c. Even though they are populating the PWB, the contractor/subcontractor must continue with the PWB coupon evaluation at the GSFC MEB laboratory or a GSFC/MEB approved laboratory and provide those results to GSFC as stated above.
d. If the PWB coupon laboratory evaluation proves that the PWB is not flight worthy, the parts and/or materials previously installed on the PWB are subject to Sections 11.5.2 and 12.6.7 of this MAR. No non-flight worthy parts/materials shall be reused on a replacement PWB.

10.3.2.2 Ground Support Equipment that Interface with Space Flight Hardware

GSE that interface directly with space flight hardware shall be designed and fabricated using space flight parts, materials, and processes for any portion of the assemblies that mate directly with the flight hardware. Mechanical and electrical GSE and associated software that directly interfaces with flight deliverable items shall be assembled and maintained to the same standards, especially calibration and configuration control, as the deliverable flight items. Parts and materials selection and reporting requirements are exempted as long as the deliverable item is not compromised including contamination.

10.3.2.3 Assemblies

Assemblies shall be fabricated using the appropriate workmanship standards listed above (i.e., NASA-STD-8739.1 for polymeric applications, NASA-STD-8739.3 for hand soldering; NASA-STD-8739.4 for crimping/cabling; NASA-STD-8739.5 for fiber optic termination and installation; NASA-STD-8739.2 for Surface Mount Soldering, etc.) and ANSI/ESD S20.20. All completed flight PWAs shall be photographed pre and post conformal coating.

10.3.2.4 Jumper “White” Wires

The use of jumper wires on any flight hardware is considered a repair and, as such, must be limited. While no documented requirement for the maximum number of jumpers is currently stated in the NASA Workmanship Courses and Certification, it is the position of the LDCM Project that repairs comprise hardware reliability. That being the case, no “white” or jumper wires shall be permitted on any spacecraft critical circuits. The use of any jumpers requires a contractor waiver submitted to the GSFC Project Office in accordance with CDRL 3.

10.3.3 <u>Documentation</u>

The contractor 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 by those standards in accordance with CDRL 75.

10.4 NEW AND ADVANCED MATERIALS AND PACKING TECHNOLOGIES

New and/or existing advanced materials and packaging technologies (e.g., multi-chip modules [MCMs], stacked memories, chip on board [COB], ball grid array [BGA], etc.) shall be reviewed and approved by the LDCM Project Parts Engineer (PPE) for EEE parts or the Materials Assurance Engineer (MAE) for materials and processes. Additionally, workmanship specialists shall be consulted in the review and approval process.

Note: This is typically addressed via a waiver, processed through the project, in accordance with CDRL 3.

10.5 HARDWARE HANDLING

The contractor shall use proper safety, ESD control and clean room practices (where appropriate) when handling flight hardware. The electrostatic charge generation and contamination potential of materials, processes, and equipment (e.g., cleaning equipment, packaging materials, purging, tent enclosures, etc.) must be addressed. Materials used in contact with flight hardware (e.g., finger cots, wipes, and swabs) must not cause contamination beyond that allowed in the project contamination control documentation.

10.6 STANDARD AND NON-STANDARD REPAIR PROCESSES/PROCEDURES

The contractor shall submit their standard and non-standard repair or rework processes/procedures to the GSFC Project Office for approval prior to their first use on the LDCM Project. These documents will form an appendix to the MAIP.

11.0 MATERIALS AND PROCESS REQUIREMENTS

11.1 GENERAL REQUIREMENTS

In accordance with CDRL 75, the contractor shall plan and implement a Materials and Processes Control Program (MPCP) to assure that all selected items for use in flight hardware meet mission objectives for quality and reliability.

All of the forms shown/referenced in this section and in the related CDRLs are GSFC forms. Equivalent contractor forms may be used with the approval of the GSFC Project Office.

11.2 MATERIALS AND PROCESSES CONTROL BOARD

The MPCP Plan shall describe the Materials and Processes Control Board (MPCB) operating procedures, membership, responsibilities, authority, meeting schedules, materials and processes MP review procedures, MP approval/disapproval procedures, GSFC involvement, and plans for updating the operating procedures. It will include the definition of the role and authority of each MPCB member and relationships with various groups within the prime and subcontractor organizations. The MPCB plans, manages, and coordinates the selection, application, and procurement requirements of all MP intended for use in the deliverable end item(s).

The contractor shall make every effort to include the GSFC LDCM MAE's participation in each MPCB meeting although their presence is not mandatory for the MPCB to convene. However, the GSFC LDCM MAE's approval is required for any items that do not fully comply with their applicable requirements to be added to the materials, processes, and/or lubrications lists. If the contractor elects to proceed prior to receiving the GSFC LDCM MAE's approval for the material (etc.) in question, the contractor shall do so at their own financial and schedule risk.

In addition to the contractor's MAE and the GSFC LDCM MAE, a GSFC Workmanship Engineer as well as other contractor and GSFC technical experts will be invited to MPCB meetings and/or review MPCB meeting reports as needed.

11.3 MANAGEMENT OF MP SELECTION

The contractor shall manage MP in accordance with criteria specified herein. MP shall be selected to assure that mission reliability and performance requirements are met. The contractor shall compile an As-designed Materials and Processes List (ADMPL) in accordance with CDRL 29 to start the MPCB activity. The ADMPL list is submitted to the MPCB, ten days prior to the first MPCB meeting. All non-compliant MP is documented on a Material Usage Agreement (MUA) (Figure 11-1) in accordance with CDRL 29. All MP approved by the MPCB will be designated as such on the ADMPL within 10 days of approval. The As-Built Materials and Processes List (ABMPL) shall be delivered to the GSFC Project Office in accordance with CDRL 42.

11.4 MATERIALS SELECTION REQUIREMENTS

11.4.1 Materials Selection

In order to anticipate and minimize materials problems during space hardware development and operation, when selecting materials and lubricants, the contractor shall 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, toxic offgassing, flammability, spacecraft charging effects, and fracture toughness as well as the properties required by each material usage or application.

11.4.2 Compliant Materials

The contractor shall use compliant materials (which do not require MUAs) in the fabrication of hardware to the extent practicable. In order to be compliant, a material must be used in a conventional application and meet the applicable selection criteria identified below:

a. Hazardous materials requirements including flammability, toxicity, and compatibility as specified in AFSPCMAN91-710V3 "Range Safety User Requirements Manual," section 10.1
b. Vacuum Outgassing requirements as defined in paragraph 11.4.6
c. Stress corrosion cracking requirements as defined in Marshall Space Flight Center (MSFC)-STD-3029

11.4.3 Non-compliant Materials

A material that does not meet the requirements of the applicable selection criteria listed in Section 11.4.1, or meet the requirements of Section 11.4.2, but is used in an unconventional application, will be considered to be a non-compliant material. The proposed use of a non-compliant material requires that a MUA (Figure 11-1) and/or a Stress Corrosion Evaluation Form (Figure 11-2) be submitted to the MPCB for review and approval. Submission is in compliance with CDRL 29.

11.4.4 Polymeric Materials

As part of the ADMPL, the contractor shall prepare and submit a polymeric materials list (Figure 11-3) to MPCB for review and approval. The information on this list will be in accordance with CDRL 29.

11.4.5 Flammability and Toxic Offgassing

Material flammability and toxic offgassing shall be determined in accordance with the test methods described in NASA-STD-6001. LDCM payload materials shall meet the requirements of AFSPCMAN91-710V3 "Range Safety User Requirements Manual."

