New COTS-inclusive parts assurance in NASA

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Outline

- Current parts situation
- NASA-STD-8739.10 Overview
- The Dual-path update
- Three-option parts assurance
- Low Risk radiation approaches
- PEAL overview

The world has changed

- The MIL-SPEC system was devised when there was limited manufacturing capability for electronics – there was little assurance that parts would work reliably
- Parts were designed prescriptively and quality metrics were established relative to the designs
- Since there were no established reliability or statistical process controls, we had to use extensive strict quality requirements to make sure that current products had minimal variability relative to previous products
- MIL-SPEC levels that involved progressively more testing, higher sample sizes, and more stressing testing were introduced
- Since then commercial manufacturing capability with statistical process controls and high-volume production dwarfed and far surpassed the MIL-SPEC system.
  - With high-volume and statistical process controls, reliability now can be established directly
  - NASA and DoD did not recognize the advanced capability of the commercial sector and demanded additional screens to be applied to parts to try to make them mimic MIL-SPEC parts and hopefully screen in quality and reliability
    - Documentation stated (with limited justification in specific contexts) that higher levels equated to higher reliability, but actually quality was conflated with reliability in general
- As technology evolved, the MIL-SPEC parts could not keep up
  - Attempts to apply MIL-SPECs to noncompliant parts became more futile as part technologies have evolved

Current Conflicts

- MIL-SPECs, by definition, fundamentally limit technology
  - The broad environmental ranges required and the ability to tolerate many forms of overtest (inherently a derating), drive firm “catalog limits”, which have been in place since inception
  - There are not and will not be well-defined “parts categories” to cover many new classes of electronics technology
- The use of MIL-SPECs to accept and qualify COTS parts conflicts with many of the premises of COTS parts
  - MIL-SPECs involve many test levels that are not based on the actual manufacturing processes or application use of the parts
  - COTS parts are optimized to levels laid out in their data sheets, which would very often be different from MIL-SPEC testing levels (neither necessary or sufficient for properly characterizing the parts for acceptance)
    - MIL-SPEC testing levels can overtest COTS parts, resulting in misleading data and/or reduced reliability and damage to parts

Soon there will be no choice

- Instruments are appearing for high end missions that cannot be manufactured with MIL-SPEC parts or parts that can be effectively screened into compliance using EEE-INST-002
  - It is a virtual certainty this will be the case for the next major flagship space telescope
- Fully COTS spacecraft are soon to be ubiquitous and over time, some will stand out as long-term reliable
  - As long as we continue to equate EEE-INST-002 screening and qualification with reliability, we will continue to misrepresent reliable systems based on COTS as “unreliable”.
  - Such spacecraft will always be frowned upon for usage within NASA
- Availability of MIL-SPEC parts, especially level 1 and many types of space-grade, is becoming a growing challenge, in addition to the growing excessive costs.
- The demand to use unavailable parts is a growing contributor to mission overruns and cancellations.

We've reached the brick wall

- For years we have been able to maintain our compliance approach for assuring parts.
- When more performance or power dissipation was needed, or smaller footprint, lighter weight, or power consumption was needed, we developed standard drawings to combine compliance and performance
- However, even modern technology parts from the past 10 years are demanding capabilities that the drawings cannot keep up with
  - You might need a daughter board to hold all the compliant capacitors you need to support your FPGA
  - Outside of all the risks and impacts from the addition of that board, what will you do with all the extra ESR?
- These special build parts do not have the volume to assure reliability or to make productive use of process controls, only to support reliability prediction
- While manufacturers are advancing processing capability along with the resilience needed designed in to support industries with critical safety needs and extreme environments such as automotive, we focus on traditional approaches of "ruggedizing" older technologies
- We have been minimizing our exploitation of innovative design and manufacture that is booming, at expense of agency capabilities

Can we slow down the use of COTS?

