NESC Assessment – Recommendations on Use of Commercial-Off-The-Shelf (COTS) Parts for NASA Missions

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Outline

- NASA Engineering and Safety Center (NESC) assessment
  - Phase I: completed in Dec 2020; finale report released for public
  - Phase II: on-going; expected to be completed in March and April 2022
- Phase I
  - Scope of the assessment, table of contents of Phase I report
  - Definitions, agency baseline parts requirements, new terminologies
  - Flow Chart for COTS parts selection, procurement, circuit application, RHA and part-, board- and system-level verification
  - NESC Findings, Observations and Recommendations
- Phase II
  - Scope of the assessment

Phase I: Scope of the Assessment

- Capture current practices on use of COTS EEE parts across NASA centers.
  - Various projects
  - Parts selection, evaluation, screening, and qualification process
- Provide NESC recommendations that could lead to future agency guidance.
- Participation from eight centers: ARC, GRC, GSFC, JPL, JSC, KSC, LaRC, MSFC.
- Available at https://ntrs.nasa.gov/search?q=20205011579
- Comments or questions, please contact - yuan.chen@nasa.gov

Phase I Report: Table of Contents

4.0 Executive Summary; 5.0 Assessment Plan ; 6.0 Problem Description

7.0 Center Practices on Use of COTS

- 7.1 Scope of the assessment and Center summaries on use of COTS
- 7.2-7.9 Eight center reports
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  - Center strategy of use of COTS
  - Center governing parts documents
  - Current practices on COTS selection, evaluation screening and qualification
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  - Center proposed recommendations
- 7.10 Current and best practices on use of COTS
  - Summary of current practices on use of COTS
  - Risk context in use of COTS
  - Best practices on COTS selection
  - Current practices on part-, board- and system-level verification
  - Best practices on COTS parts application
  - RHA consideration for COTS parts
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11.0 Lessons learned; Appendix A (Example projects with use of COTS), B (COTS parts) and C (Summary of previous NESC COTS related assessments)

Definitions

- **COTS Part:**
  - A Commercial-Off-The-Shelf part designed for commercial applications for which the part manufacturer solely establishes and controls the specifications for performance, configuration and reliability, including design, materials, processes, and testing without additional requirements imposed by users and external organizations. It is typically available for sale through commercial distributors to the public with little or no lead time.
- **NASA-screened COTS Part**:
  - A COTS part, after procurement, qualified and screened per NASA Agency, Center or Program parts requirements documents, such as EEE-INST-002 or equivalent documents, by NASA, NASA contractors, third-party or the part manufacturer.

Agency Baseline Parts Requirements

- NASA-STD-8739.10 and GSFC EEE-INST-002 (and equivalent parts documents) recommend MIL-SPEC parts as the first choice or best practice, specifying different levels of MIL-SPEC parts as baseline parts, and detailed MIL-SPEC/NASA screening and qualification requirements on non-MIL-SPEC parts.

Table 3. EEE Part Classes for Each Grade

Item	Grade 1	Grade 2	Grade 3	Grade 4
Typical Minimum Quality Class	Microcircuit: **Class S, V (hermetic) and Y (nonhermetic)** Hybrid Microcircuit: **Class K** Discrete Semiconductor: **JANS (Joint Army-Navy, Class S)** Capacitor or Resistor: **Failure Rate Level (FRL) T, S, R and tantalum caps: C & D** Other: Various	Microcircuit: **Class B or Q** Hybrid Microcircuit: **Class H** Discrete Semiconductor: **JANTXV** Capacitor or Resistor: **FRL R, P, or B-tantalum caps** Other: Various	Microcircuit: **Class M, N, T, or /883** Hybrid: **Class G, D, or E** Discrete Semiconductor: **JANTX** Capacitor or Resistor: **P or B**, and Other Other: Various, Vendor Hi-Rel Automotive Grade	Commercial (Often is PEM)

MIL-SPEC parts

Most current practices

"NASA screened COTS", i.e., COTS qualified and screened using MIL standards per EEE-INST-002

MIL-SPEC parts vs. COTS parts

- Government control or insight
  - Government has control and insight in MIL-SPEC parts, results in parts with high (but not perfect) quality and reliability 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.
- Does it mean COTS parts are low in quality and reliability? Not necessarily.
  - Government control is not prerequisite anymore for high quality and reliability parts, especially when, in recent years, some manufacturers in commercial industry have developed rigorous process controls driven by advanced technologies and commercial market, often equivalent to or exceeding government controls on MIL-SPEC parts.
  - Equally important to note that this is not universally the case and may vary from manufacturer to manufacturer.

