National Aeronautics and Space Administration

NASA Electronic Parts and Packaging (NEPP) Program: Overview and Technology Focus Areas

Responsive Technology Assurance for Civil Space

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Acronyms

Abbreviation	Definition
AMD	Advanced Micro Devices
BoK	Body of Knowledge
CAGR	Compound Annual Growth Rate
CMOS	Complementary Metal Oxide Semiconductor
COTS	Commercial Off The Shelf
CPU	Central Processing Unit
DoD	Department of Defense
DoE	Department of Energy
EEE	Electrical, Electronic, and Electromechanical
ETW	Electronics Technology Workshop
FFT	Fast Fourier Transform
FPGA	Field Programmable Gate Array
GaN	Gallium Nitride
GIDEP	Government Industry Data Exchange Program
GPU	Graphics Processing Unit
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
GSN	Goal Structuring Notation
GUI	Graphical User Interface
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
LaRC	Langley Research Center
MAPLD	Military and Aerospace Programmable Logic Devices (Workshop)
MBMA	Model-Based Mission Assurance
MRAM	Magnetic Random Access Memory
MSFC	Marshall Space Flight Center

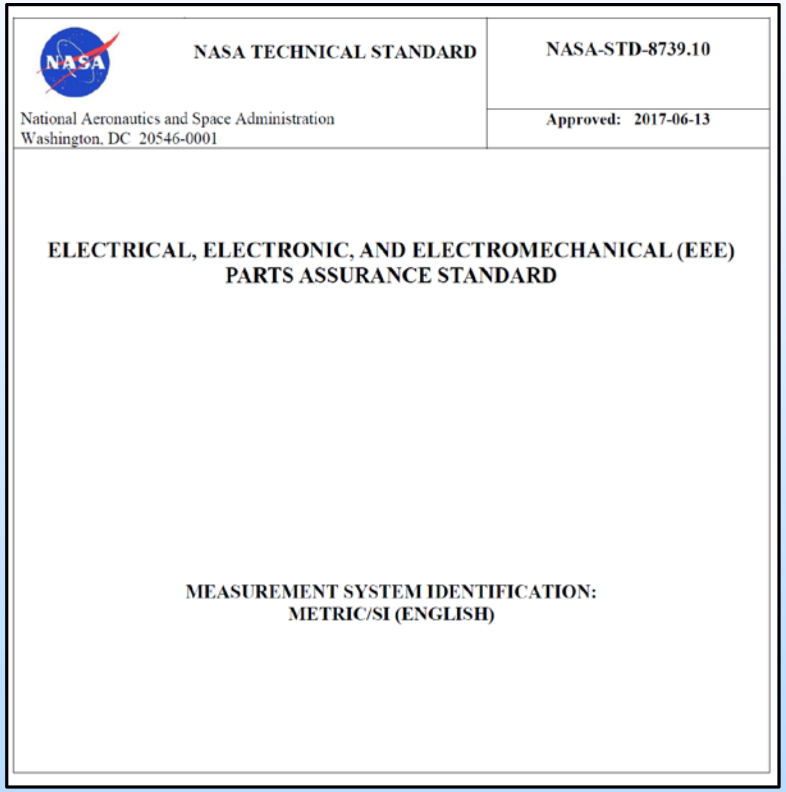
Abbreviation	Definition
NEPAG	NASA Electronic Parts Assurance Group
NEPP	NASA Electronic Parts and Packaging (Program)
NESC	NASA Engineering and Safety Center
NODIS	NASA Online Directives and Information System
OGA	Other Government Agency
OSMA	(NASA) Office of Safety and Mission Assurance
PCB	Printed Circuit Board
PoF	Physics of Failure
RDL	Redistribution Layer
RH	Radiation-hardened
RHA	Radiation Hardness Assurance
SDRAM	Synchronous Dynamic Random Access Memory
SEAM	Systems Engineering and Assurance Modeling
SEE	Single-Event Effects
SEM	Scanning Electron Microscope
SiC	Silicon Carbide
SMA	Safety and Mission Assurance
SMD	Science Mission Directorate
SME	Subject Matter Expert
SoM	System-on-Module
SSAI	Science Systems and Applications, Inc.
STMD	(NASA) Space Technology Mission Directorate
STT	Spin-Transfer Torque
TBD	To Be Determined
TOR	Technical Operating Report
TSV	Through-Silicon Via

Outline

- Continued evolution of NASA Electrical, Electronic, and Electromechanical (EEE) parts management
  - EEE Parts Manager & NEPP Program structure
  - General NASA EEE parts interfaces
- NEPP Program
  - Overview
  - Standards development and support
  - Key technology efforts for 2019
- Summary

NASA EEE Parts – Evolving Structure

- **NASA EEE parts and radiation engineering consolidation:**
  - Primary agency test and analysis activities will be at the Goddard Space Flight Center (lead Center) and the Jet Propulsion Laboratory
  - Agency EEE Parts Manager, Jonny Pellish, leads capability
- **NEPP Program remains the same:**
  - Owns EEE parts assurance processes and related technical efforts
  - NEPP Program management evolution
- **New NASA-wide document activities**


NASA TECHNICAL STANDARD

NASA-STD-8739.10

National Aeronautics and Space Administration
Washington, DC 20546-0001

Approved: 2017-06-13

ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS ASSURANCE STANDARD

MEASUREMENT SYSTEM IDENTIFICATION: METRIC/SI (ENGLISH)

https://standards.nasa.gov/

NASA EEE Parts – Interfaces

Agency EEE Parts

Assurance	Development		Facilities
Office of Safety & Mission Assurance	Office of the Chief Engineer	Flight Projects	Mission Support
- **NEPP Program** - Quality - Reliability - Workmanship	Capability Leadership NESC	Field Centers Mission Directorates	Space Environments Testing Management Office

