National Aeronautics and
Space Administration

NEPAG Report
NASA Electronic Parts Assurance Group

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The Perseverance rover deploys its equipment against the backdrop of a true Martian landscape.

Elements of this image furnished by NASA

NEPP – Mission Statement

Provide NASA's **leadership** for developing and maintaining guidance for the **screening**, **qualification**, **test**, and reliable use of EEE parts by NASA, in **collaboration** with other government agencies and industry.

NASA Electronic Parts Assurance Group (NEPAG) is a core portion of NEPP

NEPAG

NASA Electronic Parts Assurance Group (NEPAG)

NEPAG

- **NEPAG is about Standards for electronic parts; finding solutions for NASA flight projects/programs; day-to-day parts issues. We are part of Mission Assurance Standards and Capabilities (MASC) Division.**
  - Maintenance
    - Provide NASA leadership
  - Creation
    - Infuse New Technology, e.g., Class Y for Space
    - Address the advances in packaging technology, e.g., newly started task group (TG) on 2.5D/3D devices
    - Respond to user requests, e.g., a new TG on standard plastic encapsulated microcircuits (PEMs) in Space
    - Relevant TGs: 3 main and 4 support TGs open
  - Related Activities
    - Hold telecons
      - NASA Electronic Parts Assurance Group (NEPAG)
      - Government Working Group (GWG)
      - Hybrid Working Group (HWG)
    - Support Defense Logistics Agency (DLA) audits of supply chain
    - Partnerships: JEDEC, SAE, Domestic and International space organizations, DLA, GIDEP, others
    - Standard microcircuits drawing (SMD) review
    - Outreach (Publish NASA EEE Parts Bulletins; present at meetings)
    - Learn and Lunch Webinars with the supply chain
    - Parts issues resolution at JPL. Booklet in progress.
    - Other as needed

Impact of COVID-19

- **Response to COronaVIrus Disease – 2019, COVID-19 (October 2020 onwards)**
  - **Significant Impact**
    - DLA Audits and NASA ESD surveys continued to be on hold
    - DLA 19500 manufacturer qualification group set up a process to perform virtual audits. Was supported by MSFC.
  - **No / Minimal impact**
    - NEPAG, GWG, HWG telecons (No impact)
      - NEPAG – NASA Electronic Parts Assurance Group, held every week
        - Led by S. Agarwal, NASA/JPL
        - International, first Wednesday of the month
        - Domestic, every Wednesday rest of the month
      - GWG – Government Working Group, held bi-week
        - Led by K. Laird, NASA/MSFC; Co-Lead: C. Schuler, Navy Crane
      - HWG – Hybrid Working Group, held monthly
        - Led by J. Pandolf, NASA/LaRC
    - Learn@Lunch Webinars (changed to virtual only)
    - NASA Parts Bulletins (No impact)
    - SMD reviews (No impact)
    - JEDEC/SAE meetings (changed to virtual only)
    - Electronic Parts and ESD (Some impact)
    - Conferences/Meetings
      - All Virtual – ESCCON, SPWG, NEPP ETW (NETW)
      - Mixed format – JAXA MEWS
      - NASA Face-to-Screen-to-Face (F2S2F) Parts Meetings
        - Changed to all virtual format
- **Other**
  - The 8739-11 document was the subject of a NASA Technical Talk at the SAE CE-12 meeting last month. It was led by P. Majewicz, C. Green and N. Siddiqi.

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Telecons

- **NEPAG Telecons** (Core team that sets the weekly agenda: S. Agarwal, B. Brandon, P. Majewicz, J. Pandolf, J. Brusse, K. Laird, L. Harzstark/Aerospace)
  - **Held since 2000, these telecons drive the NEPAG program. The weekly cycle is shown below.**
  - **Typical Telecon Agenda Package contains**
    - List of items for discussion
    - DLA audit schedule, SMD review status, Learn@Lunch Webinars, technical meetings, list of items for discussion at next JEDEC/CE-11, CE-12.
  - ***Return on Investment for NASA flight projects***
    - ***Coordination of parts issues with DLA and the aerospace community***
  - **Q1-Q2 FY22 Status**: Had 14 Domestic and 6 International calls.
  - **Impact of Coronavirus: None**

Weekly Telecon Cycle

Wednesday	Thursday	Following Monday	Tuesday	Tuesday	Tuesday	Tuesday
Telecon Day	Send Request for Inputs for Next Telecon	Finalize Agenda with NASA/Aerospace team	Update Audit Schedule	Send Last Telecon Minutes	Contact Topic Leads	Publish Agenda Package

← Telecon Preparation Activities →

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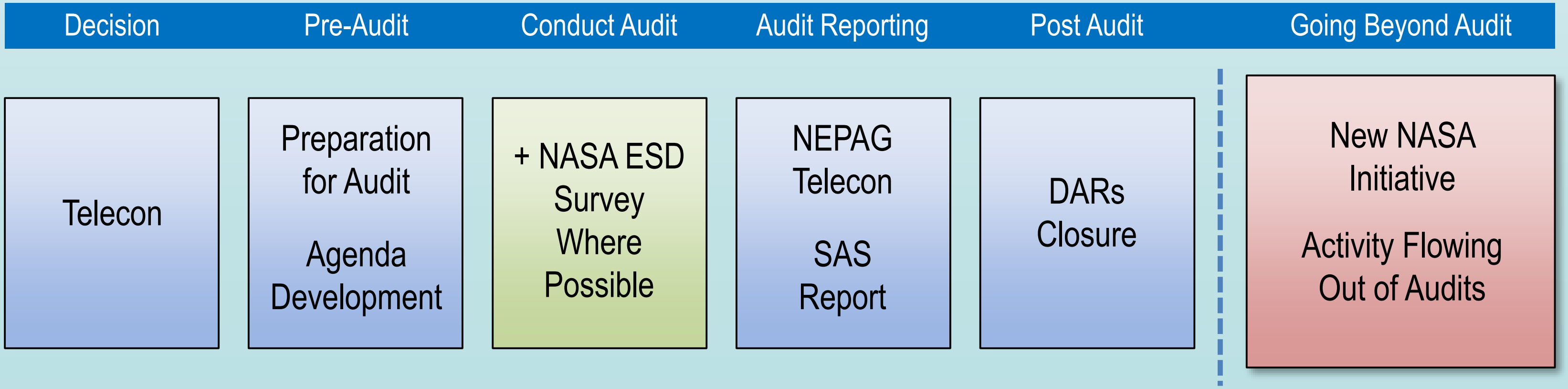
Defense Logistics Agency/Land and Maritime "DLA" Audits

- **DLA Audits**
  - **NASA supports DLA audits as technical experts. Responsibilities divided as follows:**
    - Passives: Brusse; Hybrids: Panashchenko, Pandolf and Majewicz; PWB: Gutierrez; Discretes: Damron; Connectors: Billig; Test Methods: Laird; Microcircuits: Agarwal
  - **Reports:** Verbal reports given on NEPAG telecons. SAS (Supplier Assessment System) report sent to M. O'Bryan at GSFC for posting on database at JSC.
  - ***Return on investment for NASA flight projects***
    - ***Ensure that NASA inputs are incorporated into part manufacturers' processes***
    - ***Review and resolve any parts issues with the manufacturers while on audit***
    - ***Develop contacts for future needs (e.g., finding critical parts)***
  - **FY22 Status**: NASA participated in 3 in-person audits so far.
  - **Impact of Coronavirus: Yes, major impact.**

