The NASA Electronic Parts and Packaging (NEPP) Program

An Overview

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Acronyms

Acronym	Definition
Aero	Aerospace
AFRL	Air Force Research Laboratory
BME	Base Metal Electrode
BOK	Body of Knowledge
CBRAM	Conductive Bridging Random Access Memory
CCMC	Community Coordinated Modeling Center
CDH	Central DuPage Hospital Proton Facility, Chicago Illinois
CMOS	Complementary Metal Oxide Semiconductor
CNT	Carbon Nanotube
COP	Community of Practice
COTS	Commercial Off The Shelf
CRÈME	Cosmic Ray Effects on Micro Electronics
DC	Direct Current
DLA/DSCC	Defense Logistics Agency Land and Maritime
EEE	Electrical, Electronic, and Electromechanical
ELDRS	Enhanced Low Dose Rate Sensitivity
EP	Enhanced Plastic
EPARTS	NASA Electronic Parts Database
ESA	European Space Agency
FPGA	Field Programmable Gate Array
FY	Fiscal Year
GaN	Gallium Nitride
GSFC	Goddard Space Flight Center
HUPTI	Hampton University Proton Therapy Institute
IBM	International Business Machines
IPC	International Post Corporation
IUCF	Indiana University Cyclotron Facility
JEDEC	Joint Electron Device Engineering Council
JPL	Jet Propulsion Laboratories
LaRC	Langley Research Center
LEO	Low Earth Orbit
LLUMC	James M. Slater Proton Treatment and Research Center at Loma Linda University Medical Center
MGH	Massachusetts General Hospital

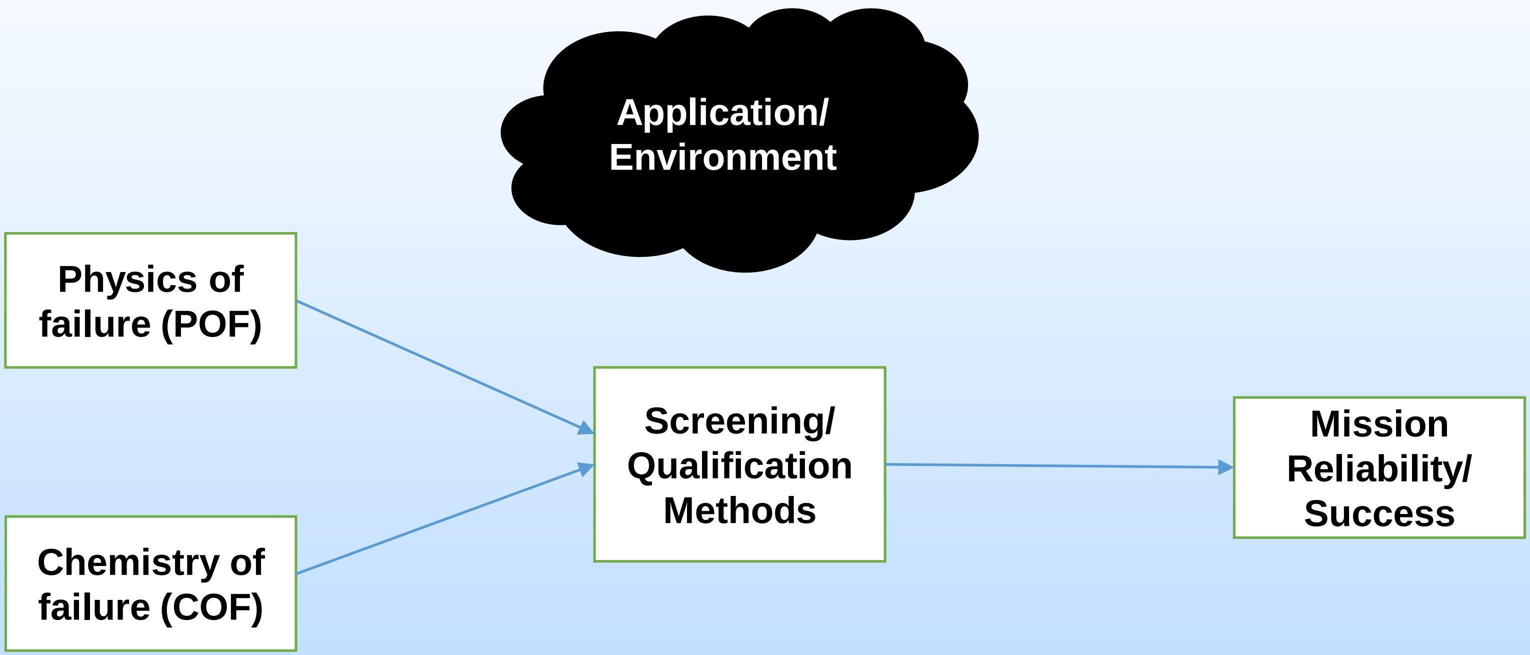
Acronym	Definition
MIL	Military
MLCC	Multi-Layer Ceramic Capacitor
MOSFETS	Metal Oxide Semiconductor Field Effect Transistors
MRAM	Magnetoresistive Random Access Memory
MRQW	Microelectronics Reliability and Qualification Working Meeting
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NAVY Crane	Naval Surface Warfare Center, Crane, Indiana
NEPAG	NASA Electronic Parts Assurance Group
NEPP	NASA Electronic Parts and Packaging
NPSL	NASA Parts Selection List
PBGA	Plastic Ball Grid Array
POC	Point of Contact
POL	Point of Load
ProCure	ProCure Center, Warrenville, Illinois
RERAM	Resistive Random Access Memory
RF	Radio Frequency
RHA	Radiation Hardness Assurance
SAS	Supplier Assessment System
SEE	Single Event Effect
SEU	Single Event Upset
SiC	Silicon Carbide
SME	Subject Matter Expert
SOC	Systems on a Chip
SOTA	State of the Art
SPOON	Space Parts on Orbit Now
SSDs	Solid State Disks
TI	Texas Instruments
TMR	Triple Modular Redundancy
TRIUMF	Tri-University Meson Facility
VCS	Voluntary Consensus Standard
VNAND	Vertical NAND

