

Robotic Lunar Exploration Program

Generic Instrument Performance Assurance Implementation User's Guide

May 30, 2005



**Goddard Space Flight Center
Greenbelt, Maryland**

**National Aeronautics and
Space Administration**

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1.0 OVERALL IMPLEMENTATION

1.1 DESCRIPTION OF OVERALL IMPLEMENTATION

The requirements of the Robotic Lunar Exploration Program Mission Assurance Requirements (430-RQMT-000006) document will be implemented in accordance with this Instrument Developer Assurance Implementation Users Guide to develop a Performance Assurance Implementation Plan (PAIP). Unless specifically addressed within this guide, the scope of application of this guide to flight and ground system hardware and software is commensurate with the defined scope of application of the performance assurance requirements in the RLEP MAR (430-RQMT-000006).

1.1.1 Assurance Management Organization

Responsibility for the application of this User's Guide to develop a Performance Assurance Implementation Plan rests with all Instrument Developer Project members and, ultimately, the Instrument Developer Project Manager and Principal Investigator. Responsibility for the management of performance and safety assurance activities described in the PAIP rests with the Instrument Developer Performance and Safety Assurance Manager (PSAM).

The primary responsibility of the PSAM is to ensure the products produced by the Instrument Developer intended for design qualification, flight and critical ground support equipment (GSE) usage meet the required levels of quality, reliability and functionality for their intended purposes. The PSAM shall be delegated the authority and responsibility to accomplish the following:

- a. Participate in design and procurement status activities
- b. Establish and implement quality, reliability and safety assurance requirements
- c. Perform internal, partner, and supplier technical risk assessment, process assessment and product evaluation
- d. Assist the Instrument Developer Project in tailoring the software/hardware development processes
- e. Review and/or approve technical documents related to hardware/software, including equipment specifications, procurement, software system requirement, assembly procedures, test procedures and payload integration procedures
- f. Oversee, track, audit and assess critical supplier operations
- g. Assist in metrics definition and assure that the development team is following the defined processes
- h. Assure the identification, implementation, and verification of safety-critical components are performed

Document and communicate quality status/problems and recommend preventative/corrective action to both the instrument development team and the GSFC Project management office.

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

When hardware that was designed, fabricated, or flown on a previous project is considered to have demonstrated compliance with all of the requirements of this document such that certain tasks need not be repeated, the Instrument Developer shall demonstrate how the hardware complies with requirements prior to being relieved from performing any tasks. Data Item Description (DID) 1-1 of the RLEP MAR (430-RQMT-000006) defines the required matrix detailing all the required information for consideration. A heritage review, with GSFC Project personnel in attendance, may be used for demonstrating compliance.

1.3 SURVEILLANCE

The work activities, operations, and documentation performed by the Instrument Developer or their suppliers are subject to evaluation, review, audit, and inspection by government-designated representatives from the Goddard Space Flight Center (GSFC) Project Office, a Government Inspection Agency (GIA), or an independent assurance contractor (IAC). The GSFC Project Office may delegate in-plant responsibilities and authority to those agencies via a letter of delegation, or a GSFC contract with an IAC.

The Instrument Developer, upon request, will provide government assurance representatives with documents, records, and equipment required to perform their assurance and safety activities. The Instrument Developer will also provide the government assurance representative(s) with an acceptable work area.

1.4 ACRONYMS AND GLOSSARY

The RLEP MAR (430-RQMT-000006) and the definitions included in implementing documents referenced herein define acronyms and terms as applied in this User's Guide.

1.5 CONTRACT DELIVERY REQUIREMENTS LIST (CDRL)

The Contract Delivery Requirements List (CDRL) contains DIDs which describe data deliverable to the GSFC Project Office. The "CDRL numbers" cited in this document refer to the "CDRL numbers" listed on the DID's contained in the CDRL. Performance assurance deliverables required from project contractors are defined in appropriate contract procurement packages and any required contractor assurance implementation plans.

Unless otherwise indicated in this User's Guide, all required documentation generated by Instrument Developer shall be provided to the GSFC Project Office by the responsible project personnel as scheduled in applicable CDRL DID. Contractor-provided assurance deliverables shall be provided upon receipt by the contract Technical Representative to the Instrument Developer project office. The PSAM shall provide review comments or approval/disapproval recommendations as appropriate to the Instrument Developer Project Manager on all assurance deliverables received for project review or approval.

1.6 REQUIREMENTS DOCUMENTS

All Instrument Developer prepared requirements documents such as the instrument specification, the instrument performance verification plan, and associated documentation such as the Risk Management Plan and System Safety Program Plan will be delivered electronically to the GSFC Project Office for analysis and comments or approval.

1.7 DOCUMENTS

1.7.1 Applicable Documents

430-RQMT-000006	Robotic Lunar Exploration Program Mission Assurance Requirements
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1.7.2 Reference Documents

AFSPC 91-710	Range User Requirements Manual
ANSI/ASQC Q9001-2000	Quality Systems – Model for Quality Assurance in Design, Development, Production, Installation, and Servicing
GSFC-STD-7000	General Environmental Verification Standard (GEVS) For GSFC Flight Programs and Projects
NASA-STD-8719.8	Expendable Launch Vehicle Payloads Safety Review Process Standard
NF1627	NASA Mishap Form
NPR 7120.5	NASA Program and Project Management Processes and Requirements
NPD 8710.3	Policy for Limiting Orbital Debris Generation
NPR 8715.3	NASA Safety Manual
NPR 8000.4	Risk Management Procedural Requirements
NPR 8621.1	NASA Procedural Requirements for Mishap Reporting, Investigating, and Recordkeeping
NSS 1740.13	Software Safety Standard
NSS 1740.14	Guidelines and Assessment Procedures for Limiting Orbital Debris

2.0 QUALITY ASSURANCE REQUIREMENTS

2.1 GENERAL REQUIREMENTS

The Instrument Developer shall define and implement a Quality Management System (QMS) that is based on ANSI/ASQC Q9001-2000, Quality Systems – Model for Quality Assurance in

Design, Development, Production, Installation, and Servicing, that properly encompasses the Instrument Developer's flight hardware and software.

The RLEP intends to allow project team institutions to use their own ANSI/ASQC Q9001 compliant system and procedures to the fullest extent possible, provided the requirements of this PAIP and the associated CDRL DIDs are satisfied.

The International Standards Organization (ISO) 9001 Quality Standard specifies requirements which determine what elements quality systems have to encompass, but it allows significant flexibility in determining which requirements actually apply and how they are implemented. It is intended that the use of the ISO 9001 Quality Standard will also allow the Instrument Developer to concentrate on value-added quality activities. The Instrument Developer's Quality Manual will be provided in accordance with CDRL, DID 2.1.

2.2 QUALITY ASSURANCE MANAGEMENT SYSTEM REQUIREMENTS AUGMENTATION

The following requirements augment the identified portions of ANSI/ASQC Q9001-2000.

Section 4.4.4:

New on-orbit design of software and ground stations hardware shall be in accordance with original system design specifications and validation processes.

Section 4.6.3:

The supplier's QA program should ensure flow-down to all major and critical suppliers of technical requirements and a process to verify compliance i.e., matrix or related documentation.

Section 4.13.2:

The reporting of failures will begin with the first power application at the lowest level of assembly or the first operation of a mechanical item. It will continue through formal acceptance by the GSFC Project Office.

Failures shall be reported to the GSFC Project Office within 24 hours of occurrence (initial report). (Refer to the CDRL, 2.2)

The final failure documentation provided to GSFC will include Material Review Board (MRB)/Failure Review Board (FRB) minutes and reports.

The Instrument Developer's review/disposition/approval of failure reports will be described in the applicable procedure(s).

3.0 **SYSTEM SAFETY REQUIREMENTS**

3.1 **GENERAL REQUIREMENTS**

The system safety program shall be implemented by all instrument developers for flight hardware, GSE, associated software, and support facilities. The system safety program shall be initiated in the concept phase of design and continue throughout all phases of the mission. GSFC shall certify safety compliance in support of the Pre-Ship Review (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 instrument development including design, development, fabrication, test, handling, storage, transportation and pre-launch activities. The program shall address hazards in the flight hardware, associated software, ground support equipment, operations, and support facilities, and shall conform to the safety review process requirements of NASA-STD-8719.8, "Expendable Launch Vehicle Payloads Safety Review Process Standard".
- b. Meets the system safety requirements of AFSPC 91-710, "Range User Requirements Manual".
- c. Meets the baseline industrial safety requirements of the institution, AFSPC 91-710 applicable Industry Standards to the extent practical to meet the National Aeronautics and Space Administration (NASA), and the Office of Safety and Health Administration (OSHA) design and operational needs, and any special contractually imposed mission unique obligations. This should be documented in the contractor's Facility Health and Safety Plan.

Specific safety requirements include the following:

- If a system failure may lead to a catastrophic hazard, the system shall have three 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.
- If a system failure may lead to a critical hazard, the system shall have two 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.
- 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 developer.

3.2 SYSTEM SAFETY DELIVERABLES

3.2.1 System Safety Program Plan

The Instrument Developer shall prepare a System Safety Program Plan (SSPP), see DID 3-1, which describes in detail, tasks and activities of system safety management and system safety engineering required to identify, evaluate, and eliminate and control hazards or reduce the associated risk to a level acceptable throughout the system life cycle.

The approved plan provides a formal basis of understanding between the developer and GSFC Code 302 on how the system safety program will be conducted to meet the range safety requirements, including general and specific provisions. The approved plan shall account for all contractually required tasks and responsibilities on an item-by-item basis, and will address the roles and responsibilities of each organization. The SSPP shall specify the hazard analyses required to be performed on flight hardware, GSE, and integration and test (I&T) and Pre-launch operations.

3.2.2 Safety Requirements Compliance Checklist

The Instrument Developer shall demonstrate that the payload is in compliance with all safety requirements and that all Nonconformance Reports (NCRs)/waivers have been submitted and approved by GSFC Code 302 and the launch site safety representative. The Instrument Developer shall document this in the Safety Requirements Compliance Checklist (refer to DID 3-2). Safety compliance shall be granted via GSFC Code 302 Safety Certification letter to the Project Manager only after verification that all applicable safety requirements have been met.

