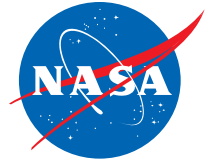


National Aeronautics and Space Administration



# Lead-Free Electronics: Issues & Concerns

2009 International Workshop on Environment and Alternative Energy

November 11, 2009

[www.nasa.gov](http://www.nasa.gov)

# Lead-Free Movement

In July 2006- Europe's ***Restriction on use of certain Hazardous Substances (RoHS) Directive*** will severely limit use of lead (Pb) and other substances in manufacture of consumer electronics sold to Europe

- Rationale: Fears over “*perceived*” harm to environment from disposal of electronic goods containing (Pb)
- Other regions are contemplating / implementing similar legislative actions to discourage use of Pb in electronic goods (e.g., China, Japan)
- US does Not have any similar federal legislation pending (some states are considering action)

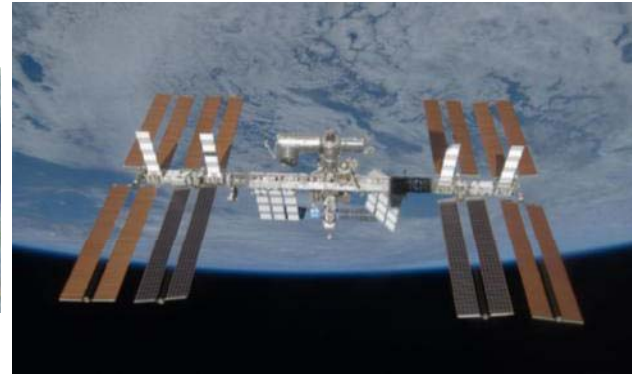
Commercial industry transitioning to Pb-free processes is well underway in order to comply and remain globally competitive

- Exemptions exist for military / aerospace, but this market sector is increasingly dependent on “commercially-available” items

# Why are Lead-Free Electronics a Problem?

Military / Aerospace / High Performance systems have unique requirements:

- High reliability and critical systems
- VERY long service life
- Extended temperature ranges
- Repairable systems
- Government acquisition programs are increasingly dependent on **commercial** electronic parts and assemblies (COTS = commercial-off-the-shelf)

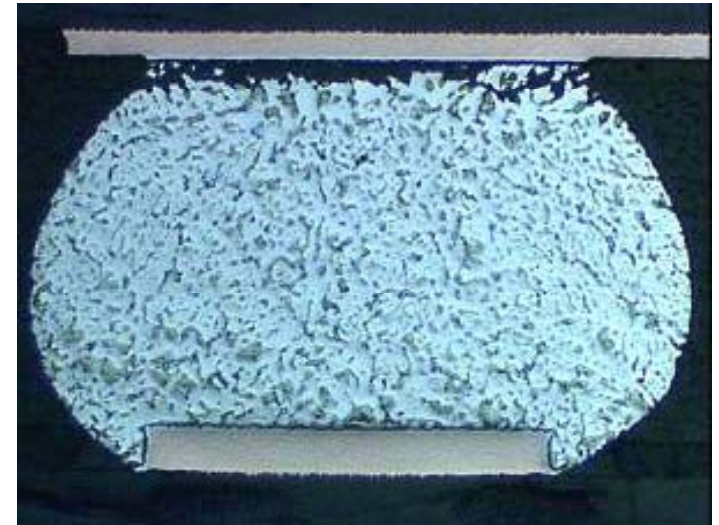


# Lead-Free Impacts

## 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 / High Performance applications



# Predominant Alternatives to Sn-Pb for Electronics Assembly

- Solders

- Tin-Silver-Copper (SAC) Alloys are Now Favored By Industry

- ***Sn3.0Ag0.5Cu (SAC305) – Likely to be Industry Preferred***

- Sn3.9Ag0.6Cu

- Multiple other Pb-free Solder Formulations Exist

- Sn-Ag, Sn-Bi, Sn-Sb, SnAgCuBi, In alloys, et al

- New Pb-free alloys being created

- Sn-Ag-Cu-X, Sn-Cu-(Ni),

- Component Finishes

- ***Pure Tin – Industry Preferred***

- Ni-Pd-Au

- Some Sn-Bi, Sn-Cu, Sn-Ag, Sn-Ag-Cu, Gold, ect.

