Echoes of the Past, Glimpses of the Future

Ongoing Trends in Assurance of EEE Parts for Spaceflight

Components for Military & Space Electronics

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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

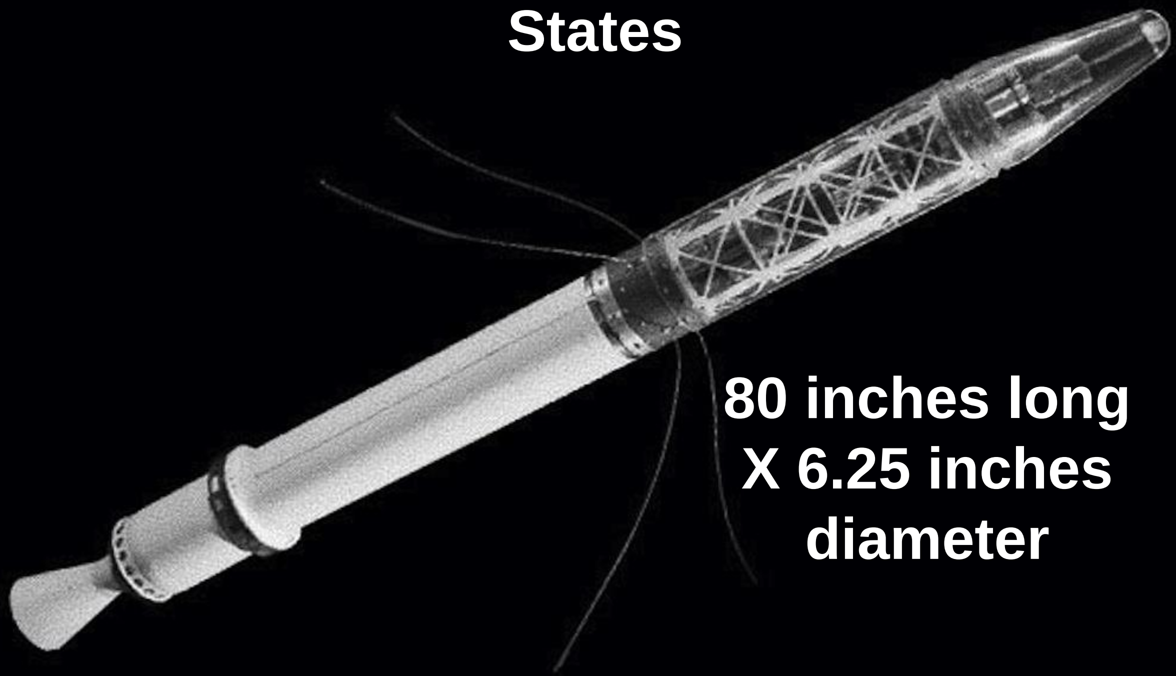
Overview from a NASA Perspective

- Early Days (Before 1987)
- Mid-life Concerns (1986 to 2003)
- Standardization (1991 to 1995 then 2001 to Present)
- Echoes of the Past
- Today's Forces for Change
- Glimpses of the Future
  - Specialized Test Facilities to screen against specific problems or normal variation
  - Board and Box Level Screening Practices
  - Robust Systems
    - Redundancy
    - Modeling
    - Self-healing Circuits

Explorer 1, Launched 12/31/1958

Explorer 1 was the first U.S. satellite and the first satellite to carry science instruments. The satellite was launched on Jan. 31, 1958, from Cape Canaveral, Fla.. Explorer 1 followed a looping flight path that orbited Earth once every 114 minutes. The satellite went as high as 2,565 kilometers (1,594 miles) and as low as 362 kilometers (225 miles) above Earth.
Credits: NASA

First Satellite launched by the United States



80 inches long X 6.25 inches diameter

https://www.nasa.gov/mission_pages/explorer/explorer-overview.html

Exciting Times

Then 1986 - CHALLENGER!