3.2.3 Safety Analyses

The Instrument Developer and GSFC Code 302 shall jointly tailor safety analysis requirements with the Range based on the complexity of the instrument.

3.2.3.1 Preliminary Hazard Analysis

The purpose of this task is to perform and document a Preliminary Hazard Analysis (PHA) to identify safety critical areas, to provide an initial assessment of hazards, and to identify requisite hazard controls and follow-on actions.

The Instrument Developer shall perform and document a PHA in accordance with DID 3-3 to obtain an initial risk assessment of a concept or system. Based on the best available data, including mishap data from similar systems and other lessons learned, hazards associated with the proposed design or function shall be evaluated for hazard severity, hazard probability, and operational constraint. Safety provisions and alternatives needed to eliminate hazards or reduce their associated risk to a level acceptable to Range Safety shall be included.

3.2.3.2 Subsystem Hazard Analysis

The purpose of this task is to perform a Subsystem Hazard Analysis (SSHA) to verify subsystem compliance with safety requirements contained in subsystem specifications and other applicable documents; 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 recommend actions necessary to eliminate identified hazards or control their associated risk to acceptable levels. The Instrument Developer shall perform an SSHA to identify all components and equipment that could result in a hazard or whose design does not satisfy contractual safety requirements.

This will include government-furnished equipment (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 shall 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 Safety Assessment Report (SAR).

3.2.3.3 System Hazard Analysis

The purpose of this task is to perform and document a System Hazard Analysis (SHA) to verify system compliance with safety requirements contained in system specifications and other applicable documents; identify previously unidentified hazards associated with the subsystem interfaces and system functional faults; assess the risk associated with the total system design, including software, and specifically of the subsystem interfaces; and recommend actions necessary to eliminate identified hazards and/or control their associated risk to acceptable levels. Results shall be documented in the SAR.

3.2.3.4 Operations Hazards Analyses (OHAs)

The Instrument Developer shall prepare an Operations Hazard Analysis (OHA) which describes the hardware and test equipment operations. The OHA shall be prepared in accordance with DID 3-4 and demonstrate that the planned I&T activities are compatible with the facility safety requirements and that any inherent hazards associated with those activities is mitigated to an acceptable level.

GSFC Code 302 is responsible for reviewing and approving the OHA as well as the organization's test and handling procedures for I&T prior to receiving the hardware at the Integration and Test Facility. GSFC Code 302 shall also review all Work Order Authorizations (WOAs) and approve all hazardous WOAs generated by the organization during I&T activities and witness all hazardous operations.

3.2.3.5 Operating and Support Hazard Analysis

Not Applicable (N/A)

3.2.3.6 Software Safety

Section 5.2.2 describes desired software safety activities to meet NASA Headquarters (HQ) guidelines. 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 developer 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.

3.3 SAFETY ASSESSMENT REPORT

The Instrument Developer shall perform and document a comprehensive evaluation of the mishap risk of their instrument. This report is used to assist the spacecraft developer/integrator in preparing the Missile System Pre-launch Safety Package (MSPSP) for submittal to the launch range. This SAR (refer to DID 3-5) shall identify all safety features of the hardware, software, and system design, as well as procedural related hazards present in the instrument.

It shall include:

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

3.4 MISSILE SYSTEM PRE-LAUNCH SAFETY PACKAGE

N/A

3.5 VERIFICATION TRACKING LOG

The Instrument Developer shall establish a “closed loop” process for tracking all hazards to acceptable closure through the use of a Verification Tracking Log (VTL), (see DID 3-7). The VTL shall be delivered with the final SAR and updated regularly as requested until all items are closed. Individual VTL items shall be closed with appropriate documentation verifying the stated hazard control has been implemented, and individual closures shall be complete prior to first operational use/restraint.

3.6 GROUND OPERATIONS PROCEDURES

The Instrument Developer shall submit, in accordance with the contract schedule, all ground operations procedures (see DID 3-8) to be used at GSFC facilities, other integration 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. GSFC Code 302 will review and approve all hazardous procedures before submittal to the launch range.

3.7 SAFETY VARIANCE

When a specific safety requirement cannot be met, the instrument developer shall submit an associated safety variance, per the NASA Safety Manual (NPR 8715.3) and DID 3-9 which identifies the hazard and shows the rationale for approval of a variance. The following definitions apply to the safety variance approval policy:

- a. Variance: Documented and approved permission to perform some act or operation contrary to established requirements.
- b. Deviation: A documented variance that authorizes departure from a particular safety requirement that does not strictly apply or where the intent of the requirement is being met through alternate means that provide an equivalent level of safety with no additional risk. The OSHA requirements (1910 29 CFR) term for deviation is alternate or supplemental standard only when it applies to OSHA requirements.
- c. Waiver: A variance that authorizes departure from a specific safety requirement where a special level of risk has been documented and accepted.

All requests for variance will be accompanied by documentation as to why the requirement can not be met, the risks 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 variance affects personal safety)

3.8 SUPPORT FOR SAFETY MEETINGS

Technical support shall be provided to the Project for Safety Working Group (SWG) meetings, Technical Interface Meetings (TIM), 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 Code 302 to discuss any situations that may arise with respect to overall project safety. Meetings are normally held as a sidebar to other reviews and meetings to minimize extra travel. There is no required number of meetings.

3.9 ORBITAL DEBRIS ASSESSMENT

The Instrument Developer shall supply the information required to support development of the Orbital Debris Assessment, (see DID-3-10), consistent with NPD 8710.3, Policy for Limiting Orbital Debris Generation and NSS 1740.14, Guidelines and Assessment Procedures for Limiting Orbital Debris in accordance with the CDRL. Design and safety activities shall take into account the instrument's contribution toward the spacecraft's ability to conform to debris generation requirements.

3.10 LAUNCH SITE SAFETY SUPPORT

The Developer 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 is required and needs to be planned and budgeted for.

3.11 MISHAP REPORTING AND INVESTIGATION

Any mishaps, incidents, hazards, and close calls will be reported on a NASA Mishap Form (NF1627) or equivalent form, per NPR 8621.1, "NASA Procedural Requirements for Mishap Reporting, Investigating, and Recordkeeping".

3.12 MISCELLANEOUS SUBMITTALS FOR RANGE USE

The following list of forms is required by range safety and shall be submitted to the Range:

- Material Selection List for Plastic Films, Foams, and Adhesive Tapes - (<http://rtreport.ksc.nasa.gov/techreports/95report/msf/ms10.html>). The list is published in GP-1098, KSC Ground Operations Safety Plan, Volume I, Safety Requirements, and is updated quarterly. Materials are evaluated for ESD, flammability, and compatibility with hypergols. (Ship-60 day to GSFC)
- Radiation forms/analysis - KHB 1860.1 (KSC Ionizing Radiation Protection Program) and KHB 1860.2 (KSC Non-Ionizing Radiation Protection Program) includes forms for ionizing and non-ionizing radiation from RF, light, laser, and radioactive sources. Forms must be completed to provide information on the radiation source(s) and the source user(s). Procedures must also be submitted. (Ship-120 days to GSFC)
- Process Waste Questionnaire (PWQ) (KSC/Eastern Range Only) - PWQ records all the hazardous materials that are brought to the range with the payload. Specific information on storage, containment, and spill control are required. (Ship - 60 days to KSC/ETR)
- Environmental Impact Statement (EIS) (KSC/Eastern Range Only) - An EIS is required to define the impact of an aborted/terminated launch. (Ship-60 days to KSC/ETR)

4.0 RELIABILITY REQUIREMENTS

4.1 GENERAL REQUIREMENTS

The Instrument Developer will plan and implement a reliability program that interacts effectively with other project disciplines, including systems engineering, hardware design, and product assurance. The program will be tailored according to the risk level to:

- a. Demonstrate that redundant functions, including alternative paths and work-arounds, are independent to the extent practicable.
- b. Demonstrate that the stress applied to parts is not excessive.
- c. Identify single failure items/points, their effect on the attainment of mission objectives, and possible safety degradation.
- d. Show that the reliability design aligns with mission design life and is consistent among the systems, subsystems, and components.
- e. Identify limited-life items and ensure that special precautions are taken to conserve their useful life for on-orbit operations.
- f. Select significant engineering parameters for the performance of trend analysis to identify performance trends during pre-launch activities.
- g. Ensure that the design permits easy replacement of parts and components and that redundant paths are easily monitored.

4.2 RELIABILITY ANALYSES

Reliability analyses will be performed concurrently with the instrument's design so that identified problem areas can be addressed and correction action taken (if required) in a timely manner.

4.2.1 Failure Modes and Effects Analysis and Critical Items List

A Failure Modes and Effects Analysis (FMEA) will be performed early in the design phase to identify system design problems. As additional design information becomes available the FMEA will be refined.

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

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

Table 4-1. Category Severity Definition

4-11

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

FMEA analysis procedures and documentation will be performed in accordance with documented procedures. Failure modes resulting in Severity Categories 1, 1R, 1S or 2 will be analyzed at a greater depth, to the single parts if necessary, to identify the cause of failure.

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

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

All failure modes that are assigned to Severity Categories 1, 1R, 1S and 2, will be itemized on a Critical Items List (CIL) and maintained with the FMEA report. (Refer to the CDRL 4.3.)

