The NASA Electronic Parts and Packaging (NEPP) Program: Overview and Update FY15 and Beyond

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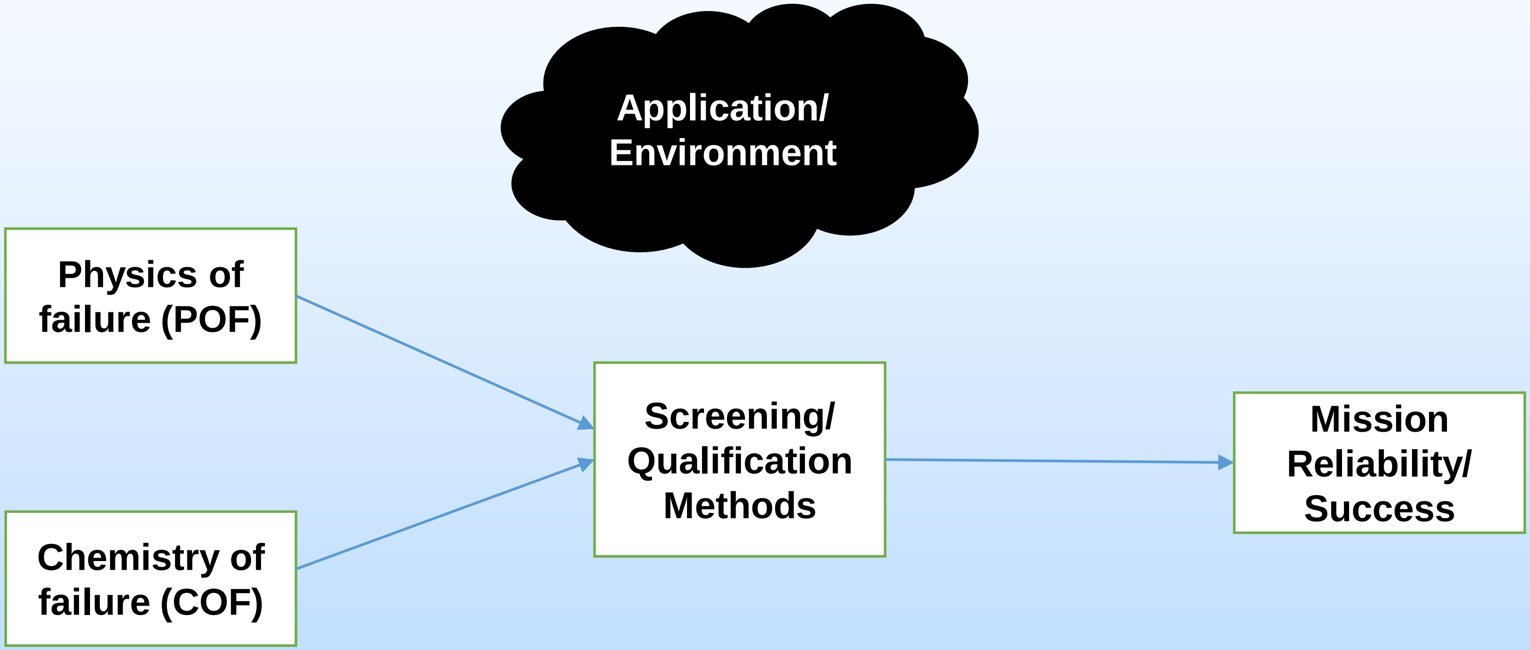
Acronyms

Acronym	Definition
AEC	Automotive Electronics Council
Aero	Aerospace
AFRL	Air Force Research Laboratory
BME	Base Metal Electrode
CA	Construction Analysis
CBRAM	Conductive Bridging Random Access Memory
CDH	Cadence Health, Central DuPage Hospital Proton Facility
CMOS	Complementary Metal Oxide Semiconductor
COTS	Commercial Off The Shelf
CSAM	Confocal Scanning Acoustic Microscopy
DWV	Dielectric Withstanding Voltage
EEE	Electrical, Electronic, and Electromechanical
FeRAM	Ferroelectric RAM
FOD	Foreign Object Debris
FPGA	Field Programmable Gate Array
FY	Fiscal Year
GaN	Gallium Nitride
GSFC	Goddard Space Flight Center
HEMTs	High-electron-mobility transistors
HP Labs	Hewlett-Packard Laboratories
HUPTI	Hampton University Proton Therapy Institute
IC	Integrated Circuit
IUCF	Indiana University Cyclotron Facility
LBNL	Lawrence Berkeley National Laboratories

Acronym	Definition
LEO	Low Earth Orbit
LLUMC	James M. Slater Proton Treatment and Research Center at Loma Linda University Medical Center
MGH	Massachusetts General Hospital
MIL	Military
MLCC	Multi-Layer Ceramic Capacitor
MOSFETS	Metal Oxide Semiconductor Field Effect Transistors
MRAM	Magnetoresistive Random Access Memory
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
NSRL	NASA Space Radiation Laboratory
POC	Point of Contact
ProCure	ProCure Center, Warrenville, Illinois
RERAM	Resistive Random Access Memory
SEE	Single Event Effect
SiC	Silicon Carbide
SME	Subject Matter Expert
SOC	Systems on a Chip
TI	Texas Instruments
TRIUMF	Tri-University Meson Facility
UCD	University of California at Davis (UCD) Crocker Nuclear Lab (CNL)
VNAND	Vertical NAND

