Training Course

Lead Free Electronics Impact on DoD Programs

DMSMS Conference 2007
Orlando, FL
29 October 2007

Agenda

1. **Lead Free Transition and Impacts**
2. Lead Free Failure Modes
3. A Comprehensive Lead Free Strategy
4. GEIA Lead Free Standards and Handbooks
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 “Tin Whisker Document
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. Summary
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

Background

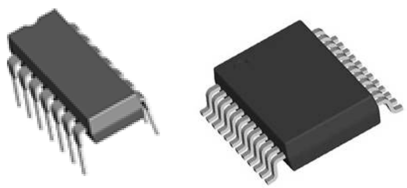
There is a global transition to lead-free

- **Reduction of Hazardous Substances (RoHS)**
  - EU Directive banning “placing on market” new electronic equipment containing specific levels of the following after July 1, 2006
    - **Lead**, Cadmium, Mercury, hexavalent chromium, polybrominated biphenyl (PBB), polybrominated diphenyl ether (PBDE) flame retardants
- **Waste Electrical and Electronic Equipment Directive (WEEE)**
  - EU directive aims to minimize the impact of electronic waste
  - Encourages and sets criteria for collection, treatment, recycling
  - Makes the *producer responsible*
- Related legislation in place or underway in China, Japan, Korea, California, and EU

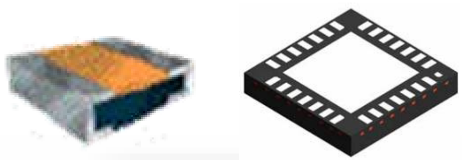
Lead-free brings new and re-emerging failure modes in electronics

How Products are Affected

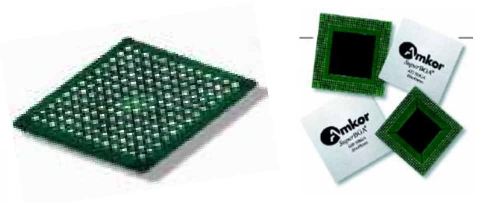
Leadframe Finish



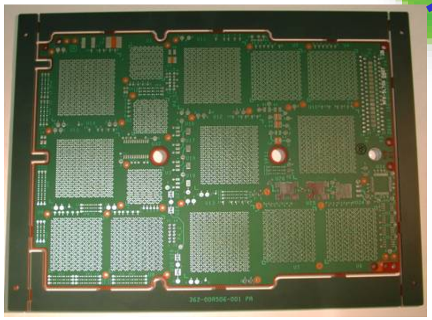
Leadless Termination Finish



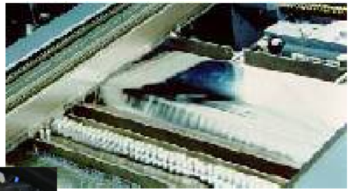
BGA Solder Balls



Common lead-free finishes on current products: matte tin, NiPdAu, SnAgCu



Today: **Tin-lead HASL**
Tin-lead plate and fused



Wave

Paste

Today: SnPb solders

Wire

Also: connector, lugs, cardguides, packages, lids, etc.

Why are Lead-Free Electronics a problem?

- DoD (and Aerospace/High Performance) systems have unique requirements:
  - High reliability and critical systems
  - VERY long service life
  - Extended temperature ranges
  - Repairable systems
- DoD acquisition programs are increasingly dependent on ***commercial*** electronic parts and assemblies (COTS)

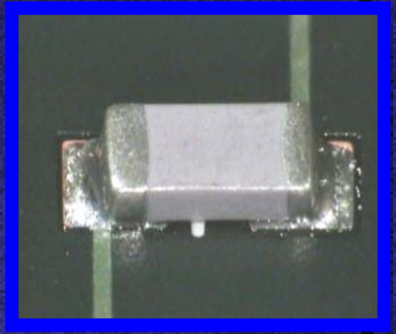
Lead-free Impacts on DoD

- Primary lead-free impacts
  - Lead-free solder issues
  - Tin whisker failures
  - Availability of leaded solder and components
  - Configuration control
  - Repair/Rework

Commercial solution strategies for lead-free may not apply to Military / Aerospace applications

Lead-free Solder Issues

- **Manufacturing**
  - Prevailing Pb-free solder replacement (SnAgCu) has ~***35°C higher*** reflow temperature
  - Can affect components and board material
  - Infant mortality / Latent failures
  - Requalification?



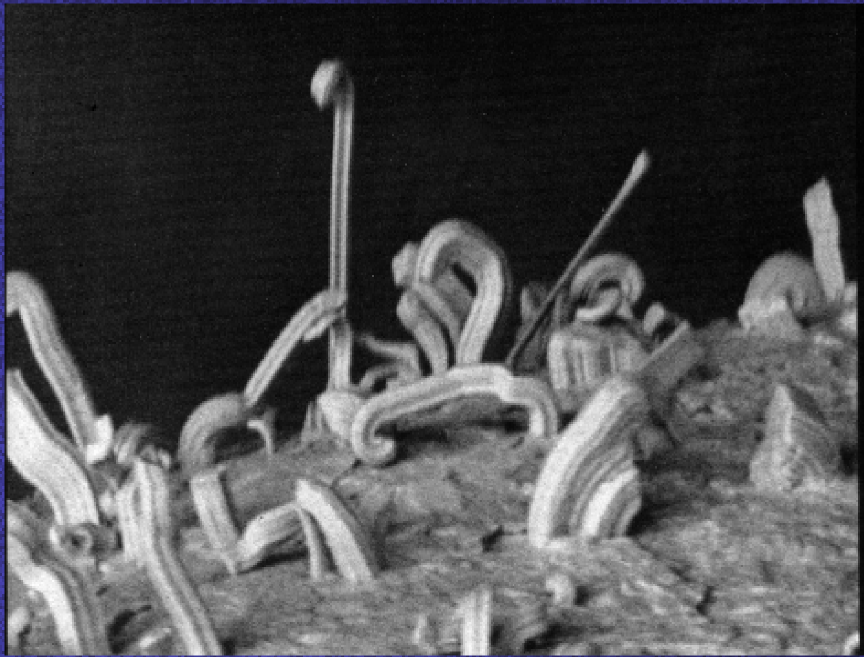
- **Solder joint reliability (durability)**
  - Pb-free alloys can fail in high stress/strain applications
  - Intermetallics between solder and lead/pad
  - Cross contamination of different alloys
  - Changed / unacceptable wetting characteristics
  - New qualification parameters

Cracked Solder Joint

- **Configuration control**
  - Must prevent mixing of incompatible alloys
  - Many components not uniquely identified
  - Repair/Rework

Tin Whisker Impacts

- **Tin whisker effects documented since the 1940's**



(Photo courtesy of NASA Goddard Space Flight Center)

- **Tin Whiskers**
  - "grow" from nearly all tin alloys
    - pure Sn (<3% Pb)
    - SnBi, SnCu, SnAgCu
    - Few microns to over 10 mm
  - Electrically conductive
  - Crystalline
- **Whisker induced failures:**
  - *Short Circuit* – bridges two adjacent pins
  - *Metal vapor arc* – high voltage and specific atmosphere can result in plasma arc capable of catastrophic damage
  - *Contamination* – whisker breaks off and interferes with mechanical, optical, or MEMS component

Lead Free Impacts

- Reduced availability of items with preferred finish and solder
  - DMSMS
  - Higher costs
  - Longer procurement cycle
  - Capacity limitations
- Configuration Management issues
  - Some component manufacturers changing lead finish without changing part number (potential for mixed stock)
- Repair/Rework
  - Cannot mix alloys on some components (e.g. BGAs)

DoD acquisition programs are increasingly dependent on ***commercial*** electronic parts and assemblies (COTS)

Lead Free Transition and Impacts

Restriction on Hazardous Substances (RoHS) is considered "… the most far reaching piece of legislation ever to impact the electronics industry."

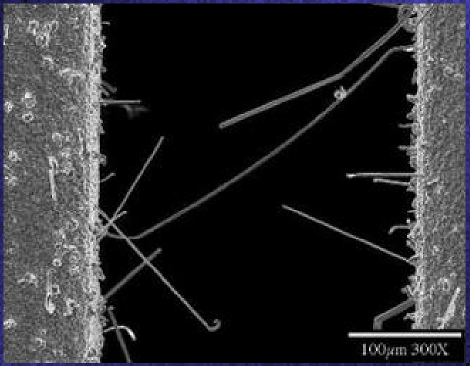
Celestica; Janes Defense Weekly, 8-24-2005

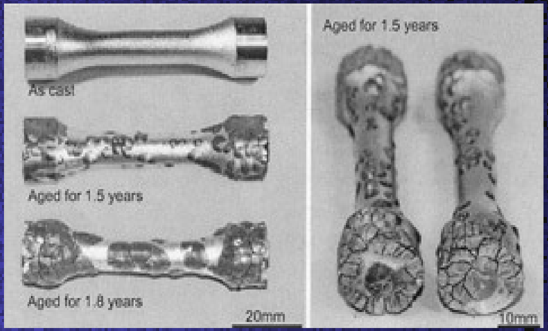
Agenda

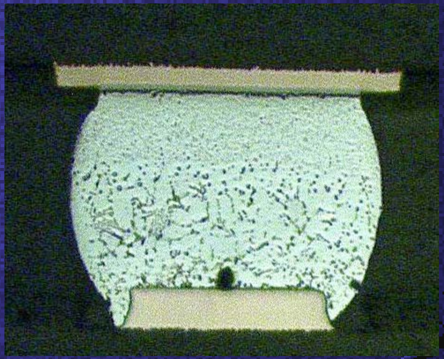
1. Lead Free Transition and Impacts
2. **Lead Free Failure Modes**
3. A Comprehensive Lead Free Strategy
4. GEIA Lead Free Standards and Handbooks
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 "Tin Whisker Document"
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. Summary
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

Lead-Free Electronics Failures

- **Tin Whiskers**
  - Shorts
  - Few microns to over 10mm length
  - Arcs at high voltage
- **Tin Plague**
  - Metal disintegrates into powder (allotropic phase change)
- **Soldering**
  - 35 C increase in processing temperatures
  - Pb-free solders require new process
  - May require new assembly equipment & circuit board laminates
  - Copper dissolution may limit the number of possible rework actions
- **Solder Reliability**
  - Less robust in severe environments
  - Incompatibility between some solders and finishes
  - No valid models for solder life





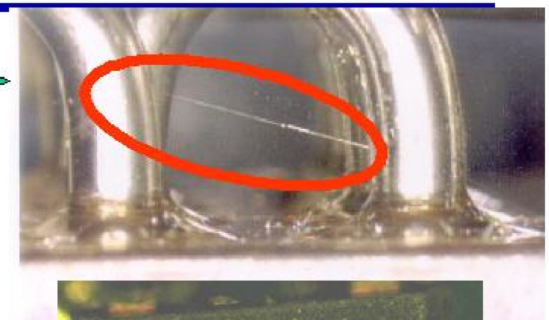


Represents a large potential cost and reliability impact

Tin Whiskers

Whisker Failure Modes

Electrical Short Circuits



- Permanent (if current < 10's of mA)
- Intermittent (if current > 10's of mA) *Whisker Melts*

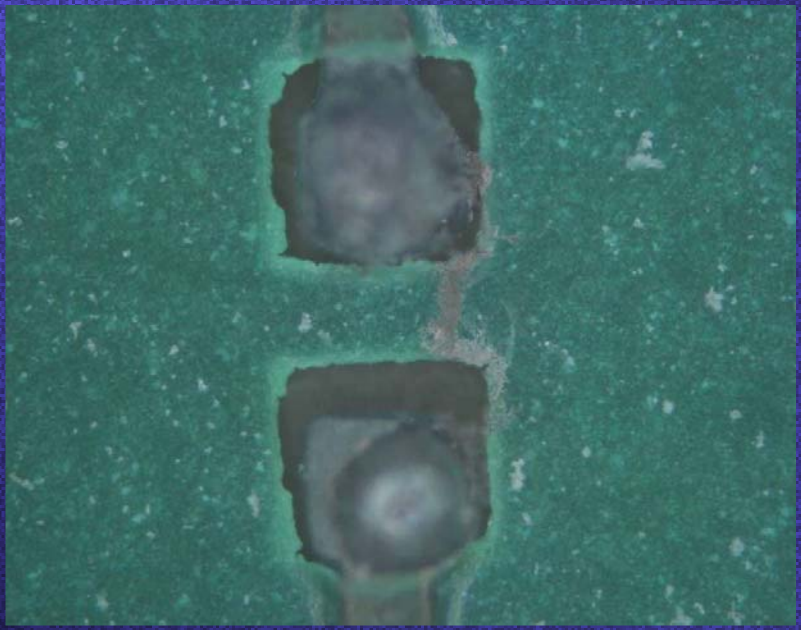
Debris/Contamination

- Interfere with Sensitive Optics or MEMS
- Shorts in Areas REMOTE From Whisker Origins
  (Zinc Whiskers on raised flooring are a PRIME Example)

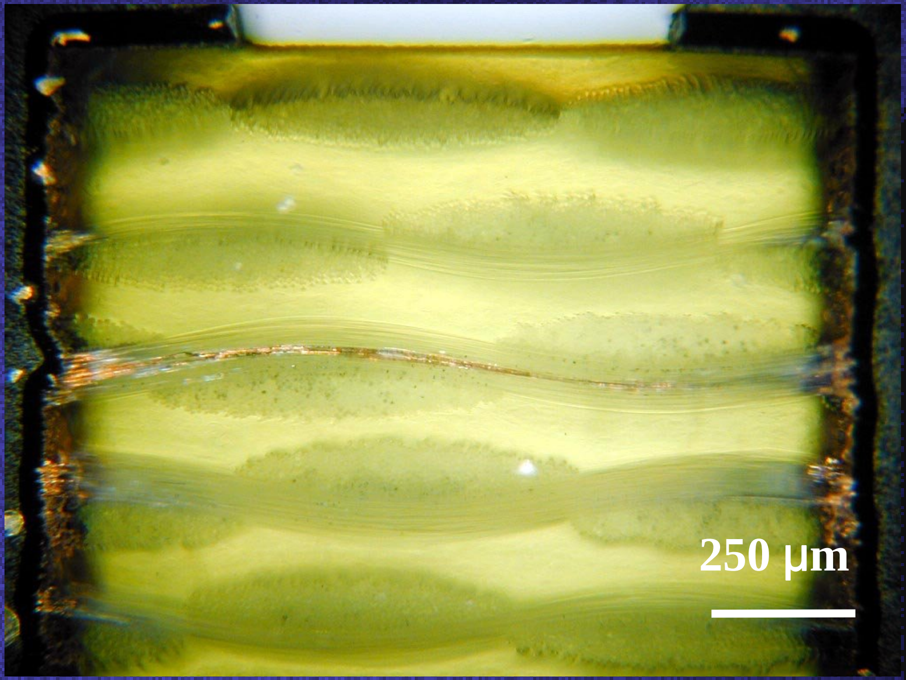
METAL VAPOR ARC

- Under Some Electrical/Atmospheric Conditions, Whisker Shorts May Vaporize into Conductive PLASMA of Metal Ions
- Plasma Forms Arc Capable of Carrying ***HUNDREDS OF AMPS! With Resulting CATASTROPHIC DAMAGE***

Electrochemical Migration



New fluxes, availability of silver, and higher reflow temperatures may increase surface resistance risk. Sn-3.5Ag Solder on Polyimide Substrate with Immersion Sn Plating



Conductive filament formation within the printed wiring board. Higher reflow temperature puts higher stress on printed wiring board and increases CFF risk.

Lead-Free Electronics Satellite Failures

On-Orbit COMMERCIAL (non-NASA) Satellite Failures

The following commercial (non-NASA) satellites have reportedly suffered on-orbit failures of their satellite control processors due to tin whisker induced short circuits where the whiskers grew on pure tin plated electromagnetic relays

Name	Launch Date	First Satellite Control Processor Failure	Redundant Satellite Control Processor Failure
Complete Losses			
GALAXY VII [PanAmSat]	27 October 1992	13 June 1998	22 November 2000
GALAXY IV [PanAmSat]	24 June 1993	(not caused by 'tin whiskers')	19 May 1998
SOLIDARIDAD 1 [SatMex]	19 November 1993	28 April 1999	27 August 2000
GALAXY IIIR [PanAmSat]	15 December 1995	21 April 2001	15 January 2006
Partial Losses			
OPTUS B1	13 August 1992	21 May 2005	Still Operational
DBS-1 [DirecTV]	17 December 1993	4 July 1998	Still Operational
PAS-4 [PanAmSat]	3 August 1995	3rd quarter 1998	Still Operational
DirecTV 3 (DirecTV)	9 June 1995	4 May 2002	Still Operational

Military Lead Free Electronics Failures

- **Military Airplane:** G. Davy, “Relay Failure Caused By Tin Whiskers", Northrop Grumman Electronic Systems Technical Article, October 2002

- **F-15 Radar:** B. Nordwall, "Air Force Links Radar Problems to Growth of Tin Whiskers", Aviation Week and Space Technology, June, 20, 1986, pp. 65-70

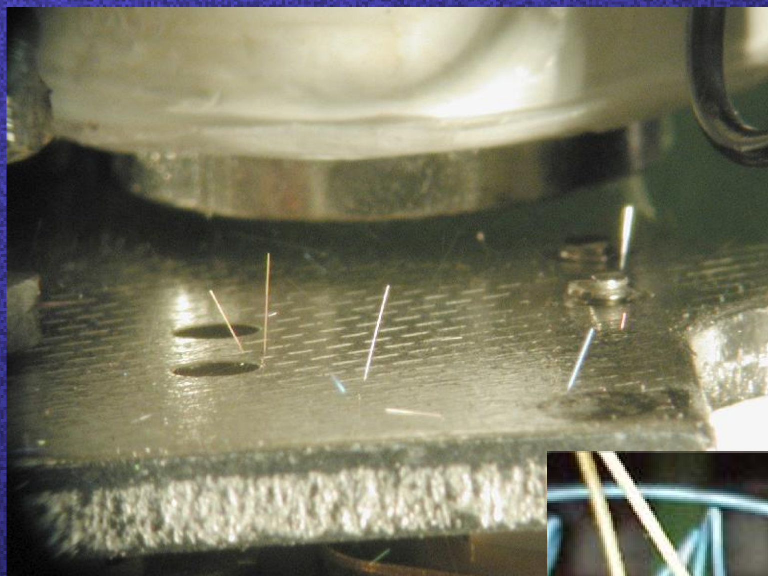
- **U.S. Missile Program:** J. Richardson, and B. Lasley, "Tin Whisker Initiated Vacuum Metal Arcing in Spacecraft Electronics," Proceedings 1992 Government Microcircuit Applications Conference, Vol. XVIII, pp. 119 - 122, November 10 - 12, 1992.