Rationale for retaining the items will be included on the CIL. The FMEA and CIL will be provided to the GSFC Project Office for review and/or audit. Results of the FMEA and implementation plan as well as the CIL will be presented at all design reviews starting with the Preliminary Design Review (PDR). The presentations will include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

4.2.2 Parts Stress Analyses

Each application of electrical, electronic, and electromechanical (EEE) parts, will be subjected to stress analyses for conformance with the applicable derating guidelines (Refer to RLEP MAR [430-RQMT-000006], Section 4.4.3.). The analyses will 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. The analyses will be performed in close coordination with the packaging reviews (See RLEP MAR [430-RQMT-000006], Section 9.5) and thermal analyses and they will be required input data for component-level design reviews. (Refer to RLEP MAR [430-RQMT-000006], Section 8.2.) The analyses will be maintained by the Instrument Developer for the GSFC Project Office to review/audit. The results of the analyses will be presented at all design reviews starting with the PDR. The presentations will include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

4.2.3 Worst Case Analyses

Worst Case Analyses may be performed on circuits where failure results in a severity category of 2 or higher question the flightworthiness of the design. If performed, the most sensitive design parameters, including those that are subject to variations that could degrade performance, will be subjected to the analysis. The adequacy of design margins in the electronic circuits, optics, electromechanical, and mechanical items will be demonstrated by analyses or test or both to ensure flightworthiness. This analysis will be made available by the Instrument Developer for GSFC Project Office review. The results of any analyses and risk mitigation plan will be presented at all design reviews starting with the PDR. The presentations will include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

The analyses will consider all parameters set at worst case limits and worst case environmental stresses for the parameter or operation being evaluated. Depending on mission parameters and parts selection methods, part parameter values for the analysis will typically include: manufacturing variability, variability due to temperature, aging effects of environment, and variability due to cumulative radiation. The analyses and updates will be made available to GSFC Project Office for information prior to manufacturing of flight hardware.

4.2.4 Reliability Assessments

When necessary/prudent or when agreed-upon with the GSFC Project Office, the Instrument Developer will perform comparative numerical reliability assessments to:

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

Reliability assessments will be integrated with the design process and other assurance practices to maximize the probability of meeting mission success criteria. The Instrument Developer will consider how the reliability assessments will incorporate definitions of failure as well as alternate and degraded operating modes that describe plausible acceptable and unacceptable levels of performance. Degraded operating modes will include failure conditions that could be alleviated or reduced significantly through the implementation of work-arounds via telemetry.

The assessments and updates will be submitted to the GSFC Project Office for information. The results of any reliability assessment will be reported at PDR and Critical Design Review (CDR). The presentations will include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

4.3 ANALYSIS OF TEST DATA

The Instrument Developer will fully utilize test information during the normal test program to assess flight equipment reliability performance and identify potential or existing problem areas.

4.3.1 Trend Analyses

As part of the routine system assessment, the Instrument Developer shall assess subsystems and components to determine measurable parameters that relate to performance stability. Selected parameters shall be 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, environmental tests, etc. The Instrument Developer shall establish a system for recording and analyzing the parameters as well as any changes from the nominal even if the levels are within specified limits. Trend analysis data shall be reviewed with the operational personnel prior to launch, and the operational personnel shall continue recording trends throughout mission life. A list of subsystem and components to be assessed and the parameters to be monitored and the trend analysis reports will be maintained.

4.3.2 Analysis of Test Results

The Instrument Developer will analyze test information, trend data, and failure investigations to evaluate reliability implications. Identified problem areas shall be documented and directed to the attention of GSFC Project Management for action. The results of the analyses will be

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

4.4 LIMITED-LIFE ITEMS

Limited-life items will be identified and managed by means of a Limited-Life List, which will be submitted for approval. (Refer to the CDRL 4.9) The list will present definitions, the impact on mission parameters, responsibilities, and a list of limited-life items, including data elements:

expected life, required life, duty cycle, and rationale for selection. The useful life period starts with fabrication and ends with the completion of the final orbital mission.

The list of limited-life items should include selected structures, thermal control surfaces, solar arrays and electromechanical mechanisms. Atomic oxygen, solar radiation, shelf-life, extreme temperatures, thermal cycling, wear and fatigue should be used to identify limited-life thermal control surfaces and structure items. All mechanisms such as batteries, compressors, seals, bearings, valves, recorders, momentum wheels, gyros, actuators, and scan devices should be included when aging, wear, fatigue and lubricant degradation limit their life. Records shall be maintained that allow evaluation of the cumulative stress (time and/or cycles) for limited-life items starting when useful life is initiated and indicating the project activity that will stress the items. The use of an item whose expected life is less than its mission design life must be approved by the GSFC Project Office by means of a program waiver.

5.0 SOFTWARE ASSURANCE REQUIREMENTS

5.1 GENERAL

The Instrument Developer shall employ a structured program (Software Quality Management System [SQMS]) for the development of software. The program shall recognize the phases of the development life cycle (requirements analysis, design, code and unit test, integration and build test, performance verification, and maintenance) and utilize appropriate mechanisms to facilitate the development effort and ensure the quality of the product. These mechanisms include documentation, reviews, verification activities, and configuration management (CM). The program shall encompass instrument flight software and firmware, ground test equipment software, and any software related to mission operations. Science and data analysis software are excluded from these requirements.

5.2 SOFTWARE QUALITY MANAGEMENT SYSTEM

The Instrument Developer's SQMS will be based on the ANSI/ASQC Q9001 Quality Standard. The following activities augment the identified portions of ANSI/ISO/ASQ Q9000-3 which provides guidance on the development of a SQMS that is based on ANSI/ASQC Q9001.

5.2.1 Reviews (Augmentation to Section 4.1.3, ANSI/ASQC Q9000-3)

There will be a series of Instrument Developer-presented formal reviews conducted by a GSFC-chaired review panel that will include independent experts in the type of software under review. The formal reviews will consist of, as a minimum, a PDR, a CDR, a Test Readiness Review (TRR), and an Acceptance Review (AR). These reviews will be coordinated with the reviews defined in Section 8. Since the Lunar Reconnaissance Orbiter (LRO) mission will not have a Software Requirements Review (SRR) it is proposed that a formal peer review of the software requirements be held within 90 days after PDR. The Instrument Developer will record minutes and action items during each review.

5.2.2 Corrective Action (Augmentation to Section 4.1, ANSI/ASQC Q9000-3)

The corrective action process will start at the establishment of a CM baseline that includes the product. The use of the formal software corrective action process will become mandatory with the first instance of the software's delivery to testing for the verification software requirements. GSFC personnel will be allowed access to problem reports and corrective action information as they are prepared.

5.2.3 Configuration Management (Augmentation to Section 4.8, ANSI/ASQC Q9000-3)

The Developer shall develop and implement a Software Configuration Management (SCM) system that provides baseline management and control of software requirements, source code, data, and documentation. The developer shall document the SCM system.

The Instrument Developer's SCM system will have a change classification and impact assessment process that results in Class 1 changes being forwarded to the GSFC Project Office for disposition. Class 1 changes are defined as those which affect system requirements, software requirements, system safety, reliability, cost, schedule, and external interfaces.

5.2.4 Inspection, Testing and Verification Matrix (Augmentation to Section 4.10.4, ANSI/ASQC Q9000-3)

As part of the Instrument Developer's effort to verify to the Government that their software is flight worthy, the Instrument Developer shall prepare and maintain a software performance verification matrix. When the document is prepared, an up-to date version will be provided to the GSFC Project Office. If a matrix is prepared, as a minimum, it will include:

- a. How each specification requirement will be verified
- b. The reference source (to the specific paragraph or line item)
- c. The method of compliance
- d. The applicable procedure references
- e. Verification results
- f. Report reference numbers

5.2.5 Final Configuration Audit and Verification (Augmentation to Section 4.10.4, ANSI/ASQC Q9000-3)

As part of the Instrument Developer's effort to verify to the GSFC Project Office that their software is flight worthy, the Instrument Developer and the GSFC Project Office shall conduct a Functional Configuration Audit (FCA) and Physical Configuration Audit (PCA) on the final delivered product and on major upgrades (defined as the change of 20% or more of the lines of code) to that product upon their mutual agreement. The Instrument Developer will provide the results of any audit(s) to the GSFC Project Office.

5.3 GFE, EXISTING AND PURCHASED SOFTWARE

If software will be provided to the Instrument Developer as GFE or if the Instrument Developer will use existing or purchased software; the Instrument Developer is responsible for the software meeting the functional, performance, and interface requirements placed upon it. The Instrument Developer is also responsible for ensuring that the software meets all applicable standards, including those for design, code, and documentation; or for securing a project waiver to those standards. Any significant modification to any piece of the existing software will be subject to all of the provisions of the Instrument Developer's SQMS and the provisions of this document. A significant modification is defined as the change of twenty percent of the lines of code in the software.

5.4 SOFTWARE SAFETY

If any software component is identified as safety critical, the Instrument Developer will conduct a software safety program on that component that complies with NSS 1740.13 "Software Safety Standard".

5.5 STATUS REPORTING

The Instrument Developer shall provide status reports to the GSFC Project Office to provide management insight into software development progress, issues, problems, actions taken, and schedules. This information shall be included in the Instrument Developer's Progress Reports to the Project or it shall be presented at the monthly or quarterly status reviews.

6.0 GROUND DATA SYSTEM REQUIREMENTS

6.1 INSTRUMENT DEVELOPER RESPONSIBILITIES

The Instrument Developer will coordinate all ground system interfaces with the project Ground Data Systems requirements documentation. Documented verification of testing and compatibility of interfaces will be made available for GSFC review prior to any flight hardware I&T.

7.0 RISK MANAGEMENT REQUIREMENTS

7.1 GENERAL REQUIREMENTS

The Instrument Developer will develop and implement a project-specific Risk Management Plan as a means to anticipate, mitigate and control risks and to focus project resources where they are needed to ensure success of the project. The NPR 7120.5, NASA Program and Project Management Processes and Requirements, is the controlling requirements/guideline used in the preparation of this plan. (Refer to CDRL 7.1) NPR 8000.4, Risk Management Procedural Requirements is a valuable asset for establishing a risk management process.

The primary activities of the Instrument Developer Continuous Risk Management process are:

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

The GSFC Project Office, the GSFC Systems Review Office (SRO) (for design reviews only), and the Instrument Developer will agree on what level of detail is appropriate for each review.

All identified reliability and quality risks will be documented, updated and reported in accordance with the Instrument Developer's Risk Management Plan. Although not all risks will be fully mitigated, all risks shall be addressed with mitigation and acceptance strategies agreed upon at appropriate mission reviews.