11.4.6 Vacuum Outgassing

Material vacuum outgassing shall be determined in accordance with American Society for Testing of Materials (ASTM) E-595. In general, a material is qualified on a product-by-product basis. However, GSFC or the MPCB may require lot testing of any material for which lot variation is suspected. Materials provided for outgas testing need to be in cured state or condition which is representative of the flight configuration. In such cases, material approval is contingent upon lot testing. Only materials for use in a vacuum environment that have a total mass loss (TML) of less than 1.00% and a collected volatile condensable materials (CVCM) of less than 0.10% will be considered compliant. All others are classified as non-compliant and require an MUA.

11.4.7 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, lubricants, solder flux, and paints will be included. The use of materials whose date code has expired requires that the contractor demonstrate, by means of appropriate tests, that the properties of the materials have not been compromised for their intended use. Usage of such materials shall first be approved by the MPCB followed by the submission of a waiver in accordance with CDRL 3 to the GSFC Project Office. When a limited-life piece part is installed in a subassembly, its usage shall be approved by the MPCB and the subassembly item shall be included in the Limited-Life Plan.

11.4.8 Inorganic Materials

In accordance with CDRL 29, and as part of the ADMPL, the contractor shall prepare and submit an inorganic materials list (Figure 11-4) to the MPCB. Additionally, the contractor may be requested to submit supporting applications data. The criteria specified in MSFC-STD-3029 shall be used to determine that metallic materials meet the stress corrosion cracking criteria. An MUA shall be submitted for each material usage that does not comply with the MSFC-STD-3029 requirements. Additionally, for the MPCB to approve usage of individual materials, a stress corrosion evaluation form may be required from the contractor.

The use of tin, zinc, and cadmium platings in any flight application requires an MUA prior to use of that material. Bright tin, cadmium, and zinc platings have the potential for developing whisker growths. For tin, these have been measured up to 11.5 microns in diameter and up to 10 mm in length. These whiskers can result in short circuits, plasma arcing, and debris generation within the spacecraft. Zinc and cadmium plating also evaporates in vacuum environments and may redeposit on optics or electronics posing potential risks to flight hardware.

11.4.9 Fasteners

As part of the materials list approval process, the MPCB will approve all flight fasteners. Towards this end, the contractor shall provide all information required by the MPCB to ensure its ability to concur with the flightworthiness of flight fasteners. The contractor shall comply with the procurement documentation and test requirements for flight hardware and critical ground support equipment fasteners contained in 541-PG-8072.1.2, "GSFC Fastener Integrity Requirements." As part of the MPCP, the contractor will submit a Fastener Control Plan in accordance with CDRL 75, to the GSFC Project Office. Material test reports for fastener lots shall be submitted to the MPCB for information. Fasteners made of plain carbon or low alloy steel must be protected from corrosion. When plating is specified, it must be compatible with the space environment. On steels harder than RC 33, plating must be applied by a process that is not embrittling to the steel.

11.4.10 Lubrication

In accordance with in CDRL 29 and as part of the ADMPL, the contractor shall prepare and submit a lubrication usage list (Figure 11-5) to MPCB. The contractor 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 accordance with the life test plan or heritage of an identical mechanism used in identical applications in accordance with CDRL 75.

11.4.11 Process Selection

In accordance with CDRL 29 as part of the ADMPL, the contractor shall prepare and submit a processes utilization list (Figure 11-6) to the MPCB. Upon request by the GSFC Project Office or the MPCB, a copy of any process will be submitted for review in accordance with CDRL 29. Manufacturing processes (e.g., lubrication, heat treatment, welding, and chemical or metallic coatings) will be carefully selected to prevent any unacceptable material property changes that could cause adverse effects of materials applications.

11.5 MANAGEMENT OF MATERIALS AND PROCESSES ENGINEERING REQUIREMENTS

11.5.1 System Design

The MPCB is responsible for ensuring that MP used throughout the system meets the application, reliability, quality, and survivability requirements as derived from the system level requirements. All MP shall be selected to meet their intended application in the predicted mission environment; e.g., radiation, thermal, ultraviolet (UV), etc.

11.5.2 Reuse of Materials

Single-Use Materials (i.e., materials designed for one-time use only) that have been installed in an assembly, and are then removed from the assembly for any reason, cannot be used again in any item of flight or spare hardware without prior approval of the MPCB. The MPCB's approval must be based on the submission of evidence that this practice does not degrade the system performance.

11.5.3 Traceability and Lot Control

The contractor shall develop and maintain a traceability and lot control plan in accordance with the requirements specified below and approved by the MPCB. It shall also be submitted to the GSFC Project Office in accordance with CDRL 75. When given a lot date code or batch number, the contractor must be capable of determining the unique piece of equipment (black box level) by serial number in which the material is installed or used.

11.5.3.1 Mechanical Materials

One hundred percent (100%) lot traceability is required for materials used in applications where a failure could jeopardize component or mission success. Traceability and production or batch lot control for materials used in other applications shall be maintained where risk and cost so dictate.

11.5.3.2 Raw Materials

Raw materials purchased by the contractor shall be accompanied by the results of non-destructive, chemical and physical tests, or Certificate of Compliance which will be made available to GSFC personnel upon request for review. These requirements also apply to any supplier used by the contractor.

11.5.4 Incoming Inspection Requirements

Each contractor/subcontractor is responsible for the performance of applicable incoming tests and inspections of materials to ensure that they meet the requirements of the procurement specification. Unless previously accomplished and accepted by government or contractor field personnel, incoming testing and inspections shall be accomplished upon receipt of the materials. The inspection and testing of materials shall be conducted in accordance with a plan approved by the MPCB.

11.5.4.1 Shelf-Life Control

The contractor shall develop a shelf life control program that identifies the shelf life limitations for all materials to be stored. The plan must specify the length of time required and minimum requirements for re-inspection, retest, and any other action required to ensure the maintenance of space flight quality and reliability. The plan shall be reviewed and approved by the MPCB. It shall also be submitted to the GSFC Project Office in accordance with CDRL 75.

11.5.5 Supplier and Vendor Selection and Surveillance

The contractor/subcontractor is responsible for the selection and qualification of MP suppliers, vendors, laboratories, and manufacturers.

11.5.6 MP Supplier and Manufacturer Surveillance (Monitoring)

The contractor/subcontractor shall establish a policy and procedures for the periodic surveillance and auditing of suppliers, vendors, laboratories, and manufacturers to ensure compliance to procurement, quality, reliability, and survivability requirements. This documentation will be available to the GSFC Project Office upon request.

11.6 COMMERCIAL OFF-THE-SHELF ITEM EQUIPMENT

The requesting user shall demonstrate to the MPCB that the COTS items meet the quality, reliability, environmental, and survivability (if required) requirements of the contract-end-item for the intended application.

11.7 FAILURE ANALYSIS

Failure analysis shall be performed on material failures experienced during assembly and testing. Failures shall be analyzed to the extent necessary to understand the failure mode and cause to detect and correct out-of-control processes, to determine the necessary corrective actions, and to determine lot disposition. The MPCB shall determine and implement appropriate corrective action for each MP failure. All failures, and the results of final failure analysis, shall be documented in a failure analysis report which shall be available to the GSFC Project Office and retrievable throughout the duration of the contract.

11.8 HANDLING

Handling (including storage) procedures shall be instituted to prevent material degradation. The handling procedures shall be retained through inspection, kitting, assembly, and identified on "build to" documentation. These procedures will be available to GSFC Project Office personnel for review.

11.9 DATA RETENTION

The program shall maintain records or incoming inspection tests, lot qualification and acceptance test data, traceability data, and other data as determined by the MPCB for a period of time specified by the GSFC Project Office.

