Real World PCB & ECAT Consultation
IBM PCB Symposium
November 2011
Outline

• IBM Engineering Services Overview
• Test Cases
  • Field Burns and Field Burns Avoided
  • Laminate Circumferential Cracks
  • CAF Study
• Technical Scope
  • Design GRs and DFM
  • Testing and Qualification
• Summary
IBM Engineering Services Overview

- **Engineering Services Scope**
  - OPs Transformations
  - Early involvement, NPI and PLM Consultation (IPD, DoX & DfSC)
  - Engineering and Manufacturing Best-Practices
  - Electrical (components, PCB, ECAT, SI), Mechanical, Thermal, Power (AC & DC), FCT, and Manufacturing
  - Strategic Supplier, OEM and Sub-tier SC Consultation
  - t=0 Testing & Reliability Test and Qualification
  - QMS & SQM (inc. DOX & LSS)
  - Cost-Down- Estimation & Reduction Consultation
  - Field and Warranty Best-Practices
**Areas of Expertise**
- Bond / Assembly / Test (0th & 1st levels)
- Electronic assembly (1st & 2nd levels)
- Commercial Procurement: sourcing, purchasing strategies, negotiation methodologies, contract writing, contract execution, relationship management
- Cost engineering
- DOX & LSS
- Electronic commodities function, quality, & reliability
- Environmental compliance technology and legislation
- Final product packaging/shipping
- Market Intelligence: industry/technology roadmaps, supplier capabilities, pricing, market analysis
- Mechanical assemblies
- Mfg. change management (configurations, ECs)
- Mfg. quality systems
- Pb-free assembly
- Power
- Printed Circuit Board manufacturing
- Reliability modeling
- Statistical Process Control
- Supplier Quality Management
- Test engineering
- Thermal engineering

**Capabilities**
- BoM optimization
- Classical testing (shock/vibration)
- Compliance testing (environmental: UL / EMI / FCC)
- Design Reviews (function, cost, manufacturability, yield, reliability)
- End-of-Life management
- Engineering Change management
- Failure analysis & constructional analysis
- Improve mfg. operations
- Manage mfg. exceptions and excursions
- Manage warranty processes (RMAs, F/A, FMEAs)
- New Product Introduction (release to mfg. and volume ramp-up)
- Rapid-response alternate sourcing for continuity of supply
- Supplier Audits and Qualifications
- Supplier Relationship Management (business and technical)
- Supply-chain reviews (supplier readiness, manufacturing readiness)
- Technical Project Management
- Technology Qualifications
- Test development & test engineering
- Training / education (business and technical)

**Tools & Databases**
- EWS—Early Warning System to predict quality
- CI—Continued Intelligence, an integration of EWS and other tools used in Engineering
- ANSYS finite-element modeling tool for thermal/mechanical analysis
- Cadence Allegro for RF/mixed-signal design
- Commodity market price dB
- Costimator cost engineering tools
- Environmental compliance dB (EMARS / CRS)
- HPSS high-frequency analog modeling tool
- Materials and Process Engineering lab (RTP, Poughkeepsie, Rochester) (mass spec., FTIR, SEM, EDACs, XRF, Thermal/mechanical, Differential Scanning Calorimetry)
- Memory test lab
- Part number technical dB (quality, reliability, approved applications)
- xPlore component dB & associated tools (supplier problem log, PCNs, TQA, QIN, environmental data, SQUIT, EWS)

**Global Resources**
- Local & regional business relationships
- Local Commercial Procurement staff
- Local Procurement Engineering staff
- Local technical auditing staff
- Local native-language speakers
- Global communications systems
- LEO Supplier Training
### IBM Engineering Services PCB Consultation Overview

<table>
<thead>
<tr>
<th>Technology</th>
<th>Design (DFM)</th>
<th>Materials</th>
<th>Process</th>
<th>Cost Reduction</th>
<th>Performance Improvement</th>
<th>Quality Improvement</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb-Free Considerations</td>
<td></td>
<td>Nail selection model for Pb-Free</td>
<td>Pb-free rework process definition &amp; guidelines impacting PCBs</td>
<td>Achieving/maintaining low cost Pb-free</td>
<td></td>
<td></td>
<td>1-day Pb-free workshop to acquaint PCB suppliers w/next-level Pb-free issues</td>
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<tr>
<td>Rigid PCB</td>
<td>Design GRs, x-section GRs, anti-smoke</td>
<td></td>
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<td>2-day ECAT workshop to acquaint PCB suppliers w/next-level ECAT issues</td>
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<tr>
<td>IC Laminates &amp; CoB</td>
<td>Design GRs/best practices: qualifications</td>
<td></td>
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<tr>
<td>Flexible/Rigid-Flex Circuits</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Cables, Connectors &amp; Interconnects</td>
<td>Component selection, design GRs/best practices: qualifications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical Fibers, Circuits, Components</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Three IBM PCB supplier ‘up the curve’ technology qualification services projects to date
- Multiple IBM ECAT supplier technology qualification projects
- >50 third party system NPI and Transformation consultation projects
Test Cases (prior / current engagements)