7.2 PROBABILISTIC RISK ASSESSMENT

The Instrument Developer shall provide all requested/required information to GSFC so that the GSFC Project Office can perform a PRA for their hardware and software. (CDRL 4.2) It shall take into account a FTA (CDRL 4.4) which the GSFC Project Office will also prepare with

information provided by the Instrument Developer. The information required will include parts lists (CDRLs 12.1 and 12.2) and schematics. Additionally, the Instrument Developer will cooperate with the GSFC Project Office as required to prepare these documents.

7.3 RISK ASSESSMENT

The Instrument Developer will provide all requested/required information to the GSFC Project Office so that the GSFC Project Office can perform an on-going risk assessment of the program including flight hardware and software. Additionally, the Instrument Developer will cooperate with the GSFC Project Office as required to prepare this assessment.

8.0 INTEGRATED INDEPENDENT REVIEW PROGRAM REQUIREMENTS

8.1 GENERAL REQUIREMENTS

The Instrument Developer will support a series of comprehensive system-level design reviews that are conducted by the GSFC SRO. The reviews will cover all aspects of flight and ground hardware, software, and operations for which the Instrument Developer has responsibility.

8.2 GSFC SYSTEM REVIEW REQUIREMENTS

For each system level review, as required by the GSFC SRO and the MAR, the Instrument Developer will:

- a. Develop and organize material for oral presentation to the Review Team. Copies of the presentation material for GSFC SRO Reviews will be sent electronically to GSFC 10 days prior to the review date.
- b. Support splinter review meetings resulting from the major review.
- c. Produce written responses to recommendations and action items resulting from the review.
- d. Summarize, as appropriate, the results of Instrument Developer reviews at the component and subsystem level.

8.3 GSFC SYSTEM REVIEW PROGRAM

The GSFC Office of Systems Safety and Mission Assurance (OSSMA) System Review Program (SRP) guidelines consists of individual, periodic reviews of all GSFC managed flight missions, flight instruments, flight spacecraft, ground systems which interface with flight hardware, unique flight support equipment, and their associated software including hardware supplied to GSFC managed flight missions.

The Instrument Developer will be reviewed by an independent System Review Team (SRT), chaired by the GSFC SRO. The planned reviews are:

- a. PDR—This review occurs early in the design phase by prior to manufacture of engineering hardware and the detail design of associated software. Where applicable, it should include the results of test bedding, breadboard testing, and software prototyping. It should also include the status of the progress in complying with the launch range safety requirements. At PDR, hazards associated with the flight hardware should be identified and documented.
- b. CDR—This review occurs after the design has been completed but prior to the start of manufacturing flight components or the coding of software. It will emphasize implementations of design approaches as well as test plans for flight systems including

the results of engineering model testing. The Instrument Developer shall present the status of the controls for the safety hazards presented in the PDR and the status of all presentations to the launch range.

- c. Mission Operations Review (MOR)—This mission-oriented review will normally take place prior to significant integration and test of the flight system and ground system. Its purpose is to review the status of the system components, including the ground system and its operational interface with the flight system. Discussions will include mission integration, test planning and the status of preparations for flight operations.
- d. Pre-Environmental Review (PER)—This review occurs prior to the start of environmental testing of the protoflight or flight system. The primary purpose of this review is to establish the readiness of the system for test and evaluate the environmental test plans.
- e. PSR—This review will take place prior to shipment of the instrument for integration with the spacecraft and for shipment of the spacecraft to the launch range. The PSR will concentrate on system performance during qualification or acceptance testing.

The Instrument Developer is also required to present the status of the tracking of the safety items listed in the VTL, the status of deliverable documents to the launch range and the status of presentations and any subsequent launch range issues or approvals prior to sending flight hardware to the range.

- f. Flight Operations Review (FOR)—While all of the previous reviews involve operations, this review will emphasize the final orbital operation plans as well as the compatibility of the flight components with GSE and ground network, including summary results of the network compatibility tests.
- g. Launch Readiness Review (LRR)—This review is to assess the overall readiness of the total system to support the flight objectives of the mission. The LRR is usually held at the launch site two to three days prior to launch.

The time, place and agenda for each of the reviews will be coordinated between the Instrument Developer Project Manager and the Review Team Chairman.

8.4 SYSTEM SAFETY

The safety aspects of the systems being reviewed are a normal consideration in the system evaluations conducted by the SRT. At each appropriate review, the Instrument Developer will demonstrate understanding of and compliance with the applicable launch range requirements, list any known noncompliance's and provide justification for any expected waiver conditions. In addition, the Instrument Developer will present the results of any safety reviews held with the Eastern or Western Test Range.

8.5 PEER REVIEW REQUIREMENTS

The Instrument Developer will implement a program of peer reviews at the component and subsystem levels. The program will, as a minimum, consist of a PDR and a CDR. In addition,

packaging reviews will 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 successfully perform its function under operating and environmental conditions during both testing and flight. The results of parts stress analyses and component packaging reviews, including the results of associated tests and analyses, 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 and substrates and their interconnections in the component design.
- c. Provisions for protection of the parts and ease of inspection.

Instrument Developer peer reviews will be conducted by personnel who are not directly responsible for design of the hardware under review. The GSFC Project Office and SRO will be invited to attend the peer reviews and will be provided 10 working days notification. The results of the reviews will be documented and the documents will be made available for review.

The peer reviews shall have requests for action (RFA) item recordation which are reviewed and assigned to appropriate personnel at the end of the reviews. Timely written responses to recommendations and action items resulting from the review are required by the developer team to the GSFC Project and System Review offices as outlined in the system review plan.

9.0 DESIGN VERIFICATION REQUIREMENTS

9.1 GENERAL REQUIREMENTS

A system performance verification program documenting the overall verification plan, implementation, and results will be developed by the Instrument Developer to ensure that the payload meets the specified mission requirements, and to provide traceability from mission specification requirements to launch and on-orbit capability. The program will consist of a series of functional demonstrations, analytical investigations, physical property measurements, and tests that simulate the environments encountered during handling and transportation, pre-launch, launch, and in-orbit. All prototype or protoflight hardware will undergo qualification to demonstrate compliance with the verification requirements of this section. In addition, all other hardware (flight, follow-on, spare and re-flight as defined in RLEP MAR Appendix B, "Hardware") will undergo acceptance in accordance with the verification requirements of this section.

The Verification Program begins with functional testing of sub-assemblies; it continues through functional and environmental testing supported by appropriate analysis, at the subsystem and Instrument Developer levels of assembly; the program concludes with end-to-end testing of the entire operational system including the Instrument Developer and MOC.

The General Environmental Verification Standard for GSFC Flight Programs and Projects (GEVS) (GSFC-STD-7000) (Refer to RLEP MAR Section 16), will be used as a baseline guide for developing the verification program. Alternative methods may be utilized provided that the net result demonstrates compliance with the intent of the requirements and has been approved by the GSFC Project office.

9.2 DOCUMENTATION REQUIREMENTS

The following documentation requirements will be delivered and approved in accordance with the CDRL of the RLEP M AR.

9.2.1 Performance Verification Plan

An instrument performance verification plan (Refer to CDRL 9.1) will be prepared defining the tasks and methods required to determine the ability of the instrument to meet each project-level performance requirement (structural, thermal, optical, electrical, guidance/control, RF/telemetry, science, mission operational, etc.) and to measure specification compliance. Limitations in the ability to verify any performance requirement will be addressed, including the addition of supplemental tests and/or analyses that will be performed and a risk assessment of the inability to verify the requirement. The plan will address how compliance with each specification requirement will be verified. If verification relies on the results of measurements and/or analyses performed at lower (or other) levels of assembly, this dependence will be described.

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

The plan should address ground support equipment used in performance testing, as well as test data reduction (analysis, software and data product) electromagnetic interference (EMI)/electromagnetic compatibility (EMC) testing should also include turn on/off transients.

Any requirements verification being deferred to orbiter level of assembly should be justified.

The following documents as defined in Sections 9.2.2 to 9.7 may be included as part of the Instrument Performance Verification Plan or as separate documents to meet the Instrument Developer needs.

9.2.2 Environmental Verification Plan

An environmental verification plan will be prepared, as part of the System Verification Plan or as a separate document, that prescribes the tests and analyses that will collectively demonstrate that the hardware and software comply with the environmental verification requirements.

The Environmental Verification Plan will provide the overall philosophy and approach to accomplishing the environmental verification program. For each test, it will include the level of assembly, the configuration of the item, objectives, test phases, and necessary functional operations.

It will also define a rationale for retest determination that does not invalidate previous verification activities. When appropriate, the interaction of the test and analysis activity will be described.

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

9.2.3 System Performance Verification Matrix

A System Performance Verification Matrix will be prepared and maintained, to show each specification requirement, the reference source (to the specific paragraph or line item), the method of compliance, applicable procedure references, results, report reference numbers, etc. This matrix will be included in the system review data packages showing the current verification status as applicable. (Refer to Section 8 of this document).

9.2.4 Environmental Test Matrix

As an adjunct to the system/environmental verification plan, an Environmental Test Matrix (ETM) will be prepared that summarizes all tests that will be performed on each component, each subsystem or instrument, and the payload. The purpose is to provide a ready reference to the contents of the test program in order to prevent the deletion of a portion thereof without an alternative means of accomplishing the objectives. All flight hardware, spares and prototypes (when appropriate) will be included in the matrix. The matrix will be prepared in conjunction with the initial environmental verification plan and will be updated as changes occur.

A complementary matrix will be kept showing the tests that have been performed on each component, subsystem, instrument, or payload (or other applicable level of assembly) including procured articles for flight. This will include tests performed on prototypes or engineering units used in the qualification program, and should indicate test results (pass/fail or malfunctions).

9.2.5 Environmental Verification Specification

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

9.2.6 Performance Verification Procedures

For each verification test activity conducted at the component, subsystem, and payload levels (or other appropriate levels) of assembly, a verification procedure will be prepared that describes the configuration of the test article, how each test activity contained in the verification plan and specification will be implemented.

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

9.2.7 Instrument Performance Verification Reports

After each component, subsystem, etc. verification activity has been completed, a report will be submitted. For each analysis activity, the report will describe the degree to which the objectives were accomplished, how well the mathematical model was validated by related test data, and other such significant results. In addition, as-run verification procedures and all test and analysis data will be retained for review.

