A Study of Lessons and Experiences of NASA Centers in the Use of Commercial Off the Shelf (COTS) Electronics

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Agenda

- Assessment Description
- Traditional Parts Selection
- Modern COTS / ILPMs
- Radiation Concerns
- Recommendations
- References / Links

Technical Assessment

The NASA Engineering and Safety Center (NESC) sponsored the assessment regarding the use of COTS parts in spaceflight systems and critical ground support equipment (GSE) at NASA Centers.

- Capture each NASA Centers' current practices, best practices, lessons learned and recommendations
- Provide recommendations and best practices based on the NESC team's discussion

Recommendations on Use of Commercial-Off-The-Shelf (COTS) Electrical, Electronic, and Electromechanical (EEE) Parts for NASA Missions

Participating Centers

Ames Research Center (ARC)
Goddard Space Flight Center (GSFC)
Johnson Space Center (JSC)
Langley Research Center (LaRC)
Glenn Research Center (GRC)
Jet Propulsion Laboratory (JPL)
Kennedy Space Center (KSC)
Marshall Space Flight Center (MSFC)

Traditional Parts Selection

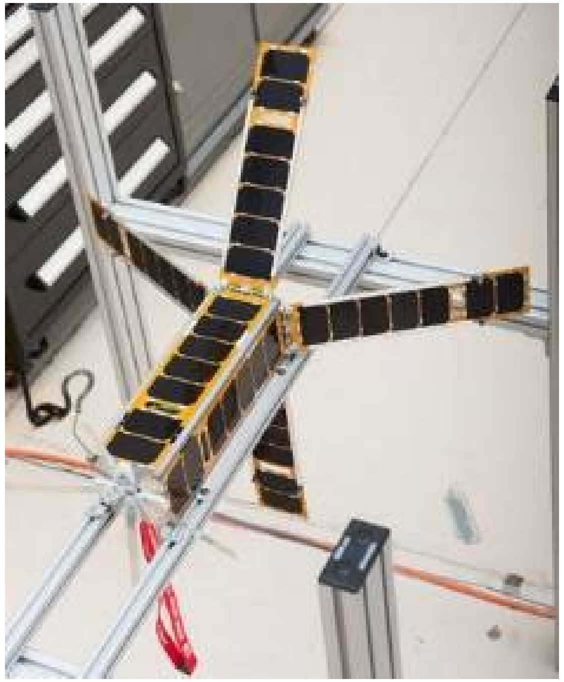
- NASA-STD-8739.10 and GSFC EEE-INST-002 recommend MIL-SPEC parts as the first choice
  1) different levels of MIL-SPEC parts as baseline parts
  2) detailed MIL-SPEC/NASA screening and qualification requirements on non MIL-SPEC parts.
- The QML process, where the government has control and insight in MIL-SPEC parts, results in parts with high (but not perfect) quality and full access to part-level verification.
- Government does not have control or insight into COTS parts, resulting in a major challenge of part-level verification or guaranteed knowledge of COTS parts. However, this does not necessarily imply that COTS parts are low in quality and reliability.

Modern COTS / ILPMs

- Some manufacturers have developed rigorous process controls driven by advanced technologies (e.g. automation) and customer requirements. It is equally important to note that this is not universally the case and may vary from manufacturer to manufacturer.
- Industry Leading Parts Manufacturers (ILPMs).
  - Manufacturer with high volume automatic production facilities and which can provide documented proof of the technology, process and product qualification, and its implementation of the best practices for “zero defects” for parts quality, reliability and workmanship.

Radiation Concerns

- Parts levels in EEE-INST-002 and equivalent documents do not indicate the level of radiation tolerance, and thus the selection of parts level 1, 2, or 3 does not imply or provide any type of radiation hardness or mitigation of radiation effects.
- MIL-SPEC parts may or may not include a radiation hardness designator signifying TID performance, but may be sensitive to SEE.
- Lot-to-lot variation of radiation sensitivity may be larger for COTS parts, since space radiation tolerance is not designed and optimized for COTS parts.



