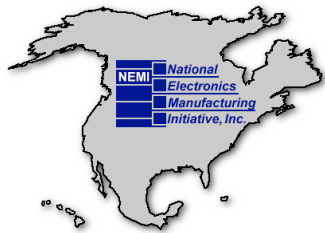




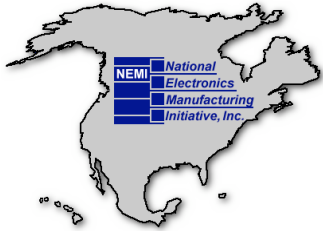
Environmental Programs and Strategies in the North American Electronics Sector: Addressing Global Expectations

Dr. Robert Pfahl

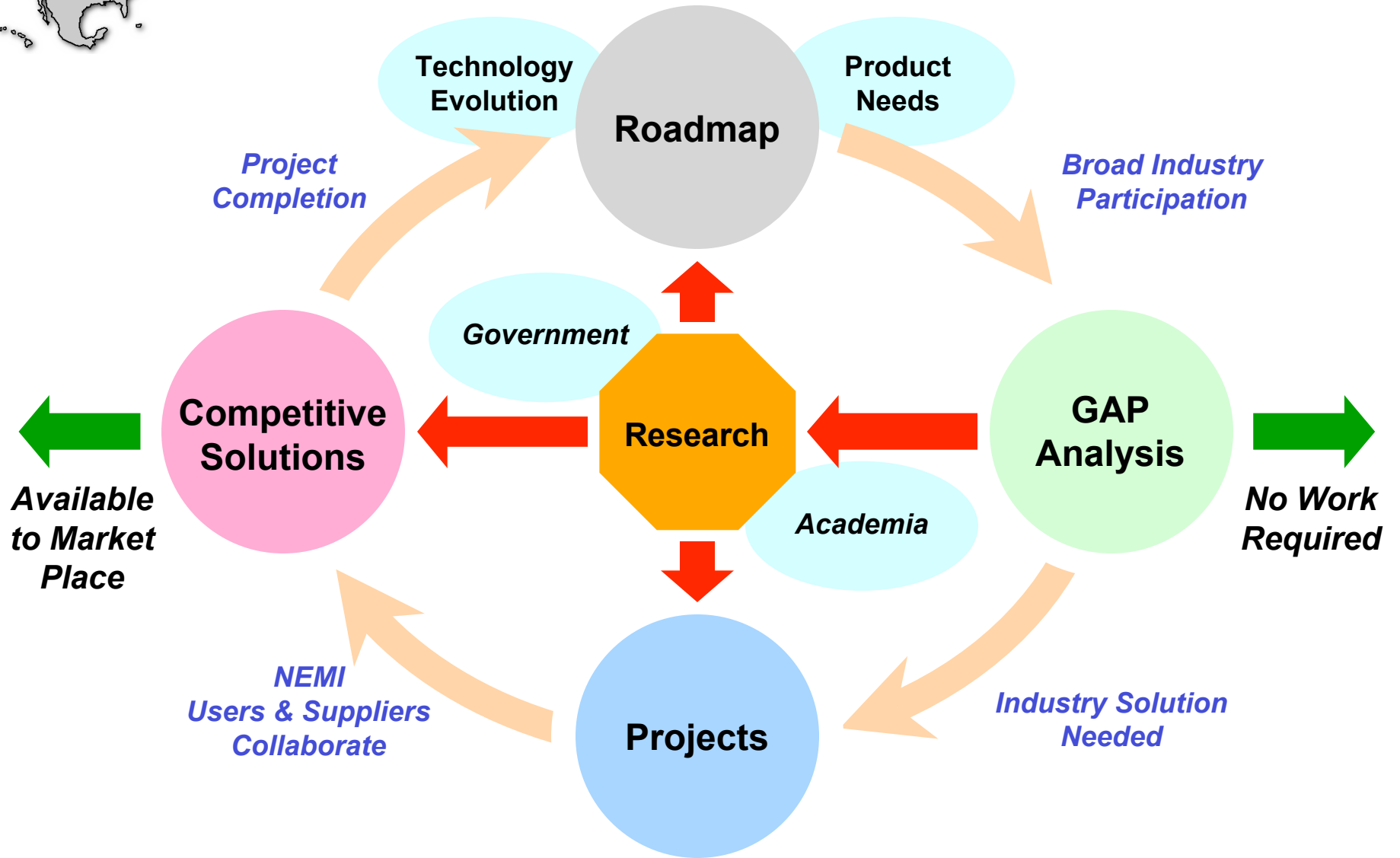


Outline

- **Status of Addressing Pb-Free Soldering Technology Gaps Identified in 2000 NEMI Roadmap**
- **Addressing the RoHS and WEEE Directive**
- **Next Steps: Addressing Business Gaps Identified in 2002 National Electronics Manufacturing Initiative (NEMI) 2000 & 2002 Environmentally Conscious Electronics Roadmaps**

