The NASA Electronic Parts and Packaging (NEPP) Program: Overview and Roadmap for FY16

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Open Access

Outline

- NEPP Overview
- NEPP Task and Technology Selection
  - Background
  - Task Roadmaps
  - Other Cool Tasks
- Summary

Sundown at SCRIPPS Proton Therapy Center,
Ken LaBel
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D</td>
<td>Three Dimensional</td>
</tr>
<tr>
<td>AF SMC</td>
<td>Air Force Space Command</td>
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<tr>
<td>AFRL</td>
<td>Air Force Research Laboratory</td>
</tr>
<tr>
<td>ARM</td>
<td>ARM Holdings Public Limited Company</td>
</tr>
<tr>
<td>BAE Systems</td>
<td>Marconi Electronic Systems (MES) and British Aerospace (BAe) merged to form BAE Systems</td>
</tr>
<tr>
<td>BGA</td>
<td>Ball Grid Array</td>
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<tr>
<td>BME</td>
<td>Base Metal Electrode</td>
</tr>
<tr>
<td>BOK</td>
<td>Body of Knowledge</td>
</tr>
<tr>
<td>CBRAM</td>
<td>Conductive Bridging Random Access Memory</td>
</tr>
<tr>
<td>CGA</td>
<td>Column Grid Array</td>
</tr>
<tr>
<td>CMOS</td>
<td>Complementary Metal Oxide Semiconductor</td>
</tr>
<tr>
<td>CN</td>
<td>CN package</td>
</tr>
<tr>
<td>COF</td>
<td>Chemistry of failure</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial Off The Shelf</td>
</tr>
<tr>
<td>CRÈME</td>
<td>Cosmic Ray Effects on Micro Electronics</td>
</tr>
<tr>
<td>DDR</td>
<td>Double Data Rate (DDR3 = Generation 3; DDR4 = Generation 4)</td>
</tr>
<tr>
<td>DLP</td>
<td>Digital Light Processing</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defense</td>
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<tr>
<td>DSP</td>
<td>Digital Signal Processing</td>
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<tr>
<td>DTRA</td>
<td>Defense Threat Reduction Agency</td>
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<tr>
<td>EEE</td>
<td>Electrical, Electronic, and Electromechanical</td>
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<tr>
<td>EPC Gen</td>
<td>Electronic Product Code Generation</td>
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<tr>
<td>FeRAM</td>
<td>Ferroelectric Random-Access Memory</td>
</tr>
<tr>
<td>FinFET</td>
<td>Fin Field Effect Transistor (the conducting channel is wrapped by a thin silicon “fin”)</td>
</tr>
<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array</td>
</tr>
<tr>
<td>FY</td>
<td>Fiscal Year</td>
</tr>
<tr>
<td>GaN</td>
<td>Gallium Nitride</td>
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<tr>
<td>HALT</td>
<td>Highly Accelerated Life Test</td>
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<tr>
<td>HAST</td>
<td>Highly Accelerated Stress Test</td>
</tr>
<tr>
<td>HEMTs</td>
<td>High-Electron-Mobility Transistors</td>
</tr>
<tr>
<td>HP Labs</td>
<td>Hewlett-Packard Laboratories</td>
</tr>
<tr>
<td>IBM/GF</td>
<td>International Business Machines/Global Foundaries</td>
</tr>
<tr>
<td>IC</td>
<td>Integrated Circuit</td>
</tr>
<tr>
<td>IR</td>
<td>Infrared</td>
</tr>
<tr>
<td>IR/Infineon</td>
<td>International Rectifier/Infineon</td>
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<tr>
<td>MBSE</td>
<td>Model-Based Systems Engineering</td>
</tr>
<tr>
<td>MOSFETs</td>
<td>Metal-Oxide-Semiconductor Field-Effect Transistors</td>
</tr>
<tr>
<td>MRAM</td>
<td>Magnetoresistive Random-Access Memory</td>
</tr>
<tr>
<td>MRQW</td>
<td>Microelectronics Reliability and Qualification Working Meeting</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NAVY Crane</td>
<td>Naval Surface Warfare Center, Crane, Indiana</td>
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<tr>
<td>NEPAG</td>
<td>NASA Electronic Parts Assurance Group</td>
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<tr>
<td>NEPP</td>
<td>NASA Electronic Parts and Packaging</td>
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<tr>
<td>NGSP</td>
<td>Next Generation Space Processor</td>
</tr>
<tr>
<td>nm</td>
<td>nanometer</td>
</tr>
<tr>
<td>NOR</td>
<td>Not OR logic gate</td>
</tr>
<tr>
<td>PBGA</td>
<td>Plastic Ball Grid Array</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
</tr>
<tr>
<td>POC</td>
<td>Point of Contact</td>
</tr>
<tr>
<td>POF</td>
<td>Physics of Failure</td>
</tr>
<tr>
<td>QFN</td>
<td>Quad Flat Pack No Lead</td>
</tr>
<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
<tr>
<td>ReRAM</td>
<td>Resistive Random Access Memory</td>
</tr>
<tr>
<td>RH</td>
<td>Radiation Hardened</td>
</tr>
<tr>
<td>RTG4</td>
<td>Radiation-Tolerant Fourth-Generation</td>
</tr>
<tr>
<td>SCRIPS</td>
<td>SCRIPPS Proton Therapy Center</td>
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<tr>
<td>SDRAM</td>
<td>Synchronous Dynamic Random Access Memory</td>
</tr>
<tr>
<td>SEE</td>
<td>Single Event Effect</td>
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<tr>
<td>SERDES</td>
<td>Serializer/Deserializer</td>
</tr>
<tr>
<td>SiC</td>
<td>Silicon Carbide</td>
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<tr>
<td>SMEs</td>
<td>Subject Matter Experts</td>
</tr>
<tr>
<td>SOC</td>
<td>Systems on a Chip</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Determined</td>
</tr>
<tr>
<td>TI</td>
<td>Texas Instruments</td>
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<tr>
<td>TRL</td>
<td>Technology Readiness Level</td>
</tr>
<tr>
<td>TSMC</td>
<td>Taiwan Semiconductor Manufacturing Company</td>
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<tr>
<td>VNAND</td>
<td>Vertical NAND</td>
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</table>
NEPP - Frame of Reference

