The NASA Electronic Parts and Packaging (NEPP) Program – FY11 Overview with Radiation Emphasis

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Unclassified
Outline

• Electronics Technology
  – Overview from the NEPP perspective
• Example Research Area
  – Physics-based Radiation Modeling
• NEPP Overview
• Radiation Lessons Learned
  – Sample Highlights from FY10
• Preliminary FY11 Plans
Insertion of New Electronics Technologies

The Big Picture Approach

- Develop knowledge-base of existing technology information
- Determine reliability/radiation gaps
- Perform ground-based tests where appropriate
  - May be sufficient to “qualify” for a specific mission, but not generically for all
- Develop technology-specific models/test protocols
  - Performance Predictions
- Validate models with flight data
  - Requires in-situ environment monitoring

Non-NEPP funded flight hardware

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parts Procurement (100+ device samples for testing only)</td>
<td>$25-1000K</td>
<td>Individual device costs can run from cents to tens of thousands</td>
</tr>
<tr>
<td>“Standard” Qualification Tests</td>
<td>$300K</td>
<td></td>
</tr>
<tr>
<td>Radiation Tests and Modeling</td>
<td>$200K</td>
<td>Assumes total dose and single event (heavy ion) only</td>
</tr>
<tr>
<td>Failure Modes Analysis</td>
<td>$200K</td>
<td>Out-of-the-box look at the “hows and whats” for non-standard research required for qualification</td>
</tr>
<tr>
<td>Additional Tests, Modeling, and Analysis based on Failure Modes</td>
<td>$300K</td>
<td></td>
</tr>
<tr>
<td>Total cost for one device type</td>
<td>$1.025-2M</td>
<td>Not all new technologies will meet standard qualification levels: technology limitations document</td>
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</tbody>
</table>
**NEPP:**

*If we used Radio Shack parts*

<table>
<thead>
<tr>
<th></th>
<th>Radio Shack</th>
<th>Space</th>
</tr>
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<tbody>
<tr>
<td><strong>Lifetime</strong></td>
<td>1-3 years, then replaced or</td>
<td>1-20 years and rarely replaceable</td>
</tr>
<tr>
<td></td>
<td>thrown out</td>
<td></td>
</tr>
<tr>
<td><strong>Thermal</strong></td>
<td>0-70C</td>
<td>-55 to +125C with extremes much</td>
</tr>
<tr>
<td></td>
<td></td>
<td>higher and lower</td>
</tr>
<tr>
<td><strong>Shock</strong></td>
<td>Oops! I dropped it. Time to</td>
<td>Launch vibration</td>
</tr>
<tr>
<td></td>
<td>get an upgrade…</td>
<td></td>
</tr>
<tr>
<td><strong>Radiation</strong></td>
<td>Dude, where’s my SPF?</td>
<td>Protons, electronics, galactic cosmic rays,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>solar, particles, plasma,…</td>
</tr>
<tr>
<td><strong>Anomaly</strong></td>
<td>Reboot or power cycle or</td>
<td>Anomaly or failure</td>
</tr>
<tr>
<td></td>
<td>return to dealer</td>
<td></td>
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</tbody>
</table>

- **NEPP is the only entity at NASA that**
  - Trains young engineers in the difference and provides a growth path for developing project parts and radiation engineers
  - Develops and validates qualification methods
    - Military and commercial standards do not cover ALL of NASA’s interests
  - Provides knowledge allowing insertion of modern devices into space systems
  - Shares and gathers knowledge with all the industry
    - If the flight projects don’t know there’s a problem…
Physics–based Modeling

Sample Gaps and Technology Dependent Implementation Issues

Gaps exist in areas such as low energy electrons, solar heavy ions, MEO, etc.

