Acronyms

- Three Dimensional (3D)
- Air Force (AF)
- Air Force Space & Missile Systems Center (AF SMC)
- Advanced Micro Devices, Inc. (AMD)
- Ames Research Center (ARC)
- AS&D, Inc. (AS&D)
- Marconi Electronic Systems (MES) and British Aerospace (BAe) merged to form BAE Systems (BAE)
- Bayesian Networks (BN)
- Body of Knowledge (BOK)
- Brigham Young University (BYU)
- Capability Leadership Teams (CLTs)
- Complementary Metal Oxide Semiconductor (CMOS)
- Commercial Off-the-Shelf (COTS)
- Cosmic Ray Effects on Micro-Electronics (CRÈME)
- Double Data Rate (DDR)
- Dis-integrated Random Access Memory (DiRAM)
- Defense Logistics Agency (DLA)
- Defense MicroElectronics Activity (DMEA)
- Department of Defense (DoD)
- Department of Energy (DOE)
- Electrical, Electronic, and Electromechanical (EEE)
- Engineering Practices (EP)
- NASA Electronic Parts Database (EPARTS)
- EEE Parts Management and Control Plan (EPMCP)
- Electrostatic Discharge (ESD)
- NEPP Electronics Technology Workshop (ETW)
- Fully Depleted Silicon-on-Insulator (FD-SOI)
- Fin Field Effect Transistor (the conducting channel is wrapped by a thin silicon "fin") (FinFET)
- Field Programmable Gate Array (FPGAs)
- Gallium Nitride (GaN)
- Government-Industry Data Exchange Program (GIDEP)
- Glenn Research Center (GRC)
- Goddard Space Flight Center (GSFC)
- Goal Structuring Notation (GSN)
- Government Working Group (GWG)
- High Bandwidth Memory (HBM)
- High Performance Spacecraft Computing (HPSC)
- Headquarters (HQ)
- Integrated Circuit (IC)
- Internal Gas Analysis (IGA)
- IPC changed its name from Institute for Interconnecting and Packaging Electronic Circuits to IPC
- Infrared (IR)
- Indiana University Cyclotron Facility (IUCF)
- Joint Electron Device Engineering Council (JEDEC)
- Jet Propulsion Laboratories (JPL)
- Johnson Space Center (JSC)
- Los Alamos National Laboratories (LANL)
- Langley Research Center (LaRC)
- Loma Linda University Medical Center (LLUMC)
- Mission Assurance Improvement Workshop (MAIW)
- Model-Based Mission Assurance (MBMA)
- Massachusetts General Hospital (MGH)
- Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET)
- Marshall Space Flight Center (MSFC)
- National Aeronautics and Space Administration (NASA)
- Naval Surface Warfare Center, Crane, Indiana (Navy Crane)
- NASA Electronic Parts Assurance Group (NEPAG)
- NASA Electronic Parts and Packaging (NEPP) Program
- NASA Engineering and Safety Center (NESC)
- Non-Military (Non-Mil)
- United States Navy National Reconnaissance Office (NRO)
- Nuclear and Space Radiation Effects Conference (NSREC)
- NASA Office of the Chief Engineer (OCE)
- NASA Office of Safety and Mission Assurance (OSMA)
- Point of Contact
- Package on Package (PoP)
- Residual Gas Analysis (RGA)
- Radiation Hardened (RH)
- Radiation Hardness Assurance (RHA)
- Society of Automotive Engineers (SAE)
- Space Asset Protection Program (SAPP)
- SCRIPPS Proton Therapy Center (SCRIPPS)
- Systems Engineering and Assurance Modeling (SEAM)
- Single Event Burnout (SEB)
- Single Event Effect (SEE)
- NASA Space Environments Testing Management Office (SETMO)
- Silicon Carbide (SiC)
- Air Force Space and Missile Systems Center (SMC)
- Subject Matter Expert (SME)
- Sandia National Laboratories (SNL)
- NASA Space Technology Mission Directorate (STMD)
- System Modeling Language (SysML)
- Technical Operating Reports (TORs)
- Tri-University Meson Facility (TRIUMF)
- Through Silicon Via (TSV)
Outline

