The NASA Electronic Parts and Packaging (NEPP) Program – Parts, Packaging, and Radiation Reliability Research on Electronics

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Unclassified

Outline

- Overview of NEPP
  - What We Do and Who We Are
  - Flight Projects
  - Technology
  - Working With Others
- Recent Highlights
- Plans for FY13
- Challenges
- Summary

Presented by Kenneth A. LaBel at 16122-13 - The 10th International Workshop on Radiation Effects on Semiconductor Devices for Space Applications (RASEDA), Tsukuba, Ibarak, Japan, December 10-12, 2012, and published on http://nepp.nasa.gov/.

NEPP – What We Do

- NEPP provides two prime functions for NASA
  - Assurance infrastructure for NASA
  - Research on advanced/new electronic devices and technologies
- We work with
  - Active and passive semiconductors
  - Electronic device packaging
  - Radiation effects on electronics
- We collaborate with others in technical areas such as
  - Workmanship
  - Alert systems
  - Standards development and maintenance
  - Engineering and technology development
- We provide an *independent* view for the safe use of electronic integrated circuits for NASA

Electrical overstress failure
in a commercial electronic device

NEPP's Two Functions

- **Assurance**
  - Customer: *Space systems in design and development*
  - Issues applicable to currently available technologies (aka, mature technologies)
  - Examples
    - Cracked capacitors
    - Power converter reliability
  - NASA Electronic Parts Assurance Group (NEPAG) - a subset of NEPP
    - Communication infrastructure
    - Audit and review support
    - Investigation into reported failures (when of potential wide-reaching impact to NASA flight projects)
- **Advanced/new electronics technology research**
  - Customer: *Space systems in early design or conceptualization*
  - Issues applicable to new technologies (or those with potential Mil/Aero applicability)
  - Examples
    - Commercial field programmable gate arrays (FPGAs)
    - Sub 32nm electronics
  - Technology evaluation
  - Development of test methods and qualification recommendations

The NEPP Program in a Nutshell

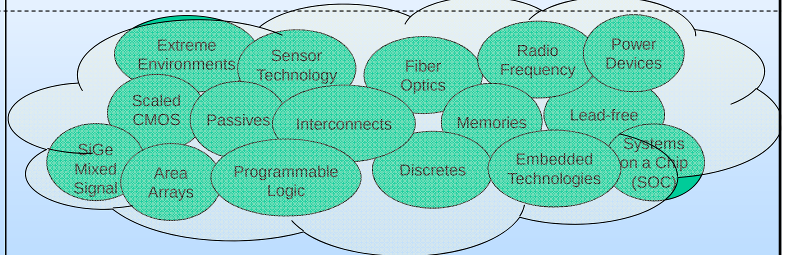
Management

Ken LaBel - *Engineering*	Mike Sampson - *Assurance*
Radiation Effects	NEPAG
Advanced Actives	Passives
NEPP Events	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

NASA EEE Parts Assurance Group (NEPAG)

- Formed in 2000
- Weekly Telecons
  - International monthly
  - Typical participation ~ 35
  - Share knowledge and experience
  - Address failures, requirements, test methods
  - Monthly international
- Audit support
- Coordinate specification and standards changes

NEPP and NASA Flight Projects

NEPP

- Works general device qualification standards
- Develops the knowledge-base on *HOW* to qualify a device used by flight projects
  - Test methods
  - Failure mode identification
  - User guidelines and lessons learned
- Works issues that are relevant across NASA

Flight Projects

- Work mission specific requirements
- Qualify a device to mission requirements or to a standard
  - Uses NEPP knowledge to perform qualification
- Work issues relevant to a specific project

NEPP provides products for use by flight projects

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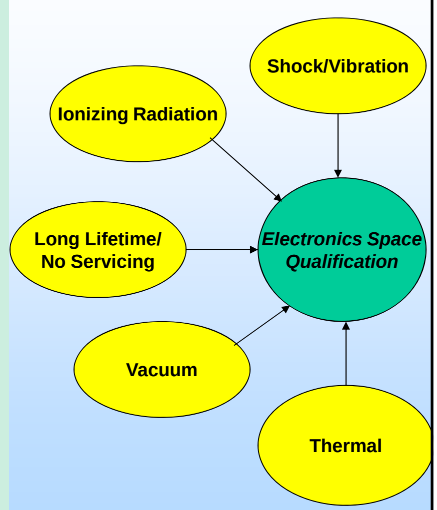
Qualifying Electronic Technologies

