Lessons Learned in Technology Transition

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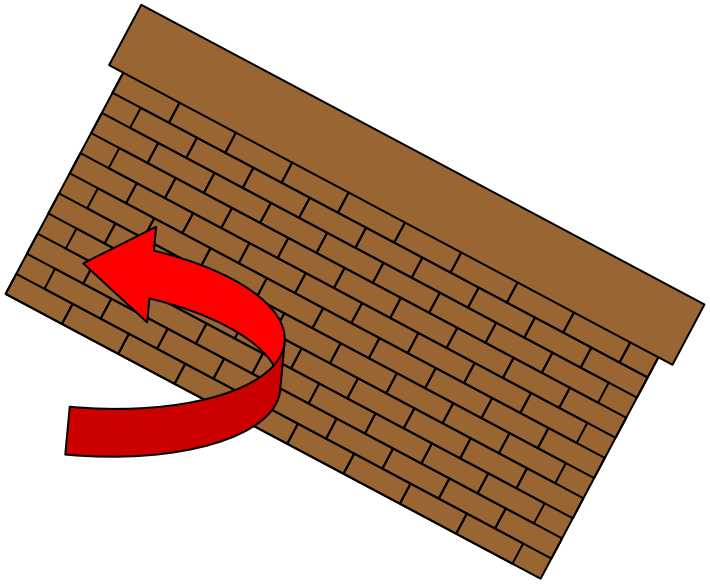
Transferring Technology through the “valley of death”

Developers with Great technologies



Production Success

Developers see opportunity for applications

Programs see risk in change
- **production cost and schedule**
- **training, supply, sustainment**
- **performance liability**

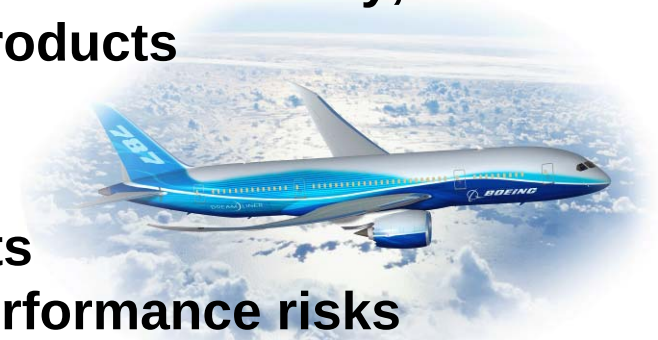
Developers need to help programs mitigate risk factors

Overview

- **Design and production process**
- **Drivers for change**
- **Specification driven processes**
- **Examples of successful transitions**
  - **Vapor degreasers**
  - **Nonchromate anodize**
  - **Cadmium Alternatives**
  - **Nonchromate primers**
  - **Basecoat/clearcoat**
- **Conclusions**

Drivers for Change in Industry

- **Make products more cost effective (improve "value")**
  - **Lower direct cost, improve schedule, increase reliability, etc.**
  - **Weight reduction is key for aerospace products**