New Terminologies Defined

- Phase I defined an *Industry Leading Parts Manufacturer (ILPM)*
  - A parts 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.
  - Phase II provides detailed criteria of ILPM and part-level verification criteria.
  - Take advantage of what commercial industry does the best - high volume automatic production manufacturer and best practices for “zero defects”
- Phase II added a new definition of “Established COTS parts from an ILPM”
  - Recommended selecting “Established COTS parts category” from *Industry Leading Parts Manufacturers*.

Phase I: Center Reports – Current Practices

- Eight Centers (ARC, GRC, GSFC, JPL, JSC, KSC, LaRC, MSFC) documented their center practices on the use of COTS and presented to the team.
  - ARC, GRC, GSFC, JPL, JSC, LaRC, MSFC use COTS in spaceflight systems, largely Class D or sub-Class D missions
  - KSC uses COTS in critical GSE
- Practices varied from Center-to-Center but consensus was reached on the following COTS selection, application and verification flow.

Phase I: NESC Findings, Observations and Recommendations (I)

- The team had 11 Findings, 7 Observations, and 13 Recommendations.
- 11 Findings:
  - COTS parts for spaceflight: F1-9
  - COTS parts and assemblies for critical GSE: F10-11
- 13 recommendations were identified and directed towards the spaceflight program or project managers, project avionics systems leads, circuit design engineers, EEE parts engineers, procurement office, etc.
    - COTS risk identification and mitigation: R-1, -2, -3
    - Verification when using COTS parts: R-4, -5
    - COTS parts selection, procurement and verification at part-level: R-6, -7, -8, -9
    - COTS application and environment: R-10
    - COTS for critical ground support systems: R-11
    - Class D and Sub-Class D missions: R-12, 13

Phase I: NESC Findings, Observations and Recommendations (II)

- **Findings include**
  - **F-1** For safety and mission critical systems on missions with Category 1-3, Class A-D, and sub-Class D, NASA has a long history of using NASA-screened COTS parts (i.e., by performing additional and full part-level screening and space qualification on the COTS parts per GSFC EEE-INST-002 or equivalent documents before incorporating them into the spaceflight system(s).
  - **F-2** For non-safety or non-mission critical systems, current center use of COTS practices range from using NASA-screened COTS parts to the best effort on part-level verification or using COTS parts without any further MIL-SPEC/NASA screening and qualification at part-level, depending on mission classification level, project requirements and risk posture.
  - **F-3** NASA has more than 15 years of using COTS without additional part-level MIL-SPEC/NASA screening and qualification in space systems in sub-Class D missions and some Class D payloads, and other non-critical applications, some in complex systems operating for years. Most of those COTS parts were from Industry Leading Parts Manufacturers.

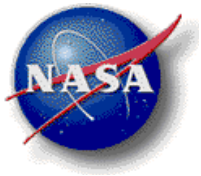
Phase I: NESC Findings, Observations and Recommendations (III)

- Recommendations include
  - **R-2**. When COTS parts are used in safety or mission critical applications without any further part-level MIL-SPEC/NASA screening and space qualification, a mission specific COTS approach tailored to project's Mission, Environment, Applications and Lifetime (MEAL) should be developed and approved by Program/Project Managers with pertinent risks clearly identified, mitigated and accepted.
  - **R-3**. For critical or single point failure applications, strategically use MIL-SPEC or NPSL parts or part/system redundancy or both where it is resource-effective (e.g., cost, schedule, or space on the board/box).
  - **R-5**.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.
  - **R-6** When selecting COTS parts for spaceflight units, Circuit Designers should work with EEE Parts Engineers to follow the best practices including, but not limited to, the following
    - Select COTS parts that meet project's MEAL requirements.
    - Select "established" COTS parts from ILPMs
    - 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 (e.g., technology generations/nodes between 2 to 8 years old);
    - Select COTS parts that are widely used in commercial electronics;
    - Recognize that leading edge technology parts may require significant specialized effort to ensure the reliability;
    - Select parts with "flight heritage" and ensure the MEAL for the new mission is within the bounds of the previous mission.

Phase I: NESC Findings, Observations and Recommendations (IV)

