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

Kenneth A. LaBel
ken.label@nasa.gov
301-286-9936

Michael J. Sampson
michael.j.sampson@nasa.gov
301-614-6233

Co- Managers, NEPP Program
NASA/GSFC
http://nepp.nasa.gov

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

Open Access

To be presented by Kenneth A. LaBel at the 2016 MRQW Microelectronics Reliability and Qualification Working Meeting, HiREV Industry Day, El Segundo, CA, February 11, 2016.

Outline

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

Sundown at SCRIPPS Proton Therapy Center, Ken LaBel

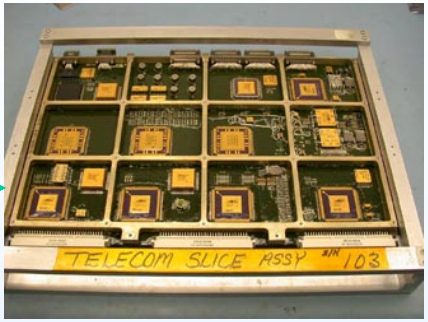
Acronyms

Acronym	Definition
3D	Three Dimensional
AF SMC	Air Force Space Command
AFRL	Air Force Research Laboratory
ARM	ARM Holdings Public Limited Company
BAE Systems	Marconi Electronic Systems (MES) and British Aerospace (BAe) merged to form BAE Systems
BGA	Ball Grid Array
BME	Base Metal Electrode
BOK	Body of Knowledge
CBRAM	Conductive Bridging Random Access Memory
CGA	Column Grid Array
CMOS	Complementary Metal Oxide Semiconductor
CN	CN package
COF	Chemistry of failure
COTS	Commercial Off The Shelf
CRÈME	Cosmic Ray Effects on Micro Electronics
DDR	Double Data Rate (DDR3 = Generation 3; DDR4 = Generation 4)
DLP	Digital Light Processing
DoD	Department of Defense
DSP	Digital Signal Processing
DTRA	Defense Threat Reduction Agency
EEE	Electrical, Electronic, and Electromechanical
EPC Gen	Electronic Product Code Generation
FeRAM	Ferroelectric Random-Access Memory
FinFET	Fin Field Effect Transistor (the conducting channel is wrapped by a thin silicon "fin")
FPGA	Field Programmable Gate Array
FY	Fiscal Year
GaN	Gallium Nitride
HALT	Highly Accelerated Life Test
HAST	Highly Accelerated Stress Test
HEMTs	High-Electron-Mobility Transistors
HP Labs	Hewlett-Packard Laboratories
IBM/GF	International Business Machines/Global Foundaries

Acronym	Definition
IC	Integrated Circuit
IR	Infrared
IR/Infineon	International Rectifier/Infineon
MBSE	Model-Based Systems Engineering
MOSFETs	Metal-Oxide-Semiconductor Field-Effect Transistors
MRAM	Magnetoresistive Random-Access Memory
MRQW	Microelectronics Reliability and Qualification Working Meeting
NASA	National Aeronautics and Space Administration
NAVY Crane	Naval Surface Warfare Center, Crane, Indiana
NEPAG	NASA Electronic Parts Assurance Group
NEPP	NASA Electronic Parts and Packaging
NGSP	Next Generation Space Processor
nm	nanometer
NOR	Not OR logic gate
PBGA	Plastic Ball Grid Array
PCB	Printed Circuit Board
POC	Point of Contact
POF	Physics of Failure
QFN	Quad Flat Pack No Lead
RAM	Random Access Memory
ReRAM	Resistive Random Access Memory
RH	Radiation Hardened
RTG4	Radiation-Tolerant Fourth-Generation
SCRIPS	SCRIPPS Proton Therapy Center
SDRAM	Synchronous Dynamic Random Access Memory
SEE	Single Event Effect
SERDES	Serializer/Deserializer
SiC	Silicon Carbide
SMEs	Subject Matter Experts
SOC	Systems on a Chip
TBD	To Be Determined
TI	Texas Instruments
TRL	Technology Readiness Level
TSMC	Taiwan Semiconductor Manufacturing Company
VNAND	Vertical NAND

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

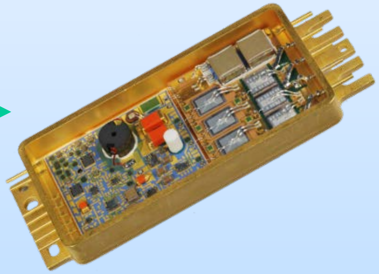
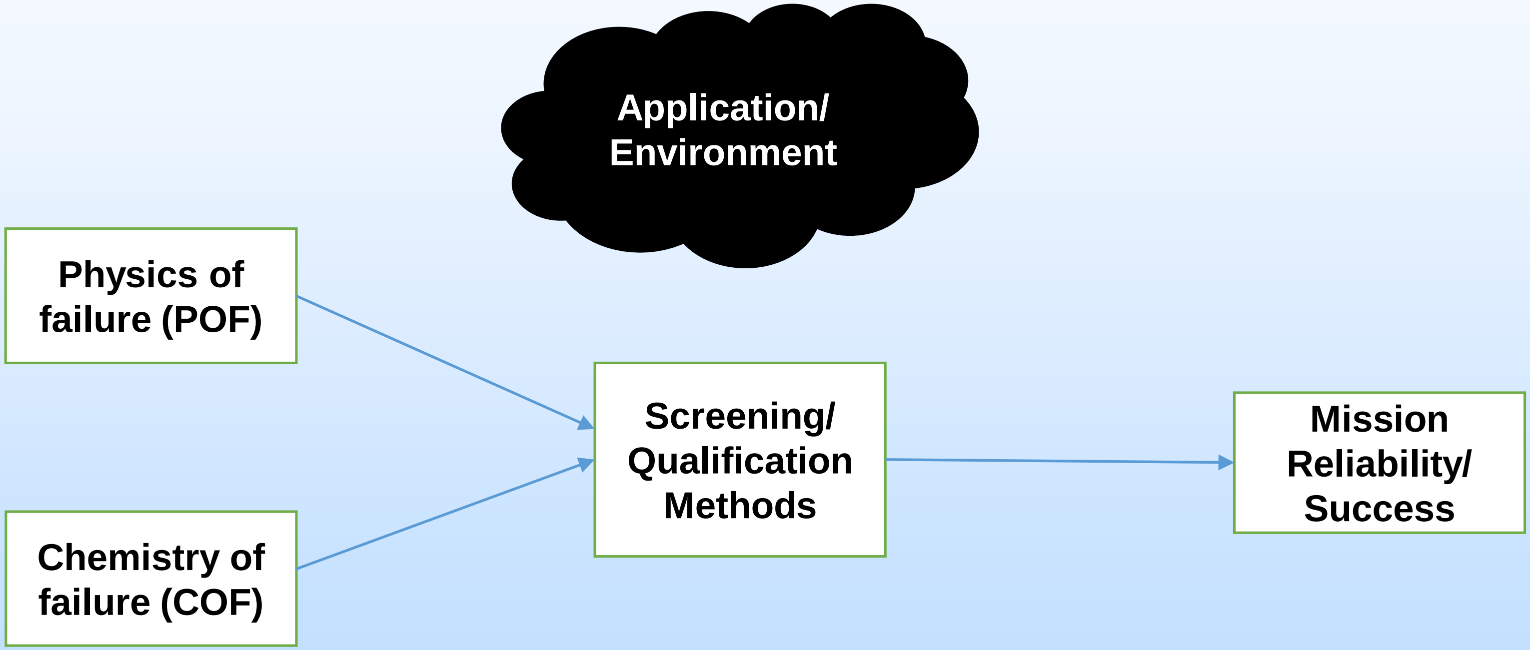


