

**Leadfree Solder**

**DRAFT**

and

**Tin Whiskers**

**Program Guidance**

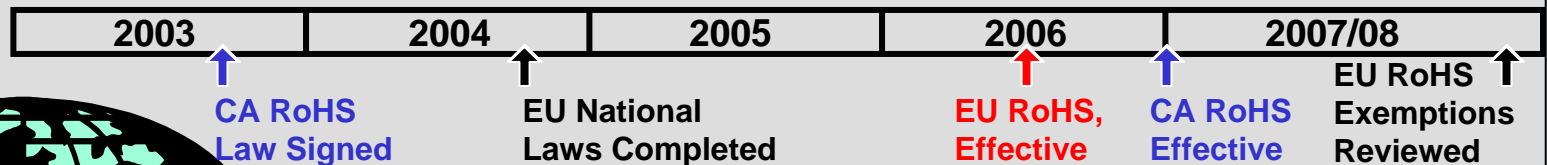
**DRAFT**

# Lead-free Electronics: A New Type of Environmental Issue for the Aerospace Industry

- 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



## Key Compliance Milestones



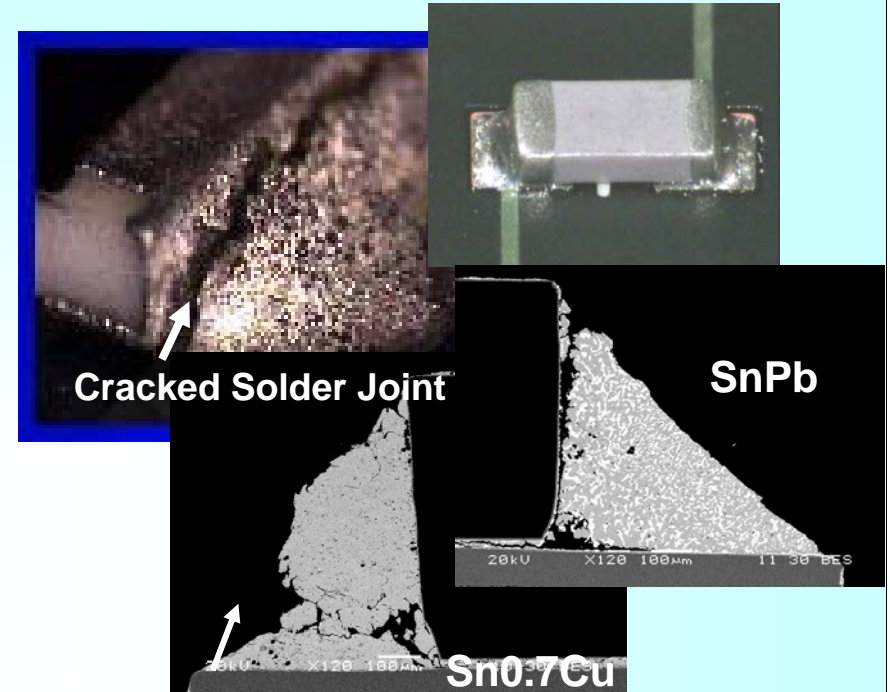
**The Global Electronics Industry Is Transitioning to Lead-free Electronics**



