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CRaTER Performance Assurance Implementation Plan

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Revision F

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Prepared by:
Brian Klatt
CRaTER Mission Assurance Manager

Reviewed by:

Rick Foster
CRaTER Program Manager

Arlin Bartels
NASA LRO Instruments Manager

Concurrence by:

Brian Klatt
MIT Mission Assurance Manager

Deborah J Salvaggio
Aerospace Program Manager

Approved by:

Ron Kolecki
NASA LRO Mission Assurance Manager

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1.0 Overall Implementation

1.1 Description

The Mission Assurance Requirements for CRaTER will be implemented in accordance with this Performance Assurance Implementation Plan (PAIP). The CRaTER PAIP describes the Mission Assurance tasks under the responsibility of Boston University Center for Space Physics (BU/CSP). When this PAIP is approved by GSFC, it shall take precedence over the LRO Mission Assurance Requirements (MAR) (431-RQMT-000174). This PAIP applies to BU/CSP, Massachusetts Institute of Technology, Kavli Institute for Astrophysics and Space Research (MKI), the Aerospace Corporation (AERO), and their sub-contractors.

1.2 Assurance Management Organization

Responsibility for the application of this PAIP rests with the CRaTER Project members and, ultimately, the CRaTER Project Manager and Principal Investigator. Responsibility for the management of Mission Assurance and Safety activities described in the PAIP rests with the CRaTER Mission Assurance Manager (MAM).

The primary responsibility of the MAM is to ensure that products produced by The CRaTER Project and intended for design qualification, flight and critical ground support equipment usage meet the required levels of quality and functionality for their intended purposes. The MAM will be delegated the authority to accomplish the following:

- *Establish and implement quality & safety assurance requirements*
- *Perform internal, partner, and supplier technical risk assessment, process assessment and product evaluation*
- *Assist the CRaTER Project in tailoring the hardware development processes*
- *Review and/or approve technical documents related to hardware, including equipment specifications, procurement, assembly procedures, test procedures and payload integration procedures*
- *Oversee and assess the operations of critical suppliers who supply flight hardware*
- *Assist in metrics definition and assure that the development team is following the defined processes*
- *Assure the identification, implementation, and verification of safety-critical components are performed*
 - *Document and communicate quality status/problems and recommend preventative/corrective action.*

1.3 Use of Heritage 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, CRaTER will demonstrate with documentation and/or analysis, how the hardware complies with requirements prior to being relieved from performing any tasks. CRaTER does not anticipate the use of heritage hardware.

1.4 Oversight

The work activities, operations, and documentation performed by the CRaTER Project or their suppliers are subject to evaluation, review, audit, and inspection by government-designated representatives from the 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 CRaTER Project, upon request, will provide government assurance representatives with documents, records, and equipment required to perform their assurance and safety activities. The CRaTER Project will also provide the government assurance representative(s) with an acceptable work area.

1.5 Acronyms

The definitions of acronyms included in this PAIP are listed at the end of the PAIP.

1.6 Contract Delivery Requirements List (CDRL)

Deliverable Mission Assurance items identified in this plan will be provided to the GSFC Project Office by the responsible CRaTER Project personnel as scheduled in the Contract Data Requirements List (CDRL) contained in the phase C/D/E Statement of Work (SOW). The MAM will provide review comments or approval/disapproval recommendations as appropriate to The CRaTER Project Manager on all assurance deliverables received for project review or approval.

1.7 Requirement Documents

CRaTER prepared requirements documents such as this PAIP will be delivered electronically to the GSFC Project Office as required. In addition, such documents will be resident and available on the MIT server at <http://snebulos.mit.edu/projects/crater/>

2.0 Quality Assurance Requirements

2.1 General

The CRaTER Project will implement a Quality Management System (QMS) that is based on the intent of ISO 9001 that properly encompasses the CRaTER's flight hardware. Internal procedures, practices, and this PAIP form the foundation of the entire Mission Assurance System. Examples of these are 99-02001, Inspection and Documentation, 99-02004, Nonconforming Material and Nonconforming Material Reports, 99-02003, Calibration for Measuring/Testing Equipment, 99-02005, Audit System, 99-02006, Receiving Inspection, 99-03001, Fabrication Documentation, 64-02017.2009, Safe Handling of Flight Hardware, and 64-02017.2010, Control of Metallic Raw materials,

2.2 Augmentation

CRaTER's QA program will ensure flow-down of all Quality Assurance requirements to all major and critical suppliers who supply flight hardware, and will verify compliance to those requirements.

