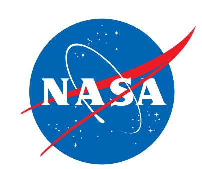

NASA GSFC EEE Parts

Failure Analysis: Isolating Integrated Circuit Electrical Damage

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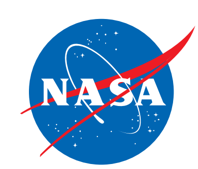
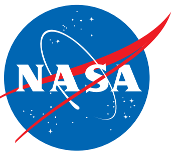
NASA GSFC Code 562 EEE Parts, Packaging, & Assembly Technologies Branch



Acronyms

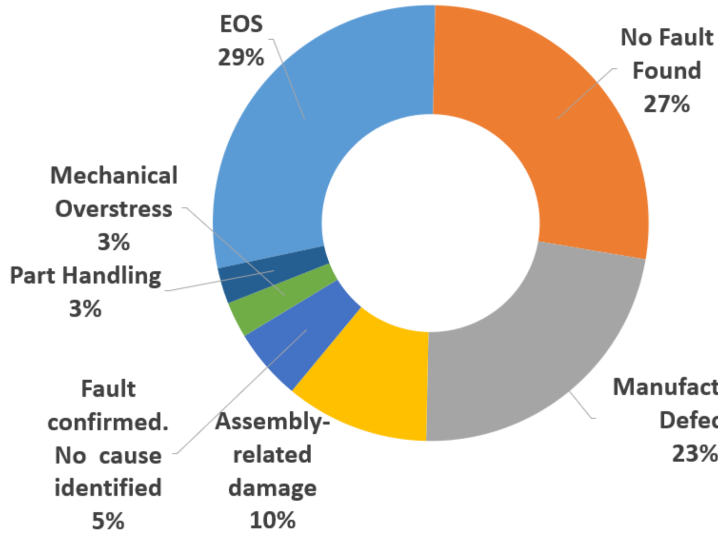
EOS	Electrical Overstress
FA	Failure Analysis
GMR	Giant Magnetoresistance
LIT	Lock-in Thermography
LSIM	Laser Signal Injection Microscopy
MCI	Magnetic Current Imaging
OBIRCH	Optical Beam Induced Resistance Change
SQUID	Superconducting Quantum Interference Device
TIVA	Thermally Induced Voltage Alteration
XIVA	Externally Induced Voltage Alteration