NEPP Overview – Mission Statement

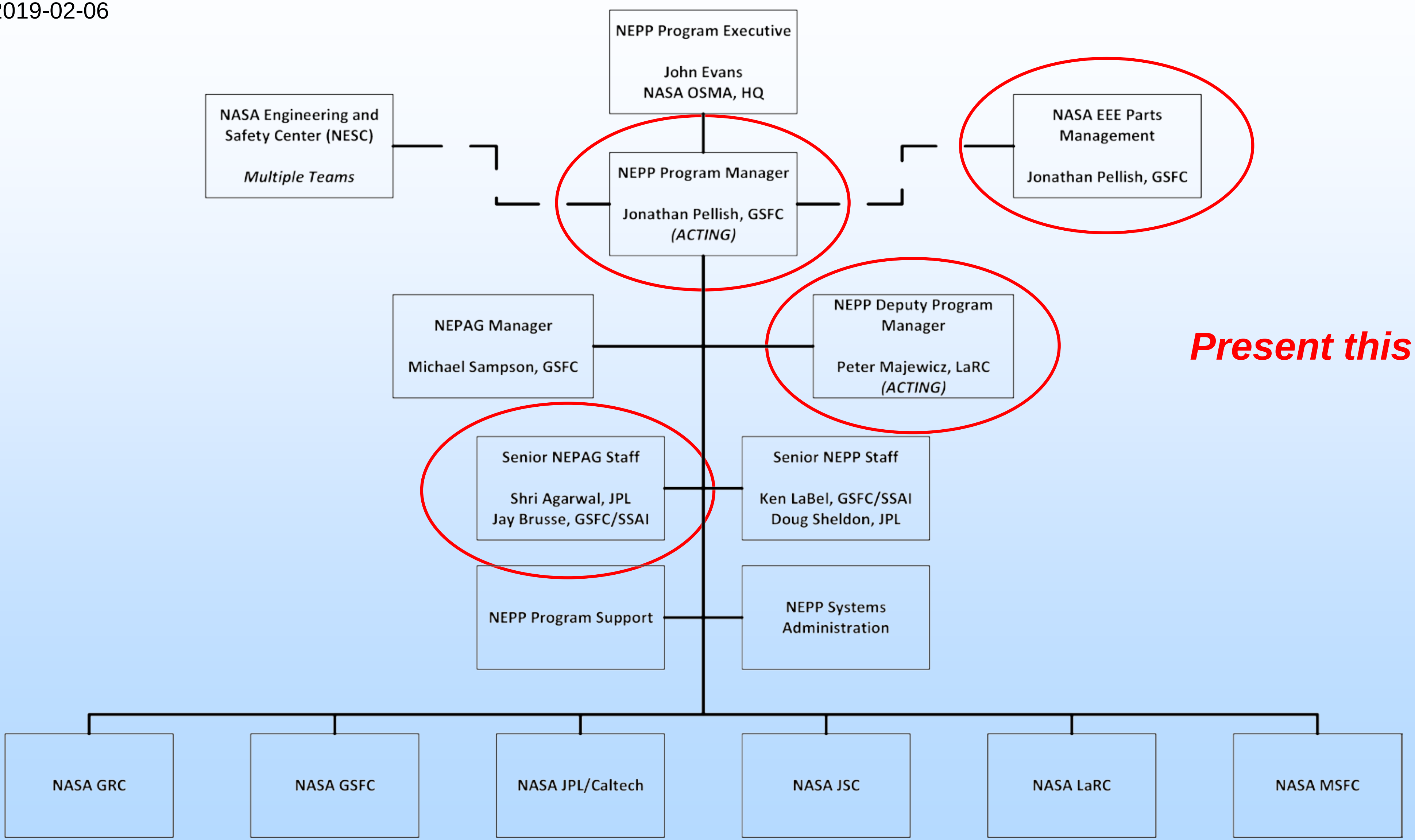
Provide NASA's leadership for developing and maintaining guidance for the screening, qualification, test, and reliable use of EEE parts by NASA, in collaboration with other government agencies and industry.

Accessible* & *Product-Oriented

Note: the NASA Electronic Parts Assurance Group (NEPAG) is a core portion of NEPP

NEPP Program – Organization Chart*

*as of 2019-02-06



Present this week

NEPP Charter Breakdown

Agency Priorities – Independent Support
- Commercial Crew
- Small Mission Reliability
- Coordination with NASA EEE Parts Mgmt., NESC, and STMD
- Collaborate with DoD/DoE on space radiation test infrastructure

Technology Evaluation
- New EEE parts/technologies
  - Ex. Advanced CMOS, GaN, SiC
- Working groups (NASA , government, aerospace)
- Screening / qualification / test / usage guidelines
- Partnering: NASA, government agencies, industry, university, international

EEE Parts Infrastructure
- NEPAG telecons and working groups
- SME capabilities
- Communication and outreach within NASA and to the greater aerospace community

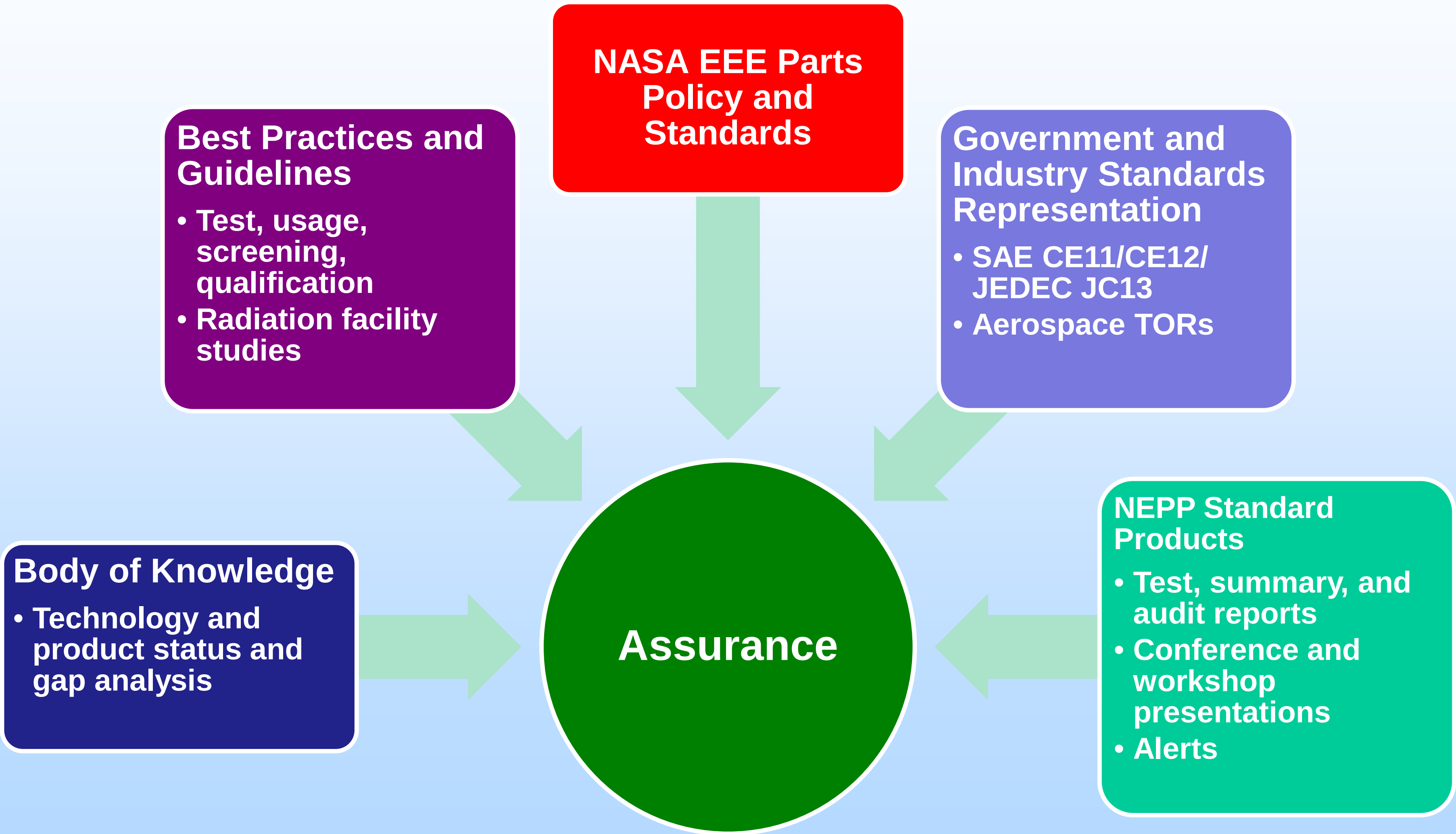
Trusted and RH Electronics
- Collaboration with NASA and other agencies, supply chain and trust / counterfeit electronics
- Support DoD efforts on trust & assurance
- Support DoD RH efforts