INTRODUCTION TO NEPP

NEPP Program - Mission and Goals

- The NEPP Mission is to:
  - Provide guidance to NASA for the selection and application of microelectronics technologies
  - Improve understanding of the risks related to the use of these technologies in the space environment
  - Ensure that appropriate research is performed to meet NASA mission assurance needs.
- NEPP's Goals are to:
  - Provide customers with appropriate and cost-effective risk knowledge to aid in:
    - Selection and application of microelectronics technologies
    - Improved understanding of risks related to the use of these technologies in the space environment
    - Appropriate evaluations to meet NASA mission assurance needs
    - Guidelines for test and application of parts technologies in space
    - Assurance infrastructure and support for technologies in use by NASA space systems

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.

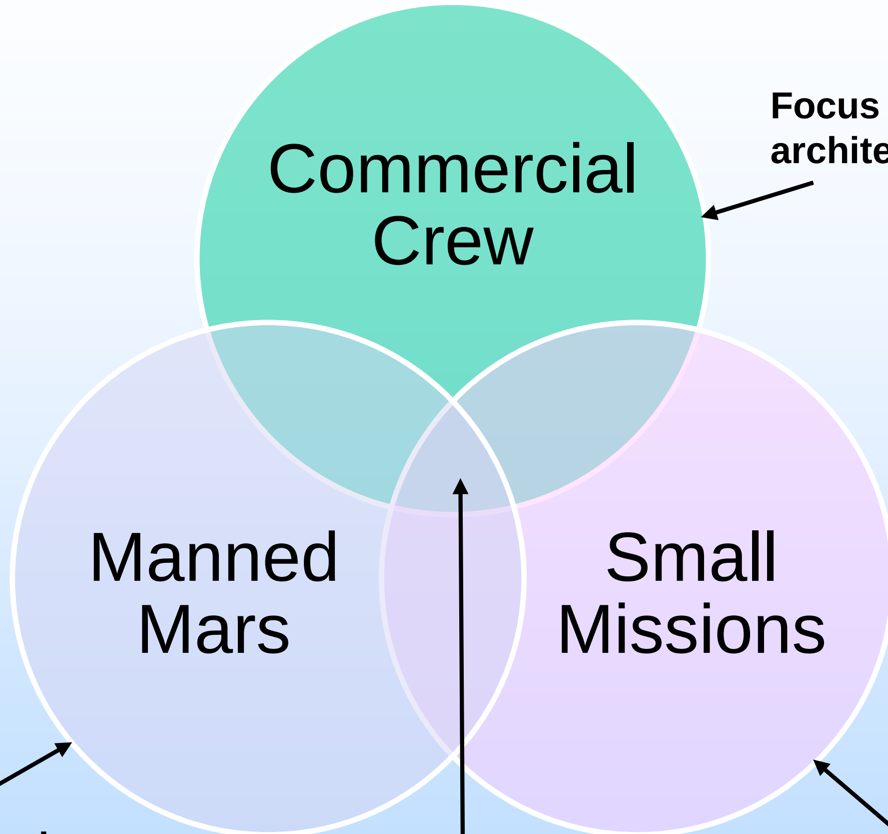
Overview

- **NEPP consists of the following Activities:**

NEPP Activity	Description
EEE Parts Reliability	New technology evaluation, test method development
Radiation Assurance	New technology evaluation, test method development
EEE Radiation Effects	New technology evaluation, test method development
EEE Parts Packaging	New technology evaluation, test method development
EEE Parts Assurance (NEPAG)	Standardization, MIL spec coordination, problem investigations
Operational	Website, Admin, Events