The Instrument Performance Verification Report will be developed and maintained “real-time” throughout the program summarizing the successful completion of verification activities, and showing that the applicable system performance specifications have been acceptably complied with prior to integration of hardware/software into the next higher level of assembly.

At the conclusion of the verification program, a final Instrument Performance Verification Report will be delivered comparing the hardware/software specifications with the final verified values (whether measured or computed).

9.3 ELECTRICAL FUNCTIONAL TEST REQUIREMENTS

The required electrical functional and performance tests specified in Section 9.2 of the RLEP MAR (along with all other calibrations, functional/performance tests, measurements, demonstrations, alignments [and alignment verifications], end-to-end tests, simulations, etc. that are part of the overall verification program) will be described in the Instrument Developer ETM.

9.4 STRUCTURAL AND MECHANICAL REQUIREMENTS

The Instrument Developer will demonstrate compliance with the structural and mechanical requirements specified in Section 9.2 of the RLEP MAR through a series of interdependent test and analysis activities. These demonstrations will verify design and specified factors of safety as well as ensure spacecraft interface compatibility, acceptable workmanship, and material integrity. The Instrument Developer will ensure through discussions/reviews with the RLEP Safety Manager that, when it is appropriate, activities needed to satisfy the safety requirements are accomplished in conjunction with these demonstrations.

When planning the tests and analyses, the Instrument Developer will consider all expected environments including those of structural loads, vibroacoustics, mechanical shock, and pressure profiles. Mass properties and mechanical functioning shall also be verified.

9.5 ELECTROMAGNETIC COMPATIBILITY REQUIREMENTS

The electromagnetic characteristics of hardware will be designed in accordance with the requirements of Lunar Reconnaissance Orbiter General Electrical Specification (Document # **TBD**) so that:

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

9.6 VACUUM, THERMAL, AND HUMIDITY REQUIREMENTS

Using equipment and/or areas with controlled environments, the Instrument Developer will conduct a set of tests and analyses that collectively demonstrate the instrument hardware's compliance with the vacuum, thermal, and humidity requirements defined in the Science Instrument to Spacecraft Interface Requirements Document (Document # **TBD**) and Sections 9.2 of the RLEP MAR. The Instrument Developer program will demonstrate that:

- a. The instrument will perform satisfactorily in the vacuum and thermal environment of space
- b. The instrument's thermal design and the thermal control system will maintain the affected hardware within the established mission thermal limits
- c. The instrument hardware will withstand, as necessary, the temperature and humidity conditions of transportation, storage, and Expendable Launch Vehicle (ELV) launch

9.7 SPACECRAFT/PAYLOAD VERIFICATION DOCUMENTATION

The documentation requirements of Section 9.2 also apply to the spacecraft/payload. Following integration of the instruments onto the spacecraft, the spacecraft System Verification Report will include the instrument information.

10.0 WORKMANSHIP AND ELECTRONIC PACKAGING

10.1 GENERAL

The Instrument Developer will plan and implement an Electronic Packaging and Processes Program to assure that all electronic packaging technologies, processes, and workmanship activities selected and applied meet mission objectives for quality and reliability.

10.2 WORKMANSHIP

The Instrument Developer shall use the following NASA and commercial workmanship standards:

- a. NASA-STD-8739.3 – Soldered Electrical Connections
- b. NASA-STD-8739.4 – Crimping, Interconnecting Cables, Harnesses, and Wiring
- c. NASA-STD-8739.5 – Fiber Optic Terminations, Cable Assemblies, and Installation
- d. ANSI/ESD S20.20 ESD Association Standard for the Development of an Electrostatic Discharge Control Program
- e. NASA-STD-8739.1 – Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Assemblies
- f. NASA-STD-8739.2 – Workmanship Standard for Surface Mount Technology
- g. IPC-2221 – Generic Standard On Printed Board Design
- h. IPC-2222 – Sectional Standard on Rigid PWB Design
- i. IPC-2223 - Sectional Design Standard for Flexible Printed Boards
- j. IPC-6011 – Generic Performance Specification for Printed Boards
- k. IPC-6012 – Qualification and Performance Specification for Rigid Printed Boards (Flight Applications supplemented with: IPC 6012B “Performance Specification Sheet for Space and Military Avionics”)
- l. IPC-6013 – Qualification and Performance Specification for Flexible Printed Boards
- m. IPC-6018 – Microwave End Product Board Inspection and Test
- n. S-312-P-003 – Procurement Spec for Rigid Printed Boards

Alternate workmanship standards may be used when approved by the project. The Instrument Developer must submit, for review and approval, the alternate standard and the differences between the alternate standard and the required standard prior to project approval.

The Instrument Developer must provide printed wiring board coupons and associated test reports in accordance with CDRL 10.1. Coupons and test reports are not required for delivery to the GSFC Project Office if the Instrument Developer has coupons evaluated by a laboratory which has been approved by the GSFC Project Office, in writing before the coupons are released for evaluation. However, the coupons and test reports must be kept by the Instrument Developer for review by GSFC.

10.3 NEW/ADVANCED PACKAGING TECHNOLOGIES

New and/or advanced packaging technologies (e.g., MCMs, stacked memories, chip on board) that have not previously been used in space flight applications must be reviewed and approved through the Parts Control Board (PCB) as defined in Section 12. When appropriate, a detailed Technology Validation Assessment Plan (TVAP) shall be developed for each new technology. A TVAP identifies the evaluations and data necessary for acceptance of the new/advanced technology for reliable use and conformance to project requirements.

New/advanced technologies may be part of the PIL and PAPL defined in Section 12 of this document.

11.0 MATERIALS, PROCESSES, AND LUBRICATION REQUIREMENTS

11.1 GENERAL REQUIREMENTS

The Instrument Developer will implement a comprehensive Materials and Processes Plan (Refer to the CDRL 11.1) beginning at the design stage of the hardware. The Materials and Processes Plan (M&PP) will help ensure the success and safety of the mission by the appropriate selection, processing, inspection, and testing of the materials and lubricants employed to meet the operational requirements for the instrument. Materials and lubrication assurance approval by GSFC is required for each usage or application in space-flight hardware.

11.2 MATERIALS SELECTION REQUIREMENTS

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

11.2.1 Compliant Materials

The Instrument Developer will use compliant materials in the fabrication of flight hardware to the extent practicable.

In order to be compliant, a material must be used in a conventional application and meet the applicable selection criteria as defined herein. A compliant material does not require a MUA.

The following material procedures define what is considered a compliant material. In general, compliant materials and processes are those that meet the following requirements:

Hazardous materials requirements as specified in ASFSCM 91-710, "Range Safety User Requirements Manual". Vacuum outgassing requirements as defined in the respective materials procedure

Stress corrosion cracking requirements as defined in MSFC-STD-3029 "Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments".

Material used in a conventional application for which there is satisfactory aerospace heritage.

Whenever possible, materials and its usage shall be "compliant".

11.2.2 Non-compliant Materials

A material that does not meet the requirements of the applicable selection criteria of Section 11.2.1 or meet the requirements of Section 11.2.1, 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 and/or a Stress Corrosion Evaluation Form or the Instrument Developer's equivalent forms (Refer to CDRLs 11.3 and 11.4) (RLEP MAR Figure 11-1), be submitted to the GSFC Project Office for approval.

11.2.3 Materials Used in "Off-the-Shelf-Hardware"

"Off-the-shelf hardware" for which a detailed materials list is not available and where the included materials cannot be easily identified and/or changed will be treated as non-compliant. The Instrument Developer will define on an MUA (CDRL 11.3), what measures will be used to ensure that all materials in the hardware are acceptable for use. Such measures might include any one or a combination of the following: hermetic sealing, vacuum bake-out, material changes for known non-compliant materials, etc. When a vacuum bake-out is the selected method, it must incorporate a quartz crystal microbalance (QCM) and cold finger to enable a determination of the duration and effectiveness of the bake-out as well as compliance with the satellite contamination plan and error budget.

11.2.4 Conventional Applications

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

11.2.5 Non-conventional Applications

The proposed use of a compliant material for an application for which there is limited satisfactory aerospace usage will be considered a non-conventional application. Under these circumstances, the GSFC Project Office and the Instrument Developer must agree for the Instrument Developer to provide any/all the information required in a Non-Conventional Material and Lubrication Report so that the GSFC Project Office may fully understand the application. In that case, the material usage will be verified for the desired application on the basis of test, similarity, analyses, inspection, existing data, or a combination of those methods.

11.2.6 Polymeric Materials

The Instrument Developer will prepare and submit a polymeric materials and composites usage list or the Instrument Developer's equivalent. (Refer to the CDRL 11.5) (Refer to RLEP MAR Figure 11-3). The list will be submitted to the GSFC Project Office for review and approval. Material acceptability will be determined on the basis of flammability, toxic offgassing, vacuum outgassing and all other materials properties relative to the application requirements and usage environment.

11.2.7 Flammability and Toxic Offgassing

Material flammability and toxic offgassing will be determined in accordance with the test methods described in NASA-STD-6001. ELV payload materials will meet the requirements of AFSCM 91-710 "Range Safety User Requirements Manual".

11.2.8 Vacuum Outgassing

Material vacuum outgassing will be determined in accordance with ASTM E-595. In general, a material is qualified on a product-by-product basis. However, the GSFC Project Office may require lot testing of any material for which lot variation is suspected. In such cases, material approval is contingent upon lot testing. Only materials that have a total mass loss (TML) less than 1.00% and a collected volatile condensable mass (CVCM) less than 0.10% will be approved for use in a vacuum environment unless application considerations listed on a MUA (DID 11.3) dictate otherwise. (The overall mission contamination control requirements may demand more stringent outgassing criteria.)