Agency Leadership
- NASA policies and procedures
- Agency guidelines, Body of Knowledge (BoK) documents, and best practices
- Coordination of government and industry standards
- Audit coordination with other government agencies
- Partnering within NASA and other agencies, industry, university, and international

EEE Parts Problem Investigations
- Agency / Industry-wide problems
- GIDEP and NASA Alert development

Mission Assurance

NEPP Product Delivery



NEPP Program / NEPAG Standards & Policy Development

- **Released NASA-STD-8739.10**
  - ***NASA EEE Parts Assurance Standard***
  - **Allows projects more flexibility to differentiate between critical/non-critical functions**
- **Updating EEE-INST-002**
  - ***Instructions for EEE Parts Selection, Screening, Qualification, and Derating***
  - **Will become new Agency-wide document**
  - **Goal is to modernize and harmonize existing documentation**
  - **Ongoing throughout calendar year 2019**
- **Updating NPR-8705.4**
  - ***Risk Classification for NASA Payloads***
  - **Appendix C – Recommended SMA-Related Program Requirements for NASA Class A-D Payloads**
  - **Goal for EEE parts is a mapping that recommends parts with respect to payload class (A-D), mission criticality (critical/noncritical), and part grade level (space, military, industrial, COTS, etc.)**

NASA Technical Standards: https://standards.nasa.gov/

NASA Online Directives Information System (NODIS): https://nodis3.gsfc.nasa.gov/

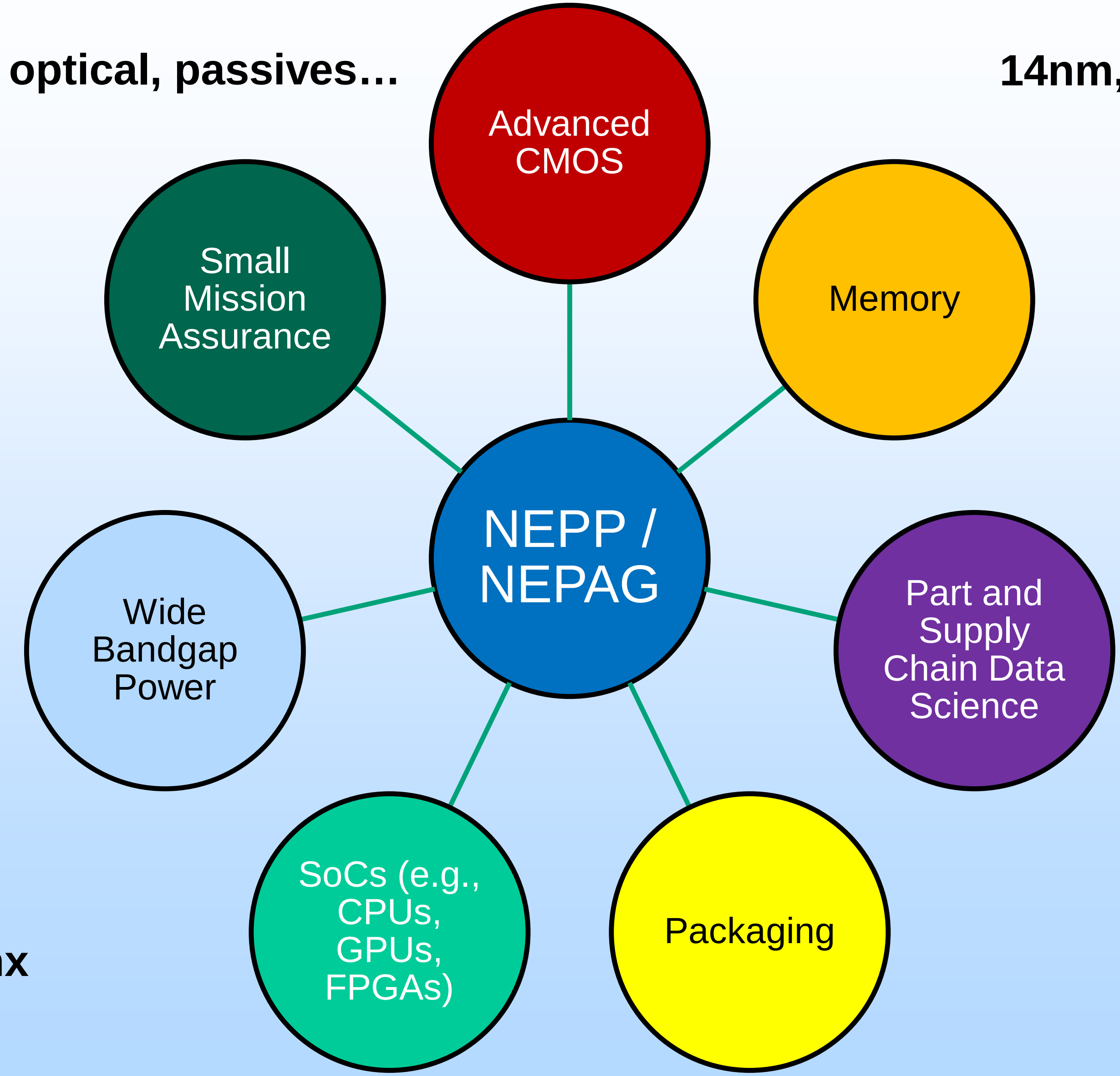
Major Technology Assurance Areas for 2019

