National Aeronautics and Space Administration

NASA

NEPP/NEPAG DC/DC Converter & Hybrid Working Group

John E. Pandolf

Lead EEE Parts Engineer

NASA Research Center

EEE Parts Office

Electronics Systems Branch

(757) – 864 - 9624

John.E.Pandolf@nasa.gov

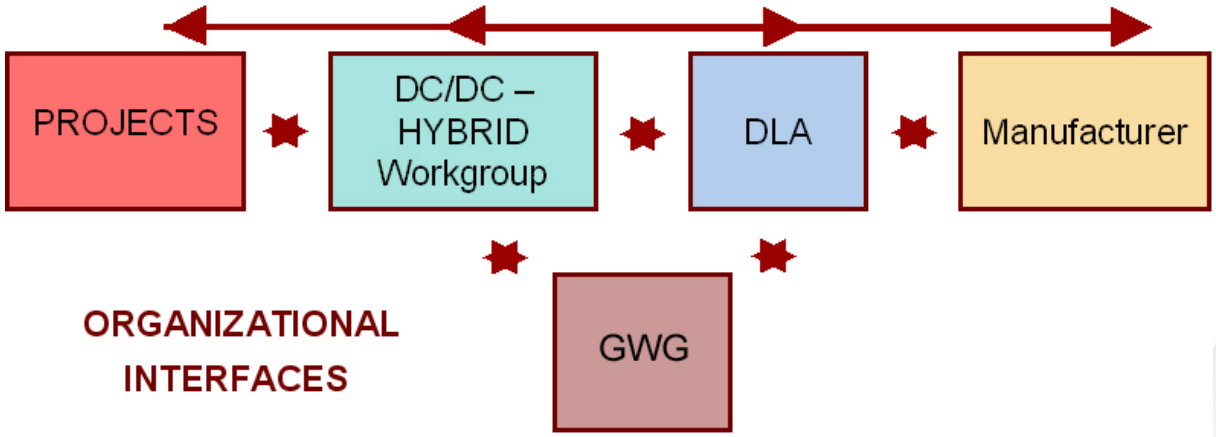
June, 2022

www.nasa.gov
http://engineering.larc.nasa.gov/

Introduction

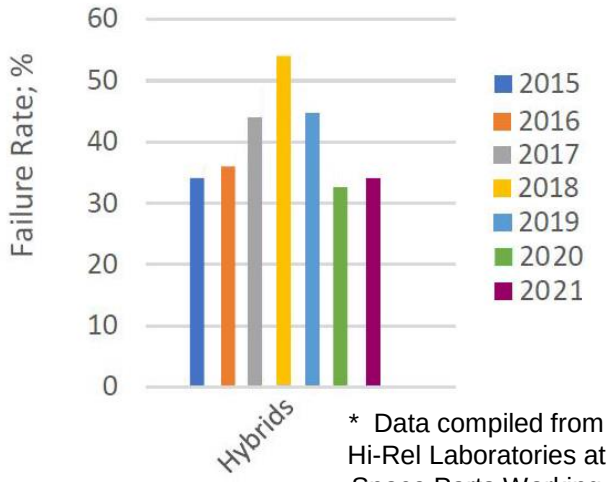
- **Mission:** Create & Maintain Working environment for the communication of critical information on key issues regarding the reliability of Hybrid Microcircuits (with specific emphasis on DC/DC Converters) addressing all aspects of product performance specifications, manufacturing, & procurement.

