National Aeronautics and
Space Administration

CxP 72053

BASELINE

RELEASE DATE: August 28, 2007

ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS MANAGEMENT AND CONTROL PLAN FOR THE ARES PROJECTS

Approved for Public Release; Distribution is Unlimited

REVISION AND HISTORY PAGE

Status	Revision No.	Description	Release Date
Baseline		Baselined by Ares I Projects Control Board Directive CE3-00-0062 (PCN CE000133, CR CLV-VI-039)	August 28, 2007

TABLE OF CONTENTS

PARAGRAPH **PAGE**

APPENDIXES

1.0 SCOPE

This plan implements requirements set forth in CxP-70133 and MSFC-STD-3012 for the MSFC controlled hardware for the Ares Projects. Requirements are specified for EEE parts activities from the equipment design and development phase through use and maintenance of the system and equipment. Some special requirements, applicable only to MSFC, are included for MSFC in-house activities. Requirements herein are intended to apply only to flight hardware, except that a requirement is levied on ground equipment connectors that mate with flight connectors.

1.1 GENERAL

Special requirements not covered by or not in conformance with the requirements of this publication shall be detailed in engineering documentation which shall take precedence over appropriate portions of this publication when approved in writing by MSFC prior to use.

1.2 APPLICABILITY

This plan applies to the following EEE part types. Part types not listed are not subject to the controls herein.

Part Types	Federal Stock Classes	Part Types	Federal Stock Classes
Capacitors	5910	Inductors	5950
Circuit Breakers	5925	Hybrids microcircuits	5962
Connectors	5935	Magnetics	5950
Crystal Oscillators	5955	Monolithic Microcircuits	5962
Diodes	5961	Relays	5945
Fiber Optic Accessories	6070	Resistors	5905
Fiber Optic Cables	6015	Switches	5930
Fiber Optic Conductors	6010	Thermistors	5905
Fiber Optic Devices	6030	Transformers	5950
Fiber Optic Interconnects	6060	Transistors	5961
Filters	5915	Wire and Cable	6145
Fuses	5920		

1.3 CHANGE AUTHORITY/RESPONSIBILITY

Proposed changes to this document shall be submitted by a Constellation Program Change Request (CR) to the appropriate Constellation Control Board for consideration and disposition.

The CR must include a complete description of the change and the rationale to justify its consideration. All such requests shall be processed in accordance with The Ares Program Configuration Management Plan. The appropriate NASA Office of Primary Responsibility (OPR) identified for The Ares Program Configuration Management Plan is MSFC.

1.4 ELEMENT EEE PARTS CONTROL BOARD (PCB)

A Parts Control Board (PCB) shall be established at the CxP Element Level III. The Element Office of Design Responsibility and all sub-contrators shall support the PCB in performing and implementing the decisions, findings and action items of the PCB. The PCB shall provide oversight for the planning, management, and coordination of the selection, application and procurement requirements of all EEE parts intended for use in the deliverable end items. The PCB findings, decisions and directions shall be within the contractual requirements, and shall be binding on the Element Office of Design Responsibility, and all sub-contractors (PCB direction to sub-contractors shall be through the Office of Design Responsibility).

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in this paragraph are applicable to the extent specified herein.

CxP 70023	Constellation Program Design Specification for Natural Environments (DSNE)
CxP 70043	Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology
CxP 70059	Constellation Program Integrated Safety, Reliability & Quality Assurance (SR&QA) Requirements

CxP 70073-01-BOOK 1	Constellation Program Configuration Management Plan
CxP 70133	Constellation Program Electrical, Electronic and Electromechanical (EEE) Parts Plan

2.2 REFERENCE DOCUMENTS

The following documents contain supplemental information to guide the user in the application of this document. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified the issue in effect on the date of invitation for bids or request for proposal shall apply.

ANSI/ESD-S20-20-1999	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment
IPC/JEDEC J-STD-033	Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices
MIL-STD-750	Test Methods for Semiconductor Devices
MIL-STD-883	Test Methods and Procedures for Microelectronics
MIL-STD-1580	Destructive Physical Analysis for Electronic, Electromagnetic, and Electromechanical Parts
MSFC-SPEC-548	Specification for Vacuum Baking Electrical Connectors for Spacelab Payloads
MSFC-SPEC-684	Specification for Vacuum Baking Electrical Cables for Spacelab Payloads
MSFC-STD-3012	EEE Parts Management and Control for MSFC Space Flight Hardware
MWI 1280.5	MSFC ALERT Processing
MWI 8060.1	Off-the-Shelf Hardware Utilization in Flight Hardware Development
SSP 30312	Electrical, Electronic, and Electromechanical (EEE) and Mechanical Parts Management and Implementation Plan for Space Station Program

SSQ21635	Connectors and Accessories, Electrical, Circular, Miniature, IVA/EVA Compatible, Space Quality,
40M39569	Connectors, Electrical, Miniature Circular, Environment Resisting, Specification for

3.0 ACRONYMS AND ABBREVIATIONS

Acronyms and abbreviations are listed in Appendix B.

4.0 REQUIREMENTS

4.1 GENERAL

This plan, or MSFC approved equivalent requirements, shall be applied to each subcontract tier for applicable equipment. The requirements of MSFC-STD-3012 for EEE parts and the implementation requirements herein shall be met. For applications with functional Criticality 1,1R#, 1S, and 2 as defined in CxP70043 Grade 1 requirements shall apply. The Ares Projects will define functional criticality of the hardware. The highest functional criticality of a box determines the minimum EEE part grade.

4.1.1 Focal Point Organization

The organization serving as the focal point in matters pertaining to this plan shall be MSFC EEE Parts Engineering.

4.2 PART QUALIFICATION

Qualification at the piece part level shall meet the requirements of MSFC-STD-3012. Where guidance is not provided within MSFC-STD-3012 for qualification of nonstandard parts, the qualification shall be equivalent to the requirements imposed on similar standard parts. Where no similar standard part exists that can be used as a guide, the part qualification shall demonstrate that the part meets the performance and environmental requirements of the hardware in which it will be used.

4.3 QUALITY ASSURANCE REQUIREMENTS

Quality assurance shall comply with the requirements of MSFC-STD-3012 and the following.

4.3.1 Procurement Sources

Parts shall be procured only from qualified manufacturers or their authorized distributors. EEE parts shall be procured to MSFC approved specifications or Source Control Documents (SCDs) from the contractor and CxP NASA approved suppliers. Purchase orders shall specify supplier delivery of data as required in the specification. NASA or designated representative shall be provided the opportunity to review purchase contract agreements.

4.3.2 Quality Conformance Inspection (QCI)

The QCI provisions of applicable military standards shall be sufficient for parts listed in military or NASA QPLs or QMLs, except as otherwise specified.

4.3.2.1 Destructive Physical Analysis (DPA)

In accordance with the PCB AIT DPA specification all microcircuits, semiconductors, and crystal oscillators, when not procured from a Military QPL/QML, shall be subjected to DPA on a sample basis from each lot. JANTX semiconductors shall also be subjected to DPA on a sample basis from each lot. The DPA shall be in accordance with MIL-STD-1580 or to an approved equivalent method. Inspection lots found to have one or more defects shall be: a. subjected to re-sampling if the results of the first sample were inconclusive, b. screened, c. scrapped, and/or d. returned to supplier, as applicable. This requirement may be met in the part manufacturer's processing, in third party laboratory testing, or by the procuring activity.

In addition a lead composition analysis shall be performed on all DPA samples (up to five) to verify a minimum of 3% lead for tin plated contacts.

4.3.2.2 In-house DPA

In-house DPA shall be performed in accordance with paragraph 4.3.2.1 with the following exceptions: 1) radiography is required, 2) die shear testing is not required when radiographic means are used to verify die attachment, 3) electrical testing is not required, and 4) RGA is required.

Where DPA requirements are differentiated by quality class, the DPA shall meet the grade requirements for the intended applications.

4.3.2.3 Verification of Metal Finish Composition

Any EEE part, not procured from a military QPL/QML, specification control document, or where prohibited materials and/or finishes per paragraph 4.4.4 below are not precluded, shall be tested for prohibited metal finishes, especially pure tin. The sample size shall be two devices or two percent of the lot, to a maximum of five samples.

4.3.3 Screening

Screening requirements shall be as listed in MSFC-STD-3012 Table V for grade 1 and Table VI for grade 2 applications, and as follows. Screening of PEMs devices shall be as specified in the PEMs Insertion guidelines. All EEE parts that receive additional screening shall have the screening attributes and variables data supplied to the procuring activity for review and approval.

4.3.3.1 Particle Impact Noise Detection (PIND)

All internal cavity devices of appropriate construction shall be tested in accordance with Method 2020 of MIL-STD-883 (for microcircuits, hybrids and crystal oscillators), Method 2052 of MIL-STD-750 (for semiconductors), or manufacturer's recommendations (for other EEE part types). This requirement may be met in the part manufacturer's processing, in third party laboratory testing, or by the procuring activity.

4.3.3.1.1 In-house PIND

In-house PIND testing shall be performed in accordance with paragraph 4.3.3.1 with the following exceptions: 1) If PIND testing is destructive, it shall be omitted, and 2) the marking ink is red (reject). All PIND rejects shall be removed from the lot and designated with one red ink dot.

4.3.3.2 Radiographic (X-Ray) Inspection

All cavity devices and solid construction (non-cavity) diodes (standard and nonstandard) shall undergo X-ray inspection per Method 2012 of MIL-STD-883 (for Microcircuits and crystal oscillators) or Method 2076 of MIL-STD-750 (for Semiconductors) or equivalent.

The radiographic inspection requirement may be met in the part manufacturer's processing, in third party laboratory testing, or by the procuring activity.

4.3.3.2.1 In-house X-Ray

In house Radiographic Inspection shall be performed in accordance with paragraph 4.3.3.2 with the following exceptions: 1) the number of views is one, unless additional views provide necessary construction details, 2) only parts serialized by the manufacturer will be serialized on the film, 3) parts with two dimensions less than 0.25 inch or with pins that may be easily damaged by handling may be X-rayed in their carrier, and 4) the marking ink shall be red (reject) and green (accept).

