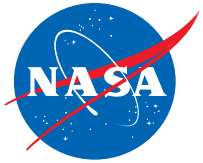
National Aeronautics and Space Administration



Lead-Free Electronics: Issues & Concerns

2009 International Workshop on Environment and Alternative Energy

November 11, 2009

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)

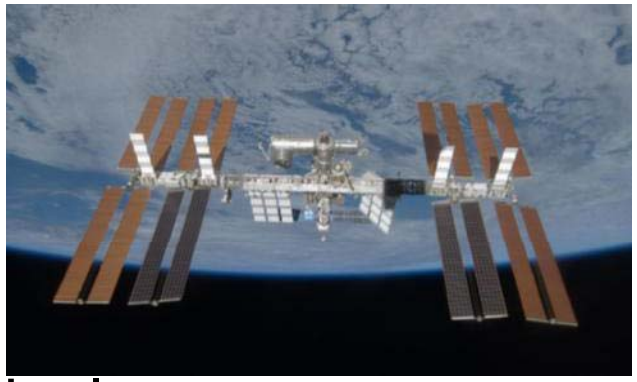
Commercial industry transitioning to Pb-free processes is well underway in order to comply and remain globally competitive

- 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



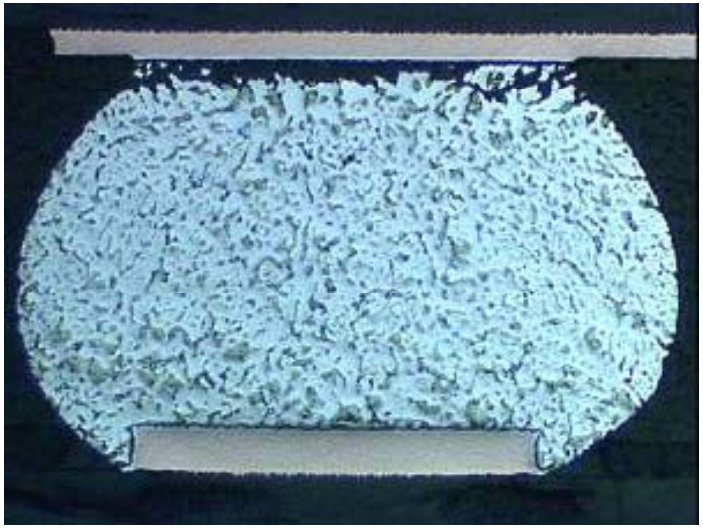
- Government acquisition programs are increasingly dependent on ***commercial*** electronic parts and assemblies (COTS = commercial-off-the-shelf)

Lead-Free Impacts

Primary lead-free impacts

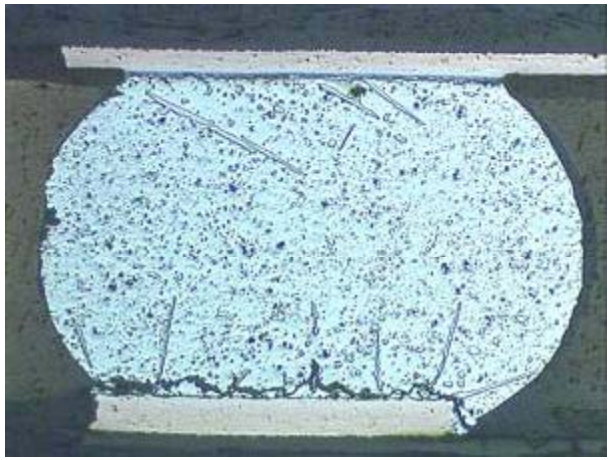
- Lead-free solder issues
- Tin whisker failures
- Availability of leaded solder and components
- Configuration control
- Repair/Rework

