Environmental Lessons Learned During The Shuttle Program

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It's Black & White: The Shuttle Was Never Meant to be Green

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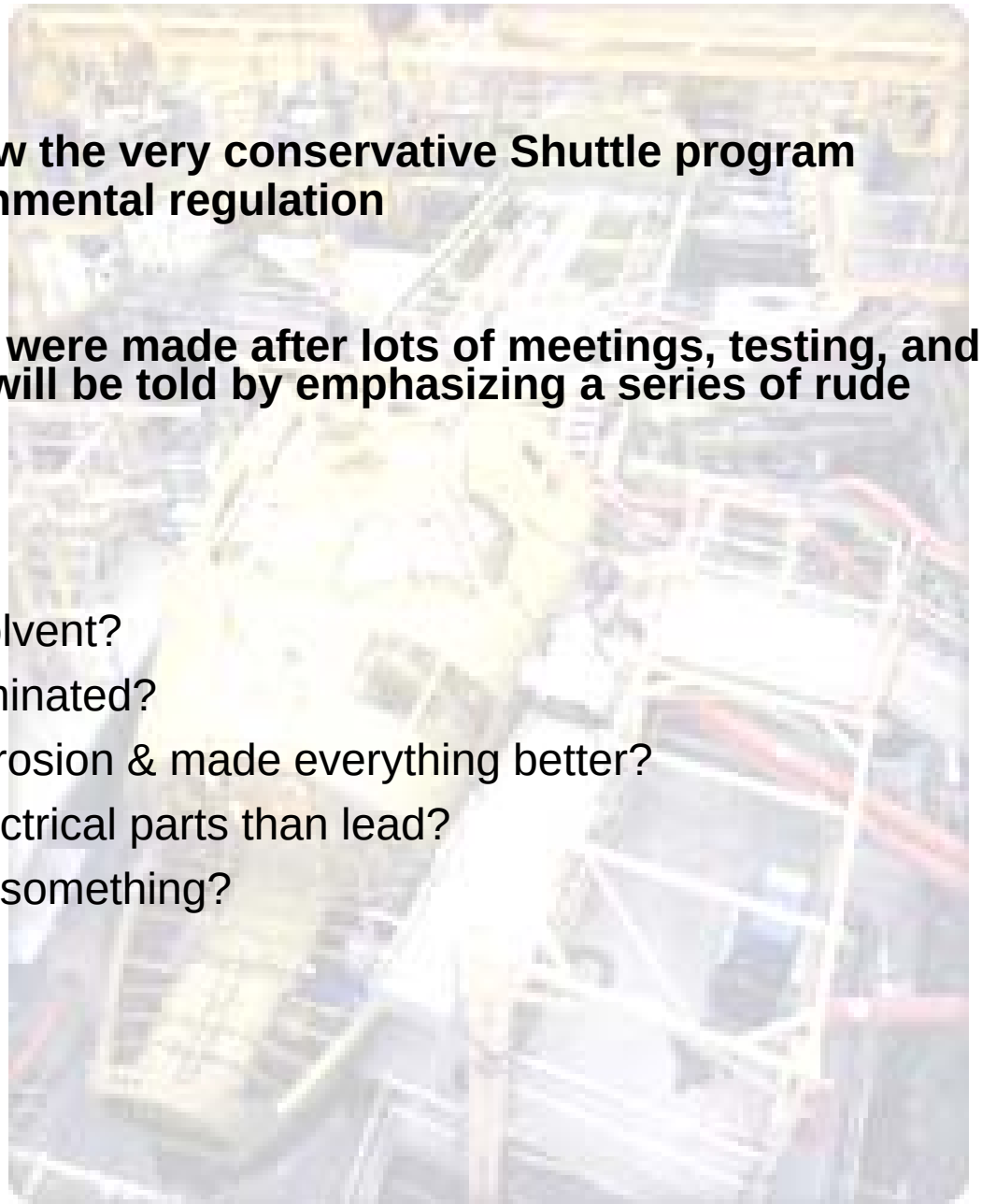