Audit Process



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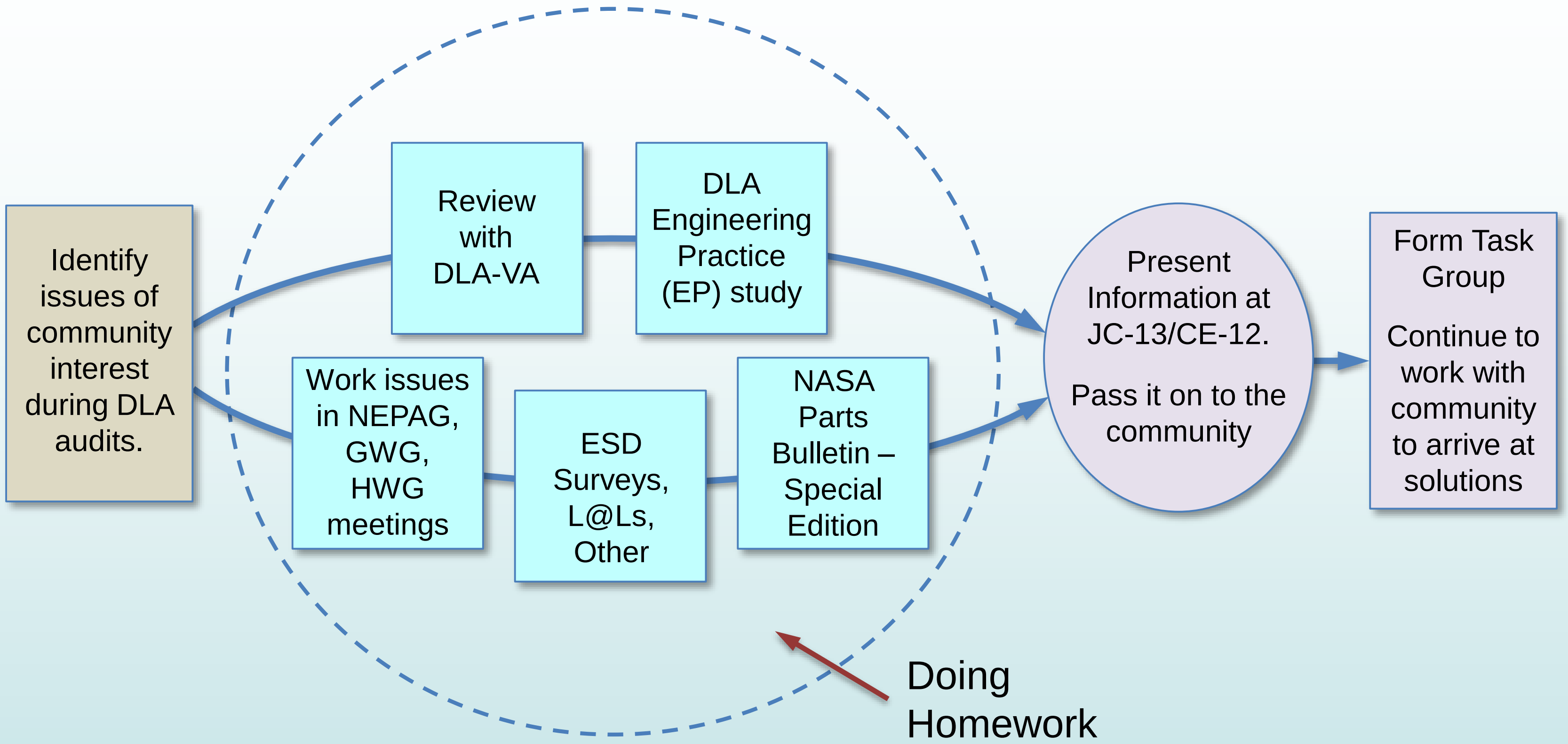
Taking Audit Findings a Step Further!



- Bring general awareness (Via NASA Bulletins, Surveys, Learn and Lunch webinars with supply chain, presentations at meetings)
- Work with DLA to conduct engineering practice (EP) study
- Generate a basic proposal and related information so the potential task group (TG) has a strong starting point.
- This path has **saved time** in working on major issues.

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Standard Microcircuit Drawings (SMDs) Review

- **SMDs Review/Standards Activity** (All centers with NEPAG Partners)
  - **NASA Specific Goals**
    - Provide comments to DLA-VA on newly drafted SMDs.
      - 10 day comment period
    - As part of QA (Qualifying Activity), review qualification data on new microcircuits
      - Several telecons are held with Aerospace, DLA and manufacturer
  - **Return on investment for NASA flight projects**
    - **NASA gets to bring in their perspective on standards issues. JC-13/CE-11/CE-12 represent a big investment on standards activity for NEPAG. NASA works with the community on standards issues.**
  - **FY22 Status Report: Reviewed 8 SMDs.**
  - **Impact of Coronavirus: No impact. Continued document reviews.**

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JEDEC JC-13 / SAE CE-11, CE-12

Support to JC-13/CE-11/CE-12

- **Work with/lead JC-13/CE-11/CE-12 communities to develop/maintain standards**
  - Co-chair CE-12, effective January 2022.
  - Member Executive Council
  - P. Majewicz is the new chair CE-11/CE-12 Space Subcommittee
  - Take CE-12 meeting notes
  - Present status update, e.g., Class Y
  - Actively support various task group meetings

- **The May 2022 meeting followed a mixed format**

- **CE-12 Leadership**
  - NASA has a big investment in these meetings
  - Agencies and the primes have to develop a succession plan

- **Return on investment: JC-13/CE-11/CE-12 represent a big investment on standards activity for NEPAG. NASA works with the community on standards issues.**

- **Future Meeting**
  - The format of the September 2022 meeting is TBD.

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FY22 New Task
NASA Parts Engineering School
Joint JPL/GSFC Activity

- Q2FY22 start
- Background work as part of Phase I
  - Summary of parts engineering disciplines at NASA JPL
  - Available training opportunities provided at JPL for new hires
  - Focused classes provided by NASA, JPL and outside organizations
  - Special projects for new hires
- Next phase: Review with JPL Component Engineering & Assurance section management and GSFC Parts management.
  - Define tasks for joint Parts Engineering School effort.
  - Determine individual tasks for JPL and GSFC and tasks to be worked jointly.

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FY22 New Task
Fracture Mechanics in Electronic Parts

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Fracture Mechanics in Electronic Parts:

- This task initiated in 2nd Quarter of FY22.
- As Phase I of this activity, we will address the parts built with plastic encapsulants.
- In Phase II, non-plastic-packaged device types will be explored.

Fracture Mechanics in Electronic Parts

Problem Statement

- Plastic encapsulants, dielectric polymers, and underfill materials are subject to delamination and cracking with thermal cycling. Crack propagation during use environment exposure, drives the potential for failure of microelectronic devices and is therefore a necessary focal point in qualification and life testing.

- Looking across the standards development covering the entire applications spectrum, it is clear that the community is making a huge investment in packages made of these materials. It, therefore, behooves us to review the fundamentals of these packages, their assembly and other related aspects.

NEPAG Small Studies FY22

Note: A total of 17 small studies were completed prior to FY22

- 18. NASA Parts Bulletin on GaN (Ovee, Khandker)
  - Done
- 19. Cloth vs metal wrist straps (514/512)
  - Some JPL suppliers have refused to follow QA clause that requires the use of metal wrist straps
  - Shri to present at upcoming JC13.2 meeting
  - Done.
- 20. New GaN Device from T.I. (NASA GaN Team)
  - TPS7H6003-SP GaN Driver
  - Will serve as a poster child to develop space flow for GaN devices
  - Ovee is the NASA coordinator. NASA Team:: JPL, GSFC, GRC, NEPP
  - First set of inputs (device pin spacing) given to T.I.
  - ESD test discussion to continue
- 21. **Support September'21 JEDEC/SAE meetings (JPL NEPAG Team)**
  - Space Subcommittee meeting chaired by Agarwal for NASA
  - CE-12 General meeting
  - Take notes, final version to be posted on SAE website
  - Done.
- 22. White Paper on Screening and Qualification (Ovee, Khandker)
  - An outreach effort
  - In progress.

NEPAG Small Studies Contd.

- 23. Post NEPAG Material on NASA SCIC Platform (Salallandia Valenzuela, Swain)
  - Suggested by HQ
  - NEPAG weekly telecon minutes. Logistics being worked.
  - Slides from L@L Webinars. Posted.
  - In progress
  - SCIC = Supply Chain Insight Central.
- 24. 8739.11 PRT Section Update
  - Sponsored J. Martinez to provide support
  - Done (Supported JPL/GSFC meeting)
- 25. Support to NASA Parts Manager
  - Moog's question on application of planar magnetics
  - Done (Magnetics parts specialist participated in GSFC/Moog/JPL meeting)
- 26. Magnetics
  - Start on Navy request to make magnetics a monthly topic on NEPAG telecons.
  - Develop a checklist of best practices and then convert it into a parts bulletin
  - Assigned to R. Swain
  - In progress.
- 27. Affordability of Parts
  - How to make parts more affordable for smaller projects/programs
  - Assigned to Nazia Ovee
  - In progress
- 28. January Space Subcommittee Meeting
  - Special Topic on Radiography (K. Laird and GWG Team – JPL to lead for Kathy)
  - JPL Support: J. Martinez, R. Evans and T. Apple
  - Done. Initial quote was 4-5 hrs (support team), actually took 40hrs+ (led the team).