Parts that pass radiographic inspection are designated with a green ink dot. All radiographic rejects shall be removed from the lot and designated with two red ink dots. Parts that fail radiographic examination shall be restricted to non-flight applications**.**

4.3.3.2.2 Real Time Radiographic Inspection (X-ray)

Real time radiographic systems must be characterized for their dose rate. The dose rate should be identified and a safe time limit established to ensure devices under test are not subjected to excessive levels of radiation.

4.3.4 Receiving Inspection

Receiving inspection by the procuring activity shall verify procurement from a qualified source and compliance with the controlling specifications. This may be accomplished by review of certifications.

4.4 APPLICATION REQUIREMENTS

4.4.1 Derating

Parts shall be derated in the application in accordance with MSFC-STD-3012 or project approved equivalent. Derating of wire and cable may also be in accordance with SSP 30312. The data shall document the results of EEE parts application and stress analysis. The data shall be submitted in electronic format for MSFC review Data format shall be compatible with the NASA EEE Parts Information Network (NEPIN).

4.4.2 Ionizing Radiation

In accordance with MSFC-STD-3012, radiation evaluation shall address all threats appropriate for the technology, application, and environment, including total ionizing dose (TID), dose rate effects, single event effects (SEE), and displacement damage as defined in CxP 70023, “Constellation Program Design Specification for Natural Environments,” sections 3.3.2 to 3.3.4, and shall be assessed on a lot-specific basis according to the project requirements.

4.4.3 Thermal Vacuum Bake

4.4.3.1 Stress Corrosion

Metal connectors and accessories that require vacuum baking to meet stress corrosion requirements shall be thermal vacuum baked in accordance with MSFC-SPEC-548. Certain connectors such as 40M39569 and SSQ21635, for example, have equivalent processing before delivery and do not require further bake out.

4.4.3.2 Outgassing

The materials used in all electrical connectors and accessories shall be evaluated in order to meet the outgassing and cleanliness requirements imposed by the project. If the materials do not meet these requirements, the component shall be vacuum baked in accordance with MSFC-SPEC-548.

Connectors and accessories that do not have a sufficient temperature rating to meet the temperature specified in MSFC-SPEC-548 can be deferred to an assembly or system level bake out. MSFC-SPEC-684 applies to harness assemblies. Any system bake out requirements will be specified and approved by the project.

4.4.4 Hazard Avoidance

Parts shall comply with the hazard avoidance requirements of MSFC-STD-3012. With the impending adoption of ROHS requirements, special care shall be taken to avoid pure tin plated parts or hardware that have a high risk of tin whisker growth.

4.5 CONFIGURATION CONTROL REQUIREMENTS

The MSFC EEE Parts Engineering organization shall review and approve all EEE parts selections. At each subcontract level, the procuring activity shall review and approve all sub tier EEE parts selections.

4.5.1 Parts Selection

Standard and nonstandard parts shall be as defined in MSFC-STD-3012.

4.5.1.1 Grade 1 Parts for Criticality 1, 1R#, 1S, and 2

For Criticality 1,1R#, 1S, and 2 applications, maximum use shall be made of Grade 1 standard parts in the design, modification, and fabrication of the flight equipment. The parts, selection, and screening shall conform to the requirements and guidelines contained in MSFC-STD-3012 Table V.

Parts selection shall be accomplished in the order indicated. A lower ranked selection shall not be used if a higher ranked selection can be obtained. Commercial quality assurance level parts shall not be used in these applications without waiver and level III project approval. PEMs shall meet the requirement of Appendix A. The objective shall be to minimize part types, utilize standard part types to the maximum extent possible, and assure that appropriate minimum quality levels are maintained.

4.5.1.2 Grade 2 Parts for Criticality 2R and 3

For Criticality 2R and 3 applications except as noted below, maximum use shall be made of Grade 2 standard parts in the design, modification, and fabrication of the flight equipment. The parts, selection, and screening shall conform to the requirements and guidelines contained in MSFC-STD-3012 Table VI. Parts selection shall be accomplished in the order indicated. A lower ranked selection shall not be used if a higher ranked selection can be obtained. The objective shall be to minimize part types, utilize standard part types to the maximum extent possible, and assure that appropriate minimum quality levels are maintained.

4.5.1.3 Grade 3 Parts for Criticality 3

When designated by the project for Criticality 3 applications, Grade 3 standard parts may be used in the design, modification, and fabrication of the flight equipment. The parts, selection, and screening shall conform to the requirements and guidelines contained in MSFC-STD-3012 Table VII. Parts selection shall be accomplished in the order indicated. A lower ranked selection shall not be used if a higher ranked selection can be obtained. The objective shall be to minimize part types, utilize standard part types to the maximum extent possible, and assure that appropriate minimum quality levels are maintained.

4.5.1.4 Grade 4 Parts for Criticality 3 Non-critical Applications

When designated by the project for Criticality 3 applications, Grade 4 standard parts may be used in the design, modification, and fabrication of the flight equipment. The parts, selection, and screening shall conform to the requirements and guidelines contained in MSFC-STD-3012 Table VIII.

4.5.2 Nonstandard Parts

4.5.2.1 Nonstandard Grade 1 Parts for Criticality 1, 1R#, 1S, and 2

For Criticality 1, 1R#, 1S, and 2 applications nonstandard parts may be used in accordance with MSFC-STD-3012 when there is no standard part with a performance capability to satisfy the application requirements or a standard part is not available. The minimum screening requirements shall be in accordance with MSFC-STD-3012 requirements for Grade 1 parts. Nonstandard parts shall be selected in the order of preference specified in MSFC-STD-3012 for Grade 1 parts. In addition, first consideration shall be given to the inherent capability of the parts to withstand the space, terrestrial, and mission environments to which the parts will be subjected.

4.5.2.2 Nonstandard Grade 2 Parts for Criticality 2R and 3

For Criticality 2R and 3 applications nonstandard parts may be used in accordance with MSFC-STD-3012 when there is no standard part with a performance capability to satisfy the application requirements or a standard part is not available. The minimum screening requirements shall be in accordance with MSFC-STD-3012 requirements for Grade 2 parts. Nonstandard parts shall be selected in the order of preference specified in MSFC-STD-3012 for Grade 2 parts. In addition, first consideration shall be given to the inherent capability of the parts to withstand the space, terrestrial, and mission environments to which the parts will be subjected.

4.5.2.3 Nonstandard Grade 3 Parts for Criticality 3

When Grade 3 parts are designated by the project for Criticality 3 applications, nonstandard parts may be used in accordance with MSFC-STD-3012 (when there is no standard part with a performance capability to satisfy the application requirement or a standard part is not available). The minimum screening requirements shall be in accordance with MSFC-STD-3012 requirements for Grade 3 parts. Nonstandard parts shall be selected in the order of preference specified in MSFC-STD-3012 for Grade 3 parts. In addition, first consideration shall be given to the inherent capability of the parts to withstand the space, terrestrial, and mission environments to which the parts will be subjected.

4.5.3 Plastic Encapsulated Microcircuits (PEMs)

PEMs used in the Ares Projects will be subject to the PEMs insertion requirements contained in the Ares Projects Parts Control Program and referenced in Appendix A, “Instructions for Plastic Encapsulated Microcircuit (PEM) Selection, Screening, and Qualification.” NSPARS are required. The requirements of Appendix A do not apply to MIL-PRF-38535 Class N qualified microcircuits. Screening and qualification requirements for Class N microcircuits shall be per MSFC-STD-3012.

4.6 PARTS RELATED DATA REQUIREMENTS

4.6.1 Nonstandard Parts Approval Request (NSPAR)

When nonstandard parts are utilized (reference 4.5.2), nonstandard part approval requests shall be in accordance with MSFC-STD-3012 and contractual data requirements. A NSPAR form (MSFC Form 4346, “Nonstandard Parts Approval Request,” or equivalent) shall be submitted to the procuring activity, and to each higher tier procuring activity, for each nonstandard part used in flight components. Pre-coordination of NSPARs with MSFC is recommended. The NSPAR shall be reviewed and approved before it is submitted to the next higher tier procuring activity. Nonstandard parts shall not be procured prior to NSPAR approval by MSFC. The rationale for use, copies of applicable part specifications, and part drawings (excluding military, NASA, and industry standards) shall be included. Copies of applicable Vendor Item Control Drawings (VICDs) shall be included. Note the VICD was formerly called a Specification Control Drawing (SCD).

4.6.1.1 In-house NSPAR Exception

NSPAR forms shall not be required for MSFC in-house design. Instead, nonstandard part approval shall be determined during coordination between MSFC designers and MSFC EEE Parts Engineering, and approval status shall be documented on the applicable As-Designed EEE Parts List.

4.6.2 As-Designed EEE Parts List

As-Designed EEE Parts Lists shall be prepared and submitted in accordance with MSFC-STD-3012 and applicable contractual data requirements. As-Designed EEE Parts Lists shall account for parts within all subassemblies, including subcontracted or procured subassemblies. The As-Designed EEE Parts List for an assembly may note the submittal and approval status of a subassembly's As-Designed EEE Parts List rather than individually list the parts for the subassembly. For the As-Designed Parts List identification and status information shall be provided as defined in paragraph 5.6.3 of MSFC-STD-3012 as a minimum. The data shall be submitted in electronic format for MSFC review. Data format shall be compatible with the NASA EEE Parts Information Network (NEPIN).

4.6.2.1 In-house As-Designed EEE Parts Lists

As-Designed EEE Parts Lists for MSFC in-house design shall be prepared in accordance with 4.6.2 above by the design activity and submitted to project management for approval.

4.6.3 As-Built EEE Parts List

As-Built EEE Parts Lists shall be submitted in accordance with MSFC-STD-3012 and applicable contractual data requirements. As-Built EEE Parts Lists shall account for parts within all subassemblies, including subcontracted or procured subassemblies, unless exempt by specific project agreement. The As-Built Parts List identification and status information shall be provided as defined in paragraph 5.6.4 of MSFC-STD-3012 as a minimum. The data shall be submitted in electronic format for MSFC review. Data format shall be compatible with the NASA EEE Parts Information Network (NEPIN).

4.6.3.1 In-house As-Built EEE Parts Lists

As-Built EEE Parts Lists for MSFC in-house manufacturing shall be prepared in accordance with 4.6.3 above by the manufacturing activity and submitted to project management.

