

# The No Lead manufacturing Initiative

*Dr. Srinivas T. Rao*

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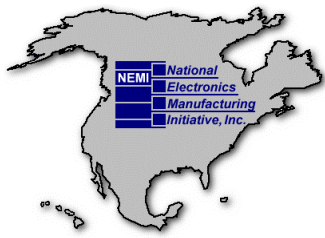
*UCLA Workshop on Lead-free Solder for Electronic, Optical,  
and MEMs Packaging and Manufacturing  
September 5<sup>th</sup> 2002*



# Address Mfg. Needs of OEMs and EMSs

- Monitor environmental legislation and adjust activities if necessary
- Recommend an 'industry standard' lead-free alloy (reflow and wave)
- Develop criteria for industry to use to evaluate Pb-free processes
- Share information in a timely manner to promote common path to Pb-free
- Develop "best practices" experimental procedures to measure mechanical, thermal, electrical and wetting properties of Pb-free solders
- Develop solder databases for properties and literature references for lead-free alloys in the public domain
- Promote modeling for reliability through generation of best possible data and modeling methods
- Work with component and PCB suppliers to develop specifications to meet higher temperature reflow conditions

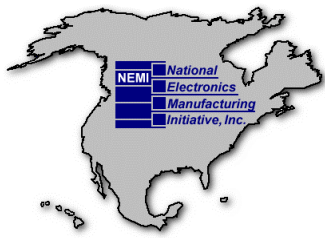
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# North America Electronics Goal

- N. American OEM's/EMS' need to prepare processes to be able to deliver Pb-free products in 2001 with an 'eye' to total Pb-elimination by 2004.
  - Japan driving "Green" consumer products.
    - Timetables seem to be holding (2001-2003)
  - NEMI companies received serious inquiries.
  - EU legislation banning lead in electronics in 2004, proposal pushed out to 2007.
    - Individual Countries can shorten timeframe.

NEMI engaged the technical side of Pb-free related to compatibility with existing assembly infrastructure.



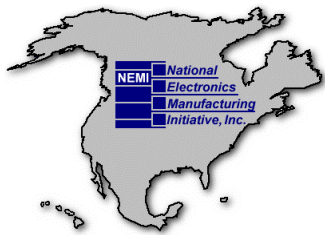
# Legislation

- **Europe: WEEE/ROHS. WEEE expected to come to a vote in 4Q 2002. Sticking point is the product take-back and company responsibility of ROHS.**
- **US: new rules regarding reporting of Pb, but no legislation on horizon for banning Pb or Pb-containing solder.**
- **Asia: No legislation, but Japanese companies are still actively engaged in eliminating Pb from electronics.**

Push back of WEEE date + lack of other legislation has taken immediate pressure off drive to implement.

But many OEMs moving forward for marketing reasons

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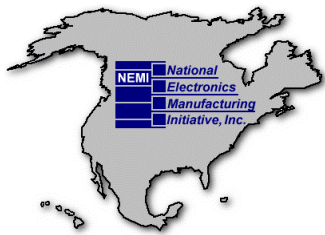


# Major Task Group Objectives

- Demonstrate capability to deliver products in volume in 2001 with Pb-free interconnects.
- ✓ Facilitate a common Pb-free solder alloy composition for N.American electronics assembly.
- ✓ Work with component and PCB suppliers to develop specifications necessary to meet higher temperature reflow conditions.
- ✓ Develop criteria that industry can use to evaluate Pb-free processes.
- ✓ Monitor environmental legislation to adjust activities if necessary.
- ✓ Share our information in a timely manner to promote common path to Pb-free .

Commonality is an overarching goal for all NEMI activities

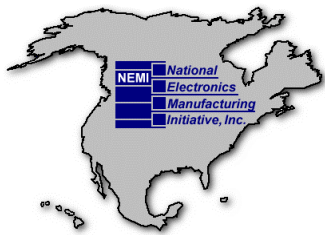
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# Worldwide Pb-free Activities

- **NCMS** –recent high temperature solder alloy project report released, Pb-free solders performed well.
- **Gintic (Singapore)** – Consortium working on process and reliability of Pb-free solders.
- **JEITA** – Continuing work on solders and tin whiskering.
- **Soldertec** – Performed reliability tests, supported SnAgCu. Now working on Tin whiskering.
- **JEDEC** – 020 revision with elevated temperatures for MSL testing out for ballot.
- **IPC** – Support with meetings, standards development.
- **EPA** – Life Cycle project. Proposal for companies to partner on a project and split cost with EPA.
- **GECI** – Promoting global cooperation and commonality.