Image courtesy NASA

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

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 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.**

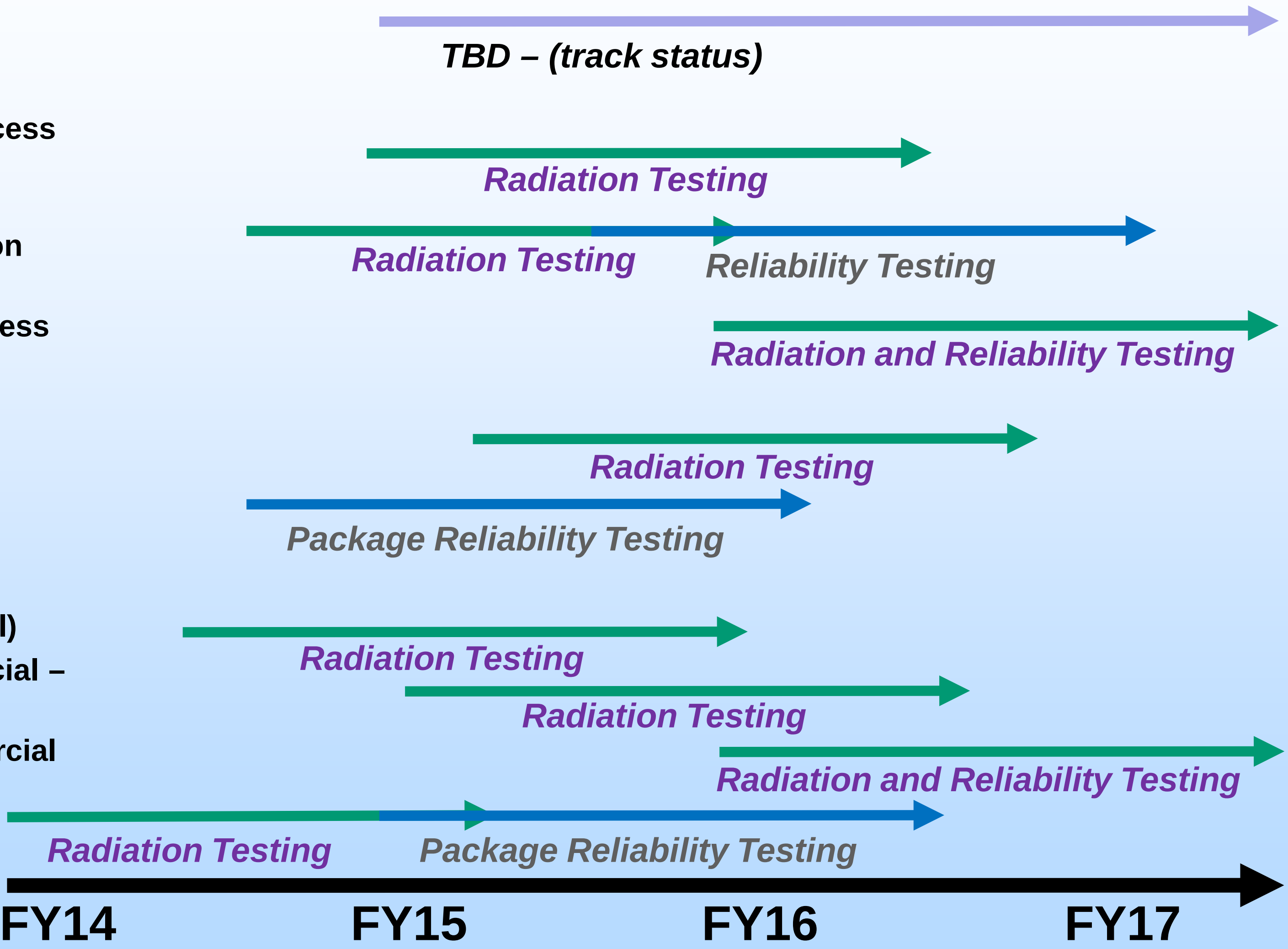
Field Programmable Gate Arrays (FPGAs)

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

Radiation Testing *Reliability Testing*

Radiation and Reliability Testing

Radiation Testing

Package Reliability Testing

Radiation Testing

Radiation Testing

Radiation and Reliability Testing

Radiation Testing *Package Reliability Testing*

Advanced Processors

Next Generation Space Processor (NGSP)