4.6.4 Government Industry Data Exchange Program (GIDEP)

GIDEP participation shall be in accordance with MSFC-STD-3012 and contractual data requirements.

4.6.5 Acute Launch Emergency Reliability Tip (ALERT)

ALERT preparation and assessment shall be in accordance with MSFC-STD-3012 and contractual data requirements. An ALERT and failure analysis program shall be established and implemented. Alerts and Problem Advisories distributed by GIDEP and reissued by MSFC as “FULL-ALERTs” shall be evaluated for impact and corrective actions, and responses shall be provided to MSFC by a systematic approach.

4.6.5.1 In-house ALERT

MSFC in-house ALERT activities shall be in accordance with MWI 1280.5.

4.6.6 Traceability

Traceability shall be provided in accordance with MSFC-STD-3012.

4.6.7 Quality Assurance Data

Results of destructive physical analysis, materials review boards, failure review boards, and parts problems reported from the field shall be documented and submitted for MSFC review.

4.6.8 Specifications and Control Drawings

Grade 1 and Grade 2 EEE parts shall be defined and controlled by military/industry standard specifications and/or by control drawings. A part control drawing, such as a VICD, shall be used to document the performance and quality assurance characteristics required for the part where there is no military/industry standard that fully documents the requirements. The activity procuring parts shall be responsible for preparation of part control drawings.

4.6.8.1 In-house Control Drawings

Preparation of part control drawings, such as VICDs, for MSFC in-house parts procurements, shall be the responsibility of the design activity, with support from EEE Parts Engineering.

4.7 LIFE-TIME PARTS AVAILABILITY REQUIREMENTS

Where feasible the projects shall procure a quantity of a part (at least 20% over actual requirement) to support equipment maintenance, planned future builds, and potential future builds where any of the following applies: (1) the part is a commercial part rather than a military or NASA standard part, (2) the applicable military or NASA standard is identified as “not for new design,” or equivalent, (3) the same part may not be available for future procurement within the life of the design, (4) the minimum buy for the part exceeds or very nearly equals the lifetime requirement for the design, or (5) the procured part requires additional screening.

4.8 MANUFACTURING HANDLING AND STORAGE REQUIREMENTS

4.8.1 Electrostatic Discharge (ESD) Control

ESD control shall be in accordance with ANSI/ESD S20.20-1999 or equivalent. The ESD measures shall be documented and implemented during all manufacturing phases such as receiving inspections, assembly, testing, repair, storage, and shipping of all items designated as ESD sensitive. Engineering documentation shall incorporate the ESD requirements of ANSI/ESD S20.20-1999 for handling ESD sensitive electronic parts and assemblies.

4.8.1.1 In-house ESD

ESD control within MSFC shall be in accordance with ANSI/ESD S20.20-1999.

4.8.2 Environmental Control

Environmental controls such as temperature, humidity, and particulate contamination shall be identified for parts handling, packaging, and storage.

4.8.3 Retest

Parts for which 5 years have transpired since screening shall be tested electrically, to the extent practical, before use.

4.8.3.1 In-house Retest

Parts intended for use within MSFC shall be retested according to paragraph 4.8.3 above.

4.8.4 Allowance for Testing Fallout

An allowance should be made for test fallout quantities in accordance with MSFC-STD-3012. Where practical, it is recommended that parts be ordered from a single lot date code to reduce the number of parts needed for destructive qualification testing.

4.8.5 Manufacturing Process Compatibility

Parts shall be compatible with hardware manufacturing processes in accordance with MSFC-STD-3012. Use of plastic encapsulated microcircuits (PEMs) shall require prior approval addressing handling, storage, moisture removal, and installation procedures as referenced in Appendix A, "Instructions for Plastic Encapsulated Microcircuit (PEM) Selection, Screening, and Qualification."

4.8.5.1 In-house Manufacturing Compatibility

Tin-lead solder dipped or equivalent lead/termination finishes are preferred for MSFC in-house use and shall be specified where this is an option. Surface mount or through-hole packages, or a combination of both, are acceptable for in-house use. Surface mount parts packaged for pick and place are preferred.

4.8.6 Suspect Parts

Use of parts affected by ALERTs and problem advisories shall be in accordance with MSFC-STD-3012 and MWI 1280.5.

4.9 OFF-THE-SHELF (OTS) ASSEMBLIES

The using design organization shall be responsible for assuring that OTS hardware and design are in compliance with the OTS requirements of MSFC-STD-3012. EEE parts selection and approval criteria specified herein do not apply to OTS hardware used in non-critical applications. OTS hardware used in Criticality 1, 1R#, 1S, 2, and 2R applications shall conform to the traceability, derating, stress analysis requirements, and rejection criteria contained herein. A methodology for using OTS hardware is provided in MWI 8060.1, "Off-the-Shelf Hardware Utilization in Flight Hardware Development."

4.10 GROUND SUPPORT EQUIPMENT (GSE)/AVIONICS INTERFACE

Test connectors that physically mate with flight hardware shall be either "flight or flight-like." Flight-like is defined as a military connector with the same physical characteristics (shell size, insert arrangement, and clocking). Flight-like connector contacts shall be compatible with the flight connector contacts and shall not damage the flight connector. The flight-like connector is required to be cleaned to the same cleanliness requirements established for the flight hardware.

Special avionics interfaces such as unique cryogenic or other feed-thrus/receptacles, coaxial, triaxial, fiber optic, etc. shall be evaluated on a case by case basis by the designers and parts engineers to establish compatible hardware interfaces.

Flight connectors and/or interfaces that require multiple mating cycles or are mate sensitive should consider the use of connector savers or equivalent methods that shelter/protect the connector pins and limit the number of mating cycles to the flight hardware interface. Connector savers shall not be used during launch and/or flight.

Appropriate inspection criteria, mating processes and procedures shall be established to prevent damage to flight interfaces and hardware.

APPENDIX A

INSTRUCTIONS FOR PLASTIC ENCAPSULATED MICROCIRCUIT (PEM) SELECTION, SCREENING, AND QUALIFICATION

APPENDIX A TABLE OF CONTENTS

PARAGRAPH **PAGE**

LIST OF TABLES

LIST OF FIGURES

PREFACE

Potential users of plastic encapsulated microcircuits (PEMs) need to be reminded that unlike the military system of producing robust high-reliability microcircuits that are designed to perform acceptably in a variety of harsh environments, PEMs are primarily designed for use in benign environments where equipment is easily accessed for repair or replacement. The methods of analysis applied to military products to demonstrate high reliability cannot always be applied to PEMs. This makes it difficult for users to characterize PEMs for two reasons:

1. Due to the major differences in design and construction, the standard test practices used to ensure that military devices are robust and have high reliability often cannot be applied to PEMs that have a smaller operating temperature range and can be susceptible to moisture absorption. In contrast, high-reliability military microcircuits usually utilize large, robust, high-temperature packages that are hermetically sealed.
2. Users of PEMs have little visibility into commercial manufacturers' proprietary design, materials, die traceability, and production processes and procedures. There is no central authority that monitors PEM commercial product for quality, and there are no controls in place that can be imposed across all commercial manufacturers to provide confidence to high-reliability users that a common acceptable level of quality exists for all PEMs manufacturers. Consequently, there is no guaranteed control over the type of reliability that is built into commercial product, and there is no guarantee that different lots from the same manufacturer are equally acceptable. And regarding application, there is no guarantee that commercial products intended for use in benign environments will provide acceptable performance and reliability in harsh space environments.

The qualification and screening processes contained in this document are intended to detect poor-quality lots and screen out early random failures from use in space flight hardware. However, since it cannot be guaranteed that quality was designed and built into PEMs that are appropriate for space applications, users cannot screen in quality that may not exist. It must be understood that due to the variety of materials, processes, and technologies used to design and produce PEMs, this test process may not accelerate and detect all failure mechanisms. While the tests herein will increase user confidence that PEMs with unknown quality can be used in space environments, such testing may not guarantee the same quality level offered by military microcircuits. PEMs should only be used where due to performance needs there are no alternatives in the military high-reliability market, and projects are willing to accept higher risk.

1.0 SCOPE

This appendix establishes a system of product assurance for PEMs. It is based partly on existing qualification system for military and aerospace components, experience accumulated by the parts engineering community, and practices or guidelines established by high-reliability electronics industry. The requirements of this appendix do not apply to MIL-PRF-38535 Class N qualified microcircuits. Screening and qualification requirements for Class N microcircuits shall be per MSFC-STD-3012.

2.0 PURPOSE

The purpose of this appendix is to mitigate the risk of PEM usage, evaluate long-term reliability of the parts, and prevent failures. Commercial PEMs are primarily designed for benign environments and are considered as high-risk parts when used in space applications. For this reason, no commercial PEMs are considered acceptable in high-reliability applications “as is.” Additional testing and analysis to assure adequate reliability and radiation tolerance are required.

3.0 APPLICABLE DOCUMENTS

JESD22-A110-B	Highly Accelerated Temperature and Humidity Stress Test (HAST)
JESD22-A113-C	Preconditioning of Non-hermetic Surface Mount Devices Prior to Reliability Testing
JESD22-A118	Accelerated Moisture Resistance – Unbiased HAST
JESD22-B106-B	Resistance to Soldering Temperature for Through-Hole Mounted Devices

4.0 ARES PROJECTS PEMs REQUIREMENTS

The use of PEMs is permitted on the Ares Projects space flight applications, provided each PEM is thoroughly evaluated for thermal, mechanical, and radiation implications of the specific application and found to meet mission requirements. PEMs shall be selected for their functional advantage and availability, not for cost savings. The steps necessary to ensure reliability usually negate any initial apparent cost advantage. A PEM shall not be substituted for a form, fit, and functional equivalent, high-reliability, hermetic device in space flight applications.

Due to the rapid change in wafer-level designs typical of commercial parts and the unknown traceability between packaging lots and wafer lots, lot-specific testing is required for PEMs. Lot-specific qualification, screening, and radiation hardness assurance analysis and/or testing shall be consistent with the required quality level as defined in this document.

Developers proposing to use PEMs shall address the following items in their Parts Control Program Plan: source selection (manufacturers and distributors), storage conditions for all stages of use, packing, shipping and handling, electrostatic discharge (ESD), screening and qualification testing, derating, radiation hardness assurance, test house selection and control, and data collection and retention.

