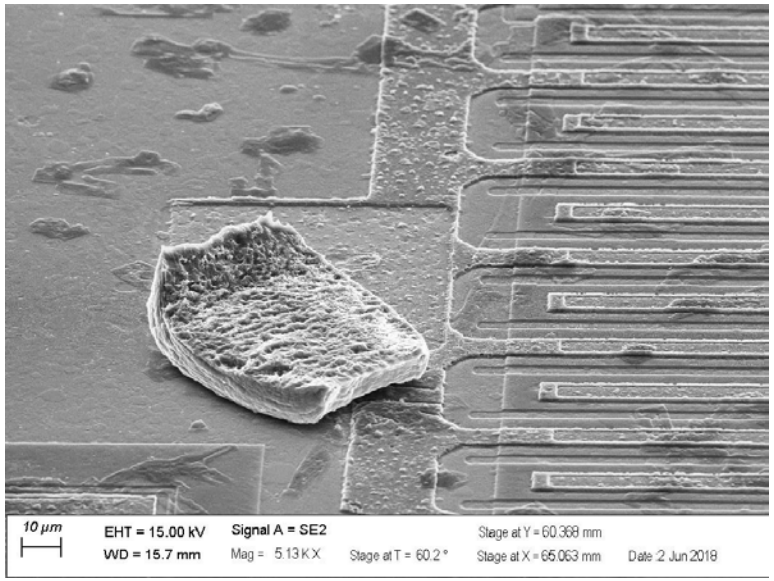
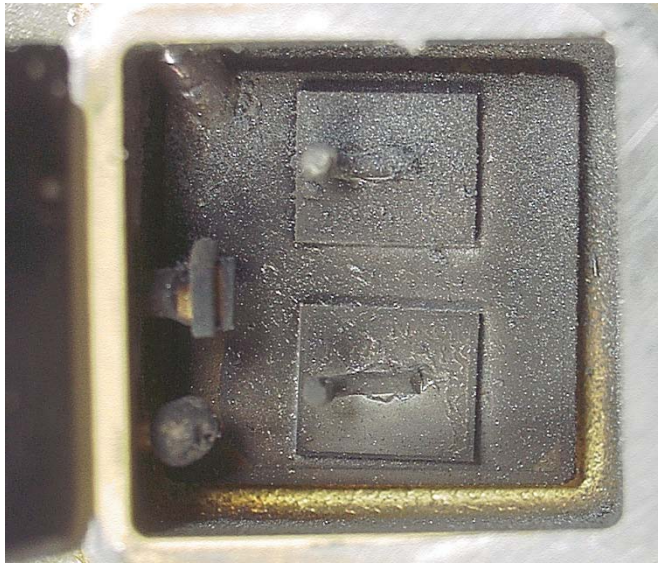
# NASA GSFC EEE Parts: DPA and FA Summary

Destructive Physical Analysis




Failure Analysis



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NASA GSFC Code 562 EEE Parts, Photonics and Assembly Branch

June 16, 2021

# Acronyms

| | |
|---|---|
| CSAM | C-Mode Scanning Acoustic Microscopy |
| DPA | Destructive Physical Analysis |
| EOS | Electrical Over Stress |
| EEE Parts | Electrical, Electronic and Electromechanical Parts |
| ESD | Electro Static Discharge |
| FA | Failure Analysis |
| GSFC | Goddard Space Flight Center |
| IGA | Internal Gas Analysis |
| NASA | National Aeronautics and Space Administration |
| PIND | Particle Impact Noise Detection |
| PEM | Plastic Encapsulated Microcircuit |
| PMA | Prohibited Materials Analysis |

# Selection of Parts for DPA

- NASA GSFC projects follow EEE-INST-002 for selection and testing of EEE parts
- EEE-INST-002 defines when DPA should be performed based on combination of factors that includes commodity type, quality level of part type selected and project level (risk tolerance)

**Table 2 SCREENING REQUIREMENTS FOR HYBRID MICROCIRCUITS (Page 2 of 2)**

| Screen | Test Methods and Conditions | Level 1 | | | Level 2 | | | Level 3 | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | H | Non-QML 5/ | K | H | Non-QML 6/ | H | Non-QML 6/ |
| 12. Radiographic 7/ | MIL-STD-883, Method 2012 | | X | X | | X | X | X | X |
| 13. External Visual 1/ | MIL-STD-883, Method 2009 | | | X | | | X | X | X |
| 14. Destructive Physical Analysis (DPA) | MIL-STD-883, Method 5009 | X | X | X | X | X | X | X | X |

**Table 3A CERAMIC CAPACITOR QUALIFICATION REQUIREMENTS 1/ (Page 2 of 3)**

| Inspection/Test | Test Methods, Conditions, and Requirements | Quantity (Accept Number) Level | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| **Group 4**<br>Humidity Steady State, Low Voltage 6/ | MIL-STD-202, Method 103, Condition A and MIL-PRF-123, Group B | 12(0)<br>X | 5(0)<br>X | N/A |
| **Group 5**<br>Solderability | MIL-STD-202, Method 208 | 5(0)<br>X | 3(0)<br>X 5/ | N/A |
| Destructive Physical Analysis | EIA-469 | X | | |

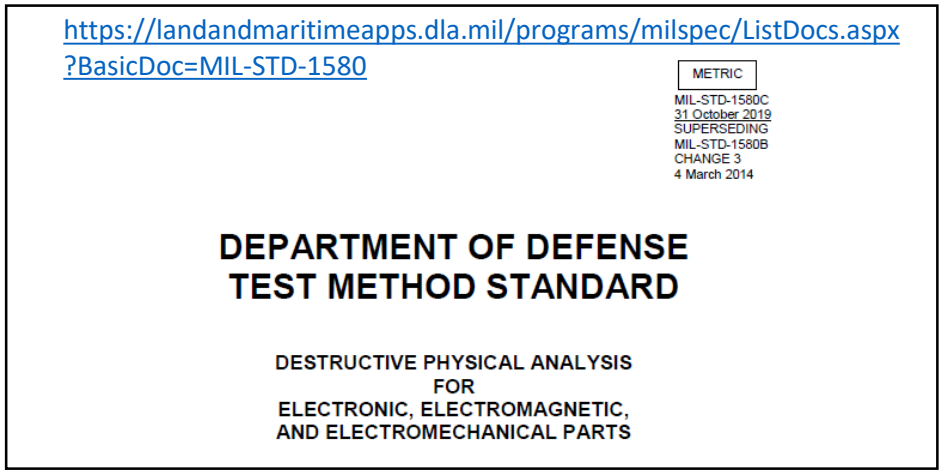
# About S-311-M-70

- DPA commonly performed per MIL-STD-1580:

  Destructive Physical Analysis for Electronic, Electromagnetic, and Electromechanical Parts

- NASA GSFC uses an internal S-311-M-70 document based on MIL-STD-1580 with several amendments:
  - Sample size
  - Prohibited Materials Analysis (PMA)
  - Capacitors
  - Ferrite beads

https://landandmaritimeapps.dla.mil/programs/milspec/ListDocs.aspx?BasicDoc=MIL-STD-1580

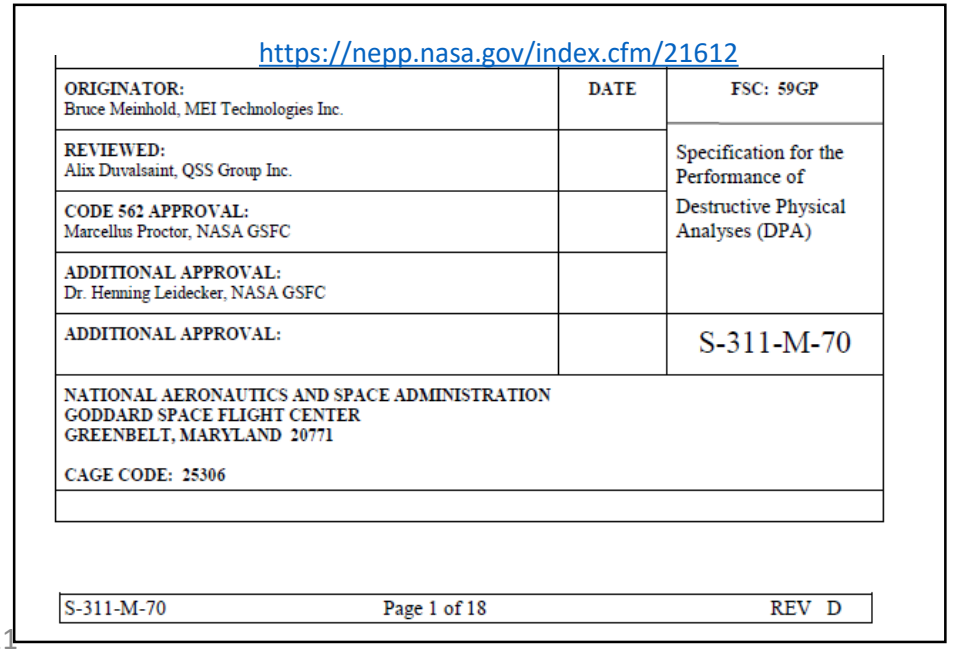


METRIC
MIL-STD-1580C
31 October 2019
SUPERSEDING
MIL-STD-1580B
CHANGE 3
4 March 2014

