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COTS Integration- *Success & Challenges in Mission Critical Systems*

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Components for Military & Space Electronics Conference

OUTLINE- *COTS Components, Assemblies, Sub-Systems*

- History- *Military Standards and Commercial Best Practices*
- COTS Product Requirements- *Industry Perspective*
- Commercial Off the Shelf (COTS)
  - *Advantages, When and How to Implement*
  - *Challenges, Risk & Opportunity Assessments*
- Case Examples- *COTS Hybrid, Cable, Active & RF Components*
- Summary- *Best Practices, Path forward for Mission Critical Systems*

History- *Military & Commercial Standards* (AIA,SIA,SAE,ISO,IPC,JEDEC,ANSI,ASTM,ASME,IEEE)

- Acquisition Reform under William Perry- *Policy approved **March 1996***

  Dr. Perry: Secretary of Defense 1994-1997, *Links provided in abstract*

  - ***"New Way of Doing Business"*** Memorandum issued **June 1994** signaled policy change!
  - Departure from Military specs: Utilize COTS products and commercial best practices where practical.
  - Exponential electronics growth driven by technology advancement- Computers, networks, the internet, and microelectronic miniaturization.
  - Sweeping changes in Engineering, Business, Quality, Product Support, Development Tools, Equipment, Materials & Technology were ***REQUIRED*** to meet demands.
  - Improvements in Speed, Performance & Integration of functional blocks required. Reductions in Die line widths, Packaging & interconnect technology.
  - Commercial "Industry" standards were NOT well-developed or adapted to defense items, following reforms having a negative impact on system readiness & reliability. IPC/JEDEC, ASA, SAE, ASTM & IEEE have come along way!
  - Defense supply base had to learn how to integrate commercial electronics and assemblies by accommodating items within the System design.
  - 30 Years Later, COTS Items with limitations are well understood!

Industrial Base has evolved! 1996 is ALSO the Inaugural year for CMSE Following CARTS!

COTS Product Requirements- *Industry Best Practices*

Semiconductor Product Release

- COST reduction, pennies at extremely high volume is ***Significant!***
- Increased / optimal yields: Process optimization OR change the performance characteristics / requirements
- Novel IP = Increase in Market Share as does early time to market!
- Iterative Performance Improvements

COTS Assemblies and System Product Release

- COST reductions through volume; Reduction in COTs item cost per unit
- Flexible designs that can tolerate changes in components & suppliers based on availability
- Process tolerances that allow high yields
- Well defined processes with high yields / minimal scrap
- Quick turn, time to market = *Increased Market Share!*

Commercial technology DRIVES innovation & cost savings, *Increases* risk on critical systems

COTS *Advantages*

Integrating COTS items into your product design:

- **COST SAVINGS-** *Volume cost per unit discount*
- **PERFORMANCE-** *Leverage latest technology and process advancements*
- **AVAILABILITY-** *Volume production, Multiple suppliers (components)*
- **Design & Reuse-** *Potential Design NRE reductions in development **IF** COTS items can be qualified for the deployed environment!*
- **Optimize Engineering Design Resources-** *Development teams dedicated to optimizing core system technologies and capabilities with an Open System Architecture*
- **Leverage Commercial Core Technologies-** *Who utilize Industry standards! FPGA's, Processors, Memory, Power Supplies, Actuators / Motors, Network Interfaces, Computers, Connectors, etc.*

Components & assemblies- Developed with Industry standards; assessed for *Military/DoD platforms*

COTS *Challenges-* *Items for consideration*

Limitations

- **Environmental-** Designed for less extreme environments. (Temperature / Vibration / Shock / Humidity / Salt fog / Altitude)
- **Use Environment-** Designed for ground fixed, mobile, benign office environments
- **COTS Life Cycle-** May incorporate ***significant*** changes iteratively or new products with little or ***NO*** notice. CN's released (not always) but not necessarily broadcast industry-wide!
- **End of Life Notices-** No Industry requirements to provide notices in advance. Lines can be closed as a business decision. Supply chain headaches for Integrators

✓System / Board / sub-assemblies *Should Be* tolerant to iterative or lifecycle component changes. (in an ideal world)

✓COTS System / Sub-assembly *Should Not* be tied to a qualified platform!

Risk and Opportunity- The Reality of COTS Components, Assemblies and Sub-systems

Class D Hybrid COTS RF Amplifier- ***Low Yields***

Industry refers to Military Standards for construction BUT relies on COTS best practices for electrical performance.

- MIL-STD-883: Test Method for Microcircuits
  - Test Method 2017: Defines materials and workmanship visual inspection Criteria.
- MIL-PRF-38534: Performance Specification
  - Defines general performance characteristics.
  - **Flexibility** to implement commercial “best practice”, while meeting the intended use and performance in Military applications.
- Class D Hybrid: Modified Frequency Range (Technically MOTS)
  - >> Supplier specified Quality / Reliability level
  - >> Reduced operating temperature range: (0°C to 70°C)
  - >> Supplier defined quality level & Inspection Criteria!

Process related non-conformances will have detrimental effects on performance!

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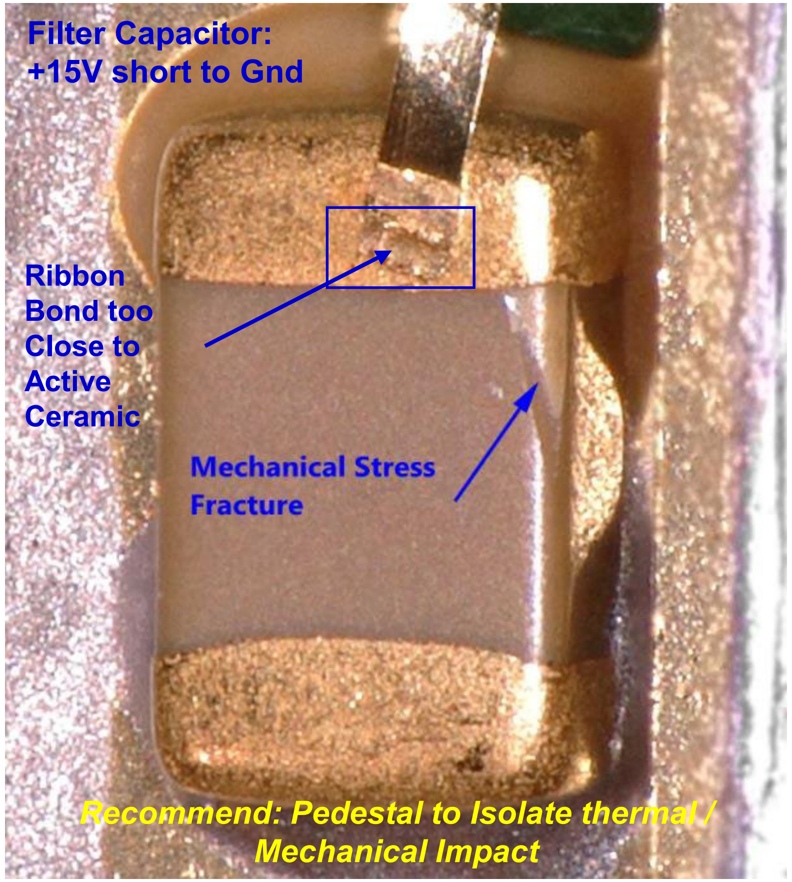
Class D- Non-conformances

