DoD Lead-free Electronics Risk Mitigation:
Program Management and Systems Engineering Overview

SERDP/ESTCP Webinar hosted by CALCE

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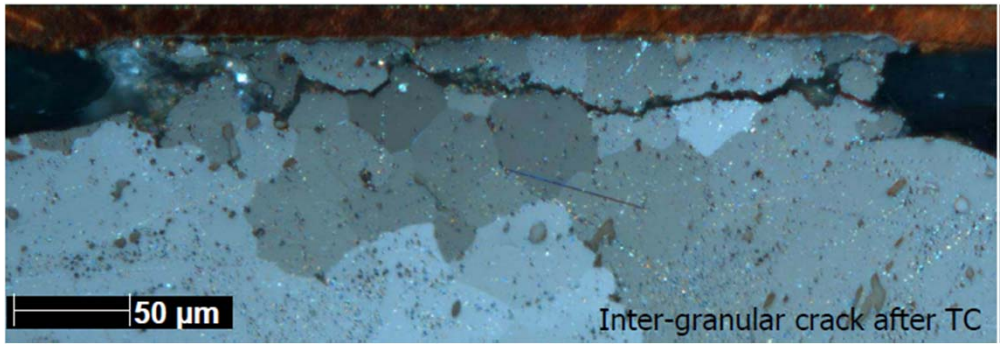
Strategic Environmental Research and Development Program (SERDP)
Environmental Security Technology Certification Program (ESTCP)

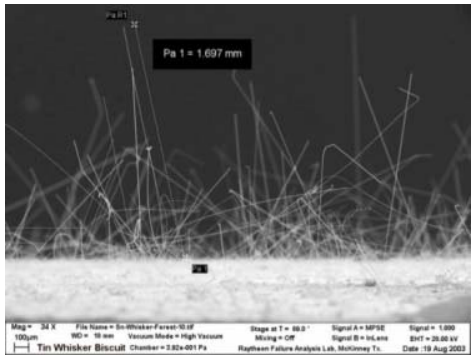
SERDP and ESTCP

Strategic Environmental Research and Development Program (SERDP)
Environmental Security Technology Certification Program (ESTCP)

- **Major sponsors of DoD lead-free mitigation research**
  - SERDP is DoD's environmental science and technology research program
  - ESTCP is DoD's environmental technology demonstration and validation program
  - Two focus areas



Lead-free solder cracking



Tin whiskers & conformal coating mitigation

SERDP Lead-free electronics research areas

Ref: https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Lead-Free-Electronics

Overview

- Global restrictions on lead increasing
  - **2006** Consumer electronics European RoHS legislation
    - 2014-2017 evolved to include servers, telecom, medical …
- DoD/supplier technical community work
  - DoD very reliant on consumer parts and materials
  - Lead-free **NOT Form–Fit–Function** interchangeable
- **Recommendations to programs**
  - **Establish a lead-free control plan (LFCP)**
    - **Materials configuration, use coating for tin whisker mitigation**
    - Use **SAE GEIA-STD-0005-1**
    - Flow down **subcontract data item DI-MGMT- 81772**
  - **Existing tin-lead qualified programs**
    - Are non-qualified **lead-free leaking in? What is new whisker risk?**
    - **Increased cost** to track changes/monitor materials
  - **New programs**: Stay tin-lead or go lead-free
    - **For lead-free:** Select alloy, create design rules, develop test protocols, mfg processes, …

Land

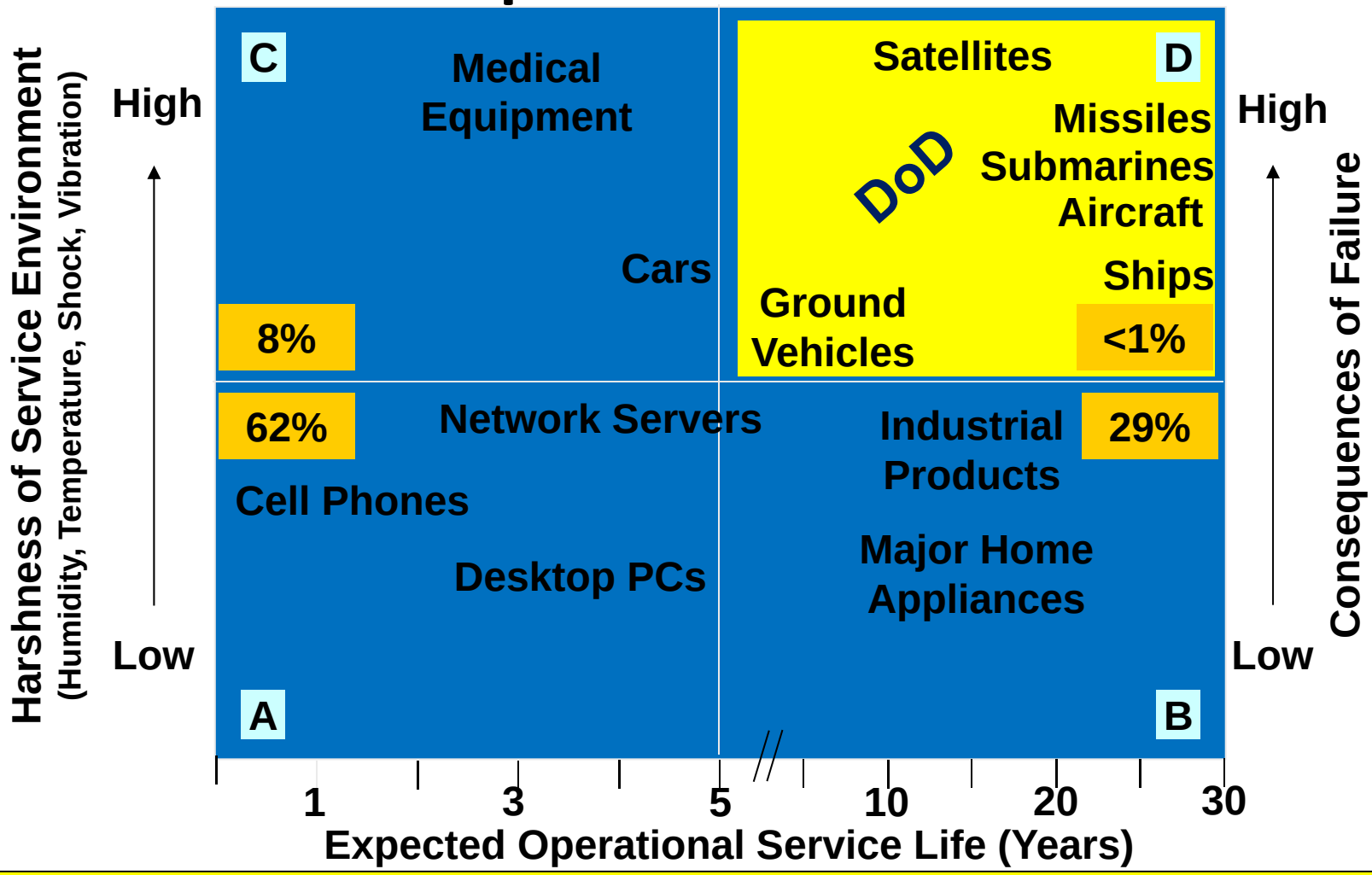
Air

Sea

A material alone is not unreliable;
The design's use of a material determines reliability

RoHS = European Union Reduction of Hazardous Substances Legislation https://www.gov.uk/guidance/rohs-compliance-and-guidance

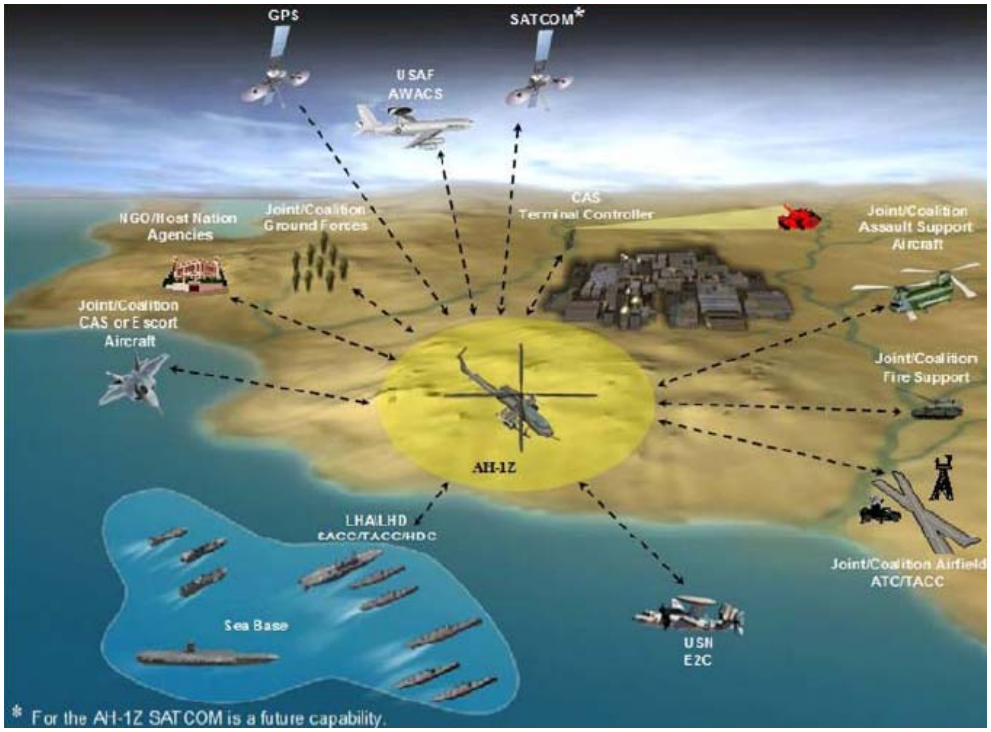
Electronics operating environment versus operational life-time



DoD electronics: Less than 1% market share; unique harsh service, high failure consequence and long service life

Mission success depends on reliable electronics

High electronics usage



Source: On-line US DoD Systems Engineering,PDUSD-Approved-TDS_AS_Outline-04-20-2011.pdf

DoD situation

- ***High Mishap Severity (MIL-STD-882)***

Risks

- ***Push a button and it doesn't go!***
  - ***Broken solder → system fails***
- ***Real-world***
  - ***<u>Safety</u> switch whisker short***
  - *Unknown armed state in storage*

