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

(Phase I)

Yuan Chen, Robert F. Hodson
NASA Langley Research Center
June 17, 2021

Scope of the Assessment

- Capture current practices on use of COTS EEE parts for various programs/projects across NASA centers.
  - Parts selection, evaluation, screening, and qualification process.
- Provide NESC recommendations that could lead to future NEPP Program and/or agency guidance.

Team List

Name	Discipline	Organization
Core Team		
Robert Hodson	NESC Lead, NASA Technical Fellow for Avionics	LaRC
Yuan Chen	Technical Lead, Parts Eng. and Reliability	LaRC
Carlton Faller	Parts Engineering	JSC
Ron Hodge	Parts/Packaging/FA	MSFC
Michael Defrancis	Parts/Packaging, SMA	JSC/SAIC
Kuok Ling	Parts Engineering	ARC
Chris Green	Parts Engineering	GSFC
Scott Gore	Parts Engineering	JPL
John Pandolf	Parts Engineering	LaRC
Erik Denson	Electrical Chief Engineer	KSC
Kristen Boomer	Parts Engineering	GRC
Angela Thoren	Parts Obsolescence	MSFC
Pete Majewicz	NEPP Manager	OSMA/GSFC
Michael Sampson	NEPAG Manager	OSMA/GSFC
Jesse Leitner	SMA	GSFC
Consultants		
Kathy Laird	Parts Engineering/FA	MSFC/NEPAG
Ray Ladbury	Parts Radiation	GSFC
David Petrick	SMA	GSFC
Jonathan Pellish	NASA EEE Parts Manager	GSFC
Dwayne Morgan	Avionics	WFF
Chris Iannello	NASA Technical Fellow for Electrical Power	KSC
Business Management		
Rebekah Hendricks	Program Analyst	LaRC/MTSO
Assessment Support		
Melinda Meredith	Project Coordinator	LaRC/AMA
Linda Burgess	Planning and Control Analyst	LaRC/AMA
Erin Moran	Technical Editor	LaRC/AMA

Participation from 8 centers: ARC, GRC, GSFC, JPL, JSC, KSC, LaRC, MSFC

Engineering, SMA, NEPP, CCP

Table of Contents

Agency Baseline Parts Requirements

- NASA-STD-8739.10 and GSFC EEE-INST-002 (and equivalent parts documents) establish the baseline requirements for use of various levels of parts including use of COTS parts.
  - NASA-STD-8739.10 establishes "a set of requirements at the Agency level to control risk and minimize the impacts of part selection and usage on reliability in NASA spaceflight hardware and critical GSE";
  - GSFC EEE-INST-002 (and equivalent parts documents) is used at Agency and Center levels for guidance on parts selection, screening and qualification requirements.
- Those documents recommend MIL-SPEC parts as the first choice or best practice, and specify
  - Different levels of MIL-SPEC parts as baseline parts, AND
  - Detailed MIL-SPEC/NASA screening and qualification requirements on non MIL-SPEC parts.
- <u>Most current practices use "NASA screened COTS", i.e., COTS qualified and screened using MIL standards per EEE-INST-002</u>

Parts Grades as defined in NASA-STD-8739.10

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

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.

Most current practices

MIL-SPEC parts vs. COTS parts

- **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.
- 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 necessary.
  - 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, 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 Terminology Defined: Industry Leading Parts Manufacturers