**DEPARTMENT OF DEFENSE**
**TEST METHOD STANDARD**

**DESTRUCTIVE PHYSICAL ANALYSIS**
**FOR**
**ELECTRONIC, ELECTROMAGNETIC,**
**AND ELECTROMECHANICAL PARTS**

https://nepp.nasa.gov/index.cfm/21612



| | | |
|---|---|---|
| **ORIGINATOR:** Bruce Meinhold, MEI Technologies Inc. | **DATE** | **FSC: 59GP** |
| **REVIEWED:** Alix Duvalsaint, QSS Group Inc. | | Specification for the Performance of Destructive Physical Analyses (DPA) |
| **CODE 562 APPROVAL:** Marcellus Proctor, NASA GSFC | | |
| **ADDITIONAL APPROVAL:** Dr. Henning Leidecker, NASA GSFC | | |
| **ADDITIONAL APPROVAL:** | | S-311-M-70 |
| **NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**<br>**GODDARD SPACE FLIGHT CENTER**<br>**GREENBELT, MARYLAND 20771**<br><br>**CAGE CODE: 25306** | | |

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# Tests Most Commonly Performed During DPA

External Visual

External Prohibited Materials Analysis (PMA)

X-Ray

PIND

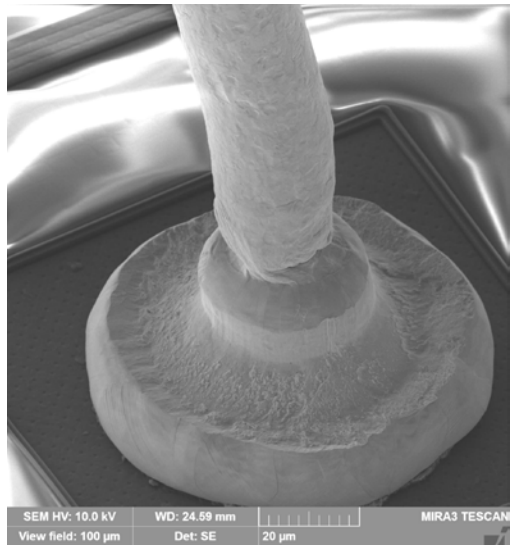
Hermeticity

Internal Gas Analysis (IGA)

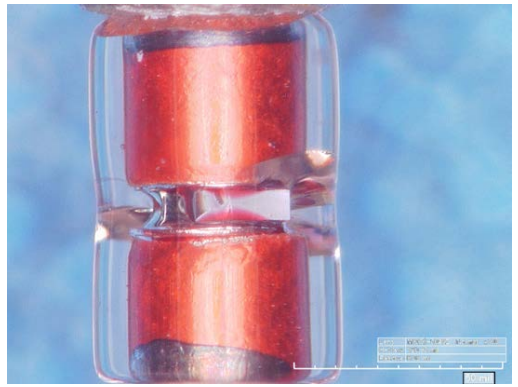
Internal Visual

Wire Pull

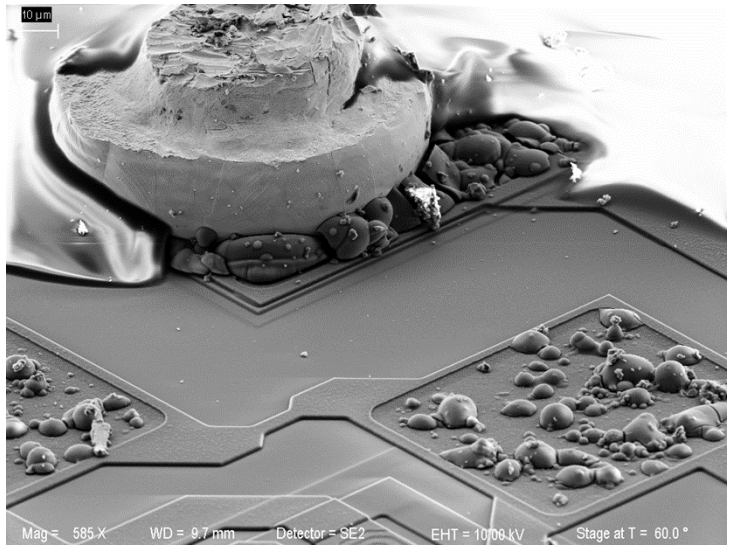
Die Shear




Wire necking above the gold ball bond – reduced wire pull strength



Gross Leak failure of diode – red dye penetrated through a crack to the die

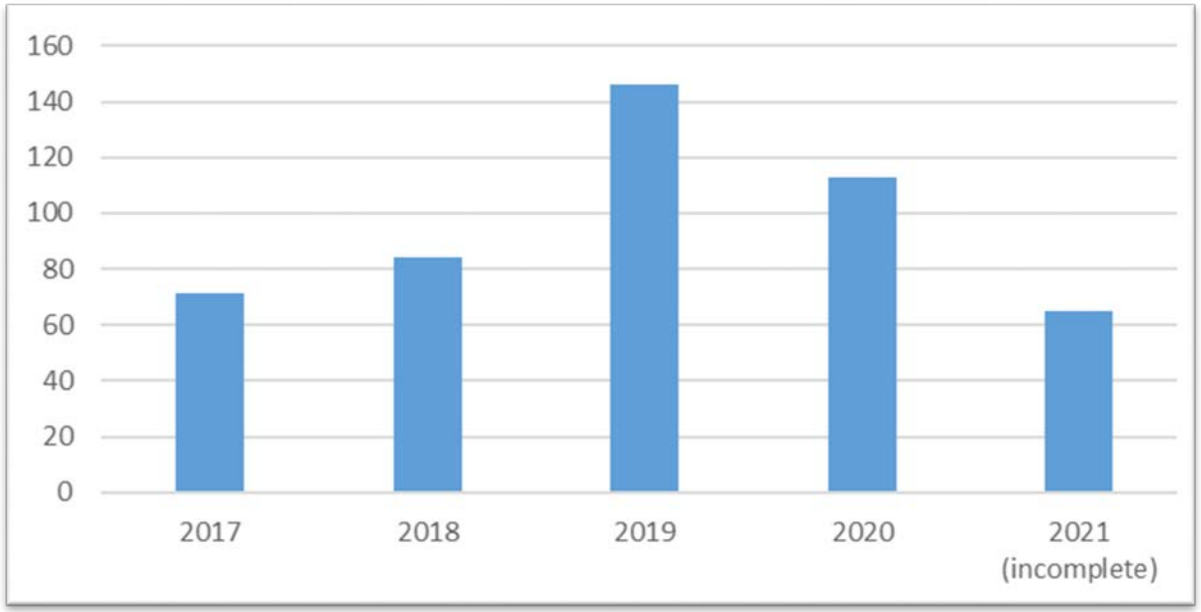



Corrosion of aluminum pad due to moisture ingress and elevated temperature exposure during screening