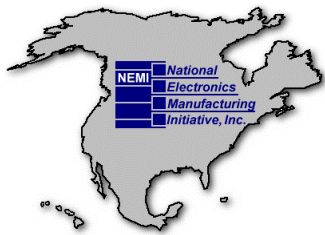
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# Cooperation/Commonality

- Maximum benefit achieved through world wide agreement and cooperation.
  - NEMI is member of GECI (Global Environmental Cooperation Initiative). HDPUG, SEMI, Soldertec, MEPTEC, SAC, ITRI Taiwan also members.
    - + Promoted single alloy SnAgCu
    - + Definition of Pb-free (0.2%)
- Update/create JEDEC standards.
  - Working with committee on J-STD-020.

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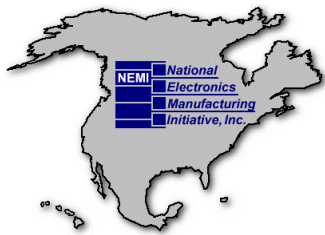


# Major Project Activities

- **Alloy – Carol Handwerker, NIST**
  - Alloy Material Property development
  - Interface w/academia, gov't agencies
- **Components/PCBs – Rich Parker, Delphi**
  - Effect of High temperature reflow
  - Pb-free terminations
- **Solder Reliability – John Sohn, NEMI**
  - Transparent test procedure
  - Common data to share with industry
- **Process Development – Jasbir Bath, Solectron**
  - Generic process for Reliability test boards
  - Process characterization benchmark
- **Tin Whisker – Swami Prasad, ChipPAC**

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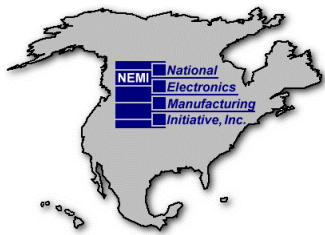


# Solder Alloy Team

**Mission: To provide the Task Force with critical data and analyses needed for making decisions with respect to solder alloys, manufacturing, and assembly reliability.**

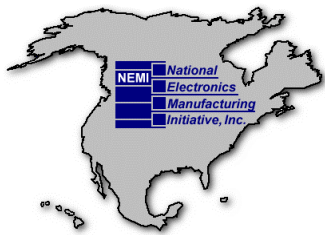
- ✓ **NEMI chose Sn-Ag-Cu, rest of world moving in that direction.**
- ✓ **Developed “best practices” experimental procedures to measure the mechanical, thermal, electrical and wetting properties of lead-free solders.**
- **Developing Solder Reliability Modeling Guidelines**
  - ✓ **Critical review of reported deformation data and models**

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# Solder Alloy Team Accomplishments

- ✓ **Conducted extensive literature search including Europe and Far East**
- ✓ **Determined ternary eutectic melting temperature of SAC as 217° C**
- ✓ **Investigated patent issues and selected 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**

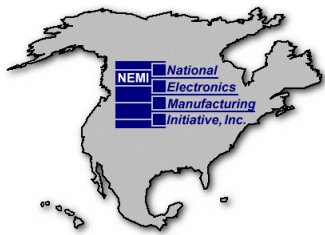


# Component Team

**Mission: To collectively work on identifying and recommending the best materials for the supplier industry to use, in delivering compatible components and PWBs that will meet the Pb-free requirements sent forth in the main task group.**

- ✓ **Previously characterized component survivability at elevated reflow temp.**
- ✓ **Characterized the optimum operating profile of maximum time, temperature and environment exposures.**
- ✓ **Recommendation for component temperatures**
  - ✓ **Reflow characterization, peak temp/board delta-T**
  - ✓ **JEDEC using our data for proposal for new standard, consistent with our position.**
- **Working with IPC (ex. ITRI) PCB project for evaluation of PCB laminates.**

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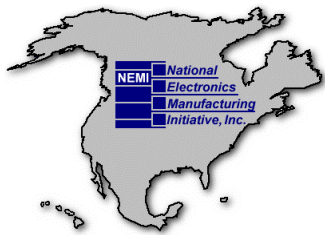


# Assembly Process Team

Mission: To demonstrate capable processes for lead-free soldering of printed wiring board assemblies.

