NASA Electronic Parts and Packaging (NEPP) Program: Overview and Technology Focus Areas

Responsive Technology Assurance for Civil Space

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## Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AMD</td>
<td>Advanced Micro Devices</td>
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<tr>
<td>BoK</td>
<td>Body of Knowledge</td>
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<tr>
<td>CAGR</td>
<td>Compound Annual Growth Rate</td>
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<tr>
<td>CMOS</td>
<td>Complementary Metal Oxide Semiconductor</td>
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<td>COTS</td>
<td>Commercial Off The Shelf</td>
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<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
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<tr>
<td>DoD</td>
<td>Department of Defense</td>
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<td>DoE</td>
<td>Department of Energy</td>
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<tr>
<td>EEE</td>
<td>Electrical, Electronic, and Electromechanical</td>
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<tr>
<td>ETW</td>
<td>Electronics Technology Workshop</td>
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<tr>
<td>FFT</td>
<td>Fast Fourier Transform</td>
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<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array</td>
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<tr>
<td>GaN</td>
<td>Gallium Nitride</td>
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<td>GIDEP</td>
<td>Government Industry Data Exchange Program</td>
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<tr>
<td>GPU</td>
<td>Graphics Processing Unit</td>
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<tr>
<td>GRC</td>
<td>Glenn Research Center</td>
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<td>GSFC</td>
<td>Goddard Space Flight Center</td>
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<tr>
<td>GSN</td>
<td>Goal Structuring Notation</td>
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<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
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<tr>
<td>JPL</td>
<td>Jet Propulsion Laboratory</td>
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<td>JSC</td>
<td>Johnson Space Center</td>
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<td>LaRC</td>
<td>Langley Research Center</td>
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<tr>
<td>MAPLD</td>
<td>Military and Aerospace Programmable Logic Devices (Workshop)</td>
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<tr>
<td>MBMA</td>
<td>Model-Based Mission Assurance</td>
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<td>MRAM</td>
<td>Magnetic Random Access Memory</td>
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<thead>
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<th>Definition</th>
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<tbody>
<tr>
<td>MSFC</td>
<td>Marshall Space Flight Center</td>
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<td>NEPAG</td>
<td>NASA Electronic Parts Assurance Group</td>
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<tr>
<td>NEPP</td>
<td>NASA Electronic Parts and Packaging (Program)</td>
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<tr>
<td>NESC</td>
<td>NASA Engineering and Safety Center</td>
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<td>NODIS</td>
<td>NASA Online Directives and Information System</td>
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<tr>
<td>OGA</td>
<td>Other Government Agency</td>
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<tr>
<td>OSMA</td>
<td>(NASA) Office of Safety and Mission Assurance</td>
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<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
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<tr>
<td>PoF</td>
<td>Physics of Failure</td>
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<tr>
<td>RDL</td>
<td>Redistribution Layer</td>
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<tr>
<td>RH</td>
<td>Radiation-hardened</td>
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<td>RHA</td>
<td>Radiation Hardness Assurance</td>
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<td>SDRAM</td>
<td>Synchronous Dynamic Random Access Memory</td>
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<td>SEAM</td>
<td>Systems Engineering and Assurance Modeling</td>
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<td>SEE</td>
<td>Single-Event Effects</td>
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<td>SiC</td>
<td>Silicon Carbide</td>
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<td>SMA</td>
<td>Safety and Mission Assurance</td>
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<td>SMD</td>
<td>Science Mission Directorate</td>
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<td>SME</td>
<td>Subject Matter Expert</td>
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<tr>
<td>SoM</td>
<td>System-on-Module</td>
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<td>SSASI</td>
<td>Science Systems and Applications, Inc.</td>
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<tr>
<td>STMD</td>
<td>(NASA) Space Technology Mission Directorate</td>
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<tr>
<td>STT</td>
<td>Spin-Transfer Torque</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Determined</td>
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<tr>
<td>TSV</td>
<td>Through-Silicon Via</td>
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Outline

• Continued evolution of NASA Electrical, Electronic, and Electromechanical (EEE) parts management
  – EEE Parts Manager & NEPP Program structure
  – General NASA EEE parts interfaces

• NEPP Program
  – Overview
  – Standards development and support
  – Key technology efforts for 2019