Other: data conversion, optical, passives…

14nm, 22nm, 32nm, & 45nm

Model-Based Mission Assurance (MBMA)

NAND / NOR, SDRAM Discrete & Embedded STT-MRAM, Crosspoint



GaN (enhancement & RF) and SiC

Supply Chain Studies, Web Scraping, Metadata Analysis, Formal Methods

AMD, Intel, Microsemi, Nvidia, Qualcomm, Xilinx

2.5D / 3D solutions, Ever-Evolving Market, Supporting Qualification Efforts

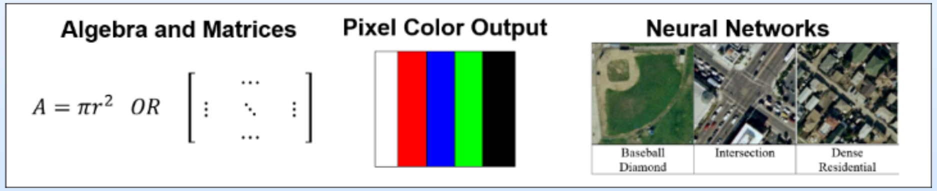
Other 2019 NEPP Program Highlights

- Increasing focus on advanced packaging assurance (2.5D / 3D)
- Executing SmallSat industrial base assessment with support from partner organizations
- Developing additional Radiation Hardness Assurance products
  - Best practices for testing at medical proton therapy facilities
  - GaN body of knowledge (in review now) and SiC RHA testing best practices
- Supporting evaluation and comparison of *Fides* vs. Physics-of-Failure (PoF)-based EEE parts reliability assessment
- Supporting commercial-off-the-shelf copper wire interconnect assessment with the NASA Engineering and Safety Center
- Examining opportunities for more significant integration of NEPP documentation into future community-consensus products (e.g., SAE)
- Continuing delivery of standard assurance products / services
  - Audit support, domestic / international coordination telecons, Government Working Group
  - BoKs, guidelines, tools, information sharing, and training

CPU and GPU Testing Highlights

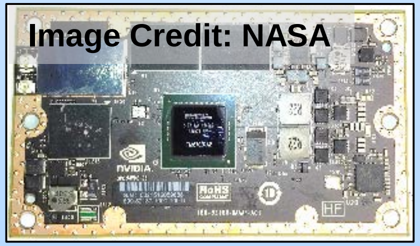
Development Milestones:

- Software payloads test suite includes:
  - Math (FFT, LinPack, PI)
  - Memory hierarchy
  - Neural networks
  - Output buffer (colors, patterns)
- Conduction cooling system and adapter plates
- Test system GUIs to control and monitor

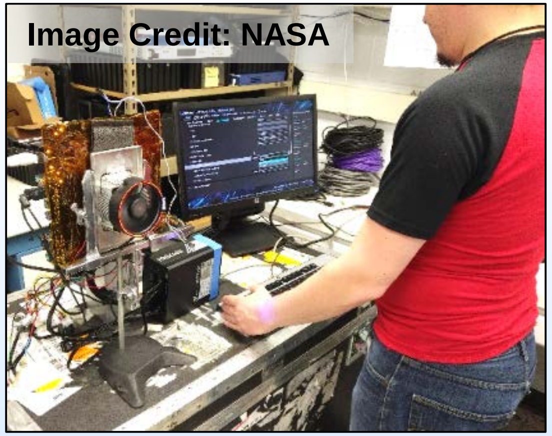


Deliverables:

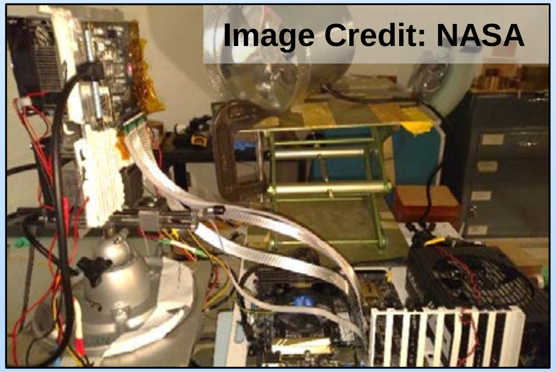
- Test reports and quarterly reports
- NEPP Body of Knowledge on Graphics Processing Devices



Nvidia GTX 1050 GPU (left), Nvidia TX1 SOM (above)



AMD Ryzen 2600 CPU – delidded, cooled through backside and socket



Nvidia GTX 1050 GPU – No heat sink, die thinned, cooled through backside

Test Devices

CPUs

- 14nm++ Intel
- 10nm AMD (Global)

CPU with eGPUs

- 14nm++ Intel
- 10nm AMD (Global)
- 10nm Qualcomm (Samsung)

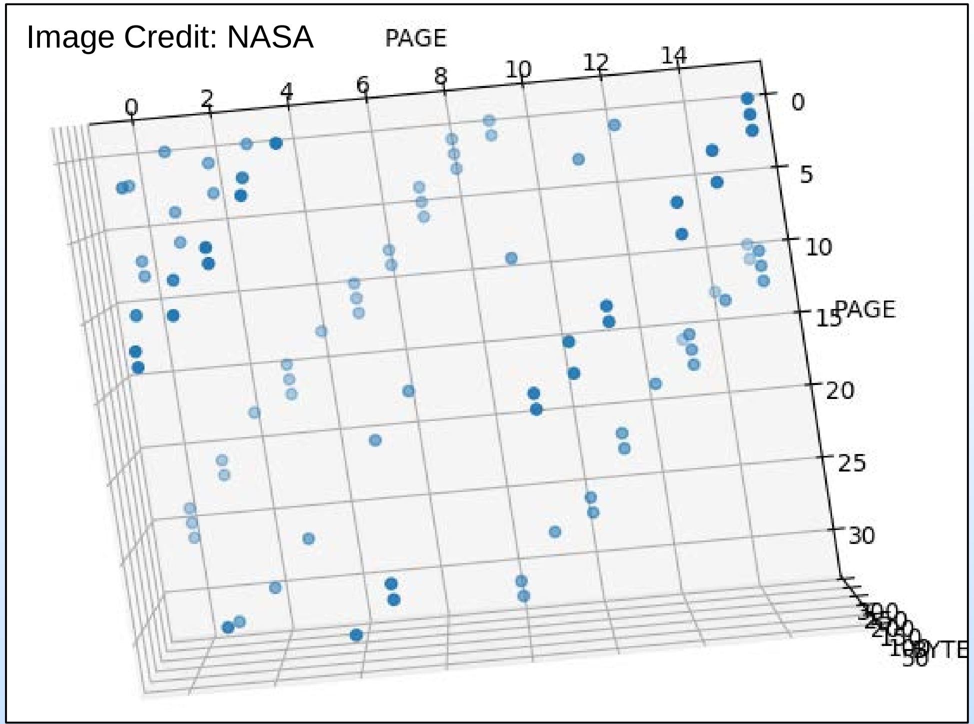
GPUs

- 14nm Nvidia GTX 1050 (& 1080)
- 12nm Nvidia RTX
- 14nm AMD Radeon RX580 & E9173
- 14nm Intel “Odyssey” GPU (TBD)

