NEPP
NASA Electronic Parts and Packaging Program

An Alternate COTS Approach for Space Missions

Peter Majewicz

NEPP Program Manager
peter.majewicz@nasa.gov

NASA/GSFC

Susana Douglas

NEPP Deputy Program Manager
NASA Electronic Parts Manager
susana.p.douglas@nasa.gov

NASA/GSFC

To be presented by S. Douglas at CMSE 2024, 02-May

Acronyms

AEC	Automotive Electronics Council
COTS	Commercial-Off-The-Shelf
Cpk	Process Capability Index
DLA	Defense Logistics Agency
DoD	Department of Defense
DPPM	Defective Parts Per Million
EEE	Electrical, Electronic, Electromechanical
EOL	End-Of-Line
ETW	Electronics Technology Workshop
FAA	Federal Aviation Administration
FIT	Failure-In-Time
FMEA	Failure Mode and Effects Analysis
GSFC	Goddard Space Flight Center
IL	In-Line
ILPM	Industry Leading Parts Manufacturer
JEDEC	Joint Electron Device Engineering Council

MEAL	Mission Environment, Application, and Lifetime
MIL-SPEC	Military Specification
NASA	National Aeronautics and Space Administration
NEPP	NASA Electronic Parts & Packaging (Program)
NESC	NASA Engineering & Safety Center
NSC	NASA Safety Center
PEAL	Parts Evaluation and Assessment Laboratory
PPAP	Production Part Approval Process
PSW	Part Submission Warrant
QML	Qualified Manufacturers List
QPL	Qualified Product List
RHA	Radiation Hardness Assurance
SMA	Safety and Mission Assurance
SMD	Standard Microcircuit Drawing
SME	Subject Matter Expert
SPC	Statistical Process Control

NASA Engineering and Safety Center Recommendations on the Use of COTS EEE Parts for NASA Missions

To be presented by S. Douglas at CMSE 2024, 02-May

NASA/TM–20220018183
NESC-RP-19-01490

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

Robert F. Hodson/NESC, Yuan Chen, and John E. Pandolf
Langley Research Center, Hampton, Virginia

Kuok Ling
Ames Research Center, Moffett Field, California

Kristen T. Boomer
Glenn Research Center, Cleveland, Ohio

Christopher M. Green, Susana P. Douglas, Jesse A. Leitner, and Peter Majewicz
Goddard Space Flight Center, Beltsville, Maryland

Scott H. Gore
Jet Propulsion Laboratory, Pasadena, California

Carlton S. Faller
Johnson Space Center, Houston, Texas

Erik C. Denson
Kennedy Space Center, Kennedy Space Center, Florida

Ronald E. Hodge
Marshall Space Flight Center, Huntsville, Alabama

Angela P. Thoren
Jacobs Space Exploration Group, Huntsville, Alabama

Michael A. Defrancis
Science Applications International Corporation, Reston, Virginia

December 2022

NESC COTS Study

- 8 NASA centers participated in this study over a span of 3 years:
  - Phase I report captured current NASA practices → no consensus on part-level verification practices and perception of risk for COTS usage: https://ntrs.nasa.gov/citations/20205011579
  - Phase II goal was to understand manufacturer processes and provide recommendations for future agency guidance on COTS usage: https://ntrs.nasa.gov/citations/20220018183
- Key terminologies defined:
  - Industry Leading Parts Manufacturer (ILPM).
  - Established COTS Part
- Criteria established for an ILPM and an Established COTS Part
- NESC overall recommendation is to select Established COTS parts from 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***
  - The extent and nature of the needed evidence will differ by mission, most likely be driven by a mission's resources and associated risk posture
  - Radiation effects not accounted for in this recommendation

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.

