National Aeronautics and Space Administration

# Reviving U. S. Military Standards to Infuse New Technology and to Meet the Needs of New Missions

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**Shri G. Agarwal**
NASA – Jet Propulsion Laboratory,
California Institute of Technology
Shri.g.agarwal@jpl.nasa.gov
818-354-5598

**Nazia Ovee**
NASA – Jet Propulsion Laboratory,
California Institute of Technology
Nazia.ovee@jpl.nasa.gov
818-354-1009


This artist's concept depicts astronauts and human habitats on Mars. NASA's Mars 2020 rover will carry a number of technologies that could make Mars safer and easier to explore for humans. JPL is building and will manage operations of the Mars 2020 rover for the NASA Science Mission Directorate at the agency's headquarters in Washington.

Image Credit: NASA


Presented at ACCEDE, Seville, Spain, 6-8Nov2019
(Assessment of Commercial Components Enabling Disruptive space Electronics)

- Thank you ESA and the ACCEDE organizing team for your invitation. It's always a great pleasure to visit with you folks and exchange ideas.
- ESA is our valued partner in NASA Electronic Parts Assurance Group (NEPAG), which is approaching its 20th anniversary.
- NEPAG is about all facets of standardization. It requires extensive communication. See next page.

# Partnering

**JEDEC JC-13 (Manufacturers)**

| | |
|---|---|
| JC-13 | Solid State Devices for Government Products |
| JC-13.1 | Discrete Semiconductors for Government Products |
| JC-13.2 | Microelectronics for Government Products |
| JC-13.4 | Radiation Hardness |
| JC-13.5 | Hybrids and Multi-chip Modules for Government Products |
| JC-13.7 | New Electronic Device Insertion for Government Products |

Joint meetings held
3 times a year

**SAE CE-11/CE-12 (Industry Users, Primes, Subs)**

| | |
|---|---|
| SAE SSTC CE-11 | Users of Passive Components |
| SAE SSTC CE-12 | Users of Solid State Devices<br>**CE-12 Management:**<br>**Chair – A. Touw**<br>**Vice Chair – (JPL) S. Agarwal** |
| SAE SSTC CE-11 & CE-12 | Space Subcommittee Chair – S. Agarwal |


**NASA Centers:**

| | |
|---|---|
| ARC | JSC |
| GRC | KSC |
| GSFC | LaRC |
| JPL | MSFC |

Weekly NEPAG and Biweekly GWG Telecons (Domestic)

Monthly Telecons (International)

**Partners from Outside NASA:**

Domestic
- JHU/APL, Others
- The Aerospace Corp,
- U.S. Air Force, U.S. Navy,
- U.S. Army, DLA,

International
- ESA, JAXA, CSA

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# Introduction

- This is the 50th anniversary of Man's landing on the moon. A lot has happened during this period. Many notable successes kept us going. The failures gave an opportunity to make process improvements.
- Thru this all, the mission assurance organizations at NASA have supported many space missions/programs, large and small. Today, that spectrum has gotten wider, ranging from smallsats/cubesats to flagship missions such as the planned Europa mission. As always, the success of each and every mission counts.
- This presentation is about infusion of new technology into U. S. military standards, and the work underway to meet the needs of new missions.
- We'll end with a couple of short videos.


From October 2018 through December 2022, NASA will mark the 50th anniversary of the Apollo Program that landed a dozen Americans on the moon between July 1969 and December 1972.

*Image Credit: NASA*

# Class Y, A New Beginning for New Technology Infusion

- ClassY was discussed in detail at this year's ESCCON.
  - It represents advancements in packaging technology, increasing functional density, and increasing operating frequency. These are ceramic based single-die system-on-a-chip (SoCs) with non-hermetic flip-chip construction, in high-pin-count ceramic column grid array (CGA) packages. These products use tiny base electrode metal (BME) capacitors for signal integrity, and vented packages for thermal management. (e.g., Xilinx Virtex-4 FPGAs)
  - To address the manufacturability, test, quality, and reliability issues unique to new non-traditional assembly/package technologies intended for space applications
    - ❖ Introduced a new concept called Package Integrity Demonstration Test Plan (PIDTP) – provided flexibility to manufacturers.
  - This initiative resulted in a major overhaul of MIL-PRF-38535, particularly with respect to requirements for flip-chip, underfill, CSAM, column grid arrays, etc. Revision K reflecting these changes was released in December 2013.
- Started JC-13.7 to address infusion of new technology

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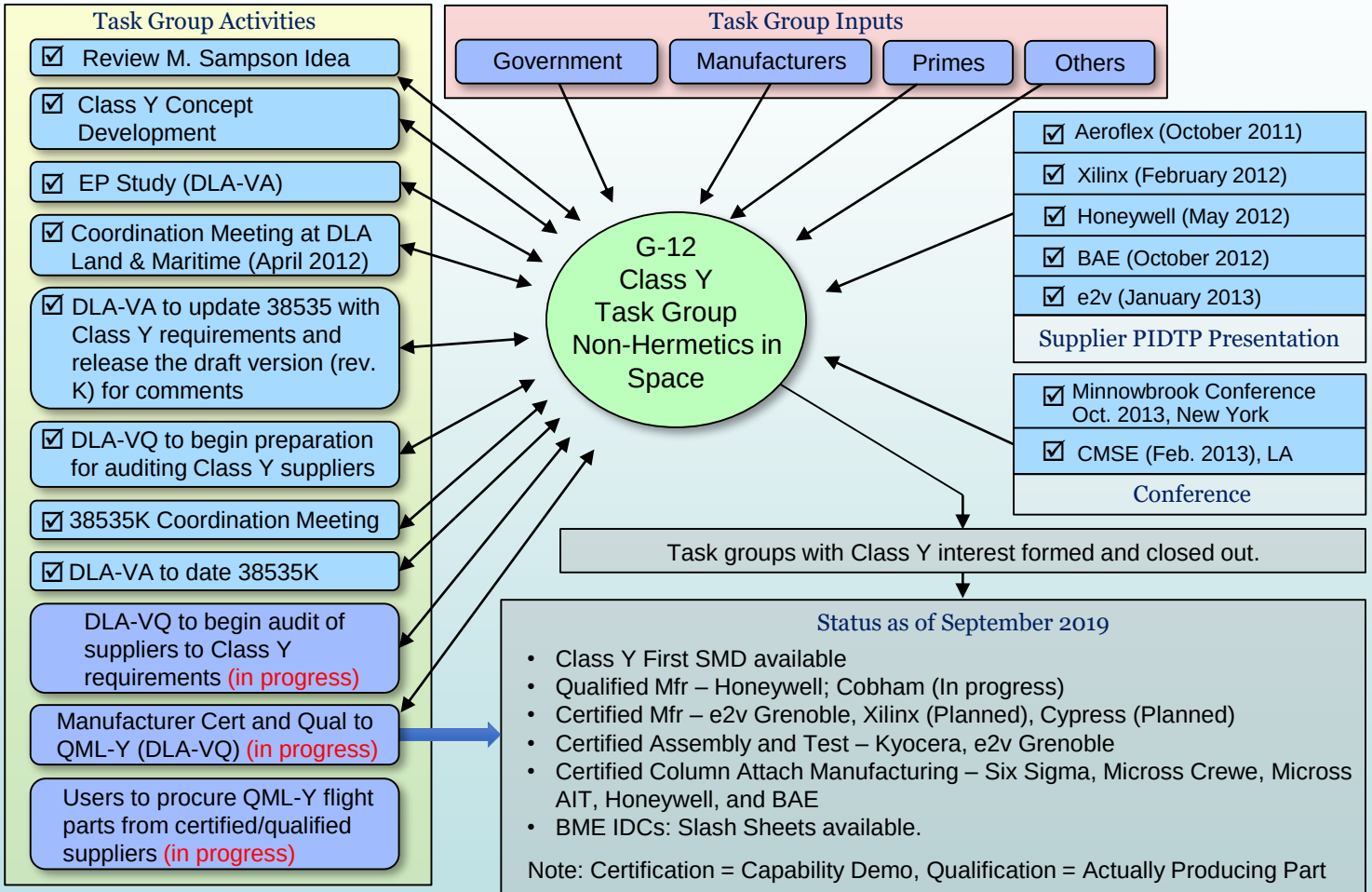
# Infusion of the New Class (Y) Technology into the QML System for Space (Status given at JEDEC in Sept. 2019)




