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Acknowledgment:
This work was sponsored by:
NASA Office of Safety & Mission Assurance

Open Access

To be presented by Kenneth A. LaBel at the 2015 Trilateral Safety & Mission Assurance Conference (TRISMAC), ESA Centre For Earth Observation (ESRIN)
Frascati, Italy, May 18-20, 2015.
# Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aero</td>
<td>Aerospace</td>
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<tr>
<td>AFRL</td>
<td>Air Force Research Laboratory</td>
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<tr>
<td>BME</td>
<td>Base Metal Electrode</td>
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<tr>
<td>BOK</td>
<td>Body of Knowledge</td>
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<tr>
<td>CBRAM</td>
<td>Conductive Bridging Random Access Memory</td>
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<tr>
<td>CCMC</td>
<td>Community Coordinated Modeling Center</td>
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<td>CDH</td>
<td>Central DuPage Hospital Proton Facility, Chicago Illinois</td>
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<tr>
<td>CMOS</td>
<td>Complementary Metal Oxide Semiconductor</td>
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<td>CNT</td>
<td>Carbon Nanotube</td>
</tr>
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<td>COP</td>
<td>Community of Practice</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial Off The Shelf</td>
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<td>CRÈME</td>
<td>Cosmic Ray Effects on Micro Electronics</td>
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<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DLA/DSCC</td>
<td>Defense Logistics Agency Land and Maritime</td>
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<tr>
<td>EEE</td>
<td>Electrical, Electronic, and Electromechanical</td>
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<tr>
<td>ELDRS</td>
<td>Enhanced Low Dose Rate Sensitivity</td>
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<td>EP</td>
<td>Enhanced Plastic</td>
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<tr>
<td>EPARTS</td>
<td>NASA Electronic Parts Database</td>
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<tr>
<td>ESA</td>
<td>European Space Agency</td>
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<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array</td>
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<tr>
<td>FY</td>
<td>Fiscal Year</td>
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<tr>
<td>GaN</td>
<td>Gallium Nitride</td>
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<tr>
<td>GSFC</td>
<td>Goddard Space Flight Center</td>
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<tr>
<td>HUPTI</td>
<td>Hampton University Proton Therapy Institute</td>
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<tr>
<td>IBM</td>
<td>International Business Machines</td>
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<tr>
<td>IPC</td>
<td>International Post Corporation</td>
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<tr>
<td>IUCF</td>
<td>Indiana University Cyclotron Facility</td>
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<tr>
<td>JEDEC</td>
<td>Joint Electron Device Engineering Council</td>
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<tr>
<td>JPL</td>
<td>Jet Propulsion Laboratories</td>
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<tr>
<td>LaRC</td>
<td>Langley Research Center</td>
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<tr>
<td>LEO</td>
<td>Low Earth Orbit</td>
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<tr>
<td>LLUMC</td>
<td>James M. Slater Proton Treatment and Research Center at Loma Linda University Medical Center</td>
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<tr>
<td>MGH</td>
<td>Massachusetts General Hospital</td>
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<thead>
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<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>MIL</td>
<td>Military</td>
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<tr>
<td>MLCC</td>
<td>Multi-Layer Ceramic Capacitor</td>
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<td>MOSFETS</td>
<td>Metal Oxide Semiconductor Field Effect Transistors</td>
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<tr>
<td>MRAM</td>
<td>Magnetoresistive Random Access Memory</td>
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<td>MRQW</td>
<td>Microelectronics Reliability and Qualification Working Meeting</td>
</tr>
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<td>MSFC</td>
<td>Marshall Space Flight Center</td>
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<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<td>NAVY</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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<td>NEPP</td>
<td>NASA Electronic Parts and Packaging</td>
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<tr>
<td>NPSL</td>
<td>NASA Parts Selection List</td>
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<tr>
<td>PBGA</td>
<td>Plastic Ball Grid Array</td>
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<tr>
<td>POC</td>
<td>Point of Contact</td>
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<td>POL</td>
<td>Point of Load</td>
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<tr>
<td>ProCure</td>
<td>ProCure Center, Warrenville, Illinois</td>
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<tr>
<td>RERAM</td>
<td>Resistive Random Access Memory</td>
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<td>RF</td>
<td>Radio Frequency</td>
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<td>RHA</td>
<td>Radiation Hardness Assurance</td>
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<tr>
<td>SAS</td>
<td>Supplier Assessment System</td>
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<tr>
<td>SEE</td>
<td>Single Event Effect</td>
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<td>SEU</td>
<td>Single Event Upset</td>
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<tr>
<td>SIC</td>
<td>Silicon Carbide</td>
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<td>SME</td>
<td>Subject Matter Expert</td>
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<tr>
<td>SOC</td>
<td>Systems on a Chip</td>
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<tr>
<td>SOTA</td>
<td>State of the Art</td>
</tr>
<tr>
<td>SPOON</td>
<td>Space Parts on Orbit Now</td>
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<tr>
<td>SSDs</td>
<td>Solid State Disks</td>
</tr>
<tr>
<td>TI</td>
<td>Texas Instruments</td>
</tr>
<tr>
<td>TMR</td>
<td>Triple Modular Redundancy</td>
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<tr>
<td>TRIUMF</td>
<td>Tri-University Meson Facility</td>
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<tr>
<td>VCS</td>
<td>Voluntary Consensus Standard</td>
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<tr>
<td>VNAND</td>
<td>Vertical NAND</td>
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To be presented by Kenneth A. LaBel at the 2015 Trilateral Safety & Mission Assurance Conference (TRISMAC), ESA Centre For Earth Observation (ESRIN) Frascati, Italy, May 18-20, 2015.
Taking a Step Back…
A Simple View of NEPP’s Perspective