INTRODUCTION TO NEPP

Taking a Step Back…
A Simple View of NEPP's Perspective



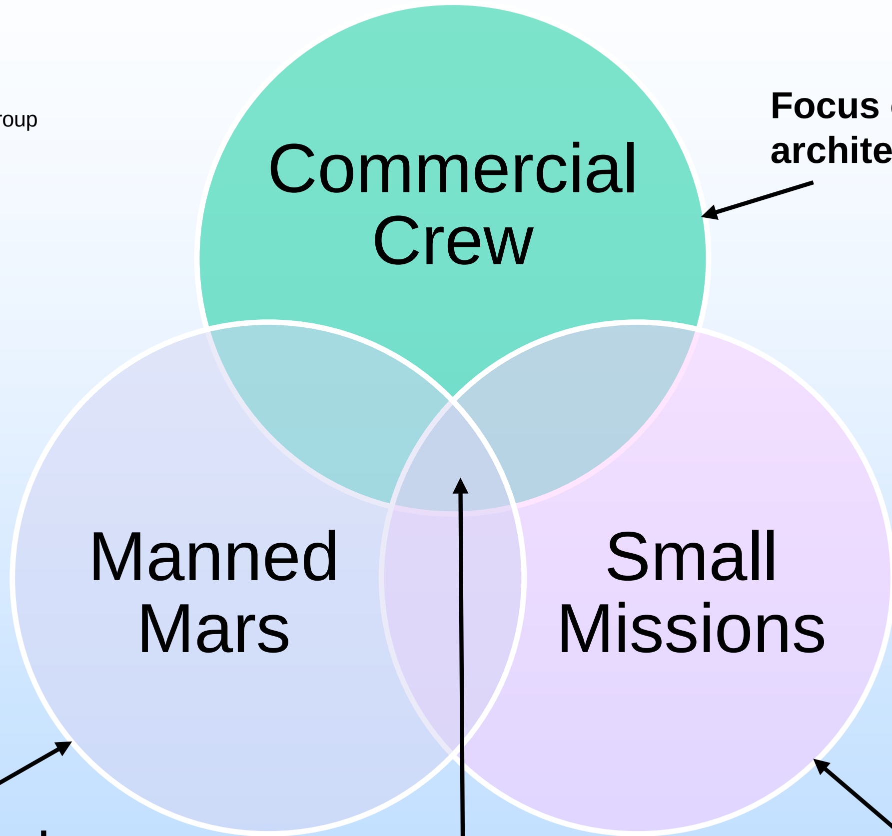
NEPP Efforts Relate to Assurance of EEE Parts –

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!*

LEO=Low Earth Orbit
NEPAG=NASA Electronic Parts Assurance Group

Focus on fail-safe architecture/electronics



Focus on reliability and radiation tolerance

Focus on cost-consciousness and low power electronics

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

Without forgetting traditional LEO and Deep-Space Robotic needs

NEPP Overview (1)

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

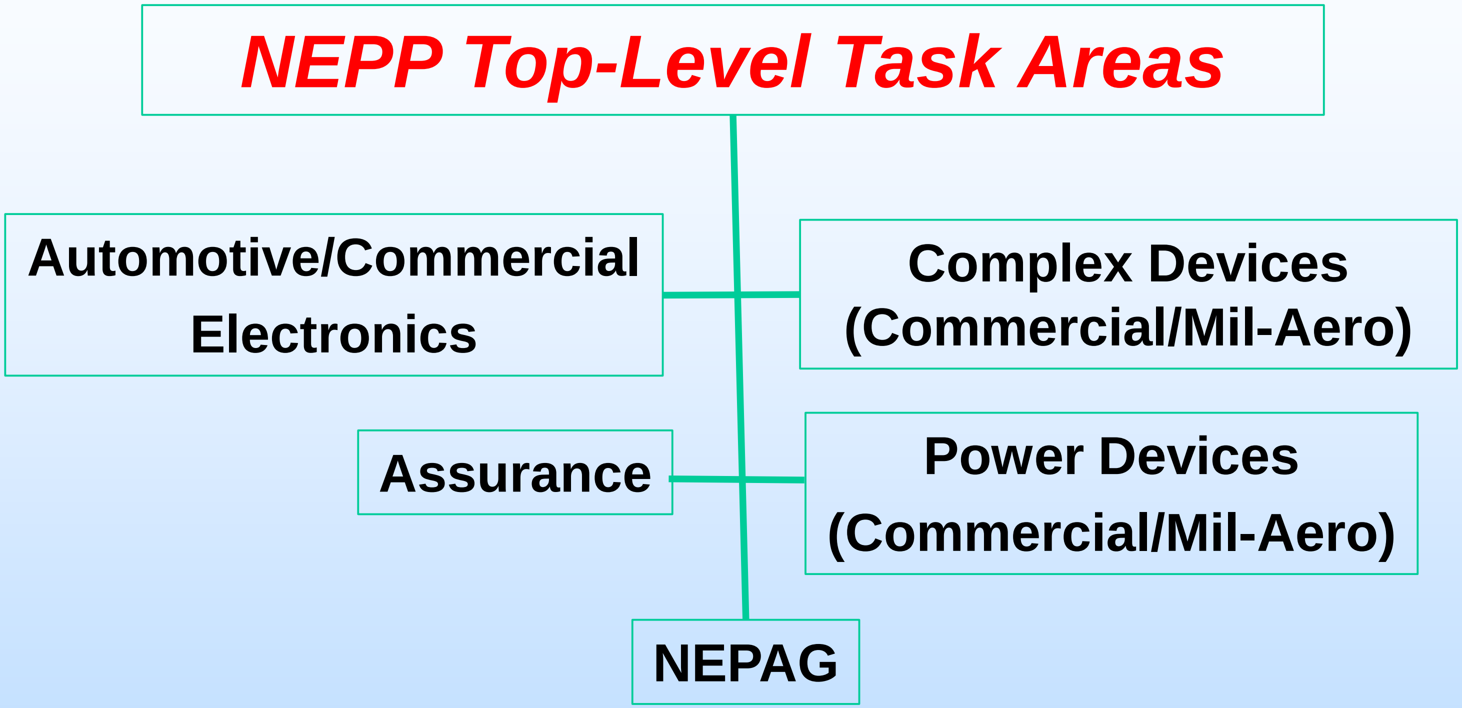
Test/Qualification Methods
Evaluate improved or more cost-effective concepts

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.

NEPP Overview (2)



As opposed to a traditional breakdown of parts, packaging, or radiation, NEPP tasks can be categorized into these five areas.

Mil=Military
Aero=Aerospace
NEPAG

NEPP TECHNOLOGY ROADMAP

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: Commercial off the shelf (COTS) to high reliability aerospace.**
- **Partnering arrangements with other organizations preferred.**
- **In general, we avoid:**
  - **Laboratory technologies, e.g., < Technology Readiness Level (TRL) 3,**
  - **Limited application devices with certain exceptions (critical application or NASA center specialization).**

Technology Investigation Roadmap Discussion

- **Technology assurance efforts through NEPAG 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 communications (serializer-deserializer (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.**
- **Note 2: "Reliability testing" may include product and/or package testing.**
- **Note 3: Roadmap updates based on early results.**