Non-Conforming Items:

- Major probe marks on substrate, traces, die, components that impact function & generates loose organic / metallic debris.
- Leads, ribbons, wires or device contact during assembly / tuning / rework processes significantly impacted that can affect functionality.
- Proximity to ground, adjacent wire intersections, missing bond wires, defective bonds etc.
- Conductive die substrate squeeze out impacting min. conductor spacing, creates shorts or displaces other devices.
- Die / Component alignment / orientation that affect functionality or reliability.
- Non-conductive / conductive material NOT *affixed* in place inside the cavity. Similar to J-STD-001

Ribbon Bond Stress Fractures, <u>Several units</u>



Manual Optical Inspection for Conformance may be subjective! (Supplier Pre-Cap)

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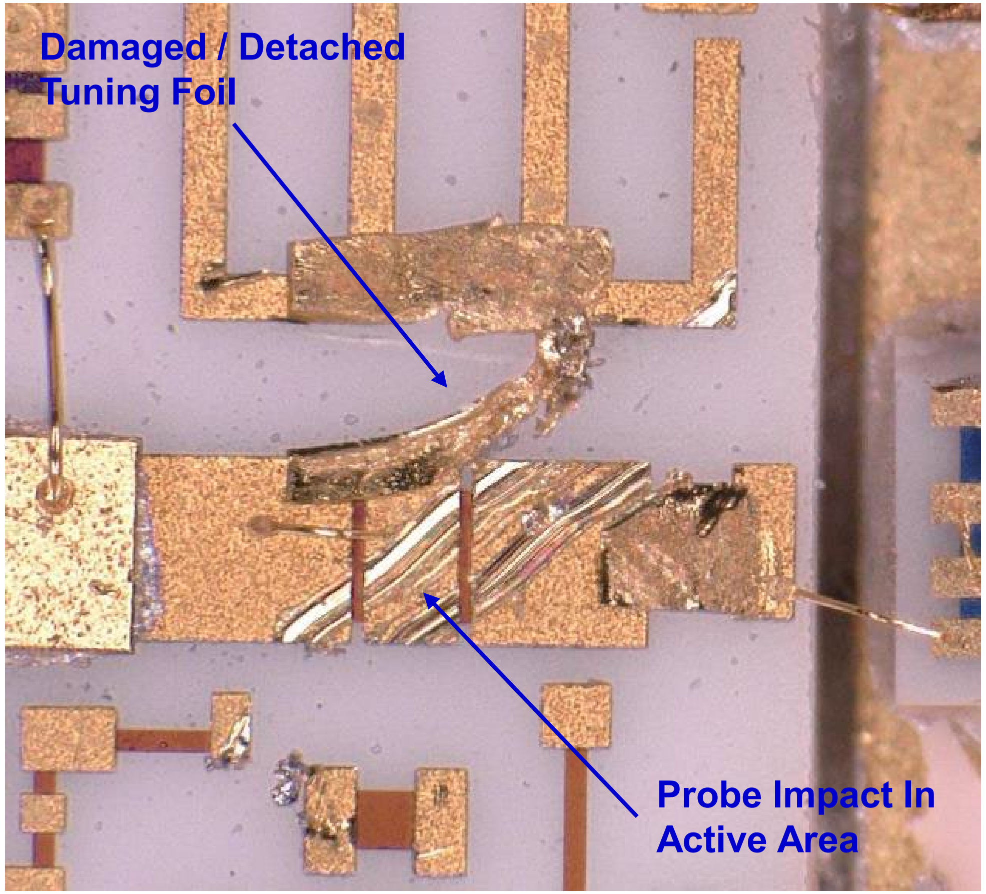
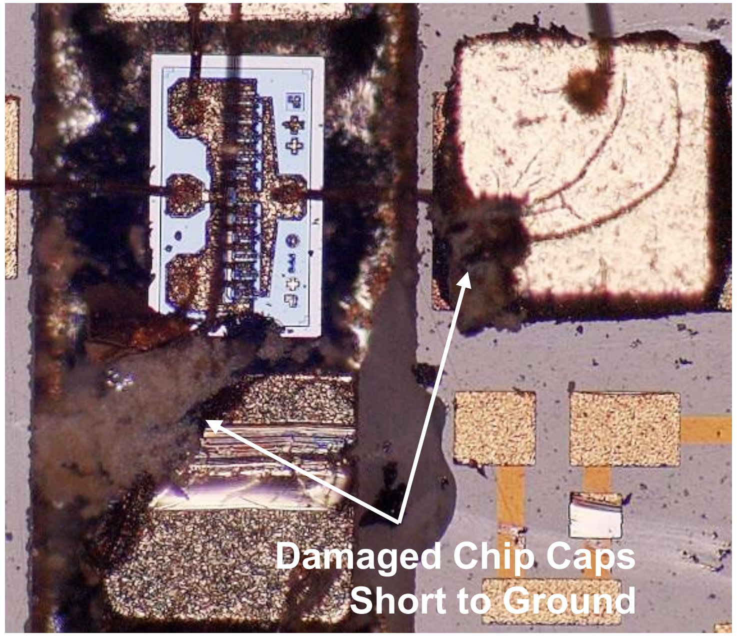
Example: COTS RF Amplifier, Findings (Post-Cap Analysis)

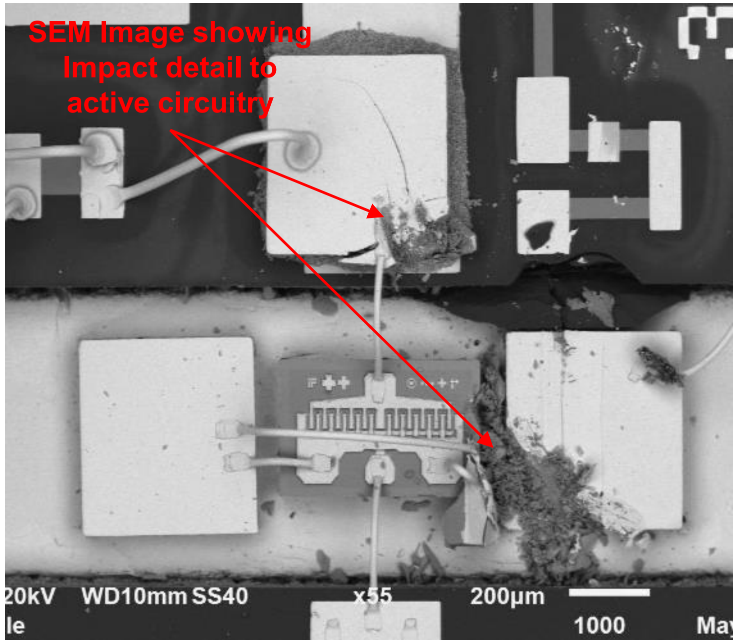
- Failures attributed to supplier assembly tuning process defects