• NASA Electrical, Electronic, and Electromechanical (EEE) Parts Changes
  – Why the Change?
  – General Agency EEE Parts Interfaces
  – EEE Parts Manager: A New Role in the Agency
  – NEPP Program Structure

• NEPP 2018
  – NEPP Overview
  – Changes in 2018
  – Key efforts, concerns, and status

• NASA Electronics Parts Assurance Group (NEPAG)
  – Standards
  – Highlights
  – Concerns
  – Parts Problems

• Summary
Capabilities are defined as a combination of technical content, workforce, specialized facilities and infrastructure, as well as unique tools and techniques.

NASA currently has 19 discipline, 7 system, 5 research, and 3 service capabilities.

EEE parts falls under the Avionics discipline within the Capability Leadership Model – EEE parts management function stood up for implementation.
NASA EEE Parts – New Structure

• NASA EEE parts consolidation:
  – Primary Agency test and analysis activities will be at the Goddard Space Flight Center (GSFC – lead Center) and the Jet Propulsion Laboratory (JPL).
  – Jonathan Pellish, the new EEE Parts Manager, will lead.
• NEPP remains virtually the same:
  – Owns the EEE parts assurance processes (and related technical efforts)
  – NEPP Management changes with eye to the future
• New NASA wide documents activities
  – NASA Standard 8739.10, Released
    • First NASA-wide EEE Parts Standard since MIL-STD-975Canceled May 1998
  – EEE-INST-002 Unification underway
General NASA EEE Parts Interfaces

Agency EEE Parts

Assurance
- Office of Safety & Mission Assurance
  - NEPP
  - Workmanship
  - Tech Fellow / Quality

Development
- Office of the Chief Engineer
- Capability Leadership
- NESC

Facilities
- Flight Projects
- Field Centers
- Mission Directorates
- Space Environments Testing Management
- Mission Support
NASA EEE Parts Manager

• Manage EEE parts workforce at the Agency level
  – Radiation effects on EEE parts are in scope, as is management of the Agency radiation facility block buy
  – GSFC is lead Center, with support from JPL
• Provide resources for Centers to acquire EEE parts workforce expertise and a forum to coordinate activities with stakeholders (e.g., OCE, OSMA, etc.) and customers
• Track the state of the Agency EEE parts workforce, including Center expertise, demand, and capacity
• Support Agency policy and technical decision-making processes
• Evolve management functions as needed

To be presented by Kenneth LaBel at the Space Parts Working Group (SPWG) Meeting, April 10-11, 2018 | Torrance, CA
NEPP Mission Statement

Provide NASA’s leadership for developing and maintaining guidance for the screening, qualification, test, and reliable use of Electrical, Electronic, and Electromechanical (EEE) parts by NASA, in collaboration with other government agencies and industry.

Note: The NASA Electronic Parts Assurance Group (NEPAG) is a portion of NEPP.
NEPP - Charter

Mission Assurance

Agency Priorities – Independent Support
- Commercial Crew
- Small Mission Reliability
- Coordination with NASA Consolidation, CLTs, NESC, STMD, SAPP, and radiation block buy
- Collaborate with DoD/DOE on space radiation test infrastructure

Technology Evaluation
- Advanced/new EEE parts/technologies
- Ex. Advanced CMOS, GaN, SiC
- Working Groups (NASA, government, aerospace)
- Screening/qualification/test/usage guidelines
- Partnering: NASA, Government Agencies, Industry, University, International

EEE Parts Infrastructure
- NEPAG Telecons and Working Groups
- SME Capabilities
- Communication and Outreach within NASA and to the greater aerospace community

Agency Leadership
- NASA Policies and Procedures
- Agency Guidelines, Body of Knowledge (BOK) documents, and Best Practices
- Coordination of Government and Industry Standards
- Audit Coordination with AF, NRO, DLA
- Partnering within NASA and other Agencies, Industry, University, and International

EEE Parts Problem Investigations
- Agency/Industry-wide problems
- GIDEP and NASA Alert development

Trusted and RH Electronics
- Collaboration with NASA and other Agency Supply Chain and Trust/Counterfeit Electronics Organizations
- Support DoD efforts on Trusted Foundries and FPGAs (w/NASA STMD and OCE/Space Asset Protection)
- Support DoD RH efforts
NEPP – Product Delivery

Related task areas:
Technology/parts evaluations lead to new best practices, guidelines,…

To be presented by Kenneth LaBel at the Space Parts Working Group (SPWG) Meeting, April 10-11, 2018 | Torrance, CA
What’s New for NEPP in FY18?