# Lead-free Electronics

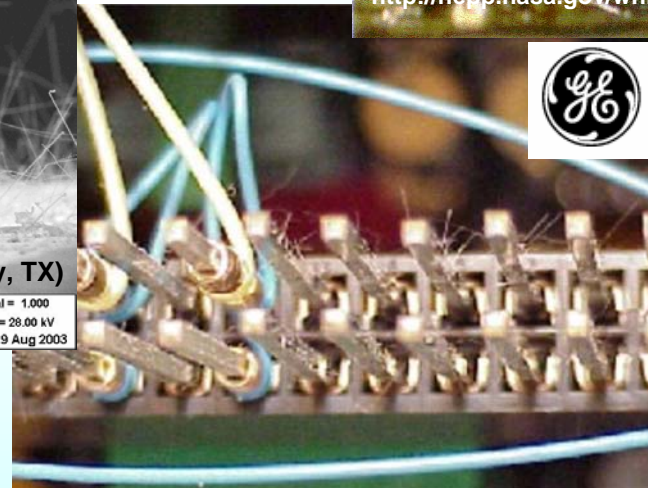
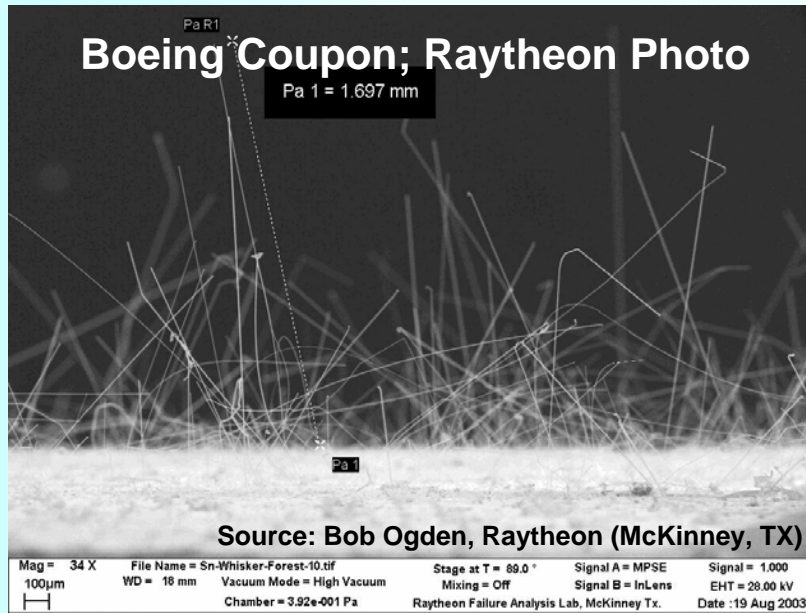
## Technology Issues Summary:

- No direct replacement for (Pb) solder
  - Lead (Pb) free alternatives higher melting points  
183°C for SnPb; 214°C to 227°C for Pb-free (melt point)
  - Semiconductors and microcircuits will see  
250°C to 270°C for 15 to 30 seconds
  - Impact to microcircuit encapsulation and die are unknown
  - Increased risk of measling, board delamination, and lifted pads
  - Processes to maintain reliability solder joints requires tighter controls
  - Pb-free alloys- greater shrinkage than Pb solder which can pull pads and cause joint cracking
- Higher tin concentration and Pb-free solder grain structure ideal for formation of tin whiskers
  - Compressive stresses relieved by ionic migration along columnar grain structure



