



When the Interconnectedness of Systems, Goes Awry



COLLINS AEROSPACE | PRATT & WHITNEY | RAYTHEON

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Components for Military & Space Electronics Conference

System Level Interconnects

- ✓ In complex system designs, wire harnesses and cable assemblies connect our Lower Replaceable Units (LRU's), sub-systems together to distribute power, digital signals, mixed analog controls and RF signals.
- ✓ Suppliers and integrators rely on Military and Industry standards to define workmanship standards and inspection requirements.
- ✓ While some workmanship details are explicitly defined, other process indicators are open to interpretation. This can lead to failures in service or render items susceptible to EMI/RFI issues.
- **Military MIL-HDBK-454, Guideline 9:** *Relates to connector workmanship, not specific to wire harnesses & cables. Applies broadly to workmanship, solder connections and Insulation.*
- **IPC/WHMA-A-620: Wire Harnesses & Cable Assemblies**
 - *Industry standard, provides design & assembly requirements acceptance criteria*
 - *Uses Class system (Class 1 – 3), very similar to Solder workmanship standard J-STD-001*
 - *Provides workmanship requirements for harnesses & terminations, lacks explicit controls for general cable assembly process indicators, consistency & quality.*

Assembly workmanship requirements require review and definition by engineering as required

Wire Harness & Cable Assembly- *Supplier Capabilities*

■ Industry Supplier Challenges-

- I. Maintaining a seasoned / experienced workforce, knowledgeable in cable fabrication, advanced solder processes & best practice in-situ quality control inspection processes (particularly, post COVID).
- II. Harness & cable assemblies, similar to Hybrid / RF component technologies are intricate manually intensive assemblies. Makes automated assembly and inspection, challenging.
- III. Like other technology sectors, the wire harness and cable industry is under pressure to consolidate operations, cut costs with mergers losing experienced key personnel along the way.

EMI Testing & Next higher assembly Integration Failures- *Reveal that assembler training, Process Controls & Inspection protocols vary significantly between suppliers*

Examples follow of compliant / non-compliant assemblies & process indicators

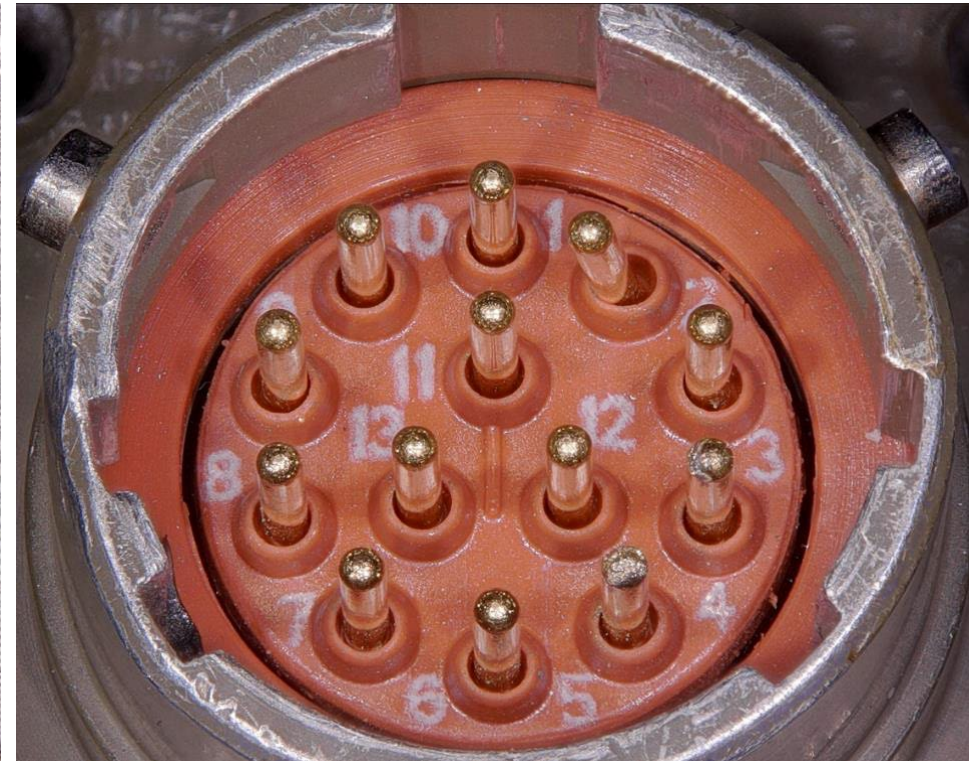
Design authority: **MAY have to impose drawing workmanship requirements to ensure reliable compliance!**

Example 1- Wire Harness Assembly, Requirements: IPC/WHMA-A-620, Class 3

Samples evaluated after failures noted in Integration test



Supplier 1

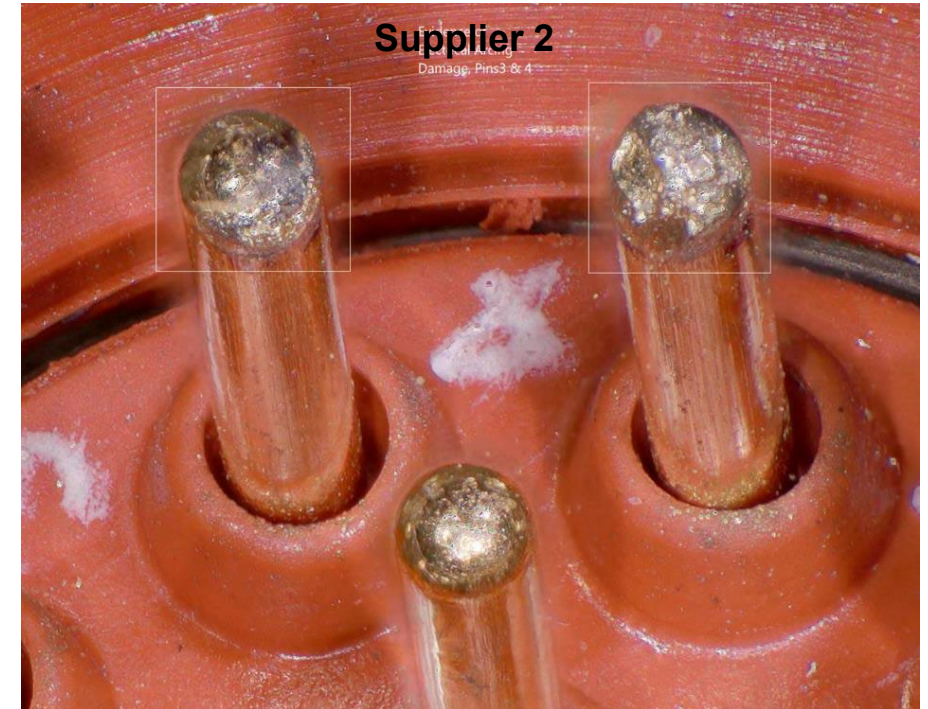
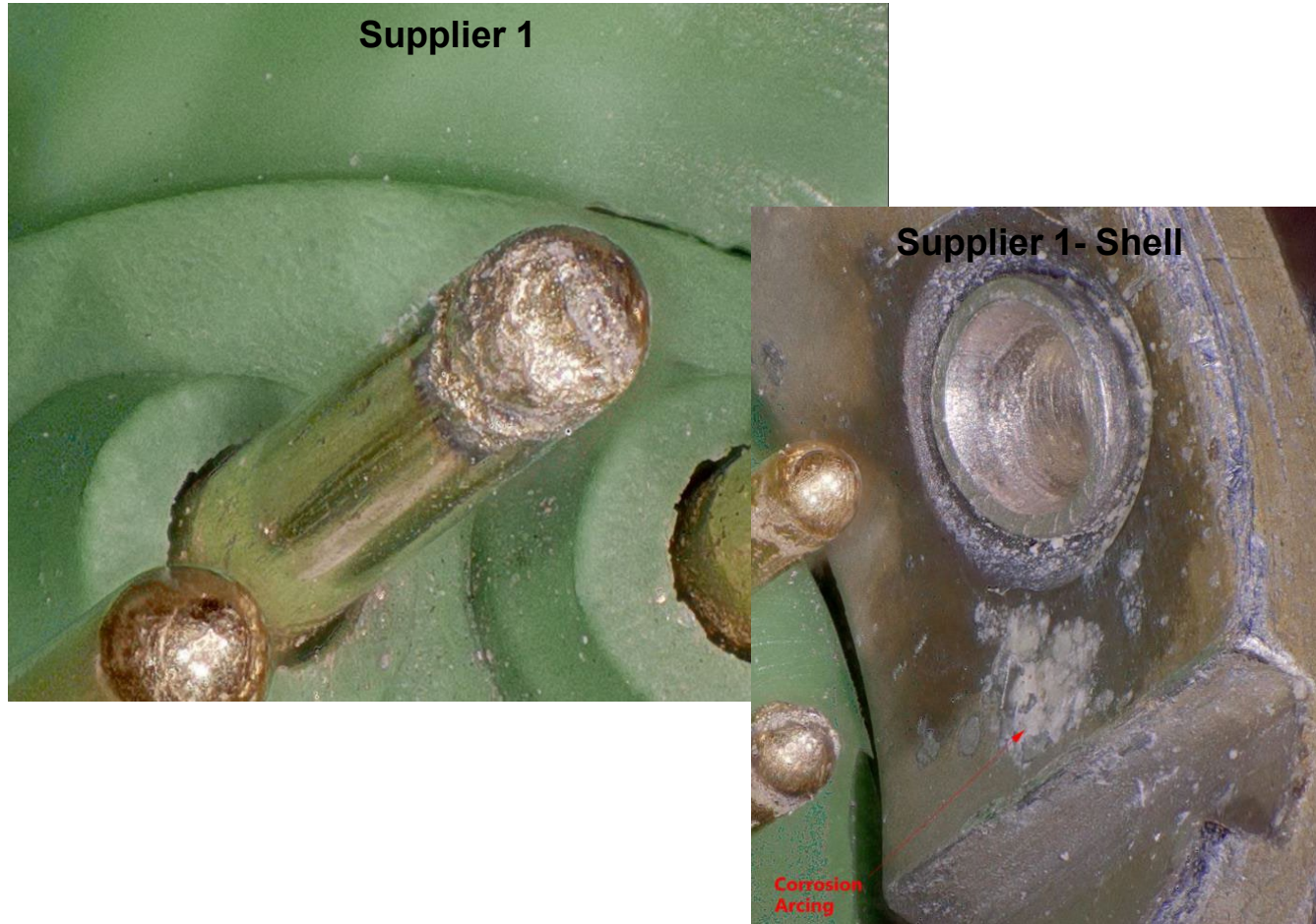