• EEE (electrical, electronic, and electromechanical) parts are:
  – All the things that are on printed circuit boards (PCB) inside of electronics boxes.

• This includes:
  – Integrated Circuits (ICs or chips) like processors and memories as well as passives such as capacitors and resistors,
  – Hybrid devices or multi-chip modules: Small packages that house multiple chips internally that are placed on the PCB, and,
  – Connectors and wires used to send electrical or power signals between boards, boxes, or systems.

• This does not include:
  – The PCB - NASA Workmanship Program responsibility.
NEPP

• NEPP was chartered during the late 1980’s to ensure appropriate commodities expertise existed to support the Agency.
  – In 1990, a subset of NEPP was created (NASA Electronic Parts Assurance Group – NEPAG) to ensure:
    • Appropriate sharing of information between the Centers and with other agencies, and,
    • Sufficient infrastructure exists to support Agency needs and to provide Agency leadership in supporting/developing EEE parts specifications, standards, guidelines, and test methods.

• NEPP has become the premier program for evaluating new EEE parts technologies and to develop insertion, test, screening, and qualification guidance.
  – We do not qualify specific parts, but develop the knowledge on HOW to qualify/test the parts.
Taking a Step Back…
A Simple View of NEPP’s Perspective of What We Do

NEPP Efforts Relate to Assurance of EEE Parts –
It’s not just the technology, but how to view the need for safe insertion into space programs.

NEPP Overview

NEPP provides the Agency infrastructure for assurance of EEE parts for space usage

Qualification guidance
To flight projects on how to qualify

Technology Evaluation
Determine new technology applicability and qualification guidance

Standards
Ensures NASA needs are represented

Test/Qualification Methods
Evaluate improved or more cost-effective concepts

Manufacturer Qualification
Support of audits and review of qualification plans/data

Risk Analysis
For all grades of EEE parts (commercial, automotive, military/aerospace, …)

Information Sharing
Lessons learned, working groups, website, weekly telecons

Subject Matter Experts
(SMEs) for NASA programs, other agencies, industry

NEPP and its subset (NEPAG) are the Agency’s points of contact (POCs) for assurance and radiation tolerance of EEE parts and their packages.

How NEPP and HiREV Complement Each Other

HiREV

- Technology forecasting (US Government needs)
- POF tools for Si and III-V electronics
- Pre-qualification efforts on
  - Base Metal Electrode (BME) Capacitors
  - Class Y packages
  - 45 and 90nm CMOS trusted foundry technology
- Reliability science
  - GaN technology
- Reliable Electronics
  - Electronic technology Physics of Failure (PoF)
- Radiation Reliability of Electronics
  - Modeling PoF in new technologies

NEPP

- Body of Knowledge (BOK) documents on new technologies
- Guideline on testing/qualification of FPGAs, memories, BME capacitors
- Evaluation of commercial products
  - BME capacitors
  - GaN/SiC devices
  - FPGAs
  - Automotive-grade electronics
- Reliable Electronics
  - Applying PoF to qualification/usage guidance
- Radiation Reliability
  - Testing for PoF on new Technologies
  - Support modeling/tools on new technologies
  - Qualification/usage guidance

HiREV utilizes test structures for detailed knowledge (model first).
NEPP utilizes commercial product for general knowledge (test first).