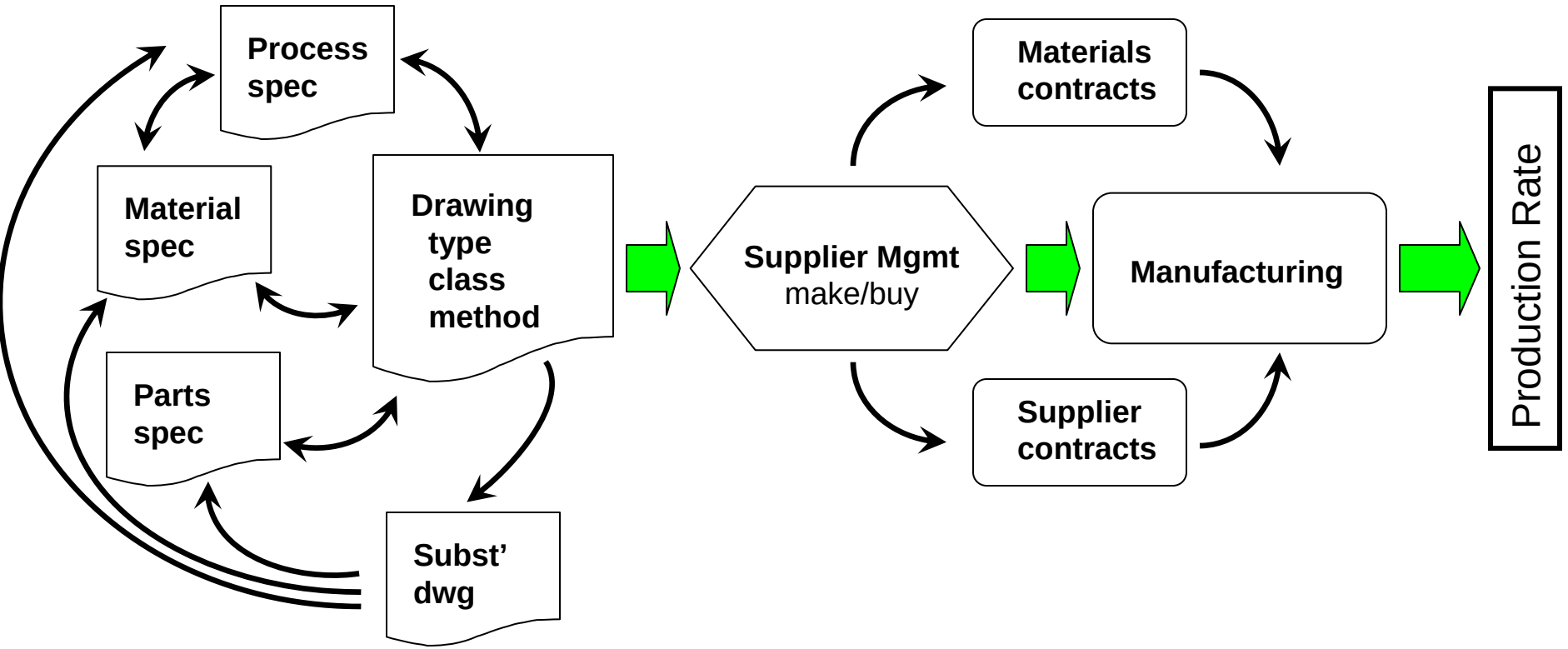


- **Regulatory requirements**
  - **Safety equipment, reporting requirements**
  - **Balance noncompliance costs versus performance risks**
  - **Balance between cost of compliance and cost of redesign and recertification**

- **Environmental regulations**
  - **Federal clean air act**
  - **OSHA and EPA requirements**
    - **Cadmium, hexavalent chromium, VOC**
  - **ReaCH**

Change in production is difficult

- **Multiple elements to drawing controlled parts**



  - **Production processes that are not drawing controlled are sometimes easier to implement**

Timing is Important

- **Product cycles have three stages**
  - **Design and definition – easiest transition point** (3-10 years)
    - **Drawings are being created/modified**
    - **Need to be production ready**
      - **Stable process and materials**
      - **Adequate supply base / be able to meet rate**
      - **Well defined performance, production, sustainment processes**
  - **Transition to production** (1-3 years)
    - **Configuration and dwgs are final**
    - **Install infrastructure/tanks/tooling/jigs/etc.**
    - **Establish supply contracts (typically long term)**
    - **Establish training and support processes**
  - **Production** (4-12 years)
    - **Execute production plan**
    - **Changes difficult at this point**
      - **Require change to dwg, supply chain, configuration mgmt & control, training**