- Joint NASA-AFRL Program for RH multi-core processor
- TBD architecture/process

RH Processor

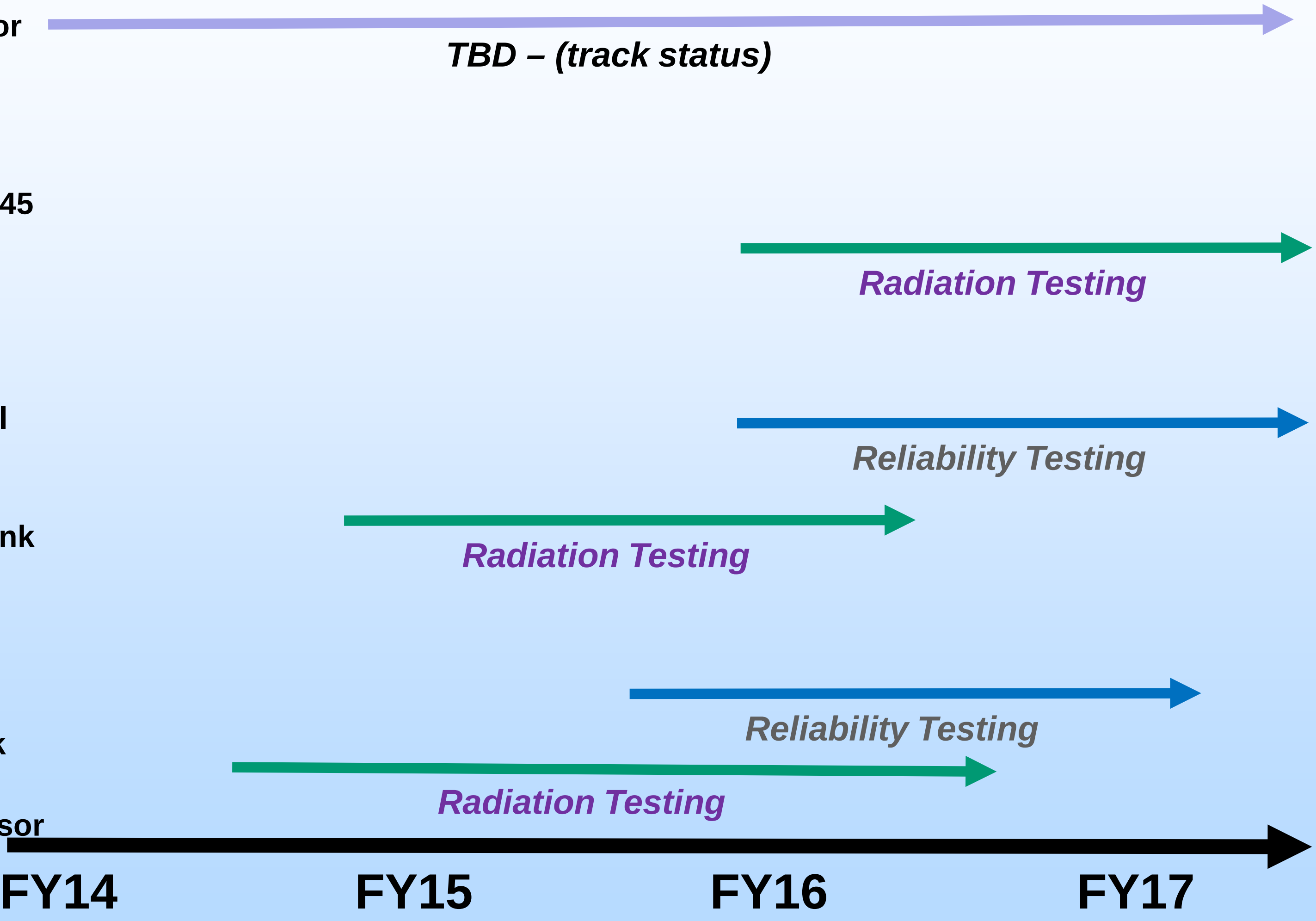
- BAE Systems RAD5510/5545
- Replacement for RAD750

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



TBD – (track status)

Radiation Testing

Reliability Testing

Radiation Testing

Reliability Testing

Radiation Testing

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

Microcontrollers and Mobile Processors (Small Missions)

