AF Cr(VI) Minimize Roadmap

Phase 1 Results

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Hexavalent chromium is widely regarded as the highest performing corrosion control treatment for aluminum components. However, due to serious environmental and health risks related to its use, regulations regarding hexavalent chrome exposure are becoming increasingly restrictive. In response, DoD acquisition chief, John J. Young, Jr., published a memo in April 2009 directing all Services to use hexavalent chrome substitutes whenever possible. Yet in many weapon systems, its use has continued due to the lack of chrome-free substitutes able to meet MIL-SPEC requirements and laboratory testing. Hexavalent chrome continues to be used in primers, coatings, and sealants across the Services and aerospace industry. This presentation will discuss efforts the Air Force has already made and its current course in finding suitable replacements for hexavalent chrome.

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CURRENT STATE OF AIR FORCE HEXAVALENT CHROMIUM REDUCTION EFFORTS

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Why Minimize Cr(VI)?

- **Long Known to be a Carcinogen**
  - Inhalation causes lung cancer
  - Recognized by ACGIH, EPA, IARC
- **Increasingly Stricter OSHA regulations**
  - Revised standard February 28, 2006
- **International Pressure**
- **OSD Policy (Young Memo)**
  - April 8, 2009
  - Extraordinary action to eliminate Cr(VI)
- **DFARS Clause (final pending)**
  - Draft April 8, 2010

Why a Roadmap?

- **Develop a comprehensive approach to Cr(VI) minimization addressing all applications**
- **Avoid duplication of effort**
- **Identify opportunities to leverage scarce resources**
- **Roadmaps proven effective in the development and implementation of new technology**
  - Determining gaps
  - Assigning roles and responsibilities

Phase 1

- **Perform Literature Search**
  - ASETS Defense
  - SERDP/ESTCP Websites
  - Secondary Internet Sources
  - AFRL reports, studies, and test data
- **Research/Summarize Potential Alternatives**
- **Create an AF Cr(VI) Use Matrix**
  - By Application
  - Potential alternatives identified
  - Progress toward Cr(VI) minimization estimated

What is an Application?

- **An application is a unique use of Cr(VI), that could be classified as unique due to:**
  - Technology (hard chrome plating, primer)
  - Process (LOS plating, immersion)
  - Subsystem (landing gear, fasteners)
  - Substrate (aluminum, magnesium, high strength steel)
- **Phase 1 identified 25 unique AF Cr(VI) applications**
- **Determining applications is critical to developing alternative materials and processes**

Phase 1 Findings

- **Six AF Cr(VI) Technologies Identified**
  - Hard chrome plating
  - Conversion coating
  - Primers
  - Sealants
  - Bonding Primer
  - Wash Primer
- **Some alternatives have been implemented**
- **Tremendous opportunities for further minimization of Cr(VI)**

Hard Chrome Plating

- **Roadmap identified 6 unique applications**
- **AF uses include landing gear, engine components, housings, bracket and fasteners**
- **Existing Cr(VI) process is an immersion process**
- **Replacement efforts to date:**
  – High Velocity Oxygen-Fuel (HVOF) of Cobalt-Tungsten Carbide alloys
  – Limited to line-of-sight processes
  – Limited to high strength steel
  – Mainly landing gear and engine components

Color Coding

- Green: Alternative has been implemented for the application by an aircraft or at a specific location (not necessarily fully tested or to be endorsed)
- Yellow: Potential alternatives have been identified, and testing or evaluation is underway, or alternative shows some promise for implementation
- Red: Potential Alternatives have been identified, but the testing and evaluation indicated some real or potential problems, or the failure to achieve the desired results
- Gray: Little or no information was available or discovered concerning RDT&E activities for this application

Hard Chrome

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Hard Chrome	LOS Plating	Engine Components	High Strength Steel	HC-1	WC/CoCr, Tribaloy 400, Tribaloy 800, Cr3C2/20(80Ni-20Cr)	Thermal Spray (HVOF)	1.4, 1.5, 1.10, 1.15, 1.27, 1.39, 1.64
Hard Chrome	LOS Plating	Landing Gear	High Strength Steel	HC-1	WC/CoCr, Tribaloy 400, Cr3C2/20(80Ni-20Cr)	Thermal Spray (HVOF)	1.8, 1.46, 1.15, 1.16, 1.27, 1.39, 1.64
Hard Chrome	LOS Plating	Engine Components	Nickel Alloys (Inconel)	HC-2	WC/CoCr, Tribaloy 400, Tribaloy 800, Cr3C2/20(80Ni-20Cr)	Thermal Spray (HVOF)	1.4, 1.5
Hard Chrome	LOS Plating	Landing Gear	Titanium	HC-3	WC/17Co, Electroless Ni	Thermal Spray (HVOF)	1.5, 1.8
Hard Chrome	Non-LOS	Housings, Brackets	High Strength Steel	HC-4	Electroless Ni, nano-composite plating	Cold Spray, Immersion	1.39
Hard Chrome	Non-LOS	Fasteners	High Strength Steel	HC-5	Electroless Ni, nano-composite plating	Cold Spray, Immersion	1.24
Hard Chrome	Non-LOS	Housings, Brackets	Magnesium	HC-6	Hi-pure Al	Cold Spray, Immersion	1.17, 1.44