Probe Impact in active areas; detached foils





Impact to Components & Die



Inadvertent probe contact during tuning manifested in failures under full power test

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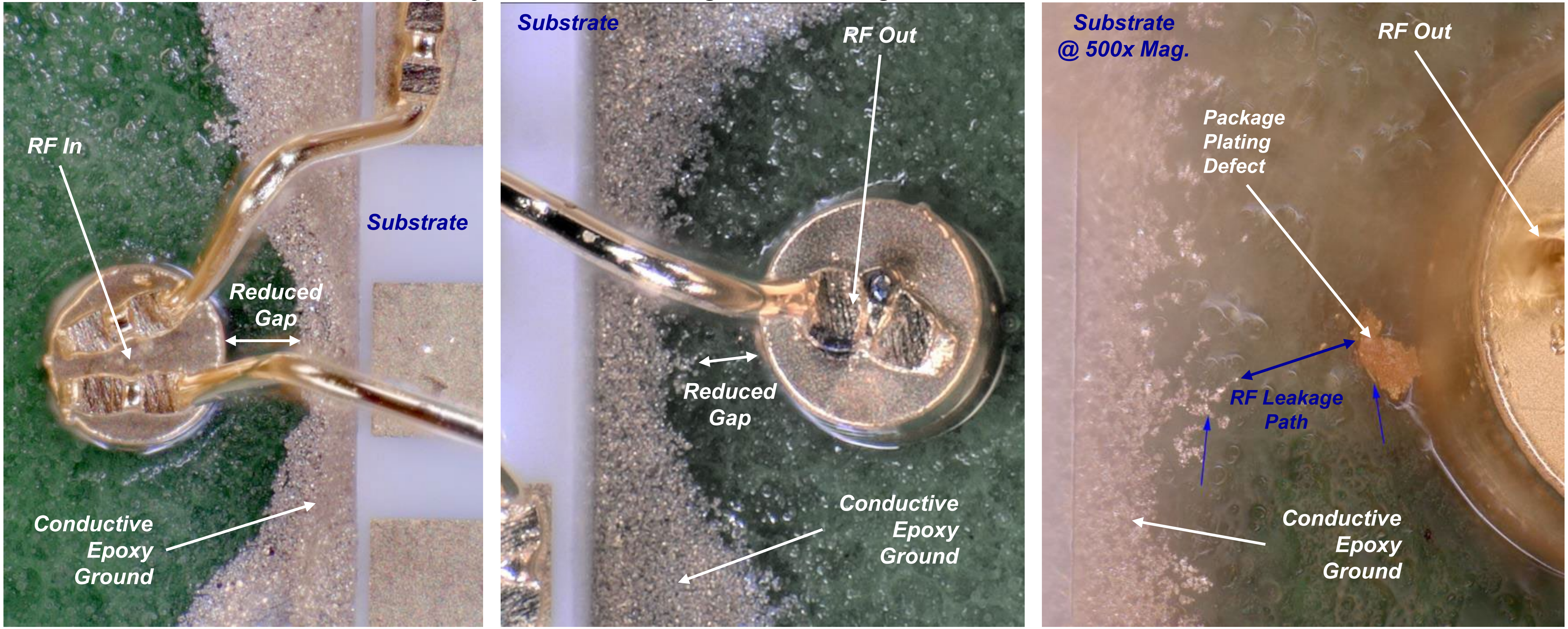
Example: COTS RF Amplifier, Findings (Post-Cap Analysis)

- Failures attributed to supplier assembly process defects

Excess Epoxy and Substrate Alignment leading to Insertion Loss & Low Gain



COTS Hybrids: Regardless of class, perform or require pre-cap. visual inspection to look for defects!

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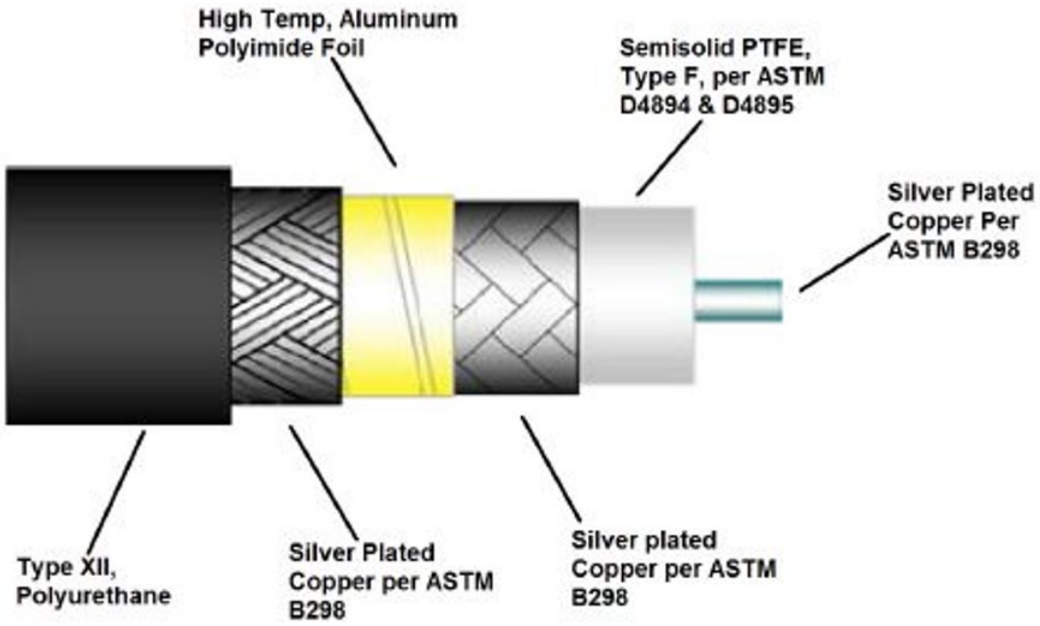
Coaxial Cable Analysis- *Test Operational Failures*