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NEPAG Small Studies Contd.

- 29. Support J. Bockman request on PBX Connectors (R. Billig)
  - Suggested by HQ
  - Done
- 30. Support J. Bockman request on Planar Magnetics (Parts Specialist)
  - Suggested by HQ
  - Done
- 31. Combine ESD bulletins into a guideline document
  - Joint 514/512 effort
  - Assigned to D. Gallaghar, S. Khadker, L. Boyle
  - New task

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Electronic Parts and ElectroStatic Discharge (ESD)

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- **Electronic Parts and ESD** (N. Ovee, M. Doe, M. Nelson, M. Han, E. Kim, S. Agarwal)
  - **NASA Specific Goals**
    - ❖ During the DLA audits of the supply chain, we realized that there were practically no requirements for ESD. Need to update standards.
    - ❖ Microcircuit pin count has increased significantly (e.g., Vertex FPGAs have 1752 columns). Current qualification standards were developed years ago with pin counts in the twenties. Applying these old device testing standards to modern high-pin count products can cause severe problems (e.g., testing times increase dramatically).
    - ❖ Furthermore, microcircuit part production is no longer under one roof, but landscape of supply chain is multiple specialty houses.
    - ❖ Costs can not be ignored – per unit price for advanced devices is approaching $200k. ESD mitigation costs are minute compared to the device unit costs.
    - ❖ ESD surveys/audits of COTS hardware/parts suppliers should be mandatory.
    - ❖ Mitigation strategies include ESD surveys, observations during audits, standards updates & outreach to the military & space communities. There is always a latency risk from ESD.
    - ❖ Outreach: NASA has published extensively on this subject (released 4 Parts Bulletins). We plan to publish a guideline document, and will continue to report at conferences.
  - ***Return on investment for NASA flight projects***
    - ❖ ***NASA initiated and led the Electronic Parts and ESD effort. We provide updates at JC-13 TG, SPWG and ETW meetings.***
    - ❖ ***Supply chain is deriving benefits from NASA ESD Surveys.***
  - **FY21 Status Report**: Presented at JC-13 TG meeting in January. Conducting limited testing per human body model (HBM). Released NASA Bulletin on ESD testing.
  - **Impact of Coronavirus: Partial – no NASA ESD surveys. Continued testing and meetings.**

NASA EEE Parts Bulletins

- **EEE Parts Bulletins** (All centers with NEPAG Partners)
  - **NASA Specific Goals**
    - ❖ An outreach activity since 2005
    - ❖ The EEE Parts Bulletin is a 4-10 page newsletter with articles of interest to the community.
      - ➢ Goal is to issue one to four times per year
      - ➢ Distribution is to few thousand individuals in the user/supplier communities
  - ***Return on investment for NASA flight projects. A unique NASA outreach activity which is appreciated by the space community around the world.***
  - **FY22 Status Report**: Released bulletin on GaN ESD testing.
  - **Impact of coronavirus: None**

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Learn at Lunch (L@L) Webinars with Supply Chain

- **NASA L@L Webinars**
  - **NASA Specific Goals**
    - ❖ Supply chain is asked to present technical descriptions of existing, new products under development, and their near-term vision. Marketing pitches are kept to a minimum.
    - ❖ Usually held on Wednesdays at lunch time
    - ❖ Audience: All NASA centers and space community. On-site and remote participation.
    - ❖ Representatives from Standards organizations (e.g., DLA and ESA) have also presented on status/trends of EEE parts specifications.
    - ❖ We gather manufacturer data on status of parts functions, e.g., A/D Converters.
    - ❖ The supply chain likes these meetings because they get to meet their customers (hardware designers, parts engineers), see the campus, etc. Separate meetings are scheduled to review any on-going issues.
    - ❖ The support is provided by JPL Component Engineering and Assurance Office (CEAO).
      - ➢ Management: M. Mojarradi, J. Bonnell, N. Sucher
      - ➢ Organizing Team: B. Brodkin, N. Ovee, S. Agarwal
  - ***Return on investment for NASA flight projects***
    - ❖ ***These Webinars give NASA (and other user community) an opportunity to get to know our supply chain.***
  - **FY22 Status**: Organized 13 Webinars so far. All were virtual.
  - **Impact of coronavirus**: Limited – supplier are no longer able to come on campus for face-to-face meetings with designers/parts engineers.

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Partnerships
(NEPAG is about collaboration)

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 **CE-12 Management:** **Co-Chairs: S. Agarwal (NASA) and A. Touw (Boeing)**
SAE SSTC CE-11 & CE-12	Space Subcommittee Chair: P. Majewicz (NASA)

NASA Centers:

ARC	JSC
GRC	KSC
GSFC	LaRC
JPL	MSFC

Weekly NEPAG and Biweekly GWG Telecons (Domestic)

Monthly Telecons (International and HWG)

Partners from Outside NASA:

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

International
- ESA, JAXA, CSA

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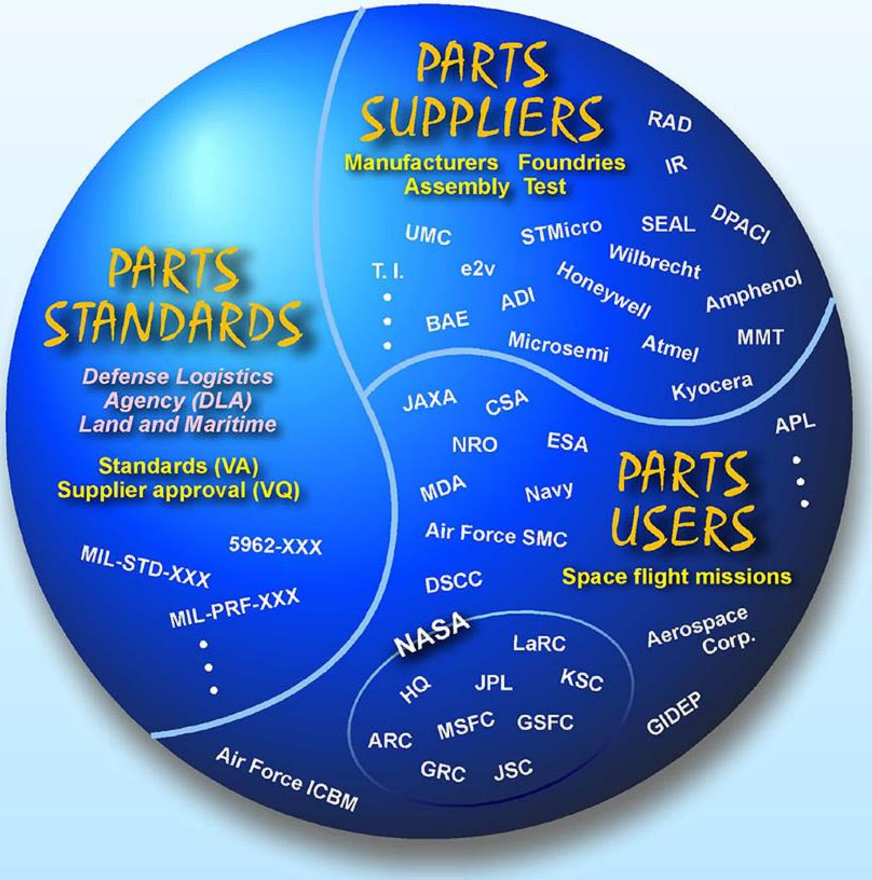
Space Parts World

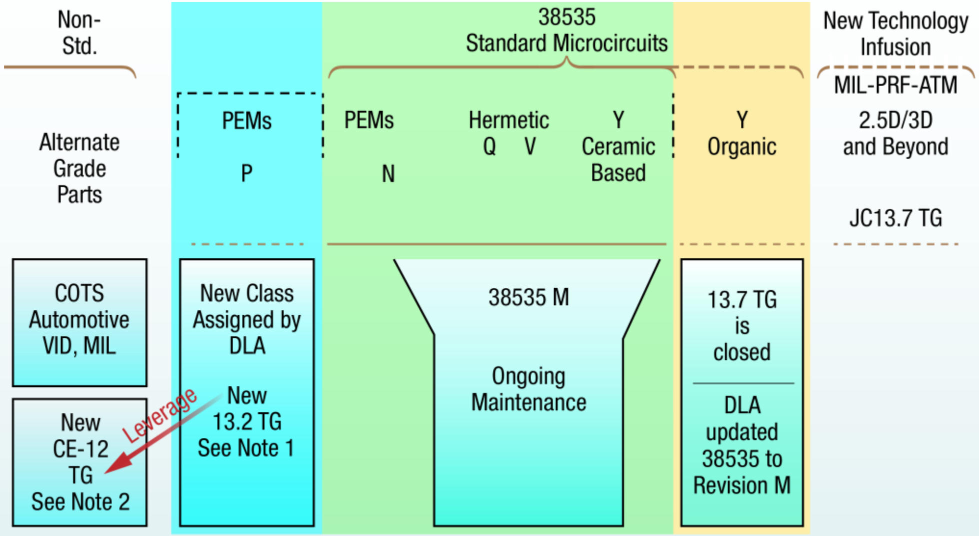
NEPAG helps to Develop/Maintain Standards for Electronic Parts



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 Co-Chair.