TBD – other

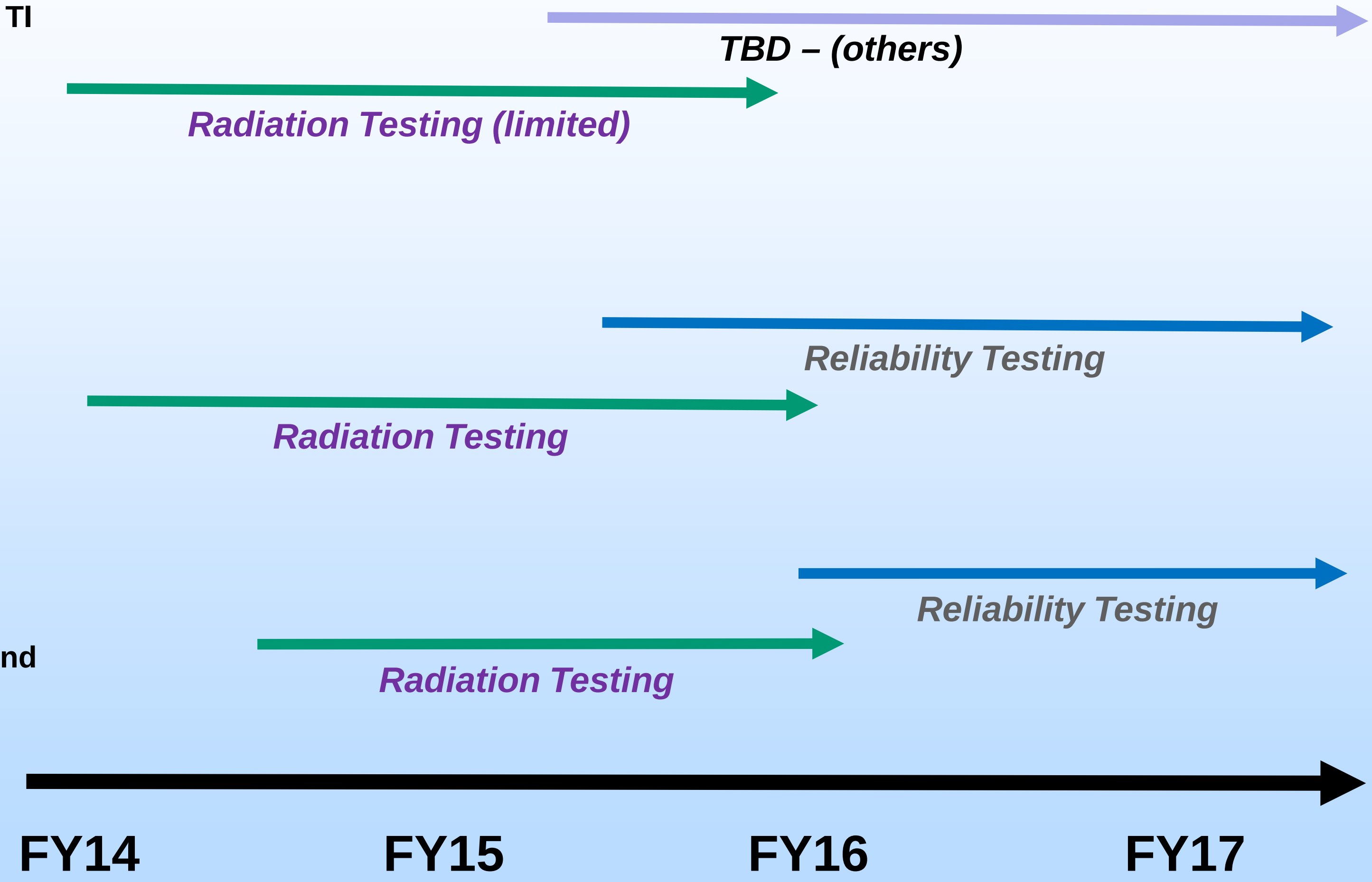
- Atmel AT91SAM9G20, and TI Sitara AM3703,
- ARM (Snapdragon), Intel Atom mobile

TI MSP430

- Popular CubeSat microcontroller
- Several varieties

Freescale MPC56XX

- 90nm on-shore fab
- Automotive Grade
- Being used for both part and board level testing



TBD – (others)

Radiation Testing (limited)

Reliability Testing

Radiation Testing

Reliability Testing

Radiation Testing

FY14 **FY15** **FY16** **FY17**

Commercial Memory Technology

- collaborative with Navy Crane

Other

- MRAM
- FeRAM

Resistive

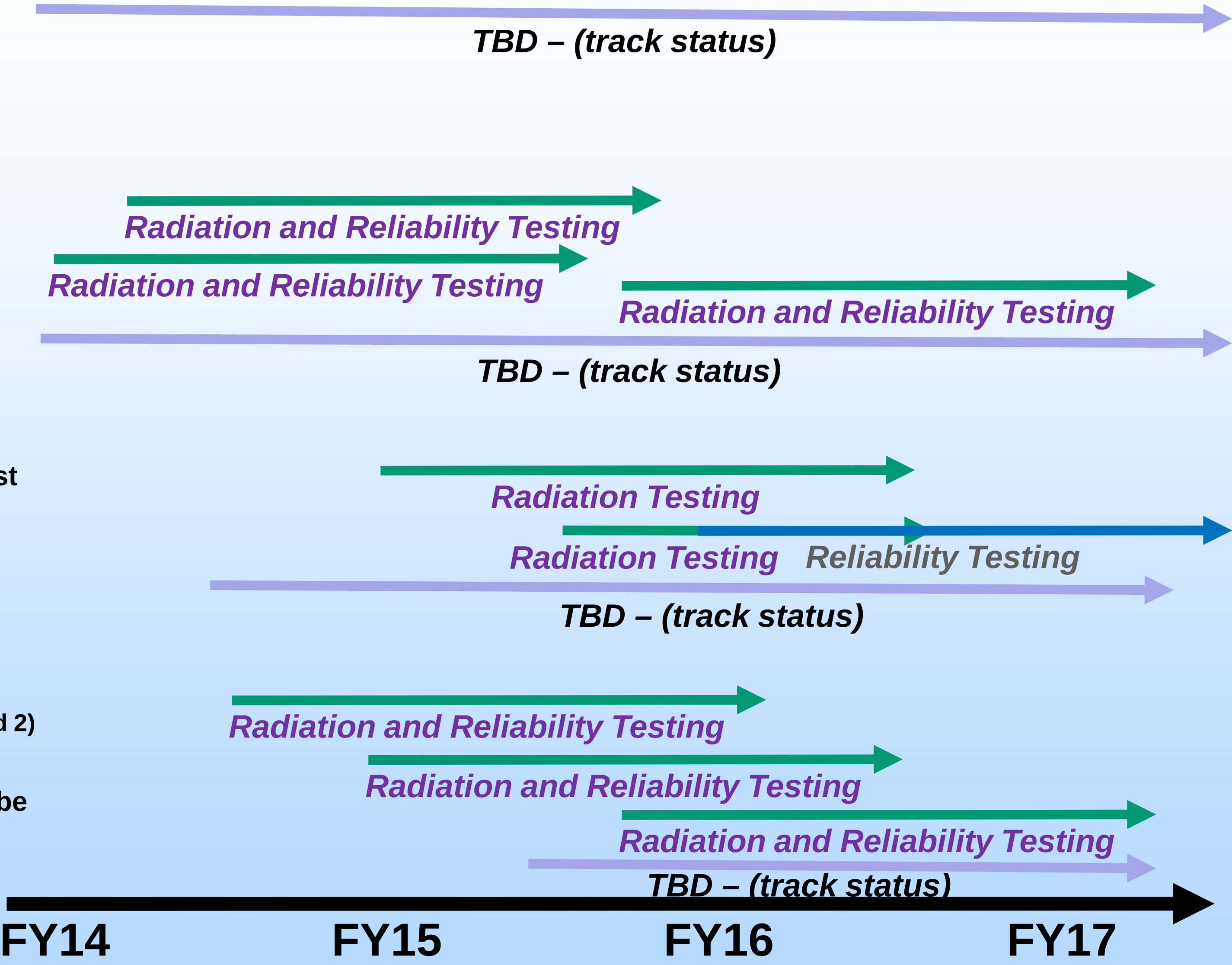
- CBRAM (Adesto)
- ReRAM (Panasonic)
- ReRAM (Tezzaron)
- TBD (HP Labs, others)