1987 - NASA EEE Parts Concerns

(From NASA Internal Document)

1. General Availability Of Class S And Class B Military Parts Is Not Adequate To Complete Most Programs. Use Of Less Desired Vendor Screened Parts Or SCDs Almost Mandatory For Most Programs.
2. Many Vendor Screened Devices (i.e. Vendor 883) Show Unacceptable Dropout Rates When Rescreened To Specifications.
3. Many Vendors Are Now Producing Devices "Off Shore." Quality Control Of These Processes And Lines Is Unknown. Changes In Critical Quality And Production Methods Can Occur Without Knowledge By The User.
4. Due To Fragmented Procurements And Low Quantity Buys, Manufacturers Show Little Interest In Providing EEE Parts To NASA Quality Levels.
5. Contamination Control At Some Manufacturers" Facilities Is Poor, Resulting In Particle Problems Occurring With Increased Frequency.
6. There Is No Standard NASA Policy On What Reliability Level Of Parts Should Be Used For Various Criticality Systems
7. Low Priority-of Funds For Conference Travel And Specialized Training Preclude Keeping Pace With Changes And Advancements In Parts Industry.
8. Lack" Of Emphasis On Replacement Of Retired Parts Specialists Has Centers Extremely Thin In Expertise In Many Areas.
9. Current NASA/Federal Procurement Cycle Makes Procurement Of EEE Parts For In-house Projects Extremely Difficult Such That Program Schedules Can Seldom Be Accommodated.
10. Vast Number Of MSFC Programs Has EEE Parts Specialists Spread Extremely Thin. "Hot Items“ Get Attention.

Black text: echoes with the present

Blue text: echoes of the past

From SPWG April 2002

NASA EEE Parts Assurance Group

Use of COTS is Unavoidable, So …?

- Functionality, availability and size are the unavoidable drivers towards COTS
- How can the risk of COTS be controlled economically?
  - Do we need to do such extensive screening?
  - Which tests are the most value-added/essential?
  - How dependable/relevant to our needs is manufacturer data?
  - Must we test/characterize every lot from every manufacturer?
- Traceability
  - How much lot-to-lot variation is there?
  - How much intra-lot variation is there?
  - Do we need to establish our own traceability system?
- Radiation, is there any way to avoid costly lot specific testing and evaluation?

Michael Sampson, et al, SPWG 2002 presentation.

04/16/02 (16)

These Are The Same Questions We Are Still Asking, 15 Years Later

2003

Columbia - January 16, 2003

Lessons Learned from Columbia and Challenger Made NASA More Risk Conscious and Careful

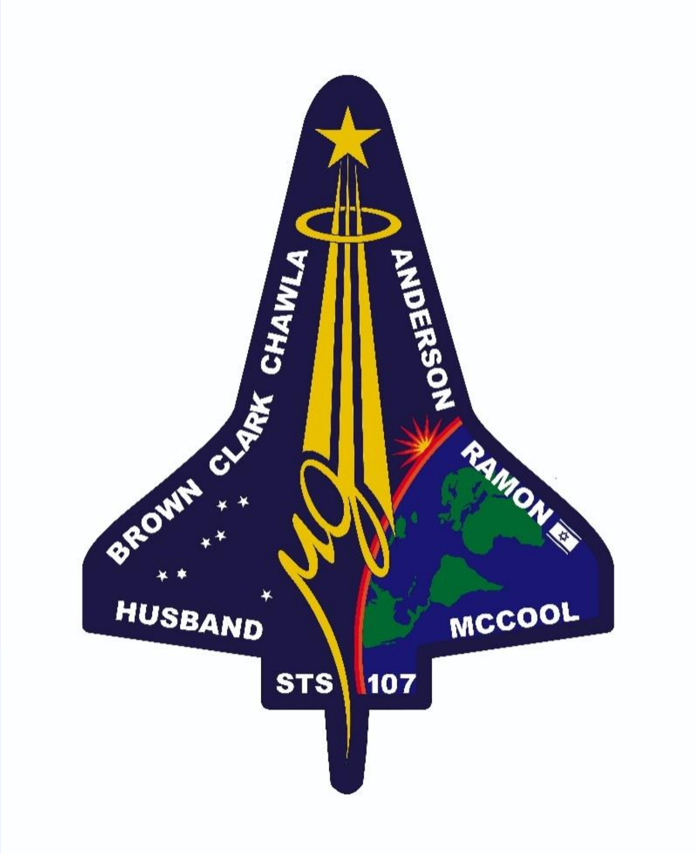


Image By NASA - http://spaceflight.nasa.gov/gallery/images/shuttle/sts-107/html/sts107-s-001.html, Public Domain, https://commons.wikimedia.org/w/index.php?curid=858875