FIGURE 11-1: MUA

MATERIAL USAGE AGREEMENT		USAGE AGREEMENT NO.:	PAGE OF
PROJECT:	SUBSYSTEM:	ORIGINATOR:	ORGANIZATION:
DETAIL DRAWING	NOMENCLATURE	USING ASSEMBLY	NOMENCLATURE
MATERIAL & SPECIFICATION		MANUFACTURER & TRADE NAME	

USAGE	THICKNESS	WEIGHT	EXPOSED AREA	ENVIRONMENT		
				PRESSURE	TEMPERATURE	MEDIA
APPLICATION:						
RATIONALE:						
ORIGINATOR:			PROJECT MANAGER:			DATE:

FIGURE 11-2: 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: ______________________________

GSFC 18-59A 3/78 FIGURE 11-3: POLYMERIC MATERIALS AND COMPOSITES

GSFC Spacecraft Inorganic Materials List

Spacecraft		System/Experiment	
Contractor		Contractor Address	
Prepared by		Phone and Fax #	
GSFC MAE		Date Prepared	
Date Rec'd		Project SAM	

Item No.	Material Identification	Condition	Application	Expected Environment	MSFC-STD-3029 Rating

USAGE LIST

GSFC 18-59B 3/78 FIGURE 11-4: INORGANIC MATERIALS AND COMPOSITES USAGE LIST

GSFC Spacecraft Polymeric Materials List

Spacecraft		System/Experiment		Date Prepared	
Contractor		Contractor Address		Phone & Fax #	
Prepared by					
GSFC MAE					
Project SAM					
Date Rec'd					

Amount Code

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.	Component	Material Identification	Mix Formula	Cure Details	Amount Code	Expected Environment	ASTM-E-595	
							%TML	%CVCM

FIGURE 11-5: LUBRICATION USAGE LIST

GSFC 18-59C 3/78

GSFC Spacecraft Lubrication Materials List

Spacecraft ____________ System/Experiment ____________
Contractor ____________ Contractor Address ____________
Prepared by ____________ Phone and Fax # ____________
GSFC MAE ____________ Date Prepared ____________
Date Rec'd ____________ Project SAM ____________

Wear Codes

Type	# Cycles	Speed
CUR continuous unidirectional rotation	A $1\text{-}10^2$	rpm rev/min
CO continuous oscillation	B $10^2\text{-}10^4$	opm osc/min
IR intermittent rotation	C $10^4\text{-}10^6$	vs variable
IO intermittent oscillation	D $>10^6$	cpm cm/min
SO small oscillation (<30)		
LO large oscillation (>30)		
CS continuous sliding		

Item No.	Component Type, Size, and Material	Proposed Lubricant and Amount	Type and # of Wear Cycles	Speed, Temp, & Atm of Operation	Type of Loads and Amount

FIGURE 11-6: MATERIALS PROCESS UTILIZATION LIST
GSFC 18-59D 3/78

GSFC Spacecraft Materials Processes List

Spacecraft ____________________ System/Experiment ____________________

Contractor ____________________ Contractor Address ____________________

Prepared by ____________________ Phone and Fax # ____________________

GSFC MAE ____________________ Date Prepared ____________________

Date Rec'd ____________________ Project SAM ____________________

Item No.	Process Type	Contractor Spec #	MIL, ASTM or other Spec #	Description of Material Processed	Spacecraft Application

12.0 PARTS REQUIREMENTS

12.1 GENERAL

The contractor shall plan and implement an EEE Parts Control Program to assure that all parts selected for use in flight hardware meet mission objectives for quality and reliability. The program shall effectively support the design and part selection processes through the launch of the LDCM observatory.

The contractor shall prepare a Parts Control Plan (PCP) describing the approach and methodology for implementing their Parts Control Program. The PCP shall be submitted to LDCM Project Office in accordance with CDRL 75. The PCP shall also define the contractor's criteria for parts selection and approval based on the guidelines delineated below. The plan shall address how the contractor ensures the flow down of the applicable parts control requirements to their suppliers.

The contractor shall select and process all parts in accordance with GSFC EEE-INST-002, "GSFC EEE Parts Selection, Screening, Qualification and Derating," for part quality level 2 or better. Exceptions for use of a lesser grade part with additional testing shall only be made on a case-by-case basis when a level 2 part is not available. Such exceptions require approval by the PCB. The contractor shall control the selection, application, evaluation, and acceptance of all parts through their PCB.

12.2 CONTRACTOR'S PROJECT PARTS ENGINEER (PPE)

The contractor shall designate one key individual to be their Project Parts Engineer who has the prime responsibility for management of their EEE parts control program. This individual shall have direct, independent, and unimpeded access to the GSFC PPEs. The PPE shall work with design engineers, radiation engineers, reliability engineers, and the GSFC PPE to perform part selection and control. Tasks performed by the contractor PPE shall include but are not limited to the following:

a. Work with GSFC PPE team to perform parts control
b. Provide Parts Control Board (PCB) agenda
c. Prepare Parts Lists and provide supporting part information for parts evaluation and approval by the PCB
d. Coordinate PCB meetings and maintain minutes
e. Develop and maintain the Parts Identification List (PIL), the Project Approved Parts List (PAPL), the As-Designed Parts List (ADPL), and the As-Built Parts List (ABPL)
f. Perform Customer Source Inspections (CSI) and audits at supplier facilities as required
g. Prepare part procurement, screening, qualification, and modification specifications, as required.
h. Disposition/track part nonconformances and part failure investigations
i. Track and report impact of Alerts and Advisories on flight hardware

12.3 PARTS CONTROL BOARD

The contractor shall establish a PCB to facilitate the management, selection, standardization, and control of parts and associated documentation for the duration of the contract. A PCB Plan shall be prepared in accordance with CDRL 75. The PCB shall be responsible for the review and approval of all EEE parts, for conformance to established criteria for parts selection, and for developing and maintaining the PAPL for the instrument. In addition, the PCB is responsible for providing assistance for all parts activities such as part failure investigations, disposition of part non-conformances, and part problem resolutions. PCB operating procedures shall be included as part of the PCP.

When parts require additional testing per GSFC EEE-INST-002 to bring them to Level 2 parts requirement, the PCB will work with the CSO to determine if the testing should be performed to Level 3 or Level 2 based on the criticality, redundancy and application of the part and the instrument.

12.3.1 PCB Responsibilities

The PCB responsibility shall include but not limited to the following:

a. Evaluation of EEE parts for conformance to established criteria and inclusion in the PAPL
b. Develop and maintain the PAPL, PIL, ADPL and ABPL
c. Review and approve EEE part derating as necessary for unique applications
d. Define testing requirements
e. Review unique applications including radiation effects
f. Track part failure investigations and non-conformances

If there are any parts issues that cannot be resolved at the PCB level, the issues shall be elevated to the CSO and to the COTR.

12.3.2 PCB Meetings and Notification

The contractor's PPE shall maintain meeting minutes or records to document all decisions made. The contractor PPE shall notify attendees at least five (5) working days in advance of upcoming meetings. Notification of PCB meetings shall include a proposed agenda and documentation necessary to conduct the review.

The contractor shall make every effort to include the GSFC LDCM PPE's participation in each PCB meeting although their presence is not mandatory for the PCB to convene. However, the GSFC LDCM PPE's approval is required for any items that do not fully comply with their applicable requirements to be added to the parts lists. If the contractor elects to proceed prior to receiving the GSFC LDCM PPE's approval for the part in question, the contractor shall do so at their own financial and schedule risk.

12.3.3 PCB Membership

As a minimum, the PCB membership shall include the contractor's Product Assurance Manager, the contractor PPE, GSFC's LDCM PPE, and (when required) GSFC's LDCM Project Radiation Engineer (PRE) and a GSFC Workmanship Engineer. The contractor PPE shall assure that the appropriate individuals with engineering knowledge and skills are represented as necessary at meetings, such as part commodity specialists, Radiation Engineers, the LDCM CSO, and/or the appropriate subsystem design engineers. When the appropriate experts cannot attend the PCB meeting, the contractor PPE shall ensure that they receive a copy of the PCB report to review.