Industry shift to lead-free solder

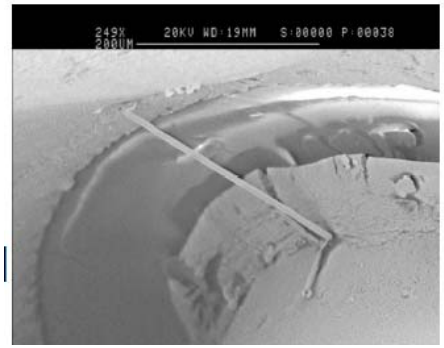
- *Added DoD electronics failure risk*

Biggest concern:

- **<u>Unknown</u>** *lead-free materials used in the wrong place at the wrong time*

Lead-Free electronics – Failure modes & issues

- **Tin whiskers (and zinc whiskers)**
  - Electrical shorts
  - Metal shards, contamination
  - Arc flash metal vapor arc risk
- **Environmental Effects**
  - **Harsh** thermal cycling, shock & vibration
    - **Lower life and brittle interface fractures**
  - **Thermal aging** reduces solder strength
  - **Some early fails beyond ESS defect screening**
- **Configuration control problems**
  - Mixed lead(Pb) and lead-free **inventory**
  - Unidentified component materials
- **Sustainment/Repair**
  - **Incompatibilities** with tin-lead solder
  - **Less-repairable** assemblies



Whisker short circuit failure on a legacy missile accelerometer

Cracked solder joint open circuit

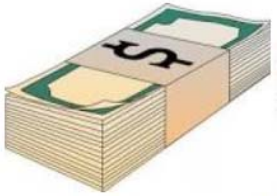
Electromagnetic relay short circuit; 115V metal vapor arc in air

Still DoD unknowns; Mitigate unquantifiable reliability impacts

ESS = environmental stress screening test for manufacturing defects

Three distinct lead-free problems

- **Escalation of acquisition and sustainment cost**
  - Due to the major global reduction in the availability of leaded electronics materials
- **Risk of failure due to tin whiskers is exacerbated**
  - By increased use of pure tin (or majority tin) finishes on components and printed circuit boards
- **Development of a clear understanding of the system performance**
  - **Reliability of new lead-free material sets**
    - **Lead-free solder fatigue, brittle interfacial fractures, tin whiskers, ….**
  - **And the test protocols needed to validate their performance**



Reliability for warfighter

Current status: TODAY

The unknown lead-free content creep can erode design margins and this problem is increasing exponentially with time

Source: 2014 AIA Joint Gov't and Industry Exec. Forum on Lead(Pb) – free Electronics

Case study: NASA Shuttle

What if your team discovered tin whiskers?

- **March 2006:** Flight Control System (FCS) **avionics box failed during vehicle testing**
- **Tin whiskers growth found**
- **July 2006: Active concern for launch**
- **No clean spares**
- **Flight safety analysis**
  - **Coating and redundant safety circuits permit next flight**
- **Cleaning methods developed for remaining flights**

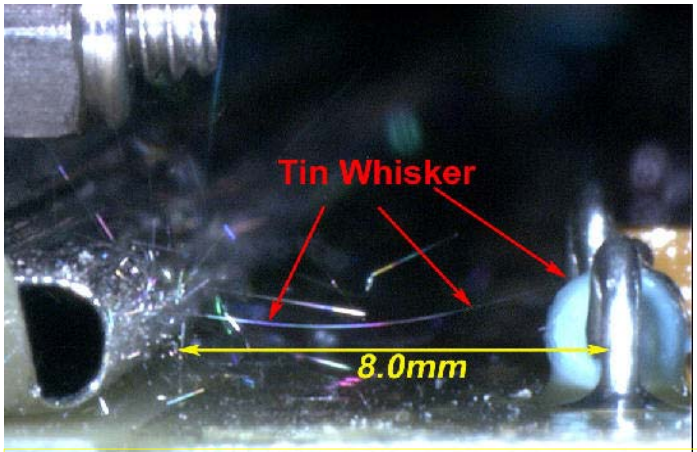


Photo Source: NASA Space Shuttle Program

NASA ~$3.4M problem

Numerous DoD program's have had "undisclosed" tin whisker issues

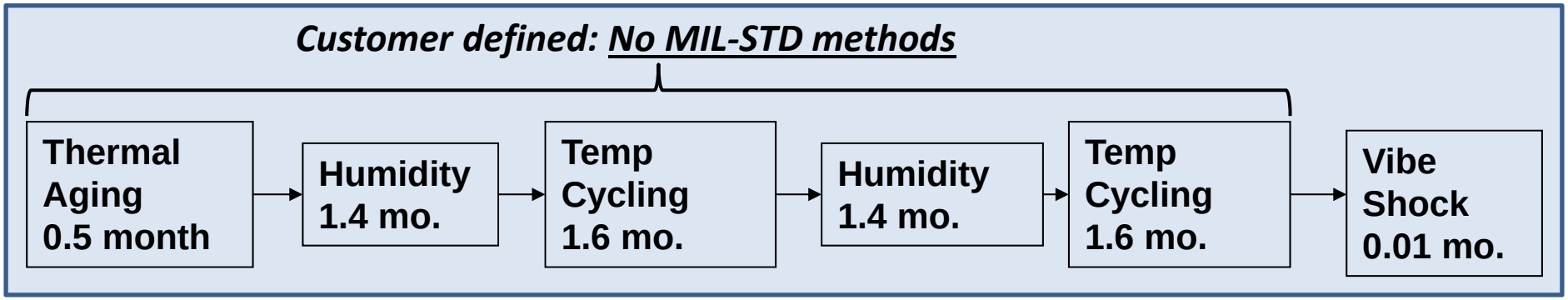
Tin whisker incident cost range: Thousands to Millions of dollars

Published: 2007 CALCE Tin whisker Symposium

Case Study:

Lead-free solder assembly qualification

- Lead-free solder joint robustness verification
- Test Protocol for <10 year applications
  - Reference SAE GEIA-STD-0005-3
  - Address aging, CTE mismatch, vibration/shock
  - Longer test times required for >10 years



One day vibration test increased to 6 – 8 months

Several successes with some routers and "Single Board Computers"
Some less than successful

Example: Combat Vehicle Electronics

MEMORY

T - DISPLAY

C - VIEWER

COMMUNICATIONS

GLOB E -

SYSTEM

ACQUISITION

SIGHT S

HAND STATION

S - CONTROLS

HULL POWER

DASHBOARD

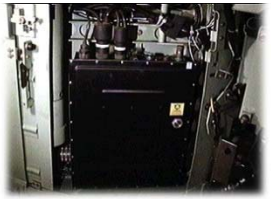
HANDSTATION

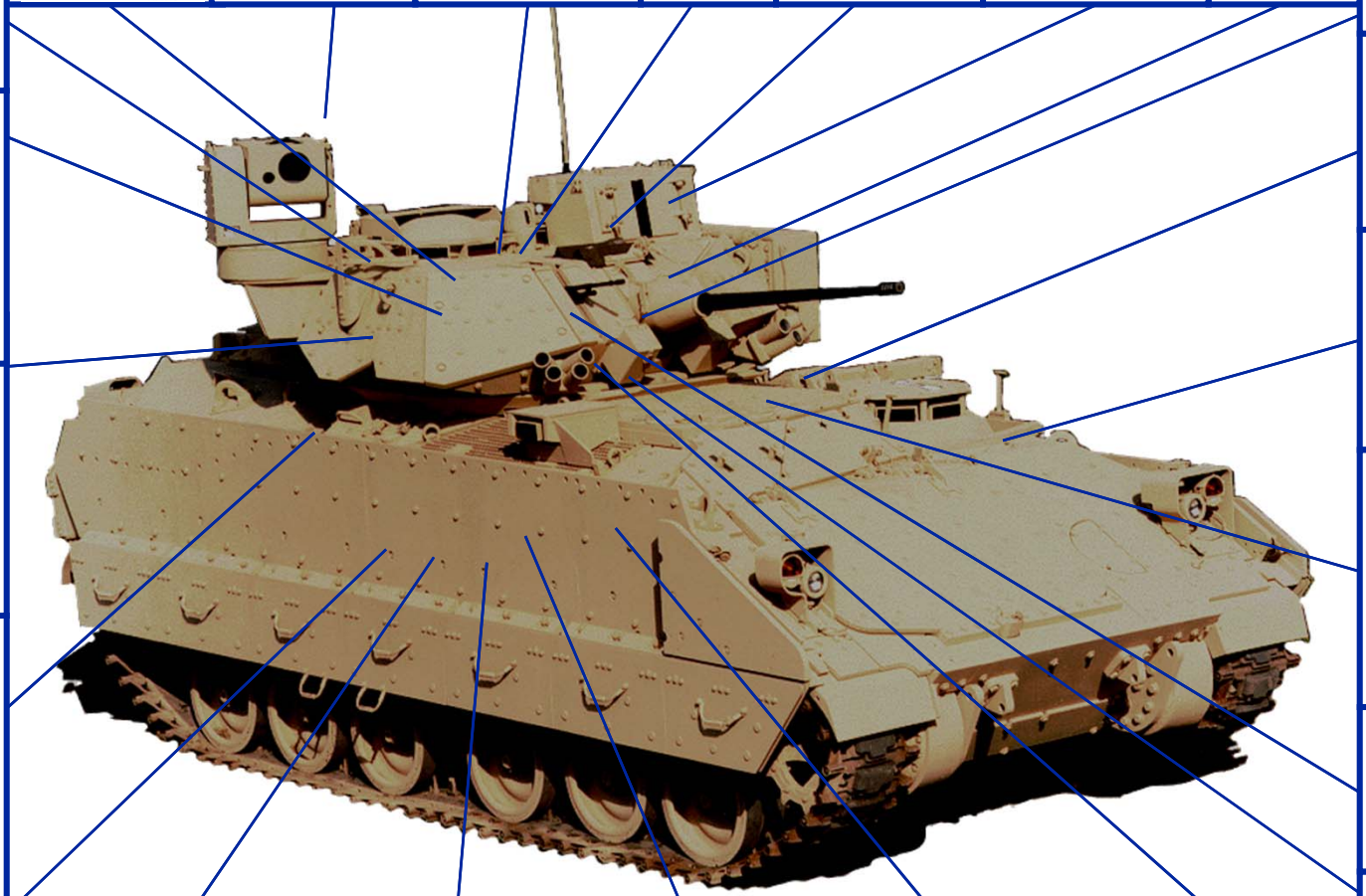
H - PROCESSING

S - DISPLAY

DATA ENTRY

T - STATION





NAVIGATION

P - CONTROL

T PROCESSOR

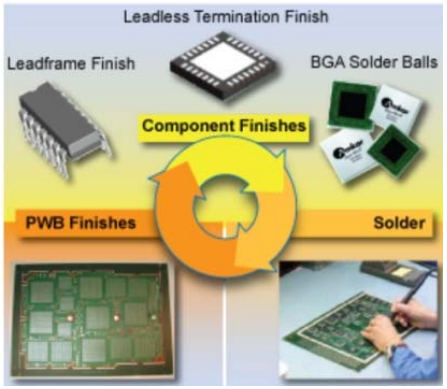
T POWER

M - CONTROL

S - CONTROL

Added tasks for Program Managers/Systems Engineering

- ✓ Check contract terms and conditions for lead-free requirements
- ✓ Create requirement definitions
- ✓ Make program level lead-free electronics decisions
  - SAE GEIA-HB-0005-1 Program Managers Handbook
  - Cost and schedule impacts for mitigations
- ✓ Create a lead-free risk management plan
  - Supplements gaps in standard reliability requirements
  - SAE GEIA-STD-0005-1 Lead-free Control Plan (LFCP)
- ✓ Inform suppliers of lead-free decisions
  - Subcontract LFCP flow down data item: DI-MGMT- 81772