Requirements for Successful Transition to Production

- ➔ **Meet Vehicle Performance Requirements**
  - **Capable Engineering properties**
    - **Meet performance specifications**
  - **Adaptable Processing characteristics**
    - **Appropriate for production environment**
- ➔ **Availability**
  - **Commercial product – production quantities**
- ➔ **Specification coverage**
  - **Technical Order / Military or industry specifications**

- **What are the "real" performance requirements?**
  - **Current specification limits?**
  - **Equal or better than today's coating systems?**

- **Maintain Safety of personnel and airframe/vehicle**

A plan for Success for new technologies

- **"Getting on the spec" is rarely successful**
  - **No incentive at engineering level to expend effort to qualify**
  - **Specs are minimum requirements**
    - **Primarily used to define and control acquisition**
    - **Programs need lots of addn'l data to mitigate risk**
  - **Specs are primarily for procurement, not design**
- **Recommendation: solve problem for one part**
  - **Requires lots of dialog with designers to identify candidates**
  - **Process/material called out directly on dwg ("point design")**
    - **Need draft mtl and process specs to support production**
  - **Gain production and in-service experience with the part**
  - **Success on one part leads to more applications**
- **For process changes evaluate effect of change of existing work package**
  - **Implementation dependent on a business case analysis**

Example: Vapor Degreasers and BSAA

- **Driver for change:**
  - **Clean Air Act banning open top degreasers, TCE, PCE**
- **Transitioned most production to emulsion degreasers**
  - **Few exceptions: honeycomb core, assemblies**
- **Closed loop vapor degreasers**
  - **Complicated process equipment**
- **Nonchromate anodize (Boric Sulfuric Acid Anodize)**
  - **Extensive fatigue, corrosion, and paint adhesion testing**
  - **Adhesion problems led to adoption of unsealed anodize for fully painted parts**
    - **Eliminates chromates in sealing process**