NEPP Perspective

- Electronics in space face hazards significantly beyond the terrestrial/commercial environment
- *Qualification requires repeatable and statistically significant testing over relevant environments to ensure mission success*
- NEPP provides the basis for understanding the "how to" for electronics qualification
- Is this needed for commercial devices?
  - Previous independent review/testing has repeatedly shown discrepancies between industry claims versus independent test results that impact reliable usage in space



... Effects on Semiconductor Devices for Space Applications (RASEDA), Tsukuba, Ibarak, Japan, December 10-12, 2012, and published on http://nepp.nasa.gov/.

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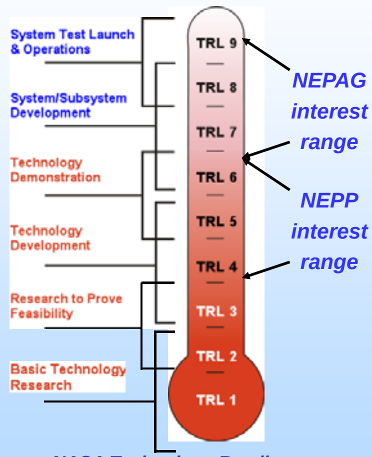
Maturity of Technology –
The NEPP Model

- NASA flight project timelines are insufficient to learn how to qualify a new technology device
  - *Sufficient time may exist to qualify a device, but not to determine HOW to qualify*
- For 2016 launch, technology freeze dates are typically 2013 or earlier
- Technology development and evaluation programs need to be in place prior to mission design
  - NEPP's strategic advanced planning on technology evaluation is critical to allow timely and safe flight project insertion of new technologies



NASA Technology Readiness Levels (TRLs)

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Sample NEPP Technology Challenges

Key Question: Can we "qualify" without high cost and schedule?

Silicon
- <32 nm CMOS
- new materials such as CNT
- FINFETs
- 3D ICs

Device Architectures
- system on a chip
- interconnects
- power distribution
- high frequencies
- application specific results

Packages
- inspection
- lead free
- failure analysis
- stacking

Connectors
- higher-speed, lower noise
- serial/parallel
- ruggedized, electro-optic

Passives
- embedded
- higher performance
- BME capacitors

Power Conversion
- widebandgap devices
- distributed architecture
- thermal modeling
- stability

Board Material
- thermal coefficients
- material interfaces

Related areas (non-NEPP)

Design Flows/Tools
- programming algorithms, application
- design rules, tools, simulation, layout
- hard/soft IP instantiation

Workmanship
- inspection, lead free
- stacking, double-sided
- signal integrity

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Sharing NEPP Knowledge

- **NEPP success is based on providing appropriate guidance to NASA flight projects**
  - **Interaction with the aerospace community, other government agencies, universities, and flight projects is critical.**
- **NEPP utilizes**
  - **NEPP Website: http://nepp.nasa.gov**
  - **NEPP 4th Annual Electronics Technology Workshop (ETW): Week of June 3rd 2013 (tentative)**
    - **HiREV (National High Reliability Electronics Virtual Center) Review Meeting to be held in conjunction**
  - **Standards working groups**
  - **Telecons (NEPAG weekly and monthly international)**
  - **Documents such as Guidelines, Lessons Learned, Bodies of Knowledge (BOKs)**

Collaboration

- **"Promote enhanced cooperation with international, industry, other U.S. government agency, and academic partners in the pursuit of our missions." –** ***Charles Bolden, NASA Administrator***
- **NEPP has a long history of collaboration. Examples include:**
  - **Direct funding and in-kind (no funds exchanged) support from DoD**
  - **Multiple universities**
    - **Vanderbilt, Georgia Tech, U of MD, Auburn University, …**
  - **Electronics manufacturers too numerous to mention!**
  - **International with major non-US government agencies**
- ***We work with the NASA flight programs, but do not perform mission specific tasks***