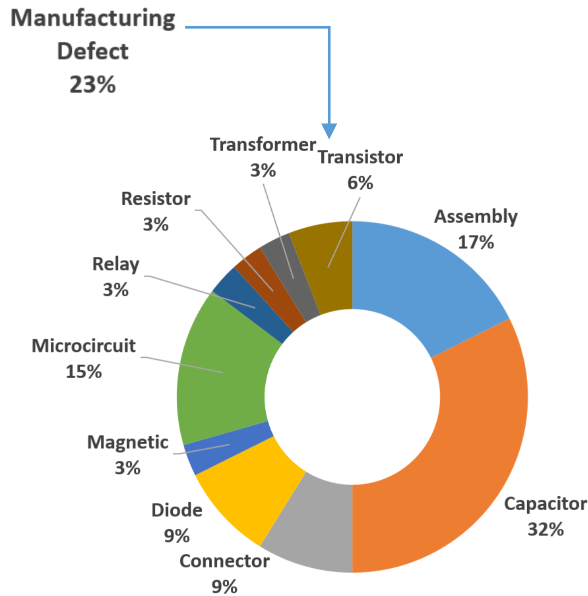


Statistics of FAs for 2017-2024*

(*) stats for 2024 are incomplete

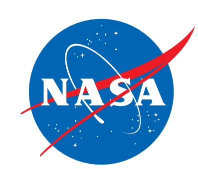
Breakdown of FA conclusions



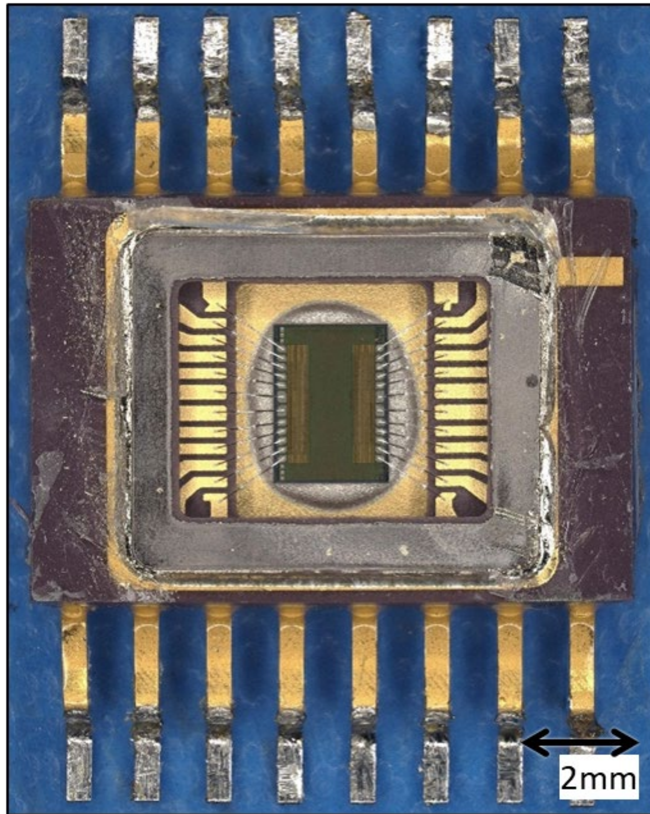


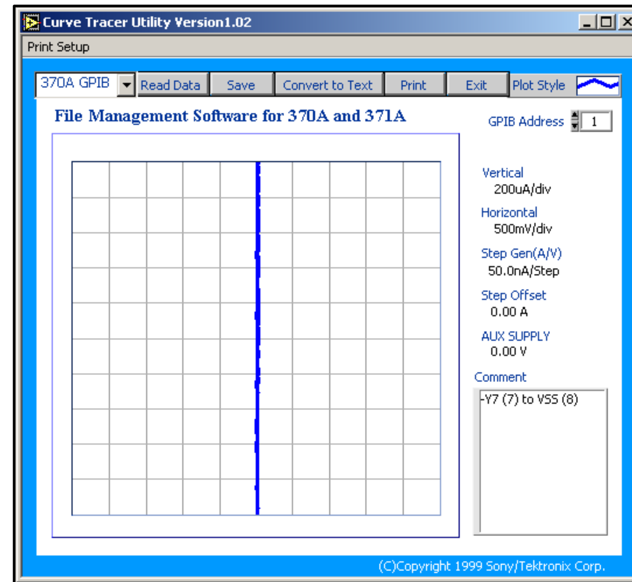
Manufacturing Defects: Breakdown by Part Types

- Perform 10-40 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 instances of assembly-related damage that are corrected with remove-and-replace of the part are not submitted for FA
  - Most failures on low-tier missions are not submitted for FA
- Most common EEE parts submitted for FA:
  - Microcircuits - 34%
  - Capacitors - 16%
  - Hybrids - 10%
- Most common failure categories:
  - Electrical Over Stress (EOS) – 29%
  - Manufacturing Defects – 23%
    - Most devices with manufacturing defects that come to FA are capacitors
    - No FAs with manufacturing defects seen in hybrids
    - Manufacturing defects in microcircuits identified recently



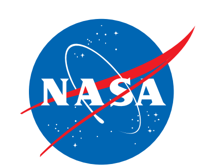
FA Isolation Case 1: Thermal Imaging



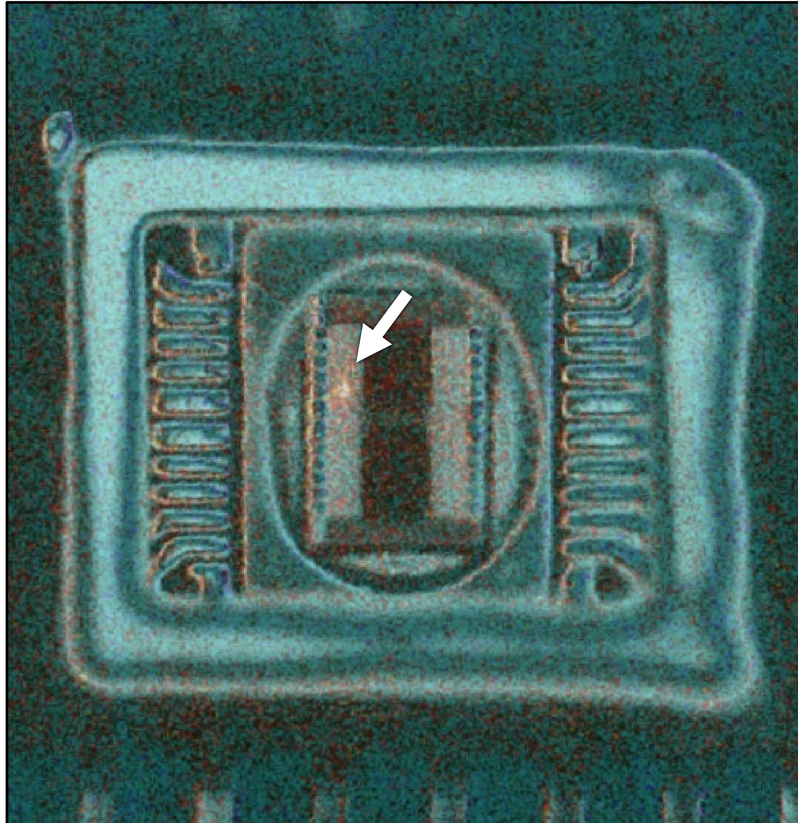


↑ *Output to ground short path*

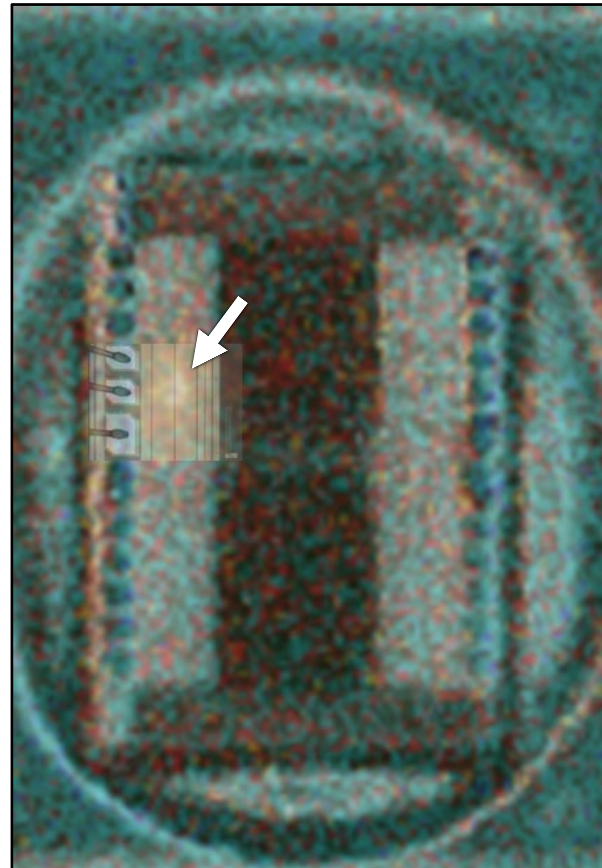
- Part description:
  - 3-line to 8-line demultiplexer
- Failure background:
  - During powerup at board-level assembly, an event occurred which led to discovery of high current through a demultiplexer output
- Failure mode:
  - A 3.8Ω short path was discovered between one of the eight outputs and ground
- Interim FA findings:
  - Following delidding, no observable damage or defect to package or die