Cadmium replacements

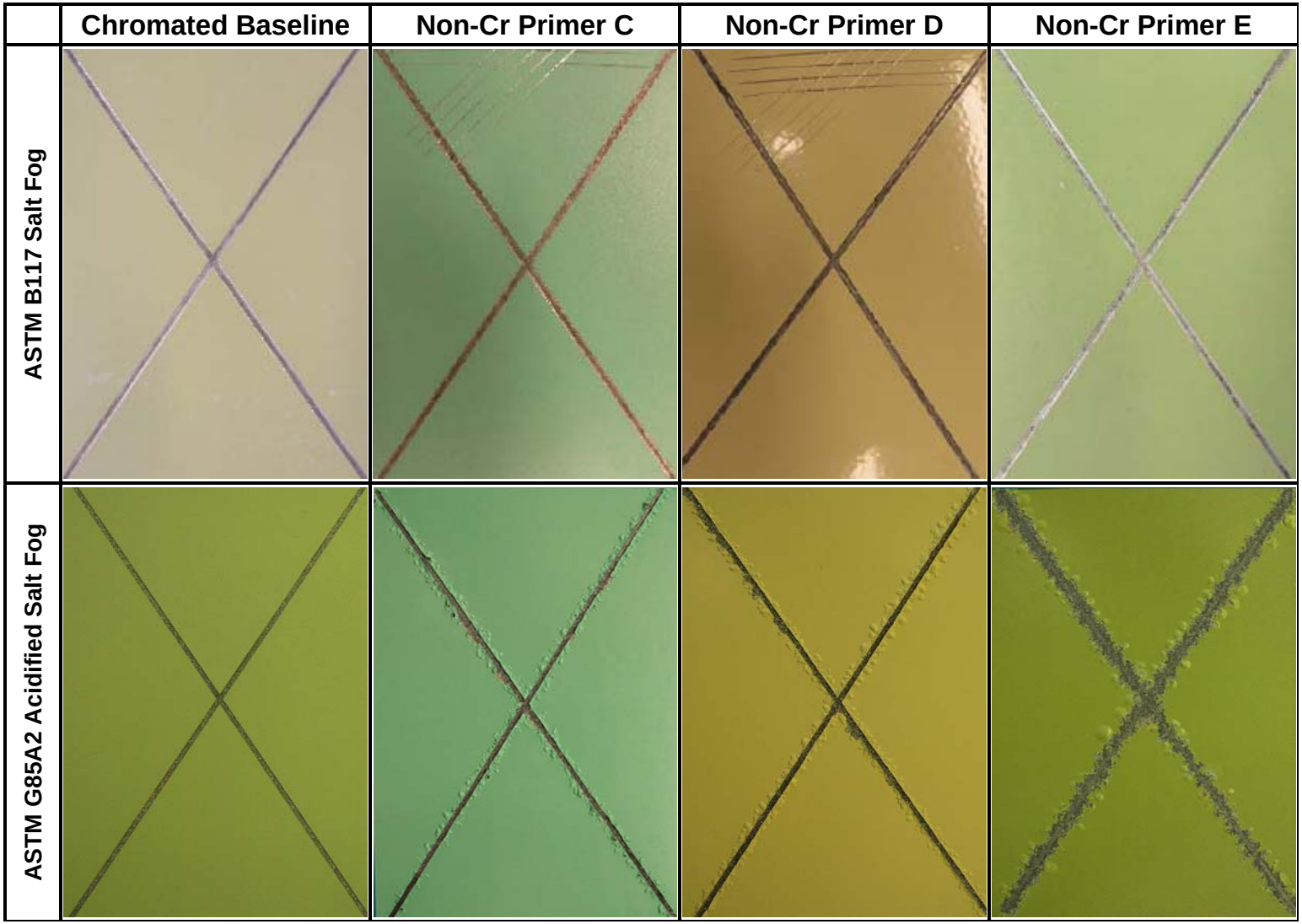
- **Driver: OSHA, REACH**
- **Ongoing development programs for aerospace**
  - **JG-PP projects for bright and LHE Cd alternatives**
  - **C-17 sponsored development with Dipsol for LHE ZnNi**
    - **Focus on C-17/AF requirements**
  - **Boeing development of LHE ZnNi**
    - **Extensive testing on landing gear, fasteners, components**
- **Implementations**
  - **Aluminum coatings on components, fasteners, connectors**
  - **Nickel based coatings on connectors**
  - **ZnNi on fasteners, some components**
  - **LHE ZnNi on components, fasteners**

  - **Balance between cost, performance, and environmental impact**

Nonchromate primers

- **Driver: OSHA, EPA**
- **Significant risk for use on critical areas of aircraft**
  - **Difficult to inspect and/or repair**
  - **Flight and/or safety critical**
  - **Painted once for life of vehicle**
- **Customer requirement: equal to or better than CrVI**
  - **Evaluation based primarily on ASTM B117 salt fog testing**
  - **Will require new type or class in specs and drawings**
    - **Military specs already have “Class N”**
  - **Drawing change required to implement**
  - **Starting to evaluate on an applications basis**
    - **Increases complexity in manufacturing**

Interior Primers

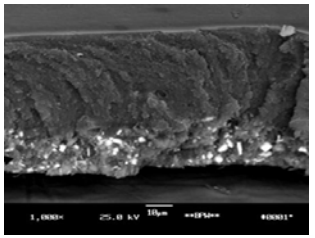


Paint Improvements

Continuous product improvement

Past Improvements

- **Paint Adhesion to Rivets (Rivet Rash)**

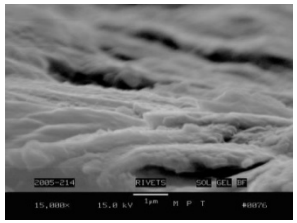


On-Going Efforts

- **Non-Chromated Exterior System**
  - **Non-chromated conversion coat and primer**
- **Non-Chrome for other areas**
- **Chemical topcoat reactivation**