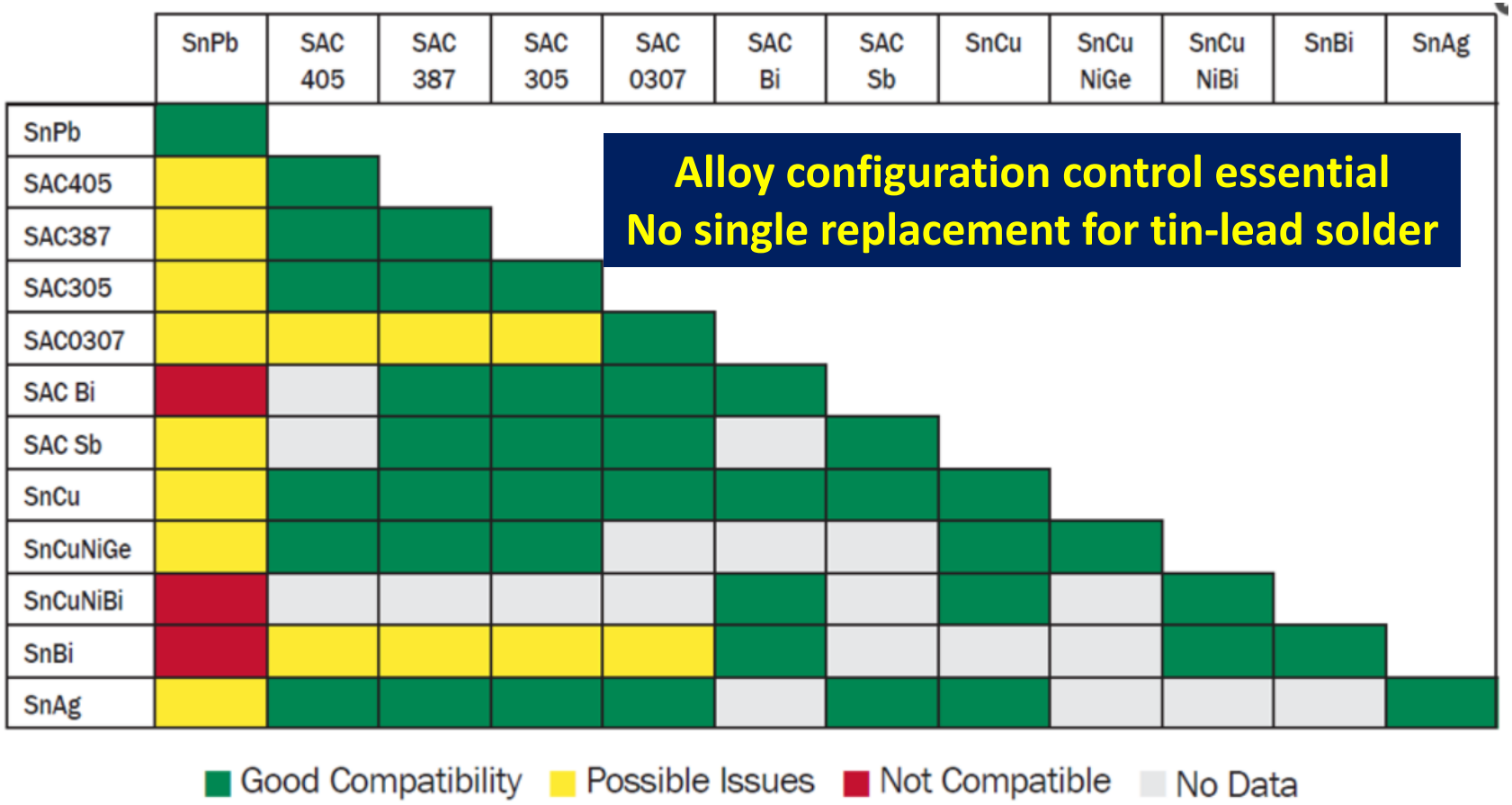
Multiple lead-free impact areas and a global supply chain

Open item for lead-free solder: No industry consensus for "Objective evidence for reliability" in harsh MIL environments
Lead-free requires testing, analysis and modeling beyond tin-lead

Solder alloy compatibility matrix

Depot repair alloy (possible options)

Original assembly alloy



Repair alloy mixtures different from original need qualification

DoD sustainment is longer than many companies exist

Source: Lead-free Manhattan Project Phase 1 report

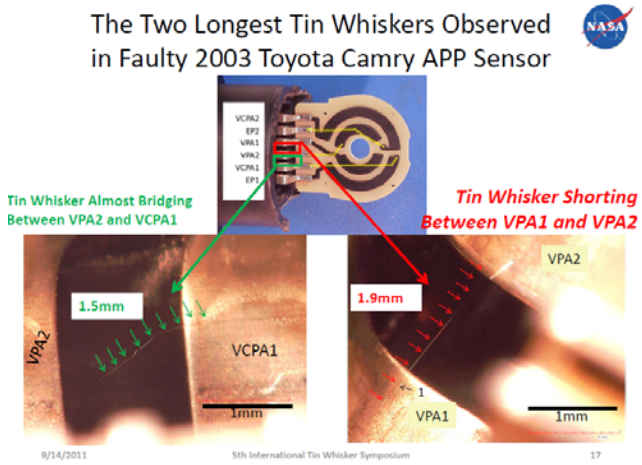
Why haven't we heard about consumer electronics failures?

- Some reasons
  - Much shorter lifetime – one year warrantee
  - Reluctance to advertise problems
    - Can have very high return rates that are not publicized
  - Out of court settlements "data sealed"
- There are lead-free learning curve experiences
  - 2Q 2009, **NVIDIA** recorded a **$196 million charge** against cost of revenue to cover **anticipated customer warranty**, repair, return, replacement and **associated costs** **arising from a weak die/packaging material set** ….

Nuclear, transportation safety, space, and military have more oversight than consumer electronics

Whisker events in industry

- I heard tin whisker issue was solved
  … but still seem to persist (Ref. NASA whisker site)
  - **2005 Tin whisker causing shutdown of millstone nuclear power station**
  - 2012 Press-in connector tin whiskers Continental AG
  - **Toyota accelerator position sensor whiskers**
  - GIDEP alerts
- Consumer JESD-201 short term test
  - Stated goal – No whiskers longer than 50 microns in two years (25% of fine pitch lead spacing)
  - But, whiskers are unpredictable
    - **CALCE: Tin samples dormant for 4 years, then grew phenomenal whiskers**
- Proactive programs and robust DoD suppliers
  - **Using SAE GEIA-STD-0005-2 whisker mitigation**
    - Conformal coating, material and circuit analysis, …
    - Need more research to improve validation



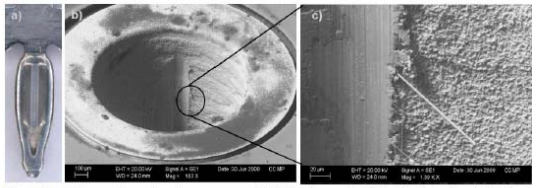


Figure 6 – a) Picture of a spring shape zone type, b) SEM micrograph of the via where the pin has been removed, c) magnified section showing the deformation line and whiskers.

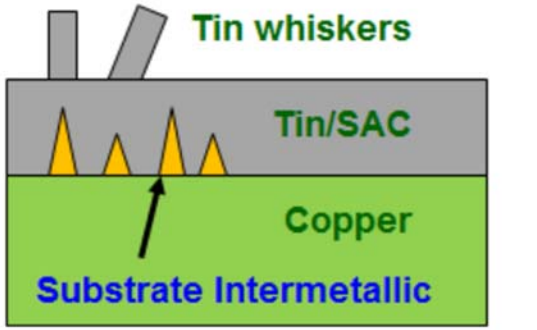
Continental 2012

Watch items: Whisker test complacency & cost reduction initiatives

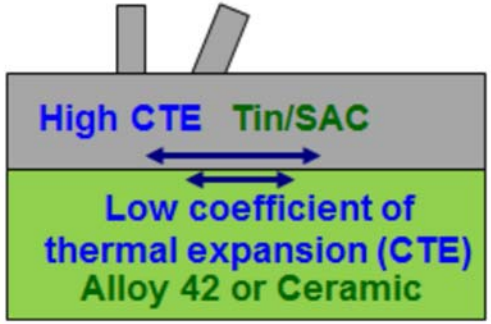
https://nepp.nasa.gov/whisker/reference/tech_papers/2006-Leidecker-Tin-Whisker-Failures.pdf