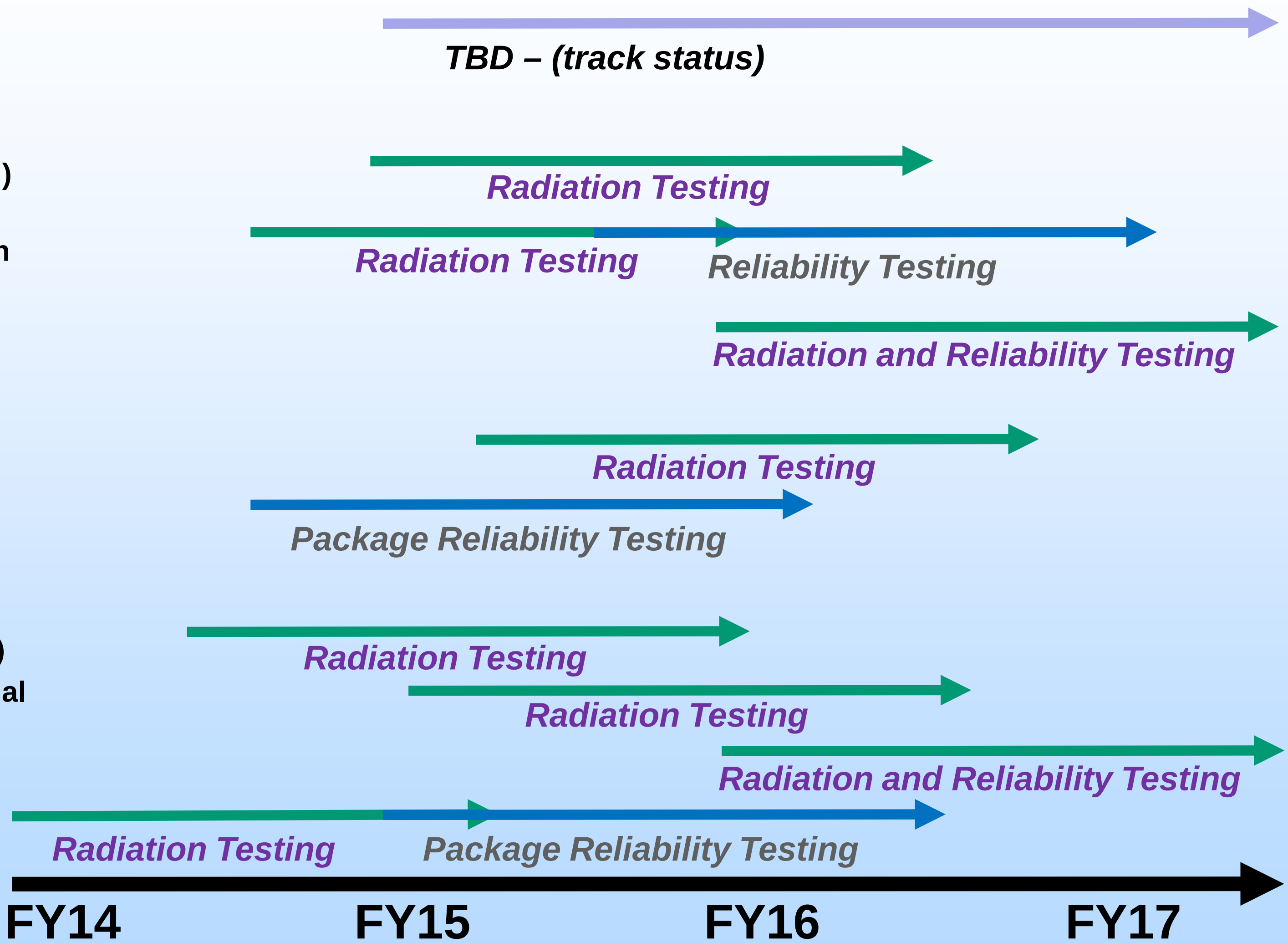
Field Programmable Gate Arrays (FPGAs)

Trusted FPGA
- **DoD Development**

Altera
- **Stratix 5 (28nm commercial)**
- **Max 10 (55nm NOR based commercial – small mission candidate)**
- **Stratix 10 (14nm Intel commercial)**

Microsemi
- **RTG4 (65nm RH)**

Xilinx
- **7 series (28nm commercial)**
- **Ultrascale (20nm commercial – planar)**
- **Ultrascale+ (16nm commercial - vertical)**
- **Virtex 5QV (65nm RH)**



FY=Fiscal Year

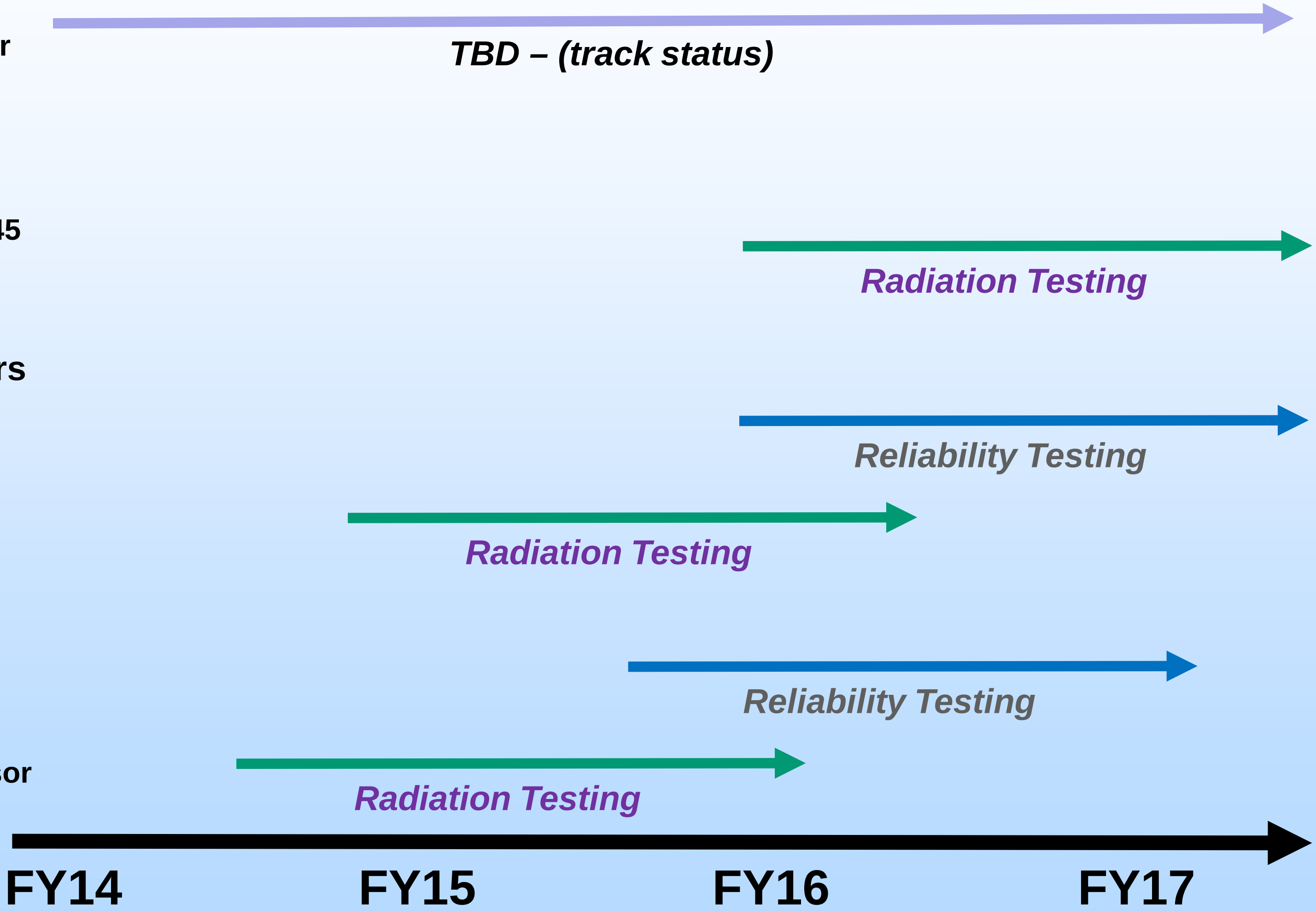
Advanced Processors

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 Broadwell Processors
- 14nm FinFET commercial
- 1st high-performance sans heatsink