BGA / CGA = Ball-Grid Array / Column-Grid Array
BME = Base Metal Electrode
IDC = Inter Digitized Capacitor

PIDTP = Package Integrity Demonstration Test Plan
SMD = Standard Microcircuit Drawing

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# A Changing Landscape (Shipping/Handling/ESD Challenge)

**A New Trend – Supply Chain Management**
**Ensuring gap-free alignment for each qualified product**
**(All entities in the supply chain must be certified/approved)**

| | |
|---|---|
| Manufacturer A | Die design |
| Manufacturer B | Fabrication |
| Manufacturer C | Wafer bumping |
| Manufacturer D | Package design and package manufacturing |
| Manufacturer E | Assembly |
| Manufacturer F | Column attach and solderability |
| Manufacturer G | Screening, electrical and package tests |
| Manufacturer H | Radiation testing |

**More Stops — More Places with ESD Risk**

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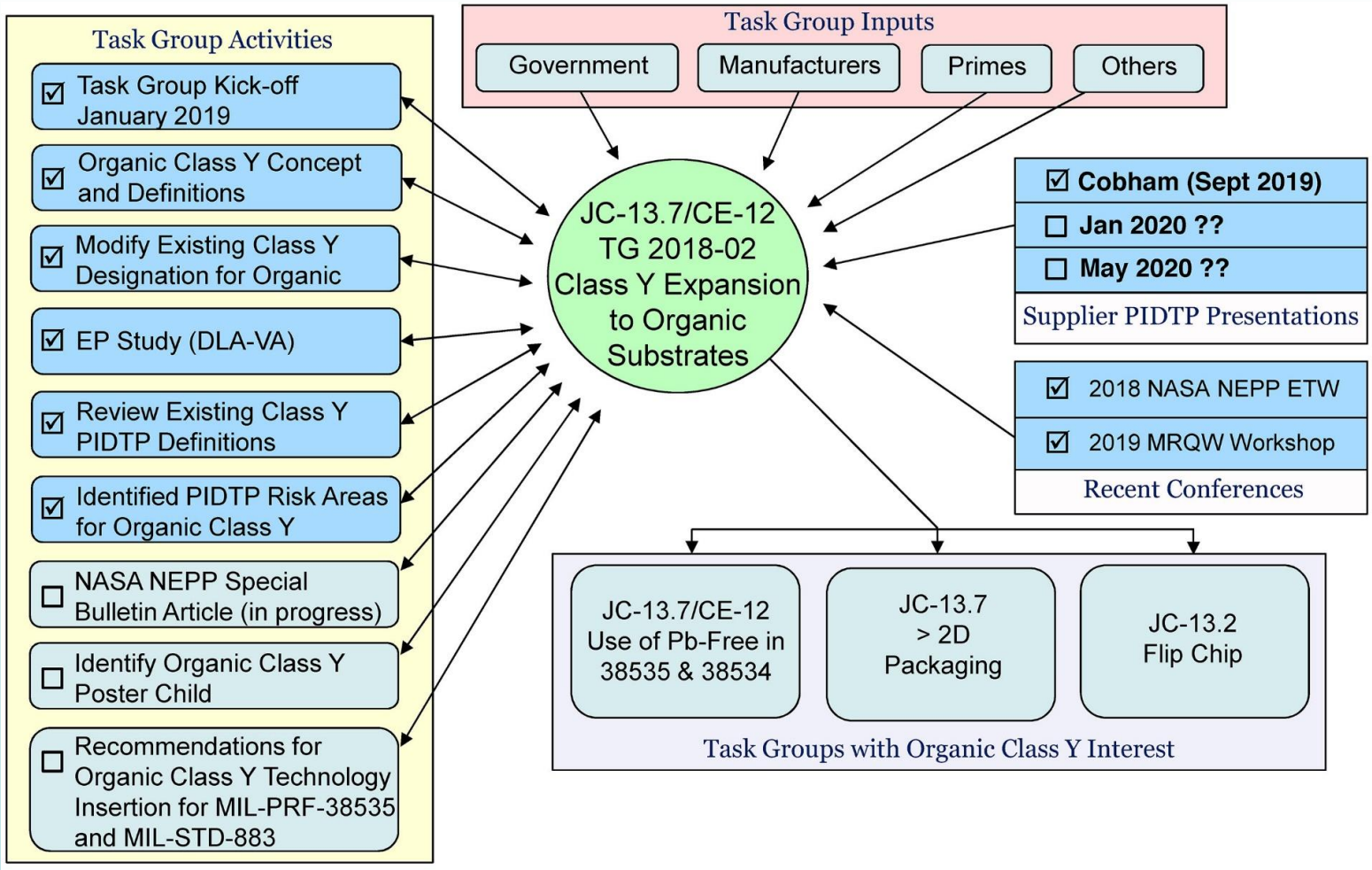
# ClassY Moving Forward

- A Follow-on to Ceramic Substrate Class Y
  - Interest in organic Class Y, and molded plastic parts is growing.
  - The JC-13.7 created a new task group on organic substrate Class Y (September 2018).
  - Related task groups started as well (next slide)
- Defense Logistics Agency (DLA) conducted an EP (Engineering Practice) study