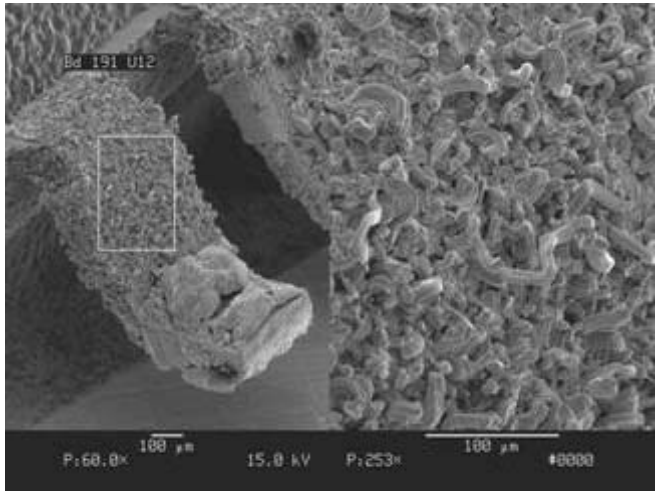
Commercial solution strategies for lead-free may not apply to Military / Aerospace / High Performance applications



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)



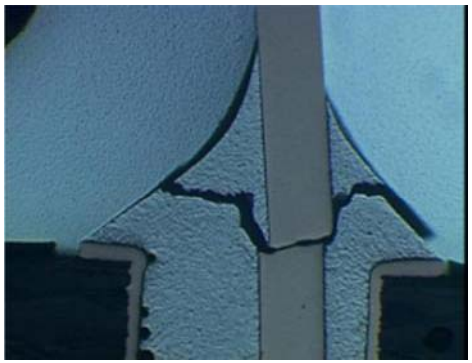


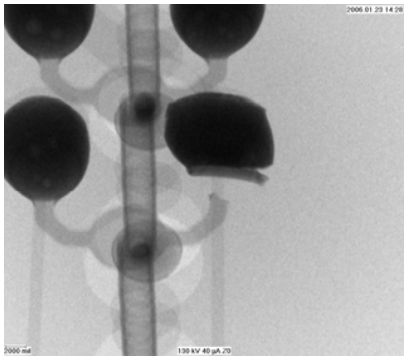
Impacts of the Pb-Free Transition

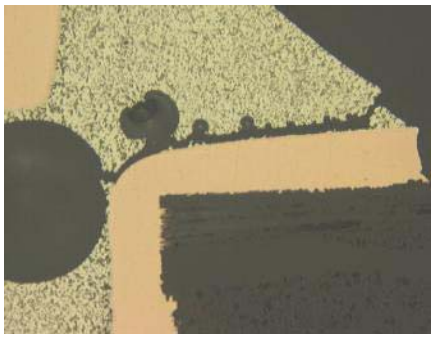
The reliability of electronic assemblies may be compromised when a Pb-free component, material or process is used (lead-free solders, materials, etc have NOT been verified to meet **Military / Aerospace / High Performance** reliability requirements)