- **Monthly Teleconferences**
  - First Wednesday of every month @ 1:00p.m. EST
    additional when / as necessary…….
  - Usual Attendees: NASA Centers & JPL, Aerospace Corporation, NAVSEA & DLA(L&M)



Background

- **Founded:** Spring 2001 time frame to help reduce risk of using DC-DC converters in hardware across the Agency. Initial thought was to provide forum for users to communicate about their converter experiences & challenges.
  - Similar forum to NEPAG meetings
  - Lead by Langley EEE Parts personnel,
  - Small User forum initially
  - All Hybrids (all MIL-PRF-38534 product)
  - Power Converters still primary focus
  - High risk commodity based on DPA Failure Rate



* Data compiled from Hi-Rel Laboratories at Space Parts Working Group Conference presentation (2000-2022)

- **Monthly Teleconferences**
  - Customer Focused - additional meetings when/as necessary…
  - Select Topics - Address User needs:
  - Guest Component Vendor Product Briefings / Participation
  - Utilize Govt.Working Group for broader scope issues – such as

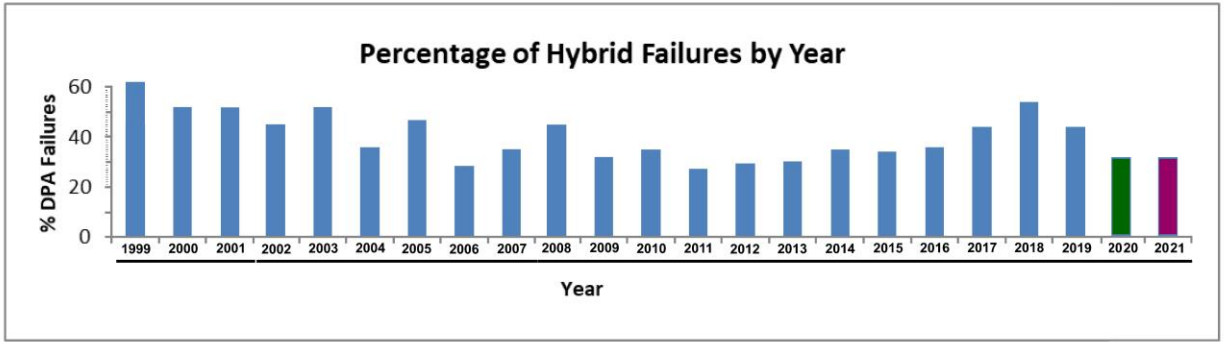
PIND, Hermeticity, Gas Analysis, Solder Seal…etc…as they apply to other commodities

Motivation

Switch Mode Power Supplies (DC/DC Converters)

- Enormously Complex due to Extreme Miniaturization
- High Risk due to type of Parts, Materials & Process used for assembly
- Paramount Programmatic Penalties [Budget, Time]
- Manufacturing challenges
  - Assembling hundreds of components using various techniques in a hermetic package (typically $1in^2 – 5in^2$)
  - Low production numbers
  - High reliability in extreme environments [verified by sampling & screening]

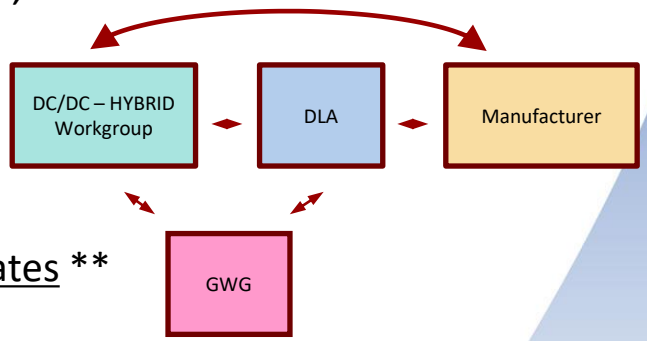
* Data compiled from Hi-Rel Laboratories at Space Parts Working Group Conference presentation (2000-2022)



Working Group Key Points

General Topics

- Sharing of data on purchases, requirements, specifications (SMDs vs. SCDs)
  - Customizations by Centers and Product Performance Issues
  - Discussions on Failure Mechanisms, Purchase Lead time and delay issues
- Sharing of information on failures, delays, GIDEPs, etc.
- Updates from Defense Logistics Agency
  - Moves, Consolidations, New ownership
  - Alternate Methods, ** specification changes/updates **



- Attendance at JEDEC / G-12 Conferences (JC-13* Government Liaison)
  - Attend 13.5 Hybrid Working Group Meetings (**Virtual** Attendance for 2021)

* JC-13 is responsible for standardizing quality and reliability methodologies for solid state products used in military, space, and other environments requiring special-use condition capabilities beyond standard commercial practices. This includes long-term reliability and/or special screening requirements.