• Field Burns and Field Burns Avoided  
  (Paul Michels, Tim Younger, Brian Olson)

Problem Overview: An IBM Blade Server (MSA) Technology B2P & licensed to an OEM. OEM’s systems experienced >12x smoke incidents. IBM’s systems experienced zero smoke.

Products Affected: OEM Blade Servers

Failure Symptoms: OEM Smoke Incident

Exposure: OEM => catastrophic; IBM => no exposure

Impact: OEM => comprehensive field roll post C/A; IBM => no impact

Root Cause: Improperly spec’d & qualified PCB laminate
Test Cases (prior / current engagements)

- Laminate Circumferential Cracks (Bruce Chamberlain, Ahmad Katnani)
Test Cases (prior / current engagements)

- **CAF Study** (John Wilson, Jeff Taylor, Steve Cain, Brian Carlson, Wayne Rothschild)

  Objective => establish reliability models for CAF f-modes; validate CAF reliability impact

**Stress Matrix**

Steady State T/H/B stress

<table>
<thead>
<tr>
<th>Cell</th>
<th>Temp (deg C)</th>
<th>Relative Humidity (%)</th>
<th>Drill Diameter (mm)</th>
<th>Via-Via Pitch / Conductor Spacing (mm)</th>
<th>Bias Voltage (volts)</th>
<th>Striations Count per sq inch / Maximum Length (um)</th>
<th>Precondition Bake</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>85</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>none</td>
</tr>
<tr>
<td>4</td>
<td>65</td>
<td>80</td>
<td>0.25mm (10 mils)</td>
<td>1 / 0.75 mm (39 / 29 mils) and 0.8 / 0.55 mm (31 / 22 mils) and 0.6 / 0.35 mm (24 / 14 mils)</td>
<td>2. 8. 15</td>
<td>50-100 per sq inch / 1200-1800 um</td>
<td>none</td>
</tr>
<tr>
<td>5</td>
<td>65</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>none</td>
</tr>
<tr>
<td>6</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>none</td>
</tr>
<tr>
<td>7A</td>
<td>50</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>none</td>
</tr>
<tr>
<td>7B</td>
<td>50</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>none</td>
</tr>
<tr>
<td>9</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24 hr @ 150°C</td>
</tr>
</tbody>
</table>
Test Cases (prior / current engagements)

- CAF Study (John Wilson, Jeff Taylor, Steve Cain, Brian Carlson, Wayne Rothschild)
Test Cases (prior / current engagements)

- **CAF Study** (John Wilson, Jeff Taylor, Steve Cain, Brian Carlson, Wayne Rothschild)

\[
\ln(t_{50}) = v = v_0 + T_{act} \left( \frac{1}{T} - \frac{1}{273+50} \right) + T_{quad} \left( \frac{1}{T} - \frac{1}{273+50} \right)^2 + A \ln(RH - \theta) + B \ln(V) + C \ln(L)
\]

- \( t_{50} \) = time required for 50% fail
- \( T \) = temperature (deg K)
- \( RH \) = Relative Humidity (percent)
- \( \theta \) = Relative Humidity Threshold (percent)
- No relative humidity threshold exists
- \( V \) = Voltage across conductors (volts)
- \( L \) = Spacing between conductors (inches)

<table>
<thead>
<tr>
<th></th>
<th>( v_0 )</th>
<th>( T_{act} )</th>
<th>( T_{quad} )</th>
<th>( A )</th>
<th>( \theta )</th>
<th>( B )</th>
<th>( C )</th>
<th>( \sigma )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected</td>
<td>50.687</td>
<td>22,551</td>
<td>70,127,542</td>
<td>-7.015</td>
<td>0</td>
<td>-0.644</td>
<td>2.379</td>
<td>1.162</td>
</tr>
<tr>
<td>St. Error (SE)</td>
<td>2.601</td>
<td>1248</td>
<td>3,971,961</td>
<td>0.543</td>
<td>0.0572</td>
<td>0.137</td>
<td>0.0436</td>
<td></td>
</tr>
<tr>
<td>95% Lower CB</td>
<td>45.59</td>
<td>20,105</td>
<td>62,342,250</td>
<td>-8.08</td>
<td>-0.76</td>
<td>2.11</td>
<td>1.08</td>
<td></td>
</tr>
<tr>
<td>95% Upper CB</td>
<td>55.78</td>
<td>24,998</td>
<td>77,912,587</td>
<td>-5.95</td>
<td>-0.53</td>
<td>2.65</td>
<td>1.25</td>
<td></td>
</tr>
</tbody>
</table>