11.2.9 Shelf-Life-Controlled Materials

Polymeric materials that have a limited shelf-life may be controlled by a process that identifies the start date (manufacturer's processing, shipment date, or date of receipt, etc.), the storage conditions associated with a specified shelf-life, and expiration date. Materials such as o-rings, rubber seals, tape, uncured polymers, lubricated bearings and paints will be included. The use of materials whose date code has expired requires that the Instrument Developer demonstrate, by means of appropriate tests, that the properties of the materials have not been compromised for their intended use. Such materials may be approved by GSFC by means of a waiver. (CDRL 11.8.) When a limited-life piece part is installed in a subassembly, its usage must be approved by GSFC. This may be accomplished by including the subassembly item in the Limited-Life List. (CDRL 4.9)

11.3 INORGANIC MATERIALS

The Instrument Developer will prepare and document an inorganic materials and composites usage list (RLEP MAR Figure 11.4) or the Instrument Developer's equivalent. (Refer to the CDRL 11.9) The list will be submitted to the GSFC Project Office for review and approval. The criteria specified in MSFC-STD-3029 will be used to determine that metallic materials meet the stress corrosion cracking criteria. An MUA (Refer to CDRL 11.3) will be submitted for each material usage that does not comply with the MSFC-STD-3029 Stress Corrosion Cracking requirements.

Additionally, for the GSFC Project Office to approve usage of individual materials, a stress corrosion evaluation form (CDRL 11.4), as discussed in Section 11.2.1 and .2, or any/all of the information contained in the stress corrosion evaluation form shall be required by GSFC from the Instrument Developer.

11.3.1 Fasteners

The Instrument Developer will 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. To document this process, the Instrument Developer shall prepare a Fastener Control Plan for submission to the GSFC Project Office. (CDRL 11.10) Additionally, it is recommended that material test reports for fastener lots be submitted to the GSFC Project Office 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 will be applied by a process that is not embrittling to the steel.

Pure tin plating is not permitted on any spaceflight hardware or EEE part.

11.4 LUBRICATION

The Instrument Developer will prepare and document a lubrication usage list (RLEP MAR Figure 11.5) or the Instrument Developer's equivalent. (Refer to the CDRL 11.11) The list shall be submitted to the GSFC Project Office for approval. The Instrument Developer may be requested to submit supporting applications data.

Lubricants will 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.

Lubricated mechanisms shall be qualified by life testing (CDRL 11.12) or heritage of an identical mechanism used in identical applications. If performed, evidence of qualification must be provided to the GSFC Project Office.

11.5 PROCESS SELECTION REQUIREMENTS

The Instrument Developer will prepare and document a material process utilization list or the Instrument Developer's equivalent (RLEP MAR Figure 11.6). (Refer to the CDRL 11.13) The list shall be submitted to GSFC for review and approval. Manufacturing processes (e.g., lubrication, heat treatment, welding, chemical or metallic coatings) shall be carefully selected to prevent any unacceptable material property changes that could cause adverse effects of materials applications.

11.6 PROCUREMENT REQUIREMENTS

11.6.1 Purchased Raw Materials

Raw materials purchased by the Instrument Developer must be accompanied by the results of nondestructive, chemical and physical tests, or a Certificate of Compliance. This information need only be provided to the GSFC Project Office when there is a direct question concerning the material's flightworthiness. (CDRL 11.14) However, the Instrument developer must retain this documentation for the life of the project.

11.6.2 Raw Materials Used in Purchased Products

The Instrument Developer will require that their suppliers meet the requirements of Section 11.6.1 of this document and provide, upon request, the results of acceptance tests and analyses performed on raw materials.

12.0 EEE PARTS REQUIREMENTS

12.1 GENERAL

The Instrument Developer will 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. This guide establishes the minimal requirements of the LRO Program standard parts baseline and is based on requirements specified in GSFC-EEE-INST-002, "Instructions for EEE Parts Selection, Screening, Qualification, and Derating", Level 2.

The minimum acceptable EEE part grade for EEE parts for this program is level 2 with 100% Particle Impact Noise Detection (PIND) screening for cavity bodied devices. This assumes that the radiation hardness requirements and system reliability goals are also being met.

The Instrument Developer will prepare a Parts Control Plan (PCP) (Refer to CDRL, DID 12.1.) describing the approach and methodology for implementing the Parts Control Program. The PCP will also define the Instrument Developer's criteria for parts selection and approval based on the guidelines of this section.

12.2 ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL PARTS

All part commodities identified in the NPSL <http://nepp.nasa.gov> are considered EEE parts and will be subjected to the requirements set forth in this section. Custom or advanced technology devices such as custom hybrid microcircuits, detectors, Application Specific Integrated Circuits (ASIC), MCM, and magnetics will also be subject to parts control appropriate for the individual technology.

12.3 PARTS CONTROL BOARD

The Instrument Developer will establish a Parts Control Board (PCB) to facilitate the management, selection, standardization, and control of parts and associated documentation for the duration of the project. The PCB will be responsible for the review and approval of all parts for conformance to established criteria, and for developing a PIL and maintaining a PAPL. In addition, the PCB will be responsible for all parts activities such as failure investigations, disposition of non-conformances, and problem resolutions. PCB operating procedures will be included as part of the PCP. The PCB shall include the GSFC Project EEE Parts Engineer as a technical consultant and for part approval. PCB meetings will be held when needed. GSFC parts engineer participation at PCB meetings is required.

12.3.1 PCB Meetings

PCB meetings will be convened as necessary to evaluate acceptance of EEE parts and/or materials in a timely manner to support the Instrument Developer Project schedule. Meetings will be held prior to the procurement of parts and/or materials. At a minimum, the PCB meetings will be convened prior to the PDR to determine the acceptability of EEE parts including those proposed for use by the instrument developer and/or subcontractors, vendors, or collaborators.

Emergency PCB meetings will be convened at the discretion of the PCB chair via telecon or e-mail to meet Project needs and schedules.

The chair will be responsible for the scheduling of PCB meetings and will notify all members, including the GSFC Project Office and the Project EEE Parts Engineer, at least 10 working days prior to each (non-emergency) meeting via telephone or e-mail.

The GSFC Project Office may participate in PCB meetings and will be notified in advance of all upcoming meetings. Meeting minutes or records will be maintained by Instrument Developer to document all decisions made and a copy provided to the GSFC Project Office within three days of convening the meeting. (Refer to the CDRL, DID 12.2.) The GSFC Project Office may elect to overturn decisions involving non-conformances within ten days after receipt of meeting minutes.

12.4 PARTS SELECTION AND PROCESSING

All EEE parts will be selected and processed in accordance with GSFC-EEE-INST-002, Instructions for EEE Parts Selection, Screening, Qualification, and Derating. The Part Quality Level 2 defined in GSFC-EEE-INST-002 will apply to this program.

Parts selected from the NPSL <http://nepp.nasa.gov> are considered Qualified. However, they shall be evaluated for compliance to the radiation and reliability requirement of the Program and must be evaluated by the PCB.

12.4.1 Parts Selection Criteria

Parts for use on the program shall be selected in order of preference as listed in this section. Parts falling into the categories for paragraphs numbered A through I shall be evaluated by the PCB for compliance to the screening requirements of GSFC-EEE-INST-002 and need not be subjected to any additional qualification or Quality Conformance Inspection (QCI) tests. Parts falling into the categories for paragraphs numbered J through L may require additional testing to be in conformance with the requirements of GSFC-EEE-INST-002. All parts must be evaluated for radiation hardness characteristics (Total Ionizing Dose [TID], Single-Event Upset [SEU], and Single-Event Latch-up [SEL]) as per the program requirement. PIND testing shall be performed on all cavity devices.

- a) Parts listed in the NSPL. Parts with flight heritage history shall be reviewed for compliance with GSFC-EEE-INST-002 Level 2 prior to use. Parts will be procured in accordance with the appropriate specification designated for that part.
- b) MIL-M-38510, Class B or better microcircuits procured from a Qualified Products List (QPL) supplier. MIL-M-38510, class B microcircuits do not require lot specific 1000-hour-life test. http://www.dscc.dla.mil/offices/sourcing_and_qualification and http://www.dscc.dla.mil/offices/doc_control.
- c) MIL-PRF-38535, Class Q or better microcircuits procured to Standard Military Drawings (SMDs) from a supplier listed in the Qualified Manufacturer List (QML) at

http://www.dsccl.dla.mil/offices/sourcing_and_qualification and
http://www.dsccl.dla.mil/offices/doc_control.

- d) MIL-PRF-38534, Class H or better hybrid microcircuits procured from a supplier listed in the QML.
- e) Microcircuits compliant with Paragraph 1.2.1 of MIL-STD-883 and procured from manufacturers having QPL or QML status for parts of the same technology. Parts procured from manufacturers without QPL or QML status shall be procured with pre-cap visual or Destructive Physical Analysis (DPA) in addition to lot-specific or generic Group C QCI data that is within one (1) year of the lot date code of the parts being procured. If Group C testing is not available, 1000 hours of life testing on 22 samples will be performed.
- f) Manufacturer's in-house reliability-processed parts provided all screening tests listed in GSFC-EEE-INST-002 for a Quality Level 2 part has been satisfied. The high-reliability process flow shall be formally documented by the manufacturer in cases in which changes would require a revision to the flow documentation. Tests not included in the manufacturer's reliability flow must be performed at an independent test facility or at GSFC. Parts shall be procured following this guideline with lot-specific or generic Group C QCI data and shall be approved by the PCB.
- g) MIL-PRF-19500, JANTX, JANTXV, and JANS semiconductors procured from a QPL-listed supplier and screened per GSFC-EEE-INST-002. The DPA requirements on JANTXV level parts will be evaluated by the PCB on a case-by-case basis. A DPA on JANTX level devices shall be performed.
- h) Established Reliability (EREL) passive components procured from a QPL-listed supplier for the appropriate military specification. Part failure rates should be in accordance to the guidelines in GSFC-EEE-INST-002 for Quality Level 2 parts.
- i) Parts previously approved by GSFC on previous flight missions for a system similar to the one being procured will be evaluated by the PCB for continued compliance to the project requirements. This will be accomplished by determining that:
 - 1) No changes have been made to the previously approved, Source Control Drawing (SCD), vendor list, or processes.
 - 2) The previous project's parts quality level is identical to the LRO Project.
 - 3) Parts have undergone effective screening.
- j) Any parts not meeting the criteria specified in paragraphs numbered A through I of this section shall be screened in accordance with the screening requirement specified in GSFC-EEE-INST-002, Quality Level 2 for each commodity. Changes in form, fit, function, reliability, or manufacturer shall be cause to require improving the screening to meet the screening requirement of GSFC-EEE-INST-002, Quality Level 2, for each appropriate commodity.
- k) Plastic Encapsulated Microcircuits (PEMs) and commercial parts should be the exception rather than the rule. If a part is available in a hermetic package and plastic package, the hermetic package will be used. The PCB will approve all PEMs. Screening and Qualification requirements shall be in accordance with GSFC-EEE-INST-002.
- l) Pre-cap inspection at subcontractor, vendor, or collaborator's facilities will be performed as required on hybrid microcircuits (Direct Current [DC]/DC converters) and other complex microcircuits, such as Application-Specific Integrated Circuits (ASICs), MCMs, and 3-D stacks as approved by the PCB. If pre-cap inspection is not performed during screening, DPA will be performed.