- COTS coaxial cable assemblies installed in motion tracking system, fails open during operational integration test.
- Evidence of outer jacket wear is present. Also noted the center conductor is a solid core.
- Signals carried are low power, mid-frequency.
- Cables are configured (routed) to accommodate motion. Fasteners and shims are also located in the routed motion path. ***Perform construction analysis (drawing compliance) & X-ray analysis to determine root cause.***



Coax cable assembly & plating requirements as noted in the drawing

Confirm proper cable construction as specified

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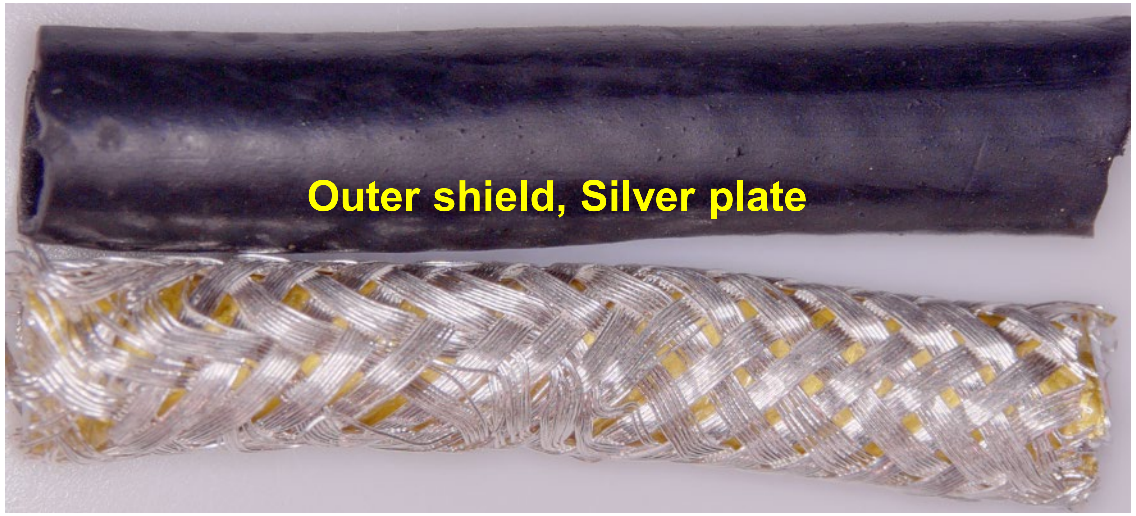
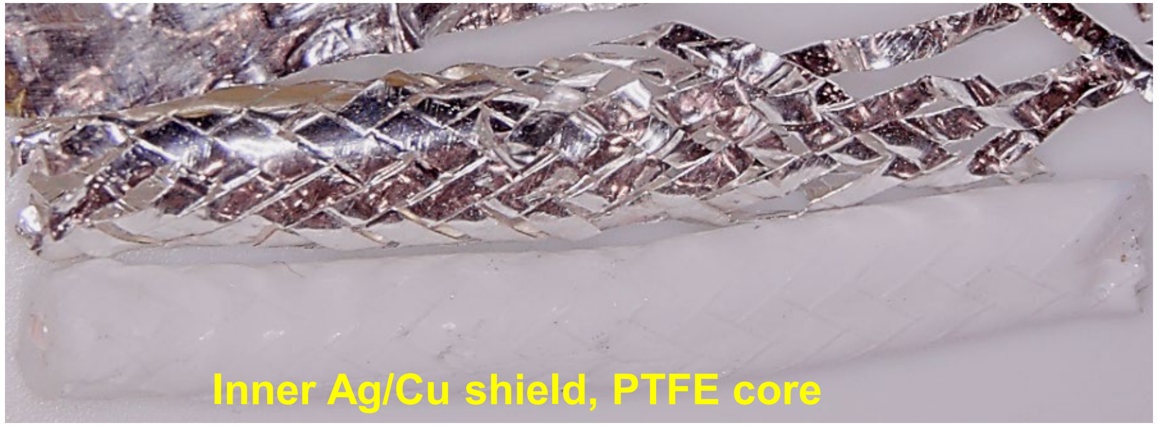
Coaxial Cable Analysis- *Construction Analysis*





Construction analysis on cable sample confirms materials specified in the drawing

XRF (Run mode) confirmed silver plating on center conductor and inner/outer shield