PEMs shall be:

1. Stored under temperature-controlled, clean conditions, protected from ESD and humidity.
2. Traceable to the branded manufacturer.
3. Procured from the manufacturer or their approved distributor.
4. Tested to verify compliance with the performance requirements of the application environment over the intended mission lifetime.
5. Tested using practices and facilities with demonstrated capabilities sufficient to handle and test the technologies involved.

Testing specified herein shall be performed as necessary to screen and qualify the devices, in order to verify compliance with the application requirements. Radiation evaluation shall address all threats appropriate for the technology, application, and environment, including Total Ionizing Dose (TID), Dose Rate Effects, Single Event Effects (SEE), and displacement damage as defined in CxP 70023, “Constellation Program Design Specification for Natural Environments,” sections 3.3.2 to 3.3.4, and shall be assessed on a lot-specific basis according to the project requirements. Existing radiation data can be used only with the review and approval of the project radiation specialist.

PEMs with manufacture dates older than 3 years before the time of installation shall not be used without MSFC EEE Parts Engineering approval.

Derating of PEMs shall be addressed with consideration of specific material, device construction, device characteristics, and application requirements.

Use of PEMs with pure tin-plated terminations requires special precautions to preclude failures caused by tin whiskers. MSFC EEE Parts Engineering approval of mitigation strategies is required.

Exceptions to testing required herein may be permitted by MSFC EEE Parts Engineering on a case-by-case basis, where it can be demonstrated that either existing lot-specific test data show acceptable results, or the use of high-risk PEMs represents low risk of functional loss should the part fail. All rationale for such exceptions shall be documented.

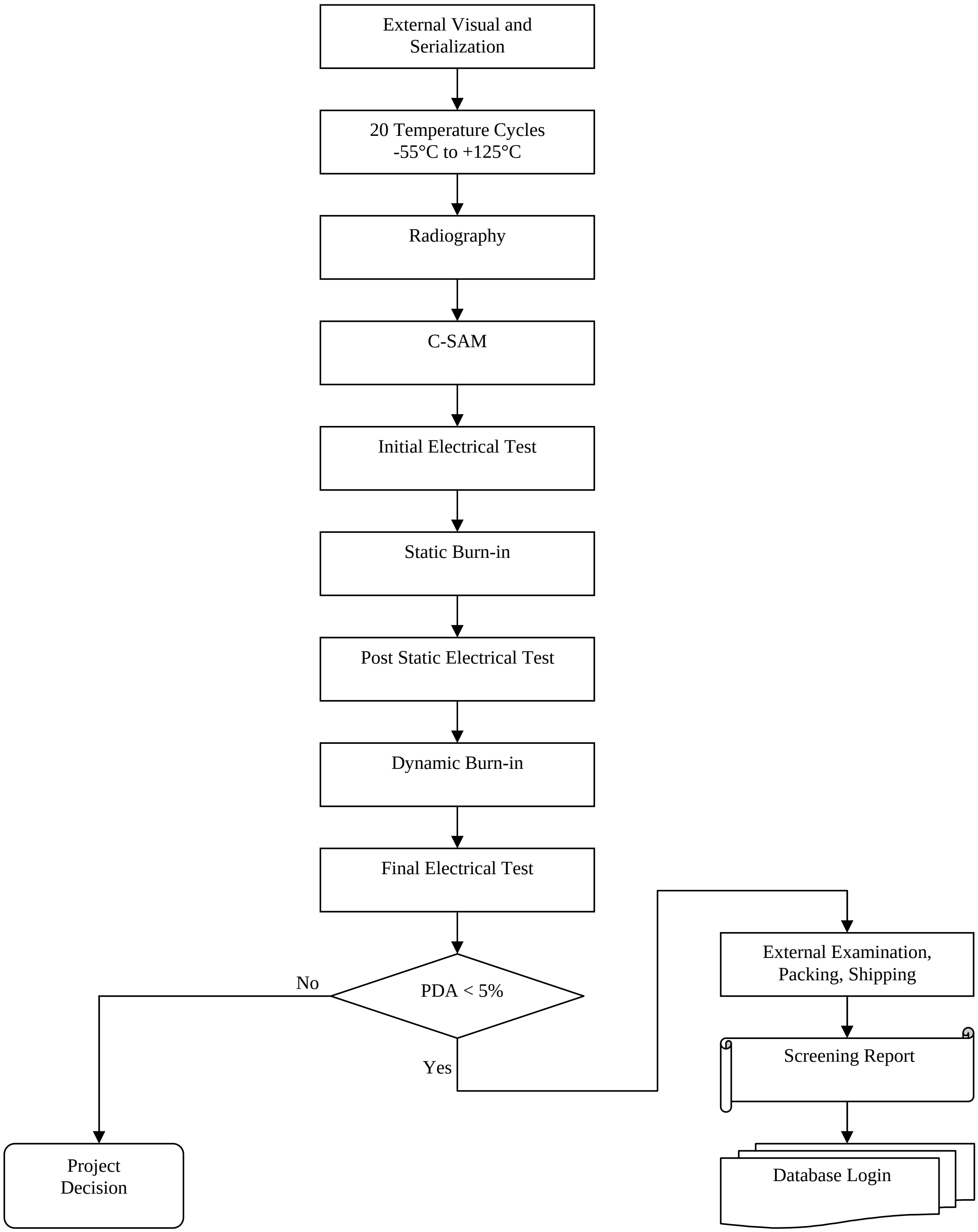
5.0 REQUIREMENTS FOR SCREENING

Screening is applied to all flight parts in each lot by testing and inspecting every sample, and proactively affects reliability of the lot. Refer to Tables 5.0-1 and 5.0-2 for screening requirements of PEMs. A typical test flow for screening of PEMs is shown in Figure 5.0-1.

6.0 REQUIREMENTS FOR QUALIFICATION

PEMs qualified according to this appendix are intended for operation within the manufacturer’s data sheet limits. Any up-rating and use of PEMs outside the manufacturer’s specified range, particularly the temperature limits, is not acceptable. Qualification samples shall be selected from screened parts.

A typical test flow for qualification of plastic encapsulated microcircuits is shown in Figure 6.0-1. Table 6.0-1 presents details of the requirements for the qualification of PEMs.



External Visual and Serialization
20 Temperature Cycles -55°C to +125°C
Radiography
C-SAM
Initial Electrical Test
Static Burn-in
Post Static Electrical Test
Dynamic Burn-in
Final Electrical Test
PDA < 5%
No
Yes
Project Decision
External Examination, Packing, Shipping
Screening Report
Database Login

Figure 5.0-1. Screening Test Flow for PEMs

Table 5.0-1. Screening Requirements for PEMs 1/

Screen	Test Method and Conditions	Grade 1 Applications	Grade 2 Applications	Grade 3 Applications
1. External visual, and serialization 2/	Per paragraph 7.2.1.	X	X	X
2. Temperature cycling	MIL-STD-883, Method 1010, Condition B (or to the manufacturer's storage temperature range, whichever is less). Temperature cycles, minimum.	20	20	20
3. Radiography 3/	Per paragraph 7.2.2.	X	X	X
4. C-SAM inspection 4/	Per paragraph 7.2.3.	X	X	X
5. Initial (pre-burn-in) electrical measurements (EM) 5/	Per device specification, at 25°C At min. and max. rated operational temperatures.	X	X	X
6. Engineering review (steps 1 to 5) 6/				
7. Static (steady-state) burn-in (BI) test at 125°C or at max. operating temperature 7/ 7a. Post static BI electrical measurements at 25°C	MIL-STD-883, Method 1015, Condition A or B. Hours, minimum depending on the BI temperature. Per device specification. Calculate Delta when applicable.	240 hrs. at 125°C 445 hrs. at 105°C 885 hrs. at 85°C 1,560 hrs. at 70°C X	160 hrs. at 125°C 300 hrs. at 105°C 590 hrs. at 85°C 1,040 hrs. at 70°C X	160 hrs. at 125°C 300 hrs. at 105°C 590 hrs. at 85°C 1,040 hrs. at 70°C X
8. Dynamic burn-in test at 125°C or at max. operating temperature 7/	MIL-STD-883, Method 1015, Condition D. Hours, minimum.	Same as test step 7.	Same as test step 7.	Same as test step 7.
9. Final parametric and functional tests	Per device specification (at 25°C, maximum, and minimum rated operating temperatures).	X	X	X
10. Calculate percent defective (steps 7 to 10) 6/	Maximum acceptable PDA.	5%	10%	10%
11. External visual/packing 2/	Per paragraph 7.2.1 and Section 9.	X	X	X

Table 5.0-1 Notes

1/ General

1.1/ Screening is performed on 100% of flight parts.

1.2/ These screening procedures are not considered as a substitute for manufacturing control, but rather as risk mitigation measures.

1.3/ It is the responsibility of the project parts engineer to submit screening test results to MSFC EEE Parts Engineering analysis for logging into the PEM database.

2/ It is recommended to combine the incoming visual inspection with the serialization and outgoing visual inspection with packaging to reduce handling and possible damage to the parts. Serialization should be performed in such a way to allow a top side C-SAM inspection. Flight parts should be handled and stored in a manner to prevent mechanical and ESD damage, contamination, and moisture absorption (see Section 9).

3/ To minimize handling, only a top view X-ray inspection is required. Focus to inspect for wire sweeping and obvious defects in the part. Depending on the results of the top view X-ray and/or part construction, a side view may be required.

4/ Acoustic Microscopy (C-SAM)

4.1/ General. Acoustic microscopy is performed to screen out defects at critical die surface and lead tip wire-bond areas of the parts. Screening, except for power devices, is performed only at the top side.

4.2/ Coated Die. Top side of the internal portion of the leads is inspected in PEMs with polymer die coating. Inspection of the die area is not required, as the die coating has low acoustic impedance that appears as a false delamination.

4.3/ Power Devices. For power devices the bottom side inspection of die attachment may be replaced with the thermal impedance measurements.