FA Isolation Case 1: Thermal Imaging

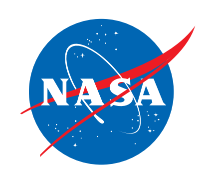


←
Thermal hotspot detected



→
Overlay of optical image places hotspot next to failing output bondpad

- Isolation technique (successful):
  - Thermal imaging
  - While biased with an external supply, a thermal camera records heat generation, then subtracts an unpowered frame from the result
  - A hotspot was observed adjacent to the failing output bondpad



FA Isolation Case 1: Thermal Imaging

1

100µm

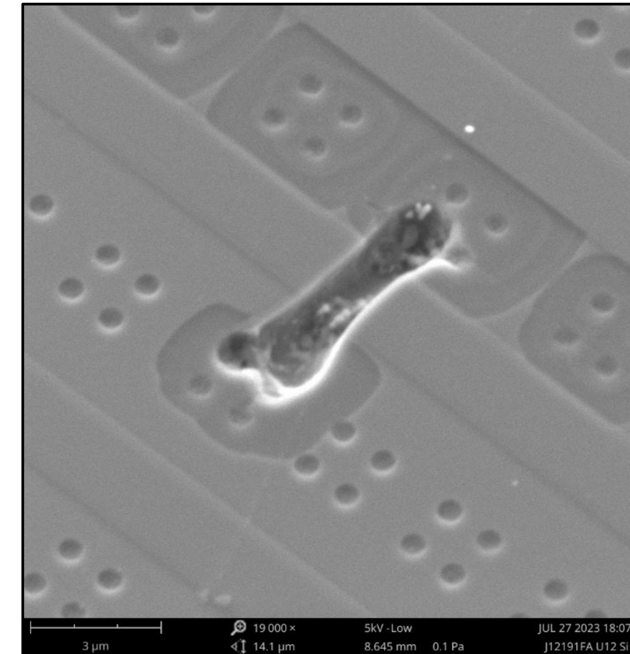
2

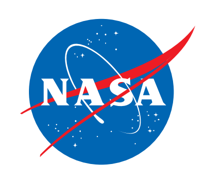
3

4

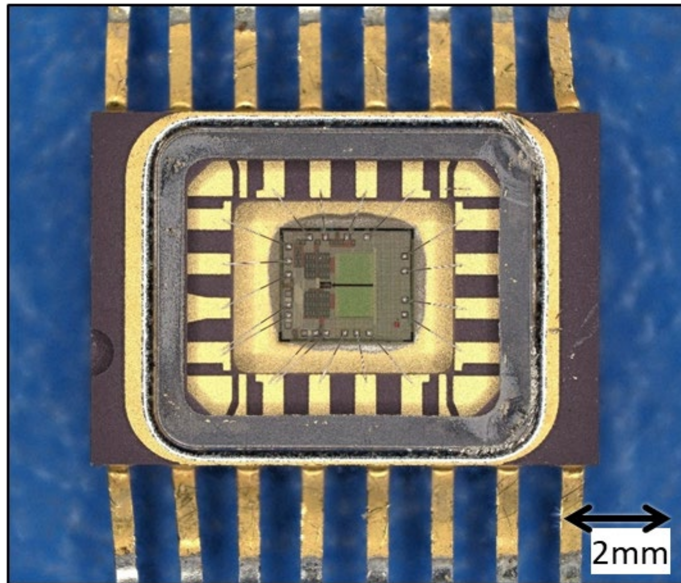
10µm

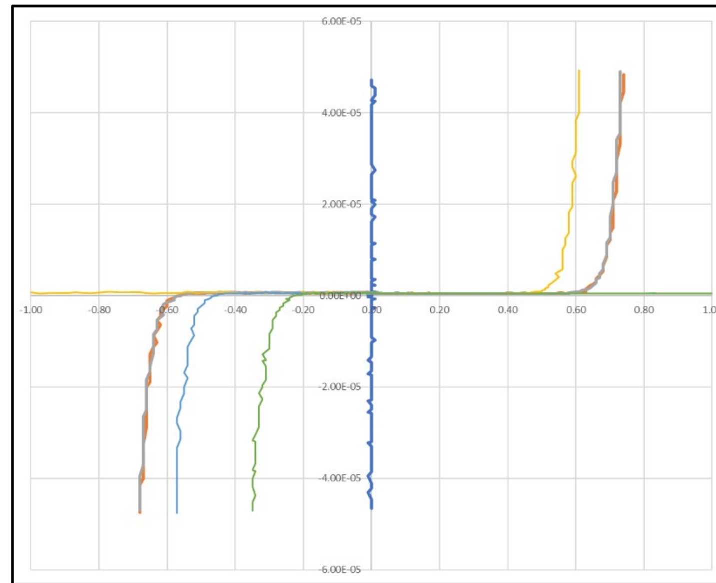
- Deprocessing methods:
  - Plasma etching, planar polishing, chemical etching
- Failure mechanism identified:
  - Electrical overstress (EOS) damage to the output driver circuitry