- **R-10** When using COTS parts in circuit designs for space applications, Circuit Designers should follow the best practices including but not limited to the following
  - Identify application-critical parameters and functionality for all parts in designs and verify by testing over application range, e.g. over operating temperature condition with margin, and exercise, at minimum, a representative range of that functionality (inclusive of the "corners"/"edges"/extremes, if possible/applicable.
  - Identify environments (e.g., thermal, vibe, helium, radiation, partial vacuum atmosphere plasma arcing/discharge) that might be problematic for parts in their applications and verify by testing and analysis to address the concern.
  - Use manufacturers' SPICE models and demonstration and/or evaluation boards for circuit verification, and implement board- and system-level verification early on in the development cycle to avoid negative impact on cost and schedule should any failure occur.
  - Use more conservative derating for COTS parts in comparison to its MIL-SPEC counterpart to achieve comparable reliability, notwithstanding other pertinent attributes of either type of part.
  - Use commercial version of radiation-tolerant parts, if available. Some parts are offered in both commercial versions and versions with known radiation tolerance (and often additional screening tests applied). Using the commercial versions of those parts can offer similar radiation tolerance, and also allow savings in cost and lead time. This needs to be evaluated on a case by case basis to ensure that the commercial version of the parts have comparable traceability to their radiation tolerant counterparts.
  - Design for radiation tolerance at board and subsystem level, if not possible at part level, by using and validating strategic redundancy, circuit mitigation (e.g. watchdog circuits) and power cycling to limit functional disruption during nondestructive radiation upsets, and reduce or eliminate (e.g. over-current protection) the effects of potentially destructive upsets such as micro-latchup and SEB failure, and other mitigations (HW & SW) through circuit designs.
  - Radiation-tolerant circuit design should play more significant role compared to individual part radiation hardness efforts, whether using COTS (or MIL-SPEC parts in this matter). For COTS parts, plan on more extensive radiation testing and mitigation than with MIL-SPEC counterparts, as there should be a greater level of expectation that radiation will cause a problem.
  - Follow COTS parts RHA considerations in Section 7.10.6 and the detailed guideline in NESC-RP-19-01489 "Guidelines for an Avionics Radiation Hardness Assurance".

Phase I: NESC Findings, Observations and Recommendations (V)



- Lack of consensus in two areas
  - **F-4** There is a lack of consensus within NASA on the perception of risk of using COTS parts for safety and mission critical applications in spaceflight systems. It varies from feelings of "high risk" when part-level MIL-SPEC/NASA screening and space qualification are not fully performed to "no elevated risk" when sound engineering is used, and part application is understood.
  - **F-5** Compared to MIL-SPEC parts, part-level verification for COTS parts used in spaceflight systems remains a major challenge, since there is no government insight or direct/formal communication channel existing with the COTS parts manufacturers.
    - There is a lack of consensus within NASA regarding the types of the parts manufacturer's evidence (e.g., manufacturers' reliability report, quality report, technology and qualification report, third-party testing, etc.) and the sources of data (e.g., manufacturers' web pages, email exchanges, site visit, etc.) that would be sufficient for part-level verification on COTS parts.
    - Current practices vary from no verification at part-level to full verification at parts level, depending on Center's practices and project's risk posture.

Phase II: Scope of the Assessment

- Capture current practices on use of COTS EEE parts from DoD and FAA.
- Provide NESC recommendations that could lead to future agency guidance.
- Participation from eight centers: ARC, GRC, GSFC, JPL, JSC, KSC, LaRC, MSFC, plus DoD (Army, MDA, Navy) and FAA.
- Understand COTS manufacturers' processes.
  - Generated a list of questions for COTS manufacturers
  - Talked to some COTS parts manufacturers to understand their processes
- Final report will be publicly available
  - Add FAA/DoD current practices
  - Add criteria of an ILPM, an established parts category from an ILPM
  - Add further guidelines on part-level verification and criteria
  - Update NESC findings, observations and recommendations on use of COTS for NASA missions

Radiation Hardness Assurance on COTS parts

- Most MIL-SPEC parts and COTS parts are not designed for space applications.
- Even MIL-SPEC parts that are designed for atmospheric or terrestrial strategic applications may not perform adequately in space, because the space radiation environment is quantitatively and qualitatively more severe than that of the atmosphere.
- Radiation threats for COTS parts do not differ from MIL-SPEC parts; however, the 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.
- 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.
- The radiation hardness assurance guideline for COTS parts or any EEE part in NESC-RP-19-01489 “Guidelines for an Avionics Radiation Hardness Assurance” or at https://ntrs.nasa.gov/citations/20180007514.

Summary

- NASA Engineering and Safety Center (NESC) assessment
  - Phase I: completed December 2020
    - Capture current practices on use of COTS EEE parts across NASA centers (ARC, GRC, GSFC, JPL, JSC, KSC, LaRC, MSFC) regarding parts selection, evaluation, screening, and qual processes.
    - Phase I report available at https://ntrs.nasa.gov/search?q=20205011579.
  - Phase II: on-going; expected to be completed in March and April 2022
    - Participation ARC, GRC, GSFC, JPL, JSC, KSC, LaRC, MSFC, plus DoD (Army, MDA, Navy) and FAA.
    - Final report will be publicly available - Add 1) FAA/DoD current practices; 2) criteria of an ILPM and an established parts category from an ILPM; 3) further guidelines on part-level verification; and 4) update NESC findings, observations and recommendations
- Establish and maintain a strong customer-manufacturer relationship.
  - Manufacturers may contact NASA Electronics and Packaging Program (NEPP) to discuss NASA-manufacturer relationship