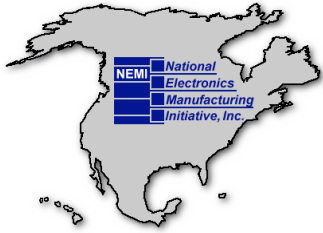


NEMI Roadmap Cycle



NEMI Implementation Cycle

Connect with and Strengthen Your Supply Chain

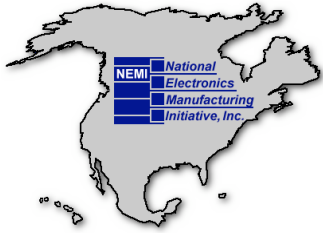


NEMI Pb-Free Projects

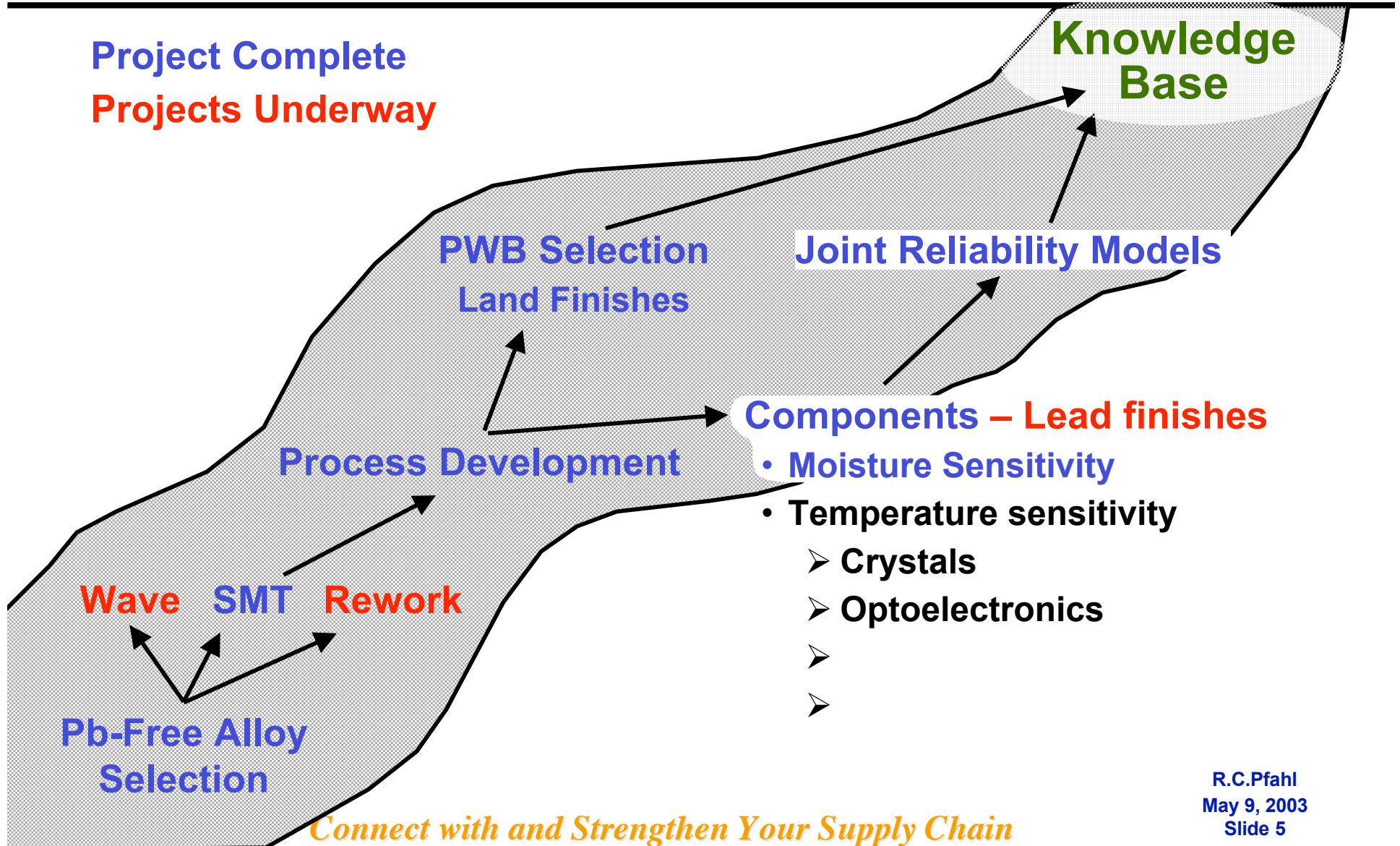
Addressing Gaps Identified in 2000 Roadmap