Microcircuit Standards Development



- Note 1: Standard PEMs for Space (QMLP) initiative using SAE AS6294 as baseline. Supported by NASA Parts Bulletins on PEMs.
- Note 2: For alternate grade microcircuits, follow the activity in 13.2 TG to avoid any duplication of effort.
- Note 3: ATM = Advanced Technology Microcircuits. Supported by NASA parts bulletin on KGD.
- Note 4: VID = Vendor Item Drawing. Contact DLA for latest information.
- Note 5: ***The boundaries separating various classes/grades must be clearly defined - future outreach activity.***

(1) The green area shows existing standards coverage.

(2) Task Groups: Some excellent progress was reported by task groups (TGs) developing standards.

(a) Organic Class Y. The draft of MIL-PRF-38535 revision M which includes Organic Class Y was released Feb 28, 2022. This is shown as the yellow area. A NASA/JPL project has baselined Organic Class Y.

(b) QMLP, Standard for rad hard/rad tolerant plastic encapsulated microcircuit (PEM) devices. The TG has developed the requirements and forwarded them to DLA for incorporation into the microcircuit's specification, MIL-PRF-38535. This would enable NASA and other agencies/users to be able to procure standard PEM (QMLP) parts for use in space applications without having to worry about upscreening, yield losses and potential non-conformances. The flight projects would realize considerable cost savings. Several manufacturers have already planned releases of their QMLP products. NASA is planning to include QMLP in its 8739.11 document. See blue shaded area in the chart above.

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NEPAG Activities (Contd.)

- **Other Significant Activities**
  - **NASA Parts Management Meetings**
    - Held two times a year. The next meeting is June 21-22, will be virtual. (B. Bodkin, S. Douglas)
  - **Component Engineering and Assurance Office (JPL Office 514)**
    - S. Agarwal Chairs the bi-weekly meetings on path to resolve flight parts issues.
      - **Wiki Page**. A wiki page has been created to simplify the effort.
      - ***Booklet.*** A booklet summarizing our experiences for the first 10 issues is being compiled. (R. Brandon, C. Marie-Peterson)
      - ***NEPAG Connection.*** Used NEPAG, GWG and HWG telecons as a resource.
      - ***Hybrid DPAs and FAs.*** Since hybrids had the most problems, created a telework task to review their DPAs and FAs. (S. Gore, T. Apple, J. Martinez, R. Evans)
      - ***MIL-STD-883/Test Method 2012 Review.*** There were questions raised on third party disposition of hybrid X-ray results. A telework task was opened to review the radiography test method for any ambiguities. This work was submitted to the HQ. The comments were also passed on to the GWG for further discussion and recommendations. (J. Bescup)
  - **Impact of Coronavirus**
    - **DLA Audits and NASA ESD Surveys were postponed**
      - A telework task was created to make **supply chain assessment**. The progress was reported on NEPAG domestic and international telecons. (I. Khan, S. Grover, L. Boyle)

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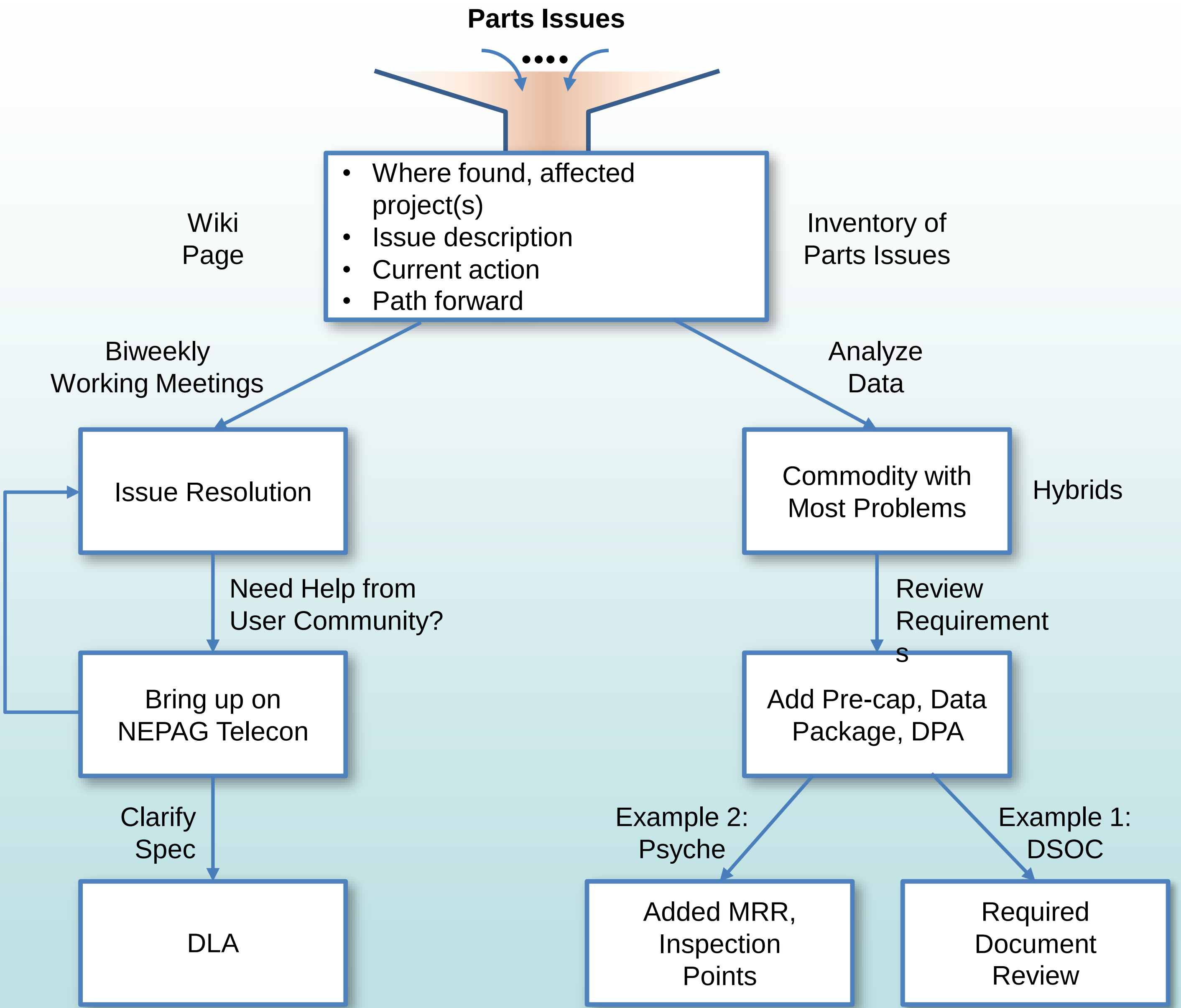
Path to Parts Issues Resolution



DLA: Defense Logistics Agency; DPA: destructive physical analysis ; DSOC: Deep Space Operations Center; MRR: Manufacturing Readiness Review.

