NASA Electronics Parts and Packaging Program
2020 Electronics Technology Workshop

Stacking Connectors & Nickel Underplating

Joe Rosol
Parts Engineer
Wire – Cable - Connectors
GSFC Code 562/ Genesis Engineering Solutions
June 17, 2020

To be presented by Joe Rosol at the 2020 NEPP Electronics Technology Workshop (ETW), NASA GSFC, Greenbelt, MD, June 15-18, 2020.

Acronyms

- Gold (Au)
- AXON Cable, Montmirail, France (AXON)
- Computer-Aided Design (CAD)
- Department of Defense (DoD)
- Electrical, Electronic & Electromechanical - Instruction (EEE-INST-002)
- Electroless Nickel Immersion Gold (ENIG)
- European Space Agency (ESA)
- Foreign Object Debris (FOD)
- Giga byte per second (Gb/s)
- Goddard Space Flight Center (GSFC)
- Hertz (Hz)
- Interconnect Devices, Incorporated; a division of Smiths Interconnect; Kansas City, Kansas (IDI)
- Low-Level Contact Resistance (LLCR)
- Mixed Flowing Gas (MFG)
- Minimum Order Quantity (MOQ's)
- Millimeters (mm)
- Milli-Ohms (m-Ohms) (mΩ)
- Millisecond (msec)
- Nanometers (nm)
- National Aeronautics and Space Administration (NASA)
- Nickel (Ni)
- Root Mean Square (RMS)
- Parts Per Billion (ppb)
- Printed Wiring Board (PWB)
- Airborn connector interposer product designator (RZ)
- Samtec Connector designator for a female ground plane connector (QFSS)
- Samtec Connector designator for a male boundary layer connector (QMSS)
- Surface Mount Technology (SMT)
- Scanning Electronic Microscope (SEM)
- Eighty-five degrees Celsius/Eighty-five percent relative humidity (85/85)

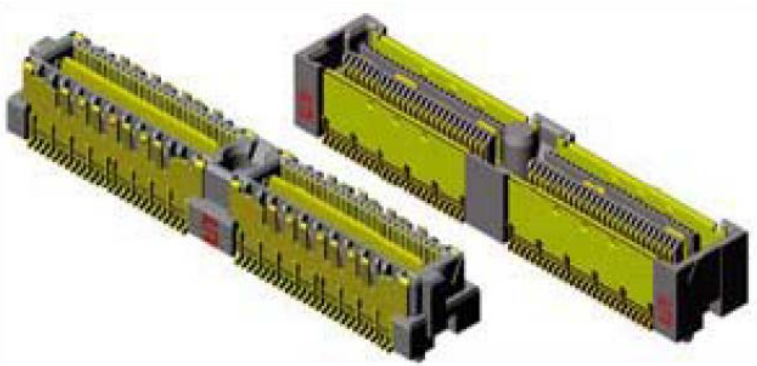
Connector Selection

- Military, NASA, ESA, DoD
  - Proven designs
  - Designed for high reliability
  - Flexible features
  - Wide range of usage
  - Favorable contact coatings
  - Corrosion resistant
  - “Universally Accepted” qualification and screening
  - For space/vacuum use, modifications are prudent
- Commercial
  - Options go beyond what’s in mil-specs
  - Fill very specific needs
  - Evaluate design for high-reliability
  - Interpret factory qual reports
  - Determine appropriate screening
  - Check spaceflight heritage
  - Justify usage to the project, if rejected by parts engineering
  - **Bain of a parts engineer’s existence**

Samtec

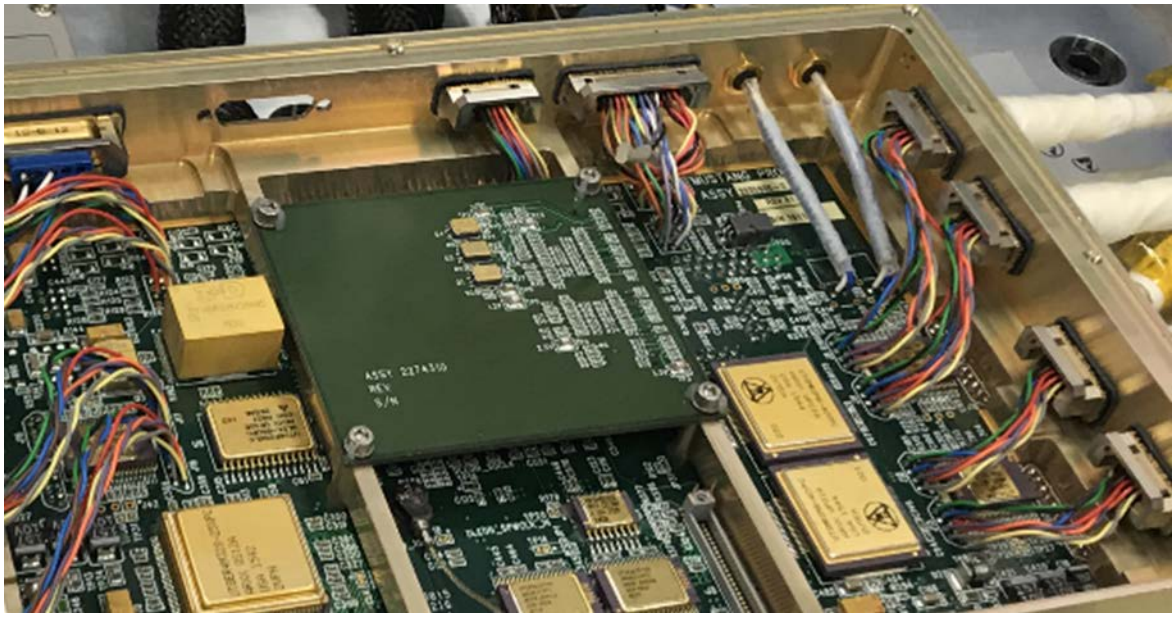
- The Swiss-Army Knife of the connector industry
- Pros:
  - Low cost
  - Molded insulators
  - Many plating options
  - Quick-turn modifications (high MOQ's?)
  - User-friendly web site
  - Download CAD formats
  - Signal integrity support
  - On-line qual reports
- Cons
  - Mostly stamped & formed contacts
  - Rough asperity areas
  - FOD/shards attached to insulators
  - Insufficient gold plating
  - Many lack fastener mounting options
  - Difficult to measure individual contact insertion & withdraw forces