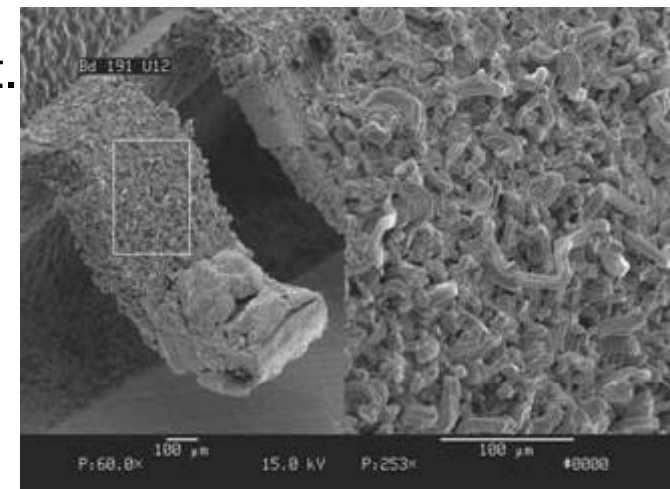
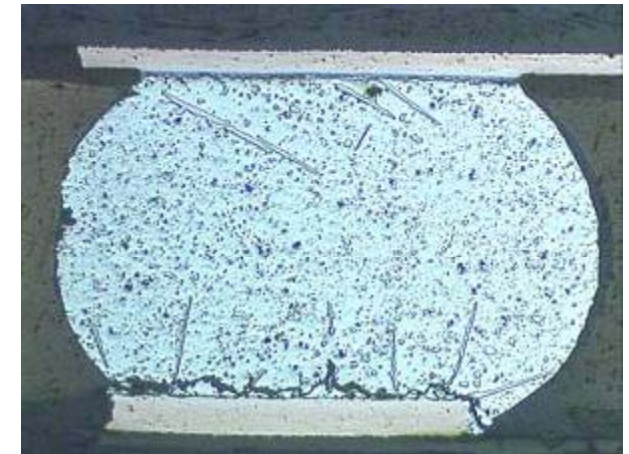
- PWA Finishes

- Immersion Ag

- Immersion Sn

- Electroless Ni Immersion Au (ENIG)

- Organic Solder Preservative (OSP)

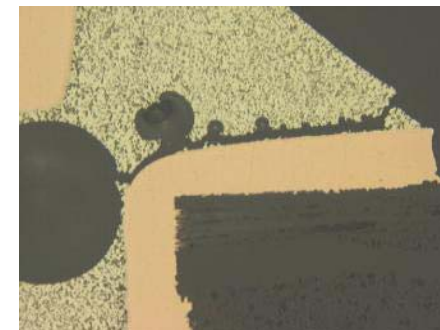
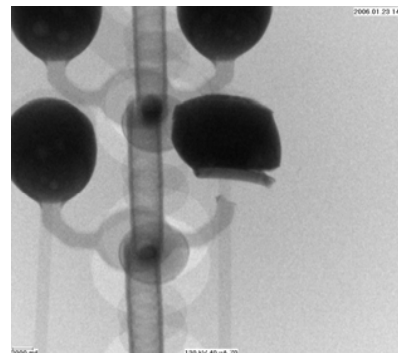
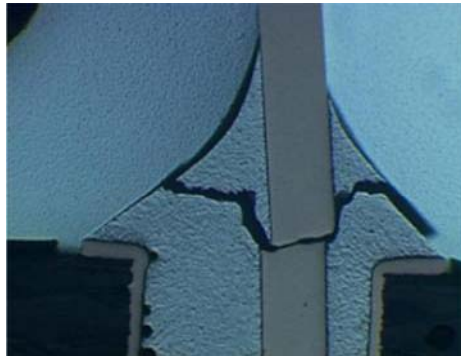


# Impacts of the Pb-Free Transition

The reliability of electronic assemblies may be compromised when a Pb-free component, material or process is used (lead-free solders, materials, etc have **NOT** been verified to meet **Military / Aerospace / High Performance** reliability requirements)

Studies to date show **Mixed Results** but in General:

- Assembling with Sn-Ag-Cu Alloys Appears to be Workable
- Performance of Sn-Ag-Cu in laboratory studies is sometimes Better than SnPb... But Sometimes Worse. Reasons are Not Clearly Understood at this Time
- Reliability Models for Pb-Free Solders are Not Mature Enough Yet to Enable Correlation Between Accelerated Test Results vs. Other Use Conditions