Physics of failure (POF)

Chemistry of failure (COF)

Screening/Qualification Methods

Application/Environment

Mission Reliability/Success

**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.**
A View of NASA Electrical, Electronic, and Electromechanical (EEE) Parts Needs – *Diversity!*

Focus on fail-safe architecture/electronics

Focus on cost-consciousness and low power electronics

Focus on reliability and radiation tolerance

Overlap areas are critical assurance infrastructure (NASA Electronic Parts Assurance Group - NEPAG)

*Without forgetting traditional LEO and Deep-Space Robotic needs*

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What EEE Parts Diversity Entails – NEPP Tenets for Planning Tasks

• Tasks should
  – Learn from the past,
  – Focus on the present, and,
  – Plan for the future.

• Tasks should have widest applicability to Agency needs.
  – Know our customer base: technologists, designers, engineers,…
  – No single NASA center interests or direct flight project support.

• Tasks should leverage partnerships with other agencies, industry, and universities.
  – Partnering with flight projects ONLY when the Agency as a whole benefits.

Note: A combined perspective on EEE parts allows an equal assurance/engineering approach to NEPP plans.
NEPP and its subset (NEPAG) are the Agency’s points of contact (POCs) for assurance and radiation tolerance of EEE parts and their packages.

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As opposed to a traditional breakdown of parts, packaging, or radiation, NEPP tasks can be categorized into these five areas. Backup slides are provided to show detailed task listing.
EEE PARTS ASSURANCE AND RISK
Understanding EEE Parts Risks

• The risk management requirements may be broken into three considerations
    • Relate to the circuit designs not being able to meet mission criteria such as jitter related to a long dwell time of a telescope on an object
  – Programmatic – “The Bad”
    • Relate to a mission missing a launch window or exceeding a budgetary cost cap which can lead to mission cancellation
  – Radiation/Reliability – “The Ugly”
    • Relate to mission meeting its lifetime and performance goals without premature failures or unexpected anomalies.
    • Assurance falls under this heading.

• Each mission determines its priorities among the three risk types
EEE Parts Risk Trade Space –
Selected Factors for the “Big Three”

• **Cost and Schedule**
  – Procurement
  – NRE
  – Maintenance
  – Qualification and test

• **Performance**
  – Bandwidth/density
  – SWaP
  – System function and criticality
  – Other mission constraints (e.g., reconfigurability)

• **System Complexity**
  – Secondary ICs (and all their associated challenges)
  – Software, etc…

• **Design Environment and Tools**
  – Existing infrastructure and heritage
  – Simulation tools

• **System operating factors**
  – Operate-through for single events
  – Survival-through for portions of the natural environment
  – Data operation (example, 95% data coverage)

• **Radiation and Reliability**
  – SEE rates
  – Lifetime (TID, thermal, reliability,…)
  – “Upscreening”

• **System Validation and Verification**

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NRE: non-recurring engineering
IC: integrated circuit
SEE: single-event effect
TID: total ionizing dose

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Generalized EEE Parts Assurance Concept

- EEE parts assurance is a spectrum of trade spaces based on two considerations:
  - Criticality: whether the mission or application is in the “must work” category, and,
  - Environment/Lifetime: how harsh the space environment for the mission is, coupled with length of mission to qualify as success.