A View of NASA Electrical, Electronic, and Electromechanical (EEE) Parts Needs – *Diversity!*

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

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What EEE Parts Diversity Entails – NEPP Tenets for Planning Tasks

- **Tasks should**
  - **Learn from the past,**
  - **Focus on the present, and,**
  - **Plan for the future.**
- **Tasks should have widest applicability to Agency needs.**
  - **Know our customer base: technologists, designers, engineers,…**
  - **No single NASA center interests or direct flight project support.**
- **Tasks should leverage partnerships with other agencies, industry, and universities.**
  - **Partnering with flight projects ONLY when the Agency as a whole benefits.**

Note:* *A combined perspective on EEE parts allows an equal assurance/engineering approach to NEPP plans.

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)

NEPP Top-Level Task Areas

- Automotive/Commercial Electronics
- Complex Devices (Commercial/Mil-Aero)
- Assurance
- Power Devices (Commercial/Mil-Aero)
- NEPAG

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

EEE PARTS ASSURANCE AND RISK

Understanding EEE Parts Risks

- **The risk management requirements may be broken into three considerations**
  - **Technical/Design – “The Good”**
    - **Relate to the circuit designs not being able to meet mission criteria such as jitter related to a long dwell time of a telescope on an object**
  - **Programmatic – “The Bad”**
    - **Relate to a mission missing a launch window or exceeding a budgetary cost cap which can lead to mission cancellation**
  - **Radiation/Reliability – “The Ugly”**
    - **Relate to mission meeting its lifetime and performance goals without premature failures or unexpected anomalies.**
    - **Assurance falls under this heading.**
- ***Each mission determines its priorities among the three risk types***

EEE Parts Risk Trade Space –
Contributing Factors for the "Big Three"

- Cost and Schedule
  - Procurement
  - NRE
  - Maintenance
  - Qualification and test
- Performance
  - Bandwidth/density
  - SWaP
  - System function and criticality
  - Other mission constraints (*e.g.*, reconfigurability)
- System Complexity
  - Secondary ICs (and associated challenges)
  - Software, etc…
- Design Environment and Tools
  - Existing infrastructure and heritage
  - Simulation tools
- System operating factors
  - Operate-through for single events
  - Survival-through for portions of the natural environment
  - Data operation (example, 95% data coverage)
- Radiation and Reliability
  - SEE rates
  - Lifetime (TID, thermal, reliability,…)
  - "Upscreening"
- System Validation and Verification