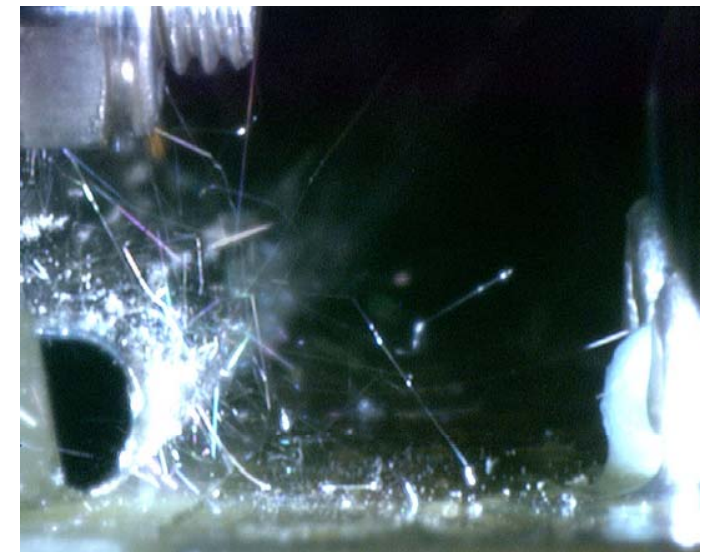
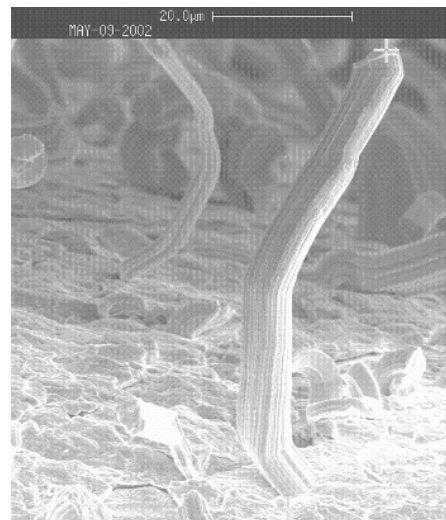
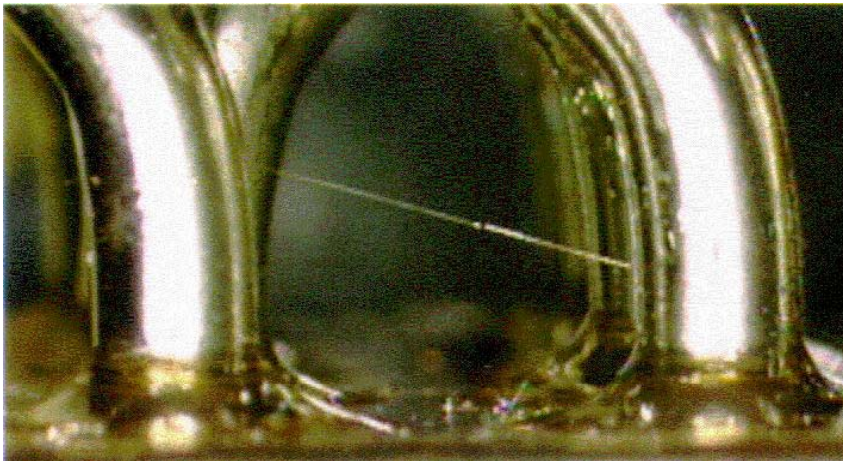


Lead-Free Electronics  
Issues & Concerns

# Impacts of the Pb-Free Transition

## Tin Whiskers

- Industry is Largely Committed to Adoption of Pure Tin Component Finishes as the Prevailing Pb-free Option
- Commercially Pure Tin Finishes Prone to Tin Whisker Formation
  - Known Reliability Hazard with Serious Implications
  - Mitigation Practices Have Benefits and Limitations
- Fundamental Understanding of Tin Whisker Growth Mechanism Does Not Yet Exist
- Validated Test Methods to “Predict” Whisker Propensity Do Not Exist Nevertheless Industry Standards are Being Adopted



# Research Efforts

## Joint Council on Aging Aircraft (JCAA)/ Joint Group on Pollution Prevention (JG-PP) Lead-Free Solder Project

The project objective was to generate comprehensive test data on the reliability of circuit cards newly manufactured and reworked with lead-free solder and subjected to simulated high-reliability (IPC Class 3) environmental conditions.

### Completed Testing

- Vibration
- Mechanical Shock
- Thermal Shock
- Thermal Cycle -55°C to +125°C
- Thermal Cycle -20°C to +80°C
- Combined Environments  
(Thermal Cycle with Vibration)
- Salt Fog
- Humidity

### Conclusions

- Component type has the greatest effect on solder joint reliability performance (greater than does solder alloy) for thermal cycling and combined environments. The plated through-hole components are more reliable than the surface mount technology components for thermal cycling and combined environments.
- The results of this study suggest that for some component types and environments, Pb-free solders are as reliable as the currently used eutectic SnPb solder. Unfortunately, this study also demonstrates that with other component types and environments, the Pb-free solders fail before the SnPb control.
- Under high-stress conditions, SnPb generally outperforms Pb-free. For low stress conditions, Pb-free generally outperforms SnPb.

