U.S. Army Toxic Metal Reduction Program: Demonstrating Alternatives to Hexavalent Chromium and Cadmium in Surface Finishing

For ASETSSDefense
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Hughes Associates, Inc.
Support to HQ, RDECOM EALSP
**U.S. Army Toxic Metal Reduction Program: Demonstrating Alternatives to Hexavalent Chromium and Cadmium in Surface Finishing**

**Hughes Associates, Inc, HQ, Army Research, Development and Engineering Command (RDECOM EALSP), Aberdeen Proving Ground, MD, 21005**

**ASSETSDefense 2014: Sustainable Surface Engineering for Aerospace and Defense, 18-20 Nov 2014, Fort Myer, VA.**
Environmental Acquisition & Logistics Sustainment Program Elements

- Sustain Mission Readiness
- Enhance Logistics Support
- Integrate Environmental Acquisition
- Improve Soldier Survivability

EALSP

- ORDNANCE ENVIRONMENTAL PROGRAM
- TOXIC METAL REDUCTION
- AIRBORNE LEAD REDUCTION
- ZERO FOOTPRINT CAMP

- STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM
- ENVIRONMENTAL SECURITY TECHNOLOGY CERTIFICATION PROGRAM
- JOINT INSENSITIVE MUNITIONS TECHNOLOGY PROGRAM
- JOINT SERVICE SOLVENT SUBSTITUTIONS

- PROTECTIVE COATING DEVELOPMENT
- MATERIAL DURABILITY TESTING
- NON-METALS RESEARCH

- RDT&E MATRIX SUPPORT
- ENVIRONMENTAL RISK MANAGEMENT
- SUPPORT TO PEOS/PMS
- OZONE DEPLETING CHEMICALS
- GREENHOUSE GASES

- DEFENSE SAFETY OVERSIGHT COUNCIL
- VOLUNTARY PROTECTION PROGRAMS
- NET ZERO INSTALLATIONS

Joint/Office of the Secretary of Defense

National Defense Center for Energy and Environment

Environmental Quality Technology

Corrosion Prevention and Control

ASA(ALT) Environmental Support Office
**Purpose:** Reduce/eliminate toxic, carcinogenic metals (e.g., hexavalent chromium (Cr(VI)), cadmium (Cd)) in Army metal plating, surface finishing

**Addresses:** High priority Army Environmental Requirements and Technology Assessment (AERTA) PP-2-02-04, OSD memo and DFARS clause

- 75% reduction in Cr(VI) used in electroplating
- 100% of Cr(VI) used in pretreatments
- 75% reduction in Cd associated with Cr(VI) finishes
- Reduction in toxic materials/waste (e.g., cyanide, phosphate sludge)

**Return on investment:** 7:1

**Usage:** 15K lbs/yr chromic acid (3 depots)
FY07: Identified as high priority Pollution Prevention (P2) requirement
FY08-14: Discretionary funding to initiate program
FY10: NDCEE Toxic Metal Impacts Survey
FY12: AMCOM G-4 detailed assessment of hazardous materials utilized in Army depot plating shops
  - Requirements
  - Alternative Technology Assessments
  - Technology Gaps
FY13: TMR approved as critical, valid funding requirement
FY14: Program Build
  - Projects must “buy-out” process completely
  - Technology Transition Agreements in coordination
FY15: Demonstration projects initiated
  - October: 1st TTA signed by PEO Aviation, CCAD

Hazardous Plating Shop Processes
- Chromic acid anodizing of aluminum*
- Aluminum conversion coatings*
- Hard chrome plating*
- Magnesium anodizing*
- Sealers and rinses*
- Stripping of anodizing and platings*
- Passivation of stainless steel*
- Cad Plating
- Nickel Plating
- Electroless Nickel
- Etching