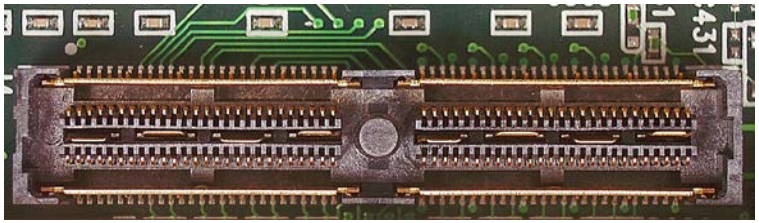
Samtec Ground Plane Connector Case Study



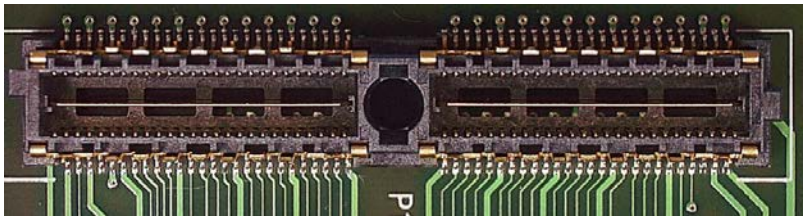
- QMSS & QFSS
  - ~$20 each
- Unique design with 25-mil pitch
- Single ground plane or shielded on both sides of stripline
- “Rugged” version
- 25Gb/s performance @ 10mm stack height
- Au plating, over 50µ-inch Ni (non-standard)
  - Signal Contact Areas 30µ-inch
  - SMT Solder Tails & Shields 10µ-inch