Supplier 2- Bent pin noted

Alternate supplier connectors: Allowed but CAN lead to mating connector fit issues between suppliers!

Example 1- Wire Harness Assembly, Requirements: IPC/WHMA-A-620, Class 3

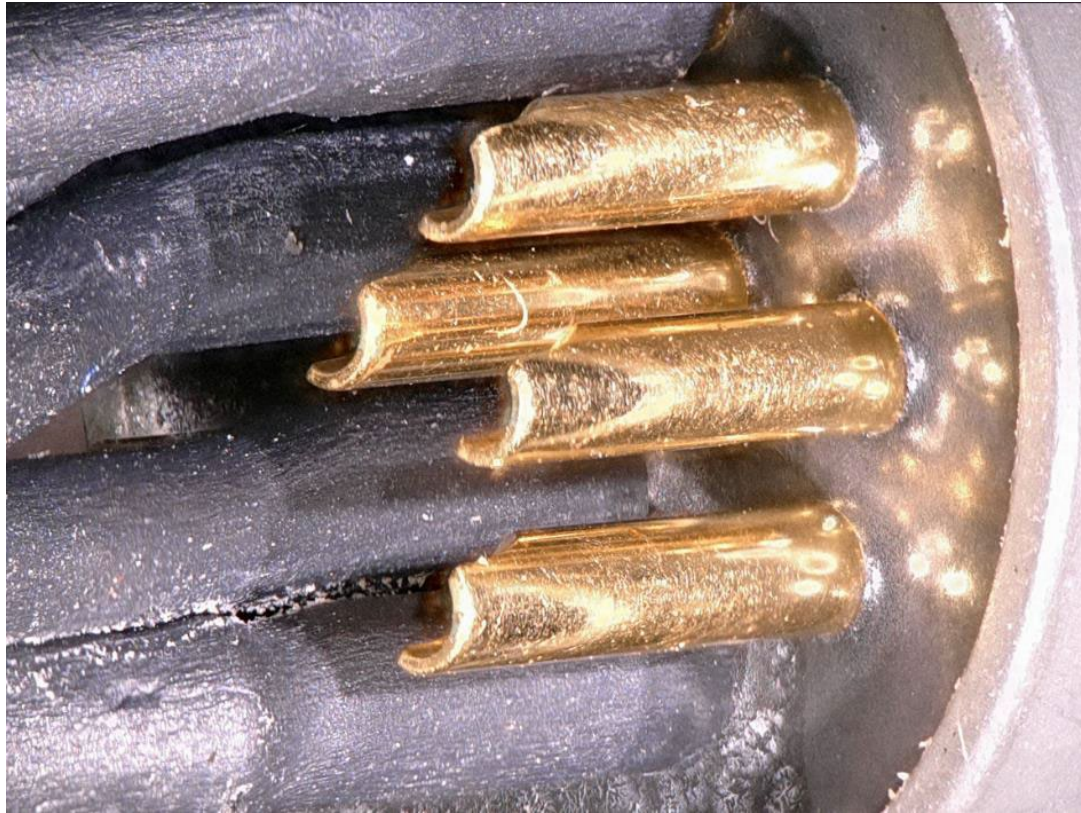
Samples evaluated after issues noted in Integration test



Arcing: Potentially related alternate supplier mating connector fit issues. Requires supplier drawing callout