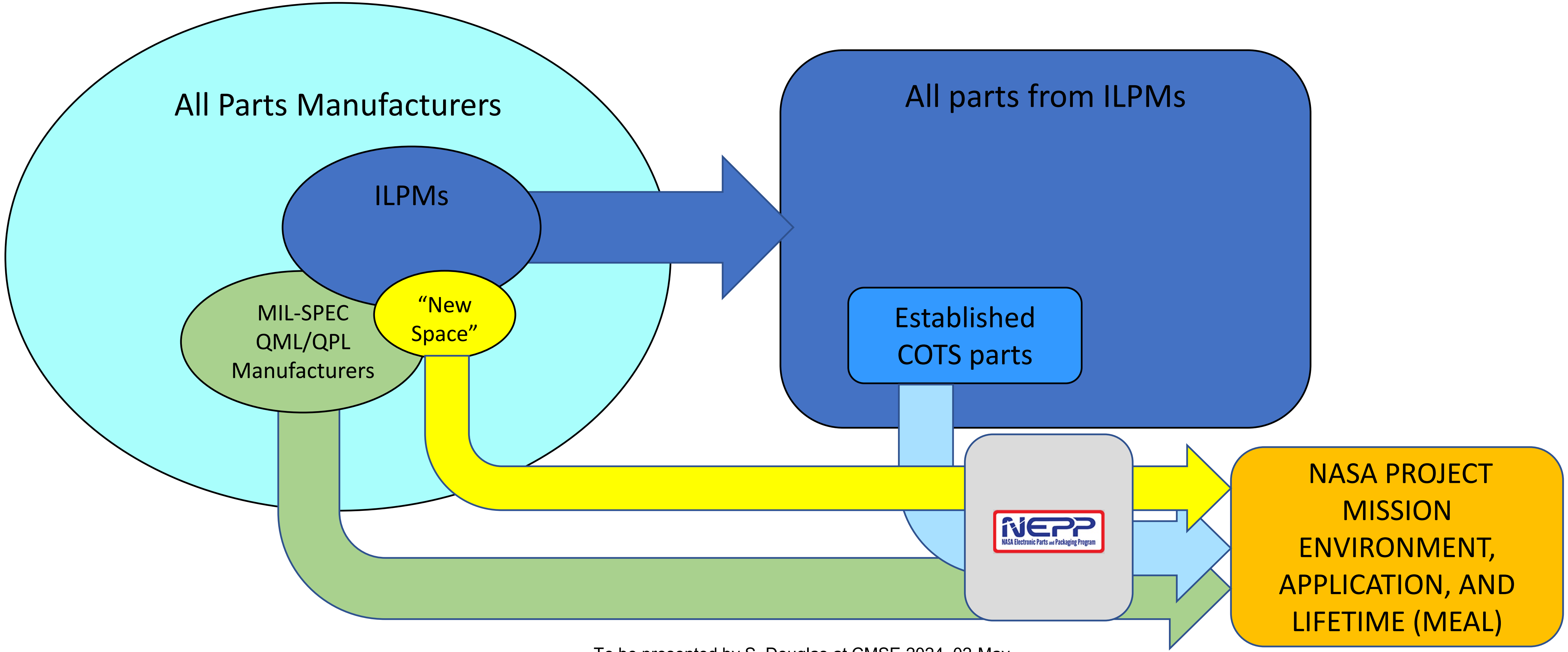
ILPM Criteria

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.

NASA COTS Implementation Approach: ILPM Pathfinder – Big Picture



Established COTS Parts 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. May or may not be 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. May or may not be designed for launch and deep space environment

Targeted ILPM / Parts Data Requests

- International Automotive Task Force (IATF) 16949:2016 certification
  - A quality management system (QMS) emphasizing defect prevention and reduction of variation and waste for continual improvement in the supply chain and assembly process
  - Supplement to ISO9001 for the automotive industry
- **Level 3** Production Part Approval Process (PPAP)
  - Automotive Industry Action Group (AIAG) developed data package, specified in the PPAP manual
  - Includes Part Submission Warrant (PSW) to validate AEC requirements have been met, with supporting data and elements specified in the AEC-Q100 Certificate of Design Construction and Qualification (CDCQ) Template
  - Design Failure Mode and Effects Analysis (DFMEA) → typically only shared onsite
  - Process FMEA (PFMEA)
  - Process control plan
  - Engineering change documents
  - Measurement system analyses

Targeted ILPM / Parts Data Requests (cont.)

- AEC-Q004 Zero-Defect strategy that demonstrates continuous improvement approaches
  - Reliability monitoring program, such as wafer level reliability, daily end of production parts testing, and including testing bias and thermal conditions, sample sizes, failure criteria, etc.
  - Processes and practices for eliminating statistical outlier parts before shipment that are within manufacturer's specification limits but outside the main population distribution
  - Control limit improvement process
- Fabrication processes stability in key processes over 12 months of production, such as process capability index (Cpk) statistics and/or statistical process control (SPC) trends
- Parts quality and reliability data, such as estimated production DPPM, field failure DPPM and/or part failure rates (FITs), ***and how those statistics are derived***
- Product yield *trends*

