Canadian Space Agency | Agence spatiale canadienne

CSA-SMA-RD-0009

Canadian Space Agency

GENERIC PRODUCT ASSURANCE REQUIREMENTS (PAR) – CLASS C

Rev. P2 (Initial Release upon Approval)

August 26, 2021

Canada

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REVISION HISTORY

Rev.	Description	Initials	Date
P1	Preliminary Release for internal review		June 2, 2021
P2	Updated preliminary version		Aug 26, 2021

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1 INTRODUCTION

1.1 CONTEXT

This Generic Product Assurance Requirements (PAR) document was produced by the Canadian Space Agency (CSA) for Space Mission Class C.

These PA requirements are applicable to Contractor, sub-contractors and suppliers. The Contractor is responsible to allocate these requirements to sub-contractors and suppliers and to ensure and monitor their implementation.

1.2 SCOPE

The requirements herein have been tailored for a CSA class C level risk of tolerance, following the methodology set forth in the CSA Project Risk Class Selection Guidelines [RD-37]. Unless otherwise stated, the scope encompasses the following:

Project Phases A, B, C, D and E for:

a) Design, development, procurement, manufacturing, assembly, integration, test, pre-launch, Launch and Early Operations Phase (LEOP), and commissioning activities; and,

b) The delivery of the space segment hardware and software.

Product Assurance (PA) activities covered by this document include the following:

a) PA Organization, Management and Control;

b) Technical Reviews;

c) Qualification Program;

d) Reliability Assurance;

e) Electrical, Electronic and Electromechanical (EEE) Parts;

f) Materials and Processes;

g) Quality Assurance (QA);

h) Software and Field Programmable Gate Arrays (FPGA) Product Assurance;

i) Verification;

j) Safety; and,

k) Configuration and Data Management (CADM).

Documentation deliverables (i.e. CDRLs) and associated Data Items Descriptions (DIDs) are defined in the project SOW.

1.3 APPLICABILITY

The Product Assurance Requirements specified herein apply to the Space Segment (including development and qualification items) as stipulated in each section of this document. The Space Segment namely includes the sub-systems and sub-assemblies designed or procured, and supplied by the Contractor as well as any applicable Ground Support Equipment (GSE) and EGSE used to

build and/or test the Space Segment. The Ground Segment is covered by a separate document [AD-04].

1.4 DOCUMENT CONVENTIONS

The wording of statements in this specification determines the disposition of requirements:

a) "MUST" is used to indicate a mandatory requirement.

b) "SHOULD" indicates a recommendation but is not mandatory.

c) "MAY" indicates an option.

d) "WILL" indicates a statement of fact or intention.

Requirements - Each requirement contained in this document consists of an identifier of the following format: PAR XXXX, where XXXX is a unique requirement number. The requirement identifier is followed by the formal requirement statement.

Text in italics located below a requirement is intended to provide guidance and clarification about the interpretation of the requirement.

Plain, non-italicized text constitutes informative statements, options, or recommendations.

Unless otherwise indicated, the acronyms "PA" and "QA" refer to the Contractor organization.

Definitions are embedded in the text when necessary.

Unless otherwise indicated, when the term "CSA" is used in the context of review- and approval-type content, it refers to an authorized representative from the CSA Safety and Mission Assurance (S&MA) group (with support from CSA's Engineering group when deemed necessary).

2 APPLICABLE DOCUMENTS

2.1 APPLICABLE DOCUMENTS

Documents in Table 2-1 form part of the requirements to the extent specified herein. Unless otherwise indicated, the latest issue in effect at the time of contract award form part of this document.

For Commercial Off the Shelf (COTS) units and subsystems originating from Europe (Categories A and B as defined in Section 4.2 herein), the European Cooperation for Space Standardization (ECSS) PA Standards / Specifications may be used in lieu of North American Standards / Specifications (e.g. military [MIL], National Aeronautics and Space Administration [NASA], IPC, etc.).

The ECSS Standards listed in Appendix A are considered an acceptable alternative and are approved by CSA.

TABLE 2-1 – APPLICABLE DOCUMENTS

AD	Document Number	Title
[AD-01]	Refer to the Project Contract	Lunar Exploration Accelerator Program Science Instruments (LSI) Phase ABCDEF Statement of Work (SOW)
[AD-02]	Refer to the Project Contract	F.10 Payloads and Research Investigation on the Surface of the Moon https://nspires.nasaprs.com/external/solicitations/summary.do?solId=%7bAD1DEAD1-7060-2C93-8CD1-780AF8FC9D54%7d&path=&method=init
[AD-03]	Refer to the Project Contract	NASA payload provider and LSI agreement
[AD-04]	CSA-SMA-RD-0007	CSA Ground Segment Quality Assurance Requirements (GS QAR)
[AD-05]	CSA-SE-PR-0001	CSA Systems Engineering Methods and Practices
[AD-06]	ANSI/ESD S20.20	Protection of Electrical and Electronic Parts, Assemblies and Equipment
[AD-07]	AS9100	Quality Management Systems – Requirements for Aviation, Space and Defense Organisations
[AD-08]	ASTM E595	Outgassing Test in a Vacuum Environment
[AD-09]	ASTM G31	Standard Practice for Laboratory Immersion Corrosion Testing of Metals
[AD-10]	DOT/FAA/AR-MMPDS-01	Metallic Materials Properties Development and Standardization
[AD-11]	ESCC-3009	Capacitors, Fixed, Chips, Ceramic dielectric, Types I and II
[AD-12]	ECSS-Q-HB-30-01A	Worst Case Analysis

AD	Document Number	Title
[AD-13]	ECSS-Q-ST-70-36C	Material selection for controlling stress-corrosion cracking
[AD-14]	GSFC EEE-INST-002	Instructions for EEE Parts Selection, Screening, and Qualification
[AD-15]	GSFC PPL-21	Goddard Space Flight Center Preferred Parts List
[AD-16]	IPC-2221	Generic Standard on Rigid Board Design
[AD-17]	IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
[AD-18]	IPC-2223	Sectional Design Standard for Flexible Printed Boards
[AD-19]	IPC-6011	Generic Performance Specification for Printed Boards
[AD-20]	IPC-6012XS (X = D or later)	Space and Military Avionics Applications Addendum to IPC-6012X Qualification and Performance Specification for Printed Boards
[AD-21]	IPC-6013	Qualification for Flexible Printed Boards
[AD-22]	IPC-A-610	Acceptability of Electronic Assemblies
[AD-23]	ISO 10007	Quality Management – Guidelines for Configuration Management
[AD-24]	ISO 10012	Quality Assurance for Measuring Equipment
[AD-25]	ISO 14620-1	Space Systems – Safety Requirements – Part 1: System Safety
[AD-26]	ISO 14644-1	Clean rooms and controlled environments-Part 1: Classification of air cleanliness
[AD-27]	ISO 14644-2	Clean rooms and controlled environments-Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1
[AD-28]	ISO 15388	Space Systems – Contamination and Cleanliness Control
[AD-29]	ISO 24113	Space Systems – Space Debris Mitigation Requirements
[AD-30]	J-STD-001S	Space applications Electronic Hardware Addendum to IPC J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies with Space Addendum
[AD-31]	MIL-HDBK-217F	Reliability Prediction for Electronic Equipment
[AD-32]	MIL-HDBK-5	Department of Defense Handbook: Metallic Materials and Elements for Aerospace Vehicle Structures
[AD-33]	MIL-HDBK-814	Ionizing Dose and Neutron Hardness Assurance Guidelines for Microcircuits and Semiconductor Devices
[AD-34]	MIL-PRF-39003	Capacitors, Fixed, Electrolytic (Solid Electrolyte), Tantalum, Established Reliability, General Specification for

AD	Document Number	Title
[AD-35]	MIL-PRF-55365	Capacitors, Fixed, Electrolytic (Tantalum) Chip, Non Established Reliability, General Specification for
[AD-36]	MIL-STD-889	Dissimilar Metals
[AD-37]	MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program
[AD-38]	MSFC-STD-3029	Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance
[AD-39]	NASA NPR 8020.12	Planetary Protection Provisions for Robotic Extraterrestrial Missions
[AD-40]	NASA-STD-6001	Flammability, Odor, Off-Gassing and Compatibility Requirements & Test Procedures for Materials that Support Combustion
[AD-41]	NASA-STD 8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
[AD-42]	NASA-STD 8739.4	Crimping, Interconnecting Cables, Harnesses, and Wiring
[AD-43]	NASA-STD 8739.5	Fiber Optic Terminations, Cable Assemblies, and Installation
[AD-44]	NPRD-95	Non-electronic Parts Reliability Data
[AD-45]	https://www.fides-reliability.org/	N/A

2.2 REFERENCE DOCUMENTS

Reference documents in Table 2-2 provide background and/or supplementary information relevant to the contents of this document.

TABLE 2-2 – REFERENCE DOCUMENTS

RD	Document Number	Title
[RD-01]	N/A	Qualification of PEMs Using Board-level Testing, Alexander Teverovsky, QSS Group, Inc./Goddard Operations
[RD-02]	N/A	Alternative Test Methods for Electronic Parts, For the NASA Electronic Parts and Packaging (NEPP) Program, 2004 Jeannette Plante, Dynamic Range Corporation
[RD-03]	AMS 2759/2-5	Heat Treatment of Steel
[RD-04]	AMS 2770	Heat Treatment of Wrought Aluminum Alloy
[RD-05]	AMS 2771	Heat Treatment of Aluminum Alloy Castings
[RD-06]	AMS 2772	Heat Treatment of Aluminum Alloy Raw Materials

RD	Document Number	Title
[RD-07]	AMS-QQ-A-250	Aluminium Alloy 6061, Plate and Sheet
[RD-08]	ASTM B209-10	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
[RD-09]	ASTM E 1417	Standard Practice for Liquid Penetrant Examination
[RD-10]	ASTM-E-1444	Magnetic Particle Inspection
[RD-11]	ASTM-E-1742	Standard Practice for Radiographic Inspection
[RD-12]	AWS C-3.2 M/C-3.2(2001)	Standard Method for Evaluating the Strength of Brazed Joints
[RD-13]	AWS C-3.7 M/C-3.7(2005)	Specification for Aluminum Brazing
[RD-14]	ECSS-Q-ST-60	Electrical, Electronic and Electromechanical (EEE) Components
[RD-15]	ECSS-Q-ST-60-13C	Commercial electrical, electronic and electromechanical (EEE) components
[RD-16]	ECSS-Q-ST-70-01C	Cleanliness and Contamination Control
[RD-17]	ECSS-Q-ST-70-02C	Thermal vacuum outgassing test for the screening of space materials
[RD-18]	ECSS-Q-ST-70-22C	Control of Limited Shelf-Life Materials
[RD-19]	FED-STD-209	Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones
[RD-20]	GSFC S-311-M-70	Specification For Destructive Physical Analysis
[RD-21]	GSFC-STD-6001	Ceramic Column Grid Array Design and Manufacturing Rules for Flight Hardware
[RD-22]	IPC-7095	Design and Assembly Process Implementation for Ball Grid Arrays (BGAs)
[RD-23]	IPC A-600	Acceptability of Printed Boards
[RD-24]	IPC/JEDEC J-STD-033	Handling, Packing, Shipping and Use of Moisture, Reflow, and Process Sensitive Devices
[RD-25]	ISO/IEC/IEEE/12207:2017	Standard for Systems and Software Engineering – Software Life Cycle Processes
[RD-26]	ISO/IEC 29110	Software Engineering – Lifecycle Profiles for Very Small Entities (VSEs)
[RD-27]	MIL-HDBK-17	Composite Materials Handbook
[RD-28]	MIL-PRF-123	Capacitors, Fixed, Ceramic Dielectric (Temperature Stable and General Purpose) High reliability, General Specification for

RD	Document Number	Title
[RD-29]	MIL-STD-498	Software Development and Documentation Standard
[RD-30]	MIL-STD-883	Test Method Standard Microcircuits
[RD-31]	MIL-STD-975	NASA Standard Electrical, Electronic, and Electromechnical (EEE) Parts List
[RD-32]	MIL-STD-1580	Destructive Physical Analysis for EEE parts
[RD-33]	MIL-STD-1629A	Military Standard for performing a Failure Mode Effects and Criticality Analysis
[RD-34]	MIL-STD-1949	Magnetic Particle Inspection
[RD-35]	NASA PEM-INST-001	Instructions for Plastic Encapsulated Microcircuit (PEM) Selection, Screening, and Qualification
[RD-36]	REP 005	ESCC Qualified Parts List
[RD-37]	CSA-PIP-GDL-0001	CSA Project Risk Class Selection Guideline
[RD-38]	NASA-HDBK-4002A	Mitigating In-Space Charging Effects – A Guideline
[RD-39]	MSFC-HDBK-527	Materials Selection List for Space Hardware Systems
[RD-40]	N/A	https://llis.nasa.gov/lesson/771

2.3 DOCUMENT PRECEDENCE

In the event of conflict between this document and other documents, the following order of document precedence is applicable.

a) The Project Contract;

b) The Project Statement of Work [AD-01];

c) The Project Mission Requirements Document (or equivalent) [AD-02];

d) The Project Product Assurance Requirements (this document); and,

e) The Project System Requirements Specification (or equivalent) [AD-03].

The Contractor is responsible to identify and notify CSA of any document conflicts.

3 PRODUCT ASSURANCE PROGRAM

3.1 PRODUCT ASSURANCE MANAGEMENT

The Product assurance management policy for this project is that a Product Assurance Implementation Plan (PAIP) is implemented throughout all phases and is managed to ensure that:

a) the PA organization, requirements, methods tools and resources are well-defined before development and implemented at each level from system down to piece part;

b) early detection, containment and prevention of product assurance aspects which could affect project requirements and having major impacts on safety, mission success and the related cost and schedule consequences;

c) risks are assessed and controlled, and that acceptability of the residual ones is evaluated;

d) the quality status and necessary visibility of the of the product is provided at any time; and,

e) the end product conforms to its specifications and that observed non-conformances are properly disposed.

PAR 0010 In accordance with (IAW) [AD-01], the Contractor must prepare and deliver a Product Assurance Implementation Plan (PAIP) to define the task descriptions, responsibilities and detailed implementation methods and compliance with the requirements defined herein.

PAR 0020 As an Annex to the PAIP, the Contractor must include a Compliance Matrix that responds to each requirement of this PA Requirements Document and applicable contractor process documents.

The Compliance Matrix should include the following:

a) a PA Compliance Statement to each requirement specified herein; For non-compliance, the Contractor should indicate a rationale and/or an alternate requirement or process;

b) the applicable Contractor process specifications, quality process as evidence and supporting the implementation of the plan.

3.2 QA SYSTEM

PAR 0030 The Contractor must have in place a QA System which meets [AD-07] requirements or equivalent standard.

PAR 0040 The Contractor PA (identified per PAR 0060) must interface with lower-tier subcontractors and suppliers regarding all Product Assurance matters to ensure the coverage of PA aspects IAW these requirements as appropriate to the procured item.

PAR 0050 The Contractor must identify to CSA all applicable non-compliance(s) to the PA requirements for the design, manufacturing, assembly and test work performed by sub-contractors/suppliers. For the non-compliances, the Contractor should provide the mission risk and mitigation processes which will be put in place to reduce risk.