All subassembly and assembly failures will be investigated per the Failure Reporting and Corrective Action System (FRACAS). FRACAS is designed to perform root-cause failure analysis and prevent recurrence of the observed failure mode.

The reporting of failures will begin with the first power application or the first operation of a mechanical item after the flight assembly or flight item has started acceptance or qualification testing, and the failure has been confirmed. It will continue through formal acceptance by the GSFC Project Office.

Failures will be reported to the GSFC Project Office within 24 hours of occurrence (initial report). The final failure documentation provided to GSFC will include existing Material Review Board (MRB)/Failure Review Board (FRB) applicable documentation.

3.0 System Safety

3.1 General

CRaTER will implement the system safety program, as defined in paragraph 3.2.1 below, for flight hardware, ground support equipment (GSE), and support facilities. The system safety program starts in the design phase and continues throughout all phases of the mission. The system safety program will accomplish the following:

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, fabrication, test, handling, storage, transportation and prelaunch activities. The program will address hazards in the flight hardware, ground support equipment, operations, and support facilities, and will conform to the safety review process requirements of NASA.

Support the system safety requirements of AFSPC 91-710, "Range User Requirements Manual".

Meet the baseline industrial safety requirements of Boston University, MIT, or Aerospace Corporation, as applicable, and meet applicable Industry Standards to the extent practical to meet NASA, and OSHA requirements. This is documented in the applicable institution's Facility Health and Safety Plan.

Specific safety requirements include the following:

If a system failure may lead to a catastrophic hazard, the system will 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 will 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.

3.2 System Safety Deliverables

3.2.1 *System Safety Program Plan*

Paragraphs 3.1 through 3.12 of this PAIP is the CRaTER System Safety Program Plan. It describes 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.

3.2.2 *Safety Analyses*

CRATER and GSFC Code 302 will jointly tailor safety analysis requirements with the Range based on the complexity of the instrument.

3.2.3 *Preliminary Hazard Analysis*

The CRaTER Project will 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 CRaTER Project will perform and document a PHA to obtain an initial risk assessment of flight hardware and non-deliverable GSE (there is no deliverable GSE). Based on the best available data,

including lessons learned, hazards associated with the proposed design or function will be evaluated for hazard severity, hazard probability, and operational constraint. Safety provisions and alternatives needed to eliminate hazards or reduce their associated risk to a level acceptable to Range Safety will be included.

3.2.4 System Hazard Analysis

The CRaTER Instrument PHA is an input to the Lunar Reconnaissance Orbiter (LRO) System Hazard Analysis. CRATER will support GSFC on the System Hazard Analysis relative to the CRaTER Project Instrument Hazards Analysis.

3.2.5 Operations Hazards Analyses (OHA)

CRaTER Instrument Hazard Analysis is an input to the Operations Hazard Analysis. CRaTER Instrument integration is performed by GSFC. The CRaTER Project will support GSFC in preparation of an Operations Hazard Analysis (OHA) that describes the hardware and test equipment operations. The OHA will 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.

3.2.6 Operating and Support Hazard Analysis

N/A

3.2.7 Software Safety

CRaTER does not have any flight software nor does it provide software for the spacecraft on-board computer. In addition, the CRaTER Project will not be providing any software for the GSFC I&T System. Therefore, this document is not applicable.

3.2.8 Safety Compliance Checklist

CRaTER makes no inputs directly to the Launch Range. All inputs for range safety are made by GSFC. CRaTER will provide inputs to GSFC for the Safety Compliance Checklist.

3.3 Safety Assessment Report

The CRaTER Project will perform and document an evaluation of the mishap risk of the instrument. This report may be used by the spacecraft developer in preparing the Missile System Prelaunch Safety Package (MSPSP) for submittal to the launch range. This safety assessment report will identify all safety features of the hardware and system design, as well as procedural related hazards present in the instrument.

It will include:

- *Safety criteria and methodology used to classify and rank hazards*
- *Results of hazard analyses*
- *Hazard reports*
- *List of hazardous materials in the instrument*
- *Conclusion and Recommendations*

3.4 Missile System Prelaunch Safety Package

The CRaTER Project will provide any necessary data requested by GSFC to produce their Missile System Safety Package. CRaTER will be launched power off and it is expected that minimal information beyond the previously mentioned safety related inputs would be required.

3.5 Safety Verification Tracking Log

The CRaTER Project will provide inputs to GSFC on hazards and safety items for the Safety Verification Tracking Log.