Consortia and Working Groups

- NEPP realizes the need to work in teams to provide better and more cost-effective solutions
- NEPP utilizes working groups for information exchange and product development
  - External examples:
    - JEDEC commercial electronics and TechAmerica G11/12 Government Users
  - Internal (NASA-only) examples:
    - DC-DC converters, point-of-load convertors, GaN/SiC, and connectors
- NEPP supports university-based research when funds allow

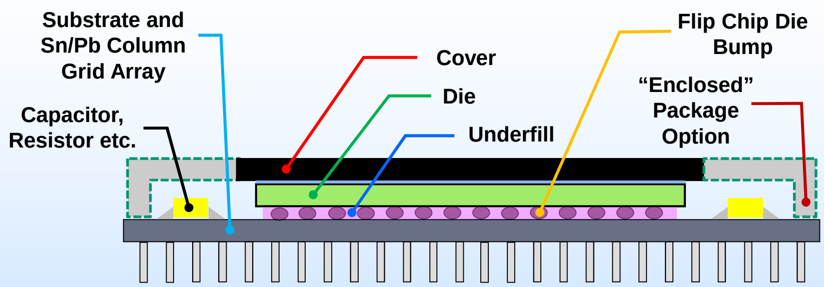
NEPP Recent Highlights (1 of 2)

- Continued leading Qualified Manufacturer's List (QML) MIL-PRF-38535 Class Y development
- Released documents:
  - Single event effects (SEE) Test Guideline for FPGAs
- Documents in review (release in FY13):
  - Flash memory radiation test guideline
  - Solid state recorder (SSR) radiation considerations
- Firsts
  - Combined radiation/reliability tests of GaN devices, DDR-class and Flash memories
  - Radiation tests of
    - 28nm TriGate processor (proprietary data)
    - 32nm SOI processor (AMD)
  - Destructive SEE observed on Schottky Diodes
  - Independent SEE test of Xilinx Virtex-5QV

NEPP Recent Highlights (2 of 2)

- 3rd NEPP Electronics Technology Workshop (ETW) - June 2012
  - 2.5 days of presentations
  - ~250 attendees including 50% via the web
- Assurance Efforts
  - Hermetic seal test method intercomparison
  - Cracked capacitor evaluation
- Recent test focuses (on-going)
  - Power devices
    - GaN, SiC, and Si Power Device (radiation and combined effects)
  - FPGAs
    - Xilinx Virtex-5QV and Commercial (radiation)
      - Underfill (reliability)
  - Point-of-load (POL) Converters

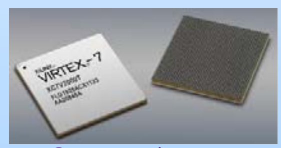
Non-hermetic IC Package, with "Space" Features(CCGA?)



Space Challenge	Some Defenses
Vacuum	Low out/off-gassing materials. Ceramics vs polymers.
Shock and vibration	Compliant / robust interconnects - wire bonds, solder balls, columns, conductive polymer
Thermal cycling	Compliant/robust interconnects, matched thermal expansion coefficients
Thermal management	Heat spreader in the lid and/or substrate, thermally conductive materials
Thousands of interconnects	Process control, planarity, solderability, substrate design
Low volume assembly	Remains a challenge
Long life	Good design, materials, parts and process control
Novel hardware	Test, test, test
Rigorous test and inspection	Testability and inspectability will always be challenges

NEPP Task Focuses – FY13

- Goals: Develop guidelines for qualification and radiation testing
  - Class Y Qualification (non-hermetic area array)
  - Flash Memory Qualification (reliability)
  - Flash Memory Testing (radiation)
  - Solid State Recorder (radiation)
  - DDR-class Memory (reliability)
- Evaluate state-of-the-art commercial electronics (reliability, radiation)
  - Memories, FPGAs, SOC Processors
  - Xilinx Virtex-7
  - Sub-32nm CMOS
  - Ipad™
  - Base Metal Electrode (BME) Capacitors