- The use of COTS is already here, no matter what requirements we impose
  - The only question is whether we want to put a spacecraft on-orbit or not
- COTS parts are not brought forward into our projects because someone wants to save a few dollars or a few weeks or eke a little bit of extra unnecessary performance.
- COTS parts are needed in order to fly mature technologies from the last 25 years
- COTS parts are needed to make systems more reliable
- COTS parts are needed because they are available
- COTS parts are needed because they do not involve excessive costs for non-value-added activities

The use vs non-use of COTS in our systems is a simple prohibition question. There is no way to stop them – you simply need to place the right boundaries to properly use them without damaging them or inflating costs unnecessarily. The tighter boundary you place on them, the more likely you will encourage poor choices and bad practices

We start at the top (NPR 8705.4)

Electronics, Electrical, and Electromechanical (EEE) Parts	**Objectives:** **Select EEE parts at an appropriate level for functions tied directly to mission success commensurate with safety, performance and environmental requirements.** **Accepted Standard:** **NASA-STD-8739.10, Electrical, Electronic, and Electromechanical (EEE) Parts Assurance Standard or OSMA endorsed NEPP interim standards**			
	Class A: ~~Level 1 parts, equivalent Source Control Drawings (SCD) or requirements per Center Parts Management Plan.~~ Assurance Level 1 parts, equivalent Source Control Drawings (SCD), requirements per Center Parts Management Plan, or documented proven developer practices that have demonstrated results, consistent with the lowest level of risk tolerance, to achieve necessary performance.	Class B:: ~~Class A criteria or Level 2 parts, equivalent SCD or requirements per Center Parts Management Plan.~~ Assurance Level 2 parts, equivalent SCD , requirements per Center Parts Management Plan, or documented proven developer practices that have demonstrated results, consistent with a low level of risk tolerance, to achieve necessary performance.	Class C: ~~Class B criteria or Level 3 parts, equivalent SCD or requirements per Center Parts Management Plan.~~ Assurance Level 3 parts, equivalent SCD , requirements per Center Parts Management Plan, or documented proven developer practices that have demonstrated results, consistent with a moderate level of risk tolerance, to achieve necessary performance.	Class D: ~~Class C criteria or Level 4 parts, equivalent SCD or requirements per Center Parts Management Plan.~~ Assurance Level 4 parts.
	EEE Parts Notes: The intent is always to select the most appropriate assurance level parts to meet mission needs and requirements. There is nothing to disallow or discourage the use of parts aligned with higher classification levels with no additional testing when they are available. However, it is highly discouraged to require higher assurance level parts as standard or across the board. It is also discouraged to screen and/or qualify parts to achieve compliance above the current recommended assurance level.			

NASA-STD-8739.10 overview

- “Parent” agency parts standard
- Provides the end-to-end guidance for parts assurance in the agency at higher level than specific screening and qualification guidance
- Introduces a few new items since EEE-INST-002
  - Level 4: COTS with no additional screening
  - Automotive and vendor hi-rel as level 3 compliant
  - Various updated technical references
- Next version will introduce some updates
  - Level will be “assurance level”, no longer ambiguous interchangeable reference to grade, reliability level, quality level, which are all significantly different
  - Will point down to two paths for parts assurance
    - Traditional: 8739.11 (based on EEE-INST-002)
    - COTS: Three-option parts assurance

How should automotive and hi-rel COTS be selected?

- Respect the datasheet
- Characterized by extensive in-production and/or post-production screening or electrical testing as evidenced by one or more of the following
  - Description in the datasheet as designed for reliable usage with credible description why
  - Manufacturer-provided documentation, such as
    - Production Part Approval Process (PPAP) document
    - Quality Manual
    - Website detailed technical information provided
  - Parts are qualified to the pertinent AEC Q-category specification (Q100, Q101, Q200)
  - Production is managed under IATF 16949 quality management system (QMS)

Dual Path update to 8739.10

Traditional: NASA-STD-8739.11	Three-option parts assurance (COTS-driven)
Traditional, proven designs	New designs
Older generation technology	Newspace developers
Minimal size, weight, and power constraints	Current generation technology
Long lead times tolerable	High constraints on size, weight, and power
Emphasis on MIL-STD quality definitions	Emphasis on modern manufacturing, high volume, and statistical process controls
Use MIL-SPEC or screen in quality	Use established reliability or strategic part testing results

Three option parts assurance

Assurance Level	PEAL option *	MIL-SPEC option	COTS option
1	VHCAI or VHCWP1	Class S, V, Y monolithic microcircuits Class K hybrid microcircuits JANS discrete semiconductors FRL T, S, R capacitors and resistors or M123 FRL C and D tantalum capacitors	ILPM & relationship with mfr & Established Part & High Volume & 100% mfr electrically tested & Statistical process control & zero-defects policy
2	HCAI or HCWP2	Class B or Q monolithic microcircuits Class H hybrid microcircuits JANTXV discrete semiconductors FRL P capacitors and resistors FRL B tantalum capacitors	ILPM or AEC qualified under IATF 16949 & 100k or more in production & Minimum 1 year in production & AQL of 0.4 or better **
3	MCAI or MCWP3	Class M, N, T, or /883 monolithic microcircuits Class G, D, or E hybrid microcircuits JANTX discrete semiconductors FRL B capacitors and resistors	Automotive or hi-rel part from reputable (proven flight history) mfr or high-volume part, mfr relationship, low field failure rate
4	N/A	N/A	no restrictions

*PEAL option is a placeholder, terms defined in PEAL reference document

**Low field failure rates or low DPPM/DPPB are appropriate alternatives

Will use of COTS cause a radiation nightmare?