Mezzanine Processor Board Application



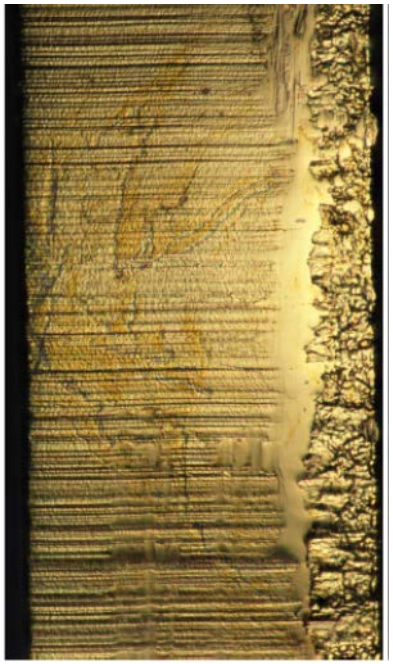


Motherboard



Daughterboard

Signal Contacts

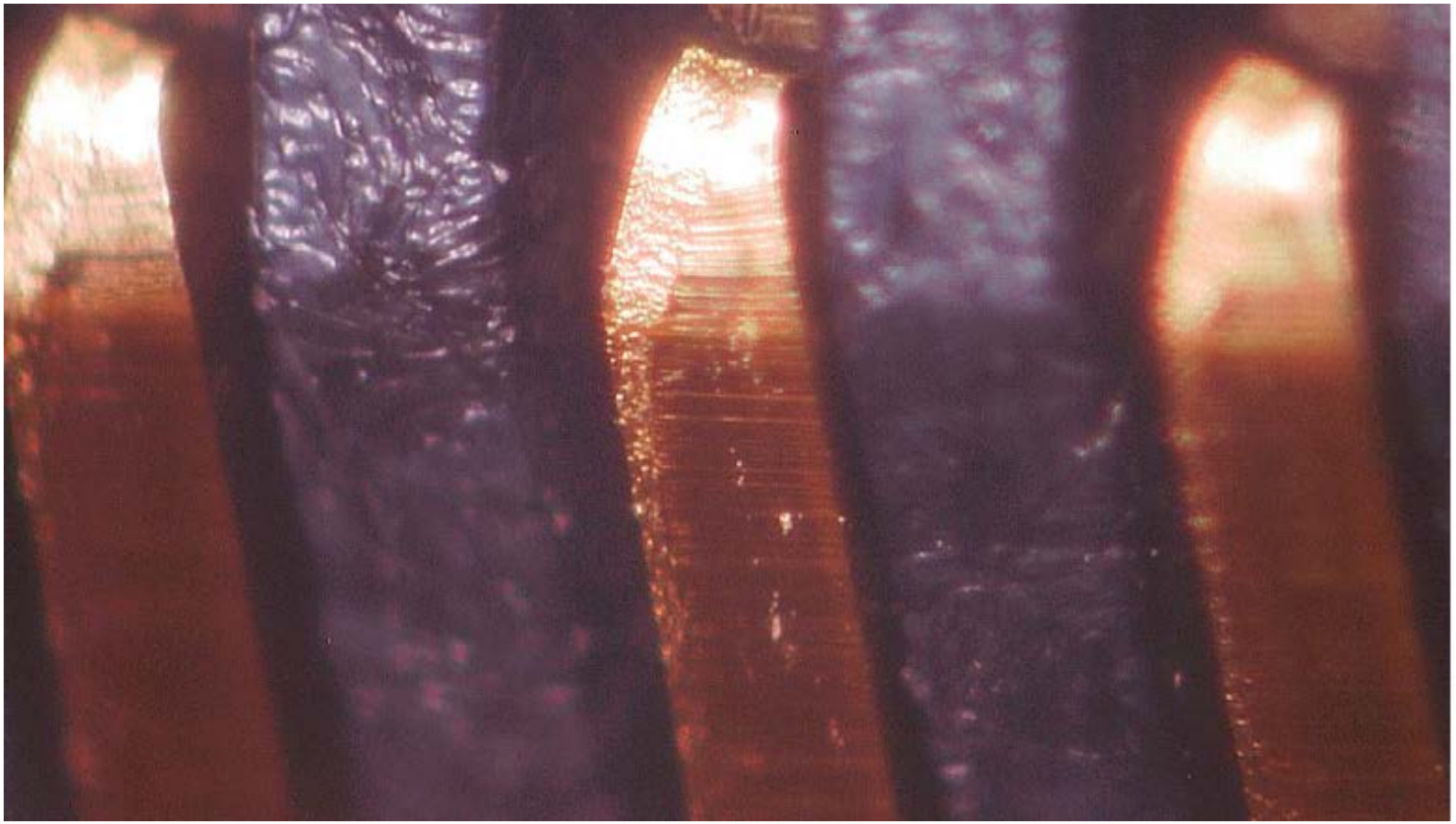


QFSS Tine Surface

QMSS Tine Surface

- Contact surfaces run along shear planes
- Goal is to minimize the burr (break) surface, maximize the parallel burnish lines
- Break surface is higher than the burnished

