Mars Science Laboratory Preliminary Mission Assurance Plan

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DOCUMENT CHANGE LOG

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TABLE OF CONTENTS

1 INTRODUCTION 1
1.1 Purpose 1
1.2 Scope 1
1.3 Applicable Documents 1
1.3.1 JPL Documents 2
1.3.2 NASA and Military Documents 3
1.3.3 Other Documents 4
1.4 Objective 4
1.5 Roles and Responsibilities 4
1.6 Environmental Requirements 5
1.7 Systems Safety 5
2 RELIABILITY ASSURANCE 5
2.1 Introduction 5
2.1.1 Scope 5
2.1.2 Purpose 5
2.1.3 Objectives 5
2.1.4 Responsibilities 6
2.2 Reliability Assurance Requirements 6
2.2.1 Success-Critical Single Failure Point (SFP) 7
2.2.2 Failure Modes, Effects, & Criticality Analysis (FMECA) 7
2.2.3 Mechanical Fault Tree Analysis (FTA) 7
2.2.4 Electrical/Electronic Worst Case Analysis (WCA) 8
2.2.5 Power Supply Transient Analysis 9
2.2.6 Electronic Parts Stress Analysis (E-PSA) 9
2.2.7 Thermal Analysis 9
2.2.8 Structural Stress Analysis 9
2.2.9 Single Event Effects Analysis (SEE) 9
2.2.10 Mechanical Worst Case Analysis 10
2.2.11 Mechanical Life Testing 10
2.3 Reliability Development Requirements 10
2.3.1 Minimum Operating Time Requirements 10
2.3.2 Support Equipment 10
2.3.3 Lessons Learned 11
2.4 Contractor Reliability Assurance Programs 11
2.4.1 Reliability Assurance Plan 11
2.4.2 Reporting 11
3 PROBLEM/FAILURE ANOMALY REPORTING 11
3.1 Scope 11
3.2 Problem/Failure Reporting Requirements 12
3.2.1 Items Covered by Reporting 12
3.2.2 P/FR Starting Points 12
3.2.3 Requirements for P/FRs 13
3.2.3.1 Incidents Requiring Reports 13
3.2.3.2 Timeliness of Reporting and Release 14
3.2.3.3 Responsibility of Reporting 14

This Document is a Preliminary Release in Support of the PIP

3.2.3.4 Form of Reporting 14
3.2.3.5 Analysis Requirements 14
3.2.3.6 Corrective Action Requirements....15
3.2.3.7 Failure Effect and Cause/Corrective Action Rating 15
3.2.3.8 Risk Assessment....16
3.2.3.9 Safety Rating and Assessment 17
3.3 Contractor Problem/Failure Reporting Requirements....17
3.3.1 General 17
3.3.2 Liaison and Submittals to JPL 18
4 ELECTRONIC PARTS ENGINEERING 19
4.1 Purpose 19
4.2 Scope 19
4.3 Technical Requirements....19
4.3.1 Mission Requirements and Environments 19
4.3.2 Parts Selection and Standardization Requirements 19
4.3.3 Standard Parts 19
4.3.3.1 Non-Standard Parts 19
4.3.4 Application Specific Integrated Circuit (ASIC) Requirements 20
4.3.4.1 Digital ASIC Test Requirements....20
4.3.4.2 Mixed-Signal ASIC Test Requirements....20
4.3.4.3 Custom Hybrid, MCM and HDI Microcircuits 20
4.4 Post-Programming Tests for Programmable Devices 21
4.5 Destructive Physical Analysis (DPA) and Residual Gas Analysis (RGA) 21
4.6 Particle Impact Noise Detection (PIND)....21
4.7 Solid Tantalum Style Capacitor Additional Screening 21
4.8 Radiation Requirements....21
4.8.1 Radiation Lot Acceptance Testing (RLAT) 21
4.8.2 Total Ionizing Dose (TID) Level....22
4.9 Enhanced Low Dose Rate Sensitivity (ELDRS) 22
4.9.1 Displacement Damage (DD) 22
4.9.2 Single Event Upset (SEU) 22
4.9.3 Single Event Transient (SET)....22
4.9.4 Single Event Latchup (SEL) 22
4.9.5 Single Event Gate Rupture (SEGR) 23
4.9.6 Single Event Burnout (SEB) 23
4.10 Electronic Parts Application and Derating 23
4.10.1 Parts Derating 23
4.10.2 Handling / Storage / Electrostatic Discharge (ESD) Control Requirements....24
4.10.3 NASA Advisories and Government Industry Data Exchange Program (GIDEP) Alerts 24
4.10.4 Failure Analysis....24
4.11 Contractors....24
5 MATERIALS & PROCESSES....25
5.1 Requirements 25
5.1.1 Selection of Materials and Processes 25
5.1.2 Standard Materials and Processes Selection....25

This Document is a Preliminary Release in Support of the PIP

5.1.3 Submittal of Material Identification and Usage Lists 25
5.1.4 Classification of MIUL Submittals 25
5.1.5 Materials Usage Agreements (MUA) 26
5.1.6 Waivers 26
5.2 Materials and Processes Review 26
5.2.1 Evaluation 26
5.2.2 Thermal Vacuum Stability and Outgassing 27
5.2.3 Flammable Materials 27
5.2.4 Galvanic Corrosion 27
5.2.5 Stress Corrosion Cracking 27
5.2.6 Welding 27
5.2.7 Non-Destructive Inspection 28
5.2.8 Shelf-Life Limited Materials 28
5.2.9 Radiation Resistance 28
5.2.10 Electrical Arc-Tracking Resistance 28
5.2.11 Hazardous Materials 28
5.2.12 Magnetic Materials 28
5.2.13 Static Charge Sensitivity 29
5.2.14 Lubricants 29
5.2.15 Fungi 29
5.2.16 Metal Migration and Whisker Growth 29
5.2.16.1 Fasteners 30
5.2.16.2 Materials 30
5.2.16.3 Materials for Fracture Critical Fasteners 30
5.2.16.4 Fastener Traceability 30
5.2.17 Design Allowables for Structural Parts 30
5.2.18 Material Traceability 31
5.2.19 Qualification of NonStandard Materials and Processes 31
5.2.20 Alerts 31
6 CONTAMINATION CONTROL 31
6.1 General 31
6.2 Assignment of Responsibility 31
6.3 Documentation Requirements 31
6.4 Acceptance Requirements 31
6.5 General Deliverable Hardware Contamination Requirements 31
6.5.1 Design Requirements 31
6.5.2 Material Requirements 32
6.5.3 Cleaning Requirements 32
6.5.4 Surface Cleanliness Requirements 32
6.5.5 Bakeout Requirements 32
6.5.6 Outgassing Verification Requirements 32
6.5.7 Protective Covers & Storage Containers 33
6.5.8 Facility Requirements 33
6.5.9 Contamination Non-Entrapment Requirements 33
6.5.10 Variance from Requirements 33
6.6 Specific Hardware Contamination Control Requirement 33

This Document is a Preliminary Release in Support of the PIP

7 HARDWARE QUALITY ASSURANCE 33
7.1 Scope 33
7.1.1 Introduction 34
7.1.2 Purpose 34
7.1.3 Applicability and Source 34
7.2 Applicable Documents 35
7.2.1 General 35
7.3 Quality Management System 35
7.4 Quality Assurance Program 35
7.4.1 Initial Quality Planning 35
7.4.1.1 Review of Project Documents 35
7.4.1.2 Pre-Procurement Activity 35
7.4.2 Training and Certification 36
7.4.3 Change Controls 36
7.4.4 Contractor Surveillance 36
7.4.5 Procurement Controls 37
7.4.6 Procurement Document Controls 37
7.4.7 Raw Materials Controls 37
7.4.8 Receiving Inspection 37
7.4.9 Sampling Inspection 38
7.4.10 Electronic Parts Inspection 38
7.4.11 Processing, Fabricating, Assembly, Test, and Inspection Control 38
7.4.12 Manufacturing, Inspection and Test Planning 38
7.4.13 Inspection 38
7.4.14 Critical Processes 39
7.4.15 Workmanship Standards 40
7.4.16 Metrology Controls 40
7.4.17 Controlled Storage 40
7.4.18 Handling, Packaging, Shipping and Storage Controls 40
7.4.19 Record Maintenance 41
7.4.20 Quality Records and Controlled Documents 41
7.4.21 Non-Conformance Reporting and Nonconforming Material Control 41
7.4.21.1 Contractor Material Review Board 41
7.4.22 Acceptance Test Verification 42
7.4.23 Environmental Testing 42
7.4.24 Functional and Acceptance Electrical Testing 42
7.4.25 Post-Test Hardware Inspection 43
7.4.26 Ground Support Equipment 43
7.4.27 Assembly Test and Launch Operations (ATLO) 43
7.4.28 End Item Data 43
7.4.29 Hardware Requirements/Certification Reviews (HRCRs) 43
7.4.30 Launch Operations Support 44
7.4.31 Government Furnished Equipment and Materials (GFE) 44
7.5 Science Instruments Furnished by International Partners 44
7.6 Quality Assurance Applications Engineering 45
7.6.1 Optical Alignment 45

8 SOFTWARE QUALITY ASSURANCE....45
8.1 Introduction....45
8.1.1 Scope....45
8.1.2 Purpose....45
8.1.3 Responsibilities....45
8.2 Contractor SQA Requirements....45
8.2.1 S/W Development Process....45
8.2.2 S/W Requirements Trace....45
8.2.3 S/W Reviews....46
8.2.4 S/W Verification and Validation (V&V)....46
8.2.5 Problem/Failure Reporting (PFR) and Tracking....46
8.2.6 S/W Configuration Management (CM)....46
8.2.7 S/W Engineering Change Request (ECR)....46
8.3 S/W Safety/Hazard/Fault Analysis....47

This Document is a Preliminary Release in Support of the PIP

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1 INTRODUCTION

1.1 Purpose

The purpose of this document is to define the mission assurance program to be applied to the development of the Mars Science Laboratory (MSL) Principal Investigator (PI) Science Instruments.

1.2 Scope

The mission assurance program identifies requirements and activities applicable to all MSL team members. All external organizations providing a flight element shall create specific discipline assurance plans, or combined into a single Mission Assurance Plan, that will define in more detail the assurance programs to be employed at their respective organizations during the flight equipment development process. Utilization of existing documentation, processes, and procedures are recommended.

1.3 Applicable Documents

The following documents of the issue in effect on date of invitation for bids, or request for proposal, or product manufacture, form a part of this document to the extent specified herein. In case of conflict, this document shall take precedence. **JPL-approved contractor equivalent documents are allowable and encouraged.**

All materials and processes used for applications including structural members, mechanical parts, packaging, cabling, and fasteners for the fabrication of flight hardware are covered by this document. These requirements are generally applicable to flight system hardware and instruments. Contractors and their subcontractors have the option of using their own materials and processes requirements documents, but prior JPL approval of such documents is required. All the requirements contained in this document shall apply to both JPL and its contractors, and shall be identified in appropriate contractual documentation. In cases of conflict between this document and any of the applicable documents listed below, this document shall take precedence.

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1.3.1 JPL Documents

FS 511316	Detail Specifications for Qualification of Critical Fasteners
JPL STD-00009	Flight Materials/Process/Fasteners/Packaging/Cabling H/W Selection Guide
JPL D-560	JPL Flight Systems Safety Requirements (601-4)
JPL D-1348	JPL Standard for Electrostatic Discharge Control
JPL D-5703	JPL Reliability Analysis Handbook
JPL D-8091	JPL Standard, Problem Failure Reporting System, Guidelines and Procedures
JPL D-8208	Spacecraft Design and Fabrication Requirements for Electronic Packaging and Cabling
JPL D-8545	JPL Derating Guidelines (Rev D)
JPL D-8671	JPL Standard for Reliability Assurance
JPL D-11119	Alert/Concerns Handbook
JPL D-15032	Procedure – Category A and B Waivers
JPL D-17868	JPL Design, Verification/Validation and Operations Principles for Flight Systems
JPL D-18002	Radiation Test Requirements for Ionization and Displacement Damage
JPL D-19426	Plastic Encapsulated Microcircuits (PEMS) Reliability/Usage Guidelines for Space Applications
JPL D-23713	JPL Software Development
JPL D-TBD	MSL Configuration Management Plan
JPL D-TBD	MSL Risk Management Plan
JPL D-TBD	MSL Software Management Plan
JPL D-TBD	MSL Project Safety Plan
JPL D-TBD	MSL Environmental Requirements Document
JPL DocID 61256	Selection of Threaded Fasteners for Flight Applications
JPL DocID 64395	Control and Use of Environmental Chambers
QAP 44.10	Receiving Inspection and Identification of Flight Bulk Materials
QAP 144.1	Quality Assurance Material Review Board Action (Rev. C)

1.3.2 NASA and Military Documents

EWR 127-1	Range Safety Manual
IEST-1246	Product cleanliness levels and contamination control program
JSC SP-R-0022A	Vacuum Stability Requirements of Polymeric Materials For Spacecraft Applications
LLIS	NASA Lessons Learned Information System (http://llis.nasa.gov)
MIL-C-39010	Coil, radio frequency, fixed, molded, established reliability general specification for
MIL-I-6870	Inspection program requirements, nondestructive for aircraft and missile materials and parts
MIL-PRF-123	General Specification for Capacitors, Fixed, Ceramic Dielectric
MIL-PRF-19500	General Performance Specification for Semiconductor Devices
MIL-PRF-38534	General Performance Specification for Hybrid Microcircuits
MIL-PRF-38535	General Performance Specification for Manufacturing Integrated Circuits
MIL-PRF-39003	General Specification for Capacitor, Fixed, Electrolytic (Solid Electrolyte), Tantalum, Established Reliability
MIL-PRF-55365	General Specification for Capacitor, Fixed, Electrolytic (Tantalum), Chip, Nonestablished Reliability, Established Reliability
MIL-STD-462	Electromagnetic interference characteristics, measurement of
MIL-STD-883	Test Methods and Procedures for Microelectronics
MIL-STD-1595	Qualification of aircraft, missile and aerospace fusion welders
MSFC-HDBK-527/JSC 09604	Materials Selection List for Space Hardware Systems
MSFC-STD-3029	Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments
NASA GSFC 311-INST-001	Instructions for EEE Parts Selection, Screening, and Qualification
NASA-STD-5003	Fracture Control Requirements for Payloads Using the Space Shuttle
NASA-STD-6001	Flammability, Odor, Offgassing and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion
QML-38534	Qualified Manufacturers List of Custom Hybrid Microcircuits Qualified Under Military Specification MIL-PRF-38534

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QML-38535	Qualified Manufacturers List of Microcircuits Manufactured to the Requirements of MIL-PRF-38535 (including Appendix A where applicable)
QPL-19500	Qualified Products List of Products Qualified under MIL-PRF-19500, General Specification for Semiconductor Devices
SSQ25000	Destructive Physical Analysis Testing Specification for the Space Station Program, Revision B

1.3.3 Other Documents

ASTM-E595	Detail Specification for Vacuum Outgassing of Polymers
ASTM-E1417	Standard Practice for Liquid Penetrant Examination
ISO 14644	Cleanrooms and Associated Controlled Environments
ISO 9001	Quality Management Systems Requirements
MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-17 (Volumes1-5)	Composite Materials Handbook
MIL-HDBK-6870	Inspection Program Requirements Nondestructive for Aircraft and Missile Materials and Parts
MIL-STD-810	Environmental Engineering Considerations and Laboratory Tests
MIL-STD*-889	Dissimilar Metals
SAE-AMS-STD-1595	Qualification of Aircraft, Missile & Aerospace Fusion Welders

1.4 Objective

The objective of the MSL mission assurance program is to identify, control, mitigate, and communicate Project risks/problems in a manner that is consistent with Project resources (e.g. funding, mass, power, risk, etc.).