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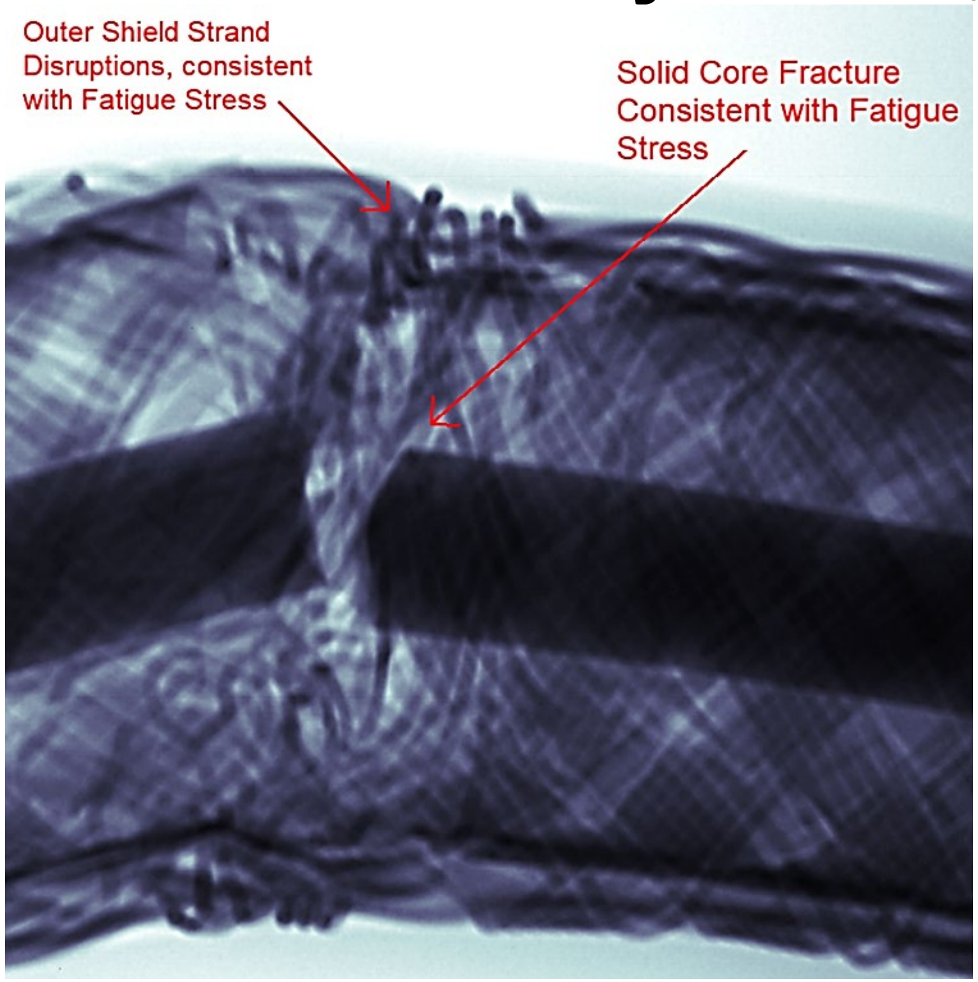
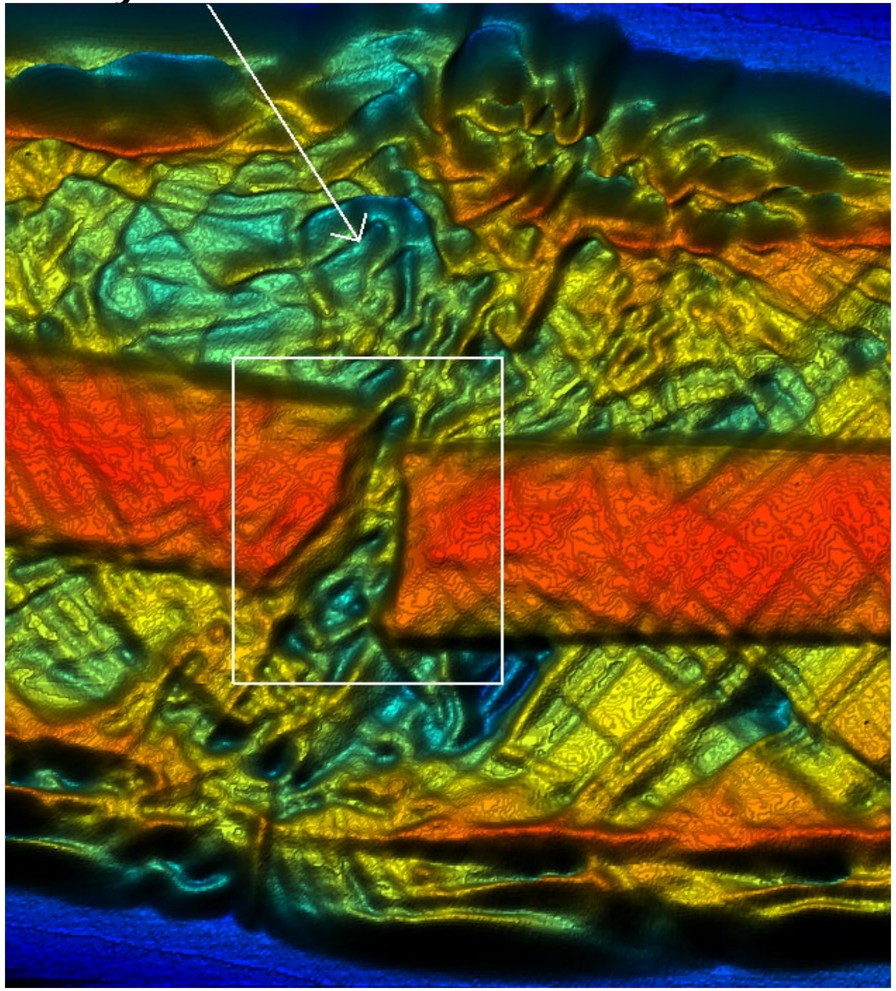
Coaxial Cable Analysis- *X-ray analysis of failed cable*





Scalloped fracture & shield disruptions (x-ray & 3D rendering), indicative of flexural fatigue failure

Experiment run on new cable flexed +/- 90 Degrees then cycled to failure for comparison

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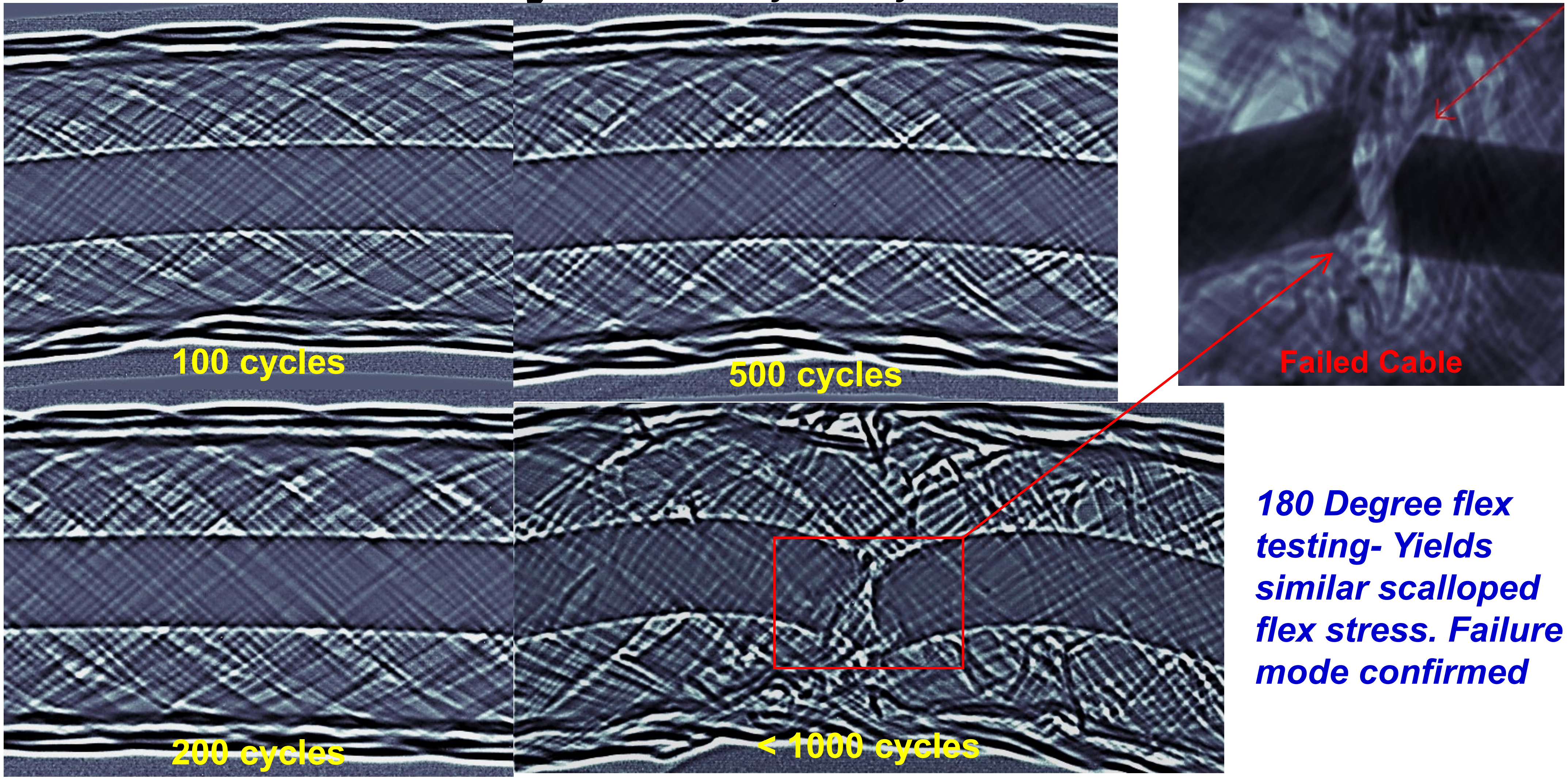
Coaxial Cable Analysis- *X-ray analysis of stress flexed cable*



