NASA Efforts Towards a Holistic COTS Approach for Space Avionics

NASA Engineering and Safety Center (NESC)
NASA Electronic Parts and Packaging (NEPP) Program

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Acronyms

AEC	Automotive Electronics Council
CCA	Circuit Card Assembly
COTS	Commercial-Off-The-Shelf
DDD	Displacement Damage Dose
DoD	Department of Defense
DPPM	Defective Parts Per Million
DSEE	Destructive SEE
EEE	Electrical, Electronic, Electromechanical
FAA	Federal Aviation Administration
FIT	Failure-In-Time
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
ILPM	Industry Leading Parts Manufacturer
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
LET	Linear Energy Transfer
MEAL	Mission, Environment, Application, and Lifetime
MIL-SPEC	Military Specification

MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NDSEE	Non-destructive SEE
NEPP	NASA Electronic Parts & Packaging (Program)
NESC	NASA Engineering & Safety Center
PEAL	Parts Evaluation and Assessment Laboratory
PPAP	Production Part Approval Process
RHA	Radiation Hardness Assurance
SEB	Single-Event Burnout
SEGR/SEDR	Single-Event Gate/Dielectric Rupture
SEE	Single-Event Effect(s)
SEECA	SEE Criticality Analysis
SEFI	Single-Event Functional Interrupt
SEL	Single-Event Latchup
SET	Single-Event Transient
SEU	Single-Event Upset
SPC	Statistical Process Control
TID	Total Ionizing Dose
TNID	Total Non-Ionizing Dose

NESC EEE COTS Technical Assessment

- Phase I
  - Capture current practices on using COTS parts across NASA centers
  - Provide NESC recommendations that could lead to future agency guidance
  - Participation from eight centers: ARC, GRC, GSFC, JPL, JSC, KSC, LaRC, MSFC
  - Phase I report publicly released, available at https://ntrs.nasa.gov/citations/20205011579
  - Lack of consensus within NASA in Phase I requiring 2nd phase to address
    - Part-level verification and perception of risk of using COTS parts
- Phase II
  - Capture current practices on using COTS parts from DoD and FAA
    - Phase I team plus DoD (Army, MDA, Navy) and Federal Aviation Administration (FAA)
  - Understand COTS manufacturers' processes
  - Generated a list of questions for COTS manufacturers and talked to eight COTS parts manufacturers to understand their processes
  - Provide NESC recommendations that could lead to future agency guidance
  - Phase II final report publicly released, available at https://ntrs.nasa.gov/citations/20220018183

NESC EEE COTS Assessment Key Considerations

- COTS definition applied:

  A part for which the manufacturer solely establishes and controls specifications for configuration, performance, quality, and reliability. This includes design, materials, processes, assembly, and testing with no Government-imposed requirements (i.e., no Government oversight). COTS parts typically are available on a manufacturer's catalog (e.g., website) or from various distributors.

- NESC overall recommendation is to select "Established COTS parts" from Industry Leading Parts Manufacturers (ILPMs) and when doing so, MIL-SPEC or similar screening and lot acceptance testing can be reduced or eliminated where evidence of sufficient quality and reliability exists
  - Provides guidance on part- and board-level verification for NASA missions per risk class ***but no implementation details***
  - The extent and nature of the needed evidence will differ by mission, most likely driven by a mission's resources, associated risk posture, and environment
  - ***Does not address radiation concerns***
- Recommended NEPP to perform a pathfinder study to explore implementing the NESC guidance and provide updates to NASA standards accordingly

What Is An ILPM?

NESC report defined an **Industry Leading Parts Manufacturer (ILPM)** as:

> A parts manufacturer with high volume automated 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.

ILPM Criteria

1. Must have at least one Established COTS Part category
2. Willing to share parts quality and reliability data with NASA (DPPM, FIT) and how those statistics are derived
3. Willing to provide NASA documents substantiating parts quality and reliability
4. Willing to work with NASA or prime contractors to maintain a strong customer-manufacturer relationship (preference for on-site visit)