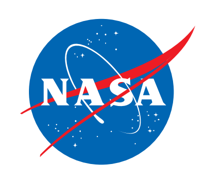
FA Isolation Case 2: Magnetic Current Imaging



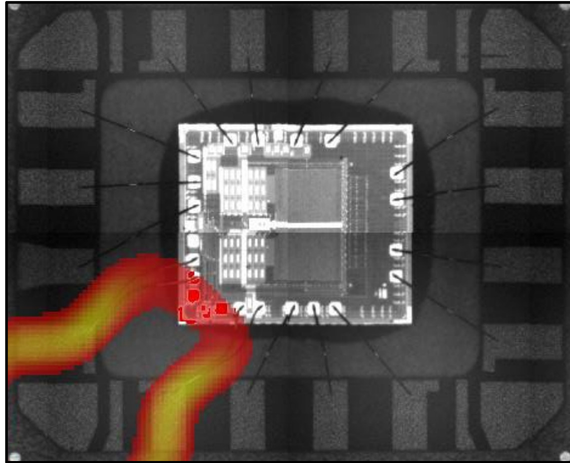


↑ *Supply to ground short path in blue*

- Part description:
  - Engineering model low-power analog-to-digital converter
- Failure background:
  - During probing of this unit at board-level assembly, the supply rail went into overcurrent mode
- Failure mode:
  - A 4.4Ω short path was discovered between this unit's analog supply and ground
- Interim FA findings:
  - Following delidding, no observable damage or defect to package or die