3.6 Ground Operations Procedures

The CRaTER Project will submit all ground operations procedures to be used at GSFC facilities, other integration facilities, or the launch site. Any hazardous operations, as well as the procedures to control them will be identified and highlighted. Any launch site procedures will comply with the launch site and NASA safety regulations.

3.7 Safety Variance

When a specific safety requirement cannot be met, the CRaTER Project will submit an associated safety variance that identifies the hazard and shows the rationale for approval of a variance. The following definitions apply to the safety variance approval policy:

- *Variance: Documented and approved permission to perform some act or operation contrary to established requirements.*
- *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.*
- *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, and the duration of the variance.

3.8 Support for Safety Meetings

Technical support will 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.

3.9 Orbital Debris Assessment

The CRaTER Project will supply the information required to support development of the Orbital Debris Assessment, for Limiting Orbital Debris Generation. Design and safety activities will 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 CRaTER Project will provide manpower requirements necessary for safety support of all operations at the launch site that relate to the CRaTER instrument.

3.11 Mishap Reporting and Investigation

Any mishaps, incidents, hazards, and close calls will be reported to NASA-GSFC.

3.12 Miscellaneous Submittals for Range Use

The Materials Identification and Utilization List (MIUL) will detail all Plastics, Films, Foams, and Adhesive Tapes. Similarly, the Hazard Analysis Report Form will identify all ionizing radiation sources and handling procedures. GSFC may submit these documents to the Range as necessary. CRaTER Project personnel will not be taking any hardware or materials to the range. Therefore, submittal of a Process Waste Questionnaire (PWQ) is not applicable.

4.0 **Reliability Requirements**

4.1 **General**

The CRaTER Project will implement a reliability program that interacts effectively with other project disciplines, including systems engineering, hardware design, and product assurance. Section 4.1 through section 4.3 of this PAIP is the CRaTER Reliability Program Plan. The program will be tailored according to the risk level to:

- *Demonstrate that the stress applied to parts is not excessive.*
- *Identify single failure items/points and their effect in the Failure Modes and Effects Analysis (FMEA) and attainment of mission objectives,*
- *Perform an Instrument Reliability Assessment by producing a reliability prediction and calculating the probability of Mission Success (P_s).*
- *Identify limited shelf life items and ensure that expired shelf life materials are not used.*

4.2 **Reliability Analysis**

Reliability analyses will be performed concurrently with the instrument's design so that identified problem areas can be addressed and corrective action taken in a timely manner. Probabilistic Risk Assessment (PRA) and Fault Tree Analysis (FTA) will be performed by GSFC. CRaTER will provide inputs as requested in support these Reliability Analyses.

4.2.1 ***Failure Modes and Effects Analysis and Critical Items List***

A Failure Modes and Effects Analysis (FMEA) will be performed to identify system design problems.

Failure modes will be assessed at the component interface level. This is the interface between the CRaTER Instrument and the Spacecraft. Each failure mode will be assessed for the effect at that level of analysis. The failure mode will be assigned a severity category based on the most severe effect caused by a failure.

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

Table 4-1 Category Severity Definition

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

4.2.2 *Parts Stress Analyses*

All EEE parts will undergo part stress analysis to insure that the part is not overstressed and that the application meets the derating requirements. Derating requirements are taken from EEE-INST-002.

4.2.3 *Reliability Assessments*

The CRaTER Project will perform an Instrument Reliability Assessment by producing a part-count reliability prediction and calculating the probability of Mission Success (P_s).

4.3 *Analysis of test Data*

The CRaTER Project will fully utilize test information during the normal test program to assess flight equipment reliability performance and identify potential or existing problem areas. Parameters to be monitored will be identified and the analysis will be reported to GSFC.

5.0 Software Assurance

CRaTER does not have any flight software nor does it provide software for the spacecraft on-board computer. In addition, the CRaTER Project will not be providing any software for the GSFC I&T System. Therefore, this section is not applicable.

6.0 Ground Data System Requirements

The CRaTER Project 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

The CRaTER Project will identify project-specific risks to anticipate, mitigate and control risks and to focus project resources where they are needed to ensure success of CRaTER. The CRaTER Risk Management Plan is CRaTER document number 32-01202 and is available from the CRaTER engineering web site at <http://snebulos.mit.edu/projects/crater>

8.0 Integrated Independent Review Requirements

8.1 *General*

The CRaTER Project will support a series of comprehensive system-level design reviews that are conducted by the GSFC Systems Review Office (SRO). The reviews will cover all aspects of flight and ground hardware, software, and operations for which The CRaTER Project has responsibility.

