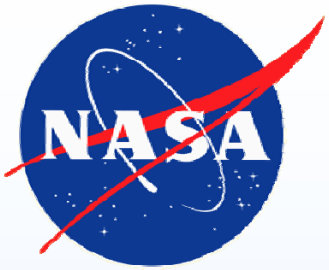

Memories and NASA Spacecraft: Part 2 – Future Developments

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Presented by Kenneth A. LaBel at the 11th European Conference on Radiation and its Effects on Components and Systems (RADECS) conference, Radiation Effects on Non Volatile Memories Thematic Workshop, 9/20/2010, Langenfeld, Austria.

Abstract

- **In this presentation, we delineate the NASA Electronic Parts and Packaging (NEPP) approach to future NVM evaluation and qualification efforts**

Outline of Presentation

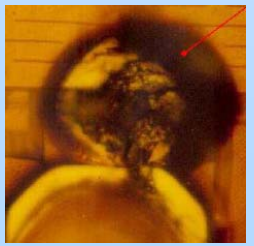
- NEPP Overview
- NEPP General FY11 Plans
- NEPP and NVMs

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.
- NEPP does not qualify specific devices, but determines HOW to qualify as well as investigating new radiation/reliability concerns

Electrical overstress failure

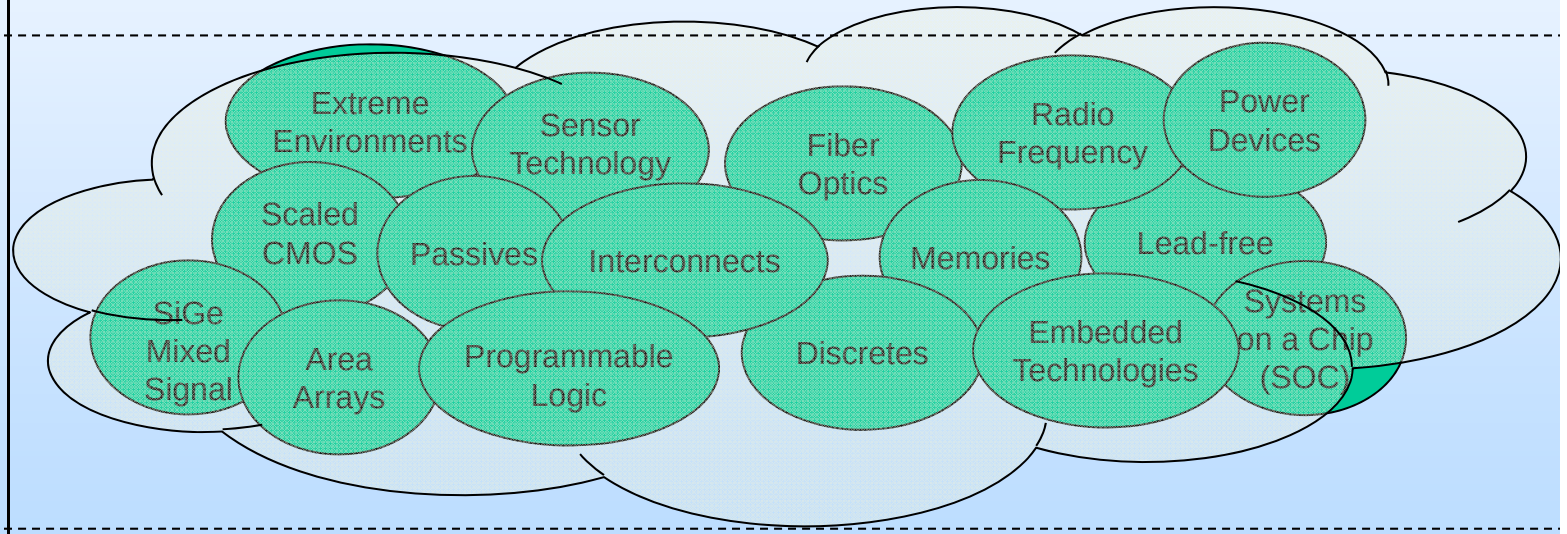
in a commercial electronic device



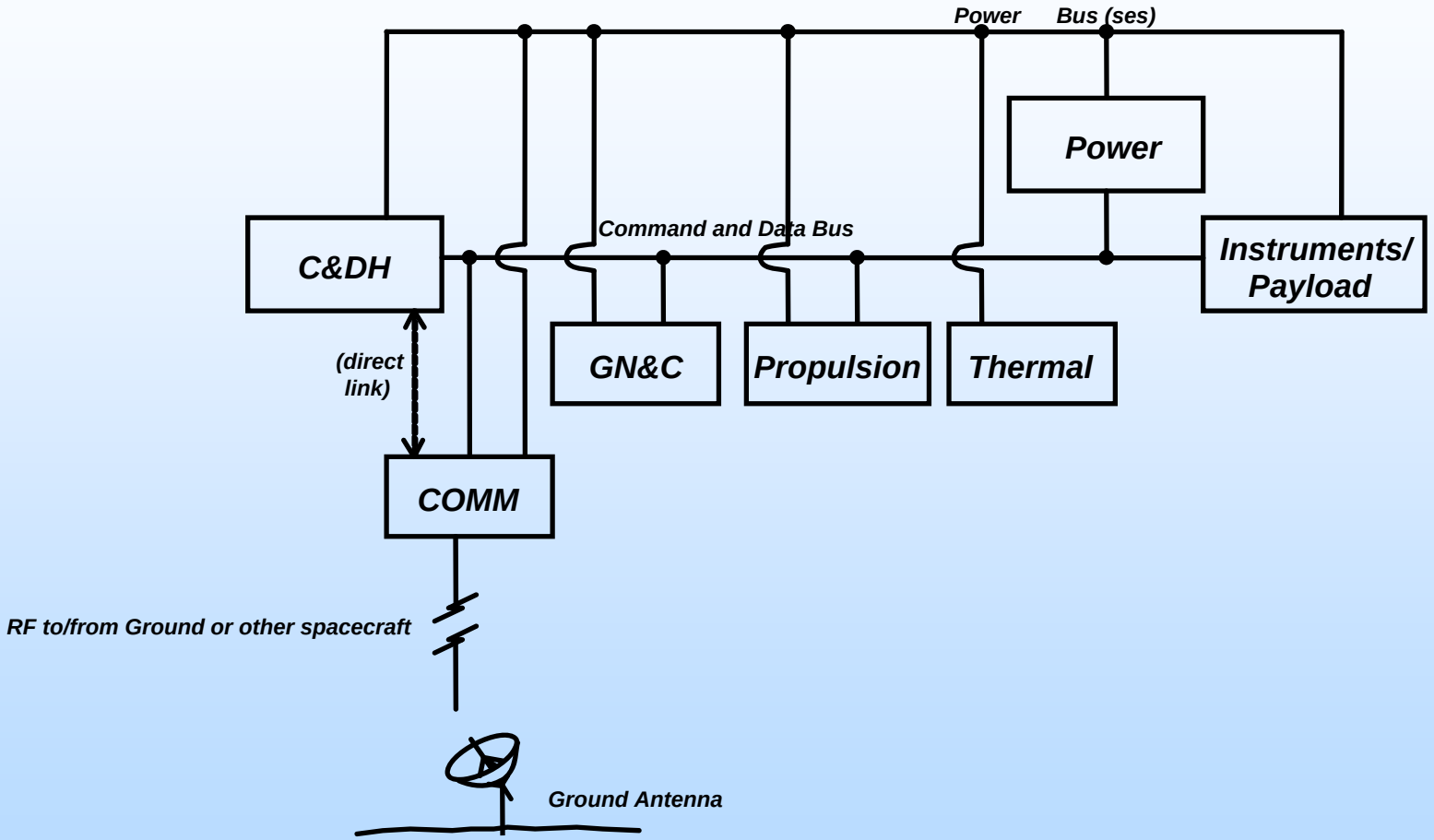
NEPP Works Two Sides of the Equation

- **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**