1.5 Roles and Responsibilities

Team members are responsible for the development, control, and implementation of the Mission assurance program at their organizations. Team members are also responsible for communicating their mission assurance plans, implementation status, concerns, and issues to the MSL Project Office. As issues/problems/failures arise, risk (programmatic/mission) mitigation actions are the responsibility of the team members organization that has the issue/problem/failure. Where issues/problems/failures and resulting mitigation actions, cross team member interfaces the impacted team member(s) and the MSL Project Office shall be informed in a timely manner. The objective of the mitigation effort shall be focused on minimizing impacts to the MSL Project as a whole. In addition to the internal communications discussed above, the MSL mission assurance team, with the project office, is responsible for communication with the National Aeronautics and Space Administration (NASA) on all aspects of the Mission Assurance program. These communications will take the form of the Mission Assurance team's participation in periodic Project reviews, as well as other less formal means.

The MSL Mission Assurance Manager (MAM), as a member of the MSL Project staff, reports to the Project Manager and the independent Jet Propulsion Laboratory (JPL) Safety and Mission Assurance Directorate on all aspects of the mission assurance program and implementation status. In addition the MSL MAM is responsible for the coordination of Mission Assurances tasks between team organizations, including the elements described in this plan, and risk management. In particular the MAM will provide Project level perspective/commonality support for electronic parts, quality assurance, environmental requirements, materials and processes, configuration management, risk management, reliability and safety.

The MAM is responsible for acquiring insight into the planning and implementation of Mission Assurance throughout the MSL Project. In support of this responsibility, team members shall provide access to documentation and information regarding analyses, test reports, failure reports, and other documents as requested by the MAM.

1.6 Environmental Requirements

The environmental requirements for the Science Payload are contained in the Payload Information Package (PIP). All Science Instruments shall meet the requirements indicated in the PIP and provide to JPL the items indicated in the CDRL and DRD exhibits. Deviations from these requirements shall be reviewed and approved by the MSL Environmental Requirements Engineer.

1.7 Systems Safety

All Science Instrument providers shall comply with the Systems Safety requirements contained in JPL D-560. Deviations from this document shall be reviewed and approved by the MSL Systems Safety Engineer. Science Instrument providers shall deliver the items contained in the CDRL and DRD exhibits.

The Instrument Provider shall provide, as a minimum, all necessary data input for inclusion into the Missile System Pre-launch Safety Package (MSPSP), including analysis for specific hazards that may be associated with the instrument.

2 RELIABILITY ASSURANCE

2.1 Introduction

2.1.1 Scope

This section establishes the reliability assurance requirements to be satisfied and activities to be implemented during the design, fabrication, integration, test, and delivery of all hardware elements for the MSL Project.

2.1.2 Purpose

The purpose of this section is to define the reliability assurance requirements, which when satisfied, will serve as verification that all assemblies and subsystems meet their hardware performance requirements in the intended operating environment.

2.1.3 Objectives

The objectives of this section are to identify the reliability tasks and activities necessary to accomplish the mission goals. To this end, the following specific objectives apply:

- Assure that adequate consideration is given to reliability during the design and development of the hardware.
- Assure that possible sources of high risk are identified and where possible eliminated through the design verification & validation process.

2.1.4 Responsibilities

Primary responsibility for the implementation and accomplishment of activities that satisfy the requirements of this section belongs to the responsible design agencies and their respective contractors and subcontractors. Technical adequacy of the analyses shall be verified and approved by JPL independent review or concurrent engineering generation of the analyses. All hardware developers shall extend these requirements to their subcontractors and suppliers through appropriate contractual documentation.

2.2 Reliability Assurance Requirements

Analyses of the hardware design shall be performed to ensure proper built-in reliability and consistency with mission requirements and objectives. The analyses shall be performed concurrently with the design effort. The following reliability analyses shall be performed consistent with the intent of JPL D-5703, "Reliability Analyses Handbook."

- Failure Modes, Effects, and Criticality Analysis (FMECA)
- Mechanical/Electromechanical Fault Tree Analysis (FTA)
- Worst Case Circuit Analysis (WCA)
- Electrical Parts Stress Analysis (E-PSA)
- Power Supply Transient Analysis
- Thermal Stress Analysis
- Structural Stress Analysis
- Single Event Effect Analysis (SEE)

FMECA criticality on Spacecraft or Rover functionality will be assessed by the JPL Spacecraft System Engineer and the JPL Reliability Engineer.

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Responsible design agencies within JPL, as well as in contractor and subcontractor organizations, shall be responsible for performing, documenting, and updating all of their analyses as required. Analysis documentation shall include relevant backup data such as circuit description, schematics, functional or logical block diagrams, functional I/F requirements, parts lists, results summary and conclusions. Analysis documentation guidelines are outlined in JPL D-5703. All analyses shall be maintained in a current state and reflect the currently approved design. The design agencies shall take appropriate actions driven by the results of each analysis.

For inherited hardware, existing analyses may be satisfactory if applicability is demonstrated by verification that all originally applied requirements, environments, and other bounding conditions envelope the corresponding elements required by the current application and if the analyses were adequately performed to these conditions. Analyses shall be performed and documented.

2.2.1 Success-Critical Single Failure Point (SFP)

Mission success critical SFPs are not permitted. PI Science Instruments are not considered mission critical. All system level SFPs shall be identified and documented in a SFP list. Project shall maintain a mission SFP exemption list. There shall be no **Safety** critical single failure points (i.e., equipment, software, or functions which, if nonfunctional, inoperative, or incorrectly performed, could result in injury to personnel or damage to equipment).

2.2.2 Failure Modes, Effects, & Criticality Analysis (FMECA)

The main objective of a FMECA is to identify success-critical Single Failure Points (SFPs) and to verify that failures will not propagate and damage other hardware. The FMECAs shall be performed and documented to analyze postulated failures and identify the potential resultant effects. FMECAs shall be performed at both the system level and at the cruise stage, descent stage and rover subsystem levels.

Interface FMECAs shall be performed at all subsystem, instrument, and GSE interfaces and anywhere block or functional redundancy is employed. As a minimum, these shall:

- Consider all operational modes.
- Be performed at the subsystem level interfaces to the piece part level to verify that a failure in any interface circuit cannot propagate to and/or damage the interfacing circuit and or damage hardware in another fault containment region.
- Consider all parts that could be reasonably expected to produce an anomalous condition at the interface that would not otherwise be addressed (e.g., a DC-DC converter, internal to the assembly, that does not have over-voltage protection)
- Verify that a failure in a non-critical circuit (e.g., telemetry, current monitoring) will not affect the performance of a critical function in a non-redundant circuit.
- Verify that failures in ground support or test equipment (including power lines) cannot propagate to and damage the flight hardware.

2.2.3 Mechanical Fault Tree Analysis (FTA)

A Fault Tree Analysis (FTA) shall be performed on mechanical and electromechanical devices used which affect physical external configuration or interfaces. A FTA of internal mechanisms is recommended. The FTA will address failure modes capable of occurring down to the lowest

level piece part. This analysis shall be accomplished by first defining the top event failure mode, then determining possible causes, considering effects based on the subsystem and system functional description. Following this determination, an assessment of preventive measures and alternate modes of operation to avoid failure shall be performed. The corrective actions shall be documented as described in JPL D-5703. From the results of these analyses, engineering decisions can be made by the cognizant design organization that indicate whether or not additional analysis, testing, inspection, or other steps should be taken to increase the reliability of the assembly. These decisions shall be reported at the design reviews subsequent to completing the analysis.

2.2.4 Electrical/Electronic Worst Case Analysis (WCA)

A WCA shall be documented for all circuit designs to demonstrate that sufficient operating margins exist for all operating conditions and performance requirements considering the combination of the following:

(a) Part temperature range, based on those stated in the environmental requirements document. The part case temperature for WCA shall be as follows:
   a. Minimum part case temperature shall be the minimum qualification thermal control surface (TCS) temperature.
   b. Maximum part case temperature shall be the maximum qualification TCS temperature + temperature rise to the case.
   c. If the thermal analysis indicates a part temperature outside of the specified range, the WCA must be amended to take into account the predicted temperatures from the thermal analysis.

(b) Piece part initial tolerance
(c) Part aging for the operating life of the mission including ground test time
(d) Radiation effects
(e) Special factors such as shock, vibration, or vacuum where such conditions would contribute to variations in the circuit parameters, voltage, frequency, and load variations shall also be included.

The analysis shall be an extreme value analysis (EVA) or extreme value with temperature tracking, in that the value for each of the variable parameters shall be set to limits that will drive the output to a maximum (or minimum) and shall consider AC, DC, and transient condition effects on the circuit. Piece part parametric data obtained from testing will be incorporated into the WCA as appropriate.

Analysis of protective circuitry shall be performed to ensure proper operation if a fault were to occur. (i.e., Assume a fault condition occurred such that the protective circuit is operating and will continue to operate under worst case conditions.)

Electrical noise on power lines, including ground differences, and interface signal lines shall be considered. Power supply turn on and turn off transients shall be included.

The documentation of the WCAs shall describe all identifiable deficiencies and performance restrictions.

2.2.5 Power Supply Transient Analysis

A Power Supply Transient analysis shall be performed to determine the effects on the power system of all power converters which use cruise stage or rover power. The analysis shall verify compliance with all applicable electrical system and EMC requirements for the following:

a. Transient performance
- Inrush surge current at subsystem turn-on
- Surge current due to mode changes
- Conducted electrical noise generation delivered to input power lines

b. Power demand
- Power consumption

c. Overload protection circuits
- Fuses: operating margin
- Current limiters: protection capabilities, limit level, duration
- Grounding configuration compliance

2.2.6 Electronic Parts Stress Analysis (E-PSA)

Parts Stress Analysis shall be performed and documented to verify that the applied stress on each piece part does not exceed the de-rating values established in JPL D-8545, or approved equivalent. All analyses shall be documented on JPL-provided or approved forms. Contractors may use their own forms with JPL reliability and cognizant technical manager approval. The stress analysis shall utilize the predicted part case temperature over the qualification temperature range or a piece part thermal analysis.

2.2.7 Thermal Analysis

An analysis of the effects of the thermal environment, including worst case estimates, shall be performed on mechanical and electromechanical systems/assemblies for all anticipated environmental conditions, including thermal cycling. The analysis shall be performed assuming the design temperature extremes. The analysis shall include possible fatigue and the effect of thermal cycling on solder joints, conformal coating and other critical situations.

Piece-part thermal analysis shall address the effect of the thermal environment and the worst case operating modes, over the Qualification temperature range. The piece-part thermal analysis shall provide all part case temperature rises from the thermal control surface (TCS). The analysis shall also provide maximum semiconductor junction temperatures.

2.2.8 Structural Stress Analysis

Structural stress analysis shall be performed on mechanical and electromechanical subsystems/assemblies. The analysis shall address the effects to be experienced by the structure due to the dynamic environment (i.e., acceleration, shock, vibration, and acoustic noise), including worst case estimates for design environmental conditions. The analysis shall also address material fatigue.

2.2.9 Single Event Effects Analysis (SEE)

Circuit designs containing SEE sensitive parts shall be analyzed to minimize the effect of SEE and to assure compliance with system/subsystem level requirements. Performance requirements

for operation during SEE are as follows:

- Temporary loss of function or loss of data shall be permitted provided that the loss does not compromise subsystem/instrument health, full performance can be recovered rapidly, and there is no time in the mission that the loss is mission critical.
- Fault traceability shall be provided in the telemetry stream to the greatest extent practical for all anomalies involving SEEs.
- Irreversible actions shall not be permitted. The flight hardware shall have no parts that may experience unrecoverable radiation induced latch-up or gate rupture.

2.2.10 Mechanical Worst Case Analysis

Mechanical analyses are to be performed to ensure that worst case mechanical tolerances and thermal environments cannot adversely affect the performance of mechanical and/or optical assemblies. This should be part of the usual design analyses, as good design practice, and should be verified during assembly and test.