Freescale P5020/5040
- Commercial 45nm network processor
- Preparation for RH processor



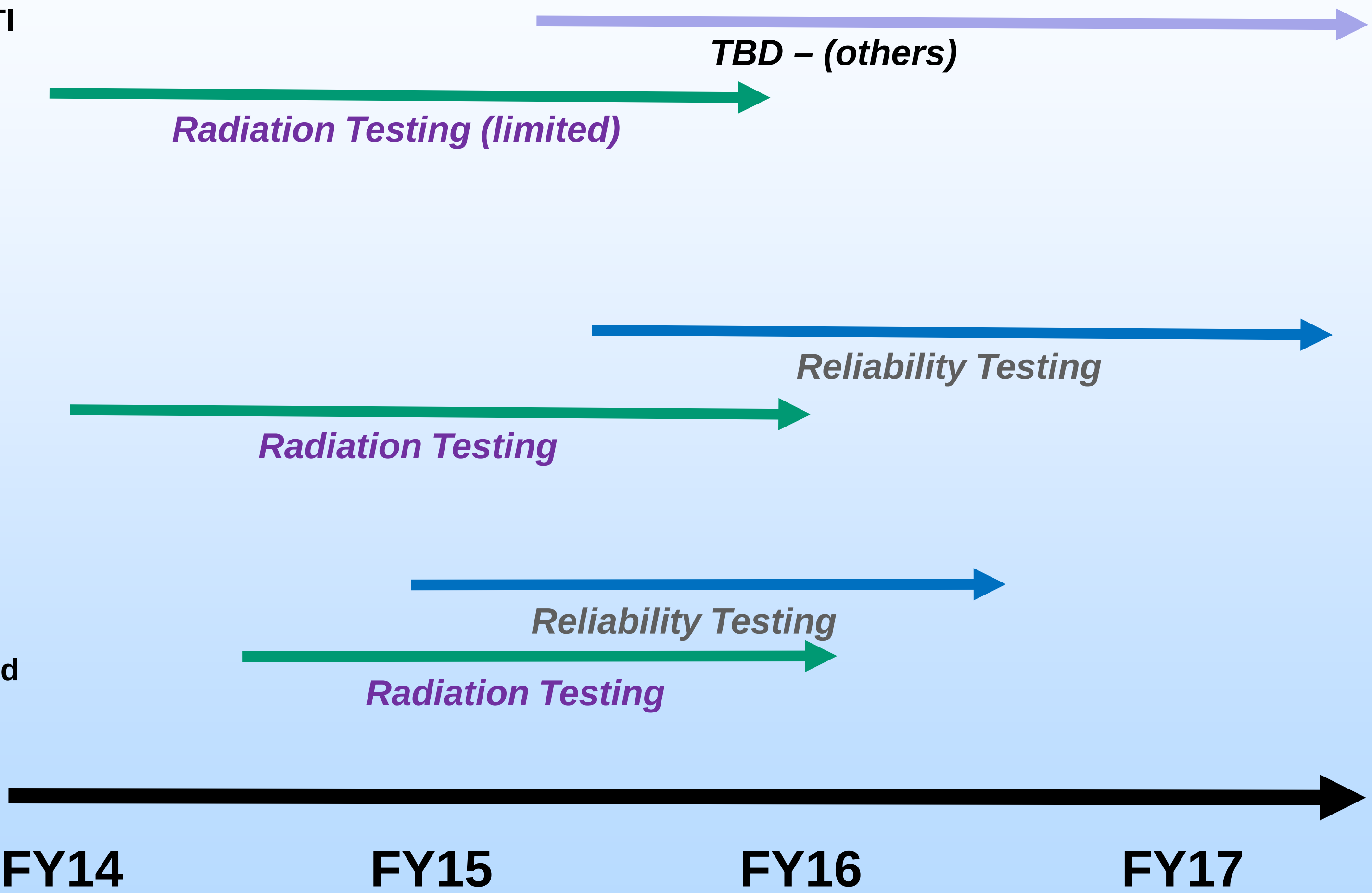
Note: Future considerations include automotive "self-driving" processor options.

