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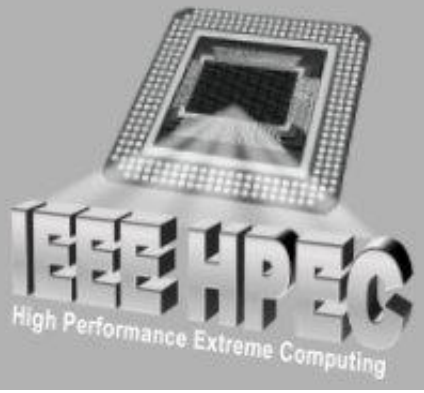


# Ruggedization of MXM Graphics Modules

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# Outline

- Introduction – What is an MXM Graphics Module?
- MXM Use in Rugged HPEC Systems
- MXM Ruggedization Risks
- Harsh Environment Testing
  - Shock & Vibration
  - Environmental Testing
  - Thermal Testing
- Conclusions

# MXM Graphics Module

- Mobile PCI Express (MXM) is an interconnect standard for GPUs in laptops and servers
  - Allows for easy upgrades with standardized socket
  - MXM-SIG controlled by nVidia
  - Latest specification revision is 3.0
  - Type A (82 x 70mm) and Type B (82 x 105mm)
  - Module integrates GPU, memory and power supply onto a small PCB

# MXM Use in HPEC Systems

- Benefits for use in HPEC systems
  - Allows for easy upgrades with standardized socket
  - Leverages electrical interface design work
  - Functional density offered by mezzanine form factor
  - Thermal benefit offered by mezzanine form factor
  - Some GPUs are only offered in MXM form factor
- Drawbacks of MXM use in rugged HPEC systems
  - Not designed for harsh environments

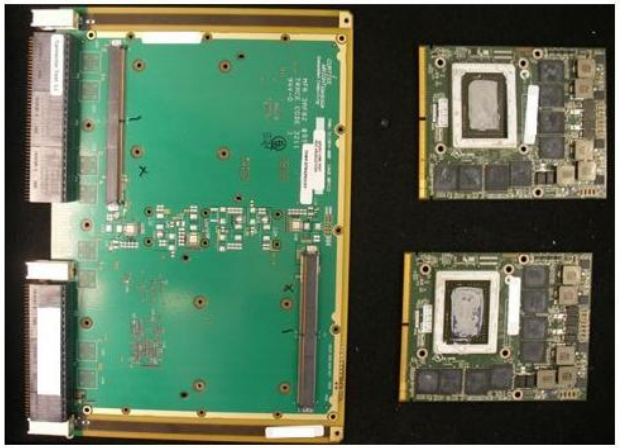
# MXM Ruggedization Risks

| Risk | Description | Test | Mitigation |
|---|---|---|---|
| Connector contact fretting | Vibration can cause fretting corrosion failures | Shock and vibration | Stiffening and possibly lubrication |
| Contact corrosion | Exposure to humidity and contaminants can corrode contacts | Humidity and mixed flowing gas | Custom connector (if required) |
| GPU cooling | GPU can be 50W+ | Full operation over extended temp. range | Thermal design analyzed prior to test |
| Temperature range | Components on MXM are commercial temp. range | Full operation over extended temp. range | 100% ESS during production or pre-screening |

The above list of risks is not exhaustive…

# Shock & Vibration Testing

- Rugged air cooled test vehicle
  - 6U (233x160mm) VPX with 2 MXMs
  - Higher displacements than conduction, ∴ worse case

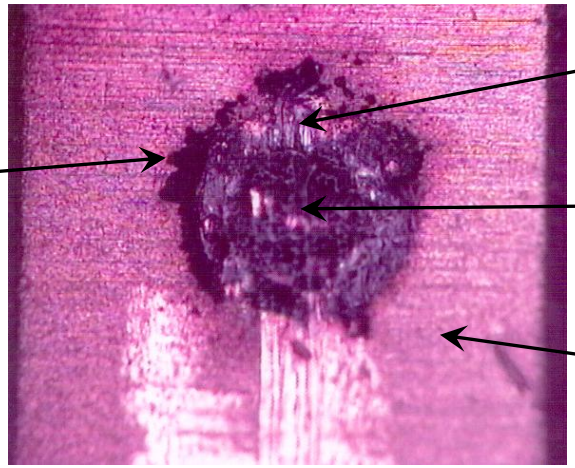


- CWCDS shock & vibration test specification

| Tests | Levels | Frequency range | Duration |
|---|---|---|---|
| Sine vibration | 10 g | 5-2000 Hz | 10 minutes |
| Mechanical shock | 30 g peak | N/A | 11ms, 18 hits total in 6 directions |
| Random vibration | 0.002 $g^2$/Hz @ 5 Hz<br>0.04 $g^2$/Hz @ 15 Hz<br>0.04 $g^2$/Hz @ 2 kHz | 5-2000 Hz | 1 hour/axis<br>(3 orthogonal axes) |