4.4/ Rejection Criteria.

a. Cracks in plastic package intersecting bond wires.
b. Internal cracks extending from any lead finger to any other internal feature (lead finger, chip, die attach paddle) if crack length is more than half of the corresponding distance.
c. Any crack in the package breaking the surface.
d. Any void in molding compound crossing wire bond.
e. Any measurable amount of de-lamination between plastic and die.
f. De-lamination of more than half of the backside of the die paddle/plastic interface.
g. Complete lead-finger de-lamination from the plastic (either top or backside)
h. Delamination of the lead-finger that includes the wirebound area.
i. Delamination of the top tie bar area for more than half of its length.

NOTE: If rejectable internal cracks or delaminations are suspected, a polished cross section may be required to verify the suspected site.

5/ Electrical Measurements

5.1/ Special Testing. In addition to parametric and functional measurements per data sheets, supplement and/or innovative testing techniques (e.g. IDDQ leakage currents, thermal impedance, output noise, etc.) can be used to select better quality parts from the lot (cherry pick) as flight candidates. These techniques should be certified and approved by MSFC EEE Parts Engineering.

5.2/ Failure modes (parametric or catastrophic) should be recorded for each failed part.

6/ Engineering Review

6.1/ More than 10% C-SAM rejects might require additional evaluation of thermo-mechanical integrity of the lot or its replacement.

6.2/ Most established PEMs manufacturers guarantee 3-sigma level process minimum, which means that less than X 0.27% of the parts can be out of specification. Excessive fallout during initial electrical measurements at room temperature may be due to a poor quality of the lot or effect of temperature cycling performed before electrical measurements, or it might be an indication of problems with the testing lab. When excessive rejects are experienced, the project parts engineer decides whether a lot replacement or additional evaluation is needed based on observed failure modes and results of failure analysis. Excessive rejects during initial electrical measurements may be a legitimate cause for lot replacement.

7/ Burn-in (BI)

7.1/ General. Burn-in is a complex, product-specific test and if possible should be conducted by the manufacturer of the part. If a user performs this test, special care should be taken not to exceed absolute maximum current, voltage, and die temperature limits.

7.2/ Burn-in Temperature. If burn-in at 125°C is not appropriate, the burn-in ambient temperature shall be limited to the maximum operating temperature per the device specifications provided by the manufacturer.

7.3/ Junction Temperature. The junction temperature during BI testing should not exceed the absolute maximum rated junction temperature for the part.

7.4/ Molding Material Glass Transition Temperature. Reliability of the PEMs, which are manufactured with low Tg molding compounds (Tg < 120°C), is difficult to assess, and such parts are not recommended for space projects without additional extensive analysis and testing. Glass transition temperature measurements are recommended prior to BI if usage of low Tg molding compound for the lot is suspected.

7.5/ Steady-state burn-in is performed on all linear and mixed-signal devices (see Table 5.0-2 for details on burn-in conditions). The duration of steady-state burn-in can be reduced 50% if the parts are to be subjected to dynamic burn-in testing.

7.6/ Dynamic burn-in is not required for parts operating under steady-state conditions, e.g. voltage references, temperature sensors, etc.

7.7/ Only one type of BI test, either static or dynamic, is required for Grade 2 and Grade 3 parts.

7.8/ Under special circumstances, when it is technically and economically viable, and for components which are difficult to assess at the piece part level, alternative testing in lieu of static and/or dynamic BI testing (for example, board-level burn-in) may be permitted. It is the responsibility of the project engineer to document and submit a rationale for the technical feasibility and equivalency of the alternative testing to the project and MSFC EEE Parts Engineering for approval. Board-level burn-in shall not be routinely substituted for piece part burn-in as a convenience.

Table 5.0-2. Burn-in and Electrical Measurement Requirements for PEMs

IC Type	Required Burn-In 1/		Delta	Electrical Measurement 3/, 4/
	Static (Condition C) 2/	Dynamic (Condition D) 2/		
Digital Bipolar & Digital MOS/ BiCMOS: LOGIC (Gates, Buffers, Flip-Flops, Multiplexers, Registers, and Counters) RAMs FIFOs Microprocessors Interface Peripherals ASICs FPGA, PROM, PAL	Not required for Digital Bipolar Technology. Required for Digital MOS Technology. $V_{IN} = V_{DD}$ across one-half input pins and V_{SS} across the remaining inputs. $V_{OUT} = 0.5\ V_{DD}$ through R_L	Required for both technologies. V_{in} = Square wave, 50% duty cycle to input pins and control pins. Frequency = 100 Hz to 1 MHz. $V_{OUT} = V_{CC}/2$ or $V_{DD}/2$ through R_L.	ΔI_{CC} or ΔI_{DD}	DC: V_{IC}, V_{OH}, V_{OL}, $I_{CC}(I_{EE})$, I_{IL}, I_{IH}, I_{DD}, I_{OZL}, I_{OZH}, I_{OS} AC: T_{PLH}, T_{PHL}, T_{TLH}, T_{THL}, T_{PZH}, T_{PHZ}, T_{PLZ}, T_{PZL}, TA, T_S, T_H Functional Tests: a) For simple logic devices, verify truth table. b) For complex logic devices such as ASIC, FPGA, and microprocessors, functional testing should include fault coverage calculations. c) For PROMs, check fuse map; for RAMs, perform pattern sensitive tests such as March, Galpat, etc.
Linear MOS, Bipolar, and Bi-FET: 5/ Op-Amp, Instrument Amplifiers, S/H, and Comparator	V_{out} terminated to ground through R_L	V_{in} = Square wave or sine wave. F = 10Hz to 100 KHz, 50% duty cycle. V_{out} terminated to ground through R_L	ΔI_{IB} ΔI_{IO} ΔV_{IO}	DC: I_{CC}, I_{EE}, I_{IO}, V_{IO}, V_{OPP}, A_V, CMRR, PSRR AC: Slew rate
Linear MOS, Bipolar and JFET: 5/ Line Drivers and Receivers	$V_{in} = V_{DD}$ max across one-half input pins and V_{SS} across the remaining inputs.	V_{in} = Square wave at a specified frequency and duty cycle. $V_{out} = V_{CC}$ through R_L	ΔI_{CC} ΔI_{IH}	DC: V_{OH}, V_{OL}, I_{CC}, I_{IL}, I_{IH}, I_{OS} AC: T_{PLH}, T_{PHL}, T_{TLH}, T_{THL} Functional Test
Linear MOS, Bi-FET, and Bipolar: 5/ Analog Switches and Multiplexers	$V_{in} = V_{DD}$ max across one-half of inputs and V_{SS} across the other remaining inputs. $V_{out} = \pm V_{CC}$ through R_L	V_{in} = Square wave. F = 100 KHz and 50% duty cycle. $V_{out} = \pm V_{CC}$ through R_L	ΔI_{CC} $\Delta I_{D(OFF)}$ $\Delta I_{S(OFF)}$ $\Delta R_{(ON)}$	DC: I_{CC}, $I_{D(ON)}$, $R_{(ON)}$, $I_{D(OFF)}$, $I_{S(ON)}$, $I_{S(OFF)}$ AC: $T_{(ON)}$, $T_{(OFF)}$ break-before- make- time
Linear Bipolar: Voltage Regulators	V_{out} terminated to ground through R_L	Not required	ΔI_{SCD} ΔV_{OUT}	DC: I_{CC}, V_{OUT}, I_{OS}, line/load regulation

Table 5.0-2. Burn-in and Electrical Measurement Requirements for PEMs (continued)

Linear Bipolar: Pulse-width-modulator	Not required	V_{out} terminated to ground through R_L. R_{ext}, C_{ext} connected if applicable.	ΔI_{IO} ΔV_{REF}	DC: V_{REF}, I_{IB}, I_{IO}, I_{OS}, V_{IO}, V_{OL}, V_{OH}, A_V, CMRR, PSRR AC: T_R, T_F, f_{OSC}
Linear CMOS Timers	$T_A \geq 125°C$. $V_{out} = V_{CC}$ through R_L	Not required	ΔI_{CEX} ΔV_{OH} ΔV_{OL}	DC: V_{TRIG}, V_{TH}, V_R, V_{OL}, V_{OH}, V_{SAT}, I_{CC}, I_{TRIG}, I_{TH}, I_R, I_{CEX} AC: T_{TLH}, T_{THL}
Mixed Signal MOS, Bi-CMOS and Bipolar: 5/ Analog to Digital (A/D) Converters.	V_{in} = Max analog DC input. $V_{out} = V_{CC}/2$ through R_L.	V_{in} = Analog input to generate maximum digital codes. $V_{out} = V_{CC}/2$ through R_L	ΔI_{CC} ΔI_{EE} ΔV_{IO}	DC: V_{REF}, V_{OH}, V_{OL}, V_{IO}, I_{CC}, I_{EE}, I_{IL}, I_{IH}, I_{OZL}, I_{OZH}, I_{OS}, Zero Error, Gain Error, Linearity Error. AC: T_C, T_S, T_H Functional Test: Verify codes
Mixed Signal MOS, Bi-CMOS and Bipolar 5/ Digital to Analog (D/A) Converters.	$V_{in} = V_{DD}$ on one-half data inputs and V_{SS} on remaining inputs. V_{out} terminated to ground through R_L	V_{in} = Apply appropriate digital codes for all inputs and for control signals. V_{out} terminated to ground through R_L.	ΔI_{CC} ΔI_{EE}	DC: I_{CC}, I_{EE}, I_{IL}, I_{IH}, I_{OZL}, I_{OZH}, I_{OS}, Zero Error, Gain Error, Linearity Error, PSRR AC: T_C, T_S, T_H Functional Test: Verify codes

Table 5.0-2 Notes

1/ Reference MIL-STD-883, Method 1015. Static and dynamic burn-in shall be performed at maximum recommended operating supply voltage with Vin and RL selected to assure that the junction temperature shall not exceed Tjmax specified for the device type.

2/ See Table 5.0-1 for BI ambient temperature condition.

3/ These are typical recommended electrical parameters. Since electrical parameters are device dependent, refer to detail specifications for actual DC and AC parametric test conditions and limits.

4/ For digital devices, all DC parameters, functional tests, and switching tests shall be performed at 25°C, at minimum operating temperature and at maximum operating temperature. For linear devices, all DC parameters shall be tested at 25°C, at minimum operating temperature and at maximum operating temperature. All AC and switching tests shall be performed at 25°C.