Future Advancements

- **High durability, efficient topcoat systems (BCCC)**



Nonchromate Exterior Decorative Paint

- **Driver: Paint adhesion failure on rivets**

- **Maintained rivet part configuration**
  - **added boegel/AC-131 as “finish”**
  - **Extensive validation of fatigue and NDI compatibility**
- **Boegel/AC-131 replaced Alodine 1000 for additional adhesion enhancement**
  - **Benefit: reduced Cr(VI), reduced rinse water and flow time**
  - **Challenge: depainting is more difficult**
- **NonCr(VI) primer implemented on all models**
  - **Validation of corrosion protection, fluid and topcoat compatibility**
  - **Complete nonchromate finish system from metal skin out**

Aerospace's Oldest Exterior Coating Issue

Paint Loss from Rivet Head (Rivet Rash)

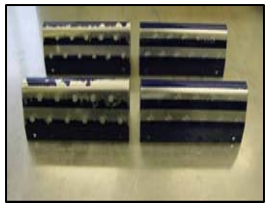
Major Applications of Boegel EPII as Pretreatment

Trials on F-15 and KC-135

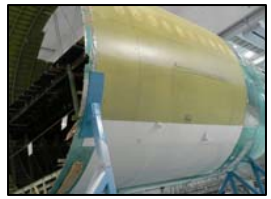
Use on All 777 Titanium Tail Cones

Trial on a 777-200LR Test Aircraft

Repaint 777-200LR for Delivery



Process Optimization



Scale-up Test on Fuselage Test Tube

2005 2006

2007 2008

Implement on All 747,767, & 777 Aircrafts

Use on 787 Line No.1

737 Trials 3 Aircrafts

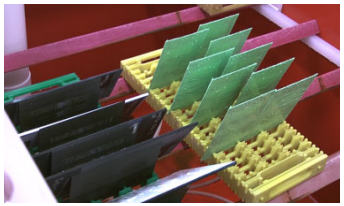
Implement on All 737's

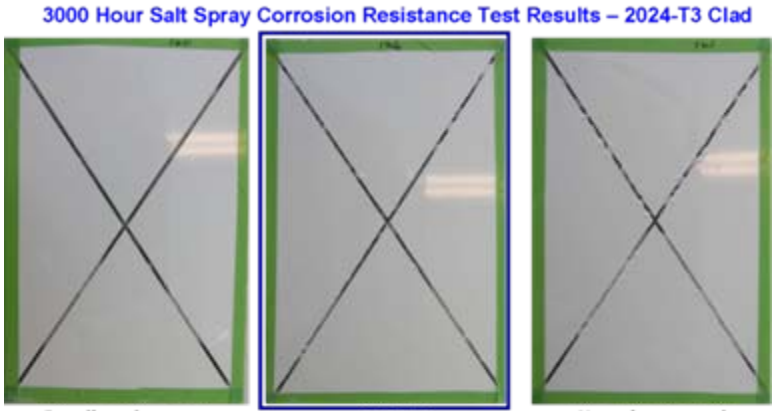
Fleet Survey on Sol-gel Aircraft

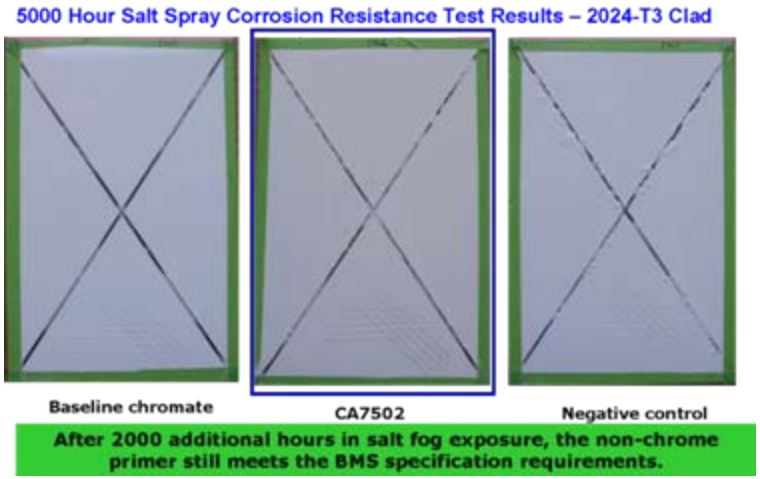
Use on Navy's P-8A Poseidon (737 Derivative)

