NASA Electrical, Electronic and Electromechanical (EEE) Parts Assurance
An Overview

NASA STEP Level 2

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NASA/GSFC

http://nepp.nasa.gov

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NASA Office of Safety & Mission Assurance

Open Access
Acronyms

- American Association of Independent Advisors (AAIA)
- Automotive Electronics Council (AEC)
- United States Army Aviation and Missile Research Development and Engineering Center (AMRDEC)
- Applied Physics Laboratory (APL)
- Appendix (Appdx)
- Ames Procedural Requirements (APR)
- Ames Research Center
- Commercial Off The Shelf (COTS)
- Canadian Space Agency
- Defense Logistics Agency (DLA)
- Electrical, Electronic, and Electromechanical (EEE)
- Express Logistics Carriers (ELCs)
- Environment Control
- Engineering Practice (EP)
- Electronic Parts Application Reporting & Tracking System (EPARTS)
- EEE Parts Management and Control Plan (EPMCP)
- European Space Agency (ESA)
- Electrostatic Discharge (ESD)
- Electronic Components & Standardization (EZSS)
- Field Programmable Gate Array (FPGA)
- Government-Industry Data Exchange Program (GiDEP)
- Glenn Research Center (GRC)
- Ground Support Equipment (GSE)
- Goddard Space Flight Center (GSFC)
- Human Body Model (HBM)
- NASA Headquarters (HQ)
- IPC is an Association Connecting Electronics Industries. In 1999, IPC changed its name from Institute for Interconnecting and Packaging Electronic Circuits to IPC.
- Institutional Parts Program Requirements (IPPR)
- International Space Station (ISS)
- International Traffic in Arms Regulations (ITAR)
- Japan Aerospace Exploration Agency (JAXA)
- Joint Electron Device Engineering Council (JEDEC)
- NASA Jet Propulsion Laboratory (JPL)
- Johnson Space Center (JSC)
- Kennedy Space Center (KSC)
- Langley Research Center (LaRC)
- Air Force Life Cycle Management Center (LCMC)
- Missile Defense Agency (MDA)
- Military (MIL)
- Military Specifications (MIL Spec)
- Multi-Layer Ceramic Chip Capacitors (MLCC)
- Marshall Space Flight Center (MSFC)
- National Aeronautics and Space Administration (NASA)
- Naval Sea Systems Command (NAVSEA)
- The NASA Electronic Parts Assurance Group (NEPAG)
- The NASA Electronic Parts and Packaging (NEPP) Program
- NASA Policy Directive (NPD)
- A thin layer of p-type semiconductor sandwiched between two n-type semiconductors (NPN)
- NASA Procedural Requirements (NPR)
- NASA Parts Selection List (NPSL)
- National Reconnaissance Office (NRO)
- Office of Management and Budget (OMB)
- Office of Safety and Mission Assurance (OSMA)
- Part Acquisition & Review System (PARS)
- Parts Engineering Technical Standard (PETS)
- Parts, Materials, and Processes Control Board (PMPCB)
- Package on Package (PoP)
- Production Part Approval Process (PPAP)
- Preferred Parts List (PPL)
- Quad Flat-Pack (QFP)
- Qualified Manufacturers List (QML)
- Qualified Product List (QPL)
- Society of Automotive Engineers (SAE)
- Safety and Mission Assurance (SMA)
- Space and Missile Systems Center (SMC)
- System on Chip (SOC)
- Space Station Program (SSP)
- NASA Safety and Mission Assurance Technical Excellence Program (STEP)
- NASA Technology Readiness Levels (TRLs)
- United States Air Force (USAF)
Outline

• Introduction
  o So, What is a EEE Part?
• NASA EEE Parts Assurance Structure
  o Documentation - NASA-STD-8739.10
• NASA Electronic Parts and Packaging (NEPP) Program
  o NASA Electronic Parts Assurance Group (NEPAG)
• Examples of Assurance Challenges
  o EEE Part-level ESD risks
  o Automotive EEE Parts
  o EEE Part problem investigations
    • Reverse-bias of tantalum capacitors
    • Cracking of ceramic chip capacitors
    • Counterfeit trending
• Future Challenges
• Summary and Comments
### EEE Part Types Per
### Table 1 of NASA-STD-8739.10