# Shock & Vibration Testing

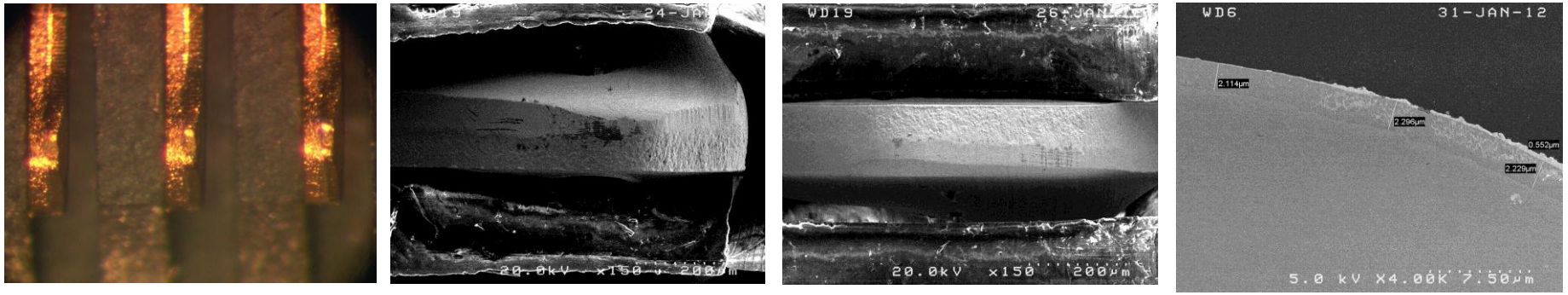
- Performance verification: Visual inspection and SEM/EDX of connector contacts
  - Provides the earliest indication of fretting issues, well before electrical testing
  - Database of previous tests used to correlate wear severity to probability of electrical failure




*Example of Severe Fretting Corrosion on Connector Contact causing Electrical Failure*

# S&V Test Results

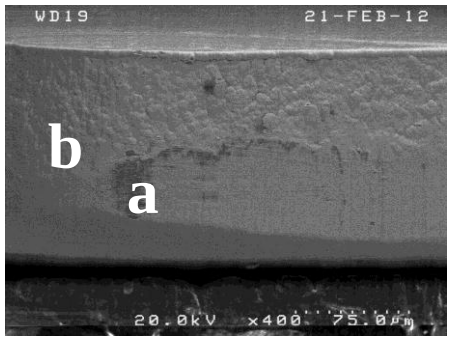
- Base case (stiffened but not lubricated)
  - Degree of fretting wear varied across each of two connectors (more wear on ganged power and ground pins)
  - Worst case wear was through outer gold plating, but large majority (85-90%) of nickel underplating still intact
    - This amount of wear is not associated with electrical failure
  - Typical wear (signal pins) did not penetrate outer gold plating

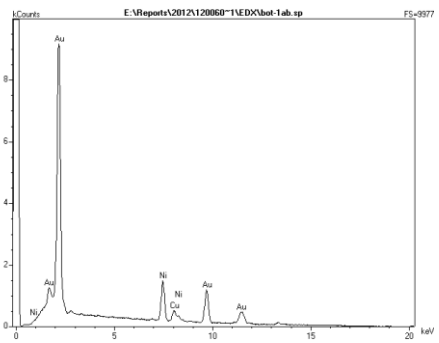


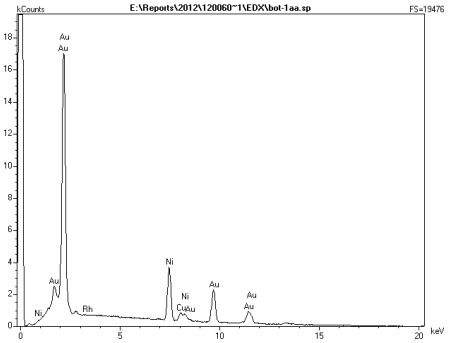

*Sample analysis images (left to right): Optical, SEM (worst case), SEM (typical signal), X-section (worst case)*