- A reminder
  - Additional environment protection can be anything from shielding to thermal control to fault tolerant design.
  - Anomalies and failures are what happens when the protection isn’t sufficient.
Applying These Concepts to EEE Parts

- The matrix on the following slide illustrates this using a modified risk approach (image on this slide).
  - Note that the green areas are where commercial off the shelf (COTS) electronics may be considered apropos while the red may require traditional EEE parts assurance approaches (i.e., NASA Level 1 or 2 parts – these are equivalent to the Mil/Aero grade components for space).
  - While not specifically called out here, other grades between commercial and Mil/Aero such as automotive are part of the trade space.
## Notional EEE Parts Usage Factors

### Environment/Lifetime

<table>
<thead>
<tr>
<th>Criticality</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>COTS upscreening/part testing optional; do no harm (to others)</td>
<td>COTS upscreening/testing recommended; fault-tolerance suggested; do no harm (to others)</td>
<td>Rad hard suggested. COTS upscreening/testing recommended; fault tolerance recommended</td>
</tr>
<tr>
<td>Medium</td>
<td>COTS upscreening/testing recommended; fault-tolerance suggested</td>
<td>COTS upscreening/testing recommended; fault-tolerance recommended</td>
<td>Level 1 or 2, rad hard suggested. Full upscreening for COTS. Fault tolerant designs for COTS.</td>
</tr>
<tr>
<td>High</td>
<td>Level 1 or 2 suggested. COTS upscreening/testing recommended. Fault tolerant designs for COTS.</td>
<td>Level 1 or 2, rad hard suggested. Full upscreening for COTS. Fault tolerant designs for COTS.</td>
<td>Level 1 or 2, rad hard recommended. Full upscreening for COTS. Fault tolerant designs for COTS.</td>
</tr>
</tbody>
</table>
Comments on the “Matrix” Wording

• “Optional” – implies that you might get away without this, but there’s possible risk if you don’t.
• “Suggested” – implies that it is a good idea to do this, but there’s some increased risk if you don’t.
• “Recommended” – implies that this should be done and there’s probable risk if you don’t.
• Where just the item is listed (ex., “full upscreening on COTS”) – this should be done to meet the criticality and environment/lifetime concerns. There is definite risk if you don’t

Good mission planning identifies where on the matrix a mission/application lies.
NEPP FOR THE NEW FRONTIER – “COST CONSCIOUS MISSIONS”: IS BETTER THE ENEMY OF GOOD ENOUGH?
NEPP Tenets for Cost-Conscious Missions

• The following charts will provide a sampling of our current recommendations and thoughts on “saving money”.
• General topic areas for the following charts:
  – Using existing resources,
  – Grades of EEE parts,
  – Alternate screening/qualification approaches, and,
  – Fault tolerance.

“A typical new car is equipped with more than 50 computers, designed to operate under extreme conditions for extended periods of time.”

Using Spare Parts and Other Resources

• Make use of existing resources.
  – Are there spare devices available at your agency or within your control?
    • Flight procurements usually include extra device samples.
      – This can include connectors to capacitors to FPGAs.
    • Some may be fully screened and even be radiation hardened/tested.
      – You may still have to perform some additional tests, but it’s still a lower cost.
    • Engage parts/radiation engineers early to help find and evaluate designers “choices” of EEE parts.
      – Use their added value to help with the choices and even on fault tolerance approaches.

• If spare parts are not available, try to use parts with a “history of use”.
  – These parts perform similarly to the “history” EEE parts
    • Not guaranteed

• Higher risk:
  – Choose devices built on the same process/design rules by the same manufacturer.

• If you absolutely need something new, you will pay for the qualification or take the risk.
Background on EEE Parts Grades

- EEE parts are available in grades.
  - Designed and tested for specific environmental characteristics.
    - Operating temperature range, pressure/vacuum, radiation exposure, shock, vibration,…
  - Examples of Grades:
    - Aerospace, Military, Automotive, Medical, Extended Performance/Temperature-Commercial (EP), and Commercial Off the Shelf (COTS).