A test version of Orion on July 2

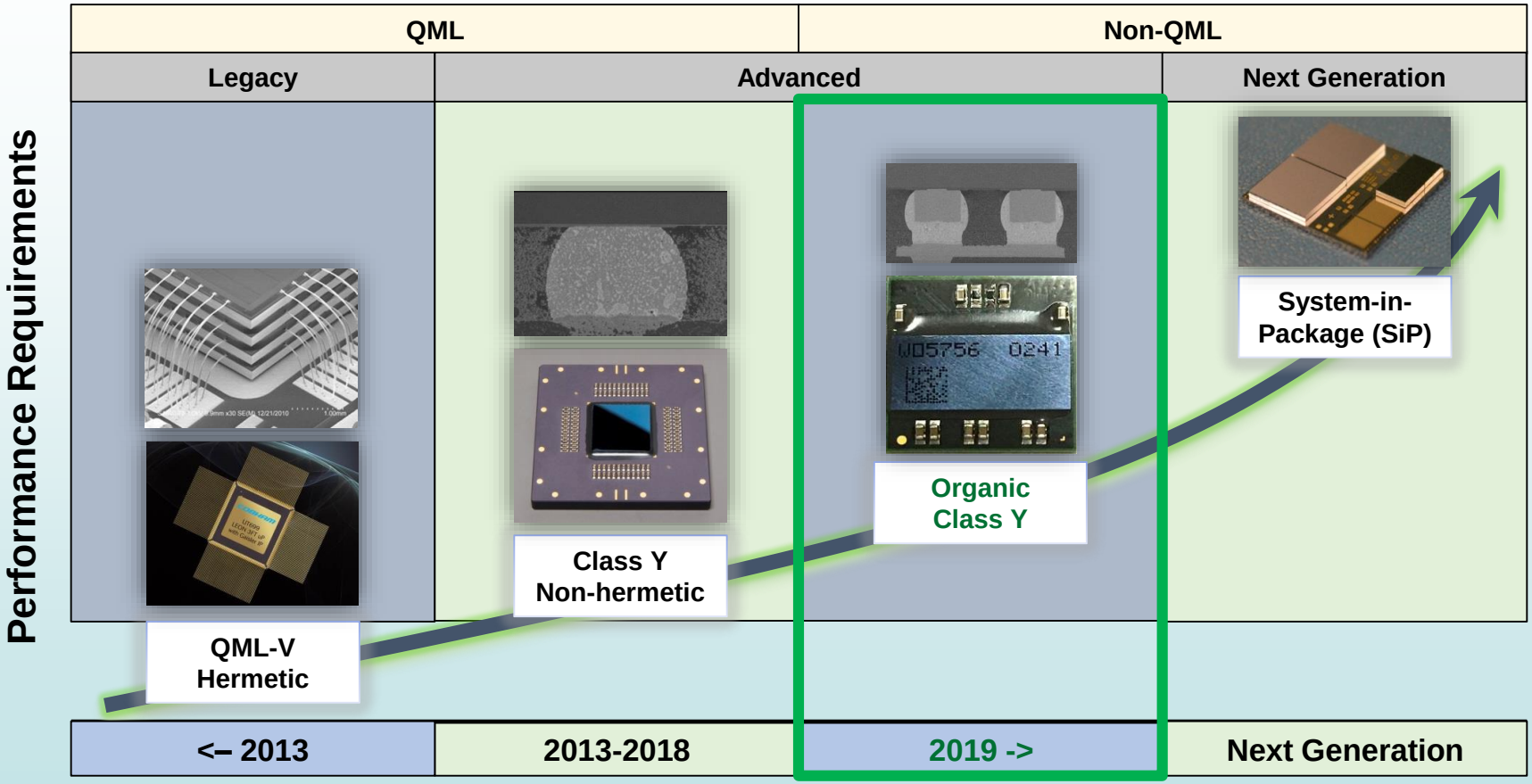
# JC-13.7/CE-12 Task Group 2018 – 02
## Organic Class Y Status Slide (updated September 2019)




Slide courtesy COBHAM

# Next Generation Package Technology for Space

## Development Roadmap for Space Applications




**Package Technology Availability**

Credit: Scott Popelar, Cobham, 2019 MRQW, February 7, 2019

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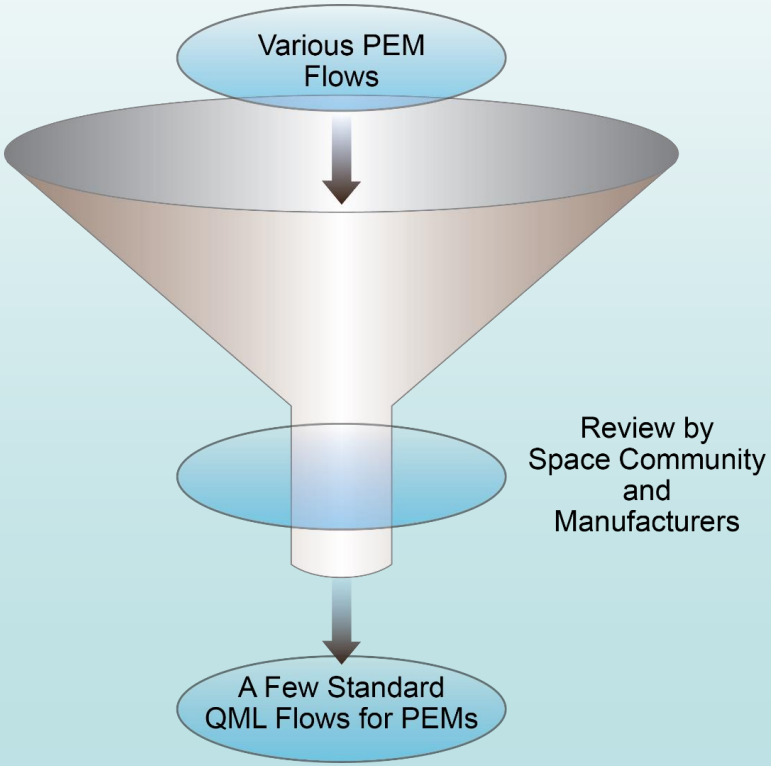
# Cubesats for Deep Space Exploration

- Growing Use of NASA Cubesats
  - Many new NASA missions are Cubesats and Smallsats. Major suppliers, such as Texas Instruments, Analog Devices, Cobham, and Renesas, offer a range of up to seven solutions depending on quality, reliability, radiation, and cost. (This is not to say that the demand for standard QML products are going away – the manufacturers have reported robust sales of standard microcircuits.)

- Newer Applications
  - CubeSats
  - SmallSats

Standardizing on a few well-defined flows rather than multiple flows defined by each manufacturer or by each standards group (including Automotive and VID parts).
SAE AS6294, developed by CE-12, would be a good starting point.

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# JC-13.7/CE-12
## DLA Engineering Practice (EP) Study

**EP study on**
**Update of non-hermetic microcircuits class N (military, terrestrial and avionics application and class Y (Space application) to MIL-PRF-38535.**

I. OBJECTIVE: The purpose of this Engineering Practice (EP) Study is to obtain input and justification from the military services, microcircuit manufacturers, and space application user's communities, concerning the update/addition of non-hermetic class N (military, terrestrial and avionics application) and class Y (non-hermetic Space application) microcircuits to MIL-PRF-38535.

II. BACKGROUND: MIL-PRF-38535 offered non-hermetic class N (plastic package) and class Y (ceramic substrate non-hermetic device for space application). In table IB, class N has an inclusive table that comprises screening and QCI tests requirement, which called tests/monitors for plastic package. However, this inclusive table fails to distinguish between screening and QCI test flows that creates confusion with periodic QCI test monitoring issue as well as product reliability.

On the other hand, design requirement of modern electronics satellite/warfare systems are growing faster and moving forward with an advance and complex package technologies. Considering complexity of new technologies and device packaging techniques, JEDEC CE-12 formed a task groups (TG) for exploring the state of the art class Y concept to develop a new organic substrate flip chip devices, and 2D, 2.5D and 3D package technology requirements for qualification and screening of non-hermetic microcircuits packages for space applications.

Accordingly, to bring advancement and adopting new package technologies into QML system to MIL-PRF-38535, DLA Land and Maritime-VAC is conducting an EP study (phase 1) which includes:

(1) Update class N with separating screening and QCI tables to make robust high reliability plastic encapsulated microcircuits(PEM) devices for military, terrestrial and avionics application;

(2) Update/create a new appendix K (Next Gen) with other appendix/sections update for non-hermetic microcircuits devices that includes organic/ceramic substrate flip chip devices, 2D, 2.5D and 3D package technology requirements for space applications.