Overview (From a 2003 Presentation)

- **Today's Major Challenge for EEE Parts Assurance - Commercial-Off-The-Shelf (COTS)**
- **Standardization - Uses and Benefits**
- **NASA's History with EEE Parts Standardization**
- **"New" Options for EEE Part Standardization**
  - **AQEC**
  - **By Manufacturer**
  - **By Higher Level Assembly**
- **Conclusions**

From JAXA Microelectronics Workshop (MEWS) 2003

Today's Drivers for Change (2003)

1) Cost-Constrained Missions
2) Tight Schedules
3) Aggressive Science and Technology Goals

- COTS Frequently Seen as a Solution to All Three
- COTS Can be the ONLY Solution Where Essential Technology Capability is the Driver

But, the Hidden Costs and Complications of a COTS-Based Solution Can Surprise the Unwary

(MEWS 2003)

Conclusions MEWS 2003

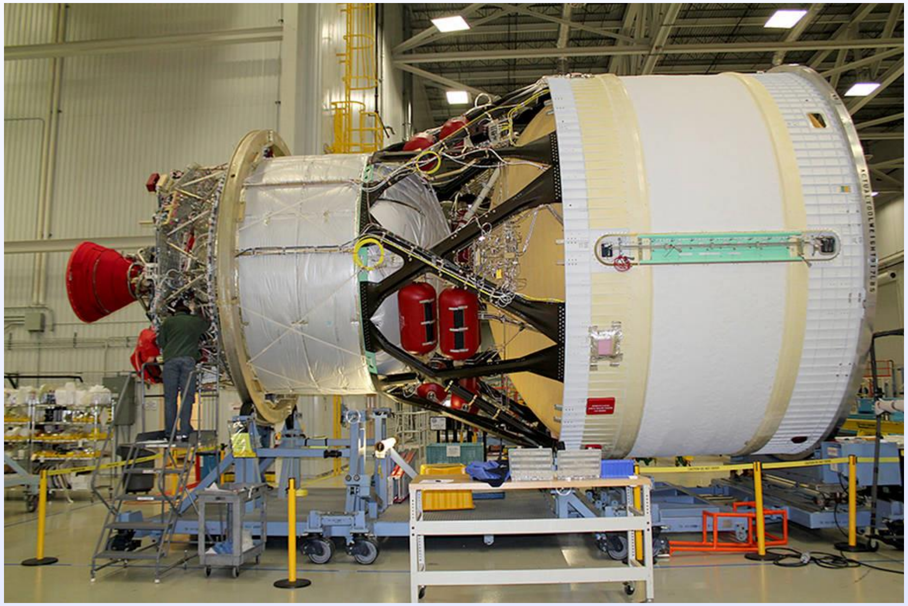
- Standardization Continues As a Key Strategy in NASA's Approach to EEE Parts Assurance
- Increasing Use of COTS Parts Makes Traditional, Parts-focused Standardization Much More Difficult
- Three Strategies for Standardization Approaches That Could Accommodate COTS Have Been Suggested
- COTS Compatible Standardization Is Likely to Require a NASA Culture Change to Achieve Success Through Any of the Three Suggested Options
- It Seems Unlikely That Any of the Three Options Will Achieve the Assurance of Reliability Enjoyed With MIL Parts

(MEWS 2003)

Today - A Tipping Point?

- Commercial launch vehicles for International Space Station (ISS) re-supply
- Commercial launch vehicles for human-rated missions to the ISS and … beyond
- Cubesats and Smallsats – what rules for EEE parts selection, qualification and application make sense?
- Cost is the dominant driver
- Anticipate greater use of commercial, non-hermetic parts
- Well-established processes to achieve assurance of system reliability require major updating
- The Space Launch System (SLS)

Space Launch System (SLS) and Orion



https://www.nasa.gov/exploration/systems/sls/multimedia/images.html

Commercial Space

- Commercial Space is expanding rapidly with more and more getting involved all the time
- NASA's future will include commercial systems to:
  - Launch NASA experiments and astronauts
  - Provide crew-rated systems to service the International Space Station and explore our solar system. Moon, Mars?
  - Provide innovative solutions to improve performance and reduce costs

