SAND2011-6963C

Programmatic Challenges of Pb-Free Technology for the High-Reliability Electronics Industry

Paul T. Vianco

Sandia National Laboratories
Albuquerque, NM
Phone: 505-844-3429
Email: ptvianc@sandia.gov

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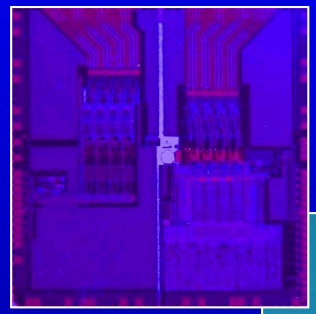
High-Reliability Electronics

- 63Sn-37Pb (Sn-Pb) interconnection technology has a proven track-record of providing manufacturability, reliability, and sustainability across the aerospace and defense (A&D) industries

- There is no apparent technical basis to change to a Pb-free solution in order to realize, or to even improve upon, these successes.



Why fix, what isn't broken ???

Changing Business Climate

- **Non-technical forces are driving the way in which the A&D industry delivers electronics assemblies.**

In-house manufacturing capacity is being replaced with outside supplier services

"Re-enterprising" has driven decisions to curtail some manufacturing capabilities, including electronics assembly .

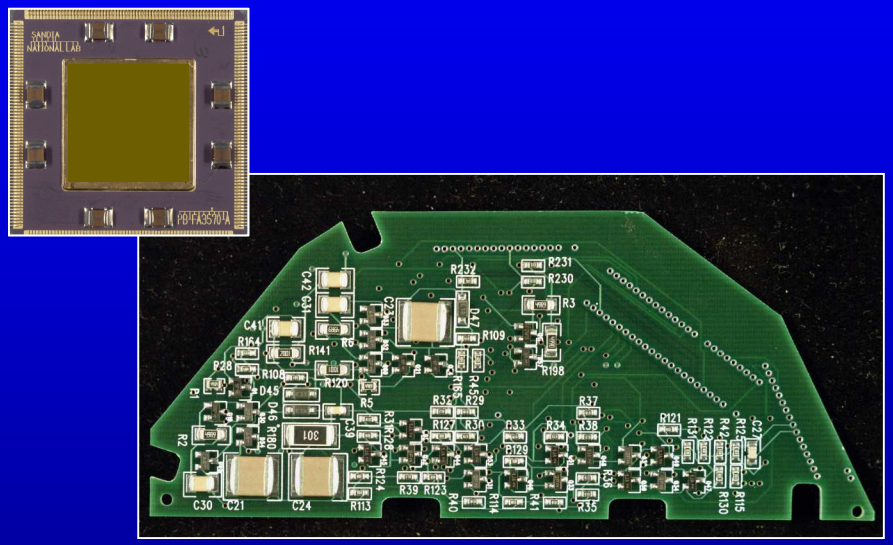
Outside suppliers are being forced into Pb-free solutions by their commercial customers

It is not in the supplier's best interest, from either a manufacturing engineering or a business perspective, to maintain both a SnPb and a Pb-free assembly capability.

The A&D industry must addresses a future in which a Pb-free solution is the only option for its commercially-supplied electronics.

Changing Business Climate

- **Performance-based procurement …**



- **A&D institutions have had to relinquish control over materials, components, and manufacturing to commercial suppliers – *some are even overseas*.**

The Loss of Sn-Pb Technology

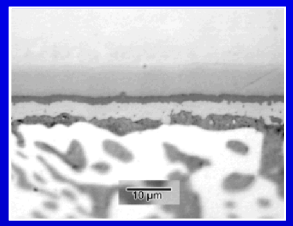
- The viability of Sn-Pb solders will not be lost due to a "step-function" decline in materials availability.
- Instead, the viability of Sn-Pb technology will be lost because of cost premiums and protracted schedules.
- However, an important concern is not that there will be a phase-out of Sn-Pb technology …

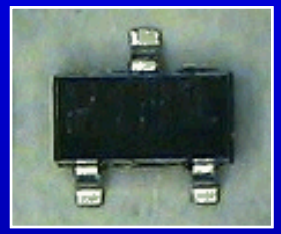
  … rather, it is when and, in particular, *when with respect to the specific program schedules.*