Example 1- Wire Harness Assembly, Requirements: IPC/WHMA-A-620, Class 3

Samples evaluated after issues noted in Integration test



Supplier 1 Shrink Sleeve missing

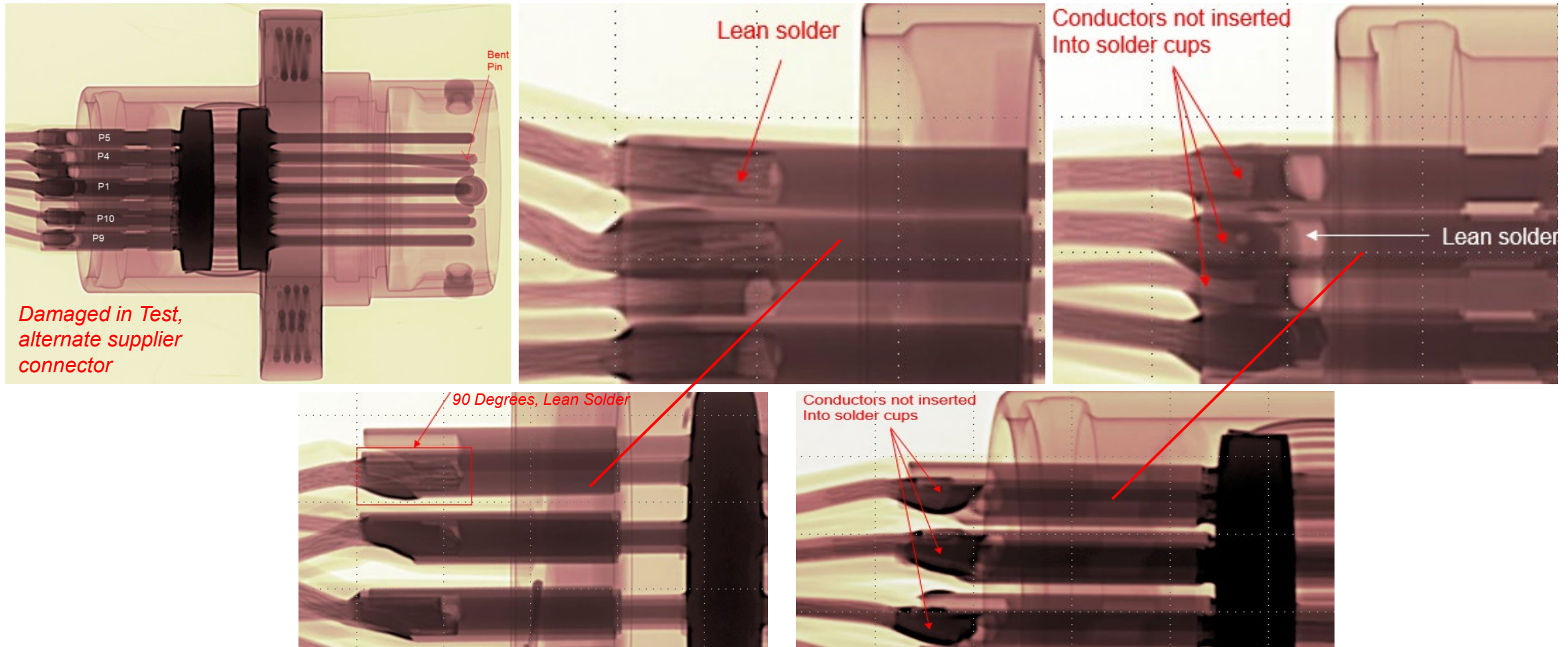


Test cable comparison

Shrink Sleeve unused pins: *Required in standard & drawing, Potential short points on the system side!*

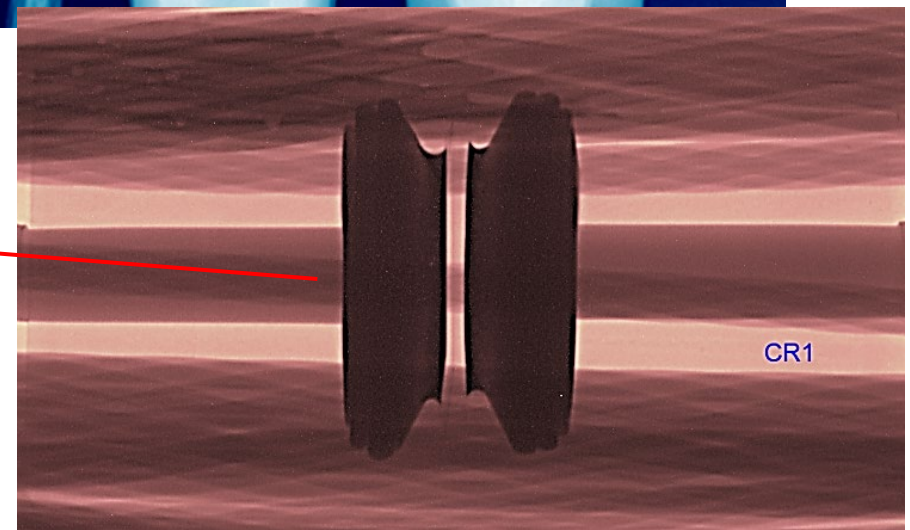
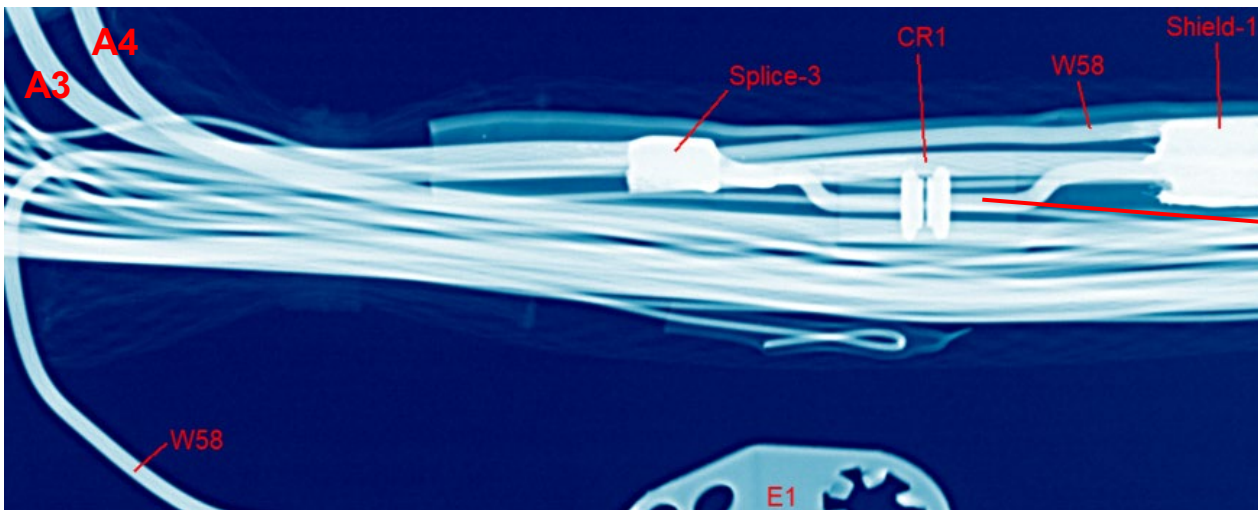
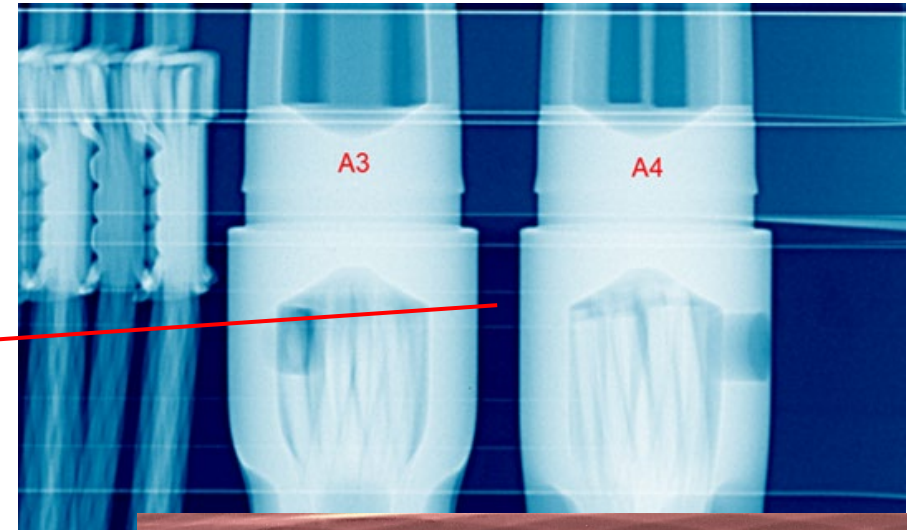
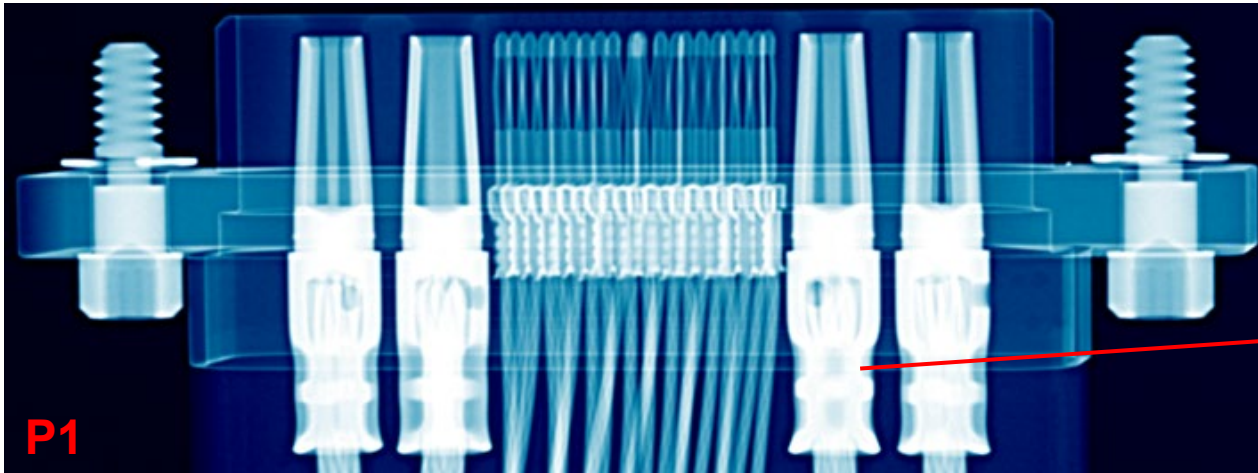
Example 1- Wire Harness Assembly, Requirements: IPC/WHMA-A-620, Class 3