2.2.11 Mechanical Life Testing

Mechanical/electromechanical hardware exhibiting mechanical wear-out life limiting characteristics shall be capable of at least three (3) times the sum of nominal ground and mission life requirements.

Life testing is required if it cannot be shown by cumulative experience or prior life testing, that the hardware is capable of at least three (3) times the sum of nominal ground and mission life, for the high cycle hardware; and at least ten (10) times the sum of ground and mission life, for single shot hardware.

Life Tests shall be conducted under environments representative of in-flight conditions (including some test time at expected flight extremes) and with environments and loads representative of in-flight conditions.

Life testing is not required for electronics on/off cycles.

Units exposed to life testing shall not later be used for flight.

2.3 Reliability Development Requirements

2.3.1 Minimum Operating Time Requirements

Instrument electronics assemblies shall accumulate at least 300 hours of operation prior to system integration (the last 100 hours to be failure free as a goal). After integration, instruments will accumulate at least an additional 200 hours prior to launch.

2.3.2 Support Equipment

The level of reliability typically required for flight hardware is not warranted for support equipment (SE). SE that connects to flight units for test or evaluation shall be analyzed for compatibility with the hardware. Particular care and attention shall be directed at providing assurance that any failure experienced in the SE does not result in degradation or damage to the

flight hardware. As a minimum, the following shall support the SE design and use:

- Protective adapters, including connector savers.
- Over-voltage protection for power source
- FMEAs to be performed on the SE hardware interface to verify that a failure in the SE will not propagate across the interface and cause degradation or damage to the hardware under test.
- Problem Failure Reports

2.3.3 Lessons Learned

The project and the subsystems shall review NASA Lessons Learned [http://llis.nasa.gov] Failure Lessons Learned and report on these issues at design reviews.

2.4 Contractor Reliability Assurance Programs

2.4.1 Reliability Assurance Plan

Contractors supplying any hardware or ground support equipment will either use this plan or develop a Reliability Assurance Plan consistent with the requirements of this section, to the extent specified in the contract Statement of Work. The contractor's plan will cover all contractor reliability assurance activities and those of subcontractors and suppliers. The plan must be approved by the JPL Contract Technical Manager, JPL Reliability Engineering, and the Mission Assurance Manager.

2.4.2 Reporting

Contractor reporting and data submittal will be as specified in the contract Statement of Work.

3 PROBLEM/FAILURE ANOMALY REPORTING

3.1 Scope

This Problem/Failure reporting, analysis, and corrective action program covers all Project flight configured hardware (qualification, protoflight, flight, and flight-type, including engineering model), flight software, support equipment and associated software, and test equipment that mates with flight hardware and associated software problem/failures arising from activities which are:

(a) Directly under the responsibility of the JPL personnel;
(b) Associated with implementation, integration, testing, and operation of hardware and software while at JPL, or under JPL control and cognizance;
(c) At the facility of the hardware and/or software contractors and subcontractors, unless the contractor's and subcontractor's problem/failure system is equivalent and has been authorized for use.

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Unless otherwise specified, the term “support equipment” shall include electrical, mechanical, or other support equipment, test equipment, and commercial test equipment. This document applies to all activities affecting flight hardware and software up to and including launch.

3.2 Problem/Failure Reporting Requirements

Project and Task hardware and software shall be supported by a comprehensive problem/failure reporting, analysis, and corrective action program. The following sections explain the report types (including the hardware and software to which they are applicable), starting points, and the requirements for reporting and closure. The provisions of this document apply to all activities affecting these items up to and including Assembly, Test, and Launch Operations (ATLO) and launch. Deviations from these requirements shall be documented in a waiver generated per the Project Configuration Management Plan.

3.2.1 Items Covered by Reporting

The following items shall be covered for all "incidents" defined in 3.1.

(a) Hardware
   1. Flight and flight-like hardware items (including qualification and protoflight hardware) covering:
      a. Assemblages of parts or components, subassemblies, assemblies, subsystem, system hardware levels; including circuit boards, welded modules, mechanical assemblies.
      b. Parts subsequent to screening or Quality Conformance Inspection (QCI) testing, including electronic, electrical, and electro-mechanical, mechanical, optical, purchased items, special parts, hybrids, fabricated items.

   2. Support, test and facility equipment
      Unless otherwise specified, the term "support equipment" shall include electrical, mechanical, or other support equipment, test equipment, commercial test equipment, etc.

(b) Software
   1. Software resident in flight hardware
   2. Software resident in subsystem/system support equipment not including science data analysis software

3.2.2 P/FR Starting Points

The required starting points for problem/failure reporting are defined below for the various "items" and for "reportable incidents". Reporting requirements continue during all subsequent phases of testing, launch preparation, and launch.

(a) Hardware (flight and flight-like). Reporting shall start at the first application of power subsequent to piece part screening for electronic parts, at the first functional check of mechanical assemblies or devices subsequent to identification as flight configured hardware.

(b) Hardware (support equipment or test equipment). Reporting shall start with equipment acceptance for project operations and shall continue throughout the period of use of the equipment.

(c) Software (Flight, Ground, and Support equipment). Reporting shall start with applications subsequent to software acceptance or during use with flight or flight-type hardware, including qualification or protoflight items.

(d) Environmental Testing or Pre-Conditioning. During environmental testing or pre-conditioning processing (e.g., outgassing) of flight configured hardware, a test facility problem or failure requires the initiation of two P/FRs. One P/FR is assigned to the testing or processing organization to accomplish analysis and correction of the problem with the facility, equipment, procedure or operations; the second P/FR is assigned to the cognizant flight hardware or software engineer for analysis and appropriate correction of any effect(s) on the involved flight hardware. Each report shall cross reference the other report. Incidents involving only flight hardware problems/failures, and not facility, require only one report against the affected flight hardware.

(e) Handling/storage. All handling or storage incidents involving flight or flight-type hardware or software items which may have been damaged, stressed or degraded require the initiation of two P/FRs. One P/FR is assigned to the handling/storage organization to accomplish analysis and correction of the problem associated with procedures, facilities, or equipment or operations. The second P/FR is assigned to the hardware or software cognizant subsystem for analysis and appropriate correction of any effect(s) on the involved hardware or software. Each P/FR shall cross-reference the other.

3.2.3 Requirements for P/FRs

This section outlines the requirements for P/FRs.

3.2.3.1 Incidents Requiring Reports

As a minimum, the following incidents shall require the initiation of a P/FR:

(a) Hardware failures, damage, problems, malfunctions, anomalies, procedure problems, nonstandard or unexpected results, and incidents of performance outside specification limits; also incidents of anomalous dynamic performance such as glitches, drifts, transients, stepping, or oscillation within specification limits.
(b) Software and procedure problems, errors, and ambiguities encountered with the software while utilized with Project hardware, while being checked in preparation for operation with Project hardware, or while in the workstation environment.
(c) Support equipment, test equipment, or test facilities problems, failures, and anomalous performance, including procedures and operator actions, while being utilized in conjunction with Project hardware or while being checked in preparation for operation with Project hardware.
(d) Incidents involving actual or potential damage to hardware, software, or injury to personnel, from testing, handling, shipping, or storage.

3.2.3.2 Timeliness of Reporting and Release

Reportable incidents shall be documented within one working day of incident/observation. The incident shall be reported without delay, regardless of its apparent magnitude, any initial assessment of criticality, or the existence of possible explanations. The appropriate information should be entered into the JPL Anomaly Reporting System, or Contractor equivalent, within two days of the incident.

3.2.3.3 Responsibility of Reporting

Any individual observing a reportable incident has a responsibility to originate a P/FR unless it is ascertained that the incident has been reported by another person. However, the individual in charge of the activity, or of the flight-type hardware, software, test equipment, or support equipment at the time a reportable incident occurs has the primary responsibility to originate the P/FR.

3.2.3.4 Form of Reporting

All problem/failure incidents shall be documented by entering the appropriate information electronically into the JPL Unified Problem Reporting System (UPRS) or an equivalent system that has prior Project Reliability Engineer approval.

3.2.3.5 Analysis Requirements

Analyses of the P/FRs shall be conducted to the extent necessary to define the problem, determine the failure mechanism root cause, identify whether parts may have been overstressed as a result of the failure, address the effect of the incident on associated elements of the subsystem and the system (including near and long-term effects on desired functional performance), and determine any necessary corrective action. The proposed corrective action shall be analyzed to ensure that the implementation will address both the problem and any interactions with other elements of the subsystem and the system.

a) Flight-type hardware analyses. The following analyses shall be conducted for problems or failures of flight-type hardware:
    1. Stress analyses. Electrical, mechanical, and/or other applicable stress analyses shall be conducted to assess the effect of the problem/failure on affected elements of the involved equipment, and on elements of other equipment with which it interfaces.
    2. Part failure analyses. Any part from a flight certified lot that fails or degrades beyond specification limits shall be subjected to a part failure analysis, unless it is known with certainty that human error, improper installation, or other external cause induced the failure.

(b) Support equipment and facility hardware analyses. Analyses of the problem/failure cause and corrective action for incidents involving non flight-type hardware need be conducted only to the extent necessary to isolate the cause to the equipment level, determine the effects on flight-type hardware (overstress, design changes, etc.), and verify that the problem/failure will not recur. Particular attention shall be focused on those problem/failures which, if they were to recur, might result in injury to personnel or damage to flight-type equipment.

3.2.3.6 Corrective Action Requirements

When corrective action is implemented, documents defining changes in design configuration or document revisions shall be processed in accordance with the project's management plan and referenced on the P/FR prior to closeout review and approval. The P/FR will remain open until the closure of all reference documentation (e.g. ECR, waivers).

Verification of corrective action shall involve appropriate analyses, breadboard or prototype tests, re-performance of qualification, protoflight or acceptance tests, regression testing, or the completion of special tests to ensure that the correction has been accomplished. After completion of the corrective action, the item must again be subjected to the conditions under which the problem/failure occurred and must perform successfully under those conditions.

3.2.3.7 Failure Effect and Cause/Corrective Action Rating

Each P/FR shall be assigned a Failure Effect rating and Cause/Corrective Action rating. These ratings are based on the following criteria:
The Failure Effect Rating is an assessment of the consequence or the impact of the problem or failure if it had occurred in flight. It is not an assessment of the adequacy of the corrective action. Redundancy shall not be considered in making this assessment. The assessment shall be 1, 2, or 3 based on the criteria listed below.

Rating 1: Negligible effect on mission performance and system safety.

(a) No appreciable change in functional capability.
(b) Minor degradation of engineering or science capability.
(c) Support Equipment (SE) or Test Equipment (TE) problem/failure.
(d) SE, TE, or operator induced failure.
(e) Workmanship failures found at initial test opportunity.
(f) Causes negligible operational difficulties or constraints.
(g) Negligible or no reduction in lifetime.

Rating 2: Significant effect on mission performance or system safety.

(a) Appreciable change/degradation in functional capability.
(b) Appreciable degradation of engineering or science capability.
(c) Causes significant operational difficulties or constraints.
(d) Significant reduction in lifetime.

Rating 3: Major or catastrophic effect on mission performance or system safety.

(a) Major change/degradation in functional capability.
(b) Major degradation of engineering or science capability.
(c) Causes major operational difficulties or constraints.
(d) Major reduction in lifetime.

The Cause/Corrective Action Rating is an assessment of the certainty that the exact failure cause has been determined and that the corrective action will eliminate any known possibility of recurrence of the problem/failure in flight.
The assessment shall be 1, 2, 3, or 4 based on the criteria listed below.

(a) Rating 1: Known Cause/Certainty in corrective action.
Analysis, corrective action and verification of correction are considered to have determined the cause and have defined an effective corrective action that has been implemented and verified by test or other demonstration. No known possibility of recurrence.

(b) Rating 2: Unknown Cause/Certainty in corrective action.
The cause could not be completely determined, but an effective corrective action has been implemented and verified by test or other demonstration; or the problem/failure (observed incident) could not be repeated in tests or checkouts. No known possibility of recurrence.

(c) Rating 3: Known Cause/Uncertainty in corrective action.
Analysis, corrective action and verification of correction are considered to have determined the cause, but effective corrective action has not been implemented and verified by test or other demonstration. Some possibility of recurrence exists.

(d) Rating 4: Unknown Cause/Uncertainty in corrective action.
The cause could not be completely determined and no effective corrective action has been implemented and verified by test or other demonstration. Some possibility of recurrence exists.

3.2.3.8 Risk Assessment

Preliminary rating in accordance with Section 2.3.7 shall be assigned within ten (10) working days of the incident date. Final risk ratings shall be assigned prior to closure of the P/FR. In the event of conflict the Mission Assurance Manager determines the disposition of the final risk rating.
P/FRs having a Failure Effect Rating of 2 or 3 coupled with a Failure Cause/Corrective Action rating of 3 or 4 are defined as “potential Red Flag” P/FRs. “Red Flag” P/FRs are those that have full concurrence from all signatories indicating the Project acceptance of the risk. Table 1 gives a matrix representation of the risk ratings for ease of identification.

(a) Development or DP/FRs that are a potential Red Flag or DP/FRs that impact flight hardware or flight software shall be converted to P/FRs and be subjected to the P/FR review/approval process.
(b) Red Flag P/FRs must include a statement regarding the rationale for accepting the residual risk. See Appendix D for the Red Flag summary form.
(c) The JPL Project Manager and the Contractor Project Manager (if applicable) shall review, approve and sign Red Flag P/FR closures to acknowledge understanding and acceptance of the defined residual mission risk.
(d) All Red Flag P/FRs shall be discussed at subsequent formal reviews.

Table A-1 P/FR ratings

Failure Effect			Failure Cause/Corrective Action	
Negligible	1		1	Known cause/Certainty in corrective action. No known possibility of recurrence in flight.
Significant	2		2	Unknown cause/Certainty in corrective action. No known possibility of recurrence in flight.
Major	3	RED FLAG	3	Known cause/Uncertainty in corrective action. Some known possibility of recurrence in flight.
			4	Unknown cause/Uncertainty in corrective action. Some known possibility of recurrence in flight.