NASA's Changing Landscape

- With NASA's New Era Of Commercial Providers And Small Space Missions (I.E. Cubesats, Etc…) Other Approaches Are Being Considered To Find More Cost-effective Approaches To Meeting Mission Requirements.
- A Few Of The Considerations For This Emerging Space Include, But Are Not Limited To:
  – Increased Reliance On Fault Tolerance, Architectural Approaches, And Even Constellation Spacecraft Sparing,
  – Leverage On The Improved Defect Reliability Of High Yield COTS, Automotive, Industrial, And Medical Grades Of Electronics,
  – Use Of Higher-assembly Level Testing,
  – Reliance On New Tools For Model-based Mission Assurance (MBMA), Circuit Simulation And Verification, As Well As Physics Of Failure (PoF), And,
  – Improved Communication On Considerations, Lessons Learned And Guidelines.

NEPP's Focus Areas for 2017

- Automotive Parts (COTS/PEMs) Evaluations Continue
  – Could they be the Future Standard Part?
- Radiation Assessments of Complex Parts
  – Field Programmable Gate Arrays, Processors, etc.
- 2.5D and 3D Packaging –
  – Development of a Body of Knowledge (BoK) Report
  – Government/Industry Discussions about Assurance Testing/Screening Methods and Qualification
- Standardization Support, Focused on MIL Parts
  – However, NASA Perspective is being Expanded
- Investigating Innovative Approaches to Qualification and Screening for non-MIL Parts, Board-level, Box-level etc.
- Reliability Modeling

Considerations for the Future

AS USUAL, it is all about SWaP = SIZE WEIGHT AND POWER but also COST and RELIABILITY

Lessons Learned on COTS for Space

- In an ideal world (and given limitations of full state space coverage), you'd want to:
  - Test at the device level to provide input for fault tolerant design. And,
  - Test at the system level to validate design approaches
    - Possibly uncover additional fault modes (statistics of test coverage).
- Lots of folks are trying to do the 2nd and mistakenly calling it qualification when it's really "system validation" (with inherent risk)…

Lessons Learned on COTS for Space (2)

- Understanding the criticality of the application is the key to performing adequate testing and validation for risk management
  – However, even “good” ground testing and designs can be surprised due to random/Markov nature of SEEs and challenges related to “completeness” nature of ground beam testing (coverage of targets and operating states)
- Improving data sharing between not only NASA projects, but the greater aerospace industry leads to improved failure mode knowledge
  – Required as input for designers and for efficient determination of additional data needed
  – MSL learned from Juno in a critical functionality area
    - What might have happened without it?

