The NASA Electronic Parts and Packaging (NEPP) Program – Overview for FY14

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Unclassified

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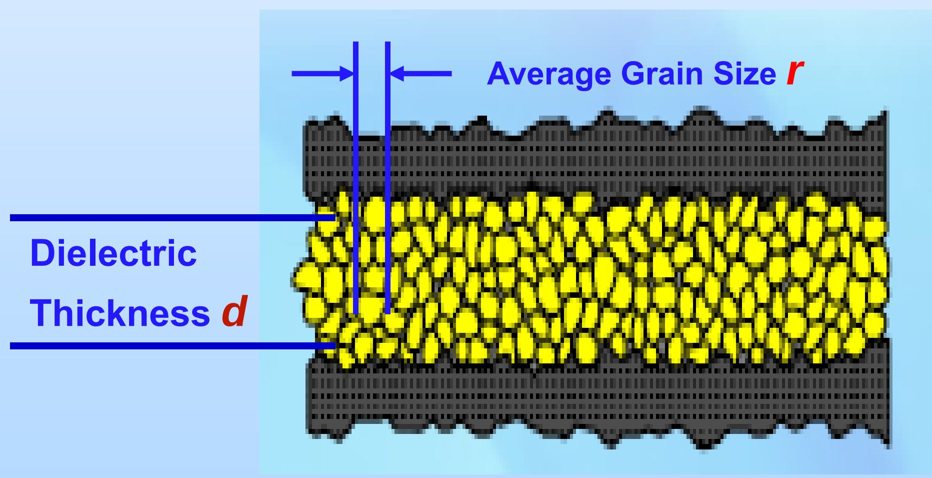
Outline

- Acronym List
- Overview of NEPP
  - What We Do and Who We Are
  - Working with Others
- Plans for FY14
- Recent Highlights
- Parts "Graveyard"
- Summary



Multi-Layer Ceramic Capacitor (MLCC)

Acronyms (page 1 of 2)

Acronym	Definition
3D	Three Dimensional
ADC	Analog to Digital Converter
Aero	Aerospace
ARC	Ames Research Center
BME	Base Metal Electrode
BOK	Body of Knowledge
CALCE	Center for Advanced Life Cycle Engineering
CAVE	Center for Advanced Vehicle and Extreme Environment Electronics
CBRAM	Conductive Bridging Random Access Memory
CCAs	Standard Capacitance
CMOS	Complementary Metal Oxide Semiconductor
CNES	Centre National d'Etudes Spatiales
COP	Community of Practice
CSA	Canadian Space Agency
DAC	Digital to Analog Converter
DARPA	Defense Advanced Research Projects Agency
DC	Direct Current
DDR	Double Data Rate
DLA/DSCC	Defense Logistics Agency Land and Maritime
DLA-VA	Defense Logistics Agency Land and Maritime, Document Standardization Division
DLA-VQ	Defense Logistics Agency Land and Maritime, Sourcing and Qualifications Division (VQ)
DSP	Digital Signal Processor
DTRA	Defense Threat Reduction Agency (DTRA)
EEE	Electrical, Electronic, and Electromechanical
ELDRS	Enhanced Low Dose Rate Sensitivity

Acronym	Definition
EP	Engineering Practices
EPARTS	NASA Electronic Parts Database
ESA	European Space Agency
ETW	Electronics Technology Workshop
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FPGA	Field Programmable Gate Array
FT	fault tolerance
FY	Fiscal Year
G11	Component Parts Committee
G12	Solid State Devices Committee
GaAs	Gallium Arsenide
GaN	Gallium Nitride
GIDEP	Government Industry Data Exchange Program
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
HALT	Highly Accelerated Life Test
HiREV	High Reliability Virtual Electronics Center
IARPA	Intelligence Advanced Research Projects Activity
IBM	International Business Machines
ICBM	Intercontinental Ballistic Missile
ICs	Integrated Circuits
IP	Intellectual Property
IR	Infrared
JAXA	Japanese Space Agency
JEDEC	Joint Electron Device Engineering Council
JHU-APL	Johns Hopkins University Applied Physics Laboratory

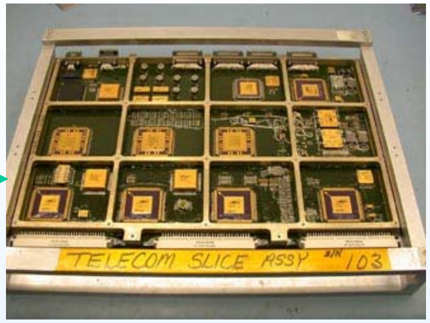
Acronyms (page 2 of 2)

Acronym	Definition
JPL	Jet Propulsion Laboratories
JSC	Johnson Space Center
KSC	Kennedy Space Center
LaRC	Langley Research Center
LEAP	Leading Edge Access Program
MDA	Missile Defense Agency
MEMS	Microelectromechanical Structure
MIL	Military
MLCC	Multi-Layer Ceramic Capacitor
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MRQW	Microelectronics Reliability and Qualification Working Meeting
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NAVSEA	Naval Sea Systems Command
NEN	NASA Engineering Network (NEN)
NEPAG	NASA Electronic Parts Assurance Group
NEPP	NASA Electronic Parts and Packaging
NGC	Northrop Grumman Corporation
NPSL	NASA Parts Selection List
NRO	National Reconnaissance Office
NSA	National Security Agency
NSP	National Space Programs
NSWC	Naval Surface Warefare Center
PA	Parts Analysis
PBGA	Plastic Ball Grid Array

Acronym	Definition
PCB	printed circuit boards
POF	Physics of Failure
PoF	Physics of Failure
POL	Point of Load
QML	Qualified Manufacturer List
QML-Y	Qualified Manufacturers List Class Y
RERAM	Resistive Random Access Memory
RERAM	Resistive Random Access Memory
RF	Radio Frequency
SAE	Society of Automotive Engineers
SAS	Supplier Assessment System
SEU	Single Event Upset
SiC	Silicon Carbide
SMC	Space and Missile Command
SME	subject matter expertise
SOC	Systems on a Chip
SW	Southwest
TI	Texas Instruments
TiW	Titanium Tungsten
TMR	Triple Modular Redundancy
TRL	Technology Readiness Level
US	United States
USAF	United States Air Force
USN	United States Navy
VCS	Voluntary Consensus Standards
VNAND	Vertical NAND
XRTC	Xilinx Radiation Test Consortia