ALBUS Cubesat Credit: NASA/GSFC

Radiation Concerns

- Applicable archival radiation data (e.g., TID, TNID, and/or SEE) for COTS parts may be difficult to find due to the large number of COTS manufacturers and their short product life cycles.
- For heavy ion SEE testing, ensuring that ions penetrate sufficiently to traverse device sensitive volumes often requires the active die surface be exposed and possibly thinned.
- Complicated SOTA parts usually require sophisticated test equipment, which is expensive and difficult to use in radiation test facility environments.
- Traceability is not always possible for COTS parts, casting doubt about the validity of qualification testing vice recurring lot acceptance testing.

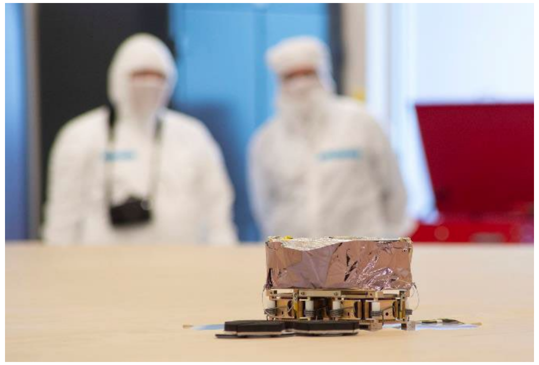
Recommendations

- Programs/Projects should understand and effectively manage the risk of COTS, using a holistic approach. Risk should be considered in the appropriate context, based on knowledge of the parts being used, the manufacturers, and how the parts are being used.
- A Mission, Environment, Applications and Lifetime (MEAL) assessment should be developed and approved by Program/Project Managers with pertinent risks clearly identified, mitigated and accepted, when COTS parts are used in safety or mission critical applications.
- COTS parts verification should be performed at part-, board-, and/or system-level. If verification is largely based on the manufacturer's data, then the recommended practice is to test the system at least 1,000 hours of accumulated power-on time, to reduce the risk of failures after launch.

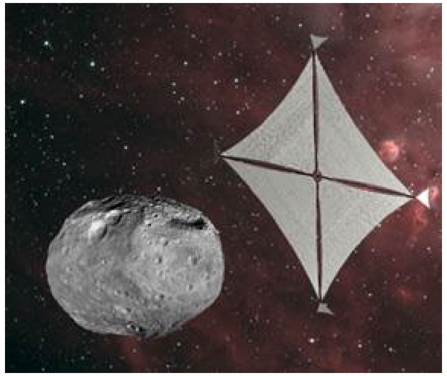
Recommendations

- When using COTS parts, program/project should build multiple revisions of engineering units to start functional testing, environmental testing, qualification, and verification early in the design cycle so that any issue can be addressed to minimize the impact on system risk, cost, and schedule. Most applicable for Class D and sub-Class D projects.

- EEE Parts Engineers should perform obsolescence analysis on COTS parts



NEA Scout packaged sail prior to deployment
Credit: NASA MSFC



NEA Scout surveying a target asteroid
Credit: NASA MSFC

Recommendations

- **EEE Parts Engineers** should follow the best practices
  - Perform parts manufacturer assessment
  - Understand parts technology.
  - Recognize part-level verification may require a different set of testing other than MIL-SPEC standards
  - Establish and maintain an ongoing relationship with parts manufacturers, especially with their local offices.
  - Monitor manufacturer changes through the monitoring of PCNs, GIDEPs, and other Alerts. Recent changes should be reviewed and the appropriate parties notified.