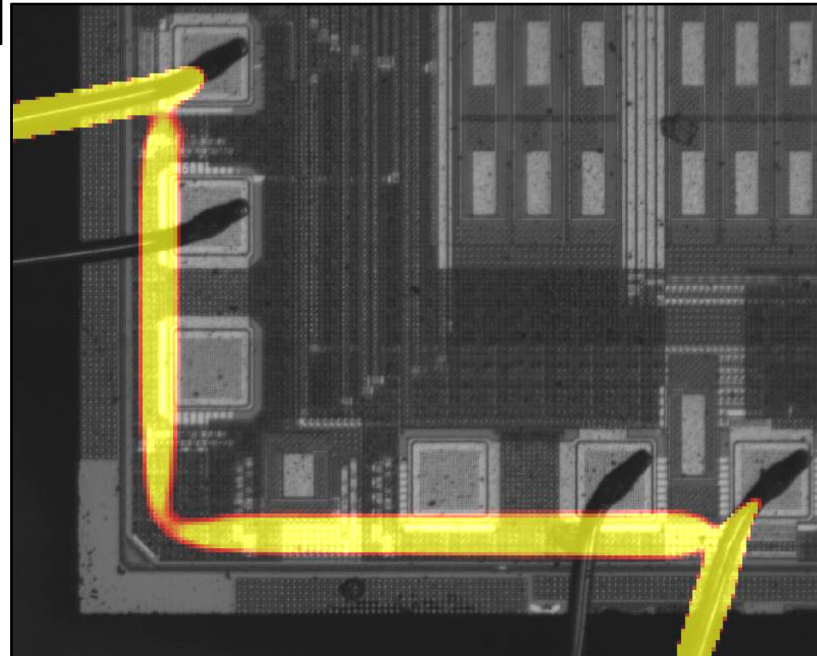


FA Isolation Case 2: Magnetic Current Imaging

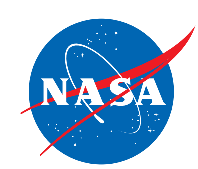


← *SQUID detects current flow, but precise failure site is not resolvable*

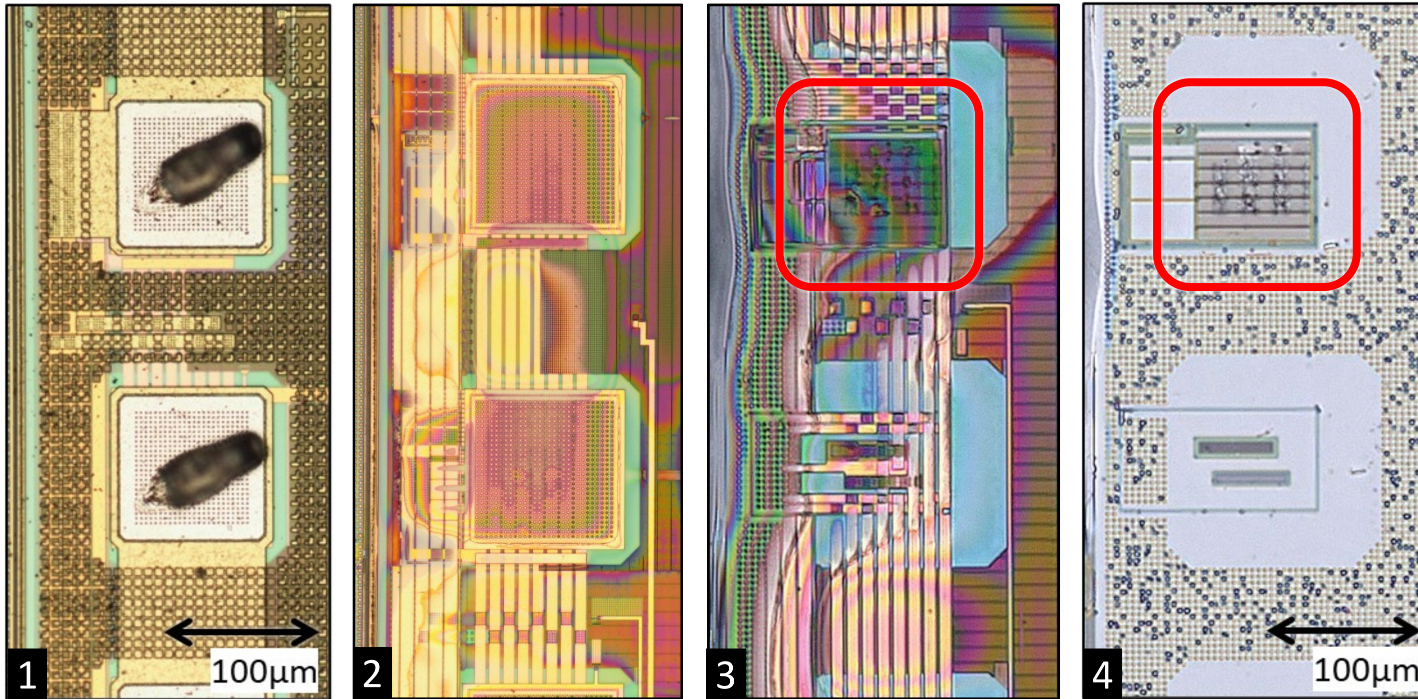
GMR detector identifies current path along periphery between supply and ground bondpads →



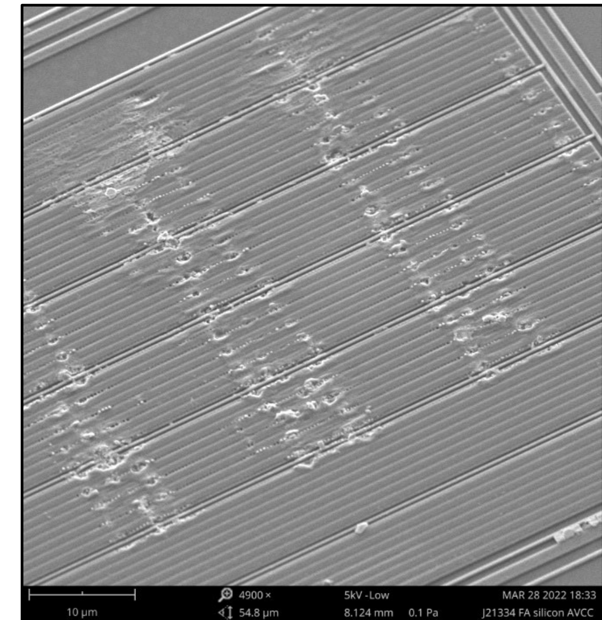
- Isolation technique 1 (unsuccessful):
  - Thermal imaging
  - No hotspot was observed
- Isolation technique 2 (successful):
  - Low-mag magnetic current imaging (MCI) using superconducting quantum interference device (SQUID) detector
  - Improved resolution provided by giant magnetoresistance (GMR) detector
  - A current path was resolved along supply periphery metallization