DLA Land and Maritime-VAC is requesting to review all attachment and send comments and feedback to DLA within the stipulated time for discussion and further development. Survey questionnaire (**see attachment # 1**) to evaluate the industries overall opinion for adding/updating class N and class Y devices package construction technical issues. Proposed non-hermetic class N and class Y devices screening and QCI requirements (**see attachment # 2**). Proposed update Appendix H (new technology qualification including PIDTP update (**see attachment # 3**). Proposed addition of Appendix K (Next Gen) for non-hermetic class Y devices including organic/ceramic substrate flip chip device, 2D, 2.5D and 3D package technology requirements for space applications (**see attachment # 4**).

# Conclusion

- New technology infusion is an on-going challenge.
- NASA supports a wide spectrum of space missions/programs ranging from smallsats/cubesats to flagship missions such as Juno and the planned Europa mission. The success of each mission is important.
- NASA is working with the space community to help infuse new technologies during the coming decade. ESD aspects should not be ignored. We encourage the world wide space community to get/stay involved in developing/updating standards.
- ACCEDE is a useful resource in these endeavors.

Thank you!

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# Short Videos on MarCO and Mars Helicopter

Here are the URLs for the videos

- Cubesats support to Insight Lander
  - Mars Cube One, or MarCO was a Cubesat mission comprising two functionally identical six-unit Cubesats accompanying the Insight Mars Lander.
  - Excerpts from November 27, 2018 email from the Office of JPL Director:
    - We knew almost immediately that Insight had landed safely thanks to MarCO A and B.
    - By successfully relaying data from another planet, this technology experiment has opened new possibilities for space exploration.

- MarCO – First Interplanetary Cubesat Mission Video URL

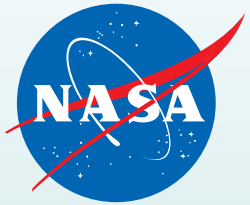
  https://www.jpl.nasa.gov/video/details.php?id=1381

- The Mars Helicopter for Mars 2020
  - Weighing at less than 4 lbs, the Mars Helicopter will be part of the Mars 2020 Rover mission. Many challenges include withstanding temperatures dipping down to -130F (-90C).

- NASA Chopper Ready for a Spin on Mars Video URL

  https://www.jpl.nasa.gov/video/details.php?id=1579

# http://nepp.nasa.gov




**ACKNOWLEDGMENTS**
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Government sponsorship acknowledged.

# BACKUP MATERIAL

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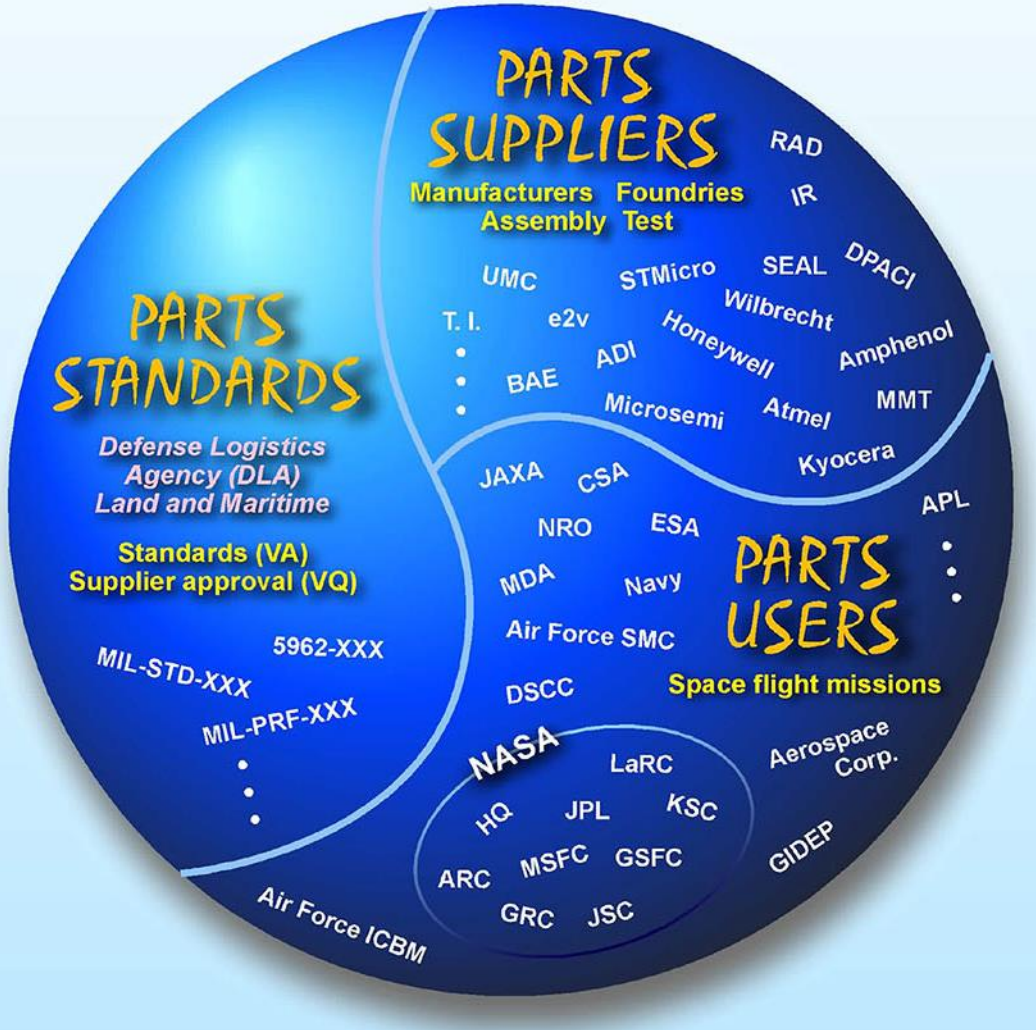
# Space Parts World