<table>
<thead>
<tr>
<th>Part Types</th>
<th>Federal Stock Classes</th>
<th>Part Types</th>
<th>Federal Stock Classes</th>
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<tbody>
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<td>Capacitors</td>
<td>5910</td>
<td>Hybrid microcircuits (including dc/dc converters, opto-electronics, RF, and microwave devices)</td>
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<td>Circuit Breakers</td>
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<td>Magnetics, Inductors &amp; Transformers</td>
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<td>Connectors</td>
<td>5935</td>
<td>Monolithic Microcircuits</td>
<td>5962</td>
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<td>Crystal &amp; Crystal Oscillators</td>
<td>5955</td>
<td>Relays</td>
<td>5945</td>
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<td>Diodes</td>
<td>5961</td>
<td>Resistors</td>
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<td>Fiber Optic Accessories</td>
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<td>Switches</td>
<td>5930</td>
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<td>Fiber Optic Cables</td>
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<td>Thermistors</td>
<td>5905</td>
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<td>Fiber Optic Devices</td>
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<td>5915</td>
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<td></td>
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<tr>
<td>Fuses</td>
<td>5920</td>
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<td></td>
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</tbody>
</table>
EEE Parts and Space Applications

- EEE parts are available in “grades”
  - Designed and tested for specific environmental characteristics.
    - E.g., Operating temperature range, vacuum, radiation exposure,…
  - Examples: Aerospace, Military, Automotive, Medical, Extended-Temperature-Commercial, and Commercial

- Aerospace Grade is the traditional choice for space usage, but has relatively few available parts and their performance lags behind commercial counterparts (speed, power).
  - Designed and tested for radiation and reliability for space usage.

- NASA uses a wide range of EEE part grades depending on many factors (technical, programmatic, and risk).
Compilation of Assorted EEE Parts Photos

Source: NASA GSFC Code 562 Parts Analysis Laboratory
Compiled by Jay Brusse/ASRC AS&D at NASA GSFC
Some Typical EEE Parts used by NASA

Ceramic Chip Capacitor

Tantalum Chip

Cross Section
More Capacitors

Wet Slug Tantalum Capacitor

Metallized Film Capacitor

Internal Construction

Internal Features
Resistors

Resistor, Wirewound

Resistor, Foil
Microcircuits

Field Programmable Gate Array (FPGA) in a Quad Flat-Pack (QFP)

Hybrid Microcircuit DC/DC Converter

Package 2.2” X 2.7”

Internal Construction
Connectors & Electrical Contacts

Circular Connector

D-Subminiature Connector

Coaxial, Radio Frequency Connector

Socket and Pin Contacts
Frequency Control Devices

Crystal Oscillator “Hybrid”  Internal Construction

Crystal

Internal Construction
Old Versus New Relay Technologies

Case Removed

Mechanical

Solid-State,
Opto-
Isolated
Discrete Semiconductors

MOSFET, P-Channel

NPN Silicon Switching Transistor

Internal Construction

Magnetics

Transformer

Internal Construction

Power Inductor

Internal Construction
Circuit Protection Devices

**Cartridge Fuse**

**Internal Construction**

**Solid Body Fuse**

**Internal Construction**

And They Can Be Very SMALL
A Little History

• In 1976, MIL-STD-975, the “Standard Parts List for Flight and Mission-Essential Ground Support Equipment”, was Released by NASA MSFC
  o Later Re-titled “NASA Standard Electrical, Electronic, And Electromechanical (EEE) Parts List”
• Established a process where parts designated “standard” reflected proven performance, reliability and consistency
  o Standard parts required minimal post procurement testing or analysis compared to Non-standard
  o Most were MIL spec., when MIL spec. was state- of-the-art
• In 1998, 975 was canceled without replacement and the NASA Centers were left to develop parts management procedures
• NASA has a parts policy, NPD 8730.2, which covers EEE parts, mechanical parts and materials at a high level but very limited detailed guidance for EEE parts
• There had been no NASA Standard for EEE Parts Assurance until NOW, NASA-STD-8739.10
Current Policy Documents