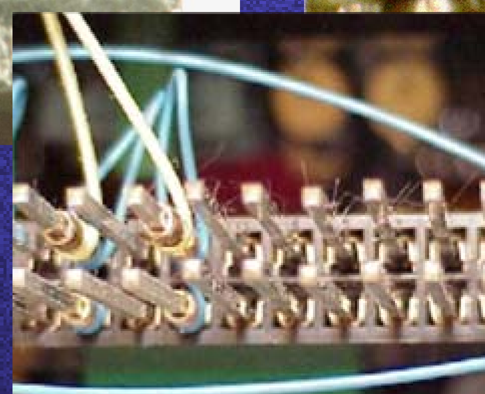
Tin Whiskers and the Space Shuttle

NASA Shuttle Logistics Depot - Tin Whisker Video related to the Space Shuttle, Apr. 2007

Tin Whiskers – They're Back!

Component suppliers are commonly transitioning to pure tin finish
- Pure tin plating is prone to whisker formation





Whiskers are high aspect ratio, essentially perfect single crystals

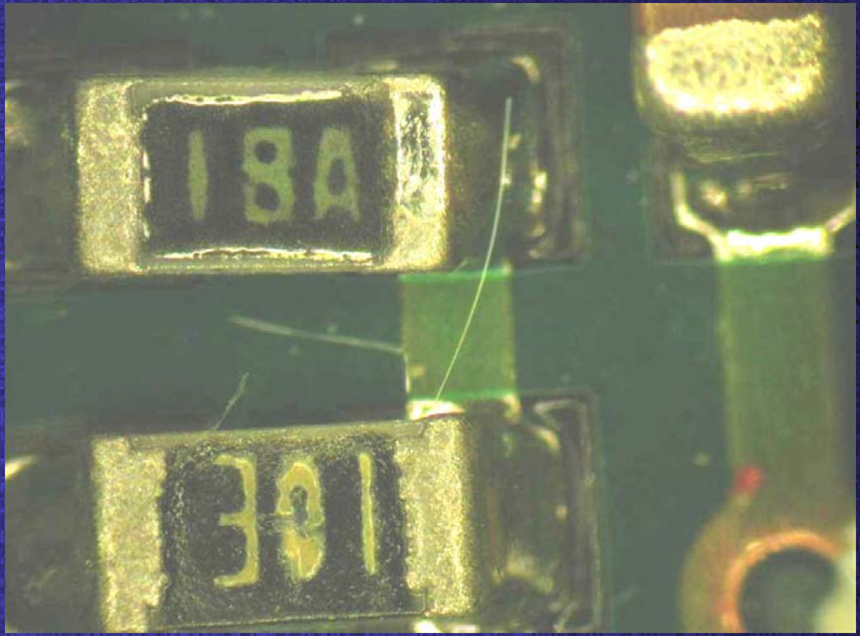
Tin Whiskers are a Documented Cause of Satellite Failures and Air Vehicle Sub-System Malfunctions

Tin Whiskers – They're Back!

Tin Whiskers Inside Ka waveguide

Tin whiskers inside Ka waveguide (Stereo Microscope Image)

Tin Whiskers broken from RF Shield, scattered onto RF circuitry



(Courtesy NASA Goddard Tin Whisker website)

Known Tin Whisker Enablers

- **Compressive stresses in the plated coating from the plating process (current density, chemistry, temperature, agitation, and others)**
- **Intermetallic compound (IMC) formation between the tin and other metals, such as copper, silver and nickel and internal plated deposit compressive stresses resulting from these IMC growths over time**
- **External mechanical stresses applied to the tin, such as torqued screws, scratches and bending**
- **To a degree, the grain structure of the plated tin**

Tin Whisker Mitigation Obstacles

- No Known way to consistently accelerate the whisker phenomenon without changing the growth mechanism of spontaneous whiskers – unlike solder joints

- Long incubation times are common for spontaneous whiskers (Millstone Nuclear Powerplant shutdown in 2005 – whisker shorted relay after 8 years service)

Whisker Short Failed Nuclear Powerplant Relay

- Internally conflicting literature on the subject (excessive mis-information)

Tin Whisker "Inconvenient Truths"

After years of investigation and 1000's of studies:

- **No adequate Pb-free solution has yet been found for preventing Sn-whisker formation.**
  - **— Alloying with Pb unfortunately still remains one of the best mitigation strategies**

- **Some degree of Sn-whisker formation & growth have been found on all reported Sn-mitigation strategies including:**
  - **150°C annealed devices**
  - **Reflowed devices**
  - **Ni underplated device**
  - **Use of "Matte" rather than "Bright" Sn Plating**

Solder Joint Attachment Failures

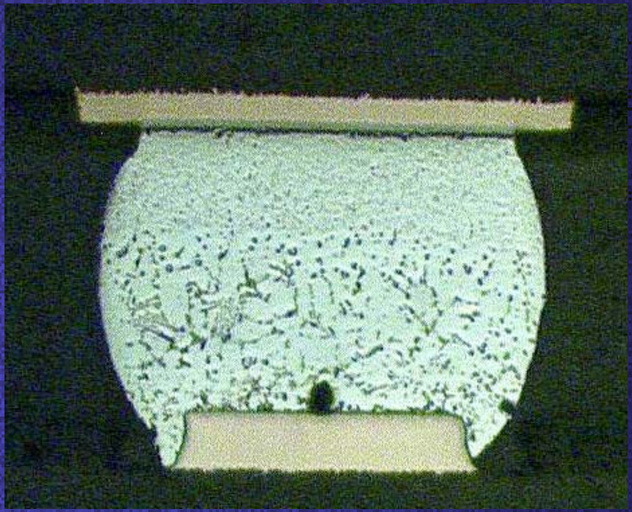
JGPP Lead-Free Solder Tests

Before Thermal Cycle

After Thermal Cycle

JGPP Lead-Free Solder Tests

Lead-Free Ball Grid Array Contact Soldered With Tin-Lead Solder Paste Showing Incomplete Mixing and Poor Long Term Reliability



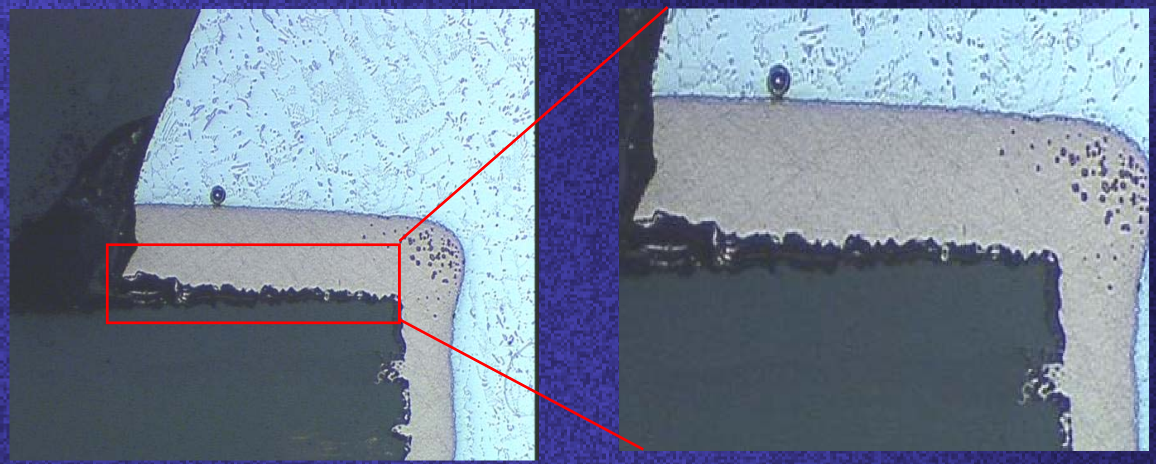
Note: BGA solder joint (left) would pass IPC inspection criteria, but would have reliability issues reflected in cross section (on right)

JGPP Lead-Free Solder Tests

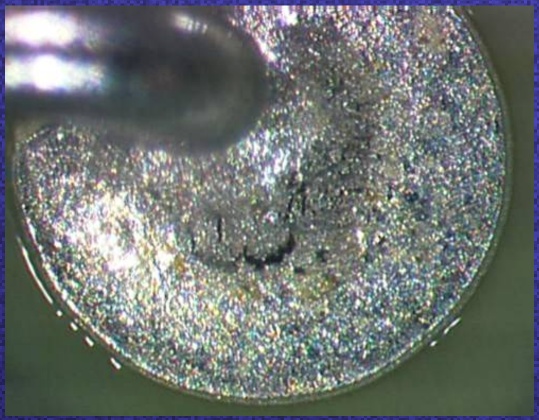
Additional JCAA/JG-PP Results:

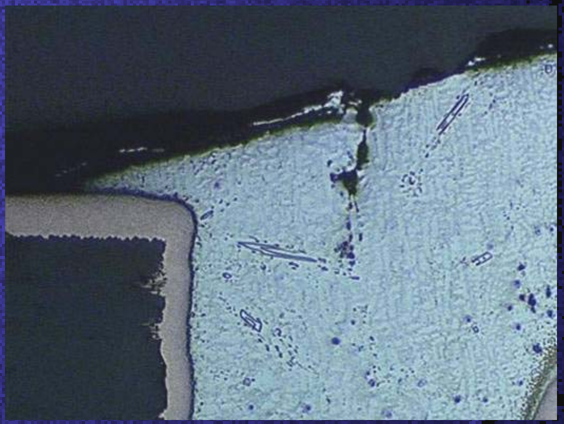
- **JCAA/JGPP Consortia Joint Test Report**
- **(JTP) Contains Final Report and Data**
- **Weblink: http://acqp2.nasa.gov/LFS.htm**
- **NASA Phase II POC**
  - **Kurt Kessel**
  - **Phone: (321) 867-8480**
  - **Email: Kurt.Kessel-1@ksc.nasa.gov**

Lead-Free Manufacturing for Navy Systems



Test Vehicle showing lead-free pad lifting

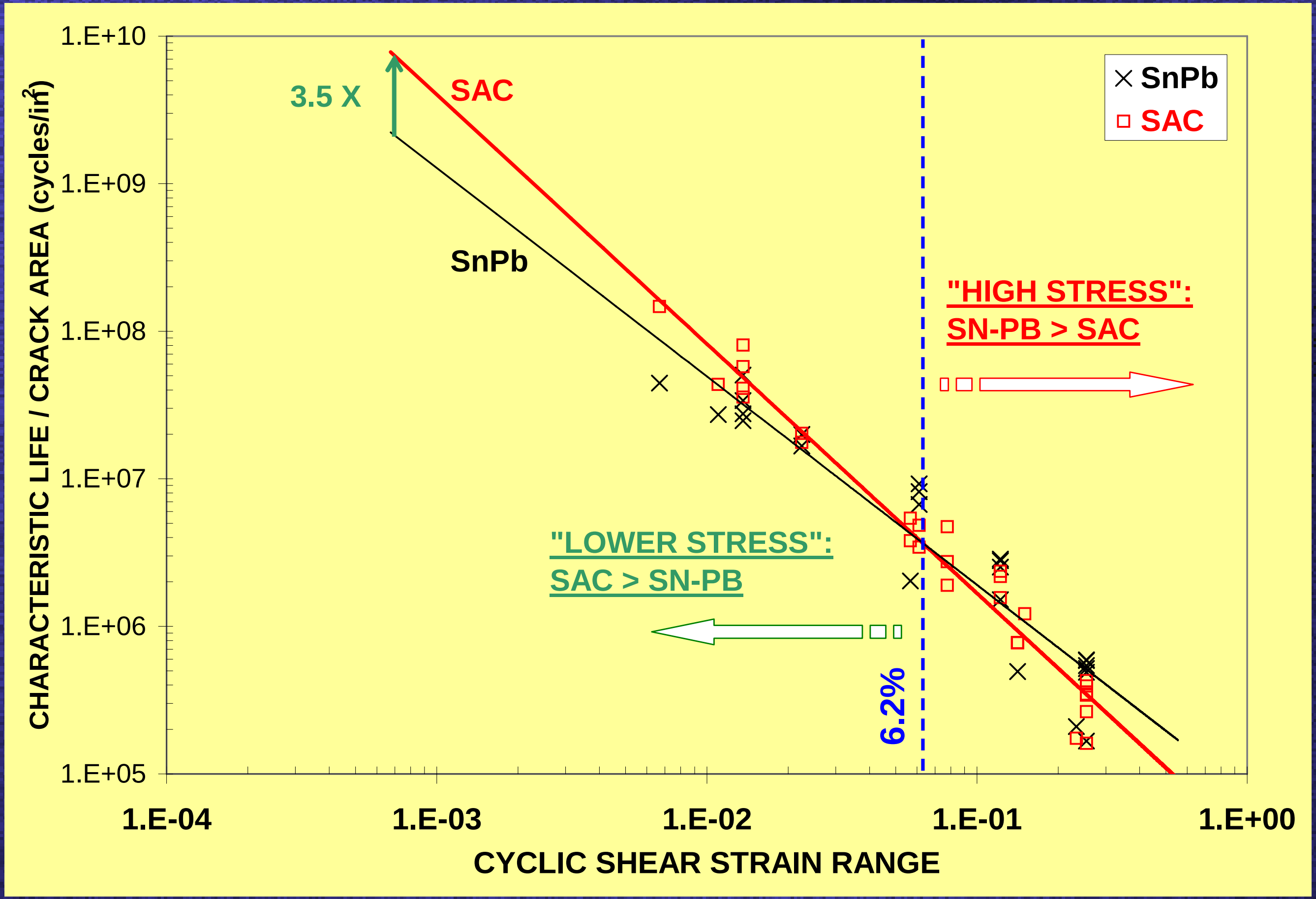




Test Vehicle showing shrinkage void

Lead-Free Manufacturing for Navy Systems

Example – Literature Predicted Trend



Difference in slopes suggests opposite reliability under low and high stress conditions

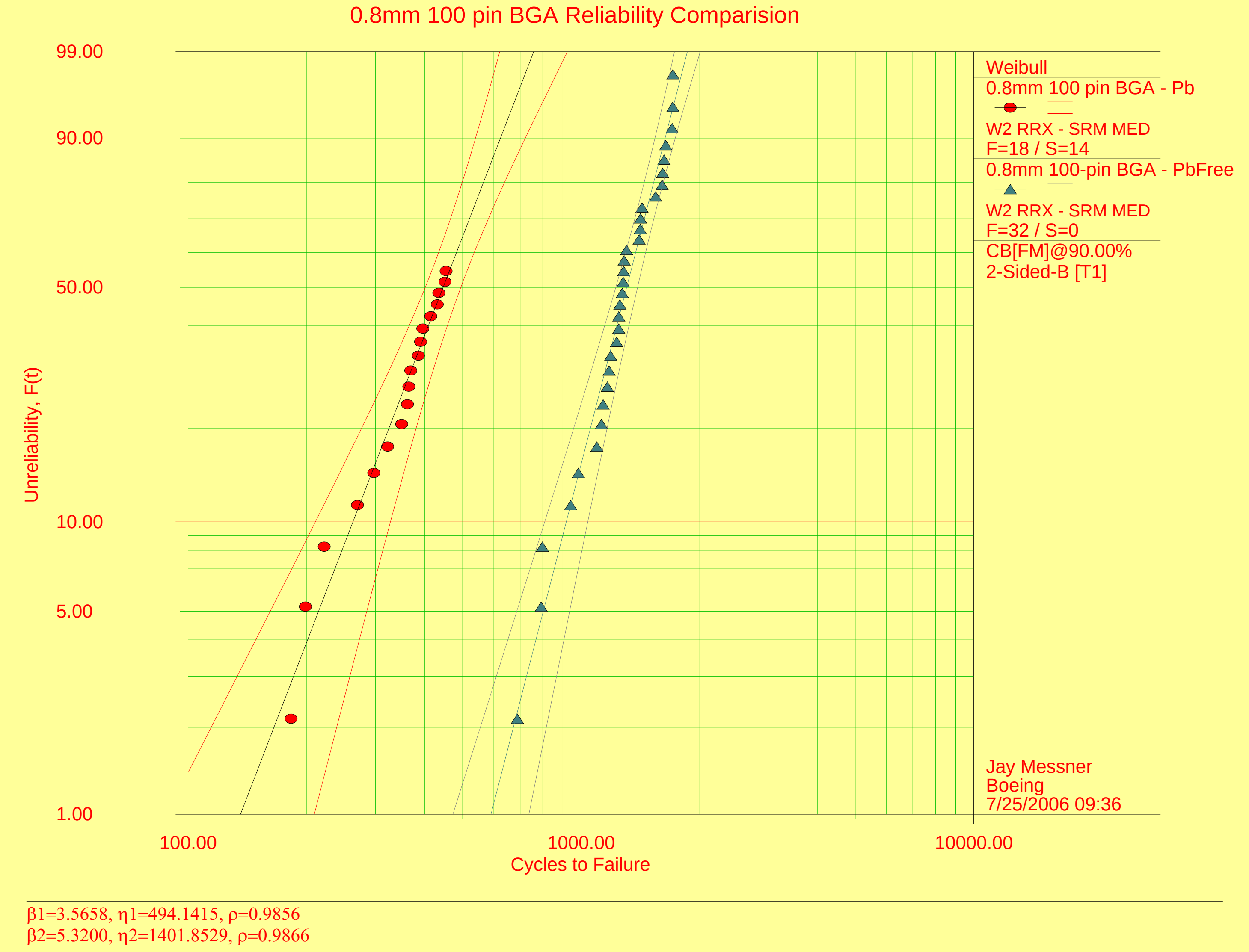
Do not use for life predictions or AF calculations