• Summary
NASA EEE Parts – Evolving Structure

• NASA EEE parts and radiation engineering consolidation:
  – Primary agency test and analysis activities will be at the Goddard Space Flight Center (lead Center) and the Jet Propulsion Laboratory
  – Agency EEE Parts Manager, Jonathan Pellish, leads capability

• NEPP Program remains the same:
  – Owns the EEE parts assurance processes and related technical efforts
  – NEPP Program management evolution

• New NASA-wide document activities

https://standards.nasa.gov/
NASA EEE Parts – Interfaces

Agency EEE Parts

Assurance
Office of Safety & Mission Assurance
- NEPP Program
  - Quality
  - Reliability
  - Workmanship

Development
Office of the Chief Engineer
Capability Leadership
NESC

Facilities
Flight Projects
Field Centers
Mission Directorates
Mission Support
Space Environments Testing Management Office

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

Accessible & Product-Oriented

Note: the NASA Electronic Parts Assurance Group (NEPAG) is a core portion of NEPP
NEPP Program – Organization Chart*

*as of 2019-02-06
NEPP Charter Breakdown

**Mission Assurance**

### 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 other government agencies
- 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

### Technology Evaluation
- 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

### Agency Priorities – Independent Support
- Commercial Crew
- Small Mission Reliability
- Coordination with NASA EEE Parts Mgmt., NESC, and STMD
- Collaborate with DoD/DoE on space radiation test infrastructure

### Trusted and RH Electronics
- Collaboration with NASA and other agencies, supply chain and trust / counterfeit electronics
- Support DoD efforts on trust & assurance
- Support DoD RH efforts

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

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NEPP Product Delivery

**Assurance**

**Body of Knowledge**
- Technology and product status and gap analysis

**NASA EEE Parts Policy and Standards**

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

**Government and Industry Standards Representation**
- SAE CE11/CE12/JEDEC JC13
- Aerospace TORs

**NEPP Standard Products**
- Test, summary, and audit reports
- Conference and workshop presentations
- Alerts
NEPP Program / NEPAG Standards & Policy Development

- Released NASA-STD-8739.10
  - NASA EEE Parts Assurance Standard
  - Allows projects more flexibility to differentiate between critical/non-critical functions

- Updating EEE-INST-002
  - Instructions for EEE Parts Selection, Screening, Qualification, and Derating
  - Will become new Agency-wide document
  - Goal is to modernize and harmonize existing Agency documents
  - Ongoing throughout 2019

- Updating NPR-8705.4
  - Risk Classification for NASA Payloads
  - Appendix C – Recommended SMA-Related Program Requirements for NASA Class A-D Payloads
  - Goal for EEE parts is a mapping that recommends parts with respect to payload class (A-D), mission criticality (critical/noncritical), and part grade level (space, military, industrial, COTS, etc.)

NASA Technical Standards: [https://standards.nasa.gov/](https://standards.nasa.gov/)
Major Technology Assurance Areas for 2019

NEPP / NEPAG

Advanced CMOS

Memory

Part and Supply Chain Data Science

Packaging

SoCs (e.g., CPUs, GPUs, FPGAs)

Wide Bandgap Power

Small Mission Assurance

Model-Based Mission Assurance (MBMA)

GaN (enhancement & RF) and SiC

AMD, Intel, Microsemi, Nvidia, Qualcomm, Xilinx

NAND/NOR, SDRAM Discrete & Embedded STT-MRAM, Crosspoint

Supply Chain Studies, Web Scraping, Metadata Analysis, Formal Methods

2.5D / 3D solutions, Ever-Evolving Market, Supporting Qualification Efforts

Other: data conversion, optical,…

14nm, 22nm, 32nm, & 45nm
Other 2019 NEPP Program Highlights

- Increasing focus on advanced packaging assurance (2.5D / 3D)
- Executing SmallSat industrial base assessment with support from partner organizations
- Developing additional Radiation Hardness Assurance products
  - Best practices for testing at medical proton therapy facilities
  - GaN body of knowledge (in review now) and SiC RHA testing best practices
- Supporting evaluation and comparison of *Fides* vs. Physics-of-Failure (PoF)-based EEE parts reliability assessment
- Supporting commercial-off-the-shelf copper wire interconnect assessment with the NASA Engineering and Safety Center
- Examining opportunities for more significant integration of NEPP documentation into future community-consensus products (e.g., SAE)
- Continuing delivery of standard assurance products / services
  - Audit support, domestic / international coordination telecons, Government Working Group
  - BoKs, guidelines, tools, information sharing, and training
CPU and GPU Testing Highlights

