NASA’s Changing Electronics Landscape: NEPP Focus, Agency Alignment, and Technology Development

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

Jonathan A. Pellish
NASA EEE Parts Manager
jonathan.pellish@nasa.gov

To be presented by Kenneth A. LaBel and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.
<table>
<thead>
<tr>
<th>Acronyms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three Dimensional (3D)</td>
</tr>
<tr>
<td>Air Force (AF)</td>
</tr>
<tr>
<td>Air Force Space &amp; Missile Systems Center (AF SMC)</td>
</tr>
<tr>
<td>Advanced Micro Devices, Inc. (AMD)</td>
</tr>
<tr>
<td>Ames Research Center (ARC)</td>
</tr>
<tr>
<td>Marconi Electronic Systems (MES) and British Aerospace (BAe) merged to form BAE Systems (BAE)</td>
</tr>
<tr>
<td>Bayesian Networks (BN)</td>
</tr>
<tr>
<td>Body of Knowledge (BOK)</td>
</tr>
<tr>
<td>Brigham Young University (BYU)</td>
</tr>
<tr>
<td>Capability Leadership Teams (CLTs)</td>
</tr>
<tr>
<td>Complementary Metal Oxide Semiconductor (CMOS)</td>
</tr>
<tr>
<td>Commercial Off-the-Shelf (COTS)</td>
</tr>
<tr>
<td>Cosmic Ray Effects on Micro-Electronics (CRÈME)</td>
</tr>
<tr>
<td>Double Data Rate (DDR)</td>
</tr>
<tr>
<td>Dis-integrated Random Access Memory (DiRAM)</td>
</tr>
<tr>
<td>Defense Logistics Agency (DLA)</td>
</tr>
<tr>
<td>Defense MicroElectronics Activity (DMEA)</td>
</tr>
<tr>
<td>Department of Defense (DoD)</td>
</tr>
<tr>
<td>Department of Energy (DOE)</td>
</tr>
<tr>
<td>Electrical, Electronic, and Electromechanical (EEE)</td>
</tr>
<tr>
<td>NEPP Electronics Technology Workshop (ETW)</td>
</tr>
<tr>
<td>fully depleted silicon-on-insulator (FD-SOI)</td>
</tr>
<tr>
<td>Fin Field Effect Transistor (the conducting channel is wrapped by a thin silicon &quot;fin&quot;) (FinFET)</td>
</tr>
<tr>
<td>Field Programmable Gate Array (FPGAs)</td>
</tr>
<tr>
<td>Gallium Nitride (GaN)</td>
</tr>
<tr>
<td>Government-Industry Data Exchange Program (GIDEP)</td>
</tr>
<tr>
<td>Goddard Space Flight Center (GSFC)</td>
</tr>
<tr>
<td>Goal Structuring Notation (GSN)</td>
</tr>
<tr>
<td>High Bandwidth Memory (HBM)</td>
</tr>
<tr>
<td>High Performance Spacecraft Computing (HPSC)</td>
</tr>
<tr>
<td>Integrated Circuit (IC)</td>
</tr>
<tr>
<td>Infrared (IR)</td>
</tr>
<tr>
<td>Indiana University Cyclotron Facility (IUCF)</td>
</tr>
<tr>
<td>Joint Electron Device Engineering Council (JEDEC)</td>
</tr>
<tr>
<td>Jet Propulsion Laboratories (JPL)</td>
</tr>
<tr>
<td>Los Alamos National Laboratories (LANL)</td>
</tr>
<tr>
<td>Loma Linda University Medical Center (LLUMC)</td>
</tr>
<tr>
<td>Mission Assurance Improvement Workshop (MAIW)</td>
</tr>
<tr>
<td>Model-Based Mission Assurance (MBMA)</td>
</tr>
<tr>
<td>Massachusetts General Hospital (MGH)</td>
</tr>
<tr>
<td>Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET)</td>
</tr>
<tr>
<td>National Aeronautics and Space Administration (NASA)</td>
</tr>
<tr>
<td>Naval Surface Warfare Center, Crane, Indiana (Navy Crane)</td>
</tr>
<tr>
<td>NASA Electronic Parts Assurance Group (NEPAG)</td>
</tr>
<tr>
<td>NASA Electronic Parts and Packaging (NEPP) Program</td>
</tr>
<tr>
<td>NASA Engineering and Safety Center (NESC)</td>
</tr>
<tr>
<td>Non-Military (Non-Mil)</td>
</tr>
<tr>
<td>United States Navy National Reconnaissance Office (NRO)</td>
</tr>
<tr>
<td>NASA Office of the Chief Engineer (OCE)</td>
</tr>
<tr>
<td>NASA Office of Safety and Mission Assurance (OSMA)</td>
</tr>
<tr>
<td>Package on Package (PoP)</td>
</tr>
<tr>
<td>Radiation Hardened (RH)</td>
</tr>
<tr>
<td>Radiation Hardness Assurance (RHA)</td>
</tr>
<tr>
<td>Society of Automotive Engineers (SAE)</td>
</tr>
<tr>
<td>Space Asset Protection Program (SAPP)</td>
</tr>
<tr>
<td>SCRIPPS Proton Therapy Center (SCRIPPS)</td>
</tr>
<tr>
<td>Systems Engineering and Assurance Modeling (SEAM)</td>
</tr>
<tr>
<td>Single Event Burnout (SEB)</td>
</tr>
<tr>
<td>Single Event Effect (SEE)</td>
</tr>
<tr>
<td>NASA Space Environments Testing Management Office (SETMO)</td>
</tr>
<tr>
<td>Silicon Carbide (SiC)</td>
</tr>
<tr>
<td>Air Force Space and Missile Systems Center (SMC)</td>
</tr>
<tr>
<td>Subject Matter Expert (SME)</td>
</tr>
<tr>
<td>Sandia National Laboratories (SNL)</td>
</tr>
<tr>
<td>NASA Space Technology Mission Directorate (STMD)</td>
</tr>
<tr>
<td>System Modeling Language (SysML)</td>
</tr>
<tr>
<td>Technical Operating Reports (TORs)</td>
</tr>
<tr>
<td>Tri-University Meson Facility (TRIUMF)</td>
</tr>
<tr>
<td>Through Silicon Via (TSV)</td>
</tr>
</tbody>
</table>
Outline