Dwell time, frequency effects etc… not included

E-mail: jpclech@aol.com, URL: http://jpclech.com Tel.: +1 (973)746-3796

Lead-Free Manufacturing for Navy Systems

ManTech Experience



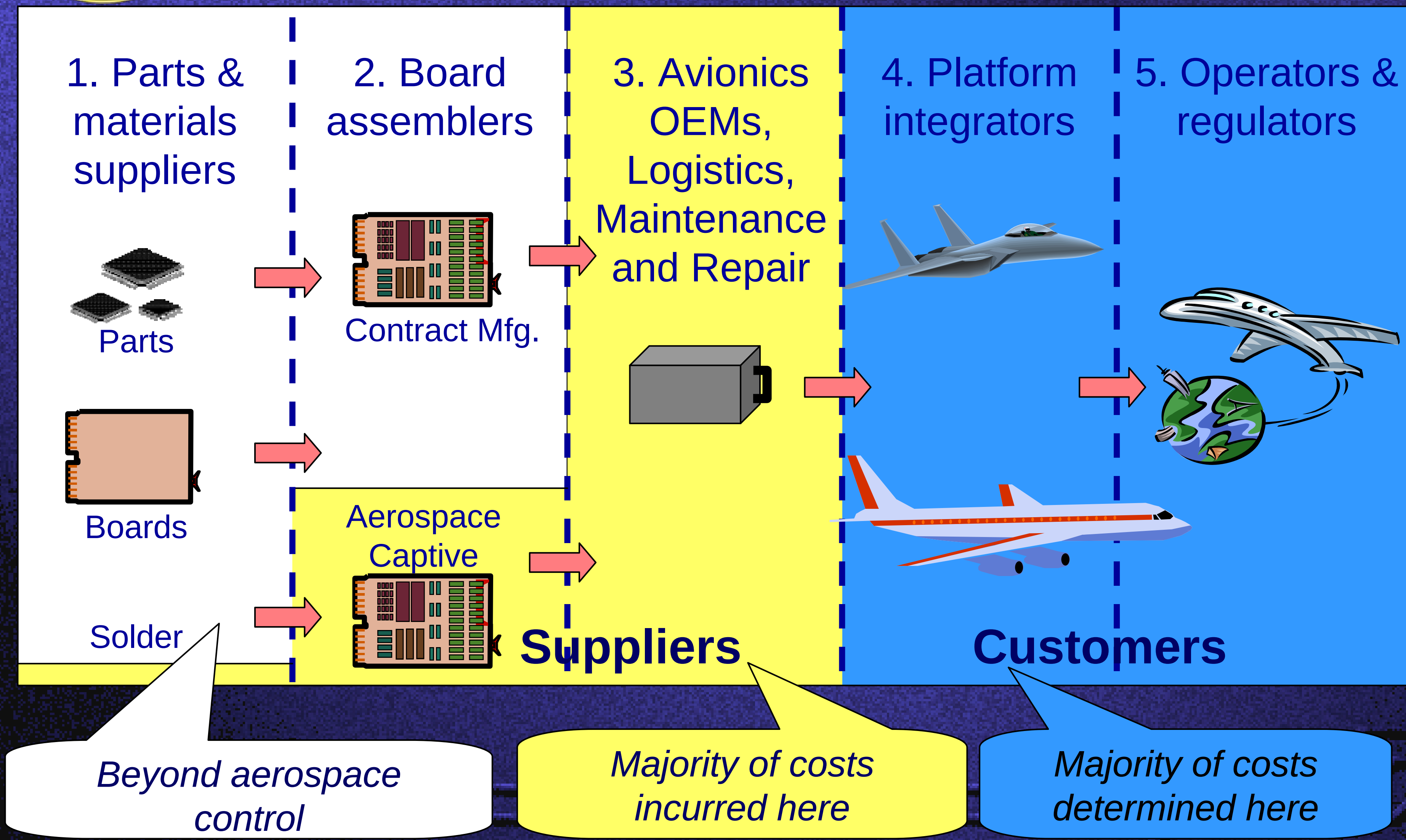
Conclusions

- Four Main Failure Mechanisms
  - Whiskers
  - Solder Joint Reliability
  - Circuit Board
  - Moisture Sensitivity
- Literature Can Be Misleading
  - Whiskers
  - Tin Pest
  - Solder Joint Reliability

Agenda

1. Lead Free Transition and Impacts
2. Lead Free Failure Modes
3. **A Comprehensive Lead Free Strategy**
4. GEIA Lead Free Standards and Handbooks
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 “Tin Whisker Document
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. Summary
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

The Avionics Supply Chain



Effects of the European Directives on the Military/Aerospace Industry

The move towards lead-free electronics is driven by RoHS and WEEE European directives

- **Disruptive** to the aerospace industry
- **Neither drive nor resist it**
- **Must work together** in response to it
- **Must ensure** that our systems are ***Reliable, Repairable, Supportable, Safe, Affordable, Airworthy, Certifiable***

Lead-Free technology can impact any program regardless of whether the program itself is exempt or bound by environmental regulations.

Military & Commercial Aerospace Industries

- **Reality**
  - **Component manufacturers have already switched** and are currently delivering components with lead-free component finishes.
  - **Aerospace suppliers sell** commercially in US and **worldwide**.
  - **Cost prohibitive for suppliers** to put in separate soldering lines.
- **Military and Aerospace will be "swept along" by a supply chain** that is beyond our control

Mil/Aero Lead-Free Efforts

- Military and Aerospace related lead-free efforts
  - DoD Executive Lead Free IPT
  - DoD Lead Free Working Group
  - Government, industry and academic lead-free research efforts
  - LEAP Working Group

The commercial industry has spent millions in development and conversion to lead free
They have not solved all the technical issues

ELF IPT

Executive Lead-Free Integrated Process Team
(ELF IPT)

- Identify DoD specific issues
  - Lead-free roadmap
  - Business case/cost impacts
  - Contract language
  - Gap analysis
- Coordinate service efforts
- Access to Government Policymakers
  - Provide policy guidance to DoD Lead Free WG

Senior Membership from:

Air Force	Army	DLA	DMEA
FAA	NASA	Navy	Industry

DoD Lead Free WG

- Lead Free Working Group
  - Government only
- Created to address Policy and Funding issues for lead-free
- Draft LF Policy developed with input from ELFIPT and LFWG members
- Formal Charter and Policy in coordination
- Expect DoD lead-free policy issued at Undersecretary of Defense level

Mil / Aero Lead-free Efforts

- University of Maryland - CALCE
  - Computer Aided Life Cycle Engineering (CALCE) Electronic Products and Systems Center (EPSC)
  - Several “science projects” and tools related to lead-free and tin whisker
- NASA – Goddard Space Flight Center
  - Extensive research and documentation on tin whisker effects
  - Check out the pictures!
- JCAA/JG-PP and NASA Kennedy
  - Lead-Free Solder Testing for High-Reliability Applications
  - Four solders tested in MIL qualification tests
  - Test results published May 2006
- Navy – ONR
  - Office of Naval Research (ONR) - Best Manufacturing Practices Center of Excellence (BMPCOE)
  - Ongoing tin whisker research with Raytheon, CALCE, NASA, Boeing, Honeywell, Northrop Grumman

NASA-DoD Lead-Free Electronics Project

- Multi-year project to address reliability impacts
  - Rework of lead-free alloys
  - Mixing of lead-free and SnPb alloys
  - Several package types (TSOP, BGA, PDIP, etc)
  - Multiple solder alloys (SnPb, SAC305, SN100C)
- Environmental profile (proposed)
  - Thermal cycle -55°C to +125°C
  - Thermal cycle -20°C to +80°C
  - Vibration
  - Combined environments (thermal + vibration)
  - Mechanical shock
  - Drop testing
- Launched November 2006
  - Follow-on to JCAA/JGPP LFS Project

AIA-AMC-GEIA Lead-free Electronics in Aerospace Project Working Group (LEAP WG)

- Formed in 2004 as AIA Lead-free Aerospace Electronics Working Group
- Includes all stakeholders (market segments, supply chain, geographic regions)
- Addresses issues that are:
  - Unique to aerospace and military
  - Within control of aerospace and military

- Currently over 100 corporations plus numerous US and European government agencies and educational institutions actively participate.

AIA = Aerospace Industries Association
GEIA = Government Engineering and Information Technology Association
AMC = Avionics Maintenance Conference

Partial List of LEAP Member and Consulting Organizations (as of Feb 07)

- AAI Corp
- ADS Transicoil
- Aerospace Corp
- Airbus
- Air Canada
- AMETEK Rotron
- Avtech Corp
- Axsys
- BAE Systems
- Barfield
- Boeing Company
- Bombardier Aero
- Celestica
- Cie Barco
- Corfin Industries
- CSP Inc
- Curtiss-Wright
- Delta Airlines
- Diehl Avionik
- DfR Solutions
- DPACI
- EADS
- Eaton Aerospace
- Elbit Systems

- ELDEC
- FEDEX
- Fischer Technology
- Gables Engineering
- Garmin International
- General Dynamics
- Gixel
- Goodrich
- Hamilton-Sunstrand
- Harris Corp
- Hispano-Suiza
- Honeywell
- IBM
- Intel
- Internat Rectifier
- Intersil
- IMEC
- IPC
- ITB, Inc
- ITT
- Jabil Circuit
- Japan Airlines
- Kidde Aerospace
- L-3

- Lansdale Semicon
- LCIE
- Linear Tech Corp
- Lockheed-Martin
- Lufthansa Technik
- Mascorp
- Matsushita Avionic
- MBDA
- Medtronic
- Meehan Electonics
- Microsemi Corp
- MOOG
- National Semicon
- Northrop Grumman
- Orbital Sciences Corp
- ORS Labs
- Panasonic Avionic
- Parker
- Phillips Medical
- Purdue University
- QTEC
- Raytheon
- Rockwell Collins

- Rolls Royce
- Safe Flight Instr
- SBS Technologies
- Six Sigma
- Smiths Aerospace
- Space Dynamics
- Stilwell Baker
- Teldix
- Teledyne Controls
- Terma AS
- Texas Instruments
- Textron
- Thales
- Trimle
- TTI, Inc
- Tyco
- UIC
- United Tech Corp
- Univ of Alabama
- Univ of Maryland
- Univ of Missouri
- Vishay Semicon
- Vibro-Meter
- Wyle Labs

- AIA
- AMC
- American Competitive Institute (ACI)
- ARINC
- BMPCOE
- BSI
- CALCE
- Defense Acq Univ
- DMEA
- DOD (USAF, Navy, Army, Coast Guard)
- Euro Space Agency
- FAA
- GAMA
- GEIA
- IEQC
- NASA
- NIST

AIA-GEIA-AMC Lead-free Electronics in Aerospace Project Working Group

The purpose of LEAP is to develop and implement actionable deliverable items that enable the aerospace industry to accommodate the global use of lead-free electronics. The deliverable items address problems that are unique to, and are within the control of the aerospace industry.

- Goals & Objectives:
  - Enable the aerospace industry, on an ongoing basis, to accommodate the global electronics transition to lead-free electronics
  - Provide a common set of standards to be used by suppliers and customers to address issues related to lead-free electronics ("level playing field")
  - Provide avenues of communication between the aerospace industry and customers
  - Provide avenues of communication within the aerospace industry

Actionable Deliverables

- **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 in Aerospace and High Performance Electronic Systems
- **GEIA-HB-0005-1** Program Management / Systems Engineering Guidelines for Managing the Transition to Lead-free Electronics
- **GEIA-HB-0005-2** Technical Guidelines for Aerospace and High Performance Electronic Systems Containing Lead-free Solder
- **GEIA-STD-0005-3** Performance and Qualification Testing for Aerospace and High Performance Electronics Containing Lead-free Solder
- **GEIA-HB-0005-3** Rework, Repair and Maintainability for Aerospace and High Performance Electronics Containing Lead-free Solder
- **GEIA-HB-0005-4** Reliability Assessment for Aerospace and High Performance Electronics Containing Lead-free Solder
- **New Document** proposed concerning Configuration Control

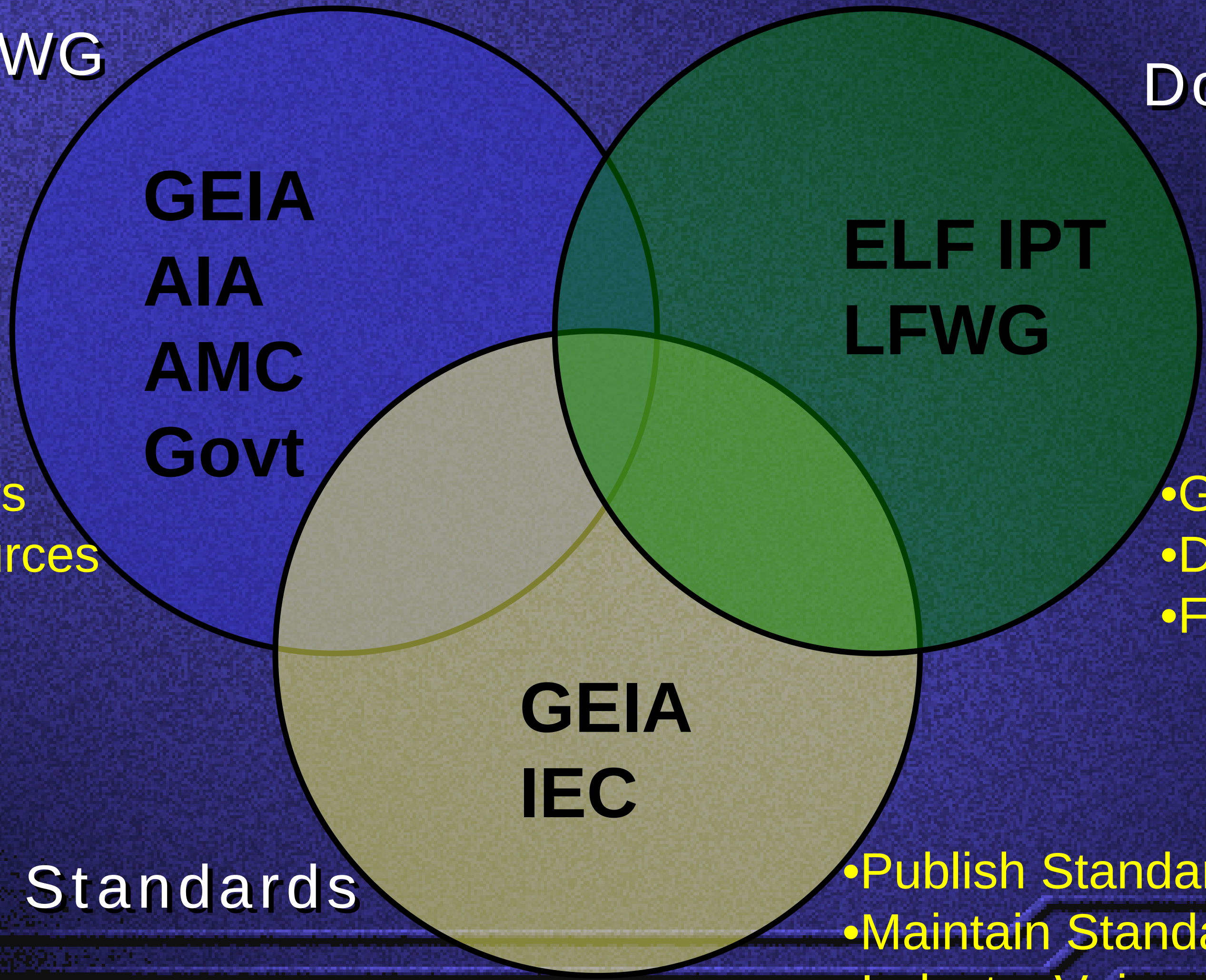
Actionable Deliverables

GEIA-STD-0005-1	Performance Standard	Lloyd Condra, Boeing	Published GEIA 30 June 2006	Submit to IEC 31 March 2007
GEIA-STD-0005-2	Tin Whiskers	Anduin Touw, Boeing	Published GEIA 30 June 2006	Submit to IEC 31 March 2007
GEIA-HB-0005-1	Program Mgmt Guide	Pat Amick, Boeing	Published GEIA 30 June 2006	Submit to IEC 31 March 2007
GEIA-HB-0005-2	Technical Guidelines	Stephan Meschter, BAE	Submitted GEIA 31 Jan 2007	Proposed 30 June 2007
GEIA-STD-0005-3 (in work)	Performance & Qual Testing	Tony Rafanelli, Raytheon	Proposed 30 Jun 2007	Proposed 31 Dec 2007
GEIA-HB-0005-3 (in work)	Rework / Repair	Tim Kalt, USAF	Proposed 30 Sep 2007	Proposed 31 Mar 2008
GEIA-HB-0005-4 (in work)	Reliability Assessment	John Biel, Smiths Aerospace	Proposed 30 Sep 2007	Proposed 31 Mar 2008
New Document	Configuration Control	Dan Korte, Rockwell Collins	New Document	New Document