A preliminary rating in accordance with 2.3.7 above shall be assigned within 10 working days of the incident date to determine if there are potential Red Flag issues.

3.2.3.9 Safety Rating and Assessment

The Systems Safety Engineer shall review P/FRs to determine if they represent any potentially adverse effects to personnel or hardware safety. P/FRs with a personnel or hardware safety issue shall have a safety risk assessment assigned by the JPL Systems Safety Office and shall be signed by the JPL Systems Safety Engineer and the Contractor Safety Engineer (if applicable). It is the responsibility of each P/FR reviewer to determine that the assigned safety ratings are appropriate.

3.3 Contractor Problem/Failure Reporting Requirements

3.3.1 General

Each Contractor organization external to JPL that is providing hardware and/or software shall establish a system for controlling and monitoring the status of problem/failure reports prepared under its cognizance. The requirements for such a system shall be in accordance with this document. The use of a contractor's problem/failure reporting form requires the approval of the JPL Reliability Engineer and the Project Mission Assurance Manager. Contractors shall pass these requirements down to subcontractors and suppliers.

3.3.2 Liaison and Submittals to JPL

(a) The initial submittal to JPL shall consist of a JPL P/FR Form or equivalent as approved by JPL with at least Section I (Description) completed, or a copy of the Contractor's report as released with initial reporting data sections completed. The submittal shall be sent electronically to the JPL Unified Problem Reporting System (UPRS) or entered directly into the web-based UPRS system within 2 working days of the incident. The UPRS will then electronically inform the Contract Technical Manager and JPL Cognizant Engineer that the report is in the JPL UPRS automated system. The Monthly Technical Progress Reports shall include a summary of P/FRs generated during the reporting period.

(b) Interim submittals to JPL shall consist of updated releases of the Contractor's report and copies of referenced supplemental data and documents. Submittals shall be sent to the JPL UPRS.

(c) The final submittal to JPL shall consist of the Contractor's signed P/FR with copies of referenced supplemental data/documents not previously submitted. Submittals shall be sent to the JPL UPRS.

(d) Prior to submittal of a Contractor signed P/FR to JPL, the verification analysis and corrective action must be reviewed and approved by both the contractor's Project Engineer and the Contractor's Product Assurance Manager. Also, in the case of Red Flag P/FRs, the Contractor's Project Manager must review and approve the P/FR. After receipt of a Contractor signed P/FR at JPL, the report shall be reviewed by the JPL cognizant engineer or the PEM. The P/FR shall not be considered closed by the contractor until it has been approved by the JPL cognizant engineer, the PEM, Reliability Engineer and in the case of red flag P/FRs, the Mission Assurance Manager and Project/Instrument Manager.

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4 ELECTRONIC PARTS ENGINEERING

4.1 Purpose

Every Electrical, Electronic and Electromechanical (EEE) part intended for use in space flight shall be reviewed and approved for compatibility with the intended space environment and mission life. This document defines the baseline parts program requirements for all JPL missions including both spacecraft and instruments. Additional parts requirements may be necessary as a function of mission success requirements.

4.2 Scope

The EEE parts program requirements specified herein shall apply to each organization, both internal and external to JPL, supplying EEE parts used in flight hardware. Instrument providers are required to submit to JPL their Parts Program Implementation Plan. Throughout this document, the term "EEE parts" refers to the flight EEE parts intended for use in flight hardware.

4.3 Technical Requirements

4.3.1 Mission Requirements and Environments

The parts requirements are driven by the mission life requirements, thermal and radiation requirements specified in the Payload Information Package (PIP). All parts requirements shall satisfy the mission environmental requirements as specified in the PIP.

4.3.2 Parts Selection and Standardization Requirements

Only parts of acceptable quality, reliability, and radiation compliance, as demonstrated through test and/or analysis that meet or exceed the mission performance and reliability requirements, will be selected for use. Each supplier of flight electronics and EEE parts will ensure that part selections are appropriate for specific assembly requirements and are consistent with the overall parts program requirements. The availability and cost/risk effectiveness of Level 1 parts shall be considered before COTS parts become the design baseline.

4.3.3 Standard Parts

For the project, standard parts shall be defined as those that meet or exceed any of the following reliability standards:

- NASA GSFC 311-INST-001, Level 1
- MIL-PRF-38534 Class K QML Source
- MIL-PRF-38535 Class V, QML-38535
- MIL-PRF-19500 JANS, QPL-19500
- NASA GSFC 311-INST-001, Level 2,
- MIL-PRF-38534, Class H, QML-38534 with PIND, DPA and radiographics upscreening
- MIL-PRF-38535, Class Q, QML-38535
- MIL-PRF-19500, JANTXV, QPL-19500
- Military Established Reliability (ER) passive devices, Failure Rate Level S or R

4.3.3.1 Non-Standard Parts

Parts not meeting the minimum quality and reliability criteria of standard parts in 4.3.3 are defined as non-standard parts. Unique, custom parts (e.g., ASICs and Custom Hybrids) and

commercial parts (COTS, PEMs, etc.) are considered non-standard. All non-standard parts shall be upgraded/screened to the standards of 4.3.3 and as specified on individual NSPARs (Non-Standard Part Approval Request) by the Parts Engineering and Radiation Specialists. Plastic parts shall be screened and qualified in accordance with JPL D-19426, Plastic Encapsulated Microcircuits (PEMs) Reliability/Usage Guidelines for Space Applications, or contractor equivalent.

4.3.4 Application Specific Integrated Circuit (ASIC) Requirements

4.3.4.1 Digital ASIC Test Requirements

Digital logic circuitry in ASICs (including microprocessor, microcontroller and all custom designs) shall be tested to at least 95% stuck-at fault coverage as is defined by MIL-STD-883, Method 5012. In addition, each major functional element of the design shall be tested to at least 90% stuck-at fault coverage.

Quiescent current (all vector Iddq method) tests shall be based on a set of vectors that will toggle 95% of the nodes. In addition, each major functional element of the design shall be tested to at least 90% node toggle coverage.

Additional tests shall be conducted at room temperature and at maximum rated (hot and cold) temperature that include:

- Operating speed (or maximum testable speed) functional test to verify all functions of the design and,
- DC and AC parametric test vectors in compliance with the ASIC specification.

4.3.4.2 Mixed-Signal ASIC Test Requirements

For Mixed-signal ASICs with large monolithic digital elements that amount to more than 10% of the design and more than 500 gates, these digital elements shall meet the requirements in paragraph 2.4.1.

For Mixed-signal ASICs which are predominantly analog circuits with intermingled flip-flops, registers and counters that amount to less than 10% of the overall design complexity and less than 500 gates, these intermingled digital elements are exempt from the requirements in paragraph 2.4.1.

Analog, digital, and mixed signal ASICs shall be modeled or simulated and compared with test data.

Additional tests shall be conducted at room temperature and at maximum rated (hot and cold) temperature that include:

- Operating speed (or maximum testable speed) functional test to verify all functions of the design and,
- DC and AC parametric test vectors in compliance with the ASIC specification.

4.3.4.3 Custom Hybrid, MCM and HDI Microcircuits

Custom hybrid devices designed and fabricated by non-QML sources shall be in conformance with requirements of Class K reliability level of MIL-PRF-38534. Custom hybrid QML sources shall be in conformance with Class H reliability level of MIL-PRF-38534 with a recommended additional 10-piece Class K element evaluation for each device type. Pre-cap visual inspection

and document review (e.g. element evaluation, burn-in data and rework travelers) prior to seal shall be required for all hybrids.

To ensure high yields in small lot production runs, all substrates for use in custom hybrids or MCMs, shall be subjected to MIL-PRF-38534 substrate element evaluation.

The Hybrid Parts Specialist will identify in-process inspection points commensurate with Project requirements and will be called out in the travelers and inspected by QA.

4.4 Post-Programming Tests for Programmable Devices

For "one time" programmable devices (i.e. PROMs and FPGAs) any device that fails to program correctly on the first attempt shall be rejected without exception. After programming DC parametric and at-speed functional testing shall be performed at three temperatures: at room temperature and maximum specified hot and cold temperatures.

The at-speed functional tests shall verify all functions, operating modes, fault responses (including initialization and resets) and the specified performance of the design.

4.5 Destructive Physical Analysis (DPA) and Residual Gas Analysis (RGA)

DPAs and RGAs shall be performed per the requirements of SSQ25000 of each manufacturing lot date code when required. Ceramic capacitors rated at < 100V and used in < 10V applications shall be subjected to DPA. The dielectric thickness shall be verified to be a minimum of 0.8 mils.

4.6 Particle Impact Noise Detection (PIND)

When required, PIND shall be performed in accordance with MIL-STD-883, Method 2020, Condition “A”. Parts being PIND tested will be subjected to one pass only. Rejects will be removed from the lot and the remainder of the parts will be considered to be acceptable.

4.7 Solid Tantalum Style Capacitor Additional Screening

All solid tantalum capacitors shall be subjected to 100% surge current testing. The CWR type capacitors shall be tested in accordance with test option B of MIL-PRF-55365, the CSS type capacitors shall be tested in accordance with the appropriate slash sheet of MIL-C-39003.

4.8 Radiation Requirements

All parts shall be evaluated for radiation Total Ionizing Dose (TID), Displacement Damage (DD) and Single Event Effect (SEE) sensitivity, relative to the radiation requirements as defined in the Payload Information Package (PIP). Use of existing radiation test data shall require approval by the Radiation Specialist. Where no radiation data are available, all candidate radiation-sensitive parts shall undergo characterization testing and/or lot acceptance testing or be shown by analysis based on test data to be compatible with the application radiation levels. The effects of Total Ionizing Dose and Displacement Damage are not independent. The combined effects of TID and DD shall meet the RDF requirements of the PIP.

4.8.1 Radiation Lot Acceptance Testing (RLAT)

Device types that are not fabricated on a radiation hardened process shall be subjected to RLAT. Use of existing radiation test data in lieu of RLAT will be approved by the Radiation Specialist.

Radiation related testing and evaluations shall be done in accordance with MIL-STD-883, Method 1019 or JPL approved equivalent.

4.8.2 Total Ionizing Dose (TID) Level

All flight parts shall operate within post-irradiation specification limits following exposure to the expected total dose environment including the RDF specified in the PIP. Radiation characterization should be performed beyond the total dose environment, including the RDF as defined in the PIP, to account for lot variation. The TID radiation environment includes all radiation components, X-rays, gamma rays, protons, electrons, neutrons and heavy ions.

4.9 Enhanced Low Dose Rate Sensitivity (ELDRS)

All linear bipolar and BiCMOS ICs shall be evaluated for susceptibility to ELDRS by the Radiation Specialist. Where testing is required (i.e., when no recent data exists), tests shall be performed at a dose rate less than or equal to 0.005 rad(Si)/s to the required radiation level, as defined in the PIP. Testing shall be in accordance with MIL-STD-883, Method 1019.7 except that the dose rate shall be as specified above. Furthermore, such testing shall be performed on both biased as well as unbiased parts, since in many cases, the unbiased case is the most sensitive. Parametric degradation due to ELDRS should be accounted for in the circuit worst case analysis.

4.9.1 Displacement Damage (DD)

All devices shall be evaluated for susceptibility to DD. All devices shall operate within specification limits following exposure to the expected environment, including the RDF, as specified in the PIP Potentially susceptible parts include, but are not limited to, optical devices, photo-detectors, charge-coupled devices, optocouplers, LEDs, laser diodes and precision bipolar linear devices.

4.9.2 Single Event Upset (SEU)

All microcircuits containing bi-stable elements (e.g. flip-flops, counters, RAMs, microprocessors, etc.) shall be characterized so that an upset rate calculation can be performed. All parts shall be tested to a fluency of 10^7 ions/cm².

The requirements for parts SEU acceptability are:

- No upsets observed during SEU testing to an LET of 75 MeV-cm^2/mg, or
- Verification of device bit error rate of 10^{-10} per day or better in the galactic cosmic ray environment

4.9.3 Single Event Transient (SET)

Single Event Transients (SET) occur on both digital and analog microcircuits due to protons and heavy ions. Parts for which an SET would unacceptably impact system operation shall be evaluated for SET.

4.9.4 Single Event Latchup (SEL)

All CMOS and BiCMOS devices (including those with epitaxial layers) shall be subject to latchup evaluation. When testing is required, parts shall be tested to a fluence of 10^7 ions/cm² or after 100 events have been recorded, whichever occurs first.. The beam angle will not exceed 60 degrees and test ions will have an effective range greater than 35 microns. Bias will be at

specified maximum voltage. Tests will be performed at room ambient and at elevated temperature of 125°C or the maximum specified operating temperature of the part.

The requirements for parts SEL susceptibility are:

1. No latchup to an LET of 75 MeV-cm^2/mg, or
2. Verification that the device latchup probability in the mission environment be < 10^{-4} /device-year for parts that exhibit latchup between 35 Mev-cm^2/mg and 75 MeV-cm^2/mg.

4.9.5 Single Event Gate Rupture (SEGR)

All power MOSFETs operated in the off-mode may be susceptible to, and shall be evaluated for, single event gate rupture (SEGR) at the worst case application V_{GS} and V_{DS} values. The survival voltage (V_{DS}) shall be established from exposure to a minimum fluence of 10^6 ions/cm² of an ion with a minimum LET of 37 MeV-cm^2/mg and with a range based on device voltage rating as shown in the table below, Table 5–1. Testing will be performed with normal beam incidence and at room ambient temperature. The application voltage shall be derated to 75% of the established survival voltage.