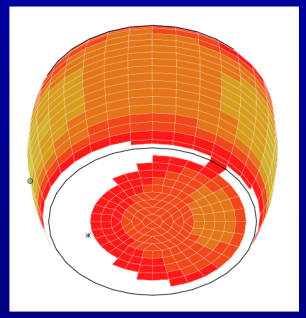
- Case in point … *The need to change solder alloys that then requires revalidation and requalification.*

The Path Forward

- **The electronics industry *as a whole* has a better foot-hold on Pb-free technology after 20 years, than it has had on Sn-Pb technology after 90 years of use.**
  - **Fundamental materials science**
  - **Surface finishes**
  - **Fluxes / pastes/ cored wire**
  - **Manufacturing** *(… not quite)*
  - **Reliability** *(test and modeling)*
  - **Supply chain management**

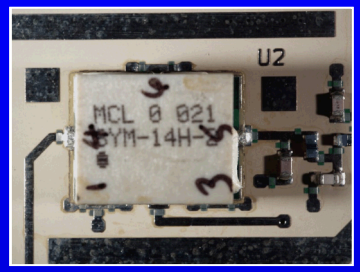




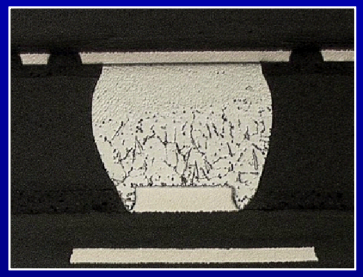


The Most Pressing *Technical* Issues

- **Surface finishes:**
  - Sn whiskers
  - Alternative finishes
- **Materials:**
  - Multiple solder alloy
- **Manufacturing:**
  - Heat, heat, heat, …
- **Long-term reliability**
  - Mixed solders
  - Shock and vibration



Sn whiskers in COTS hybrids



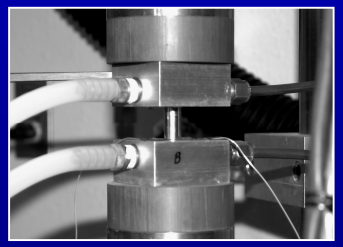
SAC305/Sn-Pb mixed solder joints: legacy and new hardware

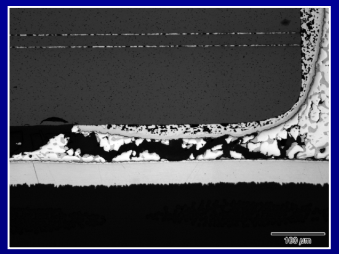
The Path Forward

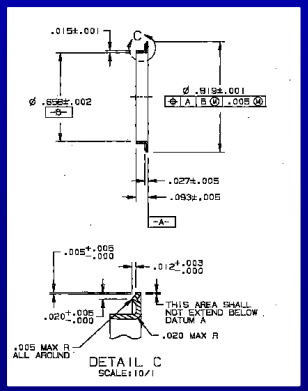
- A successful Pb-free solution must be executed as a:

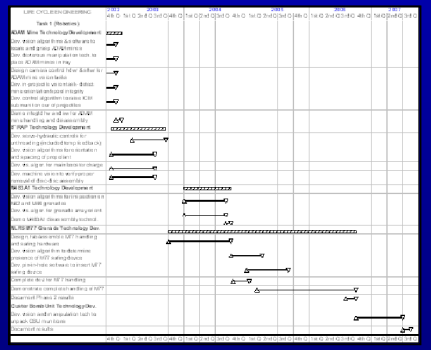
Technology – program partnership

- It has been the experience at Sandia, through the development of a Pb-free product that is concurrent with COTS implementation, that technology and programmatic functions ***must support each other***.









