# Lead-free Electronics: What's the Problem, Really?

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# Pb-free Electronics Risks



***EU Restriction of Hazardous Substances (RoHS) Directive banned use of lead (Pb) in commercial electronics sold in EU as of 7/1/06, impacting global COTS electronics market***

## Unintended Consequences

**"Tin Whisker" Short Circuits**

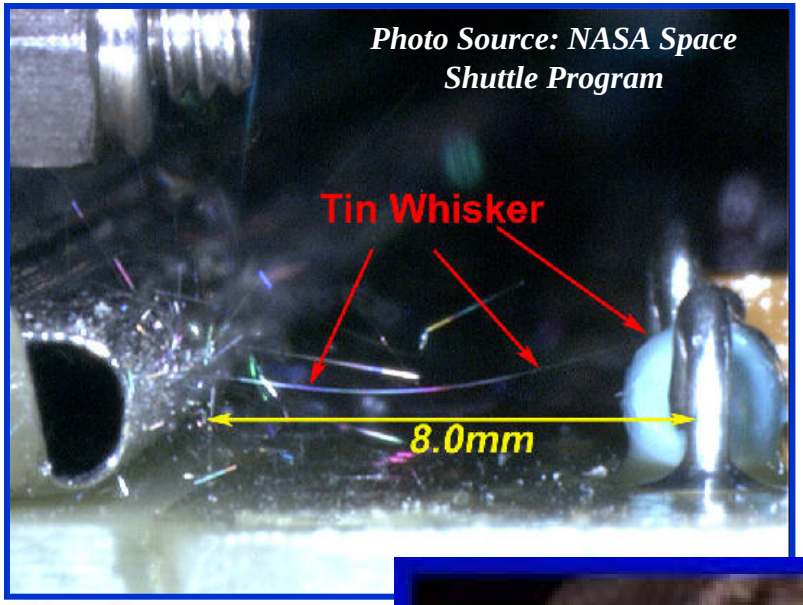
- Electrically conductive
- Can metal vapor arc

**Pb-free Solder Issues**

- Fractures in high shock & vibration environments
- Has higher melting temps
- Incompatibilities with SnPb Solder
- Less repairable assemblies

**Configuration Control Nightmare!**

- Unidentified component alloys
- Mixed Pb & Pb-free inventory



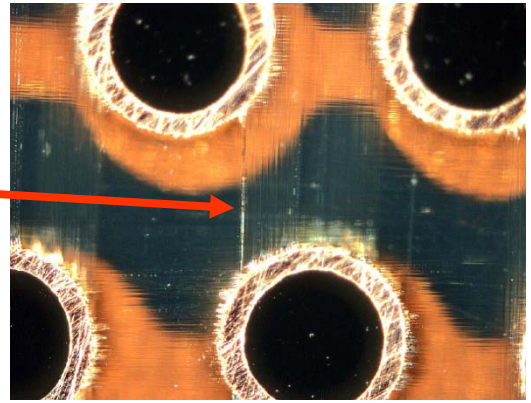

Electromagnetic Relay Vapor Arc Damage

# Impact on Aerospace & Defense



- No universally acceptable technical solutions in sight to replace SnPb in Aerospace & Defense (A&D) applications
  - Conformal coatings only mitigate tin whiskers
  - Pb-free solder joint reliability decreased for shock and has corrosion issues
  - SAC305 solder dissolves copper, impacting rework and repair
  - Conductive Anodic Filament (CAF) problem is re-emerging due to higher CCA processing temperatures using Pb-free solders
- Current technical approaches are all still “mitigations” and not “elimination” of the Pb-free electronics issues

**Conductive Anodic Filament (CAF) in Circuit Card Assembly (CCA)**



*Ref: “Lead Free PCB Projects Update,” Wayne Jones, Advanced Research of Electronic Assemblies Consortium, February 2008*

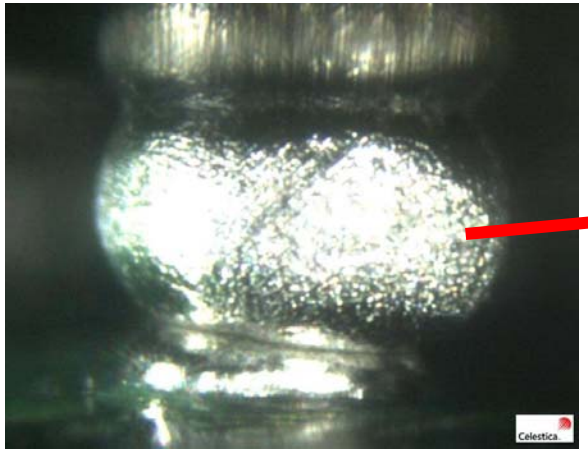
# Any Recent Failures?