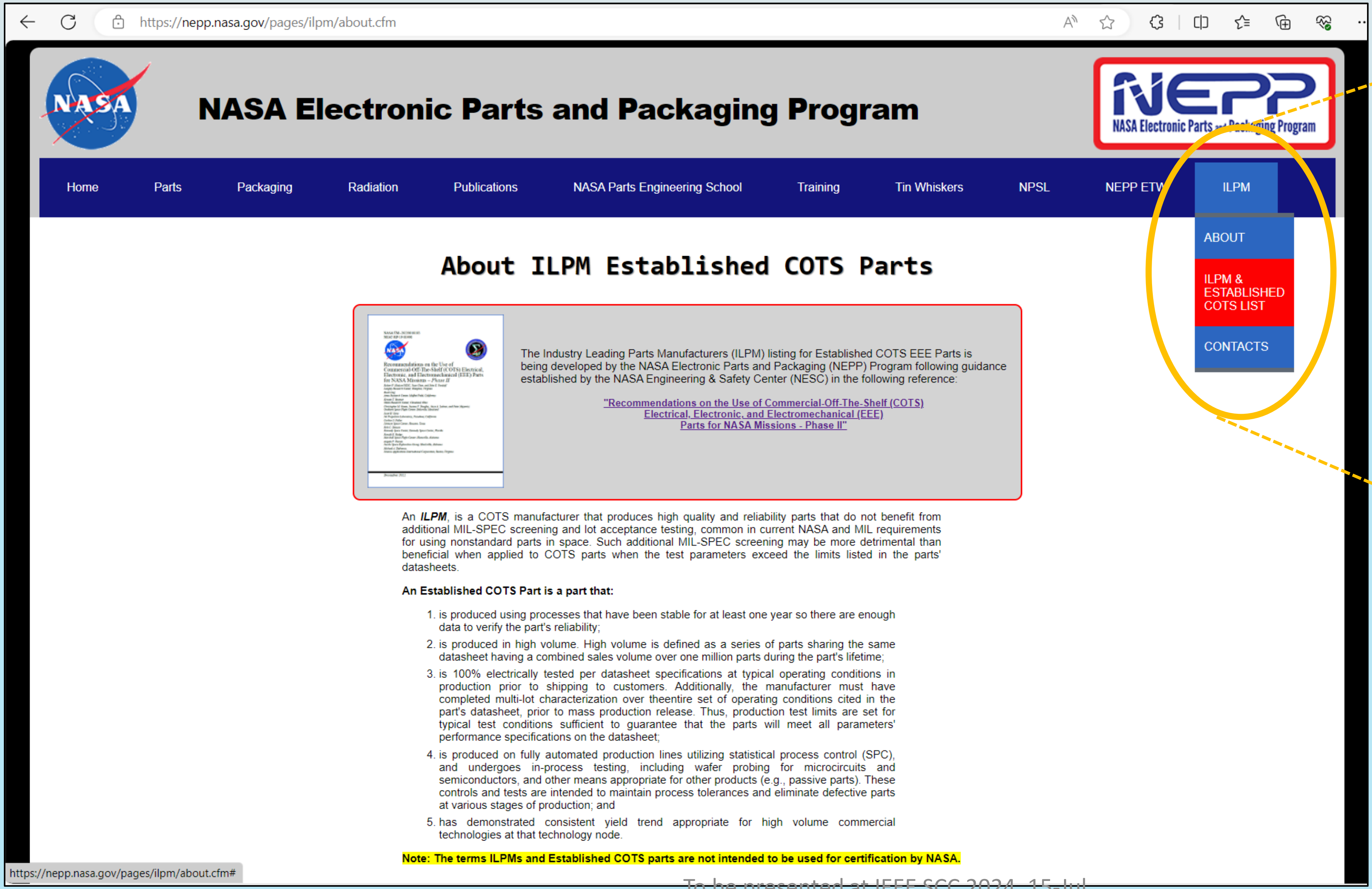
An Established COTS Part Is a Part That:

- Is produced using processes that have been stable for **at least one year** so there are enough data to verify the part's reliability.
- Is produced in **high volume**. High volume is defined as a series of parts sharing the same datasheet having a combined sales volume over one million parts during the part's lifetime.
- Is **100% electrically tested per datasheet specifications** at typical operating conditions in production. Additionally, the manufacturer must have completed multi-lot characterization over the entire set of operating conditions cited in the part's datasheet, prior to mass production release.
- Is produced on fully **automated production lines** utilizing statistical process control (SPC), and undergoes in-process testing, including wafer probing for microcircuits and semiconductors, and other means appropriate for other products (e.g., passive parts).
- Has demonstrated **consistent yield** trend appropriate for high volume commercial technologies at that technology node.

Established COTS Part Comparison

ILPM Established COTS Parts	MIL-SPEC Parts	NASA-Screened COTS Parts
1. Produced by an ILPM 2. Automated production line 3. High-volume parts 4. 100% electrical testing 5. Reliability monitoring 6. Process and parts qualification 7. Typically, non-standardized drawings and datasheets 8. Only a small percentage are rated for space radiation 9. Generally not designed for launch and deep space environment	1. Automated production line 2. Not typically high-volume 3. 100% MIL-SPEC screened 4. Lot acceptance 5. Process and parts qualification 6. Standardized drawings, datasheets and MIL specs 7. Only a small percentage are rated for space radiation 8. May or may not be designed for launch and deep space environment	1. May or may not have automated production line 2. May or may not be high volume 3. Post procurement 100% screened 4. Lot acceptance 5. Typically, non-standardized drawings and datasheets 6. Only a small percentage are rated for space radiation 7. Generally not designed for launch and deep space environment

Announcing the First ILPM!



https://nepp.nasa.gov/pages/ilpm/about.cfm

NASA Electronic Parts and Packaging Program

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ABOUT
ILPM & ESTABLISHED COTS LIST
CONTACTS

About ILPM Established COTS Parts

The Industry Leading Parts Manufacturers (ILPM) listing for Established COTS EEE Parts is being developed by the NASA Electronic Parts and Packaging (NEPP) Program following guidance established by the NASA Engineering & Safety Center (NESC) in the following reference:

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

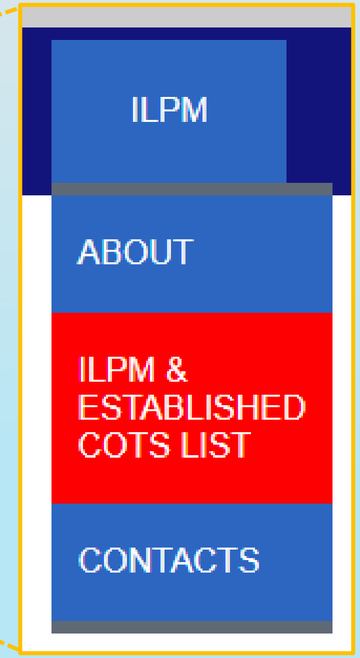
An ***ILPM***, is a COTS manufacturer that produces high quality and reliability parts that do not benefit from additional MIL-SPEC screening and lot acceptance testing, common in current NASA and MIL requirements for using nonstandard parts in space. Such additional MIL-SPEC screening may be more detrimental than beneficial when applied to COTS parts when the test parameters exceed the limits listed in the parts' datasheets.