12.4 PART SELECTION AND PROCESSING

12.4.1 General

All part commodities identified in GSFC EEE-INST-002 are considered EEE parts and shall be subject to the requirements set forth in this chapter. EEE part types that do not fall in to any of the categories covered in GSFC EEE-INST-002 shall be reviewed by the PCB and evaluated using the closest NASA, Defense Supply Center Columbus (DSCC) or government controlled specification. In the event a suitable government baseline specification does not exist; the PCB shall identify the best available industry standard for that particular commodity and develop the appropriate procurement, screening, and qualification specification.

12.4.2 Parts Selection

Parts shall be selected in accordance with GSFC EEE-INST-002 quality level 2 or better. Exceptions for use of a lower grade shall only be made on a case-by-case basis when a level 2 part is unavailable, and such exceptions require approval by the PCB. The use of a lower grade part requires additional testing to be performed in accordance with GSFC EEE-INST-002 to upgrade the part to level 2 or as agreed upon by the PCB.

Parts selected from the NASA Part Selection List (NPSL) for quality level 2 or better are preferred. All other EEE parts shall be selected, manufactured, processed, screened, and qualified, as a minimum, in the same manner as the nearest applicable quality level 2 device.

GSFC EEE-INST-002 contains value-added testing for a number of parts listed in the NPSL. The NPSL is available at: http://nepp.nasa.gov/npsl. These tests include Particle Impact Noise Detection (PIND) testing for EEE devices with internal cavities, surge current testing for tantalum capacitors, and dielectric screening for several types of ceramic capacitors. These and any other value-added tests listed in GSFC EEE-INST-002 shall be performed to enhance the reliability of parts. PCB approval is required when there is any deviation from the screening or qualification tests as specified in GSFC EEE-INST-002.

12.4.3 Radiation Requirements for Parts Selection

An appropriate radiation hardness assurance program shall be developed and conducted through the PCB and the GSFC PRE based on project requirements. The Parts Control Plan shall address all phases of the flight hardware development including the design, test, and production. The contractor shall address all requirements as stated in the project radiation hardness plan and pass this requirement onto any subcontractors. The Radiation Hardness Assurance Plan shall be submitted to the GSFC Project Office in accordance with CDRL 75.

12.4.3.1 Specification of the Radiation Environment

The radiation environment for the LDCM spacecraft shall be specified using established codes, models, and algorithms. This includes the trapped particle environment, galactic cosmic ray environment, and solar particle event environment, and induced environments such as that caused by a radioisotope thermal generator (RTG).

12.4.3.2 Radiation Transport Analysis

When deemed necessary, transport calculations for the incident radiations shall be performed for shielding appropriate for the LDCM spacecraft using established codes.

12.4.3.3 Evaluation of Radiation Effects in Microelectronic Devices and Integrated Circuits

All parts shall be selected to perform nominally in the predicted radiation environment including the applicable Radiation Design Margin (RDM). The radiation environment causes the following three main degradation effects which must be accounted for in all active parts selection:

a. Total Ionizing Dose (TID) (including Enhanced Low Dose Rate [ELDR] effects) – Parts shall be selected to ensure adequate performance in the application, up to a dose of twice the expected mission dose. Linear bipolar parts shall be assumed to be ELDR susceptible unless the parts have been successfully tested and shown insensitive.

b. Single-Event Effects (SEE) – Parts must be assessed for the potential nondestructive effects such as single-event upsets (SEUs) or single-event transients (SETs) which require analysis of the circuit application on a case-by-case basis. Parts susceptible to destructive effects such as single-event latch-ups (SELs) shall be avoided or subjected to analyses that demonstrate that the vulnerability does not occur under the conditions of the part's application. Parts susceptible to nondestructive single-event effects shall be subjected to analyses and testing sufficient to demonstrate that these effects do not compromise their required functionality. If performance demands the use of a SEL susceptible part, measures shall be implemented to ensure that SEL induced damages (both prompt and latent) are mitigated and that spacecraft performance is not compromised. These measures must be approved by the GSFC PRE and PPE before the part can be added to the PAPL. Applied voltages for power Metal-Oxide-Semiconductor Field Effect Transistors (MOSFETs), Field Effect Transistors (FETs), and bipolar junction transistors (BJT) shall be in the safe operating ranges for these devices based on Single-Event Gate Rupture (SEGR)/Single-Event Burn-out (SEB) test data.

c. Displacement Damage – Parts shall be able to withstand the displacement damage to high energy protons, to twice the fluence expected in the predicted LDCM spacecraft environment. (This effect can cause significant damage in optical devices.)

These effects and others may require individual part application analysis to be performed as necessary by the PRE. The contractor shall document the radiation analysis of each part as applicable.

12.4.3.4 Qualification of Parts for Use

Part qualification for the LDCM spacecraft shall be based on data for parts and conditions that are representative of flight parts and applications. For total ionizing dose or displacement damage effects, parts shall be qualified by showing that parts from the same wafer diffusion lot date code and tested under conditions that bound the LDCM application(s) meet all requirements for their applications after exposure to two times (2x) the expected mission dose (TID and/or displacement damage). For single-event effects, qualification shall be based on test data on parts representative of the flight lot and under applications at least as stringent as the LDCM application(s). Alternatively, parts will be considered qualified if radiation testing shows that the effects specified in Section 12.4.3.3 do not compromise the mission.

12.4.4 <u>Custom or Advanced Technology Devices</u>

The following devices shall be subject to parts control including a parts and packaging design review (appropriate for the individual technology) by the PCB:

a. Custom microcircuits such as Application Specific Integrated Circuits, Hybrid Microcircuits, Multi-Chip Modules, and D/C Power Converters
b. Field Programmable Gate Array (FPGA) based designs
c. Custom microwave devices and Microwave Monolithic Integrated Circuits (MMICs)
d. High power microwave devices. All microwave device designs with a output power greater than 10 watts Radio Frequency (RF) at S-band and Ku-band and 1 watt RF at Ka-band or higher shall be reviewed by NASA for multipactor margin and other critical RF reliability considerations (e.g., hermetic packaging, hydrogen poisoning, design margins, etc.).
e. Embedded passive or active component substrates or PWBs

The design review shall include element evaluation to assure each element's reliability (review shall include such items as burn-in, voltage conditioning, sample size, element derating, etc.) and device construction and assembly process including materials evaluation (for such items as contamination concerns, metals whisker concerns, and adequate material thermal matching). Materials specialists may be consulted as necessary. The PCB chair shall chair the review and invite all required contractor, subcontractor, supplier, vendor, and GSFC personnel (e.g., subject matter experts, systems engineering, Mission Assurance personnel, etc.). A Customer Source Inspection may be required.

A procurement specification may be required for parts in this category based on the recommendation of the PCB. These specifications shall fully describe the item being procured and shall include physical, mechanical, environmental, electrical test requirements, and quality assurance provisions necessary to control manufacture and acceptance. Screening requirements designated for the part can be included in the procurement specification. Test conditions, burn-in circuits, failure criteria, and lot rejection criteria shall also be included. For lot acceptance or rejection, the Percentage of Defectives Allowable (PDA) in a screened lot shall be in accordance with that prescribed in the closest military part specification and/or GSFC EEE-INST-002.

12.4.5 Plastic Encapsulated Microcircuits (PEMs)

The use of Plastic Encapsulated Microcircuits is discouraged; however, when use of PEMs is necessary to achieve unique performance requirements that cannot be achieved by using hermetic high reliability microcircuits, plastic encapsulated parts must meet the requirements of GSFC EEE-INST-002. The PCB shall review the procurement specification, application of part, and storage processes for plastic encapsulated parts to assure that all aspects of GSFC EEE-INST-002 have been met.