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



TBD – (track status)

Radiation and Reliability Testing

Radiation and Reliability Testing

Radiation and Reliability Testing

TBD – (track status)

Radiation Testing

Radiation Testing *Reliability Testing*

TBD – (track status)

Radiation and Reliability Testing

Radiation and Reliability Testing

Radiation and Reliability Testing

TBD – (track status)

Small Missions

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

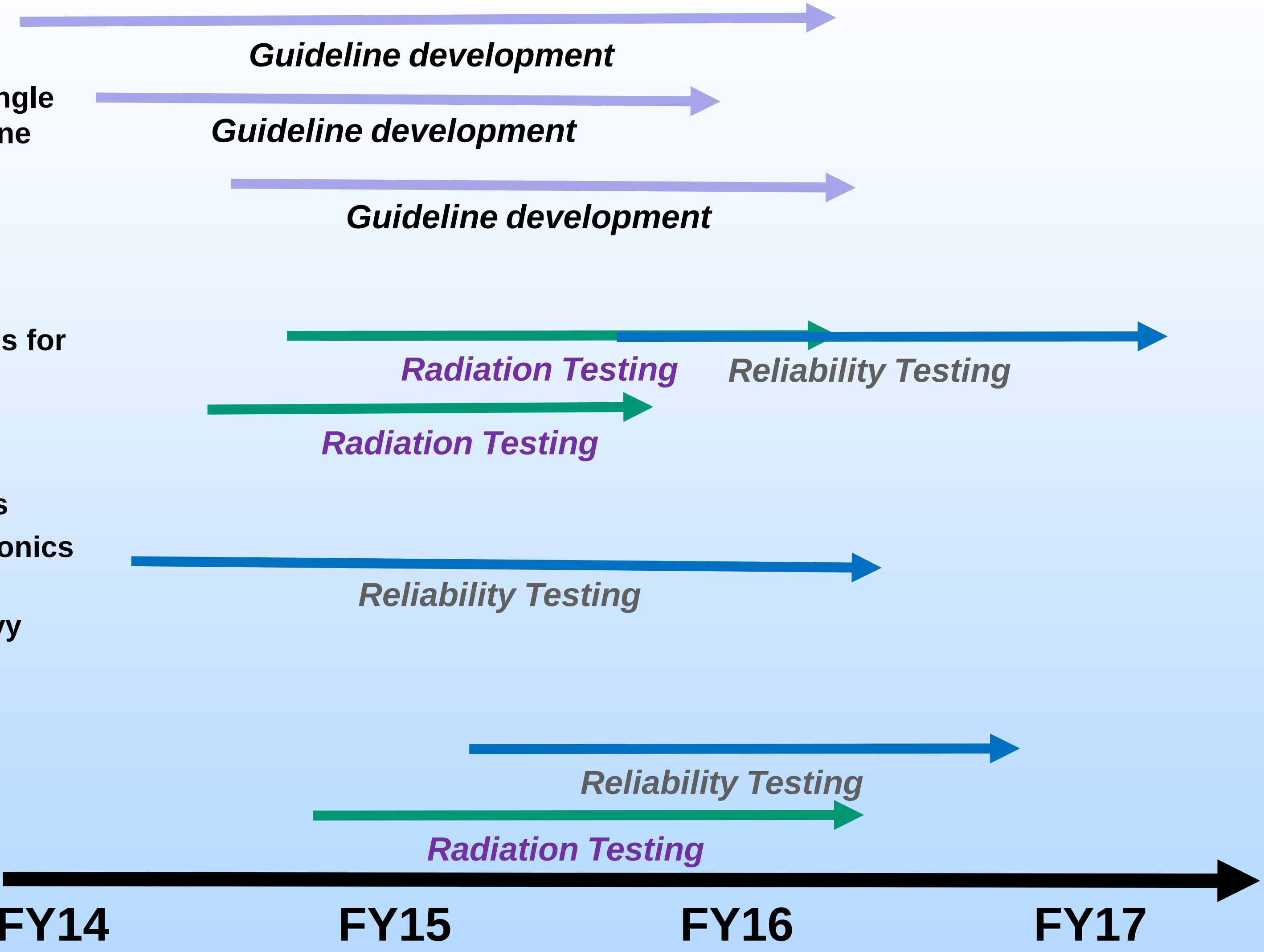
- See commodities roadmaps for processors, power
- CubeSat Star Tracker

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



Guideline development

Guideline development

Guideline development

Radiation Testing *Reliability Testing*

Radiation Testing

Reliability Testing

Reliability Testing

Radiation Testing

FY14 FY15 FY16 FY17

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)