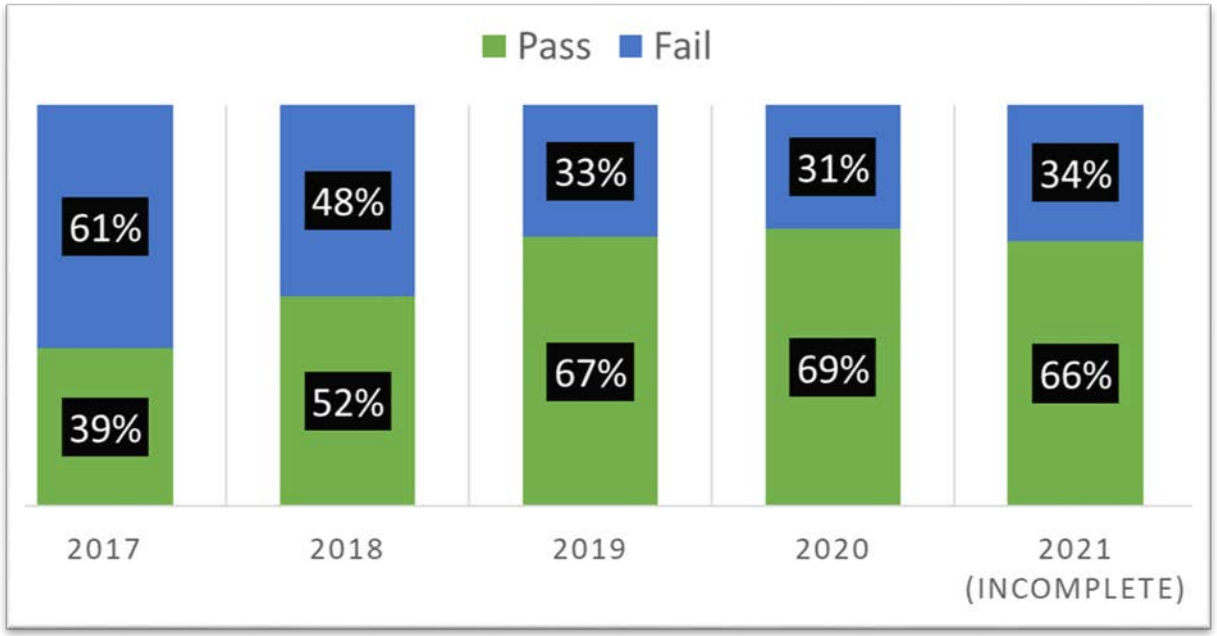
# Statistics of DPAs for 2017-2021*

(*) stats for 2021 are incomplete

## Total number of DPAs per year



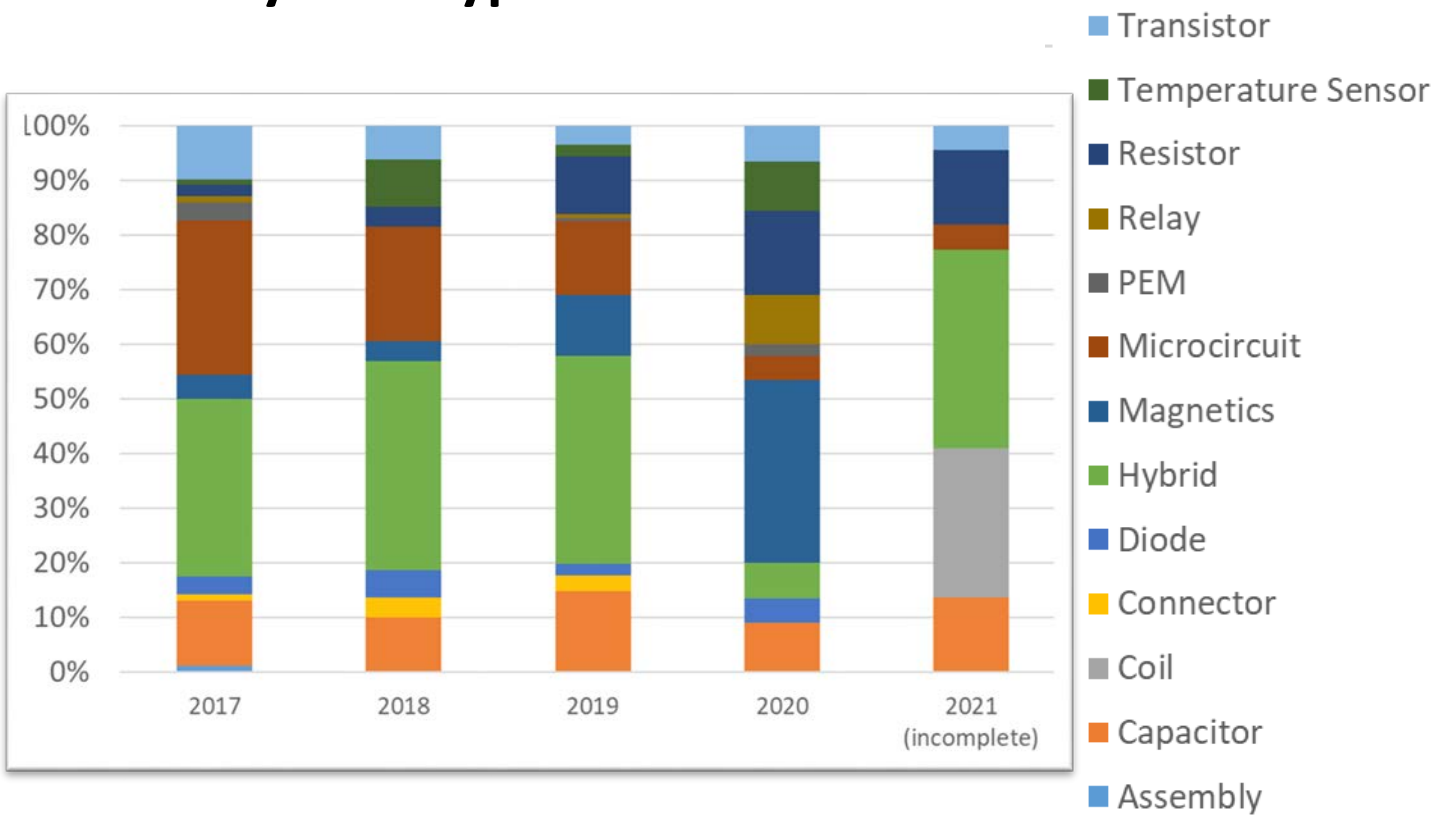

## Overall DPA Failure Rate



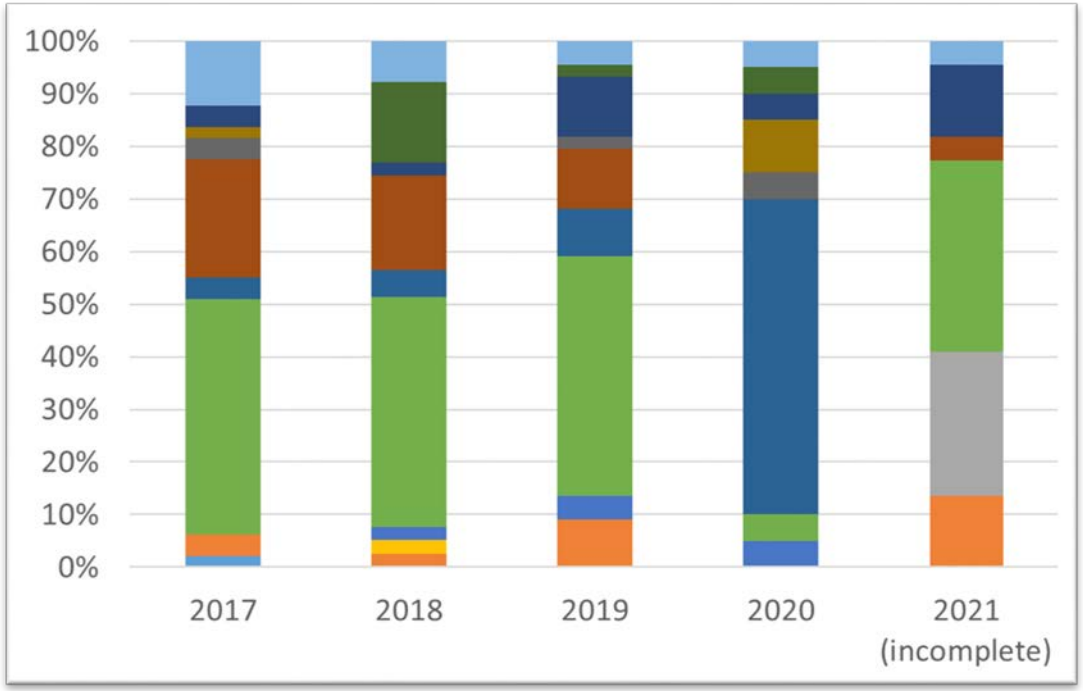
# DPA Failures for 2017-2021*

(*) stats for 2021 are incomplete

## DPAs by Part Type




## DPA Failure Rate by Part Type

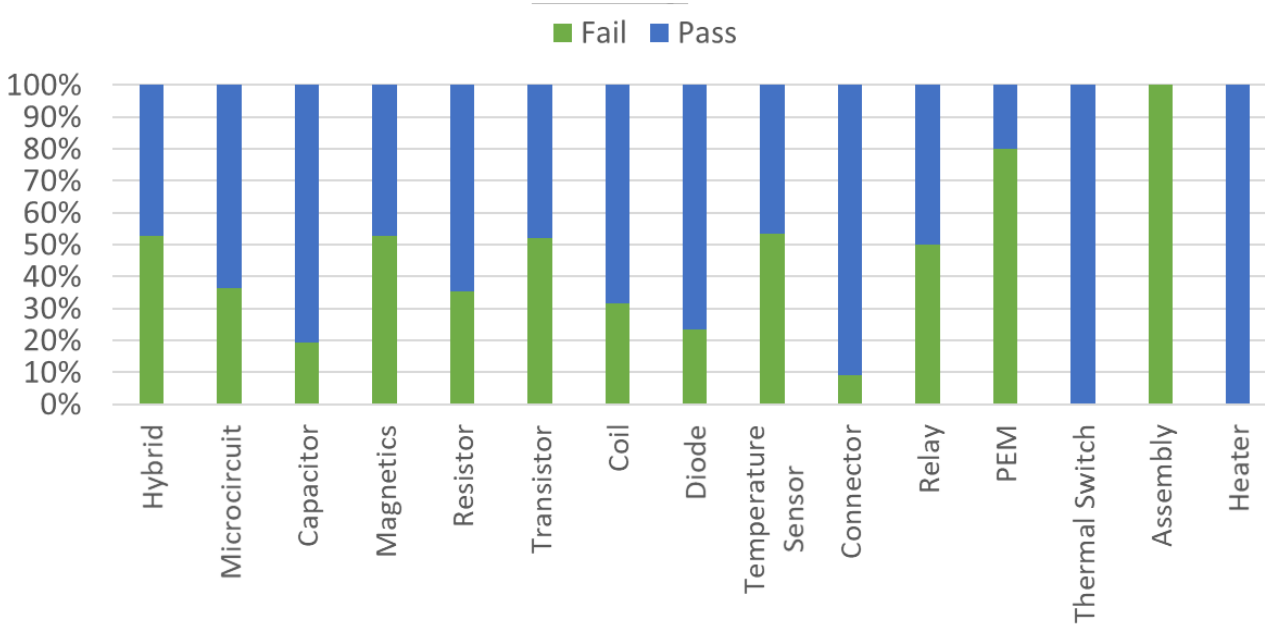


# Failure Rate by Part Type 2017-2021*

(*) stats for 2021 are incomplete

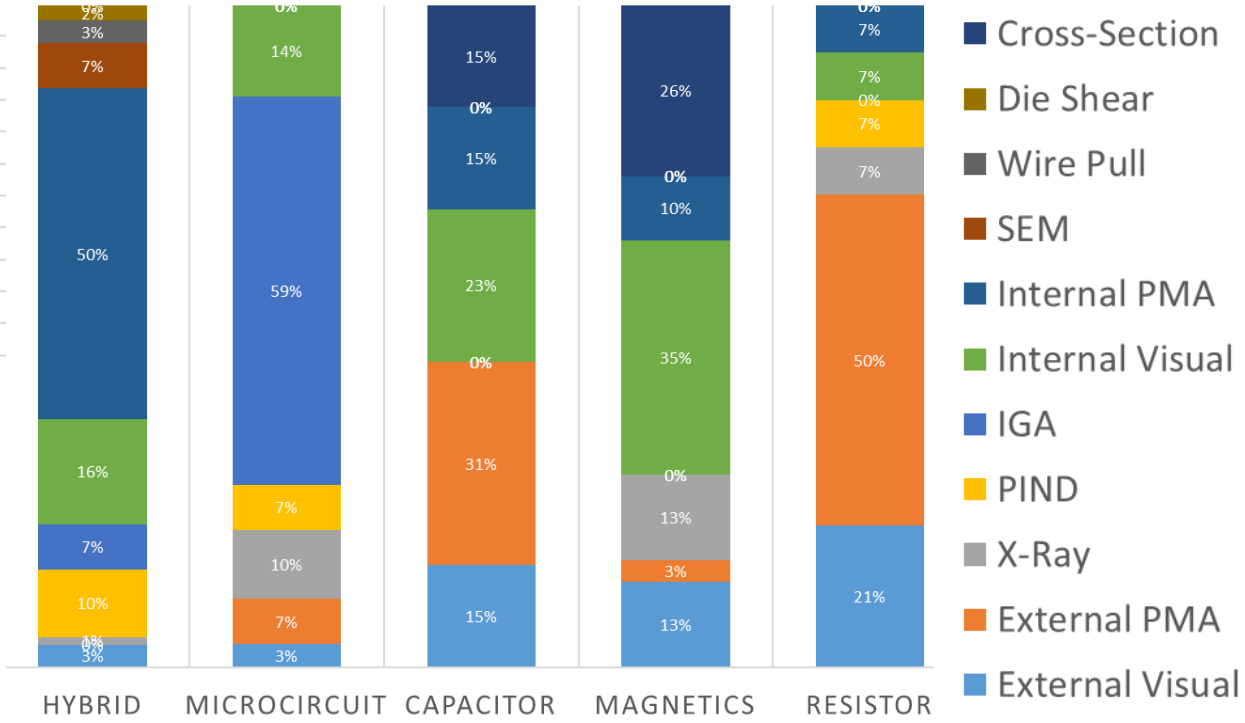