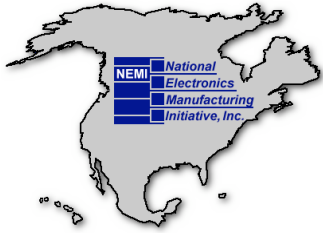
- **The NEMI projects have moved the industry forward in knowledge and understanding of Pb-free materials and processes.**
- **Continuing to work to fill in knowledge gaps.**
- **Building the knowledge base equivalent to today's SnPb solder will not be done overnight.**
- **NEMI is open to working with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

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

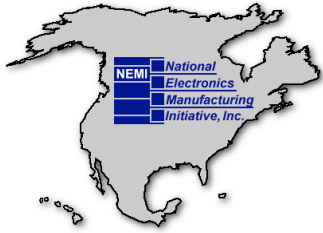




Roadmap of Lead Free Assembly

- **Driving forces for Lead Free Assembly are many**
 - ✓ Market
 - ✓ Regulation
 - ✓ Reputation
- **Impact of these forces varies depending on**
 - ✓ Product segment (e.g. consumer, business, automotive)
 - ✓ Regional focus
 - ✓ Company strategy
- **NEMI Strategy is to ensure supply chain readiness for Lead Free Assembly**
- **Actual crossover is a business decision (based on above factors)**

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Participants in NEMI Pb-Free Projects

OEMs/EMS

Alcatel
Celestica
Cisco

Delphi/Delco
Hewlett-Packard
IBM
Intel
Jabil
Kodak
Lace Technologies
Lucent
Motorola
Nortel Networks
Sanmina-SCI
Solectron
StorageTek

Material Suppliers

Alpha Metals
Cookson
Heraeus
Indium
Kester
Shipley

Components
AMD
ChipPac
Intel
Motorola
Texas Instruments

FCI Electronics

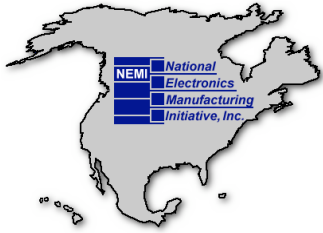
Govt. & Other

NIST
SUNY-B/IEEC
IPC

Equipment

Agilent
CMAP
BTU
Universal
Vitronics-Soltec

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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 Whisker Test

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

Lead-Free Assembly & Rework

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

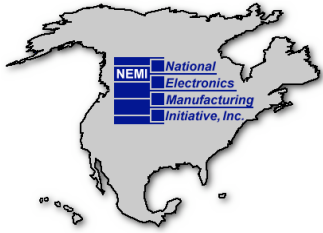
Tin Whisker Modeling

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

Tin Whisker User Group

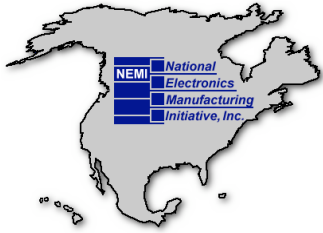
Chair: George Galyon, IBM
Co-Chair: Richard Coyle, Lucent

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Pb-Free Project Summaries

- **Lead-Free Assembly Project:** (Chair: Edwin Bradley, Motorola; Co-Chair: Richard Charbonneau, StorageTek)
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: Started Q1, 1999 - **Completed Q4, 2002**
- **Pb-free Assembly and Rework Project:** (Chair; Charles Reynolds, IBM; Co-Chair: Jerry Gleason, HP) Status: Started February 2002 - **15% Completed**
- **Tin Whisker Modeling project:** (Chair: George Galyon, IBM; Co-Chair: Maureen Williams, NIST) Status: Started February 2002 - **50% Completed**
- **Tin Whisker Accelerated Test Project:** (Nick Vo, Motorola, ChipPAC, Inc., Chair, Mark Kwoka, Intersil and Jack McCullen, Intel Co-Chairs) Status: Started February 2002 - **90% Completed**