NESC COTS Study 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.*

- Provides guidance, not implementation details, on part- and board-level verification for NASA missions per risk class
- Proposed ILPM process is not the same as MIL-SPEC vendor qualification processes
- Does not address associated lifecycle costs of using COTS parts
- Does not distinguish between critical or non-critical systems in recommendations
- Does not address radiation concerns, references the NESC Avionics Radiation Hardness Assurance (RHA) Guidelines for guidance: https://ntrs.nasa.gov/citations/20180007514
  - The above RHA guidelines document in turn called out the need for **a NASA Radiation Hardness Assurance (RHA) standard** (now in peer review)

Radiation Considerations

- New NASA RHA Standard for Space Flight Hardware (coming soon!) defines criteria for five different RHA taxonomies based on mission risk tolerance posture, expected system-level mitigation for radiation effects, expected Mission Environment, Application, and Lifetime (MEAL), etc.
- Integrates the RHA activities into the program schedule / project lifecycle and clearly defines when project risks related to lack of adherence to recommended radiation strategies should be documented and handled at the project level

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·cm^2/mg)	Risk avoidance (commonly, 37 MeV·cm^2/mg)	Risk avoidance (commonly, 37 MeV·cm^2/mg)[8-5]	High energy protons for DSEE[8-6]	None
SEL/other DSEE acceptance criteria[8-6]	Risk avoidance (commonly, 75 MeV·cm^2/mg) or quantification	Risk avoidance (commonly, 37 MeV·cm^2/mg) or quantification	Risk avoidance (commonly, 37 MeV·cm^2/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	

[8-1]RHA 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.

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

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

[8-4]Based on structure layout of the device

[8-5]Test LET may be reduced to program-agreed level (e.g., to 20-30 MeV·cm^2/mg) due to practical considerations

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

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

ILPM Pathfinder Publishing Plan

NASA Electronic Parts and Packaging Program

NEPP NASA Electronic Parts and Packaging Program

NASA Electronic Parts and Packaging Program

Home | Parts | Packaging | Radiation | Publications | NASA Parts Engineering School | Training | Tin Whiskers | NPSL | ILPM

NASA Parts Engineering School

The NASA Electronic Parts and Packaging (NEPP) Program is encouraging the development of a NASA Parts Engineering School Program via collaboration with NASA Centers and university partners. *Learn more...*

Event Upcoming (Registration Closed): NASA EEE Parts Engineer 101 Training Event hosted by JPL - Online Only
December 5 - 6, 2023
View the final agenda

prev next

About the NEPP Program

The NEPP Program generates technical knowledge and recommendations about electrical, electronic, electromechanical (EEE) part performance, application, failure modes, test methods, reliability and supply chain quality within the context of NASA space flight missions and hardware. This information is made available to the NASA and high-reliability aerospace community through publications, web pages and links published on this website.

ILPM

- About
- "Criteria"
- ILPM & Established COTS List
- Commodity drop down
- Contacts

COMING SOON!

NEPP ILPM Pathfinder Lessons Learned

- Manufacturers with an existing space product line will have reservations with participating
  - NASA needs to clearly document the use cases for ILPM Established COTS Parts → parts assurance standard updates in work
  - Buy-in from overall space community allows for increased buying power and manufacturer cooperation
- A shift in mindset for parts assessments in space applications is required
  - Assessing manufacturer test methodologies for COTS, if different than standard MIL-SPEC approaches, is not straight-forward and will require commodity expertise to resolve
  - ILPM Established COTS Parts listing will not directly address how to implement parts usage on all class missions, as a MEAL-driven approach is emphasized
- Further guidance is still needed on how to implement parts usage on all class missions
  - Decision to use is fully project-driven and project parts and systems engineers (and approving management) may not have the know-how to provide recommendations outside of the traditional NASA-screened COTS approach
  - Requires subject matter expertise to support parts usage recommendations
- The ILPM process is best handled through a NASA onsite visit with necessary manufacturing and quality support from the supplier to expedite the assessment process, with prior submission of shareable data to NASA for review
  - Commodity subject matter expertise is needed in the ILPM process to ask the right questions
  - Current infrastructure within NASA is lacking to provide the needed level of support for effective implementation and to provide guidance on ILPM Established COTS Parts implementation for all missions

A Future NASA EEE Parts Capability: Parts Evaluation and Assessment Laboratory (PEAL)

