Lead Free Soldering Summit

July 13 – July 14, 2005
American Competitiveness Institute
Philadelphia, Pennsylvania

Wednesday - July 13, 2005

Discussion: Identify what Lead Free Soldering research and development activities have been done supporting the military and aerospace electronics community – **What Do We Know?**

- Lead Free Soldering Summit Opening Remarks – L. Whiteman, ACI

  - Currently, the military and aerospace electronics communities are exempt from the EU Legislation requiring Lead Free Soldering. However, the military and aerospace electronics market represents approximately 1% of the entire electronics market. Therefore, when commercial markets go Lead Free, the military and aerospace markets will be forced to go Lead Free.

  - Lead Free Soldering is not just a manufacturing problem. It impacts the entire military and aerospace electronics supply chain and life cycle.

- JCAA/JG-PP Lead-Free Solder Testing for High-Reliability Applications – B. Greene / K. Kessel, ITB

  - Lead Free soldering processes require modifications to operate at higher temperatures. Component management is critical. Components were not labeled correctly. Incorrect component finishes was provided to the program.

  - Solder joint reliability is a function of the solder alloy, the type of Environmental Stress Test performed, the component type, the component lead/ball finish, the component location and orientation on the board, and whether the component was reworked or not.

  - 100% lead-free is workable, but need to work out details for high-reliability applications. Concern is the unpredictability associated with the transition phase / mixed assemblies.

  - The JCAA/JG-PP Lead-Free Soldering Program will be presenting data at the SMTA International Conference at Chicago, Illinois in September, 2005 and the APEX Conference at Anaheim, California in February, 2006.

- Lockheed Martin ACI Lead Free Soldering Rapid Response Project – R. Inacker, Lockheed Martin

  - Reviewed the Manufacturing Site Survey performed by ACI and Lockheed Martin, a limited AEGIS Lead Free Soldering production build and reliability evaluation of Lockheed Martin's Moorestown, New Jersey facility.

  - Determined that Lockheed Martin's Moorestown, New Jersey facility is capable of building hardware with Lead Free solders, but the processes require optimization. Lead Free Soldered AEGIS hardware manufactured passed electrical and environmental tests.

- Lead Free Manufacturing for Navy Systems – M. Nelson, ACI

  - ACI and its Industrial Advisory Board (IAB) have initiated this project. The project goals are to develop Lead Free Soldering Process for Navy applications and to "functionally test" deliverable Navy hardware soldered with Lead Free solders.

  - The project output is to produce the Lead Free Soldering Guidelines For High Reliability Applications. ACI anticipates the guidelines will be updated periodically as technology matures.

  - The project started in February, 2005, and will be completed by April, 2006.

- European Space Agency Lead Free Soldering Position Summary – B. Dunn c/o L. Whiteman, ACI

  - The European Space Agency (ESA) strictly prohibits the use of Tin plated components, boards and assemblies. Their solder alloy manufacturers and circuit board manufacturers will continue to supply Tin Lead solders and board finishes.

  - Components will be pre-tinned with Tin Lead (SnPb) solders prior to production.

- Rolls-Royce and 'Lead-free' – R. Gregory, Rolls Royce

  - For the short term, Rolls-Royce will continue to specify the use of Tin/Lead solder, and will assure build subcontractors use only components that have leads finished with materials that are compatible with this solder.

  - Rolls Royce will continue research into the reliability aspects of components, the
  - associated solder joints and manufacturing processes.

  - Rolls Royce will enhance their Configuration Control systems during this transition stage. For 'new' designs, Rolls Royce will try to reduce the number of joints, by

introducing Hybridise circuitry and to utilize Gate Array technology. New designs will have components and substrates which are compatible Lead-free manufacturing processes.

- In the Long Term, Rolls Royce will instruct a change to a Lead-free solder and associated
- manufacturing processes if appropriate specify process limitations are defined.