Development Milestones:
- Software payloads test suite includes:
  - Math (FFT, LinPack, PI)
  - Memory hierarchy
  - Neural networks
  - Output buffer (colors, patterns)
- Conduction cooling system and adapter plates
- Test system GUIs to control and monitor

Deliverables:
- Test reports and quarterly reports
- NEPP Body of Knowledge on Graphics Processing Devices

Test Devices

CPUs
- 14nm++ Intel
- 10nm AMD (Global)

CPU with eGPUs
- 14nm++ Intel
- 10nm AMD (Global)
- 10nm Qualcomm (Samsung)

GPUs
- 14nm Nvidia GTX 1050 (& 1080)
- 12nm Nvidia RTX
- 14nm AMD Radeon RX580 & E9173
- 14nm Intel “Odyssey” GPU (TBD)

System-on-Chip
- 20nm Nvidia Tegra X1
- 16nm Nvidia Tegra X2
- 12nm Nvidia Tegra Xavier
- 10nm Qualcomm Snapdragon 850
- 7nm Qualcomm Snapdragon 8cx

Advanced Technology Evaluation Examples

Angled heavy ion tracks in 3-D NAND Flash
Micron MT29F1T08CMHBB
256 Gb die, MLC, 32 layers, piece-part testing
T. Wilcox et al., SEE/MAPLD 2018.

Heavy ion cross sections
GlobalFoundries 45 & 32 nm PDSOI, 22 nm FDSOI
Static Random Access Memories
M. Casey et al., IEEE NSREC 2018.
Collaboration with DMEA, Sandia, and GlobalFoundries

Pace of technology evolution and growth of evaluation requirements continue to generate new demands:
1) diversified subject matter expertise; 2) more access to a wider variety of radiation test facilities

Image Credit: NASA
Ever-Changing Advanced Packaging

- Driven almost entirely by size, weight, and power – not to improve reliability
- Unless very explicitly designed from the ground up, these technologies are expected to have at best break even reliability compared with heritage Plastic Encapsulated Microcircuits
- Are there general approaches for essentially custom solutions?
Evolving Landscape for SmallSat Assurance Support

Multiple Collaborations
- Academia
- Industry
- OGAs

Accessibile

Continued focus on Model-Based Mission Assurance (MBMA)

Product-Focused

Linking Program Tasks to Community Focus Areas / Needs

NASA's Reliability and Maintainability Standard (NASA-STD-8729.1) serves as a template to build assurance cases for systems in space missions
- Starting with RHA cases for COTS and small missions
- Supports the Goal Structuring Notations (GSN) standard to build assurance case models
- Supports a subset of block diagram models in the SysML modeling standard
- Extends the internal block diagram models to allow specification of discrete fault propagation

https://modelbasedassurance.org/ (hosted at Vanderbilt University)
Concluding Thoughts (no particular order)

• High-performance components imply complex testing and qualification. Cost of qualification is increasing at an exponential (aka “Moore’s law”) rate and can reduce new technology options.

• Flight heritage on smallsat missions is not sufficient justification for use on flagship missions
  – Challenge of how leverage smallsat mission success remains an open area for study and collaboration

• Modeling and simulation of complex 2.5D/3D packaging technologies will be required to understand root cause failure mechanisms

• GaN commercial growth is expected to be almost 80% CAGR – implies that reliability issues dominate the ability to grow
  – Significant motivation on vendors to improve reliability of GaN and for us to leverage this improvement – GaN-on-Silicon will be a turning point in device reliability and needs to be evaluated

• Data analytics (e.g., machine learning, data scrapping, etc.) techniques are a unique opportunity to enhance and foster collaborations between organizations in order to share data bases
10th Annual NEPP Electronics Technology Workshop (ETW)

Scheduled dates:
June 17-20, 2019
NASA/GSFC and on-line

https://nepp.nasa.gov/

Advanced Technology Reliability

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

Image credit: Vanderbilt / NASA

Radiation Testing

Commercial IC Packaging

Image credit: NASA

Please join us for the jointly held

2019 Single Event Effects (SEE) Symposium and

Military and Aerospace Programmable Logic Devices (MAPLD) Workshop

May 20-23, 2019

at the Marriott La Jolla, CA, USA

Registration for the meeting is open

Early registration (attendees & exhibitors) ends and hotel room block closes on Friday, April 19, 2019

https://seemapld.org/