**DPA Failure Rate by Part Type**

**(2017-2021 Lumped)**



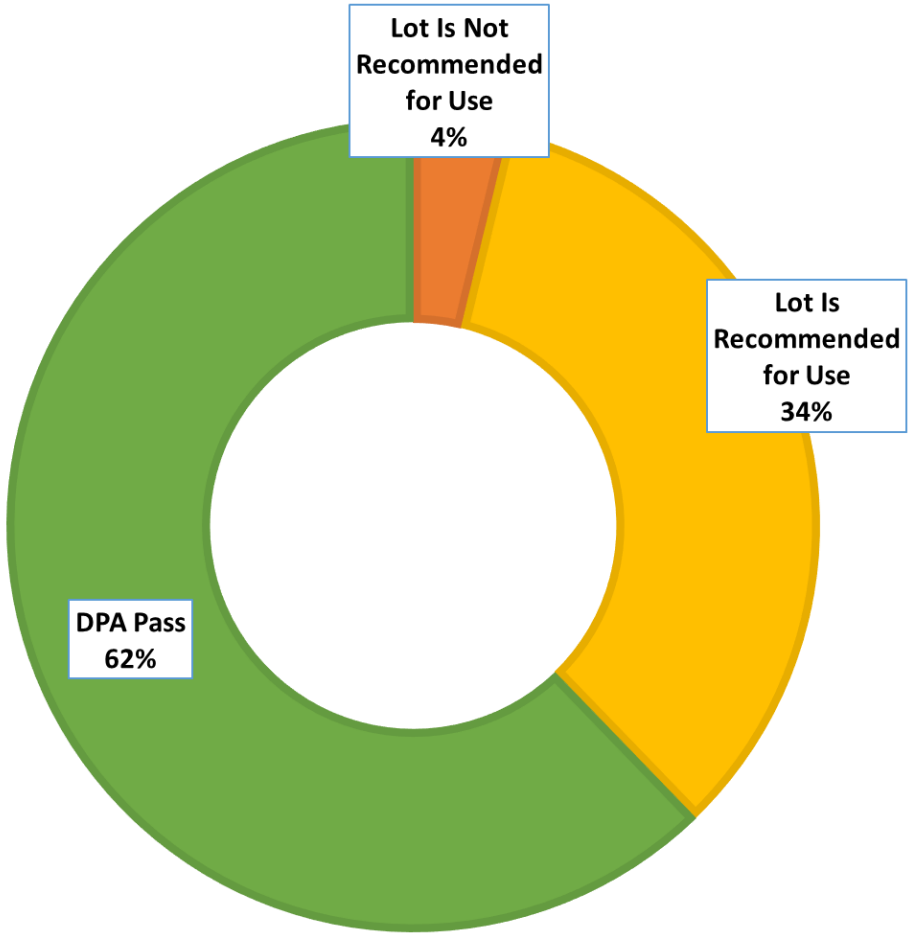

**Breakdown of DPA Failures within a Part Type by Test Type**

**(2017-2021 Lumped)**



# Disposition of DPAs for 2017-2021*

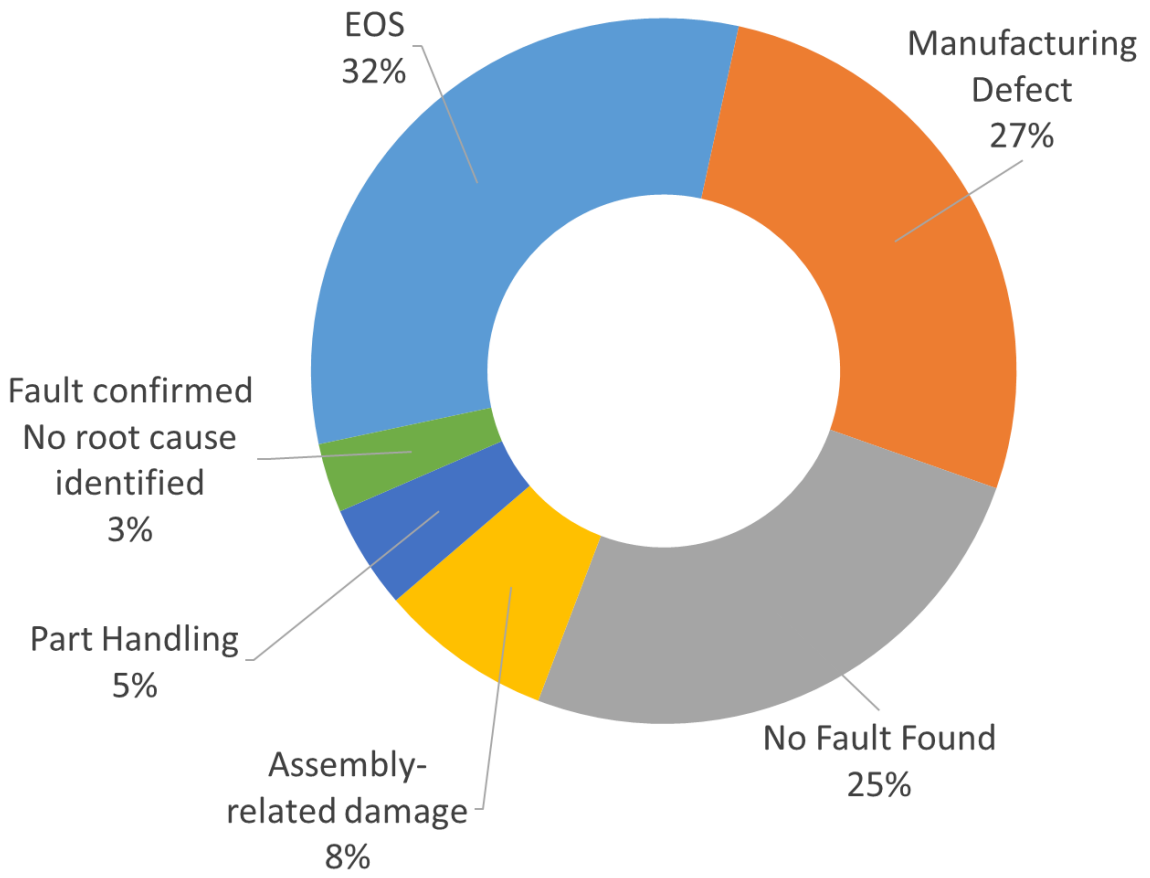
(*) stats for 2021 are incomplete




- DPA failures per S-311-M-70 (based on MIL-STD-1580) are dispositioned by a Failure Review Board to assess risk to the flight project
- Through review of data and/or performing additional testing, a lot may be deemed acceptable for use
- Examples of lots that failed DPA but were accepted for use
  - Failure of a transistor for external prohibited materials analysis (PMA) accepted as-is after solder dip is performed on the entire lot
  - Failure of a hybrid for internal prohibited materials analysis (PMA) accepted as-is for some vendors with known use of Pb-free materials inside the part
  - Failure of a hybrid for Internal Gas Analysis (IGA) showing fluorocarbon is accepted as-is after manufacturer demonstrates the fluorocarbon came from cleaning solution used prior to lid seal