- Lead-Free from "One" NASA Perspective – M. Sampson, NASA

  - Tin Whiskers is a major concern to military and aerospace electronics. There is no single technique to mitigate against tin whiskers except "don't use pure tin".

  - After 6 years, inspection of tin-plated test coupons suggests whiskers have been able to grow along the surface beneath the Uralane conformal coating ("mole runs"). If confirmed, conformal coating will be shown to have limitations as a whisker mitigation strategy.

  - Currently test methods recommended by iNEMI have been proposed to JEDEC as the basis for a test method standard and a qualification standard. The technical validation for this is very weak.

  - Popular lead-free replacement for 60/40 tin/lead may be susceptible to solder joint embrittlement due to formation of voids (Kirkendall) and "black pad" under some test conditions. The test conditions may not be representative of the majority of use conditions. this is a concern given the current lack of good long term reliability data on lead-free solders

- Technology Assessment of Technology Assessment of Lead-Free Electronics – C. Handwerker, NIST

  - A review of the Lead Free Soldering research performed by NIST was provided. A summary of iNEMI's Lead Free Soldering Program was presented.

  - Phase diagrams describing the melting and cooling characteristics of SnAgCu solder alloy was presented. It explained why it was critical to reach the 240°C temperature to assure the SnAgCu solder was in a fully liquid state.

  - Transition Issues include:

    - **Surface Finishes**: Accommodating SnAgCu higher reflow temperatures is even more of a challenge; second side reflow; 5X thermal excursions. OSP presents more problems with Lead Free Alloys.

    - **Sn-Ag-Cu solders with Sn/Pb balls**: No discernable issues

    - **Sn-Ag-Cu balls with Sn/Pb solders** – May be some issues of backward compatibility with respect to reliability for area array joints. Must use SAC reflow profile

    - **Sn-Ag-Cu solders with Sn/ Pb surface finishes** - Through-hole fillet lifting

  - iNEMI Findings:

    - There are no major impediments to Pb-free SMT reflow processes for IPC Class 2 printed circuit assembly.

    - The accelerated thermal cycle (ATC) thermal fatigue life of Pb-free solder joints appears to be longer than the control SnPb assemblies.

    - Large Pb-free assemblies can only withstand ~50% of the mechanical bend force and deflection when compared to tin-lead (SnPb) assemblies.

    - The reliability of reworked area array components (BGAs, etc.) was poorer that that of as-assembled / non-reworked assemblies, and the rework processes adversely impacted adjacent component solder joints (collateral damage) through secondary reflow effects.

- The Impact of Reflowing A Lead Free Solder Alloy Using A Tin/Lead Solder Alloy Reflow Profile On Solder Joint Integrity - D. Hillman, Rockwell Collins

  - Objective: To evaluate the solder joint integrity impact of reflowing a Pb-free solder alloy using a tin/lead reflow profile on BGA components.

  - Conclusion: Area array components (ball grid arrays, chip scale packages, flip chip packages) with Pb-free solder sphere alloys should not be reflowed using a tin/lead reflow profile due to the resulting non-uniform solder joint microstructure and potential poor board surface finish wetting interactions.

  - Recommendation: Additional investigation should be conducted with immersion tin, immersion silver, and organic solderability preservative (OSP) printed wiring board finishes to determine if area array components with Pb-free solder sphere alloys reflowed using a tin/lead reflow profile will result in solder joint integrity degradation

- Raytheon's Pro-Active Approach in Addressing the Challenges Associated with Lead-Free Technologies in COTS Equipment – A. Rafanelli, Raytheon

  - A description of Raytheon's Commercialization Team was provided. Original team was comprised of working groups when legacy companies RES, HAC, TI Defense Systems, and E-Systems completed their merger in January of 1998. The team has transformed into one working group addressing key industry-level component issues regarding lead-free.

  - Commercialization Team's Lead Free Soldering Task Force's charter is to oversee all company activities in lead-free technology risk identification and mitigation.