12.4.6 Verification Testing

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

12.4.7 Parts Approved on Prior Projects

Parts previously approved by GSFC for other projects via prior PCB activity or a Nonstandard Parts Approval Request (NSPAR) shall not be granted "Grandfather approval" on LDCM. However, existing approval packages may be brought to the PCB as an aid to present candidate parts for approval. (Preparation of NSPARs is not a requirement for LDCM). Such candidate parts shall be evaluated by the PCB for compliance to current Project requirements by determining that:

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

12.4.8 Parts Used in Off-the-Shelf Assemblies

Units or assemblies that are purchased as "off-the-shelf" hardware items shall be subjected to an evaluation of the parts used within them. The parts shall be evaluated for screening compliance to GSFC EEE-INST-002, established reliability level, and include a radiation analysis. Units may be required to undergo modification for use of higher reliability parts or radiation hardened parts. Modifications such as additional shielding for radiation effectiveness or replacing radiation-soft parts with radiation-hardened parts may be required and shall be subject to PRE approval as part of the PCB approval activities.

12.5 PART ANALYSIS

12.5.1 Destructive Physical Analysis

A sample of each lot date code of Field Programmable Gate Arrays (FPGAs), hybrid microcircuits, microcircuits, 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." The PCB on a case-by-case basis shall consider variation to the DPA sample size requirements due to part complexity, availability, or cost.

12.5.2 Failed EEE Parts

The contractor shall have a plan to report all EEE component failures during EEE part screening and qualification; during qualification and acceptance testing of flight hardware - beginning with the first application of power at the subassembly level and continuing through, unit, subsystem, and system levels. A FRB shall be convened, if recommended by the PCB. The failure reporting plan shall include identification of failed parts, notification to GSFC within five (5) business days after time of failure, retrieval of failed/overstressed parts, part failure analysis and documentation of all pertinent information related to each failure. The failure reporting plan shall be documented and presented to the PCB for review and approval.

12.5.3 Failure Analysis

When a component part Failure Analysis (FA) is necessary to support a FRB activity, the contractor shall prepare a part Failure Analysis Report. The contractor PPE shall submit the completed report to the PCB for review and approval in order to assure proper documentation is presented for the FRB. The failure report form shall as a minimum, provide the following information:

a. The failed part's identity (i.e., part name, part number, reference designator, manufacturer, manufacturing lot/date code, and part serial number if applicable), and symptoms by which the failure was identified; i.e., the conditions observed as opposed to those expected
b. The name of the unit or subsystem on which the failure occurred, date of failure, the test phase, and the environment in which the test was being conducted
c. An indication of whether the failure of the part or item in question constitutes a primary or a secondary (collateral) failure (i.e., a failure caused by another failure in the circuit and not a failure on its own merit)
d. The results of the failure analyses conducted and the nature of the rework/retest/corrective action taken in response.

The completed failure report shall include copies of any supporting photographs, x-rays, metallurgical data, microprobe or spectrographic data, Scanning Electronic Microscope (SEM) photographs, pertinent variables (electrical and radiation) data, etc. Radiation data shall be submitted where it is deemed pertinent to the failure mechanism. The FRB shall achieve a timely resolution and closure of each failure incident and will document the findings.

12.6 ADDITIONAL REQUIREMENTS

12.6.1 Parts Age Control

All parts procured with date codes greater than five (5) years from the date of manufacture to date of procurement shall be subjected to a re-screen and sample DPA per PCB recommendation. Alternate test plans may be used as approved by the PCB on a case-by-case basis. Parts taken from user inventory older than 5 years do not require re-screening provided they have been properly stored and their use has been approved by the PCB. Proper storage is defined as maintaining the parts within their rated temperature range and protected from conditions that create electrostatic damage or contaminants that may affect their functionality (e.g., corrosive atmospheres that damage the plating on the leads or terminations). Parts over 10 years old from the date of manufacture to the date of procurement shall not be procured.

12.6.2 Derating

All EEE parts shall be used in accordance with the derating guidelines of GSFC EEE-INST-002. The contractor's derating policy may be used in place of the GSFC guidelines and shall be submitted with contractor's PCP for approval by the PCB. Any component that exceeds the manufacturer's temperature limit specification or does not meet the derating guidelines of GSFC EEE-INST-002 shall be reviewed and approved by the PCB before use.

12.6.3 GIDEP Alerts

The contractor shall be responsible for the review and disposition of all GIDEP Alerts on parts proposed for flight use. In addition, any NASA Alerts and Advisories provided to the contractor by GSFC shall be reviewed and dispositioned. Alert applicability, impact, and corrective actions shall be continuously documented and reported to GSFC. The review process shall continue until launch. See Chapter 15.

12.6.4 Prohibited Metals

Pure tin (Sn), pure cadmium (Cd), and pure zinc (Zn) shall not be used as an internal or external finish on any EEE parts and associated hardware. These materials are susceptible to spontaneous whisker growth that can lead to electrical short circuits.

Procurement specifications that prohibit the use of pure tin, cadmium, or zinc plating are recommended. An independent verification of plating composition shall be carried-out by the contractor if recommended by the PCB. Material characterization methods such as Energy Dispersive Spectroscopy (EDS) or X-ray Fluorescence (XRF) should be used for verifying that prohibited materials are not present in internal or external finishes.

12.6.5 Traceability

The contractor shall utilize traceability database(s) that shall provide the capability to retrieve historical records of EEE parts from initial procurement and receipt through storage, kitting, assembly, test, and final acceptance of the deliverable product. Also, the database shall permit traceability to the procurement document and shall provide for:

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

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

12.6.6 ESD Control

The contractor shall ensure that storage areas, laboratories, and work areas that receive, distribute, assemble, disassemble, handle, test, or repair electrostatic discharge sensitive (ESDS) equipment are inspected and ESD-certified for proper equipment and handling procedures in accordance with Chapter 14. The contractor shall assess their ESD requirements and determine what level of precaution is necessary to ensure that their ESDS parts are protected. For parts and assemblies that have an ESD sensitivity level of 250 volts or less, extra precautions (such as Ionizers, controlled environment, and proper equipment/personnel grounding) are required to protect from ESD events.

12.6.7 Reuse of Parts

Parts that have been installed in an assembly, and are then removed from the assembly for any reason, cannot be used again in any item of flight or spare hardware without prior approval of the PCB. The

PCB's approval must be based on the submission of evidence that this practice does not degrade the system performance.

12.7 PARTS LISTS

The contractor shall develop and maintain a PIL, PAPL, and ADPL for the duration of the project in accordance with CDRL 27. Parts must be approved for listing on the PAPL before initiation of procurement activity. Long Lead items shall be identified on the PIL and have conditional approval from the PCB before procurement.

12.7.1 Parts Identification List (PIL)

The PIL shall list all parts proposed for use in flight hardware. The PIL is prepared from design team inputs or supplier inputs to be used for presenting and tracking candidate parts to the PCB. The PIL shall include, as a minimum, the following information: Part type, manufacturer's generic part number, part description, manufacturer, procurement specification, comments, and Federal Stock Class.

12.7.2 Project Approved Parts List (PAPL)

The PAPL shall list only approved parts for flight hardware and shall be the combined listing of all parts submitted through PILs that are approved by the PCB plus approval status and disposition notes. Only parts that have been evaluated and approved by the PCB shall be listed in the PAPL. The PCB shall assure standardization of parts listed in the PAPL across various systems and subsystems.

12.7.3 As-Designed Parts List (ADPL)

The contractor PPE shall establish an ADPL as soon as practical after the preliminary design release. The GSFC PPE shall maintain a copy of the ADPL in the GSFC Parts Database, and will work with the contractor's design team to keep the list(s) current.