GSFC-EEE-INST-002 shall be used as a reference document while preparing Part Specifications and SCDs when required.

12.4.2 Custom Devices

In addition to applicable requirements of 311-INST-002, custom microcircuits, hybrid microcircuits, MCM, ASIC, magnetics, etc. planned for use by the Instrument Developer will be subjected to a design review.

The review may be conducted as part of the PCB activity. The design review will address, at a minimum, derating of elements, method used to assure each element reliability, assembly process and materials, and method for assuring adequate thermal matching of materials.

12.4.2.1 Magnetics

Magnetic devices (e.g., transformers and inductors) shall be assembled and screened to requirements of MIL-STD-981 and MIL-PRF-27 wherever possible or as per source control documents.

12.4.2.2 Capacitors

50-volt (V) ceramic capacitors used in applications < 10V DC will require steady state humidity low-voltage testing on 12 samples in accordance with MIL-PRF-123. Tantalum Capacitors shall require 100 percent surge current testing in accordance with MIL-PRF-39003/10 for leaded capacitors or MIL-PRF-55365/4 for chip capacitors. NPSL application notes shall be followed.

12.4.2.3 Relays

Relays not subjected to small pore cleaning and internal visual inspection shall require DPA. No relays with pure tin enclosures, headers, or terminal pins will be used.

12.4.3 Derating

All EEE parts will be used in accordance with the derating guidelines of the GSFC-EEE-INST-002. The Instrument Developer will maintain documentation on parts derating analysis and will make it available for GSFC Project Office review.

12.4.4 Parts Stress Analysis

Each application of EEE parts will be subjected to stress analyses for conformance with the applicable derating guidelines as specified in EEE-INST-001. The analyses will 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. The analyses will be performed in close coordination with the packaging reviews and thermal analyses and they will be required input data for component-level design reviews. The analyses with summary sheets and updates will be maintained at the developer's facility for the Government to review/audit. (Refer to the CDRL, DID 12.3.) The results of the analyses will be presented at all design reviews starting with a preliminary report at the PDR. The presentations will include comments on how the

analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

12.4.5 Radiation Hardness

All parts will be selected to meet their intended application in the predicted mission radiation environment. The radiation environment consists of two separate effects, those of total ionizing dose and single-event effects. The Instrument Developer will document the analysis for each part with respect to both effects.

12.4.6 Verification Testing

Verification of screening or qualification tests by re-testing is not required unless deemed necessary as indicated by failure history, GIDEP Alerts, or other reliability concerns. If required, testing will be in accordance with GSFC-EEE-INST-002 as determined by the PCB. The Instrument Developer, however, will be responsible for the performance of supplier audits, surveys, source inspections, witnessing of tests, and/or data review to verify conformance to established requirements.

12.4.7 Destructive Physical Analysis

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

12.4.8 Failure Analysis

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

12.4.9 Parts Age Control

Parts drawn from controlled storage after 5 years from the date of the last full screen must be subjected to a full 100 percent re-screen and sample DPA as decided by the PCB. Alternative test plans may be used as determined and approved by the PCB on a case-by case basis. Parts over 10 years from the date of the last full screen or stored in other than controlled conditions where they are exposed to the elements or sources of contamination shall not be used.

12.5 PARTS LISTS

The Instrument Developer will create and maintain a PIL which becomes the PAPL after approval by the PCB for the duration of the project. All parts must be approved before initiation of flight procurement activity. The PAPL will be converted to an ABPL and will be submitted to GSFC as a final ABPL. (Refer to the CDRL, DID 12.4.)

12.5.1 Parts Traceability Control

Traceability records for all parts from incoming inspection through board installation will be maintained. Parts replacement control traceability shall also be tracked for all parts replaced. Records of all flight parts, including all part failures from the unit level acceptance testing and all destructive test samples, shall be kept on file for the life of the program and part lists shall be updated.

12.6 PARTS REUSE

EEE parts, which have been installed in an assembly, and removed for any reason, shall not be used again in flight hardware, unless removal, retest, and reinstallation procedures have been approved by the PCB.

12.7 ALERTS

The Instrument Developer PCB will be responsible for the review and disposition of GIDEP Alerts for applicability to the parts proposed for use or incorporated into the design. In addition, any NASA Alerts and Advisories provided to the Instrument Developer by GSFC will be reviewed and dispositioned. Alert applicability, impact, and corrective actions will be documented and reported to the GSFC Project Office with the monthly management or quality assurance report. Additionally, when appropriate, the Instrument Developer will prepare, or assist GSFC personnel in preparing Alerts. (CDRL, DID 12.5) A GIDEP/ALERT matrix will be developed and maintained by the Instrument Developer (RLEP MAR section 14) (CDRL 12.6).

13.0 CONTAMINATION CONTROL REQUIREMENTS

13.1 GENERAL

The Instrument Developer will plan and implement a contamination control program applicable to the hardware. The program will establish the specific cleanliness requirements and delineate the approaches in a Contamination Control Plan (CCP). (Refer to the CDRL 13.1)

13.2 CONTAMINATION CONTROL PLAN

The Instrument Developer will prepare a CCP that describes the procedures and controls that will be followed to control contamination. The CCP will define a contamination allowance for performance degradation of contamination sensitive hardware such that, even in the degraded state, the hardware will meet its mission objectives. The CCP will establish the implementation and describe the methods that will be used to measure and maintain the levels of cleanliness required during each of the various phases of the hardware's lifetime. In general, all mission hardware should be compatible with the most contamination-sensitive components.

Performance Assurance personnel will monitor the fabrication, assembly and testing activities for compliance with the CCP. Out of tolerance conditions will result in a request for corrective action to responsible personnel and be processed per the developer's nonconformance corrective action reporting system as outlined in their quality manual.

13.3 MATERIAL OUTGASSING

All materials shall be screened in accordance with NASA Reference Publication 1124, Outgassing Data for Selecting Spacecraft Materials. Individual material outgassing data will be established based on hardware's operating conditions and reviewed by GSFC.

13.4 THERMAL VACUUM BAKEOUT

The Instrument Developer will determine the need to perform thermal vacuum bakeouts of flight hardware. If performed, the parameters of such bakeouts (e.g., temperature, duration, and pressure) must be individualized depending on materials used, the fabrication environment, and the established contamination allowance.

13.5 HARDWARE HANDLING

The Instrument Developer 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 addressed.

13.6 MATERIAL PRECAUTIONS

Aerospace experience has demonstrated the need for an advisory on the procurement and use of Kapton tapes in electrostatic discharge (ESD) controlled areas. Unless specified on procurements and tested for conformance, Kapton tape adhesive can be manufactured with either acrylic or silicone in nature. The silicone adhesive has proven to contaminate sensitive spaceflight hardware and therefore must not be used on any aerospace system. Only acrylic adhesive is approved for spaceflight hardware.

14.0 ELECTROSTATIC DISCHARGE CONTROL

14.1 GENERAL

The instrument developer will establish and maintain an ESD program that complies with 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).

Documentation of compliance with ESD controls during electronic hardware fabrication (including daily recording of wrist strap usage) will be maintained and audited by quality assurance. Continuous ESD monitoring devices are preferred while handling flight electronics.

Special ESD program requirements shall be defined and controls shall be implemented in accordance with the sensitivity of EEE parts and electronic packaging as applicable.

15.0 END ITEM DATA PACKAGE

The developer will prepare an End Item Data Package (EIDP) that consists of the following documentation which will be submitted at the instrument PSR.

Acceptance testing (as run) procedures and reports including total number of failure free testing

Environmental Testing (as run) reports

Final Assembly Work Order

Material Certification or Analysis Forms

Waivers, Deviations or MUA

As-built EEE parts list

As-built materials list

End Item Inspection report

Nonconformance or problem/failure reports and corrective action summaries

List of Open items or one time occurrences

As-built final assembly drawing

Any pertinent analyses (mechanical, electrical, reliability, stress, thermal, worst case)

As-built configuration list (Item, Manufacturer, Model, etc)

Certificate of Compliance signed by management

**APPENDIX A. CONTRACT DELIVERABLE REQUIREMENTS LIST (CDRL) AND
DATA ITEM DESCRIPTION (DID)**

CDRL Number	Name of Document	Delivery to GSFC
1.1	Heritage Hardware Matrix or Report	<ul style="list-style-type: none"> • 30 days prior to PDR. Updates as Developed. • Final due 0020 to GSFC 45 days prior to CDR.
2.1	Quality Manual	60 days after contract award
2.2	Problem Failure Reports (PFRs)	Within 24 hours of occurrence
2.3	Subcontractor Assurance Verification Matrix	Initial maintained throughout system fabrication. Final due 30 days prior to PSR
3.1	System Safety Program Plan	At first program review
3.2	Safety Requirements Compliance Checklist	With each submittal of the SAR
3.3	Preliminary Hazard Analysis (PHA)	30 days prior to PDR
3.4	Operations Hazard Analysis	<ul style="list-style-type: none"> • Preliminary 45 days prior to shipping to GSFC • Final 15 days prior to shipping to GSFC
3.5	Safety Assessment Report (SAR)	<ul style="list-style-type: none"> • Preliminary 30 days after Instrument PDR, • Update 30 days prior to Instrument CDR, • Final 30 days prior to instrument delivery
3.6	MSPSP	N/A
3.7	OHA VTL	With OHA
3.8	Ground Operations Procedures	At Launch Range: <ul style="list-style-type: none"> • 60 days prior to PSR, • Final submit to Range 45 days prior to use At GSFC: <ul style="list-style-type: none"> • 7 days prior to first operational use
3-9	Safety Variances	As required
3-10	Inputs to ODA	As requested
4.9	Limited-Life Items List	<ul style="list-style-type: none"> • Preliminary 30 days before PDR for review. • Final 30 days before CDR for approval. • Updates as changes are made; between CDR and delivery, for approval
5.1	Software Assurance Plan	<ul style="list-style-type: none"> • Initial draft due 90 days after contract award. • Final due no later than requirements phase. • Updated periodically throughout the lifecycle, if necessary.
5.2	Software Management Plan	<ul style="list-style-type: none"> • Initial draft due 90 days after contract award. • Final due no later than requirements phase. • Updated periodically throughout the lifecycle, if necessary.
5.3	Software Configuration Management Plan	<ul style="list-style-type: none"> • Initial draft due 90 days after contract award. • Final due no later than requirements phase. • Updated periodically throughout the lifecycle, if necessary.
5.4	Software Reliability Plan	<ul style="list-style-type: none"> • Initial draft due 90 days after contract award. • Final due no later than requirements phase. • Updated periodically throughout the lifecycle, if necessary.