Parts Selection

Develop/maintain manufacturer relationships

Solicit new sources of supply

Test & Evaluation

Develop appropriate value-added test plans

Document part limitations

Parts Acquisition

Track supply chain concerns

Maintain strategic supplies of critical parts

Parts Database

Build/maintain a preferred parts list

Feedback loop for post-launch performance

Methods for Selecting Parts

NASA Electronic Parts and Packaging Program

Quality/Performance Expectation

CURRENT METHOD

MIL-SPEC PARTS → MIL-SPECs / Test Methods / SMDs / Slash Sheets / DLA / In-line (IL) and End of Line Testing (EOL) →

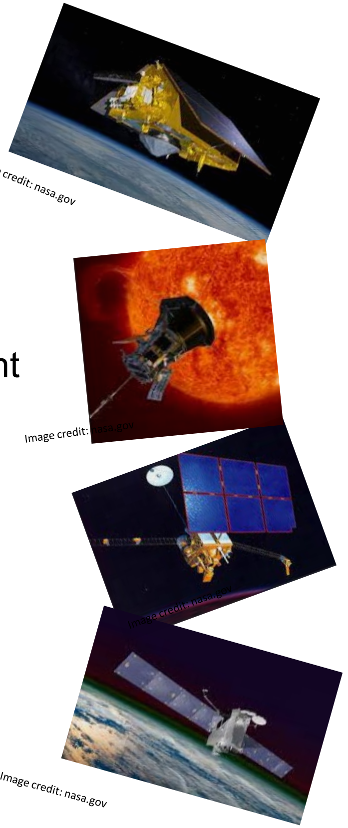
COMMERCIAL PARTS → Data Sheets / Online info → EOL Testing →

PEAL

COMMERCIAL PARTS → Manufacturer Information /Data Sheets (SME's, Parts Lab, ILPM) →

ADDED TESTING

Mission
Environment
Application
Lifetime



Methods for Selecting Parts

NEPP NASA Electronic Parts and Packaging Program

Quality/Performance Expectation

MIL-SPEC

MIL-SPEC PARTS → MIL-SPECs / Test Methods / SMDs / Slash Sheets / DLA / In-line (IL) and End of Line Testing (EOL) →

COMMERCIAL PARTS → Data Sheets / Online info → EOL Testing →

PEAL

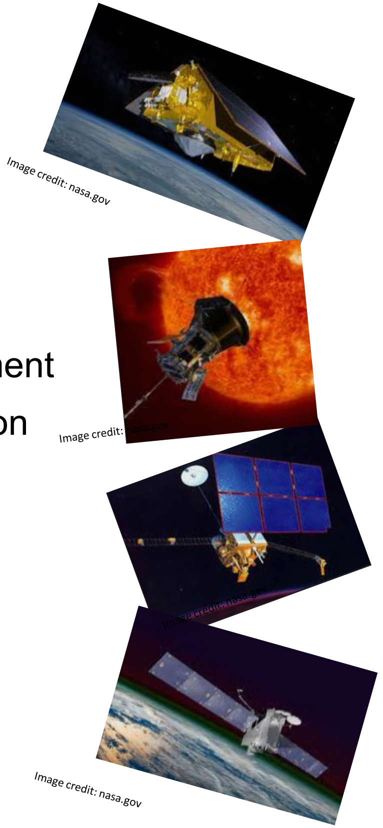
COMMERCIAL PARTS → Manufacturer Information /Data Sheets →