5/ For Grades 2 and 3 parts only one BI test, static or dynamic is required.

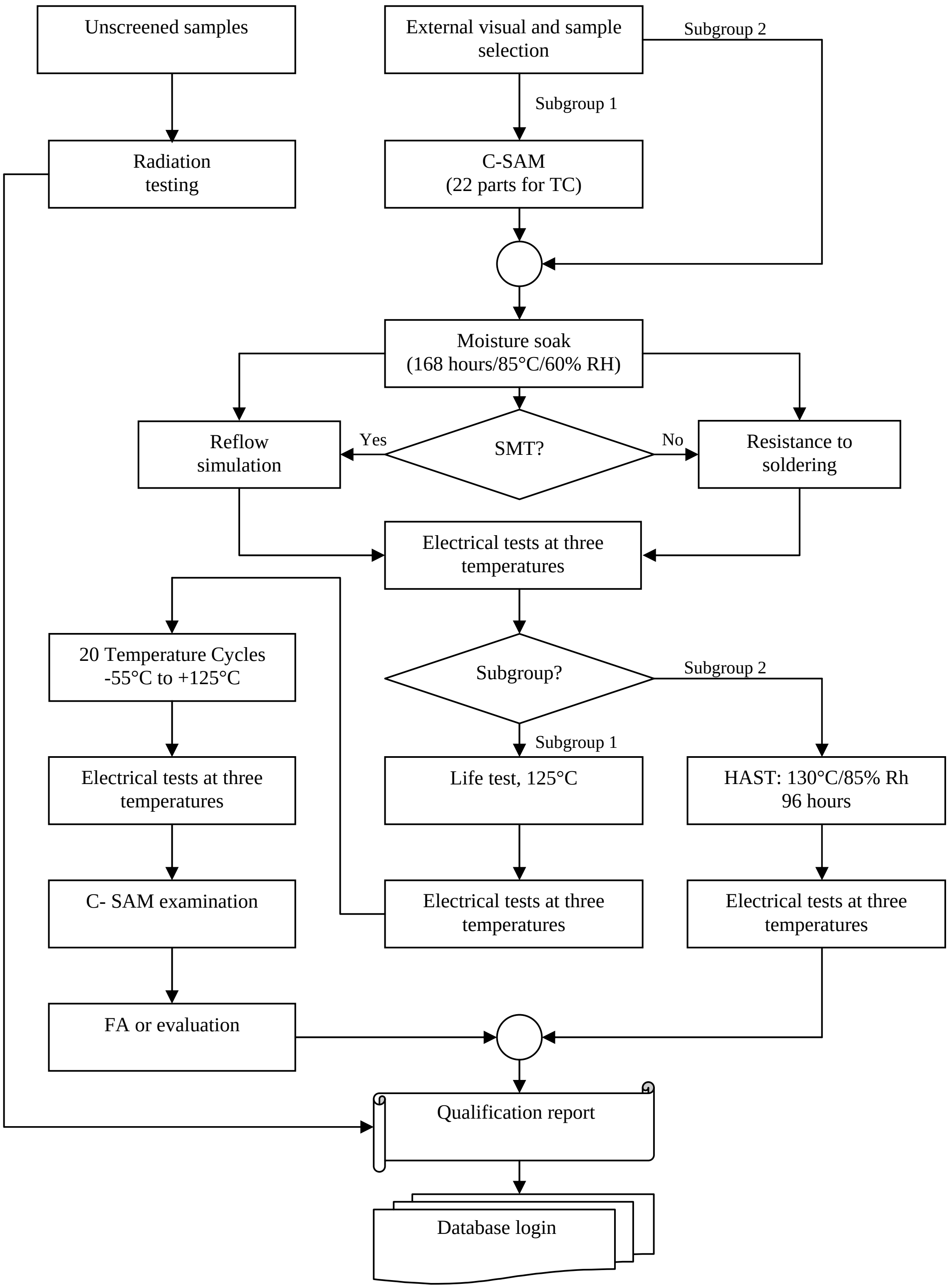


Figure 6.0-1. Qualification Test Flow for PEMs

Table 6.0-1. Qualification Requirements for PEMs 1/

Process	Sub Test	Test Methods & Conditions	QTY (Failures)		
			Grade 1	Grade 2	Grade 3
1. External Visual Inspection 2/		Paragraph 7.3.1	32	32	17
2. Radiation Analysis		TID and SEE	3/	3/	3/
3. Baseline C-SAM	Parts in Subgroup 1 only	Paragraph 7.2.3	22	22	N/A
4. Preconditioning	Moisture soak 4/	JESD22-A113-C, paragraph 3.1.5 per applicable moisture sensitivity level	32	32	17
	SMT Devices Reflow simulation (with flux application, cleaning, and drying)	JESD22-A113-C, paragraphs 3.1.6 through 3.1.9. Peak solder reflow temperature +235°C	32	32	17
	Through-hole devices Resistance to soldering temperature	JESD22-B106-B	32	32	17
5. Electrical Measurements	Per device specification	Measure at 25°C, min. and max. rated temperatures.	32 (0)	32 (0)	17 (0)
6. Life Testing Subgroup 1	HTOL, 125°C 5/, 6/	MIL-STD-883, Method 1005, Condition D. Hours minimum	22 1,500	22 1,000	10 500
	Electrical measurement (per specification)	Measure at 25°C, min. and max. rated temperatures.	22 (0)	22 (0)	10 (0)
7. Temperature Cycling Subgroup 1	Temperature cycling 5/, 7/	MIL-STD-883, Method 1010, Condition B, -55°C to 125°C Cycles, minimum	22 500	22 200	10 100
	Electrical measurement (per specification)	Measure at 25°C, min. and max. rated temperatures.	22 (0)	22 (0)	10 (0)
	C-SAM 8/	Paragraph 7.3.3	22	22	N/A
	DPA or FA	9/	X	X	N/A
8. Highly Accelerated stress test (HAST) Subgroup 2	Biased HAST 5/	JESD22-A110-B, with continuous bias. (96 hours, +130°C, 85% RH)	10	N/A	N/A
	Unbiased HAST 5/	JESD22-A118, Condition A (96 hours, +130°C, 85% RH)	N/A	10	7
	Electrical measurement (per specification)	Measure at 25°C, min. and max. rated temperatures.	N/A	10 (0)	7 (0)

Notes on following page.

Table 6.0-1 Notes

1/ General

1.1/ All parts shall be selected from a screened lot.

1.2/ It is the responsibility of the project parts engineer to submit qualification test results to MSFC EEE Parts Engineering for logging into the PEM database.

1.3/ For Grade 4, qualification at the piece part level is not required. However, since commercial parts receive no screening and offer no notification of changes to design or processes it is recommended that qualification criteria listed be used when the schedule and funding will allow it.

2/ Quantities referenced in paragraph 7.2.1 are not applicable.

3/ Radiation hardness of the parts must be assessed on a lot-specific basis according to the project requirements. Unscreened samples can be used for this test so that analysis can be completed prior to screening and qualification. An additional number of samples, depending on radiation requirements, shall be provided by the project to perform this test.

4/ Moisture soak is performed as a part of preconditioning to mimic worst-case moisture absorption conditions of the PEM molding material, which could cause PEMs to be damaged during soldering to boards.

5/ Conditions of the temperature cycling, HAST, and high temperature life testing (HTOL) can be tailored according to specifics of the device application with MSFC EEE Parts Engineering approval. Guidelines for application-tailored qualification testing of PEMs shall be developed by MSFC EEE Parts Engineering.

6/ 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 appropriately.

7/ Temperature cycling is performed after HTOL testing on the same samples only for economic reasons. This test can be also performed on a separate group of parts if additional samples are provided (22, 22, and 10 samples for Grades 1, 2, and 3, respectively).

8/ This C-SAM examination is performed to estimate mechanical damage to the part due to temperature cycling and reflow simulation (or resistance to soldering test) by comparing acoustic images with the baseline measurement results.

9/ Failure analysis is performed on any failures during qualification tests to determine whether they are caused by lot-related defects, manufacturing process problems, or improper testing. If no failures are observed, a special evaluation (DPA) shall be performed to ensure that no degradation of wire bonding, cratering, and mechanical damage to glassivation and metallization systems occurred (for Grade 1 and 2 parts only).

7.0 PHYSICAL ANALYSIS

This section describes purpose, test flow, and procedures for destructive physical analysis (DPA) and construction analysis (CA) of commercial PEMs and is intended to supplement MIL-STD-1580. CA shall be performed before any screening or qualification testing, and DPA shall be performed after screening.

7.1 PURPOSES OF DPA AND CA FOR PEMS

Both DPA and CA provide important information regarding design, workmanship, and process defects related to a PEM manufacturer lot. This information can be used for tailoring of screening and qualification test plans to focus on specific areas of reliability concerns. Table 7.1-1 defines the tests for both DPA and CA.

Table 7.1-1. Tests for CA and DPA

TEST	DPA	CA
External visual inspection (paragraph 7.2.1)	X	X
Radiography (paragraph 7.2.2)	X	X
Lead finish composition (paragraph 7.2.3)	X	X
Acoustic Microscopy (C-SAM) (paragraph 7.2.4)	X	
Package Level Cross Section (paragraph 7.2.5)	X	X
Decapsulation (paragraph 7.2.6)	X	X
Internal visual inspection (paragraph 7.2.7)	X	X
Bond Pull Test (paragraph 7.2.8)	X	
SEM (paragraph 7.2.9)	X	X
Glassivation Integrity Test (paragraph 7.2.10)	X	
Report Submittal	X	

Destructive Physical Analysis is used to determine whether the lot has any design, material, workmanship, or process flaws that may not show up during screening and qualification tests and cause degradation or failures during the hardware integration period and spacecraft mission lifetime. An important benefit of DPA is to provide for comparison analysis of design and technology, to identify product change, to provide baseline data in the event of subsequent failures and application problems, and to provide data for physics of failure analysis. DPA for PEMs should focus on three major areas of concern: integrity of the package, quality of assembly, and defects in the die. This analysis should also evaluate package-and die-level homogeneity of the lot. For this purpose, samples for DPA should be selected randomly from different portions of the lot. When obvious gross defects are revealed during DPA, it is usually an indication that manufacturer's processes are out of control, and a replacement of the lot might be required. Anomalies revealed by DPA raise concerns regarding quality and reliability of the parts. These concerns may be further addressed by tailoring screening and qualification procedures or by performing additional design evaluation and testing of the parts.