Conversion Coatings

- **Roadmap identified 7 unique AF applications**
  - Includes pretreatment, sealers, anodizing and passivation
  - Includes a variety of substrates
- **Generally used as part of a paint system containing Cr(VI) primer**
- **Implemented alternatives include:**
  - Trivalent chromium process (TCP) – Navy,
  - Alodine 5200/5700
  - PreKote
- **No fully Cr(VI)-free paint system approved to date**

Conversion Coating

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Conversion Coating	Pretreatment	Plate & Sheet	Aluminum	CC-1	TCP +EPA	Conventional (immersion)	1.23
Conversion Coating	Pretreatment	Plate & Sheet	Aluminum	CC-1	PreKote, Alodine 5700, Sol-Gel, Dorado Kote 7, Low Chrome (LC) 1 and 2, Garabond X 4707	Conventional	1.1, 1.35, 1.61
Conversion Coating	Touch-up	Plate & Sheet	Aluminum	CC-2	AC-131BB, AC-X67, Alodine 871, Alodine 5700, Chemseal 100, PreKote	Conventional	1.1
Conversion Coating	Immersion, brush-on	Housings	Magnesium	CC-3	Tagnite (Si-based)	Conventional (immersion)	1.18, 1.30
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	Alodine 5200/5700, K permanganate, fluorotitanic acid, TCP+ and Iridite	Conventional (immersion)	1.19
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	Hi-Silicon zeolite (SiO_4-AlO_4)	Conventional (immersion)	1.41

Conversion Coating - continued

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	Electro-active polymers (EAP)	Conventional (immersion)	1.43
Conversion Coating	Immersion, brush-on	Plate & Sheet	Aluminum	CC-4	TCP+	Conventional (immersion)	1.5, 1.25
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	TCP+	Conventional (immersion)	1.1, 1.5, 1.6, 1.23, 1.27
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	TCP+	Conventional (immersion)	1.12, 1.23
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	Sol-gel	Plasma Spray	1.2, 1.5, 1.7
Conversion Coating	Anodizing	Plate, sheet & component	Aluminum	CC-5	Sulfuric/TCP rinse, Boric-sulphuric anodize, Keronite/Tagnite	Conventional (immersion)	1.12
Conversion Coating	Passivation	Plate, sheet & component	Steel	CC-5	TCP+	Conventional (immersion)	1.12, 1.45
Conversion Coating	Post Treatment	Fasteners	Steel: SS, Cd-plated	CC-6	Pur Aluminum, Metal flake dip-spin	Organic topcoat	1.11
Conversion Coating	Post Treatment	PAD/CAD	Stainless Steel	CC-7	TCP over Zinc-phospate	Conventional (immersion)	1.36

Primer

- **Single largest use of Cr(VI) by volume**
- **Roadmap identified 4 primer applications**
  – Interior v. Exterior
  – Primer removal
- **Generally used in a paint system that implements a Cr(VI) pretreatment**
- **Promising/implemented alternatives;**
  – Two Deft primers (02GN084 and 44GN098)
  – Akzo 2100 MgRP
- **No fully Cr(VI)-free paint system approved to date**

Primer Coating

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Primer	Coating	Interior/Structure	Aluminum	PR-1	Akzo 2100MgRP; Deft 44GN098; Deft 02GN084	Conventional	1.1, 1.27
Primer	Coating	Interior/Structure	Al, SS, Mg, Ti, Composite	PR-1	Magnesium-rich	Conventional	1.63
Primer	Coating	Exterior	Al, SS, Mg, Ti, Composite	PR-2	Deft 02GN083, 02GN084	Conventional	1.12
Primer	Coating	Exterior	Al, SS, Mg, Ti, Composite	PR-2	Inhibitors: RE diphenyl phosphate, IO salt/BTTSA, hydrotalcite-organidisulfide	Conventional	1.42
Primer	Coating	Exterior	Al, SS, Mg, Ti, Composite	PR-2	Epoxy-silane	Conventional	1.3
Primer	Coating	Exterior	Aluminum	PR-2	TCP+	Conventional	1.12
Primer	Coating	Exterior	Aluminum	PR-2	Akzo 10PW22-8; Deft 44GN098	Conventional	1.1
Primer	Coating	Exterior	Al, SS, Mg, Ti, Composite	PR-2	Magnesium-rich	Conventional	1.61, 1.62, 1.63
Primer	Coating	Munitions	Al, SS, Mg, Ti, Composite	PR-3		Conventional	
Primer	Removal	All	All	PR-4		Laser	