Courtesy eetimes.com

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Sample NEPP Areas – Radiation Effects

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

Legend
- DoD and NASA funded
- NASA-only funded
- Unfunded in FY13

NEPP Research Categories – Active Electronics (1 of 2)

SiGe. Mixed Signal
- IBM 9hp
- SiGe Physics Modeling
- Advanced Data Conversion, Amplifiers, Drivers
- Architectural comparison

Develops students at Georgia Tech

Scaled CMOS
- Commercial Devices
- Memories – Non-volatile, volatile
- FPGAs
- Processors, SOCs
- Structured ASICS
- Test Structures
- Silicon on Insulator (SOI)
- Ultra-low power
- Below 32nm
- CNTs
- RHBD Support

Partners include: DoD, IBM, TI, Intel, Boeing, Aeroflex, Xilinx, Microsemi

Sensor Technologies
- IR
- Visible
- Cryo SEL
- Others

Partners at: AFRL, Cypress, Ball

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

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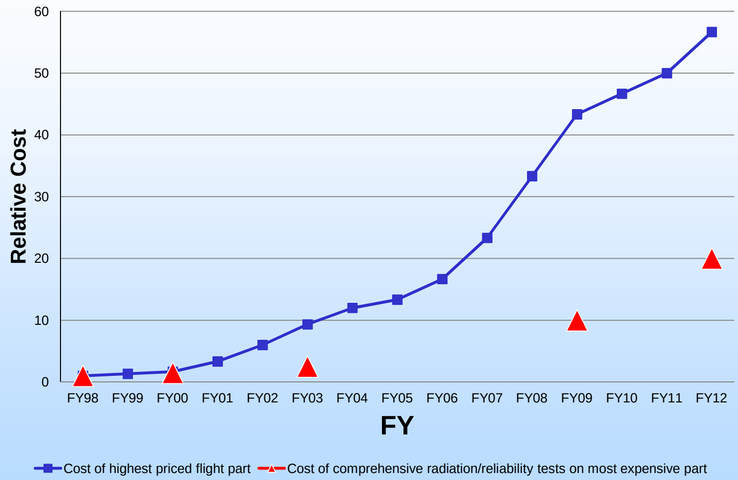
Estimated Test/Parts Costs Normalized to FY98



Bottom line:

Test costs have risen significantly, unfortunately NEPP budget hasn't!

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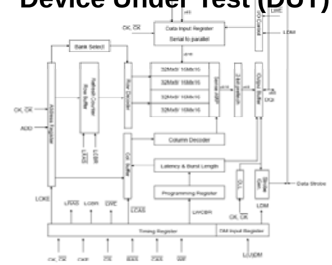
Disclaimer: Statistics and "Radiation Qualification"

Device Under Test (DUT)



Commercial 1 Gb SDRAM
- -68 operating modes
- -can operate to >500 MHz
- -Vdd 2.5V external, 1.25V internal

Single Event Effect Test Matrix

full generic testing

Amount	Item
3	Number of Samples
68	Modes of Operation
4	Test Patterns
3	Frequencies of Operation
3	Power Supply Voltages
3	Ions
3	Hours per Ion per Test Matrix Point

66096	Hours
2754	Days
7.54	Years

Doesn't include temperature variations!!!

Devices/technology are more complex: testing is as well

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Budget Challenges for FY13

- The NEPP Program had a significant budget cut in FY13
- Reduction in efforts from FY12:
  - Areas unfunded or very limited in FY13 include
    - Photonics
    - Sensors/imagers
    - Mixed signal electronics
    - Commercial systems
    - University grants (research)
  - Fewer technology evaluations/tests
  - Commodities expertise at risk
  - Travel reduction impacts number of audits and meetings supported

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 use of evaluated technologies),
  - Never forgetting our partners, and,
  - Attempting to do ***"less with less"*** (rising test costs versus NEPP budget reduction).
- We invite your feedback and collaboration and invite you to visit our website (http://nepp.nasa.gov) and join us at our annual meeting in June at NASA/GSFC or via the web.
- Questions?