Key Points (& more)

General Topics

- Manufacturer Presentations – Existing & New Product Line Introductions
- Radiation performance / Testing
- Review of DLA Audits for certification/re-certification of Manufacturer facilities
  - (No Major Supplier visits for the Last 15 months ….) (considered alternatives)
  - (Discussed the various aspects of considering Virtual Audits.) (Group was Reluctant)
- Review of Specifications
  - MIL-PRF-38534 (L), General Specification for Hybrid Microcircuits
  - MIL-STD-883, Test Method Standard for Microcircuits (X-ray, PIND, etc…)
  - Continuous Improvement efforts on existing Specification(s)
    - Element Evaluation, Worst Case Circuit Analysis(WCCA)
  - Enhance Quality Assurance Requirements for Space Application grades

Information Analysis

General Topics

- Manufacturer Proposals – Existing Product Line Compliance Challenges
  - Vendor Alternate Method Proposal Reviews
- Radiation performance / Testing
- Review of Element Evaluation Tables & Test Methods
  - (Commercial Element Electronic part screening)
  - (BME Capacitor screening , Tantalum Capacitor Weibull grading)
  - (Subject Matter Expert Consultations)
- Review of Specifications
  - MIL-PRF-38534 (L), Element Evaluation Table Integrity
  - MIL-STD-883, Test Method Standard for Microcircuits
  - Continuous Improvement efforts on existing Specifications
  - Enhance Quality Assurance Requirements for Space Application grades

Monthly Meeting Topics

Specific Monthly General Topics

- Based on Current events, Working Group User Concerns & Visionary
- Hybrid SMD Thermal Datasheet Performance Discrepancies
- Worst Case Circuit Analysis (Wording in 38534 section E.4.2.9)
- Review of Element Evaluation Tables & Alternate Test Methods
  - (Commercial Element Electronic part screening)
  - (BME Capacitor screening , Tantalum Capacitor Weibull grading)
  - (Subject Matter Expert Consultations)
- Review related Issues Associated Hybrid radiography (883-TM2012)
- Review Issues with Wire Bond to Package Lid clearance Verification
- Review Update to EEE-INST-002 (for use in the new 8739.11)

Monthly Meeting Topics(cont'd)

Additional Monthly Topics

- COVID-19 Pandemic Driven Quality/Reliability alternate Methods
  - Virtual Pre-Cap & Customer Source Inspections
  - Discussion on Expectations, Equipment Selection, usage and Methods
- Discussed Vendor Proposed Production Lot Definition
  - 38534 section 6.4.38 (Production Lot Homogeneity)
  - Discussion on Expectations for all aspects (PMP) for Purchase Order single lots
- Discussed Do's and Don'ts for Hybrid Life Test parts
- Review current status of Hybrid Vendor status & pending GIDEPS
- Review & Discuss User Community DPA failures
  - Internal Contamination
  - On-going Prohibited Materials issues (Pb Free Solders for example)

Monthly Meeting Topics(cont'd)

And Even More Monthly Topics

- We covered "a lot of ground" in 2021-2022 Lockdown Timeframe
- Manufacturer Guest Presentations
  - for current QML status
  - new product introductions
  - Alternate Method Proposals – commercial capacitor testing/element evaluation
- Review of Element Evaluation Tables for Die Thermal Testing
  - Table C-II and C-Iii
  - (Tri-Temp Disparity for Rev. L 38534 for Commercial Die Element screening)
  - (Table update introduced concerns over baseline parametric performance versus the maximum and minimum semiconductor and microcircuit dice performance)
- Metrics - 12 Month Timeframe for Meetings
  - 13 Meetings , Over-a-Dozen "Key" Topics & also tending "Walk-On" Issues
  - Average Attendance is about 12 (Attendance range is about 10-15)