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.**



PCB from Mars Rover
Image courtesy NASA

Image courtesy BAE Systems

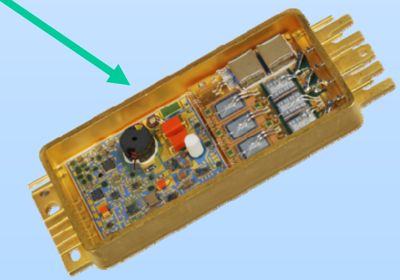


Image courtesy NASA

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EEE Parts and Space

- **EEE parts are available in "grades"**
  - **Designed and tested for specific environmental characteristics.**
    - **E.g., Operating temperature range, vacuum, radiation exposure,…**
  - **Examples: Aerospace, Military, Automotive, Medical, Extended-Temperature-Commercial, and Commercial.**
- **Aerospace Grade is the traditional choice for space usage, but has relatively few available parts and their performance lags behind commercial counterparts (speed, power).**
  - **Designed and tested for radiation and reliability for space usage.**
- **NASA uses a wide range of EEE part grades depending on many factors (technical, programmatic, and risk).**
  - ***NEPP is the Agency's independent view for understanding "safe" usage.***

NEPP Overview

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

Qualification guidance
To flight projects on how to qualify

Standards
Ensures NASA needs are represented

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

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

Technology Evaluation
Determine new technology applicability and qualification guidance

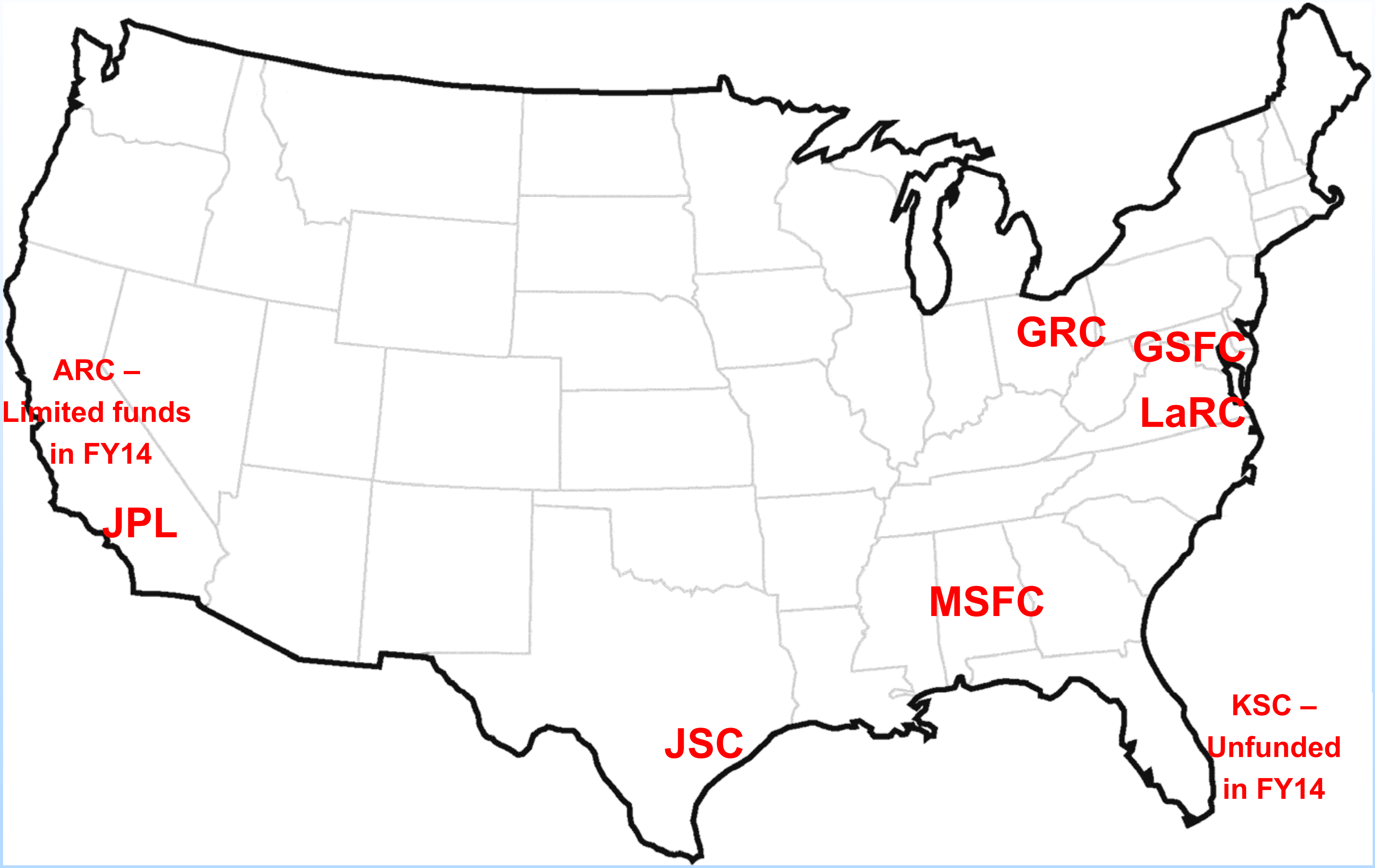
Test/Qualification Methods
Evaluate improved or more cost-effective concepts

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

Subject Matter Expertise
SMEs for NASA programs, other agencies, industry

NEPP and its subset (NASA Electronic Parts Assurance Group – NEPAG) are the Agency's POCs for reliability and radiation tolerance of EEE parts and their packages.

NEPP at the NASA Centers



NASA Electronic Parts Assurance Group (NEPAG)

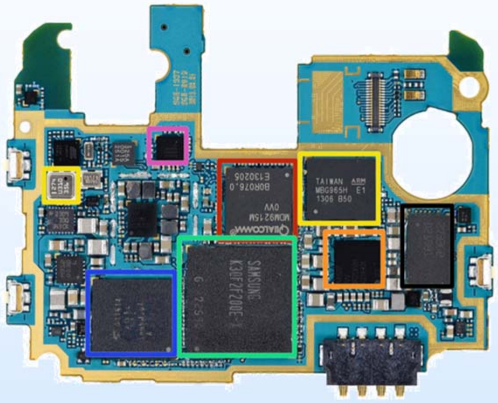
- *Subset of NEPP formed in 2000*
- **Weekly telecons**
  - **Typical participation ~ 25**
  - **Share knowledge and experience**
  - **Address failures, requirements, test methods**
  - **Monthly international**
- **Audit support**
- **Coordinate specification and standards changes**