• NPD 8730.2 NASA Parts Policy
  • Control Risk and Enhance Reliability, Covers:
    • EEE Parts, Electronic Packaging and Interconnect Systems
    • Mechanical parts and Manufacturing Materials

• NPR 8705.4 Risk Classification for NASA Payloads
  • Appendix B: Guidance on acceptable risk levels
  • Appendix C: Recommended SMA – Related Requirements
    • Critical Single Point Failures
    • EEE Part Levels
    • Reliability

• Center EEE Part Documents
  • GSFC: EEE-INST-002 (Also used by LaRC, GRC and JPL)
  • MSFC-STD-3012
  • ARC: APR 8730.2
  • JSC/ISS: SSP 30312
  • JPL: IPPR, PETS and PPL”

https://spinoff.nasa.gov/network.html
NATIONAL SPACE ADMINISTRATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D.C. 20546

ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS ASSURANCE STANDARD

MEASUREMENT SYSTEM IDENTIFICATION:
METRIC/SI (ENGLISH)

NASA/TP—2003–212242

EEE-INST-002: Instructions for EEE Parts Selection, Screening, Qualification, and Derating

Prepared by:
Dr. Kusum Sahu

Reviewed by:
Dr. Henning Leidecker

Approved by:
Darryl Luhito

April 2008, Incorporated Addendum 1

CHECK THE MASTER LIST—VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE AT https://repository.nasa.edu/docs/tp/EEE/EEE-INST-002.pdf
Goals for NASA EEE Parts Standard

• Create Agency-Level Document
  • Capture list of issues that must be addressed
  • Single document referenced in Agency contracts
  • Not overburden “higher risk” projects with excessive requirements

• Maintain Center-to-Project relationship
  • Center still has ample control
  • Project still assumes the risk
Gap Analysis of Documents

- Comparison of Agency and Center Documents
  - Topics from all source documents used for cross-reference
  - No one document covered all topics (portion shown below)
  - Agency level documents had most gaps
  - Goal was to make Agency level document that covered all topics

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>Agency</th>
<th>JPL</th>
<th>MSFC</th>
<th>GSFC</th>
<th>JSC/ISS</th>
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## Full Center EEE Parts Gap Analysis

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<th>ARC</th>
<th>GRC/K</th>
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<td>Test Results</td>
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<td>Test Report</td>
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Details

- **Applicability**
  - Flight hardware - Launch vehicles - Critical ground support equipment (GSE) - Critical ground test systems
  - Category 1 and Category 2 projects as defined by NPR 7120.5, NASA Space Flight Program and Project Management Requirements
  - Class A, B, C or D payloads as defined by NPR 8705.4, Risk Classification for NASA Payloads, Appendix A.

- **Non – Applicability**
  - Institutional projects as defined by NPR 7120.7, NASA Information Technology and Institutional Infrastructure Program and Project Requirements
  - Research and Technology Development Programs and Projects as defined by NPR 7120.8, NASA Research and Technology Program and Project Management Requirements

- **Tailoring**
  - Tailoring of the requirements contained in this Standard for application to a specific program or project per Center requirements, risk classification or acceptable risk posture shall be formally documented in the Program and Project EEE Parts Management and Control Plan (EPMCP), or equivalent, and approved by the Parts, Materials, and Processes Control Board (PMPCB), or equivalent, and the Technical Authority.
• Every EEE part intended for use in space flight and critical ground support equipment shall be reviewed and approved for compatibility with the intended environment and mission life, as applicable.

• Parts shall be selected so that flight hardware meets all performance and reliability requirements in the worst-case predicted mission environment.