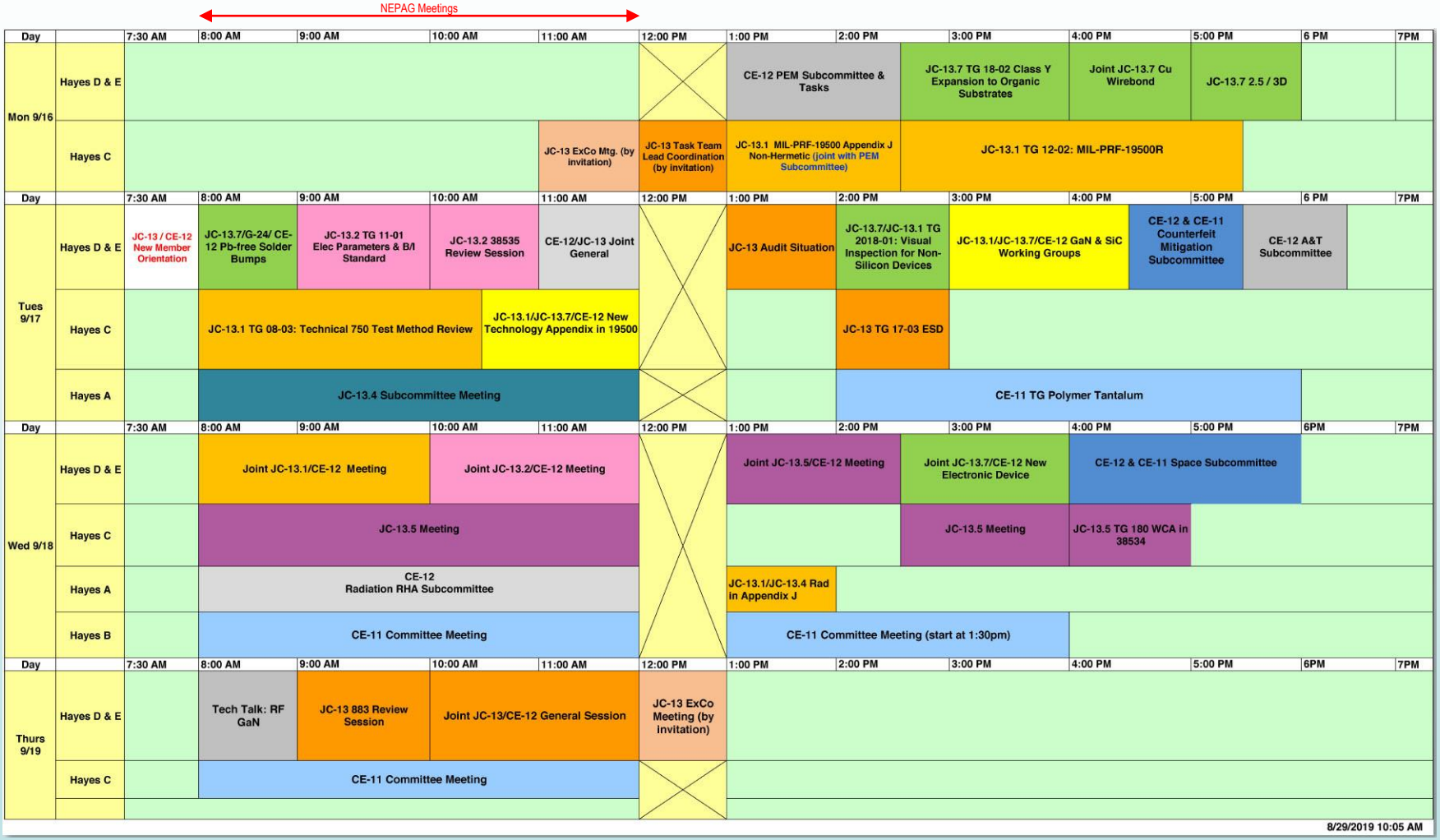
## NEPAG helps to Develop/Maintain Standards for Electronic Parts




The parts users and standards organizations work with suppliers to ensure availability of standard parts for NASA, DoD, and others. **For Space microcircuits, DLA, NASA/JPL (S. Agarwal*) and the U.S. Air Force / Aerospace Corp. (L. Harzstark) form the Qualifying Activity (QA).**

*Also Systems, Standards and Technology Council (SSTC) CE-12 Vice-Chair.

# Typical Meeting Schedule for JEDEC JC-13/CE-11/CE-12
## (September 2019)

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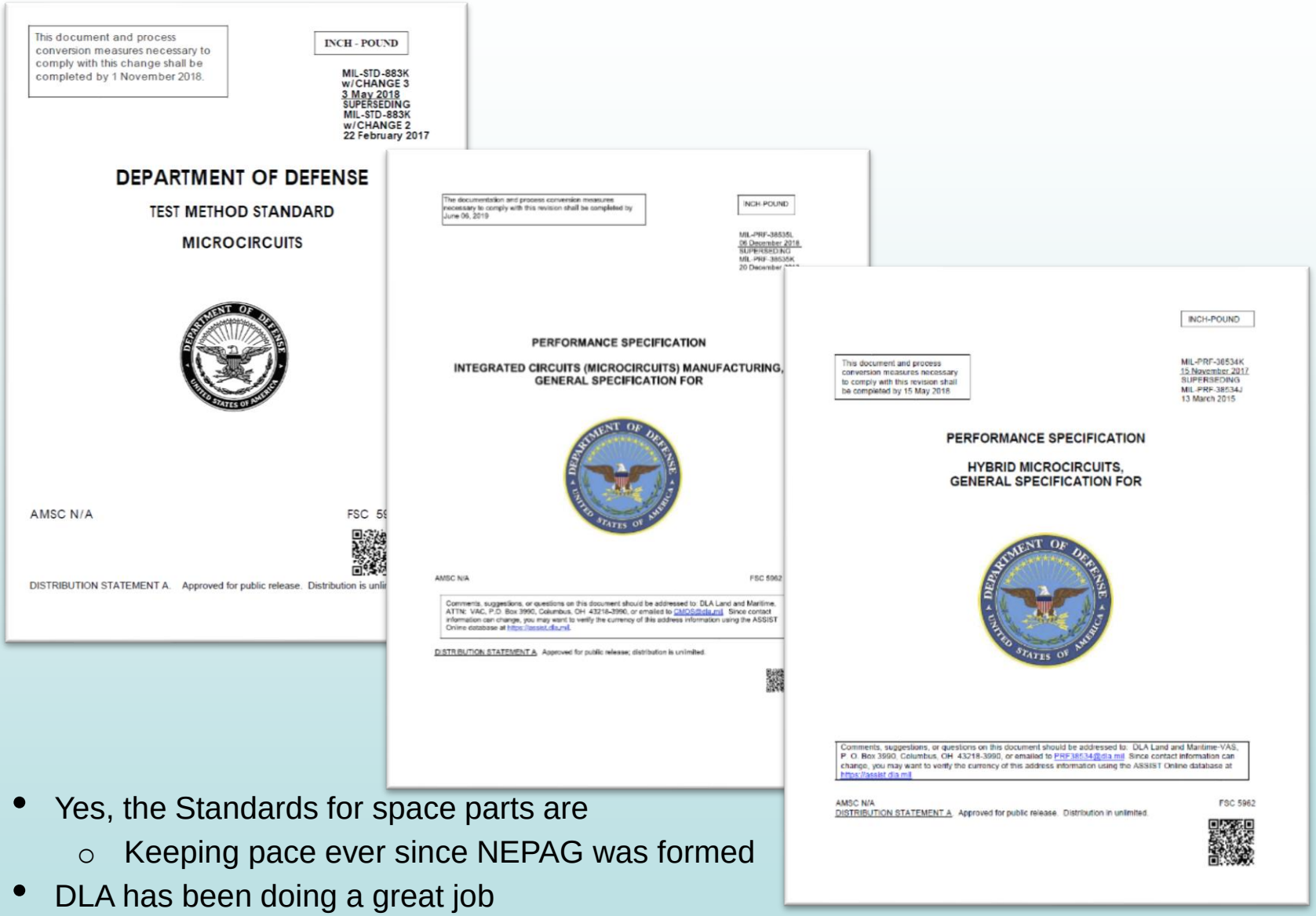
# Are Standards for Space Parts Keeping Pace with Times?