Table 5-1 Ion Range as a Function of Rated V_{DS}

Maximum Rated Drain-Source Voltage	Minimum Ion Range (microns)
≤ 100	30
100 to 250	40
250 to 400	80
400 to 1000	200

4.9.6 Single Event Burnout (SEB)

All power transistors operated in the off-mode may be susceptible to, and shall be evaluated for, single event burnout (SEB) at the worst case application V_{BE} (for bipolar devices) or V_{GS} (for MOS devices). The survival voltage (V_{CE} or V_{DS}) shall be established from exposure to a minimum fluence of 10^6 ions/cm² of an ion with a minimum LET of 37 MeV-cm^2/mg and with a range that is sufficient to penetrate the depletion depth of the device at its maximum voltage (the previous table is applicable for MOSFETs). Testing will be performed with normal beam incidence and at room ambient temperature. Test requirements for single event burnout are similar to those for SEGR except that the drain current (or collector current for bipolar transistor) must be measured to determine if burnout occurs. The application voltage shall be derated to 75% of the established survival voltage.

4.10 Electronic Parts Application and Derating

4.10.1 Parts Derating

Each part used in flight equipment shall be applied in a manner such that the temperatures experienced and electrical stresses produced when it is operating do not exceed the derating criteria defined in JPL D-8545.

4.10.2 Handling / Storage / Electrostatic Discharge (ESD) Control Requirements

ESD damage or degradation may occur in static-sensitive electronic parts during handling of the parts from procurement through incoming inspection, testing, screening, storing and final assembly/test. To protect static-sensitive parts from ESD, handling of parts shall be controlled by the requirements of JPL D-1348, or JPL approved equivalent.

4.10.3 NASA Advisories and Government Industry Data Exchange Program (GIDEP) Alerts

All hardware-delivering design agencies, both internal and external to JPL, shall assure the implementation of a system to review NASA Advisories and GIDEP Alerts, take appropriate action, and notify their respective Alert coordinators of significant parts problems that may warrant issuance of new Alerts. This activity shall continue throughout the Project's lifecycle.

Design agencies which do not presently receive Alerts directly should request distribution from the Defense Supply Center Columbus (DSCC), GIDEP Operations Center or the JPL Alert Coordinator. The design agency is responsible for reviewing all Alerts, and for immediately reporting corrective action for applicable Alerts (i.e. for parts used in the hardware) to the project and appropriate Alert Coordinator.

The design agency will present a review matrix of all Advisories and Alerts at the CDR, and at the Pre-Ship Review, that lists all of the Alerts which are pertinent to the parts used in the flight design, the possible impact should the part fail, and the actions proposed and those taken. It is the responsibility of the design agency to avoid the use of defective parts in flight equipment.

4.10.4 Failure Analysis

Failure analysis shall be performed for all part failures that occur subsequent to screening. The Parts Interface Engineer will be notified in writing within 3 days of any failure occurrence. The only exceptions are parts damaged by human error (e.g., improper installation). Analysis shall be carried to the point that lot dependency of the failure mode can be determined. Failure analysis reports will be written to document the analysis approach, the determined failure mode and mechanism (i.e., cause) responsible for the failure, and the corrective actions required to prevent recurrence of the failure.

4.11 Contractors

JPL Subcontractors, their subcontractors, Partners, and Instrument providers shall be subjected to all requirements of this document. All System contractors, JPL subcontractors and Partners shall submit to JPL, for review and approval, an implementation plan addressing how they will meet the technical requirements of this section and shall include reference to the CDRLs and DRDs. The implementation plan shall also address how these requirements will be flowed down to sub-tier contractors. This implementation plan shall be submitted to JPL for review and approval. All contractor parts lists shall be reviewed and risk rated by JPL.

5 MATERIALS & PROCESSES

5.1 Requirements

5.1.1 Selection of Materials and Processes

All materials and processes shall be qualified for the application in which they are used. Issues of flight qualification are very application specific and shall be reviewed on a case-by-case basis. In the event that a designer does not have appropriate data to indicate the suitability of a material or process, the MSL M&P Engineer and the hardware Cognizant Engineer shall generate a qualification/ evaluation plan.

5.1.2 Standard Materials and Processes Selection

JPL Document STD-00009 and MSFC-HDBK-527/JSC 09604 are recommended as sources for material selection data. The listing of a material in JPL Document STD-00009 or MSFC-HDBK- 527/JSC 09604 does not mandate blanket approval for all applications. The use of a listed material or process may be additionally restricted due to molecular or particulate contamination, magnetic properties, radiation susceptibility, electrostatic discharge properties electromagnetic interference and other environmental or operations requirements. The particular application for each material shall be reviewed and approved by the MSL M&P Engineer.

5.1.3 Submittal of Material Identification and Usage Lists

Material Identification and Usage Lists (MIULs) for materials and processes used for applications including structural members, mechanical parts, packaging, cabling, and fasteners shall be submitted by all hardware Cognizant Engineers (JPL, contractors, and suppliers). These forms (See Appendix A), or JPL-approved equivalent contractor forms, shall be filled out and submitted for approval by the MSL M&P Engineer. Preliminary MIULs should be submitted to the MSL M&P Engineer as soon as practicable in the design and engineering processes and in accordance with contractual requirements established by JPL and its contractors. Submittal of MIULs should occur one month prior to the Preliminary Design Review and one month prior to the Critical Design Review (CDR). Any open or unresolved issues are to be identified at the PDRs and CDRs. Subsequent to the CDRs, MIULs shall be updated as required and submitted as soon as practicable to the MSL M&P Engineer for review and approval. In the case of design changes, the design agency shall submit the changes to the MSL M&P Engineer for approval.

5.1.4 Classification of MIUL Submittals

The MSL M&P Engineer will classify MIUL submittals according to the following criteria. The classification given to a material or process shall be based on the acceptability of the material or process, application and controlling documentation.

1. Class 1 – Acceptable

   The identified design item combination (material/condition or cure), including specified manufacturer, is acceptable when used in the indicated application and under the control of the listed documentation, and the evaluation/qualification data and applicable documents are available and are all acceptable.

2. Class 2 – Qualified Acceptable

The identified design item combination (material/condition or cure), including manufacturer, is considered qualified acceptable when used in the indicated application, quantity, and under the control of the listed documentation, even though only limited evaluation/qualification data are available. No additional submission of data is considered warranted to improve the classification.

Class 3 – Provisional

This designation is used as a temporary classification for a design item combination (material/condition or cure) where the evaluation/qualification data or applicable documentation are available, but where a decision regarding its acceptability has not yet been made. Eventual Class 1 or Class 2 assignment is anticipated and design may proceed subject to final reclassification, although the reclassification as Class 4 is not excluded. Most Class 3 combinations should be reviewed for reclassification as either 1, 2, or 4 prior to PDR of each system. All remaining Class 3 combinations shall be reclassified prior to each subsystem's CDR.

Class 4 – Unacceptable

One or more elements of the design item combination (material/condition or cure) are considered unacceptable for the indicated application. The Project Manager or his/her designee prior to or at the CDR shall review all Class 4 design item combinations. The use of a Class 4 design item requires a Project approved waiver.

5.1.5 Materials Usage Agreements (MUA)

Material Usage Agreement (MUA) forms (See Appendix B) shall be prepared by all MSL hardware Cognizant Engineers for applications of materials and processes that do not meet the requirements specified in this document. For JPL designed hardware, MUAs shall be submitted to the MSL M&P Engineer for approval. For non-JPL designed hardware, MUAs shall be prepared for review and approval of the contractor M&P Engineer. All contractor approved MUAs shall then be submitted to the MSL M&P Engineer for final approval. If approval is not granted and use is still desired, a waiver request shall be submitted. The requirement for submittal of waivers is applicable to both JPL and contractors.

5.1.6 Waivers

For design items that have been rated Class 4, Unacceptable or MUA has not been approved and the use of such items is still desired, a waiver request shall be submitted to JPL per JPL Waiver Request and Approval Process, JPL D-15032, for review and approval.

5.2 Materials and Processes Review

5.2.1 Evaluation

Materials and Processes shall be assessed by the combined consideration of three factors: 1)

Material and Process type, including manufacturer, 2) Specific design, application or requirement, and 3) documented control provisions.

5.2.2 Thermal Vacuum Stability and Outgassing

Material thermal vacuum stability and outgassing behavior shall be compatible with the mission environment and shall not adversely affect mission performance. Materials shall meet the requirements of JSC-SP-R-0022A. Only those organic materials with a total mass loss (TML) that does not exceed 1.00 percent and a collected volatile condensable mass (CVCM) that does not exceed 0.10 percent, when tested in accordance with ASTM E595 or contractor equivalent procedures, shall be considered for use. There is a term called water vapor regain (WVR) as organic materials after vacuum outgassing test will re-absorb water when placed in atmosphere. This WVR should be subtracted from the TML for rating purposes.

Some materials that meet JSC-SP-R-0022A may not be satisfactory, particularly in areas that are extremely sensitive to contamination. In such instances, special treatments such as prolonged thermal-vacuum bake-outs shall be employed to ensure that material outgassing will not adversely affect MSL mission performance. Such thermal-vacuum bake-out procedures shall be developed with and have the approval of the MSL Contamination Control Engineer.

5.2.3 Flammable Materials

Materials shall be non-combustible or self-extinguishing to the greatest extent possible and conform to the flammability requirements of NASA-STD-6001. Rationale for use of and acceptability of flammable materials in amounts over 454 grams (1 pound) or where the longest dimension is greater than 30.5 cm (12 inches) shall be submitted in a MUA. Where flammable materials must be used, the standard hazard elimination and control requirements apply, as follows: (a) two failure tolerance on ignition sources, (b) physical separation of the flammable material from ignition sources, and (c) elimination of flame propagation paths.

5.2.4 Galvanic Corrosion

In applications where dissimilar metals will be in intimate contact, the metals shall be compatible with regard to galvanic corrosion to the greatest extent possible. Methods to minimize the potential for galvanic corrosion shall be implemented. MIL-STD-889 shall be used as a guideline for controlling dissimilar metal interactions.

5.2.5 Stress Corrosion Cracking

The use of A or B rated materials per MSFC-HDBK-527/JSC-09604, or Table I and II materials per MSFC-STD-3029, is acceptable. The materials listed in Table III, or "C" rated, should be considered for use only in applications where it can be demonstrated conclusively that the probability of stress corrosion is remote. If Table III or "C" rated materials or materials not listed in MSFC-STD-3029 or MSFC-HDBK-527/JSC-09604 are to be used, a stress corrosion evaluation form (See Appendix C) as part of an MUA shall be submitted to the MSL M&P Engineer for approval.

5.2.6 Welding

All welding operators on automatic, semi-automatic, or manual welding shall be qualified in accordance with MIL-STD-1595 or a qualification procedure approved by the MSL M&P Engineer. Weld rod or wire used as a filler metal on structural parts shall be fully certified and documented for composition, type, heat number and manufacturer, and supplied to provide

traceability to the end use item. All fracture critical welds shall be non-destructively inspected per the requirements of NASA-STD-5003.

5.2.7 Non-Destructive Inspection

Non-Destructive Evaluation (NDE) shall be conducted on highly stressed and mission or safety critical items. Non-destructive inspection (NDI) techniques shall meet the requirements of MIL-I-6870 (or contractor equivalent) for magnetic particle, radiographic, eddy current, and ultrasonic inspection. Dye penetrant inspection shall meet the requirements of ASTM E1417 (or contractor equivalent). Etching of 0.0002 to 0.0004 inches prior to inspection is required. Specifications shall be reviewed by the MSL M&P Engineer.

5.2.8 Shelf-Life Limited Materials

All materials with shelf-life sensitivity shall be used within their shelf-life limits. Extending the shelf-life of a material shall be in according to the recommendation of the suppliers. If there is no supplier's recommendation available and the extension of shelf-life is necessary, an agreement shall be sought between Contractor Materials Engineer and JPL MSL Materials and Processes Engineer.

5.2.9 Radiation Resistance

Materials used for MSL flight hardware shall be able to withstand the radiation environment specified in the MSL PIP with less than twenty percent degradation in their applicable properties. In applications where the estimated radiation dosage exceeds the twenty percent degradation level or is greater than the available test data, shielding shall be used. In assessing materials for space environmental resistance, the effects of vacuum ultraviolet, ultraviolet, gamma ray, electron, neutron and proton radiation shall be considered. In cases where there are no available data, testing may be required.

5.2.10 Electrical Arc-Tracking Resistance

Electrical wire insulation, wire accessories and materials in contact with electrical circuitry shall not be capable of arc-tracking due to electrical discharges. The use of materials that are susceptible to arc-tracking shall be documented in a MUA. If their use cannot be avoided, care shall be taken in the handling of the material to minimize the possibility of arc-tracking. In such cases, the amount of power shall also be limited.

5.2.11 Hazardous Materials

All materials that are exposed to toxic or hazardous fluids shall be evaluated for compatibility with that fluid in their intended application. All materials that are exposed to a hazardous fluid shall be rated compatible per MSFC-HDBK-527/JSC-09604. Materials rated 'A' are acceptable, while those rated 'B' shall be batch tested. Existing data showing compatibility may be used if they are submitted to JPL for review.

5.2.12 Magnetic Materials

The use of magnetic materials shall be limited, as necessary, to meet flight system hardware or instrument magnetic requirements.

5.2.13 Static Charge Sensitivity

Materials shall be evaluated to determine if their Electrostatic Discharge (ESD) characteristics are compatible with project requirements per JPL D-1348.

5.2.14 Lubricants

Suppliers of any lubricated hardware shall prevent contamination of that hardware and any critical adjacent items (i.e., mirrors, lenses, other experiments). This requirement shall encompass contamination by any means, including but not limited to outgassing, lubricant creep or by the natural wetting and wicking tendencies of the lubricant. Graphite or lubricants with significant amounts of graphite are abrasive in vacuum and shall not be used for flight hardware.

5.2.15 Fungi

Flight hardware shall be designed so that materials are not nutrients for fungi except when used in permanent hermetically sealed assemblies and other accepted and qualified parts. Other necessary fungi nutrient material applications shall require treatment by a method which will render the resulting exposed surface fungi resistant. The criteria for the determination of fungi and moisture resistance shall be those contained in MIL-STD-810.