3.3 ORGANIZATION, ROLES AND RESPONSIBILITIES

The Contractor is responsible for the successful execution of the Project. The Contractor is responsible for managing activities of the Project as defined in Section 1.2 herein.

The role of CSA is to verify the work and deliverables of the Contractor. Verification or acceptance by CSA does not relieve the Contractor from its obligation to meet Project requirements.

The CSA project team will be responsible for the management of the Project on behalf of the Government of Canada and will be the sole official representative of CSA to the Contractor throughout this Project. The role of the CSA S&MA representative is to verify that the Contractor complies with the PA Requirements.

PAR 0060 The Contractor must identify an individual as being responsible for the planning, management, implementation, and monitoring of the PA Program.

This individual should have full independence from the Project Management and Engineering functions in terms of execution of work. The appointed individual will maintain regular liaison with the CSA project S&MA representative about ongoing issues, and inform him/her of a major PA decision as soon as an issue impacting the PA Program implementation is revealed or discovered. From this point in the document, this individual will be referenced to as the "Contractor PA".

PAR 0070 A PA organizational chart identifying the PA organizational structure and lines of reporting must be presented in the PAIP.

3.3.1 Audits

The Contractor is expected to perform quality audits of their subcontractors and suppliers IAW PAR 0030 per their QA system in place.

PAR 0080 CSA personnel or its designated representatives must have the right of access to perform surveillance of the Contractor and their next tier subcontractors facilities. Provisions to accommodate such representatives will be provided by the contractor IAW [AD-01].

3.4 MANDATORY INSPECTIONS

PAR 0090 The Contractor must establish mandatory inspection points (MIP) at key inspection/test points on the project Manufacturing Flow Chart(s) as necessary to ensure maximum visibility of hardware quality-related aspects, documentation readiness, acceptance tests/first article verification at unit, subsystem and system level with consideration to the following criteria to select MIP:

a) verification of critical processes and/or items.

b) irreversible operations.

c) visibility of problem areas or non-conformance.

d) results of previous trend analysis.

PAR 0100 IAW PAR 0090, the Contractor must notify the CSA five business days in advance and have the right to perform independent MIPs at key inspection/test points.

These will be requested by CSA in response to the review of the project Manufacturing Flow Chart(s) provided by the Contractor during pre-agreed key reviews. Formal acceptance of the additional mandatory inspection point may result in a contractual change.

A MIP is a specific point during a process whereby secondary verification (e.g., independent observation and verification) of a specific characteristic, operation, or test element needs to take place before a product can be processed further. A MIP may also be used to verify compliance and status prior to project level milestone deliverables or meetings.

3.5 PROJECT REVIEWS

PAR 0110 The Contractor PA, should participate in all formal reviews identified in [AD-01]. This includes support to all milestone reviews identified in [AD-01] at the system level and major subsystem levels.

Reviews may include but are not limited to the following:

a) System Requirements Review;

b) Preliminary Design Reviews (PDRs);

c) Critical Design Reviews (CDRs);

d) S/W Reviews;

e) Manufacturing Readiness Reviews (MRRs);

f) Test Readiness Reviews (TRRs);

g) Functional and Physical Configuration Reviews;

h) Non-conformance Reviews;

i) Failure Reviews;

j) Commissioning and Test Data Reviews (TDRs);

k) EIDP and System Pre-Acceptance Reviews; and,

l) Pre-Shipment Reviews (PSR).

4 QUALIFICATION PROGRAM

4.1 GENERAL

This section covers unit and higher-level assembly qualification.

In the context of this PAR, the following definitions apply:

a) Subassembly: Two or more parts which is capable of disassembly or part replacement. Example: printed circuit board with parts installed.

b) Unit: A unit is a functional item that is viewed as a complete and separate entity for purposes of manufacturing, maintenance, or record keeping. Examples: reaction wheel, magnetometer, star tracker, GPS, sun sensor, battery, electrical harness, and transmitter. Payload instruments such as telescopes and other optical assemblies are considered units.

c) Subsystem: A subsystem is an assembly of functionally related units. It consists of two or more units and may include interconnection items such as cables or tubing, and the supporting structure to which they are mounted. Examples: electrical power, attitude control, telemetry, thermal control, and propulsion subsystems.

4.2 CLASSIFICATION FOR QUALIFICATION STATUS

A hardware unit that has been designed, fabricated or flown on previous similar missions may be considered to have demonstrated compliance with some or all of the requirements of this document based on design, manufacturing, and testing documentation as well as on-orbit performance track record based on data.

PAR 0120 The Contractor must demonstrate that flight units supplied to the project have been identified and qualified by providing supporting design analyses and qualification test reports available to CSA for review and the following categorization and associated qualification test methods are applicable.

a) Category A (Qualified) – Existing fully qualified unit: Unit built to an existing recurring design that has been qualified, and has no changes in design for the Project. No further qualification testing is required. Category A units still need to be approved by CSA to establish full qualification status. Only requires documentation review to substantiate status.

b) Category B (Modified Test Environment) – Existing unit qualified or proto-qualified on another project and whose design, manufacturing and control procedures, as well as parts, materials and processes need no modification for the present project, but which are subject to more stringent environmental conditions: Requires proto-flight level testing for first unit.

c) Category C (Modified Design) – Unit derived from an earlier qualified design but with design, manufacturing and/or control procedures or with parts, materials and processes changes: Delta qualification by test, or analysis with customer agreement and approval, is required for flight units, previously qualified or proto-qualified on other projects by contractor, to levels appropriate to application.

d) Category D (New Design) – New design: Requires full qualification test.

Per the SOW [AD-01] the Contractor is responsible to obtain all necessary documentation from proposed COTS suppliers in order to establish and verify full qualification status at QSRs.

4.3 MODEL PHILOSOPHY

PAR 0130 The Contractor must define the Model Philosophy for the Project IAW the definitions specified in [AD-05].

4.4 QUALIFICATION STATUS REVIEWS

PAR 0140 All Hardware units including units requiring update due to design changes or test requirements post the CDR will be subject to the Contractor Change Control Board review process to evaluate the impact of the changes to the qualification status and categorization previously declared and agreed to by the customer at the CDR or the Qualification Status Review (QSR) IAW [AD-01]. Changes to the qualification status must be reported to the CSA by the contractor.

QSRs should be scheduled as early as possible in the design phases such that the qualification status of all units can be established by the Mission CDR.

4.5 QUALIFICATION PROCESS REQUIREMENTS

PAR 0150 IAW [AD-01], the QSL must reference the qualification test requirements and test reports.

4.5.1 Hardware Compliance

Compliance for existing hardware will be assessed by:

a) Comparing the performance, design, environmental and interface requirements of the proposed system with those of the equipment used on previous missions;

b) Describing any modifications to hardware that might invalidate the qualification status; and,

c) Describing deviations/waivers for hardware used on previous missions and considered for re-use on the Project.

4.5.2 Design Heritage

The following criteria and definitions may be considered by CSA for purposes of establishing qualification.

a) Design Heritage: The design of a proposed end item is traceable to one that was previously designed, built, qualified and documented to space flight standards, and which met or exceeded the Project requirements, as well as at least one of the following criteria:

b) Flight Heritage: Flight heritage can be claimed when it can be factually demonstrated that previous mission-level and unit-level requirements, accumulated flight operational time and unit performance meet or exceed current Project requirements. Name of Space Project(s) on which the unit was used need(s) to be provided; or,

c) Similarity: Similarity is established when the proposed unit and the previously-qualified unit have the same design performance in a similar or more stringent environment* and

where the differences in “form and fit” can be accommodated within the system level engineering budgets for the Project; or,

d) Verification by design analysis and Qualification/Proto flight Testing specific to this Project.

The Contractor will be responsible to demonstrate similarity namely in terms of launcher, operating environment (e.g. orbit), thermal, radiation, and design life.

4.6 QUALIFICATION STATUS LIST

The Qualification Status List (QSL) to be maintained by the Contractor will summarize the qualification status of all hardware and software configuration items. This, together with any referenced supportive data will demonstrate that items are qualified for their intended application.

PAR 0160 The QSL for the configured item(s) should be submitted to CSA IAW [AD-01].

4.7 QUALIFICATION TESTING

The test level and duration for unit, subsystem and Qualification/Proto Flight Model will be defined in the [AD-03] or the approved Unit Specification.

Testing will include the following, where applicable:

a) Functional and performance testing;

b) External inspection;

c) Mass properties;

d) Sine and random vibration test;

e) Quasi static test;

f) Shock;

g) Thermal cycling test;

h) Thermal vacuum test, including Thermal balance test;

i) Electromagnetic Interference (EMI) / Electromagnetic Compatibility (EMC) testing (including radiated emissions);

j) Multipaction testing; and,

k) Passive intermodulation testing.

PAR 0170 For qualification models (i.e. QM or EQM), a Qualification Acceptance Data Package (QADP) should be produced for a unit, subsystem and system, IAW [AD-01].

4.8 FLIGHT CERTIFICATION

PAR 0180 All flight items (i.e. units, subsystems, and spacecraft) must be certified as worthy for flight with the issue of a certificate of conformance which:

a) States that the flight items have been verified to meet the requirements applied via the relevant SOW.

b) Is approved and signed by the Contractor PA and responsible Technical Lead for all flight items.

c) Is included in the associated EIDP IAW [AD-01].

The Technical Lead is a cognizant engineer within the Contractor's organization, in overall charge of technical matters on the project, and independent from management functions and personnel.

5 EEE PARTS PROGRAM

5.1 GENERAL

In the context of this PAR, a part is defined as an entity that is not normally disassembled without destroying its function. Examples of parts: resistor, integrated circuit, relay, roller bearing, etc.

The EEE requirements specified in this section are tailored IAW the degree of heritage for proposed units and subsystems.

The definition of design heritage from section 4.5.2 and the unit categorization (A, B, C, D) from section 4.2 are applicable.

PAR 0190 The criticality classification specified in Table 5-1 must apply.

TABLE 5-1 – CRITICALITY CLASSIFICATION

APPLICATION	CLASSIFICATION	
	CRITICAL	NON-CRITICAL
Unit or subsystem with any associated severity[1] item of 1, 1S, 1R, 2 or 2R	X	
Unit or subsystem with lower degrees of (i.e. 3 or 4) of associated severity[2]		X
Single Point Failure (SPF)[3], or single string unit or subsystem, where graceful degradation is not acceptable to CSA[4]	X	
Unit or subsystem where graceful degradation is deemed acceptable to CSA[5]		X

5.2 CATEGORY A (QUALIFIED) AND HERITAGE COTS

PAR 0200 For COTS units which are categorized as Category A (per section 4.2) and the flight heritage meets or exceeds duration of the mission specified in [AD-02], the EEE parts selection and qualification program used must be usable as-is provided that the contractor can demonstrate through a QSR objective evidence that the criteria for Category A or design heritage definition (per section 4.5.2) are met.

PAR 0210 The Contractor must be responsible to develop and establish all necessary mechanisms (e.g. non-disclosure agreements, contractual provisions, etc.) with industry partners, bidders, and subcontractors (as applicable) to obtain and provide the necessary evidence to establish that the criteria for design heritage or Category A are met.

Per the SOW [AD-01], the Contractor is responsible to develop teaming arrangements and partnerships that will enable sharing such evidence with CSA.

[1] Based on Contractor FMECA and IAW FMECA severity category of Table 6-1 herein
[2] Based on Contractor FMECA and IAW FMECA severity category of Table 6-1 herein
[3] As identified in the FMECA.
[4] As specified in [AD-01], [AD-02], or [AD-03].
[5] As specified in [AD-01], [AD-02], or [AD-03].

5.3 CATEGORY B (MODIFIED TEST ENVIRONMENT)

PAR 0220 EEE parts in Category B COTS unit must be processed IAW the requirements of section 5.2, subject to PAR 0230.

PAR 0230 If, during the proto-flight testing of a Category B unit, a test failure, anomaly, or issue warrants a change (e.g. substitution to an existing EEE part, or incorporation of new EEE part), such change must be processed IAW the Category C approach of section 5.4.

5.4 CATEGORY C (MODIFIED DESIGNS)

5.4.1 Critical Applications

PAR 0240 When a Category C (per section 4.2) unit is classified as critical IAW Table 5-1, any EEE-related modification with respect to the heritage design must meet the applicable requirements of section 5.5 herein.

5.4.2 Non-Critical Applications

PAR 0250 When a Category C (per section 4.2) unit is classified as non-critical IAW Table 5-1, any EEE-related modification with respect to the heritage design must meet the minimum part quality level for non-critical applications specified in Table 5-2, as well as contractor and subcontractor EEE parts and product assurance requirements.

5.5 CATEGORY D (NEW DESIGNS)

5.5.1 EEE Plan

PAR 0260 The Contractor must establish and maintain a plan for controlling the specification, selection, approval, application, qualification, screening and burn-in as well as acceptance of all high reliability electrical, electronic and electromechanical (EEE) parts, as applicable to their usage in the manufacture of deliverable flight and qualification items. The EEE parts program plan, including COTS parts control plan, should be described as part of the PAIP.

5.5.2 EEE Parts Selection

PAR 0270 The Contract must select the parts so that the equipment meets all requirements specified in the procurement specification.

PAR 0280 Where a part will be used in a critical application IAW Table 5-1, preference should be given to parts selected from the following lists or their equivalent:

a) Level 1, 2, 3 Parts listed in NASA Parts Selection List (NPSL) (All application notes in NPSL, [AD-14] and [AD-15] apply);

b) Level B, C parts listed in ESCC QPL (As for a lot acceptance test (LAT), LAT2 or Lot Validation Test (LVT) subgroup 2 will be performed on each lot);

c) parts listed in Part I of European Preferred Parts List (EPPL);

d) Level 1, 2, 3 parts listed in [AD-14];

e) Grade 1, 2 parts listed in [AD-15];

f) parts (a quality level which is based on the NPSL level 1, 2, 3) listed in MIL QPL (All application notes in NPSL, [AD-14] and [AD-15] apply);

g) Japan Aerospace Exploration Agency (JAXA) Qualified Parts List available at: https://eeepitnl.tksc.jaxa.jp/en.

h) parts approved (NSPAR or PAD) by CSA for other equivalent space programs;

i) parts, which are demonstrated to meet the requirements of intended use by qualification testing, materials testing or similarity;

j) QML PEM Parts.

The parts that meet the selection criteria above, a) to g), are considered as space qualified parts.

PAR 0290 Parts that do not meet the selection criteria specified in PAR 0280, a) to g), and determined to be critical in terms of mission performance per Table 5-1, are non-standard parts. For such parts, all of the applicable part related screening and qualification data and procurement documentation must be made available or submitted to the CSA for approval (e.g. NSPAR, PAD, DCL, PCB) IAW [AD-01] prior to procurement.

PAR 0300 The manufacturer of non-space qualified parts should be requested to have established, high reliability parts manufacturing program and good experience in supplying parts for space use.

PAR 0310 The minimum part quality level must be IAW Table 5-2.