- Yes, the Standards for space parts are
  - Keeping pace ever since NEPAG was formed
- DLA has been doing a great job

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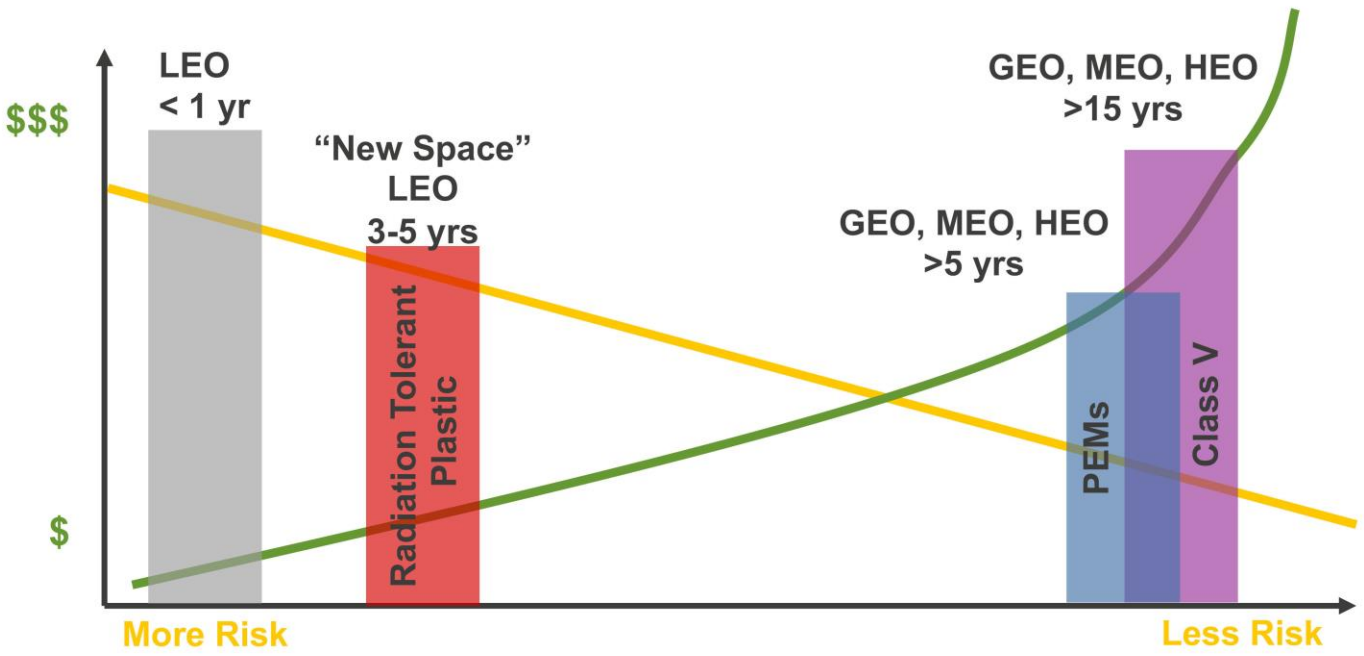
# Renesas (Formerly Intersil)





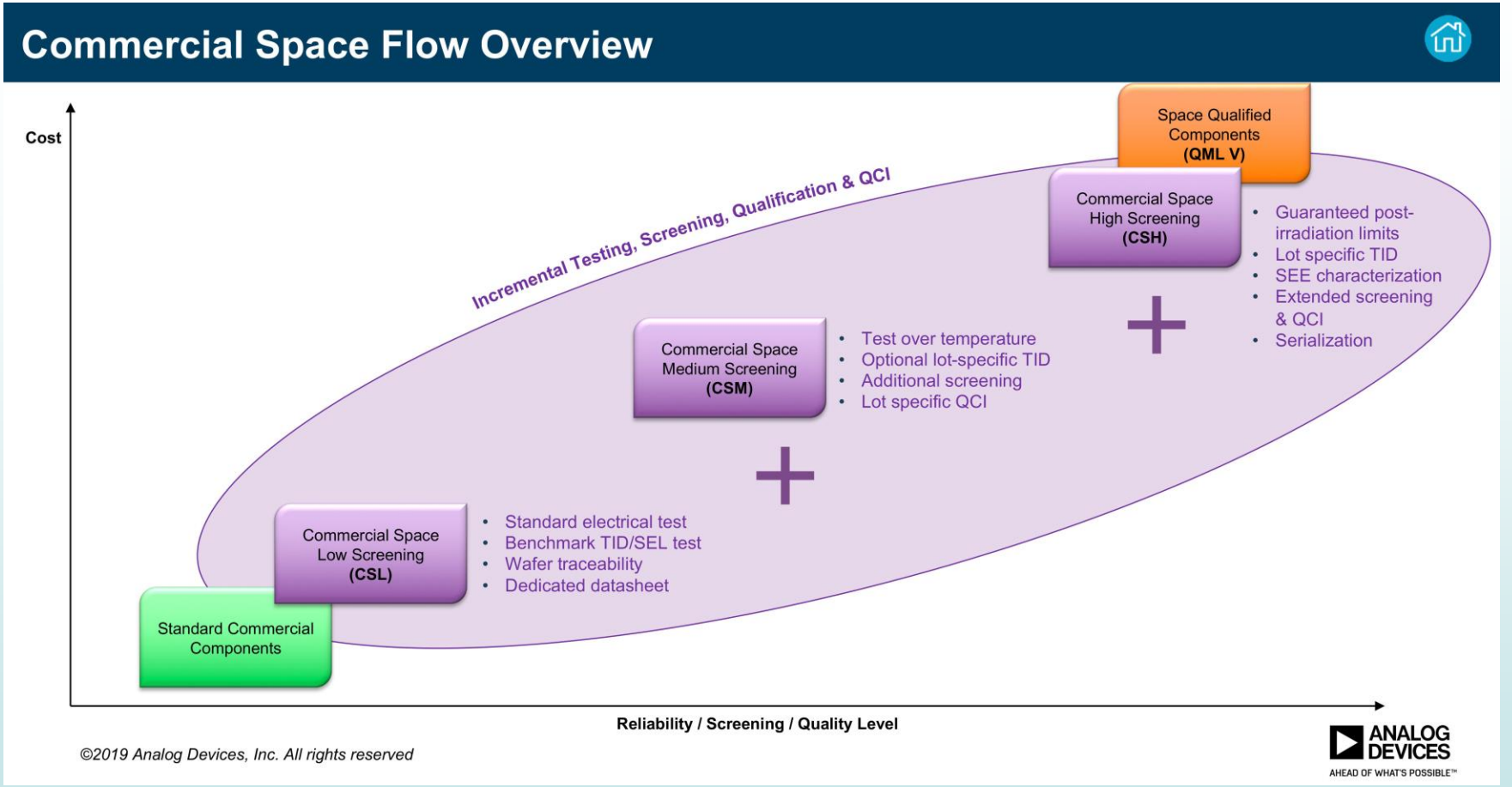

BIG IDEAS FOR EVERY SPACE

RENESAS



- Newer products use a mix of Rad Hard and commercially developed products. Renesas calls this the Radiation Tolerant (RT) Plastic flow.
- This flow is based on SAE International Aerospace Standard AS6294/1.
- Contact manufacturer for current version of this chart.

# Analog Devices, Inc. (ADI)




Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.

- ADI is offering three grades of commercial space products as shown above: CSL, CSM and CSH.
- Prior to their acquisition by ADI, Linear Tech (LTC) had developed the RT (Radiation Tolerant) family of products. CSH replaces the RT family. (Linear Tech delivered PEM LTC1604 24-bit A/D converter screened to a flow developed with NASA)
- Contact manufacturer for the current version of this chart.