Recommendations

- **EEE Parts Engineers & Circuit Designers**
  - Select COTS parts that meet project's MEAL requirements.
  - Select COTS parts from ILPMs and the **highest commercial grades** parts available with each ILPM
  - Select manufacturers that possess DLA certifications for their other product lines and the highest commercial grades parts available.
  - Select COTS parts designed and manufactured with matured technologies Select COTS parts that are widely used in commercial electronics.
  - Recognize that leading edge technology parts may require significant specialized effort to qualify & screen
  - Select parts with "flight heritage" and ensure the MEAL for the new mission is within the bounds of the previous mission.

Recommendations

- **Circuit Designers**
  - Identify application-critical parameters and functionality for all parts in designs and verify by testing over application range
  - Identify environments that might be problematic for parts in their applications and verify by testing and analysis
  - Use manufacturers' SPICE models and demonstration and/or evaluation boards for circuit verification
  - Use more conservative derating for COTS parts in comparison to its MIL-SPEC counterpart
  - Use commercial version of radiation-tolerant parts, if available
  - Design for radiation tolerance at board and subsystem level, if not possible at part level.

Recommendations

- **Project Procurement Organization and EEE Parts Engineers**
  - Procure COTS parts from OCMs and authorized distributers.
  - Obtain CoC and lot trace code so that parts can be traceable to a specific manufacturer, part number, and lot number.
  - Communicate with the OCMs and authorized distributors to ensure the parts are from the same wafer lots, and/or procure one reel of the parts to maximize the probability.
  - Procure a minimum quantity of 20 percent over the number of parts required to support equipment maintenance, testing and potential future builds.

Controls for SLS /MPCV Arms & Umbilicals Credit: NASA KSC

Future Work

- **Phase II Effort (currently in progress)**
  - Codifying criteria for ILPMs
  - Include COTS Selection Practices from other US Government Agencies
    - US Navy
    - Missile Defense Agency
    - Federal Aviation Administration
    - Others
  - Include discussions with COTS manufacturers about process controls and quality metrics.

To be presented virtually by Peter Majewicz and Yuan Chen at the TRISMC Conference, May 17-20, 2021.

References / Links

- **Recommendations on Use of Commercial-Off-The-Shelf (COTS) Electrical, Electronic, and Electromechanical (EEE) Parts for NASA Missions - NESC Document #: NESC-RP-19-01490**
  - **https://ntrs.nasa.gov/search?q=20205011579**

- **Guidelines for Verification Strategies to Minimize Risk Based on Mission, Environment, Application and Lifetime (MEAL), June, 2018. NASA/TM–2018-220074,**
  - https://ntrs.nasa.gov/citations/20180007514