8.2 *GSFC System Review Requirements*

8.3 *General*

For each system level review, The CRaTER Project will:

- *Develop and organize material for oral presentation to the Review Team. Copies of the presentation material for GSFC SRO Reviews will be sent to GSFC prior to the review date.*

- *Support splinter review meetings resulting from the major review.*
- *Produce written responses to recommendations and action items resulting from the review.*
- *Summarize, as appropriate, the results of CRaTER Reviews at the component and subsystem level.*

8.4 Formal Reviews

The planned instrument reviews are:

- *Preliminary Design Review (PDR)–The Functional & Performance Requirements Document (F&PRD) and the ICDs will be presented and discussed.*
- *Critical Design Review (CDR)– This review will emphasize implementations of design approaches as well as test plans for flight systems including the results of engineering model testing. CRaTER will present the status of the controls for the safety hazards presented in the PDR.*
- *Mission Operations Review (MOR)– Topics include status of hardware design, fabrication, test and calibration, software development and testing, integration plans, interface status, command and telemetry requirements, environmental testing plans and flight operations planning. The results of Technical Peer Reviews will be included in the CDR.*
- *Pre-Environmental Review (PER)–The CRaTER Project will present test plans for evaluation and to establish the readiness of the system for test.*
- *Pre-Shipment Review (PSR)– The CRaTER Project will present the results of the environmental testing, compliance with the F&PRD and ICDs, and the completeness of the End Item Data Package (EIDP). Status and closure of pre-delivery problem/failure reports will also be presented.*
- *Flight Operations Review (FOR)– The CRaTER Project will present hardware and facility readiness, a walk-through of uplink planning and the downlink analysis process, and a review of the data analysis software.*
- *Peer Reviews. The CRaTER Project will conduct Peer Reviews as detailed in the Crater Configuration Management and Review Process document, 32-01201*

9.0 Design Verification Requirements

9.1 General

The CRaTER Project will develop a system performance verification program documenting the overall verification plan, implementation, and results. This will ensure that the instrument meets the specified mission requirements, and 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 flight hardware will undergo qualification and/or acceptance testing in accordance with the verification requirements.

The Verification Program begins with functional testing of sub-assemblies; it continues through functional and environmental testing, acceptance testing, and concludes with end-to-end testing of the entire CRaTER instrument.

The General Environmental Verification Standard (GEVS), GSFC-STD-7000 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 Verification Documentation

The following documentation requirements will be delivered and approved in accordance with the Contract Deliverables Requirements List (CDRL) contained in the Statement of Work.

9.2.1 *Performance and Environmental Verification Plan*

A CRaTER Instrument performance and environmental verification plan will be prepared defining the tasks and methods required to determine the ability of the instrument to meet each project-level performance and environmental requirement (structural, thermal, electrical, 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 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 will address ground support equipment used in performance and environmental testing, as well as test data reduction (analysis, software and data product). Any requirements verification being deferred to orbiter level of assembly will be justified.

9.2.2 *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, and applicable procedure references.

9.2.3 *Environmental Test Matrix (ETM)*

An environmental test matrix will be prepared that summarizes all tests that will be performed on each instrument. All flight hardware, and flight 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.

Records will be kept showing the tests that have been performed on each subsystem and instrument including procured articles for flight. This will include tests performed on prototypes or engineering units used in the qualification program, and will indicate test results (pass/fail or malfunctions).

9.2.4 *Verification Procedures*

The CRaTER Project will prepare test procedures for each verification test activity conducted at the instrument level that describes the configuration of the test item.

Test procedures will contain details such as instrumentation monitoring, test parameters, pass/fail criteria, quality control checkpoints, and reporting requirements. Blank data sheets will be included in the test procedures providing test and data documentation each time a test is performed. The procedures also will address safety and contamination control provisions.

9.2.5 Instrument Verification Reports

By the very nature of the CRaTER test procedures, a test report is prepared each time a test is performed. For each analysis activity, a 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 Verification Reports will be developed and maintained “real-time” throughout the program summarizing the successful completion of verification activities, and showing that the applicable instrument performance specifications has been acceptably achieved.

At the conclusion of the verification program, a final Instrument Performance Verification Report will be assembled and delivered to GSFC.

Verification requirements will be monitored and tracked as a check-off of the verification matrix.

9.3 Structural and Mechanical Requirements

The CRaTER Project will demonstrate compliance with the structural and mechanical requirements 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 CRaTER Project will ensure through discussions/reviews with the LRO 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 CRaTER Project 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.