A Comprehensive Strategy

LEAP-WG

DoD



•Stakeholders
•Tech Resources
•"Experts"

•Gov Access
•DoD Policy
•Funding

Standards

•Publish Standards
•Maintain Standards
•Industry Voice

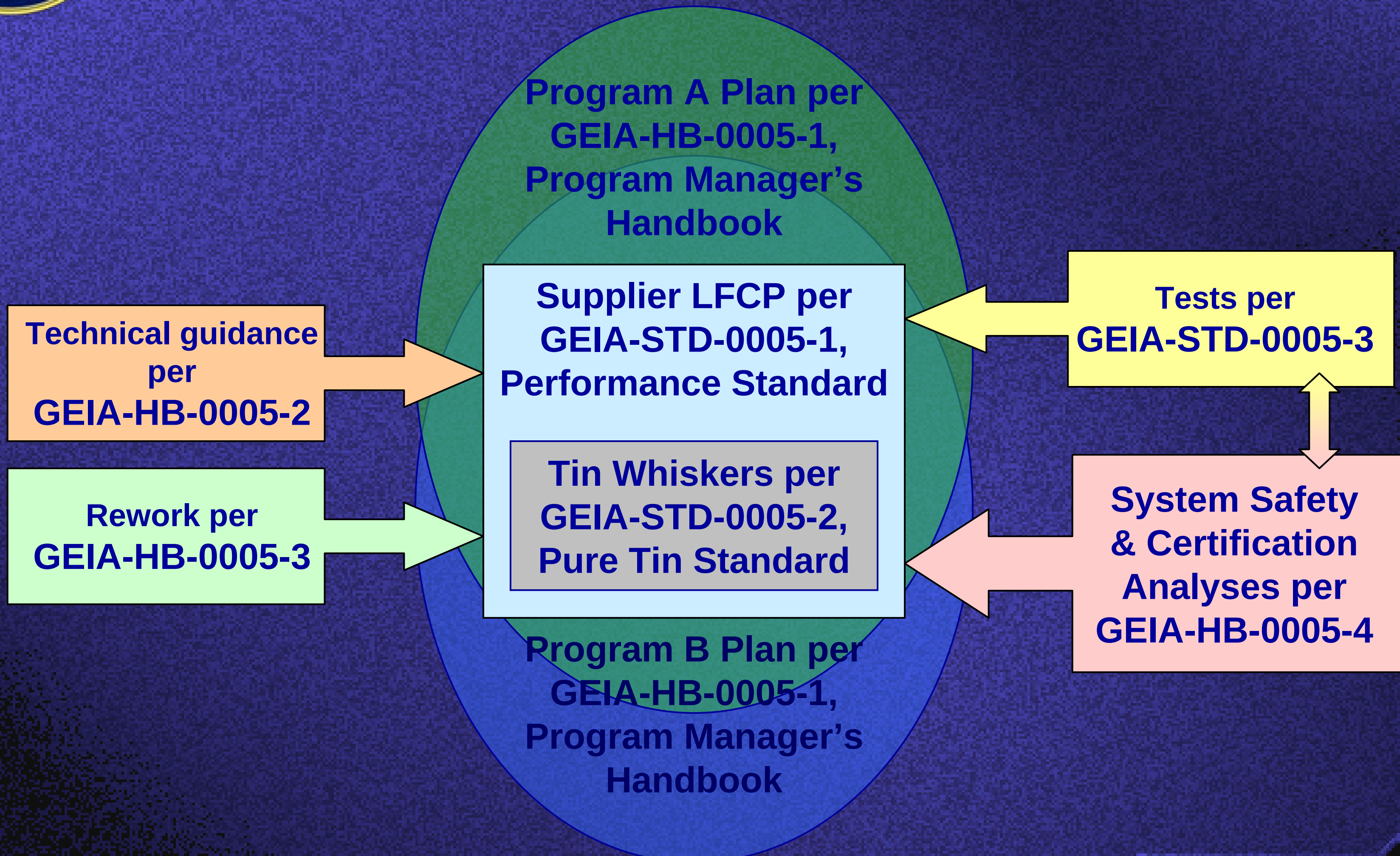
Agenda

1. Lead Free Transition and Impacts
2. Lead Free Failure Modes
3. A Comprehensive Lead Free Strategy
4. **GEIA Lead Free Standards and Handbooks**
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 "Tin Whisker Document
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. Summary
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

GEIA Lead Free Standards and Handbooks

- **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 in Aerospace and High Performance Electronic Systems
- **GEIA-HB-0005-1** Program Management / Systems Engineering Guidelines for Managing the Transition to Lead-free Electronics
- **GEIA-HB-0005-2** Technical Guidelines for Aerospace and High Performance Electronic Systems Containing Lead-free Solder
- **GEIA-STD-0005-3** Performance and Qualification Testing for Aerospace and High Performance Electronics Containing Lead-free Solder
- **GEIA-HB-0005-3** Rework, Repair and Maintainability for Aerospace and High Performance Electronics Containing Lead-free Solder
- **GEIA-HB-0005-4** Reliability Assessment for Aerospace and High Performance Electronics Containing Lead-free Solder

How the Documents Work Together



Agenda

1. Lead Free Transition and Impacts
2. **Lead Free Failure Modes**
3. A Comprehensive Lead Free Strategy
4. GEIA Lead Free Standards and Handbooks
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 “Tin Whisker Document
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. Summary
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

GEIA-STD-0005-1

- **GEIA-STD-0005-1 <u>Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder</u>**
  - Defines requirements for documenting processes in a Plan that assures customers that aerospace and military electronic systems containing lead-free solder will satisfy the applicable requirements for performance, reliability, airworthiness, safety, and certifiability throughout the life of the system.
  - Lists the high-level requirements for such processes and areas of concern to the aerospace and military that must be addressed by the processes.

What is GEIA-STD-0005-1?

- "This document specifies that users develop and implement written Lead Free Control Plans (LFCP). The purpose of the plan is to document processes that assure the Plan owners, their customers, and all other stakeholders that aerospace and high performance high-reliability electronics systems will continue to be reliable, safe, producible, affordable, and supportable."

  - LEAP WG White Paper, 12/2/2006

What is a Lead-free Control Plan (LFCP)?

- An LFCP Is not (necessarily)
  - A Plan to introduce lead-free solder into the Plan owner's products.
  - A Plan to prohibit the use of lead-free solder
  - A Plan to do anything the Plan Owner wants
- An LFCP is:
  - A set of documented processes to assure that the objectives of GEIA-STD-0005-1 are met by the Plan Owner

GEIA-STD-0005-1 Objectives

- **5.1 Reliability**
  - The processes and materials related to the use of Pb-free solder are capable of producing reliable products.
- **5.2 Configuration control and product identification**
  - The configurations of all systems, equipment, assemblies, sub-assemblies, and piece parts are identified and controlled.
- **5.3 Risks and limitations of use**
  - Risks and limitation of use of the Plan owner's products, due to the use of Pb-free solders, are identified, and information is provided to control them.
- **5.4 Deleterious effects of tin whiskers**
  - The deleterious effects of tin whiskers are mitigated.
- **5.5 Repair, rework, maintenance, and support**
  - Repair, rework, maintenance, and support activities are controlled in a manner that controls effects of Pb-free solder materials and processes.

Only Two Requirements:

- 1. State what you are going to do (documented processes)
- 2. Show how this satisfies the objectives of GEIA-STD-0005-1

Options (from the LFCP Template)

- 1) {LFCP owner} will make the transition to lead-free solder, including component termination materials, board finish materials, and assembly materials, by (date of completion); and this LFCP references the documented processes required to do so.
- 2) {LFCP owner} will not make the transition to lead-free electronics, and the documented processes referenced in this LFCP assure that no lead-free component termination materials, board finish materials, and assembly materials are present in {LFCP owner}'s end item products.
- 3) {LFCP owner} will operate parallel lead-free and lead-bearing assembly processes, and the documented processes referenced in this LFCP assure that those processes are controlled adequately to address the requirements of GEIA-STD-0005-1 and GEIA-STD-0005-2.
- 4) {LFCP owner} will operate a "mixed assembly" operation, in which tin-lead assembly alloys will be used in conjunction with components with lead-free termination materials or finishes, and/or printed wiring boards with with lead-free surface finishes. The processes documented in this LFCP are controlled and assure that the requirements of GEIA-STD-0005-1 and GEIA-STD-0005-2 are satisfied.
- 5) {LFCP owner} will implement processes and methods to respond to the transition to lead free electronics only as directed by individual customers.

Stages of the Transition

- **The LFCP owner's sub-assemblies, e.g., printed wiring assemblies, may be in one of the following stages of the transition to lead-free electronics:**
  - 1) Those designed as lead-bearing, and which will remain lead-bearing.
  - 2) Those designed as lead-bearing, and which have evolved to include lead-free electronics.
  - 3) Those designed as lead-bearing, and which are intentionally transitioned to lead-free.
  - 4) Those designed as lead-free.

Who Should Prepare an LFCP?

- **Any aerospace organization that wants to assure its customer(s) that it is in control of its products with regard to the transition to lead-free electronics.**
  - **Contractual requirements may impact the preparation, content, and use of the LFCP**
- ***Every aerospace supplier and/or program has at least one LFCP***

The LFCP Process

Off-line (not program-specific):

Corporate-level customer requirement for LFCP, compliant to GEIA-STD-0005 -1 and -2

→

Supplier documents baseline processes in corporate-level LFCP

→

One-time LFCP approval

On-line (program-specific):

Approved LFCP is proposal or contract deliverable

→

Negotiate deviations and incremental costs for each program

→

Contract

Agenda

1. Lead Free Transition and Impacts
2. **Lead Free Failure Modes**
3. A Comprehensive Lead Free Strategy
4. GEIA Lead Free Standards and Handbooks
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 “Tin Whisker Document
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. Summary
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

GEIA-STD-0005-2

- **GEIA-STD-0005-2 <u>Standard for Mitigating the Effects of Tin in Aerospace and High Performance Electronic Systems</u>**
  - Describes processes for mitigating the detrimental effects of tin whiskers in electronic systems used in military, aerospace, and other high-reliability applications.
  - Intended for use to document processes used to assure performance, reliability, airworthiness, safety, and certifiability of electronic systems in which harmful forms of tin may be introduced into the production or maintenance process.

Document Concept

- Tin whisker risk cannot be accurately quantified
  - Models exist for whisker growth and shorting, but are still immature
  - Risk algorithms exist for comparing applications but do not map to probability of failure
- Different programs and applications have different tolerances for the ambiguous tin whisker risk
  - Programs that have seen a tin whisker failure tend to be extremely (overly?) conservative
  - Programs that have not had documented tin whisker failures tend to be (overly?) optimistic
  - Tolerance needs to take into account possible risk of whiskers and possible impact of whiskers

Document Concept (cont)

- Document designed to provide a framework by which suppliers and customers can communicate more clearly about how big a risk they consider whisker and what actions they are taking as a result
  - Not a step-by-step cookbook for removing tin whisker risk entirely

Defining Tin

- ***Pb-free Tin*** is defined to be any tin alloy with <3% lead (Pb) content by weight
- Frequently defined by >97% tin but not sure research supports other alloys yet
- Need to consider whether for testing purposes (lot screens) whether need more margin for "rough" tests
- Standard only deals with finishes, not attachment solder
  - Assumption has been that whiskers do not form from bulk solder joint, only from original finishes due to stresses
  - May need to revisit assumption based on recent data
  - STD will be revised to include bulk joint materials if needed

Overview of Control Levels

- ***Level 1***. No restrictions on Pb-free tin finish use.
- ***Level 2***. Pb-free tin finish is allowed under some circumstances.
  - ***Level 2A.*** Use of **Pb-free tin finish without explicit controls is acceptable under most circumstances** but the likelihood of whiskers and methods used to estimate their impact and mitigation strategies will be documented. Pb-free tin finish may be prohibited in some specific circumstances called out in contractual documents.
  - ***Level 2B***. **Pb-free tin finishes may be used but only with customer approved and specified control measures. These Pb-free tin finish approvals may be blanket approvals** for multiple components and applications within the system. Pb-free tin finish may be prohibited in some specific circumstances called out in contractual documents.
  - ***Level 2C***. **Restricted use of Pb-free tin finish.** Pb-free tin finish is prohibited unless an exception is made. Specific instruction on use of Pb-free tin finish and required control measures to be provided and reviewed on a case-by-case basis.
- ***Level 3***. Use of **Pb-free tin finish is prohibited** and measures must be taken to verify compliance.

Lead Free Control Levels

	Documentation of Tin Use	Detection and Control	Mitigation	Risk Analysis
Level 1	Supplier: General information on finishes used.	None.	None.	None.
Level 2A	Supplier: General information on finishes used. Customer: List of any applications where tin is not allowed.	None.	None.	At the process level: analyses showing: risk assessment.
Level 2B	Supplier: List of families and categories that will use tin Customer: List of any applications where tin is not allowed.	Should have sampling of receipts material tested	Should have at least two mitigation methods be employed.	At the family level: analyses: analyses showing: risk assessment.
Level 2C	Supplier: List of all instances of pure tin. Customer: List of any applications where tin is not allowed.	Shall have sampling of receipts material tested	Shall have at least two mitigation methods	At the instance level: analyses showing: risk assessment.
Level 3	Supplier: Documentation of lot screen results.	Shall tests at least one part per lot / batch received	Not applicable. No tin is to be used so no risk analysis is required.	Not applicable. No tin is to be used so no risk analysis is required.

Level Selection

- 5 factors to consider
  1. Propensity of the tin surface in question to grow whiskers of a given length, in a given abundance, in a given time frame.
  2. Ability of whiskers growing from that surface to create an electrical short
  3. Ability of whiskers to break off and to migrate to a different location in the system
  4. Vulnerability of the system to suffer performance degradation due to electrical shorts such as are created by tin whiskers (including plasma events).
  5. Vulnerability of the system to suffer performance degradation to micromechanical dysfunction that could be created by tin whiskers.

Level Selection

- Programs with risk of plasma events will probably want to pick a very high level
- Programs with infrequent test and maintenance schedules and/or very long missions will probably want to pick a very high level
- Programs with shorter missions, more tolerant circuits, and frequent test and maintenance may be able to select lower levels

Level Usage

- There are several ways to use the control levels
  - Some programs may chose a level for the entire program
  - Some programs may chose levels for individual hardware elements / units
  - Some programs may chose levels for hardware based on previously defined criticality levels
  - Etc.
- Any of these methods can work, but plans should always be very clear in the way the control levels will be utilized

Agreement of Level with Customer

- **Level selection will likely be a negotiation with your customers**
- Pick a level that will be applicable to most of your customers
  - If you are building a lot of space product, plan on a level 3 or 2C
  - If you are building a lot of commercial avionics, you can probably plan on a lower level 2 category
- **TALK TO YOUR CUSTOMERS BEFORE YOU FINALIZE YOUR DECISION**
  - Tell them what you are thinking and why to get their input
- May need to have different plans and levels for different product lines
- Negotiate additional work for higher levels with special customers
  - If you have one customer that wants a higher level than all your others, set your baseline plan for the majority of your customers and negotiate customization with the special customer
- Make sure to get level agreement in writing with the customer

Flow Down of Requirements

- Requirements for control levels 2B, 2C, and 3 apply to lower tier suppliers
- That means the level and/or its requirements are required to be flowed to the lower tier suppliers

OR

- It means that the supplier needs to document how they are going to verify that the requirements are being met

- Control plan should address
  - How requirements are flowed to lower tier suppliers

  OR

  - How the supplier will verify received product and repair / rework if necessary

Level Requirements: Documentation of Tin Use

- Levels 2B and 2C require maintenance of lists of applications and / or components with tin
  - 2B requires list of any part or application families with approvals and any specific cases that go beyond those families
  - 2C requires lists of every part AND every application the part is used in
- Control Plan should address:
  - How list maintained
  - Where list stored
  - How approvals will be obtained
- For Level 1 and 2A, the control plan should list any general rules about tin use
  - For example, if the company only buys tin parts that have been through the JEDEC / iNEMI test protocol successfully or only selects matte tin parts, that should be listed in this section

Level Requirements: Detection and Control of Pb-free Finishes

- Even with requirements for Pb in contracts and POs and even with CoC's showing Pb, there are frequent escapes of pure tin parts
- To prevent escapes, verification of materials is required for some levels
- Methods might include XRF, EDX, or other analysis techniques
- Level 2C requires sample monitoring (recommended for 2B)
  - Control Plan should explain sampling plan (size, frequency, etc.), state basic method for analysis, and reference method / process documents
- Level 3 requires Lot Monitoring
  - Control plan should state basic method for analysis and reference method / process documents
- If different processes are used for different types of materials (e.g. mechanical vs. hi-rel, DPA-ed vs. not DPA-ed) the control plan should explain these variations
- State whether exception to screening made for gold-colored finishes

Level Requirements: Risk Mitigation

- Levels 2B and 2C require use of at least 2 mitigation categories
- Types of mitigations
  - Design for Impact Reduction
  - Lower Risk Finish Selection
    - E.g., Matte tin over nickel
    - Other finishes with accompanying documentation as to why it reduces risk
    - Heat treatments (reflow, annealing, etc)
  - Tin Finish Replacement
    - Solder dip but not 100% replacement (i.e., parts get hand-dipped before installation)
    - Documentation of amount of tin finish covered by solder during installation
  - Conformal Coat
    - Finish coated AND other surface coated