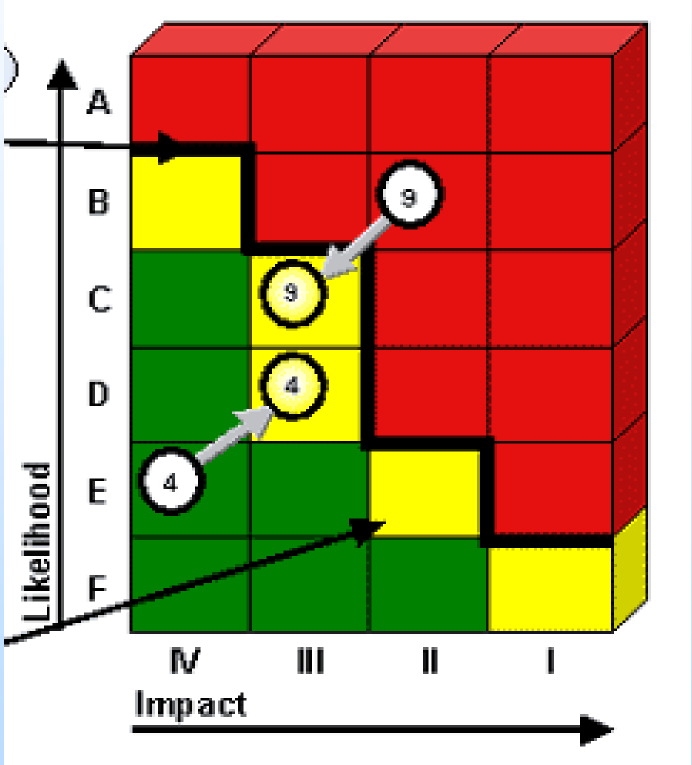
Generalized EEE Parts Assurance Concept

- **EEE parts assurance is a spectrum of trade spaces based on two considerations:**
  - **Criticality:** **whether the mission or application is in the "must work" category, and,**
  - **Environment/Lifetime:** **how harsh the space environment for the mission is, coupled with length of mission to qualify as success.**
- **A reminder**
  - **Additional environment protection can be anything from shielding to thermal control to fault tolerant design.**
  - ***Anomalies and failures are what happens when the protection isn't sufficient.***
- **Affordable**

AND, does it HAVE to work or do you just WANT it to work?

Applying These Concepts to EEE Parts

- The matrix on the following slide illustrates this using a modified risk approach (image on this slide). NOTE:
  - Green areas are where commercial off the shelf (COTS) electronics may be OK to use
  - Red may require traditional EEE parts assurance approaches (i.e., NASA Level 1 or 2 parts – these are equivalent to the Mil/Aero grade components for space).
  - Yellow may demand a mix of strategies
  - While not specifically called out here, other grades between commercial and Mil/Aero such as automotive are part of the trade space.



Notional EEE Parts Usage Factors

Environment/Lifetime

Criticality

	Low	Medium	High
Low	**COTS upscreening/ part testing optional; do no harm (to others)**	**COTS upscreening/ testing recommended; fault-tolerance suggested; do no harm (to others)**	**Rad hard suggested. COTS upscreening/ testing recommended; fault tolerance recommended**
Medium	**COTS upscreening/ testing recommended; fault-tolerance suggested**	**COTS upscreening/ testing recommended; fault-tolerance recommended**	**Level 1 or 2, rad hard suggested. Full upscreening for COTS. Fault tolerant designs for COTS.**
High	**Level 1 or 2 suggested. COTS upscreening/ testing recommended. Fault tolerant designs for COTS.**	**Level 1 or 2, rad hard suggested. Full upscreening for COTS. Fault tolerant designs for COTS.**	**Level 1 or 2, rad hard recommended. Full upscreening for COTS. Fault tolerant designs for COTS.**

Comments on the “Matrix” Wording

- **“Optional” – implies that you might get away without this, but there’s possible risk if you don’t.**
- **“Suggested” – implies that it is a good idea to do this, and there’s some increased risk if you don’t.**
- **“Recommended” – implies that this should be done and there’s probable risk if you don’t.**
- **Where just the item is listed (ex., “full upscreening on COTS”) – this should be done to meet the criticality and environment/lifetime concerns. There is definite risk if you don’t**

Good mission planning identifies where on the matrix a mission/application lies.

NEPP FOR THE NEW FRONTIER – "COST CONSCIOUS MISSIONS":

IS BETTER THE ENEMY OF GOOD ENOUGH?

AGAIN! Does it HAVE to work or do you just WANT it to work?

NEPP Tenets for Cost-Conscious Missions

- **The following charts will provide a sampling of our current recommendations and thoughts on "saving money".**
- **General topic areas for the following charts:**
  - **Using existing resources,**
  - **Grades of EEE parts,**
  - **Alternate screening/qualification approaches, and,**
  - **Fault tolerance.**

"A typical new car is equipped with more than 50 computers, designed to operate under extreme conditions for extended periods of time."

http://semiengineering.com/week-35-automotive-at-dac/

Using Spare Parts and Other Resources

- **Make use of existing resources.**
  - **Are there spare devices available at your Agency or within your control?**
    - **Flight procurements usually include extra device samples.**
    - **Some may be fully screened and even be radiation hardened/tested.**
    - **Engage parts/radiation engineers early to help find and evaluate designers' "choices" of EEE parts.**
- **If spare parts are not available, try to use parts with a "history of use".**
  - **These parts perform similarly to the "legacy" EEE parts**
    - ***BUT not guaranteed***
- **Higher risk:**
  - **Choose devices built on the same process/design rules by the same manufacturer.**
- ***If you absolutely need something new, you will pay for the qualification or take the risk.***