- It certainly can if you're in a radiation environment and you pretend it's not there, but that has **nothing** to do with COTS.
- Typically, about 90% of the overall part count even for large missions are not radiation-hardness-assured (because they don't need to be).
  - The majority of places where COTS are really needed are for non-susceptible parts, such as most passives
- The problem is no different from that of using a 5962-XXX microcircuit or a JANS2NXXXX BJT (neither of which is radiation hardness assured)
- For reference, an IRHM58160 is a COTS part (and it is radiation hardness assured).
- No matter whether you use COTS, MIL-SPEC or "special drawing" parts, radiation should be addressed in the same way
- As we transition to newer technologies and higher performance, we will have to think about radiation mitigation in different ways because parts with RHA will almost always be multiple generations behind
  - However, some of the new technology parts will be less susceptible to radiation by the nature of their designs (thinner gate oxides, etc)

Intelligent use of COTS is of insignificant difference from our current parts assurance practices from a radiation standpoint

Low risk Radiation Approaches

1. Traditional: RHA, lot-specific radiation testing, or analysis
2. Newspace conservative: Strategic radiation testing of active parts, combined with circuit and system design mitigations
3. Full system radiation-tolerant design and rad-hard by design approaches, with RHA or testing for front-line defenders and NVRAM

*see http://dx.doi.org/10.13140/RG.2.2.34502.28480 for info on on-orbit radiation data collection

Radiation approach depends on environment, specific active parts used, shielding in the system, and organizational preference and **has no relationship to the allowance of COTS**

Parts Evaluation & Acceptance Lab (PEAL)

- Reconstitution of a major institutional capability that assured reliable parts usage in the early days of NASA
- Driven by the reality of COTS dominance in the market, the necessity to exploit commercial capabilities, and gain the confidence needed to fly parts in low-risk tolerance missions.
- Part testing approaches always begin with an interaction with the manufacturer and consideration of manufacturing approach
- NASA employees (JPL-inclusive) and in-house contractors
  - Select and procure parts for characterization
    - Consider unfamiliar parts used and proposed on new and recent missions as top priority
    - Gather input from scientists, component designers, instrument developers
    - **Primary focus should be on part technologies, though specific "part number" assessments should also be performed to properly evolve from current approaches and to monitor trends in specific part design changes over time**
  - Determine screening and lot acceptance tests (LAT) to be employed for future project usage
    - or determination that manufacturer screening/LAT or statistical process controls as designed are sufficient
  - Establish tactical and strategic radiation assessments
  - Perform reliability testing and analyses
  - Determine required post-procurement actions (if any) for each part
  - Maintain parts selection list
    - Part-number-specific assessments over time can be used to characterize evolving trends for some individual part designs to understand risks of obsolescence and the motivations for changes in part design and manufacture
- This is a strategic, Agency-level activity that provides structure for parts selection and acceptance for future missions, not a part acceptance laboratory for missions in development

Summary

- The combination of supply chain issues and evolution along with the need to fly current technology drive the need for broad use of COTS
- The evolution of technology and manufacturing processes has created an insurmountable differential between design/manufacture of parts and most MIL-SPEC-based upscreening processes
- Successful history of usage combined with the findings of the NESC COTS Phase 2 study demonstrate a readiness to step forward with an expanded use of COTS
  - There are many considerations and COTS encompasses an infinite trade space, so thoughtful implementation with proper engineering judgment is necessary
  - No cookbook will apply, so thoughtful engineering is needed
- While radiation considerations demand thoughtful space implementation of current technologies, this has nothing to do with COTS.
- A long-term broad COTS usage approach in NASA will require a capability such as PEAL since there will never be guidance to cover all situations

Approach Categorization (excerpt)