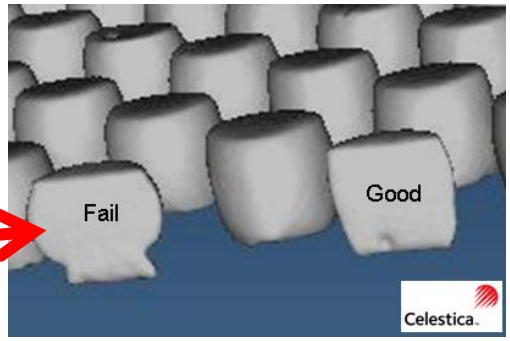
## SAC BGA Rework "Head in Pillow (HiP)" Defect

- **Problem: Intermittent ATC open failure after rework (2000 I/O BGA with 1 open joint)**
- **Lab Analysis: Metallurgical analysis found "head-on-pillow" and differential cooling between balls and paste**
- **Result: SAC process requires regular calibration of reflow heaters**
- **Other Causes: BGA ball contamination, warpage**

BGA Ball Open (HiP)

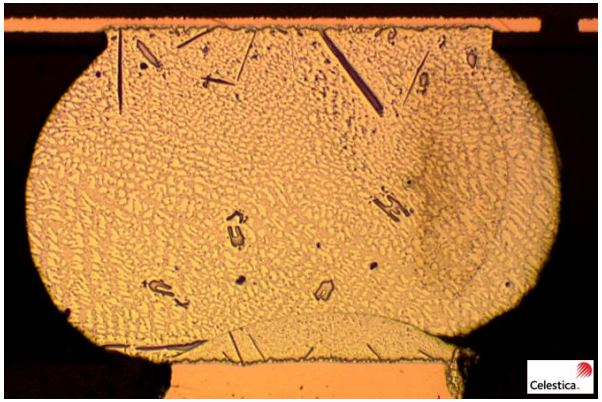



3D X-ray Reconstruction

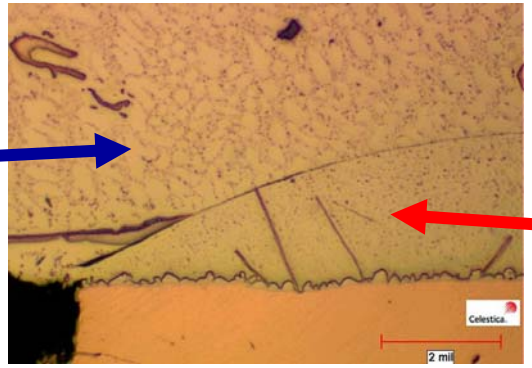



***Photos Provided by Celestica***

Paste & SAC Ball Not Wetted




Large Sn Dendrite Indicates Slower Cooling at Component Side

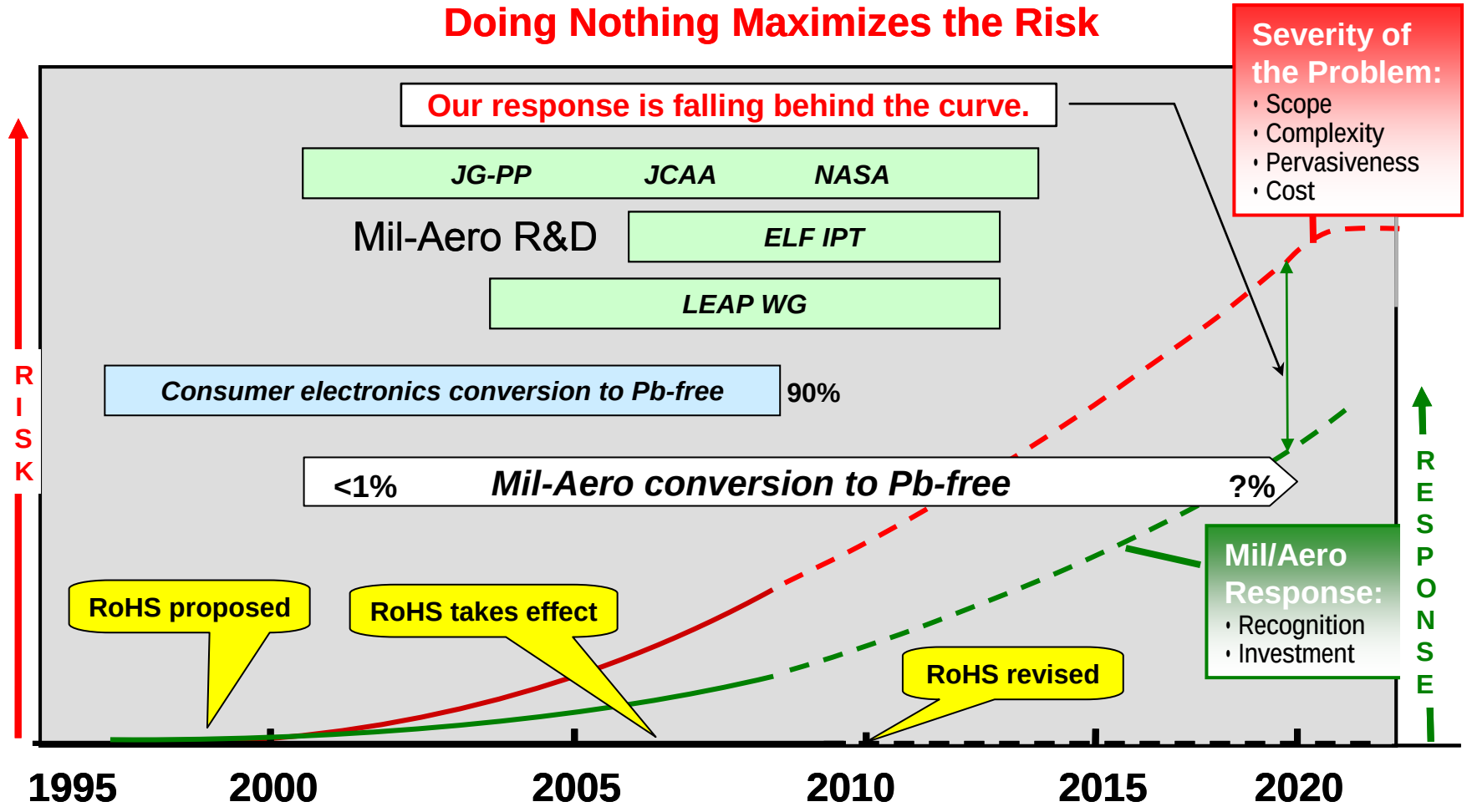



SAC Paste Resolidified Before Wetting to BGA

# A&D Response to Pb-free Electronics

*"We did our job, but the job is not done."*



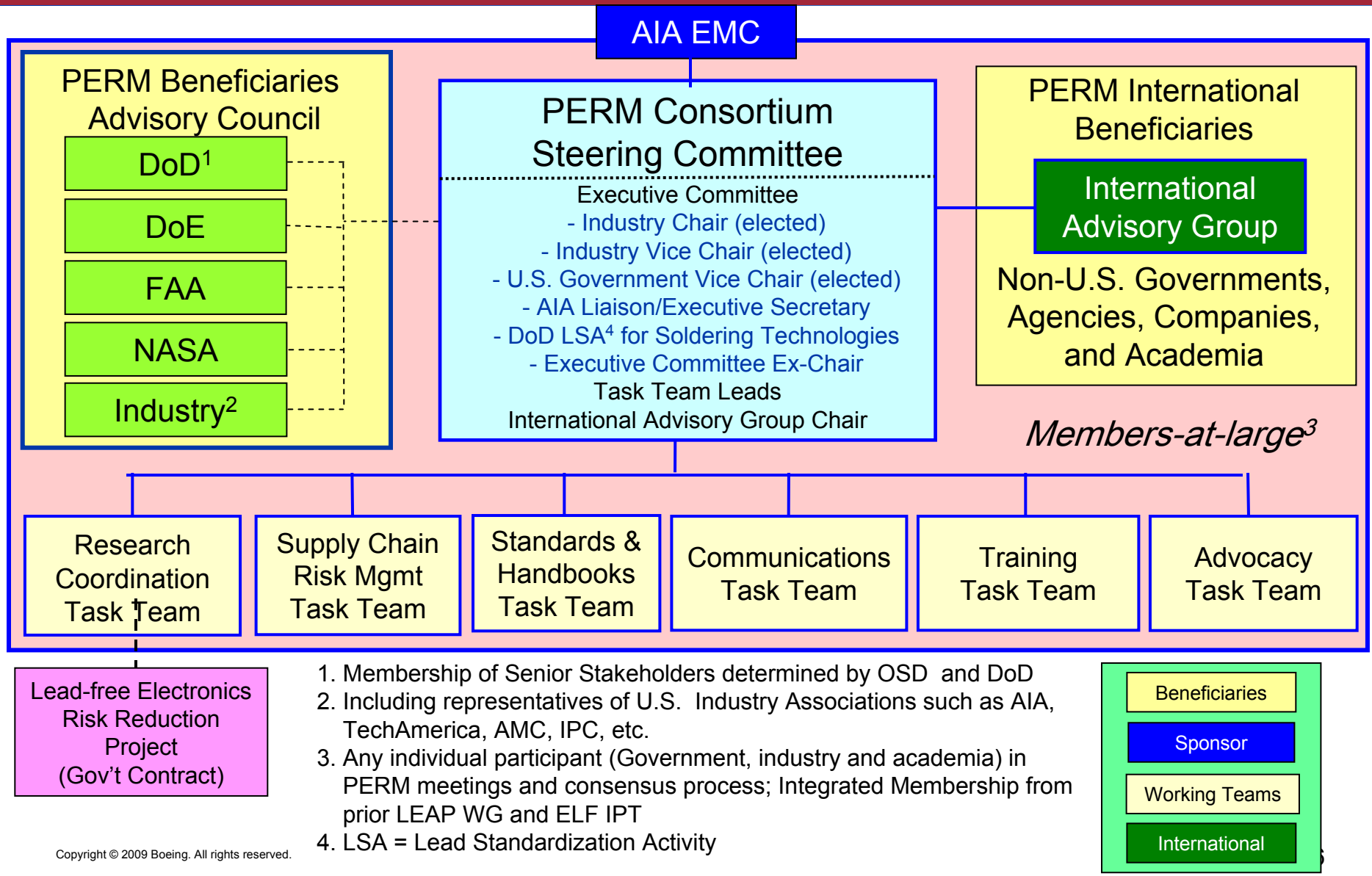