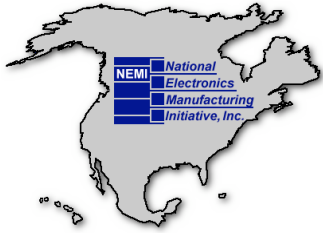


Solder Alloy Group

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**

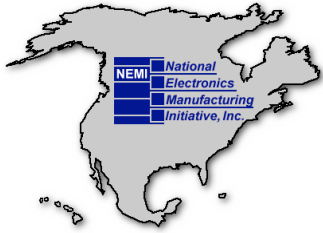
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Alloy Team Accomplishments

- ✓ 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. <http://www.metallurgy.nist.gov/solder>
- ✓ Database developed for archiving information on NEMI thermal cycling test vehicles needed for FEA.

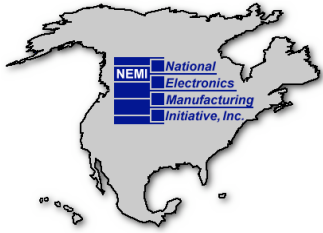
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Component Group

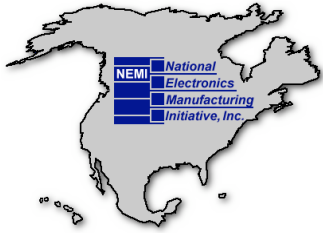
Mission: Identify and recommend the best materials for the supplier industry to use, which meet the Pb-free requirements set by the main task group.

- ✓ **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 Group 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, 240°C max achievable for large ICs, 250°C max for small ICs on boards \square 0.92” thick



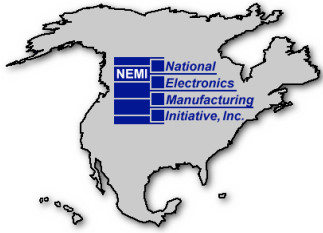
Process Development Group

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

- ✓ Most thorough study of lead-free SMT 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

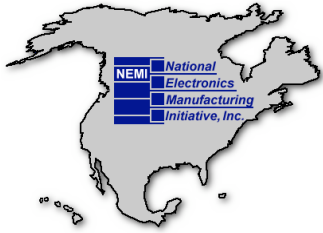
Demonstrated high quality Pb-free solder joints for reliability testing

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Process Development Group 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**



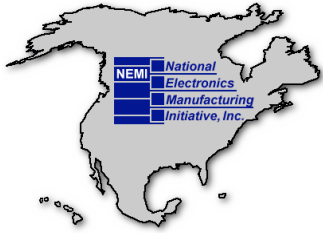
Reliability Group

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 at least as reliable as eutectic Sn-Pb based on standard reliability testing

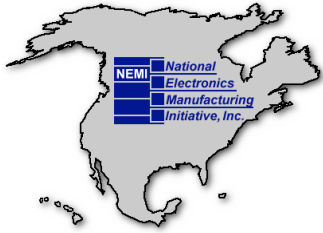
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NEMI Pb-free Reliability Group Conclusions

- **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**
- **Three 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**

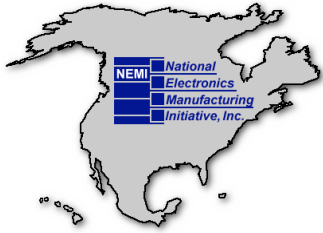
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Follow-on Work

- **Much work still needed to implement/understand SnAgCu solders. Projects underway on**
 - ✓ **Board laminates & ability to withstand higher temperature**
 - ✓ **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**

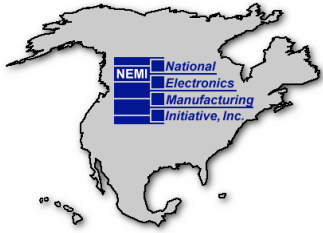
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Pb-free Assembly & Rework Project