An Established COTS Part is a part that:

1. is produced using processes that have been stable for at least one year so there are enough data to verify the part's reliability;
2. is produced in high volume. High volume is defined as a series of parts sharing the same datasheet having a combined sales volume over one million parts during the part's lifetime;
3. is 100% electrically tested per datasheet specifications at typical operating conditions in production prior to shipping to customers. Additionally, the manufacturer must have completed multi-lot characterization over theentire set of operating conditions cited in the part's datasheet, prior to mass production release. Thus, production test limits are set for typical test conditions sufficient to guarantee that the parts will meet all parameters' performance specifications on the datasheet;
4. is produced on fully automated production lines utilizing statistical process control (SPC), and undergoes in-process testing, including wafer probing for microcircuits and semiconductors, and other means appropriate for other products (e.g., passive parts). These controls and tests are intended to maintain process tolerances and eliminate defective parts at various stages of production; and
5. has demonstrated consistent yield trend appropriate for high volume commercial technologies at that technology node.

Note: The terms ILPMs and Established COTS parts are not intended to be used for certification by NASA.

https://nepp.nasa.gov/pages/ilpm/about.cfm#



ILPM Established COTS Parts List
Susumu RG Series Thin Film Resistors

Date Added	Last ILPM Assessment Date	Manufacturer	Address	CAGE Code	Commodity	Established COTS Parts Designation	Comment	NASA Point of Contact
5/23/2024	5/23/2024	Susumu	Obama, Japan Suzhou, China	J5312	Resistor, Thin Film, Surface Mount, High Precision	RG series (sizes 0201, 0402, 0603, 0805, 1206)	AEC-Q200 Compliant	TBD [Creating generic email, e.g., ILPM_POC@nasa.gov]

ILPM Established COTS Parts List
Susumu RG Series Thin Film Resistors

Submitted Documents	Manufacturer Internal Qualification Test Periodicity	NASA ILPM Assessment Documents	Links
• Annotated ILPM questionnaire • General ILPM discussion documents, including "Company Presentation Sep 2023" and additional responses to NASA questioning (Oct 2023 thru May 2024) • PPAP Level 3: D23-0403, 10-Oct-2023) • FIT Rate: RGR-S22005, 30-Aug-2022) • Reliability Test Data for all sizes: 1) RG3216: RGR-S22012E, 13-Jul-2022 2) RG2012: RGR-S22011E, 13-Jul-2022 3) RG1608: RGR-S22013E, 13-Jul-2022 4) RG1005: RGR-S21033E, 13-Jul-2022 5) RG0603: RGR-S22029E, 29-Nov-2022 • Additional 3000hr life test data at rated power for RG1005, RG1608, RG2012, RG3216: RGR-S21045E, 9-Mar-2022 • Design and Manufacturing Change Management Rule (UM4060003-02, Rev Date 2022/12/30) • List of items subject to change notification (UM4060015-00, Rev Date 2021/09/02)	Once at product qualification, sample set of reliability tests once per year	• ILPM Established COTS Parts Criteria Matrix • NASA summary: Susumu Thin Film Chip Resistor FIT Rate Calculation Comparison with MIL-PRF-55342 Established Reliability Failure Rate Level (FRL) Estimate (MIL-STD-690)	https://www.susumu.co.jp/common/pdf/n_catalog_partition01_en.pdf?v=20180406

- ***List*** of provided of NASA ILPM assessment documents ***(not actual documents)***
- Manufacturer internal qualification test periodicity
- Link to ILPM Established COTS Parts Criteria Matrix