Non-Chromated Exterior Decorative Primer

- **Screen Candidates/ Qualification testing**
  - **Requirements**
    - **Good 3000 hour salt spray corrosion resistance**
    - **Acceptable 168 hour filiform corrosion resistance**
    - **Good rain erosion paint adhesion**
  - **Beyond Requirements**
    - **Good 5000 hour salt spray corrosion resistance**
    - **Acceptable 2000 hour filiform corrosion resistance**





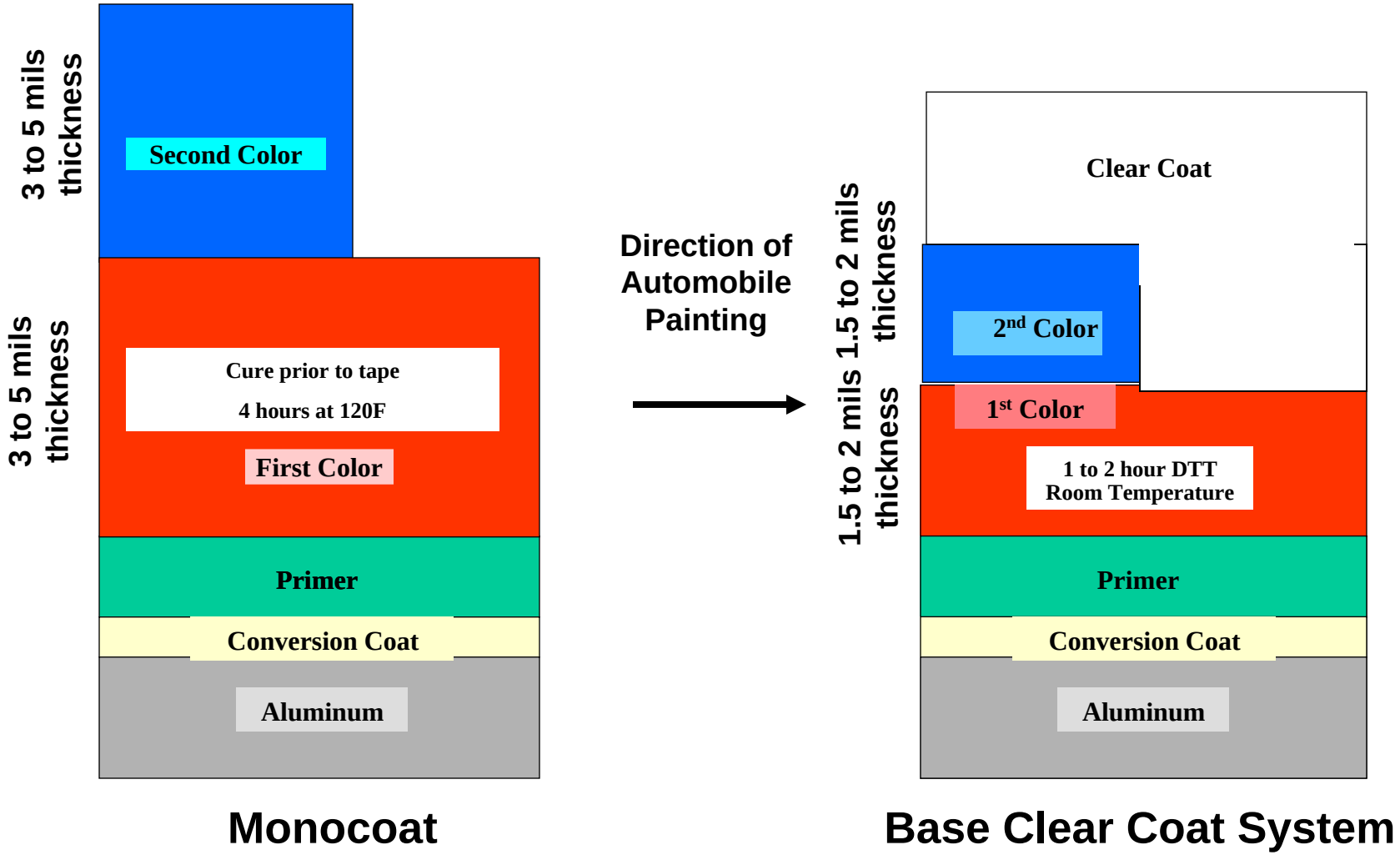


Basecoat/Clearcoat

- **Driver: Performance (durabilty), production time**
- **Replaces decorative fuselage urethane topcoat**
  - **Modeled after automotive system**
  - **System applies faster and thinner than conventional**
    - **Weight and flow time advantage**
  - **Better environmental durability**
  - **Solvent durability improving**
  - **Repair with conventional monocoats**