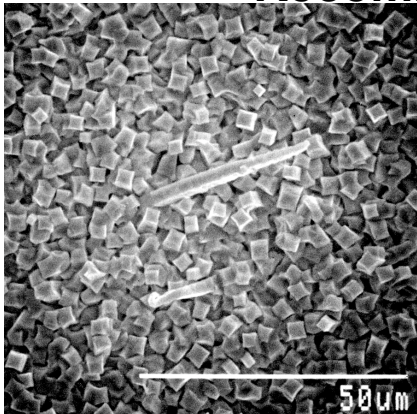
- **Chair: Charles Reynolds, IBM**
- **Co-Chair: Jerry Gleason – HP**
- **Pick up areas not covered by initial NEMI work:**
 - ✓ **Large, Thick Boards**
 - ✓ **Wider range of components**
 - ✓ **Rework (including design rule impact)**
 - ✓ **Combined surface and thru-hole assembly**

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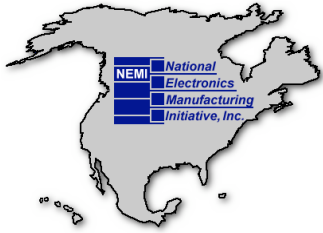


Tin Whisker Projects

- **Modeling Chair: George Gaylon, IBM**
- **Test 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**



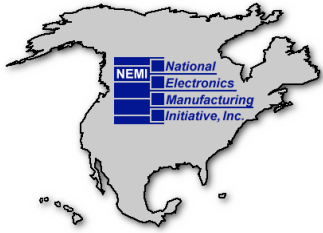
Example of tin whisker
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Pb-Free Technology Status

- **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.**
- **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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NEMI 2002 Environmentally Conscious Electronics Roadmap

Situation Analysis: Market

- **Customers**

- ✓ **Industrial**

- **Materials Declarations are required in the Auto Industry and will Penetrate the Electronics Industry**

- **Standard information declarations developed by EIA**
 - **No Automotive Standards**

- ✓ **Consumers**

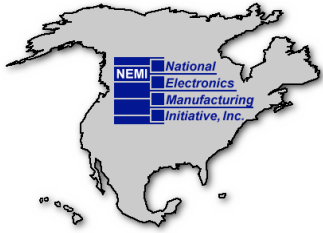
- **Limited Markets**

- **Environmental Labels**

- ✓ **Increasing pressure for labels**

- ✓ **Energy use is widely labeled**

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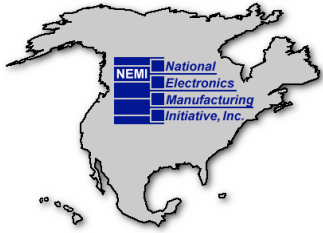


NEMI 2002 Environmentally Conscious Electronics Roadmap

Situation Analysis: Legislative

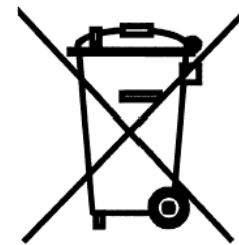
- **Increasing Environmental Legislative Activity**
 - ✓ **End-of-Life Disposal Legislation in Europe, United States, and Japan**
 - **Electric Home Appliances Recycling Law in Japan (1998)**
 - **WEEE in Europe (2002)**
 - **Automotive Legislation in Europe**
 - **EOL legislation pending in 20 states**
 - ✓ **Hazardous Materials in Europe, Japan, and U.S. States**
 - **RoHS in Europe (Pb, Br-FR, Cd, Hg, Cr+6) (2002)**
 - **Proposition 65 in California**
 - **Hg in New England**
 - **Materials Declaration by Suppliers**

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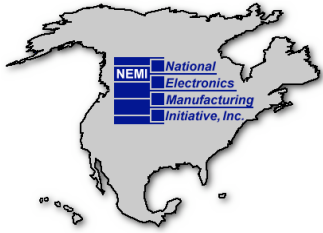


WEEE Goal: Take-back and Recycling

- **Take-back**
 - ✓ Producers will fund collection, treatment, recovery & disposal of End of life electronics from the final holder.
- **Treatment**
 - ✓ Batteries, PWBs (mobile phones generally, else > 10 cm²), external electric cables, and plastic containing brominated flame retardants must be removed from the product and treated separately.
 - ✓ Rate of recovery must reach 70% - 80% of WEEE sent for treatment.
- **Documentation**
 - ✓ Must provide recyclers information on disassembly, components, materials, and location of dangerous substances.
 - ✓ The crossed dust bin symbol has to be put on product or packaging.