Summary:

- **The following charts describe how the very conservative Shuttle program adapted to ever-changing environmental regulation**
- **Although the necessary changes were made after lots of meetings, testing, and specification changes, the story will be told by emphasizing a series of rude awakenings & lessons learned**
- **Do you remember when ……**
  - Freon was a miracle cleaning solvent?
  - Ozone was a pollutant to be eliminated?
  - Hexavalent chrome stopped corrosion & made everything better?
  - There was no other finish for electrical parts than lead?
  - It didn't matter where you made something?

Even if You are Building The Shuttle You Can't Poison Your Neighbors

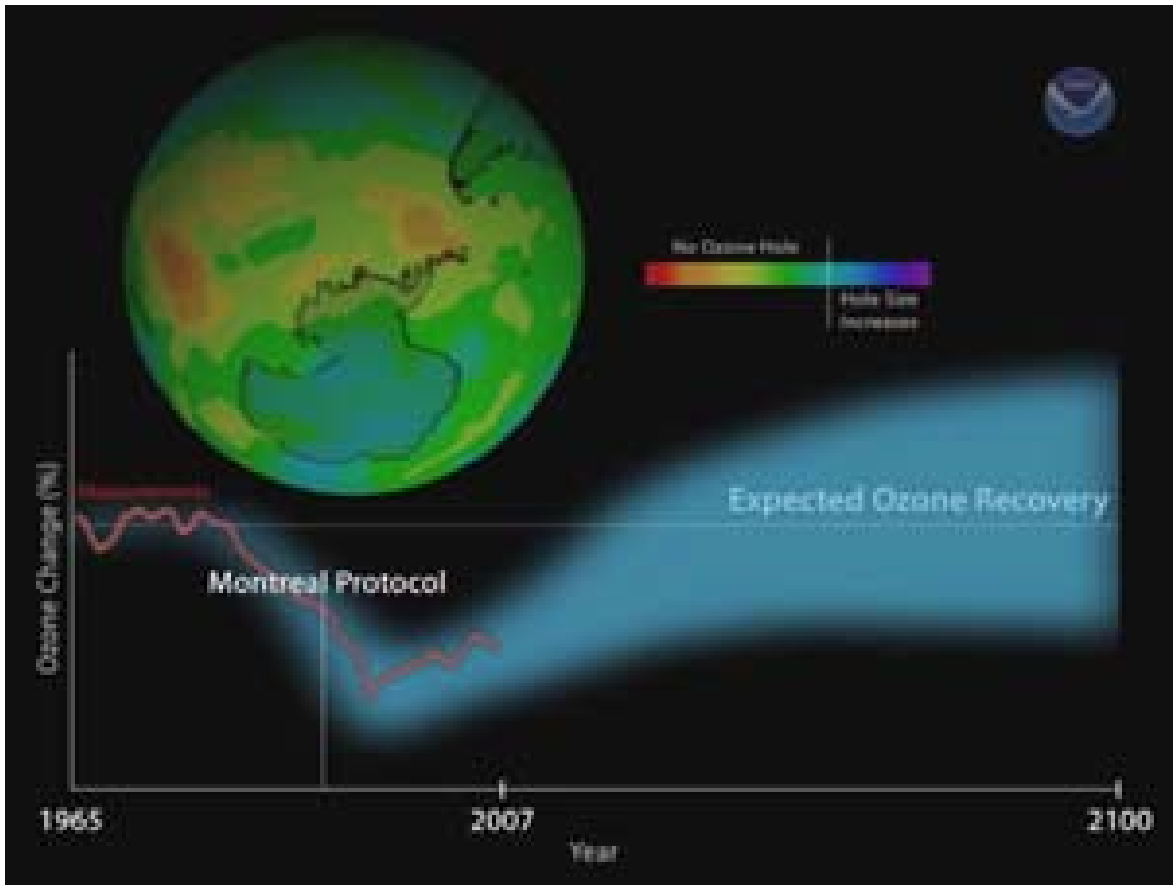
- **Back in the 70s it made sense to build much of the Shuttle Orbiter in Southern California**
  - Apollo legacy facilities & staff
  - Huge supplier base
- **By the mid 80s the Southern California Air Quality Management District (SCAQMD) began to produce "technology forcing" rules**
- **Some of these rules required notification of those nearby that they were at risk**
  - "At Risk" usually translated to 1 in a million or 10,000 additional cancers due to a lifetime of being nearby the manufacturing in question