# Research Efforts

## NASA-DoD Lead-Free Electronics Project

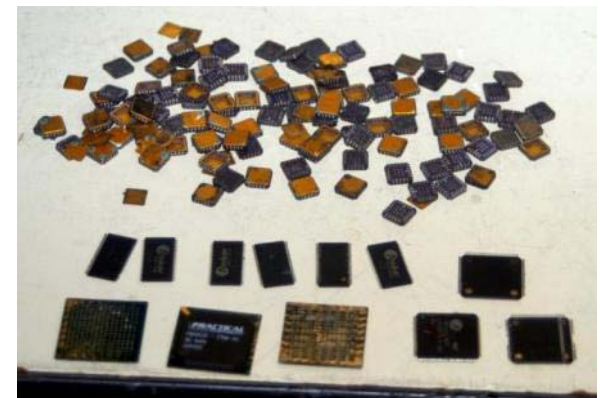
The NASA-DoD Lead-Free Electronics Project testing will build on the results from the JCAA/JGPP LFS Project focusing on the rework (Rwk.) of SnPb and lead-free solder alloys and will include the mixing of SnPb and lead-free solder alloys.

### Testing

- Vibration
- Mechanical Shock
- Drop Testing
- Thermal Cycle -55°C to +125°C
- Thermal Cycle -20°C to +80°C
- Combined Environments  
(Thermal Cycle with Vibration)
- Copper Erosion
- Interconnect Stress Testing

### Progress

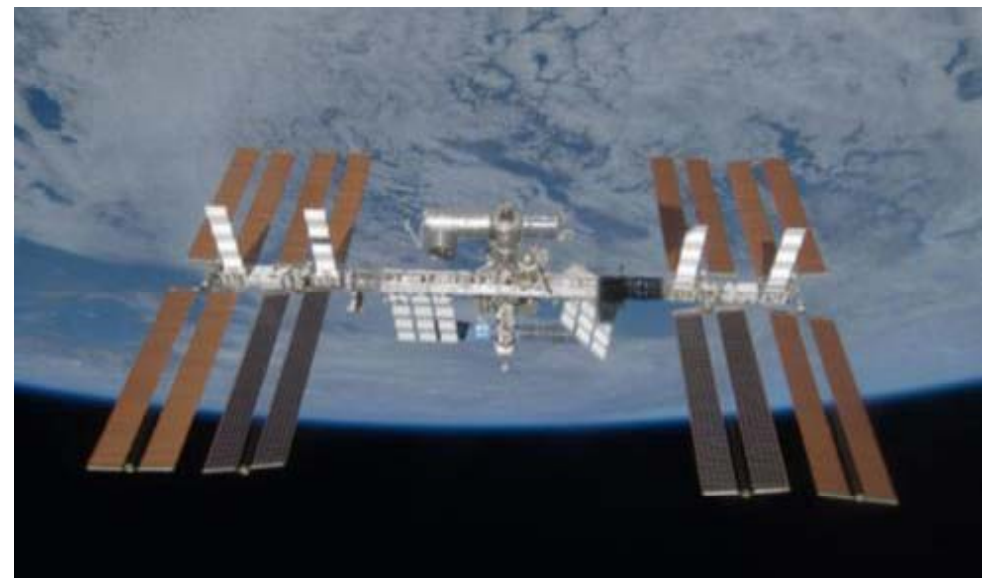
- Combined Environments Testing complete
- Mechanical Shock Testing complete
- Drop Testing complete
- Thermal Cycle -55°C to +125°C = 700 cycles completed
- Thermal Cycle -20°C to +80°C = 2000 cycles completed
- First half of Vibration Testing complete



# Research Efforts

## Lead-free Technology Experiment in Space Environment (LTESE)

- 1 small active package containing test boards and a data acquisition system; integrated into MISSE 7
  - One Im-Ag board with Pb-free parts using Pb-free solder (COTS simulation)
  - One SnPb board with Pb-free parts using SnPb solder (Inadvertent incorporation)
  - One SnPb/SnPb control board (Control board)
  - One data system board
  - Desired environment is exposure to space environment for ~1 year
    - Mission – STS-129
    - Orbiter - Atlantis
    - Launch Target - November 12, 2009



# Next?

## Testing Functional Electronics Assemblies

- Testing has focused on “dummy” test assemblies
- Need test data from functioning assemblies
  - Does Pb-Free affect the functionality of high reliability electronics

## Field Testing

- Testing has focused on laboratory testing
- Need test data from actual harsh environments
  - How will Pb-Free perform in real-world environments





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