NASA Electronic Parts and Packaging (NEPP) Program - Technology

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Sundown at SCRIPPS Proton Therapy Center, Ken LaBel

Acronyms

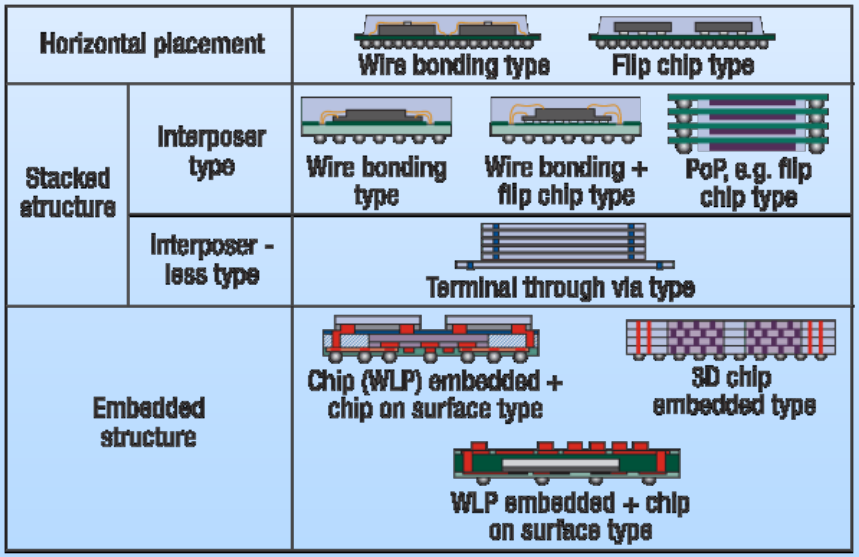
Acronym	Definition
3D	Three Dimensional
3DICs	3D Integrated Circuits
ADCs	Analog to Digital Converters
AF	Air Force
AFRL	Air Force Research Laboratory
AFSMC	Air Force Space and Missile Systems Center
BOK	Body of Knowledge
BYU	Brigham Young University
CIO	Chief Information Officer
CLTs	NASA CIO Leadership Teams
CMOS	Complementary Metal Oxide Semiconductor
COTS	Commercial Off The Shelf (COTS)
COTS	Commercial Off The Shelf
DACs	Digital-to-Analog Donverters
DC	Direct Current
DDR	Double Data Rate (DDR3 = Generation 3; DDR4 = Generation 4)
DIMM	Dual in-Line Memory Module
DiRAM	Dis-integrated Random Access Memory
DLA	Defense Logistics Agency
DMEA	Defense MicroElectronics Activity
DoD	Department of Defense
DOE	Department of Energy
EEE	Electrical, Electronic, and Electromechanical
FPGA	Field Programmable Gate Array
GaN	Gallium Nitride
GCR	Galactic Cosmic Ray
GIDEP	Government-Industry Data Exchange Program
GPU	Graphics Processing Unit
HiREV	High Reliability Virtual Electronics Center
IC	Integrated Circuit
IUCF	Indiana University Cyclotron Facility
JEDEC	Joint Electron Device Engineering Council (JEDEC)
JFAC	Joint Federated Assurance Center

Acronym	Definition
LANL	Los Alamos National Laboratories
MBMA	Model-Based Missions Assurance
MDA	Missile Defense Agency
MPSOC	Multiprocessor System-on-Chip
NASA	National Aeronautics and Space Administration
Navy Crane	Naval Surface Warfare Center, Crane, Indiana
NEPAG	NASA EEE Parts Assurance Group
NEPP	NASA Electronic Parts and Packaging
NESC	NASA National Electric Safety Code
NRL	Naval Research Laboratory
NRO	United States Navy National Reconnaissance Office
NSWC Crane	Naval Surface Warfare Center, Crane Division
OCE	Office of the Chief Engineer
PCB	Printed Circuit Board
POL	point of load
PoP	Package on Package
R&M	Reliability and Maintainability
RH	Radiation Hardened
SAE	Society of Automotive Engineers (SAE)
SAPP	Space Asset Protection Program
SBIR	Small Business Innovation Research
SCRIPPS	SCRIPPS Proton Therapy Center
SEE	Single Event Effect
SiC	Silicon Carbide
SiC	Silicon Carbide
SiGe	Silicon-Germanium
SMDs	Selected Item Descriptions
SME	Small and Medium-sized Enterprises
SNL	Sandia National Laboratories
SOC	Systems on a Chip
STMD	NASA's Space Technology Mission Directorate
STMD	Space Technology Mission Directorate
TOR	Technical Operating Report
WLP	Wafer Level Packaging

Outline

- NEPP Frame of Reference and Overview
- NEPP Tasks and Technology Selection
  - NEPP Technology Criteria
  - Selective Task "Roadmaps" including COTS
- Protons and Pictures
- Summary