### EEE Part Grade Description

<table>
<thead>
<tr>
<th>SUMMARY</th>
<th>LEVEL OF IN-PROCESS CONTROLS AND SCREENING</th>
<th>COST/ PART</th>
<th>POTENTIAL UPSCREEN COST</th>
<th>TYPICAL USE</th>
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</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Space quality class qualified parts or equivalent.</td>
<td>Highest</td>
<td>Highest</td>
<td>Low</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Full Military quality class qualified parts or equivalent.</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Low Military quality class parts and Vendor Hi-Rel or equivalent. Screened automotive grade EEE parts.</td>
<td>Medium</td>
<td>Moderate</td>
<td>High</td>
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<tr>
<td><strong>4</strong></td>
<td>&quot;Commercial&quot; quality class parts. Qualification data at manufacturer’s discretion. No government process monitors incorporated during manufacturing.</td>
<td>Variable</td>
<td>Lowest</td>
<td>Highest</td>
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</tbody>
</table>
Content of NASA-STD-8739.10

1. Scope
2. Applicable Documents
3. Acronyms and Definitions
4. EEE Parts Classification
5. EEE Parts Selection Requirements
6. EEE Parts Assurance and Control Requirements
   1. Scope
   2. Qualification – Environmental and life testing (often accelerated)
   3. Screening – 100% test for burn-in and parametrics
   4. Government Industry Data Exchange Program (GIDEP) Review
   5. Receiving Inspection
   6. Environmental Control and Storage Requirements
   7. Electrostatic Discharge (ESD) Control
   8. Re-use of EEE Parts
7. EEE Parts Procurement, Obsolescence and Counterfeit Avoidance
8. EEE Parts Documentation and Organization
   Lists of Appendices and Tables

Documentation

- **Program / Project EEE Parts Management and Control Plan (EPMCP)**
  - Plan can be stand-alone documents of part of Project Product Assurance Plan
  - Specific Issue Plans may be contained in EPMCP or stand-alone doc’s

- **Parts Lists**
  - (EPARTS recommended)
  - As Designed Parts List
  - Approval Record
  - As Built Parts List

- **Analyses**
  - Derating Analysis
  - Parts Obsolescence
Specific Issue Plans

- Radiation Hardness Assurance Plan
- Counterfeit Control Plan
- Restricted Materials Plan
  - NASA-STD-6016 - Standard Materials and Processes Requirements for Spacecraft
- Red Plague Control Plan
  - IPC J-STD-001 ES - Space Applications Electronic Hardware Addendum to IPC J-STD-001E Requirements for Soldered Electrical and Electronic Assemblies

Prohibited Materials: Sn, Hg, Zn, Cd …
Current Status of NASA-STD-8739.10

- **Workgroup participation from NASA Centers handling space electronics**
  - LaRC, GSFC, MSFC, KSC, JSC, ARC, GRC & JPL
- **Stakeholder Review**
  - 238 comments submitted, all resolved
  - Approximately 1 year duration
  - 11 Center/Organizations [#comments]
    - ARC [1], GRC [18], GSFC [33], HQ (OSMA) [51], JPL [20], JSC [72], KSC [3], LaRC [9], MSFC [1], NSC [25], SSC [1]
- Document has been approved by the Office of Safety and Mission Assurance (OSMA) at NASA HQ
- Currently waiting on export control (ITAR) and legal reviews
- Currently available to NASA only, requires sign in through IdMax:
Leveraged off JPL’s “Part Acquisition & Review System” (PARS)
- Primary Purpose: Track Parts status from initial upload (Parts Lists) through Review, Approval and Procurement
- Repository of all data for Parts, Reviews, Testing, Up-screening, Waivers…

Current Status
- Operational with participating Centers:
  - MSFC, LaRC, ARC, KSC, and GRC.
  - JPL and JSC not currently using the database but participating in EPARTS working group.
- Behind NASA firewall and accessible by all Centers through Launchpad credential.
NEPP and NEPAG

- Chartered in the 1980’s to ensure electronic commodities expertise supported the Agency.
  - The NASA Electronic Parts Assurance Group (NEPAG) was created in 2000, as a sub-element of NEPP for
    - Information sharing between NASA Centers and other agencies, and
    - Sufficient infrastructure to support Agency needs and leadership in EEE Parts Assurance
- NEPP evaluates new EEE parts technologies and develops insertion, test, screening, and qualification guidance.
- NEPAG supports audits, specification and standard reviews, failure investigations etc. AND
- Maintains the NASA Parts Selection List (NPSL)
Insertion of New Technologies – NEPP/NEPAG Focus

• NASA mission timeframes rarely allow for a technology development path

• For a 2017 launch, technology freeze dates are likely 2014 or earlier
  - There may be time to qualify (test) a device, but there may not be time to develop/validate a new technology solution!