The "10,000 ft. Level"

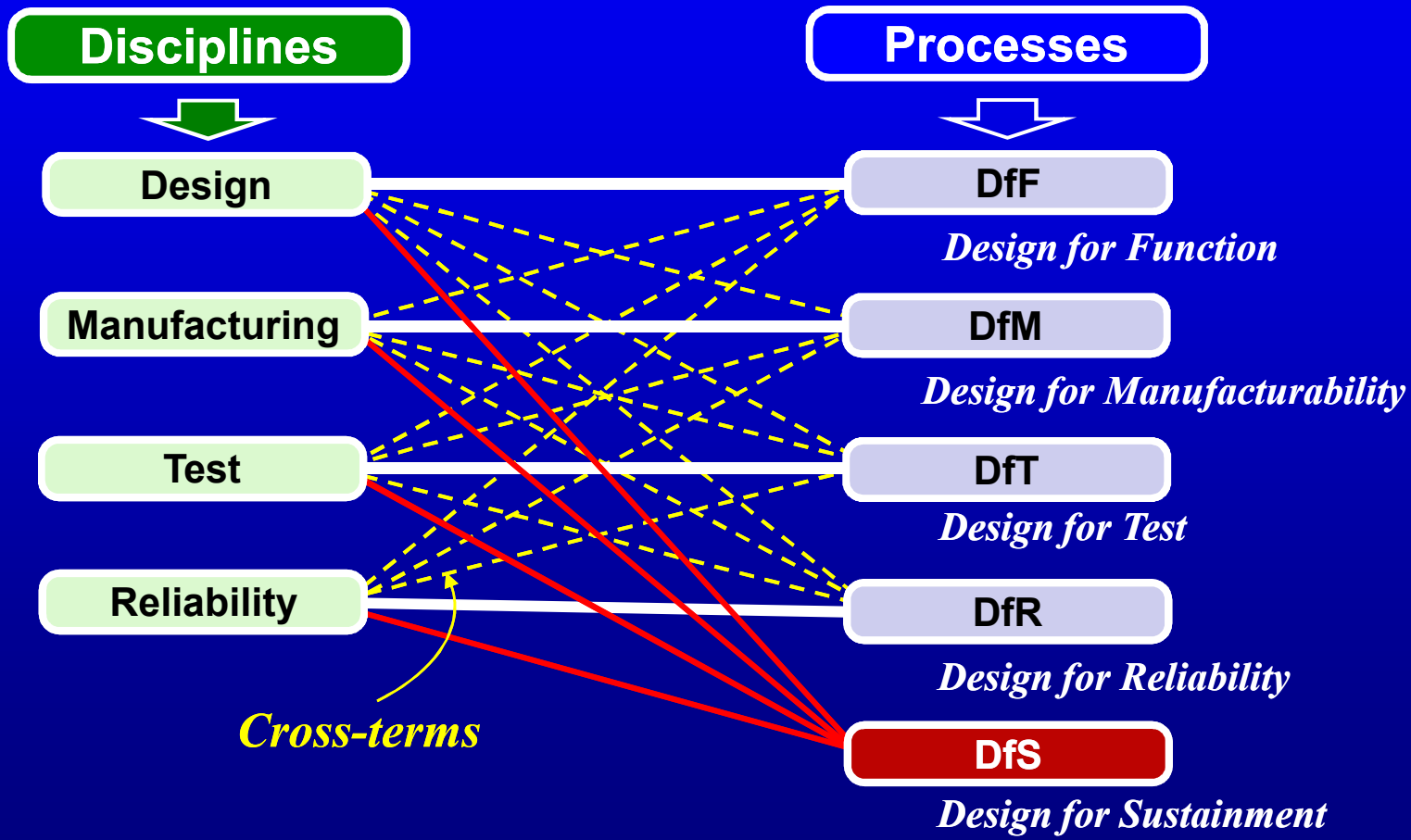
- A fully integrated approach is the *only* path that works.

A&D companies are learning the value of this approach …

… sometimes, "the hard way".

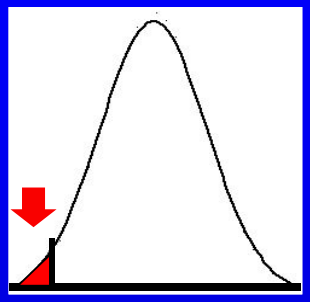
Why We *MUST* Do Business in this Manner

- Often, the development of high-reliability, complex systems fails to appreciate the "cross-term" effects.