9.4 Electromagnetic Compatibility (EMC) Requirements

The electromagnetic characteristics of hardware will be designed so that:

- *The instrument and its elements do not generate electromagnetic interference 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.*
- *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.*

9.5 Vacuum, Thermal and Humidity Requirements

Using equipment and/or areas with controlled environments; the CRaTER Project will conduct a set of tests and analyses that collectively demonstrate the instrument hardware’s compliance with the vacuum, thermal, and humidity requirements. The CRaTER Project will demonstrate that:

- *The instrument will perform satisfactorily in the vacuum and thermal environment of space*
- *The instrument’s thermal sub- system will maintain the affected hardware within the established mission thermal limits*
- *The instrument hardware will withstand, as necessary, the temperature and humidity conditions of test, transportation, storage, and ELV launch*

10.0 Workmanship and Electronic Packaging

10.1 General

The CRaTER Project has workmanship standards in place and procedures that meet the objective of ISO 9001 standards. The CRaTER Project will meet the intent of ISO 9001.

10.2 Workmanship

The CRaTER Project will adhere to the following NASA and commercial workmanship standards:

- *NASA-STD-8739.1 – Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Assemblies*
- *NASA-STD-8739.2 – Workmanship Standard for Surface Mount Technology*
- *NASA-STD-8739.3 – Soldered Electrical Connections*
- *NASA-STD-8739.4 – Crimping, Interconnecting Cables, Harnesses, and Wiring*
- *NASA-STD-8739.7 - Electrostatic Discharge (ESD) Avoidance*
- *IPC-2221 –Generic Standard On Printed Board Design (Class 3, Level A)*
- *IPC-2222 – Sectional Standard on Rigid PWB Design (Class 3, Level A)*
- *IPC-6011 – Generic Performance Specification for Printed Boards (Class 3, Level A)*
- *IPC-6012 – Qualification and Performance Specification for Rigid Printed Boards (Flight Applications supplemented with: IPC-6012B “Performance Specification Sheet for Space and Military Avionics”) Boards (Class 3, Level A)*

The CRaTER Project will insure independent analysis of printed wiring board coupons before boards are populated. Coupons will either be sent to GSFC for analysis or they will be evaluated by a laboratory, which has been approved by GSFC. Coupons and test reports will be available for review by GSFC.

Only trained and certified technicians and inspectors will be used for fabrication of flight hardware and critical GSE.

10.3 New/Advanced Packaging Technology

The CRaTER Project does not anticipate use of any new and/or advanced packaging technologies (e.g., MCMs, stacked memories, chip on board) that have not previously been used in space flight applications. If this event does arise, it will be reviewed and approved through the Parts Control Board (PCB).

11.0 Materials, Processes and Lubrication Requirements

11.1 General

The CRaTER Project will control Materials and Processes beginning at the design stage of the hardware. This will help ensure the success and safety of the mission by the appropriate selection, processing, inspection, and testing of the materials employed to meet the operational requirements for the instrument. . Section 11.1 through section 11.8.2 of this PAIP is the CRaTER Materials and Processes Control Program Plan.

11.2 Material Selection

The CRaTER Project will, when selecting materials, consider potential problem areas such as radiation effects, thermal cycling, galvanic corrosion, hydrogen embrittlement, contamination of cooled surfaces, composite materials, useful life, vacuum outgassing, toxic offgassing, flammability and fracture toughness as well as the properties required by each material usage on CRaTER. Materials subject to stress corrosion cracking will not be used. 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 considered. Most materials selected will be approved materials previously used successfully in space flight hardware. Those exceptions such as the Tissue Equivalent Plastic (TEP) used in the CRaTER Telescope will be tested to establish compliance with CRaTER requirements.

In the event that a material or process does not meet the GSFC space flight requirements, the CRaTER Project will prepare and submit to GSFC, a Materials Usage Agreement (MUA), Materials Waiver, and/or a Stress Corrosion Evaluation Form for approval.

11.3 Shelf-Life-Controlled Materials and Limited Life Items

Limited shelf-life materials are controlled at receiving 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, and paints will be included. Materials whose shelf life has expired will not be used. Items with limited life due to age, cycling, wear, usage, etc. will be documented/listed and submitted to GSFC. CRaTER does not expect to have any Limited Life Items.