- ✓ **Most thorough study of lead-free assembly to date**
- ✓ **Demonstrated high quality joints for reliability testing**
- ✓ **Report generation and review**
  - ✓ X-ray solder inspection of BGAs
  - ✓ Acoustic microscopy of packages
  - ✓ AOI of solder joints
  - ✓ Solder paste performance
  - ✓ Rework

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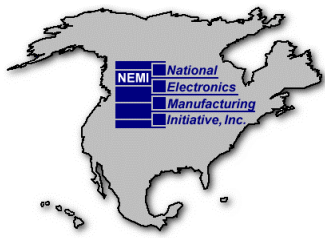


# Reliability Team

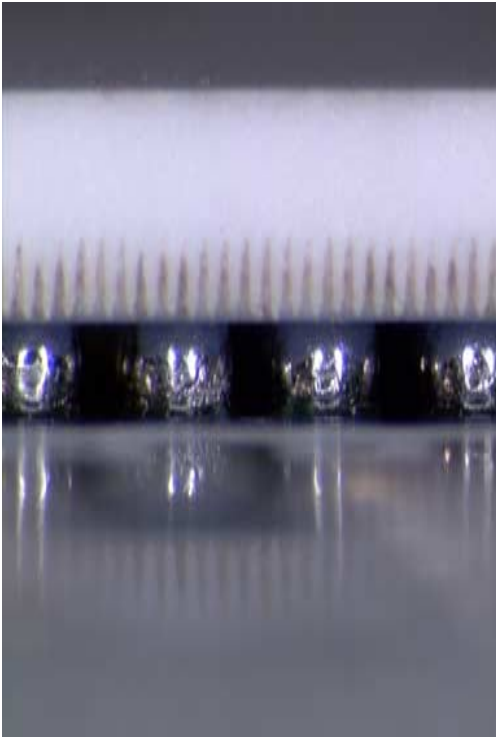
**Mission: To perform reliability testing for selected solders, components and board finishes using an approved test vehicle.**

- ✓ **Thorough experiment covering various components, solder/lead combinations, failure analysis, statistical analysis.**
- ✓ **Reliability tests**
  - ✓ **Thermal Cycling**
  - ✓ **Three-point Bend Testing**
  - ✓ **Electrochemical Migration**
- **Failure analysis and root cause of TC failures**
  - ✓ **Red dye penetrant**
  - ✓ **Metallurgical cross-section**
  - ✓ **Very detailed and thorough FA process.**
- ✓ **Statistical Data Analysis on TC results**
- **Data to go into alloy group database**