TABLE 5-2 – MINIMUM PART QUALITY LEVEL

APPLICATION	MINIMUM PART QUALITY LEVEL[1]	
	LEVEL 2	LEVEL 3
Critical IAW Table 5-1	X	
Non-Critical IAW Table 5-1		X[2]

Exceptions for use of a non-standard part which does not meet the program screening requirements but has been previously qualified for another space project will only be made on a case-by-case basis provided that the part is screened and qualified to equivalent NASA, Military, or ECSS quality requirements. Such exceptions will be considered by the PCB in accordance with section 5.5.3. The PCB will balance performance, cost, and schedule when making a decision on part quality and reliability exceptions.

The Contractor may follow an alternative approach to Parts Selection if the Contractor can demonstrate that the proposed parts are suitable for use in the intended application subject to CSA S&MA approval.

[1] Part Quality Level IAW GSFC EEE INST-002

[2] For Plastic Encapsulated Microcircuits (PEMs), including plastic encapsulated transistors and diodes, refer to section 5.5.5 herein

5.5.3 Parts Control Board (PCB)

PAR 0320 For parts that fall within the scope of requirement PAR 0290, and for which CSA requires additional discussion and/or clarification on the submitted NSPAR or PAD, the Contractor must establish a PCB or a similar documented system which consist of the following members:

a) Contractor Parts Engineer (PE);

b) Contractor design engineer(s);

c) Subcontractors PE (as required); and,

d) CSA S&MA representative.

The purpose of the PCB is to facilitate the management, selection, standardization, and control of all EEE parts and associated documentation for the duration of the contract.

PAR 0330 The PCB operating procedures may include the following responsibilities:

a) Evaluation of EEE parts for conformance to established criteria and inclusion in the DCL;

b) Review and approval of EEE part derating as necessary for unique applications;

c) When necessary definition of testing requirements including Value Added Testing;

d) Review of non-preferred applications (including radiation effects);

e) Review of part Alerts, failure investigations and Non-conformances related to a part selection;

f) Confirmation of update to parts lists where applicable;

g) Maintain PCB meeting minutes or records to document key discussion points and all decisions made and provide a copy to attendees within five business days of convening the meeting; and,

h) Obtain and provide the required documentation (such as controlled procurement specifications, datasheets, and reports with screening, lot acceptance, and Value Added Testing details where applicable) as rationale to support the approval of each EEE part.

PAR 0340 The Contractor must provide a PCB meeting notification to CSA five business days in advance of the meeting and identify and provide the reference documentation for all of the parts to be reviewed .

PAR 0350 IAW [AD-01], the Contractor must provide a Declared Components List (DCL) to CSA.

5.5.4 Parts Specifications and Procurement

PAR 0360 The Contractor must use a controlled documentation system for procurement of parts.

PAR 0370 The part procurement activity must be done with the use of a specification (MIL, ECSS), or Contractor/Manufacturer Source Control Drawing, or configuration-controlled Manufacturer datasheet, including as appropriate the performance parameters, package descriptions, materials and screening and qualification requirements for the applicable part type aligned with mission requirements.

PAR 0380 Parts for flight equipment and flight spares must be procured directly from the approved manufacturer or when traceability can be established, procured from a manufacturer authorized distributor.

An authorized distributor is one that is officially and contractually authorised by the manufacturer.

PAR 0390 A manufacturer or authorized distributor Certificate of Conformance for parts must be obtained, and traceable to the manufacturers' part number, lot date code and/or serial number of parts being procured.

5.5.4.1 Custom Programmable Microcircuits, Hybrids, and Multi-Chip Modules (MCMs)

Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), and hybrids are considered parts.

PAR 0400 Screening requirements designated for the part must be included in the procurement specification as well as any other requirements deemed necessary based on the criticality of the part procured.

PAR 0410 For parts that fall within the scope of PAR 0290 lot acceptance or rejection, the Percentage of Defectives Allowable (PDA) in a screened lot must be IAW that prescribed in the closest military part specification as agreed during the PCB meeting.

5.5.5 Plastic Encapsulated Microcircuits (PEM)

The PEM requirements herein are adapted from NASA GSFC [RD-35] and ECSS [RD-15], and are applicable only to plastic-encapsulated active monolithic integrated circuits, transistors, and diodes.

PAR 0420 For parts that fall within the scope of PAR 0290 the Contractor and PCB must review the procurement specification or datasheet for required testing, and also review application, procurement and storage processes for the plastic encapsulated part(s).

PAR 0430 To avoid introduction of latent defects during testing, handling, and storing of the flight parts, all parts with a moisture sensitivity level (MSL) of less than 2 (per [RD-24]) should be handled as 2a-5a level parts (this typically requires a 24 hr bake at 125°C for parts with thickness of ~2.5 mm or less; and a 48 hr bake at 125°C for parts with thickness ranging from 2.5-4.5 mm).

Moisture and contamination can penetrate through plastic packages and cause degradation and failures during testing of the parts, solder reflow process, and operation after integration into the system.

5.5.5.1 Evaluation

PAR 0440 For parts that fall within the scope of PAR 0290, the Contractor must ensure that each manufactured lot of EEE PEM parts undergoes evaluation IAW Table 5-3 and review the procurement specification or datasheet for required testing, and also review application, procurement and storage processes for the plastic encapsulated part(s).

TABLE 5-3 – EVALUATION REQUIREMENTS FOR PEM

	TEST	SAMPLING	METHOD / CRITERIA	COMMENTS
1	Construction analysis	As agreed per PCB. (5 parts recommended.)	Procedure for PCB approval.	Testing, analyses, and destructive/non-destructive inspections will cover: • Design and construction technology • Materials used • Inherent reliability aspects • Quality of workmanship • Potential hazards The Contractor may refer to [RD-15] for constructional analysis guidelines.
2	Radiation evaluation	See comments.	See comments.	The contractor is responsible to assess and ensure the flightworthiness of radiation-sensitive PEM parts in accordance with applicable requirements of section 6.7.

5.5.5.2 Screening

PAR 0450 For parts that fall within the scope of PAR 0290, the Contractor must ensure that each PEM part used for flight (including flight spares) is screened IAW Table 5-4.

TABLE 5-4 – SCREENING REQUIREMENTS FOR PEM

	TEST	SAMPLING	METHOD / CONDITIONS	COMMENTS
1	C-SAM	100%	[RD-35] Section 5.3.3	• May be omitted if criteria for representative data (see text below PAR 0460) is met. • A 1-hour bake at 125 °C should be performed to remove moisture from the parts after immersion into the water bath of an acoustic microscope.
2	Pre-burn-in electrical measurements	100%	Per device specification or datasheet, at 25 °C (ambient temperature).	• Piece-part level burn-in may be omitted if assembly-level burn-in will be performed. • Burn-in is a *stress* test as opposed to an *endurance* test; as such if the contractor elects to perform assembly-level burn-in, the test duration and temperature will require prior PCB approval and will need to be in line with the temperatures and durations presented in the previous column. Assembly-level testing at long-duration and at/below ambient temperature is not acceptable. • In order to avoid overstress, the junction temperature during burn-in testing should not exceed the absolute maximum rated junction temperature for the part. In the case of an assembly-level burn-in, the contractor will need to take into consideration the maximum ratings of all parts forming the assembly.
3	Burn-in (static or dynamic)	100%	**STATIC:** [RD-30], Method 1015, condition A or B. **DYNAMIC:** [RD-30], Method 1015, condition D. Required burn-in duration and ambient test temperature for static and dynamic: 160 hrs. at 125 °C, or 300 hrs. at 105 °C, or 590 hrs. at 85°C, or 1,040 hrs. at 70 °C	
4	Post-burn-in electrical measurements	100%	**STATIC:** Per device specification or datasheet, at 25 °C (ambient temperature). **DYNAMIC:** Per device specification or datasheet (at 25 °C, maximum, and minimum rated operating temperatures).	
5	Percent Defective Allowable (PDA)	N/A	Maximum acceptable PDA is 10%.	• Calculated from steps 2 to 4 • Not applicable to assembly-level burn-in
6	External visual inspection	100%	[RD-30], Method 2009	Also inspect for the following defects: Package deformation/ Foreign inclusions in the package, voids and cracks in the plastic/ deformed leads.

5.5.5.3 Qualification (Lot Evaluation)

PAR 0460 For parts that fall within the scope of PAR 0290, the Contractor must ensure that each lot of PEM parts is subjected to a lot acceptance procedure per Table 5-5, unless representative data are made available to the PCB for review.

Data may be considered representative if all following conditions are met:

a) Parts are procured from the same manufacturer and have the same package with no major change in the manufacturing process, part design, and part construction;

b) Data is less than two years old when compared to the proposed Lot Date Code(s); and,

c) The PCB approves the representativeness of the data.

In case of partial available data, the supplier will be responsible to perform any complementary lot acceptance tests.

TABLE 5-5 – LOT EVALUATION REQUIREMENTS FOR PEM

	TEST	SAMPLING	METHOD / CRITERIA	COMMENTS
1	High Temperature Operating Life (HTOL)	10 Parts	[RD-30], Method 1005, Cond. D, 500 hours minimum	• Test conditions may be tailored according to specifics of the device application, for PCB consideration and CSA approval. • The junction temperature should not exceed the absolute maximum rated junction temperature for the part. If 125 °C ambient causes the maximum rated junction temperature to be exceeded, the ambient temperature should be decreased correspondingly.
2	Electrical measurement (per specification)	10 Parts, no failures allowed	Measure at 25 °C, min. & max. rated temperatures.	N/A

5.5.6 Value Added Testing

The following sub-sections describe value-added tests referenced in [AD-14] performed for space applications in order to provide for enhanced reliability of parts and provide for increased subsystem reliability, by increasing the overall probability of mission success.

5.5.6.1 Particle Impact Noise Detection

PAR 0470 All parts with internal cavities must pass Particle Impact Noise Detection (PIND) screening conducted IAW the applicable specification. Any device failing this test will be prohibited from use in any flight application.

5.5.6.2 Surge Current Screening for Tantalum Capacitors

PAR 0480 All solid tantalum capacitors used in filtering applications must be subjected to surge current screening, as follows:

a) Chip capacitors (CWR06 types for example) tested IAW [AD-35]/4 (25°C only); and,

b) Leaded devices (M39003/01 for example) tested IAW [AD-34]/9 (25°C only).

5.5.7 Part Analysis

The Part Analysis requirements in subsections 5.5.7.1 to 5.5.8.5 are applicable to EEE parts that fall within the scope of PAR 0290.

5.5.7.1 Destructive Physical Analysis

PAR 0490 Unless otherwise stated, the Destructive Physical Analysis (DPA) tests, procedures, sample size and criteria is commensurate with CSA's risk tolerance level* and must be as specified in Table 5-6.

TABLE 5-6 – DPA APPLICABILITY

DPA Applicability	CSA Class A*	CSA Class B*	CSA Class C*	CSA Class D*
Required:	Per [AD-14]	Per [AD-14]	Integrated circuits per [AD-14] Hybrids per [AD-14] MLCC per [AD-14]	N/A
Optional:	N/A	N/A	Others part types per [AD-14]	All part types per [AD-14]

** as defined in [RD-37].*

The Contractor's procedures for DPA may be used subject to approval by the PCB.

If a range of multilayer ceramic capacitors is procured from the same manufacturer and lot/date code, the DPA may be limited to a sample from the high, medium and low values of the range.

The PCB on a case-by-case basis will consider variation to the DPA sample size requirements, due to part complexity, risk, availability or cost.

PAR 0500 The DPA results must be reviewed by the Contractor PE and be used as part of the lot acceptance criteria.

5.5.7.2 Humidity Steady State Low Voltage (HSSLV) Testing

PAR 0510 For non-standard and non-QPL MLCCs used in critical applications IAW Table 5-1, a lot specific Humidity Steady State Low Voltage acceptance testing must be performed IAW [AD-11] for V rated < 50V and C > 1µF.

5.5.7.3 Failure Analysis

PAR 0520 When a component part Failure Analysis is necessary to support a Failure Review Board (FRB) or Non-conformance Review Board (NCRB), the Contractor must provide the analysis report essential to achieve a timely resolution and closeout of each failure incident, including the following information as a minimum:

a) The failed part's identity (part name, part number, reference designator, manufacturer, manufacturing lot / date code, and part serial number, if applicable), and symptoms by which the failure was identified (the conditions observed as opposed to those expected);

b) The name of the unit or subsystem in which the failure occurred, the unit part number, serial number and reference Non-conformance Report, the contract number, date of failure, the test phase (including test setup), and the environment in which the test was being conducted;

c) The results of the failure analyses conducted and the nature of the rework / retest / corrective action taken in response;

d) An indication of whether the failure of the part or item in question constitutes a primary or a secondary (collateral) failure; and,

e) Any supporting data including: analyzes, photographs, x-rays, metallurgical data, microprobe or spectrographic data, scanning electron microscope photographs, pertinent variables (electrical and radiation) data, etc.

5.5.8 Additional Part Requirements

5.5.8.1 Derating and Stress Analysis

PAR 0530 All EEE parts must be used IAW the derating guidelines of the EEE Parts Selection, Screening, Qualifications and Derating [AD-14]. The Contractor may propose alternative derating criteria based on success experience for CSA's review, if necessary.

5.5.8.2 Parts Age Control

PAR 0540 All EEE parts manufactured seven or more years before the date of usage must be identified, segregated (NCRB control) and dispositioned per the PCB decision.

PAR 0550 Parts stored in uncontrolled conditions where they are exposed to the elements, electrostatic charge build-up, or sources of contamination must not be used.

5.5.8.3 Traceability

PAR 0560 Each procured EEE part must be traceable to a manufacturer assigned trace code such that:

a) Each trace code is maintained as-is through the entire supply chain including distributor.

b) The traceability of EEE parts during installation in equipment is ensured by the Contractor through maintaining the traceability to the manufacturer's trace code number of the EEE parts actually mounted.

The expression "trace code" means at least one of the following: a lot number, a batch number, and/or a serial number.

5.5.8.3.1 Pure Tin

Pure tin finishes promote growth of "tin whiskers", which can cause serious reliability problems in space systems. The technical details of tin whisker growth and control are not completely understood; but their effects need to be controlled.

Pb-free tin is defined to be any tin alloy with no more than 97% tin content by weight. This means that some Pb-free finishes other than pure tin, such as tin-bismuth and tin-copper, are considered to be "tin" for the purposes of this document. Many of these alloys have not been assessed for whiskering behaviour.

PAR 0570 The Contractor must provide to CSA for consideration and approval and implement a standard process for pure tin mitigation, which includes the following information:

a) Controls and processes that assure the affected assemblies will perform as intended within the expected parameters of the mission, e.g. environment, duration, etc.;

b) Identification of every incidence of Pb-free Tin technology recorded;

c) A minimum of two mitigation measures IAW Section 5.5.8.3.1.1 herein when the Pb-free Tin finish is not completely replaced through a re-plating or HSD process; and,

d) Any special design requirements, mitigation measures, test and qualification requirements, quality inspection and screening, marking and identification, maintenance, and repair processes.

e) Controls that will prevent the use of electrical / electronic cavity-bodied components (i.e.: hybrid, relay, crystal cans, MEMS, etc.) identified as having internal surfaces, plating, metallization, etc. with a Pb-free Tin finish.