Level Requirements: Risk Mitigation (cont)

- Control Plan should document:
  - Any standard mitigations that are always used
  - Order of preference for mitigation categories (if exists)
  - List of platings that are considered to be low risk (if applicable)
  - Type of conformal coating used
  - References to processes that institute design rules or implement techniques for mitigation
  - Process by which mitigations are checked to exist
  - Documentation and data retention process for specific mitigations for each tin application (if applicable)

Warning about Mitigations

- Almost all mitigations are known to have examples of whiskers
  - Lengths and densities of whiskers vary
  - Some mitigations are more effective than others
- More than two mitigations are always better
- For any mitigation selected, it is necessary to understand WHY the mitigator is adequate for the application
  - Don't assume that just saying "We have nickel underplate and conformal coat" is good enough for everything
  - You'll need to justify the appropriateness of the mitigation for your application in the analysis portion of the requirements

Level Requirements: Analysis and Test of Mitigation Effectiveness

- Three basic approaches to standardized risk assessment
  1. Assignment of "cognizant subject matter experts“ or board to review, record rationale, and signoff each risk assessment.
  2. Establishment of a set of rules-based criteria that define conditions under which the risks are deemed to be acceptable.
  3. Development of an algorithm that encompasses risk factors of concern that can be used to define a metric of risk on a standard basis.
- Many companies use a combination of the three techniques
- Control Plan should document the assessment process
- Control plan or assessment process should document
  - Who makes the assessment decision
  - Rules or criteria for assessing whisker risk
  - Rules or criteria for assessing whisker impact
  - Test methods/field data evaluated and evaluation process
  - Algorithms or other quantitative assessment performed
  - Where detailed reports on specific parts and/or applications are maintained

Overview of Tin Whisker Control Plan

- Document what level you plan on achieving
- Document any exceptions / variations on the requirements
  - E.g., maybe you are going to follow Level 2C but you want a general exception for tin-silver finishes for use in high temp applications
- Document any activities to control and monitor Pb-free finish introduction
- Document mitigation strategies used
- Document test and analysis process
  - Reference company process if exists
  - Any rules for mitigation strategy effectiveness
  - Any rules for addressing whisker impact
- Document where detailed reports and approvals are maintained

Conclusions

- Compliance to GEIA-STD-0005-2 is flexible
- That flexibility means more information needs to be documented by the supplier
- The control plan should document the overall process, any standard rules, and information about how to find more detail
- Detailed processes should explain how mitigations applied and how analyses performed
- Detailed reports should show what mitigations are in place and why they are effective for a specific application or family

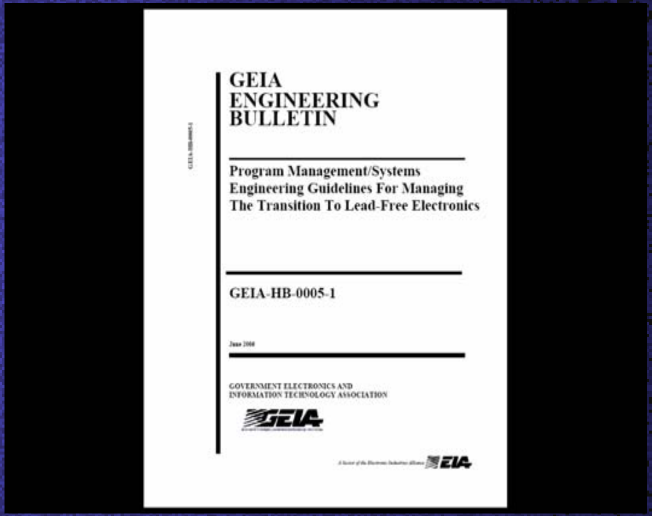
Agenda

1. Lead Free Transition and Impacts
2. **Lead Free Failure Modes**
3. A Comprehensive Lead Free Strategy
4. GEIA Lead Free Standards and Handbooks
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 "Tin Whisker Document
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. Summary
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

GEIA-HB-0005-1

GEIA-HB-0005-1 Program Management / Systems Engineering Guidelines for Managing the Transition to Lead-free Electronics

- Handbook for program management / systems engineering management to use for managing the transition to lead-free electronics
- To assist the program manager / systems engineer in assuring that the performance, reliability, airworthiness, safety and certifiability of product(s), in accordance with GEIA-STD-0005-1


GEIA
ENGINEERING
BULLETIN

Program Management/Systems Engineering Guidelines For Managing The Transition To Lead-Free Electronics

GEIA-HB-0005-1

GOVERNMENT ELECTRONICS AND INFORMATION TECHNOLOGY ASSOCIATION

GEIA

EIA

GEIA-HB-0005-1

Program Management / System Engineering Guidelines for Managing the Transition to Lead-free Electronics

Team Leader: Pat Amick, Boeing
Team: Boeing, ACI, AIA, Bombardier, EADS, FAA, Lockheed-Martin, Raytheon, Parker, USN

Scope:

- **Handbook for program management** / systems engineering management to use **for managing the transition** to lead-free electronics.
- To **assist the program manager** / systems engineer **in assuring** that the **performance, reliability, airworthiness, safety and certifiability** of product(s), in accordance with GEIA-STD-0005-1.
- Intended for guidance only.

Program Management Concerns

- Reliability
- Configuration Control
- Risk Management
- Detrimental Effects of Tin
- Rework / Repair and Maintenance

- Cost
- COTS
- Quality
- Contractual Language
- Program Constraints
- System Engineering Management Plan

We care about what we've always cared about !!!

PM Concerns - Reliability

- **Understand how the transition** to Pb-free **may affect the reliability** of the program.

- **Need to understand:**
  - If units and/or systems will **include both Sn/Pb and Pb-free** assemblies, piece parts, printed wiring boards
  - Effects of **mixing Sn/Pb and Pb-free solder**
  - Effects on **package types/geometry**
  - **Reaction to** the program's **use environment**

- **Should consider a common reliability data collection** during all phases of the program to facilitate systems performance improvement.

PM Concerns – Configuration Control

- **Understand** the appropriate **configuration controls necessary for the program's environment** and at **what level** (i.e., piece part, assembly, unit, system)
- **Ensure** that appropriate and **<u>demonstrated</u> processes are in place** at suppliers
- Consider requiring a **Parts, Materials, and Processes (PMP) Plan** with appropriate **Quality Control Procedures**.
  - The plan **should include sub-contractor controls** that affect the reliability of the end product.

PM Concerns – Risk Management

- **Risk identification and risk assessment** need to be performed **for the** Pb-free **transition** for the particular environmental conditions of the program.

- Risks need to be **identified early and a mitigation strategy engaged.**

- Should ensure that a **complete risk management** plan is in place.

PM Concerns – Detrimental Effects of Tin

- Pb-free tin finishes in an avionics or high performance system can have **detrimental effects to functionality** of the system as **tin whiskers** can spontaneously grow from the surfaces.

- **Understand and agree** to the supplier's plan **for either:**
  - **Eliminating use of** Pb-free **tin** in their product (through life-time buys or reprocessing piece parts),

    OR

  - **Accepting** Pb-free tin in their product (**and addressing and mitigating the risks**).

PM Concerns – Rework / Repair and Maintenance

- Concern if **Sn/Pb and Pb-free solders** and/or piece parts are **used on the same assemblies**.

- Should be **aware of** the **higher risks** associated **with field rework/repair and maintenance** when standard solder materials (i.e. 60% tin/40% lead or 63% tin/37% lead) are used on Pb-free assemblies and/or piece parts or visa versa.

PM Concerns – Cost

- The costs of the Pb-free transition **need to be quantified** and decisions need to be made as to **who will assume the costs**.
- The PM should be aware that the **situation is likely to be dynamic** over the next several years.
- **Added costs** may come from additional **risk management determination, configuration controls, rework/repair and maintenance changes, drawing changes, possible redesign, re-qualifying/delta qualifying, etc.**

PM Concerns – COTS

- Commercial-off-the-shelf (COTS) is always a **critical concern** for a program manager.
  - The **very nature of COTS may allow Pb-free substitution** irrespective of program requirements.
  - The product **may contain COTS Pb-free soldered assemblies** as well as **Pb-free-finished piece parts**.

- **Understand the supplier's controls** to mitigate the risks associated with Pb-free finished piece parts and COTS assemblies.

- **Ensure** that the **PMP Plan** for the program is being adequately **updated and addresses how** lead-free piece parts and assemblies will be **identified and tracked**.

PM Concerns – Quality

- Quality is a **critical consideration** in the transition to Pb-free.
- The PM needs to be **assured** that the **final product meets the technical and operational requirements** with the specified reliability at all levels.
- This **includes flow of requirements, implementation and documentation through and to subcontractors**.

PM Concerns – Contractual Language

- Appropriate contractual language needs to be included in new contracts that **describe the customer requirements** regarding Pb-free parts.

PM Concerns – Program Constraints

- The PM needs to be proactive in **understanding all of the impacts to** the program **schedule** (including all integrated master schedule line items).

- Consideration needs to be paid to **changes in the delivery schedule** due to **requalification/delta qualification** of Pb-free parts, additional **reliability testing**, **lifetime buys** of long-lead SnPb-finished piece parts, etc.

PM Concerns – SEMP

- The PM should **reassess the program's System Engineering Management Plan**, if one exists, and ensure that it has been updated to include the Pb-free transition controls for the program.

Appendices

- ***Appendix A*** describes a **matrix of product tier level versus** associated **risks** with respect to a Pb-free transition.

- ***Appendix B*** contains **links** to the European Union Directives and Executive Order 13148.

- ***Appendix C*** contains a **General Program Manager Checklist** for dealing with Pb-free Issues, based on GEIA-HB-0005-1.
  - **Requirements Issues**
  - **Supplier Management Issues**
  - **Schedule Issues**
  - **Cost Issues**
  - **Configuration Control Issues**

- ***Appendix D*** contains a General **Manufacturing Process Assessment Checklist** to assess supplier compliance to GEIA-STD-0005-1.

- ***Appendix E*** describes **recommended program language** to assure performance, reliability, airworthiness, safety, and certifiability of Pb-free products.

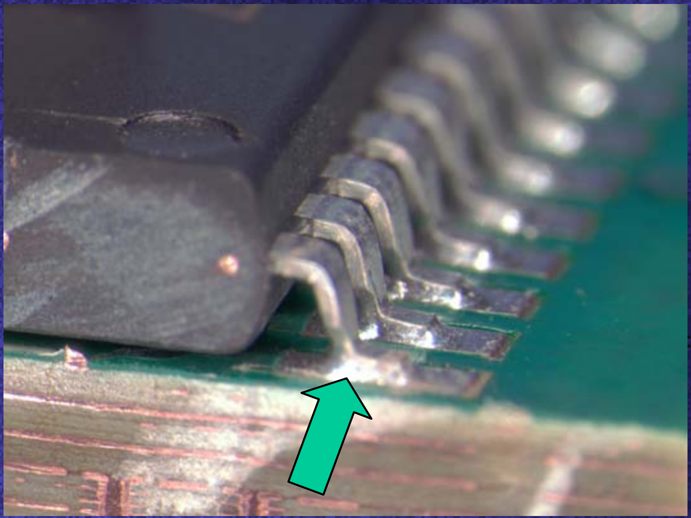
Agenda

1. Lead Free Transition and Impacts
2. **Lead Free Failure Modes**
3. A Comprehensive Lead Free Strategy
4. GEIA Lead Free Standards and Handbooks
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 “Tin Whisker Document
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. Summary
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

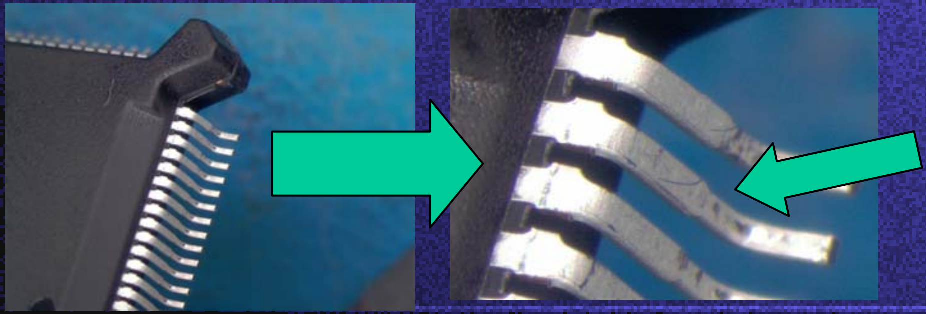
Pb-free impact to electronic assemblies

- Restriction of Hazardous Substances (RoHS) by European Union - July 1, 2006
  - Lead(Pb) ***one*** of six restricted materials

- Impacts solder and finishes
- Impacts soldering temperature
- Impacts insulation material system



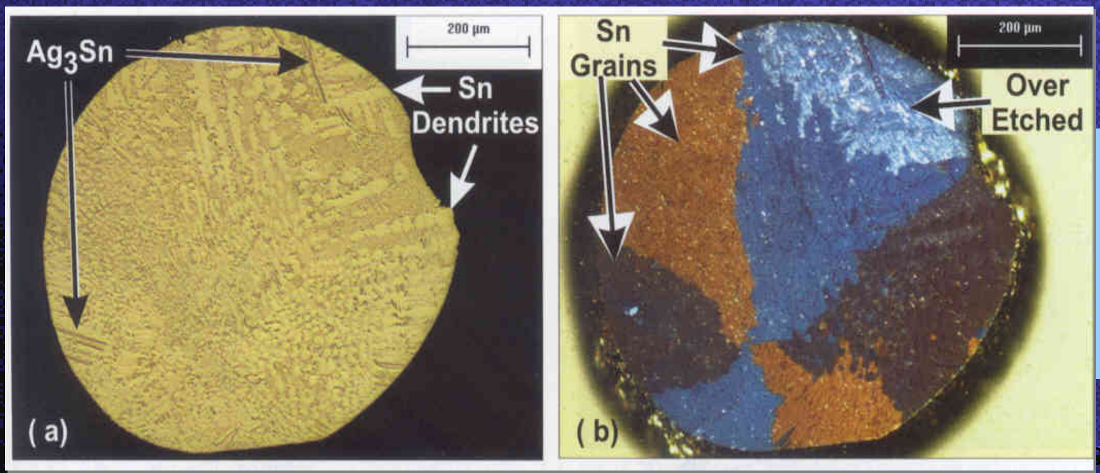
Solder Change:
From: 63% Tin, 37% Lead
To: Tin-Silver-Copper or others
Note: this also triggers other changes



Finish Change:
From: Tin-Lead
To: Pure Tin

What's the problem; it is just solder?

- Who would consider changing the alloy of an airplane wing or a turbine blade without a lot of materials testing and analysis?
- It is no longer "just solder"
- Surface-mount technology changed the game:
  - Solder provides structural connection
  - Solder behaves like a viscoplastic material
- During the SMT insertion into high performance applications in the '80s, much was learned that can be applied to Pb-free
- Pb-free solder is different from Sn-Pb

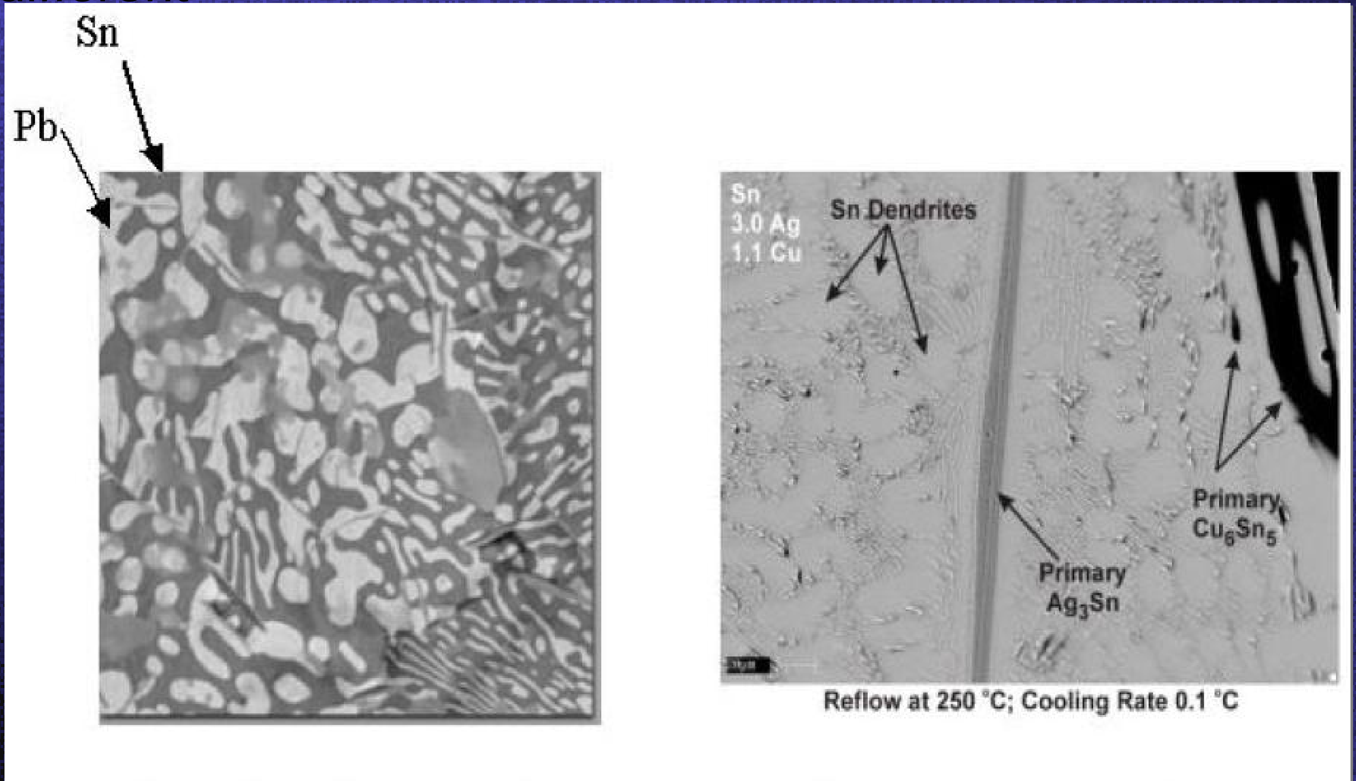


Cross-polarized inspection reveals SnAgCu BGA ball with ~10 grains

…pounds in Sn-Ag-Cu Solder," J. Electronic Materials, Vol. 33, No. 12 (2004) pp 1429-1439.