Approach	Example	Risk Factors	Resource Usage	Performance/ Tech infusion
1. COTS by exception, FMRR or lot-specific radiation testing	Traditional space	3	10	10
2. COTS inclusive, FMRR or lot-specific radiation testing	Traditional space w/expanded COTS	2	7	5
3. COTS inclusive, FMRR or strategic (non-lot-specific) radiation testing		4	4	2
4. COTS inclusive, FMRR, strategic (non-lot-specific) radiation testing with select radiation tolerant design		3	4-5	2
5. COTS inclusive, strategic (non-lot-specific) radiation testing with select rad-tolerant design	Newspace conservative	3	4-5	2
6. COTS inclusive, full rad-tolerant design, FMRR or strategic rad testing for front-line defenders and NVRAM	NASA ARC	1-2	2-4.	2-5
7. COTS inclusive, no radiation testing or FMRR, select rad-tolerant design	Aerocube	4-6	1-2	1-2
8. COTS inclusive, no consideration of radiation	Cheap and fast	10	1	1
9. MIL-SPEC exclusive, no radiation testing, FMRR, or rad-tolerant design	For reference only	10	6	10

Scores: Risk Factors, Resource Usage, Performance/Tech infusion

Low risk modern approach

Medium-high risk Rapid technology infusion

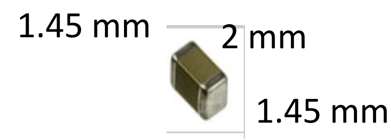
Traditional+COTS

Fast, cheap, high risk

Part Evolution

CDR35BX474AKUS
0.47uF, 50V
TTI: 100MOQ/$2.60ea

G311P838AFX475K2R1
4.7uF, 50V
TTI: 50MOQ/$278ea



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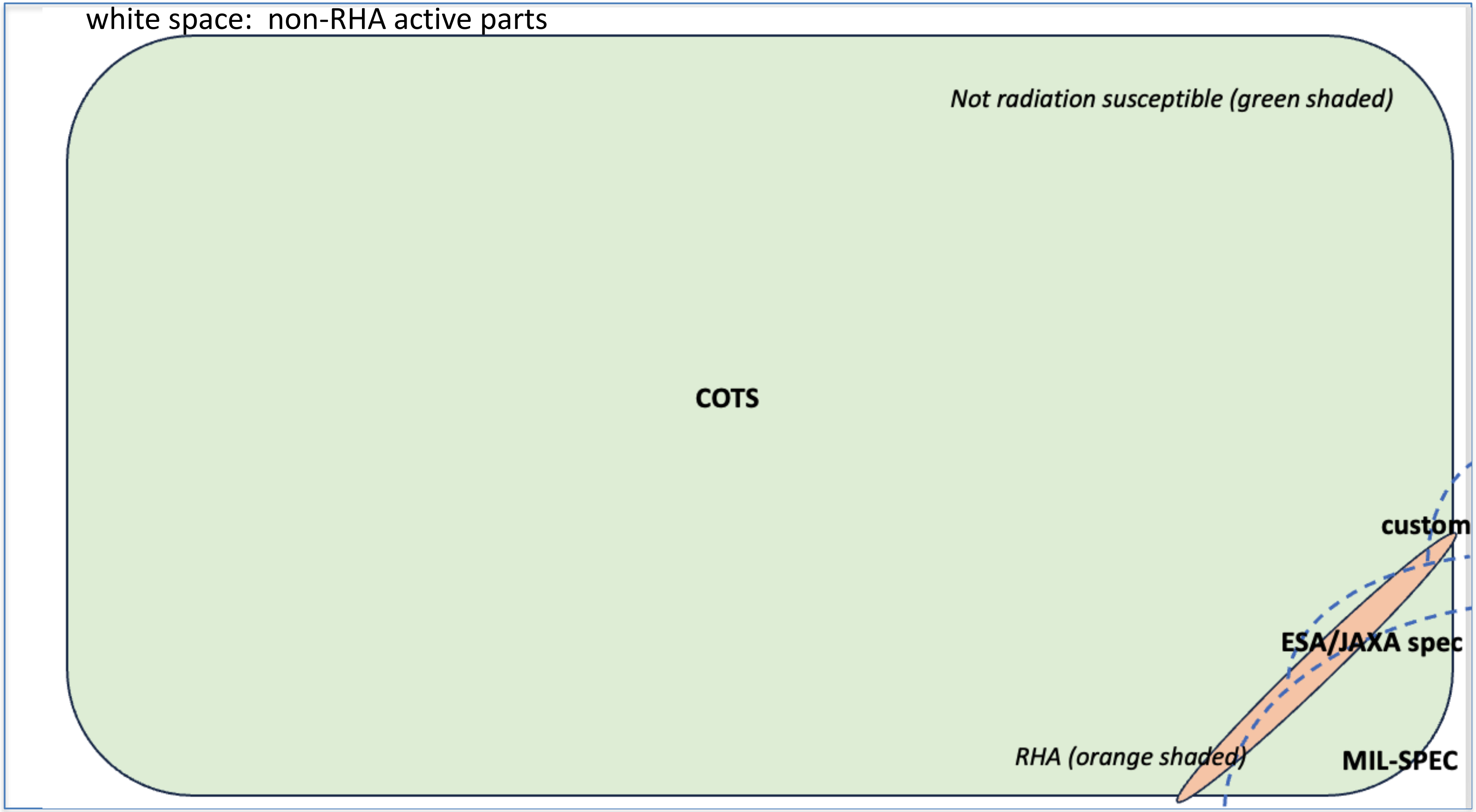
New technology does not mean less reliable or radiation sensitive