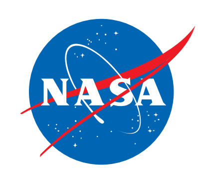


FA Isolation Case 2: Magnetic Current Imaging

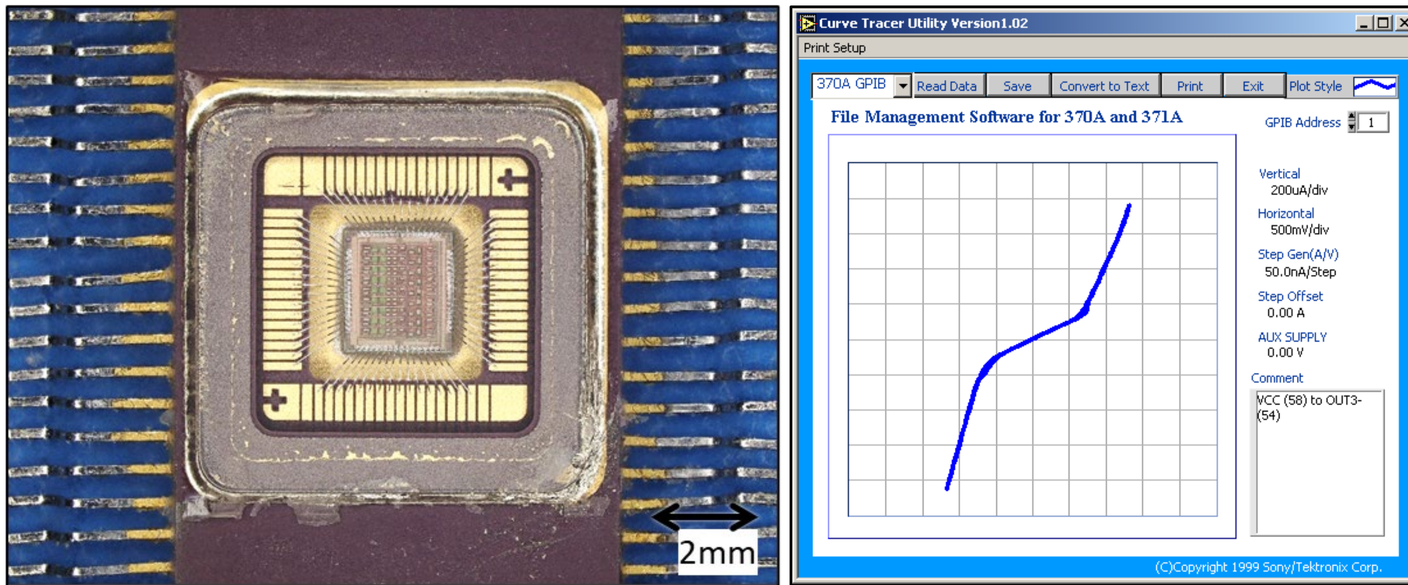


- Deprocessing methods:
  - Plasma etching, chemical etching, planar polishing
- Failure mechanism identified:
  - Electrical overstress (EOS) damage to the analog supply protection circuitry



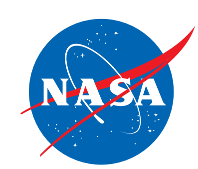


FA Isolation Case 3: Laser Signal Injection Microscopy



↑ *Leakage path from supply to output*

- Part description:
  - 8-channel crosspoint switch
- Failure background:
  - During powerup at board-level assembly, low resistance was observed on an output channel
- Failure mode:
  - A 5.0kΩ origin leakage path was discovered between this unit's supply and an output channel
- Interim FA findings:
  - Following delidding, no observable damage or defect to package or die



FA Isolation Case 3: Laser Signal Injection Microscopy

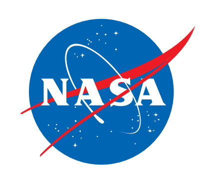
Reference optical image →

100µm

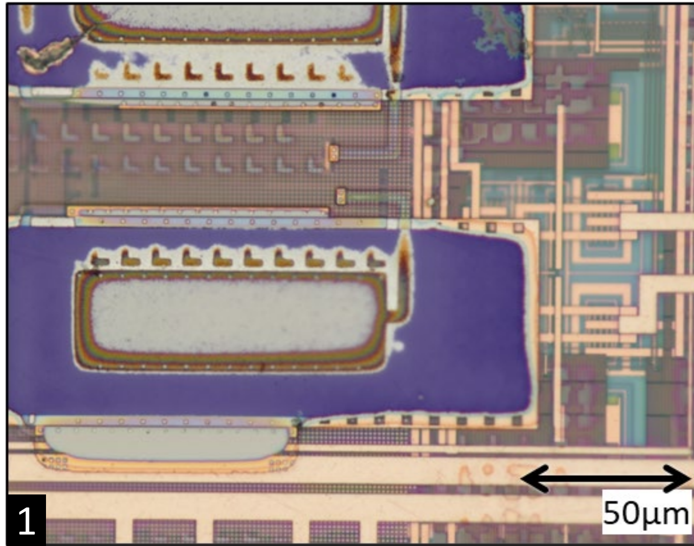
↓ *XIVA result*

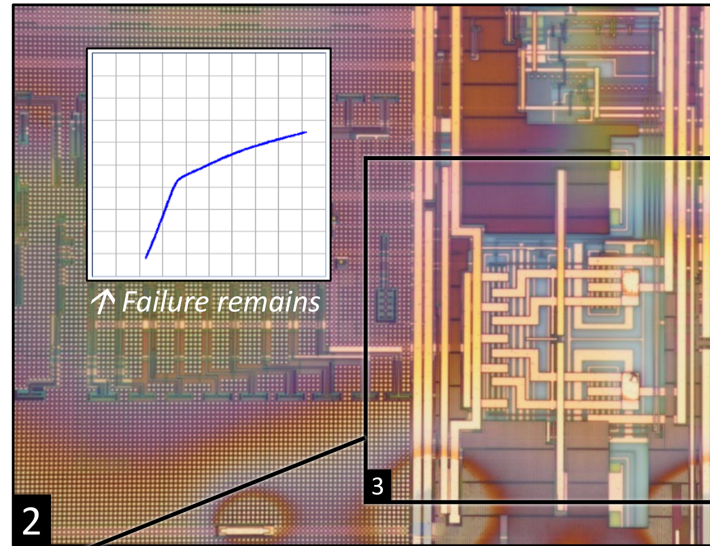
Scan reversed and slowed ↓

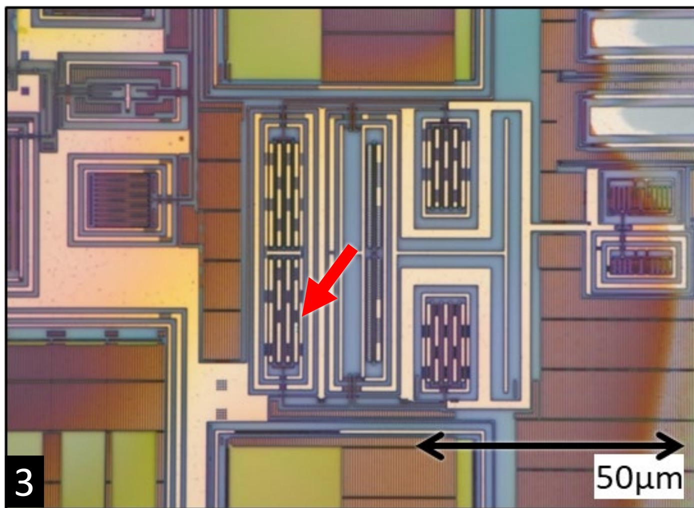
- Isolation technique 1 (unsuccessful):
  - Thermal imaging
  - No hotspot was detected
- Isolation technique 2 (successful):
  - LSIM (laser signal injection microscopy)
  - Several types are used in industry (OBIRCH, TIVA, XIVA, others) varying by laser wavelength and supply biasing method
  - While biased, a thermal laser scans the die surface
  - Locations are marked where the laser affects supply stability
  - Alteration sites were yielded at and beside an interlevel capacitor within a module connected to the failing output