180 Degree flex testing- Yields similar scalloped flex stress. Failure mode confirmed

Routing is optimized. Recommend- fasteners / shims guarded in movement path, consider stranded core

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RF CCA- 60V N-Channel MOSFET, 2N7002

I. **40-50% yield @ board level test**. Q501 Failed for FM distortion, with ***decreased*** output.

II. Supplier mounted IC's (SOT-23) appear different than repair stock. *Initially indicted as counterfeit*

III. Engineering provided spice model & details of the test fixture failure mode. Shift in charging time

IV. Common switching device; (4) OCM's Identified on the design specification ASL

Analysis- "K" newer date code ***less capacitance*** (D-S, D-G)

Circuit functions as On/Off switch appropriately

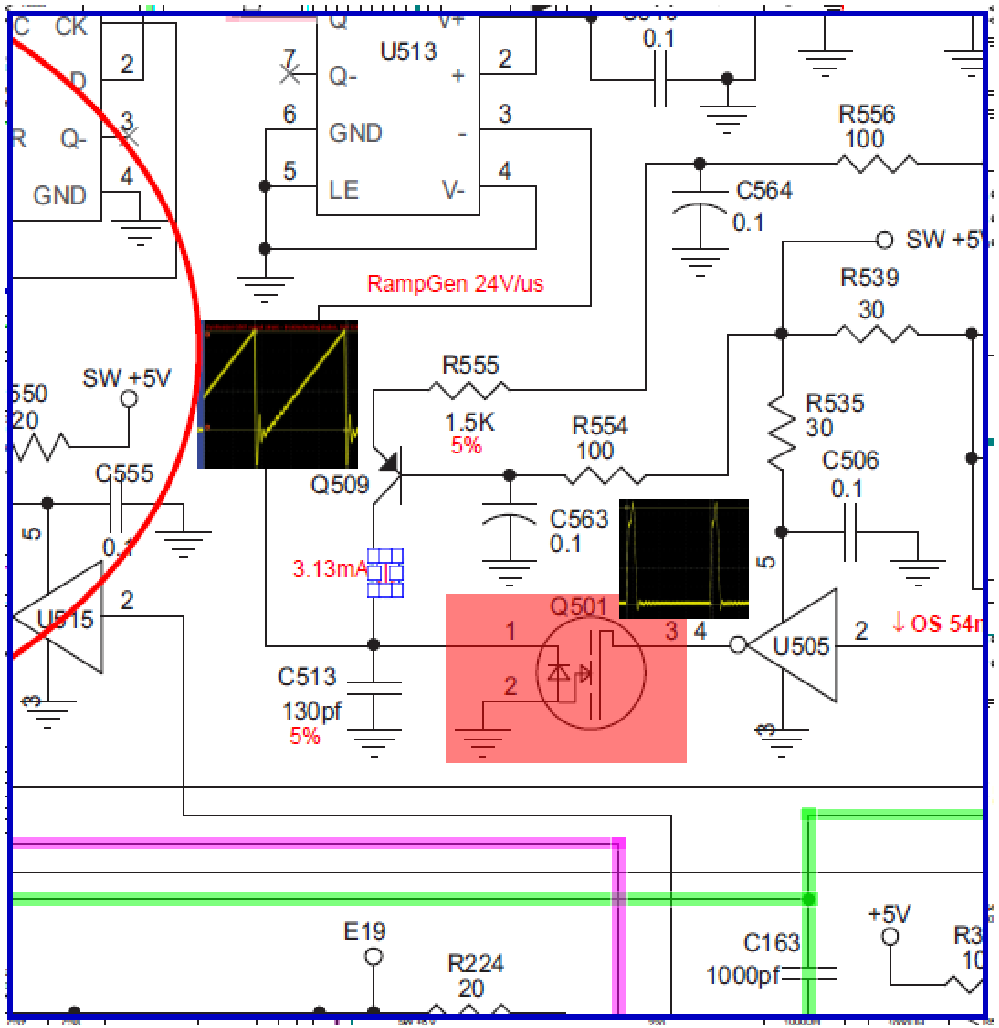
Device OFF: Source charges capacitor at the drain
- Generates saw tooth waveform

Device ON: Capacitor discharges, saw tooth starts near 0V

Steeper saw tooth related to less capacitance

Legacy circuit function DEPENDENT on MOSFET timing & capacitance attributes!

In Circuit Spice Model



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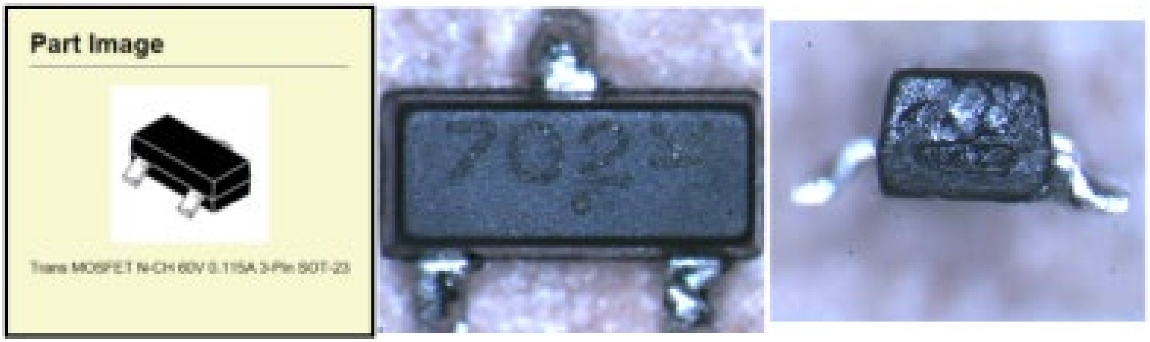
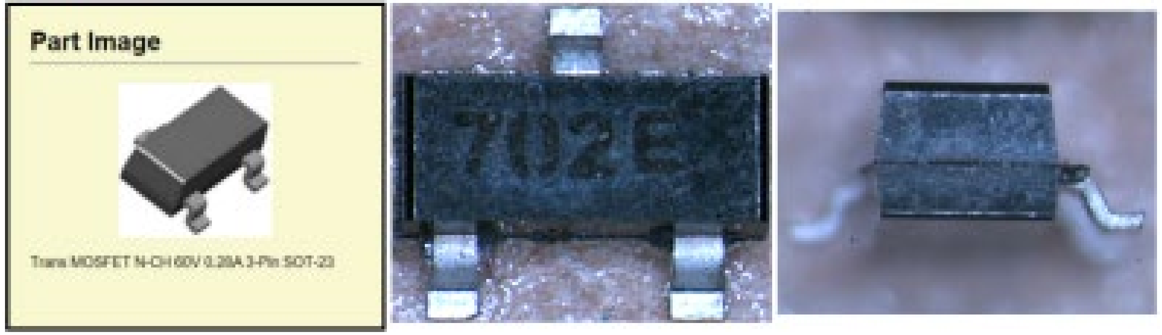
RF CCA- MOSFET supplier assessments & curve trace analysis