JG-PP: Joint Group on Pollution Prevention
JCAA: Joint Council on Aging Aircraft

ELF IPT: Executive Lead-Free Integrated Process Team
LEAP WG: Lead-free Electronics in Aerospace Project Working Group

# Pb-free Electronics Risk Management (PERM) Consortium






1. Membership of Senior Stakeholders determined by OSD and DoD
2. Including representatives of U.S. Industry Associations such as AIA, TechAmerica, AMC, IPC, etc.
3. Any individual participant (Government, industry and academia) in PERM meetings and consensus process; Integrated Membership from prior LEAP WG and ELF IPT
4. LSA = Lead Standardization Activity

# Lead Free Standards and Handbooks From the LEAP WG



| *RELEASED* | |
|---|---|
| *GEIA-STD-0005-1* | *Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder* |
| *Lead Free Control Plan (LFCP)* | *Compliance Template for compliance to GEIA-STD-0005-1* |
| *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* |
| *In Work* | |
| *GEIA-HB-0005-4* | *Reliability Assessment for Aerospace and High Performance Electronics Containing Lead-free Solder* |

# *Pb-free Electronics Risk Reduction Project*



Phase 1: Benchmark current best practices to deal with Pb-free electronics (2 weeks, April-May 2009)

- Funded by Navy ManTech Benchmarking & Best Practices Center of Excellence
- Report available for download at the B2P COE Website (http://www.navyb2pcoe.org/b2p_news.html) and the Defense Acquisition University Lead-free Website (https://acc.dau.mil/leadfree)

Phase 2: Define the Risk Reduction Roadmap to address the gaps (2 weeks, August 2009)

- Funded by Joint Defense Manufacturing Technology Panel (JDMTP)
- Developed a 36-month Roadmap for Phase 3 execution
- Report with Roadmap and ROM cost estimates – 2010 release