Background on EEE Parts Grades

- EEE parts are available in **grades.**
  - Designed and tested for specific environmental characteristics.
    - Operating temperature range, pressure/vacuum, radiation exposure, shock, vibration,…
  - Examples of Grades:
    - Aerospace, Military, Automotive, Medical, Extended Performance/Temperature-Commercial (EP), and Commercial Off the Shelf (COTS).
- **Aerospace Grade**
  - Traditional choice for space usage.
    - Designed and tested for reliability and often radiation for space usage.
  - Relatively few available parts and their performance lags behind commercial counterparts (speed, power).
- NEPP has a long history of evaluating grades other than Aerospace or Military.
  - Current focus is on Automotive and Commercial.
    - Automotive parts are less expensive than Aerospace counterparts.
      - *The BIG question is their reliability/radiation-tolerance in space applications.*

A Few Upfront Comments

- Aerospace Grade electronics are typically designed and tested to survive a wide range of environment exposures:
  - -55C to +125C, as an example.
- This allows a “generic” qualification by a manufacturer to encompass a wide array of user mission needs (i.e., one test for a lot of folks rather than a new test for each customer).
- Commercial off the shelf (COTS) for terrestrial usage aren’t designed/tested to these same levels.
  - This doesn’t mean they won’t work in a mission, but implies that you have to find a means of either reducing or accepting risk.

Temperature Rating Versus "Need"

- **Aerospace and Military grades are qualified for usage via exhaustive temperature cycles at -55C to +125C.**
  - **This is a conservative approach allowing vendors to qualify once for the majority of space customers.**
  - **But what if we want to use parts not rated for this wide range?**
- **Actual mission profile thermal excursions are mission unique.**
  - **May be relatively benign when compared to the standard "Mil grade" temperature range.**
    - **However, there may be thousands of temperature cycles to consider.**
  - **What's the appropriate testing? Conservative or reduced levels?**
- ***Operation outside of the rated temperature, while possible, entails risk.***

Automotive Electronics – NEPP Tasks

- **Develop a body of knowledge (BOK) document, highlighting the Automotive Electronics Council (AEC) documents as well as discussions with manufacturers.**
  - **Summary implies a need for “relationships” between vendor and buyer is necessary to coordinate screening/qualification requirements.**
- **Subject of a presentation on Friday morning**

Do We Need Traditional Parts Screening/Qualification?

- **Traditional testing was developed as a conservative means of bounding risk using temperature and voltage acceleration factors and adequate sample size statistics.**
  - **Are downscaled or alternate approaches adequate for cost-conscious missions?**
- **Board level tests – how do they correlate to part level tests?**
  - **Temperature range for tests are limited to “weakest link” on the board (use 0 to 70/85C).**
    - **How many temperature cycles are needed to demonstrate reliability?**
  - **Modern boards usually have localized power conversion.**
    - **Implies changes to input voltages may not accelerate degradation due to voltage regulation.**
  - **Besides the stress mechanisms,**
    - **As opposed to access of every pin and full test vectors, board level has limits on input/output capabilities, operational tests, and visibility of “failures”.**
  - **Appropriate sample size for statistics also challenges.**
- ***Question to consider: how do we quantify the risk reduction?***

Fault Tolerance to Increase "Parts" Reliability?

- **Means to make a system more "reliable/available" can occur at many levels:**
  - **Operational**
    - **Ex., no operation in the South Atlantic Anomaly (proton hazard)**
  - **System**
    - **Ex., redundant boxes/busses or swarms (with spares) of nanosats**
  - **Circuit/software**
    - **Ex., error detection and correction (EDAC) of memory devices**
  - **Device (part)**
    - **Ex., triple-modular redundancy (TMR) voting of internal logic within the device**
  - **Transistor**
    - **Ex., use of annular transistors for TID improvement**
  - **Material**
    - **Ex., addition of an epi substrate to reduce SEE charge collection (or other substrate engineering)**

The question remains:

How effective is the fault tolerance in increasing reliability?

Will Fault Tolerance Work When We Haven't Tested the Parts?

- **The System May Work, But What Level of Confidence Exists That It Will?**
  - **What are the "unknown unknowns"? Can we account for them?**
  - **How do you calculate risk with unscreened/untested EEE parts?**
  - **Do you have common mode failure potential in your design? (i.e., an identical redundant string rather than having independent redundant strings)**
  - **How do you adequately validate a fault tolerant system for space?**
    - **If, for example, 95% of faults are able to be recovered from, how critical are the other 5%?**
    - **Is there any "dead time during recovery?**
- **If we go back to the "Matrix", how critical is your function and harsh your environment/lifetime?**
  - **This will likely provide the "answers" to the above questions.**

Good engineers can invent infinite solutions,
but the solution used must be adequately validated and the risks accepted.

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 some thoughts on EEE Parts Assurance for Cost-Conscious Missions.**
  - **Knowledge is always a key**