5.5.8.3.1.1 Mitigation Techniques

PAR 0580 Components, sub-assemblies, assemblies, and mechanical hardware identified as having Pb-free Tin (i.e. surfaces, plating, metallization, etc.) but which by package design or engineering decision are not protected by SnPb re-plating or HSD, must be protected by at least two process or design mitigation techniques from the following listing to reduce or eliminate the risks created by metallic whisker formation and/or tin pest in the expected end-use application/environment:

a) Design – Components, sub-assemblies, assemblies, and mechanical hardware identified as having external surfaces, plated, metallization, etc. with a Pb-free Tin finish physically positioned or mechanically isolated to ensure the growth of conductive whiskers does not adversely affect performance or reliability.

b) Direct line-of-sight spacing between electrically uncommon conductive surfaces is such that a nominal whisker growth rate of 1mm/yr. over the life of the mission does not violate minimum electrical spacing requirements.

c) External surfaces, plating, metallization, etc. with a Pb-free Tin finish fully coated with conformal coating with a total cured finish of not less than 100µm [0.004 in].

d) Embedment / Encapsulation – Embedment or encapsulating material that fully wets and covers all surfaces of parts and areas specified by the approved engineering documentation. Cured material to be void-free, compatible with the hardware and mission environment, and have no adverse effect on the hardware performance or reliability.

Other mitigations to be considered. The use of SMDs with a Matte tin plating and Nickel plating reduces the risk of tin whisker growth. The Contractor is encouraged to use devices which passed the JEDEC JESD22A121 Measuring Tin Whisker, or JEDEC 201 (proposal) Environmental Acceptance Requirements for Tin.

5.5.8.3.2 Other Prohibited Materials

PAR 0590 The use of the materials listed in Section 7.2.12 must be prohibited in the construction and surface finish of EEE hardware, unless pre-approved by CSA as per PAR 0050.

5.5.8.4 Alerts

PAR 0600 The Contractor must process all Alerts and Problem Advisories received from the Government Industry Data Exchange Program (GIDEP), ESA Alert System (EAS), part manufacturers or CSA, as follows:

a) Assess and document applicability;

b) Analyze and document the impact of applicable alerts and problem advisories;

c) Implement and document corrective actions for applicable alerts and problem advisories; and,

d) Share with CSA, upon request, applicability, analysis, and corrective actions taken.

Alerts may also be raised against development tools, such as those involved in FPGA development.

5.5.8.5 Connector Back Shells

PAR 0610 Right angle connector back shells where the mounting hardware or jack posts run through the inside of the back shell must be verified and an insulating sleeve installed to ensure the jack post screw threads do not cut though the wire insulation during the next higher level of assembly.

6 RELIABILITY

6.1 RELIABILITY ASSURANCE PROGRAM

The purpose of the Reliability Assurance Program is to provide assurance that the Space Segment is designed in such a manner to maximize the probability of successful operation over the required mission life. This is to be achieved by performing analyses of the Space Segment design and improving the design as necessary.

The approach to spacecraft reliability is based on reliability improvement techniques including:

a) Fault Removal (Failure Analysis);

b) Fault Tolerance (redundancy);

c) Fault Avoidance, including:

1. Review of manufacturing procedures;
2. Control of stress factors through the use of conservative design practices;
3. Analyzing electrical stresses on parts and applying de-rating factors;
4. Applying design margins to address mechanical stresses; and,
5. Testing, especially life cycle tests for bearings, mechanisms and other life limited items.

6.2 RELIABILITY PREDICTION

The applicability of requirements and associated CDRLs invoked in this section will be based on requirements from [AD-02], and work stipulated in [AD-01] respectively.

PAR 0620 Reliability prediction should be performed to implement a reliability designs trade-off, if applicable, and demonstrate that the failure rate of the systems, sub-systems and units can meet reliability requirement over the operational life.

PAR 0630 During the preliminary design phase, the reliability prediction should be performed using the parts count method or equivalent method.

PAR 0640 During the critical design phase, the reliability prediction analysis should be performed and updated using the stress analysis method or equivalent.

PAR 0650 Failure rate of each part should use data from the following sources:

a) MIL-HDBK-217F [AD-31] Prediction;

b) FIDES https://www.fides-reliability.org/ [AD-45];

c) Non-electronic Parts Reliability Data [AD-44];

d) Original Equipment Manufacturer (OEM) Field or Life Test Data; and,

e) COTS hardware that has a proven track record and for which the reliability data is known.

PAR 0660 Data from OEM's test data and/or data used from previous space projects, should be supported by providing reference material to CSA for review.

PAR 0670 As for the method of parts stress or equivalent, the result of the parts stress analysis must be applied for the electrical stress. Also, the temperature stress used in this analysis should also be taken from the result of the parts stress analysis based on average temperature in orbit. If average temperature in orbit is not defined clearly, average temperature should be estimated by Formula below.

Average Temp. = Minimum Temp. at BOL /2 + Maximum Temp. at EOL/2

The quality factors (Πq) used in the reliability predictions are those corresponding to the procured base part. Any additional up screening applied on the procured part is considered a risk mitigation but will not improve reliability or quality of the actual part.

PAR 0680 Non-operating multiplication factors must be used to assess the reliability of non-operational equipment:

a) electrical or electronic items assumed to have 1/10 (one tenth) of the failure rate of active items;

b) mechanical items assumed to have 1/100 (one hundredth) of the failure rate of active items.

PAR 0690 The analysis data package must include the following as a minimum and be submitted to CSA IAW [AD-01]:

a) reliability block diagram;

b) failure rates for each block of reliability block diagram;

c) mathematical models or applicable dynamic model data;

d) probability of success results; and,

e) comparison of results with specified requirements.

6.3 FMECA

The primary purpose of the Failure Modes, Effects and Criticality Analysis (FMECA) is to identify design risks, issues, address single points of failure, fault propagation mechanisms, and workarounds. A FMECA for each mission phases (deployment and on orbit performance) will be available and presented at the PDR, and again at the CDR with necessary updates reflecting the finalized design.

PAR 0700 An assembly level (unit level) and subsystem and/or system level, FMECA must be performed at the preliminary design phase.

PAR 0710 At the critical/detail design phase, a detailed analysis including design changes must be performed and the assembly level and subsystem and/or system level analysis updated.

PAR 0720 For a piece part level FMECA, interface failure effects (i.e. between power lines, telemetry and command lines, any signal line, etc.) must also be performed.

The Contractor is encouraged to perform the FMECA iteratively, starting as early as possible in the design phase to ensure that any design changes from design reviews, analyses, non-compliances or other reasons do not introduce new failure modes or criticalities into the system.

PAR 0730 A functional hazard analysis at the unit level should be performed for the Ground Support Equipment used prior to the testing of the flight hardware.

PAR 0740 The failure mode must be categorized according to the severity of the failure effects. The severity categories are defined in Table 6-1. Single point failures (SPF) will be identified and summarized based on the FMECA. A mitigation or elimination of the SPF will be a key activity of the FMECA.

PAR 0750 SPFs must be identified and reported to CSA for review.

TABLE 6-1 – SEVERITY CATEGORIES

SEVERITY CATEGORIES	ASSSEMBLY/ EQUIPEMENT LEVEL	SUBSYSTEM LEVEL	SPACECRAFT SYSTEM LEVEL
1 (Catastrophic)	Failure mode results in risk of loss or degradation of other equipment (risk of failure propagation).	Failure mode results in risk of loss or degradation of other functional subsystems (risk of failure propagation) or constitutes a hazard.	Failure mode results in complete loss of the spacecraft system and all its missions (referring to specified requirements) or constitutes a catastrophic safety hazard.
2 (Critical)	Failure mode results in complete loss of operational capability of equipment under consideration.	Failure mode results in complete loss of operational capability of subsystems under consideration.	Failure mode results in partial loss or severe degradation of mission.
3 (Major)	Failure mode results in severe degradation of operational capability of equipment under consideration.	Failure mode results in severe degradation of operational capability of subsystems under consideration.	Failure mode results in only minor or negligible degradation of mission.
4 (Minor)	Failure mode results in only minor or negligible degradation of equipment under consideration.	Failure mode results in only minor or negligible degradation of subsystems under consideration.	No category 4 for a spacecraft system level

PAR 0760 The FMECA must be submitted to CSA IAW [AD-01].

6.4 CRITICAL ITEMS

PAR 0770 Unit-level Critical Items Lists (CIL) must be submitted to CSA IAW [AD-01].

Critical Items will include items that require special attention because of complexity, use of unproven state-of-the art technology or non space qualified processes, possible reliability or lifetime problems, or because they have one or more failure modes which could cause significant performance degradation, or loss of function.

PAR 0780 The following items must be classified as critical item for the project:

a) items not qualified including, EEE parts, materials and processes;

b) items with highly sensitive processes;

c) items which are difficult to test on ground;

d) items containing limited life parts;
e) items which are radiation-sensitive;
f) items using new technologies;
g) items causing critical, catastrophic hazards or fault propagation;
h) critical single point failures;
i) other items identified by the risk assessment analysis;
j) excessive long lead parts;
k) EEE components subject to export license constraints;
l) EEE components containing dangerous elements;
m) EEE components out of acceptable de-rating conditions;
n) material with particular constraints for storage; and,
o) software critical items.

PAR 0790 Whenever a critical item is identified based on one or more of the above criteria, a risk mitigation strategy that will reduce the risk of use to an acceptable level must be included as part of the CIL and submitted to CSA IAW [AD-01].

6.5 WORST CASE ANALYSIS

The objective of the Worst Case Analysis (WCA) is to assess the capability of the end product to accomplish all performance requirements over the life of the mission under worst-case conditions.

PAR 0800 For units that are not Category A, or units that don't have flight heritage (per section 4.5.2 definition) covering the required mission duration, the Contractor must perform and document either of the following*:

a) A unit-level WCA covering as a minimum critical applications as defined in Table 5-1 herein, and addressing the parameters defined in the SOW set at the worst-case limits and worst-case environmental stresses; or,
b) For units with an EQM or QM model philosophy, a unit-level Voltage & Temperature Margin Test (VTMT) designed to demonstrate BOL and EOL margins when accounting for radiation effects, initial tolerance variations, aging, and unit-to-unit variations.

**In case of COTS units and units with flight heritage (Section 4.5.2), CSA may accept other verifiable sources of information, subject to approval by the CSA.*

More information about the VTMT test is available on the NASA website at [RD-40].

PAR 0810 The Contractor should ensure that margins are IAW [AD-12] in the design of electronic circuits and electromechanical/mechanical items, and that those margins are demonstrated by analysis or test.

PAR 0820 The WCA analysis must be submitted to CSA IAW [AD-01].

6.6 PARTS DERATING AND STRESS ANALYSIS

PAR 0830 Parts derating and application review for all equipment on the spacecraft must be performed to ensure that application of each part meets the derating criteria under maximum temperature of acceptance test (AT) condition. As a minimum, the following should be reported in stress analysis work sheet:

a) parts description;

b) parts type;

c) parts number;

d) assembly name;

e) drawing number;

f) temperature range (both rated and applied temperatures); and,

g) electrical value (both rated value, applied value and stress ratio).

This analysis should include stress during transient under worst case condition. Derating criteria of each part type should be as is required in the appropriate performance specification.

The most stressful part level parameters are typically obtained from the unit-level WCAs.

PAR 0840 The parts stress analysis should be performed concurrently with the packaging and thermal design and at the most stressful part level parameter values that can result from the specified performance and environmental requirements on the assembly.

PAR 0850 All parts stress that exceeds derating criteria must be reviewed and corrective action taken.

PAR 0860 The parts stress analysis must be submitted to CSA IAW [AD-01].

6.7 RADIATION ANALYSIS

PAR 0870 The Contractor must provide a space radiation hardness plan that will be implemented during the project phase. This plan may be part of the PAIP.

6.7.1 Part-Level Considerations

PAR 0880 An assessment of performance must be conducted for radiation sensitive parts to show that the designs will meet their performance requirements after being subjected to the radiation environment defined in the [AD-03] or derived unit-level specification, for a two times (2x) mission duration.

For Total Ionizing Dose (TID), and Total Non-Ionizing Dose (TNID)[1] 2x mission duration corresponds to 2x the expected mission dose.

PAR 0890 The Contractor should perform a detailed shielding/sectorial analysis in order to establish the true TID and TNID[8] seen at the piece part level within the integrated unit.

The sectorial analysis uses Ray Tracing Technique that applies the Dose Depth Curve to estimate the total dose received at a specific location through the varying shielding thickness.

[1] Also known as Displacement Damage Dose (DDD).

PAR 0900 TNID[8], is applicable, to optics, optoelectronics, bipolar technology, and for all other parts susceptible to radiation effects such as Total Ionizing Dose (TID) and Single Event Effects (SEE), the Contractor must provide relevant radiation characterization data to CSA for consideration and approval, or otherwise subject the affected part(s) to testing related to the applicable radiation effect(s) in order to provide the radiation characterization data.

CSA reserves the right to determine whether radiation characterization data is relevant or not for each instance of radiation susceptible part. This determination will take into account such factors as: design and construction, technology, manufacturing processes, part number comparison, test methods, date codes, etc. The need for component level radiation testing, as well as the sample size (recommend three parts minimum) to be tested will be processed by the PCB.

TNID is mainly generated by proton, neutron, and to a lesser extent by electrons causing atom displacement and lattice destruction. The displacement damage analysis necessitates the assessment of the Non-Ionizing Energy Loss (NIEL) renormalisation of the spectrum that takes into account the damage impact of a particle of a defined energy.

6.7.2 Assembly-Level Considerations

PAR 0910 The design must be subjected to radiation hardening techniques (e.g. circuit redesign, part or box shielding) when analysis shows that performance requirements will not be met at the end of life due to degradation caused by radiation.

PAR 0920 Radiation hardened parts should be used whenever possible to minimize weight increases due to additional shielding.

6.7.3 Single-Event Effects (SEE)

PAR 0930 Parts must be assessed for the potential of Single Event Upset (SEU), Single Event Transient (SET), and Single Event Functional Interrupts (SEFI), which requires analysis of the circuit application on a case-by-case basis.

PAR 0940 If performance demands the use of a part susceptible to Single Event Latch-up (SEL), Single Event Gate Rupture (SEGR), or Single Event Burnout (SEB), measures must be implemented to ensure that SEL, SEGR, and SEB induced damage (both prompt and latent) is mitigated and that the mission success is not compromised.

These measures are subject to CSA approval before the part can be added to the DCL.

6.7.4 Enhanced Low Dose Rate (ELDRS)

PAR 0950 Bipolar, BiCMOS, and Optoelectronic parts should have passed ELDRS testing to a maximum dose rate of 0.05 rad(Si)/s prior to be deemed acceptable from a radiation perspective.

6.7.5 Mitigation of Radiation Effects

PAR 0960 The effects of radiation should be mitigated by using radiation tolerant parts, screening or radiation hardened circuits per the radiation guidelines of [AD-33].

