



Status of Pb-Free Activities in the North American Supply Chain

Dr. Robert Pfahl

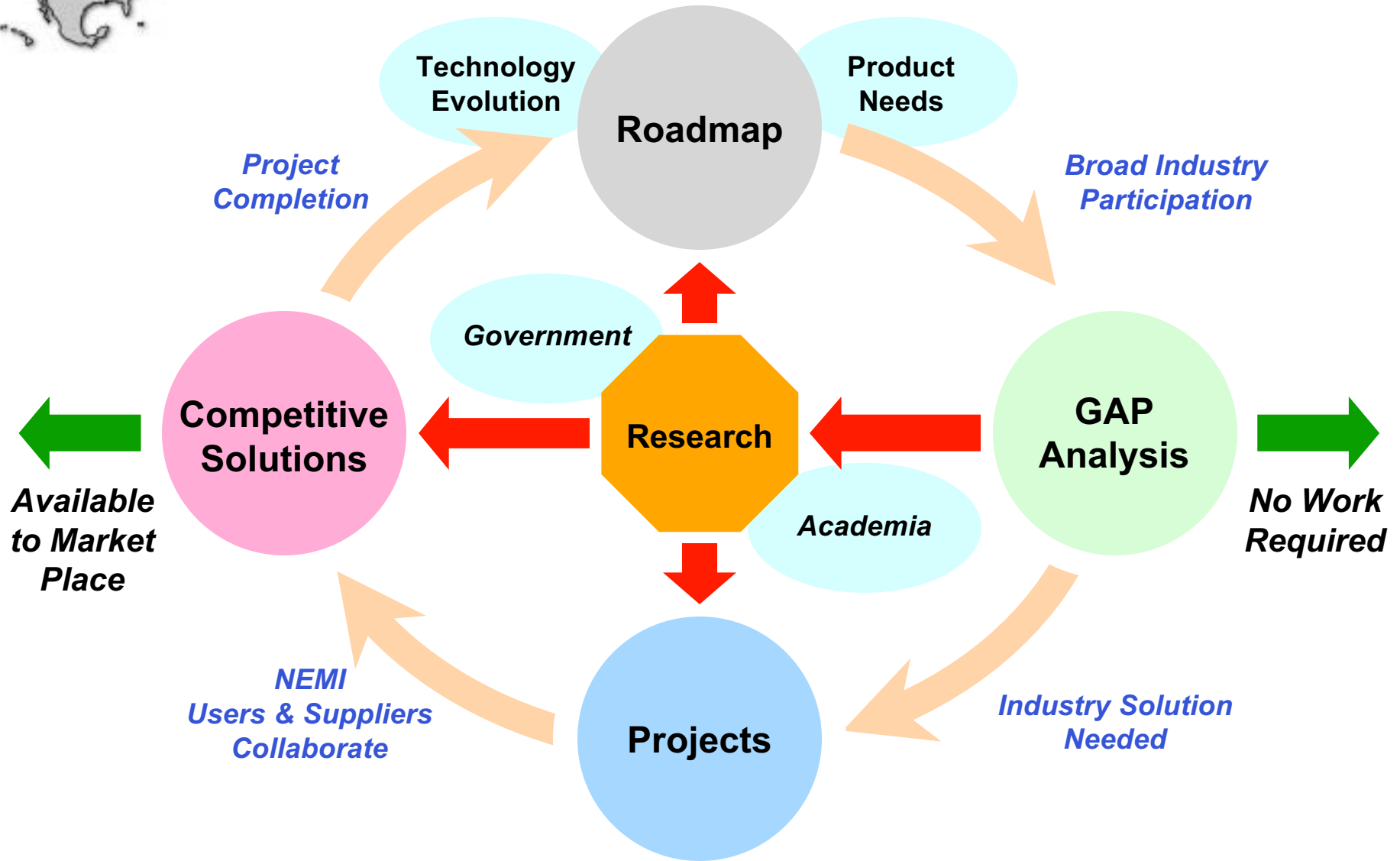


Outline

- **Status of Addressing Pb-Free Soldering Gaps Identified in 2000 NEMI Roadmap**
- **Next Steps: Addressing Gaps Identified in 2002**