• Agency EEE Parts Manager
  – Support efforts on workforce, facilities, etc…

• Increased delivery of assurance products
  – BOKs, Guidelines, Tools, Information Sharing, Training
  – Unification of NASA documentation (NEPAG)

• Increased discussion on the role of standardization processes (NEPAG)

• Increased emphasis on
  – Guidance and understanding of small missions such as CubeSats
  – Model-based mission assurance (MBMA) and radiation tool “standardization”
  – Changing EEE parts industry such as the move to “mid-space”
  – Partnering with other NASA organizations, Agencies, and universities
    • Expansion of outreach in all these areas

• Significant update of the NEPP website planned
  – Easier to find guidance and search for data
  – New tie-ins to the SmallSat community

• First look at “big data” analyses…
NEPP Small Mission Efforts and MBMA (w/ NASA MBMA Program)

Tenet: the best ideas will die on the vine without integration into standard approaches or tools.
It's all about access.

https://modelbasedassurance.org/

https://www.nasa.gov/smallsat-institute

NASA/GSFC (Campola)
Small Mission RHA
TBD
Small Mission EEE Parts Best Practices

NASA/GSFC (Campola)
Emerging Modeling
Vanderbilt University
Web-based tool (SEAM)
Notional RHA Tool (R-GENTIC)

Saint Louis University
CubeSat Success Study

JPL
CubeSat EEE Parts Databases

TBD
CubeSat EEE Parts Testing

TBD
Resilience, autonomy

NASA/GSFC (Campola)
Small Mission RHA
TBD
Small Mission EEE Parts Best Practices

NASA/GSFC (Xapsos)
RHA Confidence Approach

Air Force SMC
CubeSat Supply Chain and “Mid-space” Grade Electronics Survey and Requirements Definition

Vanderbilt University
GSN Exemplar (SEE) – complete
TBD
GSN Exemplar – EEE parts reliability

NASA/GSFC (Berg)
SEE Classic Reliability
Vanderbilt
CRÈME Toolsuite

Vanderbilt University
BN follow-on
BN integrated into SEAM

NASA/GSFC (Xapsos)
Small Mission EEE Parts Best Practices

Other
Integration with Small Spacecraft Virtual Institute (NASA/ARC)
https://www.nasa.gov/smallsat-institute

Other
MAIW
SmallSat Reliability Initiative (NASA/AF/ others)
NEPP – Processors, Systems on a Chip (SOC), and Field Programmable Gate Arrays (FPGAs)

Best Practices and Guidelines

Radiation Hardened Processor Evaluation
- BAE RAD55XX
- Vorago (microcontrollers)
- Support High Performance Spacecraft Computing (HPSC)

State of the Art COTS Processors
- Sub 32nm CMOS, FinFETs, etc
- Samsung, Intel, AMD
- Neural Networks

“Space” FPGAs
- Microsemi RTG4
- Xilinx MPSOC+
- ESA Brave (future)
- “Trusted” FPGA (future)

Graphics Processor Units (GPUs)
- Intel, AMD, Nvidia
- Enabling data processing

COTS FPGAs
- Xilinx Ultrascale
- Intel Cyclone 10
- Mitigation evaluation
- TBD Others

Partnering
- Processors: Navy Crane, BAE/NRO-
- FPGAs: AF SMC, SNL, LANL, BYU,…
- Microsemi, Xilinx, Synopsis
- Cubic Aerospace

Potential task areas:
- artificial intelligence (AI) hardware, Intel Stratix 10

To be presented by Kenneth LaBel at the Space Parts Working Group (SPWG) Meeting, April 10-11, 2018 | Torrance, CA
NEPP – Memories