Solder Microstructure

- The mechanical response of Sn-Pb Solder is dominated by the micron-scale inclusions of the relatively soft Pb
- SnAgCu structure is more complex - mechanical response is different

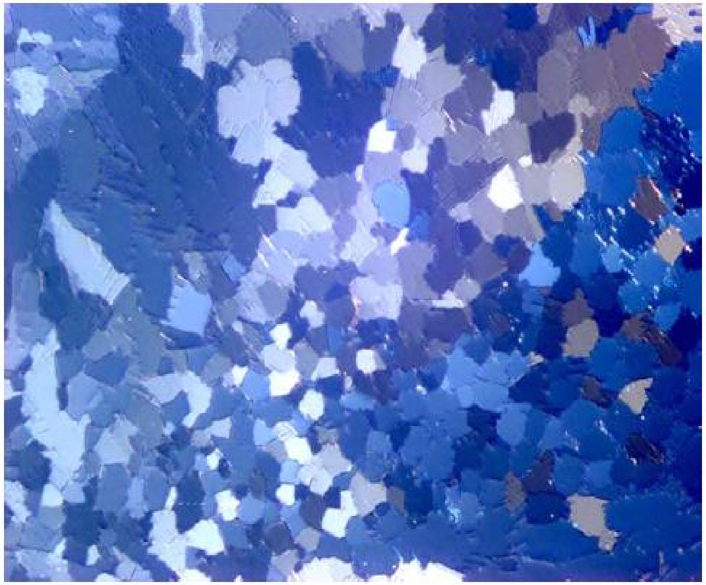


Canonical PbSn eutectic　　　Pb free SnAgCu near eutectic

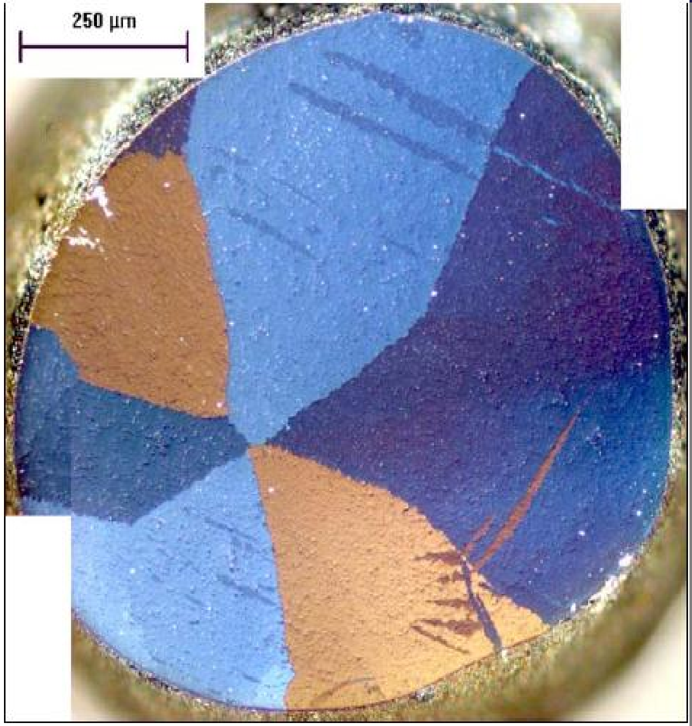
E. Cotts, Binghamton University, at the Universal Instruments Consortium Meeting, June 2006

Alloy additions impact grain structure

- A little bit of copper significantly changes the grain structure



~Sn-3.5Ag



~Sn-3.5Ag-0.6Cu

L.P. Lehman and S.N. Athanvale et. al, “Growth of Sn and Intermetallic Compounds in Sn-Ag-Cu Solder,” J. Electronic Materials, Vol. 33, No. 12 (2004) pp 1429-1439.

Failures in electronics hardware

Environmental conditions

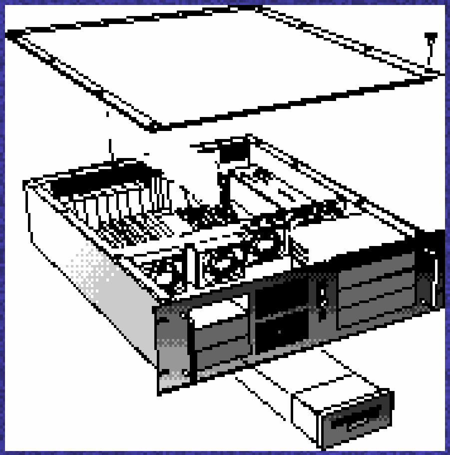
- Temperature
- Vibration
- Acceleration
- Moisture
- Pressure
- Ionic contamination
- Radiation

Operational conditions

- Power
- Current
- Voltage

People

- Training/skill level



Failure modes

- Parameter drift
- Short
- Open

Types of failure

- Overstress
- Wearout

Failure mechanisms

Failure mechanism interactions

- Complimentary
- Competitive

(M. Osterman, CALCE Center - University of Maryland, Presentation at the 9th Meeting of the AIA/GEIA/AMC LEAP Working Group, Tucson, March2006)

Pb-free SnAgCu (SAC) Solder mechanical response

Pb-Free SnAgCu applies more stress to pads and is less ductile

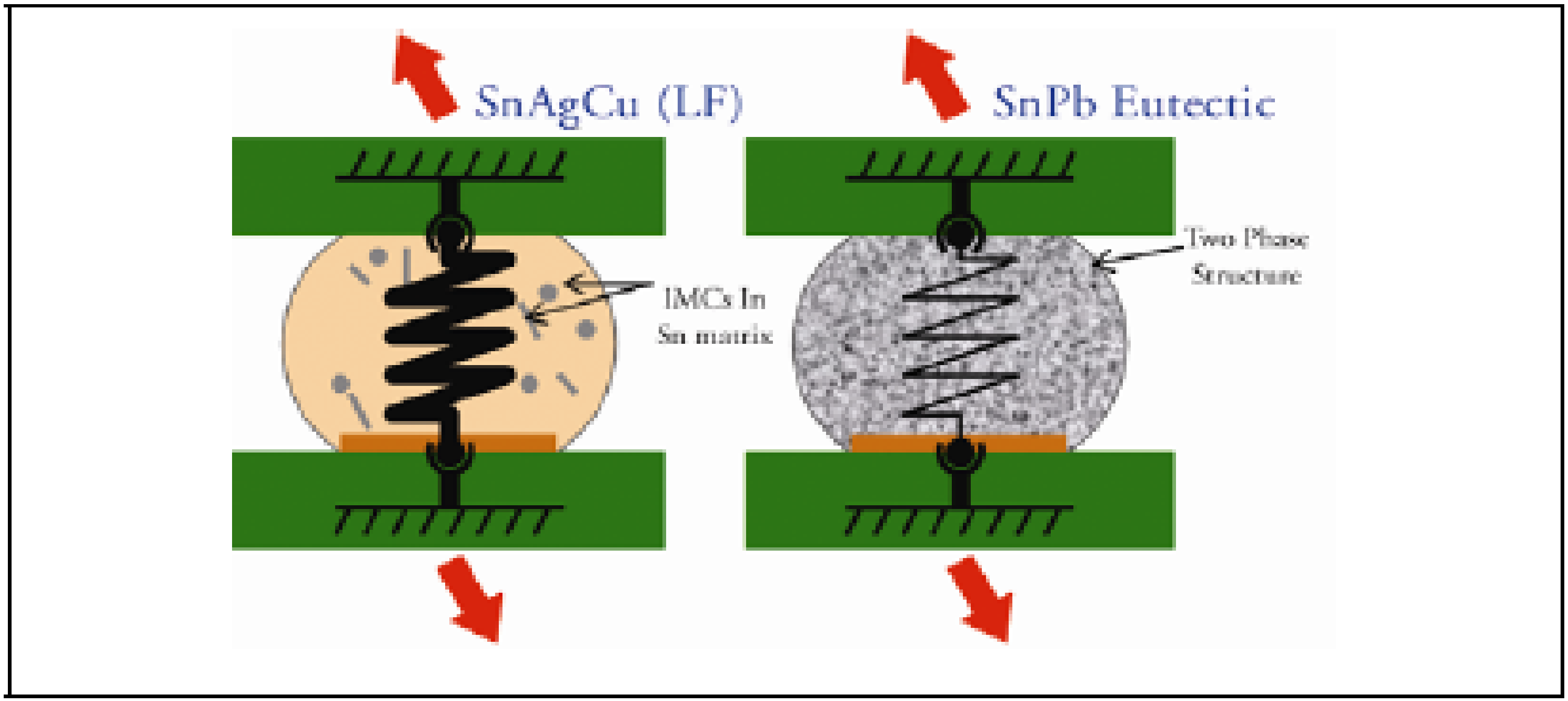


Figure G2-6: BGA Solder Joint Mechanical Integrity

Ref: Denny Fritz – SAIC "Tin whisker" telecon presentation, July 25, 2007

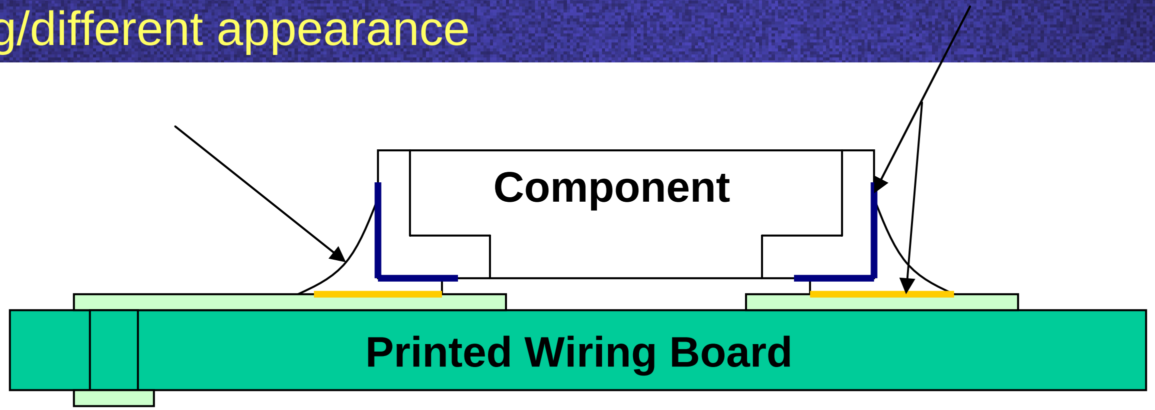
What makes this challenging?

Pb-free solder:

- Multiple Pb-free alloys
- Higher Sn content
- Higher processing temperature
- Different fatigue characteristics
- Solder alloy compatibility
- New solder fluxes
- Greater copper dissolution
- Less wetting/different appearance

Intermetallic

- Increased Sn content yields thicker (i.e., weaker) IMCs
- Voiding of Cu from IMC growth
- Rapid loading is main concern
- Sn-Cu-Ni IMCs nuances



Pb-free solder thermo-mechanical behavior is different from Sn-Pb

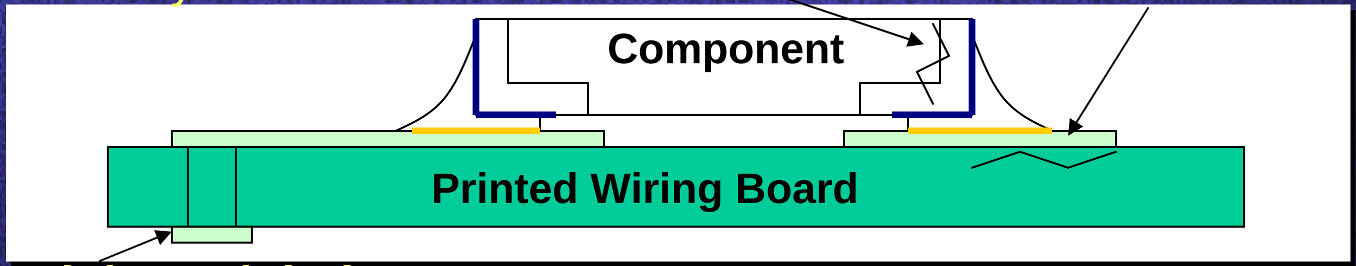
Ref: Meschter DMSMS 2006

What else?

Printed Wiring Board and Component
- New materials that can withstand higher soldering temperatures
- CAF/SIR Service risk from high soldering temperatures and new fluxes
- Delamination/decomposition/moisture sensitivity

Component termination metal:
- Increased terminal stress
- Solderability of finish

PWB Pad
- Laminate/pad fracture
- Solderability of finish



Plated through hole
- Higher soldering temperature increases stress
- Pad susceptible to dissolution during “Wave Solder”
- New aspect ratio design rules?

Ref: Meschter
DMSMS 2006

Pb-free transition is driving changes to a majority of the material system

What about Pb-free consumer electronics?

- 1 to 3 year life requirement
- Materials have changed
  - PCB laminates
  - Surface finishes
  - Component constructions
  - Solder pastes
  - Fluxes
  - Wave bar solder
  - Hand repair and cleaning chemistries
- Associated assembly processes have changed
  - SMT (Surface mount technology) and Wave
  - Hot gas rework
  - Solder fountain rework
  - Hand repair
  - Test

Kelly, M., et.al., "Qualification of a Lead-free Card Assembly and Test Process for a Server Complexity PCBA" SMTA 2007

Consumer electronics have new material sets and assembly processes with unknown long term reliability and field performance.

What aerospace has that consumer electronics doesn't:

- 20 yr. service, configuration management, solderable shelf life, repair, and solder compatibility issues
- Qualification requirements
  - "As built" with Pb-free
  - When mixed with Sn-Pb
  - Rework/repair: single(multiple) alloy(s) and process(es)
- Long-term harsh-service reliability considerations
  - Solder reliability is dependent on the parts, the PWB, the metallurgy and the environment
  - Significant vibration/shock or combined thermal and vibration

Ref: Meschter DMSMS 2006

GEIA-HB-0005-2 Technical Guidelines Scope

- For use as technical guidance, by aerospace/defense industry, in developing and implementing designs and processes to assure the continued performance, quality, reliability, safety, airworthiness, configuration control, affordability, maintainability, and supportability of high performance aerospace systems (AHP)
  - Pb-free finishes with Sn-Pb eutectic solder
  - Pb-free BGAs with Sn-Pb eutectic solder
  - Pb-free solder
- For application to aerospace products
  - May also be applied (with discretion) to other products with similar characteristics (e.g., low-volume, rugged use environments, high reliability, long lifetime, and reparability)

GEIA-HB-0005-2 Technical Guidelines Features

- Use methodologies to support GEIA-STD-0005-1, "Performance Standard for High Performance Electronic Systems Containing Pb-Free Solder."
- HB-0005-2 is an industry consensus document
- Amongst the millions of Pb-free related papers, HB-0005-2 captures the data relevant to high performance electronic systems
- Contains lessons learned from previous experience with Pb-Free aerospace electronic systems.
  - lessons learned give specific references to solder alloys and other materials, and their expected applicability to various operating environmental conditions
  - lessons learned are intended for guidance only (not guarantees of success in any given application)
- Changes for the next revision are being accumulated

The GEIA-HB-0005-2 Team

ACI	DMEA	NASA-Kennedy
AIA	Diehl-Avionik	Naval Warfare Center
Air Force	EADS	NAVSEA Crane
Army	ESA	Northrop Grumman
BAE Systems	Harris Corp.	Parker ESD
Boeing	Honeywell	Raytheon
Bombardier Aerospace	Kiddie Aerospace	Rockwell Collins
Celestica	Lockheed Martin	Rolls Royce NNPPI
Curtiss Wright	Matsushita Avionics	Thales
DFR Solutions	Meditronics	University of Maryland - CALCE

Technical Content

- General Pb-Free Solder Alloy Behavior
- System Level Service Environment
- High Performance Electronics Testing
- Solder Joint Reliability Considerations
- Piece-parts
- Printed Wiring Boards
- Printed Wiring Board Assemblies
- Module Assembly Considerations
- Aerospace Wiring Considerations
- Rework/Repair
- Generic Life Testing
- Similarity Analysis

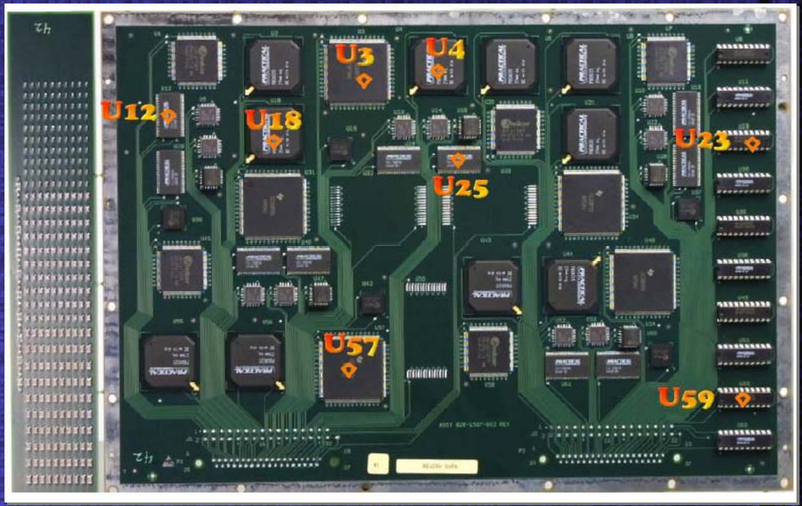
Some Technical Highlights in the document