NEMI Roadmap Cycle



NEMI Implementation Cycle

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NEMI Pb-Free Projects

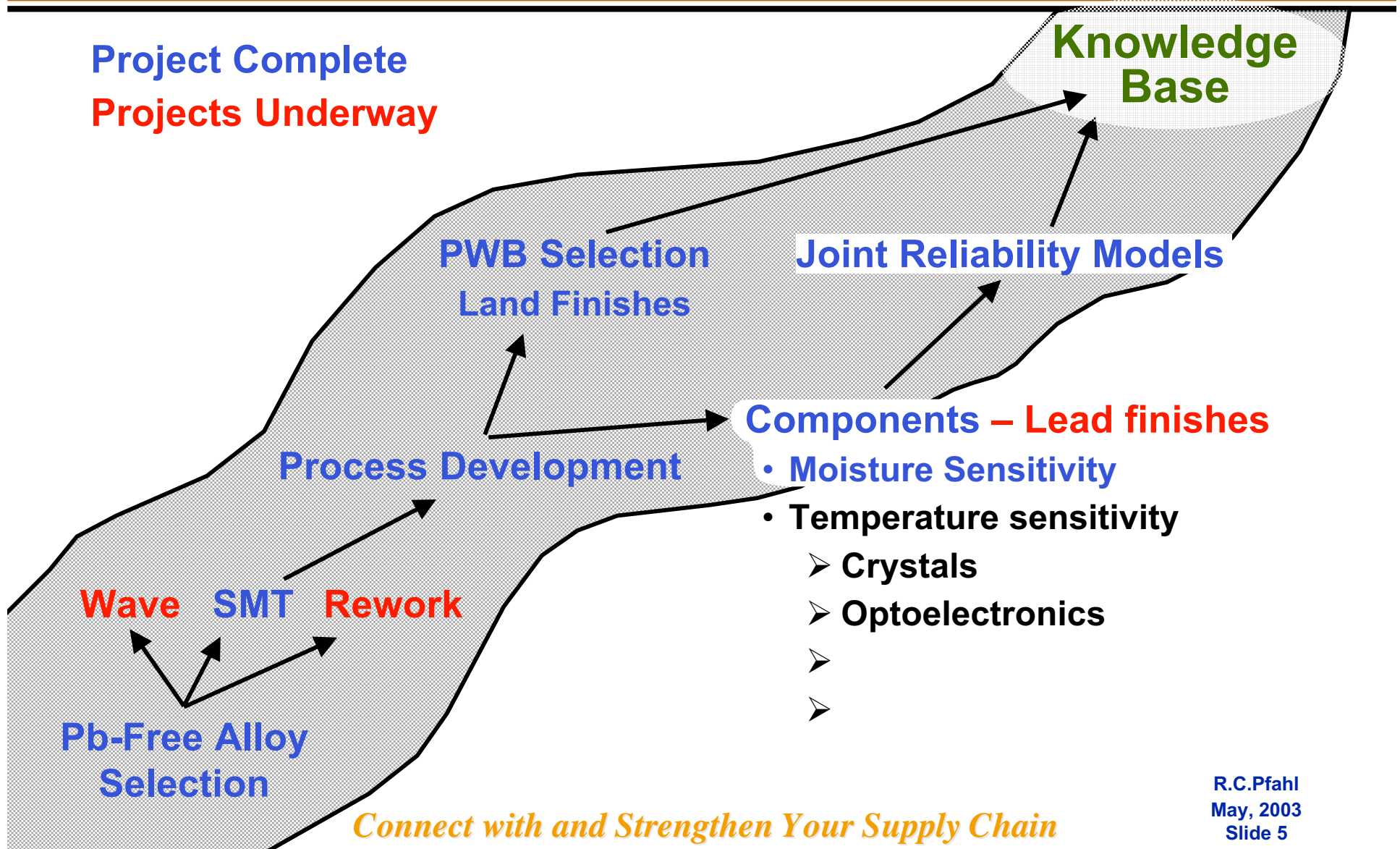
Addressing Gaps Identified in 2000 Roadmap