The NEPP Program

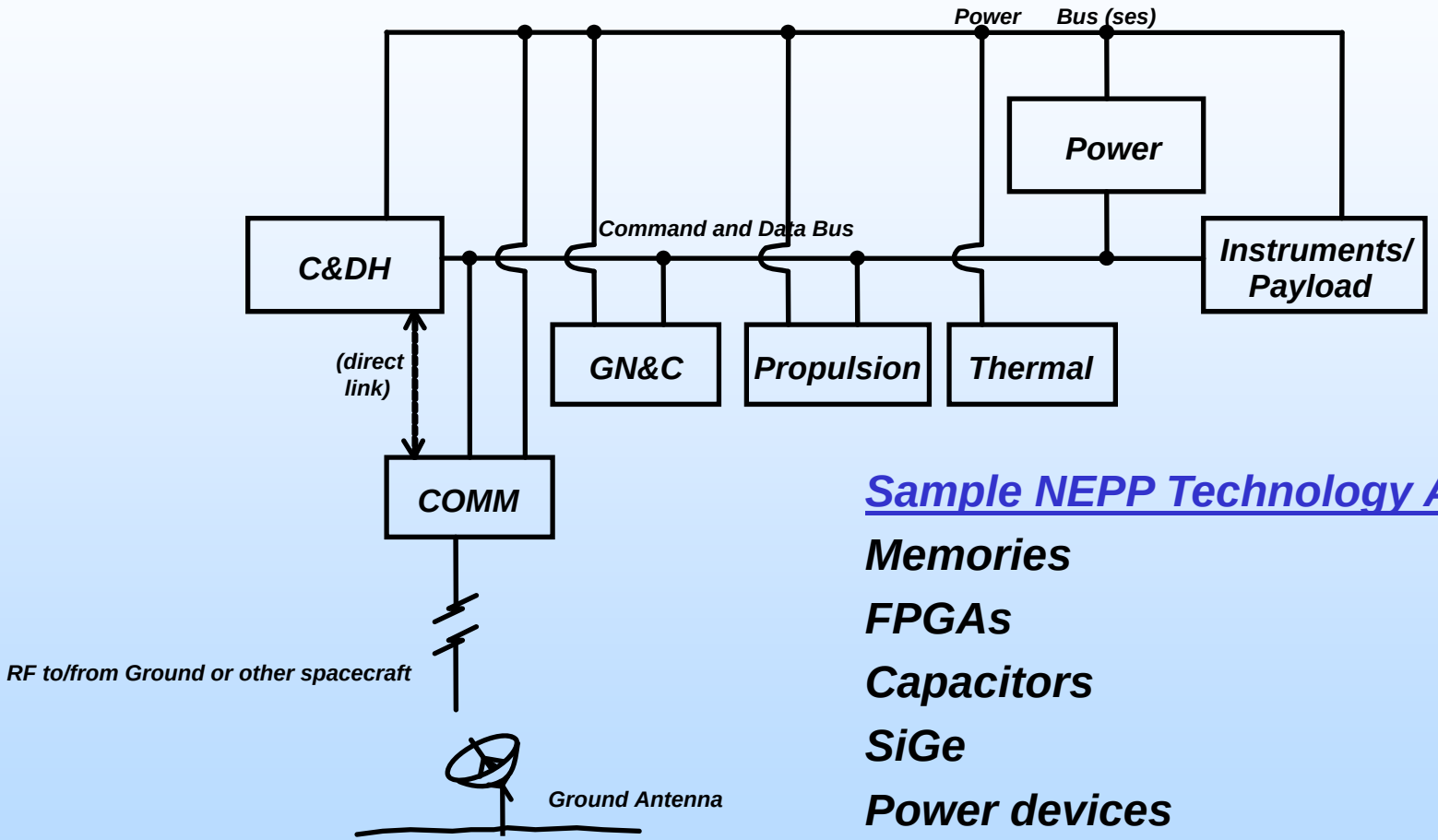
Management	**Ken LaBel** Radiation Effects Advanced Actives NEPP Events **Mike Sampson** NEPAG Passives Packaging
Core Elements	Electronic Parts Reliability Radiation Effects Parts Assurance (NEPAG) Advanced Packaging Information Dissemination
Focus Technologies	
Products/ Deliverables	Guidelines Specifications and Standards Test Methods Website Content NASA Parts Selection List Tools Data Technical Reports Bodies of Knowledge Conference Papers