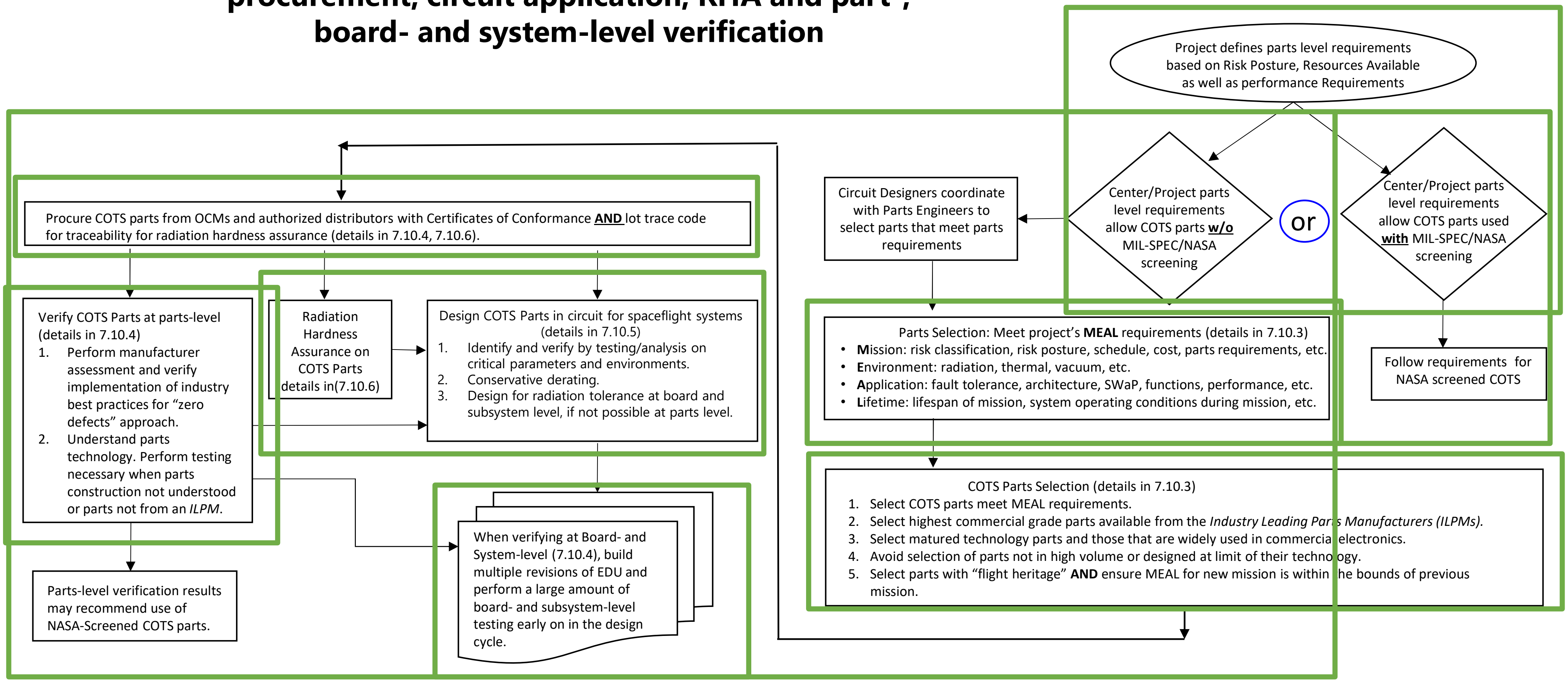
- Defined an *Industry Leading Parts Manufacturer (ILPM)*
  - A parts manufacturer with high volume automatic production facilities and which can provide documented proof of the technology, process and product qualification, and its implementation of the best practices for "zero defects" for parts quality, reliability and workmanship.
  - Detailed criteria of ILPM and part-level verification criteria to be addressed in Phase II.
- Recommended selecting COTS parts from *Industry Leading Parts Manufacturers*.
  - Take advantage of what commercial industry does the best - high volume automatic production manufacturer

Center Reports

- Eight Centers (ARC, GRC, GSFC, JPL, JSC, KSC, LaRC, MSFC) documented there 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

Flow Chart for COTS parts selection, procurement, circuit application, RHA and part-, board- and system-level verification



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.
- <u>The radiation hardness assurance guideline for COTS parts or any EEE part will be included in NESC-RP-19-01489 "Guidelines for an Avionics Radiation Hardness Assurance" (on-going assessment currently writing its final report).</u>

FORS

- The team has had extensive discussions on COTS-related topics, and has 11 Findings, 7 Observations, and 13 Recommendations.
  - The recommendations are in the areas of COTS parts risk identification and mitigation; COTS parts selection, procurement, verification at part-level and beyond, obsolescence; COTS parts in circuit designs and in radiation environment; use of COTS parts for Class D and sub-Class D missions, COTS parts and assembly for GSE.

  - The team opted for detailed FORs to convey specific information to cognizant engineers and managers

Findings (I) - COTS parts for spaceflight systems

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-1a. For safety and mission critical systems on Category 1-3 and Class A-C missions, NASA Center current practices typically use NASA-screened COTS parts.