- External Environment Models
- Target Interactions
- Technology Tests and Models
- Performance Tools
- Circuit Application
- Prediction

- Spacecraft CAD Model
- Induced Environment
- Target Interaction Models
- Prediction

CAD model selection may vary with proximity to technology
Environment granularity may vary with technology effect of interest (i.e., TID differs from detector noise)
Choice of tools hinges on technology concern (SEE, TID, noise, etc.);
Requires test/model program
Device response may not reflect technology response
NEPP Mission

- To provide guidance to NASA:
  - Selection and application of microelectronics technologies
  - Improved understanding of risks related to the use of these technologies in the space environment
  - Appropriate evaluations to meet NASA mission assurance needs for electronic systems

- NEPP evaluates new* and emerging** electronic parts technologies and provides assurance support for technologies in current use in NASA spaceflight systems

*New – Recently marketed, commercially available
** Emerging – Available in limited quantities for evaluation, on path to commercial products
NEPP Overview

- NEPP supports all of NASA for >20 years
  - 7 NASA Centers and JPL actively participate
- The NEPP Program focuses on the reliability aspects of electronic devices
  - Three prime technical areas: Parts (die), Packaging, and Radiation
- Alternately, reliability may be viewed as:
  - Lifetime, inherent failure and design issues related to the electronic parts technology and packaging,
  - Effects of space radiation and the space environment on these technologies, and
  - Creation and maintenance of the assurance support infrastructure required for mission success.

Electrical overstress failure in a commercial electronic device
NEPP Works Two Sides of the Equation

• **Assurance**
  – *Issues that are applicable to space systems being designed and built (i.e., currently available technologies)*
  – Examples
    • Cracked capacitors
    • DC-DC converter reliability
    • Enhanced Low Dose Rate Sensitivity (ELDRS)
  – Communication infrastructure via website and working groups
    • NASA Electronic Parts Assurance Group (NEPAG)
  – Audit and review support

• **New electronics technology**
  – *Issues that are applicable to the next generation of space systems in conceptualization or preliminary design*
  – Examples
    • 45-90 nm CMOS
    • SiGe
    • State-of-the-art FPGAs
  – Collaboration with manufacturers and government programs for test, evaluation, and modeling
  – Development of new predictive performance tools
NEPP Organization

GSFC
- Mike Sampson
  - Radiation, Advanced-Actives
- Ken LaBel
  - Passives, Packaging Specifications

JPL
- Chuck Barnes, Shri Agarwal
  - Radiation Actives, Connectors Fiber Optics Packaging

JSC
- Darilyn Gaston, Tom Orton
  - Connectors, Wire and Cable

LaRC
- John Pandolf Pete Majewicz
  - Actives DC/DC Converters

KSC
- Chi Yeh

GSFC
- Rich Williams, Jay Brusse
  - Radiation Passives Fiber Optics Specifications

Kuok Ling

GRC
- Eric Overton, Dick Patterson
  - Extreme-Environments-Testing

LaRC
- John Pandolf Pete Majewicz
  - Actives DC/DC Converters

Collaboration

• “Promote enhanced cooperation with international, industry, other U.S. government agency, and academic partners in the pursuit of our missions.” – Charles Bolden, NASA Administrator

• NEPP has a long history of collaboration. For radiation efforts:
  – Direct funding from DTRA (co-fund many radiation tasks) and NRO as well as in-kind from AFRL, NRL, SNL, etc…
  – Multiple universities including Vanderbilt, Georgia Tech, …
  – Too numerous manufacturers to mention!
  – International with ESA, JAXA,…
Typical Spacecraft Electrical Architecture

- C&DH
- GN&C
- Propulsion
- Thermal
- Instruments/Payload
- Power Bus (ses)
- Command and Data Bus
- Power
- COMM

- RF to/from Ground or other spacecraft
- Ground Antenna

- (direct link)
Typical Spacecraft Electrical Architecture

The 90/90 Goal

Sample NEPP Technology Areas
- Memories
- FPGAs
- Capacitors
- SiGe
- Power devices

90% of NEPP efforts should support 90% of NASA flight missions
Typical Spacecraft Electrical Architecture

The 90/90 Goal - Example

Sample NEPP Technology Areas

Memories

Used in any processing application and for data storage on a spacecraft.
What Did We Learn in FY10? - Highlights

• Low proton energy testing is real and has LOTS of people nervous
  – Big questions still exist on
    • How to test
    • How to predict
    • How to protect
  – Keep in mind: if you harden for heavy ions, you might well be okay for this issue

• Cryogenic latchup
  – Once thought impossible to happen, has now been proved to be real
  – How widespread is the question and if there’s consistency on temperature range.
    • The sky’s not falling, but need to have data and not hand wave…
NEPP Has a Wide Range of Efforts