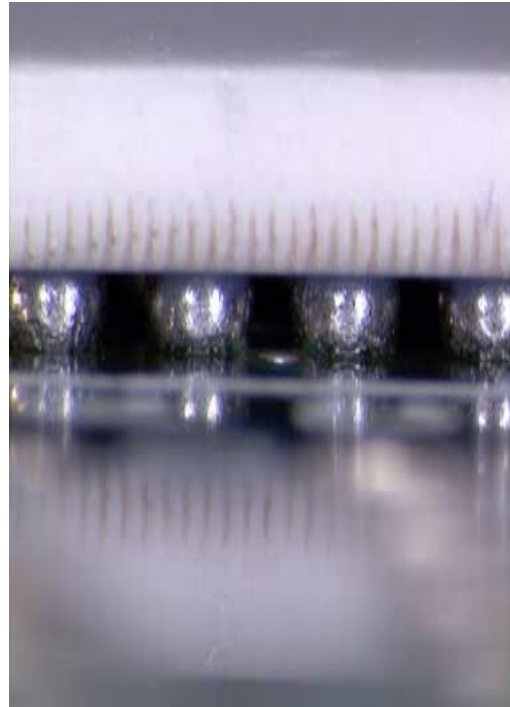
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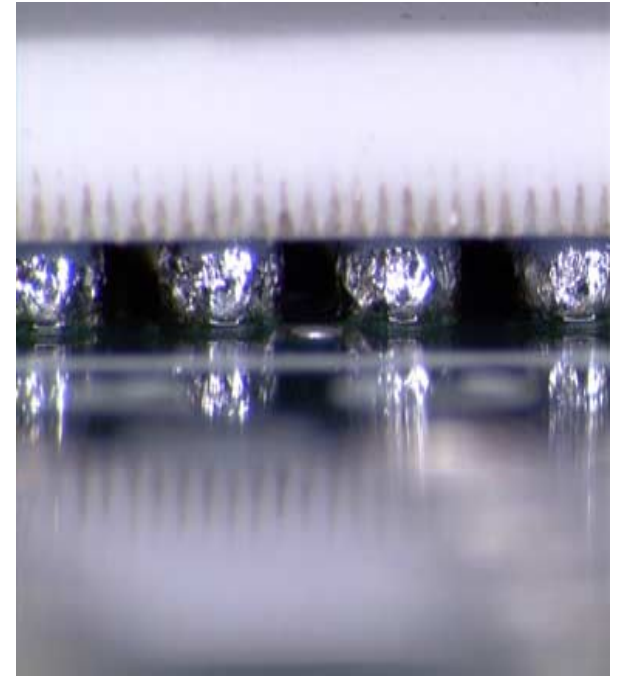
# Universal Build Visual Inspection Results: CBGA