Advanced 3D packaging provides challenges for radiation and reliability testing



International Electronics Manufacturing Initiative (iNEMI) 2009 Industry Roadmap

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

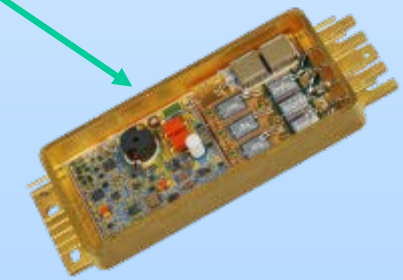
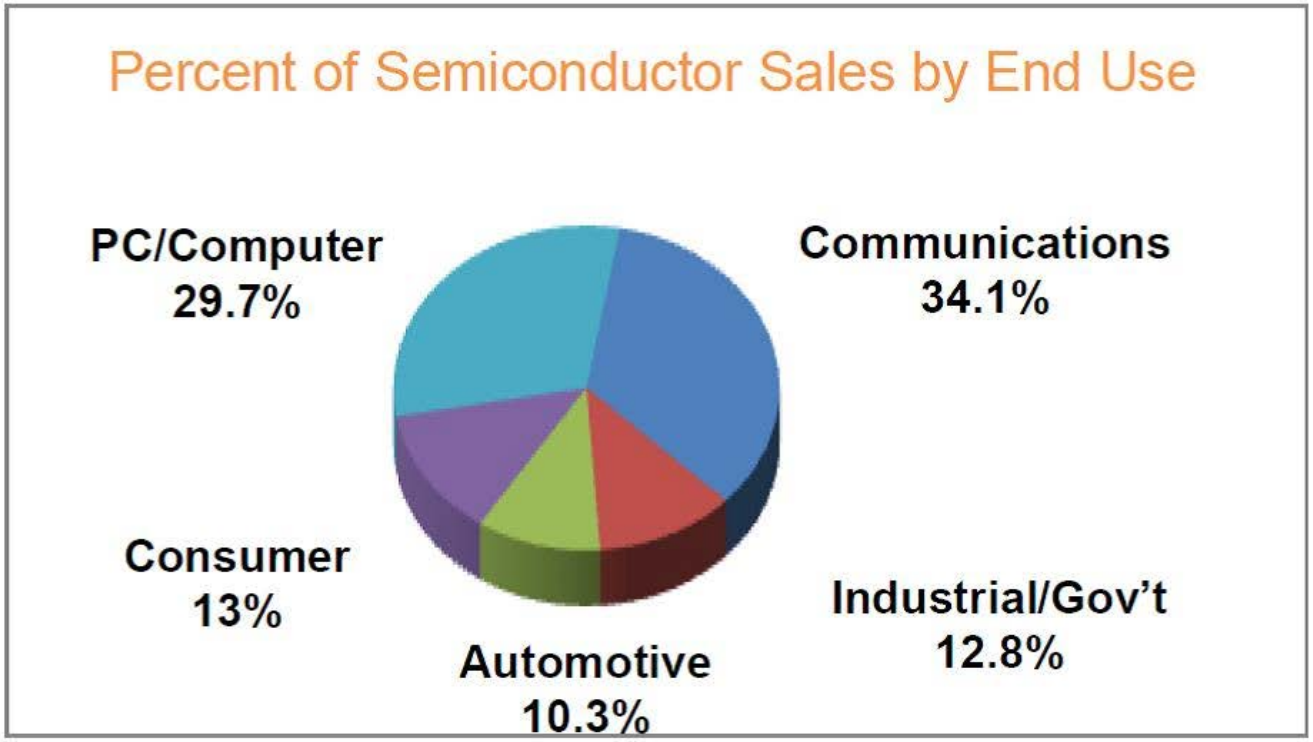


Image courtesy NASA

Motivational Factors

2015 Global Semiconductor Market: $335 Billion



Source: WSTS End Use Report, 2015
Note: Military is <1% and is included in Industrial/Gov't

Military and Aerospace share is estimated at ~$3.1B in 2015.
Aerospace is a small percentage of this amount.

For comparison, in 1975

the Military and Aerospace market share was ~$50%!