PAR 0970 Radiation tolerant circuits should be designed using the following considerations:

a) Design Considerations:

1. Derating;
2. Transistor SEE Safe Operating Area (SOA);
3. Design margins (fan out, timing, drive current);
4. Error Detection and Correction (EDAC) for digital circuits;
5. Memory scrubbing;
6. Shielding (both spacecraft shielding and thickness of equipment enclosure); and,
7. Cold redundancy.

b) Prevention of Single Event latch up and Single Event upsets:

1. Electrical characteristics;
2. Latch up protection circuits; and,
3. EDAC for memory and data storage registers and data related components.

6.8 ELECTROSTATIC DISCHARGE

PAR 0980 There must be no floating conductors on mechanical and electrical parts (e.g., isolated conductors, connector pins, radiation spot shields).

This requirement can be achieved through the use of adequate bleed paths using proven design best practices such as those specified in [RD-38]. Alternatively, the contractor may demonstrate in a QSR that: 1) the unit has flight heritage (IAW section 4.5.2) in an ESD environment equal to or worse to that of the intended mission, or 2) there is no ESD hazard, assuming the electron spectrum for the mission.

7 MECHANICAL PARTS, MATERIALS AND PROCESSES PROGRAM

7.1 OBJECTIVES

The objective of the Mechanical Parts, Materials and Processes program is to establish and implement the requirements for the selection and control of mechanical parts, materials and processes. These requirements are applicable to subcontractors and suppliers.

7.2 MATERIALS AND PROCESS SELECTION

7.2.1 Generalities

PAR 0990 All materials and processes required to be used in the fabrication of space hardware must be selected from the approved Declared Materials and Processes Lists created and maintained by the Contractor for the Project and delivered to CSA IAW [AD-01].

Material selection is regulated by heritage, vacuum stability, spacecraft charging effects, atomic oxygen susceptibility, processing requirements, cured properties, and potential to generate contaminants.

The Contractor is encouraged to select materials from [RD-39], Materials List for Space Hardware Systems, and may also wish to request access to, and consult the NASA MAPTIS database for the purpose of materials selection. MAPTIS is accessible here: http://maptis.nasa.gov/home.aspx.

PAR 1000 Any materials and Ground Support Equipment (GSE) used on the ground for testing in a space type environment must be subject to relevant space environment requirements if it physically interfaces with flight equipment at the interface, excluding TVAC per PAR 1010.

Any GSE or material that will physically interface with flight equipment, or which will be subject to space conditions/stresses could degrade performance if not properly screened.

PAR 1010 When electrical or mechanical ground support equipment materials interface with the flight equipment or are used in thermal vacuum with flight equipment, the Contractor must take into consideration possible contamination, surface degradation, electro-mechanical and chemical effects to the flight equipment.

7.2.2 Materials Selection Criterion

PAR 1020 Organic materials must have been tested IAW [AD-08].

PAR 1030 The Contractor must use and verify the following parameters and criterion during the material selection process:

a) Outgassing (applicable to organic materials);

   1. A-rated: (TML* < 1.0%; Collected Volatile Condensable Material [CVCM] <0.10%; without cure or bake out) – acceptable as is;
   2. B-rated: (TML* < 1.0%; CVCM < 0.10%; with cure or bake out) - acceptable as is (B-rated material with appropriate cure specified will be automatically approved);

3. C-rated: (TML*< 3.0%; CVCM < 1.0%) – approval required;
4. R-rated: prohibited; and,
5. Unknown or insufficient data – requires testing.

b) Stress Corrosion Cracking (SCC), the use of materials that are susceptible to stress corrosion cracking avoided whenever possible;

Material susceptibility to SCC is assessed and selected using [AD-38] or [AD-13].

c) Flammability, the use of flammable materials avoided whenever possible;

For flammability, meet [AD-40]. Flammability is a concern during ground operations, Assembly, Integration and Test (AIT) and launch.

d) Limited Life Items;

Limited life items are identified and controlled.

e) Atomic Oxygen Effects;

Atomic oxygen effects include reactivity of organic complexes, binder erosion of paint fillers, volatilization and scaling of metal such as osmium and silver.

f) dissimilar metals: allowed potential difference is 0,5V;

g) radiation resistance; and,

h) applicable previous successful usage on long life space programs.

* A TML greater than 1.0% is acceptable provided that the Recovered Mass Loss (RML) is less than or equal to 1.0% once the Water Vapor Regained (WVR) is subtracted. The RML is basically the TML value that does not include reabsorbed water or RML=TML-WVR.

7.2.3 Fracture Control

Fracture Control is assessed IAW the applicable NASA or ECSS standard.

PAR 1040 Critical high-strength fasteners or pressurized systems must be assessed from a fracture mechanics viewpoint before they are accepted for use.

PAR 1050 The structural analysis must address and identify the Fracture Critical items and verification methods such as non-destructive inspections or tests to screen Fracture Critical items or parts.

7.2.4 Materials Used in COTS Equipment

PAR 1060 The Contractor must provide to CSA the measures used to ensure that all materials in the hardware are acceptable for use.

Such measures might include any one or a combination of the following: hermetic sealing, vacuum bake out, material changes for known non-compliant materials, etc.

PAR 1070 When a vacuum bake-out is the selected method, it must be performed IAW the approved contamination control plan and demonstrate compliance with the Project-specific allowances and error budget.

7.2.5 Organic Materials

PAR 1080 Lubricants must be stable under vacuum environments and over the temperature range of operation and meet the outgassing limits.

PAR 1090 The design life of lubricants must be such that:

a) Lubricants do not degrade in their application nor come in contact with another lubricant in any application; and,

b) Lubricants meet the design life requirements including storage.

Silicone-based thermal grease should be avoided unless used on heritage hardware and with an explicit method for removal of silicone residues.

7.2.6 Inorganic Materials

PAR 1100 All exposed inorganic materials must have a specified surface treatment such that no bare metal surface is exposed.

PAR 1110 Metallic materials selected for use on flight hardware must be corrosion resistant or protected from corrosive environments.

Such protection may be achieved through: finishing, prevention of moisture condensation on corrosion-susceptible hardware, environmental controls, or use of seals and metallurgical joints.

PAR 1120 Use of dissimilar metals, as defined by [AD-36], in contact, must be limited to applications where the potential difference is 0.5V.

PAR 1130 When use is unavoidable, dissimilar metals must be protected against galvanic corrosion by a method listed in [AD-36].

PAR 1140 Composite materials containing graphite fibres must be treated as graphite in [AD-36].

PAR 1150 If applicable, Metallic and non-metallic materials that are exposed to propellants for the fluid system or that may be exposed to the propellant(s) must not be allowed to catalyze or accelerate fluid decomposition when tested IAW [AD-40].

PAR 1160 Metallic materials directly exposed to propellants must not be allowed to exhibit surface corrosion in excess of a rate of 1 mil per year when tested IAW [AD-09].

PAR 1170 Exterior and exposed materials (primarily thermal control materials) must be capable of functioning as intended in the orbital charged particle radiation and atomic oxygen environment.

7.2.7 Process Selection and Criteria

PAR 1180 The selection of processes must meet:

a) adequacy of the process specifications, standards and process maintenance program and procurement;

b) qualification status of the previous application to long-life space programs and/or certification of personnel by demonstration and test programs;

c) certification of the processes and equipment;

d) use of approved materials;

e) soldering of space assemblies IAW [AD-30] or equivalent;

f) soldering and Electronic assembly of ground support equipment and ground segment IAW [AD-22], [AD-30] Class 2 standards;

g) Crimping, cables, harnesses and wiring IAW [AD-42] or equivalent; and,

h) Polymeric application IAW [AD-41] or equivalent.

PAR 1190 The use of the following special processes must be documented as part of a declared processes list (DPL) and executed IAW a military, SAE, ASTM, or other international standard, and the status of personnel and machine certification recorded and maintained for review by CSA at the design review and/or MRR:

a) Metallurgical Joining;

b) Dissimilar metals welding;

c) Brazing including cleaning operations and cleanliness verification;

d) Inspection of welded joints;

e) Dye penetrant inspection;

f) Heat treatment of metallic fabricated parts;

g) Surface finish; and,

h) Surface preparation of surfaces used for adhesive bonding, coating, sealing and thermal coating applications.

7.2.8 Chlorinated Fluorocarbons

PAR 1200 All Parts, Materials and Processes must be free of Chlorinated Fluorocarbons (CFCs) as mandated by Canadian governmental and provincial regulations, as applicable.

7.2.9 Age Sensitive Materials

Many raw and non-metallic flight materials have a shelf life specified by the manufacturer.

PAR 1210 All flight materials with a specified shelf life must be controlled by a shelf-life control program.

PAR 1220 Expired material must be prohibited from use or be re-certified prior to use in flight hardware IAW the manufacturer's approved functional tests performed and/or under the direction and surveillance of the NCRB.

7.2.10 Fracture Integrity Assurance

The Contractor is responsible to verify and procure fasteners from a trusted source to ensure they are not counterfeit.

PAR 1230 For structural applications, mechanical testing or proof loading must be used to verify the structural integrity for fasteners which are application specific fabricated or which are procured from a non military qualified manufacturer or supplier.

7.2.11 Allowable Mechanical Properties

PAR 1240 Values for allowable mechanical properties of structural materials in their design environment must be taken IAW the referenced requirements of MMPDS-01 [AD-10] or MIL-HDBK-5 [AD-32].

When conforming to [AD-10], B-Basis material values may be used in redundant structure in which the failure of a component would result in a safe redistribution of applied loads to other load-carrying members. Conforming to [AD-10], S-basis material values may be used for materials in lieu of A-Basis and B-Basis values where lot acceptance testing is a procurement specification requirement. Typical-Basis material values are not allowed.

When conforming to [AD-32], material "B" allowable values may be used in redundant structure in which the failure of a component would result in a safe redistribution of applied loads to other load-carrying members. Conforming to [AD-32], material "S" allowable may be used for materials in lieu of "A" and "B" allowable where lot acceptance testing is a procurement specification requirement.

7.2.12 Prohibited Materials

PAR 1250 The use of the following materials must be prohibited in the construction and surface finish of space hardware unless pre-approved by CSA as per PAR 0050.

a) Beryllium oxide (except if it is contained in a sealed part and identified);

b) Cadmium;

c) Zinc;

d) Lithium (except if used in Batteries);

e) Magnesium;

f) Mercury or Mercury compounds;

g) Radioactive material;

h) Pure tin (electroplated or fused);

i) Corrosive fluxes and corrosive generating silicone sealants;

j) Silver;

k) Polyvinyl Chloride (PVC);

l) The use of non-metallic materials that are subject to cold flow under load, for example Teflon wire insulation; and,

m) Teflon coatings or insulation on exterior and exposed materials.

7.3 QUALIFICATION OF MECHANICAL PARTS, MATERIALS AND PROCESSES

PAR 1260 The mechanical parts, materials and processes used on flight equipment must be space qualified, meaning:

a) Selection criteria of Section 7.2 of this document are satisfied;

b) Verifiable evidence of successful flight heritage for the material and process exists; or

c) Verifiable process qualification (representative of mission duration and environment) test data exists.

PAR 1270 Mechanical parts, materials or processes that have not been previously flight qualified for the intended application or that do not comply with the specifications in this document must be considered non-standard and require completion of a qualification program against the project qualification environment prior to their use.

Material and Process qualification is independent of a design or end item deliverable qualification.

7.3.1 Area Array Packages

PAR 1280 Implementation of Ball Grid Array (BGA) package technologies should be IAW [RD-22] or equivalent standard and must be subject to the applicable mission process qualification for CSA approval.

PAR 1290 Implementation of Ceramic Column Grid Array (CCGA) package technologies should be IAW [RD-21] or equivalent standard and must be subject to the applicable mission process qualification for CSA approval.

For Category A and B units, CSA reserves the right to review qualification reports and will seek confirmation that there was no change to the process. For Category C and D units, CSA reserves the right to review and approve the intended process.

7.4 DECLARED MECHANICAL PARTS, MATERIALS AND PROCESSES LISTS

PAR 1300 The Contractor, subcontractors and suppliers must maintain as-designed/as-built mechanical parts, materials and processes lists IAW [AD-01].

For COTS units and subsystems which are procured from a European supplier, the declared lists issued IAW the ECSS requirements is acceptable.

8 QUALITY ASSURANCE PROGRAM

8.1 OBJECTIVES

The objectives of the QA Program are to establish, verify, document and ensure compliance with design control requirements and quality criteria during all phases of the contract.

8.2 DESIGN AND DEVELOPMENT REVIEWS

8.2.1 Design Standards

8.2.1.1 Printed Wiring Boards

The Printed Wiring Board (PWB) manufacturing and acceptance requirements in section 8.4.2.1 Workmanship are based on using PWBs designed IAW the [AD-16], [AD-17] and [AD-18] PWB design standards.

PAR 1310 Space flight PWB designs should not include features that prevent the finished boards from complying with the requirements of [AD-20].

The Contractor is encouraged to use the design rules established by the IPC-2200 series to ensure the PWB manufacturing tolerances are achieved and the final PWB reliability meets the applicable IPC class IAW [AD-20], and the workmanship standards specified in section 8.4.2.

8.2.1.2 Assemblies

PAR 1320 The design must take into consideration the design rules and requirements specified in the assembly workmanship requirements listed in Section 8.4.2.

8.2.2 In Process Reviews

PAR 1330 The Contractor must review the As Designed Parts Lists (ADPL) and the As Built Parts Lists (ABPL) configurations.

PAR 1340 The Contractor must reconcile the differences between the ABPL and ADPL and provide the status as part of the EIDP.

PAR 1350 The Contractor must ensure that all engineering and manufacturing documentation is approved and controlled prior to use.

8.3 PROCUREMENT

The Contractor is responsible to ensure the adequacy and quality of procured hardware, processes and services. Although functional/performance aspects of procurement are the responsibility of engineering, there is also a need to verify that the procured items will meet all other requirements (i.e. non-functional).

PAR 1360 The Contractor must verify the procurement documentation quality requirements are included and monitor supplier performance and assure that corrective action is initiated and implemented where non-compliance is observed.

PAR 1370 The contractor must maintain a list of suppliers that includes the approval status and scope of approval i.e. product type/process family.

8.3.1 Source Inspection

PAR 1380 The Contractor should perform source inspection to evaluate the production processes for critical items as defined in the CIL, at the supplier's premises for compliance to the applicable quality standards when one or more of the following conditions exists:

a) In-process or end item process controls used by the supplier have an effect on the quality of the articles and the quality cannot be verified by inspection or test of the procured articles;

b) Special handling or test equipment and facilities are required and are not available other than at the source;

c) Supplier performance or quality history is marginal; and,

d) The inspection or test to be performed will be used to verify the deliverable end item conformance to the contractual requirements and will not be subsequently repeated.

Any inspection or test carried out at a supplier's facility by representatives of CSA will not relieve the Contractor of its responsibility to ensure product conformance, nor will it prejudice the right of CSA to reject items subsequently found not to conform.

8.3.2 Incoming Inspection and Records

PAR 1390 The Contractor must ensure that all incoming inspections and records are IAW procurement policies and procedures.

PAR 1400 Incoming inspections must be performed on all material, including Government Furnished Equipment (GFE) items.

PAR 1410 Documentation accompanying hardware must indicate the inspection status of the hardware and include the testing methods, results of inspections, discrepancies and records of rework accomplished.