Elements Promoting and Suppressing Tin Whiskers

Added element	Solubility Limit	Sn whisker (plating)		Experiment Duration
	(wt%) (6)	Promoter	Suppressor (2)	
Ag * 2-5% (20) 2-4% (9)	0.04 (12,13)	—	—	(20) > Significantly worse than Sn-10Pb after 3 months of aging at 52°C (126 °F). (9) > Reduces whisker growth.
Cu	0.0063 (12,13)	1.0 (14), 1.5 (23), 1.4-3.7 (24) & 3.0-36.5% (10)	—	(23) 9 days (24) 2 hours to 15 days
Bi * 2-4% (8,9) 5-10% (20) Not specified (21)	21.00	—	—	(8) > 3-4 months nucleation delay at RT (9) > Partially effective after 3 months of aging at 50°C (122 °F). (20) > Similar to SnPb10 after 3 months of aging at 52°C (126 °F). (21) > No whisker growth after 4 months of aging at 51°C (124 °F).
Pb	2.50	—	> 3.0% (7), ≥ 1.0% (16)	(16) 1 year to 12 years
Ni	nil	—	12-35% (8,11)	(8) > Sn-35Ni, no whisker nucleation after 48 months at RT.
Sb * 2-3% (8)	10.50	—	—	(8) > 3-4 months nucleation delay at RT
Al	nil	?		
Zn	0.33	9% (22)	—	(22) > 21 days to nucleate whiskers at 50°C (122 °F)

Pb-Free Alloys

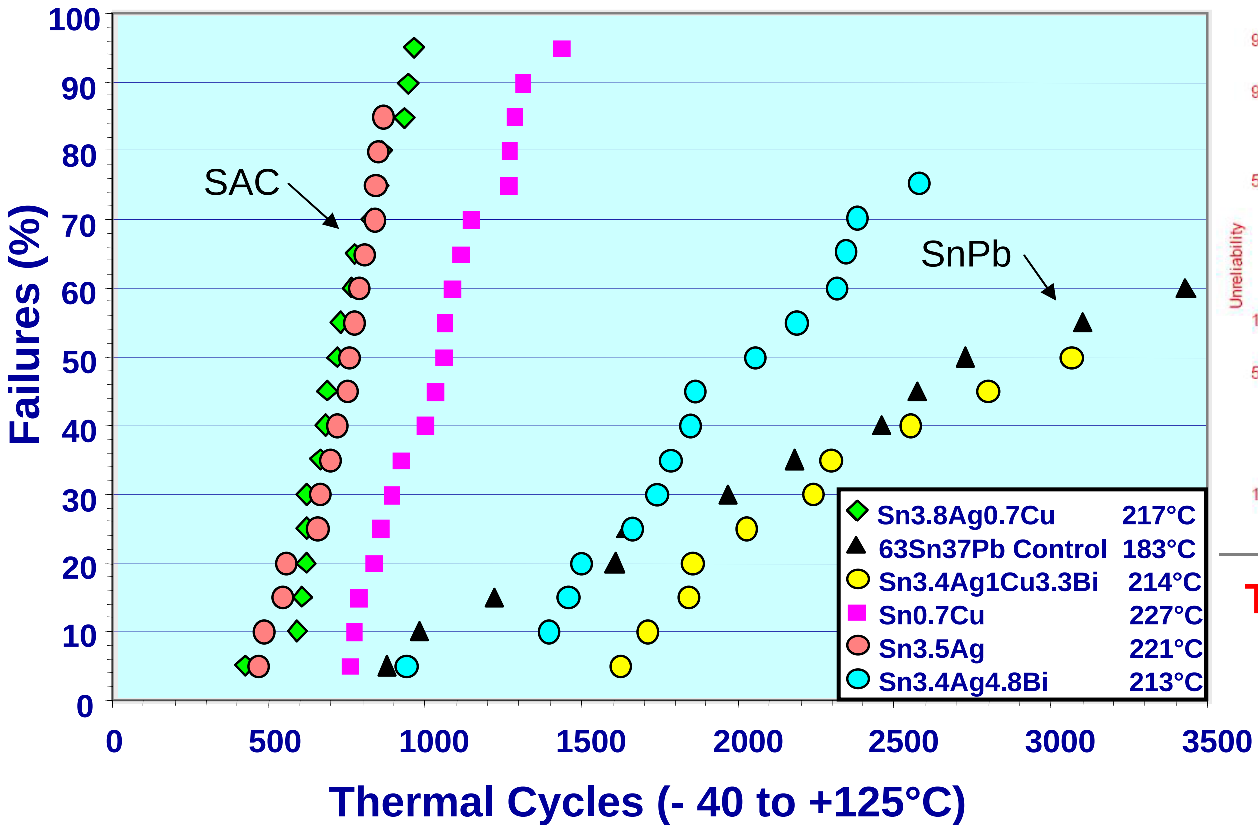
- MIL Environment Test Data on some promising Pb-free alloys
  - SAC387 (Sn-3.8Ag-0.7Cu)
    - JCAA/JGPP Testing
  - NASA-DoD Testing about to start
    - SAC305 (Sn-3Ag-0.5Cu)
    - Nihon SN100C
      (Sn-0.7Cu-0.05Ni+Ge trace)
- Consumer electronics industry is still tweeking alloys to improve drop shock performance
  - SAC105 (Sn-1.0Ag-0.5Cu) – reduce Ag lower stiffness
  - SAC105 with Mn additions – improve intermetallic toughness after thermal aging
  - And to reduce copper dissolution
    - SAC310 (Sn-3Ag-1Cu)
    - Nihon Sn100C

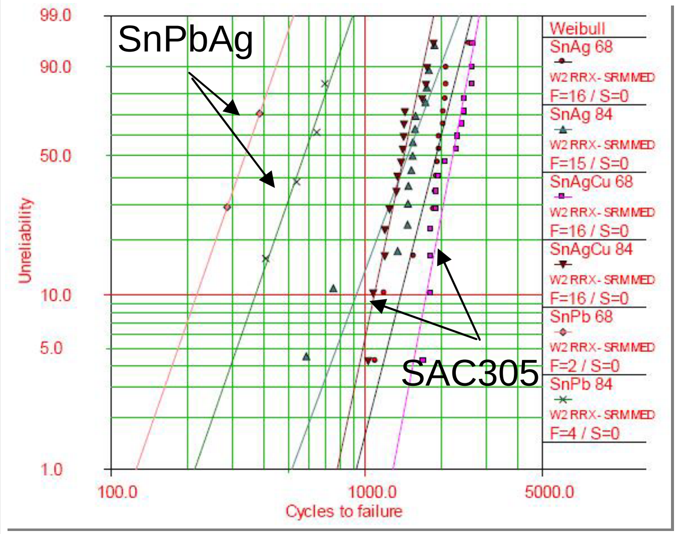


SAC305 or SN100C are strong candidates

Ref: Meschter Boeing Lead-free conference, Anaheim Nov. 15, 2007

Pb-free solder interconnect fatigue in temperature cycling





Thermal Cycles (-50 to +50 °C)

Higher strain range, Sn-Pb better than SAC Pb-free
Opposite is true for lower temperature ranges.

What is the impact of high stress/strain temp. cycling?

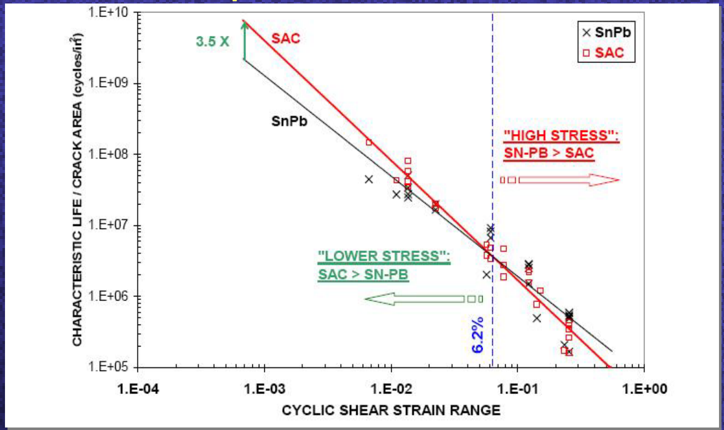
Accelerated Testing

-High Temperature Differences

-55 to +125 °C

High Stress

-SnPb out performs SAC



Clech, J.P., "Lead-Free and Mixed Assembly Solder Joint Reliability Trends", IPC APEX 2004

Actual Service can vary by application

- High Temperature Differences
  - -55 to +125 °C
  - High Stress

  SnPb out performs SAC

  Re-design to lower stress in SAC

- Mission temperatures often have a mix

  Notional example:

% of time	Temperature Range
5%	Very Cold: -55 to -20 °C
15%	Cold: -20 to 10 °C
50%	Normal: 0 to 70 °C
15%	Hot: 60 to 100 °C
5%	Very Hot: 100 C to 125 °C
10%	Storage: -55 to +125 °C

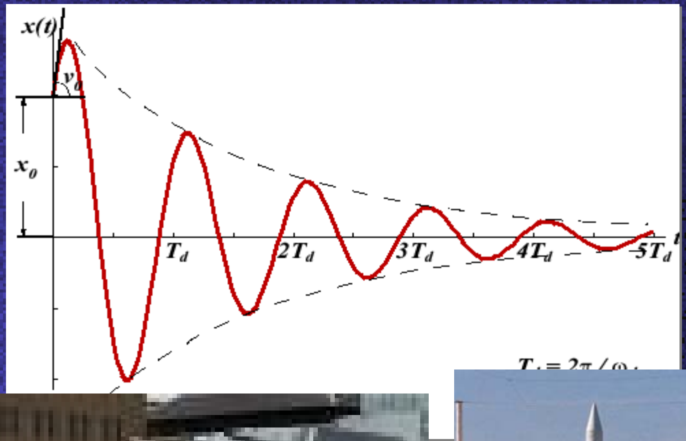
Analysis and test required

Need modeling and test to evaluate applications

Ref: Meschter Boeing Lead-free conference, Anaheim Nov. 15, 2007

Vibration/shock loading – Little data available

- Vibration/shock performance was a tough topic with Sn-Pb solder,
- Vibration/shock: Not much available data
  - Cell phone drop-shock testing driving consumer electronics industry
  - Data from JCAA/JGPP testing
- *Combined* vibration and temperature cycling: Not much data available
  - Data from JCAA/JGPP testing suggests SnPb eutectic better than SAC
- What heritage Sn-Pb tests need to be different for Pb-free?
- Aerospace industry is working to close this knowledge gap

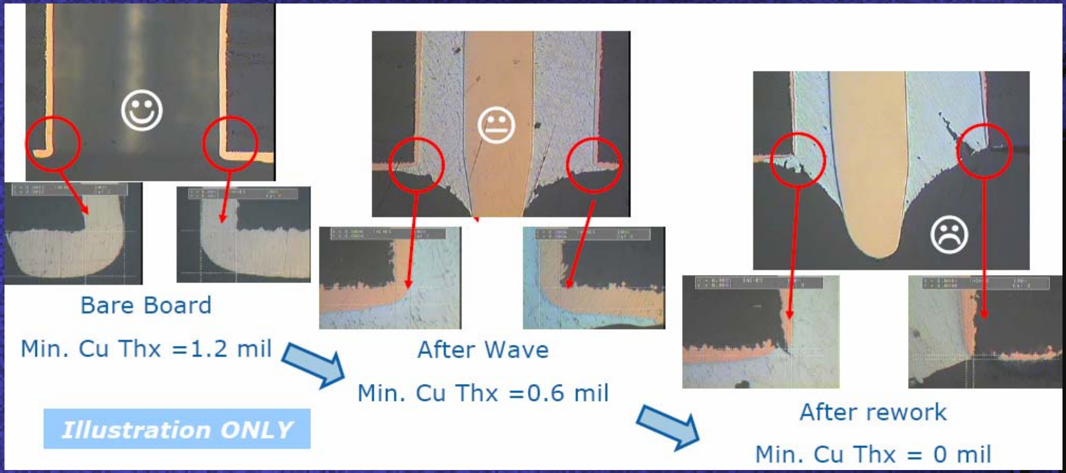


Ref: Meschter DMSMS 2006

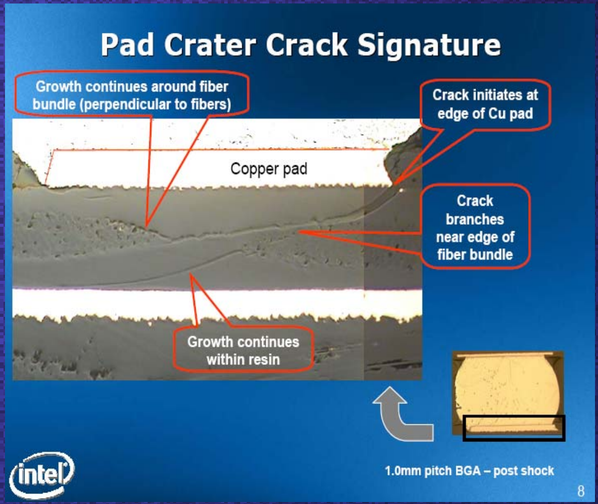
May need to thermal aging prior to performing MIL-STD-810 vibe/shock tests

Copper dissolution and BGA pad cratering

- Copper dissolves when in contact with SAC alloys
  - Higher temperature + High Sn = High dissolution
  - Need to leave enough copper for subsequent repair



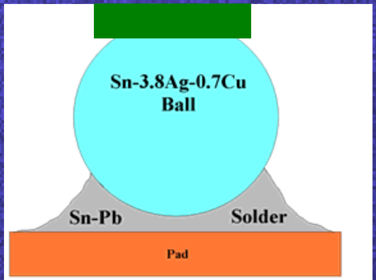
- BGA PWB pad cratering
  - Exact cause being worked
    - Vibe/Shock loading
    - Can it be seen in environmental stress screening?

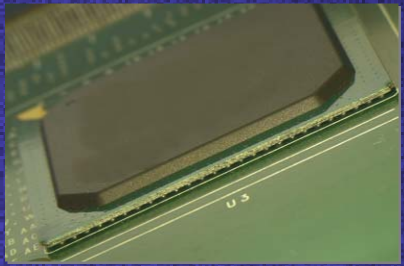


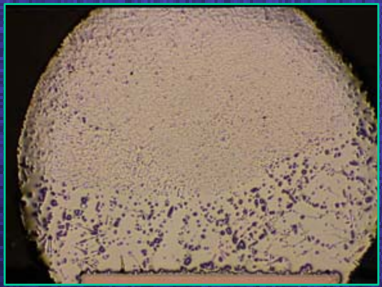
Two key Pb-free issues that need to be considered for high performance applications

Ref: Meschter Boeing Lead-free conference, Anaheim Nov. 15, 2007

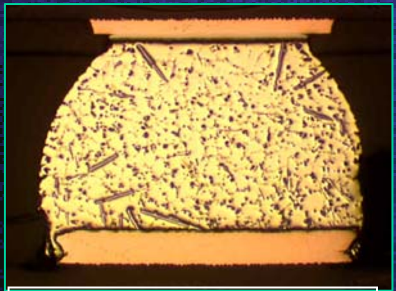
BGAs: Mixing of alloys – today's problem







Undesirable joint:
A moderate volume of Sn-Pb results in *partial* dissolution of Pb-free ball



A little better joint:
More Sn-Pb results in a fairly *uniform* composition and phase distribution.
-Tighter solder process window required

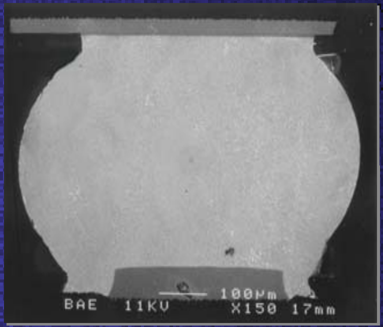
P. Snugovsky
Celestica (2006)