ILPM Established COTS Part Criteria Matrix

ITEM #	ILPM ESTABLISHED COTS PART CRITERIA	RG Series Resistors
1	**Established COTS parts criteria**	
1a	Produced using processes stablized for > one year	Yes
1b	Produced and sold in high volume (> 1M)	Yes
1c	100% electrically tested for datasheet parameters + other 100% inspection	Yes (THD, visual, HV test)
1d	Produced on fully automated lines with SPC and in-process testing	Yes based on high volume manufacturing output. SPC and in-process testing discussed in items 3d, 3e, and 4 below.
1e	Consistent yield	Yield is monitored and used for future improvement plans
2	**ILPM Criteria**	
2a	Has at least one Established COTS part	RG series resistors
2b	End of production DPPM and method of derivation	None reported. Susumu does not calculate.
2c	Field failure DPPM and method of derivation	Manufacturer sets PPM target annually (based on confirmed field failures)
2d	Parts failure rate or FIT rate	RGR-S22005E: FIT rate < 0.010 FIT, 60% confidence level, JIS-C-5003 Attachment Table 1 is applied
2e	Designed operating life and method of derivation	FIT rate data is comprised of ~20 years worth of testing using moisture as the primary stress parameter (20C/60%RH test condition). See comparison of Susumu FIT rate calculation to MIL-PRF-55342 Failure Rate Level (FRL) estimate. Activation energy for wearout failure mechanism and method of derivation provided.
3	AEC-Q004 Zero Defect Framework related practices	
3a	Defect Elimination Process / Infant Mortality Detection	Yes per PPAP D23-0403
3b	Statistical outlier part elimination before shipment	Yes per PPAP D23-0403 and additional information provided
3c	Reliability monitoring program (wafer level and daily end of production parts testing, to include testing bias and thermal conditions, sample sizes, and failure criteria)	Tests, conditions, tolerances, sample sizes as detailed in RG52-4005-E. Initial qualification on thousands of pieces, continuous reliability since then done on 10-20 pcs per product. Process maintained through SPC. Tests done on low/mid/high resistance value range. Susumu also conducts a set of reliability tests once a year for every chip size of RG series (0402, 0603, 0805 and 1206).
3d	Control limit improvement process	Yes per PPAP D23-0403, including embedded RG52-4005-E Version 60 Control Plan (amended 13-Sep-2022)
3e	IATF 16949 certification or equivalent	ISO/TS16949 certification Nov 2004 at JQA, Mar 2011 at China Suzhou.
4	Level 3 PPAP	PPAP D23-0403 provided
	OR	
ALT-4a	Construction / Cross-section Analysis	Part construction shared during ILPM discussion documents--no further hard documentation provided. Dimensions/materials detailed on part specification RG00-4146.
ALT-4b	Design FMEA	Confidential--not shared
ALT-4c	Process FMEA, to include wearout mechanisms and associated activation energies	PPAP Process-FMEA: RG05-4004 Rev. 36
ALT-4d	Process Control Plan	Process flow chart: RG52-4005-E Version 60
ALT-4e	Material Performance Test Results	PPAP Reliability Test data document: RGR-S22012E
ALT-4f	Process studies	PPAP Dimensional Results portion of Reliability Test Data RGR-S22012E-1
ALT-4g	Engineering change documents and process	Yes: Design and Manufacturing Change Management Rule UM4060003 Rev. 02 and UM4060015-00 Revision Date:2021/09/02 documents provided
ALT-4h	Measurement system analyses	PPAP page 156: Gage Repeatability and Reproducibility Data Collection Sheet