• Technology development and evaluation programs need to be in place prior to mission design
  - Strategic planning for/by NEPP on technologies is critical

NASA Technology Readiness Levels (TRLs)
Program Highlights

- **NEPAG has celebrated 17 years of stimulating, weekly discussions and knowledge interchange that is/has been Educational, Influential, Collaborative, and Current**
  - New multi-agency Working Group established for coordinated disposition of proposed changes to specifications and standards

- **NEPAG acts as the NASA Custodian in the Military Standardization Program**

- Working with Aerospace Corporation to develop an agreement to share support of MIL QPL/QML audits led by the Defense Logistics Agency Land and Maritime

- NEPP evaluates new parts and packaging technologies and publishes guidance for qualification for space use

- NEPP performs Total Ionizing Dose (TID) and Single Event Effects (SEE) testing to characterize the sensitivity (or hardness) of new and emerging technologies known as Radiation Hardness Assurance (RHA)
Importance of ESD

• Potentially affects everything, even mechanical parts, and there are major differences among the multiple ESD specs in use.

• There are ongoing efforts by various standards groups toward harmonizing the different standards.

• 1686 is the original MIL document for ESD testing and control, and it could be built up into a major ESD spec. However, Office of Management and Budget (OMB) Circular A-119 favors Industry Standards over government ones.


**NASA Concern - ESD**

**Electro Static Discharge (ESD)**

- **MIL-STD-883, Test Method 3015**
  - Too old, long test times
  - Needs to be revisited for new technology
    - Smaller feature sizes, lots of contacts/pins, advanced packaging (2.5/3D)
  - 883 vs JEDEC (3 zaps/pin vs 1 zap/pin, for HBM test)
  - Equipment used to assemble/process parts/wafers need closer look – special talk at Space subcommittee meeting
  - Generic issue; applies to all parts military/space (and COTS)

- **MIL-PRF-38535, Microcircuits:**
  - Clarify requirements
    - No specific ESD requirements for wafer foundries

- **NASA EEE Parts Bulletin**
  - Published a special edition on ESD, 2\textsuperscript{nd} part published soon

- **NASA ESD Surveys**
  - Conducted to bring awareness
AEC “Q” Specs

Qualification Requirements for EEE Parts FAMILIES

Intended for use by Automotive Market

http://www.aecouncil.com/AECDocuments.html

AEC Q-100
Microcircuits

AEC Q-101
Discrete Semiconductors

AEC Q-200
Passives
Alternate Grade Electronics: Automotive

- NEPP has three goals for automotive electronics efforts
  - Determine exactly what: “automotive grade” does or does not entail.
    - Includes understanding:
      - Automotive Electronics Council (AEC) documents, and,
      - Manufacturer Production Part Approval Process (PPAP).
  - Perform “snapshot” screening and testing on representative automotive grade electronics.
  - Explore adaption of resilient automotive electronics system concepts for use in space applications.
## NEPP Evaluation of Automotive Grade EEE Parts