# Cobham Colorado Springs

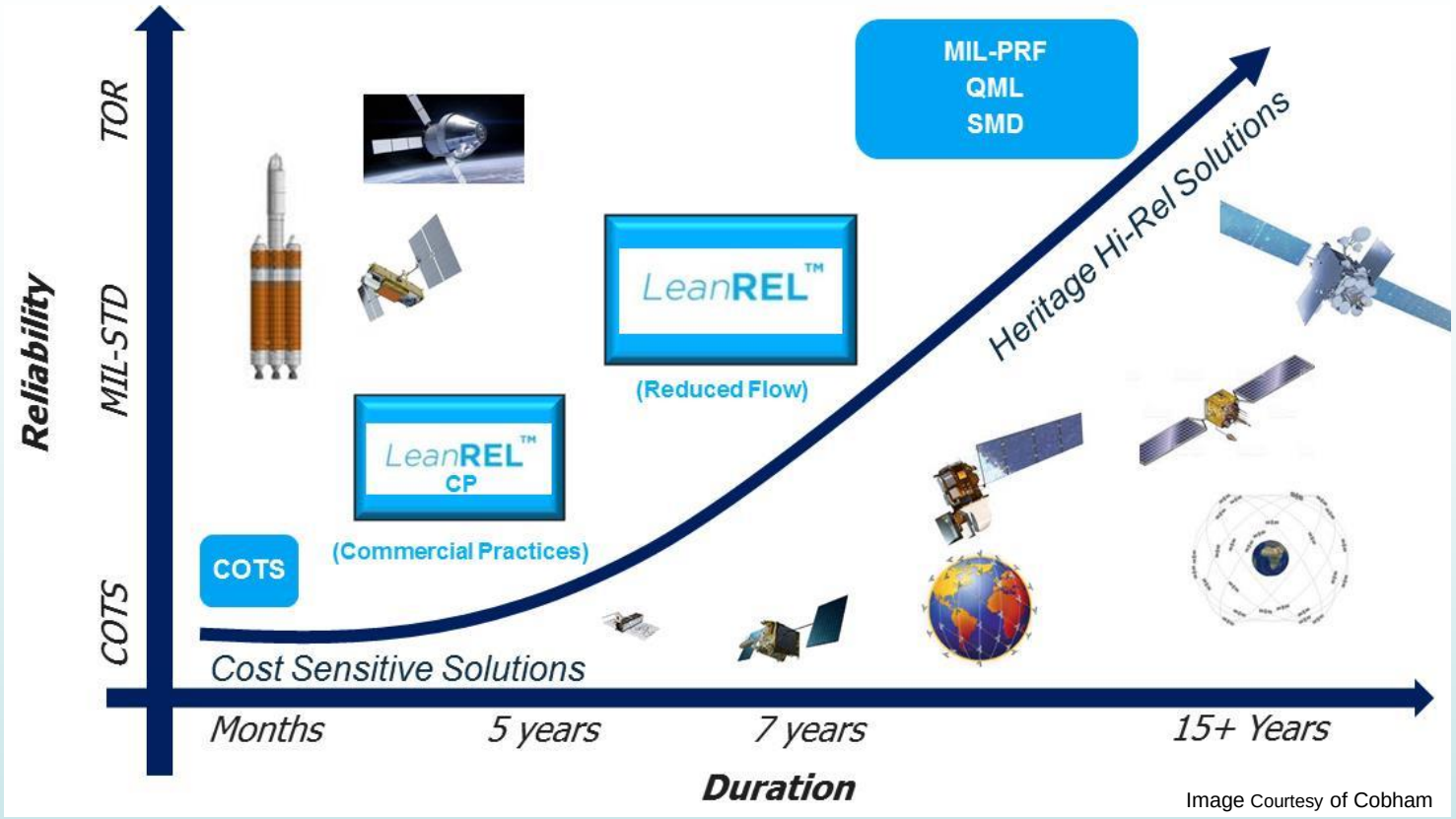



Image Courtesy of Cobham

- Cobham is working to define product technologies and associated screening flows optimized and suitable for constellation space applications.
- Their LeanREL approach is aimed at meeting the mission assurance requirements for radiation performance, reliability, traceability, and cost.
- For PEMs the advantages of small footprint and mass, high performance and low cost, must be weighed against the challenges in defining acceptable flows for space.
- Contact Manufacturer for the current version of this chart.

# Texas Instruments (TI)

## Space EP Baseline Controlled Flow

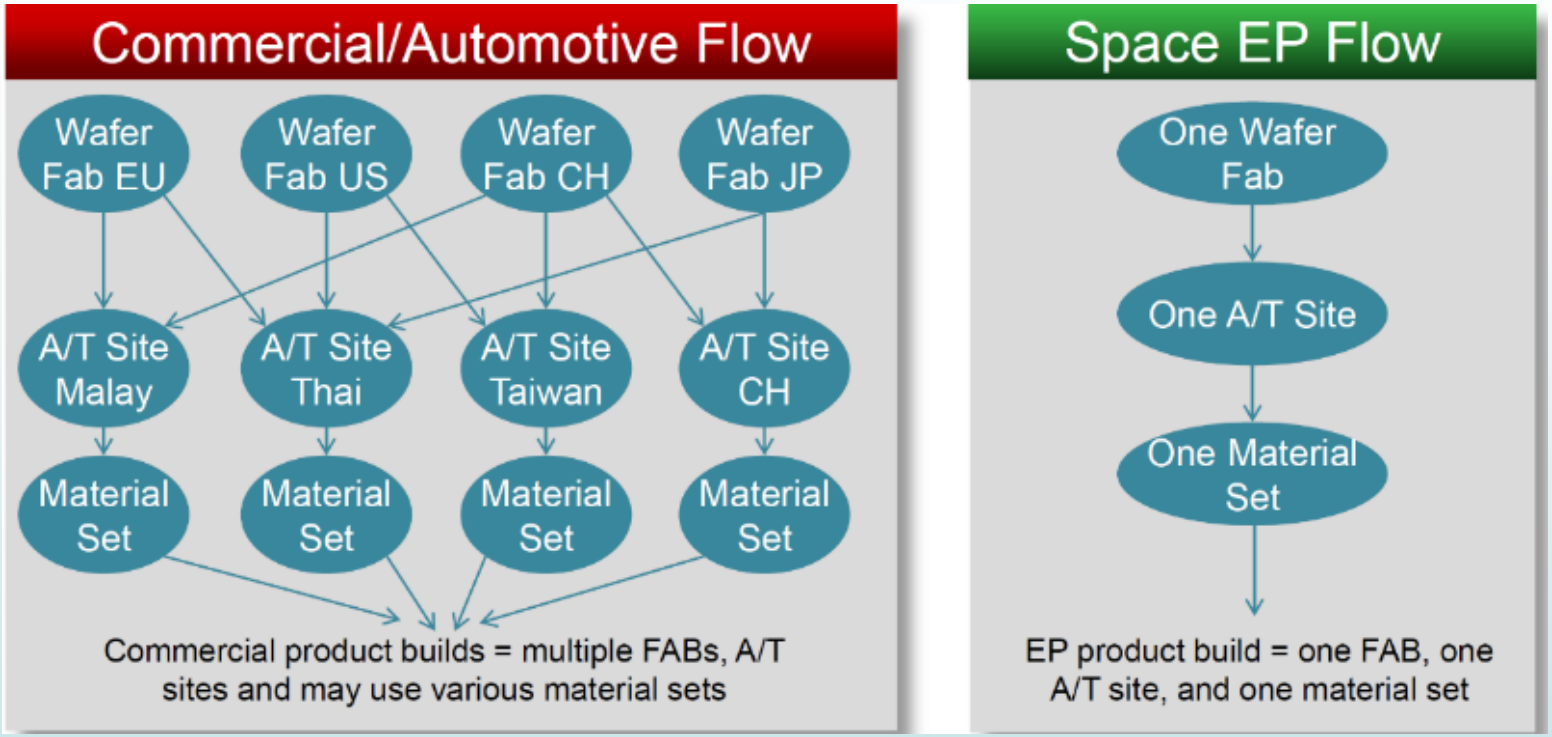



Image Courtesy of Texas Instruments

- The above chart provided by TI shows that their commercial/automotive products maybe built at multiple foundries, assembly/test facilities and may use various material sets.
- Contact manufacturer for a current version of this chart.