SME's | Parts Lab | ILPM

Feedback

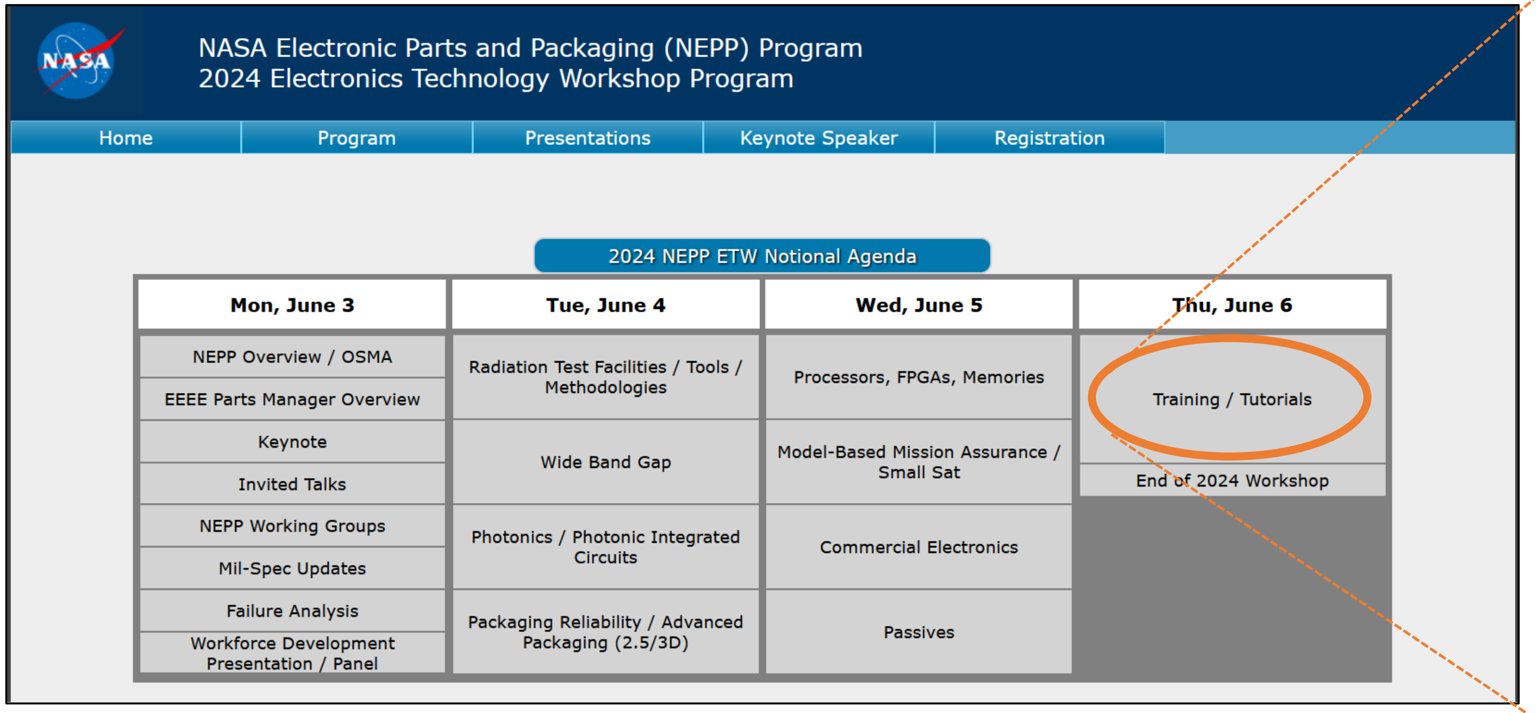
ADDED TESTING

Mission
Environment
Application
Lifetime



NASA Workforce Training

Educating the workforce on how to implement the ILPM COTS approach successfully is key!