Lesson #1: What You are Doing & Where You are Doing it Matters

- **Manufacturing had to reduce the use of toxic chemicals, or else notify employees & neighbors of elevated risk**
- **Can operations be moved to Mexico, or the desert (Palmdale)?**
- **Air scrubbers, HVLP paint guns, & other emission capture devices suddenly became of interest**
- **Engineering received it's first request to look at alternative processes and materials in 1986**

The EPA Can't "Ban" a Solvent – Can It?

- **Environmental regulations were viewed by the Orbiter Program in 1990 as more of a local problem to California**
- **This all changed with the Montreal Protocol & Clean Air Act, banning the production and import of Class 1 ozone depleting compounds**
- **Orbiter depended on Freon 113 for almost all critical cleaning**
- **At this point the Program began to take an interest in environmental regulations**



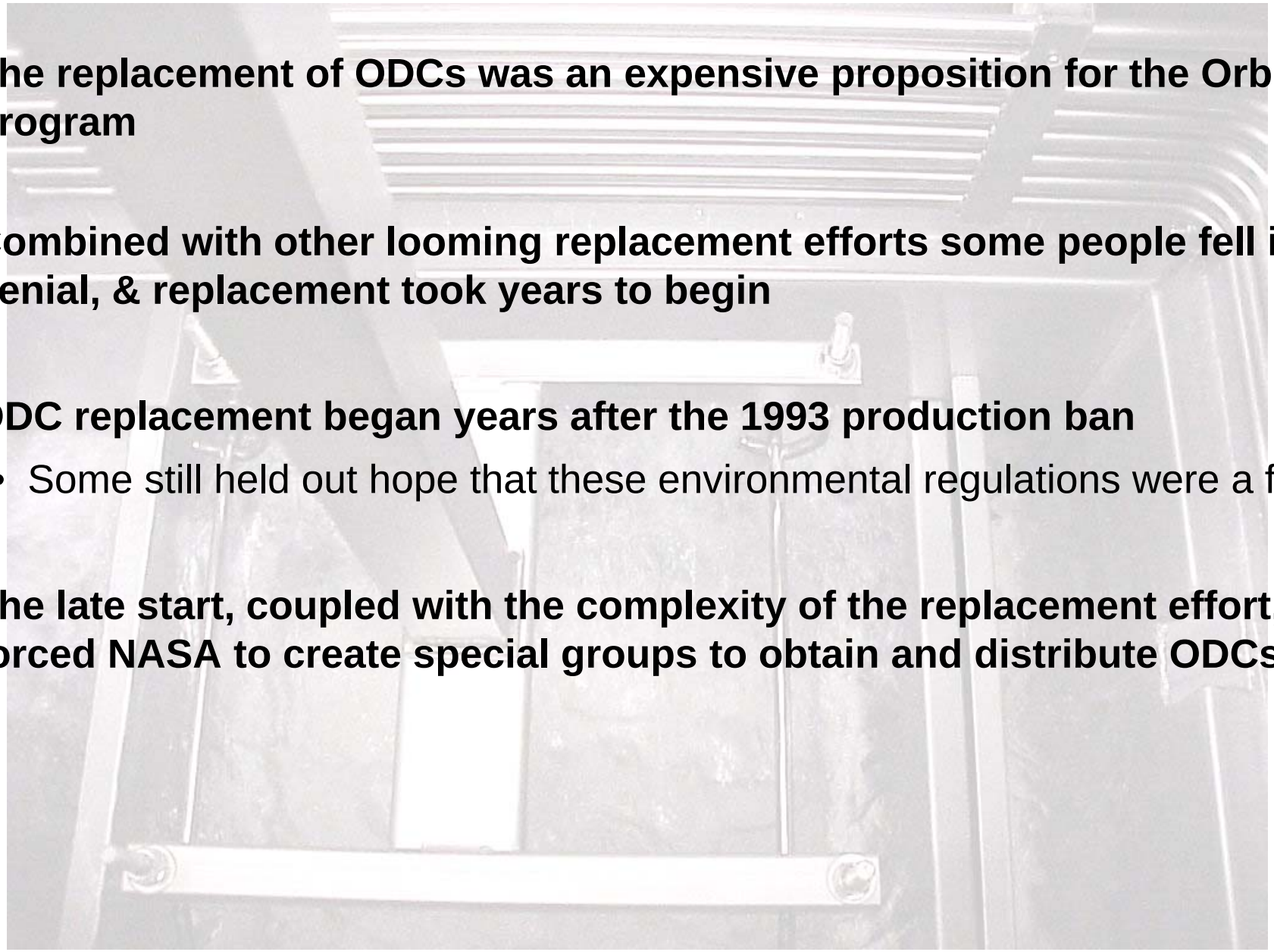
Lesson #2: Environmental Issues Can Quickly Become Logistical Issues