*Contains Cr6+
<table>
<thead>
<tr>
<th>Process</th>
<th>Specification</th>
<th>Hazardous Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum Conversion Coating</td>
<td>MIL-C-5541-E, MIL-DTL-81706B</td>
<td>Sodium Dichromate</td>
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<tr>
<td>Aluminum Anodize</td>
<td>MIL-A-8625F Type I and IB</td>
<td>Chromic Acid, Sodium Dichromate, Chromium Trioxide</td>
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<tr>
<td>Cadmium Brush Plate</td>
<td>MIL-STD-865C</td>
<td>Cadmium Special, Cadmium Alkaline, Cadmium Acid</td>
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<tr>
<td>Cadmium Plating</td>
<td>SAE AMS-QQ-P-416B Type II</td>
<td>Cadmium Oxide, Sodium Cyanide, Cadmium, Nickel Chloride, Iridite</td>
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<tr>
<td>Hard Chrome Plate</td>
<td>SAE AMS-QQ-C-320</td>
<td>Chromic Acid</td>
</tr>
<tr>
<td>Copper Plating</td>
<td>ASTM 2418F</td>
<td>Copper Cyanide, Sodium Cyanide, Sodium Dichromate, Nickel Sulfate, Nickel Sulfamate</td>
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<tr>
<td>Electroless Nickel</td>
<td>AMS2404F</td>
<td>Nickel Chloride</td>
</tr>
<tr>
<td>Magnesium Anodize - Conversion Coating</td>
<td>AMS-M-3171 Type III, IV, VI</td>
<td>Chromic Acid, Sodium Dichromate</td>
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<tr>
<td>Nickel Plating</td>
<td>SAE AMS QQ-N-290</td>
<td>Nickel Chloride, Nickel Sulfate, Nickel Sulfamate</td>
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<tr>
<td>Passivate</td>
<td>SAE AMS 2700B</td>
<td>Sodium Dichromate</td>
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<tr>
<td>Phosphate</td>
<td>MIL-DTL-16232G, TT-C-490, Type I</td>
<td>Chromium Trioxide, Chromic Acid</td>
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<tr>
<td>Silver Plating</td>
<td>ASTM B700-97</td>
<td>Potassium Cyanide, Silver Cyanide</td>
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<tr>
<td>Wash Primer</td>
<td>DOD-P-15328, TT-C-490F</td>
<td>Zinc chromate</td>
</tr>
<tr>
<td>Start</td>
<td>Project Title</td>
<td></td>
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<td>-------------------------------------------------------------------------------</td>
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<tr>
<td>FY12/FY15</td>
<td>Cr(VI)-Free, Low VOC Alternatives for Spray-In-Place, Mixed Metal Pretreatment</td>
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<tr>
<td>FY13/FY15</td>
<td>Cr(VI)-Free Surface Activation and Preparation for Metal Plating</td>
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<tr>
<td>FY14</td>
<td>Cr(VI)-Free Hard Chrome Electroplating</td>
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<td>FY14</td>
<td>Cr(VI)-Free Conversion Coatings</td>
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<tr>
<td>FY15</td>
<td>Cr(VI)-Free Aluminum Anodizing</td>
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<td>FY15</td>
<td>Cyanide-Free Copper and Silver Electroplating</td>
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<td>FY15</td>
<td>Toxicity Assessments and Testing of Alternative Materials and Processes</td>
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<tr>
<td>FY15</td>
<td>Cold Spray - Large Caliber Gun Barrel Coatings and Donor Tubes</td>
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<tr>
<td>FY15</td>
<td>Cold Spray - Portable System and Internal Diameter Applications</td>
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<td>Citric Acid Passivation</td>
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<td></td>
<td>Cadmium-Free Connectors and Fasteners</td>
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<td></td>
<td>Cadmium-Free Plating for Components</td>
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<tr>
<td></td>
<td>Dichromate-Free Sealers / Primers</td>
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<tr>
<td></td>
<td>Cr(VI)-Free Sealants and Adhesives</td>
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</table>
**Objective:** Eliminate Cr(VI) in multi-metal spray-on pretreatment applications (alternative to wash primer)

**Magnitude of impact:**
- Reduce Cr(VI) by 24K lbs/year, VOCs by 2.4M lbs/year
- Potential violation of volatile organic compounds (VOCs) emission limits could restrict maintenance activities
- Eventual cancellation of DOD-P-15328 technology gap

**Intended end product:** Validated Cr(VI) spray applied chemical pretreatments for multi-metal applications per TT-C-490F