Backups

FY12 NEPP Technology Efforts – Part 1

Radiation Hardness Assurance (RHA) and Guidelines

Low proton energy SEE test guide – Jonathan Pellish, NASA/GSFC

Ultra-ELDRS and ELDRS on Discretes – Dakai Chen, NASA/GSFC

IR Array Lessons Learned – Cheryl Marshall, NASA/GSFC

FPGA Standard SEE Test Guide – Melanie Berg, MEI Technologies – NASA/GSFC

Flash Memory Qualification Guide - Doug Sheldon, JPL

NVM Standard Radiation Test Guide – Tim Oldham, Dell – NASA/GSFC

NVM Combined Radiation and Reliability Effects – Tim Oldham, Dell – NASA/GSFC

DDR2 Combined Radiation and Reliability Effects - Ray Ladbury, NASA/GSFC

Updated Solid State Recorder Guidelines – Ray Ladbury, NASA/GSFC

Correlation of LASER to Heavy Ion Millibeam with FLASH Memories - Tim Oldham, Dell – NASA/GSFC

SEE Test Planning Guide – Ken LaBel, NASA/GSFC

Hydrogen and ELDRS – Philippe Adell, JPL

Devices

FPGA – Xilinx Virtex 5QV (SIRF) Independent SEE Testing - Melanie Berg, MEI Technologies – NASA/GSFC

FPGA – Commercial Virtex 5 SEE – Melanie Berg, MEI Technologies – NASA/GSFC

FPGA - Microsemi RTAX4000DSP SEE and ProASIC TID/SEE - Melanie Berg, MEI Technologies – NASA/GSFC

FPGA – Microsemi ProASIC Reliability – Doug Sheldon, JPL

Class Y (non-hermetic area array packaged device qualification) and related tests (Xilinx and Aeroflex packages/devices) – Doug Sheldon, JPL

FLASH Memory Radiation Effects – Tim Oldham, Dell – NASA/GSFC and Farohk Irom, JPL

Alternate NVM – MRAM/FRAM Reliability – Jason Heidecker, JPL

DDR2/3 Radiation Effects and Combined Effects – Ray Ladbury, NASA/GSFC

DDR2/3 Reliability – Steve Guertin, JPL

Newly Developed Si Power MOSFETs – Leif Scheick, JPL and Jean Marie Lauenstein, NASA/GSFC

System on a Chip (SOC) Radiation Testing – Steve Guertin, JPL

Newly Developed POLs Radiation and Reliability – Dakai Chen, NASA/GSFC and Philippe Adell, JPL

FY12 NEPP Technology Efforts – Part 2

CMOS Technology

IBM Technology and Radiation– Jonathan Pellish, NASA/GSFC w/ IBM, SNL, and NRL
INTEL Technology and Radiation (22nm FinFET processor – TID/Dose Rate) – Ken LaBel, NASA/GSFC w/INTEL, NAVSEA Crane
Tower Jazz Radiation Testing – Jonathan Pellish, NASA/GSFC and Melanie Berg, MEI – NASA/GSFC
Lyric Semiconductor Radiation – Jonathan Pellish, NASA/GSFC
Complex CMOS Device SEE Modeling – Vanderbilt University and Melanie Berg, NASA/GSFC
Physics-Based Modeling for SEE - Vanderbilt University

CMOS Radiation Testing TBD Others: TI, ON, Cypress, STM

III-V, Widebandgap, and RF

90nm SiGe Radiation Effects (IBM 9hp) – Georgia Tech and Paul Marshall, NASA/GSFC – Consultant

SiC and GaN Power Device Radiation Testing – Megan Casey, NASA/GSFC and Leif Scheick, JPL
RF Device Screening Practices (Reliability) – Mark White, JPL
SiC and GaN Power Device NASA Working Group – Leif Scheick
SiC and GaN Reliability Testing – Richard Patterson, NASA-GRC
Miscellaneous SiGe Device Radiation Testing – NASA/GSFC
TBD GaAs HEXFET Radiation – NASA/GSFC: We are tracking ESA research and determining applicability