System-on-Chip

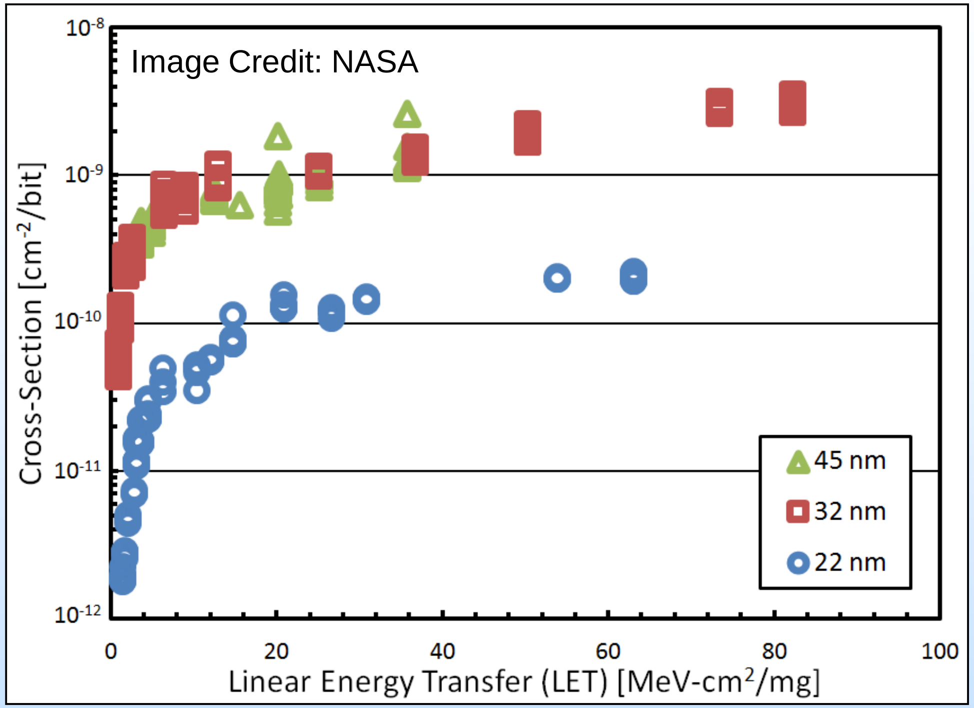
- 20nm Nvidia Tegra X1
- 16nm Nvidia Tegra X2
- 12nm Nvidia Tegra Xavier
- 10nm Qualcomm Snapdragon 850
- 7nm Qualcomm Snapdragon 8cx

Advanced Technology Evaluation Examples



Angled heavy ion tracks in 3-D NAND Flash
Micron MT29F1T08CMHBB
256 Gb die, MLC, 32 layers, piece-part testing

T. Wilcox et al., SEE/MAPLD 2018.



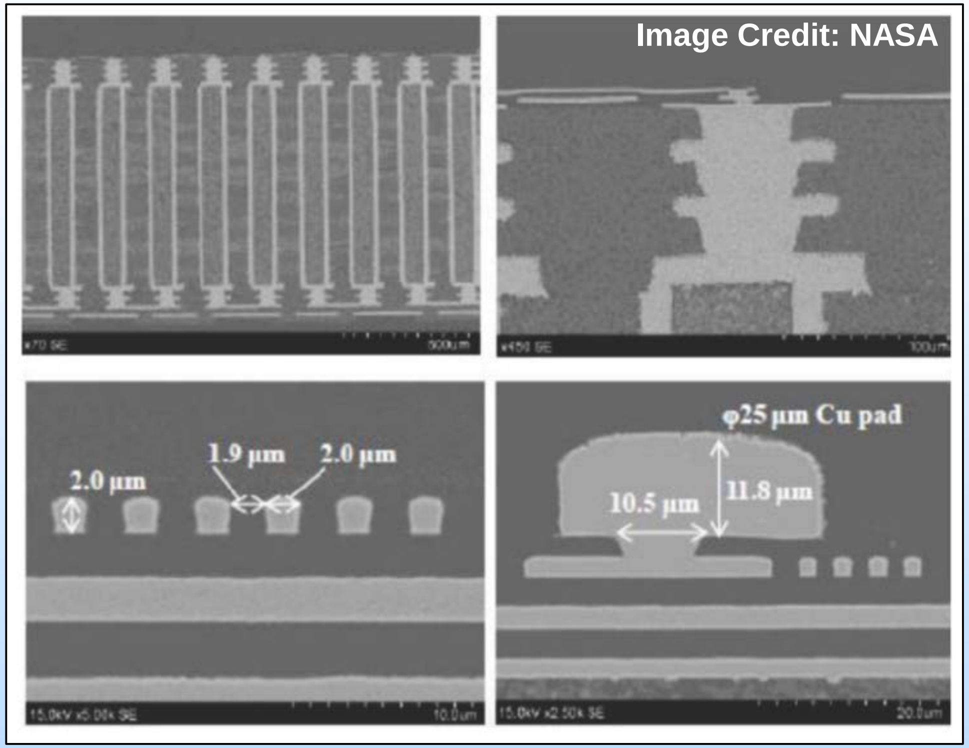
Heavy ion cross sections
GlobalFoundries 45 & 32 nm PDSOI, 22 nm FDSOI
Static Random Access Memories

M. Casey et al., IEEE NSREC 2018.
Collaboration with DMEA, Sandia, and GlobalFoundries

Pace of technology evolution and growth of evaluation requirements continue to generate new demands: 1) diversified subject matter expertise; 2) more access to a wider variety of radiation test facilities