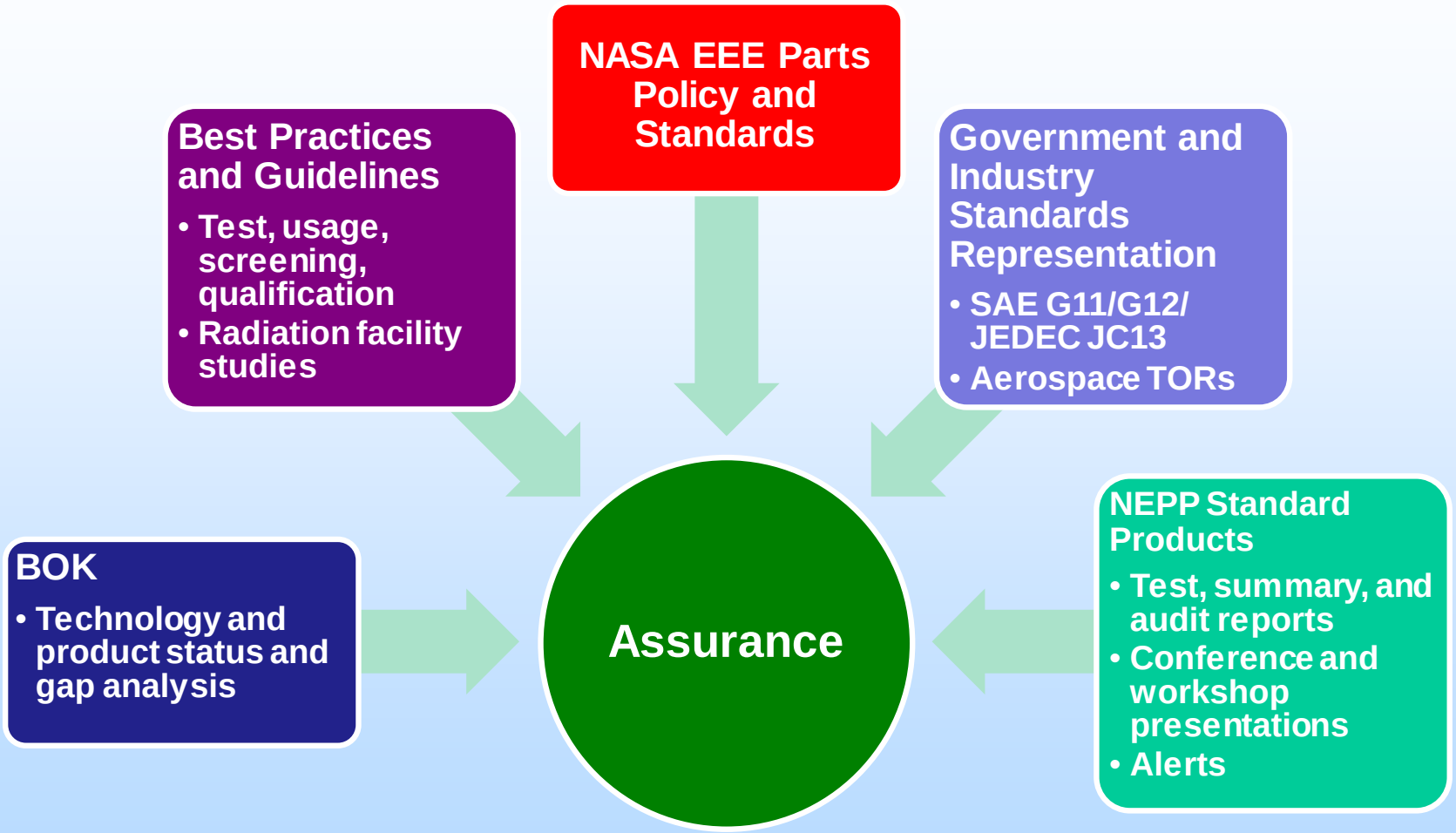
Conclusion: Mil/Aero community has to leverage other industries

NEPP - Charter

BOK Documents

- **What goes into a BOK**
  - An overview of the technology
  - An overview of technology applicability to space/aeronautics
  - An overview of technology maturity, produceability and/or commercial availability
  - Reliability, qualification, and/or radiation knowledge-base
  - Technology direction or extent of the reliability issue for the future Identification of experts, technology sources, test houses, etc.
  - Facilities/capabilities
  - Recommendation for follow-on NEPP task (if applicable)
- **Examples of BOKs**
  - Recently released
    - Copper Wirebonds (now in update), SiC, Integrated Photonics
  - Already in development
    - Automotive Electronics, Graphics Processing Units (GPUs), 3D Integrated Circuits (3DICs), Fiber Optics
  - New starts: Mil-Aero product updates
    - DC-DC
    - Converters, Point of Load (POL) Converters, Analog to Digital Converters (ADCs)

NEPP – Product Delivery



Related task areas:

Technology/parts evaluations lead to new best practices, etc…

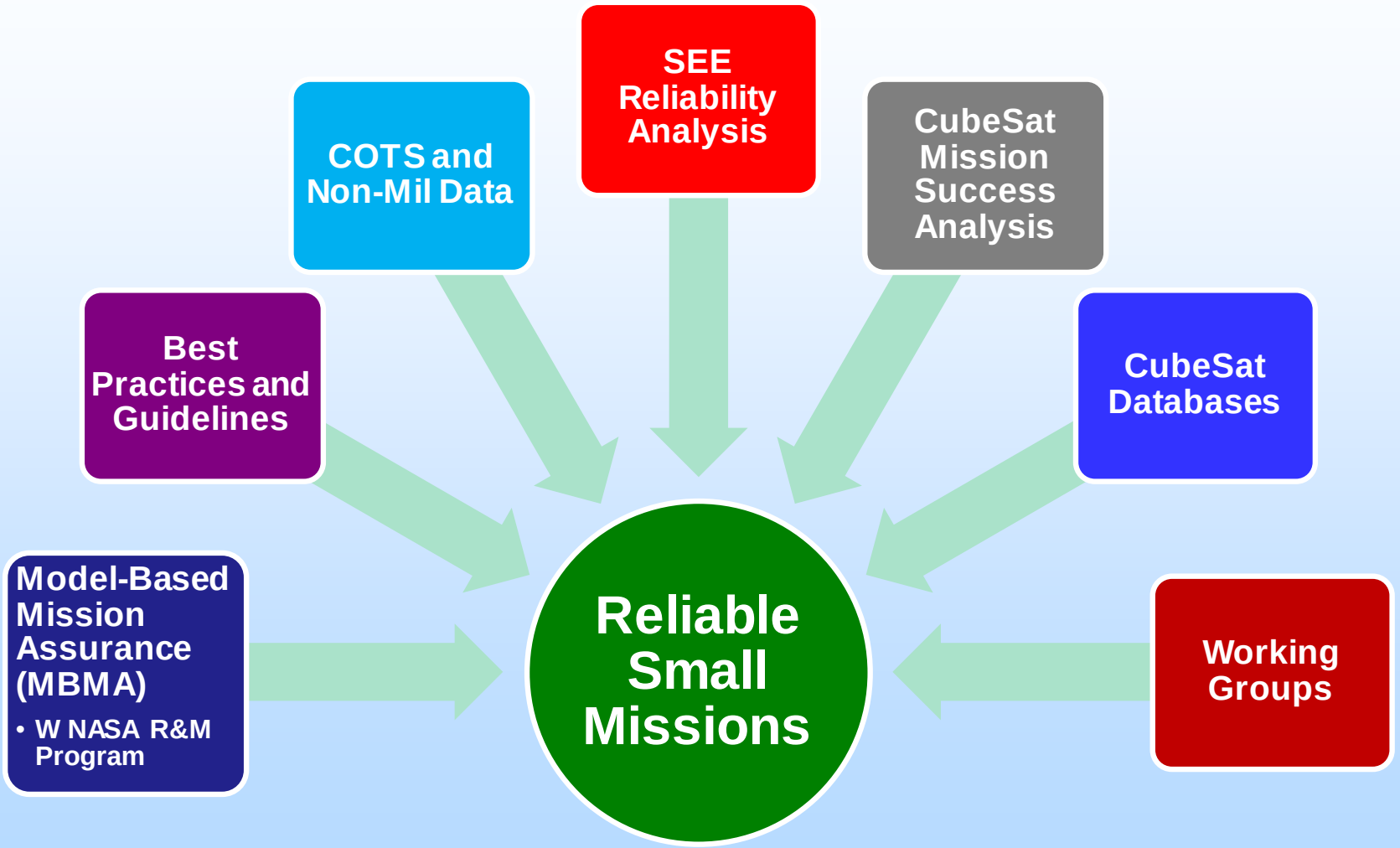
NEPP – Deeper Dive for Tasks

- **NEPP has multiple rationale for evaluating a specific device or technology:**
  - **If the device/technology has the potential for widespread usage across the Agency,**
  - **If the device has true enabling characteristics for next generation mission needs, or,**
  - **As a means of gathering assurance information for future mission insertion or screening/qualification methods.**
- **Technologies must be "on a path to commercialization" (i.e., planned industry product)**
- **Partnering with other Agencies, industry, and universities is encouraged**