Typical Spacecraft Electrical Architecture



Typical Spacecraft Electrical Architecture

The 90/90 Goal



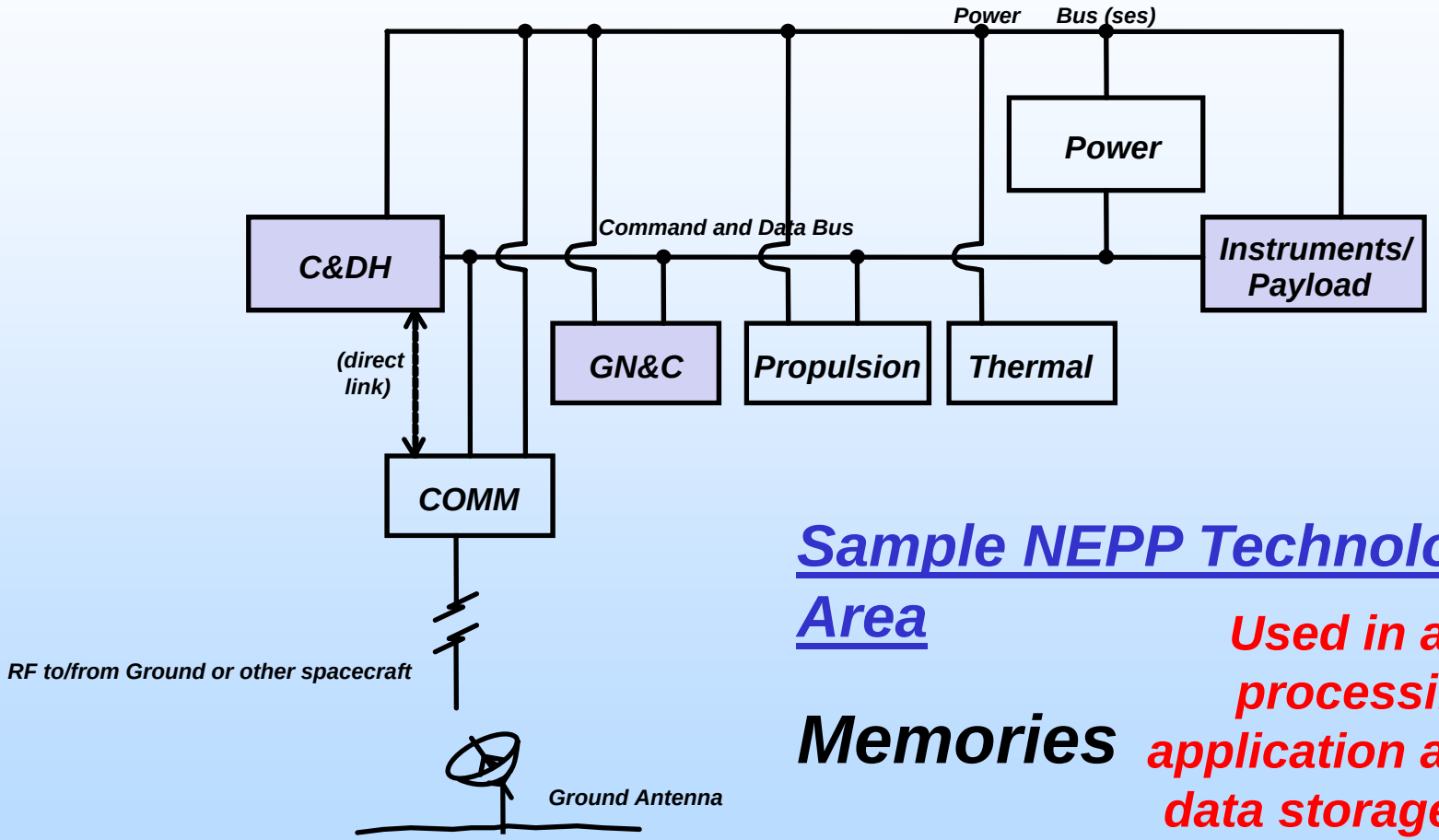
Sample NEPP Technology Areas

- 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 Area

Memories

Used in any processing application and for data storage on a spacecraft.

Generic issue!

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**
- **Currently in FY11 planning cycle**
  - ***PRELIMINARY PLANS FOLLOW***
    - **Active devices only shown (packaging, NEPAG – not shown)**

FY11 Radiation Plans for NEPP Core (1)