- Time to failure is a function of Temp, RH, bias voltage and spacing between conductors
- Time to failure decreases as temperature increases from low temp to 68c and then time to failure increases as temp moves above 68c
- Time to failure decreases as Relative Humidity increases
- Time to failure decreases as bias voltage increases
- Time to failure decreases as spacing between conductors decreases
- High acceleration for temperature and relative humidity
- No Relative Humidity Threshold
# Engineering Services for Server-class PCB Consultation

## PCB Technology Definition: Overview

<table>
<thead>
<tr>
<th>PCB design attribute</th>
<th>ERIC PN 16G5 493</th>
<th>FRED PN 87G52 28</th>
<th>RED ATTN PN 63P4851</th>
<th>RUBY PN 38J0453</th>
<th>ELLE PN 38J0453</th>
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</thead>
<tbody>
<tr>
<td>minimum nominal line width (int'l) [mils]</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>line width tolerance [mils]</td>
<td>±1</td>
<td>±0.5</td>
<td>±0.75 (1oz); ±0.5 (1/2 oz)</td>
<td>±0.75 / ±0.5</td>
<td>±0.75 / ±0.5</td>
</tr>
<tr>
<td>minimum line width (neck-down) [mils]</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>minimum line-line spacing [mils]</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>4 (preferred)</td>
<td>4 (preferred)</td>
</tr>
<tr>
<td>minimum line-line spacing (neck-down) [mils]</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>minimum PTH diameter [mils]</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>minimum via-via pitch [mils]</td>
<td>50 (1.27mm)</td>
<td>40 (1mm)</td>
<td>40 (1mm)</td>
<td>31.5 (0.8mm)</td>
<td>31.5 (0.8mm)</td>
</tr>
<tr>
<td>laminate parameters:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>losstangent (@1GHz)</td>
<td>n/a</td>
<td>std loss = 0.023</td>
<td>s tld loss = 0.023 or 0.006 - 0.013</td>
<td>0.013 - 0.023 (std)</td>
<td>0.013 - 0.023 (std)</td>
</tr>
<tr>
<td>dielectric constant (@1MHz)</td>
<td>n/a</td>
<td>n/a</td>
<td>&lt; 4.3</td>
<td>3.8-4.8 (std)</td>
<td>3.8-4.8 (std)</td>
</tr>
<tr>
<td>minimum copper weight [oz]</td>
<td>1</td>
<td>½</td>
<td>½ (LL or 1 ft)</td>
<td>½ (1 more common)</td>
<td>½ (1 more common)</td>
</tr>
<tr>
<td>copper profile [PC]</td>
<td>n/a</td>
<td>s tld profile</td>
<td>s tld profile</td>
<td>LP or VLP</td>
<td>LP or VLP</td>
</tr>
<tr>
<td>maximum copper weight [oz]</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>maximum layer count</td>
<td>18</td>
<td>30</td>
<td>n/a</td>
<td>14 or 16</td>
<td></td>
</tr>
<tr>
<td>maximum PCB thickness [mils]</td>
<td>95</td>
<td>120</td>
<td>n/a (AR driven)</td>
<td>n/a (AR driven)</td>
<td>75 - 78</td>
</tr>
</tbody>
</table>

1. maxly d and thickness defined by construction limits (AR) and qualification activity
2. FTH diam-dependent
3. profile control required for atten-controlled (Robj)
P:Cs: then low profile (LP) or very low profile (VLP) req'd
* heavier Cu being investigated for future designs. Needs qualification.
### Technical Scope

- **Testing and Qualification** (example IBM Specifications and Industry Standards)