Markings & dimensional analysis:

Failing devices = OCM1

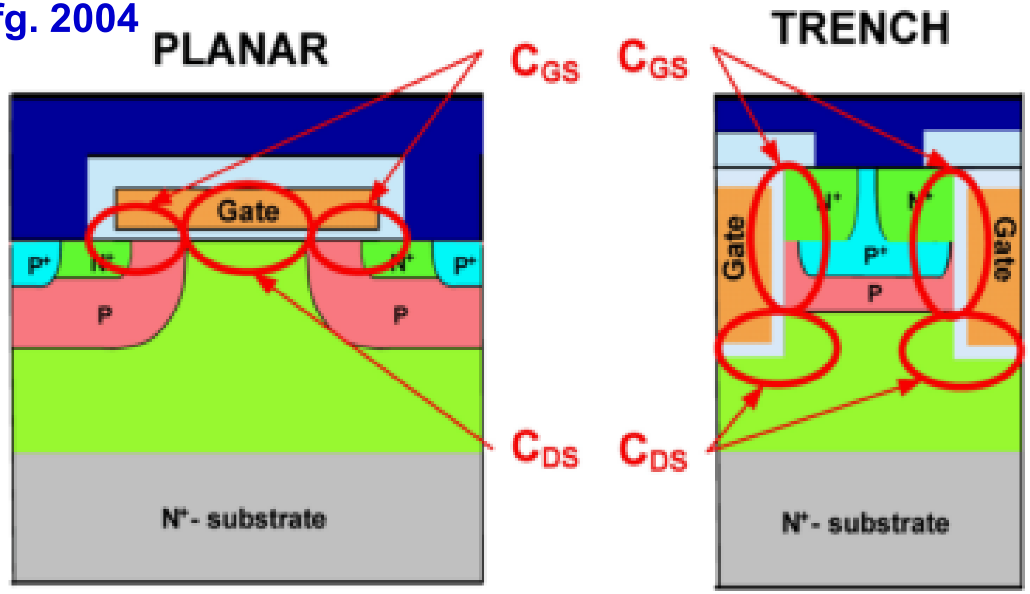
DC “K” = Mfg. 2011/13/15



Repair stock ***RESTORES*** circuit performance

Repair stock = Legacy OCM2

DC “E” = Mfg. 2004



Curve Trace Analysis-

Vf & Gain: Function properly, Increased gain in Newer device

✓ **OCM1** migrated from Planar to Trench FET architecture in 2009- **Die shrink, Larger Yield, Increased switching speed**

✓ **OCM1** Tests confirm increased switching speed & reduced output capacitance **Improvements for <u>new</u> designs EFFECTS time dependent legacy circuits!**

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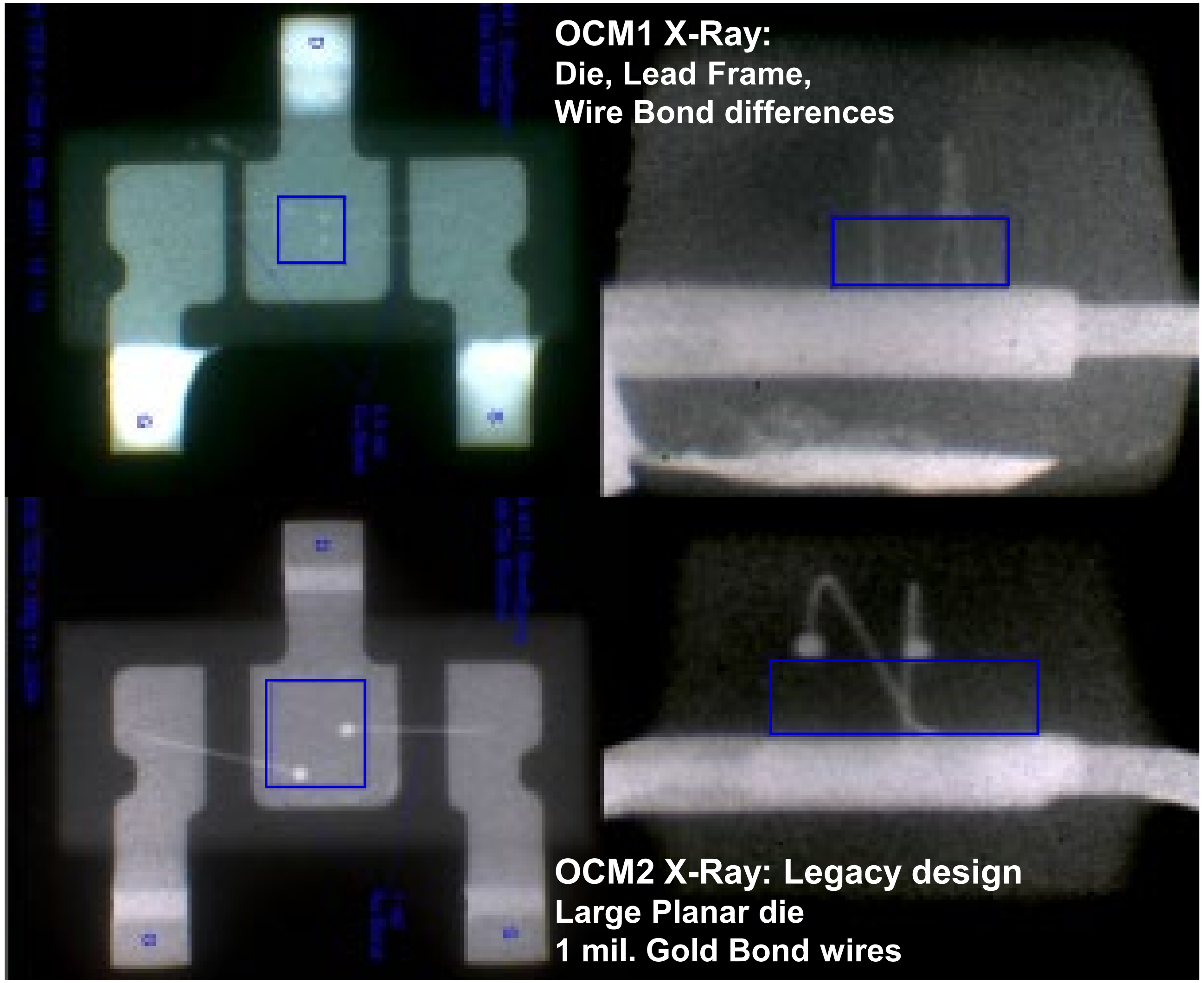
RF CCA- MOSFET X-ray verifies construction differences