# Phase 3 ROM Cost Estimate



*36-month, $105M* Risk Reduction Program will enable continued use of Pb-free COTS electronics in A&D products*

| WBS | Risk Reduction Project Area | ROM Cost in 2010 $ (M) | | | |
|---|---|---|---|---|---|
| | | Year 1 | Year 2 | Year 3 | TOTAL |
| A | Tin Whiskers | $ 6.3 | $ 6.8 | $ 6.5 | $ 19.7 |
| B | Assembly | $ 3.2 | $ 4.0 | $ 3.0 | $ 10.2 |
| C | Solder Joints | $ 13.9 | $ 19.4 | $ 13.3 | $ 46.6 |
| D | Components | $ 1.2 | $ 2.6 | $ 2.1 | $ 5.9 |
| E | Printed Circuit Boards (PCBs) | $ 3.9 | $ 5.2 | $ 3.5 | $ 12.6 |
| | TOTAL | $ 28.5 | $ 38.0 | $ 28.5 | $ 95.0 |

"Cultural Issues" for Pb-free Electronics are as challenging as the Technical Issues, making it more difficult to obtain risk reduction funding

***Fundamental objective is to resolve knowledge gaps for use of Pb-free electronics in A&D products as quickly as possible!***

**Includes $10M project management cost*

# *So, $105M will solve the problem, right?*



**The scientist: What do I need to know?**
New knowledge

**The engineer: What do I need to do?**
Actionable deliverables

**The supply chain manager: What do I need to require?**
Deliverables in contracts

**The manufacturing engineer: What do I need to deliver?**

**The quality/mfg. engineer: What do I need to verify?**
Deliverable verification processes

**The executive: What strategies/policies do I need to implement?**

# Hard Questions

## *PERM Supply Chain Management Task Team*



1. **Are we trading engineering problems for supplier management problems?**
   -Collaborative solutions – not adversarial
2. **Is the global electronics supply chain so complex that effective supplier management for high-performance, low volume electronics is impossible?**
   -Static vs. dynamic solutions
3. **Is the "traditional" aerospace approach to supplier management based on market concepts that are rapidly becoming obsolete?**
   -"Fit them into us" or "fit us into them"
4. **Is the aerospace applications envelope so broad and demanding that COTS content makes it impossible to define and guarantee system or subsystem reliability?**
   -"Adapt" or "control"
5. **Is the current trend toward less reliable electronics in general?**
   -Unreliability in – reliability out

-

# The Electronic Supply Chain



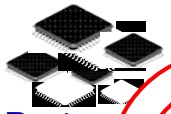
**Using components targeted for other markets**
**(what we *cannot* control)**

**To build products that must meet mil-aero requirements**
**(what we *must* control)**

**Aerospace Electronics**
- **Depends on materials and components developed for other industries**
- **Vastly different lifecycle applications**