  - Key data now being acquired to characterize lead-free behavior including:

    - Constitutive relationships

    - Parameter effects during environmental test

    - Understanding intermetallic conditions

  - Raytheon Enterprise Core Tin Whisker Teams significant accomplishments include:

    - Tin Whisker Mitigation Policy

    - Integrated Defense Systems (IDS) Design Guidelines for Metal Whisker Risk Mitigation

    - Material Quality Directive for supplier management

    - Tin control Engineering Directives

- Research on Risk Assessment, Mitigation, and Management for and Management for Pb-free Electronics – M. Osterman, CALCE
  - A summary of CALCE research activities in Lead Free Soldering was provided. This included a Lead Free Roadmap of the various tests being performed. Research on Tin whisker mitigation and elimination is being performed.
  - Significant accomplishments with Raytheon and the CALCE Tin Whiskers Industry Working Group include:
    - Generation of tin whiskers experiences and case studies paper
    - Generation of a mitigation guide
    - Compilation of supplier data, based on supplier surveys, on actions being taken by suppliers on lead-free compatible finishes
    - Tin Whisker Application Specific Risk Assessment Algorithm, care of D. Pinsky, Raytheon – Andover.
    - Program to commercialize whisker mitigation processes
    - Draft report on tin whisker testing
- SnPb Solder Analysis by X-ray Fluorescence Spectroscopy – G. Efronson, Fischer Technologies
  - XRF Spectroscopy is a non-destructive quick test to determine component finishes. It requires no sample preparation, minimum time (30-60 s).
  - It's scanning capabilities can determine RoHS compliance to the following levels:
    - Pb, Hg, Br <10ppm
    - Cd, Cr < 20 ppm
  - Fischer Technologies demonstrated X-ray Fluorescence (XRF) Spectroscopy at ACI's Demonstration Factory.

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Discussion: Identify areas of concern that requires additional research and development – **What Do We Need To Know?**

- AIA-AMC-GEIA Lead-free Electronics in Aerospace Project – A. Touw, Boeing

  - Established in 2004 as AIA Lead-free Aerospace Electronics Working Group, it includes all stakeholders (market segments, supply chain, geographic regions). The team addresses issues that are unique to aerospace and military, and within control of aerospace and military.

  - Purpose: To develop and implement actionable deliverable items that will enable the aerospace industry to accommodate the global transition to lead-free electronics.

  - The team is developing a series of guidelines to support Lead Free Soldering:

    - GEIA-STD-0005-1, Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder

    - GEIA-STD-0005-2, Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems

    - GEIA-HB-0005-1, Program Manager's Handbook

    - GEIA-HB-0005-2, Technical Guidelines for Using Lead-free Solder in Aerospace Applications

Document Number	Title	Task Leader	GEIA Document	IEC Document
GEIA-HB-0005-1	Program Management/ Systems Engineering Management Guidelines for Managing the Transition to Lead-free Electronics	Pat Amick (Boeing)	30 June 2006	30 June 2007
GEIA-HB-0005-2	Technical Guidelines for Aerospace Electronic Systems Containing Lead-free Solder	Stephan Meschter (BAE)	30 June 2006	30 June 2007
GEIA-STD-0005-1	Performance Standard for Aerospace and Military Electronic Systems Containing Lead-free Solder	Lloyd Condra (Boeing)	30 June 2006	31 Dec. 2006
GEIA-STD-0005-2	Standard for Mitigating the Deleterious Effects of Tin in High-Reliability Electronic Systems	Anduin Touw (Boeing)	31 Dec. 2005	31 Dec. 2006