5.2.16 Metal Migration and Whisker Growth

Metal migration has been reported for silver, gold, copper and tin on devices such as integrated circuits and circuit boards. Metal migration occurring electrolytically involves:

a. Electro-dissolution
b. Ion transport
c. Electro-deposition

The metallic material is oxidized, producing ions that are transported through an electrolyte by electrical migration, diffusion, or convection. Cathodic reduction of the metal ions then occurs at dendritic nucleation sites. Failure is caused by the resulting conductive path formed across the dielectric between biased electrodes. This phenomenon shall be taken into consideration in electronic applications.

Whiskers can grow on tin, zinc, cadmium, and silver and can grow long enough to cause electrical shorts in circuitry. Use of these materials in electronic applications shall be monitored and modified (e.g., with additives or substitution of alloys for pure metals) to avoid the phenomenon of whisker growth.

Avoid the use of pure tin plated components if possible. Utilization of procurement specifications that have clear restrictions against the use of pure tin plating is highly recommended. Alloys of tin and lead are generally considered to be acceptable where the alloy contains a minimum of 3% lead by weight.

Review all specification drawings and procurement documents to assure that the prohibited coating is not specified and revise drawings as necessary to specify the correct alloy composition and to prohibit pure tine or tin alloy (greater than 97% Sn by weight) coatings. As a redundant measure, designers should utilize protective methods such as conformal coating, foam, or

insulators to prevent short circuits due to whiskers. (Certain circuit designs such as radio frequency or RF may not be compatible with coatings, foam, etc.)

Post procurement verification that pure tin plating is not supplied should be exercised. Users are advised to analyze the plating composition of the products received as an independent verification. Typically, verification of correct tin alloy composition on parts and materials is by X-ray fluorescence, or scanning electron microscopy (SEM) with energy dispersive X-ray fluorescence (EDAX). Consult M&P engineer for recommendations of specific techniques.

5.2.16.1 Fasteners

Fasteners used in the MSL project shall be selected based on the criteria contained in JPL DocID 61256. Fasteners shall be selected from the JPL Preferred Fastener List (PFL) to the greatest extent possible. Where fasteners are used in critical applications, JPL Process Specification FS 511316, Detail Specifications for Qualification of Critical Fasteners, shall be followed. The JPL Fastener Specialist shall approve all fastener selections.

5.2.16.2 Materials

All threaded fasteners shall be fabricated from materials that have a high resistance to Stress Corrosion Cracking (SCC). Materials that have moderate or low resistance to SCC are not acceptable for use as fasteners.

5.2.16.3 Materials for Fracture Critical Fasteners

Fracture critical fasteners shall not be fabricated from materials which have low fracture toughness (a material is considered to have low fracture toughness if the ratio of fracture toughness to tensile yield strength, KIC/Fty is less than 1.66 $mm^{1/2}$ (0.33 $in^{1/2}$)). Fracture critical fasteners shall not be fabricated from Ti-6Al-4V.

5.2.16.4 Fastener Traceability

All threaded fasteners used for flight applications shall be certified. Fasteners used in structural applications shall have critical certification, requiring documentation of chemical and physical test results traceable to both heat and lot numbers, as described in JPL DocID 61256. Fasteners used in non-structural applications shall have, as a minimum, a certificate of conformance.

5.2.17 Design Allowables for Structural Parts

Statistically based material design allowables shall be used for structural analysis of MSL flight hardware to the greatest extent possible. MIL-HDBK-5 and MIL-HDBK-17 are primary sources of statistically based material property data. A-basis allowables shall be used for pressure vessels and for all metallic structures. A-basis allowables shall also be used for structures where failure of a single load path would result in loss of structural integrity. For redundant structures where failure of a structural elements would result in a safe redistribution of applied loads to other load-carrying members, “B” basis materials allowables may be used. Specification allowables (“S” basis allowables) may be used for materials in lieu of “A” and “B” basis allowables where lot-to-lot testing is a specification requirement. Coupon testing shall be conducted and all test values shall be equal to or higher than the “S” basis allowable. If a different protocol for design allowables is followed, a justification shall be presented to the MSL M&P Engineer.

5.2.18 Material Traceability

Traceability of all materials incorporated into flight hardware shall be maintained. Records of material manufacturer, date of manufacturer, batch and lot identification numbers, applicable materials and process specifications, expiration date, and purchase order numbers shall be recorded. For the acceptance and traceability of flight bulk materials, including materials received on spools, in bottles, cans or kits, Quality Assurance Procedure QAP 44.10, 'Receiving Inspection and Identification of Flight Bulk Materials', or contractor's equivalent, shall be followed.

5.2.19 Qualification of NonStandard Materials and Processes

Qualification plans and associated data for non-standard materials and processes shall be submitted to JPL for review and approval. The data shall also be included in the MIUL.

5.2.20 Alerts

Materials issues identified by NASA and/or JPL Lessons Learned and/or by Government/Industry Data Exchange Programs (GIDEP), NASA Safety, or JPL Quality Alerts shall be evaluated for relevance to the MSL Project.

6 CONTAMINATION CONTROL

6.1 General

Contamination Control requirements are derived from specific conditions associated with the flight system and instruments, regarding functional limitations, optical performance degradation requirements, thermal surface property requirements, planetary protection needs, as well as safety and reliability requirements. The following general deliverable hardware contamination requirements are delineated in the Project Contamination Control Plan, and can be superceded by requirements associated with specific hardware.

6.2 Assignment of Responsibility

It is the responsibility of the hardware supplier to deliver hardware capable of meeting all Contamination Control Requirements. The hardware supplier is also responsible for decontamination performance of hardware designed to have such capability.

6.3 Documentation Requirements

The hardware supplier is required to provide necessary contamination control compliance documents prior to hardware acceptance.

6.4 Acceptance Requirements

Hardware that meets the general hardware contamination requirements and specific requirements shall be deemed acceptable by Contamination Control.

6.5 General Deliverable Hardware Contamination Requirements

6.5.1 Design Requirements

No entrapped volumes shall be permitted with the exception of hermetically sealed volumes. Exposed adhesive lines shall not have direct view of any optics. Venting shall be from a more

stringent area to a lesser stringent area. Any potential for vent impingement shall be noted and its impact assessed by the responsible contamination engineer. Enclosed volumes, such as electronics boxes, spacecraft compartments, and multi-layer insulation that vents to the external environment, shall be designed to vent through screen filters (0.3 microns, absolute).

6.5.2 Material Requirements

All materials used shall be space qualified, shall not shed particles and shall have the following outgassing characteristics: 1) less than 1 percent total mass loss (TML) and less than 0.1 percent collected volatile condensable mass (CVCM) per ASTM method E-595, and 2) Additional, more stringent, outgassing requirements delineated in specific hardware contamination control requirements. Outgassing data regarding all adhesives, mold release agents and lubricants shall be submitted to the contamination and materials engineers for approval prior to use.

6.5.3 Cleaning Requirements

All hardware shall be cleaned to required levels prior to vacuum outgassing measurement. All hardware surfaces with the exception of optics shall be capable of withstanding isopropyl alcohol and ethanol cleaning. Hardware suppliers are also required to recommend at least one type of cleaning solvent for deliverable hardware. All hardware surfaces with the exception of optics shall be capable of withstanding HEPA vacuum brushing.

6.5.4 Surface Cleanliness Requirements

All optical components and associated hardware shall be delivered with surface cleanliness at MIL-STD 1246C level 150A or better. All other components shall be delivered with surface cleanliness at MIL-STD 1246C level 300A or better.

6.5.5 Bakeout Requirements

The following hardware shall undergo thermal-vacuum conditioning, i.e., “bakeout”:

Solar Arrays
MLI
Antenna(s)
Electronics Boxes
Harnesses and Cabling
Spacecraft Structure
Painted Optical baffles
Any component with a view to a contamination critical surface

*Bakeout times and temperatures will be prescribed in the Mission Contamination Control Plan. Pressure for bakeouts shall be $< 5x10^{-5}$ torr.

6.5.6 Outgassing Verification Requirements

Hardware in contamination critical locations shall be required to pass outgassing requirements as delineated in specific hardware contamination control requirements.

Solar Arrays (measured along the vented edge, cell side, and back [painted] side)

Integrated instrument payloads (measured at primary vent)

Spacecraft bus (measured at primary vent)

Any component with a view to a contamination critical surface

Molecular outgassing from hardware at its maximum service temperature plus 10 (+/-2) degrees C in a vacuum shall not exceed a rate of 1 x 10^{-7} g/cm^2 hour. This will be measured by a temperature-controlled quartz crystal microbalance (TQCM) operating at 10 +/-2 degrees C below the coolest sensitive surface temperature. The hardware shall be certified at its measured outgassing rate and should be placed in an appropriate clean container immediately after the measurement test. Exposing hardware to an uncontrolled environment after measurement can invalidate the outgassing certification. Hardware thermal vacuum bake out shall be used to achieve the desired outgassing rate.

6.5.7 Protective Covers & Storage Containers

Clean removable cover(s) shall be provided for any hardware that has the potential to accumulate environmental contamination fallout. Clean containers shall be provided for the transportation and storage of deliverable hardware. The cleanliness of cover and container surfaces facing the hardware shall be maintained at the same level as the hardware itself.

6.5.8 Facility Requirements

Hardware manufactured in areas exceeding the ISO-14644-1 Class ISO 8 environment should undergo proper cleaning before assembly. Any assembly excluding optics shall be made in an ISO-14644-1 Class ISO 8 or better environment. Final preparation of optical assemblies should occur in an ISO-14644-1 Class ISO 7 or better environment. An ISO-14644-1 Class ISO 5 or better environment with vertical down-flow tent or clean bench should be used for installing optical elements and open optical assemblies.

6.5.9 Contamination Non-Entrapment Requirements

Hardware shall not entrap contaminants at any stage of the hardware buildup. Areas that become inaccessible for cleaning at higher levels of assembly shall be verified to meet applicable cleanliness requirements prior to final closeout.

6.5.10 Variance from Requirements

Variance from contamination requirements can be made: 1) by substituting with comparable requirements, 2) by an assessment that concludes impact of the variance to governing project requirements is acceptable.

6.6 Specific Hardware Contamination Control Requirement

In addition to meeting the general deliverable hardware contamination control requirements, deliverable hardware must meet any additional, specific contamination control requirement(s) delineated in the Mission Contamination Control Plan and hardware-specific contamination control plans.

7 HARDWARE QUALITY ASSURANCE

7.1 Scope

This section defines the detailed hardware quality assurance requirements for contractors, vendors, and external suppliers supporting the MSL Project. Changes to this plan require approval by the MSL Project and Mission Assurance Management.

7.1.1 Introduction

This Quality Assurance Plan details the quality assurance requirements and activities to be implemented during the design, fabrication, test, and delivery of the Mars Science Laboratory (MSL) Payload Instruments. Instrument providers are required to provide to JPL a Quality Assurance Plan indicating how the requirements contained herein are to be implemented and how they are flowed down to subcontractors.

7.1.2 Purpose

This plan defines the detailed quality assurance requirements and activities to be implemented during the formulation, design, build, assemble and test (DBAT) phases of the MSL Project. Personnel responsible for implementing this plan shall provide any remedial and preventive measures that are necessary to assure the delivery of acceptable flight hardware. Provisions of this plan are applicable to all participating JPL Technical Divisions, JPL partners, contractors and/or instrument suppliers. Specific guidance for individual contractors and suppliers shall be determined jointly by a MSL engineering, procurement, and quality assurance representatives, and shall be documented in accordance with JPL's product delivery system requirements or JPL approved equivalent. This Plan recognizes the following elements as essential for an effective Quality Assurance program:

- Early technical documentation review by Quality Assurance Engineering
- Concurrent QA engineering
- Planning and management of the quality effort and the definition of quality tasks
- Early involvement of Quality Assurance Engineering at suppliers prior to contract/purchase order award
- Provisions for the detection and correction of deficiencies that could result in unsatisfactory quality and/or failure

Quality Assurance personnel will participate in preliminary and critical design reviews, design peer reviews, inheritance reviews, manufacturing readiness reviews, pre-environmental test reviews, hardware certification reviews and pre-shipment acceptance reviews. Quality Assurance personnel shall review Interface Control Drawings and all MSL Top Assembly Drawings.

7.1.3 Applicability and Source

All quality task elements that pertain to Flight, Non-flight, Test, and Ground Support Equipment for Payload Instruments are governed by this Plan. The contents of this Plan represent the application of selected quality publications, and requirements.

JPL's quality system is currently certified to the requirements of ISO 9001, the International Standard for Quality Management Systems. All Payload Instrument contractors and sub-tier contractors shall either be ISO 9001 certified, compliant or have an ISO 9001 equivalent Quality Management System. If they are not, the MSL Quality Assurance Lead Engineer and the MSL Mission Assurance Manager shall make a risk assessment and decide upon appropriate risk mitigation to be implemented.

The quality assurance activities defined in this plan shall be accomplished and/or validated by

JPL or the appropriate Instrument-supplier QA personnel.

Instrument Contractor quality assurance activities shall be defined and controlled by contractor quality assurance plans, which either pre-exist or are prepared in accordance with the appropriate procurement documents. The JPL MSL Quality Assurance Engineer (QAE) for any procurement will review and approve any required contractor quality documentation.

7.2 Applicable Documents

7.2.1 General

All hardware using this Quality Assurance Program Plan shall adhere to the quality requirements called out in this Plan (Refer to the applicable documents table at the beginning of this document).

7.3 Quality Management System

All instrument contractors and sub-tier contractors shall be ISO 9001 certified or have an ISO 9001 equivalent Quality Management System.

It is the responsibility of the instrument contractor to flow down JPL quality requirements to sub-tier vendors and to ensure that sub-tier vendors supporting the MSL Project produce hardware and services that meet JPL quality requirements. Contractors are responsible for qualifying their sub-tiers prior to contract award and for the monitoring and quality of parts produced by sub-tier vendors.