Sample NEPP Agency Collaborations

Topic	Agency(ies)	Description
3-D Integrated Circuits (ICs)	AFSMC, DMEA, AFRL, NRO, Missile Defense Agency (MDA), Navy Crane	Working Group to explore future assurance for commercial and military 3D (ICs).
Advanced processors and Systems on a Chip (SOCs)	Navy Crane	Radiation evaluation of advanced technology microprocessors and SOCs.
Advanced Non-Volatile Memories	Navy Crane	Radiation and reliability evaluation of advanced technology, non-volatile memories
Audits, Manufacturer and Test Houses	Defense Logistics Agency (DLA), Air Force Space & Missile Systems Center (AFSMC)	Joint audits of EEE parts manufacturers and test houses relevant to NASA needs
Automotive Electronics	Navy Crane, AFSMC	Evaluation of reliability of automotive electronics for space considerations.
FPGAs- Microsemi	AFSMC	Independent radiation testing of new radiation tolerant FPGA from Microsemi.
FPGAs - Xilinx	Sandia National Laboratories (SNL), Los Alamos National Laboratories (LANL)	Team for independent radiation evaluation of next generation Xilinx "space product" FPGA
Military Electronics Qualification Review	Defense Logistics Agency (DLA), Air Force Space & Missile Systems Center (AFSMC)	Review of proposed changes to MIL specs and standards as well as (SMDs), etc...
NEPP Radiation Testing	AFSMC	Cooperative effort with Air Force SMC
Proton Radiation Test Facilities	AFSMC, National Reconnaissance Office (NRO)	Team evaluation of options for proton testing now Indiana University Cyclotron Facility (IUCF) is closed
Radiation Test Facility Infrastructure Study	AFSMC, DOE	Study by National Academies of Science to review aging test facility etc.
Trusted Foundry and Trusted FPGAs	AFSMC, DMEA, AFRL, NRO, Missile Defense Agency (MDA), Navy Crane, Joint Federated Assurance Center (JFAC)	Supporting DoD studies on the future for trusted electronics and foundry access.
Trusted FPGA	AFSMC, DMEA, AFRL, NRO, Missile MDA, Navy Crane, JFAC	Supporting DoD funded effort for development of new trusted product.
Widebandgap Working Group	High Reliability Virtual Electronics Center (HiREV) - AFRL DMEA; NRL	Coordinated efforts in radiation and reliability work on both GaN and SiC widebandgap technology devices.