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

Legend
- DoD and NASA funded
- NASA-only funded
- Overguide

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

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

Sensor Technologies
- IR
- Visible
- Cryo SEL
- Others

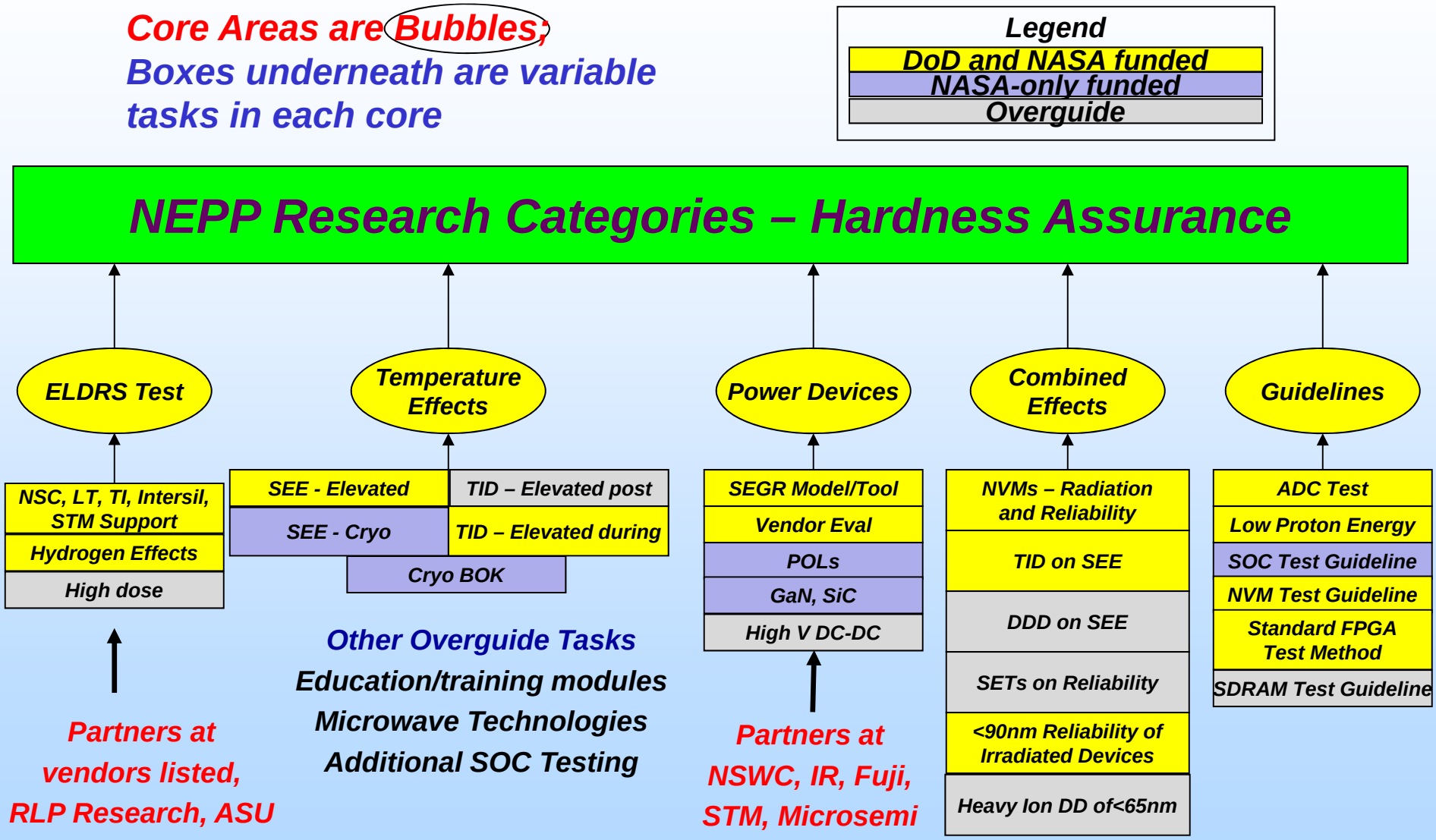
Partners at:

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

FY11 Radiation Plans for NEPP Core (2)



FY11 Parts Plans for NEPP Core (1)

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

Legend
NASA-only funded
Overguide

NEPP Research Categories – Parts Assurance

SiGe. Mixed Signal	*Scaled CMOS*		*Sensor Technologies*	*Photonics*	*Rf Electronics*
Cold temperature effects	*Commercial Devices*	*Test Structures*	*IR*	*Fiber Amplifiers*	*RF Reliability Guide*
Scaled SiGe	*Memories – Non-volatile*	*Silicon on Insulator (SOI)*	*Visible*	*Exotic-doped Fiber components*	*Advanced RF*
Advanced Data Conversion, Amplifiers, Drivers		*Ultra-low power*	*ROICs - Cryo*	*Wavelength Division Multiplexing*	
GaAs, InP, Antemonides	*FPGAs*	*32 and 45 nm*	*Others*	*Free space Optical interconnects*	
	Processors, SOCs	*CNTs*		*Fiber Data Links*	
	Memories - SDRAM	*Sub 90nm*		*Optocouplers and PM Optocouplers*	