Construction analysis is a customized sequence of applicable analytical techniques to evaluate the inherent design and robustness of a component or assembly. A well executed construction analysis examines and documents the physical characteristics including material elemental composition, dimensions and quality details of the assembly. This testing methodology was originally created to assess commercial electronic components, i.e. plastic non-hermetic packages, but can be applied to virtually any manufactured product. Each analysis employs a series of non-destructive and destructive tests appropriate for the product type.

7.2 CA AND DPA PROCEDURES

CA and DPA test flow charts are shown in Figures 7.2-1 and 7.2-2, respectively. A CA and DPA shall be performed on each manufacturer's lot. Each analysis shall use a minimum of 5 samples. When a CA or DPA is performed by a contractor, the project engineer shall submit the report to MSFC EEE Parts Engineering for review and assessment. DPA inspection lots found to have one or more defects shall be: a. subjected to re-sampling if the results of the first sample were inconclusive, b. screened, c. accepted for use with MSFC EEE Parts Engineering approval, or d. scrapped as applicable. This requirement may be met in the part manufacturer's processing, in third party laboratory testing, or by the procuring activity.

7.2.1 External Visual Examination

External visual examination shall be performed on each sample (five samples minimum) per MIL-STD-1580, Requirement 16 for PEMs.

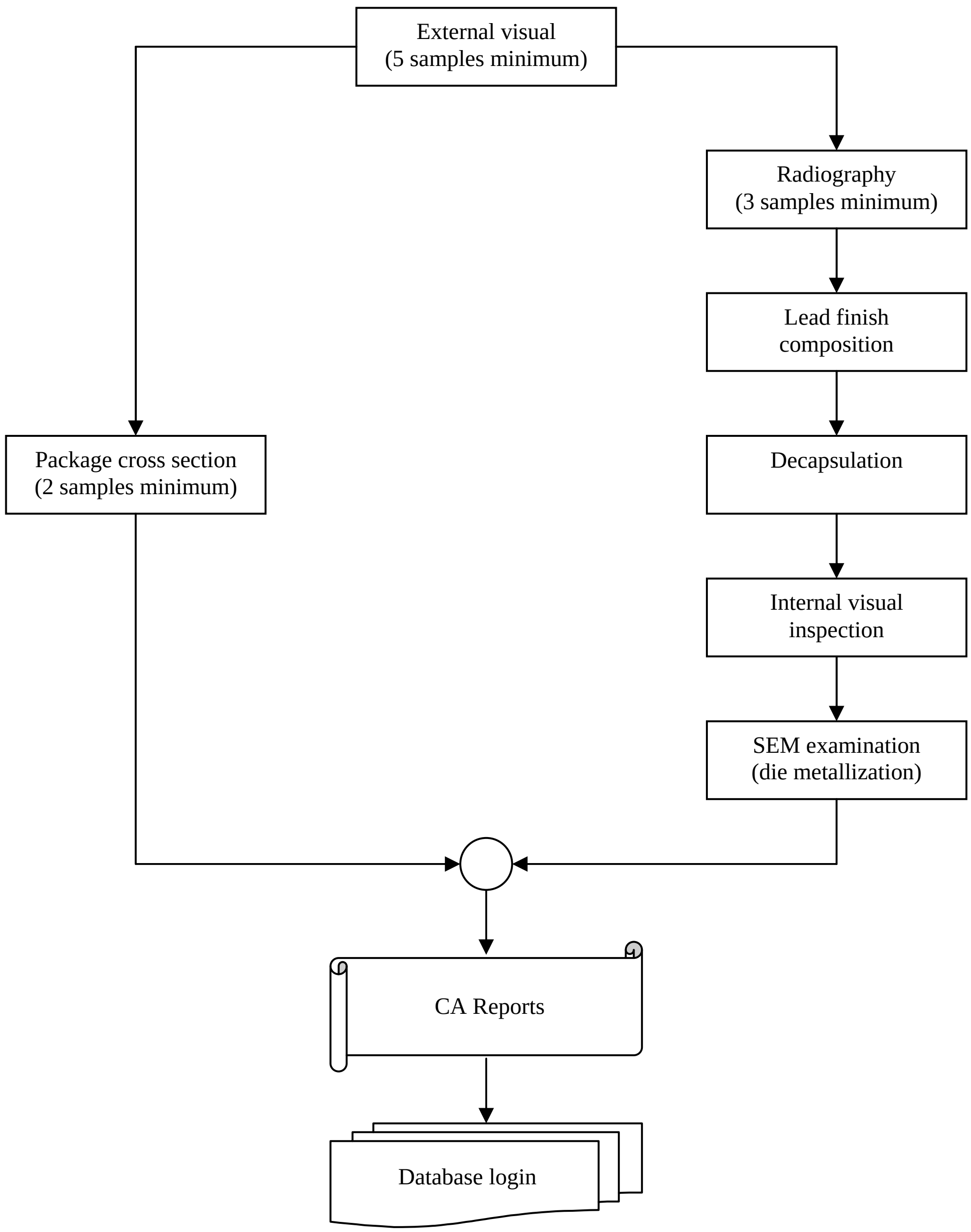


Figure 7.2-1. CA Test Flow for PEMs

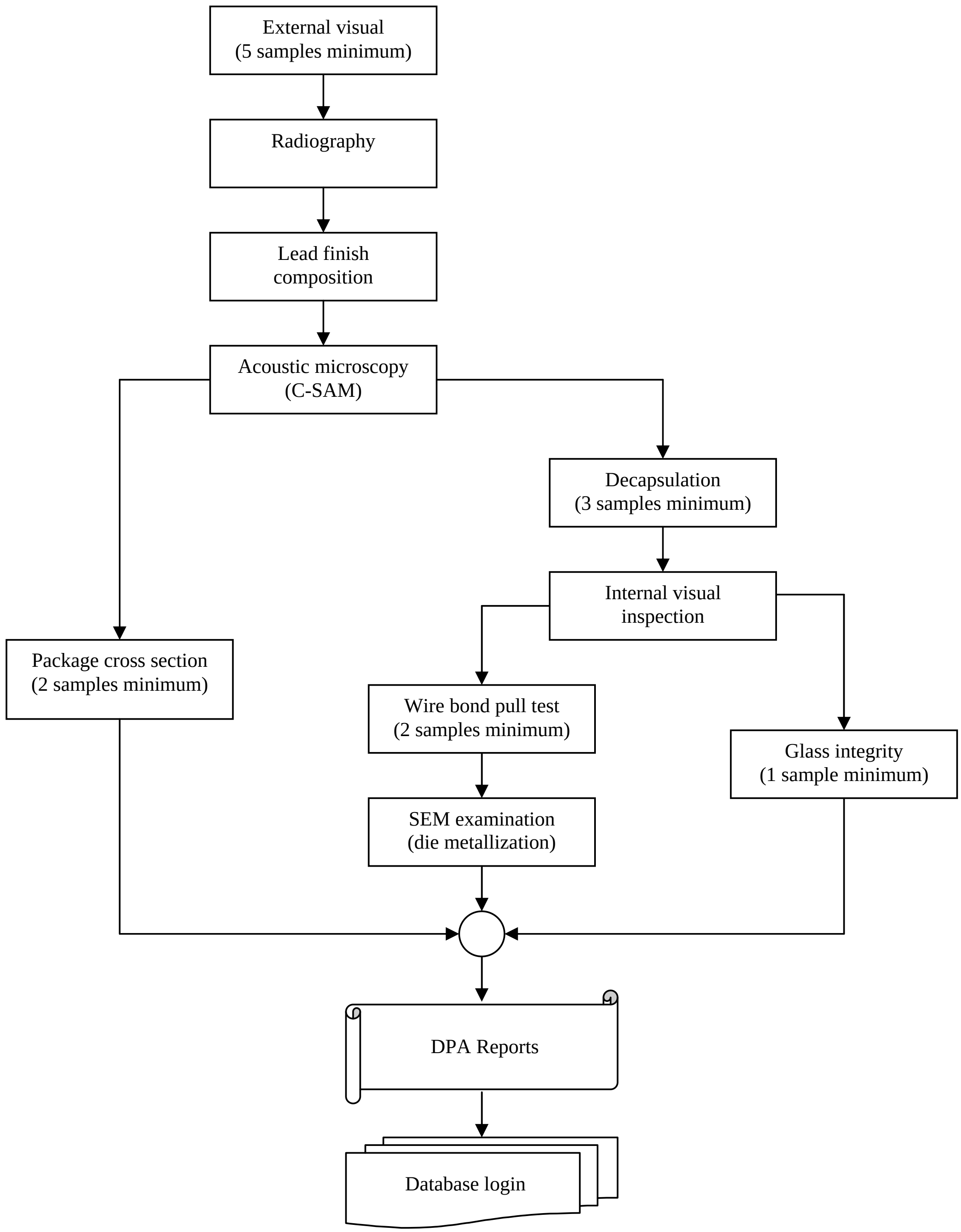


Figure 7.2-1. DPA Test Flow for PEMs

7.2.2 Radiography

Radiography shall be preformed per MIL-STD-1580, Requirement 16 for PEMs on the samples that meet the requirements of 7.2.1 (five samples minimum).

When real-time radiography is used for screening, the dose rate that the equipment emits should be estimated. Certain types of radiography can expose microcircuits to unusually high dose rates, such that damage can be introduced to sensitive parts. A radiation specialist should be consulted as necessary.

7.2.3 Lead Finish Composition

A lead composition analysis shall be performed on all DPA samples to verify a minimum of 3% lead for tin plated contacts.

7.2.4 Acoustic Microscopy (C-SAM)

This test is not used for CA.

Acoustic Microscopy shall be performed in accordance with MIL-STD-1580, Requirement 16 for PEMs on the DPA samples that meet the requirements of 7.2.3 (five samples minimum) with the following additions:

1. A clean bath and deionized water should be used during acoustic examinations of flight parts.
2. A minimum 1-hour bake at 125°C shall be performed to remove moisture from the parts after immersion into the water bath of an acoustic microscope.
3. Anomalies and/or delaminations should be verified using A-mode analysis.