20-Mar-17

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Lot Code</th>
<th>Description</th>
<th>Quantity on Test</th>
<th>Life Testing Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1302</td>
<td>Ceramic Chip Capacitor, 0805, 0.47uF, 50V</td>
<td>120</td>
<td>10khrs</td>
<td>120 pcs on test. 17 catastrophic life test failures with first occurring ~3.1khrs</td>
</tr>
<tr>
<td>B</td>
<td>1304</td>
<td>IR degradation noticed @7.5khrs; 3 catastrophic failures beyond 8khrs of test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1131</td>
<td>No Catastrophic Life Test Failures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>201028</td>
<td>120 pcs on test.</td>
<td>120</td>
<td>10khrs</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>TBD</td>
<td>few devices exhibit reduced IR (non-catastrophic)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>1247</td>
<td>Stable IR</td>
<td>79</td>
<td>8k Hrs</td>
<td>Note: Precious Metal Electrode</td>
</tr>
<tr>
<td>AA</td>
<td>N/A</td>
<td>No Catastrophic Failures; ~10% show hot DCL above spec limit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AA</td>
<td>1301</td>
<td>No Catastrophic Failures;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>TBD</td>
<td>sent boards for fabrication</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>1152</td>
<td>Two setups, 45 units each. No failures.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>1341</td>
<td>Test Program in Development</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>unknown</td>
<td>No failures to Date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>1339</td>
<td>Parametric Degradation Observed beginning TA ~ 40°C behaves like short circuit &gt;105°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>unknown</td>
<td>Test plan and test boards being validated Testing to commence 3rd or 4th QFY17</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
AEC-Q200: 0805 Ceramic Chip Capacitors, Insulation Resistance at 125°C During Life Test

- 17 Catastrophic Shorts
  - Assigned 1kohm for plotting purposes

- 3 Catastrophic Shorts
  - Assigned 1kohm for plotting purposes
Reverse-bias Tantalum Chip Capacitors

- Capacitors in International Space Station experiment pallets known as Express Logistics Carriers (ELCs) were found installed backwards
- They have so far functioned satisfactorily for more than 6 years on orbit
- The risk of failure needs to be understood to avoid further extravehicular workarounds (one avionics pallet out of four has been replaced out of an abundance of caution).
- Why are the capacitors not failing and what performance envelope must they occupy to avoid failure for as long as possible?
- Experiments in progress to look at effects of voltage, temperature and humidity
Multi-layer Ceramic Capacitors (MLCCs)

- NASA has recently experienced 2 on-orbit MLCC anomalies on one project and a failure on a different project
  - Characteristics duplicated on spare hardware
- Both came from same 2010 lot
- Investigation has found previous indications of similar anomalies going back to at least 2004 and a discovery of another NASA instrument failure in 2014 traceable to the same problem (2005 lot)
- Anomalies are a gradual, yet significant increase in leakage currents and are associated with internal delaminations (delams) present in the lots and cross dielectric cracks in the anomalous parts
- Handling and soldering stresses may be causing a sub-population to develop new or exacerbate pre-existing delams, cracks or other weak features in the parts. They passed all MIL specification tests
  - Exploratory experiments are ongoing
- Indications are this problem was recognized years ago but not communicated in a way NASA could hear
Some Upcoming Challenges

- Complexity issues for inspection, screening, device preparation, and test
  - 2.5/3D Packages/ICs
  - Package on Package (PoP) Commercial Devices
  - An FPGA combined with an SOC (MPSOC+ from Xilinx)
  - Cu Wirebonds

- Assurance
  - Automotive and catalog commercial EEE parts?
  - Increasing risk with a worldwide supplier base
    - Standardization Source Consolidation. *What if the only source left is in an inhospitable or unauditable part of the world?*
Summary and Comments

- Assuring the Performance and Reliability of EEE Parts is a Multi-disciplinary Endeavor
- The EEE Parts Specialist Needs to Know Key Properties, Features, Behaviors and Methods for:
  - Materials – Metals, Organics, Ceramics, Alloys, Composites etc.
  - Processes – Soldering, Welding, Bonding, Casting, Crimping, Encapsulating, Etching, Plating etc.
  - Environmental Testing – Temperature, Humidity, Shock, Vibration, Radiation Effects, Hermeticity, etc.
  - Electrical Testing – Dynamic, Steady-state, Accelerated, Parametric, Automated, etc.
  - Analysis – Non-destructive, Destructive, X-ray, Microscopy, (visual, ultrasonic, electronic, x-ray fluorescence), etc.
- And of Course, the EEE Parts Specialist Needs a Basic Understanding of Circuit Functions and Applications
Questions?

https://nepp.nasa.gov