# Evaluating Automotive Parts for Potential NASA Applications – Cont'd

AEC Q specifications are Qualification Requirements Only, Focused on:

- A One-Time INITIAL QUALIFICATION of a Device Family
  - "Device Family" is Common Materials, Processes, Designs, Manufacturing Location, etc.
  - "Generic Data" may be used provided relevance of data can be demonstrated
- Requirements for REQUALIFICATION
  - Provides recommendations as needed
- Requirements for process change notification (PCN) to automotive customers
- THEY DO NOT PROHIBIT PURE TIN

– Whisker mitigation is recommended!

# DLA's VID (Vendor Item Drawing) Program


## Current Supplier's Program Benefits

1. Single Standardization Document
2. Controlled baseline.
3. Enhanced product change notification of processes, materials, electrical performance, finish, molding compounds and manufacturing locations.
4. Extended temperature performance.
5. Enhanced Pedigree - Reliability and electromigration checks, electrical characterization over temperature and confirmation of package performance over temperature.
6. Enhanced Obsolescence management.
7. No pure tin.
8. No copper wire bonds.

See the attached listing or check our website for an up to date list of product coverage.

## DSCC ANNOUNCES THE RELEASE OF A NEW TYPE OF STANDARDIZATION DOCUMENT.

DSCC

DSCC is releasing new Vendor Item Drawings (VIDs) almost daily. These documents have been created to provide a procurement vehicle for enhanced commercial products. Specifically, commercially available microcircuit products are being documented for the first time on a standardization document. Use of these DSCC VIDs will avoid the use of manufacturer generated specification control drawings (SCDs) or manufacturer's VIDs and avoid the potential proliferation of non-standard products. The participating manufacturers have agreed to provide information and services that have not traditionally been associated with commercial products. See our website for a list of documents that are currently available.

**All Vendor Item Drawings are *NOW* available on the DSCC web site**

http://www.dscc.dla.mil/Programs/MilSpec/

- Analog and digital functions offered.
- Contact DLA for updates.

# Electrostatic Discharge

- **NASA EEE Parts Bulletin (June 2018 – September 2018)**

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

**June 2018 – Sept. 2018 • Volume 10, Issue 2 (Published since 2009), April 30, 2019**

**Compendium Special Edition on Electrostatic Discharge (ESD)**

Damage from ESD is a major cost to the microcircuit industry in terms of time, money, and mission risk. The *EEE Parts Bulletin* has released three special issues on ESD, and this issue is a compendium of these three issues plus an overall view of the subject matter. The first issue dealt with the need to upgrade specifications related to ESD and suggestions for better ESD practices wherever parts are manufactured, stored, or prepared for shipment. The second ESD special issue focused on a parts failure investigation that ultimately concluded that ESD was the most likely cause of the failure. The second issue also included an important reminder about regular ESD testing. The third issue provided an example demonstrating the importance of maintaining ESD discipline and a high-level risk analysis related to electrostatic discharge. This compendium issue begins with an overview of the subject of electronic parts and ESD. Figure 1 provides a reminder that the familiar static sparking from rugs or rubber combs can generate ESD effects. ESD damage can easily go undetected.

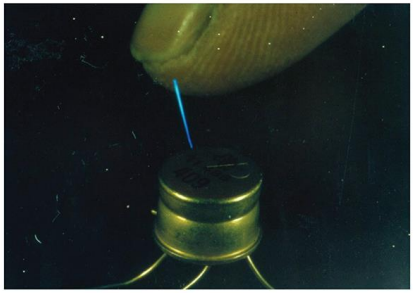


**Figure 1. Electrostatic discharge is everywhere (image courtesy of Hi-Rel Laboratories).**

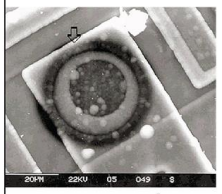
**Gaps and Mitigation Strategies for ESD**

Progressively smaller and more complex microelectronic parts have grown steadily more susceptible to ESD. Consequently, they require more testing effort.

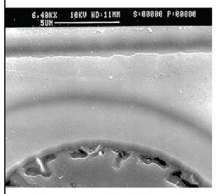
Furthermore, ESD damage can easily be too small for detection by many typical methods. As Figure 2 shows, serious ESD damage can be invisible to optical viewing and even to 6400 X by scanning electron microscope (SEM). In this instance, only a 33,000 X SEM view made the damage visible.

1

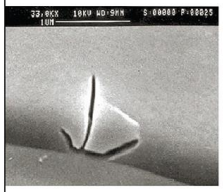
Damage Is Not Optically Visible



Not Visible at 6400 x In SEM



Damage Visible at 33,000 x In SEM



**ESD damage to most semiconductors is often so subtle that it cannot be seen without very high magnification (image courtesy of Hi-Rel Laboratories).**

Such ESD damage affects all types of commodities for both military and commercial parts, and the less-controlled commercial-off-the-shelf (COTS) parts may be affected more severely than the military.

The parts community must promote an ESD-safe environment. Such efforts must extend from parts fabrication, through shipping, and all the way through installation of parts in the final products.

NASA has supported this effort first by bringing ESD concerns to the attention of the parts community. Mitigation strategies have been developed in response to this rising threat. Mitigation strategies include NASA ESD surveys, observations during audits, standards updates (including harmonization of standards), and outreach to the military and space communities.

NASA has been supporting Defense Logistics Agency (DLA) audits of the supply chain for many years. During the audits in recent years, the auditors observed that the MIL-PRF-38535 requirements were practically non-existent regarding ESD aspects of electronic parts.

Hence, integrating ESD requirements into MIL- PRF- 38535 has become a key goal for the electronic parts community. The current qualification standards for MIL-PRF-38535 and related standards were developed years ago with pin counts in the twenties. Now, pin counts are in the hundreds or more. For instance, Virtex field-programmable gate arrays (FPGAs) have 1752 columns, and manufacturers are striving for even higher counts.

Applying the old device testing standards to modern high-pin count products can cause severe problems. Testing times and costs can increase dramatically. However, costs also drive the need for adequate quality assurance. Per-unit prices for advanced devices are approaching $200K, and the costs would multiply for failures discovered after a part was mounted or (worse) was in the field… or worst of all, in space.

Another issue is that multiple organizations have developed ESD mitigation standards/specifications. Gaps have evolved not just because of new technology, but also because of inconsistencies of standards development.

For the military and space community, the most glaring issues are as follows:

**MIL-STD-883, Test Method 3015 Issues:**

- Too old
- Does not include the charge device model (CDM), only the human body model (HBM)
- The test method needs to be revisited for smaller feature sizes down to 30 nm.
- The test method needs to be revisited for large numbers of contacts/pins, and vastly increased

2

- Continuing to conduct NASA ESD surveys.
- Interfacing with industry standards groups (e.g., JC-13, JC-14, ESDA, EC-11, EC-12).
- Working especially with the JC-13 newly-formed task group to address ESD issues. [JC-13 de-fined in the bullet above—just added standards.]
- Harmonizing ESDA 20.20, JEDEC 625, and other ESD standards.

*Final ESD Reminders*

- ESD is a serious and growing risk for electronic parts use.
- Updated standards are coming, and they will help mitigate ESD risks.
- However, the most important point to remember is that mitigation of ESD risk requires continuous vigilance in identification of risks and discipline in maintaining safeguards.

**References**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**For more information, contact**


**Shri Agarwal 818-354-5598**


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