- **Evolving clear coat to a matte finish will allow same technology on military vehicles**
  - **Improved color, durability, cleanability over conventional**

Base Coat Clear Coat (BCCC)

What is Base Coat Clear Coat?



Conclusions

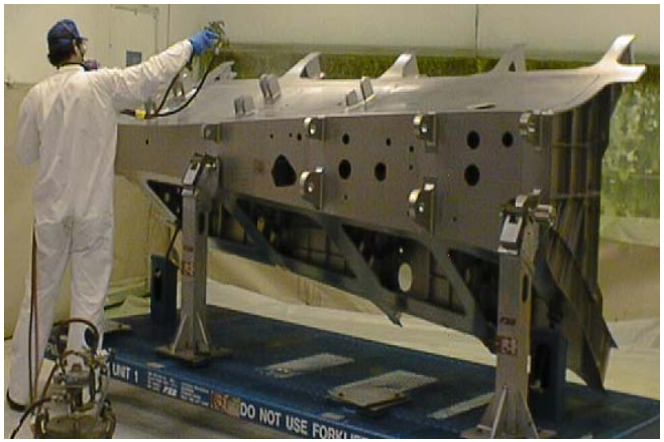
- **Listen hard to “customer”**
  - **Understand whole problem and solve that problem**
  - **Demonstrate positive benefits to offset cost/uncertainty**
- **Focus on solving problem for one part**
  - **Targets development effort**
  - **Gains customer “pull”**
  - **General use specifications will evolve for good technologies**
- **Be patient and persistent**
  - **Understand product cycles**
    - **Be “performance ready” when product is in design phase**
    - **Be “manufacturing ready” when drawings are finalized**

Questions?

Overview

- **Objective: Summary of two processes used at Boeing that reduce or eliminate the use of chromates**