Acronyms

AEC Automotive Electronics Council
AEC-Q Automotive Qualified
AI&T Assembly, Integration, and test
ALBus Advanced Electrical Bus
ARC Ames Research Center
ASIC Application Specific Integrated Circuit
ATP Acceptance Test Procedure
BBO Black Body Objects
BGA Ball Grid Array
BiCMOS Bipolar Complementary Metal–Oxide–Semiconductor
C&DH Command and Data Handling
CCP Composite Crew Program
CDR Critical Design Reviews
CERN European Council for Nuclear Research
CIL Critical Item List
CMOS Complementary Metal–Oxide–Semiconductor
CMP Configuration Management Plan
CoC Certificate of Conformance
CoP Community of Practice
COTS Commercial-Off-The-Shelf
DC-DC Direct Current to Direct Current
DDD Displacement Damage Dose
DFI Development Flight Instrumentation
DLA Defense Logistics Agency
DoD Department of Defense
DPPM Defective Parts Per Million
DRD Data Requirements Documents
DTO Demonstration Technology Objective
EBOT EVA Battery Operations Terminal
EDCPAP Engineering Directorate Certified Parts Approval Process
EDU Engineering Development Unit
EEE Electrical, Electronic, and Electromechanical
EEL Engineering Evaluation Laboratory
EGS Exploration Ground Systems
ELDRS Enhanced Low Dose Rate Sensitivity
EMC Electromagnetic Compatibility
EMI Electromagnetic Interference
EMIT Earth Surface Mineral Dust Source Investigation
FCM Flight Control Module
FILMRS Flight Imaging Launch Monitoring Real-Time System
FPGA Field Programmable Gate Array
FPIE-D Focal Plane Interface for Digital Electronics
GCR Galactic Cosmic Ray
GFE Government Furnished Equipment
GIDEP Government Industry Data Exchange Program
GPR Goddard Procedural Requirements
GRC Glenn Research Center
GSE Ground Support Equipment
GSFC Goddard Space Flight Center
H/W Hardware
HAST Highly Accelerated Stress Testing
HEOMD Human Exploration and Operations Mission Directorate
I&T Integration & Test
ILPM Industry Leading Parts Manufacturer
ISS International Space Station
IT Information Technology
IT/OT Security Assessment
IVA Intravehicular
IXPE Imaging X-Ray Polarimetry Explorer
JPL Jet Propulsion Laboratory
KDP Kennedy Documented Procedure
KSC Kennedy Space Center
LAM Laser Air Monitor
LaRC Langley Research Center
LCC Life-Cycle-Cost
LED Light Emitting Diode
LEO Low Earth Orbit
LET Limited Linear Energy Transfer
LGA Land Grid Array
LISA Laser Interferometer Space Antenna
LRU Line Replaceable Unit
LSA Logistics Support Analysis
M&P Materials and Processes
MAR Mission Assurance Requirements
MEAL Mission, Environment, Applications and Lifetime
MMOC Multi-Mission Operation Center
MPCV Multi-Purpose Crew Vehicle
MRAM Magnetoresistive Random-Access Memory
MSFC Marshall Space Flight Center
MTBF Mean Time Between Failures
NEPAG NASA Electronic Parts Assurance Group
NEPP NASA Electronic Parts and Packaging
NESC NASA Engineering and Safety Center
NIC Network Interface Card
NPR NASA Procedural Requirements
OCM Original Component Manufacturer
OEM Original Equipment Manufacturer
OMRSD Operations & Maintenance Requirements Specification Document
PCB Parts Control Board
PCB printed Circuit Board
PDR Preliminary Design Reviews
PEM Plastic Encapsulated Microcircuit
PIND Particle Impact Noise Detection
PLC Programmable Logic Controller
PMAD Power Management And Distribution
QAP Quality Assurance Plan
QMS Quality Management System
QTP Qualification Test Procedure
RF Radio Frequency
RHA Radiation Hardness Assurance
RMA Reliability, Maintainability, and Availability
RNS Relative Navigation Sensors RNS
RRM-3 Robot Refueling Mission 3 RRM-3
RSAR Reliability and Safety Assessment Report
S/W Software
SAA System Assurance Analysis
SACA Software Assurance Classification Assessment
Saffire Spacecraft Fire Safety Demonstration
SCaN Space Communications and Navigation
SDR Software-Defined Radio
SEB Single-Event Burnout
SEE Single-Event Effects
SEFI Single-Event Functional Interrupt
SEGR Single-Event Gate Rupture
SEL Single-Event Latchup
SEU Single-Event Upset
SIP System-In-Package
SLS Space Launch System
SMP Safety & Mission Assurance Plan
SOTA State-Of-The-Art
SpaceDOC II Spaceflight Systems Development and Operations Contract
SRR System Requirements Review
SSA Software Safety Analysis
SSP Space Shuttle Program
SSS Sample Size Series
STRS Space Telecommunications Radio System
STS Silicon Turnkey Solution
SWaP Size, Weight, and Power
TID Total Ionizing Dose
TMR Triple Modular Redundancies
TNID Total Non-Ionizing Dose
TRR Test Readiness Reviews
UV Ultraviolet
UV-LED Ultraviolet Light Emitting Diode
V&V Verification & Validation
VSWIR Visible and Short-Wave Infrared
xEMU Extra-Vehicular Mobility Unit

Questions?