12.7.4 As-Built Parts List (ABPL)

An ABPL shall also be prepared and submitted to the LDCM project by the Contractor PPE in accordance with CDRL 42. The ABPL is a final compilation of all parts as installed in flight equipment with additional "as-installed" part information such as manufacturer name, CAGE code, lot-date code, part serial number (if applicable). Provisions shall be in place to find the quantity used and provide traceability to the box or board location through build paperwork. The manufacturer's plant specific Commercial and Government Equity (CAGE) code is preferred, but if unknown, the manufacturer's general CAGE code is sufficient.

12.8 DATA REQUIREMENTS

Upon request, summary data shall be provided to the PPE for all testing performed as applicable. The contractor shall ensure that variable data (both read and record) is recorded for initial, interim and final electrical test points as applicable. The contractor shall provide this data to GSFC upon request.

For flight lots with samples subjected to Radiation Lot Acceptance Testing (RLAT), the radiation report that identifies parameter degradation behavior shall be provided to the PCB. Variables data acquired during radiation testing shall be kept available to GSFC as applicable.

Each contractor and supplier shall perform, or be responsible for the performance of applicable incoming inspections and shall provide data to ensure that products meet the requirements of the procurement specification.

12.9 RETENTION OF DATA, PART TEST SAMPLES AND REMOVED PARTS

The contractor shall have a method in place for the retention of data generated for parts tested and used in flight hardware. The data shall be kept on file in order to facilitate future risk assessment and technical evaluation, as needed. In addition, the contractor shall retain all part functional failures and all destructive and non-flight non-destructive test samples which could be used for the future validation of parts for performance under certain conditions not previously accounted for. These devices shall be kept until the end of mission. PIND test failures may be submitted for DPA or radiation testing. Data shall be retained for the useful life of the spacecraft unless otherwise permitted by the PCB. All historical quality records and data required to support these records shall be retained through the end of the contract and shall be provided to GSFC upon request.

13.0 CONTAMINATION CONTROL REQUIREMENTS

13.1 GENERAL

In accordance with CDRL 75, the contractor shall plan and implement a Contamination Control Program appropriate for the hardware. The program establishes the specific cleanliness requirements and delineates the approaches to be followed in a Contamination Control Plan (CCP).

13.2 CONTAMINATION CONTROL PLAN

The contractor shall prepare a CCP that describes the procedures that shall be followed to control contamination, establishing the implementation and describing the 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 shall be compatible with the most contamination-sensitive components. 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.

13.3 CONTAMINATION CONTROL VERIFICATION PROCESS

The contractor is responsible for developing a contamination control verification process. The verification process will be performed in the order listed below and submitted to the GSFC Project Office in accordance with CDRL 75:

a. Determination of contamination sensitivity
b. Determination of a contamination allowance
c. Determination of a contamination budget
d. Development and implementation of a contamination control plan

13.4 MATERIAL OUTGASSING

In accordance with ASTM E-595, NASA RP 1124 will be used as a guide. Individual material outgassing data is established based on each component's operating conditions. Established material outgassing data shall be verified and reviewed by the GSFC Project Office.

13.5 THERMAL VACUUM BAKEOUT

The contractor will perform thermal vacuum bakeouts as required to meet the project's contamination requirements. The parameters of such bakeouts (e.g., pressure, temperature, duration, and outgassing requirements) must be individualized depending on materials used, the fabrication environment, and the established contamination allowance. Thermal vacuum bakeouts shall be monitored with a Quartz Crystal Microbalance (QCM) and a cold finger (or a collector plate in lieu of a cold finger) at a representative location. Thermal vacuum bakeout results shall be made available to and reviewed by the GSFC Project Office.

13.6 HARDWARE HANDLING

The contractor will practice clean room standards in handling hardware. The contamination potential of material and equipment used in cleaning, handling, packaging, tent enclosures, shipping containers, bagging (e.g., anti-static film materials), and purging will be described in detail in handling plans/procedures for each subsystem or component at each phase of assembly, integration, test, and launch. This documentation will be submitted to the GSFC Project Office in accordance with CDRL 58 and CDRL 75.

14.0 ELECTROSTATIC DISCHARGE CONTROL

14.1 GENERAL

In accordance with CDRL 75, the contractor shall document and implement an ESD Control Program to assure that all manufacturing, inspection, testing, and other processes will not compromise mission objectives for quality and reliability due to ESD events.

14.2 APPLICABLE DOCUMENTS

The current status and/or any application notes for ANSI/ESD S20.20, "ESD Association Standard for the Development of an Electrostatic Discharge Control Program for protection of electrical and electronic parts, assemblies, and equipment (excluding electrically initiated explosive devices)," and its subordinate documents can be obtained at http://www.esda.org/standards.html. The most current version of this standard will be used for this procurement.

14.3 ELECTROSTATIC DISCHARGE CONTROL REQUIREMENTS

The contractor will document and implement an ESD Control Program in accordance with ANSI/ESD S20.20 suitable to protect the most sensitive component involved in the project. At a minimum, the ESD Control Program must address training, protected work area procedures, tools and processing equipment, 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 must be certified as having completed the required training, appropriate to their involvement, as defined in the contractor's ESD Control Plan prior to handling any electronic hardware.

Electronic hardware shall be manufactured, inspected, tested, or otherwise processed only at designated ESD protective work areas. Electronic hardware shall be properly packaged in ESD protective packaging at all times when not actively being manufactured, inspected, tested, or otherwise processed.

Materials selected for packaging or protecting ESD sensitive devices shall not leach chemicals, leave residues, or otherwise contaminate parts or assemblies; e.g., "pink poly" is well known for its outgassing of contaminants and will only be used for storing documentation or other non-hardware uses.

15.0 GIDEP ALERTS AND PROBLEM ADVISORIES

The contractor shall participate in the GIDEP in accordance with the requirements of the "GIDEP Operations Manual" (SO300-BT-PRO-010) and the "GIDEP Requirements Guide" (SO300-BU-GYD-010) available from the GIDEP Operations Center, Post Office (PO) Box 8000, Corona, California 92878-8000. For information on GIDEP, refer to the following web site: http://www.gidep.org.

Starting at contract award, the contractor shall review, upon receipt, all GIDEP Alerts, GIDEP Safe-Alerts, GIDEP Problem Advisories, GIDEP Agency Action Notices, NASA Alerts, and NASA Advisories and any informally documented component or materials issues presented by GSFC's OSSMA, LDCM Project Office, LDCM Quality Engineer, LDCM Parts or Materials Engineering, and/or the LDCM CSO to determine if they affect the contractor products produced for NASA. (Hereafter, all the aforementioned documentation shall be referred to as "Alerts.") The contractor shall submit a completed GSFC Forms 4-37, "Problem Impact Statement: Parts, Materials and Safety," to the LDCM Project Office for each part or material covered by an Alert .These forms, can be found at http://gdms.gsfc.nasa.gov/gdmsnew/home.jsp. The contractor shall ensure that all subcontractors, suppliers, and vendors review each Alert. For all Alerts that the contractor determines could have a negative effect on the mission (e.g. in performance, reliability, lifetime, safety, etc.), the contractor shall recommend corrective action to eliminate or mitigate the negative effect. Upon review of the recommendation, the Government will either direct the recommended action or direct other action to address the Alert. This Alert review process shall continue up to launch; i.e., the LDCM observatory shall not be launched with an open Alert. Additionally, this shall be a continuous process with all previously dispositioned alerts reviewed against each design change or update. It shall also be the contractor's responsibility to ensure that no Alert issued prior to contract award affects program hardware including hardware produced/provided by subcontractors, suppliers, and vendors.