HiREV PoF on early TRL’s feeds NEPP focus on insertion/qualification.

Technology Selection Criteria for NEPP Investigation

• The technologies should satisfy all or most of the following criteria:
  – Wide applicability,
  – Product level or in productization, and,
  – No distinction: COTS to hi-reliability aerospace.

• In general, we avoid:
  – Laboratory technologies, e.g., <TRL3,
  – Limited application devices with certain exceptions (critical application or NASA center specialization).

• Note: Partnering arrangements with other organizations preferred.
  – Industry examples: Microsemi, Xilinx, Altera (Intel), TI
  – Other U.S. Government: AF SMC, AFRL, DTRA, Navy Crane
Technology Investigation Roadmap Discussion

- Technology assurance efforts are not explicitly included except on “Small Missions” chart.
  - Guidelines are a product of many technology evaluation tasks.
- Only major product categories shown.
- Technology areas not on Roadmap but under consideration include:
  - Electro-optics (fiber optics),
  - Advanced analog and mixed-signal devices,
  - Imaging sensors,
  - Modeling and simulation,
  - High-speed communication (SERDES, fast data switches), and,
  - Adjunct processors (eg., graphics, signal processing)
- Note 1: Advanced CMOS technologies not explicitly included:
  - NEPP leverages samples from ongoing DoD and/or commercial sources.
  - 14nm is current target (IBM/GF, INTEL).
- Note 2: “Reliability testing” may include product and/or package testing.
Field Programmable Gate Arrays (FPGAs)

Trusted FPGA
- DoD Development

Altera
- Stratix 5 (28nm TSMC process commercial)
- Max 10 (55nm NOR based commercial – small mission candidate)
- Stratix 10 (14nm Intel process commercial)

Microsemi
- RTG4 (65nm RH)

Xilinx
- 7 series (28nm commercial)
- Ultrascale (20nm commercial – planar)
- Ultrascale+ (16nm commercial - vertical)
- Virtex 5QV (65nm RH)

TBD – (track status)

Radiation Testing
Reliability Testing
Radiation and Reliability Testing
Package Reliability Testing

FY14 FY15 FY16 FY17

Advanced Processors

Next Generation Space Processor (NGSP)
- Joint NASA-AFRL Program for RH multi-core processor
- TBD architecture/process

RH Processor
- BAE Systems RAD5510/5545
- Replacement for RAD750

Intel Processors (w/Navy Crane)
- 14nm FinFET commercial (5th and 6th generation)
- 5th generation is 1st high-performance sans heatsink (lower power for performance)

Freescale P5020/5040
- Commercial 45nm network processor
- Preparation for RH processor

Note: Future considerations under discussion include automotive “self-driving” processor options.

Microcontrollers and Mobile Processors (Small Missions)

TBD – other
- Atmel AT91SAM9G20, and TI Sitara AM3703,
- ARM (Snapdragon), Intel Atom mobile
- Freescale MPC56XX
  - 90nm on-shore fab
  - Automotive Grade
  - Being used for both part and board level testing
- TI MSP430
  - Popular CubeSat microcontroller
  - Several varieties
- Radiation Testing (limited)
- Reliability Testing
- Radiation Testing (limited)
- Reliability Testing
- Radiation Testing (limited)
- Reliability Testing

FY14 FY15 FY16 FY17

TBD – (others)

Commercial Memory Technology
- collaborative with Navy Crane

Other
- MRAM
- FeRAM

Resistive
- CBRAM (Adesto)
- ReRAM (Panasonic)
- ReRAM (Tezzaron)
- TBD (HP Labs, others)

DDR 3/4
- Intelligent Memory (robust cell twinning)
- Micron 16nm DDR3
- TBD – other commercial

FLASH
- Samsung VNAND (gen 1 and 2)
- Micron 16nm planar
- Micron Hybrid memory Cube
- TBD - other commercial

Radiation Testing: TBD – (track status)
Reliability Testing: TBD – (track status)

EEE Parts Guidelines
- Small missions (Class D, CubeSat – 2 documents)
- System on a chip (SOC) single event effects (SEE) guideline
- Proton board level test guideline