**Tin-lead paste/  
tin-lead CBGA  
(Shiny joint)**

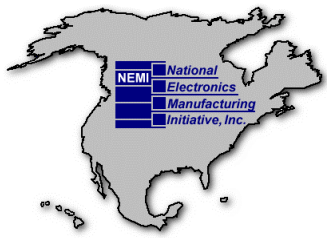


**Lead-free paste/  
Tin-lead CBGA  
(Dull joint)**

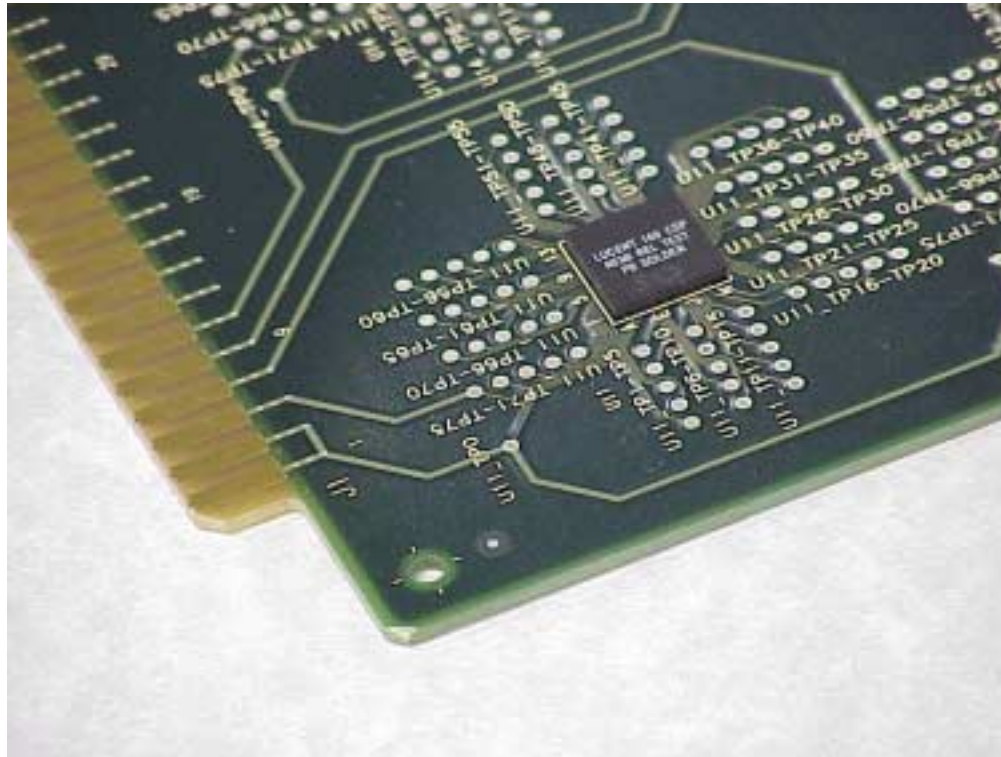


**Lead-free paste/  
lead-free CBGA  
(Cratered joint)**

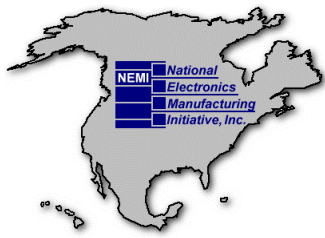
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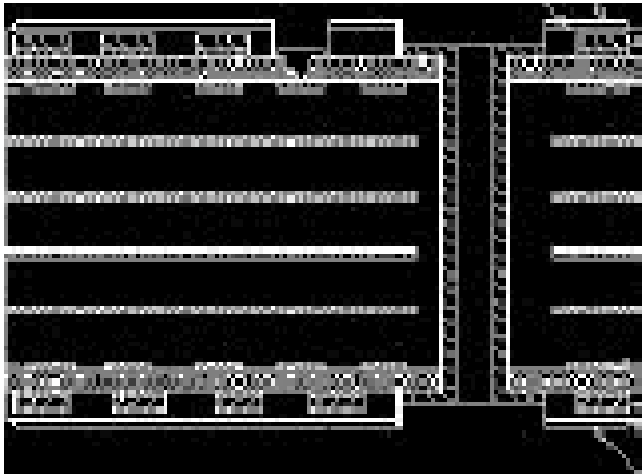
# Test Vehicle (169CSP)



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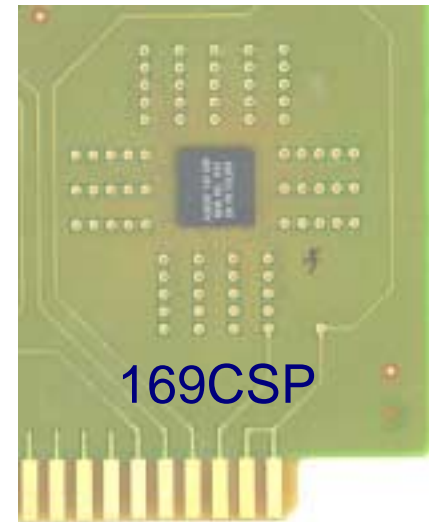


# Board details: 169CSP



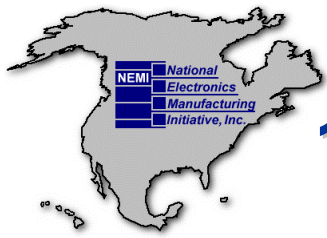
- ← 1 component side
- ← 2 internal signal
- ← 3 dummy plane
- ← 4 dummy plane
- ← 5 dummy plane
- ← 6 dummy plane
- ← 7 internal signal
- ← 8 circuit side

8 layer board, 0.062" thick, FR-4,  
T<sub>g</sub> ~ 170°C, microvia technology  
Immersion silver finish