Sharing NEPP Knowledge

- **NEPP success is based on providing appropriate guidance to NASA flight projects.**
  - **Interaction with the aerospace community, other government agencies, universities, and flight projects is critical.**
- **NEPP utilizes**
  - **NEPP Website (http://nepp.nasa.gov),**
  - **NEPP 5th Annual Electronics Technology Workshop (ETW): June 17-19, 2014,**
    - **High Reliability Virtual Electronics Center (HiREV) day planned**
  - **NEW: EEE Parts for Small Missions, Sep 10-11, 2014**
  - **Standards working groups,**
  - **Telecons (NEPAG weekly and monthly international), and,**
  - **Documents such as Guidelines, Lessons Learned, Bodies of Knowledge (BOKs), and, Technical Papers.**

How NASA is Changing: NEPP Workshop on EEE Parts for Class D Missions and CubeSats

- **NEPP held a one day agency-internal workshop at NASA/GSFC on Sep 24, 2013.**
  - **160 attendees participated across the agency.**
    - **Roughly 50% on-site, 50% via the web**
  - **It was co-sponsored by NASA Offices of Safety and Mission Assurance and NASA Chief Engineer.**
  - **The workshop covered presentations on:**
    - **Examples from various Centers (GSFC, JPL, and ARC),**
    - **Electronics challenges and classes of electronics, and**
    - **Discussion of "go-forward" approaches, relevant guidance, and guidelines/policy.**
  - **Post-workshop plans include:**
    - **Develop "rule of thumb" guidance in the near,**
    - **Develop more detailed guidelines/policy as appropriate in FY14,**
    - **Organize a new NASA Engineering Network (NEN) Community of Practice (COP),**
    - **Coordinate with EPARTS database for features applicable to Class D/CubeSats,**
    - **Modify NEPP evaluation plans to more actively support CubeSat (generic) needs (i.e., use of automotive electronics, "standard" recommended parts, etc…), and**
    - **Consider alternative part qualification evaluation focusing on effectiveness of board level test approaches.**



Galaxy S4 Phone Processor Board

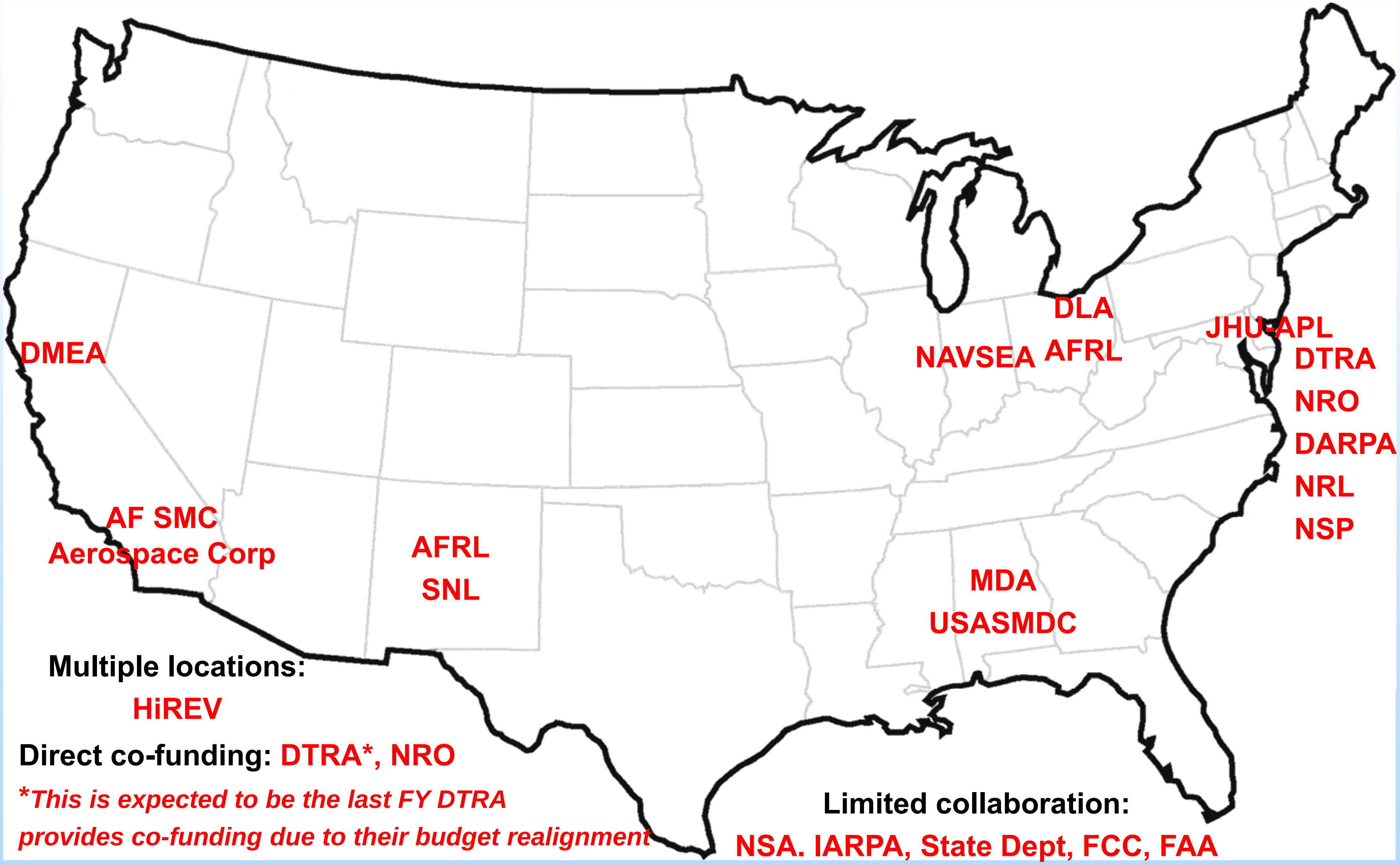
http://www.ifixit.com/Teardown/Samsung+Galaxy+S4+Teardown/13947/2

This small motherboard provides an order of magnitude more processing capability than a traditional military/radiation hardened option. Options like this have already been flown on CubeSats, but "rules" don't exist on determining appropriate risk/reliability trades for specific needs.