- Aerospace Grade
  - Traditional choice for space usage.
    - Designed and tested for reliability and often radiation for space usage.
  - Relatively few available parts and their performance lags behind commercial counterparts (speed, power).

- NEPP has a long history of evaluating grades other than Aerospace or Military.
  - Current focus is on Automotive and Commercial.
    - Automotive parts are less expensive than Aerospace counterparts.
      - The BIG question is on reliability/radiation for space.

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A Few Upfront Comments

• Aerospace Grade electronics are typically designed and tested to survive a wide range of environment exposures:
  – -55C to +125C, as an example.

• This allows a “generic” qualification by a manufacturer to encompass a wide array of user mission needs (i.e., one test for a lot of folks rather than a new test for each customer).

• Commercial off the shelf (COTS) for terrestrial usage aren’t designed/tested to these same levels.
  – This doesn’t mean they won’t work in a mission, but implies that you have to find a means of either reducing or accepting risk.
Temperature Rating Versus “Need”

• Aerospace and Military grades are qualified for usage via exhaustive temperature cycles at -55C to +125C.
  – This is a conservative approach allowing vendors to qualify once for the majority of space customers.
  – But what if we want to use parts not rated for this wide range?
• Actual mission profile thermal excursions are mission unique.
  – May be relatively when compared to the standard “Mil grade” temperature range.
    • However, there may be thousands of temperature cycles to consider.
  – What’s the appropriate testing? Conservative or reduced levels?
• Operation outside of the rated temperature, while possible, entails risk.
Automotive Electronics – NEPP Tasks

• Develop a body of knowledge (BOK) document, highlighting the Automotive Electronics Council (AEC) documents as well as discussions with manufacturers.
  – Summary eludes to the need for “relationships” between vendor and buyer being necessary to coordinate screening/qualification requirements.

• Evaluate (reliability) selected automotive grade electronics (in collaboration with Navy Crane).
  – ICs, Capacitors, and, Discretes.
  – *Early results are promising.*

• Evaluate (radiation/reliability) of an automotive grade microcontroller.

• Review ISO 26262: (Automotive) Functional Safety Standard—reliability requirement is extremely strict for safety critical systems.
  – Architectural fault tolerance approaches may have commonality.

• Working with Micron (automotive systems/advanced technology).
  – *Does design for terrestrial soft error tolerance (device/architectures) help for space usage?*

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Do We Need Traditional Parts Screening/Qualification?

• Traditional testing was developed as a conservative means of bounding risk using temperature and voltage acceleration factors and adequate sample size statistics.
  – Are downscaled or alternate approaches adequate for cost-conscious missions?

• Board level tests – how do they correlate to part level tests?
  – Temperature range for tests are limited to “weakest link” on the board (use 0 to 70/85C).
    • What number of temperature cycles are needed for reliability?
  – Modern boards usually have localized power conversion.
    • Implies changes to input voltages may not accelerate degradation due to voltage regulation.
  – Besides the stress mechanisms,
    • As opposed to access of every pin and full test vectors, board level has limits on input/output capabilities, operational tests, and visibility of “failures”.

  – Appropriate sample size for statistics also challenges.

• Question to consider: how do we quantify the risk reduction?
Fault Tolerance to Increase “Parts” Reliability?

- Means of making a system more “reliable/available” can occur at many levels:
  - Operational
    - Ex., no operation in the South Atlantic Anomaly (proton hazard)
  - System
    - Ex., redundant boxes/busses or swarms (with spares) of nanosats
  - Circuit/software
    - Ex., error detection and correction (EDAC) of memory devices
  - Device (part)
    - Ex., triple-modular redundancy (TMR) voting of internal logic within the device
  - Transistor
    - Ex., use of annular transistors for TID improvement
  - Material
    - Ex., addition of an epi substrate to reduce SEE charge collection (or other substrate engineering)

The question remains:

How effective is the fault tolerance in increasing reliability?

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Will Fault Tolerance Work When We Haven’t Tested the Parts?

- The System May Work, But What Level of Confidence Exists That It Will?
  - What are the “unknown unknowns”? Can we account for them?
  - How do you calculate risk with unscreened/untested EEE parts?
  - Do you have common mode failure potential in your design? (i.e., a identical redundant string rather than having independent redundant strings)
  - How do you adequately validate a fault tolerant system for space?
    - If, for example, 95% of faults are able to be recovered from, how critical are the other 5%?
    - Is there any “dead time during recovery?”