11.4 Materials identification and usage list (MIUL)

The CRaTER Project will document all materials and processes used in space flight hardware. This documentation will be maintained and submitted prior to CDR, as the Materials Identification and Usage List (MIUL). An update of the MIUL will be prepared and submitted as the As-Built Materials List at the Pre-Ship Review. The MIUL will detail the material name, manufacturer, manufacturer's part number, and next higher-level assembly.

11.5 Fasteners

The CRaTER Project will procure MS and NAS, fasteners, fabricated by approved manufacturers, from authorized distributors. Typically, Accurate Fastener of Boston is used as that distributor. Certificates of Compliance (C of Cs) are provided with these fasteners, as well as chemical and physical test reports, when requested. Fastener documentation is available for GSFC review. This procedure has been effective in avoiding counterfeit fasteners. The CRaTER instrument will be fastened to the instrument deck of the spacecraft with number 10 fasteners, provided by GSFC. The largest fastener used inside the CRaTER Instrument will not be larger than number 8. Fasteners will be screened for visual and dimensional requirements. This paragraph is the CRaTER Fastener Control Program Plan.

11.6 Lubrication

CRaTER does not have any mechanisms or moving parts. Therefore there is no need for a Mechanism Life Test Plan. No lubricants are anticipated. The Materials Identification and Usage List (MIUL) will detail any and all lubricants if they are used in CRaTER.

11.7 Process Selection Requirements

The CRaTER Project will document the material processes used on flight hardware. The list will be submitted in the Materials Identification and Usage List (MIUL). The only material process anticipated at this time is chemical or metallic coatings. This process will be done in accordance with the applicable Military Standard process. These processes shall be carefully selected to prevent unacceptable changes in material properties during exposure to flight environments.

11.8 Procurement Requirements

11.8.1 Purchased Raw Materials

Raw materials purchased for flight hardware are accompanied by the results of nondestructive, chemical and physical tests, and a Certificate of Compliance (C of C). This information is kept on file for at least ten years or until the material is consumed, whichever is longer.

11.8.2 Raw Materials Used in Purchased Products

Raw materials used in purchased products will either be provided by the CRaTER Project or meet the materials test requirements above, if supplied by the seller. Applicable requirements of this PAIP will be flowed down to all suppliers.

12.0 EEE Parts Requirements

12.1 General

The CRaTER Project has an Electrical, Electronic, and Electromechanical (EEE) Parts Control Program in place to assure that all parts selected for use in flight hardware meet mission objectives for quality and reliability. This program is based on requirements specified in EEE-INST-002, "Instructions for EEE Parts Selection, Screening, Qualification, and Derating". The minimum acceptable EEE part grade for this program is level 2 with 100% Particle Impact Noise Detection (PIND) screening for cavity bodied active devices. This assumes that the radiation hardness requirements and system reliability goals are also being met. Section 12.1 through section 12.13 of this PAIP is the CRaTER EEE Parts Control Program Plan.

12.2 Electrical, Electronic and Electromechanical (EEE) Parts

All part types listed in the NASA Parts Selection List (NPSL) are considered EEE parts and will be treated in accordance with EEE-INST-002, Level 2. Multi-chip Modules (MCMs) and Standard Hybrid microcircuits are not considered custom or advanced technology devices. Hybrids and MCMs will undergo CSI and be treated per the applicable section of EEE-INST-002.

12.3 Part Control Board (PCB)

All EEE Parts for the CRaTER Project will be controlled by the Mission Assurance Manager, and will be documented in the CRaTER EEE Parts database. This database will describe each part, common part number (P/N), procurement P/N, part manufacturer, qualification status, PCB Status, additional screens and status, TID, SEU, SEL, next higher assembly, quantity, procurement information, and inventory status. The PCB column will indicate acceptance of the part for flight design by the Part Control Board (PCB), which is the CRaTER Mission Assurance Manager. The database is always a work in progress and will be available to GSFC on the CRaTER website. This list will be submitted as the Program Approved Parts List (PAPL) and Parts Identification List (PIL). It will also serve as the As-Built Parts List. Part activities such as failure investigations, disposition of non-conformances, and problem resolutions are the responsibility of the Mission Assurance Manager

12.4 Parts Selection and Screening

All EEE parts will be selected and processed in accordance with EEE-INST-002, Instructions for EEE Parts Selection, Screening, Qualification, and Derating. Parts selected from the NASA Parts Selection List (NPSL) are considered Qualified. This includes parts documented in Standard Microcircuit Drawings (SMDs). EEE Parts will 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 will be selected in order of preference as listed in this section. Parts falling into the categories for the paragraphs below will be evaluated for compliance to the screening requirements of 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. All parts will be evaluated for radiation hardness characteristics (Total Ionizing Dose [TID], Single-Event Upset [SEU], and Single-Event Latch-up [SEL]). Particle Impact Noise Detection (PIND) testing will be performed on all cavity devices.