EEE Parts Assessment Flow Using the ILPM Process

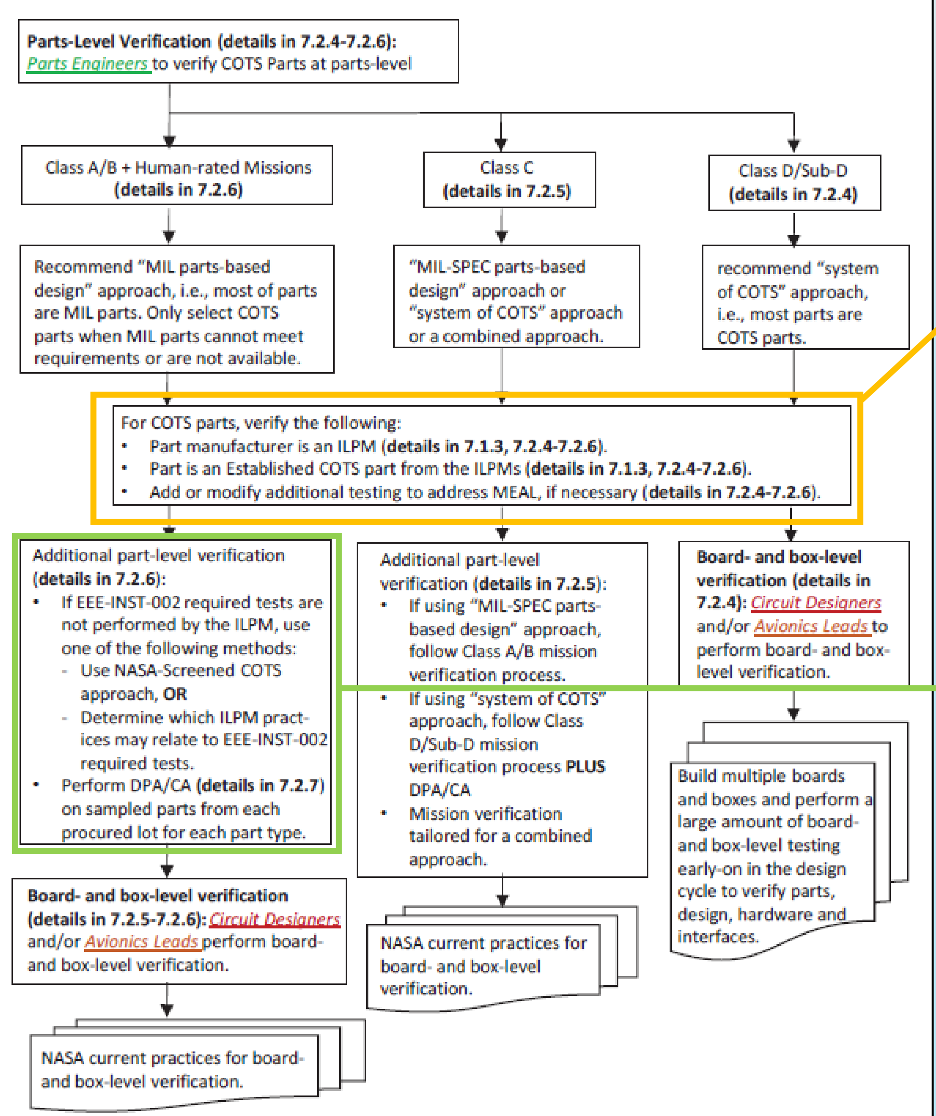


Figure 7.2-2. NESC Recommendations on Part-level Verification

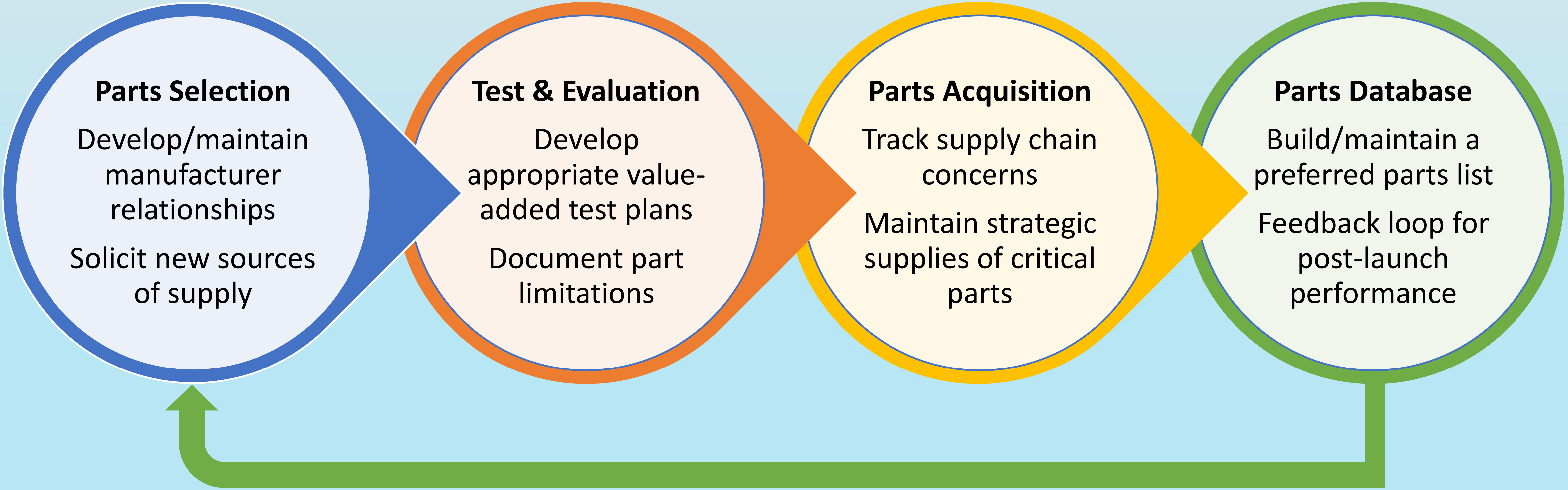
NEPP ILPM Pathfinder activities are targeted here.

For COTS parts, verify the following:
- Part manufacturer is an ILPM (**details in 7.1.3, 7.2.4-7.2.6**).
- Part is an Established COTS part from the ILPMs (**details in 7.1.3, 7.2.4-7.2.6**).
- Add or modify additional testing to address MEAL, if necessary (**details in 7.2.4-7.2.6**).

Additional part-level verification (**details in 7.2.6**):
- If EEE-INST-002 required tests are not performed by the ILPM, use one of the following methods:
  - Use NASA-Screened COTS approach, **OR**
  - Determine which ILPM practices may relate to EEE-INST-002 required tests.
- Perform DPA/CA (**details in 7.2.7**) on sampled parts from each procured lot for each part type.

Implementation of ILPM Established COTS part usage in a mission is project-driven for now. Executing at an agency-level is best.

The Pursuit of a Future NASA EEE Parts Capability: Parts Evaluation and Assessment Laboratory (PEAL)



PEAL would be an Agency-level capability aimed at developing the strategic use of EEE COTS parts utilizing the ILPM process while also addressing radiation effects, for the benefit of all NASA missions

NASA Radiation Hardness Assurance (RHA) Standard

Prescribes the process for radiation program integration

- Levies requirements for:
  - RHA schedule
  - RHA deliverables
- Requires programs & projects to accept a risk if the schedule / deliverables are not met

Prescribes the process for programs and projects to baseline their RHA approach

- Defines RHA process taxonomy & correlation w/ MEAL*
- Prescribes the program scrutiny required to baseline the RHA approach
  - Up to accepting a risk

- Leverages NASA Risk Management Process
  - Mitigation plan, risk tracking to closure

*Mission, Environment, Application, and Lifetime

RHA Standard Highlights

- This is a process standard
  - How to implement an RHA program consistent with the MEAL criteria
- Provides a framework for RHA integration at system level
  - Establishes a schedule for RHA activities and deliverables
- Establishes a taxonomy of RHA approaches “Categories of RHA programs”
  - Much more than a radiation taxonomy of EEEE parts
  - Scope of RHA, System-level aspects/criteria, EEEE-Part-level criteria
- Establishes a process for baselining the program or project RHA approach
  - Allows for alternative RHA approaches with risk-informed program-level buy-in
  - The RHA taxonomy and MEAL factors determine the required level of program scrutiny
- Leverages the NASA risk process
  - Risks are not intended as a negative, but as a visibility & resource tool to enable efficient direction of resources
- Additional non-prescriptive information critical to the correct interpretation of the intent of the standard is provided in the appendix sections

RHA Taxonomy Example

Table 6. SEE Taxonomy – RHA Scope and Assurance

RHA Category	S1	S2	S3	S4	S5
Risk tolerance posture	Low	Low-Medium	Medium-High	High	Very High
Purpose of SEE RHA	Assures reliability (DSEE) and	Assures reliability (DSEE) and	Provides targeted assurance	Provides some assurance of	N/A
Surviva					
A prior will be					
Availab produc					
A prior availab					
Anticip testing					