Example: The COTS "1% Defect" Problem

- **Low-frequency (1%) component-level failures have been observed with commercial off-the-shelf (COTS) and MIL-COTS parts, using Sn-Pb solder:**
  - **Multi-layer chip capacitor**
  - **Glass-body diodes**
  - **Tantalum capacitors**
  - **Chip resistors**



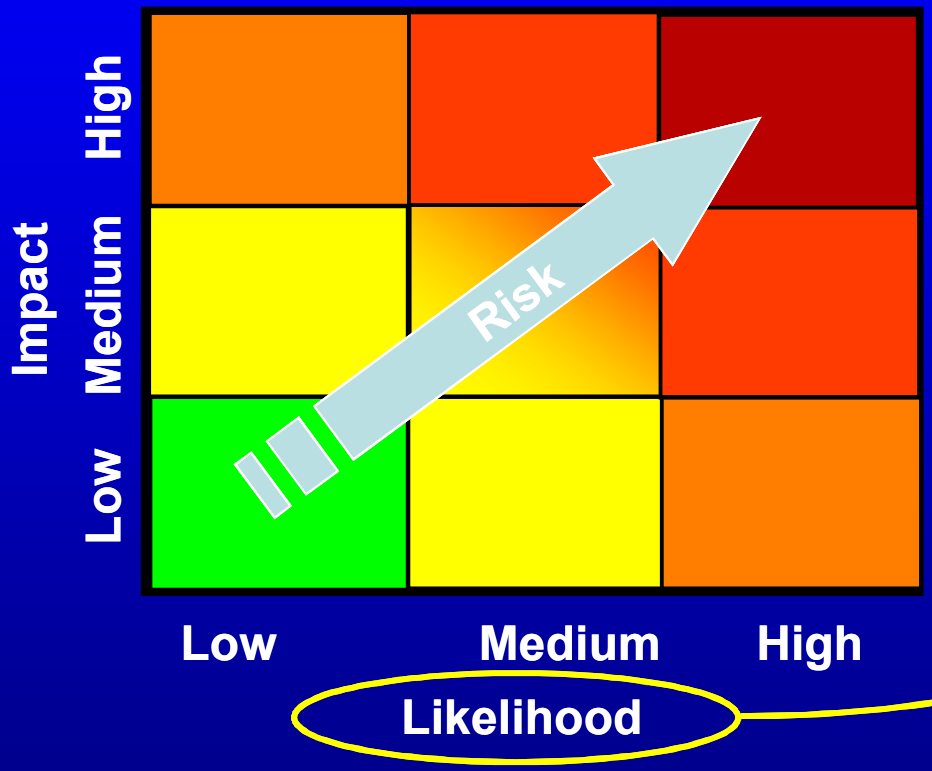
"1%" Problem

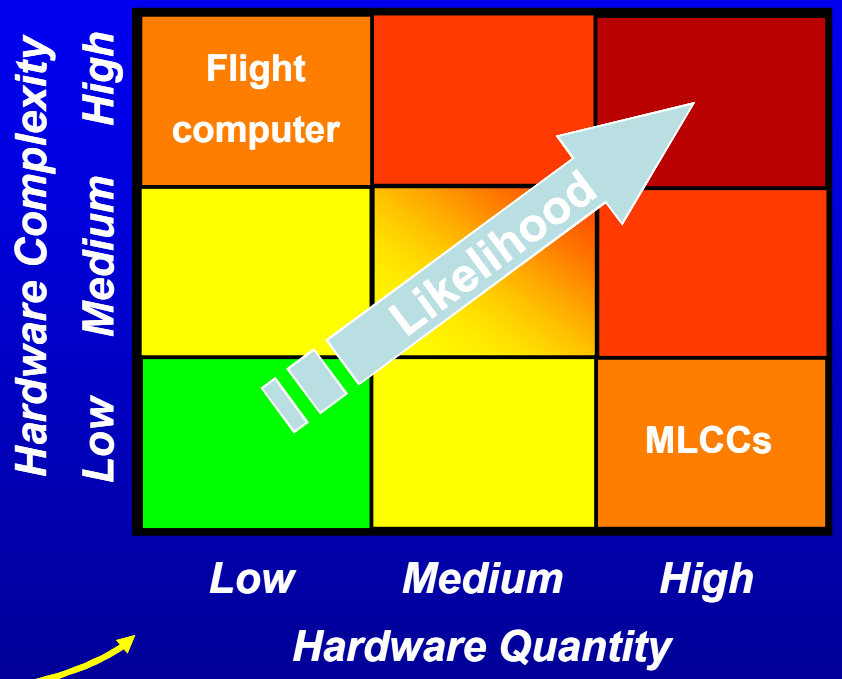
Commercial products cannot be blamed entirely for the "1%" defect issue; we may have already been headed down this road even with MIL-grade components, due to greater system complexity and increased functionality requirements.