- If we go back to the “Matrix”, how critical is your function and harsh your environment/lifetime?
  - This will likely provide the “answers” to the above questions.

Good engineers can invent infinite solutions, but the solution used must be adequately validated and the risks accepted.
Summary

• NEPP is an agency-wide program that endeavors to provide added-value to the greater aerospace community.
  – Always looking at the big picture (widest potential space usage of evaluated technologies and NEPP products).
  – We look to the future by learning from our past.

• We’ve provided some thoughts on EEE Parts Assurance for Cost-Conscious Missions.
  – Knowledge is always a key

• Next NEPP Workshop planned for June 23-26 2015.
  – Will be a mix of traditional June meeting plus CubeSat focus.
  – On-site open to U.S. only.
  – Web access available to international participants.

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Backup
Updating the NEPP Roadmap

• Starting in 2014, NEPP began modifying its roadmap to accommodate tasks supporting cost-conscious missions. Key areas include:
  – Automotive Electronics (parts grade, safety critical),
  – Small Mission Guidance,
  – Board Level Testing, and
  – Additional COTS evaluations focused on CubeSat electronic needs.

• Note: An early deliverable of NEPP tasks:
  – Body of Knowledge (BOK) – a document that collects known information about a subject including maturity, testing, and reliability.
    • It is often a predecessor to technology evaluation or guideline development tasks.
FY15 NEPP Core – Automotive/Commercial Electronics

Core Areas are Bubbles; Boxes underneath are variable tasks in each core

NEPP Research Category – Automotive/Commercial Electronics

Automotive Electronics

Alternate Test Approaches

Mobile Processors

Microcontrollers

Advanced, Processors

Guidance, Documents

BOK on specs, standards, and vendor approaches (NEPAG)

Extended Temperature Evaluation of Automotive Capacitors

Reliability evaluation of ceramic capacitors, discrete transistors, and microcircuits

Effectiveness of Board Level Testing for Piecepart Qualification (will utilize boards with automotive microcontrollers)

Intel Atom, Qualcomm Snapdragon Processors (radiation only)

Freescale Automotive Microcontroller (+ board) Radiation, Reliability

Freescale P5040 Network Processor (IP for next generation BAE Systems Rad Hard Processor)

Rule of thumb documents

CubeSat Parts Database

COP

Policy, Guidelines

Microcontroller recommendations

Medical Electronics BOK

BOK = Body of Knowledge
COP = Community of Practice
FY = Fiscal Year
TI = Texas Instruments

Work performed by NASA and Navy Crane

TI EP parts; Automotive safety critical study

TBD:

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FY15 NEPP Core - Complex Devices

Core Areas are Bubbles; Boxes underneath are variable tasks in each core

NEPP Research Category – Complex Devices (Commercial/Mil-Aero)

- **FPGAs – Radiation**
  - Xilinx Virtex 5QV
  - Xilinx 20nm Virtex-7, Kintex-7
  - Xilinx Zynq
- **FPGAs – Reliability**
  - Xilinx Virtex 5QV Daisy Chain Package Evaluation
  - Xilinx 28nm
    - Microsemi RT4G Daisy Chain Package Evaluation
- **Advanced Packaging**
  - Class Y, N Support
    - HALT for PBGA + others
  - Thermal Interface Materials
  - Area Array Column Guideline
  - Commercial Stacked (SSDs)
  - Class Y and IPC
- **Memory Devices (COTS)**
  - Resistive Memory (RERAM, CBRAM)
    - Radiation, Reliability
    - 3D Structure
    - FLASH Memory
    - Samsung VNAND Radiation, Reliability
  - DDR3 Memory Radiation, Reliability
  - Micron 16nm planar FLASH Radiation, Reliability
- **Advanced CMOS**
  - IBM trusted foundry
    - 14-32 nm Radiation
  - Robustchip/Cisco
    - 28nm and below Radiation
  - Intel
    - 14 nm Radiation
  - Other technologies (MRAM, CNT)

Legend

- **NEPP Ongoing Task**
- **FY15 New Start**
- **Overguide/Pending Availability**