Factors contributing to whiskering

Compressive stress believed to promote whisker growth



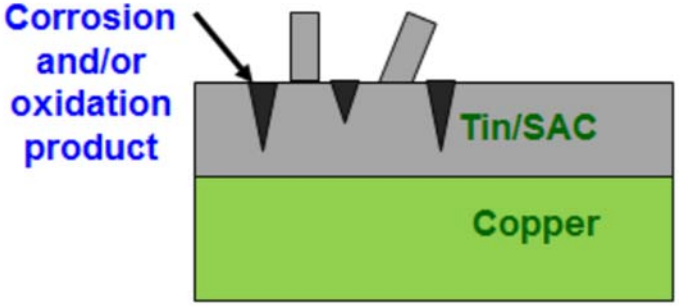
Use, storage and thermal cycling



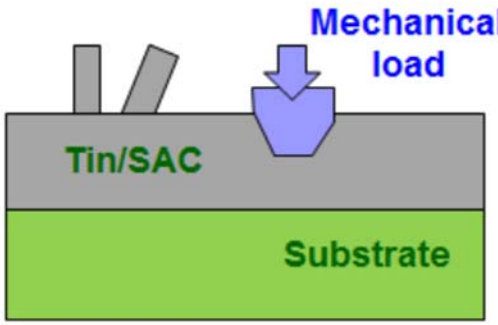
Thermal cycling

No voltage required for whisker growth

Whisker growth clock starts after assembly



Corrosive and/or high humidity atmospheres

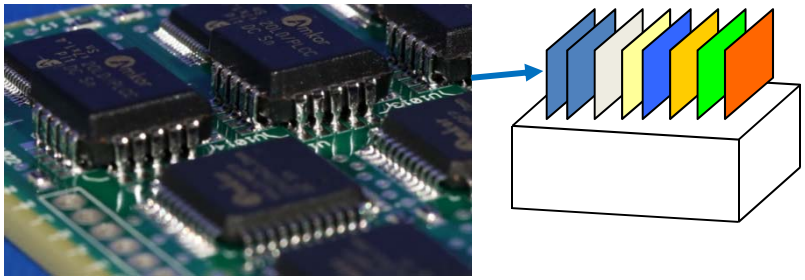


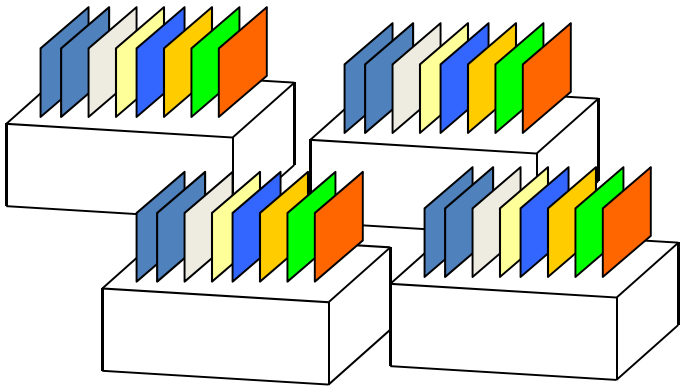
Clamping screws, connector contacts, etc.

Many DoD applications have all four whisker stress sources

SAC = Sn-Ag-Cu solder

Tin whisker risk in a typical box



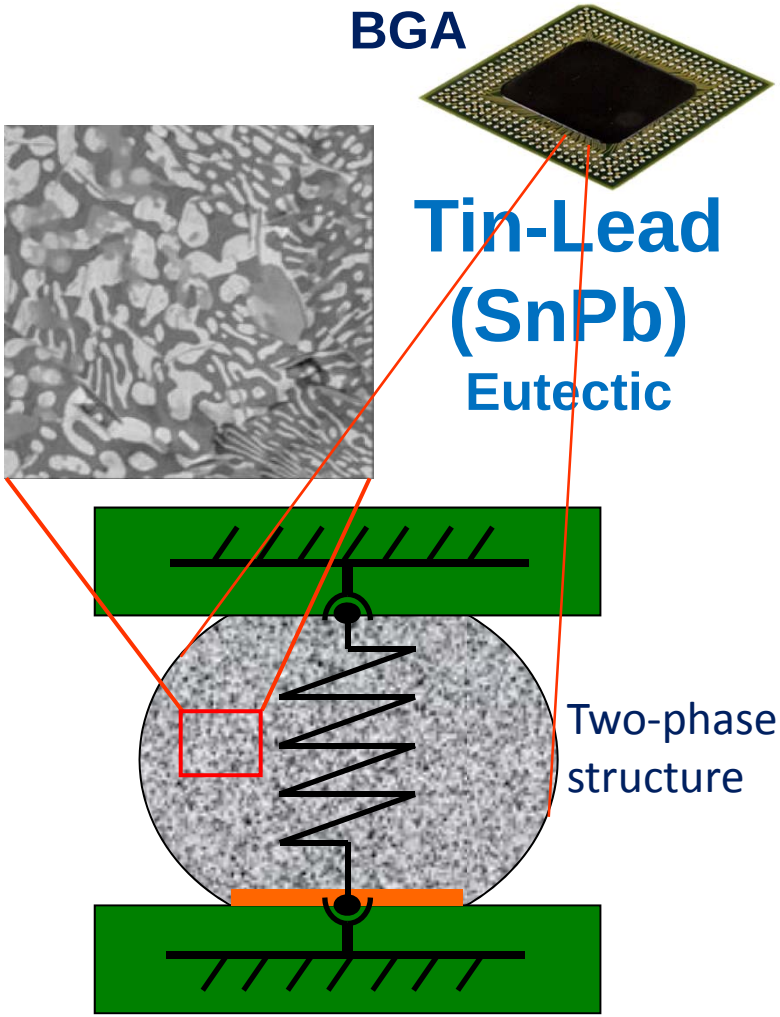


Description	# of leads
Analog 1	2009
Analog 2	2009
Analog 3	2009
Power Supply	326
Digital 1	2573
Digital 2	2573
CPU 1	3656
CPU 2	3656
Box total:	**18811**
Boxes/year	1000
Years	10
Total Leads	**188,110,000**

188 million leads fielded over 10 years

Whisker mitigation essential; verified coating, solder coverage, etc.

Heritage tin-lead solder



40 year DoD tin-lead evolution:

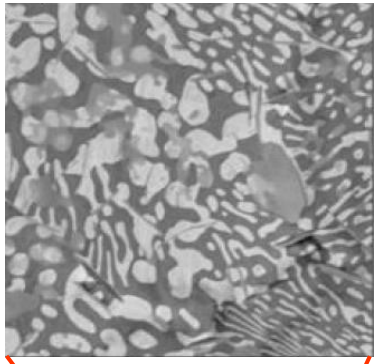
- Extensive field experience
- Tough homogenous solder
  - Simple two phase system
- Strong tin-copper and tin-nickel intermetallic bonding to pads
  - No solder to pad interfacial fractures
- Established
  - Design rules
  - Program ESS protocols (e.g. NAVMAT)
  - Objective evidence for reliability
    - Fatigue life models
      - Thermal cycling, vibration, shock
    - Program validated mil-spec qualification and reliability growth test methods