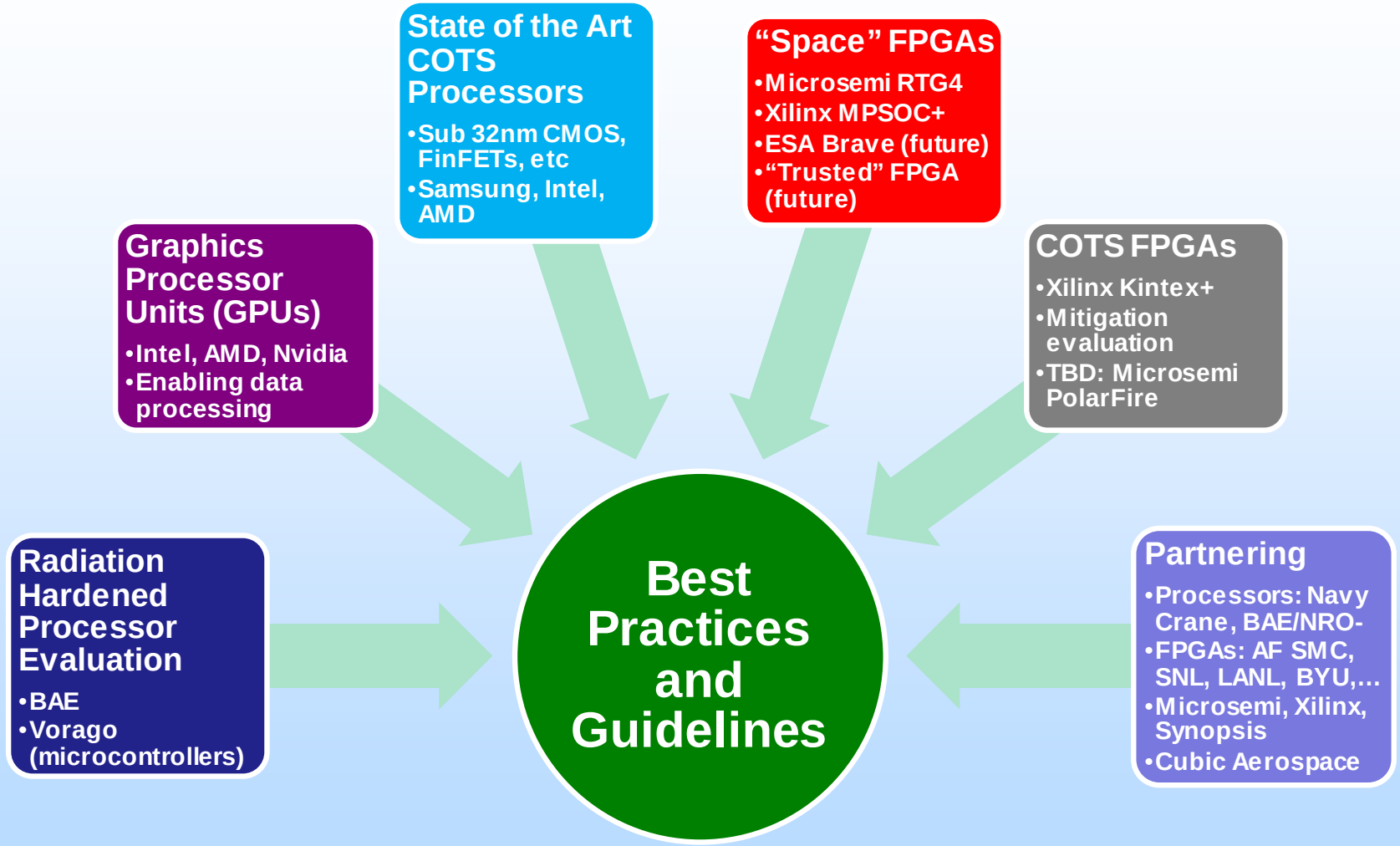
NEPP - Small Mission Efforts



Potential future task areas: automotive and avionics resilience

To be presented by Kenneth A. LaBel at the 2017 NASA Electronics Parts and Packaging (NEPP) Electronics Technology Workshop (ETW), NASA Goddard Space Flight Center, Greenbelt, MD, June 26-29, 2017.

NEPP – Processors, Systems on a Chip (SOC), and Field Programmable Gate Arrays (FPGAs)



Potential future task areas:

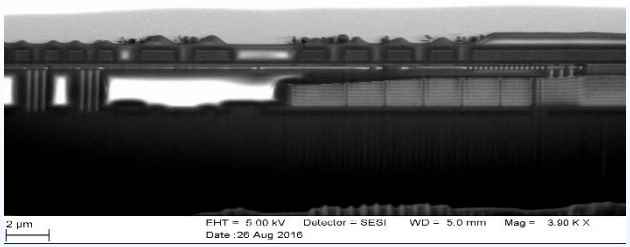
artificial intelligence (AI) hardware, Intel Stratix 10

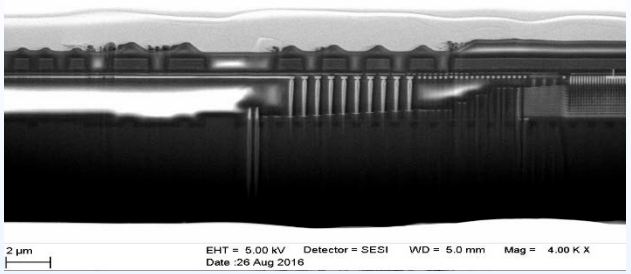
NEPP – Memories

Related task areas:

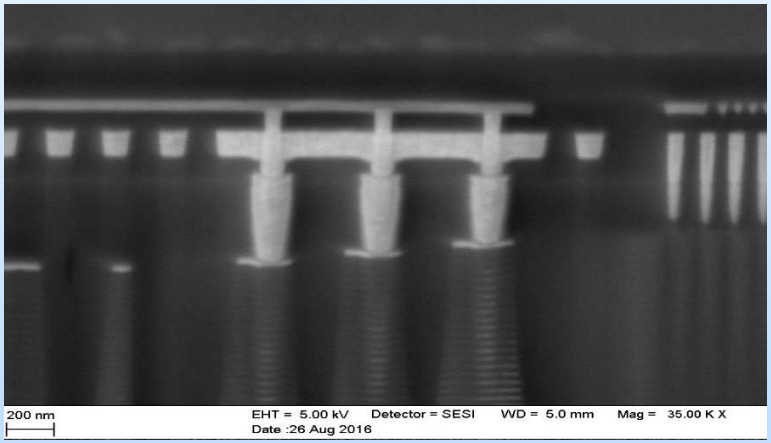
Deprocessing for single event testing (also w/processors, FPGAs,…)

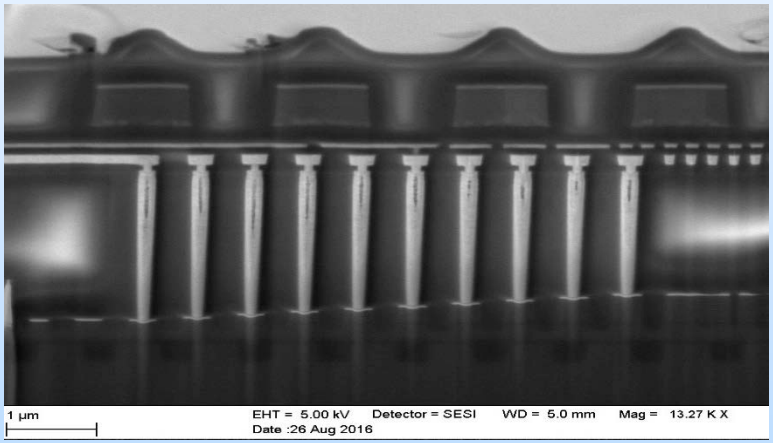
Hynix 3D 1X nm NAND FIB Cross-Section





Cross section showing FLASH array transition to periphery. Connections are identified for reference to higher magnification images in slides 10-11. Cross sections were taken along the Y-Axis