Factors: Effecting function in legacy circuit

1. OCM1 migrated to copper wire, 0.5 mil with industry wide transition. Double wire bond D-S required ***DUE to increased bond strike force***

2. Bond wire length, orientation, quantity & lead frame differences effect
   - Gain
   - Noise susceptibility

   Results in Increased FM distortion



Die Shrink & wire bond change Effects Circuit performance!

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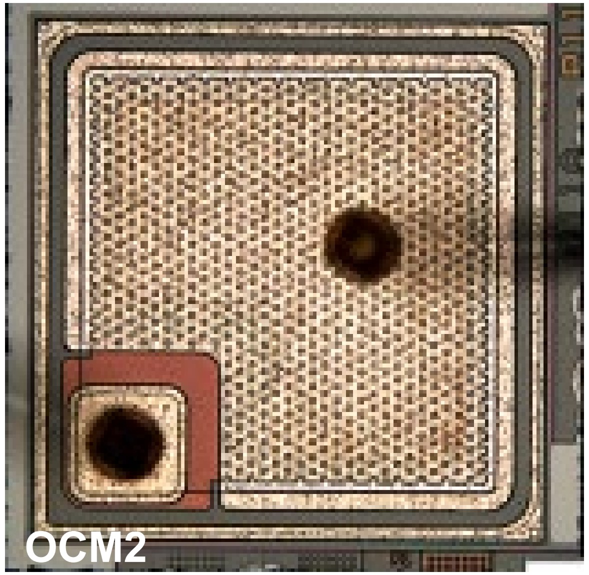
RF CCA- 60V N-Channel MOSFET, 2N7002

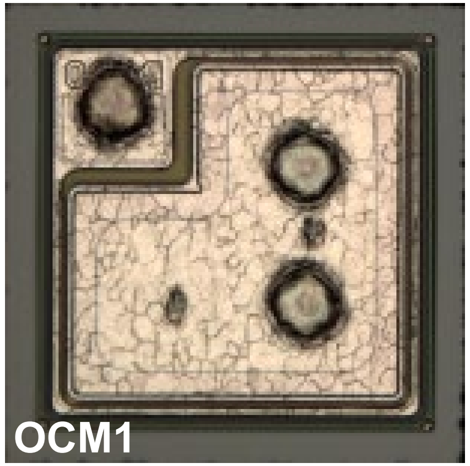
Factors: Effecting function in legacy circuit

3. Reduced C(D-S) & C(G-S) output capacitance effects
   - **State timing in circuit**
   - **Reduced noise tolerance. Additional wire increases distortion!**

[Images NOT to scale]



OCM2 De-Cap
Die Area 669 x 671 = 448,899μm^2



OCM1 De-Cap
Die Area 392 x 393 = 154,056μm^2

Findings: PCN / EOL notifications were released but did not migrate through program channels, impacting production

Recommend: *Modify circuit timing with added capacitance to accommodate planar & trench FET technology*

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Conclusions- *Recommended Actions & Preventive Measures*

- Commercial OCM's iteratively make changes to:
  - REDUCE Cost, Improve yield, throughput and Increase market share
  - Improve function and performance OR relocate factories
- Assess COTS items & best practices, utilizing Industry based standards
  - Form, Fit, Function impact ***Varies greatly!*** Engage SME's and cross-functional teams
  - Supplier Datasheet Updates / Releases, Technical Content, PCN / EOL Notices ***Varies!***
- For New & Legacy systems- *Test and Qualify everything!*
  - Perform review of component availability & PCN's, PRIOR to build, ***repeat*** periodically!
  - Specify replacement COTS items, as necessary
  - PCN impact may require testing and additional testing
- Impact of architectural, process or supplier changes can be Costly!
  - REQUIRES analysis from SME's: Materials, Mechanical, Electrical, Components, Supply Chain, Operations Quality / Mission Assurance, Failure Analysis & The Customer!

THANK YOU FOR YOUR TIME!

Abstract

2026 marks 30 years since Department of War policies were implemented to utilize COTS products and best practices where practical. COTS components and assemblies benefits include market availability, volume production cost savings and performance advantages offered by companies in various technology sectors. The challenge of Integrating COTS items in harsh aerospace & defense environments, is to ensure they can operate as intended and that the system design is tolerant of material and process variances associated with high volume COTS products.

With items such as circuit card assemblies (CCA's) intelligent sensors & power supplies, the use of COTS electronics is essential to take advantage of latest technology advances and contain cost. This presentation covers analysis methods needed to assess COTS assembly performance. Examples will be provided of COTS integration challenges and lessons learned associated with integrating and qualifying COTS items in mission critical systems.

OSW History; Dr. Perry: https://history.defense.gov/Multimedia/Biographies/Article-View/Article/571282/william-j-perry/

Dr. Perry Memorandum "A new way of doing business": https://legacy.sae.org/standardsdev/military/milperry.htm

Author BIO

Aaron DerMarderosian is a Senior Principal Electrical & Electronics Engineer at RTX, working in the defense segment's Failure Analysis Laboratory in Largo, Florida. With over 30 years of engineering experience, Aaron specializes in leading failure investigations and related disciplines. His expertise includes counterfeit detection and avoidance, COTS (Commercial Off-The-Shelf) and hardware security integration assessments, root cause analysis of failed components, materials, electronic assemblies and processes.

Aaron has presented at multiple conferences, including IEEE, SMTA, Defense Industrial Base, and RTX internal technical events. He is a senior member of the IEEE and a member of SMTA. Additionally, Aaron serves as an RTX company Co-Chair lead for the COTS Community of Practice (CoP) and has received multiple honors, including individual, team, and technical, innovation and inventors' awards. He holds a Bachelor of Science degree in Electrical Engineering Technology from Northeastern University.