7.2.5 Package Level Cross-Sectioning

Forty percent of the samples (two intact samples minimum) shall be subjected to package level cross-sectioning. The DPA samples shall meet the requirements of 7.2.4; the CA samples shall meet the requirements of 7.2.3.

Inspect the package and die for the following defects:

1. Defects and cracks in the package.
2. Condition of die attachment.
3. Lead frame/molding compound delamination.
4. Condition of wire bonding at contact pads.

5. Contact pad cratering.
6. Condition of wire bonding at lead frame
7. Anomalies in molding compound (e.g., red particles might indicate the presence of red phosphorus used as a flame retardant; this type of flame retardant might cause part failure).
8. SEM examination at the package level cross section is performed optionally to obtain more details of anomalies observed during optical examination.

7.2.5.1 Cross-Sectioning Procedure

Half of the samples shall be sectioned parallel along the leads of one side of the package to halfway into the die. The remaining samples shall be sectioned perpendicular to the leads to halfway into the die. Cross-sectional planes shall be selected to cross wire bond to die and wire bond to lead frame. If suitable, a sample can be divided into two parts before potting as long as a cross-section parallel to the leads is performed on one half and a cross-section perpendicular to the same leads is performed on the other half. Each plane of cross section shall be examined microscopically first at a low power (30X to 60X) magnification and then at a high power magnification (75X to 200X). Optical examination of the bonds shall be performed at up to 1,000X magnification. Pictures of all defective bonds and package faults, as well as at least one picture of a typical bond, die attachment, and overall package layout, should be taken.

7.2.5.2 Evaluation Criteria

The following defects shall be considered as gross defects causing the lot to be rejected:

1. Package cracks and delaminations: Any evidence of external cracks other than between the lead and plastic at the lead entrance; large voids and delamination at the die attachment, die surface, and lead finger tips.
2. Bonding: Lifted and shifted bonds, excessive intermetallic formation at the periphery of the ball bond.
3. Molding compound: Voids and cracks in vicinity of bonding wires, presence of red phosphorus or other corrosive materials.
4. Leads: Pure tin (Sn) finish of the leads (< 3% lead minimum), delamination of finish.

The following shall be considered as reliability concerns and additional testing and screening of the lot might be necessary:

1. Package cracks and delaminations: Any evidence of delamination or cracking of more than 0.5 of the lead or tie bar length.
2. Bonding: Abnormalities in intermetallic compound formation, cratering.
3. Die attach: Voiding of more than 50%.
4. Molding compound: Foreign intrusions.

7.2.6 Decapsulation

Decapsulation shall be performed per MIL-STD-1580, Requirement 16 for PEMs on 60% of the samples (three samples minimum).

7.2.7 Internal Visual Inspection

The decapsulated samples shall be subjected to internal visual inspection per MIL-STD-1580, Requirement 16 for PEMs.

7.2.8 Bond Pull Test

This test is not used for CA.

Forty percent of the samples (two samples minimum) that met the requirements of 7.2.7 shall be subjected to bond pull testing per MIL-STD-1580, Requirement 16 for PEMs.

7.2.9 Examination Using Scanning Electron Microscope (SEM)

Forty percent of the samples (two samples minimum) that met the requirements of 7.2.7 shall be subjected to SEM analysis per MIL-STD-1580, Requirement 16 for PEMs.

7.2.10 Glassivation Layer Integrity

This test is not used for CA.

Twenty percent of the samples that met the requirements of 7.2.7 (one sample minimum) shall be examined per MIL-STD-883, Method 2021, “Glassivation Layer Integrity.”

8.0 DERATING REQUIREMENTS

General derating requirements are listed in Table 8.0-1. Taking a conservative approach, derating requirements for PEMs should be more stringent than the requirements for their high-reliability equivalents. In some cases additional derating may be required based on specific application, design, and technology of the part. All part-specific derating shall be approved by the project and MSFC EEE Parts Engineering.

Table 8.0-1. Derating Requirements for PEMs

Stress Parameter	Derating Equation/Factor	
	Digital	Linear /Mixed Signal
Maximum Supply Voltage 1/	$V_{n.r.}+0.5*(V_{max.r.}-V_{n.r.})$	$V_{n.r.}+0.8*(V_{max.r.}-V_{n.r.})$
Maximum Input Voltage	-	0.8
Maximum Operating Junction Temperature 2/	0.8 or 95°C, whichever is lesser	0.7 or 85°C, whichever is lesser
Maximum Output Current	0.8	0.7
Maximum Operating Frequency	0.8	0.7

Table 8.0-1 Notes

1/ Vn.r. is the nominal rated power supply voltage; Vmax.r. is the maximum rated power supply voltage.

2/ For power devices, do not exceed 110°C or 40°C below the manufacturer's rating, whichever is lower.

9.0 HANDLING AND STORAGE REQUIREMENTS

Handling and storage shall be in accordance with CxP 70059, MSFC-STD-3012, and J-STD-033 with the following additions.

Detailed procedures for handling, storing, and maintenance of PEMs and assemblies shall be developed. The IPC/JEDEC standard J-STD-033 can be used when applicable as a guideline for safe handling and packing of PEMs regarding moisture sensitivity. The requirements should follow the entire ground-phase handling of parts including piece part testing, storage prior to installation, and board/system-level testing and storage after installation and integration into the system.

10.0 MANUFACTURER INFORMATION

This section describes guidelines for acquiring information from the manufacturer of PEMs, which might be useful to assess quality of the parts.

Table 10.0-1 displays questions to be posed and manufacturer data available from Web sites, which would help to evaluate the ability of the manufacturer to produce parts with consistent quality and to provide acceptable customer support. The data are combined in four categories: general information about the part, part design and lifespan assessment, manufacturer assessment, and process assessment.

This information is of mutual interest for the parts engineering community and might be useful for different projects. For this reason, the project parts engineer should submit a spreadsheet in a standard format according to Table10.0-1 to MSFC EEE Parts Engineering for logging into the PEMs database.

Table 10.0-1. Manufacturer Information

Category	#	Information/Question
General Information	1.1	Part number
	1.2	Function
	1.3	Date code
	1.4	Package type
	1.5	Manufacturer
Part Attributes	2.1	Die process technology
	2.2	ESD sensitivity level
	2.3	Moisture sensitivity level
	2.4	Date of last die revision
	2.5	Date of introduction to the market
	2.6	Expected date for obsolescence
	2.7	Product storing policy (years to keep in stock)
	2.8	Packing parts for shipment, moisture control
	2.9	Type of molding compound and characteristics (glassivation temperature, CTE, flame retardant)
Manufacturer Data	3.1	Vendor facility (location)
	3.2	Point of contact for quality assurance
	3.3	Quality certification of the vendor (ISO 9000 or equivalent)
	3.4	Mask revision control
	3.5	Application support
	3.6	Part traceability

Continues on next page

Table 10.0-1. Manufacturer Information
(continued)

Category	#	Information/Question
Process	4.1	Availability of Statistical Process Control (SPC) data
	4.2	What kind of 100% outgoing inspection and screening is used?
	4.3	Availability of test flowchart
	4.5	Availability of reliability and quality assurance handbook
	4.6	Average outgoing quality (AOQ) 1/
	4.7	Major process capability indexes for the part (Cpk) 2/
	4.8	Acceptable proportion of failures at high temperature measurements
	4.9	Radiation hardness of the process or of similar parts
	4.10	Are there any military parts manufactured using same technology?

Table 10.0-1 Notes

1/ AOQ is the proportion of parts that are outside the manufacturer specification limits. Currently the quality assurance system employed by most established PEMs manufacturers guarantees a minimum of a 3-sigma level process. This means that AOQ = 2,700 ppm or 0.27% of all shipped parts might have parameters out of the data sheet specification. In some cases this level of failures is below 0.1% and even less than two failures in 109 parts for a 6-sigma manufacturer. However, the parts manufactured by a 6-sigma process have higher quality only when the parts are used and operate at relatively low temperatures. For example, a 6-sigma commercial product, when used in automotive applications, is considered a 3-sigma product.

2/ Cpk is a measure of how well the process fits within the specification limits. It relates process variations to the specification limits using a “natural tolerance”, 3σ, and is applicable only for normal distribution. Cpk = [min (HSL - μ), (μ - LSL)]/ (3σ), where HSL is the higher specification limit, LSL is the lower specification limit, μ is the mean value, and σ is the standard deviation. Larger Cpk values indicate lesser variations in the process and more consistent quality of the product.

APPENDIX B

ACRONYMS AND ABBREVIATIONS

AIT	Analysis & Integration Team
ALERT	Acute Launch Emergency Reliability Tip
ANSI	American National Standards Institute
CA	Construction Analysis
CEV	Crew Exploration Vehicle
CR	Change Request
C-SAM	C-mode Scanning Acoustic Microscopy
DPA	Destructive Physical Analysis
EEE	Electrical, Electronic and Electromechanical
ESD	Electrostatic Discharge
GIDEP	Government Industry Data Exchange Program
GSE	Ground Support Equipment
IPC	Institute of Interconnecting and Packaging Electronic Circuits
JEDEC	Joint Electron Device Engineering Council
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NEPIN	NASA EEE Parts Information Network
NSPAR	Nonstandard Part Approval Request
OPR	Office of Primary Responsibility
OTS	Off-the-Shelf
PCB	Parts Control Board
PDA	Percent Defective Allowable
PEM	Plastic Encapsulated Microcircuit
PIND	Particle Impact Noise Detection
QCI	Quality Conformance Inspection
QML	Qualified Manufacturer List
QPL	Qualified Parts List
RGA	Residual Gas Analysis
ROHS	Reduction of Hazardous Substances
SBU	Sensitive But Unclassified
SCD	Specification Control Drawing
SEE	Single Event Effects
SEM	Scanning Electron Microscope

TBD	To Be Determined
TID	Total Ionizing Dose
VICD	Vendor Item Control Drawing

APPENDIX C

OPEN WORK

Table B-2 lists the specific To Be Resolved (TBR) issues in the document that are not yet known.

Table B-2 To Be Resolved Issues

TBR	Section	Description