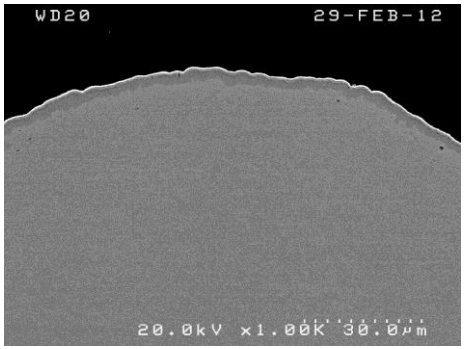
# S&V Test Results

- Mitigated case (stiffened and lubricated)
  - No gold wear-through on any pins
  - Lubricant may need further testing (e.g. dust + vibration)





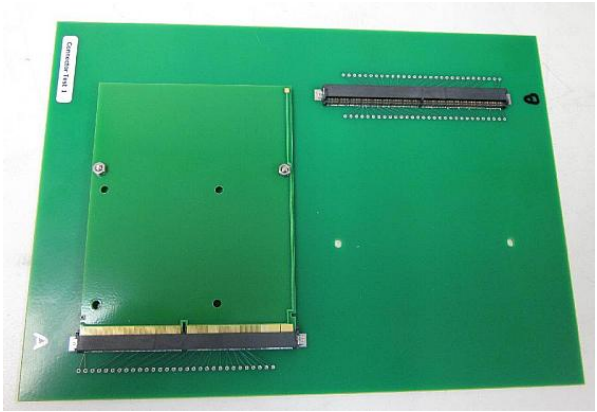





*Sample analysis images (left to right): Worst case (mitigated), EDX (area 'a'), EDX (area 'b'), X-section*

# Environmental Testing

- Custom test vehicle
  - 6U-ish with 2 MXMs
  - Connections for LLCR (low-level contact resistance)



- Environmental test specification

| Tests | Levels | Duration | Specification |
|---|---|---|---|
| Durability + Humidity | 90-95% RH, 25-65°C | 500 hours | EIA-364, TP 31 |
| Durability + Mixed Flowing Gas | 30°C, 70% RH | 20 days | EIA-364, TP 65 |

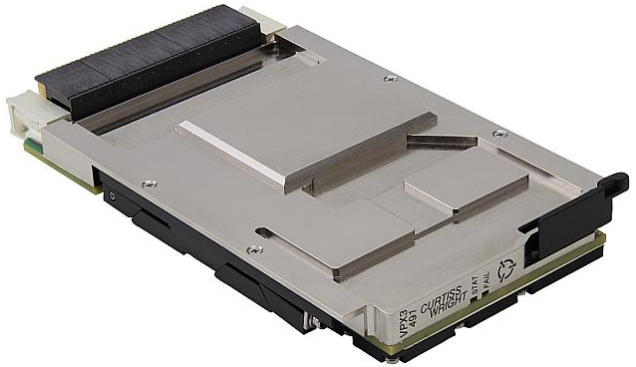
# Environmental Test Results

- Performance verification tests: low-level contact resistance (LLCR), insulation resistance (IR), dielectric withstanding voltage (DWV)
- Pass/fail defined in MXM Module Electromechanical Spec (e.g. LLCR of 55 mΩ max.)
- All tests passed

| Test | LLCR (mΩ, max.) | IR (MΩ) | DWV |
|---|---|---|---|
| Durability + Humidity | 50.2 (unmitigated)<br>35.7 (mitigated) | >50,000 | Passed |
| Durability + Mixed Flowing Gas | 36.1 (unmitigated)<br>33.6 (mitigated) | N/A | N/A |

# Thermal Qualification Testing

- CWCDS thermal qualification test
  - Performed on 6U and 3U products
  - Temperature extremes are beyond specification (-40 to 71°C)
  - Multiple cycles (but not a thermal cycling test)
  - Multiple cold and hot starts after soak
  - Functional stress test
- Results
  - Pass (no functional failures)



*3U conduction module with 1 MXM*

*6U air cooled module with 2 MXMs*

# Conclusions

- The use of MXM modules in harsh environments demands a comprehensive risk evaluation.
- Three areas of testing were used as examples of risk assessment: shock & vibration, environmental, and thermal qualification. Other tests are also required.
- The full suite of test results shows that MXMs can be successfully deployed in harsh environments, when integrated into specially designed, rugged carrier cards.

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# Thank you

# Q & A