Tin-lead material set is proven

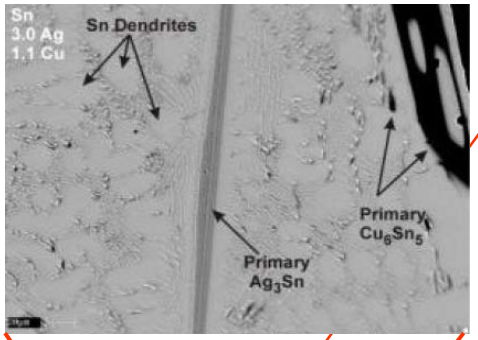
ESS = environmental stress screening

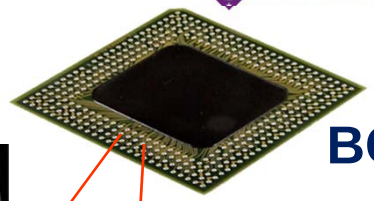
Lead-free solder

Lead-free findings over ~10 years of commercial use



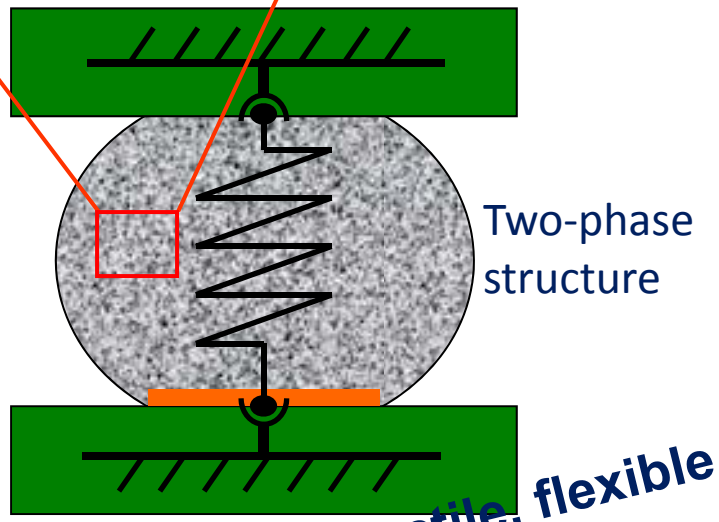
Tin-Lead (SnPb)
Eutectic





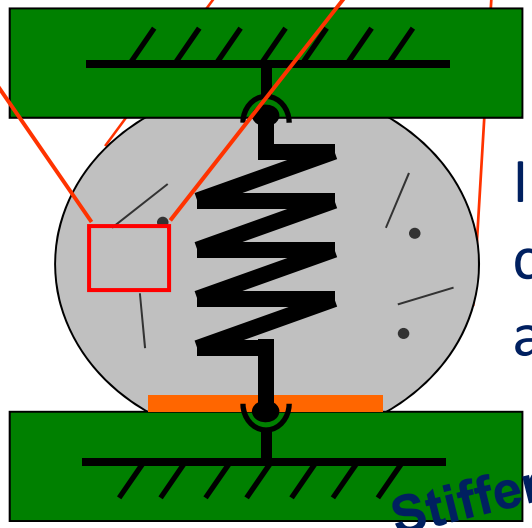
BGA

Lead-free SnAgCu
Lead-Free



Two-phase structure

Ductile, flexible



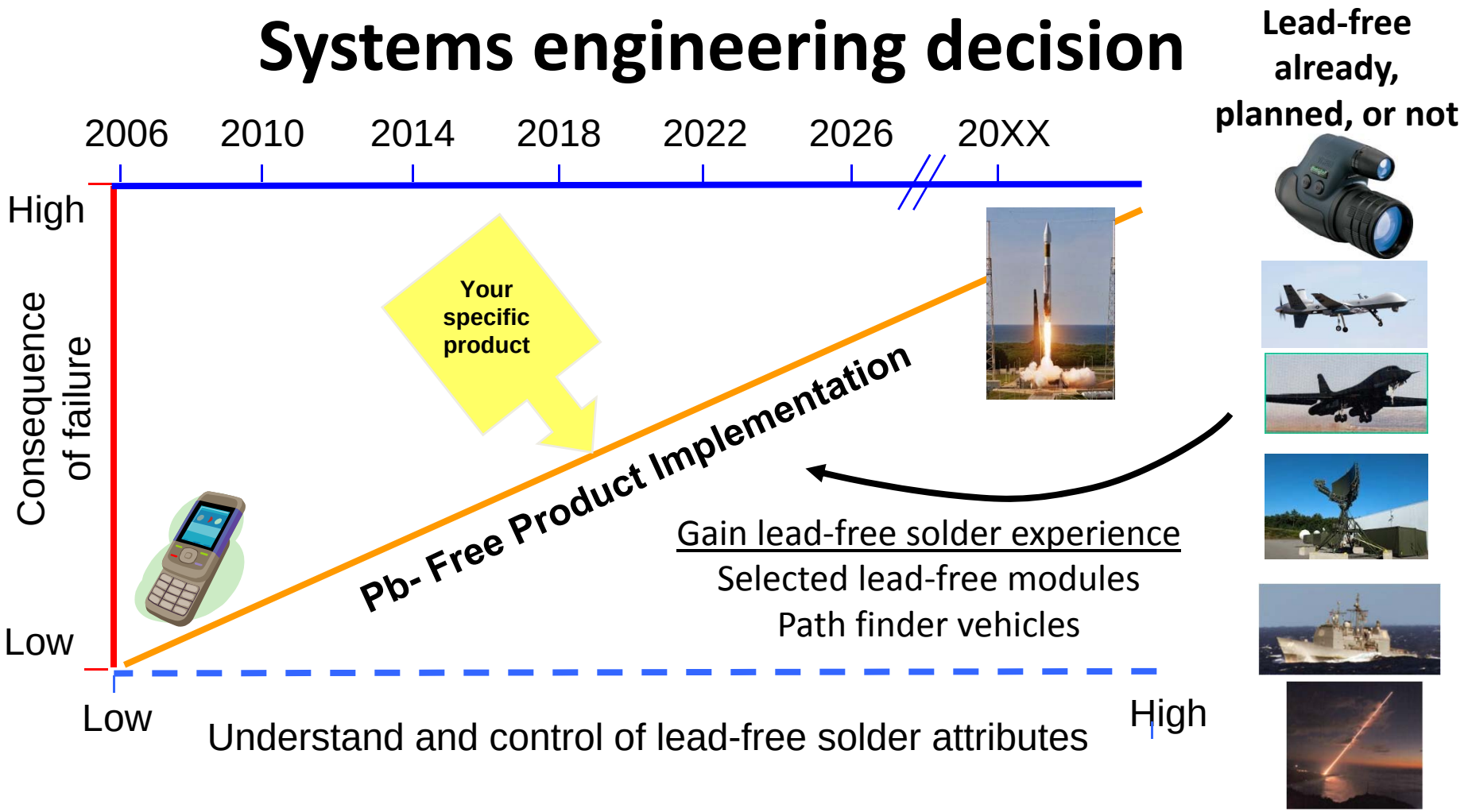
Inter-metallic compounds in a tin matrix

Stiffer solder, More brittle interfaces

<u>New design rules to prevent open circuits for</u>:
Thermal cycling fatigue, drop shock and board handling brittle fractures …

DoD Questions remain: Vibration, aging, combinations (thermal/vibe/shock)

Implementation of lead-free process: Systems engineering decision



Must decide when and where lead-free material sets can be used

Lead-free parts and solder:
Risks and opportunities

Risks	Opportunities

• **Knowledge gaps**
  • Design rules, manufacturing, reliability analysis/test
• **Equipment gaps**
  • Manufacturing, repair, sustainment, segregated stock, etc.
• **Tin whisker mitigation insufficient**
• **Selected alloy may change**
  • Materials configuration control
• **Solder stress too high for reliable joints**
  • Further stress reduction needed
	• **Leverage commercial materials and practitioners**
	• **Better solder fatigue life in less harsh environments**
	• **Less part refinishing**
	• **Improved sustainment**
	• **Lower long term cost**
	  • Improved parts availability
	  • Reduced parts reprocessing
	• **Future lead-free alloy and materials improvements**

Research, investment and experience will close lead-free knowledge gaps

Application review: Enabling lead-free materials

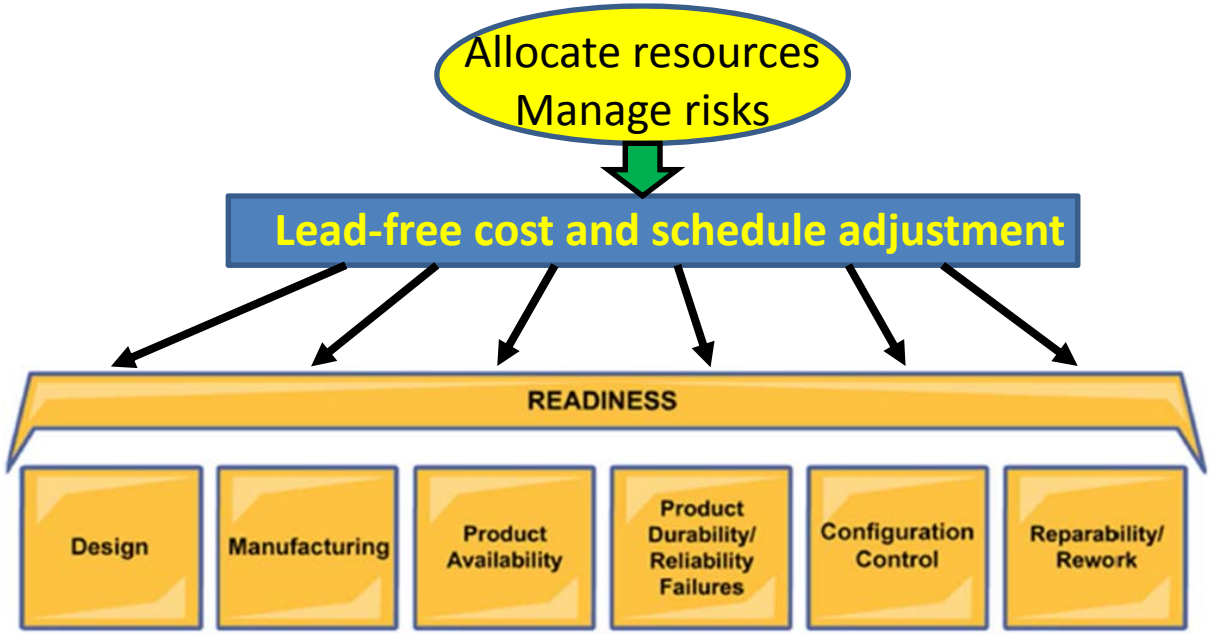
- Programs, systems engineering and design team task:
  - **No "as-good-or-better" lead-free replacement solder** for tin-lead that is industry accepted in all mil/aero environments
  - **Is SAC 305 (Sn-3.0Ag-0.5Cu) good enough?**
- Lead-free use in less harsh environment applications
  - Lead-free solder alloys will work in conditions like "server/telecom"
  - **With whisker mitigation**
- Lead-free use in more harsh environments
  - Lead-free solder with **reduced solder stress designs and whisker mitigation**
  - **Modified test protocols** for solder aging and tin whiskers
  - **Applications having good maintenance accessibility**

Keep lead-free out until better understood

Gain lead-free experience

Need to have a lead-free control plan
SAE GEIA-STD-0005-1 & DI-MGMT- 81772

Adjustments to standard processes



6 months to qualify refinishing parts from lead-free to heritage tin-lead

1 – 2 months standard refinishing cycle time

1 person to track piece part materials (commercial product change notices are open loop)

2 – 3 years to qualify lead-free design rules

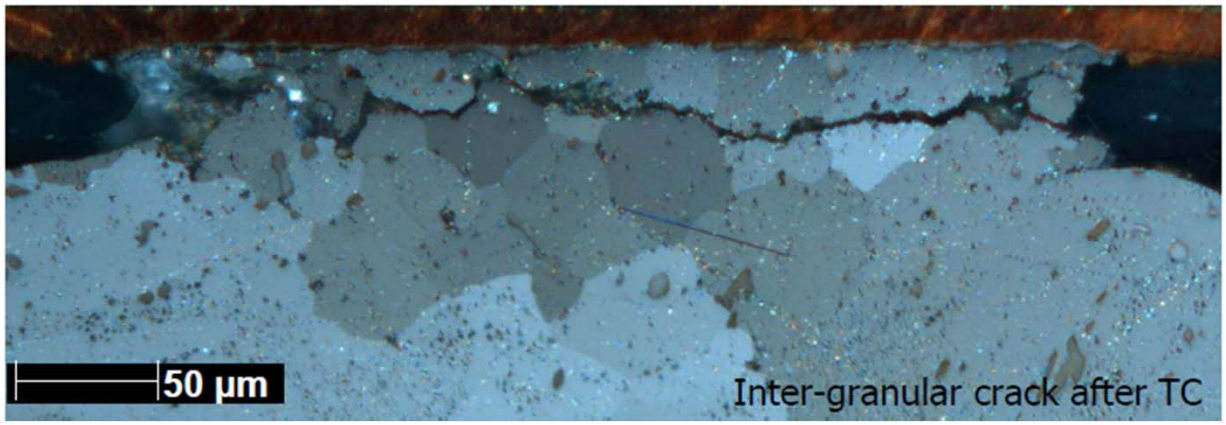
$10K – $100K or more for alloy verification

6 – 8 months for product qualification

Standard parts/materials and processes (PM&P) controls can accommodate lead-free risk management activities

