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

(Phase I)

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Scope of the Assessment, Phase I

- 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 NEPP Program and/or agency guidance.

- Participation from eight centers: ARC, GRC, GSFC, JPL, JSC, KSC, LaRC, MSFC
- Available at https://ntrs.nasa.gov/search?q=20205011579

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Agency Baseline Parts Requirements

- **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-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 (Grades 1–3) ← Most current practices → "NASA screened COTS"

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.

"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 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.

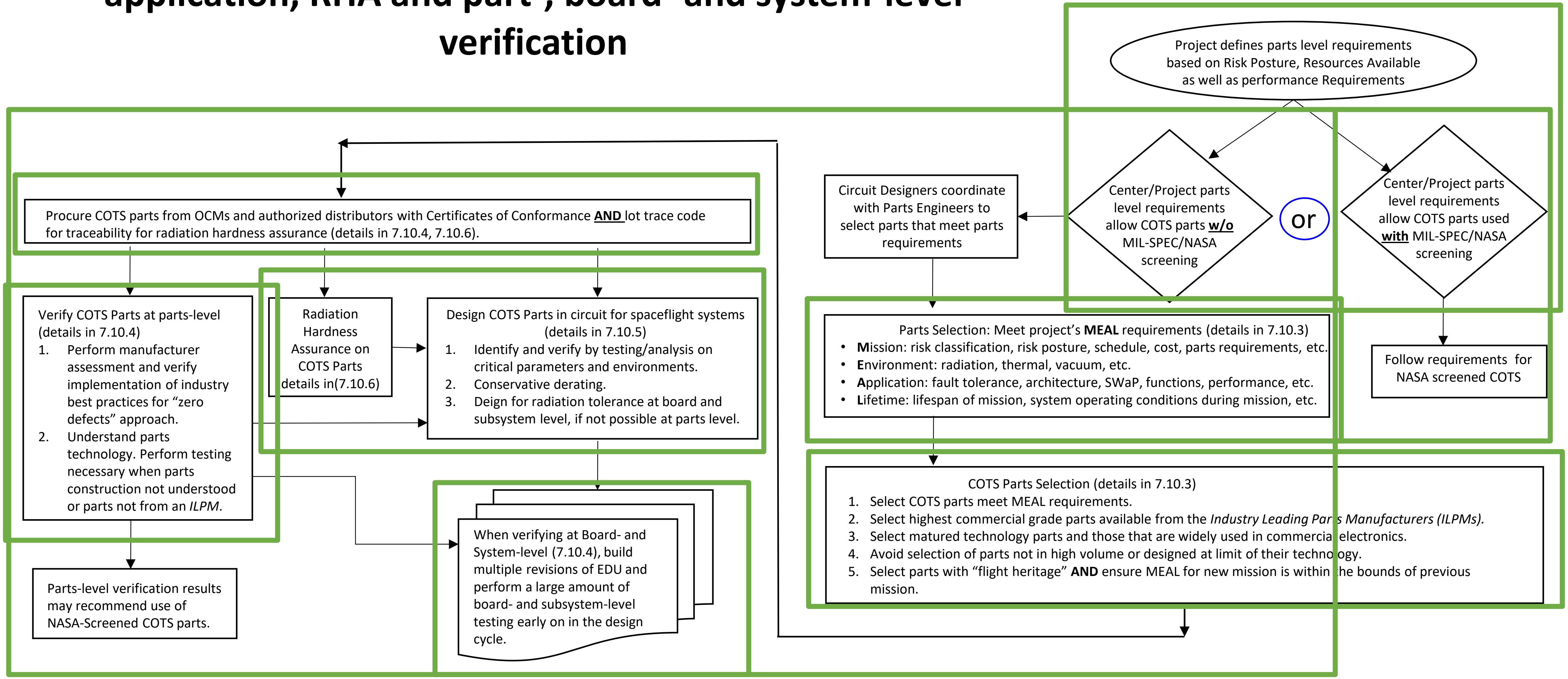
New Terminology Defined: Industry Leading Parts Manufacturers

- 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 and best practices for “zero defects”

Center Reports

- 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

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.
- 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.

NESC Findings, Observations and Recommendations (FORs)

- The team has had extensive discussions on COTS-related topics, and has 11 Findings, 7 Observations, and 13 Recommendations.
    - 11 Findings – 9 on COTS parts for spaceflight, and 2 on COTS parts and assemblies for critical GSE
        - The team opted for detailed FORs to convey specific information to cognizant engineers and managers
        - Sub-bullets under each Finding not included in the presentation, please refer to the report/TM for details

Nine Findings - 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-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.
- **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.
- **F-6** Not all COTS parts are created equal due to wide variability in parts manufacturers’ process control and quality assurance.
- **F-7** COTS parts, and most MIL-SPEC parts, are not designed and manufactured for space environments.
- **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.

Two Findings - 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-11 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-13Program/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 II

- Final report - update the TI-19-01490 Phase I report
  - Add FAA/DoD current practices
  - Add criteria of an ILPM
    - Generate a list of questions for COTS manufacturers 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
  - Add further NASA guidance on part-level verification and criteria
  - Update recommendations on use of COTS

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