Samples evaluated after issues noted in Integration test



Class 3 Solder Requirements: Called out in drawing & industry spec! Workmanship issues

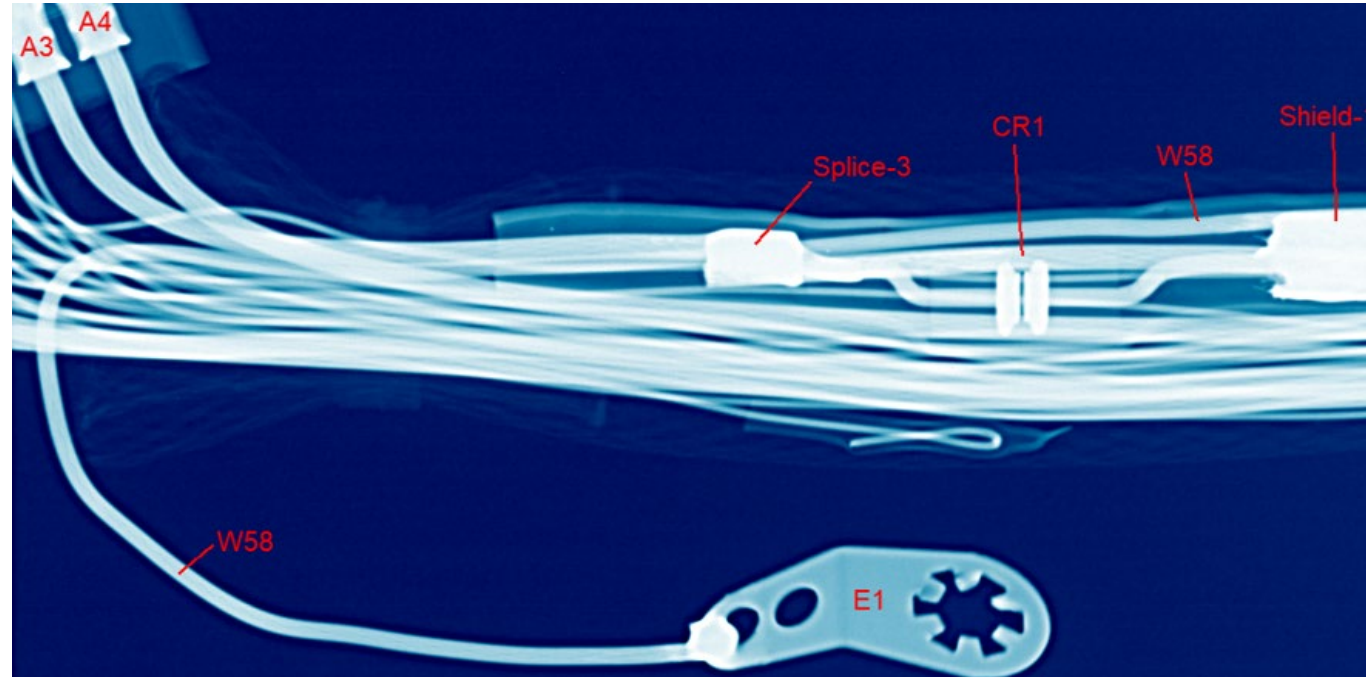
Example 2- Cable Assembly, Requirements: IPC/WHMA-A-620 C3 & MIL-HDK-454 G9



X-ray Review: Finds no shorts & located the TVS diode. No physical polarity marking (visible on diode body)

Example 2- Cable Assembly, Requirements: IPC/WHMA-A-620 C3 & MIL-HDK-454 G9

Electrically confirmed 40-50% diodes installed in reverse



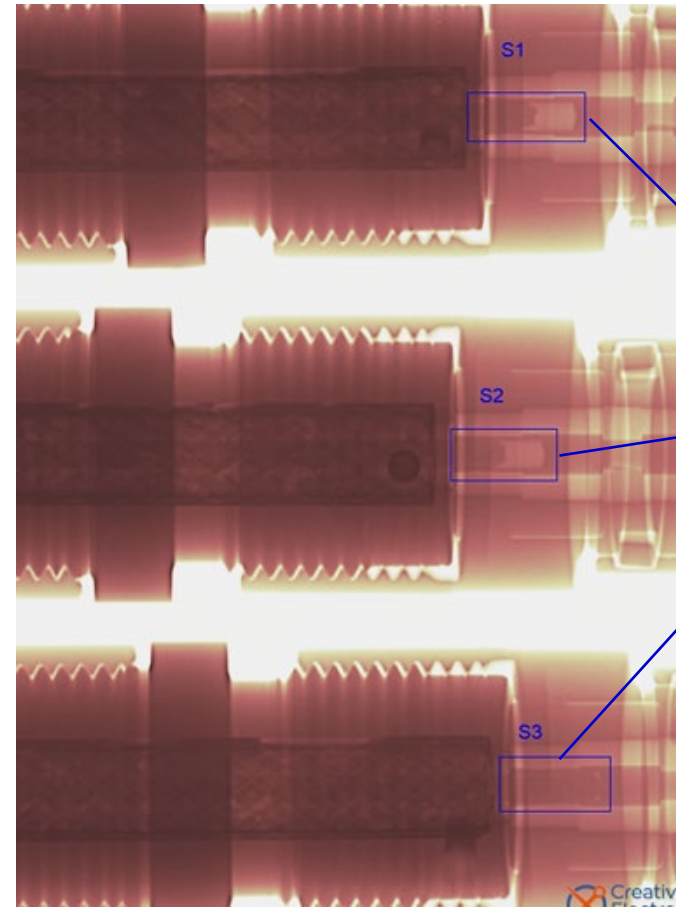
DMM switched to diode function: **Correct wired diode response per the drawing**

1. (+) lead on A3 (28V); (-) lead on E1/A4 = No Response / Open Circuit
 2. (-) lead on A3 (28V); (+) lead on E1/A4 = 0.5 to 0.6V forward diode response
- Any other results indicate TVS reverse polarity, open or short issue

Drawing covers Supplier workmanship issue; not covered explicitly in the standards

Example 3- Cable Assembly, Requirements: MIL-HDK-454 G9; MIL-STD-461 (EMI/EMC) & MIL-STD-2169 (HEMP)