- **Logistics realized that a new threat to material availability existed**

- **The procurement, transportation, and storage of banned solvents turned out to be a real challenge**
  - Orbiter needed to find out where the ODCs were used
  - Travel to each site to find out why the ODCs were being used
  - Review each application regarding why so much was being used
  - Eliminate waste wherever possible
  - Replace wherever technically feasible

- **NASA has learned this lesson so well you can still find a rail car with Freon 113 at KSC**

The Republicans Will Give us Our Solvent Back

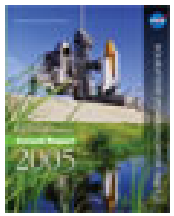


- **The replacement of ODCs was an expensive proposition for the Orbiter program**
- **Combined with other looming replacement efforts some people fell into denial, & replacement took years to begin**
- **ODC replacement began years after the 1993 production ban**
  - Some still held out hope that these environmental regulations were a fad
- **The late start, coupled with the complexity of the replacement effort, forced NASA to create special groups to obtain and distribute ODCs**

Lesson #3: Overcoming the Technical Challenges Requires a Proactive Response

- **Replacing a critical material for use in manned space takes more time than for other replacement applications**
  - Accelerating replacement efforts critical to meeting regulatory targets

- **The Shuttle Program created the SRTT, and later the SEA (Shuttle Environmental Team) in order to be more proactive**
  - The team reviews & influences environmental regulation before it becomes law
    - Several spacecraft exemptions created
  - Team members collaborate on common problems to accelerate replacement work
  - Team leadership advises program management on risk areas
  - The team is now working on passing along lessons learned to Constellation, & documenting the work done during the Shuttle Program






Good News …. It Will Only Take A Year to Buy Our Primer

- **The Shuttle program is not flexible when it comes to material changes**
  - Suppliers are required to notify the program in advance of any changes
- **The Orbiter primer is a good example of this inflexibility (a chromated, high VOC coating)**
  - The primer's formula is "locked" – requalification would cost over 1M $
  - Almost all of the other customers are gone – Orbiter can use via exemption
  - Manufacturer sold several times, & now makes one batch per year
- **A non-chrome, low VOC replacement was qualified to mitigate the obsolescence risk**
  - Non-chrome replacement is available off-the-shelf