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CHECK WITH RLEP DATABASE AT:

<https://lunarngin.gsfc.nasa.gov/>

TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.

CDRL Number	Name of Document	Delivery to GSFC
5.5	Software Requirements Specification	<ul style="list-style-type: none"> • Initial draft due upon customer/supplier agreement on software functionality. • Final due no later than the CDR. • Updated periodically throughout the lifecycle, as necessitated by requirement changes.
7.1	Risk Management Plan	<ul style="list-style-type: none"> • Preliminary 30 days before PDR for GSFC review. • Final 30 days before CDR for GSFC review. • Updates as required including changes for GSFC review.
9.1	System Performance Verification Plan	<ul style="list-style-type: none"> • Preliminary at PDR for GSFC review. • Final at CDR for GSFC approval • Updates as required.
9.2	Performance Verification Procedure	30 days prior to test for GSFC approval.
9.3	Verification Reports	<ul style="list-style-type: none"> • Preliminary report 72 hours after test for GSFC information. • Final report 30 days after verification activity for GSFC information • System Performance Verification Report: Preliminary at CDR. • Final report 30 days following on-orbit check out.
10.1	Printed Wiring Board (PWB) Test Coupons	Prior to population of flight PWBs. Applies individually to each procured lot of boards.
11.1	Materials and Processes Control Program Plan.	The MPCP shall be developed and delivered as part of the proposal for GSFC review. Final is due 90 days after contract award.
11.2	As-Designed Materials, and Processes List	The ADMPL shall be submitted to the RLEP 30 days prior to the PDR.
11.3	Materials Usage Agreement (MUA)	Provide to the MAE, with the polymeric and composite materials usage list, flammable materials usage list, odor and toxic offgassing materials usage list or the inorganic materials usage list for approval.
11.4	Stress Corrosion Evaluation Form	Provide to GSFC MAE for review. Initial at PDR final due 45 days prior to CDR.
11.5	Polymeric Materials and Composites Usage List	<ul style="list-style-type: none"> • Provide to the GSFC Project Office 30 days before developer PDR for review • 30 days before developer CDR for approval • 30 days before acceptance for approval.
11.8	Materials Waiver	Provide to the GSFC Project Office for approval 30 days prior to the CDR or use
11.9	Inorganic Materials and Composites Usage List	<ul style="list-style-type: none"> • Provide to the GSFC Project Office 30 days before developer PDR for review • 30 days before developer CDR for approval • 30 days before acceptance for approval.
11.10	Fastener Control Plan	Provide with proposal for GSFC review and 30 days before the PDR for approval.
11.11	Lubrication Usage List	• Provide to the GSFC Project Office 30 days before developer

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CDRL Number	Name of Document	Delivery to GSFC
		<p>PDR for review</p> <ul style="list-style-type: none"> • 30 days before developer CDR for approval • 30 days before acceptance for approval.
11.12	Life Test Plan for Lubricated Mechanisms	<ul style="list-style-type: none"> • Provide to the GSFC Project Office 30 days before developer PDR for review • 30 days before developer CDR for approval • 30 days before acceptance for approval.
11.13	Material Process Utilization List	<ul style="list-style-type: none"> • Provide to the GSFC Project Office • 30 days before developer PDR for review • 30 days before developer CDR for approval • 30 days before acceptance for approval.
11.14	Certificate of Raw Material Compliance	Provide to the GSFC Project 15 days after request.
12.1	EEE Parts Control Plan (PCP)	The PCP will be developed and delivered for GSFC review with, or incorporated into, the developer's Assurance Implementation Plan. It will be delivered for GSFC approval. Any subsequent revisions must be delivered to GSFC for approval.
12.2	Parts Control Board (PCB) Reports	PCB reports will be submitted to GSFC for review within five workdays after each PCB meeting.
12.3	Parts Stress Analysis	The analysis is due 30 work days before CDR for GSFC review at the developer's facility. Updates as required, with any changes clearly indicated, are to be available at the developer's site for GSFC review.
12.4	Parts Identification List (PIL)	The initial parts list delivery will be due to GSFC for approval 30 days prior to the PDR. Subsequent revisions (with all changes clearly noted on a hard copy) will be delivered to GSFC in a timely manner for approval with an updated revision due 30 days prior to the CDR and as mandated by list changes.. The As-Built Parts List (ABPL) will be developed from this document/database and will be submitted to GSFC for review 60 days prior to delivery of the end item.
12.5	Alert / Advisory Disposition Preparation	<p>Respond to GSFC within 25 calendar days of receipt of Alert/Advisory. Alert/advisory impacts, if any, should be discussed at technical reviews and PCB meetings. This information will be provided for GSFC information; however, GSFC must concur with the developer that all flight hardware is flight worthy.</p> <p>Developer-prepared alerts/advisories will be prepared within 60 days in coordination with GSFC, as needed.</p>
12.6	GIDEP Matrix	Provide updated matrix with monthly management reports to GSFC
13.1	Contamination Control Plan	<ul style="list-style-type: none"> • Provide to the Project Office 30 days before PDR for GSFC review

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CDRL Number	Name of Document	Delivery to GSFC
		<ul style="list-style-type: none">• Provide to the Project Office 30 days before the CDR for approval.

APPENDIX B. ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	DEFINITION
ABPL	As-Built Parts List
ABML	As-Built Materials List
AR	Acceptance Review
ASIC	Application Specific Integrated Circuits
CCP	Contamination Control Plan
CDR	Critical Design Review
CDRL	Contract Delivery Requirements List
CIL	Critical Items List
CVCM	Collected Volatile Condensable Mass
DID	Data Item Descriptions
DPA	Destructive Physical Analysis
EEE	Electrical, Electronic, and Electromechanical
ELV	Expendable Launch Vehicle
ER	Eastern Range
EREL	Established Reliability
ESD	Electrostatic Discharge
ETM	Environmental Test Matrix
FCA	Functional Configuration Audit
FMEA	Failure Modes and Effects Analysis
FOR	Flight Operations Review
FRB	Failure Review Board
FTA	Fault Tree Analysis
GEVS-SE	General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components
GFE	Government-furnished Equipment
GIA	Government Inspection Agency
GIDEP	Government Industry Data Exchange Program
GSFC	Goddard Space Flight Center
I&T	Integration and Test
IAC	Independent Assurance Contractor
ICD	Interface Control Document
IRD	Interface Requirements Document
KSC	Kennedy Space Center
LRO	Lunar Reconnaissance Orbiter
LRR	Launch Readiness Review
M&PP	Materials and Processes Plan
MAE	Materials Assurance Engineer
MAR	Mission Assurance Requirements
MCM	Multi-Chip Module
MOC	Mission Operations Center

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Abbreviation/ Acronym	DEFINITION
MOR	Mission Operations Review
MRB	Material Review Board
MSPSP	Missile System Prelaunch Safety Package
MUA	Materials Usage Agreement
NPSL	NASA Parts Selection List
NSPAR	Nonstandard Parts Approval Request
OHA	Operations Hazard Analysis
OSSMA	Office of Systems Safety and Mission Assurance
PAIP	Performance Assurance Implementation Plan
PAPL	Project Approved Parts List
PCA	Physical Configuration Audit
PCB	Parts Control Board
PCP	Parts Control Plan
PDR	Preliminary Design Review
PEM	Plastic Encapsulated Microcircuit
PER	Pre-Environmental Review
PFR	Problem Failure Report
PI	Principal Investigator
PIL	Parts Identification List
PIND	Particle Impact Noise Detection
PRA	Probabilistic Risk Assessment
PSAM	Performance and Safety Assurance Manager
PSM	Project Safety Manager
PSR	Pre-Shipment Review
PWB	Printed Wiring Board
QCI	Quality Conformance Inspection
QCM	Quartz Crystal Microbalance
QML	Qualified Manufacturer List
QMS	Quality Management System
QPL	Qualified Products List
RF	Radio Frequency
RFA	Request for Action
RLEP	Robotic Lunar Exploration Program
RP	Reference Publication
RPP	Reliability Program Plan
SAR	Safety Assessment Report
SCD	Source Control Drawing
SCM	Software Configuration Management
SEL	Single Event Latch-up
SEU	Single Event Upset
SMD	Standard Military Drawing

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Abbreviation/ Acronym	DEFINITION
SQMS	Software Quality Management System
SRO	Systems Review Office
SRP	System Review Program
SRR	Software Requirements Review
SRT	System Review Team
SSPP	System Safety Program Plan
STS	Space Transportation System
TBD	To be determined
TID	Total Ionizing Dose
TRR	Test Readiness Review
TVAP	Technology Validation Assessment Plan
WR	Western Range