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Next Step: A "Parts Issues Booklet"

- The wiki page contains over 125 parts issues
  - How to use this data/disseminate this experience base to others while safeguarding information that might be vendor/JPL project– proprietary
  - Concept of a booklet evolved
- Create a booklet that
  - Captures the technical essence (summary) of each parts issue
    - In consultation with parts SMEs
- Share with NASA centers

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BACK - UP

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NEPAG Activities in Q1-Q2FY21

Activity	Q1	Q2	Q3	Q4	Total
*FY21					
DLA Audits Supported	**	**			0
NASA ESD Surveys	**	**			0
Standard Microcircuit Drawings (SMDs)	4	2			6
Domestic Telecons (Average Attendance)	7 (42)	7 (39)			14 (41)
International Telecons (Average Attendance)	3 (35)	3 (37)			6 (36)
NASA EEE Parts Bulletins	1	1			2
Learn @ Lunch Webinars	4	5			9
Meetings/Conferences (Agarwal)	1	1			2
JPL Inputs on INST Update		Done 3-29-21			
*Supported by: B. Bodkin, A. Hanelli, S. Khandker, N. Ovee, D. Gallagher, M. Han, R. Swain, K. Munsell, J. Martinez, C. Ashbury, A. Azizi, R. Evans, I. Khan, L. Boyle, S. Grover, M. Do, P. Spence, T. Gutierrez. **Postponed					

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NEPAG Activities in FY19 (No Covid) vs FY20 (Covid)

(COVID-19 impacted travel activities, such as Audits/Surveys. Meetings were changed to virtual format)

Activity	Q1	Q2	Q3	Q4	Total
FY19 (No COVID)					
DLA Audits Supported	5	2	7	12	26
NASA ESD Surveys	1	1	1		3
Standard Microcircuit Drawings (SMDs) & Slash Sheets	5	7	2	1	15
Domestic Telecons (Average Attendance)	6 (30)	10 (32)	5 (33)	8 (32)	29 (32)
Intl Telecons (Average Attendance)	2 (27)	2 (28)	3 (29)	2 (27)	9 (28)
EEE Parts Bulletin			1		1
Learn@Lunch Webinars	2	3	5	4	14
Meetings/Conferences (Agarwal)	1	1	3	2	7
FY20 (COVID from Q2 to FY End)					
DLA Audits Supported	5	3	**	**	8
NASA ESD Surveys	**	**	**	**	**
Standard Microcircuit Drawings (SMDs) & Slash Sheets	2	5	9	4	20
Domestic Telecons (Average Attendance)	7 (32)	9 (39)	9 (49)	8 (51)	33 (43)
Intl Telecons (Average Attendance)	3 (29)	2 (29)	3 (40)	2 (40)	10 (34)
EEE Parts Bulletin			1	*1	1+*1
Learn@Lunch Webinars	4	8	2	5	19
Meetings/Conferences (Agarwal)	4	2***	1***	1***	7

- * 1 Bulletin in review by NASA centers.
- ** Postponed ***Virtual

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NASA EEE Parts Bulletin, May 15, 2020

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

October 2019–March 2020 • Volume 11, Issue 1,[1] May 15, 2020

Non-Hermetic and Plastic-Encapsulated Microcircuits

The mission assurance organizations at NASA have supported many large and small space missions and programs over the years. Today that spectrum has expanded, ranging from flagship missions such as Mars 2020 with its Perseverance Rover, Europa Clipper, and the proposed Europa Lander, to SmallSats/CubeSats such as the Temporal Experiment for Storms and Tropical Systems—Demonstration (TEMPEST-D) and Mars Cube One (MarCO). Plastic-encapsulated microcircuits (PEMs) have become more attractive since leading-edge alternatives are not available as space-qualified products. PEMs generally have smaller footprints and are lighter than the ceramic packages used in space-qualified products [1]. As the demand and use of non-hermetic and plastic-encapsulated microcircuits for space has increased, the scope of what future missions are capable of has also widened. This changing climate related to EEE parts selection presents new challenges for NASA, which—as always—holds the success of every mission paramount.

Growing Use of NASA SmallSats and CubeSats

Due to the need for low-cost communications satellites and new businesses evolving around Earth-observation services, there's been an increased interest in the use of CubeSats and SmallSats. Many NASA centers have been involved in developing and flying CubeSats and SmallSats, working together with multiple universities and industry partners. These undertakings require new product solutions for smaller, lighter, and lower-cost spacecraft, which cannot be produced using traditional space-qualified electronic parts.

The reliability and radiation requirements for CubeSats and SmallSats are significantly lower than for larger spacecraft because these smaller satellites operate mainly in low Earth or geosynchronous orbits (LEO or GEO, as opposed to deep space) and for relatively short periods. Radiation-hardened, high-reliability, space-grade parts are often too expensive for such missions and do not match well with their requirements.

There are a few notable exceptions to the usual use of CubeSats, particularly MarCO-A and MarCO-B, which were the first CubeSats to fly to deep space, where they successfully supported the Interior Exploration Using Seismic Investigations, Geodesy, and Heat Transport (InSight) mission by relaying data to Earth from Mars during the entry, descent and landing stage (Figure 1). MarCO successfully demonstrated a "bring-your-own" communications-relay option for use by future Mars missions in the critical few minutes between Martian atmospheric entry and touchdown. Further, by verifying that CubeSats are a viable technology for interplanetary missions, and feasible on a short development timeline, this technology demonstration could lead to many other applications to explore and study our solar system.

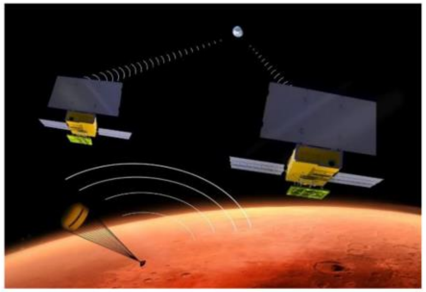

Figure 1. MarCO accompanying the InSight Mars lander and relaying data to Earth as it landed on Mars.

[1] The EEE Parts Bulletin was not published in fiscal year 2019 (FY19). The two issues of Volume 10 were published in FY18.

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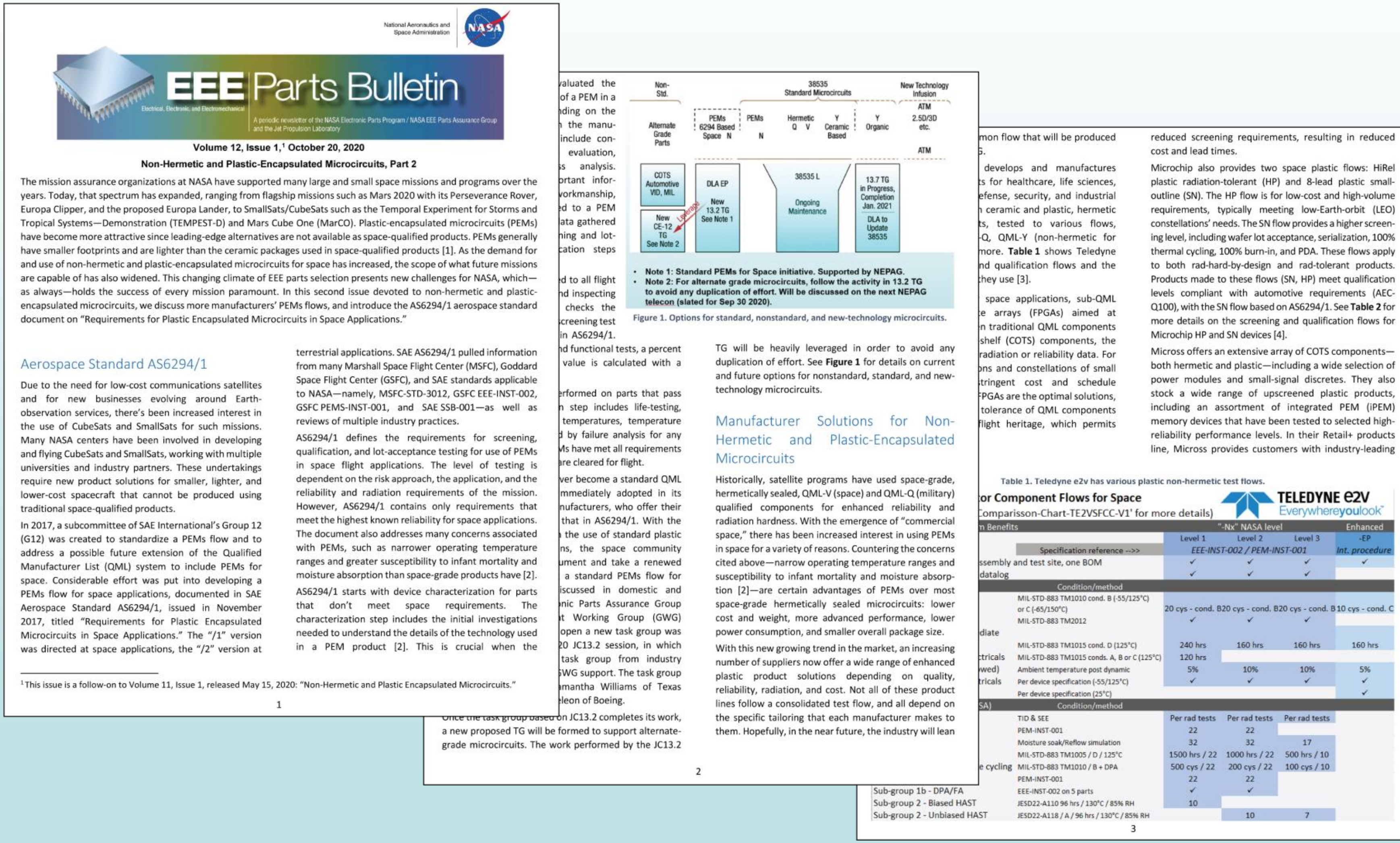
NEPP NASA Electronic Parts and Packaging Program