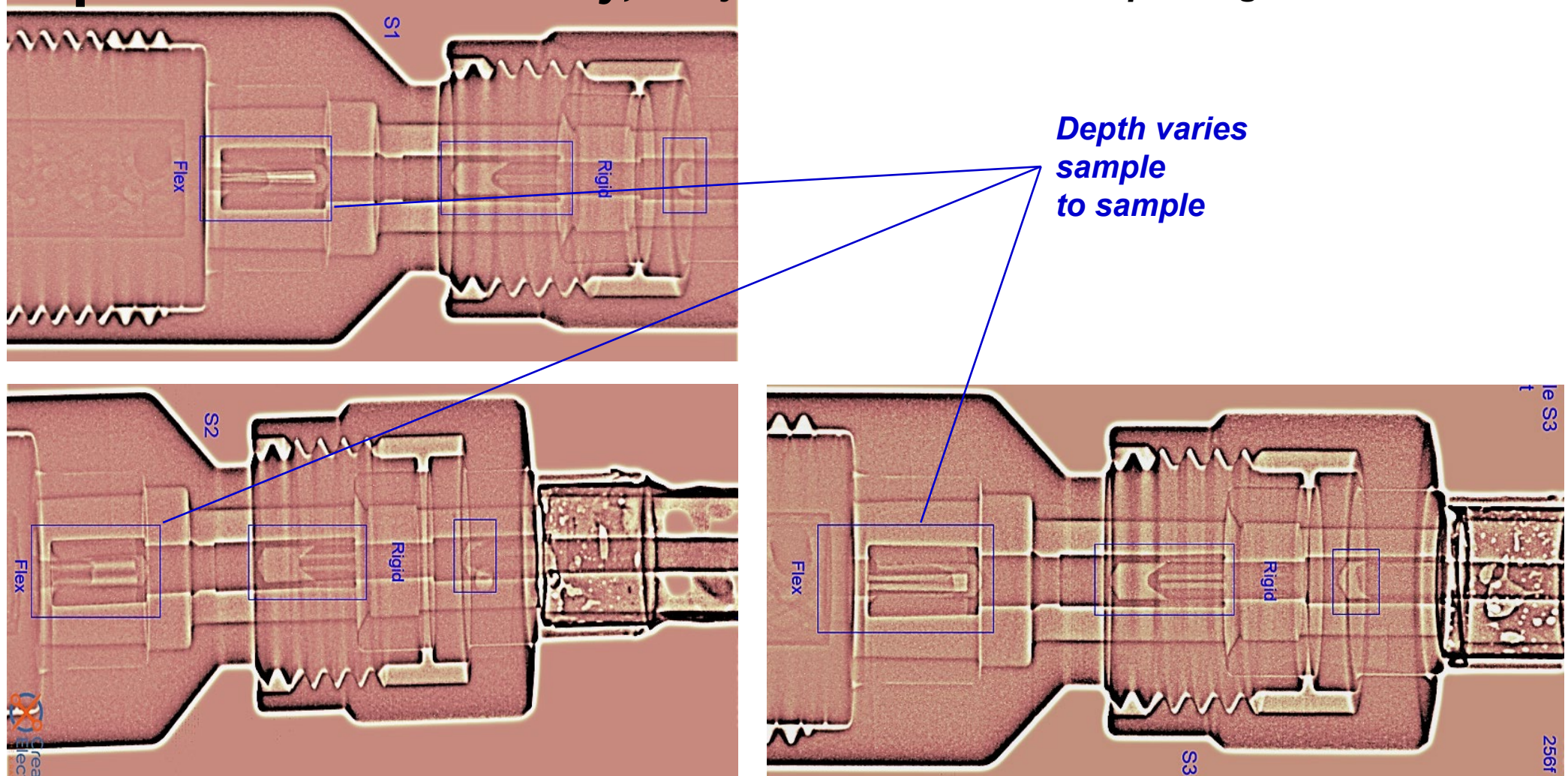
High Frequency Semi-Rigid Coax: Samples screened due to other program quality issues



Depth varies sample to sample

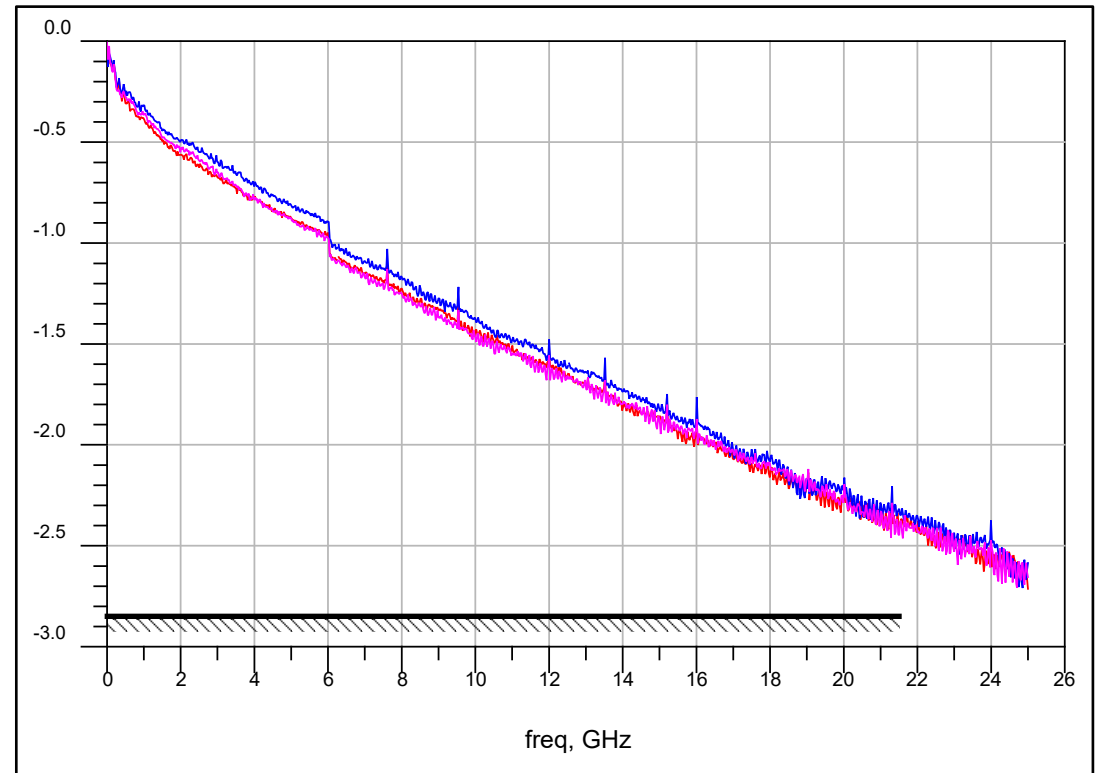
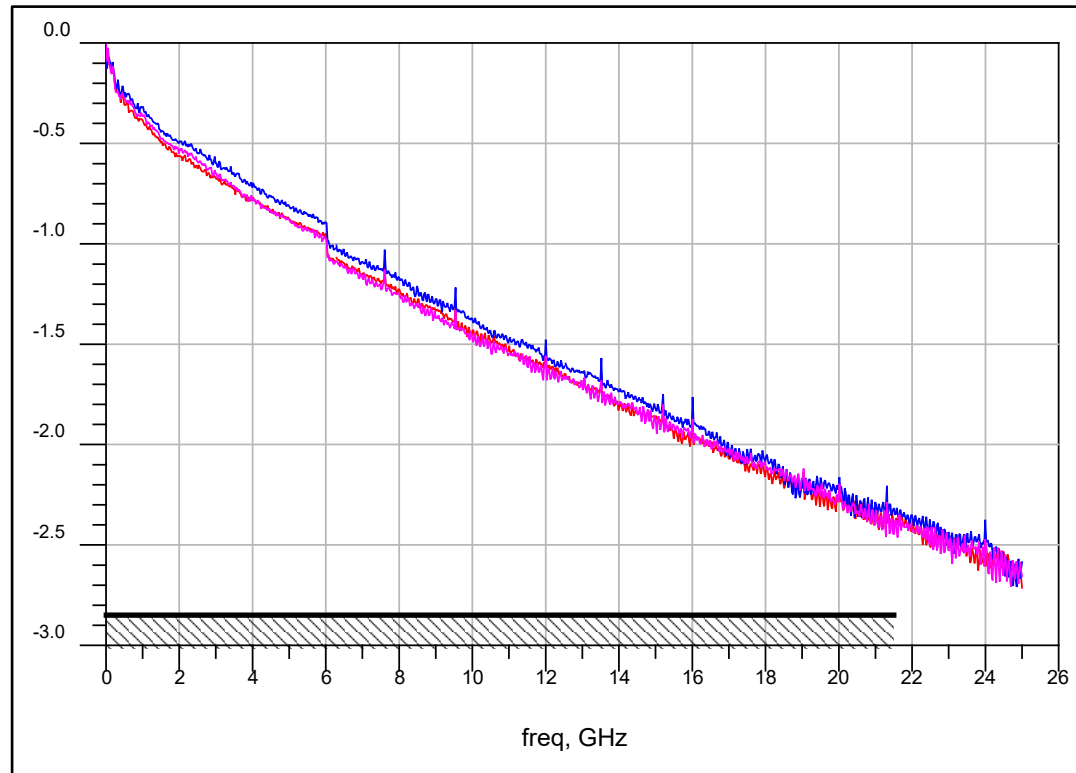
Excellent construction, Issue noted: *Reduced mating RF Pin penetration. Retraction, Insertion Loss, VSWR risk*