**Technology:**
- Commercially available metal pretreatment technologies on multiple substrates and mixed metal assemblies
  1. Zircobond 4200 (zirconium immersion chemistry)
  2. Oxsilan 9810/2 (organo-silane polymers)
  3. Bonderite (phosphoric acid, hexafluorotitanic acid, Mn)

**Weapon systems impacted:** All systems currently using DOD-P-15328 chromated wash primer (including MRAP, Stryker, HMMWV, ground support equipment (GSE))

**Transition Path:** TT-C-490F Qualified Product Database

**POC:** Jack Kelley, ARL, john.v.kelley8.civ@mail.mil

**IPT:** ARL, Letterkenny Army Depot (LEAD), Red River Army Depot, (RRAD), Anniston Army Depot (ANAD), Henkel, PPG

**Yearly Progress:**
- FY12: Laboratory Testing
- FY13: Down-selection/Outdoor testing
- FY14: Demo at LEAD
- FY15: Demo at RRAD and ANAD
- FY16: QPD for TT-C-490
Objective: Eliminate chromic acid (Cr(VI)) used in stripping anodized coatings from aluminum

Magnitude of impact:
- Eliminate 1,400 lbs/year of chromic acid at Corpus Christi Army Depot (CCAD) in anodize stripping processes

Intended end product: Validated Cr(VI) free chemical stripper for anodized coating on aluminum (Type I, Type III and alternative processes)

Technology: Commercially available chemical strippers
- NaOH Stripper/Deoxider
- LNC Deoxidizer (ferric sulfate, nitric acid, HF)
- Sikorsky (proprietary)
- Stripol ANO
- Metalast ADS 1000 (sulfuric acid)

Weapon systems impacted: All systems that use anodized aluminum, including ground tactical and support equipment and aviation systems

Transition Path: Revision to MIL-A-8625

POC: Jack Kelley, ARL, john.v.kelley8.civ@mail.mil

IPT: ARL, AMCOM, AMRDEC, ANAD, PEO-Stryker Brigade Combat Team, Hubbard Hall, Henkel, Chemetall, AMZ Manufacturing, PPI Aerospace

FY14
- Develop testing protocol
- Laboratory testing

FY15
- Down-select

FY16
- Demonstration at ANAD/CCAD

FY17
- Specification revisions
• **Objective:** Eliminate Cr(VI) from electroplated hard chrome (EHC) processes

• **Magnitude of impact:**
  - Eliminate 5 tons of chromic acid used in EHC in Army depot operations (ANAD, CCAD, Rock Island Arsenal)

• **Intended end product:** Cr(VI)-free Non-Line of Sight (NLOS) plating process that results in a hard chrome plate that meets AMS 2460 performance requirements

• **Technology:** Faraday Technologies developed process
  - Trivalent chromium (Cr(III)) bath chemistry
  - Pulsed, reverse waveform rectifiers/power supply
  - Non-lead anodes
  - Leverage: SBIR for stripping chrome plating

• **Weapon systems impacted:** All aircraft maintained at CCAD (UH-60; AH-64; AH-1; CH-47); M1 tank, Stryker, Howitzer at ANAD; processes at RIA

• **Transition Path:** Individual MEOs, CCAD process standard

• **POC:** Michael Johnson, AMCOM, michael.l.johnson17.ctr@mail.mil

• **IPT:** AMCOM, AED, ARL, PEO Aviation, Utility Helicopter Project Office, CCAD, Faraday Technologies