6-1"Tar
6-2Prot
6-3This
6-4Risk
6-5See I
6-6Refer to Ap
6-7High energy

Table 7. SEE Taxonomy – System-level RHA criteria

RHA Category	S1	S2	S3	S4	S5
RHA integral to the design process	Yes	Yes	Yes	Selectively at project discretion	Not required
System-level LOE	SEE threats to reliability and	SEE threats to reliability and	SEE threats to availability do	None to interface-limited[7-2]	None to interface-limited[7-2]
SEEC					

7-1Par
7-2E.g
7-3For

Table 8. SEE Taxonomy – EEEE-part-level criteria

RHA Category	S1	S2	S3	S4	S5
SEE part selection criteria	**Enforced**	**Enforced**	**Enforced**	**Enforced**	**Not enforced**
SEE data type[8-1,8-2, 8-3]	Piece-part	CCA- and/or piece-part	CCA- and/or piece-part	CCA-level test	None
SEGR/SEB/SEDR acceptance criteria[8-4]	Risk avoidance (commonly, 37 MeV·cm²/mg)	Risk avoidance (commonly, 37 MeV·cm²/mg)	Risk avoidance (commonly, 37 MeV·cm²/mg)[8-5]	High energy protons for DSEE[8-6]	None
SEL/other DSEE acceptance criteria[8-6]	Risk avoidance (commonly, 75 MeV·cm²/mg) or quantification	Risk avoidance (commonly, 37 MeV·cm²/mg) or quantification	Risk avoidance (commonly, 37 MeV·cm²/mg) or quantification[8-5]	High energy protons for DSEE[8-6]	None
NDSEE acceptance criteria	Likelihood and criticality assessed and meet project requirements.	Likelihood and criticality assessed and meet project requirements.	Likelihood and criticality assessed and meet project requirements for critical systems.	Likelihood and criticality assessed and meet project requirements for critical systems.	None
SEE data representative of flight parts[8-7]	Required	Required	Recommended	Recommended as feasible	

8-1RHA guarantees are provided by US military standard, other government/industry organizations, or manufacturer/vendor. RHA parts are subject to lot traceability and manufacturing process change controls that vendor data may or may not provide. The radiation designator in MIL-PRF-38534/5 and MIL-PRF-19500 refers to TID only and is not indicative of any SEE guarantees. Data sheets often guarantee specific SEE characteristics only (e.g., SEL LET threshold) and must be supplemented by manufacturer/vendor- or application specific testing on flight-lot representative samples.

8-2Refer to Appendix G: RHA Evidence Hierarchy and definitions of "acceptable data" available in the literature (e.g., Poivey, 2002; Gonzales, 2018)

8-3Compliant to national and international standards to the extent practical

8-4Based on structure layout of the device

8-5Test LET may be reduced to program-agreed level (e.g., to 20-30 MeV·cm²/mg) due to practical considerations

8-6DSEE risk remaining for specific part types e.g., with thick sensitive regions [RHA guidelines]

8-7Analysis required to validate applicability of previous test data to the flight design

RHA Taxonomy Example

Table 6. SEE Taxonomy – RHA Scope and Assurance

RHA Category	S1	S2	S3	S4	S5
Risk tolerance posture	Low	Low-Medium	Medium-High	High	Very High
Purpose of SEE RHA	Assures reliability (DSEE) and	Assures reliability (DSEE) and	Provides targeted assurance	Provides some assurance of	N/A
Surviva					
A prior will be					
Availab produc					
A prior availab					
Anticip testing					

6-1"Tar
6-2Prot
6-3This
6-4Risk
6-5See I
6-6Refer to Appendix G: RHA Evidence Hierarchy and definitions of "acceptable data" available in the literature (e.g., Poivey, 2002)
6-7High energy protons (~200 MeV) often used as the main test solution. Heavy ion testing performed for specific part types e.g., with thick sensitive regions

Table 7. SEE Taxonomy – System-level RHA criteria

RHA Category	S1	S2	S3	S4	S5
RHA integral to the design process	Yes	Yes	Yes	Selectively at project discretion	Not required
System-level LOE	SEE threats to reliability and availability drive the mission success criteria. Systems architecture, circuit design, parts selection, and SW/VHDL are carefully managed throughout project or program lifecycle to meet all SEE requirements.[7-1]	SEE threats to reliability and availability drive the mission success criteria. Systems architecture, circuit design, parts selection, and SW/VHDL are carefully managed throughout project or program lifecycle to meet all SEE requirements.[7-1]	SEE threats to availability do not directly drive mission success. The system's tolerance inherent to the design, rather than extensive part test data, is expected as a primary mitigation for nondestructive SEE. Destructive SEE is managed by a strategic combination of parts testing and system design to assure reliability.[7-1]	None to interface-limited[7-2]	None to interface-limited[7-2]
SEECA	Required for all systems[7-3]	Required for all systems[7-3]	Required for critical systems	Recommended to identify driving risk to reliability, availability, and performance. Required for do-no-harm if not guaranteed by system-level mitigation	Do-no-harm strategy completely relies on system-level mitigation

7-1Part selection for risk avoidance (e.g., SEE rad-hard vs. rad-tolerant) lowers the scope of system-level LOE vs. risk quantification and analysis-driven design mitigation implementation
7-2E.g., implementation of current monitoring and power cycling capability external to the CCA
7-3For equivalent risk posture, decreased assurance at piece-part level requires increased scope at systems level for RHA design and analysis.