- Tasks vary extensively in the technologies of interest
  - Building blocks like capacitors
  - Standard products like DC-DC Converters, linear bipolar devices, and A-to-D Converters
  - New commercial devices such as FPGAs and memories
  - Test structures on emerging commercial or radiation hardened technologies
  - Specialized electronics such as IR arrays and fiber optics
  - New assurance methods and investigations
- NEPP ETW provides forum to present recent results, as well as current and future plans
- Currently in FY11 planning cycle
  - PRELIMINARY PLANS FOLLOW
**NEPAG Focus Areas**

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

- **Specs and Standards**
  - US MIL
  - VCS

- **Audits**
  - US MIL
  - Onshore
  - Offshore
  - NASA SAS Database

- **Collaborations**
  - National
  - International

- **Parts Support**
  - NPSL
    - Technical Expertise Resource
    - Bulletins
    - Connectors

- **Consortia**
  - CAVE
  - CALCE

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Legend:

- DoD and NASA Funded
- NASA-only funded
- Overguide

**Core Areas are Bubbles;**

Boxes underneath are elements in each core.
FY11 Radiation Plans for NEPP Core (1)

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

**NEPP Research Categories – Active Electronics**

- **SiGe. Mixed Signal**
  - SiGe on SOI
  - Scaled SiGe
  - Advanced Data Conversion, Amplifiers, Drivers
  - Architectural comparison
  - Develops students at Georgia Tech, Vanderbilt, Auburn

- **Scaled CMOS**
  - Commercial Devices
    - Memories – Non-volatile, volatile
      - FPGAs
      - Processors, SOCs
      - Structured ASICS
  - Test Structures
    - Silicon on Insulator (SOI)
    - Ultra-low power
    - 32 and 45 nm
    - CNTs
    - RHBD Support

- **Sensor Technologies**
  - IR
  - Visible
  - Cryo SEL
  - Others

- **Photonics**
  - Fiber Amplifiers
  - Exotic-doped Fiber components
  - Wavelength Division Multiplexing
  - Free space Optical interconnects
  - Fiber Data Links
  - Optocouplers and PM Optocouplers

- **Performance Tools**
  - 32 and 45 nm CMOS
  - SiGe
  - Low proton energy
  - Compact model based rate prediction
  - Develops students at Vanderbilt

**Legend**
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- Overguide

**Partners at:**
AFRL, Cypress, Ball, DoD, IBM, TI, Intel, Boeing, Actel, Atmel, Xilinx, Altera, Cypress

**Partners include:**
AFRL, Cypress, Ball, DoD, IBM, TI, Intel, Boeing, Actel, Atmel, Xilinx, Altera, Cypress
FY11 Radiation Plans for NEPP Core (2)

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

NEPP Research Categories – Hardness Assurance

ELDRS Test
- NSC, LT, TI, Intersil, STM Support
- Hydrogen Effects
  - High dose
- SEE - Elevated
- SEE - Cryo
- TID – Elevated during
- Cryo BOK

Temperature Effects
- TID – Elevated post

Power Devices
- SEGR Model/Tool
- Vendor Eval
- POLs
- GaN, SiC
- High V DC-DC

Combined Effects
- NVMs – Radiation and Reliability
- TID on SEE
- DDD on SEE
- SETs on Reliability
- <90nm Reliability of Irradiated Devices
- Heavy Ion DD of <65nm

Guidelines
- ADC Test
  - Low Proton Energy
  - SOC Test Guideline
  - NVM Test Guideline
  - Standard FPGA Test Method
  - SDRAM Test Guideline

Other Overguide Tasks
- Education/training modules
- Microwave Technologies
- Additional SOC Testing

Overguide Tasks
- Partners at vendors listed, RLP Research, ASU
- Partners at NSWC, IR, Fuji, STM, Microsemi

Legend
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NEPP FY11– Overview for RHET, Colorado Springs, CO- Kenneth A. LaBel, Oct 19, 2010
FY11 Parts Plans for NEPP Core (1)

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

NEPP Research Categories – Parts Assurance

Legend

<table>
<thead>
<tr>
<th>NASA-only funded</th>
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<tbody>
<tr>
<td>Overguide</td>
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</table>

**SiGe. Mixed Signal**
- Cold temperature effects
- Scaled SiGe
- Advanced Data Conversion, Amplifiers, Drivers
- GaAs, InP, Antemonides