Re-balling Pb-free BGA

Pb-free solder balls removed on part

Sn-Pb solder balls re-attached

Solder to PWB with Sn-Pb



Best Solder Joint:
Un-Mixed BGA solder Ball
- Part pad evaluation needed

Un-Mixed BGA solder ball has higher reliability

Ref: Meschter Boeing Lead-free conference, Anaheim Nov. 15, 2007

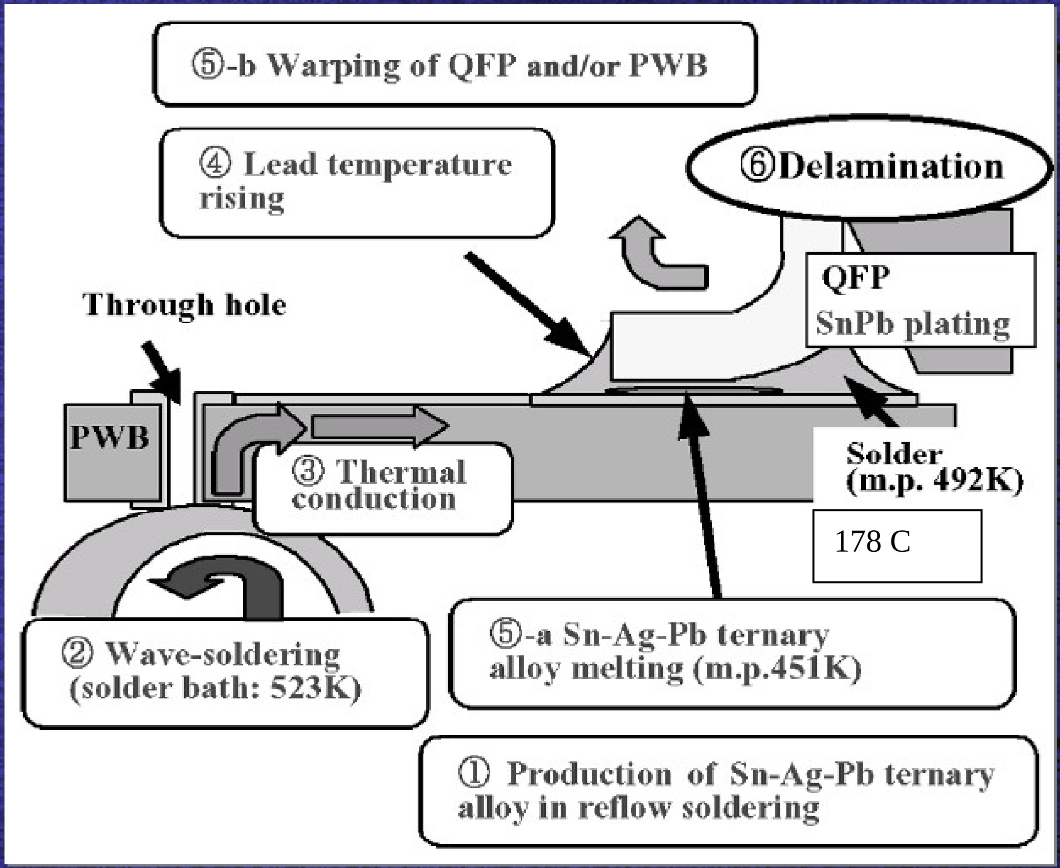
Repair Activity: NAVSEA Crane-SAIC-Purdue

- 20 year service life requires repair
- MAJOR Considerations
  - Tin Whiskers
  - Solder Joint Reliability
  - Copper Dissolution
  - Cross-Contamination of Alloys in Repair
- LESSER Considerations
  - Processing Temperatures in Assembly
  - Many Lead Free Solder Alternatives
  - Equipment/Chemistry Appropriate for Depot Repair
  - Training/Re-Training of DoD Repair Personnel
  - Supply System Screening for Lead Free

Ref: Denny Fritz – SAIC "Tin whisker" telecon presentation, July 25, 2007

Rework

- Momokawa, Y., and Ishizuka, N., "Delamination by Reheating in SMD Solder Joint Using Lead-Free Solder," NEC Res & Devlop., Vol. 44, No. 3, July 2003 pp. 251 – 255. http://www.nec.co.jp/techrep/en/r_and_d/r03/r03-no3/rd09.pdf
  - The author suspects that a somewhat lower melting point alloy (Sn-Ag-Pb, MP=451K) contributed to the separation of a SMT gull wing solder fillet during a wave soldering operation.



Technical Highlights for the next revision

- Thermal Aging and Vibration Performance
- Isothermal Fatigue

Agenda

1. Lead Free Transition and Impacts
2. **Lead Free Failure Modes**
3. A Comprehensive Lead Free Strategy
4. GEIA Lead Free Standards and Handbooks
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 “Tin Whisker Document
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. Summary
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

Agenda

- Overview, Concerns and the Need
- The LEAP Lead-Free Test Team
- Scope and Purpose of the Document
- Recent Issues
- Recent Accomplishments
- Schedule
- Final Comments

Overview, Concerns, and the Need

- Concerns with lead-free solder
  - Interconnection performance characteristics
    - Fatigue life, Mechanical strength
  - Effects of lead-free/mixed finishes (e.g. tin whiskers phenomenon)
    - This is a rapidly approaching threat to the long-term reliability of many military, avionics, and space programs.
  - Conversion of In-house lines to lead-free
  - Repair/Rework
  - Configuration Control

This document focuses on the interconnection performance characteristics

PRESENT STATE

Over the past several decades, electronics manufacturers have developed methods to conduct and interpret results from reliability tests for lead-bearing solder alloys. Since these alloys have been used almost universally in all segments of the electronics industry, and since a large body of data, knowledge, and experience has been assembled, the reliability tests for lead-bearing solder alloys are well-understood and widely accepted. When it became apparent that the use of lead-bearing alloys would decline rapidly, a large number of programs were implemented to evaluate the reliability of the lead-free interconnections.

The lead-free alloys represent a great number of material combinations, all of which have different material properties which influence test approaches. Board and component finishes also need to be considered. Thus, focus must include the concept of a lead-free system.

Overview, Concerns, and the Need

- Impacts
  - Global transition to lead-free electronics has significant impact on the electronics industry
    - Especially disruptive to aerospace and other industries that produce electronic equipment for high performance applications
    - Aerospace and High Performance (AHP) is characterized by rugged severe or harsh operating environments, long service lifetimes, and high consequences of failure.
    - AHP electronics also must be reparable at the soldered assembly level.
    - Typically, AHP industry production volumes are low; they can neither drive nor resist the transition to lead-free electronics
    - Reliability tests conducted by suppliers cannot be assumed to assure reliability in AHP applications

Document provides a framework for a test methodology concerning lead-free electronic assemblies

Overview, Concerns, and the Need

- The Need
  - What's needed is a document that provides guidance and direction which will enable designers, manufacturers, and maintainers of AHP electronics to develop and conduct performance tests of lead-free interconnections.

This presentation will provide a status report on progress in generating the document

The LEAP Lead-Free Test Team

Boeing	Curtis Wright Controls, Inc.
Raytheon Company	EADS Deutschland GmbH
Smiths Aerospace	ITB
DfR Solutions	Rockwell Collins
Thales Research & Technologies France	AMCOM
Lockheed Martin Corporation,	United Technologies
BAE Systems Platform Solutions	Celestica
University of Maryland CALCE EPSC	NAVAIR
Goodrich Corporation	Medtronic
SAIC	Sun Microsystems
Meehan Electronics Corporation	Aerospace Industries Association of America, Inc.
Honeywell	Rolls-Royce North America Inc.
NWSC-Crane	SAIC
JCAA	New Mexico Tech

Scope and Purpose of the Document

- Document Outline of Contents
  - Introduction
  - Scope
  - Default Test Methods
  - Test Protocol
  - Other Information

Scope and Purpose of the Document

- General Overview
  - Important distinctions and clarifications
    - This document provides the “how to test” information
    - Solder alloy refers to that material used as the electrical/mechanical interconnection
    - References to platings/finishes will be specified separately but are included in the concept of a solder system
      - This document will not address whisker formation (covered in GEIA-STD-0005-2 and GEIA-HB-0005-2)

The intent of the document is to provide a default method and to provide requirements for alternative methods so that avionics/defense suppliers can satisfy the reliability requirement of GEIA-STD-0005-1.

Scope and Purpose of the Document

- Objectives
  - Provide a conservative default method for testing of AHP interconnections containing lead-free solder to facilitate reliability analysis, generic qualification, product-specific qualification, and similar activities
    - The default method is intended for use by electronic equipment manufacturers, repair facilities, or programs who, for a variety of reasons, may not be able to commit the resources to develop their own methods.
  - Provide a guideline protocol, for designing and conducting one's own tests in order to facilitate interpretation of results from reliability analysis.
    - The protocol is intended for use by manufacturers or repair facilities with the necessary resources to design and conduct performance tests that are specific to their processes, products, and/or new materials

Approach would include linking material properties and other failure mechanisms !

Scope and Purpose of the Document

- Environment (Associated Tests)
  - Thermal cycling
  - Combined Environments
  - Vibration
  - Mechanical Shock

Document will provide guidance in selecting those tests that best represent use environments. The initially released version of this document will address only the above four tests. Other tests can be addressed if needed by individual organizations.

Recent Issues

- Vibration and Shock Methods
  - Deciding on referenced IPC method versus MIL-STD-810 vs program required or a combination or worst case
    - Both default and protocol cases
  - Re-look at levels; consider common sense levels to prevent overstress
- Combined Environment
  - No default approach
  - NASA/DoD LFE approach provided as information
  - Consensus is to consider a life cycle approach in designing a test program
- Acceleration Model
  - Improve comprehensibility
  - Appendix B data (presently for SAC 305)
- Considering a section on how to use the document
- Emphasize the flexibility/tailorability of the standard

Recent Accomplishments

- Improved Introduction and Scope
- Test Vehicles
  - Working card versus coupon
- Sample Sizes
  - Flexibility provided
- Default pre-conditioning method (applicable to protocol as well)
  - Thermal aging
- Default thermal cycling method
- Failure analysis methodology
  - Three approaches with “qualifiers” for each
- Concurrence on a life-cycle approach for Combined Environment Test
  - Option of considering straight combined versus sequential-cumulative (e.g. Miner’s Law) approaches

Schedule

- All outstanding team actions completed by 30 September 2007
- Incorporation of actions/inputs into document by 7 October 2007
- Final team review and comments by 29 October 2007
- Prepare document for GEIA ballot by 30 November 2007
- Submit for ballot January 2008

Final Comments

- The document does not give the answers
- Provides direction/guidance in developing suitable interconnection performance tests
- “Engineers will have to be engineers” to use the document
  - Logical, sound judgment
  - Flexibility
  - Concurrence

Thank You

- Your inputs are welcome…..Please forward them to
  - Anthony_J_Rafanelli@raytheon.com
    - 401.842.4850

Anthony J. Rafanelli
Raytheon Integrated Defense Systems
1847 West Main Road
Portsmouth, RI 02871
401.842.4850
FAX: 401.842.5239
Anthony_J_Rafanelli@raytheon.com

Agenda

1. Lead Free Transition and Impacts
2. **Lead Free Failure Modes**
3. A Comprehensive Lead Free Strategy
4. GEIA Lead Free Standards and Handbooks
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 “Tin Whisker Document
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. Summary
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

Repair / Rework Document

GEIA-HB-0005-3

Rework, Repair and Maintainability for Aerospace and High Performance Electronics Containing Lead-free Solder

Handbook Contents

Scope

- This document provides technical background, procurement guidance, engineering considerations and guidelines to assist organizations repairing and/or reworking aerospace and high performance electronic systems, whether they were assembled or previously repaired/reworked using traditional alloys such as Tin-Lead or Lead-free (Pb-free) alloys, or a combination of both solders and surface finishes. This document contains a review of known impacts and issues, processes for rework and repair, focused to provide the technical structure to allow the repair technician to execute the task.

Handbook Contents

- Major Sections of the Handbook
  - Pb-Free Concerns
  - General Rework Requirements
  - Solder Joint Reliability Considerations
  - Conductive Rework
  - Convective Rework
  - Lead Detection Methods
  - Printed Circuit Board Labeling Systems
  - BGAs – (currently in work)

Handbook Status

- Currently in DRAFT form
- Applicable to Commercial and Military Repair and Rework
- Applicability
  - Program Managers
  - Process Engineers
  - Technicians
  - Quality Assurance Inspectors

How Can You Join the HB-0005-3 Team?

- It's Simple!
- Email Tim Kalt and he will cheerfully waive the application fee and add you to the Team!

Tim Kalt
Lead Free Electronics POC
Bomber Wing
326 AESW, Wright-Patterson AFB, OH
(937) 656-5095
timothy.kalt@wpafb.af.mil

Agenda

1. Lead Free Transition and Impacts
2. **Lead Free Failure Modes**
3. A Comprehensive Lead Free Strategy
4. GEIA Lead Free Standards and Handbooks
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 "Tin Whisker Document
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. Summary
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

What is the Reliability Document?

- **GEIA-HB-0005-4** Reliability Assessment for Aerospace and High Performance Electronics Containing Lead-free Solder

This document will describe the methods of reliability assessment, modeling, reliability impacts on design, and failure rate predictions. This effort is underway and we are defining the content.

GEIA-HB-0005-4 Methodology

- Purpose of Methodology section
  - Define what's needed to do an analysis
  - Explain the "why's" of what's needed
- Define environment
  - Define bounds for LRU environments, e.g. avionics, engines, etc.
    - Allow for actual measurements or similarity from like product
    - Point to other documents if available
  - Component-level environments needs to be addressed by separate analysis
    - Measurement of actual hardware
    - Analytical models for steady state temperature, ramp rate, etc.

GEIA-HB-0005-4 Assessment

- Process
- Inputs
- Analysis
- Format

GEIA-HB-0005-4 Status

- Initial Team established
- Additional support is needed
- Contact LEAP-WG for participation

Agenda

1. Lead Free Transition and Impacts
2. Lead Free Failure Modes
3. A Comprehensive Lead Free Strategy
4. GEIA Lead Free Standards and Handbooks
   - GEIA-STD-0005-1 Performance Standard
   - GEIA-STD-0005-2 "Tin Whisker Document
   - GEIA-HB-0005-1 Program Management Guidelines
   - GEIA-HB-0005-2 Technical Guidelines
   - GEIA-STD-0005-3 Performance Testing
   - GEIA-HB-0005-3 Rework and Repair
   - GEIA-HB-0005-4 Reliability Assessment
5. **Summary**
   - Acknowledgements
   - Lead Free Links
   - Points of Contact

"Lead-Free" Electronics

- Many DoD programs will NOT go lead-free
  - There are risks in current science and materials

- A Strategy (i.e.: Lead Free Control Plan) is needed whether a program makes the transition or not

Lead-free strategy must address all aspects of program

Lifecycle support

- Lead-free solder control plan
- Repair strategy
- Configuration control

Reliability

- Component reliability
- Solder joint reliability
- Test / Re-qualification ?

Tin whiskers

- Risk Assessment
- Mitigation methods
  - AVOID the use of PURE TIN
  - Hot solder dip
  - Conformal coating
  - Use of qualified finishes

What We Can Do ???

- **Stay informed**
- **<u>Join AIA-GEIA-AMC LEAP-WG and help with implementation of the Standards</u>**
- **Use the GEIA documents to assist with the lead-free transition of your programs**
- **For Existing Programs**
  - **Consider <u>intent</u>** of GEIA-STD-0005-1 for use on your program
  - Assess compliance of Suppliers' lead-free processes to <u>intent</u> of GEIA-STD-0005-1
- **For New Programs**
  - **Establish contract language** that imposes requirements of GEIA-STD-0005-1 and GEIA-STD-0005-2
  - Assess overall compliance of Suppliers' lead-free processes to GEIA-STD-0005-1

DoD Response to Lead-Free

- There is a global transition to lead-free
  - Lead-free solder issues
  - Tin whisker risks
  - Availability of leaded solder and components
  - New repair processes
  - Configuration control challenges
- The RISK is real…
  but it can be managed
- An extensive Government-Industry strategy is underway
- Programs must manage the transition and better engage their supply chain

*The DoD must **continue** to field reliable and supportable systems to meet mission requirements*

Thank you !!!

The ELF IPT wishes to recognize the efforts of all whom have contributed to this curriculum

- **Executive Lead Free Integrated Process Team (ELF IPT)**
- **AIA-GEIA-AMC LEAP-Working Group**
- **Defense Microelectronics Activity (DMEA)**
- **American Competitiveness Institute (ACI)**

- Fred Verdi, ACI
- Lloyd Condra, Boeing
- Pat Amick, Boeing
- Anduin Touw, Boeing
- Tim Kalt, USAF
- Mick Miller, NSWC Crane
- Rusty Rentsch, AIA
- Vance Anderson, DMEA
- Tony Rafanelli, Raytheon
- Stephan Meschter, BAE Systems
- John Biel, Smiths Aerospace
- Dave Humphrey, Honeywell
- Jay Brusse, NASA
- And many others!

Lead-Free Electronics References

ACI http://www.aciusa.org
ELF IPT http://www.leadfreedod.com
IPC Lead Free Soldering Forum http://www.leadfree.org/
JG-PP Lead Free Soldering http://www.jgpp.com/
International Center for Manufacturing Sciences http://www.ncms.org/
National Electronics Manufacturing Initiative http://www.nemi.org/
National Institute of Standards & Technology http://www.boulder.nist.gov/div853/lead%20free/solders.html
CALCE at University of Maryland http://www.calce.umd.edu/
Soldertec http://www.lead-free.org/
The SMART GROUP http://www.smartgroup.org/
National Physical Laboratory http://www.npl.co.uk/
High Density Packaging User Group (HDPUG) http://www.hdpug.org/
International Tin Research Institute http://www.itri.co.uk
Japan Electronics and Information Technology Industries Association (JEITA) http://www.jeita.or.jp/index.htm
NASA GSFC Tin Whisker Homepage http://nepp.nasa.gov/whisker/index.htm
Tin Whisker Alert Group http://www.calce.umd.edu/lead-free/tin-whiskers/
iNEMI Tin Whisker Page http://www.nemi.org/PbFreePUBLIC/index.html
Raytheon RAL homepage – Tin Whisker Risk Algorithm http://www.reliabilityanalysislab.com
Department of Trade and Industry http://www.dti.gov.uk/sustainability/
NetReg http://www.environment-agency.gov.uk/netregs/legislation/380525/477158/?lang=_e
EPA Toxics Release Inventory (TRI) Program http://www.epa.gov/tri/lawsandregs/lead/tri_pb_rule.htm
Allen & Overy http://www.allenovery.com

Points of Contact

ELF IPT

Vance Anderson
Defense Microelectronics Activity
(916)231-1646
anderson@dmea.osd.mil

LEAP-WG

Rusty Rentsch
AIA
703-358-1054
rusty.rentsch@aia-aerospace.org

Lloyd Condra
Boeing
206-655-8240
lloyd.w.condra@boeing.com