AIA-AMC-GEIA Lead-free Electronics in Aerospace Project Schedule

- Configuration Management and Logistics Impact due to Lead Free Soldering – K. Brockel, SOLE
  - A briefing on the International Society of Logistics (SOLE) was presented. A definition of Configuration Management was provided.
  - Lead Free Soldering Configuration Management issues were identified as the following:
    - Cost impact to project throughout the life cycle
    - Impact to common components across many systems
    - Reliability/Durability for difficult environments
    - Certification/Airworthiness
    - Repairs at depot and intermediate support
  - Industry a key driver to best answer to solve configuration management concerns provided that Lead Free soldering does not adversely impact Reliability, Maintainability & Supportability (RMS) metrics of systems.
  - SOLE invites all Lead Free participants to present papers, articles, and presentation to its various forums and journals.
- Air Force Program Status on Lead Free Solder- T. Kalt, USAF
  - Aeronautical Systems Center (ASC), located at Wright-Patterson AFB, Ohio, is responsible for development and acquisition for Air Force Weapon Systems. It was recently reorganized from System (SPOs) to Wing/Group/Squadrons.
  - Risks to Air Force Programs include:
    - Lead Free Soldered parts “showing up” in new developments and new modifications
    - Repair of “known and unknown” LFS parts

- Lead Free Soldering information is slowly being provided to chief engineers within the ASC hierarchy. The recent Airworthiness Advisory from ASC/EN documents:
  - Lead-free solder considered a flight safety issue
  - Move to Pb-free can create manufacturing and operational complications
  - Mention of Joint Council on Aging Aircraft project
  - Depot Repair risks remains a concern

- Impact of Lead Free Solders (LFSs) on Standard Electronic Parts in the DoD Standardization Program – D. Moore, Defense Supply Center
  - Existing specifications on low voltage, small geometry parts primarily tin lead solder formulations
  - NSA, Air Force Space & Missile Center, & others petitioned DESC (Defense Electronics Supply Center) in early 1990s to prohibit the use of pure tin plating, citing the risks caused by tin whiskers.
    - Requires lead alloys between 2 to 3% minimum if tin was used.

- SAC alloys if determined effective for high reliability military & aerospace applications, will
- drive a new set of standard parts with new part numbers.

- Many specs that previously prohibited pure tin and left the solder alloy to the manufacturer will have to redefine existing part numbers as tin lead formulations

- Configuration control of new Lead Free Solders is essential. New part numbers for Lead Free hardware must be generated to differentiate from SnPb hardware. Must avoid mixing existing stock of tin lead finishes with new Lead Free Soldered hardware in inventory

- US Army AMRDEC Lead Free Soldering Position – J. Jarvis, AMRDEC
  - Part Finishes Concerns:
    - Pure tin usage increasing, which will require supply chain management improvements.
    - Pb-free alternatives generally provide good solderability however there are concerns over tin whiskers, gold embrittlement, and immersion silver poor shelf life.

- Solder Joint Concerns:
    - Lead Free Solder Joint Reliability
    - Lead Contamination
    - Incompatible reflow temperatures for "mixed" assemblies
- Depots will continue to use Tin Lead (SnPb) solders. Depots to be warned not to use hardware finished with pure tin and bismuth. AMRDEC has concluded that there is low risk in repairing a Pb-free assembly with Tin Lead (SnPb).

- Lead Free Solder and Tin Whisker Situation Summary – D. Kayser c/o L. Whiteman, ACI
    - The directives that initiated the transition do not apply directly to aerospace, but we will have to accommodate lead-free technology. The execution of the transition is being driven from the bottom up in the electronics supply chain, and it is happening now. The greater electronics industry technology base is being developed generally without regard for high reliability, long life applications.
    - There is no direct replacement for Tin Lead (SnPb) solder.
    - Parts procurement is a major concern
        - Industry & DESC (DLA) procure parts from distributors
        - Distributors do not segregate parts and mixed date codes will be used to fill orders
        - Component Manufacturers do not provide what the component lead finish is
        - Mixed lead finishes throughout the supply system
        - Impact to rework processes and solder joint reliability
    - Action Plan: Establish interim Lead Free Soldering guidelines
        - Program Teams need awareness & guidance now. Waiting for resolution of all the issues would be detrimental
        - Include Pb-free items as part of SETR checklist
        - Consult with various Lead Free Soldering industry teams and consortiums concentrating on military and aerospace applications.