Sealants

- **Roadmap identified 4 sealant applications**
- **Used mainly to prevent dissimilar metal contact**
  - Faying surfaces
  - Installation of fasteners
- **Requires a different solution than primers in a typical coating system**
  - No topcoat
  - Inaccessible areas of the aircraft
- **Few prospective alternatives identified to date**

Sealants

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Sealant/Primer	Assembly/Post-Assy	Faying Surfaces	Al, Mg, Ti, Steel	SE-1	AC131sol-gel/23377N, Alodine5700/53022I, PreKote/AquaSur HS, PreKote/Akzo Mg-rich, Alodine5700/Akzo Mg-rich, AC-730, CS 5500CI	Conventional	1.22
Sealants	Assembly/Post-Assy	Faying Surfaces	Al, Mg, Ti, Steel	SE-2	Various PRC/DeSoto Bases/Accelerators	Conventional	1.33, 1.39
Sealants	Assembly/Post-Assy	Fastener interface	SS, Ti, Cad plating	SE-3			
Sealants	Assembly/Post-Assy	Fuel Tanks	Aluminum	SE-4			

Bonding and Wash Primers

- **Bonding Primer**
  - Critical surface prep component in adhesive structural bonding
  - Stringent and challenging requirements
  - Basic research needed to define corrosion protection requirements
- **Wash Primer**
  - Another option for pretreatment/primer prior to topcoat
  - Specification requires zinc chromate
  - Some testing of alternatives has been performed, including TCP

Bonding and Wash Primers

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Bonding	Wipe/Brush-on/Spray	Surface Prep	Metal Surfaces	BD-1		Conventional	1.66
Wash Primer	Immersion/Spray		Aluminum	WP-1	TCP+	Conventional	1.6,1.40
Wash Primer	Immersion/Spray		Magnesium	WP-2		Conventional	
Wash Primer	Immersion/Spray		Stainless Steel	WP-3		Conventional	

AFRL S&T Related Technologies

- **Cr+6 Reduction Plan**
- **Inorganic Coatings**
  - Chrome Replacement
    - Next Generation Non-Line of Sight Coatings
    - Dichromate Sealer Replacement
- **Organic Coatings**
  - Cr Free Paint Systems
    - Sicopoxy
    - Mg Rich Primer
  - UV Curable Coatings
    - Topcoats; Primer; One Coat
    - Explosion Proof UV Lamp
    - UV Paint Booth
  - Paint / Depaint Life Cycle Extension

AFRL Chrome Reduction Plan

Description

- Reduce hexavalent chromium use and waste

Approach

- Review hexavalent chromium usage in DoD to identify applications.
- Develop Strategic Implementation Plan for hexavalent chromium reduction throughout AF

Benefits

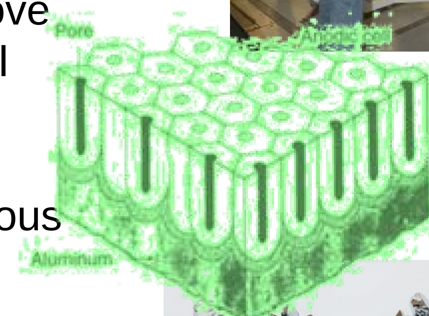
- Reduce hexavalent chromium applications in order to improve compliance to EPA, DoD, and other federal, state, and local directives.
- Addresses Executive Order 11514, CAA, CWA, RCRA, NESHAP, AFI32-7040, and AFI 32-7042, and State hazardous reduction plans

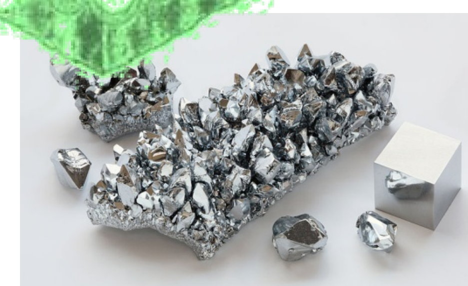
Weapon Systems

- Various aircraft components - especially landing gear, wheels, hydraulic components, fasteners; vehicles; ground support equipment