Example 3- Cable Assembly, X-ray characterization of Gaps; Edge mode



Exhaustive Search of HF Coax requirements: *Mentions mitigating penetration, issue but no explicit criteria!*

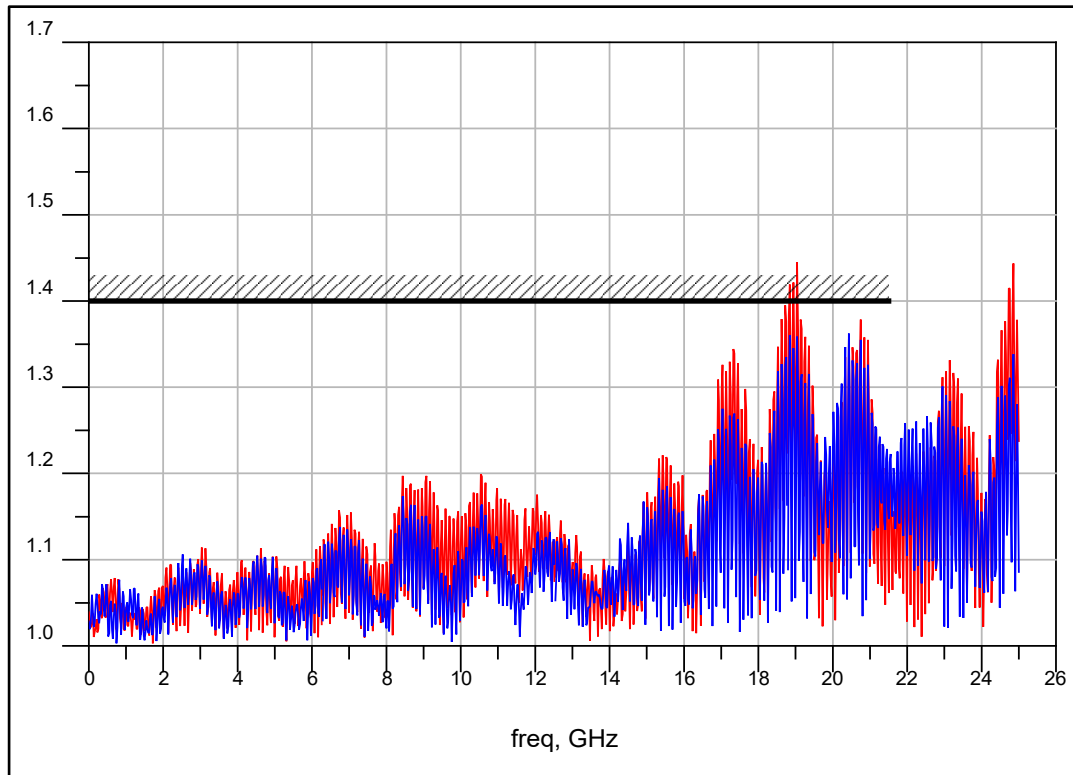
Example 3- Cable Assembly, Insertion Loss characterization. Frequency Sweep



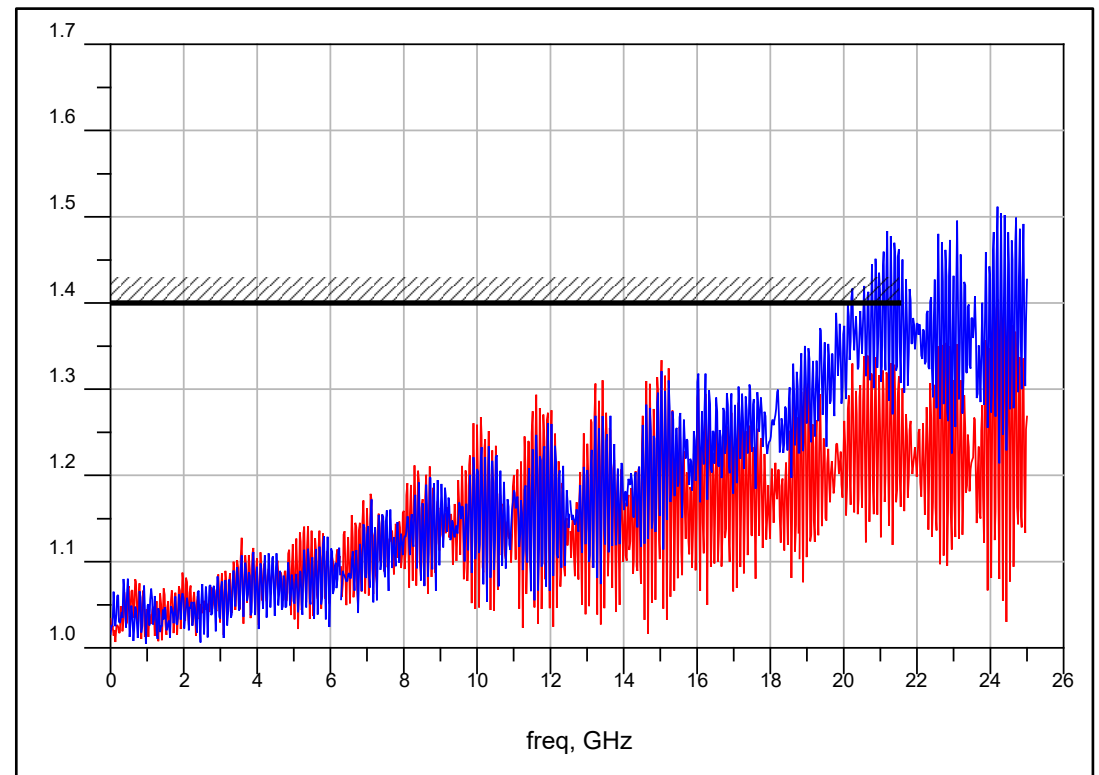
RF Characterization- SME & Eng. Fellow J. Culver
Y Axis = Loss (dB)

Samples measure in straight & coiled (worst case) configuration. **ALL cables Passed IL**