PAR 1420 Incoming inspection records must include a supplier certificate of conformance and be traceable to the part number, traceability code, inspection and test records.

8.4 MANUFACTURING

The Contractor and/or subcontractors QA will review the manufacturing flow charts and select the Key Inspection Points (KIPs) and MIPs where the Contractor QA inspection is required.

CSA reserves the right to identify and conduct its own mandatory inspections on manufacturing flow charts. These inspection points will be selected by CSA at CDR or MRR to be incorporated as part of the QA/QC inspection and test surveillance called up in the manufacturing flow charts.

8.4.1 Review of Quality Related Manufacturing Documentation

PAR 1430 Fabrication, assembly and test operations must be performed IAW approved manufacturing documentation reviewed and approved by the Contractor QA.

PAR 1440 The manufacturing documents must include as a minimum the following:

a) Item part number and configuration of governing specifications and drawings;

b) QA/QC inspection (including customer MIP) and test surveillance points with reference to the procedures and workmanship standards;

c) Special tools and fixtures;

d) Witness samples where special process verification is required;

e) Special handling, packaging and contamination control requirements;

f) Provision to record the quality status and history, as built configuration and traceability information; and,

g) Traceability to the manufacturing operator(s).

8.4.2 Workmanship Requirements

8.4.2.1 Printed Wiring Boards

PAR 1450 Flight PWBs must be manufactured IAW the applicable Class 3 requirements of the [AD-19] and [AD-21] manufacturing standards and [AD-20] for Rigid Printed Wiring Board (Space).

8.4.2.2 Assemblies

PAR 1460 Flight Assemblies must be fabricated using the workmanship standards listed below or acceptable alternates listed in Appendix A. The use of a Flying Probe test on circuit board assemblies is prohibited unless approved by CSA.

a) NASA-STD-8739.1 [AD-41]: Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies; Requirement to stake hardware is also applicable to mechanical assemblies. Requirement to coat exposed electrical terminations is required for all applications and not only for printed wiring boards assemblies.

b) J-STD-001S [AD-30]: Requirements for Soldered Electrical and Electronic Assemblies with Space Addendum;

c) NASA-STD-8739.4 [AD-42]: Crimping, Interconnecting Cables, Harnesses, and Wiring; Special design and manufacturing considerations are required when securing RF cables and harness assemblies.

d) NASA-STD-8739.5 [AD-43]: Fiber Optic Terminations, Cable Assemblies, and Installation; and,

e) ANSI/ESD S20.20 [AD-06]: Electrostatic Discharge (ESD) Control: Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices). The environmental conditions are IAW the NASA workmanship requirements.

8.4.3 Training and Certification

PAR 1470 The Contractor must establish and maintain a training and competence program of manufacturing and quality personnel to evaluate their skills, including as a minimum: workmanship, special processes, fabrication, inspection and ESD standards.

PAR 1480 The Contractor must ensure that manufacturing quality personnel are trained and certified IAW the defined program.

PAR 1490 Records of personnel competence and training must be available to CSA as required.

PAR 1500 The training and competence program must address the following as a minimum:

a) Ensure that the personnel skills required to conduct necessary tasks are identified and provided as needed;

b) Ensure that the status of personnel training is reviewed on a regular basis and appropriate records are maintained;

c) Address equipment and process certification and identify the review periods for re-certification;

d) List any special processes that require training and competence; and,

e) List authorized technical personnel to perform special processes.

8.4.4 Contamination and Cleanliness Controls

8.4.4.1 General Requirements

The requirements of Sub-Section 8.4.4.1 are applicable to all units and sub-systems of the spacecraft, regardless of contamination sensitivity.

Contaminants are defined as those materials, either at a molecular or particulate level, whose presence may degrade mission performance. The source of these contaminants may be from any material or equipment coming into contact with the hardware, the test facilities, and/or the environments to which the hardware is exposed.

PAR 1510 Contractor should establish and maintain an approved contamination/cleanliness control plan for flight hardware, with requirements for conformance specifically defining cleanliness, contamination and debris control requirements IAW [AD-28], [AD-26], [AD-27], [AD-37] or their equivalent to prevent contamination of components.

PAR 1520 Clean rooms, work stations and controlled work areas used for assembly and test of the hardware must meet the applicable workmanship and design requirements [AD-26].

PAR 1530 Cleanliness protection must be provided prior to leaving a controlled area, or whenever a storage period is planned.

PAR 1540 Transport and storage packaging material used in intimate contact with cleaned surfaces of parts and assemblies must not contain topically applied antistatic treated film.

PAR 1550 Cleaning aids and fluids must be verified on a periodic basis to ensure the contaminant levels are not exceeded, for the items to be cleaned.

The Contractor may refer to [RD-16] Annex I for a compatibility table between materials and solvents, and to Annex J for precision cleaning solvents.

PAR 1560 The Contractor must perform bake-outs on flight assemblies, harnesses and blankets IAW the following details documented in a specification:

a) bake out conditions (i.e. temperature, time, and pressure);

b) monitoring method;

c) success criteria;

d) background of the baking facility; and,

e) provisions to ensure that bake out conditions will not have a detrimental effect on the functionality of the material/item under bake out.

PAR 1570 As a minimum, all delivered items will be visibly clean; there must be no evidence of any particle or molecular contamination visible at 1x magnification when viewed from 6 to 18 inches with at least 1077 Lumens per square meter (Lm/m2) illumination.

8.4.4.2 Contamination Sensitive Equipment

The requirements of Sub-Section 8.4.4.2 are applicable to systems, sub-systems, and units containing contamination sensitive hardware such as lenses, mirrors, CCDs, and optical detectors.

PAR 1580 The Contractor must define and document cleanliness requirements in a cleanliness requirements specification for all contamination-sensitive equipment during each stage of development, integration, testing, and the launch campaign.

PAR 1590 In reply to the cleanliness requirements specification for contamination-sensitive equipment, the Contractor must document and implement a Contamination Control Plan (CCP) that describes the contamination allowances and hardware sensitivity (including contamination-sensitive hardware provided by subcontractors and suppliers), methods for control and monitoring, and verifications to confirm that the allowances have been met and list the documents or processes used to implement and control the requirements during each phase of the hardware lifetime.

The allowances determine the maximum allowed on-ground and in-orbit molecular and particulate contamination levels. The specified contamination levels are to be derived from the acceptable performance losses determined by the Contractor

PAR 1600 Cleanliness verification of hardware and facilities must take place in the following circumstances as a minimum:

a) At predetermined intervals specified in the CCP to confirm the efficiency of the established cleanliness control measures;

b) After the occurrence of an incident or anomaly that can have influenced the cleanliness conditions of the space system or clean room;

c) Before the beginning of a test campaign and launch activities to confirm that facilities conform to the CCP; and,

d) Before and after a test in a vacuum chamber.

8.4.4.2.1 Bake-out of Contamination Sensitive Assemblies

When contamination predictions exceed the allocated contamination budget, or for highly contamination sensitive hardware, bake outs of critical subassemblies before final assembly may be necessary and if so will be specified by the Contractor.

PAR 1610 The Contractor must ensure that the total amount of out gassed condensable volatile matter from a unit remains within the outgassing and particulate contamination allowances even though the materials used satisfy the outgassing requirements for TML and CVCM.

The purpose of these bake-outs is to ensure by measurement that the outgassing rate is within the allowable contamination limits IAW the performance specifications.

8.4.4.3 Planetary Protection

This section is applicable to selected extraterrestrial/planetary projects and missions.

PAR 1620 Manufacturing, assembly, test, and storage of hardware for the project must be in an environment compatible with space hardware processing cleanliness requirements and Planetary Protection provisions per [AD-39], IAW the applicable mission Category.

Mission Category will be confirmed by CSA as early as possible in the project, based in part on discussions with international partners.

8.4.5 Equipment Certification

PAR 1630 Special process control equipment must be certified and records maintained by the Contractor certifying that tests have been performed.

8.4.6 Metrology System and Equipment Calibration

PAR 1640 A documented metrology system must be implemented for the control of measurement processes IAW [AD-24] standard or equivalent.

PAR 1650 The contractor must audit and verify that measuring and test equipment in current use is calibrated and maintained.

8.5 VERIFICATION, TESTING AND INSPECTION

PAR 1660 Product compliance **will** be verified throughout the manufacturing phase(s) by inspection and testing IAW the project approved assembly, integration and test plan.

PAR 1670 The Contractor must verify and ensure the test operations meet the following:

a) Test Procedures and data sheets are approved and are IAW the Test Plan;

b) Test area and environment, handling practices, safety and calibration and validation of test equipment and software is IAW the approved Test Plan;

c) Test surveillance or process control is performed, review and validation of the test set-up and interconnections is performed prior to the start of the verification testing and is IAW the test procedures. During a test phase, the review of test data is performed and approved prior to the start of the next test phase; and,

d) The test data is reviewed and audited to assure that the parameters have been checked and are within the specification limits. Out of specification readings have been recorded on the test data sheets. Test Non-conformance reports have been issued and reported to the NCRB, and an initial review of the test anomaly has been performed.

e) Flight printed wiring board assembly testing does not use an automated Flying Probe process unless approved by the CSA.

8.5.1 Test Readiness Reviews

PAR 1680 The Contractor must conduct TRRs to assess the readiness to commence qualification and acceptance testing.

PAR 1690 The Contractor PA or delegate must be the TRR Chair.

PAR 1700 CSA reserves the right to participate in the spacecraft level, subsystems and units TRR and must be notified by the Contractor IAW [AD-01].

PAR 1710 The TRR should be conducted to ensure:

a) The As-built meet the latest As-designed hardware configurations;

b) The Software Configuration (SC), including code and tables, is approved and identified;

c) The test equipment to be used is identified, and is calibrated/validated;

d) The test equipment set-up is defined;

e) The test software versions are identified and managed by SCM;

f) The test software has been validated by test engineering and reviewed by QA;

g) The Test Procedures are released and conform to requirements and the Verification/Test Plan;

h) The Test schedule is identified;

i) The Test facilities are identified, available and comply with requirements;

j) The Test Personnel are identified and available;

k) Outstanding open work is identified; and,

l) Non-conformances have been closed or have been addressed to allow the test to proceed.

m) Applicable safety hazards and/or reports have been verified and there are no outstanding safety controls which have not been implemented such that there may be a safety hazard to personnel or equipment under test.

Open work will be identified at the TRR and addressed per TRR board decision prior to the start of test.

PAR 1720 Spacecraft Level testing must not proceed until authorized by the TRR board, including as a minimum PA and systems engineering representatives from the Contractor and CSA.

Other attendees of the TRR should include the Test Director, representatives from Design Engineering and AIT, and other experts deemed necessary.

8.5.2 Test Software

PAR 1730 Software used for performing tests must be verified and validated as meeting the Project test requirements.

PAR 1740 The test software must be reviewed and approved and placed under configuration control prior to use for qualification or acceptance testing.

8.5.3 Test Witnessing

PAR 1750 The Contractor should witness or monitor all qualification and acceptance testing events.

The CSA may witness test activities as specified in [AD-01].

8.5.4 Test Data Reviews

TDRs (input to the Test Review Board) as required by [AD-01] will be scheduled by the Contractor as soon as possible after completion of tests. During the review, the Contractor will take minutes and assign action items to resolve any discrepancies found in test data or as a result of test non-conformances.

PAR 1760 The Contractor must review test data, and check that the collected test data is complete and verifies the required performance.

PAR 1770 Participants of TDRs must include representatives from Engineering and PA.

The CSA may participate in test data reviews as specified in [AD-01].

PAR 1780 Acceptance and qualification test documentation and data must be made available to the reviewers prior to the TDR, and submitted to CSA IAW [AD-01].

PAR 1790 The TDR must include:

a) Verification that the required test data, including raw test data (if available for COTS), consolidated test results, summary test reports and test data trend analysis, is complete and demonstrates conformance to specification requirements;

b) Verification that deviations from and modifications to the Test Procedures were authorized by Engineering and PA;

c) Verification that the test Non-conformances are recorded, dispositioned, and the status of Non-conformances and associated waivers (if any) is agreed on;

d) Checking that the analysis performed demonstrates that the test results comply with specification requirements; and,

e) Authorization for the test item to proceed with further tests/processing.

8.6 IDENTIFICATION AND TRACEABILITY

PAR 1800 The Contractor must implement and maintain an effective identification and data retrieval system for parts and materials in conjunction with the deliverable end items. This traceability system will provide identification relevant to procurement, fabrication processing, inspection, test and operating records.

PAR 1810 Quality records must**:**

a) contain the results of inspections and tests, discrepancies, rework history, as well as the acceptance of each inspection and test operation by part number and lot number or serial number;

b) be authenticated by authorized and controlled quality approval stamp or by entry in a controlled electronic system used to signify acceptance of qualification and flight items as well as documentation. Such system will be traceable to the assigned individuals;

c) be maintained to demonstrate conformance to specific requirements; and,

d) be retained for a minimum of five (5) years subsequent to program completion, or as specified by [AD-01] or contract.

PAR 1820 Quality records from unit level assembly and test to spacecraft level integration must be made available to CSA for review during MIPs or other formal reviews.

PAR 1830 Where control of individual products or lots is required, the use of date codes, lot numbers, serial numbers or other equivalent identification must be used.

PAR 1840 The traceability of the Configured Items must be maintained throughout the manufacturing phase and into the spacecraft integration and test.

8.7 NON-CONFORMING ITEM CONTROL

8.7.1 Definitions and Classifications

The following terms, definitions and classifications are to be used for non-conforming items:

a) Non-conformance - Non-conformance is defined as a suspected or proven departure of a characteristic or feature of an item from the specified requirement.

b) Non-conforming Item - An item with one or more proven or suspected Non-conformances.

c) Class I Non-conformances (Major) - An item which has one or more Non-conformances including those revealed as a result of inspection and test (in itself or its component items) of an end-item (or as part of an end-item) which can have an impact on Contractor requirements in the following areas:

1. safety of people or equipment;
2. operational, functional or any technical requirements imposed by the contract;
3. reliability, maintainability, availability;
4. lifetime;
5. functional or dimensional interchangeability;
6. interfaces with hardware or software regulated by different contracts;
7. changes to or deviations from approved qualification or acceptance test procedures;
8. use of a non-standard process or materials;
9. project-specific items which are proposed to be scrapped;

10. test failures during or subsequent to formal acceptance or qualification testing;
11. for EEE components, in case of:
    a. lot or batch rejection during manufacturing, screening or testing at the manufacturer's facilities, if contractor proposes to use as is the rejected lot or batch, or to continue processing, rework or testing, although the lot or batch does not conform to the specified requirements;
    b. non-conformance detected after delivery from the EEE parts manufacturer (if the lot/batch is used):
        i. fit, form and function;
        ii. any failure during lot validation at procurement responsible level (LAT, QCI, DPA, RVT);
    c. EEE part failure in use at equipment level (manufacturing or testing).

d) Class II Non-conformances (Minor) - An item that is not covered by the Class I Non-conformance definition.

e) Test failures are to be treated as Non-conformances.