The contractor shall maintain a table or matrix of all Alerts issued on or after the contract award date including the dates the Alert was issued, added to the table/matrix, dispositioned, and closed; the Alert's applicability and the impact to the LDCM Project; and all required/implemented corrective actions taken by the contractor, subcontractors, suppliers, and vendors. The table/matrix shall include the rationale/justification for using parts/materials covered by Alerts including the names of all hardware affected and the manufacturers of the hardware (i.e., the contractor, subcontractor[s], supplier[s], and/or vendor[s]), and the risk impact to each piece of hardware listed, Alert status and disposition shall be maintained and formally reported to the LDCM Project Office in accordance with CDRL 1 and CDRL 7. It shall also be available upon request to the LDCM Project Office. Any Alerts that were issued prior to the contract award that are determined to affect the LDCM Project hardware shall be included on this table/matrix including all applicable information as listed above.

All Alerts shall be processed in a timely manner by the contractor, subcontractors, suppliers, and vendors with their addition to the contractor's Alert table/matrix within 3 days of receipt and their dispositions listed on the table/matrix within 30 days of receipt. When corrective actions cannot be completed until after the 30 days, the table/matrix shall include the estimated date of closure and the rationale/justification for the delay. This status shall be maintained and updated until closure is actually completed.

Prior to the formal submission of each parts or materials list to the LDCM Project Office, the current and complete Alert status for all items on the list shall be verified. (Refer to CDRL 42, CDRL 29, and CDRL 27.)

The contractor shall generate the appropriate failure experience data report(s) on a monthly basis, in accordance with the requirements of GIDEP SO300-BT-PRO-010 and SO300-BU-GYO-010, whenever failed or nonconforming items, that are available to other buyers, are discovered during the course of the contract. This information shall be reported to the LDCM Project Office as part of the Alert status in accordance with CDRL 31.

16.0 APPLICABLE DOCUMENTS LIST

DOCUMENT	DOCUMENT TITLE
AFSCMAN 91-710	Range Safety Users Requirements Manual
ANSI/ESD S20.20	ESD Association Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices)
ANSI/ISO/ASQC Q9001:1994	Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation, and Servicing
ANSI/ISO/ASQ Q9001:2000	American National Standard Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation and Servicing
ASTM E-595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
GIDEP S0300-BT-PRO-010	GIDEP Operations Manual
GIDEP S0300-BU-GYD-010	Government-Industry Data Exchange Program Requirements Guide
GPR 8070.4	Administration and Application of Goddard Rules for Design, Development, Verification and Operation of Flight Systems
GPR 8700.4	Technical Review Program
GPR 8700.6	Engineering Peer Reviews
GSFC-STD-1000	Rules for Design, Development, Verification, and Operation of Flight Systems
GSFC EEE-INST-002	Instructions for EEE Parts Selection, Screening, and Qualification and Derating
IEEE STD 730	IEEE Standard for Software Quality Assurance Plans
IPC A-600	Acceptability of Printed Boards
IPC-2221	Generic Standard on Printed Board Design
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
IPC-2223	Sectional Design Standard for Flexible Printed Boards
IPC-6011	Generic Performance Specifications for Printed Boards
IPC-6012	Qualification and Performance Specification for Rigid Printed Boards
IPC-6013	Qualification and Performance Specification for Flexible Printed Boards
IPC-6018	Microwave End Product Board Inspection and Test
KHB 1860.1	KSC Ionizing Radiation Protection Program
KHB 1860.2	KSC Non-Ionizing Radiation Protection Program
KNPR 8715.3	KSC Safety Practices Procedural Requirements
MIL-PRF-55365/4	General Specification for Established Reliability and Nonestablished Reliability of (Tantalum) Chip Fixed Electrolytic Capacitors
MSFC-STD-3029	Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments
NASA RP-1124	Outgassing Data for Selecting Spacecraft Materials

NPD 8710.3	NASA Policy for Limiting Orbital Debris Generation
NPR 5100.4	NASA FAR Supplement
NPR 7120.5	NASA Program and Project Management Processes and Requirements
NPR 7150.2	NASA Software Engineering Requirements
NPR 8621.1	NASA Procedures and Guidelines for Mishap Reporting, Investigating, and Record Keeping
NPR 8705.4	Risk Classification for NASA Payloads
NPR 8705.5	Probabilistic Risk Assessment (PRA) Procedures for NASA Programs and Projects
NPR 8715.3	NASA Safety Manual
NPR 8000.4	Risk Management Procedural Requirements
NASA-STD 8719.8	Expendable Launch Vehicle Payloads Safety Review Process Standard
NASA-STD 8719.9	NASA Standard for Lifting Devices and Equipment
NASA-STD 8719.13	NASA Software Safety Standard
NASA-STD 8719.17	NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems
NASA-STD 8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
NASA-STD 8739.2	Workmanship Standard for Surface Mount Technology
NASA-STD 8739.3	Workmanship Standard for Soldered Electrical Connections
NASA-STD 8739.4	Workmanship Standard for Crimping, Interconnecting Cables, Harnesses and Wiring
NASA-STD-8739.5	Workmanship Standard for Fiber Optic Terminations, Cable Assemblies and Installation
NASA-STD-8739.8	Software Assurance Standard
NSS 1740.14	Guidelines and Assessment Procedures for Limiting Orbital Debris
S-311-M-70	Specification for Destructive Physical Analysis
SAE AS9100	Aerospace Standard, Quality Systems Model for Quality Assurance, Design, Development, Production, Installation and Servicing
541-PG-8072.1.2	GSFC Fastener Integrity Requirements

Appendix A. Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
ABPL	As-Built Parts List
ADMPL	As-Designed Materials and Processes List
AFSPC	Air Force Space Command
ANSI	American National Standards Institute
ASQ	American Society for Quality
ASQC	American Society for Quality Control
ASTM	American Society for Testing of Materials
BGA	Ball Grid Array
CAGE	Commercial and Government Entity
CCB	Configuration Control Board
CCP	Contamination Control Plan
CDR	Critical Design Review
CDRL	Contract Delivery Requirements List
CIL	Critical Items List
CM	Configuration Management
CMO	Configuration Management Office
COB	Chip on Board
COTR	Contracting Officer Technical Representative
COTS	Commercial Off-the-Shelf
CRM	Continuous Risk Management
CVCM	Collected Volatile Condensable Materials
DCMA	Defense Command Management Agency
DID	Data Item Description
DoD	Department of Defense
DOORS	Dynamic Object Oriented Requirements System
DPA	Destructive Physical Analysis
DRD	Description of Required Data
DSCC	Defense Supply Center Columbus
EEE	Electrical, Electronic, and Electromechanical
EIS	Environmental Impact Statement
ELDR	Enhanced Low Dose Rate
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
ETR	Eastern Test Range
FA	Failure Analysis

Abbreviation/ Acronym	DEFINITION
FAR	Federal Acquisition Regulations
FETs	Field Effect Transistors
FMEA	Failure Modes and Effects Analysis
FRB	Failure Review Board
FRR	Flight Readiness Review
FTA	Fault Tree Analysis
GFE	Government-Furnished Equipment
GIA	Government Inspection Agency
GIDEP	Government Industry Data Exchange Program
GOTS	Government Off-the-Shelf
GPR	Goddard Procedure and Guidelines
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HTL	Hazard Tracking Log
HQ	Headquarters
I&T	Integration and Test
IAC	Independent Assurance Contractor
IEEE	Institute of Electrical and Electronics Engineers
INST	Instruction
ISO	International Organization for Standardization
IV&V	Independent Verification and Validation
KHB	Kennedy Space Center Handbook
KSC	Kennedy Space Center
LDCM	Landsat Data Continuity Mission
MAE	Materials Assurance Engineer
MAG	Mission Assurance Guidelines
MAIP	Mission Assurance Implementation Plan
MAR	Mission Assurance Requirements
MEB	Materials Engineering Branch
MOSFETs	Metal-Oxide-Semiconductor Field Effect Transistors
MOTS	Modified Off-the-Shelf
MPCB	Materials and Processes Control Board
MPCP	Materials and Processes Control Plan
MRB	Materials Review Board
MRR	Mission Readiness Review
MSFC	Marshall Space Flight Center
MSPSP	Missile System Pre-Launch Safety Data Package
MUA	Materials Usage Agreement