F-1b. For mission critical systems on Class D and sub-Class D missions, there is a wide range of differences in current Centers' practices on COTS selection and part-, board-, and system-level verification.

- Most NASA Centers (i.e., ARC, GRC, JPL, LaRC, MSFC) emphasize COTS parts selection from ILPMs (defined in Section 7.1.1 and detailed in Section 7.10.3), COTS parts past usage, and/or NASA-screened COTS parts (defined in Section 7.1.1), and/or focus on part-level verification.
- All Centers' system-level verification processes and standards have remained unchanged with use of COTS parts, even when less part-level verification performed. ARC has implemented a Center-wide practice of selecting mostly COTS parts and performing a large amount of board- and subsystem-level testing early in the design cycle.
- GSFC (Section 7.4) is flexible on their GOLD rule that requires 1000+ hours testing on hardware while reinforcing a best practice of accumulating as much testing hours (e.g., 500-1000 hours) as possible at system level especially when COTS parts used have less part-level verification.
- JSC has an alternative parts plan EDCPAP (Section 7.6.4) that starts with the requirement that every part on flight hardware should be defect-free and should be qualified to the limits of its datasheet. EDCPAP seeks to verify these requirements by gaining insight into the manufacturer's processes. If evidence that the manufacturer is following best practices for process control, screening, defect elimination, periodic testing for reliability monitoring, qualification, process change re-qualification, etc., then the part requirements are met. If such information cannot be obtained, then the "traditional" approach of part-level MIL-SPEC/NASA screening and qualification may be employed. This process is currently used primarily on low-criticality or highly failure tolerant systems due to the lack of specific criteria for vendor-provided data.

Findings (II) - COTS parts for spaceflight systems

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.

- ARC has demonstrated a successful use of COTS methodology (Section 7.2) for Class D and sub-Class D projects, focusing on risk mitigation by designing and building spaceflight system using almost all COTS parts from *ILPMs*, and performing large amount of testing at board- and subsystem-level. The methodology takes full advantage of availability and low-cost nature of COTS parts to build large quantity of multi-revision EDUs, so that concurrent engineering development of flight software, payload software, subsystem interface, form and fit, and system test procedures get started early.
- GSFC, through the evolution of multiple SpaceCube hardware builds and revisions, has substantial experience using COTS parts in flight applications on Class D and sub-Class D missions. The SpaceCube program is rooted on a robust design and test philosophy, regardless of the parts used in each assembly. All aspects of the design contain appropriate margins (parts stress and derating, thermal, interface, structural, timing, FPGA/processor/memory utilization, etc.). As a result, no system failures based on individual part performance or reliability were experienced on any mission, nor were they encountered in I&T.

Findings (III) - COTS parts for spaceflight systems

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.

- Center positions are different on use of COTS without any further part-level MIL-SPEC/NASA screening and space qualification by the users, ranging from a to d below:
  - Use of COTS without any further part-level MIL-SPEC/NASA screening and space qualification is considered as unquantifiable risk or may be high risk for Class A-D missions (JPL, MSFC).
  - Program/Project must decide to assess and subsequently accept risk if using COTS parts in critical systems. The concern is that the lack of full verification may allow bad parts to enter flight hardware that may fail in flight (JSC, LaRC, GRC).
  - The use of any arbitrarily-selected COTS part without additional part level testing or proven alternative practices would entail elevated or at least uncertain risk (GSFC, GRC).
  - With proper practices based on good systems engineering and understanding of the parts being used, COTS can be used in critical applications without elevated risk (ARC, GSFC).

Findings (IV) - COTS parts for spaceflight systems

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.

F-6 Not all COTS parts are created equal due to wide variability in parts manufacturers' process control and quality assurance.

- Some commercial manufacturers (i.e., Industry Leading Parts Manufacturer as defined in Section 7.1.1 and detailed in Section 7.10.3) with high volume production facilities have well-documented evidence for their process and technology qualification, product qualification, process control, in-line monitor and control, and well established low DPPM (defective parts per million) numbers for their catalog parts.
- Not all AEC parts are from ILPMs. AEC specifications and automotive grade part manufacturers alone does not necessarily guarantee all of the quality and production control aspects needed to be considered an ILPM (section 7.10.3)

Findings (V) - COTS parts for spaceflight systems

F-7 COTS parts, and most MIL-SPEC parts, are not designed and manufactured for space environments.