- Which has greater reliability?
  - a space-proven non-RHA part using TMR
  - An RHA part without TMR
- Which has greater reliability?
  - One RHA MOSFET with 40 nm gate oxide in an SMD-2 package
  - Three non-RHA MOSFETs with 5 nm gate oxide in DPAK

P/N	IRHNA57160	STD100N10F7
VDSS	100V	100V
ID	75A	80A
RDS(on)	12 mΩ	8 mΩ
Package	SMD-2 (~232 mm^2)	DPAK (~60 mm^2)
Weight	3.3 g	0.33 g

Radiation Venn diagram



Progression of Parts Assurance in NASA

- Pre-1995: largely MIL-SPEC (space grade, “Class S”)
- 1995: 311-INST-001 and equivalent – MIL-SPEC levels 1-3 with upscreening to make up differences in levels
- 2003: EEE-INST-002 and equivalent – levels 1-3 with upscreening to make up differences and add MIL-SPEC screens to COTS parts + derating
- 2004: NPR 8705.4 guidance – levels 1-3, aligned with classification, or “center parts management plan”
- 2017: NASA-STD-8739.10 introduces level 4 (“grade 4”) – COTS with no additional testing. Declares automotive parts and hi-rel COTS to be level 3 compliant (although not formally implemented in practice in the agency)
- 2021: NPR 8705.4A adds the option for level 4 for Class D
- 2021: SMD Class D MAR: Level 4 baseline for Class D
- 2022: NESC COTS Phase 2 report provides guidance for reliable use of COTS EEEE parts without additional testing, through careful selection

Current options for use of COTS EEEE parts in the agency

- Class D and sub-Class D: no restrictions at the agency level, COTS EEEE parts are recommended. Smart selection and use of COTS is always encouraged
  - Known parts from reputable manufacturers, sold for reliable use
  - Respect the datasheet
- Class C (level 3): Automotive and manufacturer hi-rel COTS EEEE parts are compliant as-is IAW NASA-STD-8739.10. Language is incorporated into GSFC SMA MAR templates for Class C.
- All Classes: Standard components that include internal COTS EEEE parts accepted based on history of the item relative to the current environment (part selection and assurance delegated to standard component manufacturer)

What should be done about radiation?

- Using new parts and new technologies will demand a new approach for radiation
- Any expectation that all or most parts will be rad-hard or tested for radiation from their current lots will simply cause many to collapse under their own weight (including many that have been in space successfully for decades)
- Any expectation that radhard parts are necessary and sufficient for successful on-orbit operation will lead to disappointment (as in SMAP)
- Use good system design practices – transition from rad-hard parts to rad-hard by design
  - Protect/derate your MOSFET; understand combined circuit/radiation effects!
  - Implement TMR on FPGAs
  - Be sure your processor circuit is resettable
  - Employ EDAC and protect your memory
- Use familiar parts
  - New sensitive part types (CMOS, processors, MOSFETs, memory, etc) in critical applications should invoke testing or sufficient protection
- Use components that have flown in similar environments
- NVRAM and front-line protection parts radhard
- Perform strategic testing as part of an overall parts characterization activity and remove most testing from the backs of projects (PEAL)
- **Learn from on-orbit experiences! Do not use ground-testing as your primary means for radiation assurance – it will provide a hard barrier against moving forward for many mission concepts.**