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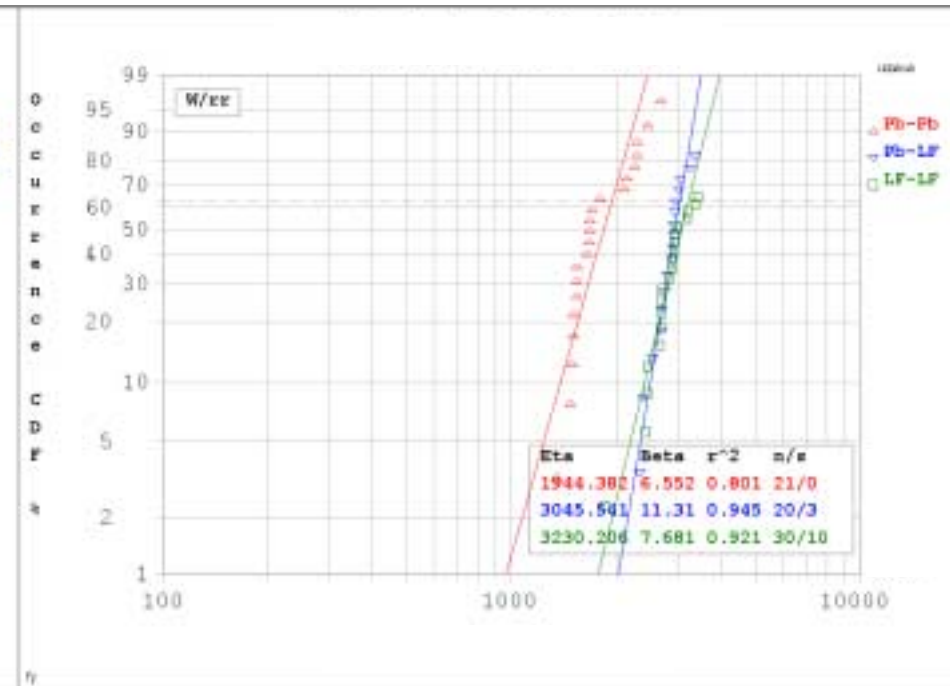
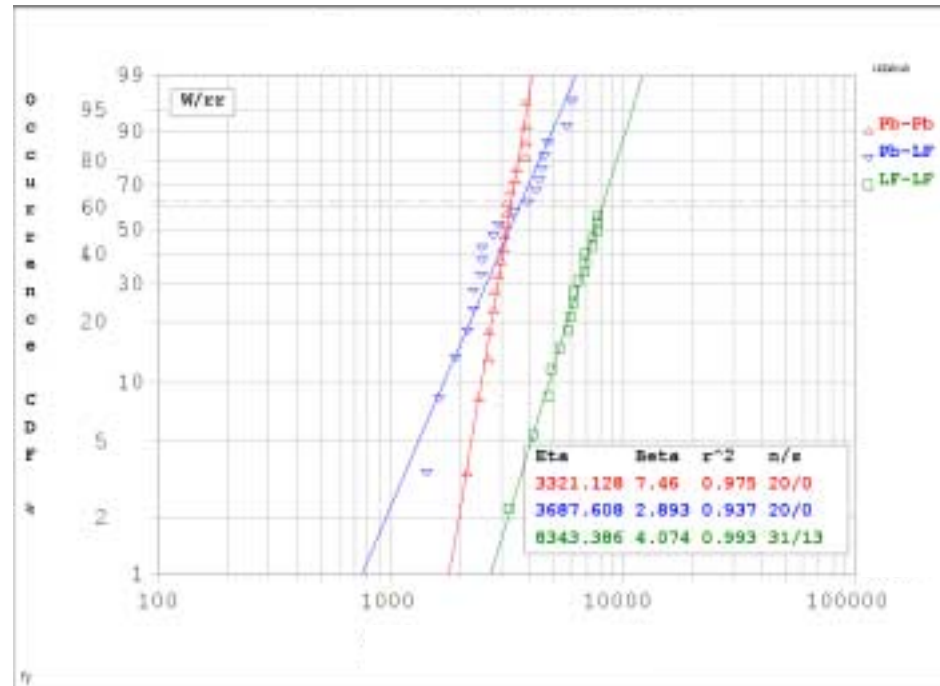