- Compared to MIL-SPEC parts, COTS parts are typically not designed to withstand the environmental (radiation, moisture, thermal, etc.) extremities as are their equivalent MIL-SPEC parts, so there should be no expectation that most COTS will survive typical MIL-SPEC screening and qualification tests at extreme conditions outside of its specified operational range.
- Radiation effects are excluded from COTS (and most MIL-SPEC parts) design trade spaces except for specialized subsets of terrestrial and atmospheric avionics applications that are sensitive to neutron and alpha particle SEE. Even in cases where terrestrial radiation effects may be addressed during the design process, space radiation effects are qualitatively and quantitatively severe, impacting preconceived system architectures in unforeseen ways.
- COTS parts may have larger variability compared to MIL-SPEC parts in radiation responses.

Findings (VI) - COTS parts for spaceflight systems

F-8 Parts derating in electrical and environmental stresses (e.g., power, voltage/current, thermal, etc.), is more critical for COTS parts (compared to MIL-SPEC parts) to lower the stress-induced degradation and failure modes, thus allowing most parts to last longer, as parts and board/system's reliability are driven by how parts are used in the application.

F-9 Center current practices on use of COTS include parts source selection, storage conditions for all stages of use, packing, shipping and handling, electrostatic discharge (ESD), screening and qualification testing, derating, radiation hardness assurance, test house selection and control, and data collection and retention for spaceflight systems.

Findings (VII) - COTS parts and assemblies for critical GSE

F-10 Large quantities of COTS parts and equipment are selected and qualified for GSE, saving design and development costs and schedule.

F-11 Current practice on use of COTS for critical GSE is full qualification per KSC standards. GSE subsystems undergo a rigorous technical review process including verification & validation testing leading to Design Certification or System Acceptance. All GSE systems go through qualification, including functional/performance, EMC, vibration, acoustic and thermal testing, and derating and screening is performed on GSE Critical Items.

NESC Recommendations

NESC recommendations were identified and directed towards the spaceflight program or project managers, project avionics systems leads, circuit design engineers, EEE parts engineers, and the NESC:

- 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

NESC Recommendations - COTS risk identification and mitigation

R-1. Programs/Projects should understand and effectively manage the risk of COTS, using a holistic approach incorporating inputs from across the project/program to make informed decisions and mitigate risk. ***(F-1, F-2, F-3, F-4, O-7)***

- 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.

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. ***(F-1, F-2, F-3, F-4, O-7)***

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). ***(F-1, F-7)***

NESC Recommendations - Verification when using COTS parts

R-4. COTS parts verification should be performed at part-, board- and/or system-level. If part-level verification is largely based on the COTS manufacturer's data, then the system should be tested 500-1,000 hours of accumulated test time, with the last 200 hours being failure free. ***(F-4, F-5, F-6, F-7, F-8, O-3, O-4, O-5, O-6, O-7***)

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. ***(F-1b, F-3)***

NESC Recommendations - COTS parts selection, procurement and verification at part-level (I)

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 (Section 7.10.3): ***(F-5, F-6, O-1, O-2,)***

- Select COTS parts that meet project's MEAL requirements.
- Select COTS parts from ILPMs and the highest commercial grades parts available with each ILPM (e.g., hi-rel parts and AEC-Q parts, SAE connectors and wires, etc.);
- 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.

NESC Recommendations - COTS parts selection, procurement and verification at part-level (II)

R-7 When purchasing COTS parts for spaceflight units, Project Procurement Organization and EEE Parts Engineers should follow the best practices including but not limited to (Sections 7.2-7.9, 7.10.6, 7.10.7): ***(F-8, O-6)***

- Procure COTS parts from OCMs and authorized distributers.
- Obtain CoC (Certificate of Conformance) 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.
- Request PPAP (Production Part Approval Process) Package (Appendix B.1) for automotive grade parts.
- Procure a minimum quantity of 20 percent over the number of parts required to support equipment maintenance, planned future builds, and potential future builds.