Ever-Changing Advanced Packaging

2D → 2.5D → 3D



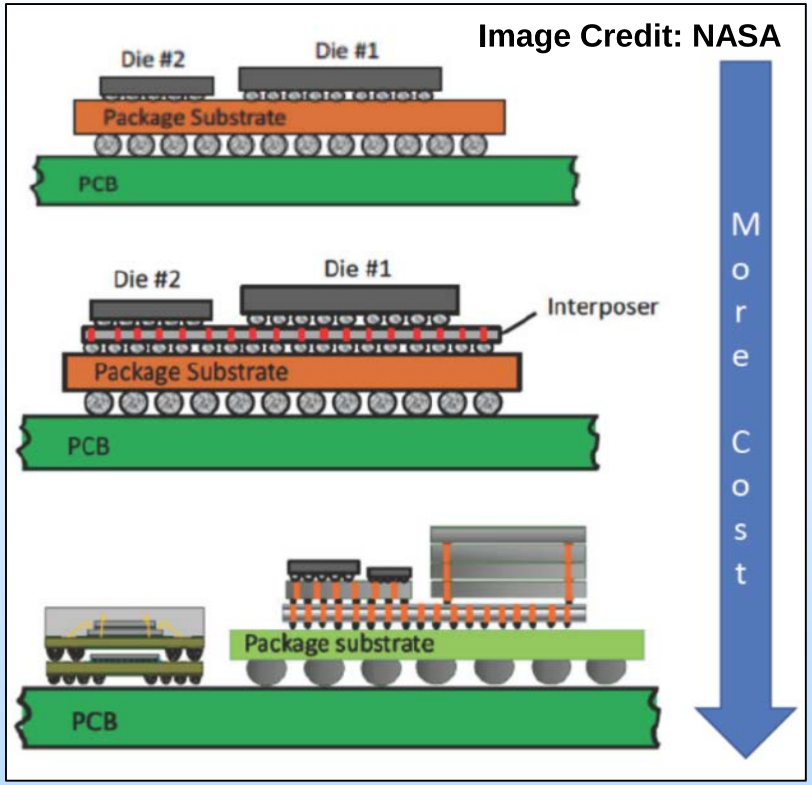


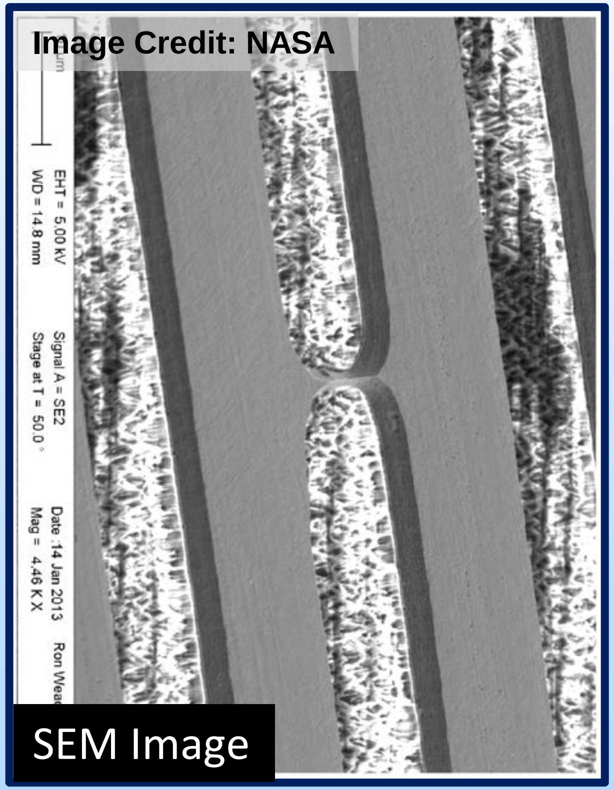
Image credits: D. Sheldon, NASA/JPL-Caltech, NEPP ETW 2018.

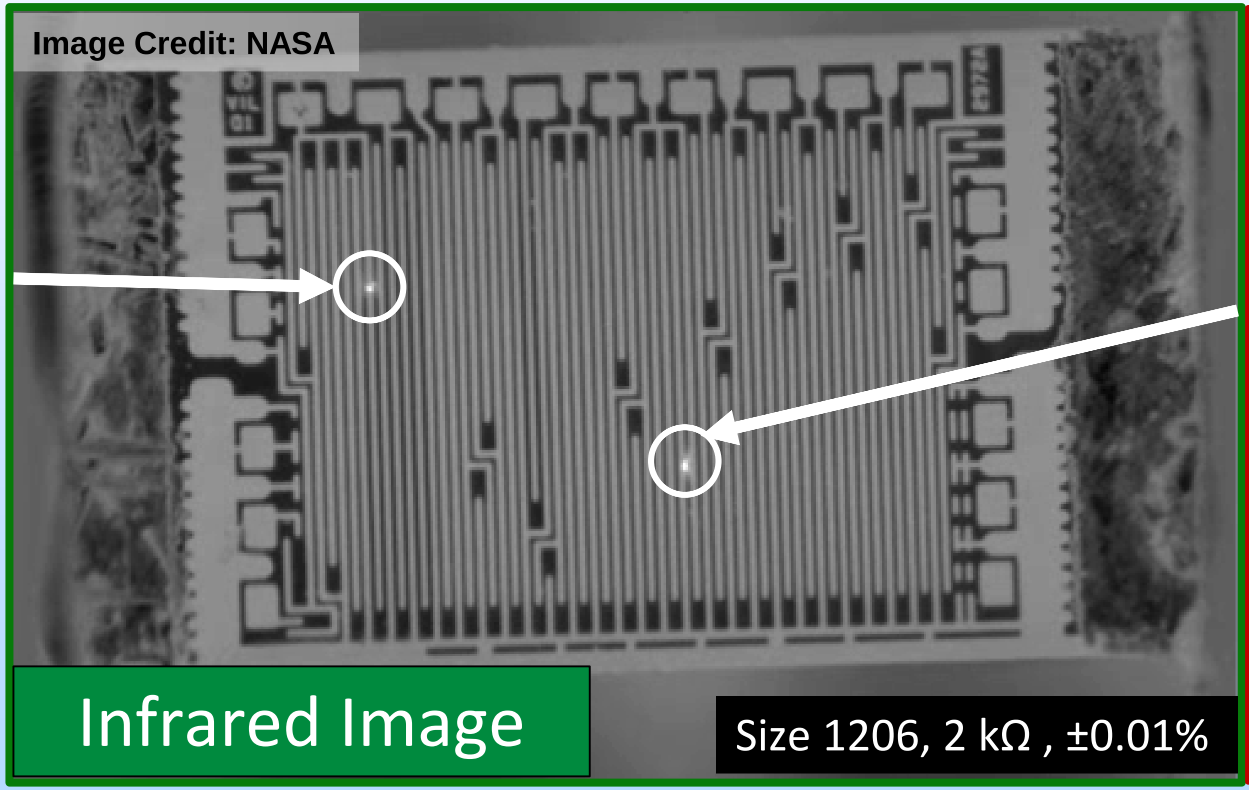
- **Driven almost entirely by size, weight, and power – usually not to improve reliability**
- **Unless explicitly designed from the ground up, these technologies are expected to have at best break even reliability compared with heritage Plastic Encapsulated Microcircuits**
- **Are there general approaches for essentially custom solutions?**