***Requirements flow-down vs. products flow-up process is disrupted here***

**1. Parts & Materials Suppliers**



**Parts**

**Boards**

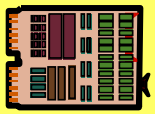
**Solder etc.**

**2. Board Assemblers**

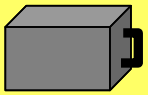
**Contract Mfg.**

3 - 6 yr Lifecycle

**Aerospace Captive**



**3. Avionics OEMs, Logistics, Maintenance and Repair**

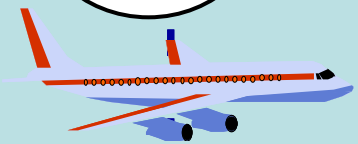


**Suppliers**

**4. Platform Integrators**

**5. Operators & Regulators**

15 - 40 yr Lifecycle



**Customers**

**Global Supply Chain**
***fundamentally limiting dependence***

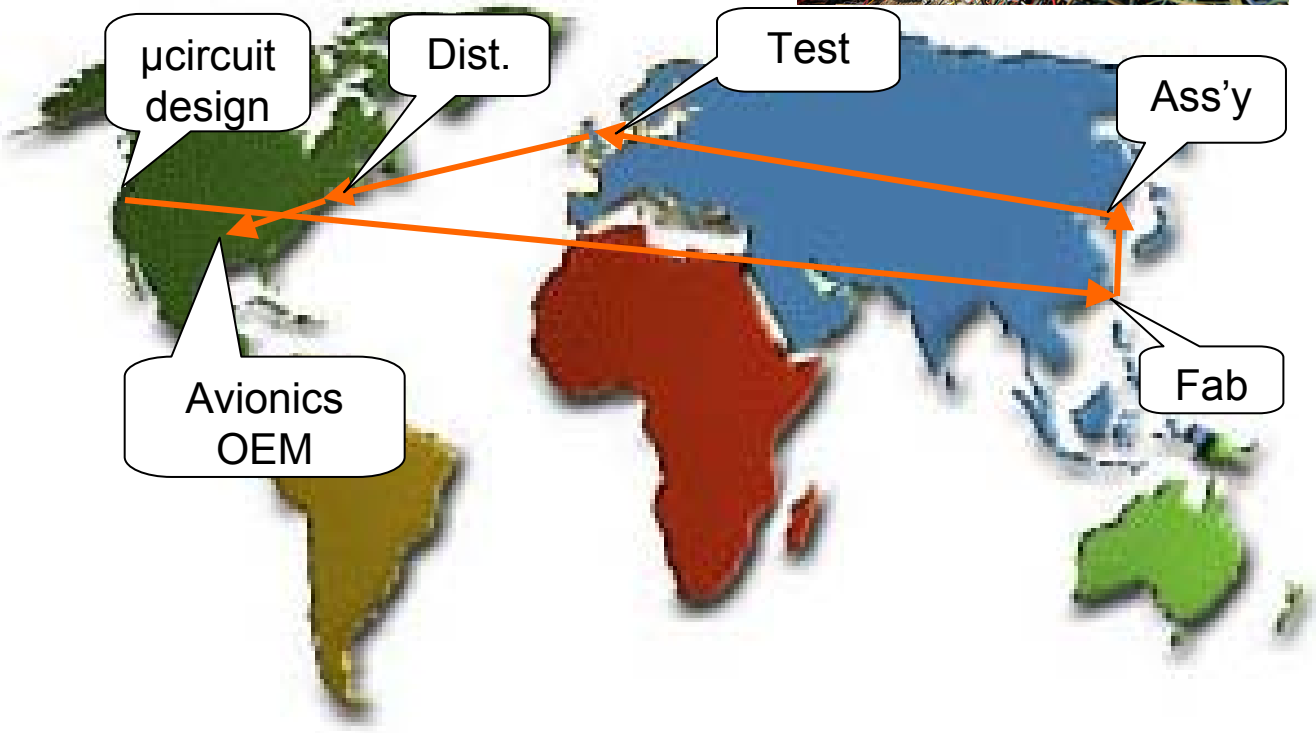
*Most **procurement** costs are incurred here*

*Most **life cycle** costs are incurred here*

# The Global Electronics Supply Chain



The global electronics supply chain is long, circuitous, and constantly changing. The number of potential combinations of links is large, and growing. The level of "control" is shrinking.

# Change…..Impact…..Response



- **Our electronics supply chain is changing quickly**
  - Globalization – new suppliers, competitors,
  - Specialized parts, assemblies, materials
  - Short design, production, service, and support lifetimes
  - Configuration control
  - Narrower operational ranges
- **New technical issues continue to emerge**
  - Failure modes, mechanisms, effects
  - Hardware/software interfaces
  - Dramatic changes in reliability assurance methods/data/tools
  - Design practices/methods/tools
  - Green electronics – Hazardous Substance Process Management

**New and unknown risks to our products impacts *All* aerospace programs:**

- System definition
- System architecture
- System design
- Acquisition
- System certification
- Acceptance procedures
- Operation and support
- Life-cycle costs