Monthly Meeting Topics(cont'd)

More Details on the Monthly Topics

- Worst Case Circuit Analysis(WCCA) - for Mil-PRF 38534
  - For Robust Product Quality/Reliability – Design, Materials, Process, Test Verification
  - WCCA Documents the Addressing of Element Variation over Product Life Cycle/Environment
  - Drives Data Sheet Performance Claims – Verifiable by Parametric Test Results
  - Support for Survey Generation– DLA Distributed/Collected Feedback – HWG Analyzed & Interpreted
  - Survey analysis & results were used to assess proposed wording acceptability.
- Production Lot Homogeneity Definition - for Mil-PRF 38534
  - For Users with Single Lot Date Code purchases – Definition defines Homogeneity of Production Lot
- BME Capacitor Element Evaluation Concerns
  - Vendor specific alternate method proposal review/consultation(s) (Voltage Levels – Stress Tesing)
- GIDEP Alert related discussions - vendor QML status - stop shipment notices
  - Substrate Vendor Certification Issue – Affected Major Hybrid Supplier – **Customer Notification Letters**

Monthly Meeting Topics(cont'd)

More Details on the Monthly Topics

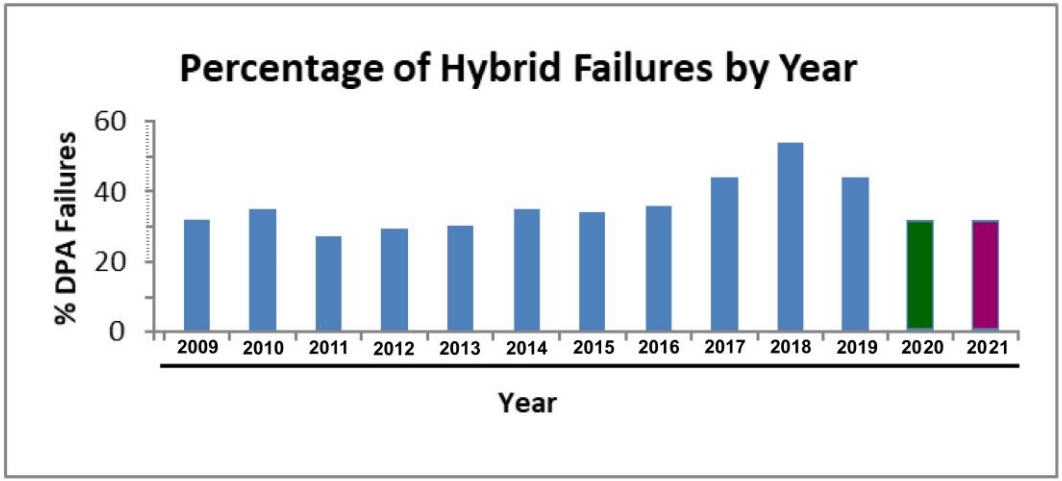
- Tri-Temp Disparity in Element Evaluation tables in section C.3.3.4.3
  - Agreement to initially test at 25'C **only** (Table C-II-1 and C-II-1a)
  - Elements go thru Burn-In at 125'C and then Post Burn-In is performed at Tri-Temp (-55,25,+125)
- User Walk On Topics –
  - Guideline for SCD formulation when qualified product is not available
- Prohibited Materials - User DPA Test Data results
  - - Pure Tin usage topic - User Experiences – Internal Inspection – High Temp Solders
- Non-Destructive Bond Pull Alternate Method review/consultation
  - Challenges when Device Bond Pads are small – but multiple wire bonds are required
  - Test Hook placement/geometries – lack of space – wire damage concerns
- JEDEC JC13.5 Meeting preparations – topic concerns
  - NASA/GWG "One Position"