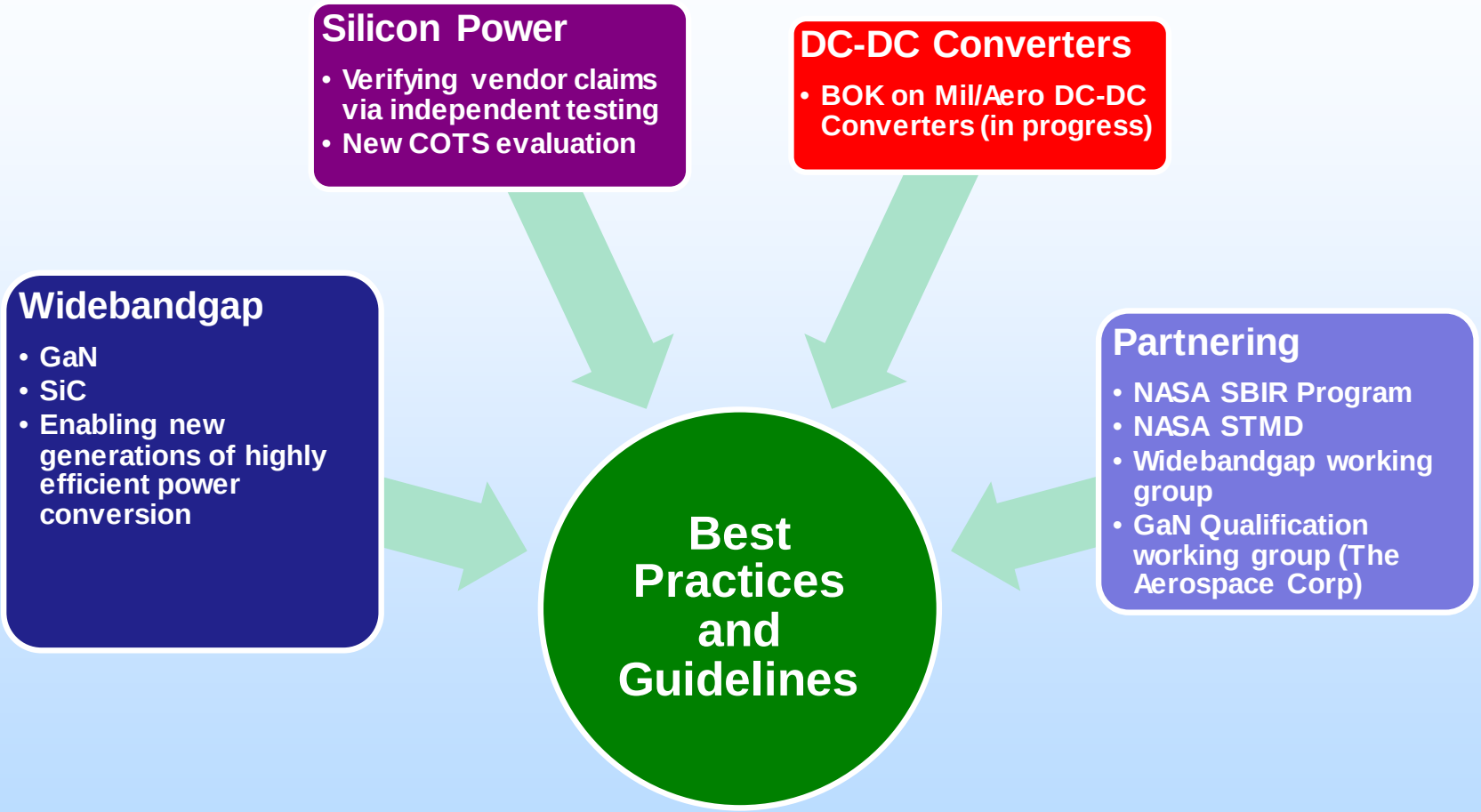




Higher magnification images of array connections 1 (left) and 2 (right)

NAND Flash provides non-volatility and extremely high memory density of interest to NASA flight projects. This work is being performed collaboratively with NSWC Crane and coordinated with NASA STMD.

NEPP – Power



Related task areas:

NEPP Hybrids Working Group and Audit Support

Among the other NEPP efforts or plans…

- Small mission and new assurance approaches (see Wednesday's sessions)
- 2.5/3D ICs and other advanced packaging (see Thursday's sessions)
- DoD and NASA STMD technology development support
  - Sub 32nm CMOS –commercial and DoD funded
- Assurance
  - Automotive electronics (see tomorrow)
  - Capacitors (see tomorrow)
  - Connectors
  - Hermetic leak testing (see tomorrow)
  - Failure issues, standards support, audits, etc… (see tomorrow)
  - Proton test facilities (see tomorrow)
  - Schottky diode radiation guidance (see tomorrow)

"A Working List of Priorities"