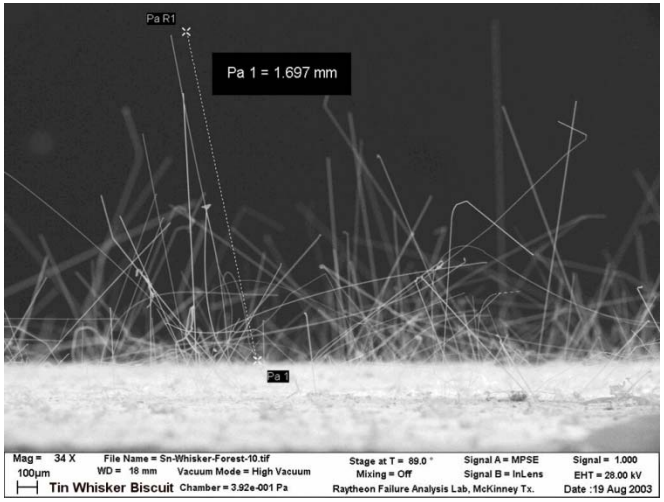
FOLLOW-ON SUPPORT WEBINARS

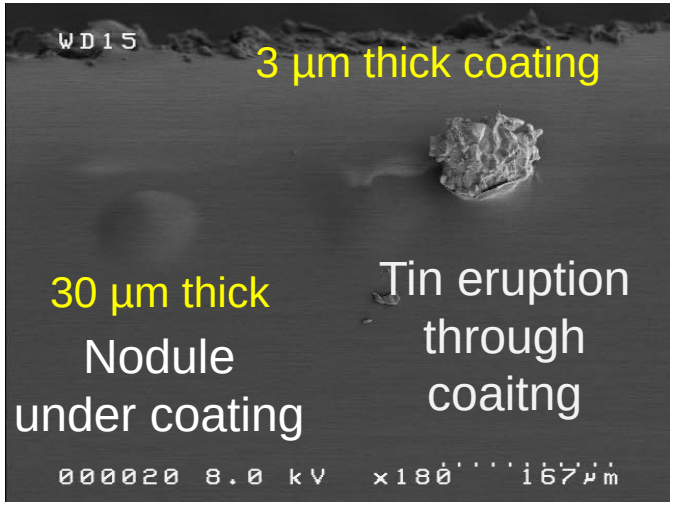
Lead-free Solder Basics for Systems Engineers



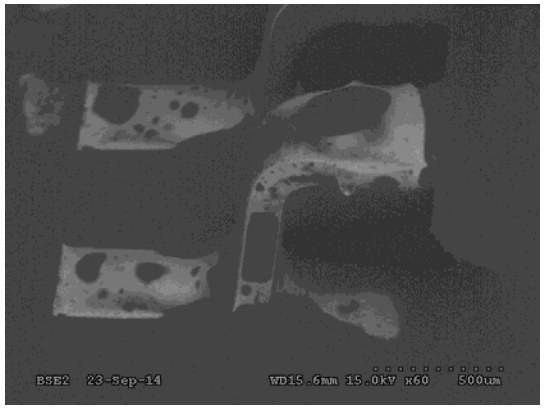
- Emphasis on solder fracture during fatigue
- Properties are determined by microstructure
- Initial microstructure depends on design and process
- Microstructure keeps changing with specific combination of storage and use conditions
- This leads to surprises and greatly complicates
  - Test requirements/protocols and interpretation of results (‘best in test’ often not ‘best in service’)
  - Modeling
- Overview outlines mechanistic understanding and practical recommendations – identifies sources for detailed info

Tin Whisker Basics for Systems Engineers





- Whisker growth factors, plating and solder
  - Materials, cleanliness and solder thickness
- Failure modes
  - Low voltage and high voltage circuits
- Short circuit mitigations
  - SAE GEIA-STD-0005-2
  - Conformal coating
- Short circuit risk modeling and assumptions



Poor coating coverage on leads

CONCLUSION

Lead-free is a continuing DoD issue because…

- **Open item: "Objective evidence for reliability" ← Needs investment**
  - Lead-free **requires testing**, analysis and modeling **beyond heritage tin-lead**
  - Industry **consensus lacking**
  - Important to precisely **define end use thermal, vibration, and shock over time**
- **Reliability requirements** have always been flowed down
  - **But,** analysis is based on **out-of-date standards** and 40 years of tin-lead use
    - e.g. **No tin plating/tin whisker factor in MIL-HDBK-217** reliability calculations
- Systems are increasingly using lead-free electronics
  - COTs to meet **costs and delivery schedules**
  - **Whisker mitigation levels differ** due to requirement interpretation variations
- **Supply chain process modification needed** to ensure lead-free material set reliability
  - More important than ever: Document and validate **all** lead-free electronics content
- Repair/Sustainment
  - **DoD owns equipment longer than some companies exist**
  - Need to know what materials are used where

Need to have a well informed customer and supply chain

Your Regular Everyday Tasks

- ✓ **Evaluate program in context of lead-free materials risks**
  - **Review contract terms and conditions**
  - How much reliability is expected by design?
  - Is programmatic reliability management needed (hot-swap, spares, etc.)?
- ✓ **Program Lead-Free Control Plan (LFCP) is critical**
  - SAE GEIA-STD-0005-1 Performance requirements (+ see supplemental slides)
  - Include with other PM&P items: e.g. counterfeit, corrosion, etc.
  - Determine tin whisker risk mitigation level. Can lead-free solder be used?
  - **Sub-contract flow down data Item: DI-MGMT- 81772**
- ✓ Consider ways to gain lead-free experience
  - Include some lead-free boards; Path finder vehicles
- ✓ Establish **lead-free team knowledge** for effective control plan review
  - Programs, Systems, Design, Manufacturing, Sourcing, Repair
- ✓ **Leverage resources and invest time, talent, and material**
  - IPC-PERM Council (meets 2 – 3 per year)
  - SERDP lead-free research, industry research

IPC-PERM = IPC Lead(**P**b)-free **E**lectronics **R**isk **M**anagement

If you don't recognize these items, program is at risk…

Supplemental slides

- Lead-free transition differences for existing and new programs
- SAE GEIA standards summary
- DoD systems lead-free resources
- Lead-free research resources
- Lead-free Control Plan Data Item Description DI-MGMT-81772
- LFCP TEMPLATE TABLE OF CONTENTS
- Understanding the electronics supply chain
- Diverse sets of criticality, equipment, and environments in DoD
- Case study: Accelerated thermal cycling testing
- Lead-free Tin-Silver-Copper (SAC): A quick microscopic look
- Tin-lead vs. lead-free: Risks and opportunities

Questions

(1) Ref. L.P. Temple 2013, Implosion: Lessons from National Security, High Reliability Spacecraft, Electronics, and the Forces that Changed Them. SME = Subject Matter Experts

SUPPLEMENTAL MATERIAL

Lead-free transition differences

Existing Programs

A. Consider SAE GEIA-STD-0005-1 for use on your program for creation of a LFCP.
B. Conduct operational risk assessment associated with the introduction of Lead-free solder and finishes into critical assemblies and subsystems to identify potential risk from failures using criticality analysis.
C. Assess compliance of suppliers' Lead-free processes to the intent of SAE GEIA-STD-005-1.
D. Ensure suppliers are meeting reassessed reliability test requirements and inspection procedures to mitigate reliability risks to an acceptable level.
E. Provide guidance for use of critical piece parts, assemblies, and subsystems.
F. Address repair, rework, and maintenance procedures.

New Programs

A. Establish contract language that aligns with the requirements of SAE GEIA-STD-0005-1 and SAE GEIA-STD-0005-2 (e.g., DI-MGMT-81772). Ensure requirements in proposals and contracts address the implications of Lead-free solder and finishes prior to contract award.
B. Conduct a review of COTS electrical subsystems to evaluate risk assessment associated with the introduction of Lead-free solder and finishes into critical assemblies and subsystems, using criticality analysis
C. Ensure suppliers can meet reassessed reliability test requirements and inspection procedures to mitigate reliability risks to an acceptable level.

Ref: DAU Training Module CLL 007, Lesson 6

SAE GEIA standards summary

- SAE GEIA-STD-0005-1
  - Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solders
- SAE GEIA-STD-0005-2
  - Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems
- SAE GEIA-STD-0005-3
  - Performance Testing for Aerospace and High Performance Electronic Interconnects Containing Lead-free Solder and Finishes
- SAE GEIA-HB-0005-1
  - Program Management/Systems Engineering Guidelines for Managing the Transition to Lead-free Electronics
- SAE GEIA-HB-0005-2
  - Technical Guidelines for Aerospace and High Performance Electronic Systems Containing Lead-free Solder and Finishes
- SAE GEIA-HB-0005-3
  - Rework/Repair Handbook to Address the Implications of Lead-free Electronics and Mixed Assemblies in Aerospace and High Performance Electronic Systems
- SAE GEIA-STD-0006
  - Requirements for Using Solder Dip to Replace the Finish on Electronic Piece Parts

DoD systems lead-free resources

- ARMY AMRDEC
  - MIL-STD-11991 (Missile Systems) contractual deliverable using DI-STDZ-81993
- Require LFCP using DI-MGMT-81772
- DMEA - Defense Microelectronics Activity
- NAVY – Office of Naval Research – Best Manufacturing Practices Center of Excellence
- Air Force - Defense Standardization Program Office (DSPO) Parts Standardization and Management Committee (PSMC) participation
- SERDP/ESTCP Research
- Defense Acquisition University
- Lead-free Electronics Portal
  - https://dap.dau.mil/acquipedia/Pages/ArticleDetails.aspx?aid=a5875288-d24c-44ba-b187-fc06c4e6983c)
  - CLL 007 Training Module Lead Free Electronics Impact on DoD Programs
- Acquisition Community Connection
  - https://acc.dau.mil/CommunityBrowser.aspx?id=724437&lang=en-US
- Lead-free Manhattan Project Reports
  - https://acc.dau.mil/CommunityBrowser.aspx?id=336265