8.7.2 Non-Conformance Preliminary Review

PAR 1850 A preliminary review should be the initial step performed by Contractor appointed personnel to determine if the non-conformance is minor and can readily be processed using the following disposition actions:

a) Scrapped, because the product is unusable for the intended purposes and cannot be economically reworked or repaired;

b) Reworked (or retested), to result in a characteristic that completely conforms to the standards, procedures, or drawing requirements;

c) Returned to supplier for rework or replacement;

d) No defect, if the preliminary review determines that the condition meets the requirement; or,

e) Referred to the NCRB when the above actions do not apply to the non-conformance.

Preliminary Review does not nullify the requirement to identify, segregate, document, report and disposition non-conformances.

PAR 1860 The non-conformance review process must include procedures for the identification and control of major and minor discrepancies. Rework-to-procedure dispositions of minor non-conformances may be processed subsequent to contractor's preliminary engineering review.

PAR 1870 A major non-conformances which cannot be disposed by such preliminary reviews must be resolved by the NCRB.

8.7.3 Non-Conformance Review Board

PAR 1880 The NCRB must be chaired by a Contractor representative responsible for ensuring that the NCRB actions are performed in compliance with this requirement and as implemented by Contractor procedures.

PAR 1890 For each reported non-conformance, there must be an investigation, engineering analysis, and documented rationale which allow determining the cause and corrective action(s) for the non-conformance.

PAR 1900 Inadequacies/deficiencies must be identified, corrected, and prevented from recurrence with objective evidence and records to fulfill the requirements of the Contract.

PAR 1910 Written authorization must be documented to disposition the non-conforming product.

PAR 1920 For a Class 1 (Major) Non-conformance, the Contractor must notify CSA IAW [AD-01] provisions.

PAR 1930 For a Class 1 (Major) Non-conformance, the contractor must submit the non-conformance report for approval by CSA prior to closure IAW [AD-01].

PAR 1940 Any proposal for change or deviation to an MRB decision, plan, disposition, or agreement must be made through a formally-reconvened MRB.

Any communications outside of the MRB (e.g. teleconferences, e-mails, meetings, etc.) will be considered null and void, and the latest formal MRB decisions, plans, dispositions, and agreements will take precedence.

8.7.4 Non-Conformance Management

PAR 1950 The Contractor must establish and maintain an effective process for management of discrepancies, Non-conformances and failures occurring during the Contract that covers hardware, software and the interfaces between hardware and software, non-conformance reports including NCRB meeting minutes, root cause and corrective action.

8.7.5 Non-Conformance Reporting

PAR 1960 The Contractor must notify CSA within 48 hours of all Class 1 (Major) non-conformances that occur on qualification or flight equipment at the unit, subsystem, or system level IAW [AD-01].

PAR 1970 The Contractor must prepare monthly status summaries of Non-conformances accordance with [AD-01] reporting provisions.

8.7.6 Non-Conformances Access

PAR 1980 The Contractor must implement necessary measures to enable CSA access to all Non-conformances reports or to databases from CSA premises when requested.

This may be achieved by e-mail distribution or by granting remote access to databases. On-site access to NCR reports and databases at Contractor premises is implied in this requirement but is not sufficient by itself.

8.8 TEST FAILURE REPORTING

PAR 1990 Test failures must be treated as Non-conformances and be dispositioned through the NCRB process.

A failure is an event in which an item becomes non-conforming. A Failure also includes unusual or unexpected behaviour or shows performance trends that indicate an inability to meet end of life requirements.

Failures that affect performance and reliability and discovered during or subsequent to formal testing are classified as Class I Non-conformances.

Faults that are not systemic faults and occur prior to TRR are subject to resolution by the subcontractor's internal review boards.

Contractor and/or subcontractors are responsible for reworking any random failures and correcting any systemic faults that occur from the TRR up to CSA acceptance of the system, unless otherwise stated in the contract.

PAR 2000 During testing the Contractor should record anomalous behaviour that is not necessarily out of specification, but could add knowledge about the idiosyncrasies of the equipment.

8.8.1 Failure Analysis, Corrective Action and Preventive Action

PAR 2010 Failure analysis reports providing details as to the probable cause of the failure and the recommended corrective and preventive action must be provided to the NCRB for review.

8.8.2 Unit Modifications Retest after Formal Testing

PAR 2020 In the event that unit modification, rework or repair is required after completion of the unit qualification and acceptance tests, the Contractor must document Non-conformances and obtain approval from CSA for retesting through the NCRB.

8.9 INSPECTIONS, HANDLING, STORAGE AND SHIPPING

8.9.1 End-Item Inspection

PAR 2030 End-Item Inspection must be performed to verify the final configuration, test results and workmanship.

PAR 2040 The storage environment and packaging of End Items, stocked parts, materials, and flight hardware including spares must be periodically verified or audited.

8.9.2 Handling, Storage and Shipping

PAR 2050 The Contractor must define the requirements for the preservation, packaging, handling, storage and shipping of articles and materials as part of the engineering documentation or manufacturing instructions. The following should be addressed:

a) Proven safety, ESD control, and clean room practices when handling flight hardware;

b) Considerations of electrostatic charge generation, potential contamination of materials, as well as associated processes and equipment (e.g. cleaning equipment, packaging materials, purging, tent enclosures, etc.);

c) Special considerations of micro-vibration, shock, ESD and cleanliness; and,

d) The use of shock indicators in addition to being affixed internally on the equipment, external shock indicators on the outside of the package should be used as a deterrent to rough handling. The shock indicator values (min-med-max) should be selected such that they envelope the design limits.

8.9.2.1 Controlled Stores

PAR 2060 Controlled stores facilities must :

a) Be provided and periodically audited to ensure identification and traceability is maintained; and,

b) Include the following minimum features: access control, ESD safeguards, cleanliness control, inventory control, and documentation.

8.9.2.2 Packaging and Shipping

PAR 2070 The Contractor must perform packaging and shipping inspections, including shipping containers IAW the approved documentation.

8.10 CONFIGURATION AND DATA MANAGEMENT

PAR 2080 The Contractor and subcontractors must maintain the spacecraft hardware, software, firmware (i.e. VHDL source code as a minimum) and documentation configuration during the assembly, integration and testing of the component/subsystem/system.

PAR 2090 The Contractor must prepare and implement a configuration management plan IAW [AD-23] or approved equivalent and submit to CSA IAW [AD-01].

PAR 2100 The Contractor must develop procedures for the administration, analysis coordination, and processing of engineering change proposals as well as deviations and waivers, from origination of the change request through required approvals or rejection.

PAR 2110 Contractor's configuration management system must formally classify all program engineering changes as Class I (major) and Class II (minor) changes.

PAR 2120 A Class I change must require approval by CSA.

A Class I change is a change that impacts the contractual/technical agreement by affecting items including one or more of the following:

a) established technical baseline after CDR;

b) operational or performance aspects;

c) mission objectives;

d) interfaces/interchangeability;

e) safety, reliability, maintainability;

f) fit, form, and function of final delivered spacecraft; and,

A Class II change is an engineering change that does not fall within the definition of a Class I change.

PAR 2130 For FPGA development, the following items should also be retained in CADM: master copies of all firmware items, manuals, net lists, tools, outputs of development tools such as synthesizer log, and licences.

PAR 2140 The Contractor must compile an EIDP for each deliverable as defined in [AD-01].

PAR 2150 The Contractor must ensure that the manufactured as-built configuration of hardware will accurately correspond to the configuration described in the released engineering as-designed documentation. Differences identified between the as-designed report and the as-built report are to be resolved prior to final acceptance for each control item and higher level assembly.

PAR 2160 Engineering change notices, change requests must be incorporated immediately for the following documents:

a) Procurement specifications;

b) Test procedures; and,

c) Interface Control.

PAR 2170 No more than a maximum of three unincorporated changes notices against a single document should be permitted.

9 SOFTWARE PRODUCT ASSURANCE PROGRAM

9.1 GENERAL

PAR 2180 A Software Product Assurance (SPA) Program must be implemented and documented using a Software Development Plan (SDP) submitted to CSA IAW [AD-01]. This plan may be part of the PAIP.

PAR 2190 The SDP must identify the software development process, verification and acceptance testing, configuration control, non-conformance control and software documentation including modified Commercial Off the Shelf software (refer to Table 9-1).

PAR 2200 The software development and SPA standards must be as defined in the SDP, and traceable to the following reference standards or equivalent:

a) ISO/IEC/IEEE 12207:2017 [RD-25]; or,

b) ISO/IEC 29110 [RD-26].

The selected standards may be tailored, to the extent allowed by the approved standard, as appropriate to the software under development.

PAR 2210 With respect to PAR 2190, the extent and justification for each tailoring decision must be documented in the SDP.

PAR 2220 Documentation needed to perform the software development tasks such as software design document, test plans and test procedures must be developed, maintained and reviewed to ensure consistency across all software work products.

9.2 ORGANIZATION AND RESPONSIBILITY

PAR 2230 A Contractor SPA Representative having responsibility for Software PA must be nominated.

9.3 SOFTWARE NON-CONFORMANCE REPORTING, DISPOSITION AND CORRECTIVE ACTION SYSTEM

PAR 2240 The Software PA representative must implement an effective system to ensure:

a) Non-conformance control is performed after the first release of the software item;

b) The prompt detection/identification, tracking, reporting and disposition of deficiencies, problems, irregular conditions and activities that are adverse to software quality;

c) Corrective action is taken; and,

d) Associated documentation is updated including the configuration status.

PAR 2250 Officially released baseline software must be subject to Non Conformance Item Control per Section 8.7 herein.

9.4 SOFTWARE CONFIGURATION MANAGEMENT

PAR 2260 The Contractor must establish and implement a software configuration management system (SCMS) to maintain the integrity of the software products produced throughout the life of the project.

PAR 2270 The SCMS must identify the configuration of the software at given points in time, systematically control changes to the configuration, and maintain the traceability of the configuration.

PAR 2280 A Software Configuration Control Board (CCB) must be formed to authorize the establishment of a software baseline library, the identification of configuration items/units, systematic control of changes to baseline and the release of software products built from the software baseline library.

9.5 SOFTWARE CATEGORIES AND APPLICABILITY

Software categories are based on the functions that they support.

PAR 2290 The Software QA must classify all the software used or developed for the project IAW the four categories specified in Table 9-1.

PAR 2300 A software analysis must be performed to assign the relevant software category to each software module.

TABLE 9-1 – SOFTWARE CATEGORY

CATEGORY	DESCRIPTION
I	Software, the failure of which may result in the loss of the mission or mission critical capabilities.
II	Software, not in Category I, that is necessary for the operation of the mission.
III	Software that is used for qualifying and accepting end items.
IV	Support software used for design and development of deliverable hardware and software. This includes COTS software such as compilers, Motif, OS such as Unix, Windows, databases such as Oracle, SQL, test stubs.

PAR 2310 Software QA activities per category must be documented in the SDP.

PAR 2320 Evaluation of COTS software must be performed by the Contractor to ensure the software meets the requirements of the project and that data rights provision is consistent with the contract (in particular, that there are no restrictions on granting license of the software to Canada as the end user).

10 FIRMWARE/FPGA DEVELOPMENT

A Firmware is a specific class of computer software that provides low-level control for device specific hardware. Firmware includes the programming of FPGA, ASIC, Complex Programmable Logic Devices (CPLD), and any Programmatic Logic section in a System-on-a-Chip (SoC) device.

10.1 GENERAL

PAR 2330 For new or modified Firmware/FPGA designs, the Contractor must develop and implement a Firmware/FPGA development plan that includes as a minimum:

a) Requirements definition and traceability to parent requirements;

b) Architectural design;

c) Detailed design;

d) Device selection and procurement, including export control considerations;

e) Core selection and procurement, with details on licensing and obfuscation;

f) Layout (i.e. Input/Output [I/O] pin-out and interfaces);

g) Prototype (i.e. breadboard and EM) implementation;

h) Development tools; and,

i) Design validation and verification.

PAR 2340 IAW [AD-01], a VDD must be produced by the Contractor to document and completely describe:

a) All the required source files version and location;

b) The tools required to generate the firmware (including version identifiers and complete setup parameters at the time they were used to produce the firmware); and,

c) A step-by-step approach that includes:

1. the build process;
2. the firmware versions;
3. the process to load the firmware on the target hardware and to verify that the firmware was properly loaded onto the target hardware; and,
4. the generated configuration item.

PAR 2350 Officially released baseline Firmware/FPGA must be subject to Non Conformance Item Control per Section 8.7 herein.

10.2 ANALYSIS AND DESIGN

PAR 2360 For new, modified or no heritage Firmware/FPGA design, the Contractor must develop an Firmware/FPGA Requirements Specification which will serve as the technical basis for the Firmware/FPGA design.

PAR 2370 For new, modified or no heritage Firmware/FPGA design, the Contractor must prepare a Firmware/FPGA Design Description Document that include:

a) Internal architecture, including description of radiation mitigation as required;

b) External interfaces design details (including register maps, electrical characteristics and pin maps for each interface);

c) Internal block/functional design explanation details, including FSM details, state diagrams as necessary;

d) Internal and external memory blocks and buffer details and use, including memory error protection and correction as necessary;

e) Internal interface details, including synchronization of asynchronous signals and clock domain crossings;

f) Processing algorithm details when necessary;

g) Reset/power-up/self-test provisions and behaviour; and,

h) Identification of all procured cores used in the design, with details on their configuration.

PAR 2380 For new, modified or no heritage Firmware/FPGA design, the Contractor must perform a WCA on all FPGA interfaces IAW Section 6.5 herein.

PAR 2390 The Contractor must define, document, and implement a coding practice that addresses as a minimum:

a) Timing margins (including clock propagation) and derating;

b) Margins on internal resources: I/O signals, registers. Memory, logic cells, Look Up Table (LUT), clocks;

c) Naming conventions;

d) Source file header format;

e) Resets;

f) Finite state machines implementation;

g) SEE mitigation;

h) Asynchronous input signals synchronization;

i) Domain crossings; and,

j) Memory content protection.

All inputs to the design that are not automatically generated and are necessary to reproduce the design should be put under CADM control.

Examples of such inputs are simulation pattern, schematics, VHDL source codes, synthesis scripts.

PAR 2400 All firmware versions installed on flight and flight spare boards must be configuration controlled and associated with a specific hardware configuration (e.g. Circuit Card Assembly where the FPGA is installed).

PAR 2410 When queried, all firmware must include a function to return its version identifier.

10.3 VALIDATION AND VERIFICATION

PAR 2420 The Contractor must define and document a test plan IAW [AD-01] which will specify verification tests that will cover full functionality under all operating modes and conditions of all FPGA devices.

This means that the whole temperature range needs to be addressed by the test plan; i.e. not only temperature extremes.

PAR 2430 The Contractor must retain objective evidence that each Firmware/FPGA requirement from the Firmware/FPGA Requirements specification has been verified IAW the agreed methods.

11 SAFETY PROGRAM

11.1 OBJECTIVES

The purpose of the Safety Program is to ensure that there are no hazards to people or equipment during the design, manufacturing, Assembly Integration and Test (AIT) of the deliverable subsystems and assemblies and associated equipment, and during the launch and operational phases of the Mission.

11.2 GENERAL SAFETY ACTIVITIES

The Contractor is responsible for System and Launch level Safety. Subcontractors and suppliers are responsible for all safety aspects whenever equipment is under their control.