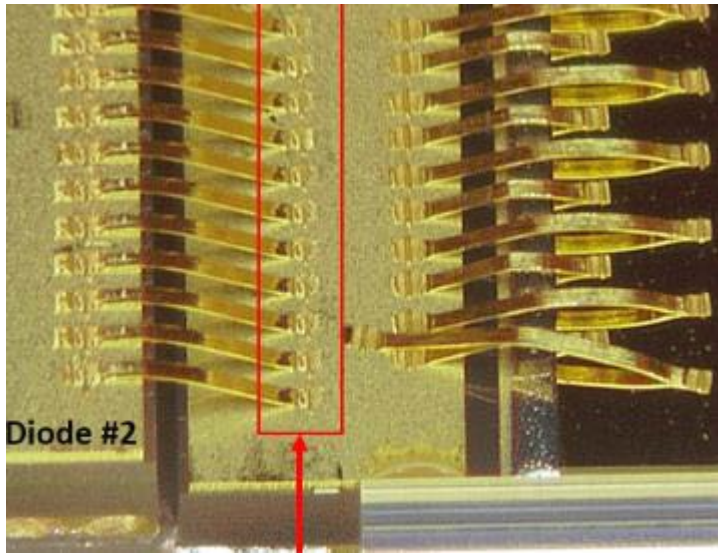
# Statistics of FAs for 2017-2021*

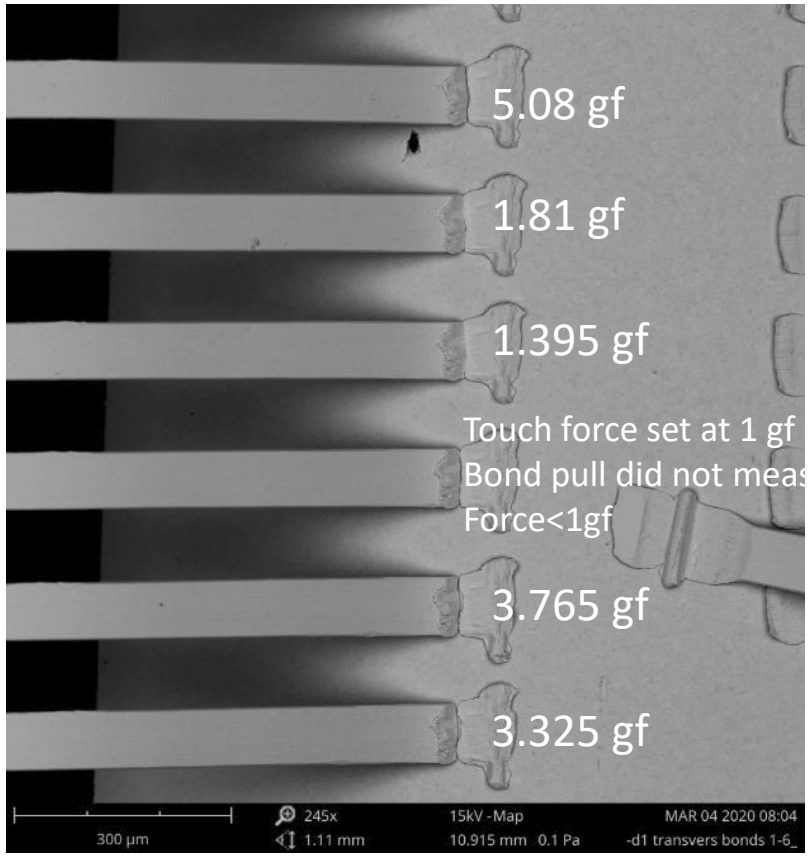
(*) stats for 2021 are incomplete

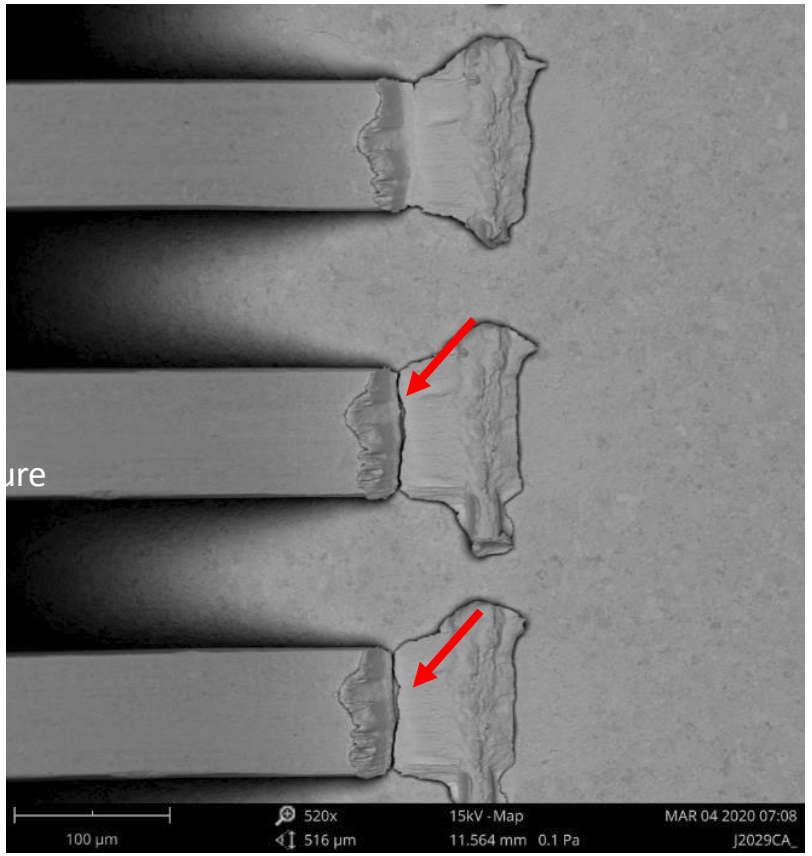



- Perform ~20 failure analyses (FA) a year, mostly for NASA GSFC projects
- FA is usually requested when EEE part has been identified as suspect or faulty during assembly inspection or testing
- Most common EEE parts submitted for FA:
  - Microcircuits - 25%
  - Capacitors - 25%
  - Hybrids - 10%
- Most common failure categories:
  - Electrical Over Stress (EOS) – 32%
  - Manufacturing Defects – 27%

# Example of DPA: Commercial Hybrid with Gold Ribbons



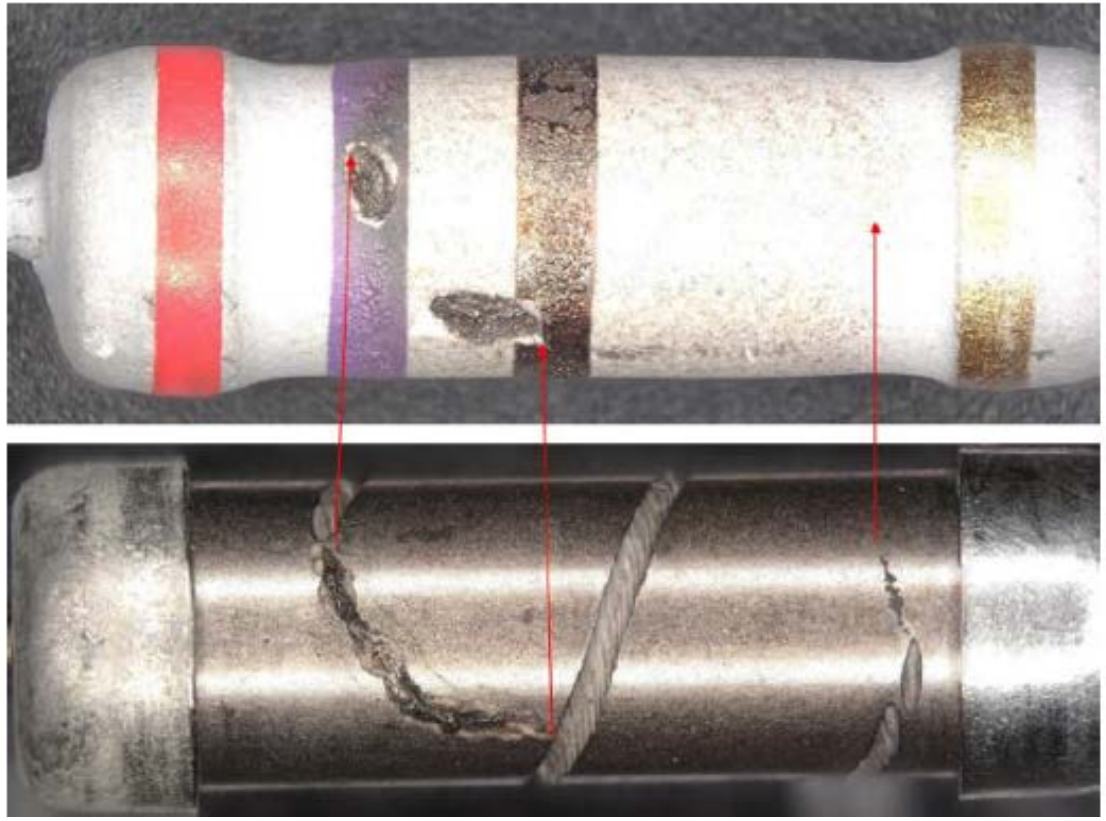



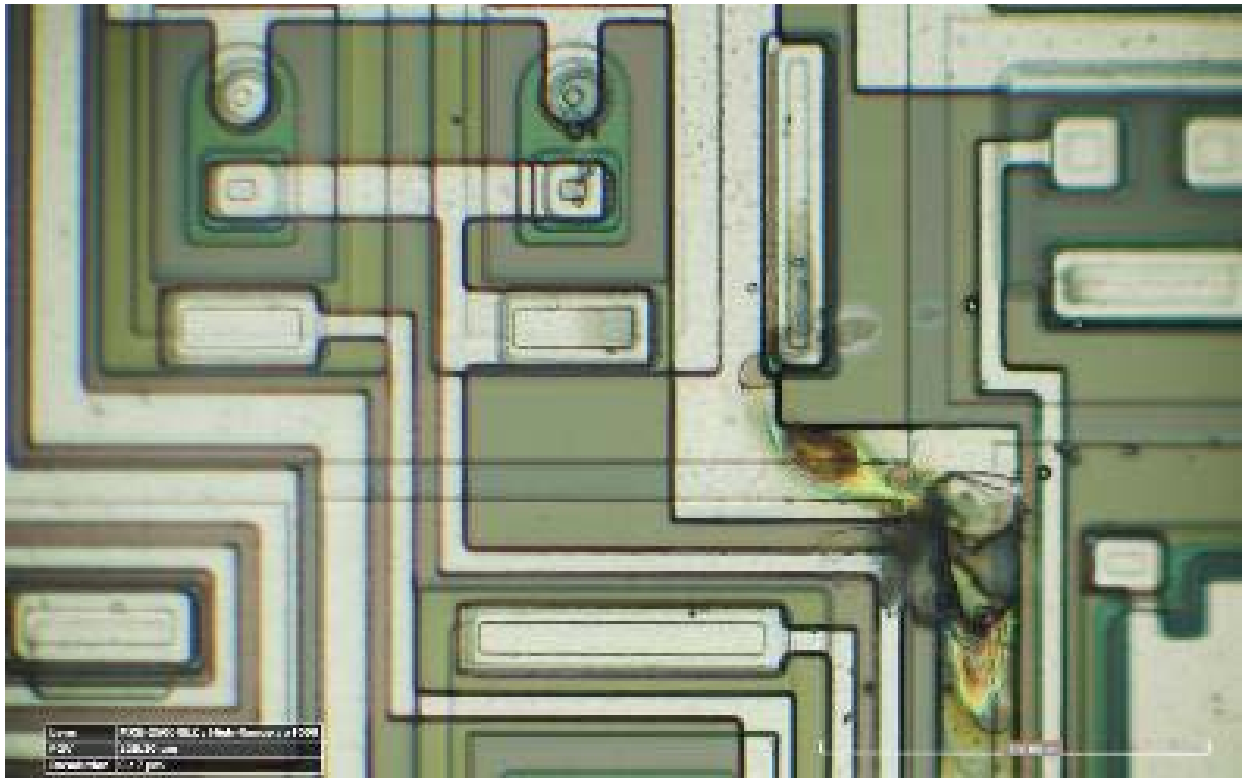

- Commercial hybrid with gold ribbon bonds that had pull strengths <1g-f to 5g-f instead of 15g-f requirement
- Close-up examination of the ribbons show a crack in the ribbon near the stich, most likely a result of improper tooling setting