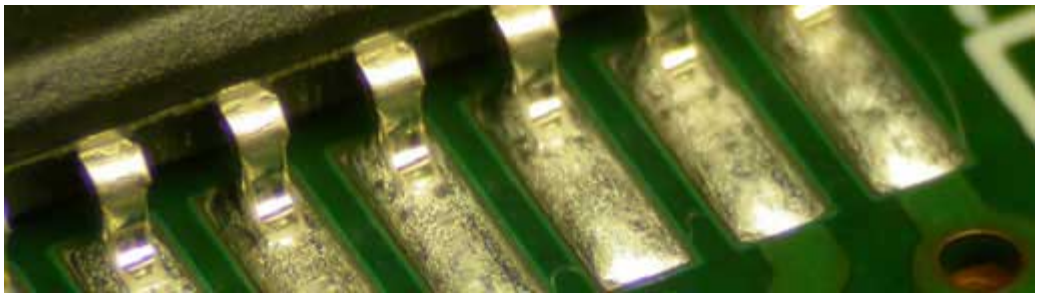
Lesson 4: Just Because it's Legal Doesn't Make it Available

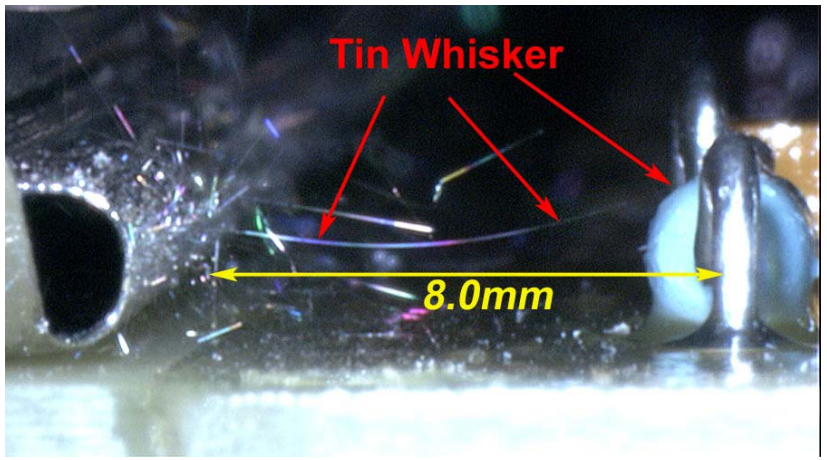
- **New regulations result in many unanticipated material changes**
  - Regulatory limits can make customer base go away prompting product obsolescence
  - Industry consolidation can affect if, where, and how a product is made

- **Lower tier suppliers may have trouble meeting new regulatory limits**
  - Strontium chromate suppliers heavily impacted by new OSHA Chrome standard
  - Powdered conversion coatings are threatened by same OSHA standard

Non Lead Leads Lead Lead Leads

- **When the Shuttle was designed & built nobody would have ever thought to use a finish that did not contain lead**
  - No requirements to use lead, or to check for lead upon receipt
- **During the mid to late 1990s a number of regulations were put into place to discourage the use of lead**
  - Many of these were European regulations
- **Most of the part suppliers began the transition from lead based finishes to non-lead (usually pure tin) around the year 2000**
  - Factories divided into a lead line and a non-lead line
  - Components with lead finishes started to become obsolete
  - Part mix-ups resulted in pure tin parts inadvertently being substituted
- **Today most of the electrical parts are lead free**