New materials/architectures
- Resistive
- Fujitsu/Panasonic
- Spin torque transfer magnetoresistive
- Avalanche, Everspin
- 3D Xpoint
- Intel Optane
- Enabling “universal” memories

DRAMs
- DDR4 test capability (in progress)
- Commercial DDR (various)
- Tezzaron DiRAM (w/HPSC)
- Enabling high performance computing

Commercial Flash
- 3D
- Samsung, Hynix, Micron, Western Digital
- Planar – TBD
- Enabling data storage density

Partnering
- Navy Crane
- NASA STMD
- Avalanche
- University of Padova

Best Practices and Guidelines

Related task areas:
Deprocessing for single event testing (also w/processors, FPGAs, …)
NEPP – Packaging

Best Practices and Guidelines

- Daisy Chain
  - PoP
  - Thru Mold Via

- Substrates
  - Cobham – FC/Organic
  - Cobham – Cu Pillar

- Non-Hermetic
  - QFN
  - PBGA

- 3D TSV Memories
  - DDR4
  - HBM

- 3D Literature review

- Partnering
  - Tezzaron
  - Aurora Semiconductor
  - Xilinx
  - Cobham

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NEPP - Small Mission and Emerging Architectures Efforts

One goal is working with Vanderbilt University on developing a MBMA toolsuite that encompasses traditional and new radiation hardness assurance (RHA) concepts and tools

To be presented by Kenneth LaBel at the Space Parts Working Group (SPWG) Meeting, April 10-11, 2018 | Torrance, CA
“Status” on Proton Test Sites (200 MeV)

• The long-time facilities (used prior to IUCF shutdown
  – Massachusetts General Hospital (MGH) Francis H. Burr Proton Therapy Center
  – Tri-University Meson Facility (TRIUMF) – Vancouver, CAN
  – James M. Slater, M.D. Proton Treatment and Research Center at Loma Linda University Medical Center (LLUMC)

• Newer locations that are/were selling or will sell time
  – California Protons Cancer Therapy Center (formerly SCRIPPS Proton Therapy Center)
    – unclear if any change of policy or not
  – Northwestern Medicine Chicago Proton Center
  – Mayo Clinic Proton Beam Therapy Program, Rochester, Minnesota and Scottsdale, AZ
    • NASA currently discussing contract options

• Coming “soon” – either currently willing or planning on access
  – ProVision (Knoxville) – successful shakeout test held in March
  – Cincinnati Children’s Proton Therapy Center
    • Discussing near-term shakeout test
  – Hampton University Proton Therapy Institute, Hampton, Virginia
    • Building a dedicated research room with planned June/July readiness

• Possibilities
  – Oklahoma City’s ProCure Proton Therapy Center
  – The Roberts Proton Therapy Center at University of Pennsylvania Health System
  – Maryland Proton Treatment Center, Baltimore, Maryland – on hold
  – M.D. Anderson Cancer Center’s Proton Center, Houston

Always open to discussions with ANY location

To be presented by Kenneth LaBel at the Space Parts Working Group (SPWG) Meeting, April 10-11, 2018 | Torrance, CA
**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 (Plan)
   1. Scope
   2. Qualification – Environmental and life testing *(includes radiation)*
   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 (Plan)
   7. Electrostatic Discharge (ESD) Control *(Plan)*
   8. Re-use of EEE Parts
7. EEE Parts Procurement, Obsolescence and Counterfeit Avoidance *(Plans)*
8. EEE Parts Documentation and Organization *(Plans)*
   Lists of Appendices and Tables

To be presented by Kenneth LaBel at the Space Parts Working Group (SPWG) Meeting, April 10-11, 2018 | Torrance, CA
Program/Project EEE Parts Management and Control Plan (EPMCP)
- Plan can be stand-alone documents or part of Project Product Assurance Plan
- Specific Issue Plans may be contained in EPMCP or stand-alone documents

Parts Lists
- (EPARTS recommended)
- As Designed, As Built Parts Lists

Analyses
- Derating, 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

Sn, Hg, Zn, Cd …
Quantity of Counterfeit EEE Parts Alerts per Year

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NASA EEE Parts Assurance Group (*NEPAG)