2024 NEPP ETW tutorials in:

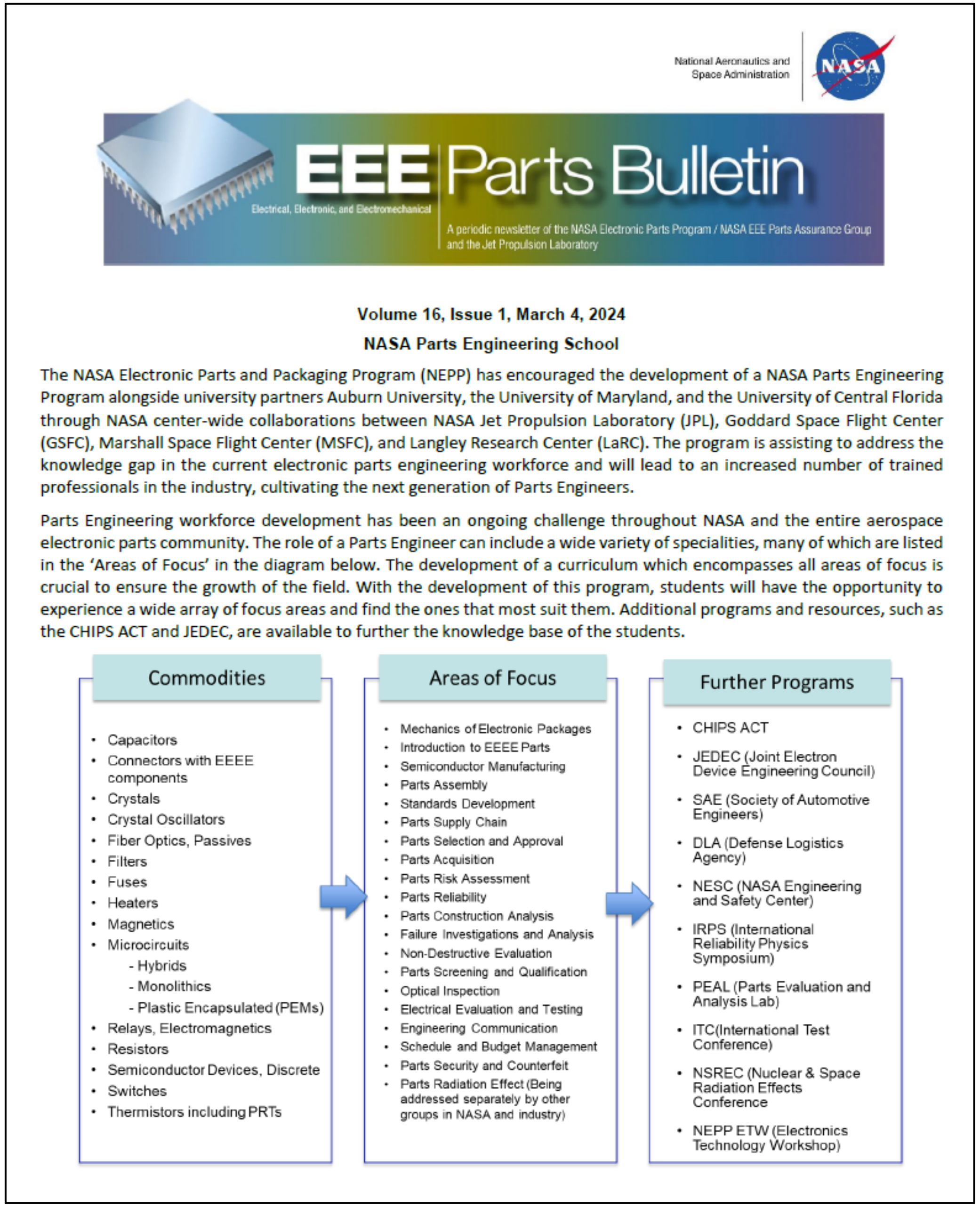
- High Volume Manufacturing Training
- High Volume Defect Prevention
- Designing with COTS

2023 NEPP ETW tutorials in:

- Statistical Interpretation of Life Test: Comparison Between MIL and JEDEC Requirements
- PPAP Tutorial
- Material available at: https://nepp.nasa.gov/workshops/etw2023/program.cfm

NASA / NEPP Parts Engineering School Program

- NASA Parts Bulletin distributed at the NEPP Electronics Technology Workshop (ETW) last year and recently updated. Also posted to the NSC SMA website: https://sma.nasa.gov
- Certificates and Master's Degree program offerings at partnering universities to supply the needed educational basis for the current and future parts engineering workforce
  - Includes coursework in **semiconductor manufacturing** and **parts reliability**
  - University of Central Florida **Electronic Parts Engineering Certificate** now offered!
  - Program website: https://www.jpl.nasa.gov/go/parts-engineering-school



National Aeronautics and Space Administration

EEE Parts Bulletin

Electrical, Electronic, and Electromechanical

A periodic newsletter of the NASA Electronic Parts Program / NASA EEE Parts Assurance Group and the Jet Propulsion Laboratory

Volume 16, Issue 1, March 4, 2024

NASA Parts Engineering School

The NASA Electronic Parts and Packaging Program (NEPP) has encouraged the development of a NASA Parts Engineering Program alongside university partners Auburn University, the University of Maryland, and the University of Central Florida through NASA center-wide collaborations between NASA Jet Propulsion Laboratory (JPL), Goddard Space Flight Center (GSFC), Marshall Space Flight Center (MSFC), and Langley Research Center (LaRC). The program is assisting to address the knowledge gap in the current electronic parts engineering workforce and will lead to an increased number of trained professionals in the industry, cultivating the next generation of Parts Engineers.

Parts Engineering workforce development has been an ongoing challenge throughout NASA and the entire aerospace electronic parts community. The role of a Parts Engineer can include a wide variety of specialities, many of which are listed in the 'Areas of Focus' in the diagram below. The development of a curriculum which encompasses all areas of focus is crucial to ensure the growth of the field. With the development of this program, students will have the opportunity to experience a wide array of focus areas and find the ones that most suit them. Additional programs and resources, such as the CHIPS ACT and JEDEC, are available to further the knowledge base of the students.

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 End