Failure Trends

Singe Decade Trending for Hybrid Microcircuits

- Based on DPA Test Results – Snapshot – Relative indicator for trending
- Used as indicator for where triage may be needed.
- Failures for various reasons (in 2021): (of the 33% that failed)
  - 42% failed Internal Visual Inspection, 19% failed X-ray
  - 15 % failed Prohibited Materials, 25% Failed SEM (scanning electronic microscopy)
  - 9% failed Bond Pull, 16% RGA (residual gas analysis), 3% External Visual
  - 11% PIND
  - 3% Hermeticity

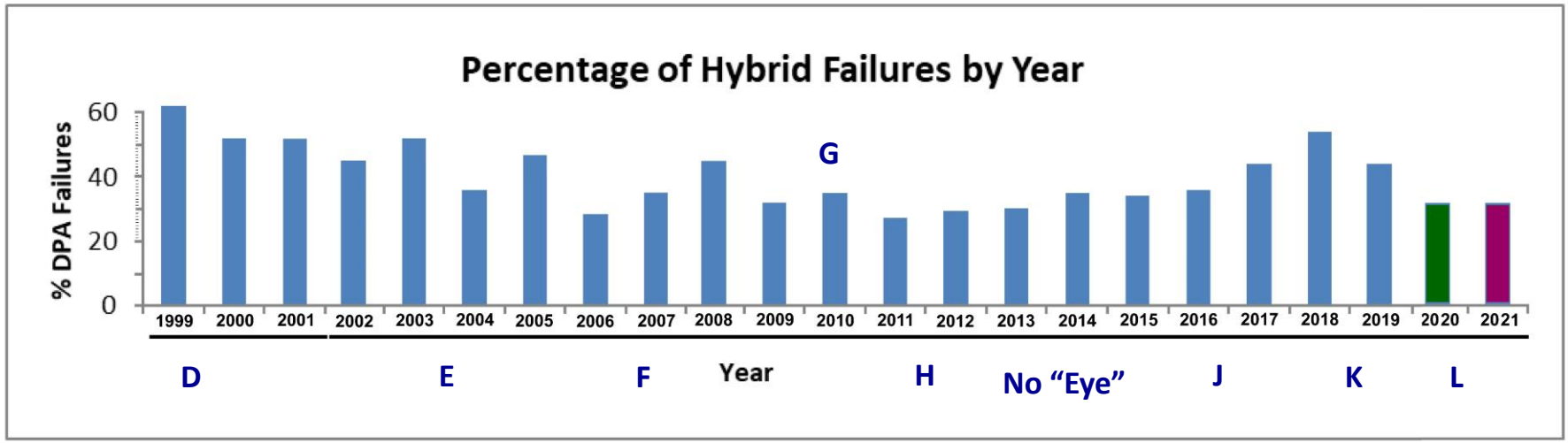
* Data compiled from Hi-Rel Laboratories at Space Parts Working Group Conference presentation (2000-2022)



Failure Trends (& more)

Two Decade Trending for Hybrid Microcircuits

- MIL-PRF-38534 rev(D) applicable for 1999
- MIL-PRF-38534 rev(K) applicable for 2019 (rev L released in Dec.'19)
  - Letters below: Denote what MIL-PRF-38534 revision was in effect



* Data compiled from Hi-Rel Laboratories at Space Parts Working Group Conference presentation (2000-2022)

There is more trending analysis work to be done here !