- **The NEMI projects have moved the industry forward in knowledge and understanding of Pb-free materials and processes.**
- **Continuing to work to fill in knowledge Gaps.**
- **Building the knowledge base equivalent to today's SnPb solder will not be done overnight.**
- **NEMI is open to working with other groups to insure that all major gaps are addressed in an effective & timely manner.**

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North American Pb-Free Activities (NEMI) Lead-Free Roadmap





Environmentally Conscious Electronics (ECE) TIG Projects

ECE Technology Integration Group (TIG)

Chair:
Rick Charbonneau, StorageTek

Lead-Free Assembly

Chair:
Edwin Bradley, PhD Motorola
Co-Chair:
Rick Charbonneau, StorageTek

Tin Whiskers HAST

Chair:
Nick Vo, Motorola
Co-Chairs:
Jack McCullen, Intel
Mark Kwoka, Intersil

Lead-Free Assembly & Rework

Chair:
Gerald Gleason, HP
Co-Chair:
Charlie Reynolds, IBM

Tin Whisker Modeling

Chair:
George Gaylon, IBM
Co-Chair:
Maureen Williams, NIST

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Pb-Free Project Summaries

- **Lead Free Assembly Project:** (Edwin Bradley, Motorola, Chair; Richard Charbonneau, StorageTek, Co-Chair)
Project Groups:
Pb Free Alloy Group, Chair: Carol Handwerker, NIST
Pb Free Process Group, Chair: Jasbir Bath, Solectron
Pb Free Component Group, Chair: Richard Parker, Delphi-Delco
Pb Free reliability Group, Chair: John Sohn, Lucent (retired)
Status: Project Started, 1Quarter 1999 - **Completed, Q4, 2002**
- **Advanced Pb-free Assembly and Rework Development Project:** (Chair Jerry Gleason, HP; Co-Chair Charles Reynolds, IBM) Status: Project Start, February 2002
Project 15% Completed
- **Tin Whisker Modeling project:** (Co-chairs George Galyon, IBM, Maureen Williams, NIST) Status: Project Start, February 2002 **Project 50% Completed**
- **Tin Whisker Accelerated Test Project:** (Nick Vo, Motorola, ChipPAC, Inc., Chair, Mark Kwoka, Intersil and Jack McCullen, Intel Co-Chairs) Status: Project Start, February 2002 **Project 90% Completed**

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Solder Alloy Project

Mission: Provide critical data and analyses needed for making decisions with respect to solder alloys, manufacturing, and assembly reliability.

- ✓ **NEMI chose Sn-3.9Ag-0.6Cu, rest of world moving close to that choice**
 - **Worked with NIST to characterize alloy phase diagram.**
- ✓ **Developed “best practices” experimental procedures to measure the mechanical, thermal, electrical and wetting properties of lead-free solders**
- ✓ **Developed Solder Reliability Modeling Guidelines**
 - **Critical review of reported deformation data and models**



Alloy Team Accomplishments

- ✓ **Lead-free solder reference database available.**
- ✓ **Determined ternary eutectic melting temperature of Sn-3.9Ag-0.6Cu.**
- ✓ **Investigated patent and materials property issues for Task Force selection of Sn-3.9Ag-0.6Cu for reflow and Sn-0.7Cu for wave.**
- ✓ **Examined sensitivity of melting behavior of Sn-Ag-Cu to composition and temperature in response to request from team members.**
- ✓ **Held workshop on modeling and data needs for lead-free solders with workshop report being used as roadmap for developing and analyzing data.**
- ✓ **Public domain properties and reference databases available on NIST website.**
- ✓ **Database developed for archiving information on NEMI thermal cycling test vehicles needed for FEA.**



Component Project

Mission: Identify and recommend the best materials for the supplier industry to use, which meet the Pb-free requirements set by the main task group.