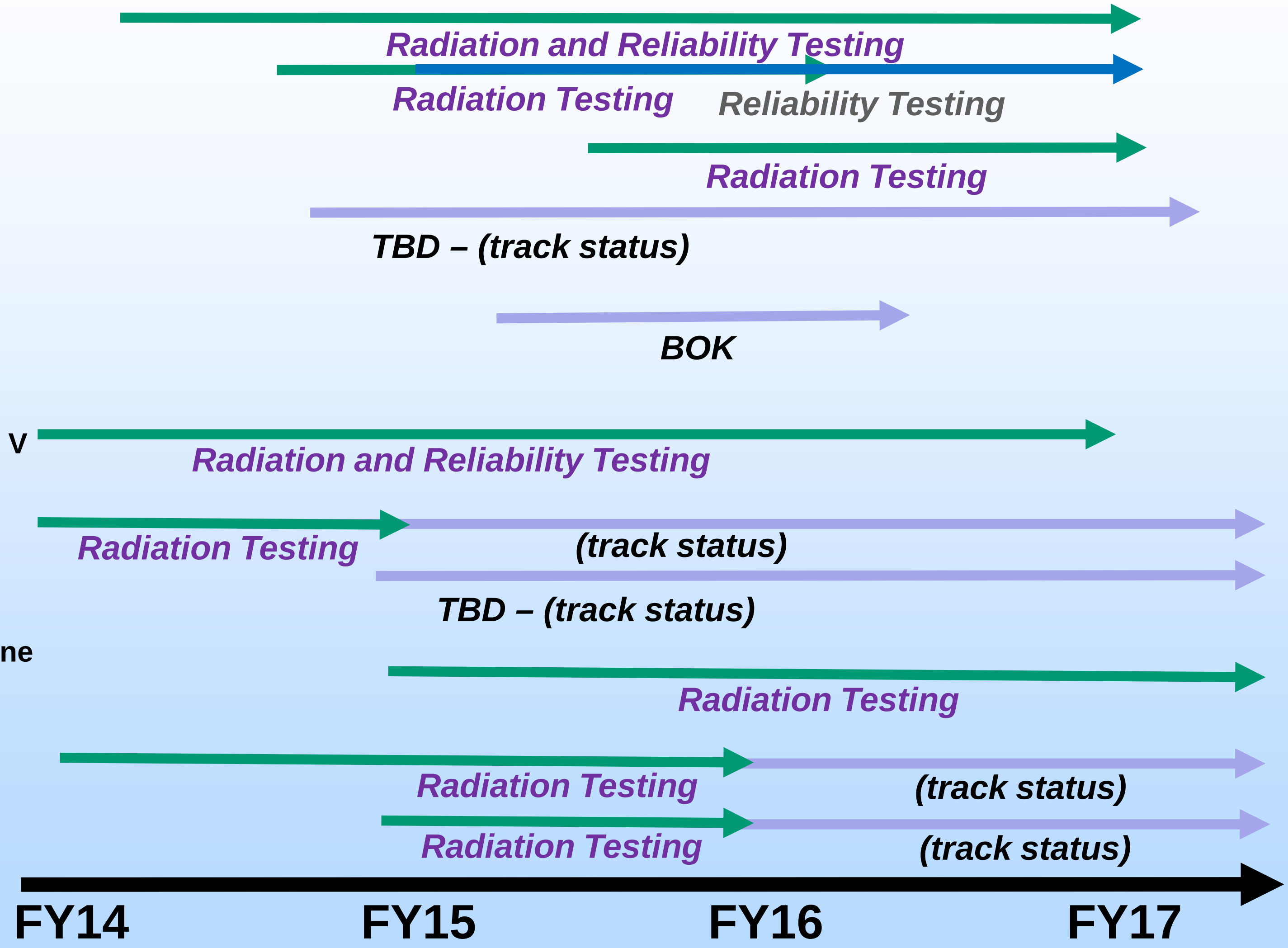
GaN Other

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



Radiation and Reliability Testing

Radiation Testing *Reliability Testing*

Radiation Testing

TBD – (track status)

BOK

Radiation and Reliability Testing

Radiation Testing *(track status)*

TBD – (track status)

Radiation Testing

Radiation Testing *(track status)*

Radiation Testing *(track status)*

FY14 **FY15** **FY16** **FY17**

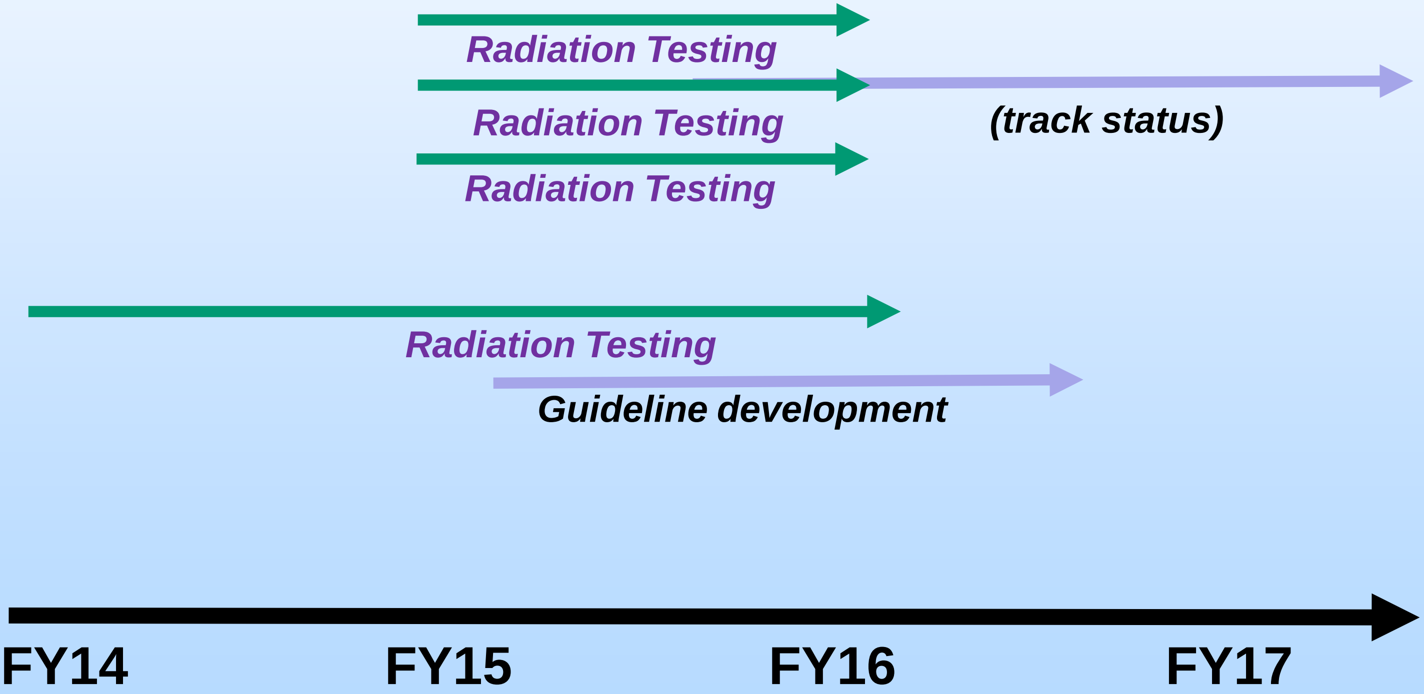
Silicon Power Devices

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

(track status)