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



TI=Texas Instruments

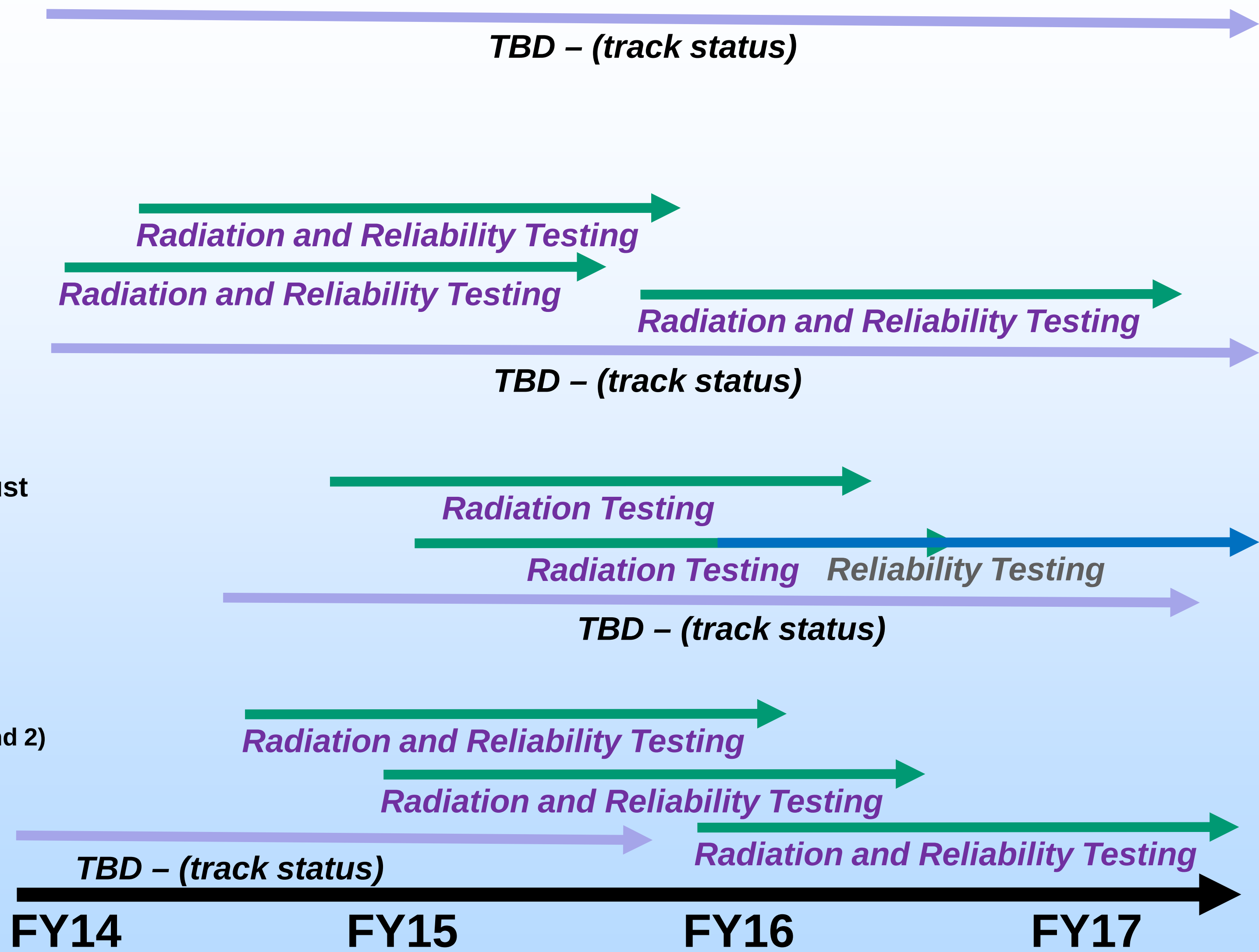
Commercial Memory Technology

Other
- MRAM
- FeRAM

Resistive
- CBRAM (Adesto)
- ReRAM (Panasonic)
- ReRAM (Tezzeron)
- 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 hypercube
- TBD - other commercial



MRAM=Magnetoresistive Random Access Memory
FeRAM=Ferroelectric RAM
CBRAM=Conductive Bridging Random Access Memory
ReRAM=Resistive Random Access Memory
HP Labs=Hewlett-Packard Laboratories
VNAND=Vertical NAND

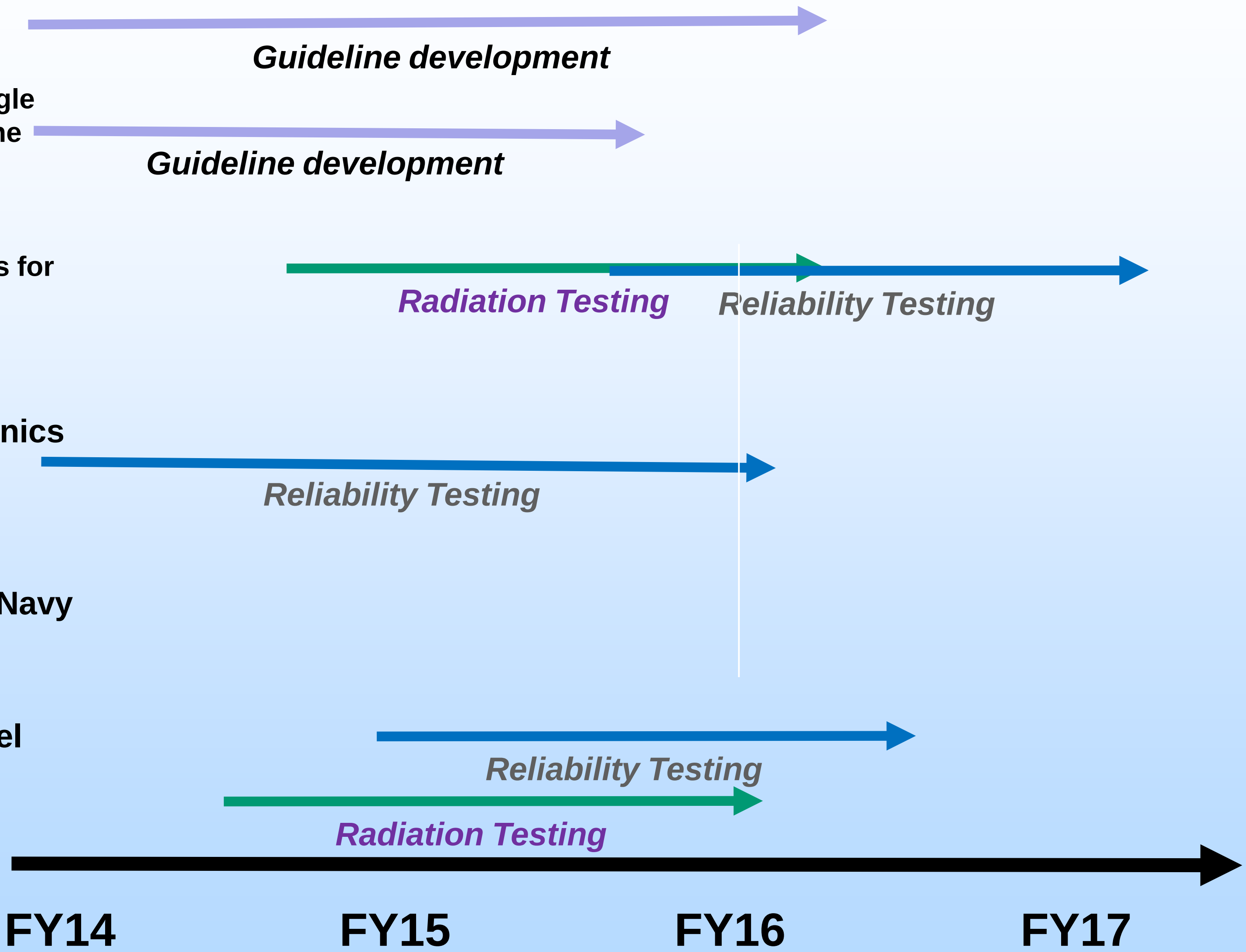
Small Missions

EEE Parts Guidelines
- Small missions (Class D, CubeSat – 2 documents)
- System on a chip (SOC single event effects (SEE) 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