NESC Recommendations - COTS parts selection, procurement and verification at part-level (III)

R-8 When verifying COTS parts at part-level, EEE Parts Engineers should follow the best practices below (Sections 7.2- through 7.9, 7.10.4): ***(F-4, F-5, F-6, F-7, F-8, O-3, O-4, O-5, O-6, O-7)***

- Perform parts manufacturer assessment. Verify parts manufacturer has documented proof of high standards for quality, reliability and workmanship as outlined in Section 7.10.3. The levels of verification can be based on published materials (e.g., Quality Manual, DPPM and FIT rates) published on the manufacturer's website, or unpublished materials obtained through direct contact with the manufacturer, or through third party.
- Perform re-evaluation on verified ILPMs periodically.
- Understand parts technology. When a COTS part's construction is not fully understood or it is not selected from an ILPM, perform DPA and/or parametric/functional testing on sample parts or and any other testing necessary (e.g., x-ray, PIND, etc.) to ensure the part meet MEAL with project risk posture.
- 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.

NESC Recommendations - COTS parts selection, procurement and verification at part-level (IV)

R-9 EEE Parts Engineers should perform obsolescence analysis on COTS parts to ensure projected part availability exceeds mission requirements over the duration of development or reuse for serviceable missions or GSE. ***(F-8, F10, F11, O-6)***

- Evaluate part life cycle to ensure availability from hardware design and part selection to procurement and installation.
- Coordinate with project to determine if design is a single or multiple build to ensure sufficient part quantities are procured.
- Review manufacturer’s life cycle management policy.
- Monitor parts lists on continuous basis for obsolescence alerts.

NESC Recommendations - COTS application and environment

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 (Sections 7.2-7.9, 7.10.5, 7.10.6): ***(F-3, F-7, F-8, O-3, O-4, O-5)***
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".

NESC Recommendations – GSE, Class D/Sub-Class D

COTS for critical ground support systems

R-12 Follow KSC's best practices (Section 7.7) for use of COTS parts, components and assemblies for GSE. ***(F10, F-11)***

Specifically for Class D and Sub-Class D missions

R-12 Program/Project Managers for Class D and Sub-Class D missions are recommended to use ARC's process and best practices for use of COTS (section 7.2) as guidelines, while also exercising good engineering judgement and ensuring the associated risks are thoroughly assessed by the Program/Project. ***(F-3)***

R-13 Program/Project Managers for Class D and Sub-Class D missions are recommended to review JSC's EDCPAP (section 7.4) process on COTS verification at part-level. ***(F-3) ****

*****Phase II is to clarify data expectations that might allow use of EDCPAP on higher criticality projects.

Phase 2

- Tasks
  - FAA/DoD knowledge capture
    - Add member participation from FAA and DoD focusing on sharing FAA and DoD's experiences and practices with use of COTS parts in their critical applications.
    - Incorporate OGA practices into NASA COTS recommendations as appropriate
  - COTS part-level verification criteria
    - Generate a list of questions for COTS manufacturers, focusing on COTS parts-level verification, and
    - Invite 6 to 8 COTS parts manufacturers to present at team's telecons addressing the questions.
      - Understand manufacturers' best practices
      - Understand how much documented proof that we realistically can expect from ILPMs
  - Develop criteria for accepting a COTS parts manufacturer as an ILPM
    - Quality management system (process controls and monitoring), qualification standards for technology and product (design rules, defect control), screening processes
- Intended Deliverable - update the TI-19-01490 final report
  - Add FAA/DoD current practices and the team's recommendations on use of COTS
  - Add further NASA guidance on part-level verification and criteria
  - Add criteria of an ILPM

Acronyms

AEC	Automotive Electronics Council
ARC	Ames Research Center
CCP	Composite Crew Program
COTS	Commercial-Off-The-Shelf
DLA	Defense Logistics Agency
DoD	Department of Defense
DPPM	Defective Parts Per Million
EDCPAP	Engineering Directorate Certified Parts Approval Process
EDU	Engineering Development Unit
EEE	Electrical, Electronic, and Electromechanical
GIDEP	Government Industry Data Exchange Program
GSE	Ground Support Equipment
ILPM	Industry Leading Parts Manufacturer
MEAL	Mission, Environment, Applications and Lifetime
NEPAG	NASA Electronic Parts Assurance Group
NEPP	NASA Electronic Parts and Packaging
NPR	NASA Procedural Requirements
NPSL	NASA Parts Selection List
OCM	Original Component Manufacturer
PIND	Particle Impact Noise Detection
RHA	Radiation Hardness Assurance
SEE	Single-Event Effects