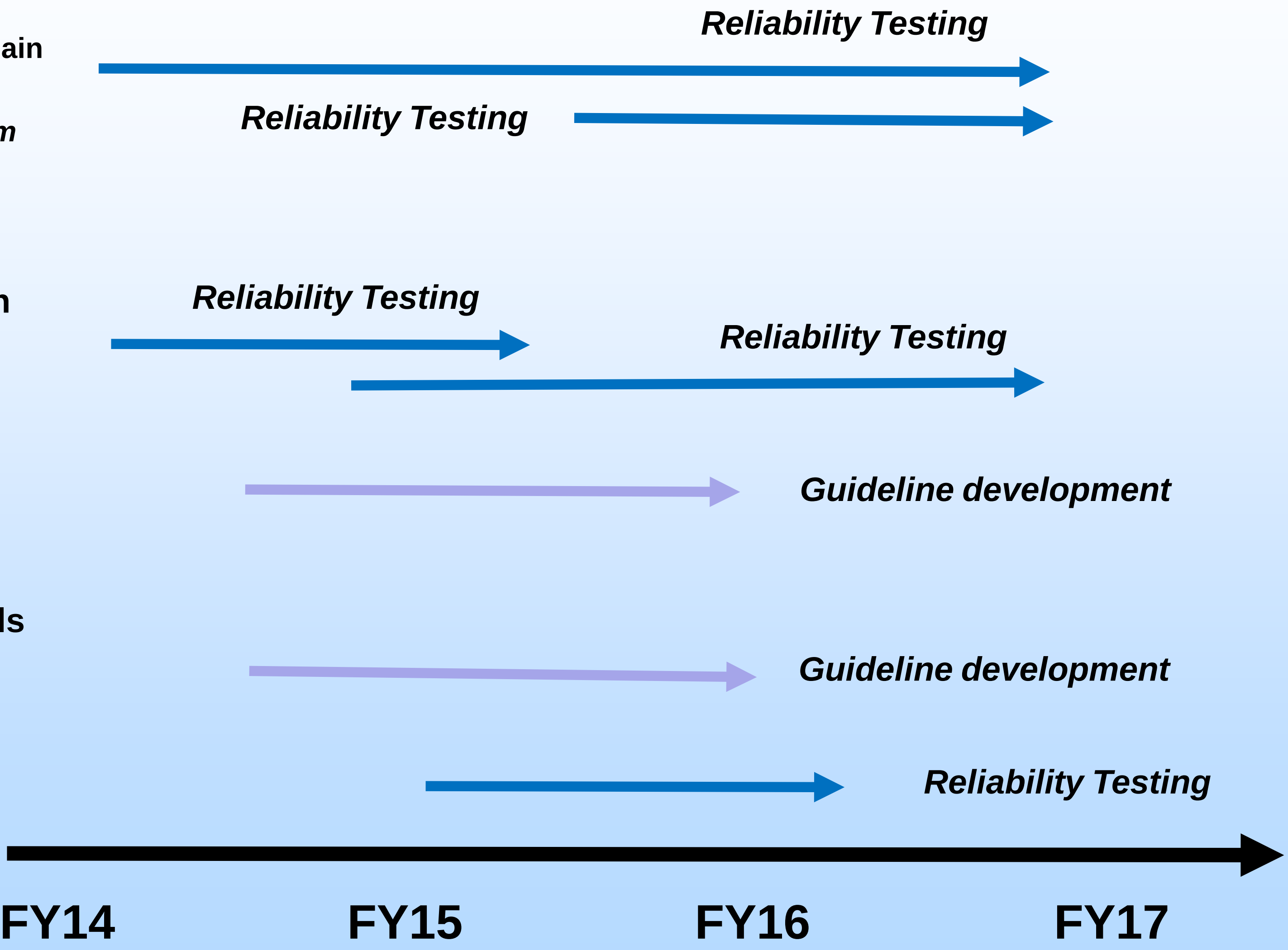
Radiation Testing

Radiation Testing

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*

Reliability Testing

Reliability Testing

HALT Methodology/Qualification

- HALT/HAST comparison
- Plastic BGA matrix

Reliability Testing

Reliability Testing

Area Array Column

- Selection guide

Guideline development

Thermal Interface Materials

- Selection guide

Guideline development

PBGA Thermal Cycle Evaluation

Reliability Testing

Packaging Technologies (2 of 2)