QMSS Male Tine – Non-flexing



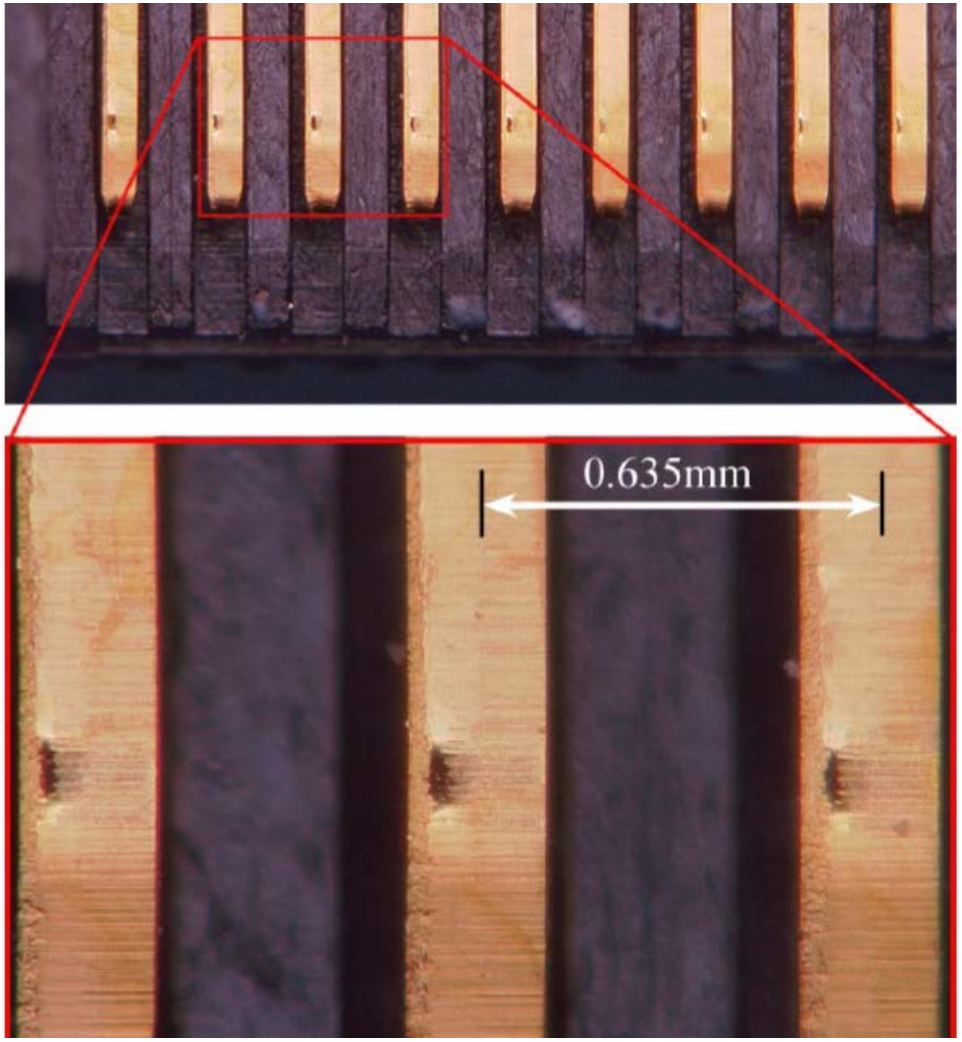
GSFC vs Samtec Dynamic Qual

- **GSFC each axis**
  - Sine Burst: 20Hz, 20g, 5 Peak Cycles
  - Sine: 20-100Hz, 12.5g, 2 octaves/min
  - Random: 20-2000 Hz, 14.1 g_{RMS}, 2 min
- Visual & SEM Analysis
  - Remove connectors from boards
  - DPA to get access
- Optical Observations
  - A few had no discernable damage
  - No nickel underplating revealed
  - Mating wear tracks seen in many cases
- SEM
  - Several pins exhibited exposed nickel
  - No exposed brass
- Connectors saw one mating cycle

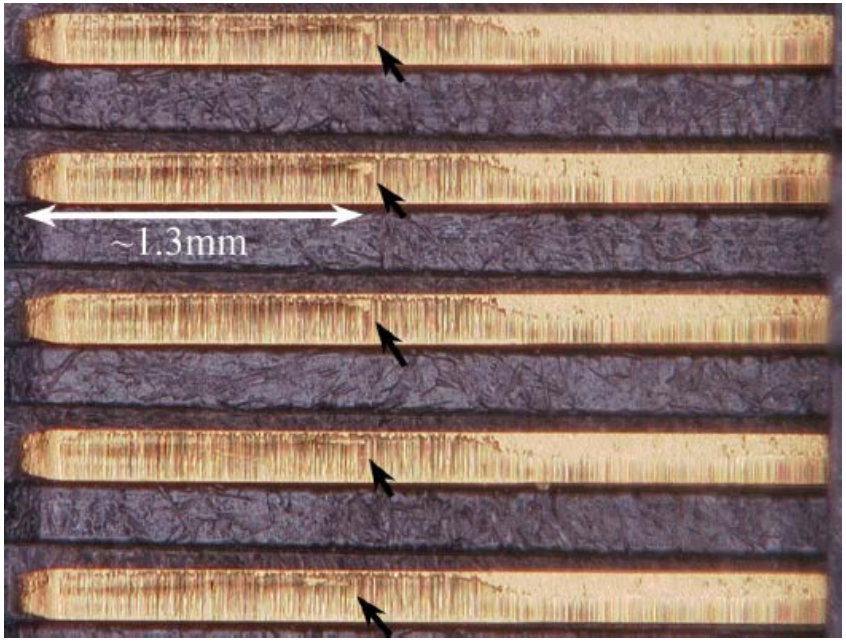
- **Samtec each axis**
  - Shock: 100g peak, 6msec, 3X
  - Sine: 20-100Hz, 12.5g, 2 octaves/min
  - Random: 50-2000 Hz, 7.56 g_{RMS}, 2 hours
- Mixed Flowing Gas
  - 10 ppb chlorine
  - 200 ppb nitrogen oxide
  - 10 ppb hydrogen sulfide
  - 100 ppb sulfur dioxide
- Low-Level Contact Resistance (LLCR)
  - R increase after 10 days <15 mΩ
- Samtec guidelines Δ LLCR

<= +5.0 mOhms:---------- Stable
+5.1 to +10.0 mOhms:---------- Minor
+10.1 to +15.0 mOhms: ---------- Acceptable
+15.1 to +50.0 mOhms: ---------- Marginal
+50.1 to +2000 mOhms: ---------- Unstable
>+2000 mOhms:---------- Open Failure