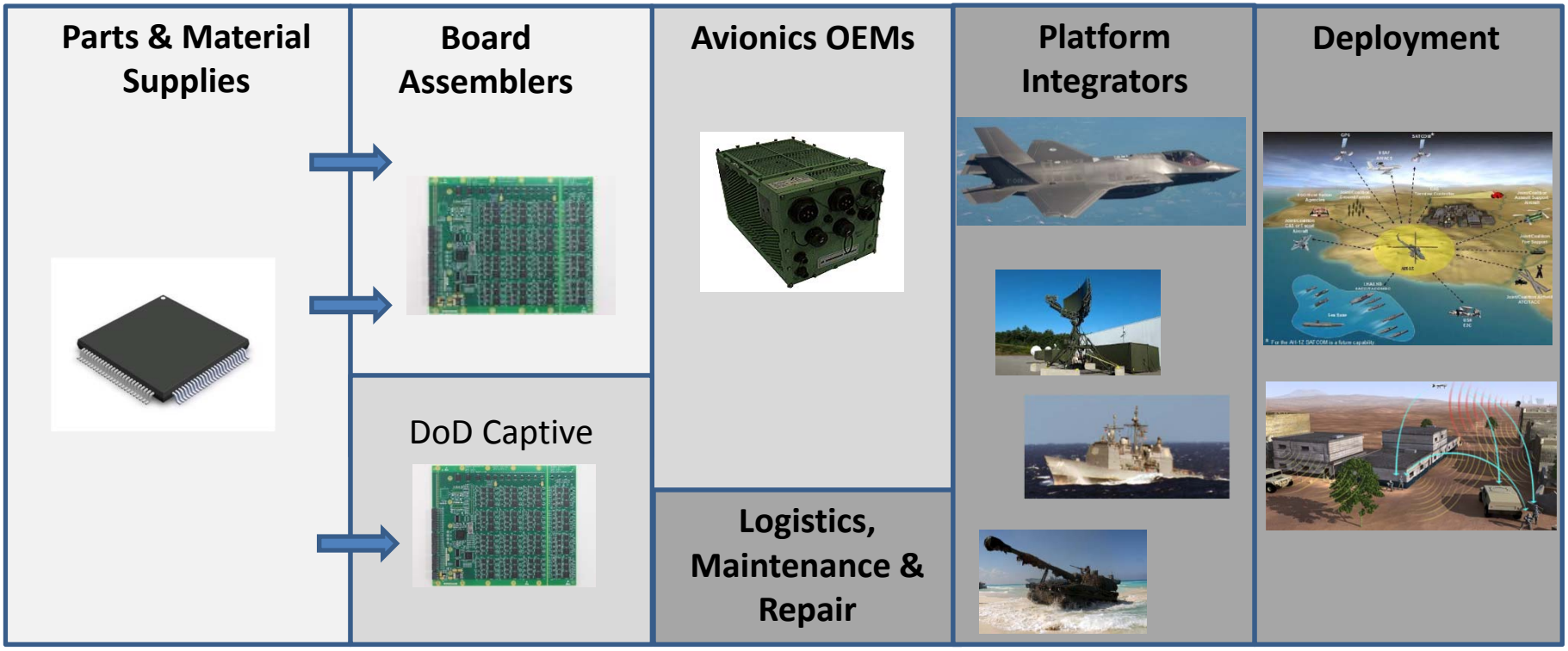
DoD systems lead-free resources (cont.)

- DoD soldering technologies working group
  - https://acc.dau.mil/adl/en-US/353254/file/49357/STWG%20Understanding%20Lead-free.pdf
- DoD documents
  - Lead standardization Activity for Solder
    - LSA SOLD-08-01 – DoD Soldering Technologies Working Group
    - LSA SOLD-08-02 – Manage by avoidance, inspection, and control plans
    - LSA SOLD-08-03 – Tech guidance and control plan for rework and repair
    - LSA SOLD-08-04 – US DoD Lead-Free Control Plan (templates -05/-06)
    - LSA SOLD-08-07 – Risk Management
    - Naval Surface Warfare Center Instruction NSWCCRANEINST 4855.18C

Lead-free research resources

- SERDP/ESTCP – DoD Strategic Environmental Research and Development/ Environmental Security Technology Certification Program
  - **Lead Free Webinar Slides**
  - **Microstructurally Adaptive Constitutive Relations and Reliability Assessment Protocols for Lead Free Solder**
  - **Novel Whisker Mitigating Composite Conformal Coat Assessment**
  - **Tin Whisker Testing and Modeling**
  - **Contributions of Stress and Oxidation on the Formation of Whiskers in Lead-Free Solders**
  - **Tin Whiskers Inorganic Coatings Evaluation (TWICE)**
  - **The Role of Trace Elements in Tin Whisker Growth**
- Auburn University - Center for Advanced Vehicle and Extreme Environment Electronics
  - Various projects studying lead-free solder reliability and tin whiskers including studying drop shock and aging effects
- CALCE University of Maryland – Center for Advanced Life Cycle Engineering
  - Several project and tools related to Lead-free and Tin Whiskers
- Binghamton University - Integrated Electronics Engineering Center (IEEC)
  - Various projects studying lead-free solder reliability, tin whiskering and conformal coating mitigation
- AREA Universal Instruments Corp. - Advanced Research in Electronics Assembly
  - Various projects studying lead-free solder reliability with an emphasis on manufacturing processes and microstructure
- Joint Council of Aging Aircraft (JGPP) Lead-free testing completed on four lead-free solder alloys. Results published
- Sandia National Labs and Ames Labs
  - Lead-free solder alloy development and tin whisker research
- NASA – Jet propulsion lab
  - Working on IPC standards for lead-free assembly reliability test protocols
- NASA – Kennedy Space Center
  - TEERM Office NASA-DoD Lead-Free Electronics (Project 2) Project Number: NT.1504NASA – DoD Phase 2 and Phase 3
- NIST
  - Archive of solder properties
- National Defense Center for Energy and Environment (NDCEE)
  - Demonstration/Validation Testing of X-Ray Fluorescence (XRF) Technology to identify Lead-free Electronics and Solder Categories
  - Development of Lead-free Training Courses and a Lead-free database

Understanding the electronics supply chain



Beyond DoD control or **costly control**

Design trade-offs
Procurement costs

Life cycle costs discovered here

Problem management costs increase exponentially later in life

Can take 5-10 years for tin whisker issues to develop

Ref. L. Condra, Lead-free Manhattan Project Phase 1 Report

Diverse sets of criticality, equipment, and environments in DoD



















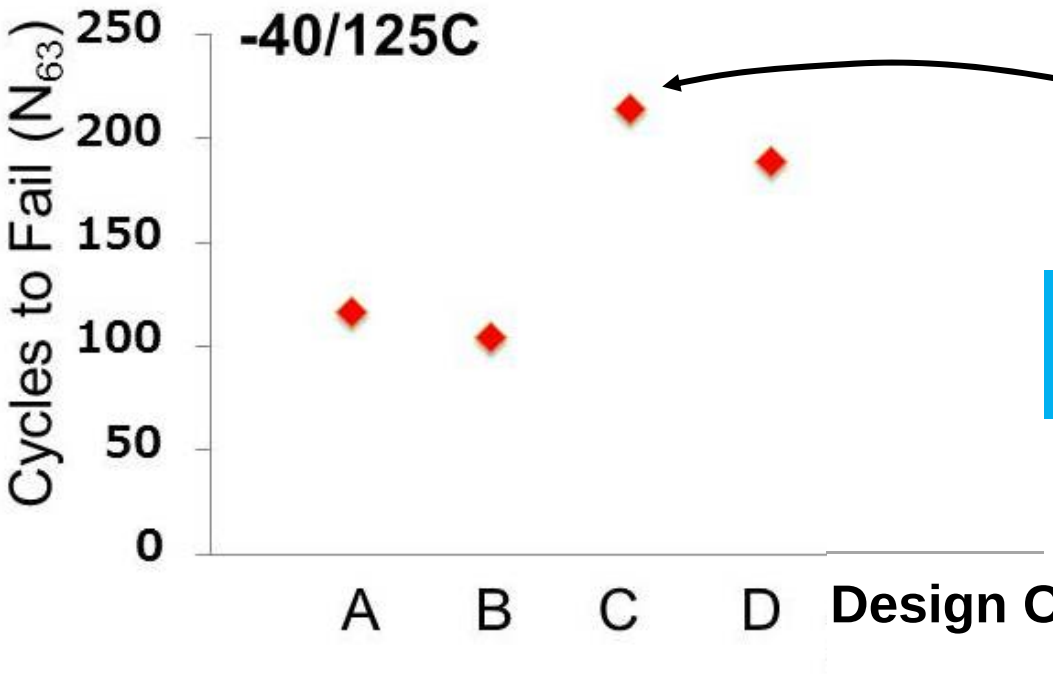

No one-size fits all solution

Lead-free management tailored to criticality of each systems and subsystem

Case study: Accelerated thermal cycling testing

Lead-free BGA assemblies

Determine design with best solder life before solder fracture



Design "C" was "best" in quick 250 accelerated test

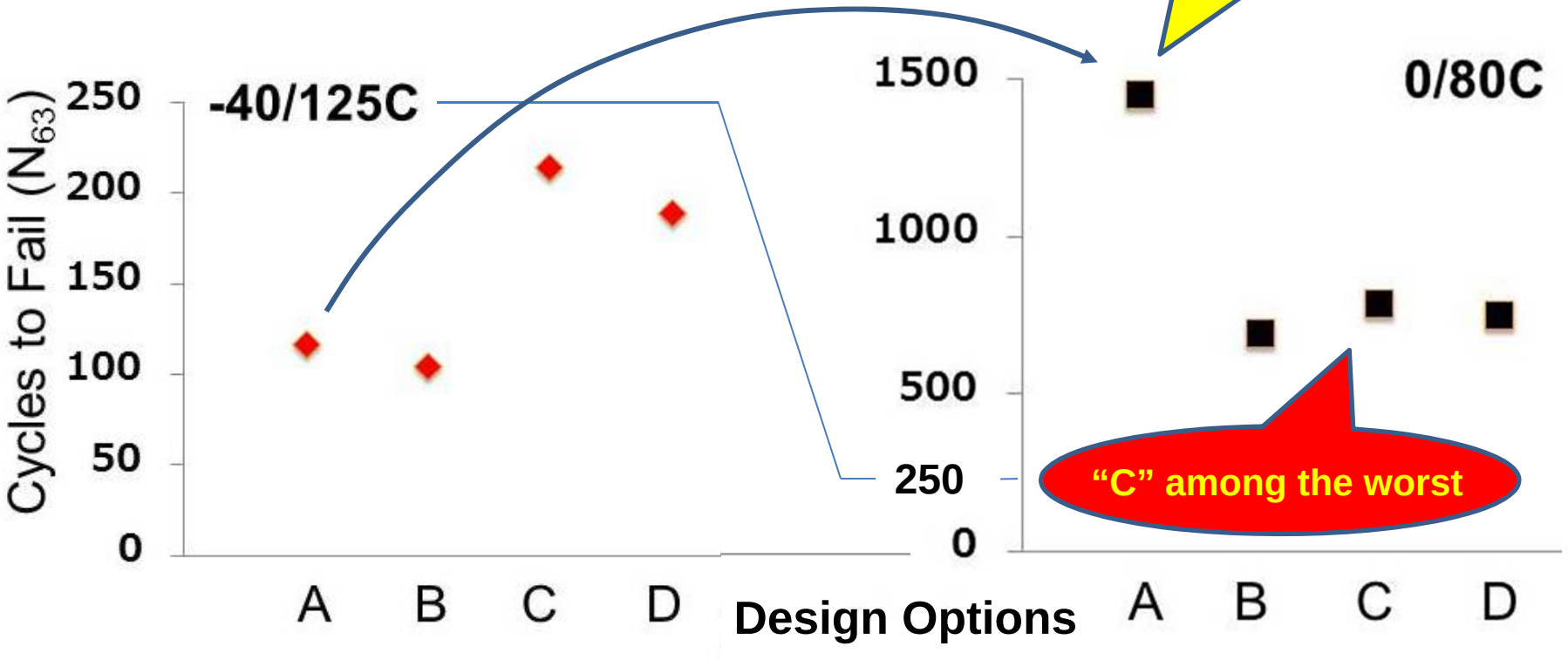
Standard heritage tin-lead practice applied to lead-free, but….