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Discussion: Establish a strategy on how to implement Lead Free Soldering in the military and aerospace electronics community – **How Do We Get There?**

- J. Kane, BAE Systems, led the discussion to list the following areas for investigation:

Lead Free Soldering	**Lead Free Soldering Parts / Components**
Soldering Processes – Hand Soldering – Wave Soldering – Reflow Soldering – Rework & Repair – Inspection	Pure Tin Component Finish Analysis – Is there an accurate Tin Whisker Risk Model? – When is re-finishing of leads necessary? – Is re-finishing sufficiently effective? – What is the solder dip process to re-finish parts? – How high up the lead must we dip? – Susceptibility for fine pitch (< 25 mil)? – Effects on discrete components? – How do we re-finish chip components?
Processing Temperatures / Heat – Effects on component mechanical reliability? – Effects on component electrical reliability? – Effects on board reliability? – Long term hardware reliability issues? – Effects on board feature reliability? o Microvias? o Pads? o Conductor runs? o Solder masks? – Lead Free grain coarsening effects?	Tin Bismuth Component Finishes – Effective Tin Whiskers mitigation tool? – Does 2-3% Bi effectively prevent whiskers? – Can 2-3% Bi finish be soldered with SnPb solder? – Can we re-finish / re-dip component leads? – If Bi must be removed, is hot solder dip effective? – Does re-finishing / re-dip work? – How compatible it is with SnPb solder?
Solder Joint Reliability – Dwell time effects in thermal cycling? – What dwells are required to model Class 3 service? Aircraft? Automotive? Space? – Mixed alloys effects in solder joints? – Pb Contamination effects? – Lead Free intermetallic growth?	SnAgCu (SAC) Component Finishes – Effective Tin Whiskers mitigation tool? – How compatible it is with SnPb solders? – Does dipping in SAC effectively prevent whiskers? – Will there be a price increase for SAC finishes? – Will SAC finishes be available for use?
	BGA Packaging – What is the risk that lead-free BGA's could be delivered by mistake? – Is there a compromise reflow profile (warmer than for eutectic SnPb) that will ensure reliable solder connections with lead-free BGA's? – Is lot testing by XRF advisable? – Is re-balling BGA's effective? – How robust is the process?

- A. Touw, Boeing, led a discussion to list the following areas of concern:
  - Do Lead Free component finishes prevent tin whiskers?
  - What Lead Free component finishes prevent tin whiskers?
  - Reliability Modeling with Lead Free solders
    - Are longer dwell times required in the model to support creep differences between SnPb and Lead Free solders?
    - Can we model Lead Free solder joints accurately?
  - What are the effects of mixing SnPb and Lead Free soldering materials?

	SnPb Processes	**Lead Free Processes**
Production	SnPb Solder SnPb Finished Boards SnPb Finished Components	Lead Free Solder Lead Free Finished Boards Lead Free Finished Components
Transition Period and Program Sustainment	SnPb Solder SnPb Finished Boards Lead Free Finished Components	Lead Free Solder SnPb Finished Boards Lead Free Finished Components
	SnPb Solder Lead Free Finished Boards SnPb Finished Components	Lead Free Solder Lead Free Finished Boards SnPb Finished Components
	SnPb Solder Lead Free Finished Boards Lead Free Finished Components	Lead Free Solder SnPb Finished Boards SnPb Finished Components