FY12 NEPP Technology Efforts – Part 3

Qualification and Packaging

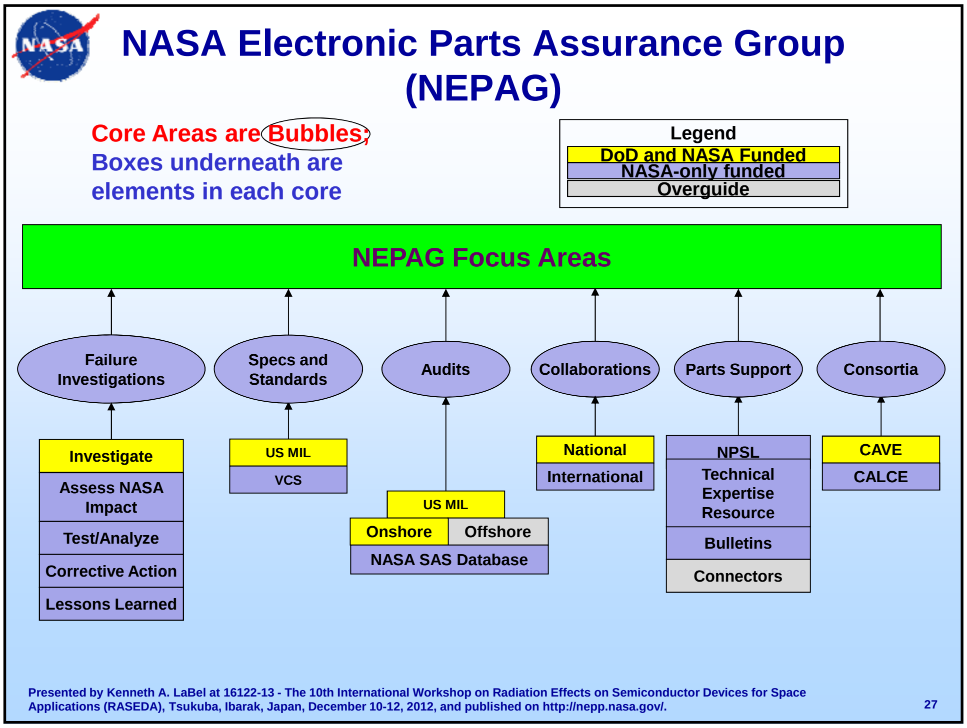
Class Y related packaging tests CCGA/PBGA, underfill, etc… – Doug Sheldon, JPL (w/many others)

Cryogenic Connector Failure Analysis – NASA/JPL
Body of Knowledge (BOK) documents on multiple packaging-related areas (TSV, 3D packages, X-ray and Workmanship, etc) – NASA/JPL
BME, Tantallum, and Polymer Capacitor Reliability/Screening – NASA/GSFC
DC-DC Converter NASA Working Group – John Pandolf, NASA/LaRC
NASA Connectors Working Group – Carlton Faller, NASA-JSC

Other

Infrared focal plane array lessons learned – Cheryl Marshall, NASA/GSFC
Development of SEGR Power MOSFET predictive technique – Jean Marie Lauenstein, NASA/GSFC

SEE Failures and Results Related to DC-DC Converter Design– Robert Gigliuto, MEI Technologies – NASA/GSFC
Point of Load NASA Working Group – Dakai Chen, NASA/GSFC
Optoelectronic Connectors and Transceivers – Melanie Ott, NASA/GSFC


NASA Electronic Parts Assurance Group (NEPAG)
Core Areas are Bubbles;
Boxes underneath are elements in each core
Legend
DoD and NASA Funded
NASA-only funded
Overguide
NEPAG Focus Areas
Failure Investigations
Specs and Standards
Audits
Collaborations
Parts Support
Consortia
Investigate
Assess NASA Impact
Test/Analyze
Corrective Action
Lessons Learned
US MIL
VCS
US MIL
Onshore
Offshore
NASA SAS Database
National
International
NPSL
Technical Expertise Resource
Bulletins
Connectors
CAVE
CALCE
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