NASA EEE Parts Bulletin
Special Edition: Non-Hermetic and Plastic-Encapsulated Microcircuits, Part 2
URS296932, CL#20-6169



National Aeronautics and Space Administration

EEE Parts Bulletin

Electrical, Electronic, and Electromechanical

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Non-Hermetic and Plastic-Encapsulated Microcircuits, Part 2

The mission assurance organizations at NASA have supported many large and small space missions and programs over the years. Today, that spectrum has expanded, ranging from flagship missions such as Mars 2020 with its Perseverance Rover, Europa Clipper, and the proposed Europa Lander, to SmallSats/CubeSats such as the Temporal Experiment for Storms and Tropical Systems—Demonstration (TEMPEST-D) and Mars Cube One (MarCO). Plastic-encapsulated microcircuits (PEMs) have become more attractive since leading-edge alternatives are not available as space-qualified products. PEMs generally have smaller footprints and are lighter than the ceramic packages used in space-qualified products [1]. As the demand for and use of non-hermetic and plastic-encapsulated microcircuits for space has increased, the scope of what future missions are capable of has also widened. This changing climate of EEE parts selection presents new challenges for NASA, which—as always—holds the success of every mission paramount. In this second issue devoted to non-hermetic and plastic-encapsulated microcircuits, we discuss more manufacturers' PEMs flows, and introduce the AS6294/1 aerospace standard document on "Requirements for Plastic Encapsulated Microcircuits in Space Applications."

Aerospace Standard AS6294/1

Due to the need for low-cost communications satellites and for new businesses evolving around Earth-observation services, there's been increased interest in the use of CubeSats and SmallSats for such missions. Many NASA centers have been involved in developing and flying CubeSats and SmallSats, working with multiple universities and industry partners. These undertakings require new product solutions for smaller, lighter, and lower-cost spacecraft that cannot be produced using traditional space-qualified products.

In 2017, a subcommittee of SAE International's Group 12 (G12) was created to standardize a PEMs flow and to address a possible future extension of the Qualified Manufacturer List (QML) system to include PEMs for space. Considerable effort was put into developing a PEMs flow for space applications, documented in SAE Aerospace Standard AS6294/1, issued in November 2017, titled "Requirements for Plastic Encapsulated Microcircuits in Space Applications." The "/1" version was directed at space applications, the "/2" version at terrestrial applications. SAE AS6294/1 pulled information from many Marshall Space Flight Center (MSFC), Goddard Space Flight Center (GSFC), and SAE standards applicable to NASA—namely, MSFC-STD-3012, GSFC EEE-INST-002, GSFC PEMS-INST-001, and SAE SSB-001—as well as reviews of multiple industry practices.

AS6294/1 defines the requirements for screening, qualification, and lot-acceptance testing for use of PEMs in space flight applications. The level of testing is dependent on the risk approach, the application, and the reliability and radiation requirements of the mission. However, AS6294/1 contains only requirements that meet the highest known reliability for space applications. The document also addresses many concerns associated with PEMs, such as narrower operating temperature ranges and greater susceptibility to infant mortality and moisture absorption than space-grade products have [2].

AS6294/1 starts with device characterization for parts that don't meet space requirements. The characterization step includes the initial investigations needed to understand the details of the technology used in a PEM product [2]. This is crucial when the

[1] This issue is a follow-on to Volume 11, Issue 1, released May 15, 2020: "Non-Hermetic and Plastic Encapsulated Microcircuits."

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- Note 1: Standard PEMs for Space initiative. Supported by NEPAG.
- Note 2: For alternate grade microcircuits, follow the activity in 13.2 TG to avoid any duplication of effort. Will be discussed on the next NEPAG telecon (slated for Sep 30 2020).

Figure 1. Options for standard, nonstandard, and new-technology microcircuits.

TG will be heavily leveraged in order to avoid any duplication of effort. See **Figure 1** for details on current and future options for nonstandard, standard, and new-technology microcircuits.

Manufacturer Solutions for Non-Hermetic and Plastic-Encapsulated Microcircuits

Historically, satellite programs have used space-grade, hermetically sealed, QML-V (space) and QML-Q (military) qualified components for enhanced reliability and radiation hardness. With the emergence of "commercial space," there has been increased interest in using PEMs in space for a variety of reasons. Countering the concerns cited above—narrow operating temperature ranges and susceptibility to infant mortality and moisture absorption [2]—are certain advantages of PEMs over most space-grade hermetically sealed microcircuits: lower cost and weight, more advanced performance, lower power consumption, and smaller overall package size.

With this new growing trend in the market, an increasing number of suppliers now offer a wide range of enhanced plastic product solutions depending on quality, reliability, radiation, and cost. Not all of these product lines follow a consolidated test flow, and all depend on the specific tailoring that each manufacturer makes to them. Hopefully, in the near future, the industry will lean

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reduced screening requirements, resulting in reduced cost and lead times.

Microchip also provides two space plastic flows: HiRel plastic radiation-tolerant (HP) and 8-lead plastic small-outline (SN). The HP flow is for low-cost and high-volume requirements, typically meeting low-Earth-orbit (LEO) constellations' needs. The SN flow provides a higher screening level, including wafer lot acceptance, serialization, 100% thermal cycling, 100% burn-in, and PDA. These flows apply to both rad-hard-by-design and rad-tolerant products. Products made to these flows (SN, HP) meet qualification levels compliant with automotive requirements (AEC-Q100), with the SN flow based on AS6294/1. See **Table 2** for more details on the screening and qualification flows for Microchip HP and SN devices [4].

Micross offers an extensive array of COTS components—both hermetic and plastic—including a wide selection of power modules and small-signal discretes. They also stock a wide range of upscreened plastic products, including an assortment of integrated PEM (iPEM) memory devices that have been tested to selected high-reliability performance levels. In their Retail+ products line, Micross provides customers with industry-leading

Table 1. Teledyne e2v has various plastic non-hermetic test flows.

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NASA EEE Parts Bulletin
Special Edition: Comparison of Test Methods for Human Body Model (HBM) Electrostatic Discharge (ESD)

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NEPP NASA Electronic Parts and Packaging Program

National Aeronautics and Space Administration

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Special Edition: Comparison of Test Methods for Human Body Model (HBM) Electrostatic Discharge (ESD)

Damage from ESD is a cause of major costs to the microcircuit industry in terms of time, money, and mission risk. The *EEE Parts Bulletin* has released four special issues on ESD [1]–[4]. The first issue, in 2016, stressed the need to upgrade specifications related to ESD and suggested improved ESD practices wherever parts are manufactured, stored, or prepared for shipment. The second ESD special issue, in 2017, focused on a parts failure investigation that ultimately identified ESD as the most likely cause of the failure. The 2017 special issue also included an important reminder about regular ESD testing. The third issue, in 2018, provided an example demonstrating the importance of maintaining ESD discipline and high-level risk analysis related to ESD. The fourth issue, later in 2018, was a compendium of the previous three special issues and included an overall updated view of the subject matter.

The current special issue focuses on one specific aspect of ESD damage that is caused by the human body during parts handling. The susceptibility of electronic devices to such damage is characterized by the human body model (HBM). For illustration, the magnitude of electrostatic voltage built up on a chip under different handling means and relative humidity (RH) conditions is shown in **Table 1** [1]. A microcircuit device exposed to an ESD event induced by contact with a human body can easily experience an electrostatic voltage attack in the kilovolt range. Thus, a better understanding of HBM ESD events is warranted. In this issue of the *EEE Parts Bulletin*, we report on independent experimental evaluations of two popular HBM-specific test methods: MIL-STD-883 Test Method 3015.7 [5] and JEDEC JS001-2017 [6]. Similar to the latter, the Automotive Electronics Council (AEC) HBM test method is also included for reference. For a fair and straightforward comparison, a chosen microcircuit chip was subjected to HBM zaps under MIL-STD-883 and JEDEC/AEC conditions, respectively.