NEPP Partnerships

- Collaboration with other U.S. Government Agencies:
  - Co-funding of radiation effects efforts with Defense Threat Reduction Agency (DTRA) and National Reconnaissance Office (NRO),
  - In-kind efforts and information exchange with DTRA, AFSMC, AFRL, NAVSEA, DMEA, MDA, DARPA, NRL, DLA, USASMDC, SNL
    - HiREV is included in this category, and,
  - We occasionally provide subject matter expertise (SME) to other agencies on point issues (FCC, State, IARPA, FAA, NSA).
- Information exchange with international space agencies (JAXA, ESA, CNES, CSA).
- Collaboration with industry via in-kind efforts (review, test, samples)
  - Long list ranging from capacitors to FPGAs
- Collaboration with universities
  - Unfunded due to budget cuts
- Formal consortia and working group participation

Other U.S. Government Agency Partners –
Information Exchange and In-Kind



Multiple locations:
HiREV

Direct co-funding: DTRA*, NRO

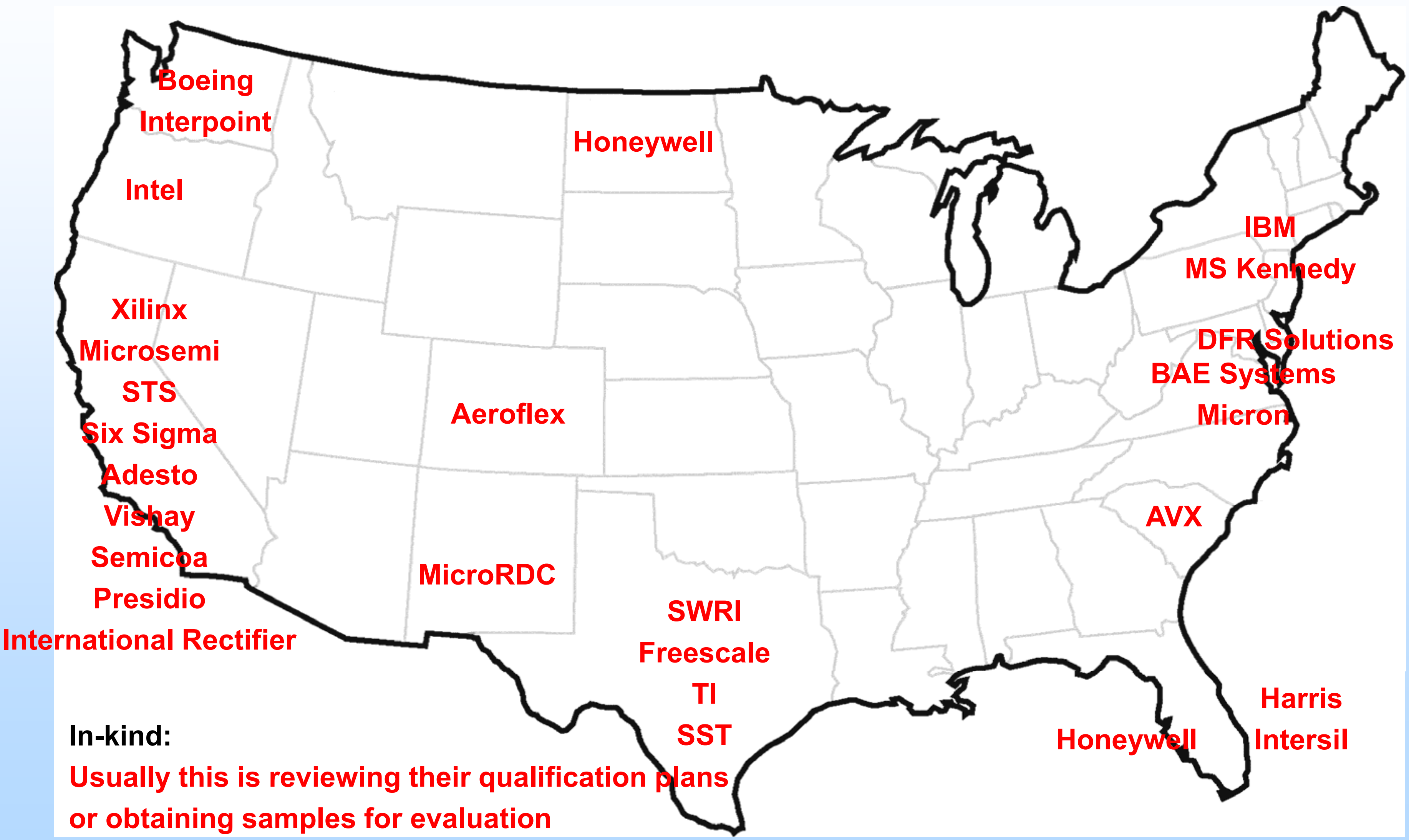
Limited collaboration:
NSA. IARPA, State Dept, FCC, FAA

**This is expected to be the last FY DTRA provides co-funding due to their budget realignment*

NEPP – International Agencies

Information Exchange Partners

Example U.S. Industry Partners –
In-Kind



In-kind:

Usually this is reviewing their qualification plans or obtaining samples for evaluation

NEPP: Universities and Consortia –
Budget Cuts Have Impacted Participation

- NEPP retains a leadership role in JEDEC and SAE G11/G12 working groups:
  - Develop standards for qualification.
- NEPP budget cuts over the last 5 years have reduced NEPP's ability to fund agency participation in consortia:
  - CAVE (Auburn),
  - CALCE (University of MD), and,
  - AVSI (Aerospace Industry).
- University research no longer funded at:
  - Vanderbilt University,
  - Georgia Tech,
  - Auburn,
  - ASU, or
  - U of MD.

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

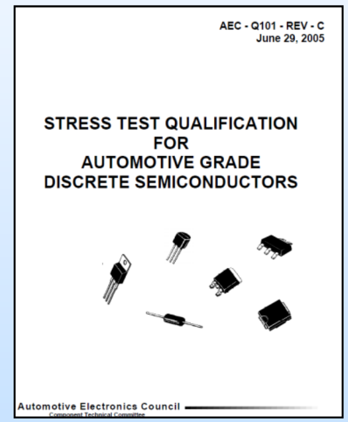
HiREV utilizes test structures for detailed knowledge (model first).

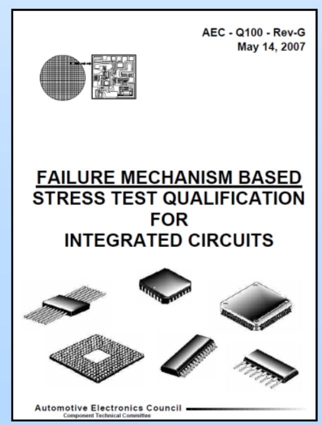
NEPP utilizes commercial product for general knowledge (test first).