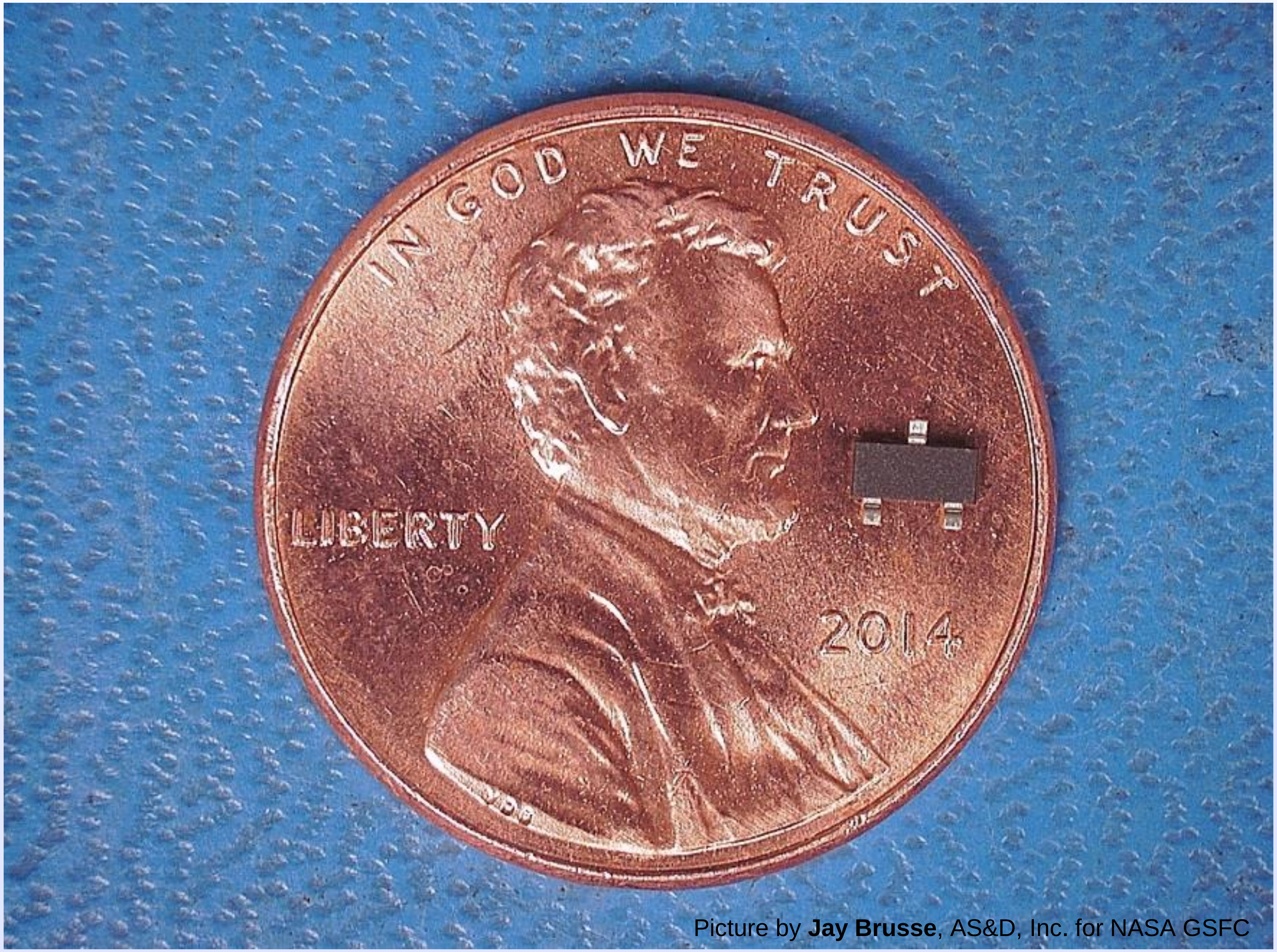
Glimpses of the Future

- Small Sats, Microsats and Cubesats (≤ NASA Class D)
  - Rapidly evolving roles: GEO, Swarms, Formations
  - "Deep Space": not yet but when ..?
- Low cost, fast turnaround, miniaturized
- Commercial Off The Shelf (COTS) parts use is steadily increasing
- Testing (screening and qualification) is difficult

Glimpses of the Future – Near Term

- Exploitation of the third dimension to permit continued increase in circuit density (2.5/3D)
  - Difficult testing challenges ahead
- Adoption of auto grade COTS as standard flight parts, within assurance constraints
  - Cost for upscreening, modeling or other approaches
- Greater reliance on design and architecture to mitigate risk from unscreened/under screened parts
  - Redundancy, particularly of critical systems
  - Self-healing parts, components and systems
- Increasing use of specialized test houses that have the capability in people and equipment to handle, test and evaluate COTS, from ultra small passives to extremely complex and dense PEMs
- Alternatives to testing/screening at the part level
  - Board and box-level present perceptivity and stress level challenges

SOT 23 Package and a Penny



Picture by **Jay Brusse**, AS&D, Inc. for NASA GSFC

SOT23-3 to SOT23-8

Hard to See – Hard to Handle!

Glimpses of the Future – Further Term

- Die-size, spacecraft on a chip (StarChip) for laser–powered, inter–star, scientific exploration
  - Project Breakthrough Starshot
  - Destination Alpha Centauri (flight time ~ 20 years)
  - Driving force: Yuri Milner
  - Executive Director: Pete Worden ex-NASA
  - Advisers: Freeman Dyson, Stephen Hawking
- Parts and components utilizing Quantum mechanics enable faster computing, more sensitive and accurate sensors, clocks unbreakable encryption
  - Once a dwindling number of challenges are overcome, part and function options will rapidly increase

The Future of EEE Parts Management/Engineering?

- Modules and subassemblies
- Quantum mechanics
- Satellites-on-a-chip
- Spintronics
- Etc., etc
- Things we have never heard of

?

The FUTURE

Prediction is Very Difficult, Especially if it is About the Future

Niels Bohr