Abbreviation/ Acronym	DEFINITION
NASA	National Aeronautics and Space Administration
NCAS	NASA Contractor Assurance Supplier
NHB	NASA Handbook
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
NPSL	NASA Parts Selection List
NSF	NASA Federal Supplement
NSPAR	Nonstandard Parts Approval Request
NSS	NASA Safety Standard
O&SHA	Operating and Support Hazard Analysis
ODA	Orbital Debris Assessment
OHA	Operational Hazard Analysis
OSSMA	Office of Systems Safety and Mission Assurance
PAPL	Project Approved Parts List
PCB	Parts Control Board
PCP	Parts Control Plan
PDA	Percentage of Defective Allowable
PDR	Preliminary Design Review
PEM	Plastic Encapsulated Microcircuit
PER	Pre-Environmental Review
PG	Procedures and Guidelines
PHA	Preliminary Hazards Analysis
PIL	Parts Identification List
PIND	Particle Impact Noise Detection
PPE	Project Parts Engineer
PRA	Probabilistic Risk Assessment
PRAP	Probabilistic Risk Assessment Plan
PRE	Project Radiation Engineer
PSR	Pre-Shipment Review
PWB	Printed Wiring Board
PWQ	Process Waste Questionnaire
QA	Quality Assurance
QCM	Quartz Crystal Microbalance
QMS	Quality Management System
R&M	Reliability and Maintainability
RDM	Radiation Design Margin
RF	Radio Frequency
RFA	Request for Action

Abbreviation/ Acronym	DEFINITION
RLAT	Radiation Lot Acceptance Test
RPP	Reliability Program Plan
RPM	Revolutions Per Minute
RSDO	Rapid Spacecraft Development Office
S&MA	Safety and Mission Assurance
SAE	Society of Automotive Engineers
SAP	Software Assurance Plan
SAR	Safety Assessment Report
SCM	Software Configuration Management
SEB	Single-Event Burn-Out
SEGR	Single-Event Gate Rupture
SEE	Single-Even Effects
SEL	Single-Event Latch up
SEM	Scanning Electronic Microscope
SET	Single-Event Transient
SEU	Single-Event Upset
SHA	System Hazard Analysis
SOW	Statement of Work
SRO	Systems Review Office
SRR	System Requirements Review
SSHA	Subsystem Safety Hazard Analysis
SSPP	System Safety Program Plan
SSRR	Spacecraft Systems Requirements Review
SWG	Safety Working Group
TID	Total Ionizing Dose
TML	Total Mass Loss
UV	Ultraviolet
V&V	Verification and Validation
VTL	Verification Tracking Log

Appendix B. Glossary/Definitions

The following definitions apply within the context of this document:

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

Assembly: See Level of Assembly.

Audit: A review of the contractor's or sub-contractor's documentation or hardware to verify that it complies with project requirements.

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

Component: See Level of Assembly.

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

Configuration Control: The systematic evaluation, coordination, and formal approval/disapproval of proposed changes, including the implementation of all approved changes to the design and production of an item with a configuration formally approved by the contractor/purchaser/both.

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

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

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

Design Specification: Generic designation for a specification that describes functional and physical requirements for an article, usually at the component level or higher levels of assembly. In its initial form, the design specification is a statement of functional requirements with only general coverage of physical and test requirements.

The design specification evolves through the project life cycle to reflect progressive refinements in performance, design, configuration, and test requirements. In many projects, the end-item specifications serve all the purposes of design specifications for the contract end-items. Design specifications provide the basis for technical and engineering management control.

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

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

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

Discrepancy: See Nonconformance.

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

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

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

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

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

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

Flight Acceptance: See Acceptance Tests.

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

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

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

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

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

Prototype Hardware: Hardware of a new design; it is subject to a design qualification test program and is not intended for flight.

Flight Hardware: Hardware to be used operationally in space. It includes the following subsets:

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

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

Spare Hardware: Hardware whose design has been proven in a design qualification test program, subject to a flight acceptance test program and used to replace flight hardware that is no longer acceptable for flight.

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

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

Instrument: See Level of Assembly.

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

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

Subassembly: A subdivision of an assembly. Examples are wire harness and loaded printed circuit boards.

Assembly: A functional subdivision of a component consisting of parts or subassemblies that perform functions necessary for the operation of the component as a whole. Examples are a power amplifier and gyroscope.

Component or unit: A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronic box, transmitter, gyro package, actuator, motor, battery. For the purposes of this document, "component" and "unit" are used interchangeably.

Section: A structurally integrated set of components and integrating hardware that form a subdivision of a subsystem, module, etc. A section forms a testable level of assembly, such as components/units mounted into a structural mounting tray or panel-like assembly, or components that are stacked.

Subsystem: A functional subdivision of a payload consisting of two or more components. Examples are structural, attitude control, electrical power, and communication subsystems. Also included as subsystems of the payload are the science instruments or experiments.

Instrument: A SC subsystem consisting of sensors and associated hardware for making measurements or observations in space. For the purposes of this document, an instrument is considered a subsystem (of the SC).

Module: A major subdivision of the payload that is viewed as a physical and functional entity for the purposes of analysis, manufacturing, testing, and record keeping. Examples include SC bus, science payload and upper stage vehicle.

Payload: An integrated assemblage of modules, subsystems, etc., designed to perform a specified mission in space. For the purposes of this document, "payload" and "spacecraft" are used interchangeably. Other terms used to designate this level of assembly are Laboratory, Observatory, and satellite.

Spacecraft: See Payload. Other terms used to designate this level of assembly are Laboratory, Observatory, and satellite.

Limit Level: The maximum expected flight.

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

Maintainability: A measure of the ease and rapidity with which a system or equipment can be restored to operational status following a failure. It is characteristic of equipment design and installation, personnel availability in the required skill levels, adequacy of maintenance procedures and test equipment, and the physical environment under which maintenance is performed.

Margin: The amount by which hardware capability exceeds mission requirements.

Mission Assurance: The integrated use of the tasks of system safety, reliability assurance engineering, maintainability engineering, mission environmental engineering, materials and processes engineering, electronic parts engineering, quality assurance, software assurance, configuration management, and risk management to support NASA projects.

Module: See Level of Assembly.

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

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

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

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

Part: See Level of Assembly.

Payload: See Level of Assembly.

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

Protoflight Testing: See Hardware.

Prototype Testing: See Hardware.

Qualification: See Design Qualification Tests.

Red Tag/Green Tag: Physical tags affixed to flight hardware that mean: red (remove before flight) and green (enable before flight).

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

Reliability: The probability that an item will perform its intended function for a specified interval under stated conditions.

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

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

Section: See Level of Assembly.

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

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

Spacecraft: See Level of Assembly.

Subassembly: See Level of Assembly.

Subsystem: See Level of Assembly.

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

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

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

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

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

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

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

Unit: See Level of Assembly.

Validation: The process of evaluating software during, or at the end of, the software development process to determine whether it satisfies specified requirements.

Verification: The process of evaluating software to determine whether the products of a given development phase (or activity) satisfy the conditions imposed at the start of that phase (or activity).

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

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

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