NEPP Evaluation Automotive Grade Parts – Current Status

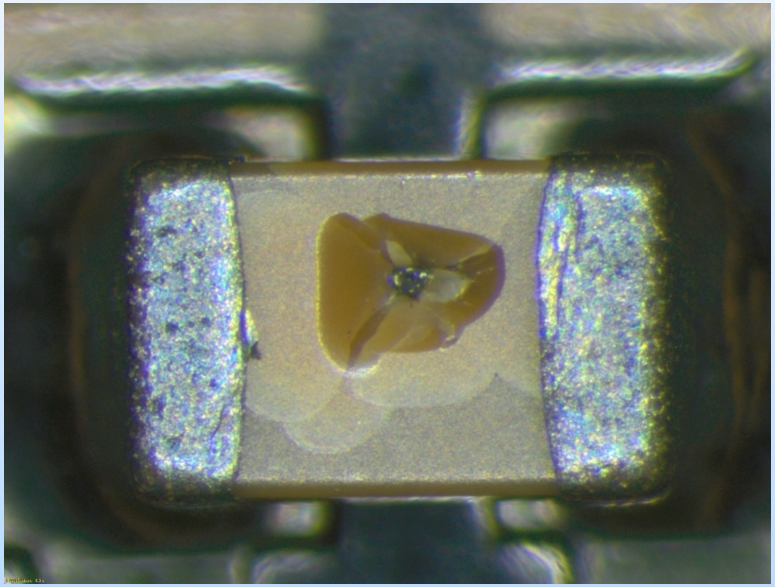
Parts were purchased through distributors as Automotive Electronics Council (AEC) Q-"XXX" Automotive Grade

Commodity	Test	Status	Comments
Ceramic Capacitors 3 Different Mfrs Base Metal Electrode (BME), 0805, 0.47uF, 50V	Construction Analysis	Complete	• *At their own discretion a manufacturer supplied devices made with "flexible termination"*
	Initial Parametric Measurements	Complete	• No Failures • *DWV known to produce negative cap shift* • *Mfrs recommend bake-out to restore cap*
	Life Test (2x Vrated, 125°C)	> 6000 Hrs Complete (Progressing to 10k hours)	• *1 lot exhibits 5 life test failures (120pc) up to 6000 hrs* • *2 failures at 3100 hrs; 3 failures at 4700 hrs* • 2 lots exhibit no life test failures up to ~5500 hrs
Integrated Circuits 2 Different Mfrs 1 digital IC (Diff Bus Driver; 1 linear IC (Comparator)	Construction Analysis	In Process	• *FOD on Terminals "As-Received" (Linear IC)* • Tg measurements complete • CSAM complete for digital IC • CA to be performed at end of test
	Initial Parametric Measurements	In Process	• No Failures for digital IC • Linear IC to be tested 04/15
	Burn-In & Life Test	Begin 04/15	
Discrete Semiconductors	Construction Analysis	Awaiting input	Awaiting input
	Initial Parametric Measurements	Awaiting input	Awaiting input
	Burn-In & Life Test	Awaiting input	Awaiting input

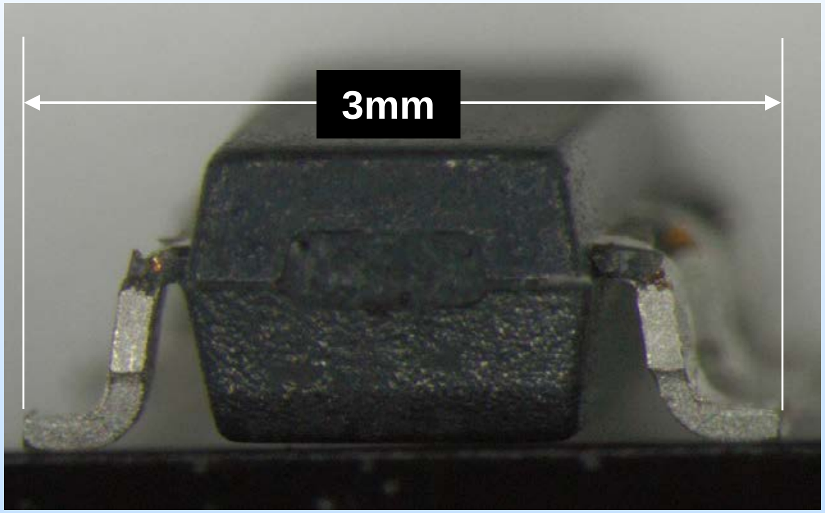
CSAM=Confocal Scanning Acoustic Microscopy
CA=Construction Analysis
DWV=Dielectric Withstanding Voltage

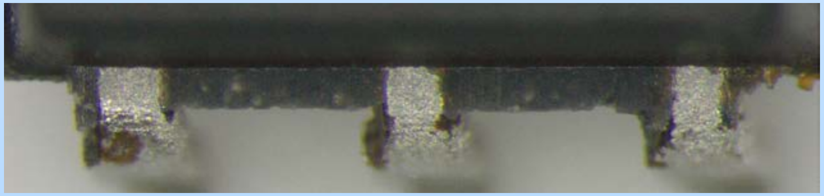
Observations from
NEPP Automotive Grade EEE Parts Evaluation

MLCC Life Test Failure
Catastrophic Short Circuit



FOD on IC Terminations "As-Received"





EEE=Electrical, Electronic, and Electromechanical
MLCC=Multi-Layer Ceramic Capacitor
FOD=Foreign Object Debris
IC=Integrated Circuit