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

FY14 - NEPP Evaluation of
Automotive Electronic Parts

- **Questions to be answered:**
  - ***What are automotive grade parts, who makes them, what standards exist, and can NASA leverage them for reliable use in space?***
- **NEPP objectives:**
  - **Develop a BOK on automotive grade parts,**
  - **Test a range of electronic parts (capacitors to transistors to processors), and**
  - **Develop a guideline for NASA usage.**
- **Testing will be performed by NASA and NSWC Crane.**
- **Early results on selected automotive grade capacitors indicate aging/de-aging behavior variance.**
  - **This behavior could be due to dielectric differences between military-grade parts and the selected test articles (higher volumetric efficiency).**



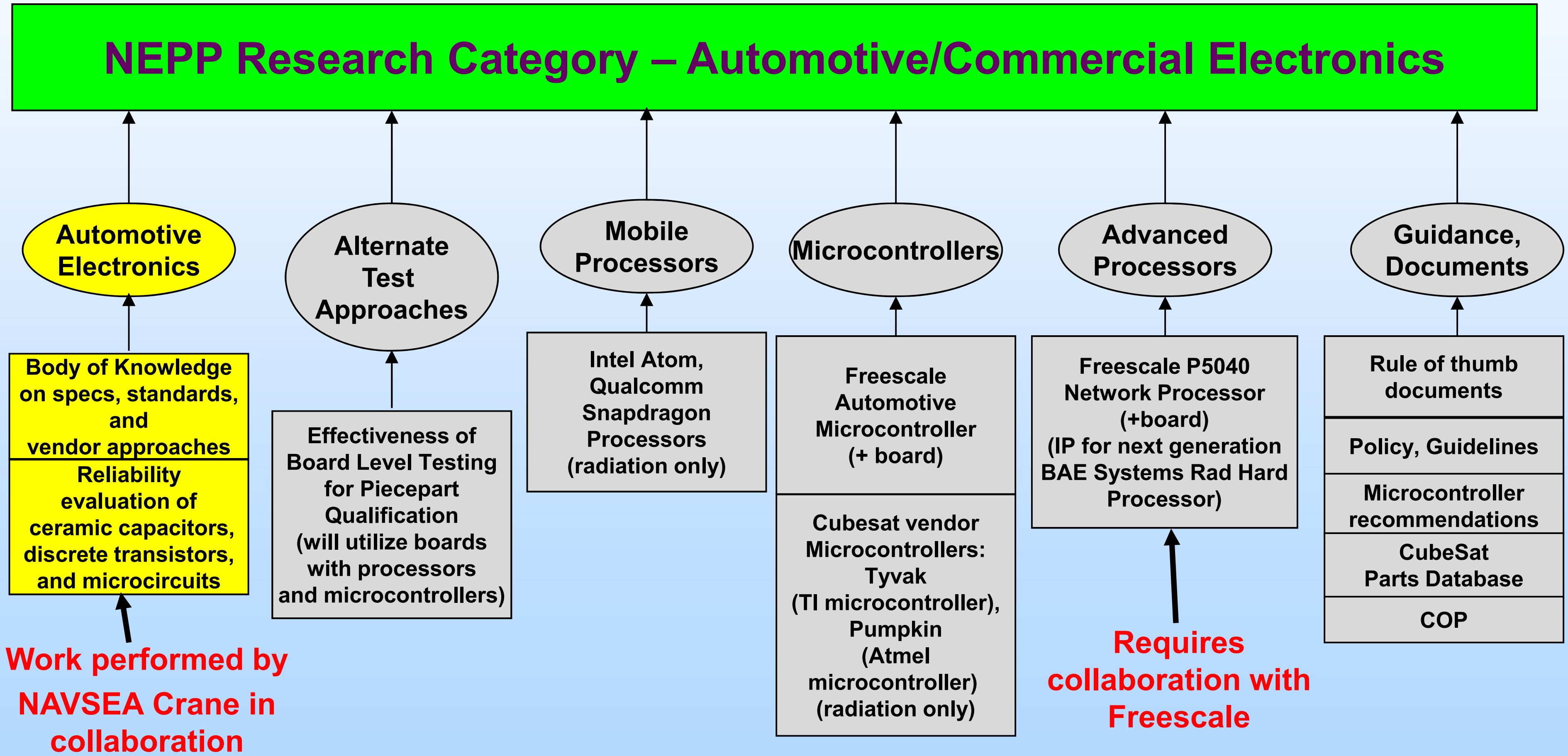


http://www.aecouncil.com/AECDocuments.html

FY14 NEPP Core –
Automotive/Commercial Electronics (Small Missions)

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

Legend
NEPP Ongoing Task
FY14 Proposed New Start



FY14 NEPP Core - Complex Devices

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

Legend

- NEPP Ongoing Task
- FY14 Proposed New Start

NEPP Research Category – Complex Devices

FPGAs – Radiation

- Xilinx Virtex 5QV
- Commercial Xilinx 28nm Virtex-7, Kintex-7
- FPGA SOCs Xilinx Zynq, Microsemi SmartFusion 2
- New Microsemi and ATMEL
- Embedded Coldfire™

FPGAs – Reliability

- Xilinx Virtex 5QV Daisy Chain Package Evaluation
- FPGA SOCs Xilinx Zynq, Microsemi SmartFusion 2

Area Array Packages

- Class Y QML
- Class Y and IPC
- HALT for PBGA
- Thermal Interface Materials
- Solder Bump Comparison
- Flip Chip Interconnect

Memory Devices

- Resistive Memory (RERAM, CBRAM) Radiation, Reliability
- 3D Structure FLASH Memory Samsung VNAND Radiation, Reliability
- DDR3 Memory Radiation, Reliability

Advanced CMOS

- IBM trusted foundry 14-32 nm Radiation
- Intel 14 nm Radiation
- DARPA LEAP Program (32 nm) Radiation