- *Parts listed in the NASA parts selection list (NSPL). Parts with flight heritage. Parts will be procured in accordance with the appropriate specification designated for that part.*
- *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.*
- *MIL-PRF-38535, Class Q or better microcircuits procured to Standard Military Drawings (SMDs) from a supplier listed in the Qualified Manufacturer List (QML38535).*
- *MIL-PRF-38534, Class H or better hybrid microcircuits will be procured with CRaTER pre-seal visual examination from a supplier listed in QML38534.*
- *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 will be procured with CRaTER pre-seal visual examination 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.*
- *Manufacturer's in-house reliability-processed parts provided all screening tests listed in EEE-INST-002 for a Quality Level 2 part has been satisfied. The high-reliability process flow must 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 will be performed by the manufacturer or at an independent test facility or at GSFC. Parts will be procured following this guideline with lot-specific or generic Group C QCI data and will be approved by the PCB.*
- *MIL-PRF-19500, JANTX, JANTXV, and JANS semiconductors procured from a QPL-listed supplier and screened per 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 will be performed.*
- *Established Reliability (EREL) passive components procured from a QPL-listed supplier for the appropriate military specification. Part failure rates will be in accordance to the guidelines in EEE-INST-002 for Quality Level 2 parts.*
- *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:*
- *No changes have been made to the previously approved, Source Control Drawing (SCD), vendor list, or processes.*

- *The previous project's parts quality level is identical to the LRO project.*
- *Parts have undergone effective screening.*
- *Any parts not meeting the criteria specified in the paragraphs above, of this section, will be screened in accordance with the screening requirement specified in EEE-INST-002, Quality Level 2 for each commodity.*

Pre-cap inspection at subcontractor, vendor, or collaborator's facilities will be performed on hybrid microcircuits, DC/DC converters, and other complex microcircuits, such as Application-Specific Integrated Circuits (ASICs), multi-chip modules, and 3-D stacks. EEE-INST-002 is used as a reference document in Part Specifications and Source Control Drawings (SCDs).

12.4.1.1 Custom Devices

In addition to applicable requirements of EEE-INST-002, custom EEE Parts planned for use by the CRaTER Project 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.

12.4.1.2 Magnetics

Magnetic devices will be assembled and screened to the requirements of MIL-STD-981 and MIL-PRF-27 wherever possible, as detailed in the SCD.

12.4.1.3 Relays

Relays are not anticipated in the CRaTER design.

12.5 Parts Stress Analysis and Derating

All EEE parts will be used in accordance with the derating guidelines of EEE-INST-002. In addition, (EEE) parts will be subjected to stress analyses for conformance with the applicable derating guidelines as specified in EEE-INST-002. The analyses will be performed at the most stressful values that result from specified performance and environmental requirements (e.g., temperature, power, and voltage) on the assembly or component. CRaTER will maintain the analyses with updates.

12.6 Radiation Hardness

All parts will be selected to meet their intended application in the predicted mission radiation environment. The radiation environment consists of total dose and single-event effects. The CRaTER Project EEE Parts Database will detail the tolerance of each part with respect to both effects.

12.7 Destructive Physical Analysis

A sample of each lot date code of microcircuits, hybrid microcircuits, and semiconductor devices will not be subjected to a Destructive Physical Analysis (DPA). Sample DPA will be performed as directed by the PCB or where indicated in EEE-INST-002.

12.8 Failure Analysis

Failure analyses, performed by experienced personnel, will support the non-conformance reporting system. Hi-Rel Laboratories, Seal Laboratories, and Assurance Technology Corporation are typical facilities used for root cause failure analysis.

12.9 Parts Age Usage

Parts with a lot-date-code greater than 5 years from the date of the last full screen will be avoided. If this is not possible, such parts will be subjected to a full 100 percent re-screen per EEE-INST-002.

12.10 Parts List

All EEE Parts for the CRaTER Project will be documented in the CRaTER EEE Parts database. This database will describe each part, common part number (P/N), procurement P/N, part manufacturer, qualification status, PCB Status, additional screens and status, TID, SEU, SEL, next higher assembly, quantity, procurement information, and inventory status. The EEE Parts database is a work in progress and is available to GSFC on the CRaTER database. This list will be submitted as the Program Approved Parts List (PAPL) and Parts Identification List (PIL). It will also serve as the As-Built Parts List.