Notification of meetings, reviews, testing, test set-ups, inspection points, and other activities that require JPL involvement shall be given to the JPL representative in advance. Based on the manufacturing and inspection flow plan provided by the contractor's QA manager/lead, the assigned JPL QA representative will determine inspection points that require JPL QA to witness or verify. Contractors shall provide JPL QA a minimum of three working days notice for itinerant source inspections. A decision regarding supporting a Payload Instrument quality task, by itinerant or resident-QA basis, will be determined early in the Project life-cycle by agreement between the MSL Mission Assurance manager and Lead QAE.

7.4 Quality Assurance Program

7.4.1 Initial Quality Planning

7.4.1.1 Review of Project Documents

Quality planning will begin with participation by Quality Assurance personnel in the review and generation of inputs to the governing project requirement documents.

7.4.1.2 Pre-Procurement Activity

For Instrument provider subcontracts, the Lead QAE and the Procurement Quality Assurance Group(PQA) will work together it supporting the implementation of the procurement phase of the Project, by participation in the following areas of activity:

- Review procurement documentation, including Requests for Proposals (RFPs), Statements-Of-Work (SOWs), Procurement Requisitions and Equipment Specifications to ensure appropriate quality provisions and clauses are defined,

including Contractor End-Item-Data-Package requirements, DRDs and CDRLs.

- Provide the technical divisions and the procurement divisions with information concerning contractor quality system capabilities derived from previous and current quality efforts.
- Ensure contractor Quality Plan compliance to procurement requirements.
- Perform Vendor Surveys at instrument suppliers.

7.4.2 Training and Certification

Personnel performing hands-on fabrication, assembly and inspection of flight hardware shall be trained and certified to the requirements of NASA 8739.2 and .3, or contractor-equivalent document. Quality Assurance shall verify that all certifications are current and valid.

7.4.3 Change Controls

Change control shall be accomplished in accordance with the MSL Configuration Management Plan. Unless otherwise specified by the contract, the Project change-control requirements shall be flowed down to contractors. All documents shall be controlled using the procedures set forth in the MSL Project Configuration Management Plan. Quality Assurance shall participate in change control

- Maintaining master redline drawing sets, when necessary
- Verifying all approved changes are properly incorporated/implemented
- Verifying product as-built configuration

Documents pre-released or not released will be documented in accordance with the MSL Configuration Management Plan.

7.4.4 Contractor Surveillance

JPL Quality Assurance Engineers shall be assigned on a resident or itinerant basis at each contractor facility, as required. The activities will include, but are not limited to:

- Monitoring and auditing contractor quality assurance activities to assure compliance with the JPL approved contractor Quality Assurance Plan, Contract Statement-of-Work, Workmanship Standards and any other contract-binding documentation requirements.
- Participating in contractor hardware design reviews.
- Establishing and performing JPL QA mandatory hardware and documentation inspections at the contractor facility utilizing contractor manufacturing and inspection flow plans, and instructions approved by JPL.
- Monitoring Acceptance Test and design qualification test activities.
- Participating in the disposition of nonconforming material and acting as “Government Representative” on contractor Material Review Boards (MRB). JPL QA is a designated NASA Quality Representative.
- Performing final inspection at the contractor facility prior to hardware delivery to

JPL.

- Verifying the accuracy and completeness of the contractor End-Item Data Package (EIDP).
- Preparing a Final Inspection Report reflecting the hardware and documentation status.
- Reviewing and approving Supplier critical processes.
- Participation in scheduled management meetings at the contractor facility.
- Participation in supplier Fabrication/Manufacturing Readiness Reviews.
- Status-reporting back to the JPL Office of Quality Assurance and designated Project personnel.

7.4.5 Procurement Controls

When parts or materials have their inspectable attributes covered and cannot be adequately inspected at JPL, or when they are determined to be critical processes for high-risk items, JPL QA source inspection shall be performed at the supplier's facility. Records of inspection and tests performed at source will be maintained as part of the Hardware End Item Data Package (EIDP).

7.4.6 Procurement Document Controls

JPL Quality Assurance will review procurement documentation such as contracts, Purchase Orders, Statements-of-Work (SOW), Contract Data Requirements List (CDRL), Data Requirement Description (DRD) and specifications. Typically, each Contract has a set of Quality Assurance CDRLs and DRDs. They are: Contractor QA Plan (including ESD Plan), End Item Data Package (EIDP) requirements, and QA deliverable documentation such as: Inspection and Test Flow Charts, Contractors Critical Process Procedures and Workmanship Standards.

7.4.7 Raw Materials Controls

Suppliers of raw materials are required to supply certifications indicating that materials being provided are in compliance with the requirements of the procurement documents. Reports of tests required to determine conformance to applicable specifications and drawings are required for all flight hardware when requested by the cognizant hardware engineer or quality engineer, and shall be included as required deliverable documentation.

When necessary, these reports are verified by source inspection or by independent tests performed in addition to the supplier reports. When raw material is found to be non-compliant, it shall be identified and segregated from acceptable material. An Inspection Report shall be generated and disposition entered and concurred with prior to the material being released.

Material certifications will be obtained from material suppliers for all flight and design qualification hardware. At minimum, a Certificate of Conformance, signed by supplier QA, shall be obtained. In the absence of material certifications that are neither delivered to JPL nor on-file at the suppliers' facility, the materials will be qualified by test.

7.4.8 Receiving Inspection

Receiving inspection shall be performed on all flight-received materials and hardware. The

cognizant engineer is responsible for notifying Quality Assurance upon receipt of flight materials and hardware. JPL policy requires the reporting of discrepant deliveries within five (5) days of delivery. The hardware cognizant engineer(or their delegate) shall notify quality assurance of the receipt of flight hardware, support equipment that interfaces with flight hardware, or customer-furnished equipment to arrange for inspection to be performed.

7.4.9 Sampling Inspection

Sampling inspection shall be applied only to standard hardware (e.g., nuts, bolts, etc.) and will be based on the sampling tables of ANSI / ASQC Z1.4. The designated technical personnel and the Project QAE, or their designee's will approve any deviation from the ANSI/ASQC Z1.4.

7.4.10 Electronic Parts Inspection

Pre-cap inspections shall be performed on all hybrid assemblies and, when requested by cognizant hardware engineers or required by the project QA Work Agreement, on microcircuits procured for use on the MSL project. Inspection requirements and acceptance criteria will be included in purchase orders and contract statements of work.

7.4.11 Processing, Fabricating, Assembly, Test, and Inspection Control

Flight hardware or material shall have documented evidence of Quality Assurance acceptance; anything less shall be considered nonconforming. Preliminary Material Review Board action or project waiver shall be required for nonconforming hardware or material. All processes used in the fabrication of flight hardware will be qualified in accordance with NASA, JPL, or contractor equivalent requirements. Qualification of processes will be performed by the cognizant technical organization and reviewed by JPL Quality Engineering.

7.4.12 Manufacturing, Inspection and Test Planning

Procedures shall be generated used for hardware fabrication, assembly and testing. Specific assembly instructions, inspection criteria and techniques will be defined, including inspection points. Instrument Contractors shall use planning that provides clear and concise instructions defining detailed assembly instructions, inspection points, inspection criteria, and any special techniques requested for assembly operations. Quality Assurance shall review and approve manufacturing and test planning prior to its implementation.

7.4.13 Inspection

All protoflight and flight hardware shall be inspected to released drawings, specifications, and approved workmanship standards, unless otherwise specified by Project documentation. Unreleased documents will be documented on an Inspection Report or contractor-equivalent non-conformance report. Redlined documents will be maintained in accordance with the Project Configuration Management Plan.

Mechanical flight hardware will have 100% dimensional inspections performed unless otherwise specified by the approved part drawing.

For MSL Engineering Model hardware, JPL QA will verify the ICD.

The MSL Project Quality Assurance Engineer shall approve all reduced inspection programs. Hardware subjected to a reduced inspection program without the written approval of the Project QA Lead Engineer shall be considered non-compliant, and documented on an Inspection Report or contractor- equivalent non-conformance report.

All protoflight and flight hardware and materials shall be inspected at the level necessary to:

a. Assure mechanical and physical dimensions and conditions are compliant to the applicable Top Assembly and /or Mechanical Interface Control Drawings (MICDs).

b. Assure workstations and areas in which ESD-sensitive hardware is present meet the

Electrostatic Discharge (ESD) requirements as defined in JPL D-1348, or approved contractor equivalent.

c. Assure the Project Configuration Management Plan and hardware traceability requirements are met.

d. Assure the Project Safety Plan requirements are met.

e. Assure compliance with the training and certification requirements as defined in JPL D-8208, or approved contractor equivalent.

f. Assure workmanship compliance per applicable requirements.

g. Assure applicable handling, packaging, and storage requirements are documented and complied with.

h. Assure applicable handling and operating constraints have been identified and adhered to.

i. Assure that documentation accompanies the flight hardware during any transportation activities.

7.4.14 Critical Processes

Instrument Contractors must be able to demonstrate capabilities in critical processes that affect the quality of the parts or hardware being built. Contractor capabilities can be demonstrated using various methods including metrics and process control charts. Critical processes are identified as those which affect the functionality, performance, or quality of the hardware and that failure to control these processes will result in significant risk to the end item.

Controls, including written procedures, shall be established over processes for which the uniform quality of articles or materials cannot be assured solely by inspections or tests. These critical processes include, but are not limited to:

a. Plating

b. Anodizing

c. Radiography

d. Ultrasonic inspections

e. Magnetic Particle Inspection

f. Liquid Penetrant Inspection

g. Heat Treating

h. Welding

i. Die Attachment

j. Wire Bonding

k. Soldering

l. Polymeric Applications

m. Cleaning Applications

n. Fastener Torqueing

o. Crimping

p. Optical coatings

JPL Quality Engineering will review critical processes. Those procedures contained in JPL Document D-8208 shall be utilized to the degree that they provide for the necessary processes. If processes are needed, which are not contained therein, new processes shall be prepared and approved prior to process implementation. See Section 7.7 of this plan for additional support regarding new processes.

All processes used in the fabrication of JPL flight hardware shall be qualified in accordance with NASA and JPL requirements. Qualification of processes will be performed by the cognizant technical organization and approved by the Office of Quality Assurance (512).

7.4.15 Workmanship Standards

The quality of workmanship on JPL flight hardware shall meet or exceed the requirements of JPL D-8208, or contractor-equivalent approved by the MSL Lead QAE.

7.4.16 Metrology Controls

All electrical, electronic, linear, mechanical, optical, temperature and vacuum/pressure equipment used to determine or verify product conformance/acceptability shall be subject to calibration/certification. All equipment shall be within the valid calibration period at the time it is used for determination of product conformance/acceptability. All test equipment calibration on the MSL Project shall be controlled in accordance with ISO 9001, or equivalent, policies and procedures.

7.4.17 Controlled Storage

MSL Flight and critical hardware shall be maintained in controlled storage areas. The storage areas will have the necessary environmental and ESD controls required to meet project requirements. Access shall be controlled and limited to those persons involved in fabrication, test and quality assurance tasks.

7.4.18 Handling, Packaging, Shipping and Storage Controls

All Instrument Contractors shall have effective and established processes for the handling, packaging, shipping, and storage of critical hardware. All precautions should be taken in the to preclude the introduction of contamination to JPL hardware, damage to hardware due to improper packaging or electro-static discharge, and co-mingling of acceptable and unacceptable parts. Flight hardware, flight spare, engineering model, ground support equipment and other critical equipment that interfaces with flight hardware shall be handled as Critical Hardware.

7.4.19 Record Maintenance

Quality Assurance shall assist engineering in maintaining records that provide evidence of inspections, tests, as-built documentation, configuration and hardware status during all phases of fabrication, assembly, integration, and test. All records shall be readily accessible for audit review. The records shall clearly identify the hardware to its assigned project. These records shall become part of an End Item Data Package to be retained for support of the Hardware Certification Review(HRCR). Quality Assurance shall review the End-Item Data Package for completeness.

7.4.20 Quality Records and Controlled Documents

Instrument Contractors are required to retain quality records and furnish them to the MSL project. Quality records are those records which furnish objective evidence of activities performed or results achieved relating to the fabrication, assembly, integration and test of parts/hardware. Quality records include manufacturing planning records detailing specific steps performed and inspection points; test logs and/or test documents detailing the test set up (temperature setting, dwell time, etc), test duration and results achieved; records documenting non-conformances and the respective dispositions; corrective action records; calibration records; parts list for configuration management; and engineering and specification changes. Full traceability shall be maintained on all JPL hardware designated as flight, flight spare, engineering model, ground support equipment and other critical equipment that interfaces with flight hardware.

Controlled documents include test procedures, drawings, manuals, specifications, and other written documentation relating to the design, development, manufacture, and test of the hardware. Contractors are required to maintain and store controlled documents that pertain to the design, development, manufacture, and test of JPL hardware.

7.4.21 Non-Conformance Reporting and Nonconforming Material Control

Instrument Contractors shall have an effective closed loop reporting system for the handling of non-conformances with a means to measure the effectiveness of the corrective actions taken. Non-conformances that impact the performance, function, form or fit of the part or any that require non-standard critical repairs are to be elevated to the Material Review Board level, requiring JPL MSL project visibility and approval.

Project Quality Assurance personnel will maintain status of all non-conformances.

Non-conforming hardware shall be kept in areas designated only for non-conforming hardware with precautions made to prevent the co-mingling of these parts with other acceptable hardware.

7.4.21.1 Contractor Material Review Board

Provisions for documenting, dispositioning, and mitigating major and minor non-conformances shall be included in contractor Quality Assurance Plans and/or the contract Statement of Work. Contractor Quality Assurance personnel shall ensure effective corrective and preventative actions are implemented. JPL Engineering and Quality Assurance representatives shall be a member of all contractor MRBs, as referenced in applicable contract, in cases of Class 1 non-conformances. Class 1 non-conformances are those that affect the JPL interface with respect to fit, form or function.