Bump Reliability

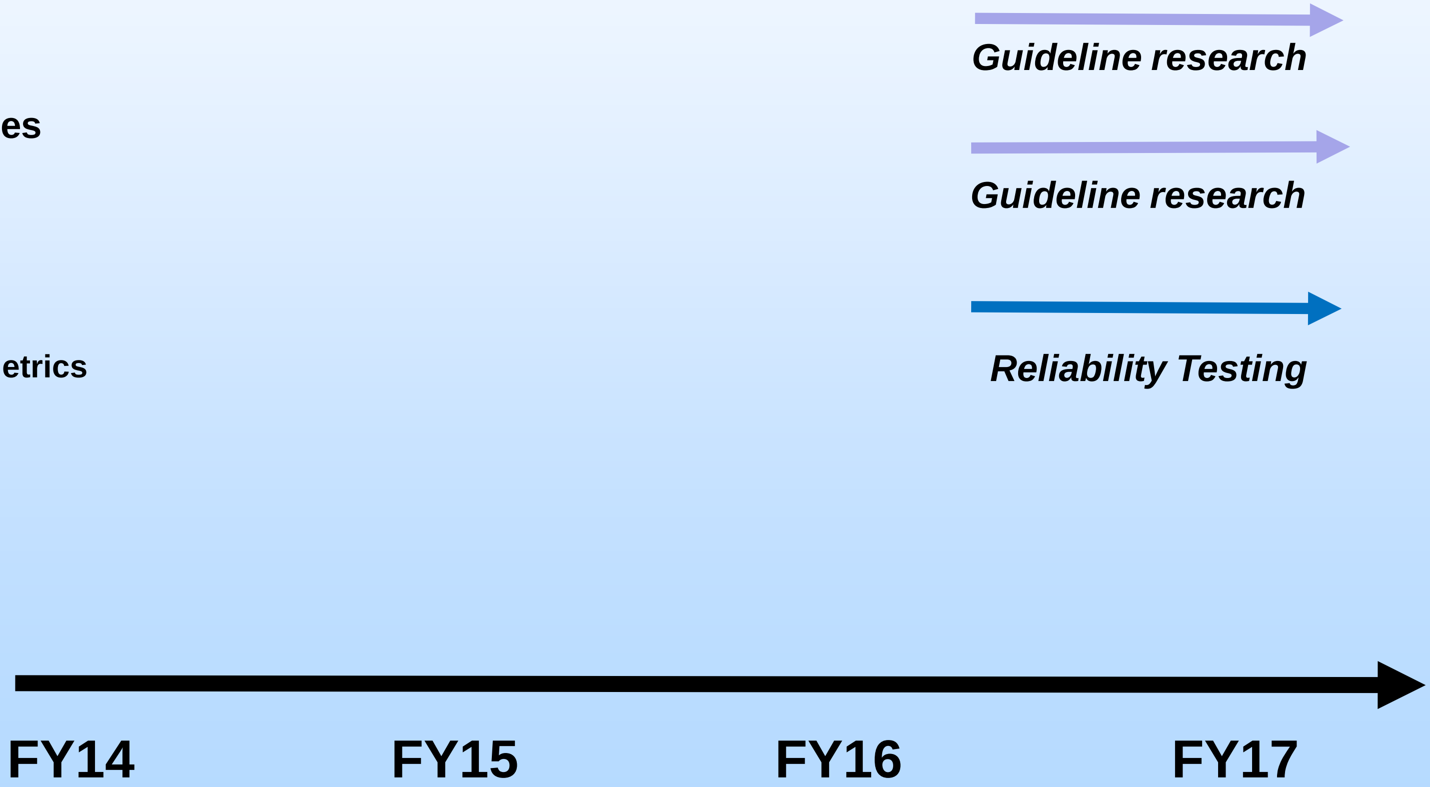
- Technology review
- Test vehicle options

3D Packaging Technologies

- Technology review
- Test vehicle options

QFN package reliability

- Reliability/Qualification metrics



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…

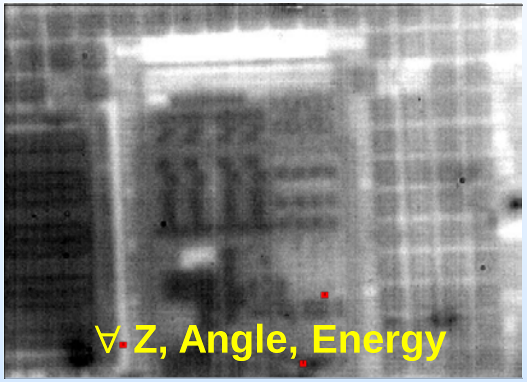
- CubeSat mission success/failure root cause analysis
  - Grant to Saint Louis University
- Using a model-based systems engineering (MBSE) approach to radiation assurance
  - Grant to Vanderbilt
  - Co-sponsored by NASA Reliability and Maintainability Program
  - Uses a tool called “Goal Structured Notation”
- 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

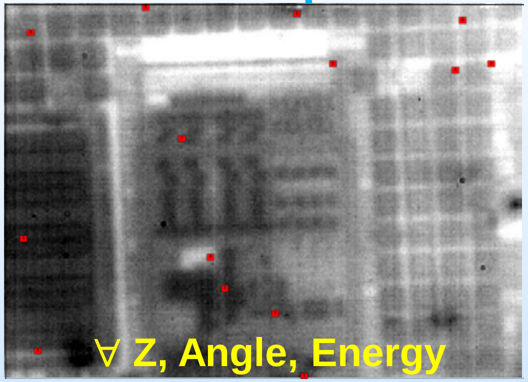
Infrared micrograph of a portion of a 512 Mb SDRAM $\sim 60 \times 70\ \mu m^2$

- **Shows both memory cells and control logic (10 yr. old tech.)**
- **Red spots are ion hits**

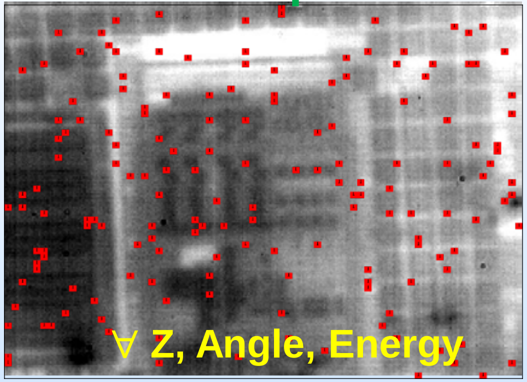
1E10 200 MeV protons/cm^2



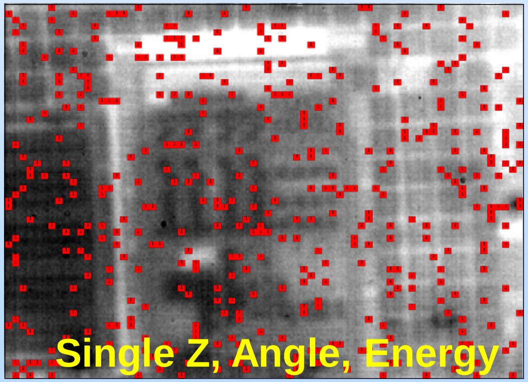
1E11 200 MeV protons/cm^2



1E12 200 MeV protons/cm^2



20% of areas this size get 0 hits for 10^{10} cm^{-2}



Coverage from 1E7 heavy ions/cm^2

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