12.11 Parts Traceability Control

As EEE Parts are received, the part number, part manufacturer, lot date code, and if applicable, the serial number are recorded. This information is carried forward in the Assembly Work Order (AWO) (traveler), on the Configuration Traceability Sheet. Traceability records are revised until flight hardware is shipped.

12.12 Parts Reuse

EEE parts, which have been installed and removed for any reason, are not used again in flight hardware.

12.13 Alerts

NASA Alerts and Advisories provided to the CRATER Project 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 project report in the Mission Assurance section. Additionally, when appropriate, CRaTER will prepare, or assist GSFC personnel in preparing Alerts. Furthermore, CRaTER will periodically submit the CRaTER design EEE Parts List (P/L) to the Government Industry Data Exchange Program (GIDEP) for matching the P/L to existing ALERTs. The CRaTER parts database includes a column where applicable ALERTs are identified for each part.

13.0 Contamination Control Requirements

CRaTER will plan and implement a contamination control program applicable to CRaTER flight hardware. The program will establish the specific cleanliness requirements and delineate the approaches in a Contamination Control Plan (CCP). The CRaTER Contamination Control Plan is CRaTER document number 32-01203.

14.0 Electrostatic Discharge Control (ESD)

CRaTER will maintain an ESD program that complies with NASA-STD-8739.7, Standard for Electrostatic Discharge Control. CRaTER Operators and Inspectors are certified/recertified to the above standard.

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 will be used while handling flight electronics.

No special ESD measures are anticipated for CRaTER.

15.0 Configuration Management

CRaTER will control the documentation and hardware through a system proven by decades of development and successful use. The CRaTER Configuration Management Procedure is detailed in CRaTER document 32-01201.

16.0 Preservation, Packing, and Handling

16.1 Preservation and Packing

Preservation, packaging, and packing shall be in accordance with the item and the system requirements. All parts that are subject to degradation by ESD shall be packaged in accordance with the approved ESD procedures.

16.2 Handling

Handling (including storage) procedures shall be instituted to prevent part and material degradation. The handling procedures shall be retained through inspection, kitting, and assembly and shall be identified on “build to” documentation. The following criteria shall be used as a minimum for establishing handling and storage procedures for parts and materials:

- *Control of environment, such as temperature, humidity, contamination, and pressure.*
- *Measures and facilities to segregate and protect parts and materials routed to different locations, such as to the materials review crib, to a laboratory for inspection, or returned to the manufacturer from unaccepted shipments.*
- *Space quality parts will be stored in easily identified containers.*
- *Control measures to limit personnel access to parts and materials during receiving inspection and storage.*
- *Facilities for interim storage of parts and materials.*
- *Provisions for protective cushioning, as required, on storage area shelves, and in storage and transportation containers.*
- *Protective features of transportation equipment design to prevent packages from being dropped or dislodged in transit.*
- *Protective bench surfaces on which parts and materials are handled during operations such as test, assembly, inspection, and organizing kits.*
- *Required use of gloves, finger cots, tweezers, or other means when handling parts to protect the parts from contact by bare hands.*
- *Provisions for protection of parts susceptible to damage by ESD.*
- *Materials in contact with the LRO/CRaTER such as finger cots, wipes, swabs, and gloves will meet LRO contamination control plan requirements.*

17.0 Data Retention

CRaTER will maintain records of incoming inspection tests, lot qualification and acceptance test data, radiation hardness assurance test data, traceability data, and other useful data as determined by the

CRaTER Mission Assurance Manager. These records and data will be maintained for not less than ten (10) years after the LRO/CRaTER launch date.

Abbreviations and Acronyms

ABPL	As-Built Parts List
ABML	As-Built Materials List
AR	Acceptance Review
ASIC	Application Specific Integrated Circuits
AWO	Assembly Work Order
BU/CSP	Boston University/Center for Space Physics
CCP	Contamination Control Plan
CDR	Critical Design Review
CDRL	Contract Delivery Requirements List
CIL	Critical Items List
C of C	Certificate of Compliance (or conformance)
CSI	Customer Source Inspection
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	General Environmental Verification Specification
GFE	Government-furnished Equipment
GIA	Government Inspection Agency
GIDEP	Government Industry Data Exchange Program
GSE	Ground Support Equipment
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
MKI	Massachusetts Institute of Technology Kavli Institute for Astrophysics and Space Research
MOC	Mission Operations Center
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
MAM	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
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