A Year in the Life of the NASA Electronic Parts and Packaging (NEPP) Program

A NASA Office of Safety and Mission Assurance (OSMA) Program

Kenneth A. LaBel,
NEPP Program Co-Manager
ken.label@nasa.gov

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D</td>
<td>Three Dimensional (3D)</td>
</tr>
<tr>
<td>AF</td>
<td>Air Force (AF)</td>
</tr>
<tr>
<td>AF SMC</td>
<td>Air Force Space and Missile Systems Center (AF SMC)</td>
</tr>
<tr>
<td>AI</td>
<td>Artificial Intelligence (AI)</td>
</tr>
<tr>
<td>ARC</td>
<td>NASA Ames Research Center (ARC)</td>
</tr>
<tr>
<td>BAE</td>
<td>BAE Systems (BAE)</td>
</tr>
<tr>
<td>BN</td>
<td>Bayesian Networks (BN)</td>
</tr>
<tr>
<td>BOK</td>
<td>Body of Knowledge (BOK)</td>
</tr>
<tr>
<td>BYU</td>
<td>Brigham Young University (BYU)</td>
</tr>
<tr>
<td>CLTs</td>
<td>NASA CIO Leadership Teams (CLTs)</td>
</tr>
<tr>
<td>CMOS</td>
<td>Complementary Metal Oxide Semiconductor (CMOS)</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial Off The Shelf (COTS)</td>
</tr>
<tr>
<td>CRÈME</td>
<td>Cosmic Ray Effects on Micro Electronics</td>
</tr>
<tr>
<td>Cu</td>
<td>Copper</td>
</tr>
<tr>
<td>DDR</td>
<td>Double Data Rate (DDR) [DDR3 = Generation 3; DDR4 = Generation 4]</td>
</tr>
<tr>
<td>DiRAM</td>
<td>Dis-integrated Random Access Memory (DiRAM)</td>
</tr>
<tr>
<td>DLA</td>
<td>Defense Logistics Agency (DLA)</td>
</tr>
<tr>
<td>DMEA</td>
<td>Defense Microelectronics Activity (DMEA)</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defense (DoD)</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of Energy (DOE)</td>
</tr>
<tr>
<td>DRAM</td>
<td>Dynamic Random-Access Memory (DRAM)</td>
</tr>
<tr>
<td>EEE</td>
<td>Electrical, Electronic, and Electromechanical (EEE)</td>
</tr>
<tr>
<td>ESA</td>
<td>European Space Agency (ESA)</td>
</tr>
<tr>
<td>ETW</td>
<td>Electronics Technology Workshop (ETW)</td>
</tr>
<tr>
<td>FD-SOI</td>
<td>Fully-Depleted Silicon-On-Insulator (FD-SOI)</td>
</tr>
<tr>
<td>FinFETs</td>
<td>Fin Field Effect Transistors (FinFETs)</td>
</tr>
<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array (FPGA)</td>
</tr>
<tr>
<td>GaN</td>
<td>Gallium Nitride (GaN)</td>
</tr>
<tr>
<td>GIDEP</td>
<td>Government-Industry Data Exchange Program (GIDEP)</td>
</tr>
<tr>
<td>GPU</td>
<td>Graphics Processing Unit (GPU)</td>
</tr>
<tr>
<td>GSN</td>
<td>Goal Structuring Notation (GSN)</td>
</tr>
<tr>
<td>HBM</td>
<td>High Bandwidth Memory (HBM)</td>
</tr>
<tr>
<td>HPSC</td>
<td>High Performance Spacecraft Computing (HPSC)</td>
</tr>
<tr>
<td>IC</td>
<td>Integrated Circuit (IC)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR</td>
<td>Infrared (IR)</td>
</tr>
<tr>
<td>JEDEC</td>
<td>Joint Electron Device Engineering Council (JEDEC)</td>
</tr>
<tr>
<td>LANL</td>
<td>Los Alamos National Laboratories (LANL)</td>
</tr>
<tr>
<td>MAIW</td>
<td>Military AI Works (MAIW)</td>
</tr>
<tr>
<td>MBMA</td>
<td>Model-Based Missions Assurance (MBMA)</td>
</tr>
<tr>
<td>Mil</td>
<td>Military (Mil)</td>
</tr>
<tr>
<td>MOSFET</td>
<td>Metal–Oxide–Semiconductor Field-Effect Transistor (MOSFET)</td>
</tr>
<tr>
<td>MPSOC</td>
<td>Multi-Processing System on Chip (MPSOC)</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration (NASA)</td>
</tr>
<tr>
<td>Navy Crane</td>
<td>Naval Surface Warfare Center, Crane, Indiana (Navy Crane)</td>
</tr>
<tr>
<td>NEPAG</td>
<td>NASA EEE Parts Assurance Group (NEPAG)</td>
</tr>
<tr>
<td>NEPP</td>
<td>NASA Electronic Parts and Packaging (NEPP) Program</td>
</tr>
<tr>
<td>NESC</td>
<td>NASA National Electric Safety Code (NESC)</td>
</tr>
<tr>
<td>NRO</td>
<td>United States Navy National Reconnaissance Office (NRO)</td>
</tr>
<tr>
<td>OCE</td>
<td>Office of the Chief Engineer (OCE)</td>
</tr>
<tr>
<td>OSMA</td>
<td>NASA Office of Safety and Mission Assurance (OSMA) Program</td>
</tr>
<tr>
<td>PBGA</td>
<td>Plastic Ball Grid Array</td>
</tr>
<tr>
<td>PoP</td>
<td>Package-on-Package (PoP)</td>
</tr>
<tr>
<td>QFN</td>
<td>Quad-Flat No-Leads (QFN)</td>
</tr>
<tr>
<td>R&amp;M</td>
<td>Reliability and Maintainability (R&amp;M)</td>
</tr>
<tr>
<td>RH</td>
<td>Radiation Hardened (RH)</td>
</tr>
<tr>
<td>RHA</td>
<td>Radiation Hardness Assurance</td>
</tr>
<tr>
<td>SAE</td>
<td>Society of Automotive Engineers (SAE)</td>
</tr>
<tr>
<td>SAPP</td>
<td>Space Asset Protection Program (SAPP)</td>
</tr>
<tr>
<td>SEAM</td>
<td>Systems Engineering and Assurance Modeling (SEAM)</td>
</tr>
<tr>
<td>SEB</td>
<td>Single Event Burnout (SEB)</td>
</tr>
<tr>
<td>SEE</td>
<td>Single Event Effect (SEE)</td>
</tr>
<tr>
<td>SiC</td>
<td>Silicon Carbide (SiC)</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium-sized Enterprises (SME)</td>
</tr>
<tr>
<td>SNL</td>
<td>Sandia National Laboratories (SNL)</td>
</tr>
<tr>
<td>SOC</td>
<td>Systems on a Chip (SOC)</td>
</tr>
<tr>
<td>STMD</td>
<td>NASA's Space Technology Mission Directorate (STMD)</td>
</tr>
<tr>
<td>SysML</td>
<td>System Modeling Language (SysML)</td>
</tr>
<tr>
<td>TOR</td>
<td>Technical Operating Report (TOR)</td>
</tr>
</tbody>
</table>
NEPP Mission Statement