- ✓ **Characterized component survivability at elevated reflow temps.**
 - Some degradation, but materials available to meet needs.
- ✓ **Characterized the optimum operating profile of maximum time, temperature and environment exposures.**
- ✓ **Recommendation for component temperatures**
 - JEDEC used our data for revised J-STD-020B standard, consistent with our position: 250°C -5/+0



Component Project Conclusions

- Large ICs stayed below **240°C peak** temperatures
 - ✓ Smaller ICs and discrete parts stayed below 250°C peak temperature
 - ✓ Manufacturing tolerances were not added to the 240°C goal:
 - Oven repeatability
 - Thermocouple repeatability (mounting, tolerance, equipment)
 - Machine to machine reproducibility
- With appropriate management of reflow process, 240C max achievable for large IC's, 250C max for small IC's on Boards $\leq 0.92''$ thick



Process Development Project

Mission: Demonstrate manufacturing processes for lead-free soldering of printed wiring board assemblies

- ✓ Most thorough study of lead-free assembly to date
- ✓ Processes developed on existing tools and equipment
- ✓ Transferred to 3rd party for Reliability hardware build
- ✓ No major problems encountered during builds
- ✓ Agilent demonstrated Feasibility X-Ray inspection for Pb-Free
- ✓ Employed Acoustic microscopy before/after reflow
 - No damage due to reflow
- ✓ Evaluated automated optical inspection tooling
- ✓ Solder paste performance – Excellent printability and wetting

Demonstrated high quality Pb-free solder joints for reliability testing

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Process Development Project Conclusions and Recommendations

- **Lead-free solder assemblies successfully manufactured with existing assembly process equipment**
- **Materials used for lead-free soldering: Adequate**
 - ✓ Solderability of lead-free solder paste is reduced compared with tin-lead.
 - ✓ Voiding tends to increase with lead-free solder paste especially with tin-lead components.
- **Equipment Used: Most existing production equipment is adequate for SMT lead-free assembly**
- **Inspection Equipment: X-Ray and Acoustic Inspection tools adequate. More work needed on AOI**



Reliability Project

Mission: Perform reliability testing for selected solders, components, and board finishes using an approved test vehicle.

- ✓ Thorough experiment covering various components, solder/lead combinations, failure analysis, statistical analysis.
- ✓ Reliability tests
 - Thermal Cycling (-40 to 125°C, 0-100°C)
 - Three-point Bend Testing of BGAs
 - Electrochemical Migration
- ✓ Very Detailed Failure analysis and root cause of TC failures
 - Red dye penetrant
 - Metallurgical cross-section and analysis

Demonstrated Pb-free Joints are more reliable than Tin-lead

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NEMI Pb-free Reliability Project Conclusions

- **Thermal Cycling (-40 to + 125°C and 0 to 100°C)**
 - ✓ LF (balls/comp finish - paste alloy) combinations performed equivalent to or better than Pb benchmark
 - ✓ Not as clear with mixed cell combinations
 - Most performed equivalent to the Pb benchmark
 - Two combinations performed worse
 - One combination performed better
- **3 Point Bend testing: no differences observed between the different combinations**
- **No Electrochemical Migration issues seen with LF alloy when evaluated per IPC-TM-650 Method 2.6.14.1**
- **Established technical feasibility of Pb-free processing and reliability of Pb-free solder joints.**

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Follow-on Work

- **Much work still needed to implement/understand SnAgCu solders. Projects underway on**
 - ✓ **Board Laminates & ability to withstand higher temp.**
 - ✓ **Board finishes for SnAgCu soldering**
 - ✓ **Component lead finishes**
 - **Tin whisker accelerated stress testing***
 - **Fundamental understanding of tin whisker formation**
 - ✓ **Component replacement & rework**
 - **Thin (0.060") and thick (0.130") Boards**
 - ✓ **Wave Solder for Pin-in-hole components**
 - ✓ **Reliability modeling of SnAgCu solder joints**

* Sharing results with JEITA & ITRI UK.