Wide Band Gap (WBG) Technology

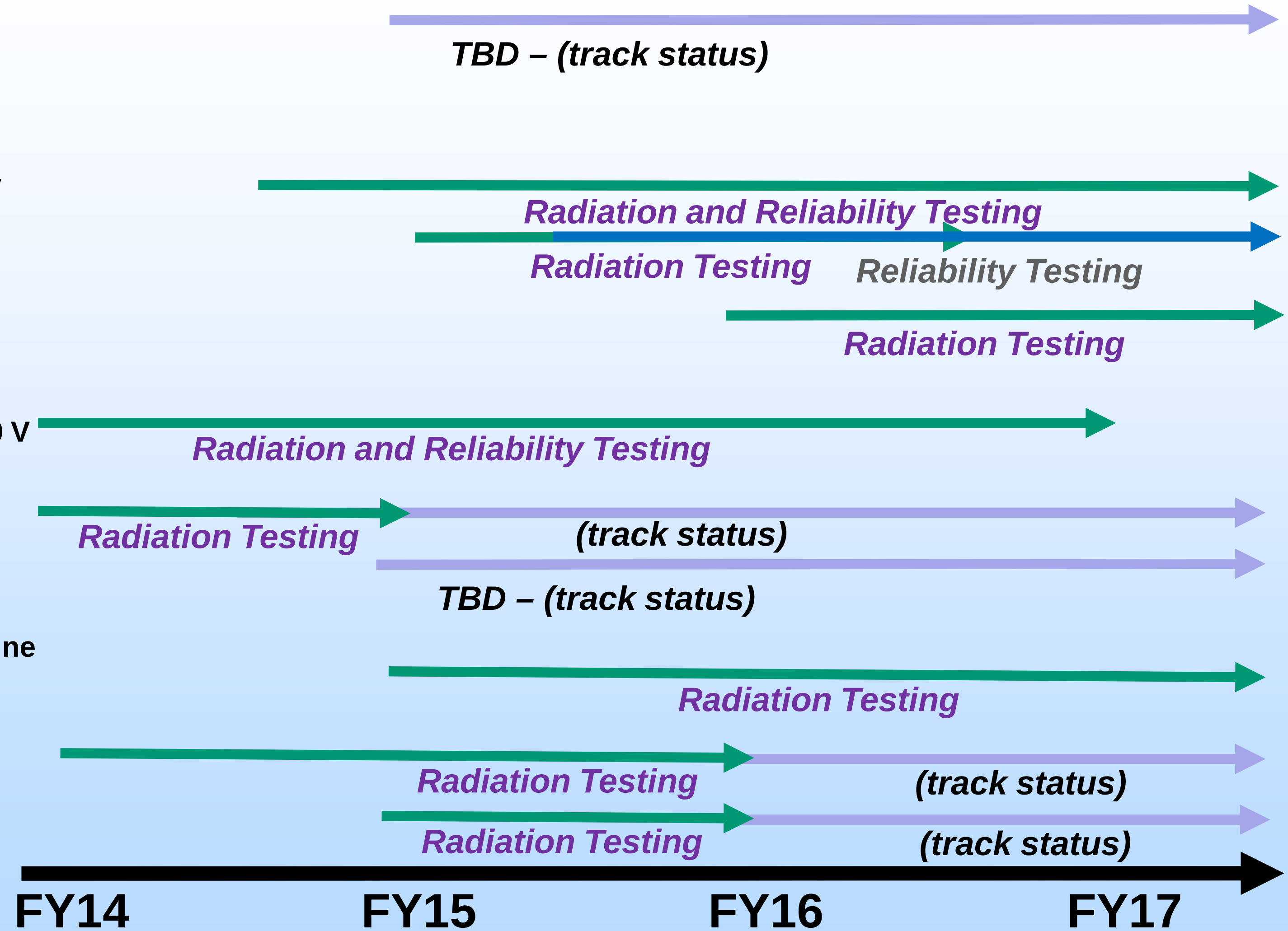
GaN Class V development
- **Microsemi with EPC**

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)**

SiC MOSFETs
- **Cree Gen 1-2 1200 V - 1700 V**
  Gen 3- narrower neck
- **STMicro baseline SEE test**
- **Rohm Trench design**

SiC Diodes
- **Manufacturer X SEE baseline and hardening efforts**

SiC ICs
- **Ozark IC**
- **Manufacturer X**



GaN=Gallium Nitride
HEMTs=High-electron-mobility transistors
SiC=Silicon Carbide
MOSFETS=Metal Oxide Semiconductor Field Effect Transistors
ICs=Integrated Circuits