Assurance

- Memory Fault Coverage
- SOC Radiation
- Synopsys TMR Tool Evaluation

FY14 NEPP Core - Power Devices

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

Legend
- NEPP Ongoing Task
- FY14 Proposed New Start

NEPP Research Category – Power Devices

Power Converters
- DC-DC Converter Working Group
- POL SEU Susceptibility

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

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

Assurance
- Standards Support

FY14 NEPP Core - Assurance

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

Legend

- NEPP Ongoing Task
- FY14 Proposed New Start

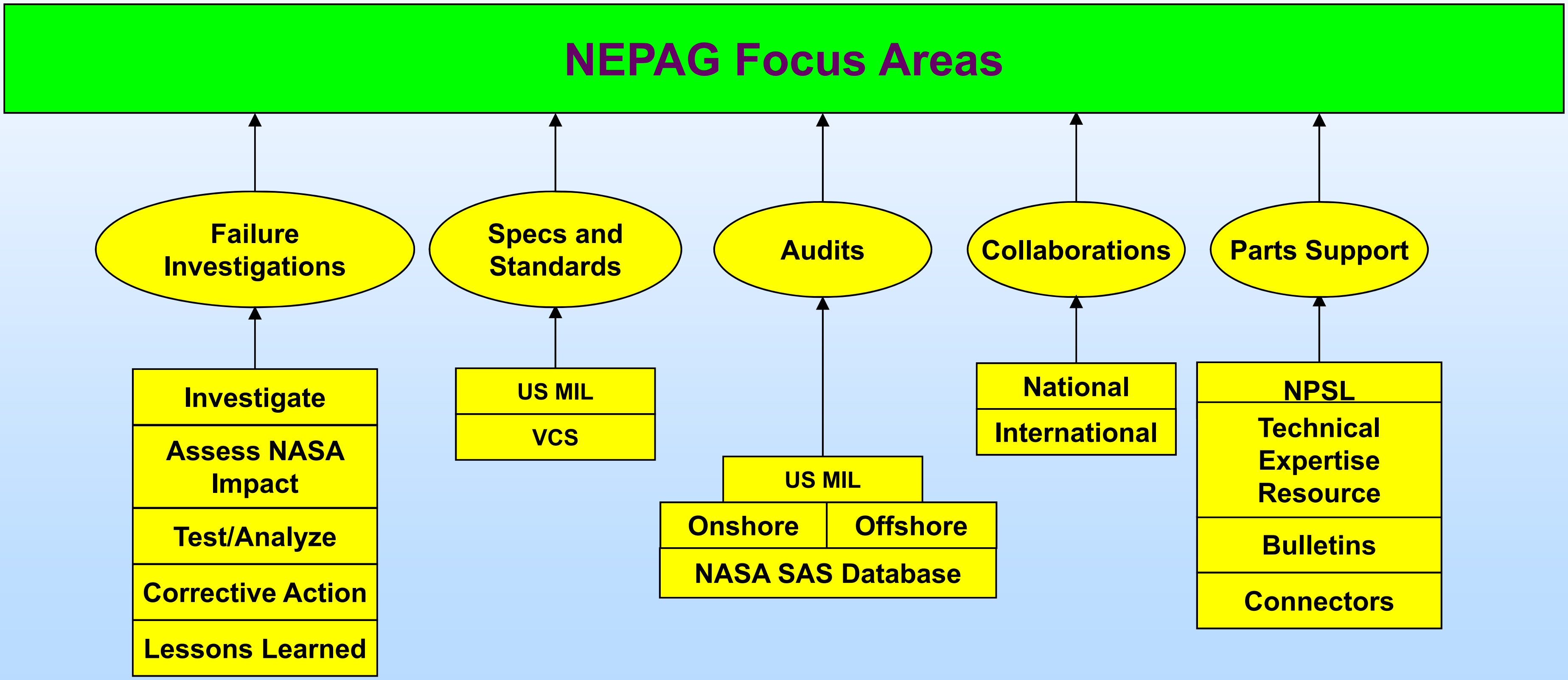
NEPP Research Category – Assurance

- **Radiation**
  - Hydrogen Effects
  - Ultra-ELDRS
  - Board level proton testing BOK
- **Parts**
  - Hermeticity
  - BME Capacitors
  - Ceramic Capacitors
  - Tantalum Capacitors
- **Packaging**
  - NEPP Roadmap Update
  - Leadless Package Trends
- **Assurance**
  - Connector Working Group
  - Low Proton Energy Test Guideline
  - NASA Parts Policy Update
  - Radiation Assurance Policy/Guidance
  - Long term Storage BOK

NASA Electronic Parts Assurance Group (NEPAG)

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

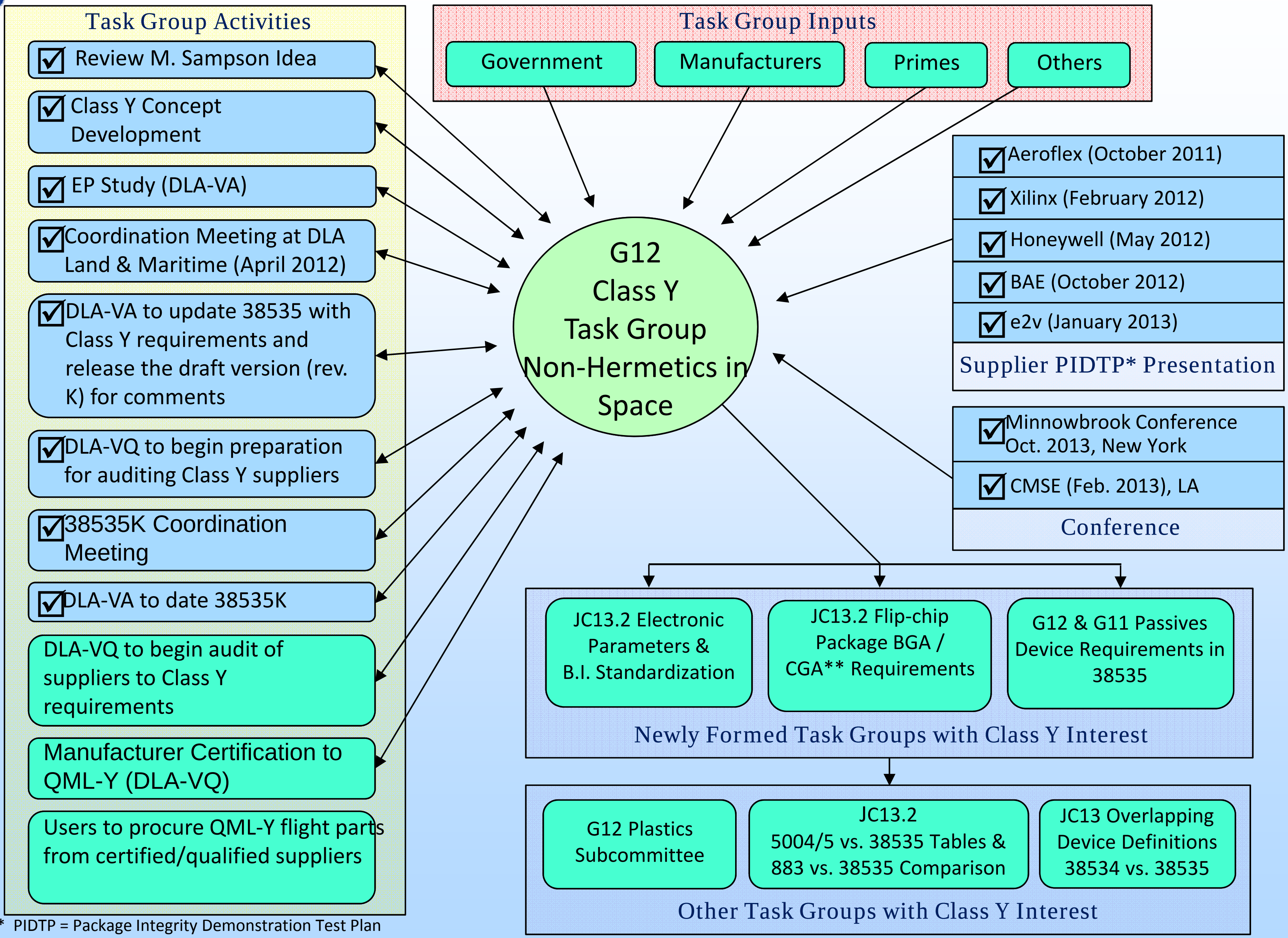
Legend
NEPP Ongoing Task
FY14 Proposed New Start