The JPL Quality Assurance Representative shall obtain the concurrence of the JPL Engineering

Representative prior to approving any recommended dispositions or vice versa. In cases where the JPL Quality Assurance and Engineering Representatives cannot agree on a disposition, a JPL MRB shall be convened. All contractor nonconformance reports shall become a part of the hardware's End-Item-Data Package (EIDP).

7.4.22 Acceptance Test Verification

Quality Assurance shall support the implementation of functional acceptance and environmental test programs. Quality Assurance personnel shall monitor component, assembly, subsystem, and system-level functional, acceptance and environmental tests. Quality Assurance shall verify that all applicable specifications and procedures have been properly authorized prior to use, and all deviations/waivers from the specifications and procedures are authorized.

7.4.23 Environmental Testing

Quality Assurance shall ensure that:

a. All environmental chambers and chamber operators are certified in accordance with JPL DocID 64395, Control and Use of Environmental Chambers, or contractor-equivalent.

b. The test area is controlled to the extent necessary to protect the test article from damage or

degradation.

c. Requirements governing safety, handling and storage, calibration, cleanliness, and environmental controls are being adhered to.

d. Test equipment and support instrumentation are within current calibration cycles.

e. Fixture evaluations, as evidenced by documentation, meet the requirements of the applicable

specifications.

f. Facility, Operational, and ESD Surveys have been completed

g. The Environmental Test Authorization and Summary, (ETAS), JPL Form 2683, has been approved, completed, and signed by the required Project personnel.

h. That Test Readiness Review checklists have been completed, if required, and all action items have been closed or dispositioned "Ok to Proceed".

i. Problem Failure Reports (PFRs) and Inspection Reports (IRs), or the contractor equivalent of both forms, are initiated when required and within the required time frame.

7.4.24 Functional and Acceptance Electrical Testing

Quality Assurance shall monitor flight hardware functional and electrical acceptance testing performed at all levels of assembly and shall ensure that:

a. Authorized test procedure is available and in use.

b. Test data and acceptance criteria are documented.

c. Test equipment is within its current calibration cycle.

d. Safety, hardware handling and required storage provisions are in effect.

e. ESD precautions are being adhered to.

f. The test area is controlled to the extent necessary to protect the hardware and personnel safety.

g. Contamination control and environmental control requirements are being adhered to.

h. Procedural and specification changes are properly documented.

i. Problem/Failure Reports (P/FRs) are initiated for any noted test anomalies, as required per the MSL PFR Plan.

7.4.25 Post-Test Hardware Inspection

Post-Test hardware inspections shall be performed to detect and document the condition of the hardware after environmental testing, with emphasis on documenting discrepancies that may have resulted from the testing. The Project Environmental Requirements Engineer(ERE) will review significant discrepancies to determine the retest requirements.

7.4.26 Ground Support Equipment

Quality Assurance involvement in Ground Support Equipment (GSE) shall be limited to the level necessary to assure:

a. Flight Hardware interfaces, mechanical and/or electrical are compliant to requirements

b. Identification that Interface FMECAs have been performed

c. Current calibration of Electrical GSE

d. Current proof-load of Mechanical GSE

e. Cleanliness and contamination control requirements are compliant

f. Proper and legible identification of the product

g. Safety requirements are satisfied and potential hazards are identified

7.4.27 Assembly Test and Launch Operations (ATLO)

Experiment and/or Instrument System integration and test Quality Assurance activities shall be performed in accordance with JPL QAP 71.0 or JPL approved equivalent.

7.4.28 End Item Data

Hardware fabricated, assembled, and/or tested shall have a data package that contains pedigree sufficient enough to validate the hardware as space-flight qualified. Contractor End Item Data Package and as-built requirements are defined in the contract Statement-of-Work, in the Contract CDRLs/DRDs or on the purchase orders.

7.4.29 Hardware Requirements/Certification Reviews (HRCRs)

MSL Quality Assurance personnel shall participate in and support Hardware Requirements and Certification Reviews (HRCRs). Specifically, Quality Assurance personnel will be responsible for the accomplishment of the following:

a. Assigned QA personnel will ensure that all elements of the HRCR form were addressed, and that QA data requirements of the HRCR are complete, accurate, and approved.

b. The MSL QA Lead Engineer shall close the HRCR form when all assigned action items are satisfied in writing and all liens on hardware are closed at receiving inspection in Assembly Test and Launch Operations (ATLO).

c. Indication, by signature, on the Hardware Requirements and Certification Review form that the hardware meets the applicable requirements and a satisfactory certification has been obtained.

d. Assure an Inspection Report has been generated which denotes inspection acceptance of the hardware or identifies any discrepancies and their dispositions.

7.4.30 Launch Operations Support

JPL Quality Assurance shall provide the necessary support to ensure a correct and safe integration of the MSL Spacecraft with the Launch Vehicle. Quality Assurance shall ensure that all Payload Instrument unique requirements (e.g.,nitrogen purge requirements) are implemented and compliant.

7.4.31 Government Furnished Equipment and Materials (GFE)

Instrument Contractors responsible for JPL Government furnished property shall control it in accordance with the applicable contract Statement-of-Work requirements and per appropriate in-house GFE procedures. JPL QA shall assure appropriate handling and storage controls are in place at all contractors.

7.5 Science Instruments Furnished by International Partners

JPL QA shall be involved with any science instruments furnished by International Partners, to the following extent:

- The MSL Project, including the MSL MAM and MSL QA Lead, will conduct a risk assessment early in the Project to determine the necessity of JPL QA performing Mandatory Inspection Points(MIPS), prior to the delivery to the Project, at the International Partners' facility. At minimum, JPL QA shall:
  - Participate in all Pre-ship review activities including End Item Data Package Review
  - Verify compliance with the electrical and mechanical interface control drawings
  - Verify the proper planetary protection and contamination controls have been implemented

7.6 Quality Assurance Applications Engineering

7.6.1 Optical Alignment

Optical Metrology personnel from JPL Office 512 shall review and approve all plans and procedures for optical metrology or alignment activity during instrument integration to the spacecraft. The review will include all alignment activities at JPL and contractor facilities. The review shall focus on determining that the best technical approach is used to meet the project goals.

8 SOFTWARE QUALITY ASSURANCE

8.1 Introduction

8.1.1 Scope

This section provides the SQA Plan for MSL software (S/W) development organizations including JPL, contractors, vendors and industrial partners. Instrument providers, contractor, vendor and industrial partner plans are contained in Section 8.2.

8.1.2 Purpose

The purpose of SQA is to achieve the highest quality-to-cost ratio within project constraints and policies, and to increase the probability of overall mission success. A series of rigorous SQA activities will be performed throughout the S/W life cycle to assure that S/W development will comply with pre-defined quality processes, and that S/W product quality will meet or exceed project requirements.

8.1.3 Responsibilities

Each S/W development organization shall perform required SQA activities described in this plan.

8.2 Contractor SQA Requirements

The requirements herein apply only to flight or ground software that is necessary for the science return from a single (non-critical) instrument, or supports the generation of mission sequences.

8.2.1 S/W Development Process

The Instrument Provider shall assist the project in tailoring the S/W development process, within the constraints of cost and schedule, and with acceptable risk. The Instrument Provider shall verify that the S/W development process complies with requirements of the JPL Software Development document (JPL D-23713), **for S/W that executes on the Spacecraft flight computer only**, and the JPL Design, Verification/Validation and Operations Principles for Flight Systems (JPL D-17868), and identify any deviations associated therewith.

The Instrument Provider shall assure that the processes and standards as specified in the S/W Management Plan (SMP) will be followed by the S/W Development Team for all kinds of S/W.

8.2.2 S/W Requirements Trace

The Instrument Provider shall verify that following two-way requirement traces will be

established to assure the completeness and correctness of S/W traceability:

- System/Subsystem Interface Requirements and S/W Requirements
- S/W Requirements and S/W Design/Implementation
- S/W Requirements and S/W Acceptance Tests

8.2.3 S/W Reviews

The Instrument Provider shall participate in and support the delivery manager in the S/W delivery review or S/W Review/Certification Requirement review (SRCR).

8.2.4 S/W Verification and Validation (V&V)

The Instrument Provider shall assure that the S/W V&V process will have adequate end-to-end S/W testing coverage, including the flight and ground data systems.

The Instrument Provider shall analyze the test objectives and assure that entry and exit criteria for each level of testing will be properly defined.

The Instrument Provider shall assure that S/W acceptance tests will encompass the following:

- Traceability Matrix exists between S/W requirements and Test Cases.
- Stress testing is adequate.

All S/W products, if intended for usage with Qualification, Protoflight, Flight or Flight Spare hardware, shall be subjected to the following Contractor SQA evaluations:

- Accuracy of as-built product identification (for all kinds of S/W)
- Existence and adequacy of an Installation Manual (**for all types of S/W that execute on the Spacecraft flight computer**)
- S/W Requirements are properly traced in a test traceability matrix or equivalent
- List of open/closed PFRs or liens against a S/W delivery. (for all kinds of S/W)

8.2.5 Problem/Failure Reporting (PFR) and Tracking

The Instrument Provider shall assure that problems, failures or anomalies found during S/W developmental tests or integration tests with hardware will be reported and tracked to closure.

The Instrument Provider shall assess the criticality of S/W related PFRs, evaluate the risks associated with their disposition, and track the proper PFR closure.

8.2.6 S/W Configuration Management (CM)

The Instrument Provider shall assist in defining and assessing the S/W Configuration Management (CM) plan and procedures.

The Instrument Provider shall assure that S/W CM will be performed (for all kinds of developed S/W) through the identification, control, audit, and status accounting of configuration items which represent the S/W at each life cycle phase of development.

8.2.7 S/W Engineering Change Request (ECR)

The Instrument Provider shall participate in assessing the impacts of S/W related ECRs, and assure that the proper ECR will be implemented and verified.

8.3 S/W Safety/Hazard/Fault Analysis

This section only applies to Safety Critical S/W (e.g., controls pyro, pressure valve, etc.) or S/W that executes on the Spacecraft flight computer.

The Instrument Provider shall assure that a S/W System Safety/Hazard/Fault Analysis will be performed on safety- and mission-critical S/W. Recommended techniques for the S/W System Safety/Hazard/Fault Analysis include:

- S/W Fault Tree Analysis (SFTA)
- S/W Failure Modes Effects and Criticality Analysis (SFMECA)

The Instrument Provider shall assure S/W safety in the following manner:

- It will not produce output values and/or timing that place the system in a hazardous state

It will properly recognize or handle H/W failures through which it must control, or to which it must respond.

Appendix A — Materials Identification and Usage List (MIUL) Forms

Materials Identification and Usage List - Non-Metallic Materials

Item No.	Material Description/ Brand Name Supplier	**Application**	Material Specifications	Thermal Vacuum Stability (%)	JPL Rating[1]	Comments
1				TML = CVCM= WVR=		
2				TML = CVCM= WVR=		
3				TML = CVCM= WVR=		
4				TML = CVCM= WVR=		
5				TML = CVCM= WVR=		
6				TML = CVCM= WVR=		
7				TML = CVCM= WVR=		

[1] 1 - acceptable, 2 - qualified acceptable, 3 - provisionally acceptable, 4 - unacceptable

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Materials Identification and Usage List - Metallic Materials

Item No.	Material Description/ Condition	Application	Material Specifications	Stress Corrosion Cracking Rating	JPL Rating[1]	Comments
1						
2						
3						
4						
5						
6						
7						

[1] 1 - acceptable, 2 - qualified acceptable, 3 - provisionally acceptable, 4 - unacceptable

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Materials Identification and Usage List - Processes

Item No.	Process	Specification	Materials Processed	Spacecraft/ Experiment Application	JPL Evaluation	
					Approve/ Disapprove[1]	Comments
1						
2						
3						
4						
5						
6						

[1] 1 - acceptable, 2 - qualified acceptable, 3 - provisionally acceptable, 4 - unacceptable

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Appendix B — Materials Usage Agreement (MUA) Form

MATERIALS USAGE AGREEMENT		USAGE AGREEMENT NO.	REVISION		PAGE OF	
PROJECT		SUBSYSTEM	ORIGINATOR	ORGANIZATION		
DETAIL DRAWING(S)		USING ASSEMBLY(S)	ITEM DESCRIPTION	ISSUE		
MATERIAL		TRADE NAME	SPECIFICATION	MANUFACTURER		
THICKNESS	WEIGHT	EXPOSED AREA	LOCATION	ENVIRONMENT		
				PRESSURE	TEMPERATURE	MEDIA
APPLICATION						
RATIONALE						
ORIGINATOR					DATE	
MATERIALS ENGINEERING EVALUATION						
APPROVAL						
CONTRACTOR M&P		DATE	JPL M&P		DATE	

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Appendix C — Stress Corrosion Evaluation Form

STRESS CORROSION EVALUATION FORM

1. PART NUMBER _____

2. PART NAME _____

3. NEXT ASSEMBLY NUMBER _____

4. MANUFACTURER _____

5. MATERIAL _____

6. HEAT TREATMENT _____

7. SIZE AND FORM _____

8. SUSTAINED TENSILE STRESS-MAGNITUDE AND DIRECTION

   a. PROCESS RESIDUAL _____

   b. ASSEMBLY _____

   c. DESIGN, STATIC _____

9. SPECIAL PROCESSING _____

10. WELDMENTS

    a. ALLOY FORM, TEMPER OF PARENT METAL _____

    b. FILLER ALLOY IF NONE, INDICATE _____

    c. WELDING PROCESS _____

    d. WELD BEAD REMOVAL - YES ( ), NO ( ) _____

    e. POST-WELD THERMAL TREATMENT _____

    f. POST-WELD STRESS RELIEF _____

11. ENVIRONMENT _____

12. PROTECTIVE FINISH _____

13. FUNCTION OF PART _____

14. EFFECT OF FAILURE _____

15. EVALUATION OF STRESS CORROSION SUSCEPTIBILITY _____

16. REMARKS _____

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