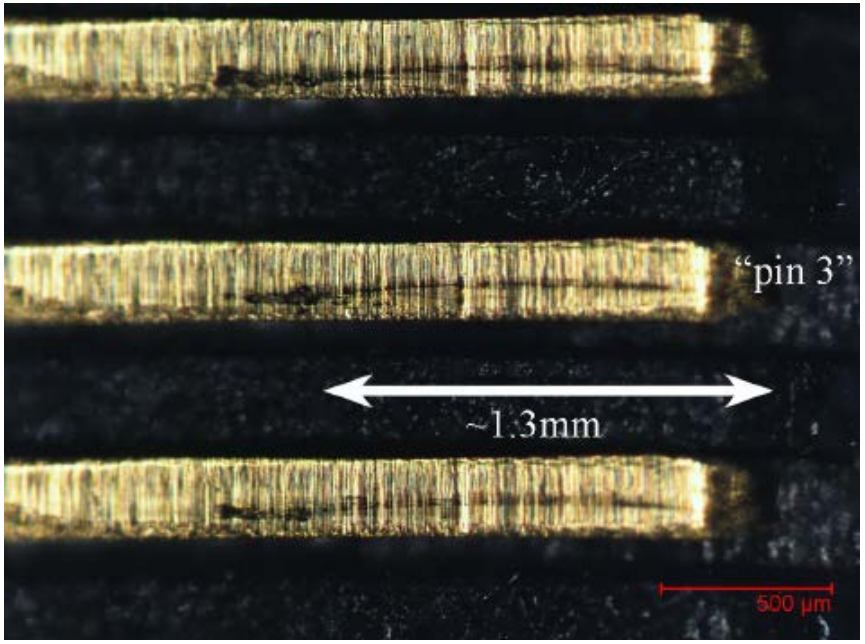
GSFC Dark-Field Optical - QFSS



GSFC Dark-Field Optical - QMSS

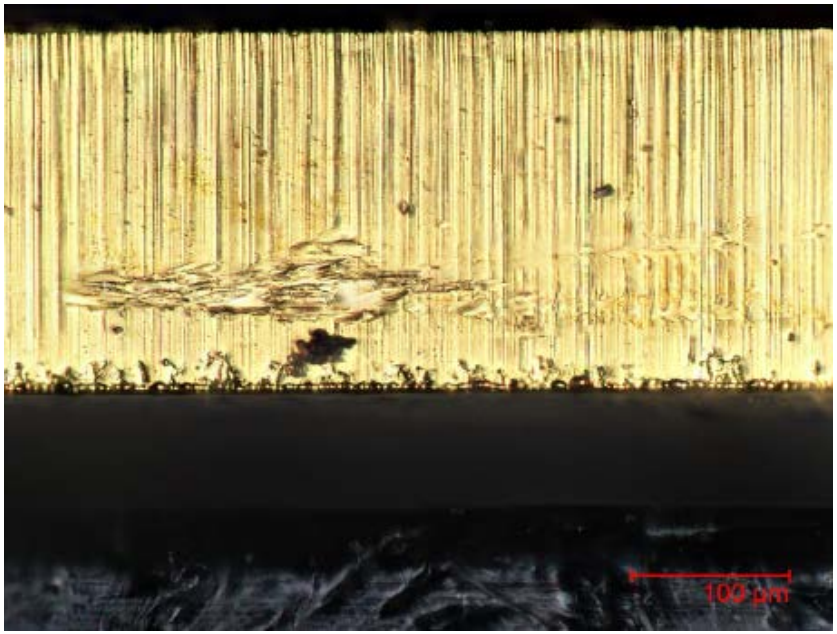


Arrow: contact locations

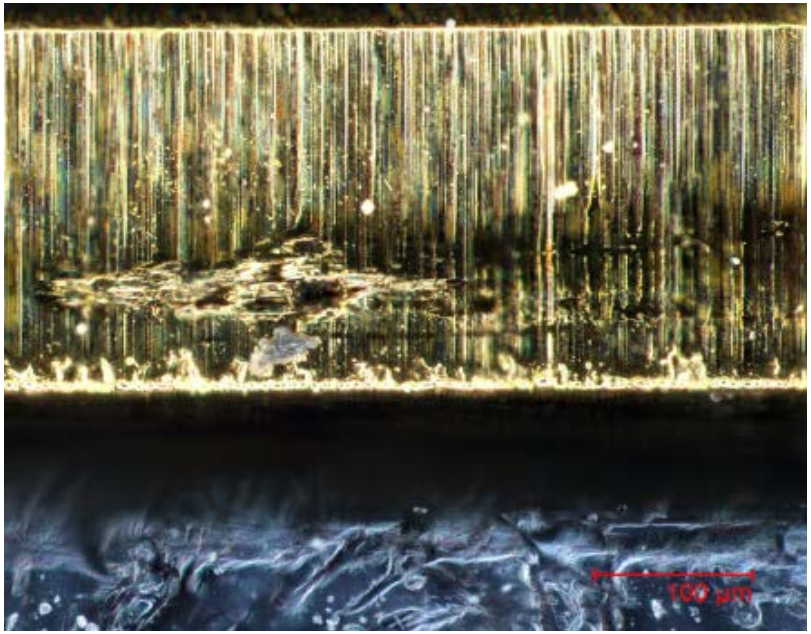


Wear tracks

GSFC Optical – QMSS
Wear From Dynamic Displacement



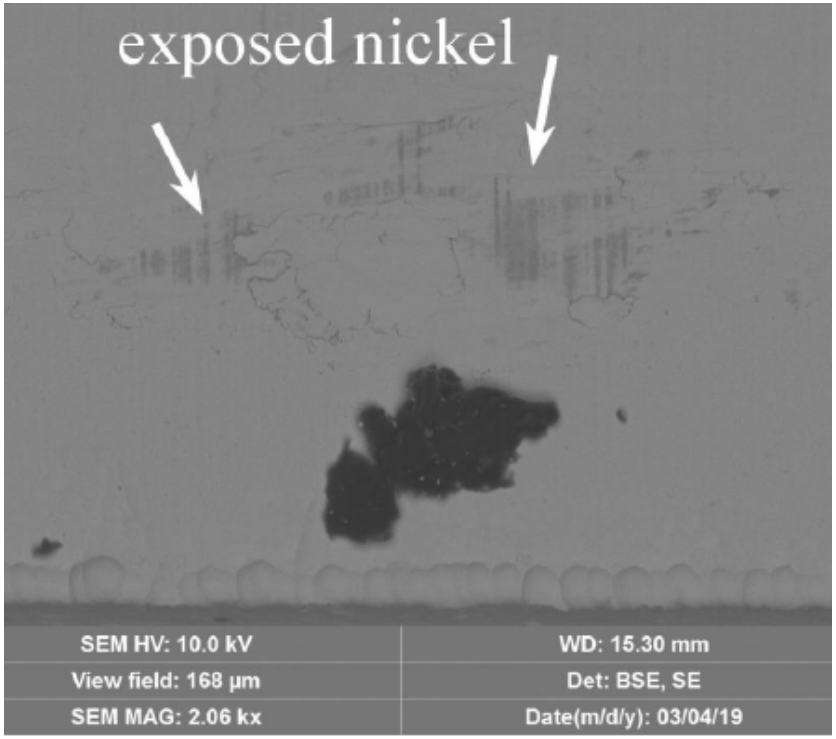
Bright Field

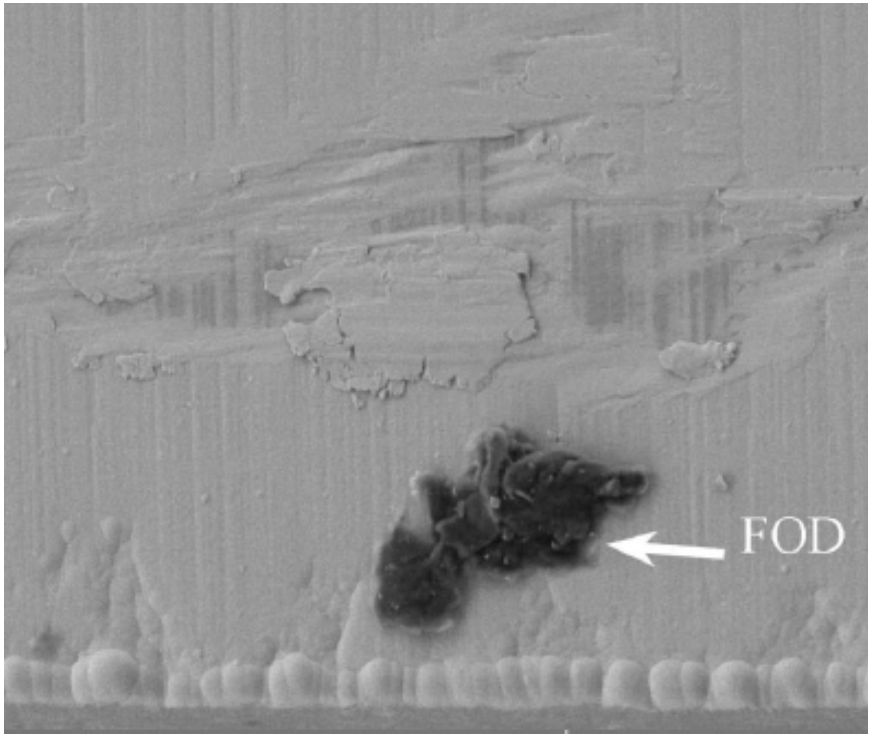


Dark Field

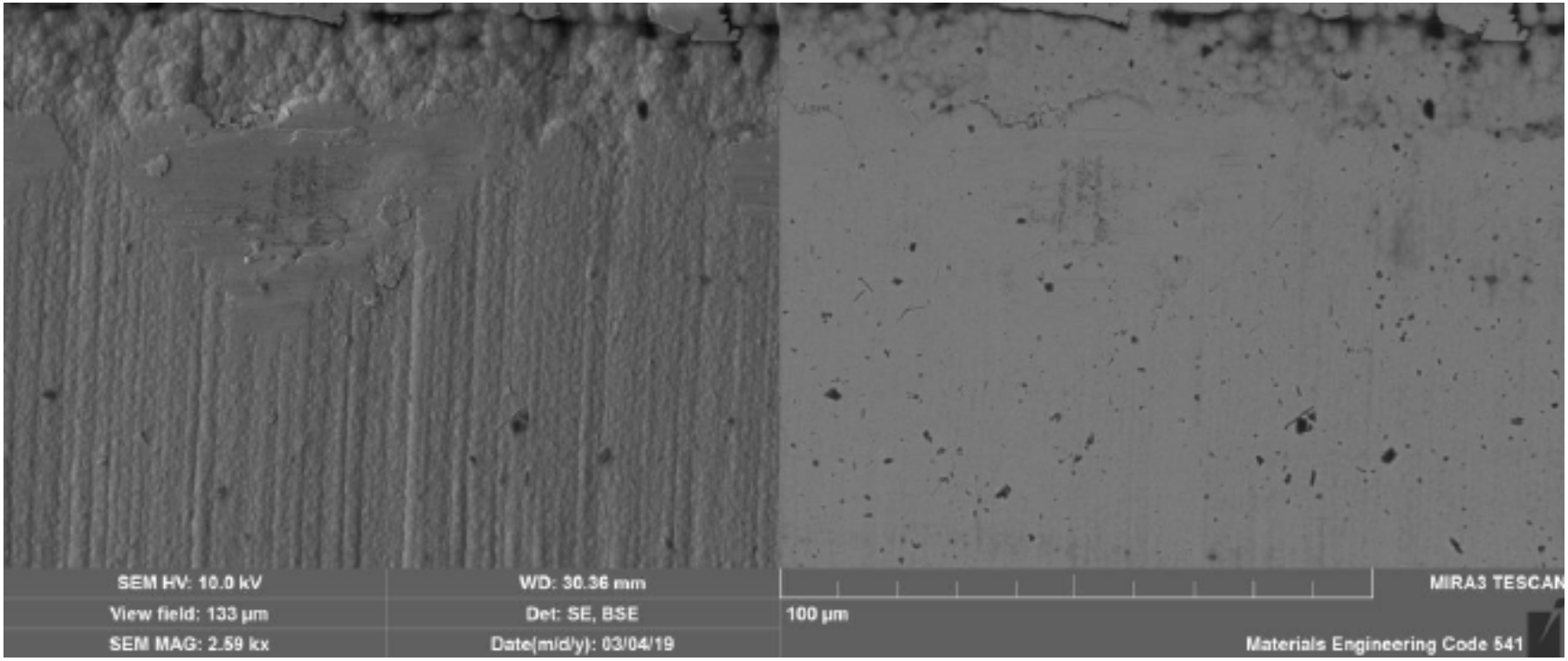
Approx. 150nm (0.006”) excursion

GSFC SEM – QMSS
Wear From Dynamic Displacement



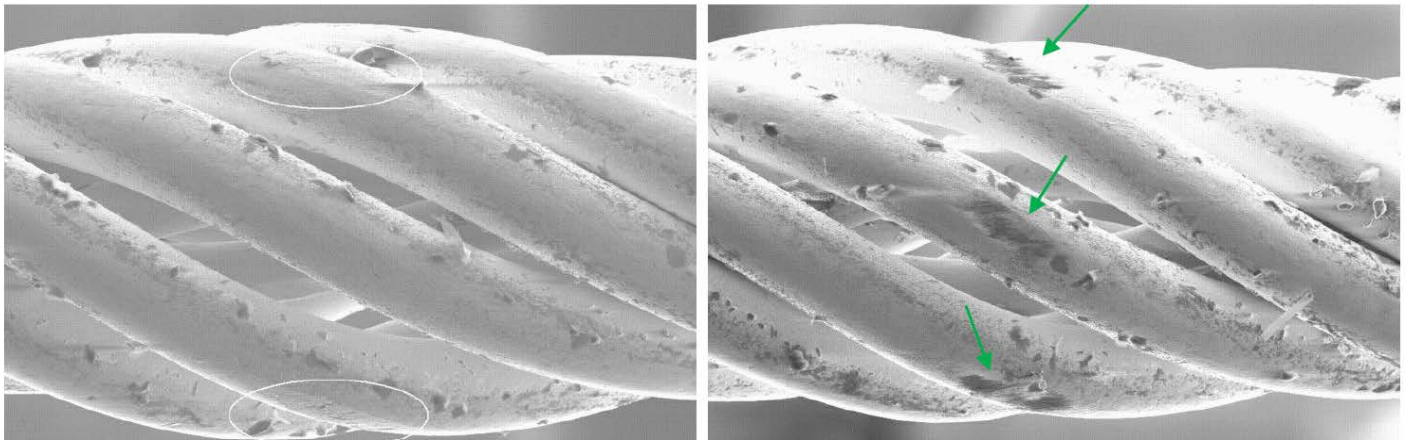


GSFC SEM – QFSS
Wear From Dynamic Displacement

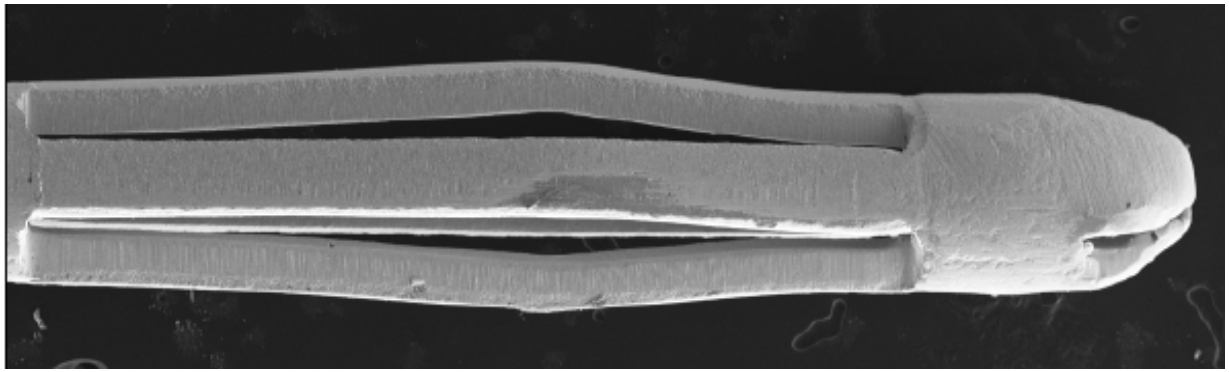


Exposed nickel in center of burnish crater

Exposed Ni After Wear Track Analyses

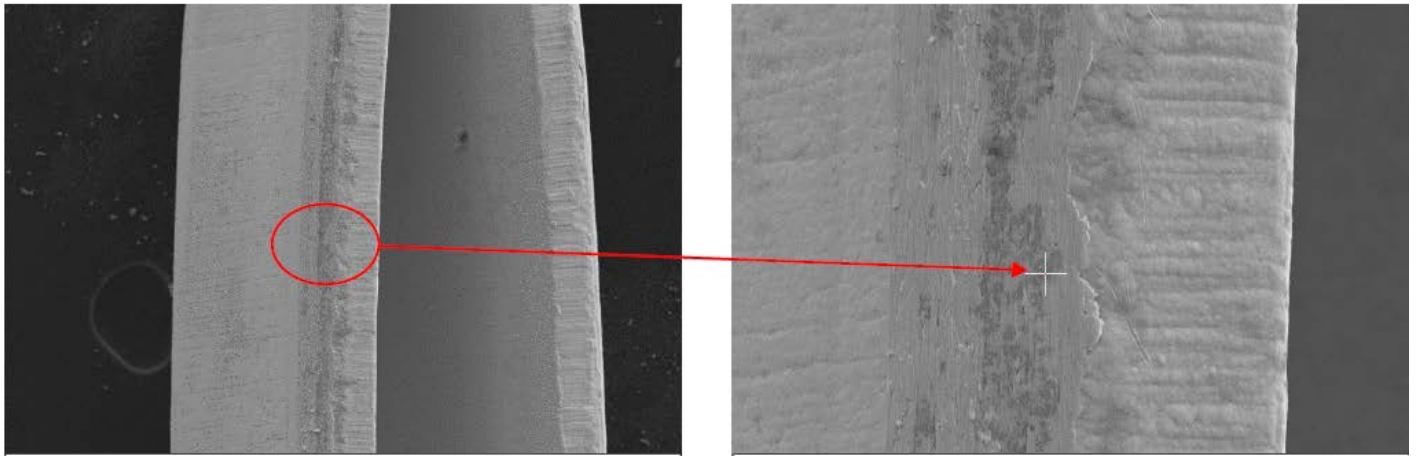