Sample Overguide Task Areas

- Fiber Optics
- Sensor Technologies (IR, visible, etc…)
- SiGe Advanced Mixed Signal
- ADC/DACs
- GaAs Electronics
- Connector Evaluation
- 3D Packages
- Flexible Electronics
- MEMS
- University Research
- CAVE/CALCE Memberships

Infusion of New Technology into the QML System
G12 Class Y Effort at a Glance



* PIDTP = Package Integrity Demonstration Test Plan

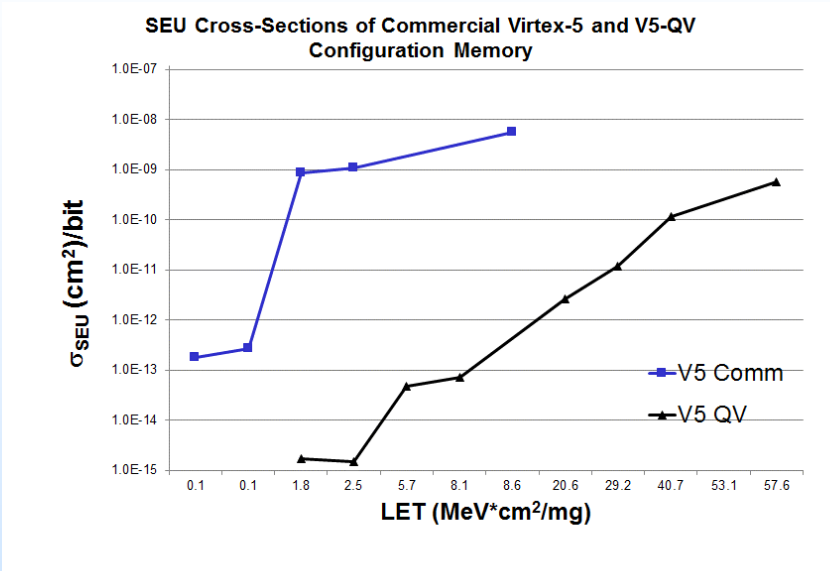
** BGA / CGA = ball-grid array / column-grid array

Xilinx V5QV FPGA – SEU Designs Tested

Test Structure	Frequency Range	Additional Fault Tolerance*
Shift registers	2KHz-300MHz	Yes
Counters	2k-150MHz	Yes
Global routes	2k-150MHz	Yes
MicroBlaze™	50MHz	Yes
Digital Signal Processors (DSP blocks)	2K-300MHz	No

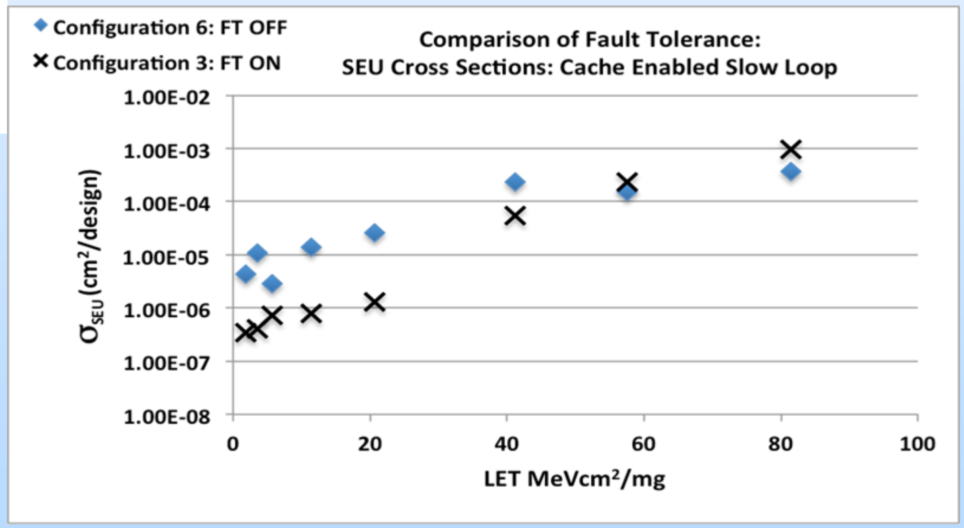
* Designs tested with additional fault tolerance also tested sans fault tolerance

Sample V5QV SEU Test Results



Configuration memory sensitivity measured was similar to that taken by the Xilinx Radiation Test Consortia (XRTC).

Note the improvement (i.e., reduced sensitivity) of the V5QV versus the commercial V5.



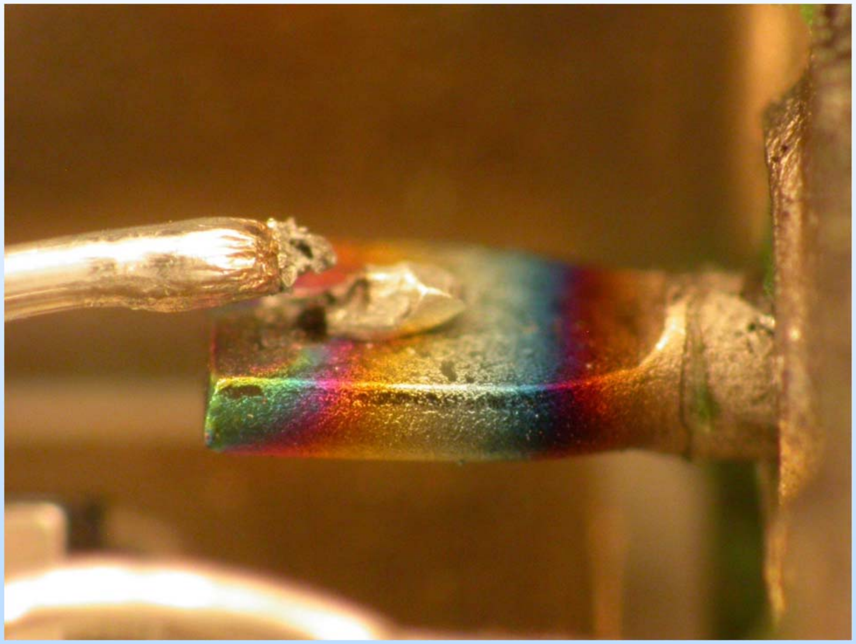
A sample of the data taken on test designs showing MicroBlaze™ processor results with fault tolerance (FT) on versus off.