**Assurance**

**Advanced CMOS**

**Memory Fault Coverage**

**SOC Radiation**

**Synopsys TMR Tool Evaluation**

**NEPP Ongoing Task**

- Overguide/Pending Availability

**FY15 New Start**

**Legend**

- CBRAM = Conductive Bridging Random Access Memory
- CNT = Computer Engineering Technology
- CMOS = Complementary Metal Oxide Semiconductor
- COTS = Commercial Off The Shelf
- FPGA = Field Programmable Gate Array
- IPC = International Post Corporation
- MRAM = Magnetoresistive Random Access Memory
- PBGA = Plastic Ball Grid Array
- RERAM = Resistive Random Access Memory
- SSDs = Solid State Disks
- TMR = Triple-Modular-Redundancy
- VNAND = Vertical NAND

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FY15 NEPP Core - Power Devices

Core Areas are Bubbles; Boxes underneath are variable tasks in each core

NEPP Research Category – Power Devices (Commercial/Mil-Aero)

- Power Converters
  - Hybrids/DC-DC Converter Working Group
  - POL Reliability + SEU Susceptibility
  - DC-DC Converter Selection Guideline

- Power MOSFETS – Silicon
  - New Mil/Aero Product Evaluation (Radiation)
  - (Cubesat) Commercial Power Systems Electronics Evaluation (Radiation)

- Widebandgap Power and RF
  - Widebandgap Working Group
  - GaN Radiation Test
  - SiC Radiation Test
  - Combined Effects Reliability

- Assurance
  - Standards Support

Legend
- NEPP Ongoing Task
- FY15 New Start
- Overguide/Pending Availability

MOSFETS = Metal Oxide Semiconductor Field Effect Transistors
GaN = Gallium Nitride
Mil/Aero = Military/Aerospace
POL = Point of Load
RF = Radio Frequency
SEU = Single Event Upset
SiC = Silicon Carbide

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FY15 NEPP Core - Assurance

Core Areas are Bubbles; Boxes underneath are variable tasks in each core

NEPP Research Category – Assurance

- Radiation
- Parts
- Packaging
- Connectors/Wire
- Assurance

Legend

- NEPP Ongoing Task
- FY15 New Start
- Overguide/Pending Availability

Ultra-ELDRS
Proton facility study
Board level proton testing Guideline
3D Inspection X-ray Dose Study
JEDEC JESD57 Update
SOTA Linears

BME Capacitors – teaming w Aerospace Corp
MLCC Reliability Guideline
Tantalum Capacitors Reliability (includes DLA drawing #103032)
Super/ Ultra Capacitors BOK
Ultra Small Passives BOK
Integrated Inductor/Resistor

NEPP Roadmap Update
Leadless Package Trends
Mermeticity Test Method Guideline/ Mil-STD Update
Copper Bondwire BOK

NASA Connector Working Group
NASA Connector Usage BOK
TBD Connector tests
Aluminum Wire Evaluation

Low Proton Energy Test Guideline

NASA Parts Policy Update
Radiation Assurance Policy/Guidance
Project Parts Database Mining
SME Support – Trusted FPGAs/ Integrity
CRÈME website

BME = Base Metal Electrode
BOK = Body of Knowledge
CRÈME = Cosmic Ray Effects on Micro Electronics
DLA = Defense Logistics Agency Land and Maritime
ELDRS = Enhanced Low Dose Rate Sensitivity
JEDEC = Joint Electron Device Engineering Council
MLCC = Multi-Layer Ceramic Capacitor
SME = Subject Matter Expert
SOTA = State of the Art

TBD:
GRC spare parts; 217 study

To be presented by Kenneth A. LaBel at the 2015 Trilateral Safety & Mission Assurance Conference (TRISMAC), ESA Centre For Earth Observation (ESRIN) Frascati, Italy, May 18-20, 2015.
FY15 NEPAG Core

Core Areas are Bubbles; Boxes underneath are elements in each core

Legend

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NEPAG Focus Areas

- Failure Investigations/Part Problems
  - Investigate
  - Assess NASA Impact
  - Test/Analyze
  - Corrective Action
  - Lessons Learned

- Specs and Standards
  - US MIL
  - VCS
  - Class N

- Audits
  - Onshore
  - Offshore
  - NASA SAS Database
  - Parts Audit – Checklist for new auditors

- Collaborations
  - National
  - International
  - Telecons

- Parts Support
  - NPSL
  - Technical Expertise Resource
  - Bulletins
  - Connectors
  - Small Mission Electronics -tie in to AFRL SPOON

Lead Centers: GSFC – passives, JPL – actives, LaRC – hybrids, MSFC - discretes

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