Table 1. Voltages experienced by electronic devices exposed to various HBM-ESD events [1].

Means of Static Generation	Electrostatic Voltages	
	10–20% RH	65–90% RH
Walking across carpet	35,000	1,500
Walking over vinyl floor	12,000	250
Worker at bench	6,000	100
Vinyl envelopes for work instructions	7,000	600
Common poly bag picked up from bench	20,000	1,200
Work chair padded with polyurethane foam	18,000	1,500

HBM Test Standards

A good overview of HBM test standards was presented in the first *EEE Parts Bulletin* special issue on ESD [1]. In this special issue, we compare and evaluate three popular HBM test standards:

1. MIL-STD-883 Test Method 3015.7 (abbreviated MIL-STD-883) [5]
2. JEDEC JS001-2017 (based on JESD22-A114, abbreviated JEDEC-JS001) [6], [7]
3. AEC-Q200-002 REV-B (abbreviated AEC-Q200) [8]

In the following sections, test methods and classifications for these three test standards are extracted from their respective specification documents. The test methods and classifications are summarized and compared in **Table 5**. There are many similarities between JEDEC-JS001 and AEC-Q200, so the primary focus of the comparison was between MIL-STD-883 and JEDEC-JS001.

AEC-Q200-002 REV-B

Test Method

AEC-Q200 stipulates: Each sample group shall be composed of 15 components (five voltage levels with three parts per voltage level) and tested using a direct contact discharge probe at one voltage level, at steps of 500 V, 1 kV, 2 kV, 4 kV, and 8 kV, or using an air discharge probe at 25 kV. Two discharges shall be applied to each pin under test within a sample group and at each stress voltage level, one with a positive polarity and one with a negative polarity.

Classifications

Classifications per AEC-Q200 are shown in **Table 4**.

Table 4. Device ESD failure threshold classifications for HBM based on AEC-Q200.

Classification	Voltage Threshold
Class 1A	0 to 500 volts (DC)
Class 1B	500 to 999 volts (DC)
Class 1C	1,000 to 1,999 volts (DC)
Class 2	2,000 to 3,999 volts (DC)
Class 3	4,000 to 5,999 volts (DC)
Class 4	6,000 to 7,999 volts (DC)
Class 5A	8,000 volts (DC) to 11,999 volts (AD)
Class 5B	12,000 to 15,999 volts (AD)
Class 5C	16,000 to 24,999 volts (AD)
Class 6	25,000 volts (AD) and above

DC = direct contact discharge; AD = air discharge.

The main differences among MIL-STD-883, JEDEC-JS001, and AEC-Q200 test methods and classifications are summarized in **Table 5**.

Table 5. Comparison of MIL-STD-883, JEDEC, and AEC test methods and classifications.

Item	MIL-STD-883	JEDEC-JS001	AEC-Q200
Sample Size	Not specified	Three	Three
First Pulse	500 V	50 V	500 V
Pulses per Zap	3 +ve pulses followed by 3 -ve pulses	1 +ve pulse followed by 1 -ve pulse	1 +ve pulse followed by 1 -ve pulse
Timing Interval between Pulses (min.)	1 second	0.3 second	Not specified
Classifications	Three main groups (1,2,3)	Four main groups (0,1,2,3) and three subgroups (OZ/OA/OB, 1A/1B/1C, 3A/3B)	Six main groups (1,2,3,4,5,6) and two subgroups (1A/1B/1C & 5A/5B/5C)

Table 7. MIL-STD 883–based test results.

SN M1

Pins	50V	100V	200V	300V
1	Failed	NA	NA	NA
2	Failed	NA	NA	NA
3	Failed	NA	NA	NA
4	Failed	NA	NA	NA
5	Failed	NA	NA	NA
6	Failed	NA	NA	NA
7	Failed	NA	NA	NA
8	Failed	NA	NA	NA
9	Pass	NA	NA	NA
11	Pass	NA	NA	NA
12	Pass	NA	NA	NA
13	Pass	NA	NA	NA
14	Failed	NA	NA	NA
15	Pass	NA	NA	NA
16	Failed	NA	NA	NA
17	Failed	NA	NA	NA
18	Pass	NA	NA	NA
19	Pass	NA	NA	NA
20	Failed	NA	NA	NA

SN M2

Pins	50V	100V	200V	300V
1	Failed	NA	NA	NA
2	Pass	NA	NA	NA
3	Failed	NA	NA	NA
4	Failed	NA	NA	NA
5	Failed	NA	NA	NA
6	Failed	NA	NA	NA
7	Failed	NA	NA	NA
8	Failed	NA	NA	NA
9	Failed	NA	NA	NA
11	Pass	NA	NA	NA
12	Failed	NA	NA	NA
13	Pass	NA	NA	NA
14	Failed	NA	NA	NA
15	Pass	NA	NA	NA
16	Failed	NA	NA	NA
17	Pass	NA	NA	NA
18	Pass	NA	NA	NA
19	Pass	NA	NA	NA
20	Failed	NA	NA	NA

SN M3

Pins	50V	100V	200V	300V
1	Pass	Pass	Pass	Failed
2	Pass	Pass	Pass	Pass
3	Pass	Pass	Pass	Failed
4	Pass	Pass	Pass	Failed
5	Pass	Pass	Pass	Failed
6	Pass	Pass	Pass	Failed
7	Pass	Pass	Pass	Failed
8	Pass	Pass	Pass	Failed
9	Pass	Pass	Pass	Failed
11	Pass	Pass	Pass	Pass
12	Pass	Pass	Pass	Pass
13	Pass	Pass	Pass	Pass
14	Pass	Pass	Pass	Pass
15	Pass	Pass	Pass	Pass
16	Pass	Pass	Pass	Pass
17	Pass	Pass	Pass	Pass
18	Pass	Pass	Pass	Pass
19	Pass	Pass	Pass	Pass
20	Pass	Pass	Pass	Pass

Pins 1–9 of the three parts consistently failed after the HBM zaps.

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NASA EEE Parts Bulletin
Special Edition: Known Good Die

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Known Good Die

There are many use cases for which engineers and designers elect to purchase bare die for their applications. They might integrate the die into a multichip module (MCM), or use it directly as a chip-on-board (COB), in order to meet size, cost, and mass constraints. In some special radio frequency (RF) applications a COB solution might be required to minimize the inductance and capacitance of integrated circuits leads. Furthermore, many manufacturers purchase bare die from other providers and integrate it into their packaged parts. The term "known good die" (KGD) is commonly used when referring to these die purchases; however, it is not well defined and might have different meanings depending on the manufacturer or specific use cases. In this bulletin, we describe what KGD might refer to and some of the detailed flows that KGD go through at different manufacturers.

"QML Die" in MIL-PRF-38535

Under MIL-PRF-38535, "QML die" can have several different meanings. The first is Qualified Manufacturers List (QML) die that is covered by Appendix A in the Standard Microcircuit Drawing (SMD) of the part that is offered in die form. This is commonly referred to as "SMD die" and is assigned a die code of "9" in the QML part number's case outline position. **Figure 1** shows an example of such a part (5962-96663). It is important to note that the manufacturers that offer the SMD die are also expected to offer the fully packaged part (per the SMD) on the QML listing.

Figure 1. SMD die example showing the die code.

For QML die products, the minimum screening steps are listed in the SMD (Section A.4.2). Some manufacturers might elect to do more testing than the minimum requirements, shown in **Figure 2** (from 5962-96663).

Figure 2. SMD die minimum screening required.

The 100% wafer probe includes functional and parametric testing sufficient to make the packaged die capable of meeting the electrical performance requirements listed in the electrical characteristics table of the SMD, which lists parameters throughout the part's rated temperature range. It is important to note that QML die is not required to go through temperature cycling or burn-in at the die level. However, as specified in MIL-PRF-38535, Section 4.2, all QML integrated circuits shall meet the requirements of the screens specified in Tables 1A and 1B of the specification whether or not the actual testing has been performed. The manufacturer might elect to eliminate or modify a screen based on supporting data that indicates that for the QML technology, the change is justified. For example, many manufacturers have optimized their wafer probe process and in agreement with the Defense Logistics Agency (DLA) perform it only at 25°C. If such a change is implemented, the manufacturer is still responsible for

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ets all of the performance, rements of MIL-PRF-38535. s is performed on packaged quality level. Furthermore, r devices to be delivered as nples from the wafer lot shall accept level of 10(0).

e is one that comes from a y/line/process that has been vered under a QML-38535 ML die sales are not listed in icate of Conformance (CoC) oved fab would exempt the erforming a site audit of the ype of QML die are: National Texas Instruments (TI), or elling their wafer/die from ies/facilities/lines/processes s.

ove, the term "KGD" is not meanings for different ent products. Currently, fine KGD.