# Examples of FA for Electrical Overstress

*Resistor overstressed by excessive overvoltage (EOS)*

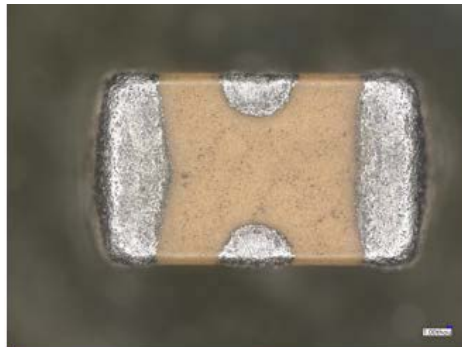


*Microcircuits overstressed by excessive overvoltage (EOS)*

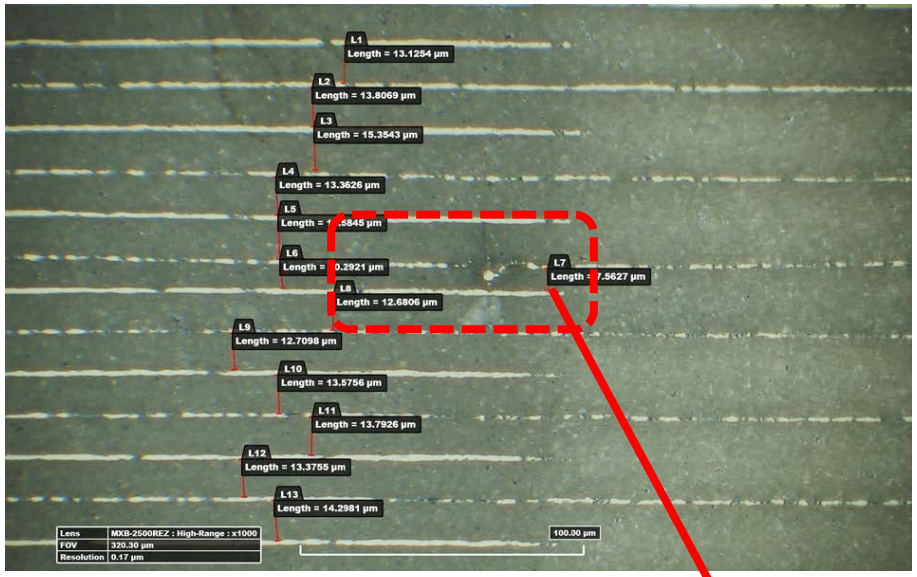


# Example of FA: Capacitor lot with thinning dielectric

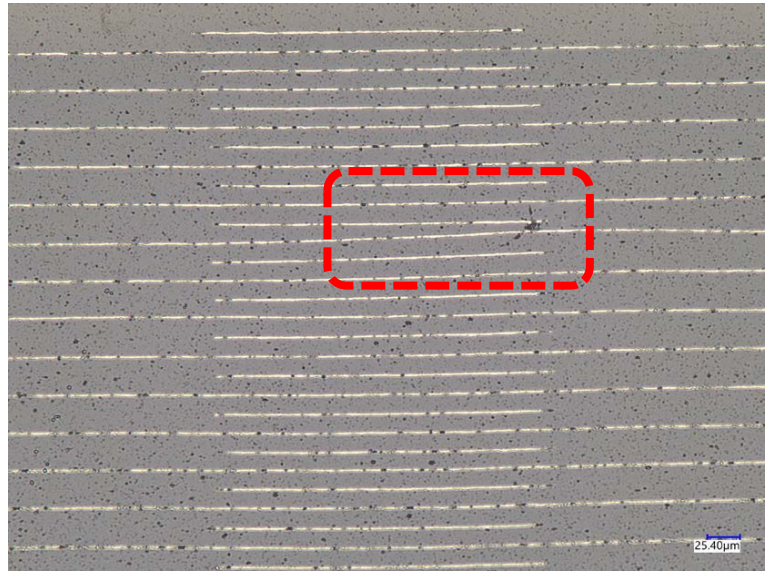
*Part overview*



*Exemplar Failure Site in Capacitor 1*

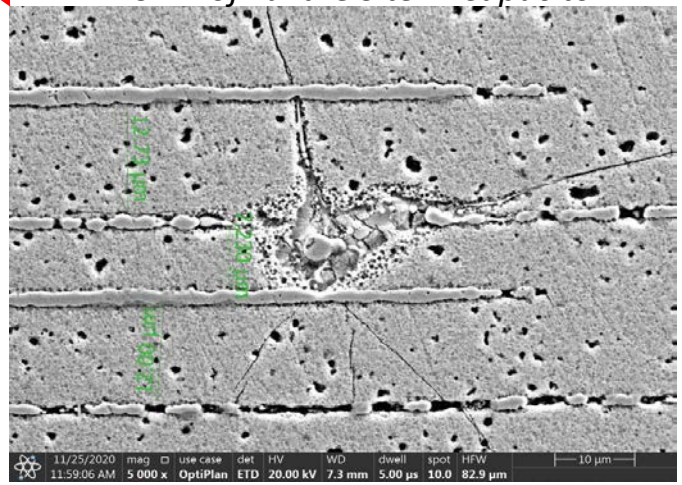



*Exemplar Failure Site in Capacitor 2*



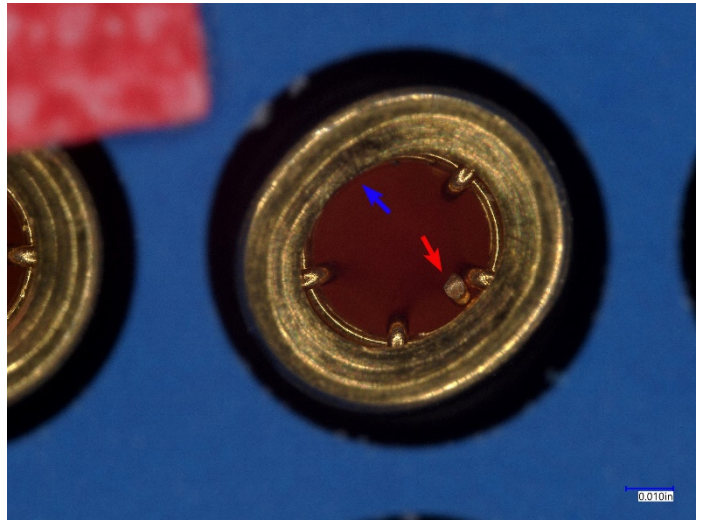

- Observed electrical leakage failures during life test of feedthrough capacitors
- Cross-section of several capacitors found thinning dielectric at the location of failure (5-9µm instead of 13µm)
- At the failure site a melt spot and cracks are a result of internal electrical short