Case study: Accelerated thermal cycling testing

Lead-free BGA assemblies

Design "C" was best in quick accelerated test

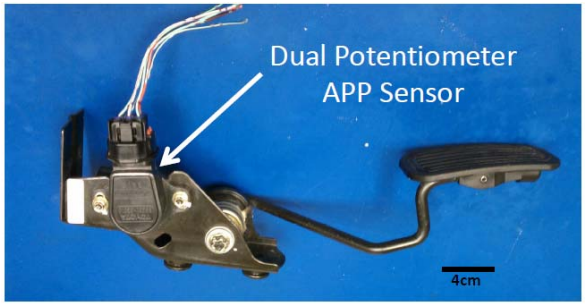
1500 cycle test
"A" is really the best in service like temperature range



Lead-free solder technology qualification

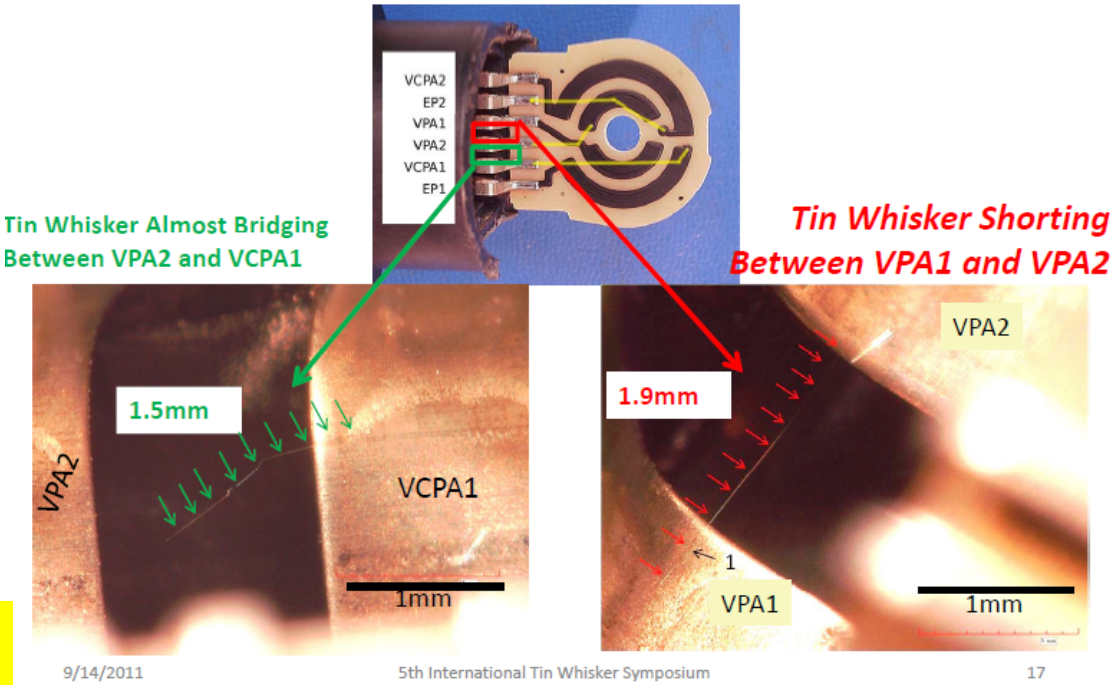
6X schedule increase for longer service environment test

Case study: Tin whiskers in accelerometer pedal position sensor failure



Digital volt meter can fuse whisker in less than a millisecond
Test result: No – fault found

The Two Longest Tin Whiskers Observed in Faulty 2003 Toyota Camry APP Sensor



Many records sealed in out-of-court settlements

Whiskers a possible, but not a primary cause for un-intended acceleration

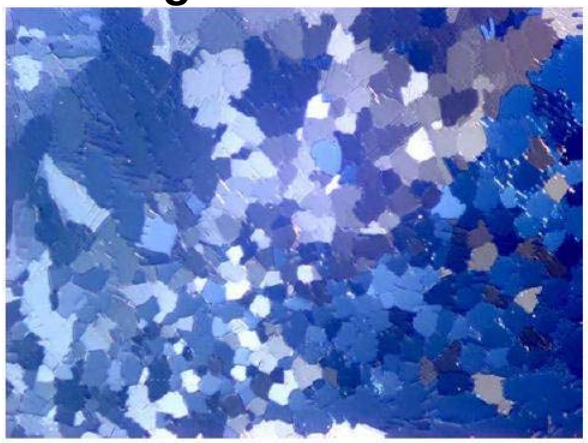
Whisker problem easily avoided with early recognition

https://nepp.nasa.gov/WHISKER/reference/tech_papers/2011-NASA-GSFC-whisker-failure-app-sensor.pdf

Lead-free Tin-Silver-Copper (SAC):
A quick microscopic look

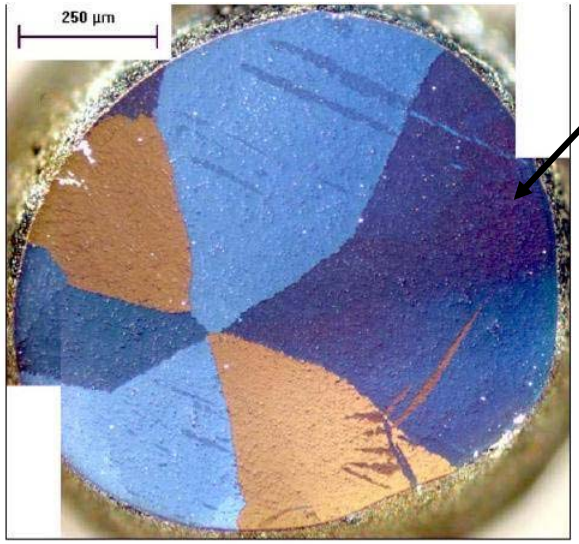
Added 0.5% copper to reduce melting point

Tin -3.5% Silver
Fine grain structure



Note: SnAg used since the 1970s with nickel finishes in hybrids

Tin-3.0% Silver-0.5% Copper



Colors show different tin grain orientations

Small fine grain structures (left) are better: more uniform, more predictable, easier to model, etc.

More in Solder webinar:

- Solidification and tin grains
- Test sequence and life
- Strange tin properties
- Etc.

Solder joint cross-sections

Special polarized microscopy needed to show tin grain structure (Unlike tin-lead solder)

A small copper change radically alters solder grain structure

Large grain joints have lower thermal cycling fatigue

Lead-free Control Plan
Data Item Description DI-MGMT- 81772

Title: Lead-Free Control Plan (LFCP)
Number: DI-MGMT- 81772
Approval Date: 20090612
AMSC Number: N9072
DTIC Applicable: N/A
Office of Primary Responsibility: SEA04RM
Applicable Forms: N/A

Use/Relationship: The Lead-Free Control Plan (LFCP) will be used to obtain essential information from contractors on how they plan to manage the risk of lead-free solders or finishes used in their products during the program's lifecycle.

This DID contains the format and content preparation instruction for the data product generated by the specific and discrete task requirement as delineated in the contract.

This DID is applicable to all new contracts and solicitations that acquire electronic systems including weapons systems containing electronic components as well as rework or repair of electronic systems or components.

The DID may also be applicable to systems already in production for major changes and block upgrades.

The reference documents cited in this DID, GEIA-STD-0005-1, "Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-Free Solder" and GEIA –STD-0005-2, "Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems", may be obtained from: Government Electronics and Information Technology Association, 2500 Wilson Boulevard, Suite 1100, Arlington, VA 22201, or as specified in the contract.

Requirements:

1. Reference documents. The applicable issue of any documents cited herein, including their approval dates and dates of any applicable amendments, notices, and revisions, shall be as specified in the contract.

2. Format. The LFCP shall be presented in the contractor's own format.

3. Content. The LFCP shall contain all of the information specified in GEIA-STD-0005-1 and GEIA-STD-0005-2.

3.1 Lead-Free Solder and Finishes. The plan shall address all lead-free solders and lead-free tin finishes in delivered products.

3.1.1 Reliability. The processes and materials utilizing lead-free solder or finishes shall be identified as capable of producing items that meet product reliability requirements.

3.1.2 Configuration Control and Product Identification. The configurations of all systems, assemblies, subassemblies, and parts shall be included and identified by version and applicable configuration identifier.

DI-MGMT-XXXX (Cont'd)

3.1.3 Risks and Limitations of use. Any risks or limitations on the use of the products due to the incorporation of lead-free solder or finishes shall be identified along with information on how to manage those risks or limitations.

3.1.4 Tin (Sn) Whiskers. Any harmful effects of Sn whiskers resulting from use of lead-free tin shall be addressed.

3.2 The plan shall contain any recommendations or changes to the product design and any contract modifications required to comply with the LFCP.

End of DI-MGMT- 81772

LFCP TEMPLATE TABLE OF CONTENTS

(based on SAE GEIA-STD-0005-1 Revision A May 2012)