AXON Micro-D after 60 mating cycles

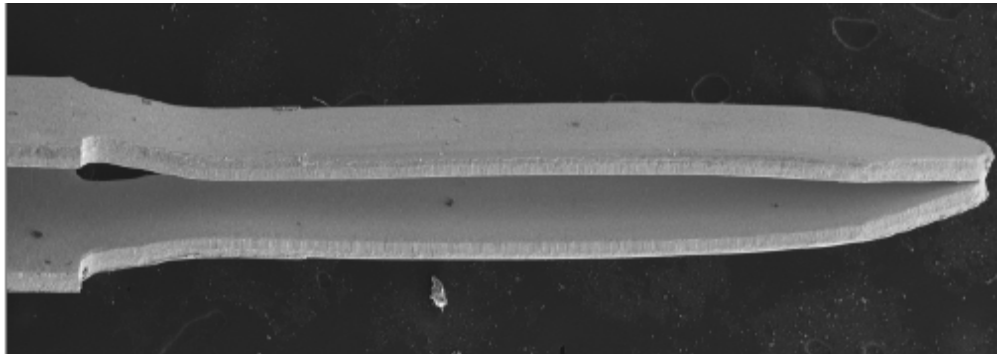


Airborn Micro-D after 100 mating cycles

Exposed Ni After Wear Track Analyses

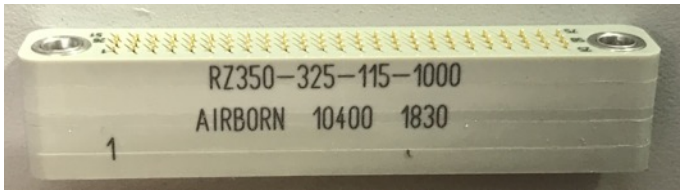


Omnetics nano after 100 mating cycles

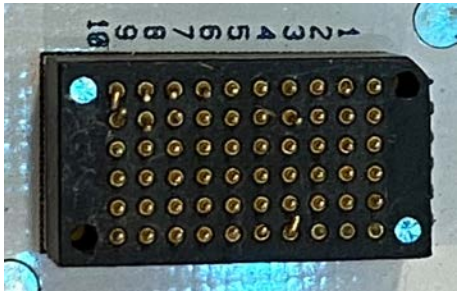


Single Contact Point - Exposed Nickel Risk?

- Au wear mechanism: polishing/burnishing
- Post-vibration from GSFC analysis shown inconsistent normal forces via visual inspection
- Samtec normal force still high enough to expose nickel
- Assuming the Samtec qual test exposed nickel at the asperities
  - Post-Mixed flowing gas test revealed <15 mΩ electrical resistance increase
- Single-point contact applications attractive option (interposers)



Airborn RZ



Smiths/IDI