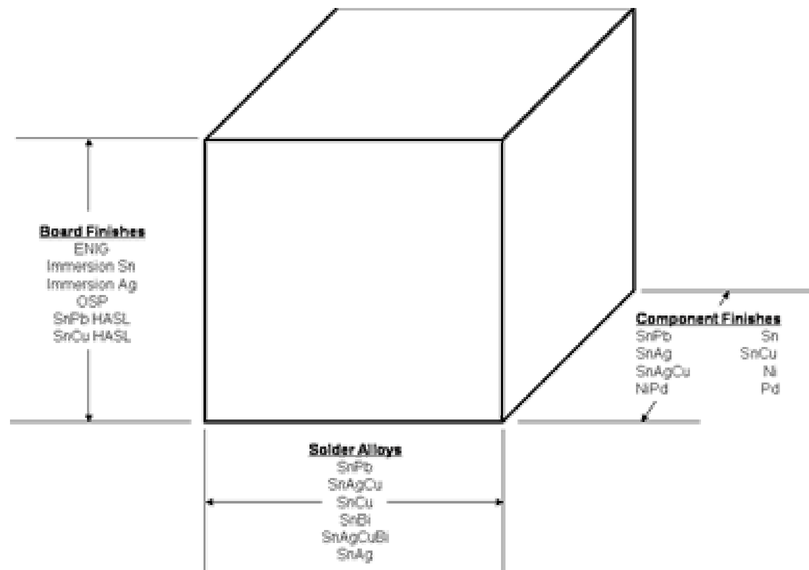

Illustration which defines the potential quantity of SnPb and Lead Free combinations

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NOTE: IPC and iNEMI have recommended that SnAgCu (SAC-305) and SnCu(Ni) be used as a Lead Free Soldering replacement for SnPb.

IPC released the study: SPVC2005-CD - Round Robin Testing and Analysis of Lead Free Solder Pastes with Alloys of Tin, Silver and Copper.

- Communication must improve within industry, government, DoD, NASA

Thursday - July -14, 2005: Lead Free Soldering Summit Conclusions

1. Needs to be better communication up and down management chains within industry, government, DoD, NASA.

2. Technical data gaps do exist. Lead Free soldering and Lead Free components / parts issues are interrelated and are not mutually exclusive.

3. Technical data gaps impact other program activities:

   - Procurement / Acquisition

   - Contracting

   - Configuration Management

4. Benefits exist for future military and aerospace meetings/forums. This will provide attendees with a better idea of timing, nature, and extent of WEEE/ROHS impact.

   - Another Lead Free Soldering Summit is highly recommended, to be held before July 1, 2006 RoHS implementation date.

     Lead Free Soldering Summit II tentative scheduled for February, 2006, at the IPC APEX Conference, Anaheim, California. D. Hillman, Rockwell Collins, will investigate having the summit at the IPC APEX Conference. A. Touw, Boeing, will investigate having the summit at Boeing in Anaheim as an alternate summit site.

   - JCAA / JG-PP Lead Free Soldering Program are scheduled to be making presentations at the following conferences:

     - SMTA International Conference, September 29; Chicago, Illinois

     - IPC APEX Conference, February 8 – February 10; Anaheim, California

Reliability test data from the JG-PP / JCAA Lead Free Soldering Program will be available at the IPC APEX Conference.

- Lead Free Manufacturing for Navy Systems Program scheduled to have their Lead Free production and rework runs completed by the IPC APEX Conference. Program status could be provided to the summit attendees.

- AIA LEAP Program will be having their next program meeting on October 10 and October 11, 2005 at Raytheon Integrated Defense Systems Naval Integration Center (NIC) in Portsmouth, Rhode Island.

5. JCAA/JGPP Lead Free Soldering Program developing the following actions:

- Draft and distribute for comment a Strategic Plan for supporting Lead Free Soldering research and development for military and aerospace applications. The plan will include:
  - What activities are being performed by other organizations and consortiums?
  - What technical data gaps exist and plans to resolve them?
  - Internal/team communications and external communications

- Near-term: Prepare a proposal to cover data gaps from JCAA/JGPP LFS
  - Do Lead Free component finishes prevent whiskers? What Lead Free component finishes prevent whiskers?
  - What are the affects of long dwells with Lead Free Solders? Will we be able to model?
  - What are the affects of mixing SnPb and Lead Free materials?

- Explore funding (FY 06 developmental + FY 07 "testing"), either direct or in-kind, relative to the above proposal as well as upcoming Summit

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