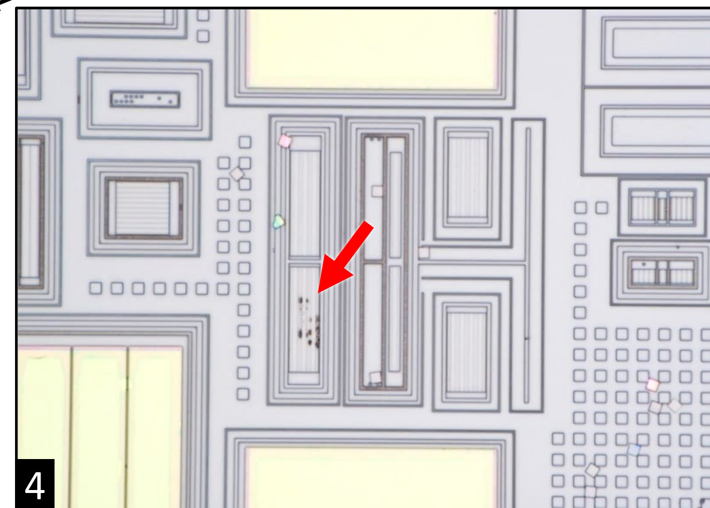


FA Isolation Case 3: Laser Signal Injection Microscopy

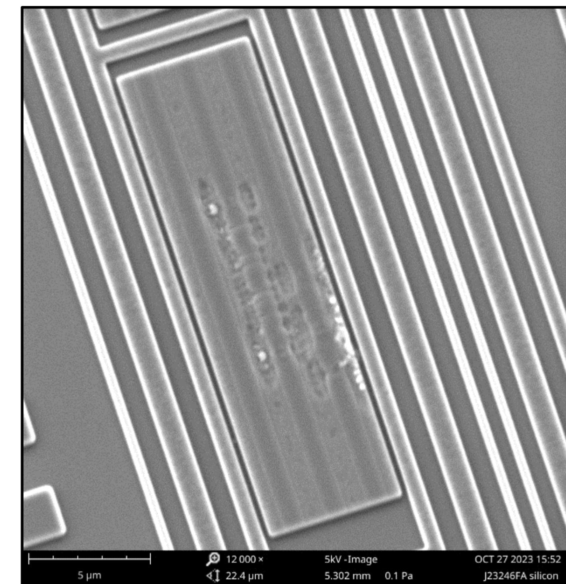


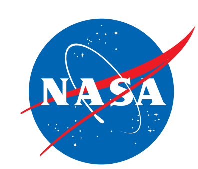




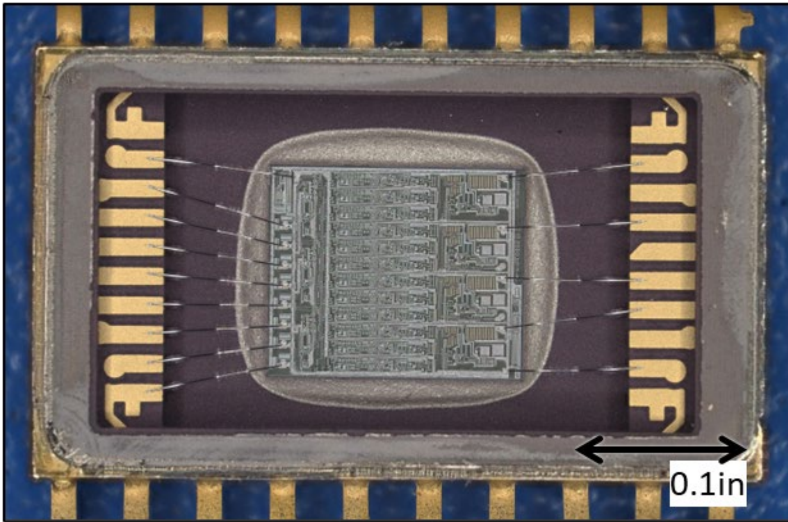


- Deprocessing methods:
  - Plasma etching, planar polishing, chemical etching; internal microprobe curve trace
- Failure mechanism identified:
  - Electrical overstress (EOS) damage to a transistor connected to the failing output signal