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



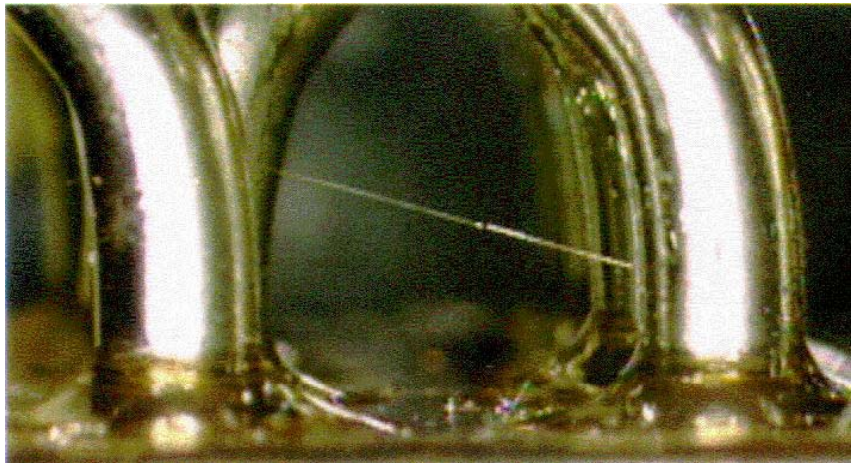


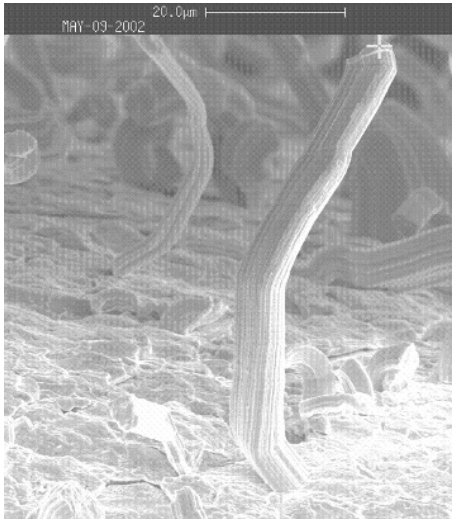


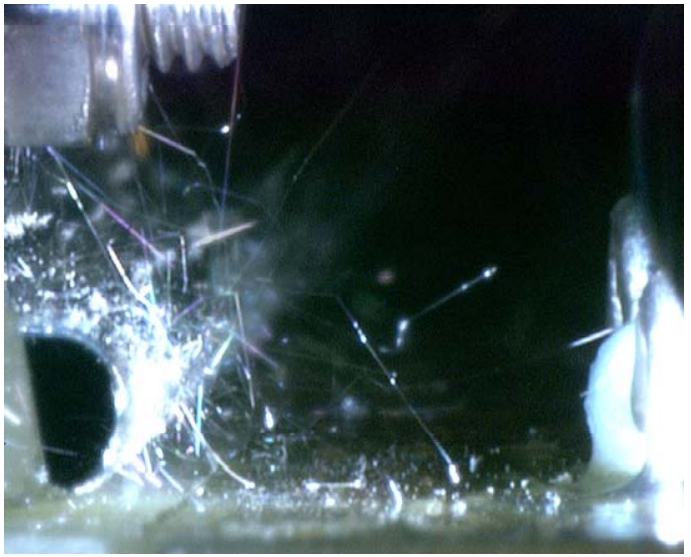
Impacts of the Pb-Free Transition

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.