- **The A&D industry *cannot* expect assistance from the supplier base, even with price premiums. These low failure rates are not critical to their prime customers, the commercial electronics industry.**

Approach: Understand the Risk

- Often, the A&D Industry neglects the fact that the "Likelihood" regime has two contributing factors.

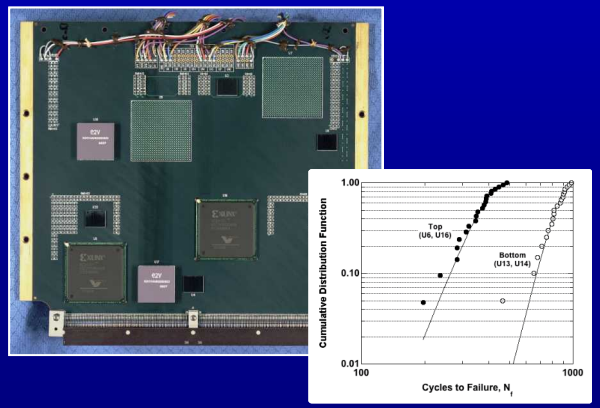




The failure of low-complexity components (or "mature technologies"), if present in large quantities within a sub-system, can significantly impact the long-term reliability of the overall system.

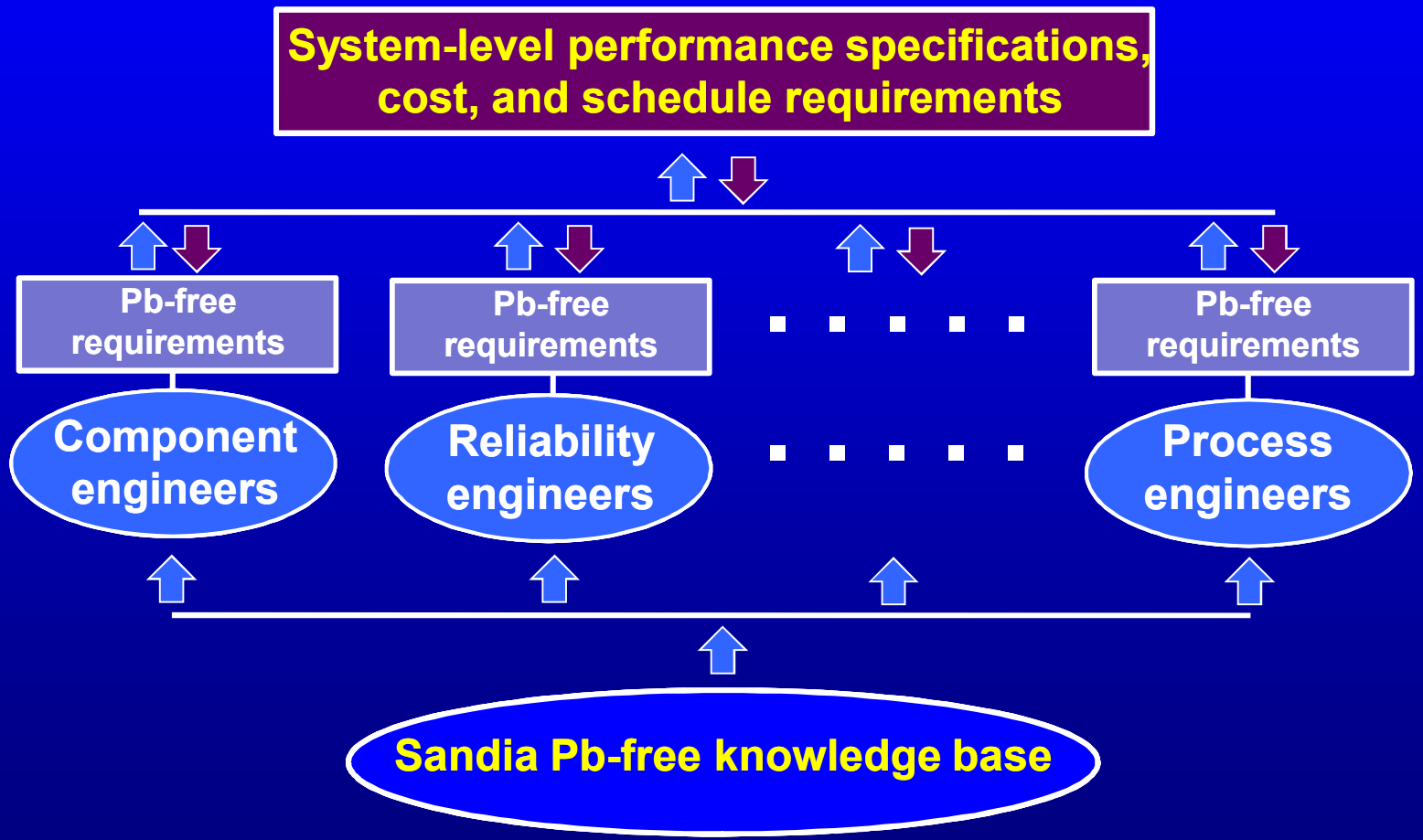
Approach: Environmental Stress Screening

- Materials, process and reliability SMEs are sensitize to complex as well as "out-of-the-spotlight" technologies.
  - Assess components, mechanical structures, etc.
  - No component or sub-system is beyond scrutiny!
  - Value of failure modes effects analysis (FMEA).
- Best approach to finding defects: develop **screening test methodologies** performed at the supplier (to keep part warranties) or in-house (loss of warranties).
  - Characterization test vehicles
  - Accelerated aging environments (HALT, HAST, etc.)
  - Apply small-sample statistical analysis techniques