**Timeline:**
- **FY14**
  - Laboratory testing (130 gallon)
- **FY15/16**
  - Process validation and characterization
- **FY17**
  - Establish Pilot Process (400 gallon)
  - Demonstration at CCAD
- **FY19**
  - Implementation
- **Objective:** Eliminate Cr(VI) in conversion coatings (CC)
- **Magnitude of impact:**
  - Eliminate 12K pounds of Cr(VI) in Al CC
  - LEAD: 20K lbs/year of Cr(VI) CC solution disposal
  - Savings of over $2.4M in chromate waste disposal
  - Consolidated ferrous and non-ferrous pretreatment line
- **Intended end product:** Multiple approved Cr(VI)-free CCs for aircraft and Ground Support Equipment (GSE) (multi-metal and composites), application by spray and immersion
- **Technology:** Assess commercially available Al pretreatments
  - Aviation: CCAD, TASM-G, Corrosion Repair Facility
  - Spray/immersion: Zirconium oxide, rare earth (Ce), silanes
  - GSE (immersion): ANAD, LEAD, Tobyhanna Army Depot
  - Zirconium oxide, rare earth (Cerium) and silanes
  - Leverage: ESTCP (LEAD) and USMC - Albany demos
- **Weapon systems impacted:** All tactical equipment that requires CARC
- **Transition Path:** TT-C-490, MIL-DTL-53072, MIL-DTL-5541, MIL-DTL-81706
- **POC:** Fred Lafferman, ARL, fred.lafferman.civ@mail.mil
- **IPT:** AMCOM, AMRDEC, AED, TACOM, LEAD, RRAD, CCAD, TASM-G, PPG Ind.
Objective: Eliminate Cr(VI) in aluminum anodizing, stripping and sealing

Magnitude of impact:
- CCAD anodize and anodize stripping baths use:
  - Anodize: 2300 gallon tank with 1500 lbs. chromic acid, added as needed (500 lbs. added in 2010-2011)
  - Stripping: 1 process line, 2050 lbs of dry chromic acid
- International regulation impact on supply chain (REACH)

Intended end product: 1) Validated Cr(VI)-free anodizing process in production environment, 2) validated Cr(VI) free chemical stripper for all forms of anodized aluminum

Technology: Two anodize technologies, Cr(VI)-free strippers
1. Sikorsky: Tartaric Sulfuric Acid Anodizing
2. NAVAIR: Thin Film Sulfuric Acid Anodizing process
3. Cr(VI)-free strippers for legacy, alternative anodize (ARL)

Weapon systems impacted: All aircraft maintained at CCAD (UH-60; AH-64; CH-47), including other Service aircraft

Transition Path: CCAD process standard, MIL-A-8625, MEO added to DMWRs

POC: Scott Howison, AMCOM, stephen.s.howison.civ@mail.mil

IPT: AMCOM, ARL, Sikorsky, AMRDEC-AED, CCAD, UH-60 Project Office (PO), AH-64E Apache PO, CH-47 PO

FY15
- Initiate laboratory testing with Sikorsky

FY16
- Laboratory evaluation of anodic coating stripper

FY17
- Implementation of stripping process

FY19
- Demonstration at CCAD
- Implementation through MEO
Objective: Eliminate cyanide from copper and silver electroplating at CCAD

Magnitude of impact:
- Cyanide alarm requirement: Up to 1 hr evacuation per alarm
- Cyanide solutions classified as a RCRA waste (F007, F008)

Intended end product:
- Non-cyanide products and processes for copper and silver plating/strike demonstrated at CCAD
- Non-chromic acid and non-cyanide stripping methods to remove copper and silver plating/strike demonstrated at CCAD

Technology:
- Leverage DoD, commercially available plating chemistry
  - E-Brite 30/30 and E-Brite Ultra Cu (Copper)
  - E-Brite 50/50 (Silver), Silver Cyless II
- Cold spray for LOS Cu or Ag deposition
- Cyanide, Cr(VI)-free stripping process for copper and silver

Transition: MEOs at CCAD

Weapon systems impacted: All aircraft maintained at CCAD (UH-60; AH-64; AH-1; CH-47)

POC: Sheree York, AMCOM, sheree.t.york.civ@mail.mil

IPT: AMCOM G-4, CCAD, EPI, AED, ARL, AH-64 PO, UH-60 PO, CH-47 PO
- **Objective:** Eliminate Cr(VI) used in plating large and medium caliber bore coatings
- **Magnitude of impact:**
  - Toxic material disposal ~$180k per year
  - Extended barrel life – 2-3x increase in life
- **Intended end product:** Cr(VI)-free, more erosion resistant bore coatings for large & medium caliber guns
- **Technology:**
  - Optimized cold spray (CS) process with tantalum (Ta), tungsten (W) and niobium (Nb) powders
  - Right-angle ID nozzle for direct CS application (large)
  - Additive manufacturing process to produce near-net formed donor tubes for explosive cladding (medium)
- **Weapon systems impacted:**
  - Large Cal: M256 120mm (chamber & bore), M284, M199, & M776 155mm (chambers only)
  - Medium Cal: M242 25mm Bushmaster, M230 30mm, GAU-12 25mm, 30mm Bushmaster II, EAPS 50mm
- **POC:** Vic Champagne, ARL, victor.k.champagne.civ@mail.mil
- **IPT:** ARL, Benet Laboratories