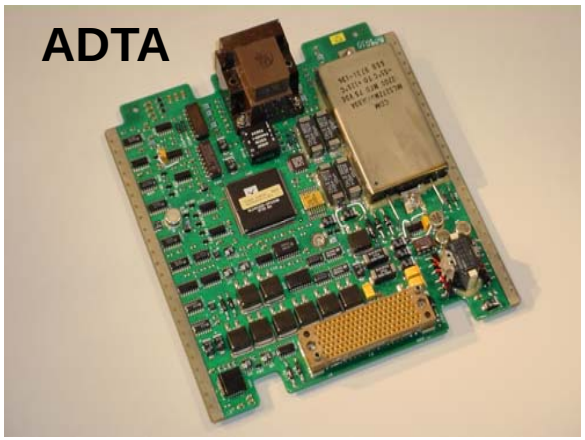
Lesson 5: European Regulation Can REACH US

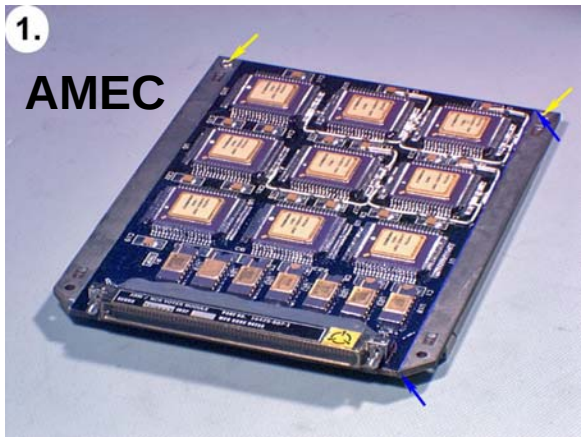
- **Approximately 99% of commercial electronic parts now have lead-free finishes**
  - Only the aviation industry still requires lead-finished electronic parts

- **Electrical part procurement requires more oversight**
  - A pure-tin mitigation plan is needed to flow requirements to lower tier suppliers
  - Every lot of parts should be tested upon receipt (x-ray fluorescence testing)

- **Future procurements will not be able to get every part with a lead based finish**
  - Risk mitigation efforts will be important
    - Hardware design (use larger standoff distance)
    - Layers of conformal coating
    - Solder dipping (new process - no reliability data yet)

XRF Unit





Wal-Mart & The Space Program

- **The Orbiter program uses hundreds of specialty products which have thousands of ingredients**
- **Foreign, Federal, State, & local regulations now target many of the above ingredients**
- **Companies such as Wal-Mart have their own rules on what their merchandise can be made from**
- **Global manufacturers want to make a product that can be sold everywhere**
- **As a result, many of the products used by the Space program will undergo slight reformulations**
  - **Aerospace requirement can be affected (weaker tape, more flammable heat shrink tubing, etc.)**

Lesson 6: Expect Product Formulations to be Dynamic

- **Product suppliers were contacted regarding plans to eliminate at-risk compounds**
  - Each of these "Xenobiotic" compounds are current, or anticipated regulatory targets

Xenobiotic Classification	Percent of Vendors Who State No Alternate Products Exist	Percent of Vendors Who State Alternate Products Are Available But No Transition is Planned	Percent of Vendors Who State Alternate Products Are Available and Transition Plan is Underway	Percent of Vendors Who State Products are Obsolete
Penta-BDE & Octa-BDE	0%	0%	0%	100%
Deca-BDE	55%	45%	0%	0%
PFOS/PFOA	66%	0%	17%	17%
AP/APE	83%	17%	0%	0%
Restricted Phthalate Esters	12%	70%	12%	6%
Bisphenol A	100%	0%	0%	0%

Environmental Challenges Will Continue to Impact NASA Programs

- **The Shuttle program had to adapt to 20 years of environmental regulation**
  - It became important where the work was being performed
  - Logistics & Engineering had to mitigate obsolescence risk
  - Integrated team established to share data, track progress, & assess risk
  - Critical materials became endangered or extinct
  - Product formulations change on a regular basis

- **Future programs should be flexible**
  - Critical materials need to be carefully controlled
    - Identify changes before the products are used
  - In most cases, the replacement product is worse than the at-risk material
    - Design to accommodate lower performance
  - Expect new regulations to target materials that are acceptable today