Note that the FT only helps at lower LETs, but is defeated at LETs above 40.

"Somewhere Over the Rainbow"

- **Part Type:** **Power Rectifier**
- **Description:**
  External mechanical stress caused catastrophic damage to the lead 3 glass seal that allowed movement of the lead and resulted in the propagation of a crack at the heel of the wire bond at the lead paddle inside the device. As the crack grew, the current path traversed a decreasing cross-sectional area of wire with an increasing electrical resistance and corresponding joule heating. The heating was such that the aluminum wire became liquid in the vicinity of the crack along the length of wire leading to the die. Residual bending stress caused the wire to spring up, disconnecting the wire. The final assault was arcing and vaporization of the last remnant of aluminum filament connecting the lead and wire.

  Workmanship and quality control are partially to blame for this failure. However, the ultimate cause of this failure was the assembly design that did not anticipate the tremendous mechanical stress that could be imposed on the delicate glass feed-through seals of this device.



Courtesy of Jay Brusse and Chris Greenwell
ASRC Federal at NASA/GSFC Code 562

"Is this A-Peeling to You?"

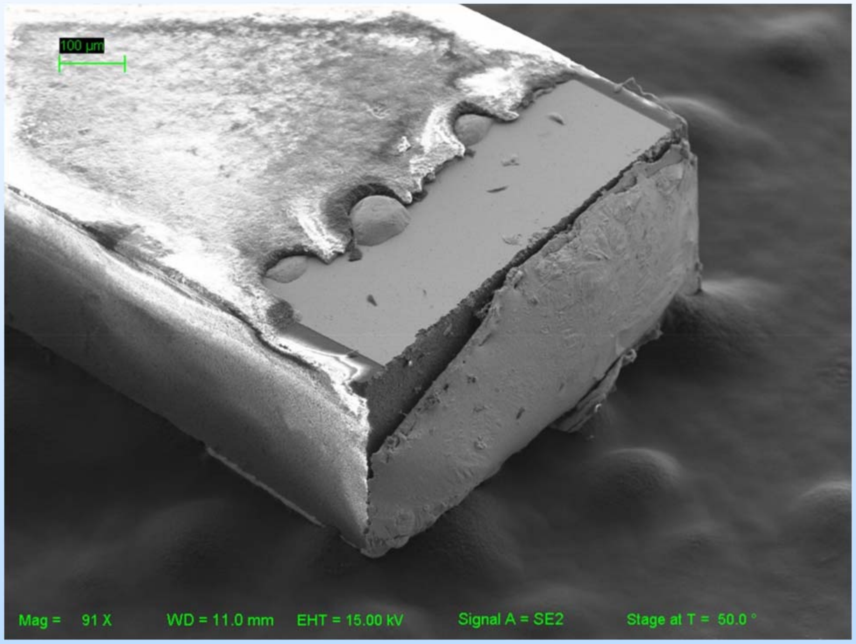
- **Part Type: 100 ohm Thin Film Chip Resistor**

- **Description:**
  The as-received condition in the Parts Analysis (PA) Lab revealed that the end termination metallization on one end was missing down to the TiW layer and that the end face metal was peeling from the alumina substrate. The device measured 5.7 kΩ between the end faces. Probing from the top side TiW layer to the good end revealed 100 Ω.

  The analysis suggests two unrelated failure mechanisms:

  1) defect in the nickel strike-to-nickel plate layers that allowed molten solder to consume or penetrate the very thin nickel strike layer and dissolve the gold layer, and

  2) improper thickness or adhesion of the TiW layer on the end face that allowed a void to develop that subsequently resulted in the observed failure. These mechanisms indicate a manufacturing defect and not an end user mishap.

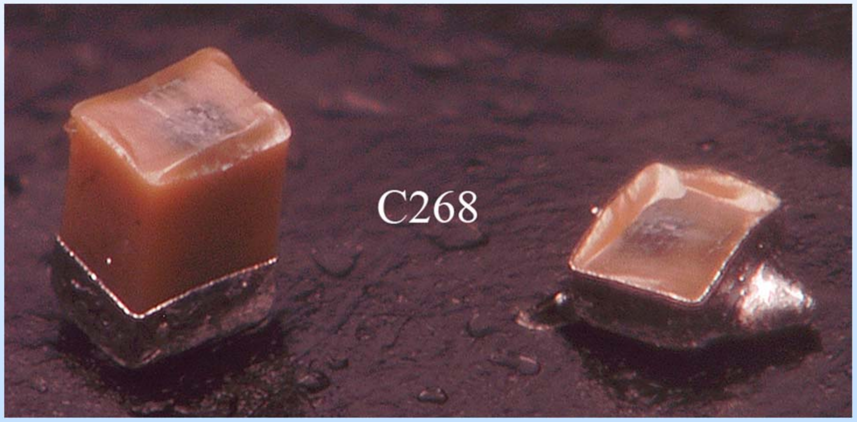


Courtesy of Jay Brusse and Chris Greenwell
ASRC Federal at NASA/GSFC Code 562

“The Front Fell Off”

- **Part Type: Ceramic Chip Capacitor**

- **Description:**
  The capacitor appears to have cracked during initial installation of the component to the CCA. Initial installation includes the original solder reflow and the probable hand solder touch-up. It is suspected that the touch-up process may have produced stresses (especially tensile stress) to the capacitor and that this resulted in the observed cracking beneath one end termination. Factors that may have contributed to the cracking failure of the capacitor include tensile forces applied to the capacitor by tools used to solder the components to the CCAs.



Courtesy of Jay Brusse and Chris Greenwell
ASRC Federal at NASA/GSFC Code 562

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 use of evaluated technologies),
  - Never forgetting our partners, and
  - Attempting to do "less with less" (static budget versus rising costs).
- We invite your feedback and collaboration. Please visit our website (http://nepp.nasa.gov).
- Join us at our annual meeting in June at NASA/GSFC or Small Missions Workshop in Sep.
- Questions?