<table>
<thead>
<tr>
<th>P/N</th>
<th>Title</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>535718</td>
<td>Acceptability of Electronic Assemblies</td>
<td>Assembly Acceptance</td>
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<tr>
<td>IPC A-610</td>
<td>Acceptability of Electronic Assemblies</td>
<td>Assembly Acceptance</td>
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<tr>
<td>IPC/JEDEC J-STD-609</td>
<td>Marking and Labeling of Components, PCBs and PCBA</td>
<td>Assembly Acceptance</td>
</tr>
<tr>
<td>IBM LMH 6.3047-020</td>
<td>Solder Alloys</td>
<td>Assembly Materials</td>
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<tr>
<td>ANSI/STD-005</td>
<td>Requirements for Solder Past</td>
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<tr>
<td>21P3543</td>
<td>VHCM Critical Assembly Spec</td>
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<tr>
<td>39J2016</td>
<td>Ventura Connector Critical Assembly Spec</td>
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<tr>
<td>97H7555</td>
<td>Heatshrink Attach Methods</td>
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<tr>
<td>97P3782</td>
<td>Product Specification for Car DCM/SCM or Bare Die DCM/Actuation Hardware</td>
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<tr>
<td>42R7126</td>
<td>Procedure for Mechanical Hinge Attach for Processor Assembly</td>
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<tr>
<td>00F829</td>
<td>Connector Process Compatibility</td>
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<tr>
<td>05L3625</td>
<td>FCPBGA Packaging Application</td>
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<td>0873444</td>
<td>Product Quality Addendum of Solder-Ball Connected (SBC)</td>
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<tr>
<td>97F4332</td>
<td>Solder-Ball Connected (SBC)</td>
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<td>87F4333</td>
<td>Surface Mount Component M</td>
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<td>7IP2788</td>
<td>Copper Column Grid Array (C) Grid Array (SAC CBGA) Mod and Solderability Specification</td>
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<tr>
<td>JEP-85</td>
<td>JEDEC Publication 95, &quot;JEDEC for Solid State and Related Products&quot;</td>
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</tr>
<tr>
<td>EIA/JEDEC J-STD-075</td>
<td>Classification of Non-IC Elect Processes</td>
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<tr>
<td>IPC/JEDEC-STD-033</td>
<td>Handling and Storage of Moisture Sensitive Components</td>
<td>Moisture Sensitivity</td>
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<tr>
<td>ANSI ESD S20.20</td>
<td>ESD Control Program standard</td>
<td>ESD Sensitivity</td>
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<td>ISO 8573-1</td>
<td>Compressed air – Part 1. Contaminants and purity classes</td>
<td>Air Purity</td>
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<tr>
<td>53P4082</td>
<td>Generic Quality, Reliability and Performance Specification for IBM Server Group Rigid Printed Circuit Boards</td>
<td>PCB</td>
</tr>
<tr>
<td>53P4944</td>
<td>Product Quality Management Requirements for IBM SYSTEM GROUP PRINTED CIRCUIT BOARD SUPPLIERS</td>
<td>PCB</td>
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</tbody>
</table>
Technical Scope

• Testing and Qualification Lab

Nondestructive Failure Analysis

– Optical Inspection
  • ERSAScope
  • AutoMontage
– Scanning Acoustic Microscopy (SAM)
– Vibrometer
– Thermal Imaging
– Time Domain Reflectometry (TDR)
– XRAY
  • 2D
  • 3D
– Fourier Transform Infrared spectrometer (FTIR)
– Replacement of Suspect Module

Nondestructive Characterization

– Shadow Moire
– Coordinate Measurement Machine (CMM)
Technical Scope

• Testing and Qualification Lab

Destructive Failure Analysis
  – Dye Penetrant Testing
    • Penetrating Dye
    • Fluorescent Dye
  – Cross Section
  – Scanning Electron Microscope/Energy Dispersive Using X-Ray Analysis (SEM/EDX)
  – Electron Spectroscopy for Chemical Analysis (ESCA)

Destructive Characterization
  – Environmental / Mechanical Stress Testing
    • Accelerated Thermal Cycling (ATC)
    • Power Cycling / Power Aging
    • Temperature & Humidity (T&H) with or without Bias
    • Shock & Vibration (S&V)
    • High Temperature Storage (HTS)
    • Bend Test
    • Knockoff test (Heatsink)
  – Cross Sectional Moire
  – Digital Image Correlation (DIC)
Summary

IBM Engineering Services can provide PCB designers, fabricators/suppliers, CMs and users with broad and deep subject matter expertise in tactical to strategic scope across global boundaries and in all PCB, interconnect and connector technologies.

IBM can support client’s (supplier-clients) development of new technologies and capabilities to intersect with internal client and/or industry roadmaps, supporting qualifications at new, expanded and/or higher technology levels.
Contact

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