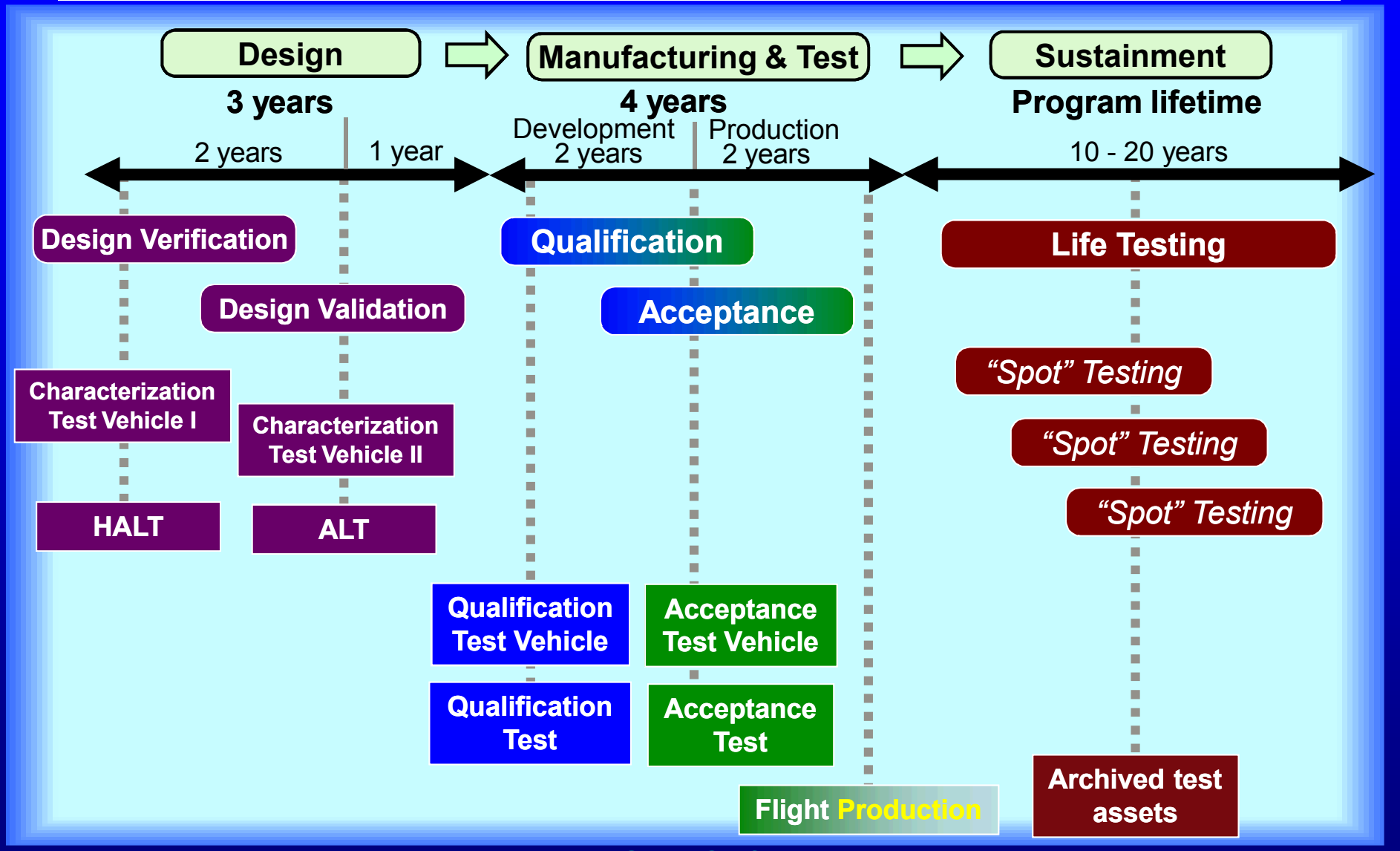


Tailor the Information Flow to the Organization

- Sandia is a "bottom-up" organization with respect to Pb-free technology … *that is <u>our</u> starting point.*