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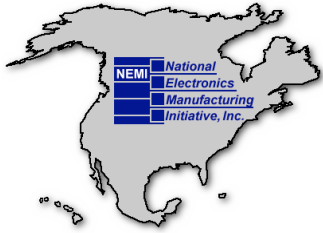


RoHS Goal: Eliminate Hazardous Substances

- **Member States shall ensure that, from July 1, 2006, new electrical and electronic equipment put on the market does not contain the following substances.**
 - ✓ **Lead (Pb)**
 - ✓ **Mercury (Hg)**
 - ✓ **Cadmium (Cd)**
 - ✓ **Hexavalent chromium (Cr VI)**
 - ✓ **Polybrominated biphenyls (PBB)**
 - ✓ **Polybrominated diphenyl ether (PBDE)**

Parliament may ban other hazardous substances in the future

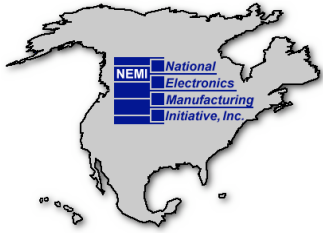
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RoHS Exclusions: Lead

- Lead in high melting temperature type solders (i.e. tin-lead solder alloys >85% lead)
- Lead in solders for servers, storage and storage array systems (exemption granted until 2010)
- Lead in solders for network infrastructure equipment for switching, signaling, transmission as well as network management for telecommunication
- Lead in electronic ceramic parts (e.g. piezoelectronic devices)
- Commission evaluates the exemptions with a view to setting a specific time limit for this exemption

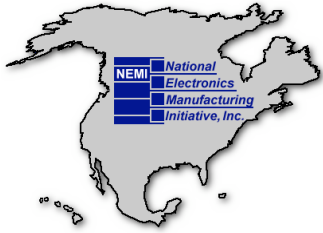
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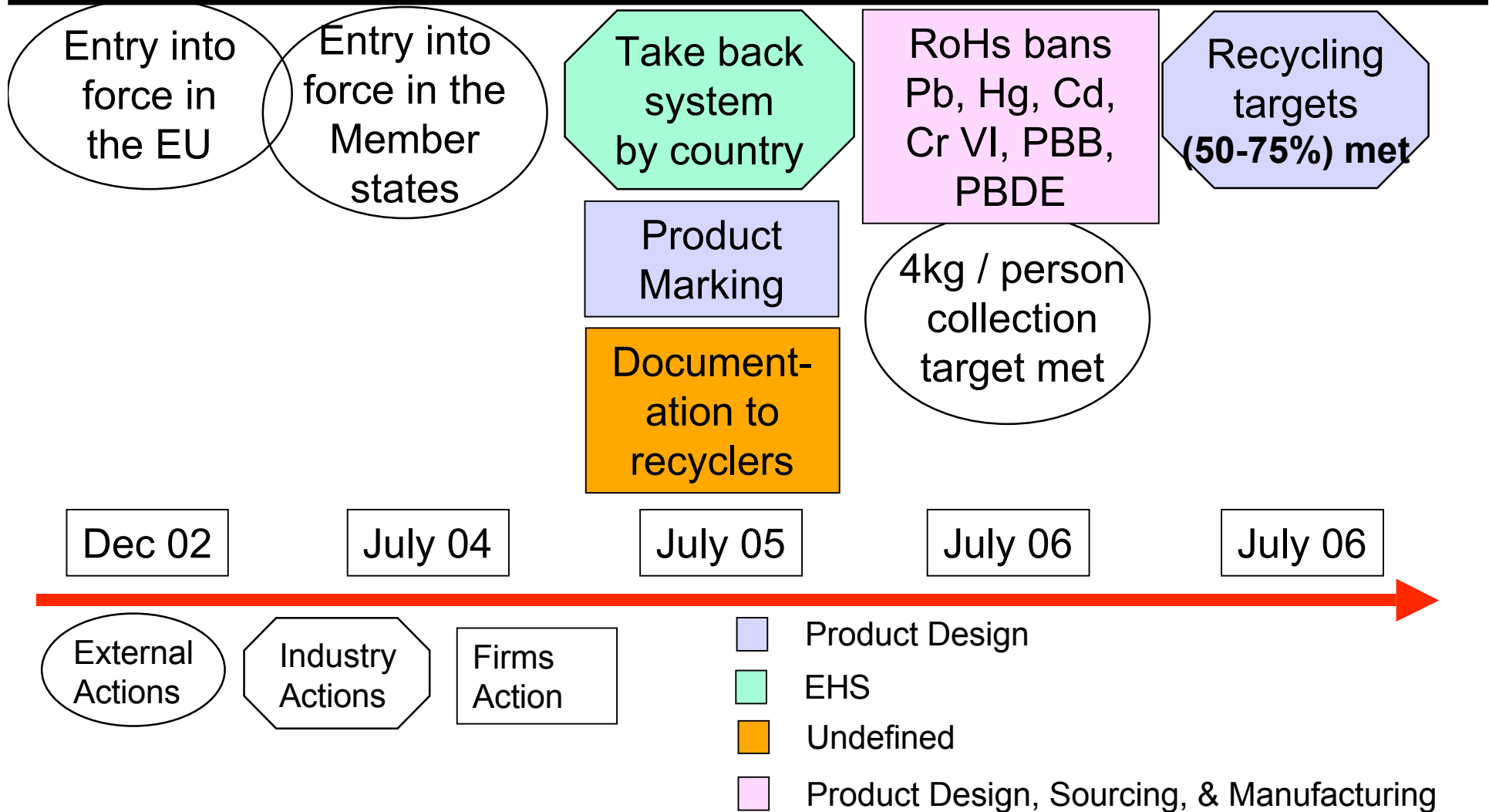
Addressing the RoHS Directive