Commodities evaluation
- See commodities roadmaps for processors, power
- CubeSat Star Tracker

Automotive grade electronics
- Multiple classes of electronics (passives, actives, ICs)
- Testing by NASA and Navy Crane

Alternate test – board level
- Freescale MPC56XX
- Automotive Grade
- Both part and board level reliability testing

Radiation Testing
Guideline development
Reliability Testing

Wide Band Gap (WBG) Technology

GaN Enhancement Mode
HEMTs
- EPC Gen 2-3, 200 V - 600 V
- GaN Systems 100 V, 650 V
- Panasonic 600 V (target)
- IR/Infineon 600 V (target)

GaN Other

SiC
- Body of Knowledge (BOK) document

SiC MOSFETs
- Cree Gen 1-2 1200 V - 1700 V
  Gen 3-4
- STMicro baseline SEE test
- Rohm Trench design

SiC Diodes
- Manufacturer X SEE baseline and hardening efforts

SiC ICs
- Ozark IC
- Manufacturer X

Silicon Power Devices

MOSFETs – Rad Hardened
- Microsemi i2MOS
- Infineon superjunction 100 V, 600 V (target)
- IR/Infineon R8 trench 20 V

Schottky Diodes
- Multiple vendors, reverse voltage ratings, and forward current ratings

Radiation Testing
Radiation Testing
Radiation Testing
(Track status)

Guideline development

FY14 FY15 FY16 FY17
Packaging Technologies (1 of 2)

High Density, Non-hermetic Column Grid Array (CGA)
- Xilinx CN/Kyocera Daisy Chain
- Microsemi Daisy Chain
- Materials analysis, long term stress, root cause failure

HALT Methodology/Qualification
- HALT/HAST comparison
- Plastic BGA matrix

Area Array Column
- Selection guide

Thermal Interface Materials
- Selection guide

PBGA Thermal Cycle Evaluation

Reliability Testing

Guideline development

Reliability Testing

Reliability Testing

Reliability Testing

Reliability Testing

FY14
FY15
FY16
FY17

Packaging Technologies (2 of 2)

Bump Reliability
- Technology review
- Test vehicle options

3D Packaging Technologies
- Technology review
- Test vehicle options

QFN package reliability
- Reliability/Qualification metrics

Guideline research
Guideline research
Reliability Testing

FY14 FY15 FY16 FY17

And Just When You Think
Your Roadmap is Set,
New Parts are Released

• Examples
  – More complex processors
    • TI Multicore DSP+ARM KeyStone II System-on-Chip (SoC)
  – Integrated “instruments”
    • TI DLP2010NIR – near IR sensing and controller
A Few Other Cool Tasks…

• CubeSat mission success/failure root cause analysis
  – Grant to Saint Louis University
• Using a model-based systems engineering (MBSE) approach to radiation assurance
  – Grant to Vanderbilt
  – Co-sponsored by NASA Reliability and Maintainability Program
  – Uses a tool called “Goal Structured Notation”
• Keeping the CRÈME website alive
  – Support to Vanderbilt
  – Just standard maintenance and operation, no upgrades
• Proton test facilities
  – See MRQW talk
• Proton fluence test levels
  – See next chart
Relative Coverage of Proton and Heavy-Ion SEE Tests

Infrared micrograph of a portion of a 512 Mb SDRAM ~60×70 μm²
- Shows both memory cells and control logic (10 yr. old tech.)
  - Red spots are ion hits

1E10 200 MeV protons/cm²  1E11 200 MeV protons/cm²  1E12 200 MeV protons/cm²

∀ Z, Angle, Energy

20% of areas this size get 0 hits for 10¹⁰ cm⁻²

Coverage from 1E7 heavy ions/cm²

Courtesy Ray Ladbury, NASA/GSFC
Summary and Comments

• NEPP Roadmaps are constantly evolving as technology and products become available.
  – Like all technology roadmaps, NEPP’s is limited to funding and resource availability.
  – Not shown are TBD passives and connector roadmaps under development.
  – Partnering is the key:
    • Government,
    • Industry, and,
    • University.

• We look forward to further opportunities to partner.

https://nepp.nasa.gov
Upcoming

• **7th Annual NEPP Electronics Technology Workshop**
  – June 13-16, 2016
  – NASA/GSFC (on-site) plus web access available
    • Registration opens in April (no cost)
  – Highlights of NEPP tasks
  – HiREV day
  – Potential special topics include:
    • 2.5/3D ICs and packaging
    • Self-driving automotive electronics