**FY13**
- Identify/Develop/Acquire materials
- Develop and design equipment

**FY14**
- Optimize ID nozzle
- Powder development

**FY15**
- Execute JTP at Benet for validation
- FY16 Demo Project Plan
Objective: Eliminate Cr(VI) in electroplated hard chrome

Magnitude of impact:
- Potential to eliminate Cr(VI) in all Line-of-Sight (LOS) hard chrome applications
- Increase throughput for dimensional restoration
- Mobile repair processes

Intended end product: Cr(VI)-free portable CS system for field repair, production process for inner diameter applications

Technology:
- Portable CS equipment with optimized ID nozzle with amorphous iron, Cr, Ni, and CrC-NiC powders
- Dimensional restoration of hard (HRC 45+) surface
- Coordinated path forward for LOS applications

Weapon systems impacted: all LOS hard chrome surfaces (e.g., U-joints for tracked vehicles, M1A1 Sun Gear, HMMWV Ring / Pinion Gears, EMI Shielding for Electronic Shelters)

POC: Vic Champagne, ARL, victor.k.champagne.civ@mail.mil

FY13
- Identify/acquire powders
- Develop Joint Test protocol

FY14
- Characterization
- Laboratory trials

FY15
- Validation on BER parts
- FY16 Demo project plan
## Example: Potential Impact of Projects at CCAD Plating Shop (Building 340)

<table>
<thead>
<tr>
<th>Project</th>
<th>% Cr(VI) Reduction</th>
<th>Start Date (Overall/CCAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr(VI)-Free Hard Chrome Electroplating</td>
<td>35</td>
<td>FY14/17</td>
</tr>
<tr>
<td>Cr (VI)-Free Aluminum Anodizing</td>
<td>13</td>
<td>FY15/17</td>
</tr>
<tr>
<td>Cr(VI)-Free Surface Activation and Preparation for Metal Plating</td>
<td>5</td>
<td>FY14/16</td>
</tr>
<tr>
<td>Cyanide-Free Copper and Silver Electroplating</td>
<td>2</td>
<td>FY15/15</td>
</tr>
<tr>
<td>Cr(VI)-Free Conversion Coatings</td>
<td>7</td>
<td>FY14/16</td>
</tr>
<tr>
<td>Tagnite Application for Legacy Components</td>
<td>15</td>
<td>FY14/15</td>
</tr>
<tr>
<td>Conversion coating for cadmium plating</td>
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<td>FYTBD</td>
</tr>
<tr>
<td>Black Oxide Sealer (Cr(VI))</td>
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<td>FYTBD</td>
</tr>
<tr>
<td>Passivation and Corrosion Treatment (Cr(VI))</td>
<td>12</td>
<td>FYTBD</td>
</tr>
<tr>
<td>Chromated sealant for Phosphate Acid Dip</td>
<td>2</td>
<td>FYTBD</td>
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<tr>
<td>TOTAL Plating Shop</td>
<td>100</td>
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</tbody>
</table>

AMCOM G-4 Estimates (2014)
U.S. Army Public Health Command will publish Toxicology Assessments for all proposed alternatives

- Literature review
- Computational modeling
- Data collection
- Toxicity Testing, if necessary

Data will inform acquisition documentation and occupational exposure requirements

- Toxicity Clearance, Health Hazard Assessment, PESHE, LCEA
- Occupational Exposure Limits
Army TMR Program will conduct demonstrations of more sustainable surface finishing processes at Army depots, installations from FY15-19.

P2 Technology Team will support transition through document changes, maintenance orders and updates to QPD.

Eliminate 100% of Cr(VI), Cd or toxic constituents in select processes Army-wide.

Seeking leveraging opportunities, data sharing, support for specification changes and promising technologies for future demonstrations.