New Screening Technique to Identify Constriction Defects in Foil Resistor Patterns

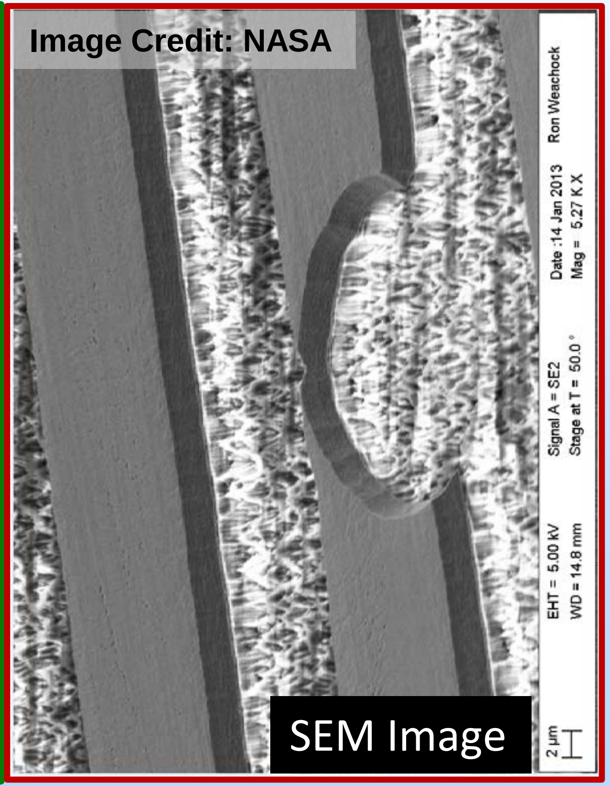
When Pulse Power is Applied Constrictions Become Easy to Detect As "Hot Spots" with Hi-Res Infrared

Bridge Defect





Notch Defect

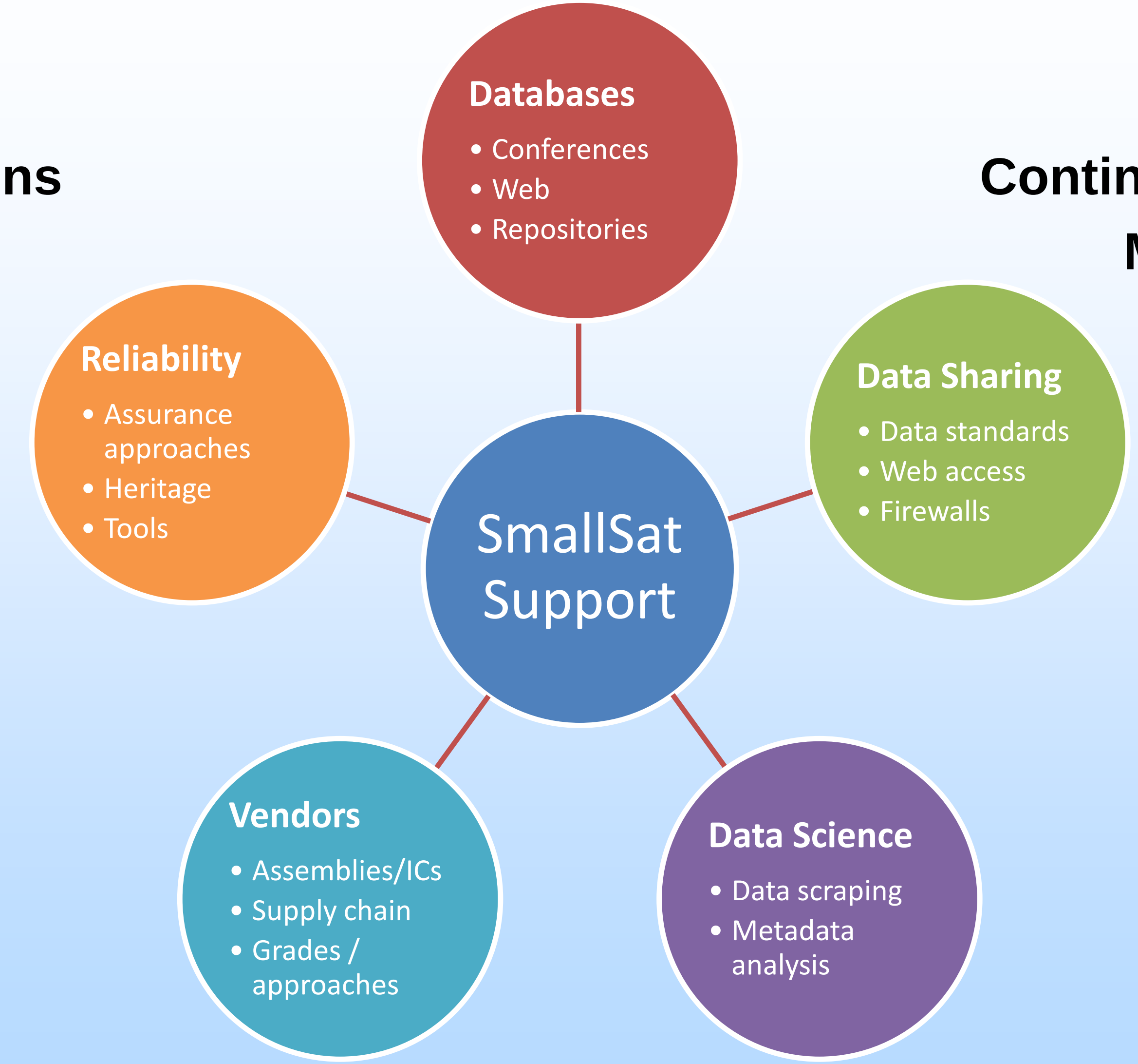


J. Brusse & L. Panashchenko, 3rd Space Passive Component Days Conference, Noordwijk, The Netherlands, October 9-12, 2018.