Example 3- Cable Assembly, VSWR (Reflected Energy). Frequency Sweep



RF Characterization- SME & Eng. Fellow J. Culver

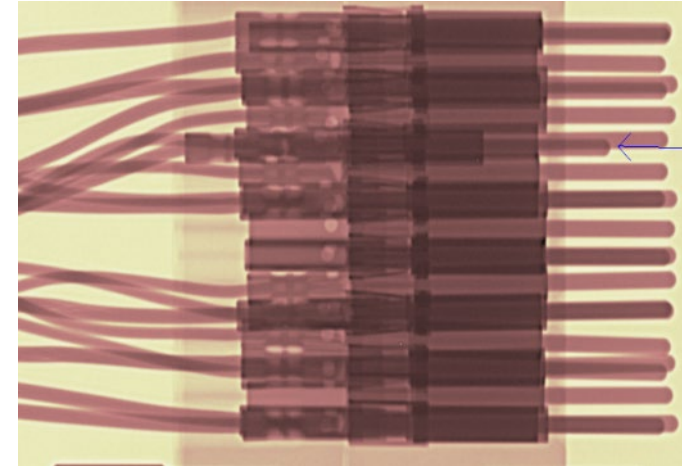
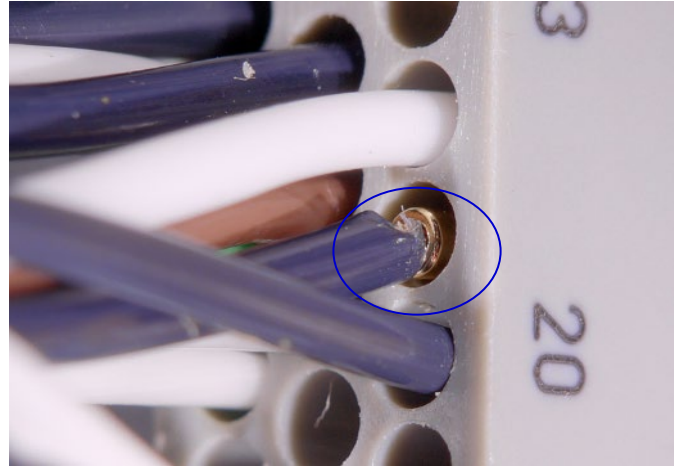
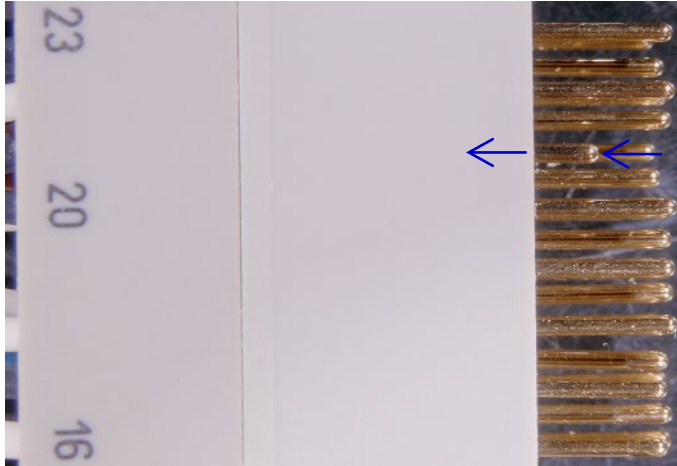


Y Axis = Voltage Standing Wave Ratio

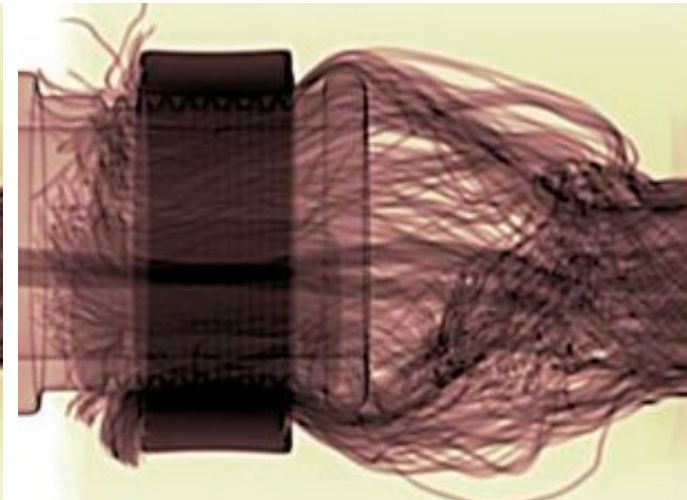
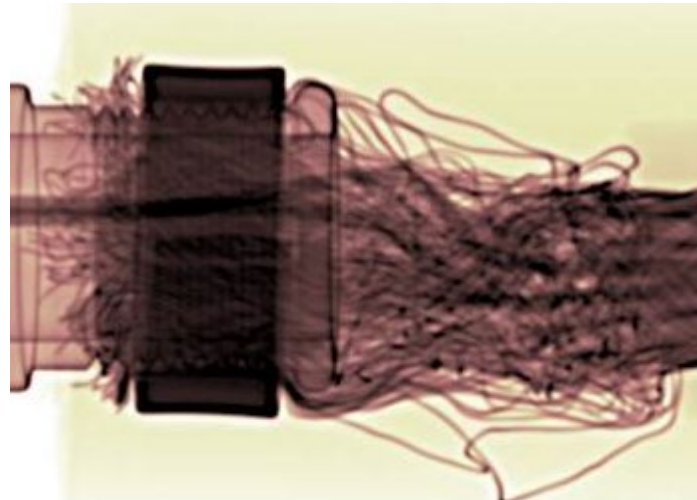
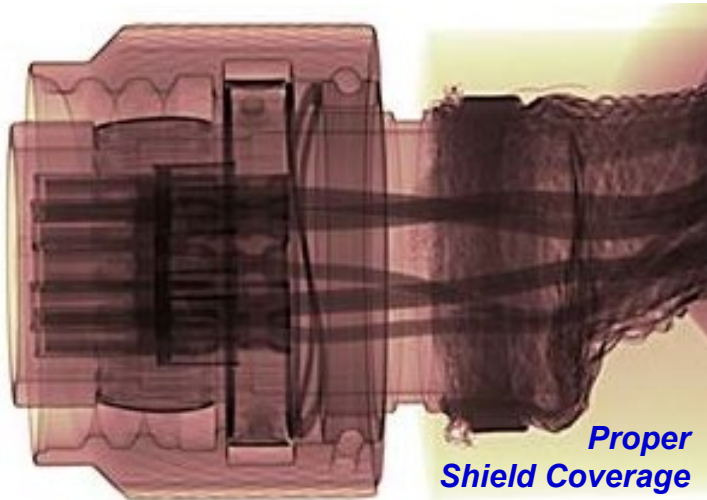
Determined conductor penetration depth was related to Industry known requirement to thermally “pre-condition” RF Coax material, PTFE & Polyimide foil tapes relax & shrink under thermal excursion. **NOT explicitly identified in drawing or Industry standards!**

Samples measure in straight & coiled (worst case) configuration. 2 of 3 Cables fail for VSWR