Provide NASA’s leadership for developing and maintaining guidance for the screening, qualification, test, and reliable usage of electrical, electronic, and electromechanical (EEE) parts by NASA, in collaboration with other government Agencies and industry.

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
NEPP - Charter

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

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 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

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
NEPP – Product Delivery

Best Practices and Guidelines
- Test, usage, screening, qualification
- Radiation facility studies

BOK
- Technology and product status and gap analysis

NASA EEE Parts Policy and Standards

Government and Industry Standards Representation
- SAE G11/G12/JEDEC JC13
- Aerospace TORs

NEPP Standard Products
- Test, summary, and audit reports
- Conference and workshop presentations
- Alerts

Assurance

Related task areas:
Technology(parts evaluations lead to new best practices, etc...

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
Body of Knowledge (BOK) Documents

- What goes into a BOK
  - An overview of the technology
  - An overview of technology applicability to space/aeronautics
  - An overview of technology maturity, produceability and/or commercial availability
  - Reliability, qualification, and/or radiation knowledge-base
  - Technology direction or extent of the reliability issue for the future
  - Identification of experts, technology sources, test houses, etc.
  - Facilities/capabilities
  - Recommendation for follow-on NEPP task (if applicable)

BODY OF KNOWLEDGE FOR SILICON CARBIDE POWER ELECTRONICS

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
What’s New for NEPP in FY18

• Increased emphasis on needs of small missions such as CubeSats and model-based mission assurance (MBMA)
  – Partnering with other NASA organizations, Agencies, and universities

• More assurance products
  – BOKs, Guidelines, Tools, Information Sharing, Training

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

• Support for Agency efforts for EEE Parts Consolidation, Radiation Beam Block Buys, and Capability Leadership Teams

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
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

Hynix 3D Flash Memory

AMD Ryzen Processor

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
NEPP – Processors, Systems on a Chip (SOC), and Field Programmable Gate Arrays (FPGAs)

Best Practices and Guidelines

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

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

COTS FPGAs
- Xilinx Kintex+
- Mitigation evaluation
- TBD: Microsemi PolarFire

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

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

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 A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
NEPP – Memories

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

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

Best Practices and Guidelines

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

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

Related task areas:
Deprocessing for single event testing (also w/processors, FPGAs,...)

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
NEPP – Packaging

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

Best Practices and Guidelines

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
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 A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
Vendor Validation Tests

GaN IC – radiation test analysis

Comparison of n-type 60V trench MOSFET SEB thresholds

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
Infrastructure Challenges

Using Proton Cancer Therapy Centers for electronics testing

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
Potential future task areas: automotive and avionics resilience

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.
NEPP Small Mission Efforts and MBMA (w/ NASA MBMA Program)

To be presented by Kenneth A. LaBel at the Radiation Hardened Electronics Technology (RHET) Conference, Colorado Springs, CO, November 6-8, 2017.

https://www.nasa.gov/small-sat-institute

https://modelbasedassurance.org/
Partnering is key

- Within
  - NASA
- With
  - Other government agencies
  - Industry
  - University
  - International
9th Annual NEPP Electronics Technology Workshop (ETW)

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

Advanced Technology Reliability
http://nepp.nasa.gov