FY11 Parts Plans for NEPP Core (2)

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

Legend
NASA-only funded
Overguide

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

NEPP and Memories

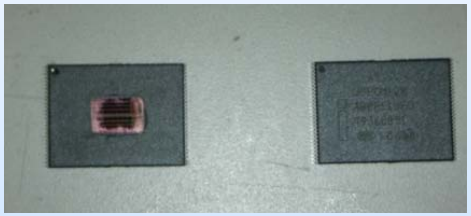
- **Top level agenda**
  - **Evaluate scaled commercial SDRAMs and NVMs**
    - **Radiation tests first**
      - ***If reasonable, reliability and combined radiation/reliability***
  - **Work with new memory technologies and manufacturers considering entry into Mil/Aero market**
    - **PCM**
    - **MRAM**
    - **RRAM**
    - **DDR3, and so on**
  - ***We do not QUALIFY devices, but evaluate suitability of devices and determine appropriate qualification methods and physics of failure***

NEPP Radiation Evaluations - NVM

- **Commercial Flash Memories**
  - **Manufacturers evaluated (1-32 Gb per device)**
    - **Micron, Samsung, Hynix, …**
    - **TID is mostly > 50 krads-Si**
      - **Biased/unbiased tests**
      - **Low and high dose rate tests (only Samsung showed significant improvement at low dose rates)**
    - **Most NVM cells have fairly good SEU tolerance and it's the surrounding circuits that have SEU sensitivity**
      - **SEL varies by manufacturer**
        - » **Current spikes noted during some heavy ion tests are being evaluated**
      - **SEFIs are a prime issue**
    - **Focus has been on Single Level Cell - SLC**
      - **Multi Level Cell - MLC has lower cell margins and data shows typically less radiation tolerance**
  - **Further scaled, MLC, and higher density to be evaluated in FY11**

Alternate Material NVMs – Repeat from This Morning

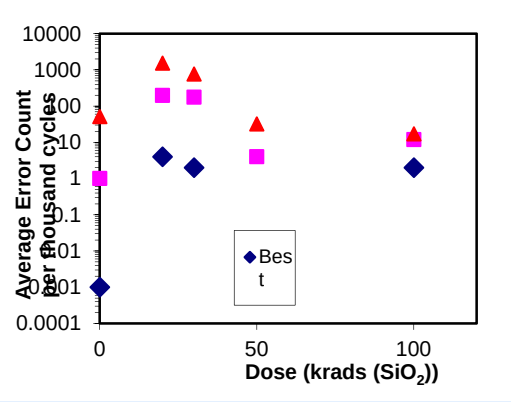
- Alternate material NVMs – evaluated as devices become available
  - Expect cell integrity to perform fairly well under irradiation on most NVMs
  - LaBel's Truism:
    - *There are ALWAYS more challenges in "qualifying" a new technology device than expected*
- Phase change memories (PCM)
  - Density, speed, and power look promising
    - Temperature is the challenge
  - Ex., Samsung, Numonyx – initial data taken
- MRAM
  - Spin Torque appears to improve SWaP metrics
  - Ex., Avalanche Technologies
- Resistive Memories
  - Ex., Unity Semiconductor, HP Labs
    - Unity's talking about a 64Gb device by next summer!
- NVSRAMs
  - Ex. Cypress
- CNT



Numonyx PCM –

Combining Radiation and Reliability - NVMs

- FY09 began new studies on Flash memories combining TID with endurance
  - Result: TID did NOT degrade endurance properties at room temperature
- Considerations for FY11
  - Perform TID and lifetime/data retention tests
    - Must be carefully planned since high temperature typically used for accelerated life/retention tests has two inherent issues with Flash/NVM
      - Anneals radiation damage
      - May cause bit flips above commercial operating temperatures
  - Develop radiation qualification guideline document
  - Continue efforts on reliability – latency, bit disturb, et al



New Flash Memory Tester - TID, Reliability, and Combined Effects