- DLA Wafer Fab Audit Moratorium
- ITT Cannon Connector Status
- Using IGA Results for Lot Acceptance
- IGA Hybrid Failure Experiences – Recent Example
- Copper Bond Wire EP Study
- IGA Lot Acceptance Discussion
- New Trends in Building Rad Hard Space ICs
- ESD Harmonization Status
- Comments on NSREC Paper re Rad Implications of Kr-85 Leak Testing
- RGA Requirement Changes

Government Working Group (GWG)

- JEDEC Proposal to Change X-ray Voiding Criteria
- MIL-STD-1580 Changes
- Standardization of Manufacturer Record Retention Requirements
- Proposed Changes to MIL-PRF-19500
- Standardization of Connector Specifications to Reduce SCDs
- Review MIL-STD-883 TM 5004
- Review MIL-STD-202 test methods
  Some methods last revised in the 1950s!
- M19500 Burn-in/Life Test Sample Size
- EP (Engineering Practices) Study Cu Bond Wire Test Requirements

To be presented by Kenneth LaBel at the Space Parts Working Group (SPWG) Meeting, April 10-11, 2018 | Torrance, CA
Recent Capacitor Issues

- NASA GSFC Report J17537
- Cross Section of ceramic chip capacitor that has developed internal low resistance path

- NASA GSFC Report J17537
- Infrared Image to detect high leakage current path inside of ceramic chip cap
NEPP-Developed Improved Screening Technique for Foil (and other) Resistors

One Resistor that Exhibited Two Delta R Changes During Life Test
Failure Mode = +10440 ppm @ 250 hours; +11365 ppm @ 2k hours

**BEFORE** Life Test
Multiple “Hot Spots” Detected
Indicating Local Bridge Type Defects

**AFTER** Life Test
Two “Hot Spots” are Gone
Indicating Fracture of Bridge Type Defects

Apply brief power pulses while examining for “hot spots” using **high-resolution infrared thermography**
Broken “Bridge” Between Gridlines
9th Annual NEPP Electronics Technology Workshop (ETW)

June 18-21, 2018
NASA/GSFC and on-line

Special sessions on:
Small Mission Success
PEMS/Cu Wirebonds
2.5/3D ICs
Discussion on audit utility

Emerging Assurance Methods
(Witulski, Vanderbilt University, NEPP ETW 2017)
Summary

• “The only constant is change”
  – However, NEPP’s responsibilities to mission assurance remain the same

• An overview has been presented of:
  – NASA’s EEE Parts structure
  – NEPP Program and it’s NEPAG subset
  – Selected highlights and recent part issues

• NEPP’s bigger concerns (only touched on)
  – Radiation test/facility infrastructure
  – Manufacturer audits
  – Semiconductor fab closures and consolidations
  – Changing space industry

• Join us at NEPP ETW to discuss these and others!

To be presented by Kenneth LaBel at the Space Parts Working Group (SPWG) Meeting, April 10-11, 2018 | Torrance, CA
Questions?

https://nepp.nasa.gov
NEPP - Working Industry/Agency-Wide Concerns

Tantalum capacitor failure

Thermal Image of failure locations

High magnitude optical images of failure locations

Cross-section of failure location

Failure analysis of Schottky diode radiation damage

To be presented by Kenneth LaBel at the Space Parts Working Group (SPWG) Meeting, April 10-11, 2018 | Torrance, CA
Vendor Validation Tests

GaN IC – radiation test analysis

Comparison of n-type 60V trench MOSFET SEB thresholds
Advanced Technologies

• Technology/device evaluations with a nod to developing test methods and user guidance

• New: collaboration with DMEA and GlobalFoundries on 22nm FD-SOI and 28nm bulk radiation evaluation
  – Discussion with other government Agencies as additional partners
Infrastructure Challenges

Using Proton Cancer Therapy Centers for electronics testing

To be presented by Kenneth LaBel at the Space Parts Working Group (SPWG) Meeting, April 10-11, 2018 | Torrance, CA