# Transition to Pb-free Components Increases the Probability of Tin Whisker Related Electronics Failures

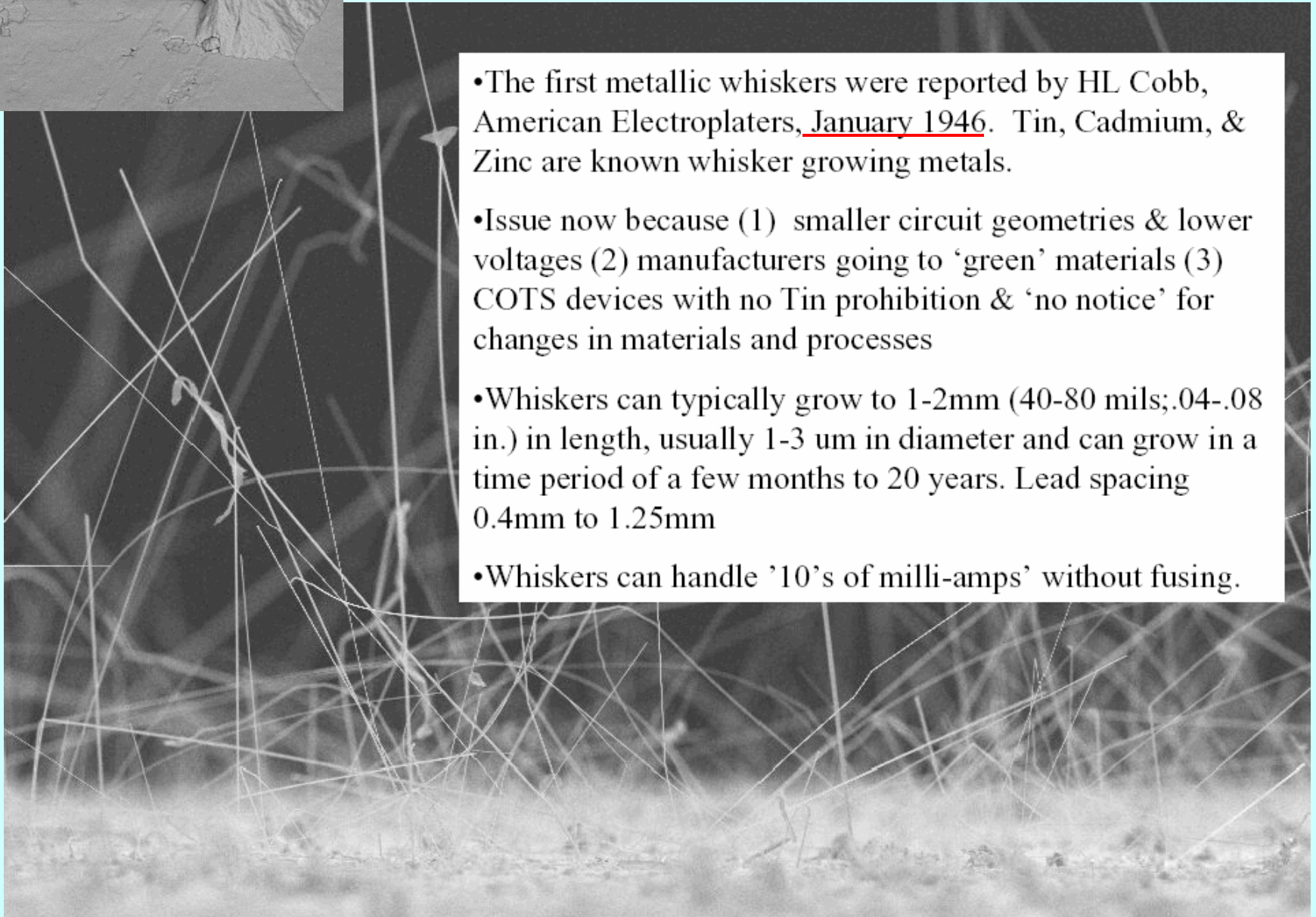
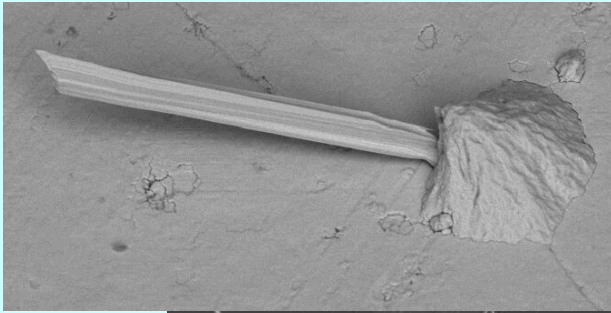
Component suppliers have transitioned to pure tin finish



- Whiskers are high aspect ratio, essentially perfect single crystals

- Crystal growth can be seen in 3000 to 6000 hrs

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



- The first metallic whiskers were reported by HL Cobb, American Electroplaters, January 1946. Tin, Cadmium, & Zinc are known whisker growing metals.
- Issue now because (1) smaller circuit geometries & lower voltages (2) manufacturers going to 'green' materials (3) COTS devices with no Tin prohibition & 'no notice' for changes in materials and processes
- Whiskers can typically grow to 1-2mm (40-80 mils;.04-.08 in.) in length, usually 1-3 um in diameter and can grow in a time period of a few months to 20 years. Lead spacing 0.4mm to 1.25mm
- Whiskers can handle '10's of milli-amps' without fusing.

## Procurement of Parts

- Industry and DESC (DLA) procure parts from distributors
  - Procurement quantities are too small and buys are sporadic
  - Supporting low rate production and sustainment
- Distributors do not segregate parts and mixed date codes will be used to fill orders
  - Component manufacturers produce parts on multiple production lines
    - Encapsulant differs
    - Lead finish can differ
- Component Manufacturers have not provided configuration on the part or within the part number what the lead finish is provided
  - Initially component coming out of Asia were using SnBi
    - Poor reliability (fatigue life substantially lower than PbSn)
  - Some manufacturers have both Pb and Pb-free finishes
  - Bright tin and Matted tin are pure tin finishes
    - Bright tin applied through a plating process can have contaminants
- **IMPACT –**
  - Do not know what lead finish we have
  - Parts with mixed lead finish are throughout the supply system
  - Impact to rework processes and reliability of the solder joint compromised