***An industry strategy is needed to identify & mitigate these impacts.***

***What organization is addressing these issues strategically?***

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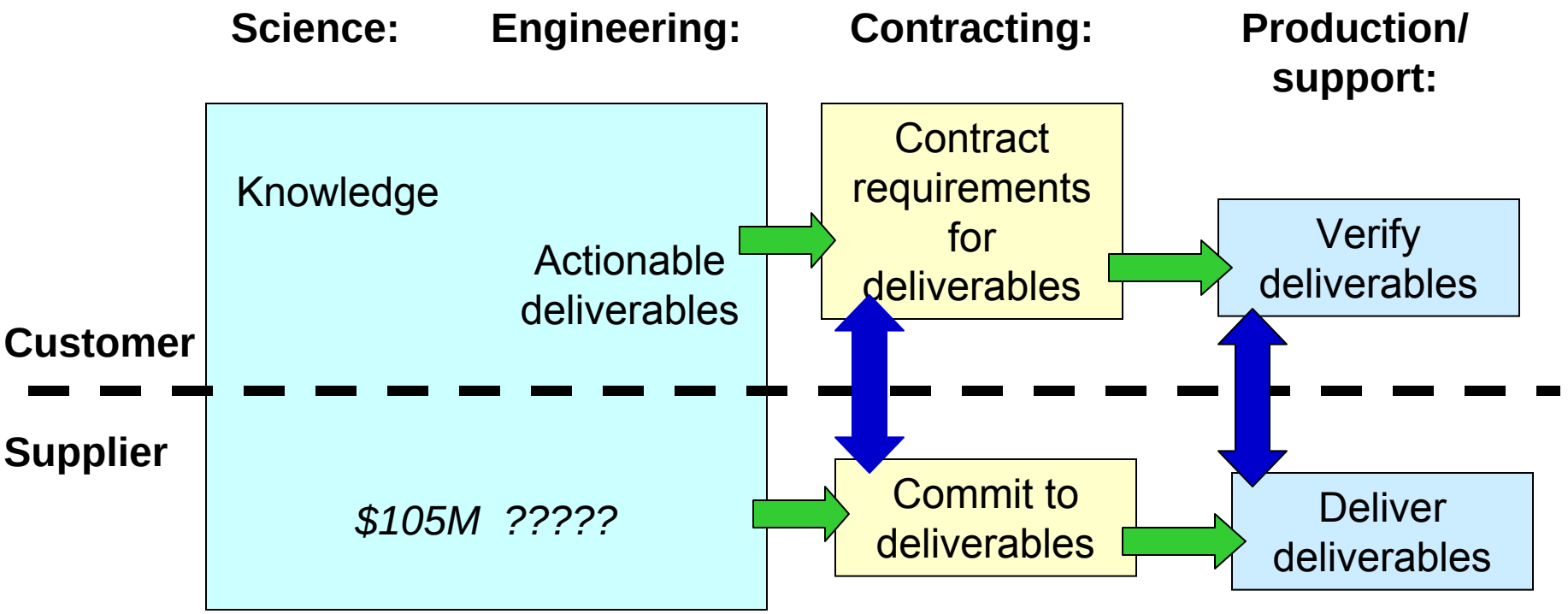
# The Strategy






***Management:***

***Develop strategy and implement through policy***

*(and update as needed)*

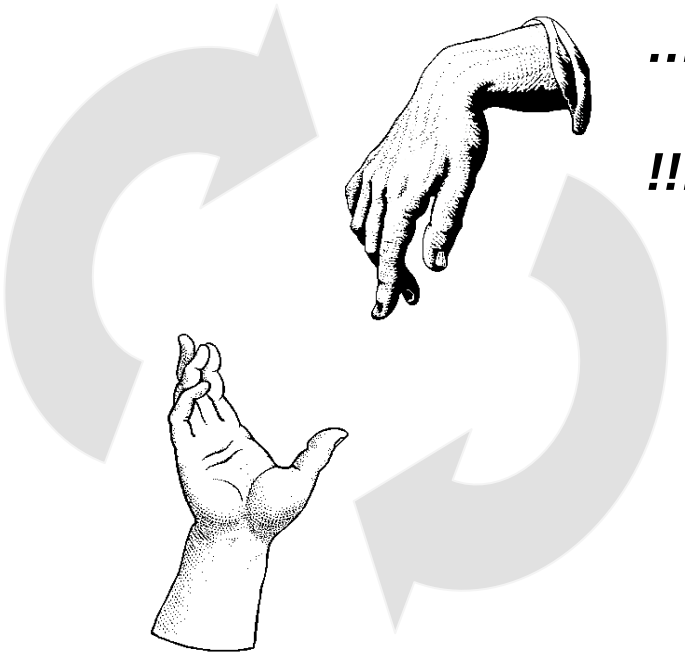
# The Conundrum



**Management**

***It's a technical problem ….***

***Find a solution !!!***



**Engineers**

***It's an enterprise issue …. What is our policy ???***

*Source: Paul Vianco, Sandia*