- **North American Pb-Free Activities (NEMI)**
 - Solder Alloy
 - Components/PWB
 - Process Development
 - Solder Reliability
 - Tin Whiskers
- **Materials of Concern (EIA)**
 - ✓ Materials Declaration Guide
 - ✓ Regulatory Tracking Tool

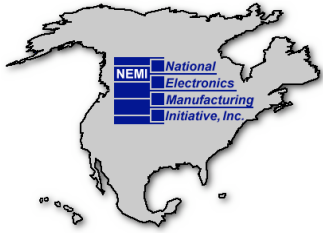
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RoHS and WEEE Timeline



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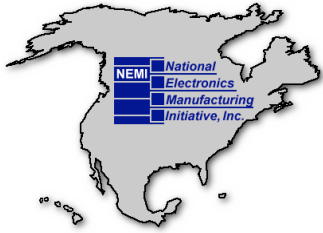


NEMI 2002 Environmentally Conscious Electronics Roadmap

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.

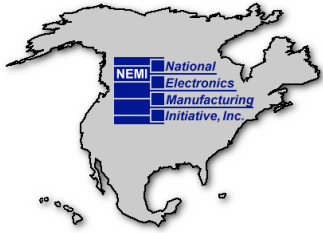
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Identified Gaps: 2002 NEMI Roadmap Environmentally Conscious Electronics

- **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**
- **OEMs need to focus on eliminating hazardous materials in cables and accessories**
- **No standards exist for communication of “materials content declaration” information**

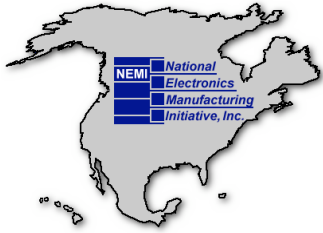
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Closing the Gaps: Proposed New NEMI Projects

- **Transition to Pb-free assembly**
 - ✓ Standardization of product/process specifications
 - ✓ Part number change management
 - ✓ Compliance/component roadmap – “standardization” requirements – date-timeline
 - ✓ Reliability & relevance of existing reliability models
- **Evaluation of “materials environmental content” data communication**
- **Testing standards for materials content data**
- **Take-back and recycling infrastructure to meet European responsibilities**
- **Eco-design R&D**

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Summary and Next Steps

- **Meetings currently are being called to establish projects to close the identified gaps.**
 - ✓ **Lead Free Transition Task Group, Chair Dave McCarron, Dell**
 - **Teleconference - October 23, 2003 1 p.m. EDT**
 - **Call-in number: 888-231-5467 - Conference ID: 113998**
 - **Objective: Develop plans to address the supply chain issues surrounding the transition to Pb-free assembly**
 - ✓ **Evaluation of “Materials Environmental Content” data communication Project**
 - **Kick-Off Teleconference –Thursday, Nov. 6, 2003 1 p.m. EST**
 - **Project objective: Evaluate the capabilities of commercial tools for environmental data exchange**
- **More information is available at:**
<http://www.nemi.org/projects/ese/index.html>