# Industry Status

- No definitive direction
- Guidance is coming but is slow
- Results from studies are inclusive

IPC has issued

IPC-J-STD-001D – Manufacturing processes

IPC-610D – Inspection acceptance criteria

GEIA has draft in-work (planned release in CY07)

GEIA-STD-0005-1, Performance Standard for Aerospace and Military

Electronic Systems Containing Lead-free Solder

GEIA-STD-0005-2, Standard for Mitigating the Deleterious Effects of Tin in

High Reliability Electronic Systems

JEDEC has been released May 05

For labeling of Pb-free components and assemblies



# Processes Changes

- Programs need to have a plan for transition and design development of new systems. Use of GEIA-STD-0005 documents as guidance
  - Component selection and parts control plan
  - Manufacturing processes
  - Tin whisker risk management – conformal coating, thermal soak, lead preparation, etc
- Design processes and means of managing design conditions.
  - Component derating and thermal management
  - Shock and vibration – allowable board level deflection
- Navy needs to specify if formation of tin whiskers creates an unacceptable risk to reliability and/or safety through the use of risk or safety hazard analysis
  - Will drive solder alloy selection and manufacturing processes

# Processes Changes

- **Solder alloy system** – Select a system with SAC alloy composition
  - Sn – , Ag – 3.0% to 4.0%, Cu – 0.5% to 0.6% Recommended by NIST
  - Alloys consistent characteristics while providing a reliable solder connection
- **Thermal Profile** - Modified thermal profile must change
  - J-STD-001 provides recommended profiles for wavesolder, surface mount and rework
  - Tighter processes controls must be maintained to obtain a consistent reliable solder joint
- **Initial problems with solder manufacturers resolved** –
  - Alloy manufactured by weight vs percent alloy composition.
    - Produced inconsistent alloy performance and characteristics -  
- need to verify processes use to create alloy
- **Flux selection** –
  - The higher melt point of the Pb-free solder requires the flux activate at a high temperature.
  - The flux must be more active to achieve proper wetting.

# Processes Changes

## Selection of printed wiring board material –

Must be capable of handling higher soldering temperatures – impacts manufacturing and rework (delamination, measling, warpage, lifted pads, & solder shrinkage)

## Selection of components –

Many component manufacturers have changed some of the encapsulants to withstand higher process temperatures – Need to consider in design component selection

## Conformal coating –

Conformal coatings must be selected as part of tin whisker risk mitigation

Most acrylic coatings would be inadequate. Recommend a two part urethane coating with sufficient thickness or hardness to preclude re-entry of a tin whisker (Paraline effective; however, costly, secondary effects, & rework issues)

## Cleaning processes –

Must be more aggressive to remove the flux residue

Processes must be properly integrated to be effective

# Processes Changes

## •Rework

- It is not recommended that a PbSn alloy be mixed with SAC alloy.
- Recommend the Navy seriously consider adding hot gas rework equipment.
  - NIST report addressing rework equipment available.

•**Legacy Systems** – The Navy needs to determine what components can be reworked within I and D level maintenance facilities. (Navy can not currently rework BGAs or many of the small pitch surface mount devices)

- Components with pure tin finish must be tinned prior to installation
- Components with SnBi or Zn need to have the finish stripped off and PbSn tinned
  - PbBi Results in a low melt temperature compound
  - Poor reliability performance. Can not handle thermal cycle or fatigue
- Current rework processes would not need to change; however, many of the practices used for Pb-free would be recommended

# Processes Changes

## •Rework

- New Systems utilizing Pb-free solder – Navy needs to specify alloy system in new acquisitions to ensure rework compatibility.

  - Components with pure tin finish must be tinned prior to installation

  - Higher solder iron temperature applied to individual pins poses higher risk of lifting pads.

  - Need to bake components prior to attempting to install on a PWB.

    - Popcorning is an even greater problem with Pb-free to avoid.

  - Conformal coatings will require harsh solvents to soften and remove. It is not recommended that acrylic coating like be Humiseal be used any longer.

    - The Navy needs to specify a family of conformal coatings to preclude the requirement of maintaining a large quantity of haz-mat and the requirement for personal trained in mixing multiple coatings

- IPC-J-STD-001D addresses general rework guidelines.

- Navy personal will need to be re-trained for properly rework and inspection of Pb-free solder connections