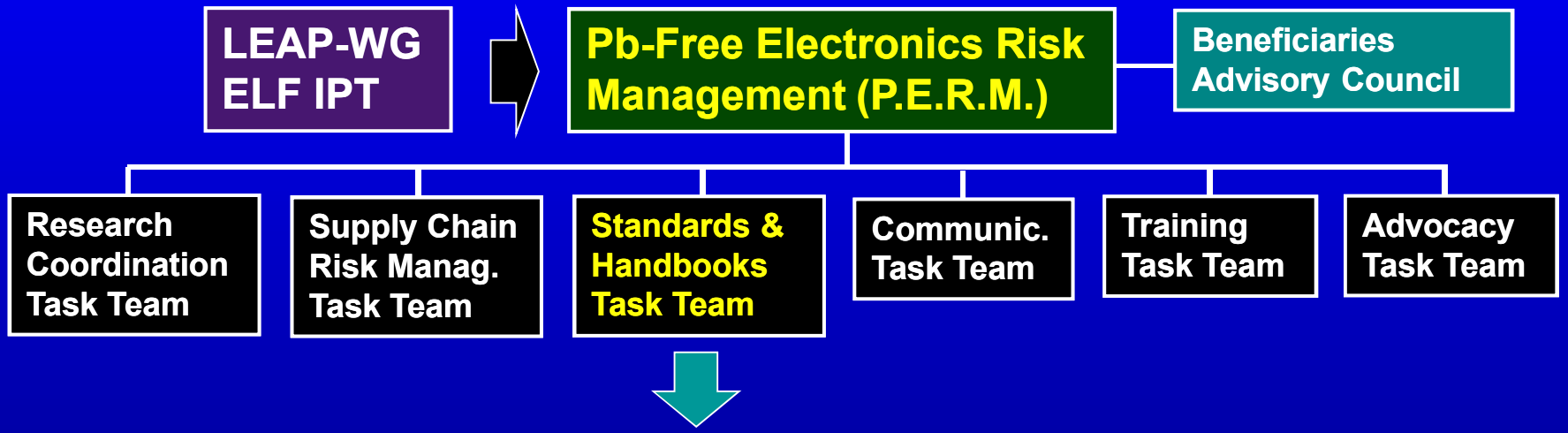


Awareness of Schedule and Investment



Standards, Specifications, and Guidelines

- Organizations such as the IPC, ASTM, JEDEC and ISO are developing ANSI consensus documents that address specifically Pb-free soldering technology.

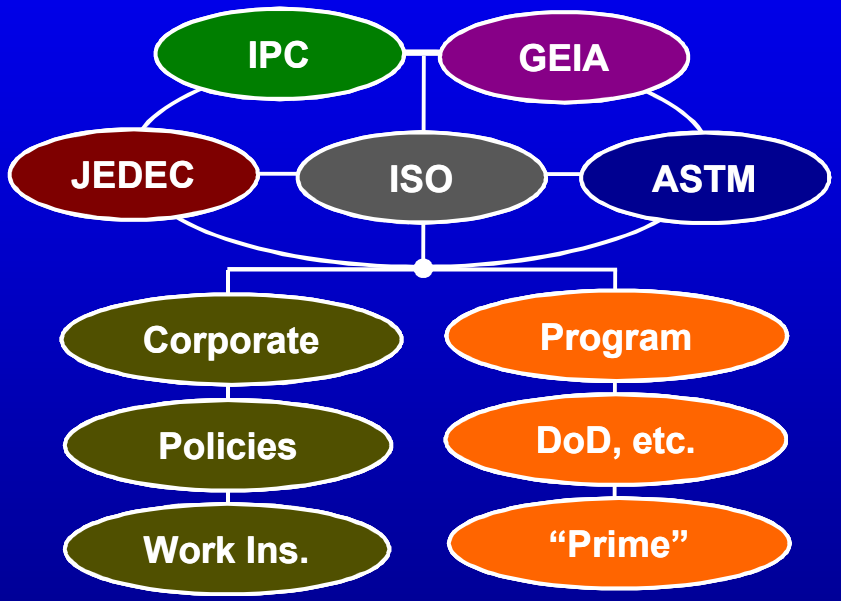


GEIA-STD-0005-3, *"Performance Testing for Aerospace and High Performance [AHP] Electronic Interconnects Containing Pb-free Solder and Finishes"*

- Tests methods: thermal cycling, shock and vibration, etc.
- Test vehicles
- Data analysis

… Where the *Real* Work Begins …

- The challenge is to integrate all of these resources into one or more documents that can be executed by the program or across a company technology:
  - Supply chain management
  - Design for Function
  - Design for Manufacturing
  - Design for Test
  - Design for Reliability and Quality Assurance (QA)
  - Design for Sustainment



- The condensed timeline of Pb-free implementation will require an *integrated effort* by technical personnel *and* program management to develop these documents.

Summary

- Today, programmatic details have surpassed the technical knowledge towards developing a Pb-free solution in the Aerospace and Defense (A&D) industry.

- Performance-based procurement and commercial off-the-shelf (COTS) supply chains have added their own "complexities" to the challenges.

- For as "standardized" as we would wish the A&D industry to be, different organization cultures as well as product lines necessitate the tailoring of standards and practices for their successful integration.

(con't)

Summary

- Planning can only go so far … The system must be exercised in order to address the programmatic challenges that are a part of a Pb-free solution.
- Washington D.C. funding sources are becoming increasingly *unsympathetic* to excessive cost overruns and schedule delays*.
- This prevailing attitude can affect the continued support of existing programs, and the ability of an organization to win future contracts*.

* Observation first made by author in April 2010, Hunstville, AL.