RHA Taxonomy Example

Table 6. SEE Taxonomy – RHA Scope and Assurance

RHA Category	S1	S2	S3	S4	S5
Risk tolerance posture	Low	Low-Medium	Medium-High	High	Very High
Purpose of SEE RHA	Assures reliability (DSEE) and availability (NDSEE) consistent with the program risk tolerance posture	Assures reliability (DSEE) and availability (NDSEE) consistent with the program risk tolerance posture	Provides targeted assurance of reliability (DSEE) and availability (high impact NDSEE)[6-1]	Provides some assurance of reliability (DSEE) and availability (NDSEE).	N/A
Survivability assurance result	Verified risk avoidance or quantification	Verified risk avoidance or quantification	Limited risk analysis[6-2]	Limited risk analysis[6-2]	None
A priori confidence reliability will be met[6-3]	High[6-4]	Limited[6-4]	Limited[6-4]	None	None
Availability assurance product	Probability quantification of all unmitigated SEE impacting mission success criteria	Probability quantification of all unmitigated SEE impacting mission success criteria	Limited risk analysis[6-5]	Limited risk analysis[6-5]	None
A priori confidence availability will be met[6-3]	High[6-4]	Limited[6-4]	Limited[6-4]	None	None
Anticipated scope of SEE testing[6-6]	Piece-part heavy ion characterization test data if not already available. Additional testing as needed for NDSEE characterization, low-LET-threshold parts proton susceptibility, CCA-level for complex system interactions (e.g., SW and HW) and NDSEE mitigation and correction validation, etc.	Combination of CCA- and piece-part-level, high-energy proton and heavy ion testing. Additional testing as needed for NDSEE characterization, low-LET-threshold parts proton susceptibility, CCA-level for complex system interactions (e.g., SW and HW) and NDSEE mitigation and correction validation, etc.	Combination of CCA- and piece-part-level, high-energy proton and heavy ion testing[6-7]	CCA-level high energy proton testing	None

[6-1]"Targeted" definition: focused on project priorities and within budget and schedule constraints
[6-2]Proton-data-derived heavy ion DSEE susceptibility quantification is unreliable
[6-3]This refers to the ability to guarantee at the inception of the RHA effort that the program required reliability and availability goals will ultimately be met.
[6-4]Risk avoidance provides guarantees. Risk quantification can be effective subject to successful implementation of RHA processes.
[6-5]See RHA Guidelines Document for CCA-level test limitations
[6-6]Refer to Appendix G: RHA Evidence Hierarchy and definitions of "acceptable data" available in the literature (e.g., Poivey, 2002)
[6-7]High energy protons (~200 MeV) often used as the main test solution. Heavy ion testing performed for specific part types e.g., with thick sensitive regions

Compliance Matrices

Table 14. RHA compliance matrix: SEE, Robotic Space Flight

8705.4A Risk Classification	S1	S2	S3	S4	S5
A	Compliant	Provisionally Compliant	Triggers Program Risk	Non-compliant	Non-compliant
B	Compliant	Provisionally Compliant	Triggers Program Risk	Non-compliant	Non-compliant
C	Compliant	Compliant	Provisionally Compliant	Non-compliant	Non-compliant
D	Compliant	Compliant	Compliant	Provisionally Compliant	Non-compliant
Less than D (e.g., 7120.8 or "do-no-harm")	No specific RHA standard is provided for projects operating outside of the 8705.4A risk classification system. Many such projects operate in environments where single-event effects will occur; projects are encouraged to consider mitigation of single-event effects strategically to increase the chance of mission success.				

Table 15. RHA compliance matrix: TID&TNID, Robotic Space Flight

8705.4A Risk Classification	D1	D2	D3	D4	D5
A	Compliant	Provisionally Compliant	Triggers Program Risk	Non-compliant	Non-compliant
B	Compliant	Provisionally Compliant	Triggers Program Risk	Non-compliant	Non-compliant
C	Compliant	Compliant	Provisionally Compliant	Provisionally Compliant	Non-compliant
D	Compliant	Compliant	Compliant	Provisionally Compliant	Non-compliant
Less than D (e.g., 7120.8 or "do-no-harm")	No specific RHA standard is provided for projects operating outside of the 8705.4A risk classification system. TID and TNID are not typically a driving risk for projects organized in this manner, but consultation with radiation effects SMEs is strongly encouraged.				

If shortcuts are taken at part level (vs. S1), program visibility is needed to ensure compensation at systems level