Samtec Nickel Underplate Evaluation

- Samtec uses two nickel underplates under their gold contacts
  - Electroless (some fixed contacts)
  - Sulfamate (all flexible contacts)
- Samtec offered test coupons
  - 2.5” x 4.0”
  - Base metal the same brass alloy
  - Nominal 50µ-inch thickness
- Artificially–age the nickel to recreate long-term ambient air exposure: 85/85 for 48 hours
- Measured change in surface resistivity – not conclusive – difficult to quantify for nickel plating on brass
- Use Auger electron spectroscopy or Ellipsometry to detect an oxide or a dielectric surface

Samtec Nickel Underplate Evaluation
Two Views – Same Set of Plates

Control

Exposed

Conclusion

- Single point contacts are common in high-density & balanced (high-speed) interconnects
- Single point contacts prohibited EEE-INST-002
  - While fretting is found in approved multi-point contacts
    - the normal forces vary – variable fretting
    - Gold-on-gold still exists
    - Multiple parallel electrical paths
- Interposer PWB pads
  - Electrolytic hard gold preferred
  - Electroless Nickel Electroless Palladium Immersion Gold?
  - Electroless Nickel Immersion Gold? (ENIG)
  - Hot Air Solder Levelling?
- Applies to compliant pin in ENIG or gold plating
- Do we accept any single point contacts based on the premise that gold-on-nickel or nickel-on-nickel asperities allow acceptable contact resistance? What risk posture?
  - Test exposed surfaces for oxidation
  - GSFC asperity test for LLCR after 85/85 and MFG

End of Presentation