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

• 2018 Activities
  – NASA Electronic Parts and Packaging (NEPP) Program
  – NASA Space Technology Mission Directorate (STMD)
  – NASA Space Environments Testing Management Office (SETMO)

• 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.
General NASA EEE Parts Interfaces

To be presented by Kenneth A. LaBel and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.

Image Credit: NASA
NASA EEE Parts Manager

• Manage consolidation and centralization of EEE parts workforce
  – 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, SETMO, 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
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.
NEPP - Charter

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

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

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

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

NASA EEE Parts Policy and Standards

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

BOK
- Technology and product status and gap analysis

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

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

To be presented by Kenneth A. LaBel and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.
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
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
  – Expansion of outreach in this area

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

• Significant update of the NEPP website planned
  – 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
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

Hynix 3D Flash Memory

AMD Ryzen Processor
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
- Neural Networks

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

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

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

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

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 and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.
NEPP – Memories

Best Practices and Guidelines

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, Wester Digital
- Planar – TBD
- Enabling data storage density

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 and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.
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
- Xilinx
- Cobham

To be presented by Kenneth A. LaBel and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.
Big goal is working with Vanderbilt University on developing a MBMA toolsuite that encompasses traditional and new radiation hardness assurance (RHA) concepts and tools.
Infrastructure Challenges

Using Proton Cancer Therapy Centers for electronics testing

To be presented by Kenneth A. LaBel and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.
“Status” on Where We Test

- 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 selling time
  - California Protons Cancer Therapy Center (formerly SCRIPPS Proton Therapy Center)
    - unclear if any change of policy or not
  - Northwestern Medicine Chicago Proton Center

- Coming “soon” – either currently willing or planning on access
  - Mayo Clinic Proton Beam Therapy Program, Rochester, Minnesota and Scottsdale, AZ
    - NASA currently discussing contract options
  - Cincinnati Children’s Proton Therapy Center
    - Load by patients/internal research has been higher than anticipated slowing down external user access
  - 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
    - Renegotiating new contract with Varian services – outcome will determine access
  - M.D. Anderson Cancer Center’s Proton Center, Houston

Always open to discussions with ANY location
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 and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.
Vendor Validation Tests

GaN IC – radiation test analysis

Comparison of n-type 60V trench MOSFET SEB thresholds

To be presented by Kenneth A. LaBel and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.
Partnering is key

- Within
  - NASA

- With
  - Other government agencies
  - Industry
  - University
  - International

To be presented by Kenneth A. LaBel and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.
9th Annual NEPP Electronics Technology Workshop (ETW)

Scheduled dates:
June 18-21, 2018

NASA/GSFC and on-line

Advanced Technology Reliability

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

Radiation Testing

Commercial IC Packaging

To be presented by Kenneth A. LaBel and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.
• Relevant efforts
  – High Performance Spacecraft Computing (HPSC)
    • “The goal of the HPSC activities is to develop a significantly improved spaceflight computing capability for NASA missions. This will be achieved by addressing the computational performance, energy management, and fault tolerance needs of NASA missions through 2030.”
    • ARM chiplet approach selected with Boeing as prime
  – Advanced Memory Technology
    • Initial manufacturing status and usage studies for advanced memory technologies relevant to HPSC needs
      – Focus on DDRX style interface devices for performance needed
    • Collaborative testing with NEPP Program
NASA SETMO

- NASA SETMO
  - Along with EEE Parts Manager, NEPP, and others have been given approval to develop “radiation common block buys” (i.e., single contracts between NASA and external radiation facilities)
  - This may allow NASA to
    - Internally prioritize access
    - Schedule regular access
    - Provide support to critical facilities
    - Aid working with new facilities (e.g., proton therapy sites, etc...)

To be presented by Kenneth A. LaBel and Jonathan A. Pellish at the Microelectronics Reliability and Qualification Working (MRQW) Meeting, El Segundo, CA, February 6-8, 2018.
https://nepp.nasa.gov