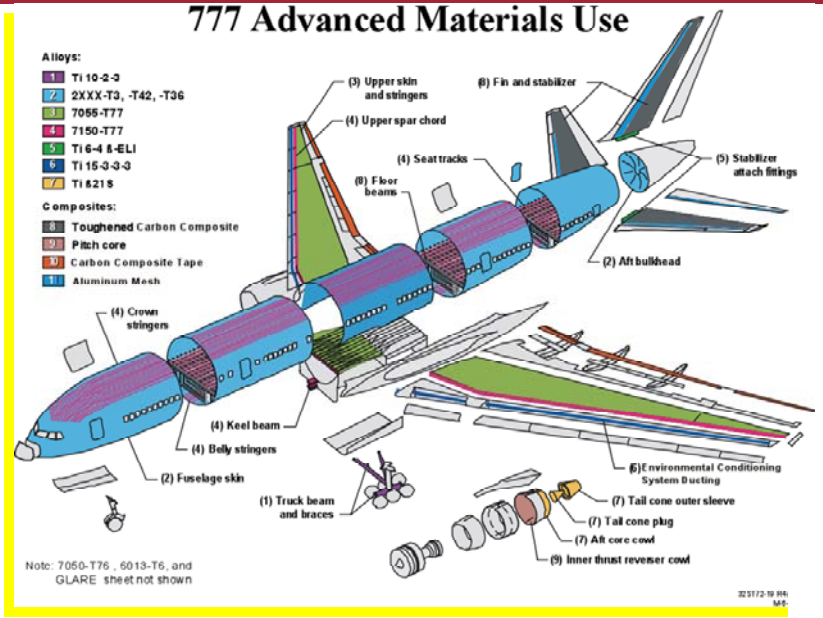
- **Boric Sulfuric Acid Anodizing (BSAA)**
  - **replaces chromic acid anodizing**
- **Boegel conversion coatings**
  - **Conversion coating based on sol-gel chemistry**

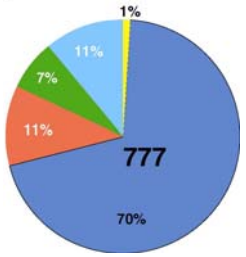


Transition to Environmentally Compliant Materials

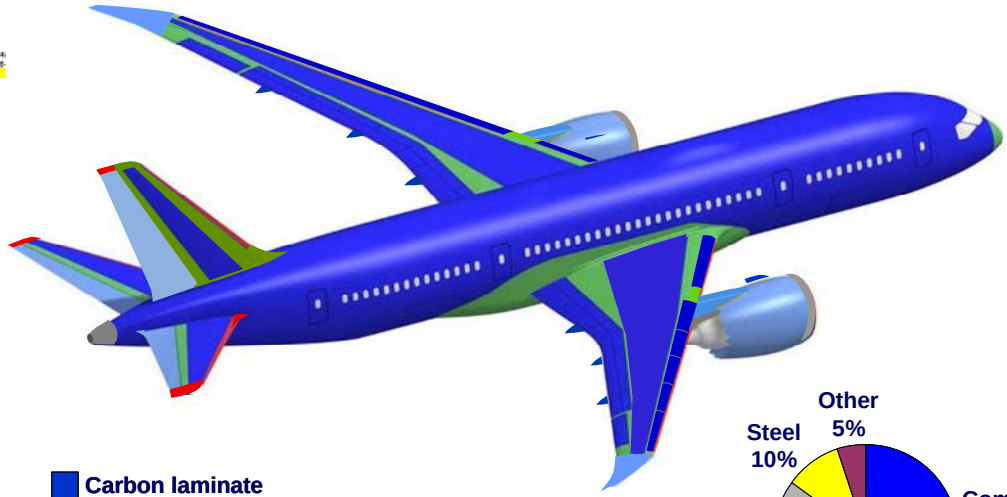
- **Elimination of chromates**
  - **70+ years of designing to the performance of chromates**
  - **All aircraft now in service are principally aluminum**
    - **Complex, poorly understood interactions between materials**
  - **The heritage systems are successful with chromates**
  - **The heritage systems must be successful with alternatives**
- **VOC/HAZMAT Elimination**
  - **Flexibility and durability of coatings change**
    - **Waterborne coatings are more porous than high solids**
      - **Affects moisture barrier and control**
  - **New runway deicers are corroding cadmium coatings**
    - **Fasteners and electrical connectors**
  - **Others?**
- **New materials present new “opportunities”**

Advanced Materials Usage





Steel
Titanium
Composite
Misc.
Aluminum



787 Composite Primary Structure

Carbon laminate
Carbon sandwich
Other composites
Aluminum
Titanium