PAR 2440 The Contractor must:

a) Establish and implement system safety program as part of PA plan IAW ISO [AD-25] or approved equivalent standards to ensure that safety is designed into the system and is maintained throughout the life cycle from design, manufacture, assembly, test, storage, transportation, launch support and launch (as applicable to the project);

b) Ensure that all design and manufacturing practices do not present any hazards to people or equipment;

c) Identify test procedures that are potentially hazardous to personnel and spacecraft during the acceptance, integration and test phases;

d) Satisfy range safety requirements* both in spacecraft design and documentation, including the submission of completed range safety forms as required;

e) Ensure compliance to all local and national safety standards**;

f) Review all test documentation to ensure that test procedures reflect conformance to safety requirements for the protection of personnel, facilities and equipment, and to minimize the hazards associated with the test performance; and,

g) Designate a safety representative responsible to implement the safety program.

*The range safety requirements depend on the activities performed at the Contractors and subcontractors facilities, the spacecraft AIT facility, and Launch.

**As dictated by the occupational and safety legislation applicable at the AIT facilities and the Launch Vehicle and Range Center used for the spacecraft launch.

11.3 HAZARD IDENTIFICATION AND SAFETY REPORTING

PAR 2450 The Contractor must identify and document hazards using hazard reports*, in accordance with the following classification:

1. **Category I**: Hazards that could result in:
    i. Loss of life, or
    ii. Loss of major systems such as launch vehicle, spacecraft, launch facility or a support facility.

2. **Category II**: Hazards that could result in:
    i. Injury to people, or
    ii. Damage to the spacecraft, the other spacecraft, major systems, or the launch vehicle.
3. **Category III**: Hazards where the worst-case effect is less than Category I and II.

* The content for hazard reports is part of the Safety Assessment Report DID specified in the SOW. This DID also includes flight safety analysis elements.

PAR 2460 The Contractor must prepare and deliver a Safety Assessment Report IAW [AD-01].

PAR 2470 The Contractor must review, track, and control all project hazard reports until their closure, to implement mitigations or actions prior to the occurrence of each hazard, and to report on the status of all hazards at Mission PDR and Mission CDR.

11.4 PHASE-SPECIFIC SAFETY ACTIVITIES

11.4.1 Design

PAR 2480 During the design phase, the Contractor and subcontractors must perform the following safety activities:

a) Evaluation of each detailed design relative to potential hazard areas;
b) Identification of controls that will be implemented to eliminate or minimize the hazard;
c) Identification of hazards introduced by equipment fault propagation, as outlined in the FMECA;
d) Identification and evaluation of any embedded software that is required for safety critical spacecraft functions;
e) Identification of proof testing required ensuring safe operation; and,
f) Identification of the effects of Electrical Ground Support Equipment and inadvertent operation of spacecraft subsystems. This will allow the test conductor to take appropriate actions to safe equipment and personnel.

11.4.2 Manufacturing

PAR 2490 During the manufacturing phase, the applicable occupational and local judicial safety standards must be applied.

11.4.3 AI&T

PAR 2500 During spacecraft AIT phase, the Contractor must:

a) Identify procedures that are a potential hazard to personnel or to the spacecraft or the major subsystems;
b) Ensure that remedial actions (warning, procedure, and alarms) are in place to ensure safety of personnel and spacecraft or major subsystem;

c) Ensure that GSE certification is current; and,

d) Ensure that the interaction of the ground control software and the spacecraft or major subsystem does not cause a hazardous condition during testing.

11.4.4 Launch Campaign and Launch

Launch campaign operations analyses are to be performed by the responsible Safety Engineer to ensure that no hazardous conditions are created by launch site operations and that system processing does not introduce hazardous conditions to the work areas.

PAR 2510 The following safety activities must be conducted prior to launch:

a) The Contractor will review all known hazardous operating procedures to identify and verify hazard controls;

b) The Contractor will review operating procedures to ensure that subsequent integration activities do not result in hazardous operations; and,

c) The Contractor will verify operating procedures to ensure that equipment that could contribute to hazardous conditions are controlled and monitored to reduce the risk of hazards.

11.5 EQUIPMENT-SPECIFIC SAFETY ACTIVITIES

The following sub-sections are only applicable when the equipment in question is part of the system.

11.5.1 Batteries

PAR 2520 Lithium ion batteries must incorporate features that minimize the risk of:

a) Single battery cell failure (e.g. such features as: specific torque values on every cell terminal to prevent overheating of the terminal due to a loose electrical connection; drainage within the battery case to remove any condensation within the battery; etc.);

b) Multiple cell failure propagation (e.g. such features as: insulation between each battery cell and between each cell and the battery case to thermally and electrically isolate the individual battery cells; incorporation of high temperature sleeving to the battery internal wiring harness to protect against short circuits; cell venting to allow any cell gasses, including electrolytes, to escape into the battery enclosure to minimize heat build-up within the battery case, etc.); and,

c) Spacecraft-level safety effects (e.g. such features as: venting of heat, gas, and pressure resulting from overcharge, extreme temperature, and short circuits; etc.).

11.5.2 Propulsion Subsystem

PAR 2530 The Safety Assessment Report must address the propulsion subsystem (if applicable), to include as a minimum:

a) Description of the system identification of design parameters for the system, and detailed descriptions and figures of system components;

b) Design and actual pressures for each component with particulars as to how components were qualified (i.e., actual test or similarity from previous design);

c) Description of the propulsion subsystem thermal control;

d) Description of associated ground support equipment and its governing design considerations;

e) Propulsion system operation, with a list of actions to be taken to respond to emergency hazardous conditions; and,

f) Operational safety precautions and a list of "do's" and "don'ts" that are considered essential to the safe handling of fuel.

11.5.3 Ordnance

PAR 2540 The Safety Assessment Report must address pyrotechnic deployment devices (if applicable) as Category "B/C" devices IAW 4.2.

PAR 2550 General safety policy requirements for ordnance operations (if applicable) must be included in the Safety Assessment Report.

11.5.4 RF Systems

PAR 2560 The Contractor's Safety Assessment Report must address the safety of the specific communications and telemetry RF systems (if applicable).

11.6 SPACE DEBRIS MITIGATION

This section is applicable to Canadian satellite missions, or when space debris mitigations are required by a partner agency (e.g. NASA, ESA).

PAR 2570 The Contractor must comply with [AD-29] requirement as listed in Appendix B.

PAR 2580 The Contractor must produce a Space Debris Mitigation Plan (SMDP) IAW [AD-01].

PAR 2590 The casualty risk must not exceed 1 in 10000 for any re-entry event (controlled or uncontrolled).

12 ACRONYMS AND ABBREVIATIONS

ABPL	As-Built Parts List
ADPL	As-Designed Parts List
AIT	Assembly, Integration and Test
AR	Acceptance Review
ASIC	Application Specific Integrated Circuits
BGA	Ball Grid Array
BOL	Beginning of Life
CCGA	Ceramic Column Grid Array
CCP	Contamination Control Plan
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CFC	Chlorinated Fluorocarbons
CIL	Critical Items List
COTS	Commercial Off The Shelf
CPLD	Complex Programmable Logic Devices
CSA	Canadian Space Agency
CSCI	Computer Software Configuration Item
CVCM	Collected Volatile Condensable Material
DCL	Declared Components List
DDD	Displacement Damage Dose
DID	Data Item Description
DPA	Destructive Physical Analysis
ECSS	European Cooperation for Space Standardization
EDAC	Error Detection and Correction
EEE	Electrical, Electronic and Electromechanical
EGSE	Electrical Ground Support Equipment
EIDP	End Item Data Package
ELDRS	Enhanced Low Dose Rate Sensitivity
EM	Engineering Model
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EOL	End of Life
EPPL	European Preferred Parts List
EQM	Engineering Qualification Model
ESA	European Space Agency

ESCC	European Space Components Coordination
ESD	Electrostatic Discharge
FMECA	Failure Modes, Effects and Criticality Analysis
FPGA	Field Programmable Gate Array
FRB	Failure Review Board
GFE	Government Furnished Equipment
GPS	Global Positioning System
GS QAR	Ground Segment Quality Assurance Requirement
GSE	Ground Support Equipment
GIDEP	Government Industry Data Exchange Program
GSFC	Goddard Space Flight Center
HSD	Hot Solder Dip
HSSLV	Humidity Steady State Low Voltage
HTOL	High Temperature Operating Life
IAW	In Accordance With
ISO	International Organization for Standardization
I/O	Inputs and Outputs
LAT	Lot Acceptance Test
LEOP	Launch and Early Operations Phase
LUT	Look Up Table
LVT	Lot Validation Test
MCM	Multi-Chip Module
MIP	Mandatory Inspection Point
MLCC	Multi Layer Ceramic Capacitor
MMPDS	Metallic Materials Properties Development and Standardization
MRR	Manufacturing Readiness Review
MS	Military Specification
MSFC	Marshall Space Flight Center
MSL	Moisture Sensitivity Level
NAS	National Aerospace Standards
NASA	National Aeronautics and Space Administration
NCRB	Non-conformance Review Board
NIEL	Nonionizing Energy Loss
NPSL	NASA Parts Selection List
NSPAR	Non-Standard Part Approval Request
OEM	Original Equipment Manufacture

PA	Product Assurance
PAD	Part Approval Document
PAIP	Product Assurance Implementation Plan
PAP	Product Assurance Program
PAR	Product Assurance Requirement(s)
Pb	Lead
PCB	Parts Control Board
PDA	Percentage of Defectives Allowable
PDR	Preliminary Design Review
PE	Parts Engineer
PEM	Plastic Encapsulated Microcircuits
PFM	Proto Flight Model
PIND	Particle Impact Noise Detection
PPL	Preferred Parts List
PVC	Polyvinyl Chloride
PWB	Printed Wiring Board
QA	Quality Assurance
QCI	Quality Conformance Inspection
QM	Qualification Model
QML	Qualified Manufacturers List
QPL	Qualified Products List
QSL	Qualification Status List
QSR	Qualification Status Review
RAM	Random Access Memory
RF	Radio Frequency
RFD	Request for Deviation
ROM	Read-Only memory
RVT	Radiation Verification Test
S&MA	Safety and Mission Assurance
SC	Software Configuration
SCC	Stress Corrosion Cracking
SCD	Source Control Document (or Drawing)
SCM	Software Configuration Management
SDF	Software Development File
SDMP	Space Debris Mitigation Plan
SDP	Software Development Plan

SE	Systems Engineering
SEB	Single Event Burnout
SEE	Single Event Effect
SEFI	Single Event Functional Interrupt
SEGR	Single Event Gate Rupture
SEL	Single Event Latch up
SEU	Single Event Upset
SET	Single Event Transient
SOA	Safe Operating Area
SoC	System-on-a-Chip
SOW	Statement of Work
SPA	Software Product Assurance
SPF	Single Point Failure
SRS	System Requirements Specification
STD	Standard
S/W	Software
TDR	Test Data Review
TID	Total Ionizing Dose
TML	Total Mass Loss
TNID	Total Non-Ionizing Dose
TPM	Technical Performance Measures
TRR	Test Readiness Review
VDD	Version Description Document
VHDL	VHSIC Hardware Description Language
V&V	Verification and Validation
WCA	Worst Case Analysis

APPENDICES

A ECSS ACCEPTABLE STANDARD

TABLE A-1 – ECSS ACCEPTABLE STANDARDS

REQUIREMENT	CSA APPLICABLE PA STANDARD	ECSS ACCEPTABLE STANDARD
Surface mount Technology	J-STD-001S	ECSS-Q-ST-70-38
Soldering electrical Technology	J-STD-001S	ECSS-Q-ST-70-08
Crimping, Interconnecting Cable Assemblies and Installation	NASA 8739.4	ECSS-Q-ST-70-18 ECSS-Q-ST-70-26
Outgassing Test in a Vacuum Environment	ASTM E595	ECSS-Q-ST-70-02
Materials Selection List for Space Hardware Systems	MSFC-HDBK-527	ECSS-Q-ST-70
Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance	MSFC-STD-3029	ECSS-Q-ST-70-36
Qualification and Performance Specification for Printed Circuit Boards	IPC-6012XS (X=D or later)	ECSS-Q-ST-70-60
Cleanliness and Contamination Control	MIL-STD-1246	ECSS-Q-ST-70-01
Clean Room Requirements	ISO 14644-1, ISO 14644-2	ECSS-Q-ST-70-50

B SPACE DEBRIS MITIGATION REQUIREMENTS

TABLE B-1 – SPACE DEBRIS MITIGATION APPLICABILITY

REQ. ID (ISO 24113)	REQUIREMENT TEXT	APPLICABILITY
6.1.1.1	See ISO Standard for text of Requirement	Yes
6.1.1.2	See ISO Standard for text of Requirement	Applicable to the launch provider, to be flowed down by the Contractor
6.1.1.3	See ISO Standard for text of Requirement	Applicable to the launch provider, to be flowed down by the Contractor
6.1.2.1	See ISO Standard for text of Requirement	Yes (If pyrotechnic devices are procured by contractor, then applicable)
6.1.2.2	See ISO Standard for text of Requirement	Applicable to the launch provider, to be flowed down by the Contractor
6.2.1	See ISO Standard for text of Requirement	Yes
6.2.2.1	See ISO Standard for text of Requirement	No*
6.2.2.2	See ISO Standard for text of Requirement	No*
6.2.2.3	See ISO Standard for text of Requirement	Yes
6.2.2.4	See ISO Standard for text of Requirement	Applicable to the launch provider, to be flowed down by the Contractor
6.2.2.5	See ISO Standard for text of Requirement	No*
6.2.2.6	See ISO Standard for text of Requirement	Yes
6.2.3.1	See ISO Standard for text of Requirement	Applicable to GEO mission only
6.2.3.2	See ISO Standard for text of Requirement	Yes
6.2.3.3	See ISO Standard for text of Requirement	Yes
6.2.3.4	See ISO Standard for text of Requirement	Yes
6.3.1.1	See ISO Standard for text of Requirement	No*
6.3.1.2	See ISO Standard for text of Requirement	No*
6.3.1.3	See ISO Standard for text of Requirement	No*
6.3.1.4	See ISO Standard for text of Requirement	Yes
6.3.1.5	See ISO Standard for text of Requirement	Yes
6.3.1.6	See ISO Standard for text of Requirement	Yes
6.3.2.1	See ISO Standard for text of Requirement	Applicable to GEO mission only
6.3.2.2	See ISO Standard for text of Requirement	Applicable to GEO mission only
6.3.2.3	See ISO Standard for text of Requirement	Applicable to GEO mission only
6.3.3.1	See ISO Standard for text of Requirement	Yes
6.3.3.2	See ISO Standard for text of Requirement	Yes
6.3.4.1	See ISO Standard for text of Requirement	No*
6.3.4.2	See ISO Standard for text of Requirement	Yes, refer to PAR 2590
7.2.1/7.2.2/ 7.2.3/7.2.4	See ISO Standard for text of Requirement	Yes, refer to PAR 2580

* Compliance to these requirements is not currently mandatory for CSA projects, but strongly recommended to achieve the international space debris mitigation effort.