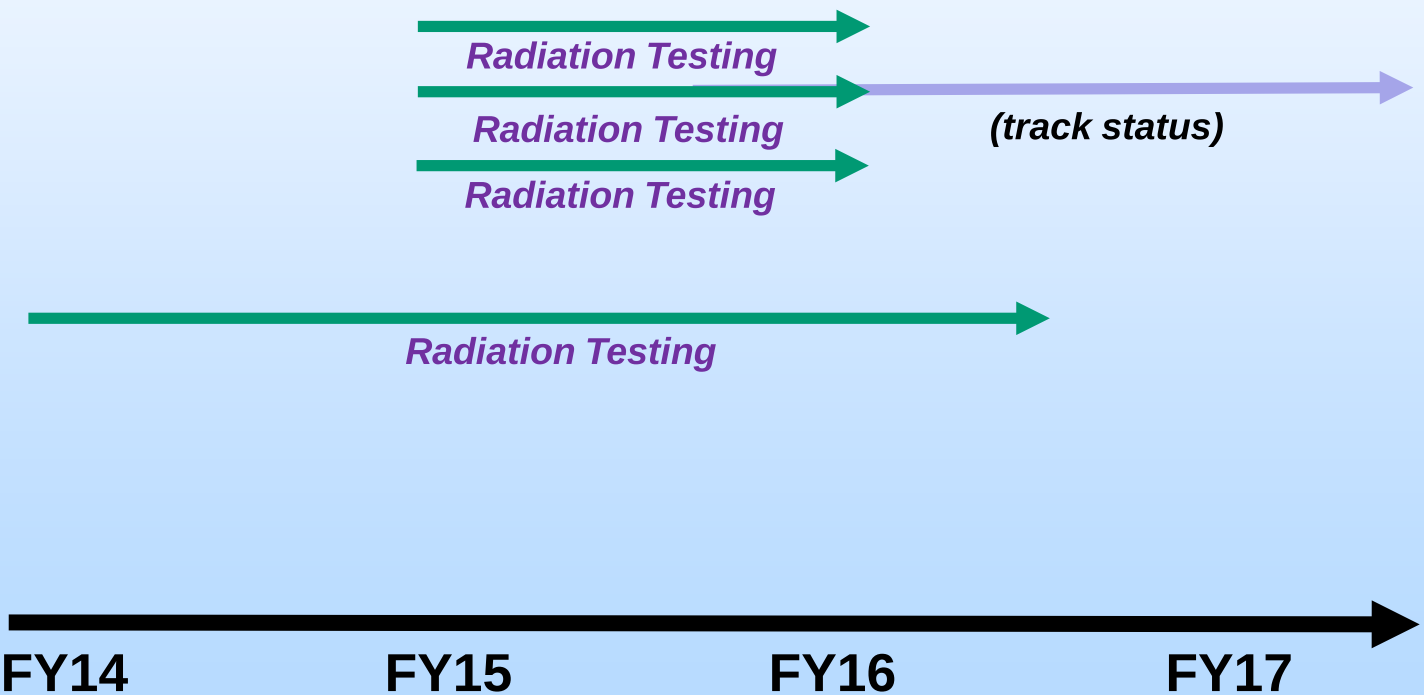
Silicon Power Devices

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**



ALL ABOUT PROTONS

Indiana University Cyclotron Facility (IUCF) Closure

- **IUCF has been the most used higher energy proton test facility for most of the U.S. space industry (electronics).**
  - **It is primarily a medical facility that NASA and others have supported to develop a parallel capability for proton testing of electronics.**
    - ***~2000+ hours of use per year for electronics testing***
  - **IUCF closed to the Space Community Usage on Oct 31, 2014.**
- **High energy Proton Test (>200 MeV) is Critical to Space Community.**
- **Possible options:**
  - **Use of Tri-University Meson Facility (TRIUMF) – Vancouver, Canada**
    - **Challenges with "border crossing", limited "cycles" of availability**
    - ***UPDATE: TRIUMF is working w US State Dept for easier access and HW transfer***
  - **Massachusetts General Hospital (MGH) Francis H. Burr Proton Therapy Center (additional access limited beyond current beam amounts),**
  - **University of California at Davis (UCD) Crocker Nuclear Lab (CNL)**
    - **Lower prime energy (63 MeV) does not meet all test requirements,**
  - **Lawrence Berkeley National Laboratories (LBNL) – (50 MeV) has similar technical challenges as CNL,**
  - **Loma Linda University Medical Center (LLUMC) and NASA Space Radiation Laboratory (NSRL) – have pulsed beam and some technical limits, and,**
  - **Multiple other proton medical therapy centers**
    - **See: http://proton-therapy.org for example listing.**
- **Ad hoc team formed to investigate options.**

Team Members
(min. 1 site visit)

- **NASA**
  - Ken LaBel, Chuck Foster (consultant)
- **The Aerospace Corporation**
  - Tom Turflinger, Andy Kostic, Rich Haas, Jeff George
- **Integrity Applications Incorporated (IAI)**
  - Brian Wie
- **Vanderbilt University**
  - Robert Reed
- **Boeing**
  - Jerry Wert, Sudhakar Shetty
- **BAE Systems**
  - Reed Lawrence, John Davis
- **Jet Propulsion Laboratory**
  - Steve Guertin

Ad Hoc "Team" Plan – Proton Therapy Sites

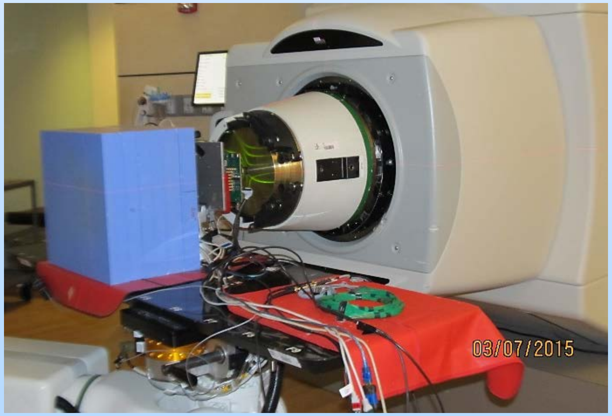
- **Contact facilities (focus on cyclotrons)**
- **Site visit to determine interest**
  - **Technical**
  - **Access**
  - **Business case**
- **Beta/shakeout tests at interested sites to determine usability**
- **Determine guidelines for usage of these sites**
- **Work logistics of access**
- **Recommendations for modifications and longer term access.**

Assumption: Facilities will have available 300-500 hours/year each (weekends). Multiple facilities required to replace IUCF in the near term.

Note: Special Session with facilities planned at Single Event Effects (SEE) Symposium – May 18-21 2015 in La Jolla, CA

Challenges Identified with Using Proton Therapy Facilities

- **Technical**
  - **Beam structure and delivery are mostly different than we are used to.** ***This is the largest technical concern.***
  - **Beam intensity control: translation between SEE test parameters and tumor delivery.**
  - **Remote-controlled movement of test article mounting stage may not exist at all sites – time hindrance.**
  - **Dosimetry at target site needs evaluation.**
  - **Beam stops required (therapy "stops" beam in patient).**
  - **Radiation dosage limits may impact some higher fluence tests.**
- **Logistics**
  - **Access**
  - **Scheduling**
  - **Cost**



Shakeout testing at Cadence Proton Center, Warrenville, IL

Proton Facility Status

	Facility	Location	Visit	Beam Attributes*	User friendly**	Hourly Rate	Invest. required	Annual Hours	Current Avail.	Short term Avail.	Long term Avail.	Beta Test
Future Facilities	Cadence Health (CDH) Proton Facility - ProCure	Warrenville, IL	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	Maybe	Maybe	Mar 7
Future Facilities	Hampton University Proton Therapy Institute (HUPTI)	Hampton, VA	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	350	No	Maybe	Maybe	TBD
Future Facilities	Provision Center for Proton Therapy	Knoxville, TN	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	No	Maybe	TBD
Future Facilities	Seattle Cancer Care Alliance Proton Therapy - ProCure	Seattle, WA	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	Maybe	Maybe	Yes
Future Facilities	University of Florida Proton Therapy Institute	Jacksonville, FL	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	No	Maybe	TBD
Future Facilities	University of Maryland Proton Treatment Center	Baltimore, MD	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	No	Maybe	TBD
Future Facilities	Scripps Proton Therapy Center	La Jolla, CA	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	Maybe	Maybe	May 1-2
Future Facilities	OKC ProCure Proton Therapy Center	OKC, OK	Y	Acceptable (cyclotron)	N/A	TBD	Yes $ TBD	500	No	Maybe	Maybe	May-June
Future Facilities	Mayo Foundation	Rochester, MN Phoenix, AZ	N	TBD (synchrotron)	TBD	TBD	TBD	TBD	No	No	TBD	TBD
Existing Facilities	Tri-University Meson Facility (TRIUMF)	Vancouver, CAN	N	Acceptable (cyclotron)	Yes	$750	No	4x/year	Yes	Yes	Yes	N/A
Existing Facilities	Slater Proton Treatment and Research Center at Loma Linda University Medical Center (LLUMC)	Loma Linda, CA	Y	Acceptable (synchrotron)	Yes	$1,000	No	1000	Yes	Yes	Yes	N/A
Existing Facilities	Mass General Francis H. Burr Proton Therapy	Boston, MA	N	Acceptable (cyclotron)	Yes	$1,000	No	< 800 hours, at capacity	Yes	Yes	Yes	N/A
Existing Facilities	NASA Space Radiation Lab (NSRL)	Brookhaven, NY	Y	Acceptable (synchrotron)	Yes	$4,700	No	> 1000 hours	Yes	Yes	Yes	N/A
	Indiana University Cyclotron Facility	Bloomington, IN	N/A	Reference	Yes	$820	N/A	2000 hours	No	No	No	N/A

*Beam size, dosimetry, flux, fluence, uniformity; **location, safety training, regulations, scheduling, payment, hazardous material handling, shipping, contracts, ITAR, etc...

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 a developing roadmap as well as few general interest items.**
- **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.**

https://nepp.nasa.gov