*SEM of Failure Site in Capacitor 1*



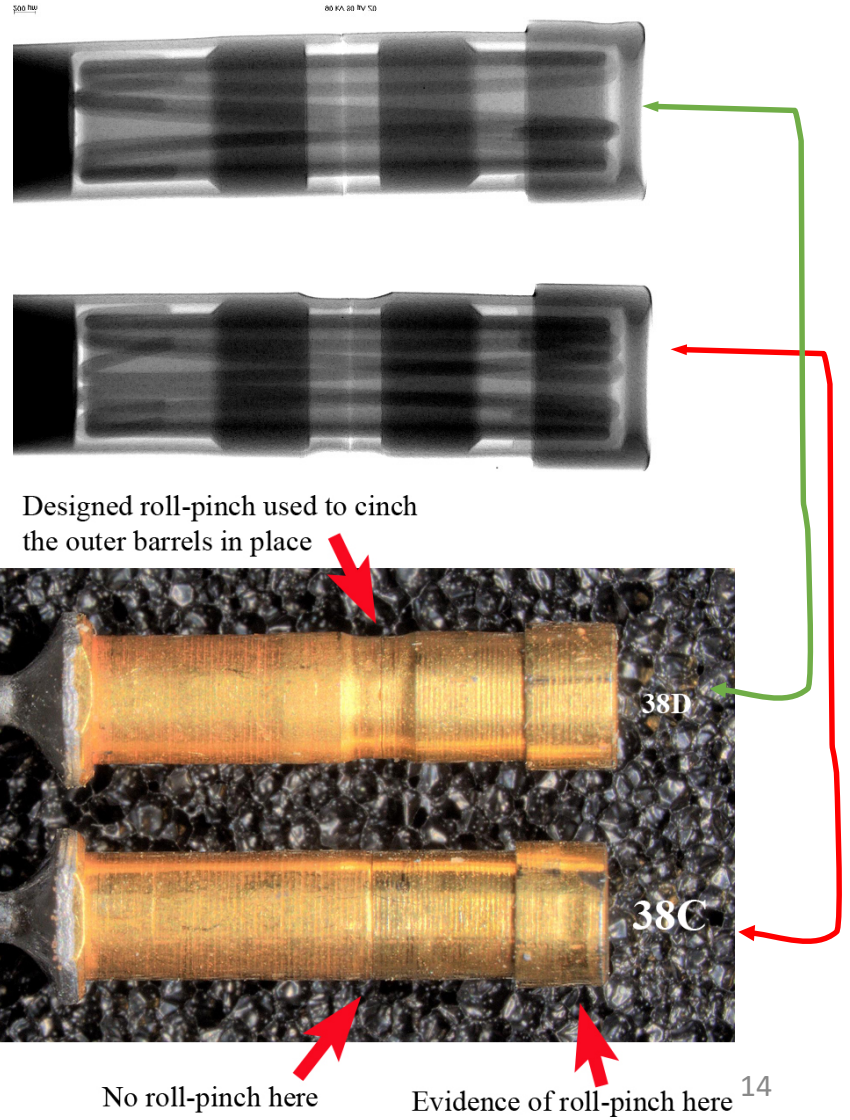
# Example of FA: PCB Socket Connector with Damaged Contact

*Close-Up of the Damaged Contact in a Connector*



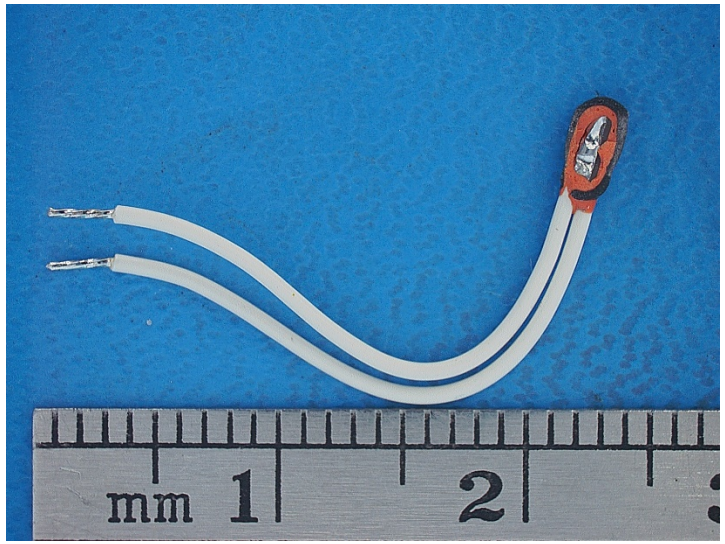

- Observed damaged contact during post-assembly visual inspection
- One of the five wires inside the contact was broken
- Contact suffered a manufacturing defect that misplaced an essential cinching roll-pinch securing the two outer barrel pieces to the contact assembly. The mishap resulted in cutting one of contact wires

*X-Ray and Optical Images of damaged and 'good' contact*

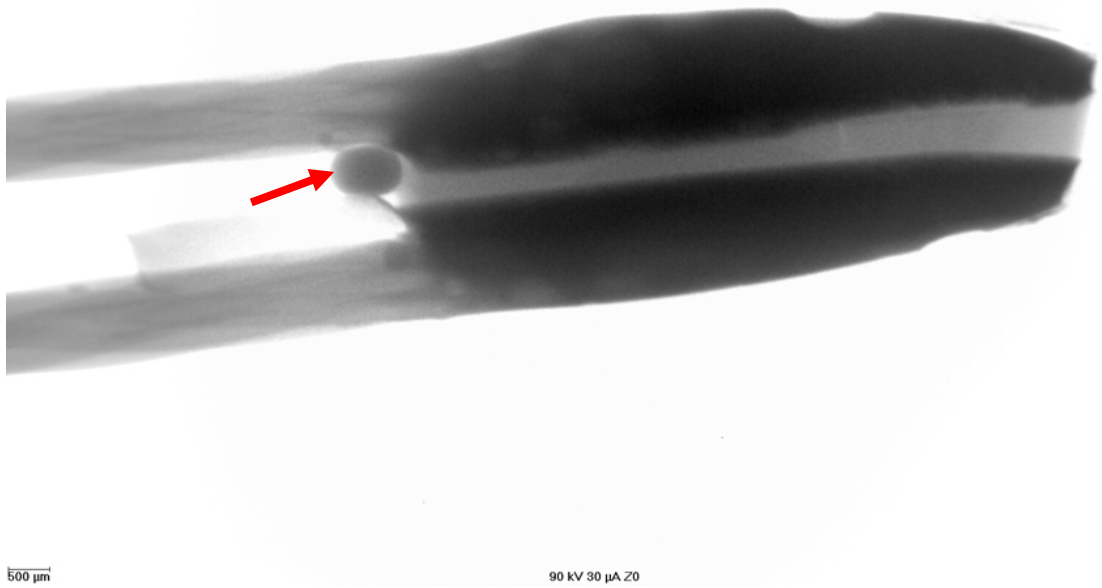


# Example of FA: Temperature Sensor With a Short

*Part overview*




*X-Ray of the failed temperature sensor showing solder bridging the wires*

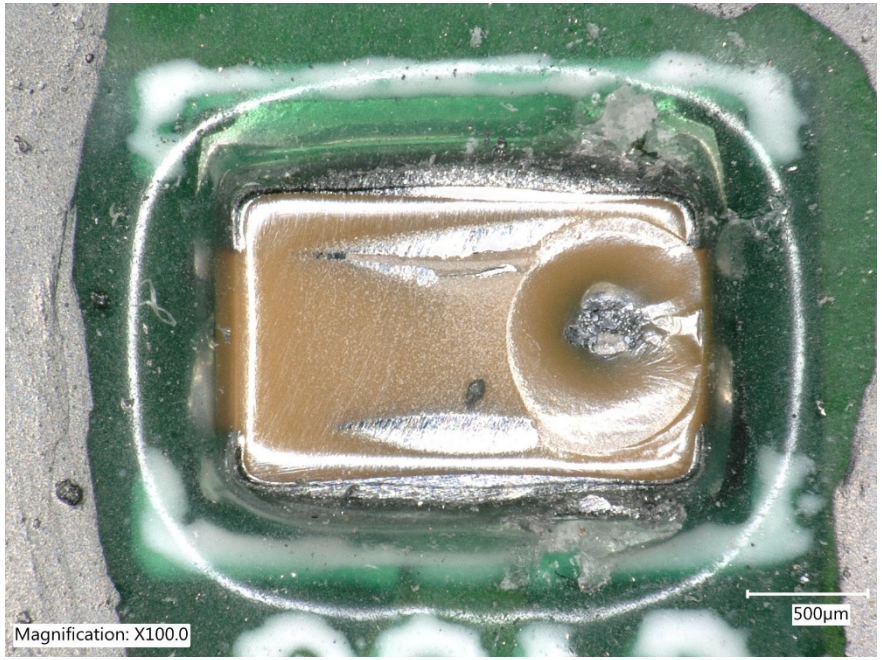



Temperature Sensor damaged during board assembly – internal solder reflowed when a component next to the sensor was touched up with soldering iron

# Summary

- DPA based on MIL-STD-1580 is a key element of GSFC Parts Selection/Screening Protocols per EEE-INST-002
  - Overall rate of non-conformances found during DPA for the past 5 years has been 42%
  - GSFC employs a DPA Failure Review Board to review/disposition lots that do not pass DPA
    - Options include reject lot, use as-is or screen/reprocess for the observed condition to provide assurance for the intended application
    - 4% of all lots are rejected for flight use
- FA in support of NASA programs
  - Microcircuits and Capacitors make up 50% of all FAs
  - EOS and Manufacturing defects account for 59% of FA findings

# Questions?




Multilayer ceramic chip capacitor with a cone-shaped piece of top plate separated after internal electrical short