- What do we need to do to enable "higher reliability" small (cost-effective) missions?
  - Improve "COTS" data sharing
  - Extend COTS testing
  - Extend model-based mission assurance
    - Guidance on "tailoring" of approaches
  - Best practices are OVERDUE for EEE parts
- Extend work with widebandgap
  - Need to deliver test guidance and additional test data
- FPGAs/Processors
  - Lots of interest in next-generation devices (CMOS, …)
- Reliability on complex technologies
  - 3D, MPSOCs, … - what do we do?
  - MPSOC

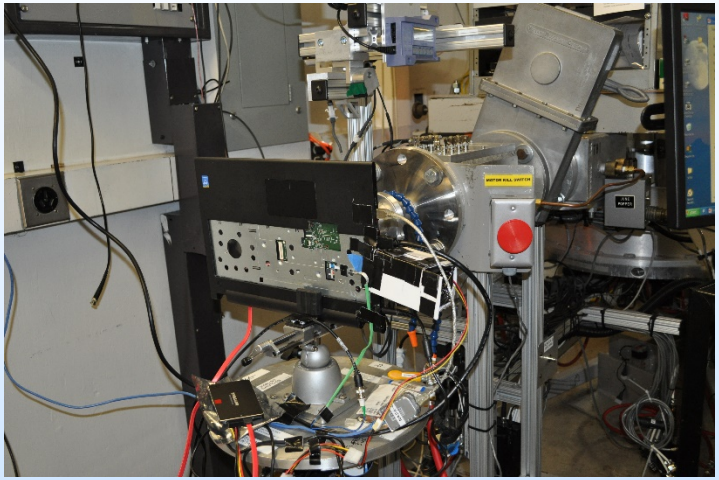
Challenges

- **Test sample access**
  - **Getting commercial devices is getting harder**
    - **Ex. Solid state drives vs. piecepart, DIMM vs. piecepart**
  - **Too small a customer to purchase?**
- **Testability**
  - **Circuit complexity (billion transistors)**
  - **Data extrapolation and analysis**
  - **Silicon vs. package**
  - **Single event challenges**
    - **Materials, thermal, speed, sensitive volume…**

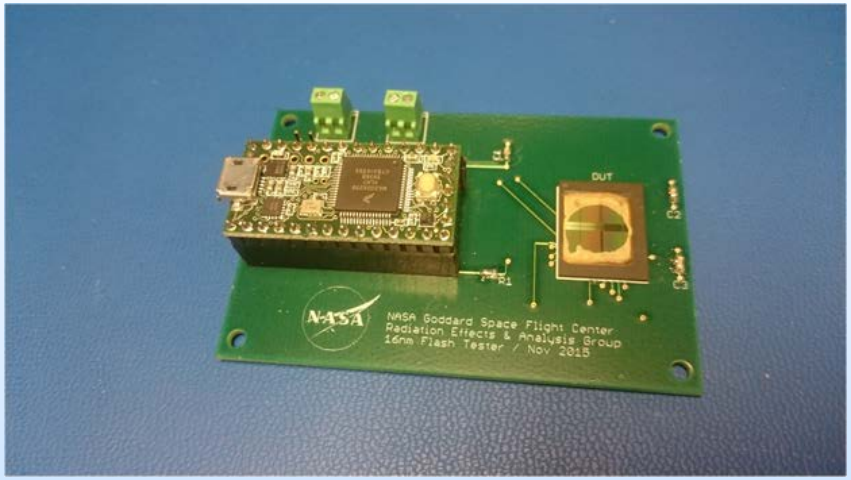
Limitations – Technology investments

- **Areas NEPP is interested in but limited or no work due to budget**
  - **Mixed signal**
    - **ADCs/DACs**
    - **SiGe**
  - **Power (test/evaluation)**
    - **DC-DC, point of loads (POLs)**
  - **Photonics**
    - **Integrated**
    - **Fiber Optics**
    - **Optocouplers**
  - **Sensors**
    - **Visible, infrared, etc…**
  - **Embedded FPGAs, and so on**

NEPP Test Pictures



NEPP and NSWC Crane members participate in a test for simulation of effects from Galactic Cosmic Ray (GCR) environment at Texas A&M University's Cyclotron Institute on Intel processors.



Flash memory microcontroller tester, adaptable for most NAND flash devices on the market. Capabilities like this are often used by flight projects after NEPP development (and, of course, NEPP tests).

Summary and Comments

- **NEPP Tasks are constantly evolving as technology and products become available.**
  - **Like all technology roadmaps, NEPP's is limited to funding and resource availability.**
    - **Many other efforts are not being shown today (60+ tasks total)**
    - **Example: CREME96 website operations is funded by NEPP (but not improvements nor CRÈME MC)**
  - **Partnering is the key:**
    - **Government,**
    - **Industry, and,**
    - **University.**
- **We look forward to further opportunities to partner.**

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