PRF-38534 defines KGD as "a ty and reliability level as an

RF-19500

ied Products List (QPL), die is s, JANHC and JANKC, which of the standard. Military- MIL-PRF-19500 JANHC die, classified as MIL-PRF-19500 e manufactured and sourced facility that has been used to e QPL. Manufacturers of QPL s can be either in-house or ust be audited and qualified See **Figure 3** for an example 9500 die (JANHCAR2N2857). specifies the screening and or JANHC and JANKC die. The requirements are congruent t evaluation requirements.

Figure 3. Example specification of a JANHC die.

JANHC and JANKC QPL die are electrically probed for key electrical parameters, and defective die are identified during this process. Wafer screening requirements are specified in Paragraphs G.5.2 through G.5.2.7. Screening consists of 100 percent electrical test, 100 percent visual inspection of die, and then additional screening of sample die assembled into packages. The minimum sample size is 10 die for each JANHC wafer inspection lot and 22 die for each JANKC wafer inspection lot. The QPL sample die will be assembled into the appropriate package by the QPL manufacturer prior to going through the screening process steps 4–7 listed in Appendix G, Table II, of MIL-PRF-19500. These include temperature cycling, mechanical shock or constant acceleration (JANKC die only), electrical test (read/record), high-temperature reverse bias (HTRB), electrical test read/record, burn-in, electrical test read/record, steady-state life (JANKC die only), electrical test read/record, wire-bond evaluation, die-shear evaluation, scanning electron microscope (JANKC die only), and radiation-hardness assurance. Appendix G, Paragraph G.5.4 specifies that die shall be stored in dry nitrogen or another inert atmosphere. All MIL-PRF-19500 QPL die are manufactured on a DLA-audited and -certified manufacturer's wafer fabrication processing facility/line. To ensure traceability, the DLA-qualified manufacturer will provide a CoC for the die manufacturer, as required per MIL-PRF-19500, Paragraph 3.7.

MIL-PRF-19500 does not define KGD, nor does it permit non-QPL die to be used in MIL-PRF-19500 qualified products.

Manufacturers' Die Offerings

Many manufacturers offer products in die form at various quality levels. For example, the following manufactures offer SMD die per MIL-PRF-38535 as described above: Analog Devices, Cobham, Honeywell, Mercury, Microchip, Micross, Renesas, STMicroelectronics (ST), and TI. Some examples of

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manufacturers that sell QPL tified wafer foundries/process chip, Semicoa, Sensitron, and section we'll describe a couple vels offered by some MIL-PRF- demonstrate a few available

pace-qualified products in die e products are offered in two Model (EM), and Flight Model ered in two different flows, the packaged products are ce Components Coordination neral manufacturing flow for own in **Figure 4**.

roelectronics die flow.

the Engineering Model Quality 1), whether they are QML or ie form come from a qualified th a CoC. The EMs are not reening or testing. ST space FM oduct's SMD (they are SMD die he FM parts follow the Die lity Specification (TN0873)[1]. sists of a visual die sort that 010 Condition A for QML-V die, . **Table 1** summarizes the EM

ectronics EM and FM die.

t identified interest from its such as burn-in or 100% high- and/or low-temperature test at electrical wafer sort (EWS), commonly referred to as KGD. ST's QML-V products are proposed in die form only when it can be agreed with DLA that an EWS at 25°C plus a wafer lot qualification test on 25 pieces at -55°C, +25°C and +125°C is sufficient to make the packaged die capable of meeting the electrical performance requirements of the SMD.

TI offers a wide variety of products in die form. TI defines KGD as "die tested to the same quality and reliability standards as their packaged equivalents" [2]. **Figure 5** shows TI's die parts categories.

Die Sales
Class Q and Class V Known Good Die - die fabricated, tested, and qualified in compliance with MIL-PRF-38535 QML Class Q or Class V and specified in a Standard Microcircuit Drawing (SMD). RHA is available.
Military and Space Grade Tested Die – Tested Die fabricated on a MIL-PRF-38535 certified manufacturing line and tested for DC and functional performance only at ambient temperature. Legacy
Known Good Die (KGD) – commercial grade die specified for full performance over a specified temperature range.
Commercial Tested Die (TD) – commercial grade die tested for DC and functional performance only at ambient temperature.

Figure 5. Texas Instruments die categories.

An example flow of a QML-V die is shown in **Figure 6**.

Example Flow (QMLV Class V die): Wafer Fabrication; Wafer Tape Mount; Multiprobe; Saw; Incoming Wafer Inspection; Sort / Pick & Place; Backgrind; Die Inspection; Post Backgrind Inspection; Pack

Figure 6. Texas Instruments example QML-V die flow.

TI's datapack available for QML die includes the data for Group C, wafer lot acceptance (Class V only), and Group E (radiation-hardness-assured only). However, the attributes (yield) and variables (read and record) are not available. TI does not offer catalog burned-in die at this time. TI does perform testing at multiprobe—for example, VBOX, GOI, and IDDQ—to ensure quality of the die. Wafer fabrication includes engineering parametric testing (test structures), wafer-level reliability testing (WLR), and outlier controls. During feasibility studies, a candidate for die sale is evaluated for packaged-device electrical-yield performance and operational life without burn-in. If either is deemed unsuitable, the device will not be released in die sale.

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Standards Update - Crystal Oscillators

- **Crystal Oscillators (Martinez, GWG, DLA-VA)**
  - **Background**
    - During the DLA audits of crystal oscillator suppliers, we found that no one was buying QPL Class S oscillators. Instead, the manufacturers were selling catalog parts to their own "Class S-like" flow.
    - Simply stated, the specification MIL-PRF-55310 was out of date and needed a lot of work.
    - DLA lead auditor at the time made presentation in CE-12 Space Subcommittee meeting chaired by NASA.
    - NEPAG GWG group worked with DLA to revise the specification (Y. Afroz of DLA-VA worked very diligently to make it happen)
  - ***Return on investment for NASA flight projects***
    - ***NASA is in a unique position to lead the community in updating requirements for the use of crystal oscillators in space.***
  - **FY19**: NASA worked with DLA and other organizations to update MIL-PRF-55310, the current released version is Rev. F.
  - **FY20**: Supported the Aerospace proposed amendment. This Amendment has manufacturers buy-in. It has been released.
  - **Impact of coronavirus: None**

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Analog to Digital Converter BoK

- **A/D BoK (N. Ovee, F. Irom)**
  - **Background**
    - The last NASA A/D selection guide was published by S. Agarwal in 2005
    - Many new products have since become available for NASA applications.
    - This effort is to update the document.
  - ***Return on investment for NASA flight projects***
    - ***The updated guide would be a resource for NASA designers of Analog-to-Digital converters.***
  - **FY19**: We collected information during L@L Webinars but due to resources limitation (flight projects had priority), the guide could not get started.
  - **FY20 Status**: The number of A/D and D/A products has proliferated in the last 15 years, (close to 1000 counting standard and non-standard parts). Therefore, this task was broken down into phases. The first phase was the radiation aspect of standard A/D and D/A devices. This phase was completed and the document delivered to the HQ. This was a NEPAG supported telework task. Rest of the work was put on hold.
  - **Impact of coronavirus: None.**

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Connectors

- **Connectors (Billig, Gutierrez as backup)**
  - **Background**
    - Connectors have had many problems
    - M. Sampson in late 2019 asked that a small task be opened to
      - Have NASA presence in some of the prime conferences
      - Support DLA audits of widely used connector suppliers
    - JPL Wire, Cable and Connector specialist Ray Billig was asked to provide support. Tony Gutierrez was designated as his back-up.
  - ***Return on investment for NASA flight projects***
    - ***NASA to help provide solutions to the nagging issues with connectors.***
  - **FY19:** (a) Participated in a DLA audit.
  - **FY20:** (a) Presented at a conference. (b) supported all NASA meeting on wires and connectors.
  - **FY21: On hold**
  - **FY22: Provided limited support**
  - **Impact of coronavirus: Yes – no audits, no technical meetings.**

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