



U.S. ARMY
RDECOM[®]

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

For ASETSDefense

18 November 2014

Noah Lieb, PE, CSP

Hughes Associates, Inc.

Support to HQ, RDECOM EALSP

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 18 NOV 2014		2. REPORT TYPE		3. DATES COVERED 00-00-2014 to 00-00-2014	
4. TITLE AND SUBTITLE U.S. Army Toxic Metal Reduction Program: Demonstrating Alternatives to Hexavalent Chromium and Cadmium in Surface Finishing				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Hughes Associates, Inc,HQ, Army Research, Development and Engineering Command (RDECOM EALSP),Aberdeen Proving Ground,MD,21005				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES ASETSDefense 2014: Sustainable Surface Engineering for Aerospace and Defense, 18-20 Nov 2014, Fort Myer, VA.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 17	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



U.S. ARMY
RDECOM

Environmental Acquisition & Logistics Sustainment Program Elements

- **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**

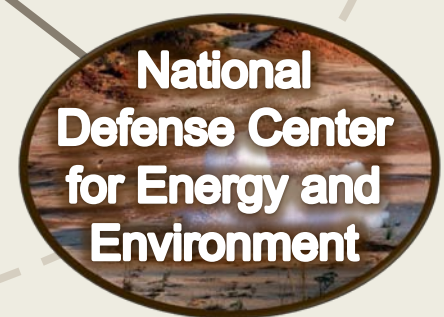


- **PROTECTIVE COATING DEVELOPMENT**
- **MATERIAL DURABILITY TESTING**
- **NON-METALS RESEARCH**

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



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





U.S. ARMY
RDECOM

Toxic Metal Reduction in Surface Finishing Processes

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



7:1 Return
on
investment

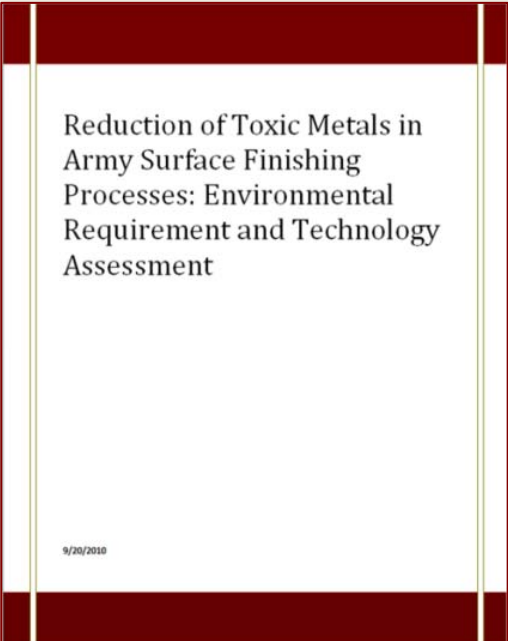
15K lbs/yr
chromic acid
(3 depots)



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)



- 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+



U.S. ARMY
RDECOM

What is the requirement?

ARMY
Environmental Quality
Technology Program



Army Environmental
Requirements and
Technology Assessments

(AERTA)

November 2012

**#2 P2TT priority
(2013)**

Process	Specification	Hazardous Chemicals
Aluminum Conversion Coating	MIL-C-5541-E MIL-DTL-81706B	Sodium Dichromate
Aluminum Anodize	MIL-A-8625F Type I and IB	Chromic Acid, Sodium Dichromate, Chromium Trioxide
Cadmium Brush Plate	MIL-STD-865C	Cadmium Special, Cadmium Alkaline, Cadmium Acid
Cadmium Plating	SAE AMS-QQ-P-416B Type II	Cadmium Oxide, Sodium Cyanide, Cadmium, Nickel Chloride, Iridite
Hard Chrome Plate	SAE AMS-QQ-C-320	Chromic Acid
Copper Plating	ASTM 2418F	Copper Cyanide, Sodium Cyanide, Sodium Dichromate
Electroless Nickel	AMS2404F	Nickel Chloride
Magnesium Anodize - Conversion Coating	AMS-M-3171 Type III, IV, VI	Chromic Acid, Sodium Dichromate
Nickel Plating	SAE AMS QQ-N-290	Nickel Chloride, Nickel Sulfate, Nickel Sulfamate
Passivate	SAE AMS 2700B	Sodium Dichromate
Phosphate	MIL-DTL-16232G TT-C-490, Type I	Chromium Trioxide, Chromic Acid
Silver Plating	ASTM B700-97	Potassium Cyanide, Silver Cyanide
Wash Primer	DOD-P-15328 TT-C-490F	Zinc chromate