Stakeholders

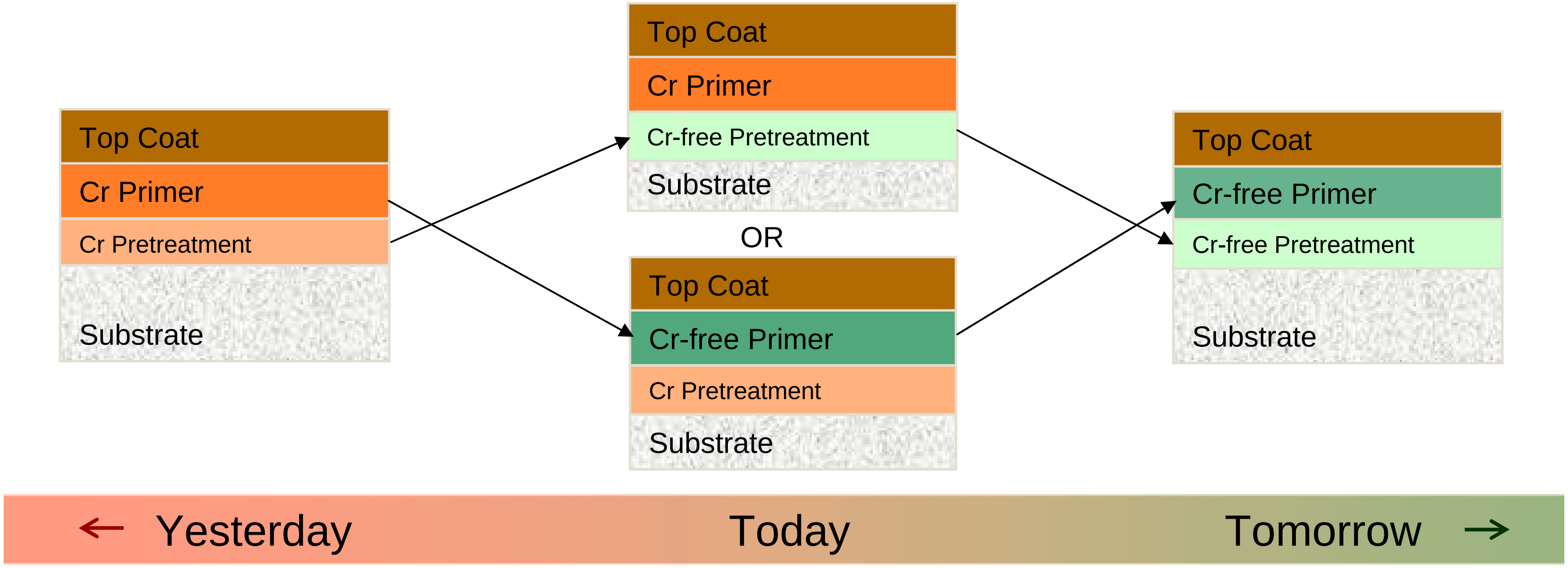
- USAF (e.g., B-1, F-16, F-18, F-22, F-35, C-5, C-17 POs, Space); ANG; Army aircraft, TACOM; NAVAIR; Coast Guard, NASA, DSCC, OEMs





AFRL Chromium-free Coating Systems Integration Plan

No qualified, completely chromium-free system yet ...



- Some individual chromium-free components cannot be combined with some MIL SPEC or other components; e.g., PreKote with Deft 02-GN-084
- AFRL currently testing two chromium-free coating systems that show most promise based on screening/performance testing

PreKote / Mg Rich (AeroDur 2100)

- **Pretreatment Manufacturer – Pantheon Chemical**
  - Approved for use in T.O. 1-1-8 with a chrome primer
  - PreKote used on F-16, T- Jets (AETC) since mid ‘90s, Hill AFB since ‘05, C-5 & C-130’s @ Robins AFB
- **Primer Manufacturer – Akzo Nobel**
  - Corrosion Inhibitor – Mg particles
    - Galvanic Corrosion protection
  - New formulation best lab corrosion test performance to date
- **System Performs as well as chrome in outdoor exposure on corrosion sensors on aircraft**
  - Parts flying on CG HH-60 rescue aircraft
- **Field testing on full aircraft in planning stages (HH-60, C-130, F-16)**
- **System in testing for qualification to MIL-PRF-32239**
- **CTIO’s choice to meet USD, Mr. Young letter**

The Road Ahead…Phase 2

- **Phase 1 has:**
  - Established the applications to use as a starting point
  - Identified much of the existing RDT&E data
- **Phase 2 will:**
  - Develop technology roadmaps
    - Identify technology gaps for each application
    - Identify intermediate steps needed
    - Identify RDT&E projects
    - Estimate funding levels and timeframes needed
  - Document Cr(VI) use and alternative implementation by weapon system