# 169CSP Weibull Analyses

0 to 100°C cycling

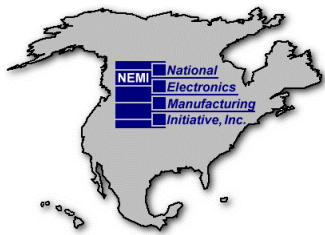
-40 to +125°C cycling



	Pb-Pb	Pb-LF	LF-LF
$\eta$ (N63)	3321	3688	8343
$\beta$	7.5	2.9	4.1

	Pb-Pb	Pb-LF	LF-LF
$\eta$ (N63)	1944	3046	3230
$\beta$	6.6	11.3	7.7

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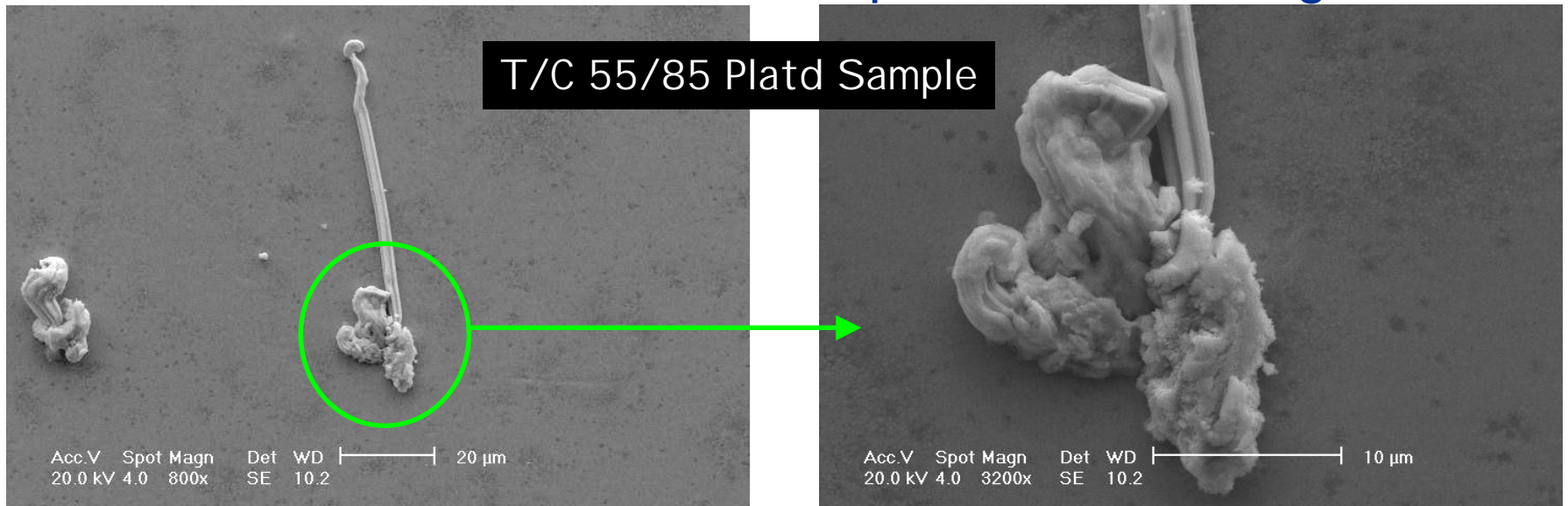


# Tin Whisker Committee: First DOE

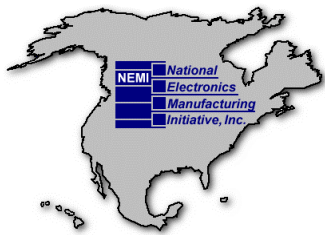
Experimental matrix formulated after review of available whisker data in industry

- included selected IC's and passive components
- variables
  - preconditioning: ambient vs temperature cycling (500 h)
  - temperature: ambient, 50-55°C, 85°C
  - humidity: ambient, 85% RH

Accelerated conditions seem to promote whisker growth



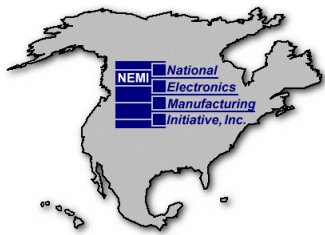
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# Project Results

- **Recommended SAC Alloy to industry**
- **Demonstrated SAC Process compatible with current tools/facilities**
- **Interim solution to MSL problem recommended**
  - Further work identified and underway
- **Initiated solder joint reliability modeling effort**
- **Reliability evaluations find SAC alloy equal to or better than PbSn**
- **Member companies have released products with new alloy to production**

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# Project Schedule

- **Project Final Report – Sept 2002**
  - **Webcast Planned for Sept. 19 from Nortel in Montreal (see [www.nemi.org](http://www.nemi.org) for details/signup)**
  
- **IEEE /Wiley Book: Q2, 2003**
  - **Integrated book covering major points of this project along with other published work to date.**