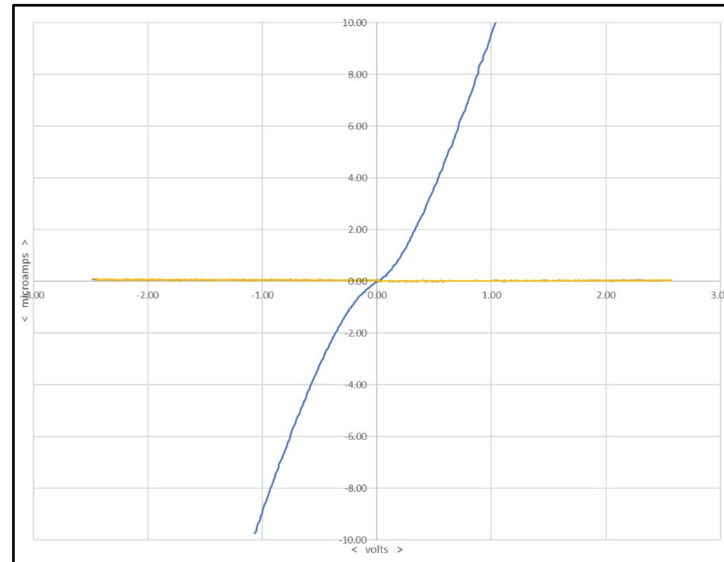




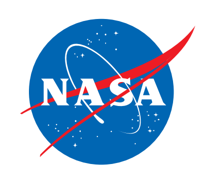
FA Isolation Case 4: Lock-in Thermography



Resistive path between differential input pair



- Part description:
  - 4-channel voltage comparator
- Failure background:
  - Project reported that an input pair combination on this unit on a flight board drew higher than normal current
- Failure mode:
  - A resistive path on the order of 134kΩ was discovered between the differential pairs of an input channel
- Interim FA findings:
  - Following delidding, no observable damage or defect to package or die



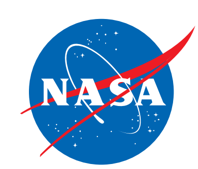
FA Isolation Case 4: Lock-in Thermography

Reference optical image

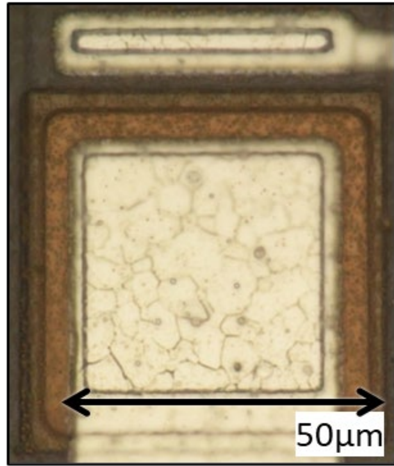
0.01in

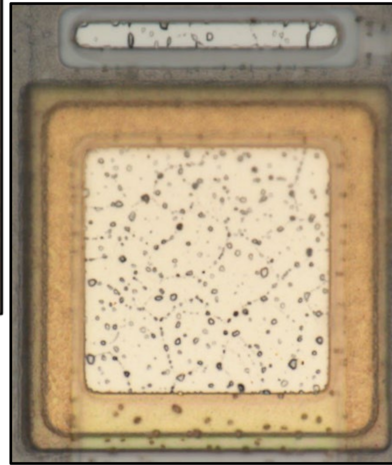
Lock-in thermography

- Isolation technique 1 (unsuccessful):
  - Thermal imaging
  - No hotspot was detected
- Isolation technique 2 (unsuccessful):
  - OBIRCH and XIVA
  - Alteration sites were inconclusive
- Isolation technique 3 (successful):
  - LIT (lock-in thermography)
  - A lock-in modulation system repeatedly applies power to the device, then deactivates
  - A thermal imaging camera monitors for heat dissipation during on cycles and subtracts off cycle dark images
  - Heat detected around a capacitor, particularly the lower right side

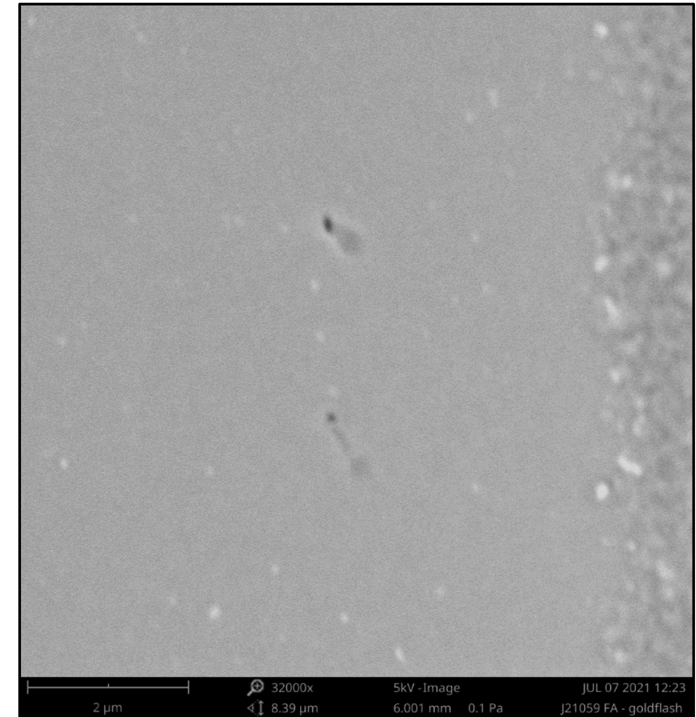


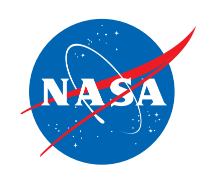
FA Isolation Case 4: Lock-in Thermography





- Deprocessing methods:
  - Plasma etching, chemical etching
- Failure mechanism identified:
  - “Pinhole” electrical damage to gate oxide used as capacitor dielectric





Thank you!