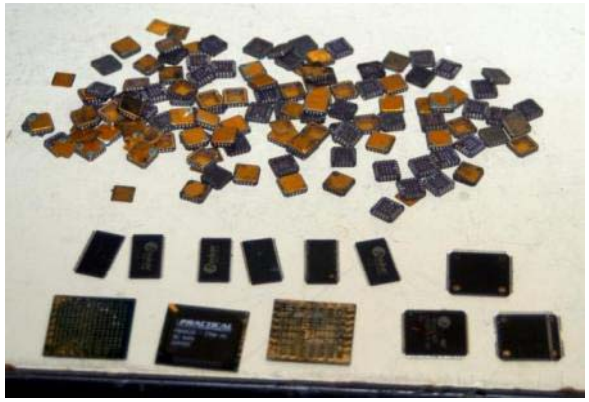
Research Efforts

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



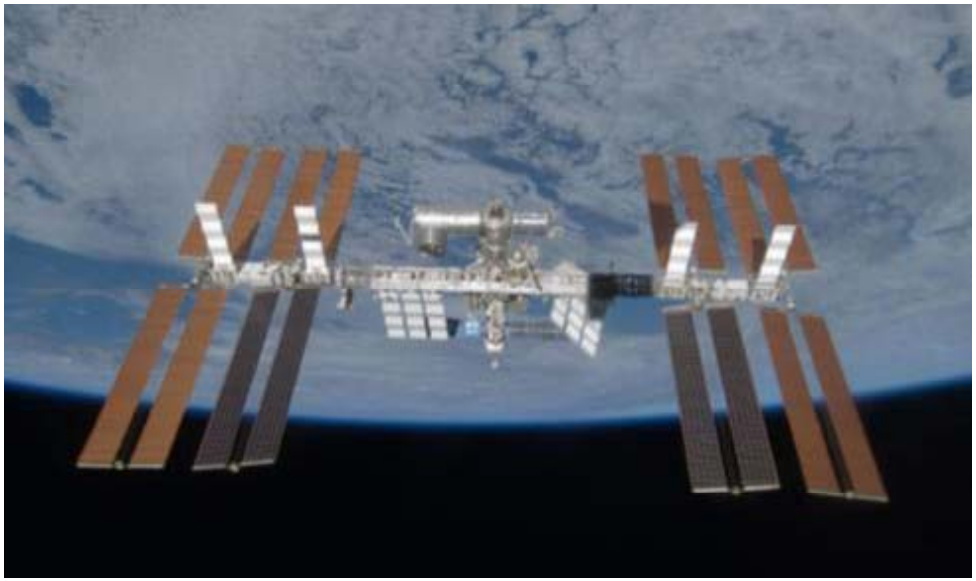
Progress

- 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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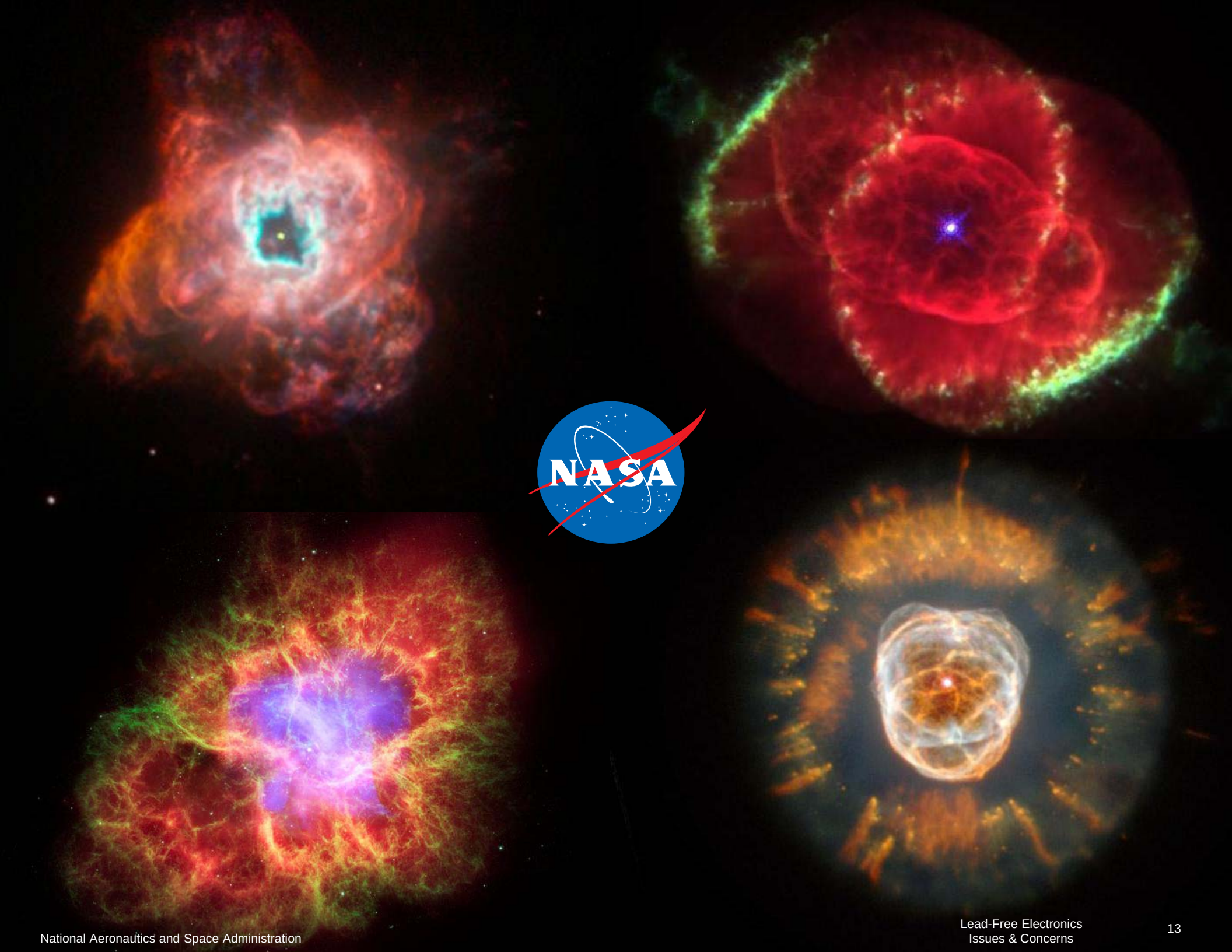
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