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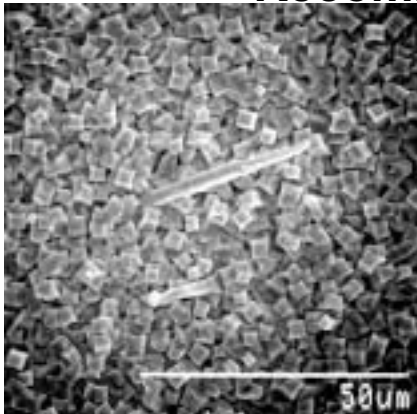
Advanced Pb-free Assembly & Rework Project

- **Chair: Jerry Gleason – HP**
- **Co-Chair: Charles Reynolds, IBM**
- **Pick up Areas not covered by initial NEMI work:**
 - ✓ **Large, Thick Boards**
 - ✓ **Wider range of components**
 - ✓ **Rework (including design rule impact)**
 - ✓ **Combined surface and thru-hole assembly**



Tin Whisker Projects

- **Modeling Chair: George Gaylon, IBM**
- **HAST Chair: Nick Vo, Motorola**
- **Objectives**
 - ✓ **Determine underlying mechanisms of whisker formation**
 - ✓ **Develop an accelerated test to determine the potential for whisker formation**
 - ✓ **Determine the acceleration factors to predict long term tendency to whisker**
 - ✓ **Recommend industry standard test to IPC/JEDEC**



Example of tin whisker
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Pb-Free Technology Status

- **The NEMI project has moved the industry forward in knowledge and understanding of Pb-free materials and processes.**
- **Continuing to work to fill in knowledge Gaps.**
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NEMI 2002 Environmentally Conscious Electronics Roadmap

Situation Analysis: Alternative Technologies

- **Alternative Technology Base**
 - ✓ Pb-free solders and process-NEMI TIG Activity
 - ✓ Br-Free PWBs and plastics are commercially available
 - ✓ Cd, Pb and Hg free plastics are available
 - ✓ Cr+6 alternatives are emerging
- **Successful Implementation into Products**
 - ✓ Widespread introduction of Pb-free solders and Br-free PWBs in Japan
 - ✓ Limited introduction of Pb-free solders and Br-free PWBs in North America
 - ✓ High temperature component qualification is an issue
 - ✓ Pb-free components are becoming available; however, lead finishes are still in debate for high reliability applications.

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Identified Gaps: 2002 NEMI Roadmap Environmentally Conscious Electronics

- **North American OEMs are not prepared to implement the Product Take Back requirements of WEEE**
- **The most pressing issues for the implementation of Pb-free solder are:**
 - ✓ **The availability of components specified to meet higher soldering temperatures**
 - ✓ **Issues of alternative finishes**
 - ✓ **Pb-Free Assembly & Rework of large systems**
- **The OEMs need to focus on eliminating hazardous materials in Cables and Accessories**
- **No standards exist for communication of “Materials Content Declaration” Information.**

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Potential Activities

Identified at March 7, 2003 Gap Analysis Meeting

- **Standards for communication of “Materials Content Declaration” Information.**
- **Supply Chain Readiness**
 - ✓ Educating Distributors
 - ✓ Flushing out the supply chain
 - ✓ Labeling Pb-free semiconductor components
- **Ecodesign-Guidelines, Tools, Templates, Metrics**
- **Take Back, Recycling Infrastructure (Europe)**
 - ✓ Benchmarking evolving services in Europe

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Next Steps

- Meeting to further discuss closing gaps will be held on Monday, May 19, 2003 at the IEEE-ISEE
- Location: Cambridge Room of the Park Plaza Hotel in Boston
- Time: 5:30-7:00 PM

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