Evolving Landscape for SmallSat Assurance Support

Multiple Collaborations
- Academia
- Industry
- OGAs

Continued focus on Model-Based Mission Assurance (MBMA)

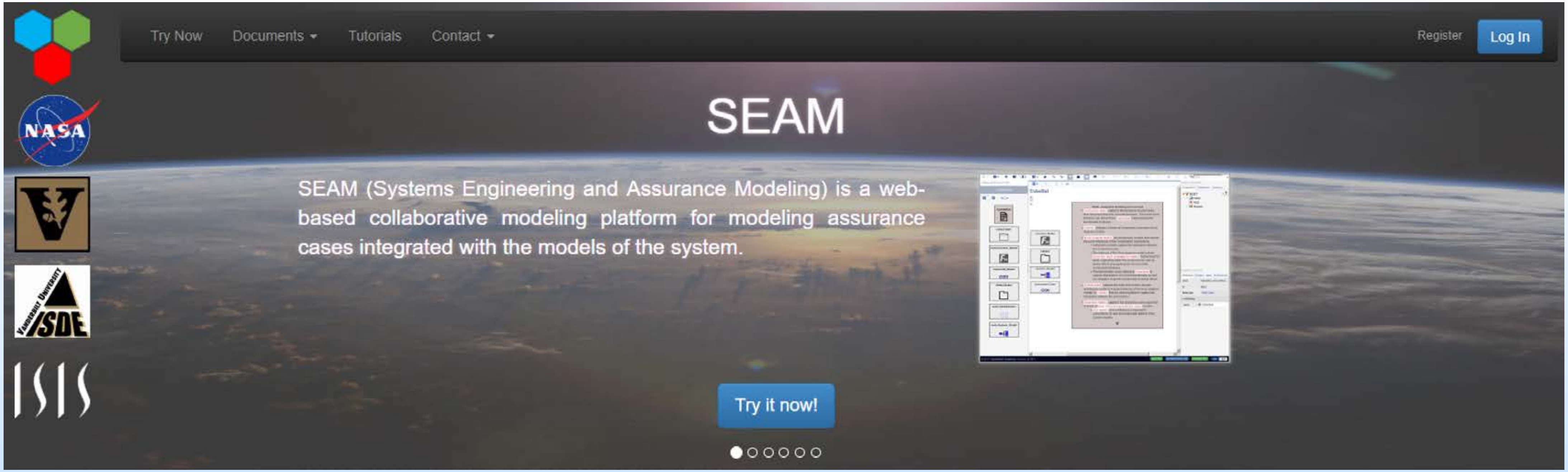


Accessible

Product-Focused

Linking Program Tasks to Community Focus Areas / Needs

MBMA Toolset Example

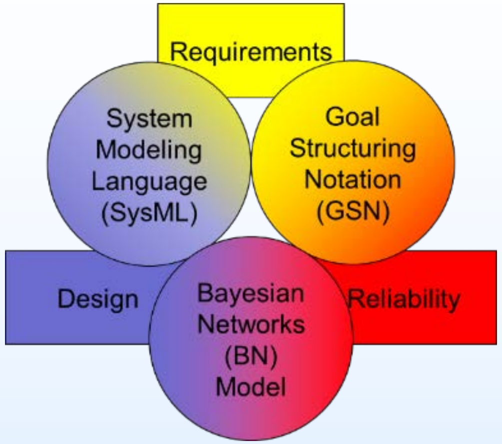


https://modelbasedassurance.org/ (developed and hosted by Vanderbilt University)

- **Uses NASA's Reliability and Maintainability Standard (NASA-STD-8729.1); serves as a template for constructing assurance cases for systems in space missions**
  - **Starting with RHA cases for COTS and small missions**
- **Supports the Goal Structuring Notations (GSN) standard to build assurance case models**
- **Supports a subset of block diagram models in the SysML modeling standard**
- **Extends the internal block diagram models to allow specification of discrete fault propagation**

Concluding Thoughts

- Data analytics (e.g., machine learning, data scraping, etc.) techniques are a unique opportunity to enhance and foster collaborations between organizations in order to share data bases
  - How can we encourage data sharing and efficient data exchange?
- High-performance components imply complex testing and qualification. Cost of qualification is increasing at an exponential (aka “Moore’s law”) rate and can reduce new technology options.
- Flight heritage on small satellite missions likely not sufficient justification for use on flagship missions
  - Challenge of how leverage small satellite mission success remains an open area for study and collaboration
- GaN commercial growth is expected to be almost 80% CAGR – implies that reliability issues dominate the ability to grow
  - Significant motivation on vendors to improve reliability of GaN and for us to leverage this improvement – GaN-on-Silicon will likely be a turning point in device reliability and needs to be evaluated
- Modeling and simulation of complex 2.5D/3D packaging technologies will be required to understand root cause failure mechanisms



Emerging Assurance Methods

(Witulski, Vanderbilt University, NEPP ETW 2017)

Image credit: Vanderbilt / NASA

10th Annual NEPP Electronics Technology Workshop (ETW)

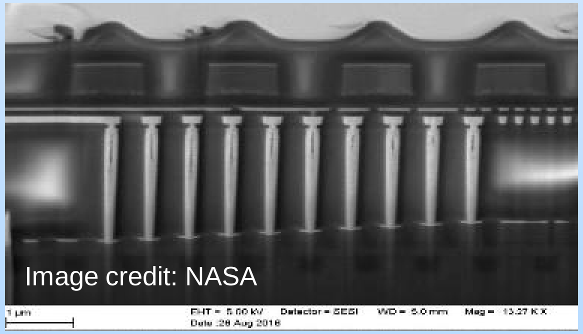
Scheduled dates:

June 17-20, 2019

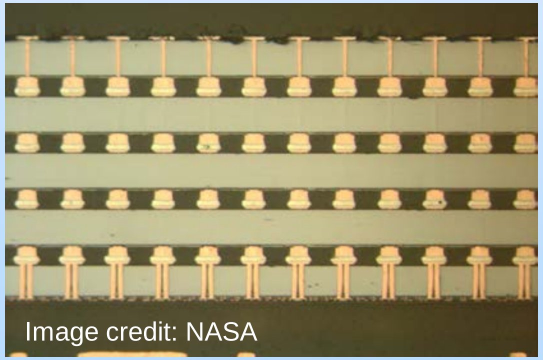
NASA/GSFC and on-line

https://nepp.nasa.gov/

Radiation Testing



Advanced Technology Reliability



Commercial IC Packaging

Please join us for the jointly held

2019 **Single Event Effects (SEE) Symposium** and

Military and Aerospace Programmable Logic Devices (MAPLD) Workshop

May 20-23, 2019

at the Marriott La Jolla, CA, USA

Registration for the meeting is open

Early registration (attendees & exhibitors) ends and hotel room block closes on Friday, April 19, 2019

https://seemapld.org/