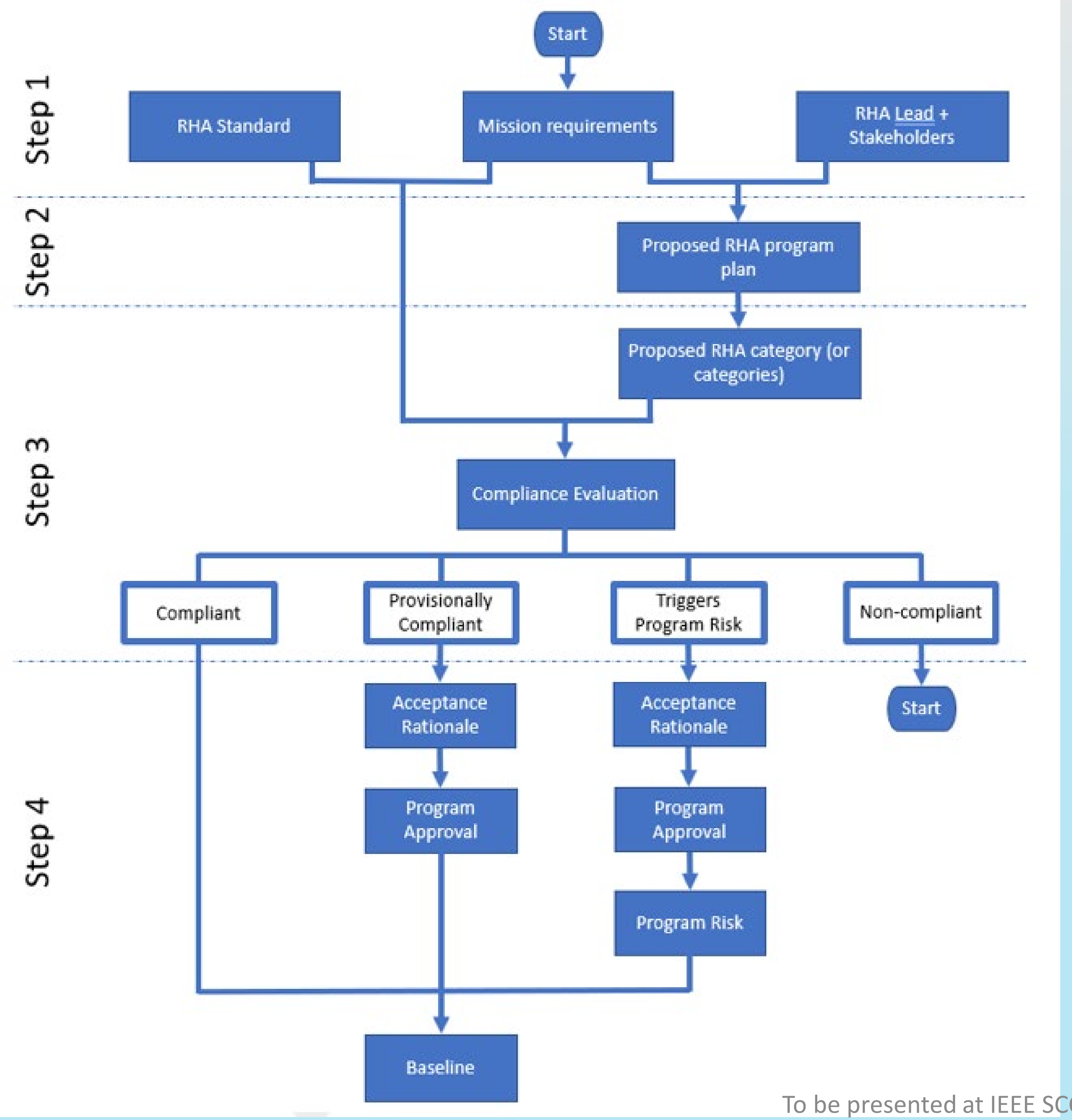
When it comes to loss of life, the project cannot take shortcuts at both part- and systems level

Table 12. RHA compliance matrix: SEE, Crewed Space Flight

Crewed Space Flight	S1	S2	S3	S4	S5
Crit1	Compliant	Triggers Program Risk	Non-compliant	Non-compliant	Non-compliant
Crit2	Compliant	Provisionally Compliant	Triggers Program Risk	Non-compliant	Non-compliant
Crit3/Non-critical	Compliant	Compliant	Provisionally Compliant	Provisionally Compliant	Non-compliant

Table 13. RHA compliance matrix: TID & TNID, Crewed Space Flight

Crewed Space Flight	D1	D2	D3	D4	D5
Crit1	Compliant	Provisionally Compliant	Triggers Program Risk	Non-compliant	Non-compliant
Crit2	Compliant	Provisionally Compliant	Triggers Program Risk	Non-compliant	Non-compliant
Crit3/Non-critical	Compliant	Compliant	Provisionally Compliant	Provisionally Compliant	Non-compliant



RHA Baseline Process

Step 1: Evaluate the mission

Step 2: Define the proposed RHA program plan

Step 3: Determine the programmatic activities required to baseline the proposed RHA approach

- Categorization per taxonomy
- Compliance evaluation

Step 4: Execute the required programmatic activities to baseline the proposed RHA approach at SRR

- This is where program visibility is pursued up to and including program risk

Conclusions

- In general, ILPM Established COTS Parts can be used with little to no additional test, given the part reliability and characteristics meet the Mission, Environment, Application, and Lifetime (MEAL)
    - Functional criticality may still warrant some level of additional test based on the mission risk posture and part-level verification obtained
- NASA currently lacks the infrastructure to implement ILPM and Established COTS Part acceptance methods into programs effectively
    - A PEAL workforce would provide the high level of strategic ILPM COTS parts implementation needed to enable the success of NASA missions
    - An update to NASA EEE parts assurance standards, in addition to training of the NASA parts engineering workforce and project management, is needed to successfully incorporate the NESC guidance into current practices
- A holistic approach with consideration for radiation hardness assurance, incorporating assembly and system-level mitigation strategies, should be adopted for effective COTS implementation
    - The NASA RHA Process Standard for Space Flight Hardware will provide programs with the RHA ecosystem needed to effectively utilize COTS in all NASA missions with the appropriate checks and balances at the part-level and system-level, based on the nature of the MEAL and tolerance for risk (final draft completed, release expected Fall 2024)

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