**Scaled CMOS**
- Commercial Devices
  - Memories – Non-volatile
  - FPGAs
  - Processors, SOCs
  - Memories - SDRAM
- Test Structures
  - Silicon on Insulator (SOI)
  - Ultra-low power
  - 32 and 45 nm
  - CNTs
  - Sub 90nm

**Sensor Technologies**
- IR
- Visible
- ROICs - Cryo
  - Others

**Photonics**
- Fiber Amplifiers
- Exotic-doped Fiber components
  - Wavelength Division Multiplexing
  - Free space Optical interconnects
  - Fiber Data Links
  - Optocouplers and PM Optocouplers

**Rf Electronics**
- RF Reliability Guide
  - Advanced RF
FY11 Parts Plans for NEPP Core (2)

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

NEPP Research Categories – Parts Assurance

- Passives
  - Polymer Caps
  - BME Caps
  - Embedded Passives
  - Advanced devices

- Temperature Effects
  - Cryo CMOS
  - Extended COTS
  - Mixed Signal - Cryo
  - Hot spot test method
  - Cryo BOK

- Power Devices
  - Power Mosfets
    - DC-DC Eval
    - POLs
    - GaN, SiC
    - High V DC-DC

- Combined Effects
  - NVMs – Radiation and Reliability
  - TID on SEE
  - DDD on SEE
  - SETs on Reliability
  - <90nm Reliability of Irradiated Devices
  - Heavy Ion DD of <65nm

- Guidelines
  - ADC Test
  - Embedded device
  - SOC Test Guideline
  - NVM Test Guideline
  - Standard FPGA Test Method
  - SDRAM Test Guideline

Other Overguide Tasks
- Education/training modules
- Microwave Technologies
- Additional SOC Testing

Legend
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- Overguide

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FY11 Core Element - Packaging

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

Legend

| NASA-only funded | Overvguide |

- NEPP Research Categories – Advanced Packaging

Area Arrays

- Ball Grid Arrays
- Column Grid Arrays
- Microcoil Spring Array
- Land Grid Arrays

Complex Non-Hermetic

- Area Array
- MIL Class Y Materials

Embedded Technologies

- Actives
- Passives

Lead-free

- Assemblies
- Tin Whiskers

Board Installation Damage

- Cracking
- Parametric Drift
- Reverse Polarity
### FY11 Rad – A little more detail

<table>
<thead>
<tr>
<th>RHA</th>
<th>Devices</th>
<th>Technology - CMOS</th>
<th>Technology - Other</th>
<th>Sensors</th>
<th>Modeling</th>
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<tbody>
<tr>
<td>Low proton energy test guide</td>
<td>FPGAs</td>
<td>IBM</td>
<td>SiC</td>
<td>Cryo SEL - ROICS</td>
<td>MOSFET - SEGR</td>
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<tr>
<td>CMOS Dose Rate - TID</td>
<td>FPGAs - SIRF (TBD)</td>
<td>TI</td>
<td>SiGe - IBM 9hp</td>
<td>IR Arrays</td>
<td>CRÈME MC Validation</td>
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<td>IR Array Lessons Learned</td>
<td>FPGA - RTAX4000DSP</td>
<td>INTEL Processors</td>
<td>SiGe - TI</td>
<td>TBD</td>
<td>32nm CMOS</td>
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<td>FPGA Standard Test</td>
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<td></td>
<td>TBD</td>
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<td>Structured ASICs</td>
<td>JAZZ</td>
<td>SiGe - other</td>
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<tr>
<td>NVM Standard Test</td>
<td>FLASH</td>
<td>ST Micro</td>
<td>GaAs HEXFETs</td>
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<td>Cryo SEL Guide</td>
<td>DDR2/3</td>
<td>Lyric Semiconductor</td>
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<td>FLASH - current spike anomaly</td>
<td>Power MOSFETs</td>
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<td>Ultra-ELDRS</td>
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<td>MAESTRO</td>
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</table>

*Not a complete list*
Summary

• NEPP provides both
  – Nuts and bolts support, and
  – Leading edge evaluation to NASA and the aerospace community
• FY11 rad efforts still under definition phase, but emphasis on “generic issues” and RHA
• Use the NEPP website to look at detailed results
  – http://nepp.nasa.gov
• Always looking for collaborations!