Performance Specification

DLA Approved QML-38534 Vendor Listing

- 31 approved vendors (Typically we discuss the top 5)
- Various functions in addition to DC-DC converters
  - Optical Imaging Detectors, RF, Amplification, Opto-couplers, Motor Controllers, Digital Communications
  - Dilemma: Products with single die and few passive parts – look like MIL-PRF-38535 type product, are qualified and approved as MIL-PRF-38534

Current Specification at Revision Level - L

- Approved December 2019 – Change Summary was about 40+
  - About 2 years of work to address related issues, rewording and change coordination (for element evaluation, **Worst Case Circuit Analysis**, periodic conformance, **Production Lot homogeneity Definition**, etc….)
- No Significant Changes
  - Completed updates to Element Evaluation Tables (Die Tri-Temp fix in the works)
  - Addressed “existing inventory” for compliance to new revision level L

Performance Changes +

- **Current Specification at Revision Level – L (continued)**
  - Rev L (Hybrid User community working to change WCCA & Single LDC at this time)
  - Element Evaluation tables are considered strong and unchanged
    - Only minor typos are considered needing attention – no philosophical
    - Microcircuit/Semiconductor Die Tri-Temp typo correction in the works
  - For Class K: “Group C inspection will be performed periodically within a maximum of five years for periodic re-qualification”.

  - In Progress for Rev M
    - Restoring / Enhancing Worst Case Circuit Analysis (WCCA) requirements
    - Rev K removed “Worst case” from “circuit design analysis” requirement
    - Add WCCA parameters such as initial tolerances, temperature, aging, radiation (if applicable)

<u>Key Performance Criteria for Robust High Quality & Reliability type products</u>

Current Actions

- **Audits**
  - No H & K Hybrid Audits since early 2020 [NASA Representation]
    - CoViD-19 Travel Impact also limited FY2021 audits (none)

      (In preparation for CoViD-19 restrictions rescinding – User community has audit "wish list" queue for major suppliers)
    - Urgent audit of manufacturer experiencing issues (as necessary)
      - or when factory/production lines are physically moved
    - Under review during typical audit
      - Derating Plan / Stress Analysis
      - Failure Analysis (Customer returns)
      - Testing

    Audit Update:

    1st Audit completed May'22
    - Reports Submitted/Available on NASA SCIC website (replaced SAS)
    - *** Still Working with JC-13.5 to get WCCA approach/wording changes implemented & ensure standardization of all hybrids application reliability performance. ***

Future Actions

- **Military Specifications**
  - MIL-STD-883 TM 2017 (Internal Inspections – Hybrids)
  - Gen Spec for Hybrids (MIL-PRF-38534) next revision level
    - Completed of Rev L work – Only Update changes envisioned (typos?)
    - Get WCCA and Production Lot definitions Updated …taking awhile.
    - Need to consider Retrospective review of changes in order to….

- **Continuous Improvements to Selection Tool(s)**
  - Over 1500+ DC-DC converter SMD's
  - Need to include Point of Load converters
  - Understand custom environmental performances
    (temperature, linear derating, WCCA etc…)

Thoughts Moving Forward

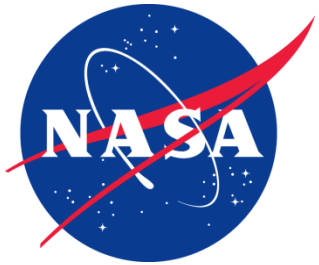
- **Where do we need to be 5 years from now.**
  - Vendor Audit Performance/Analysis and Prioritization
  - Ensure Spec. for Hybrids (MIL-PRF-38534) is “clean”/no loop holes
  - Better Selection tools for Hybrids to aid in reducing application risk

  - When do we start planning for the use of COTs related to Hybrids?
    - We’re already doing it via Alternate Method approaches with 38534 Vendors ***
    - Limited Use - via exception – heritage product – spec changes – conservative designs

  - We need to ensure continued involvement from all NASA Centers!
  - Application & Product failure data needed for awareness/metrics
  - Need information on procurements, failures, CSI’s , lessons learned, etc.
  - Virtual Inspection Tools – We can Thank CoVid for this inspiration.

    But acceptance of applicability/use will be slow by the user community.

QUESTIONS / FEEDBACK


NASA