Example 4- Various workmanship issues Identified



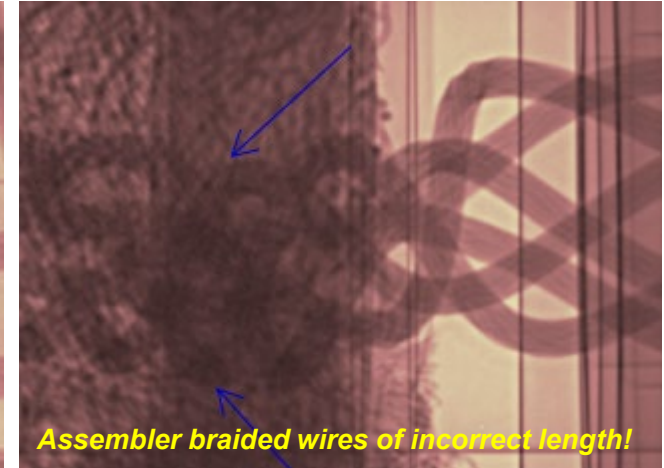
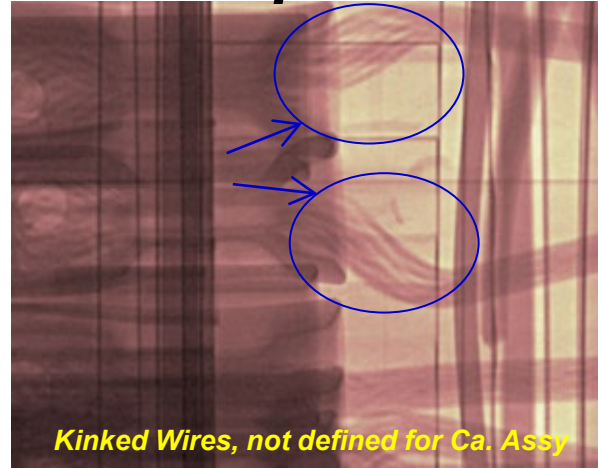
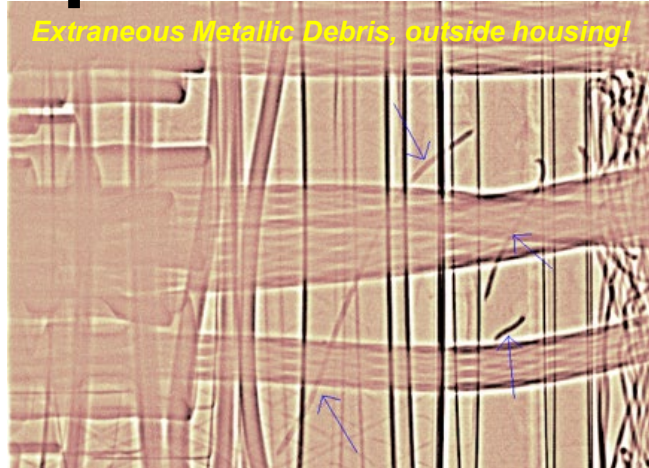
Incorrect Pin Insertion: Defined in IPC/WHMA-A-620, Class 3



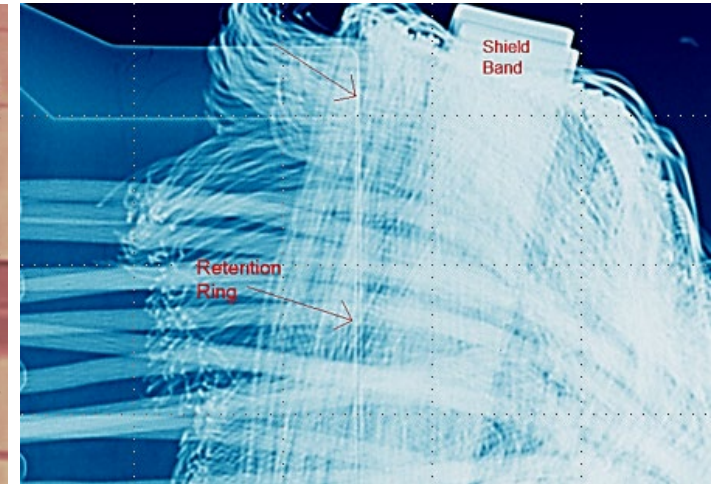
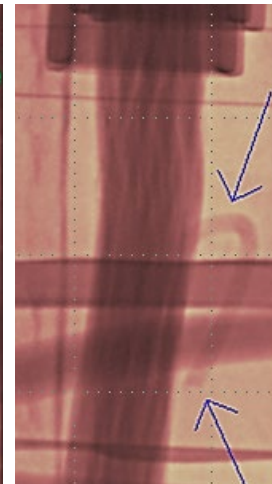
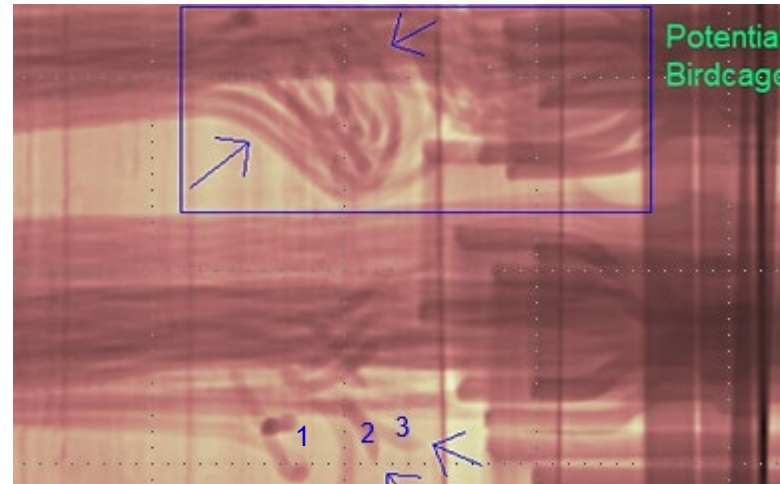
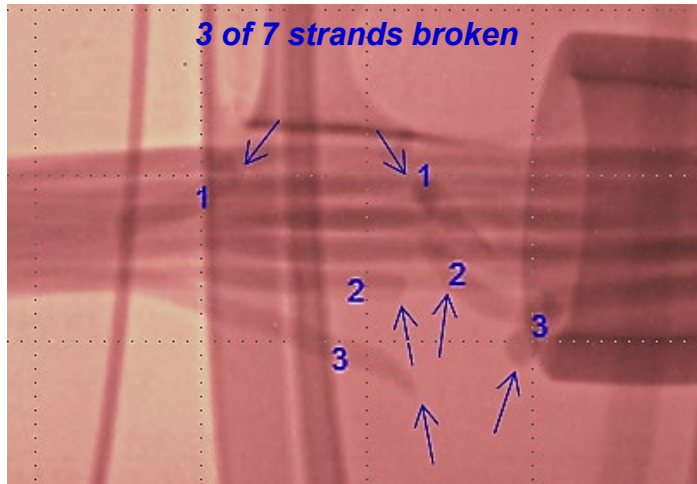
Improper Construction: *REQUIRES Drawing callout!*

Standards require review to ensure quality / workmanship issues that affect reliability & function are addressed!

Example 4- Various workmanship issues Identified



Process indicators: Not explicitly called out in standards or drawing!



Broken wires & Construction: covered in IPC/WHMA-A-620, Class 3

Standards require review to ensure quality / workmanship issues that affect reliability & function are addressed!

Conclusions- *Recommended Actions, Preventive Measures*

- **Military and Industry Standards for Quality and Workmanship:**
 - Process errors that can impact reliability or functionality are not explicitly defined for Cables Assemblies.
 - Military Standards for EMI/RFI & HEMP related immunity provide explicit performance requirements but fall short of defining material construction requirements to ensure performance across frequency spectra.
 - As noted in a portion of construction errors and process indicators presented today, some suppliers may get “creative” in how they deal with assembly mistakes!
- **Drawing Design Reviews:**
 - Mil & Industry Standards called out in harness & cable drawings MUST be reviewed, to ensure that the assembly will be constructed by the supplier, in accordance with internal process quality standards in mind.
 - Items such as shield construction, double banding and 360 housing coverage for EMI, will HAVE to be called out in the drawing, as it’s not called out in the standards.
 - While “bird caging” & kinks that reduce electrical clearances are specified for terminals and harnesses, this does not explicitly cover EMI shielded cable assemblies (standard is not clear on this).
 - Extraneous wires from “fold-over” crimping is covered in the IPC spec. it does not call out requirements for cables.
 - Although broken wires from cutting or kinked wires are not allowed, it’s worth re-iterating on the drawing!

***THANK YOU FOR
YOUR TIME!***



Abstract

When we think of component failures, we envision electronic devices or assemblies suffering from unintended operational environments resulting in electrical overstress or damaged parts from Electro-static discharge. Just as important are the items, which interconnect our sub-systems and systems to provide power, data and RF signals between the system functional blocks.

Without backplanes, wire harnesses and cable assemblies, we simply could not integrate items into a useable system. Cables these days even integrate electronics such as Diodes, Transient Voltage Protection devices and EMI filters (L/C-PI). This presentation will review cable construction issues which are considered unacceptable under MIL-HDBK-454 Guideline 9 & IPC/WHMA-A-620, Class 3 and items where drawing definitions are required.

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.