U.S. ARMY
RDECOM

FY15-19 Planned TMR Projects

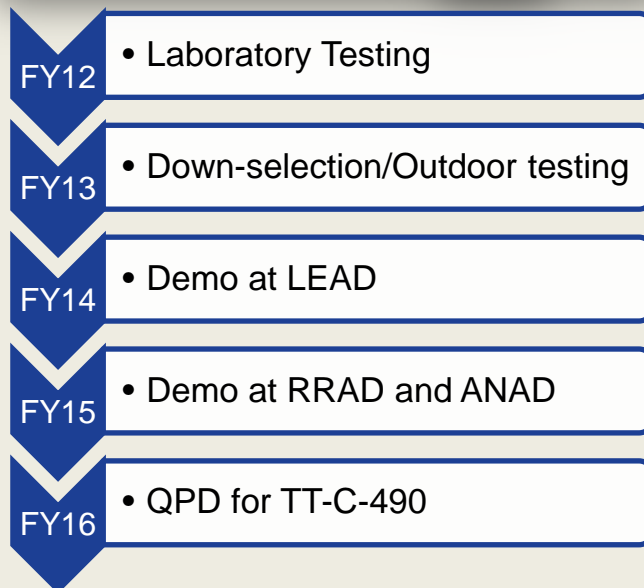
Start	Project Title
FY12/FY15	Cr(VI)-Free, Low VOC Alternatives for Spray-In-Place, Mixed Metal Pretreatment
FY13/FY15	Cr(VI)-Free Surface Activation and Preparation for Metal Plating
FY14	Cr(VI)-Free Hard Chrome Electroplating
FY14	Cr(VI)-Free Conversion Coatings
FY15	Cr(VI)-Free Aluminum Anodizing
FY15	Cyanide-Free Copper and Silver Electroplating
FY15	Toxicity Assessments and Testing of Alternative Materials and Processes
	Cold Spray - Large Caliber Gun Barrel Coatings and Donor Tubes
	Cold Spray - Portable System and Internal Diameter Applications
	Citric Acid Passivation
	Cadmium-Free Connectors and Fasteners
	Cadmium-Free Plating for Components
	Dichromate-Free Sealers / Primers
	Cr(VI)-Free Sealants and Adhesives



U.S. ARMY
RDECOM

Cr(VI)-Free Low VOC Alternatives for Spray-in-Place, Mixed Metal Pretreatments, TMR 12-01

- **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





U.S. ARMY
RDECOM

Cr(VI)-Free Surface Activation and Preparation for Metal Plating, TMR 13-03

- **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

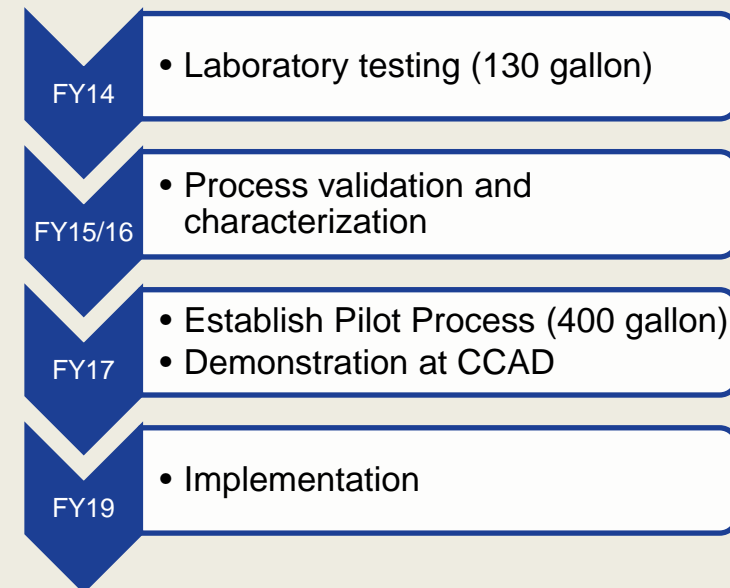
- Demonstration at ANAD/CCAD

FY17

- Specification revisions

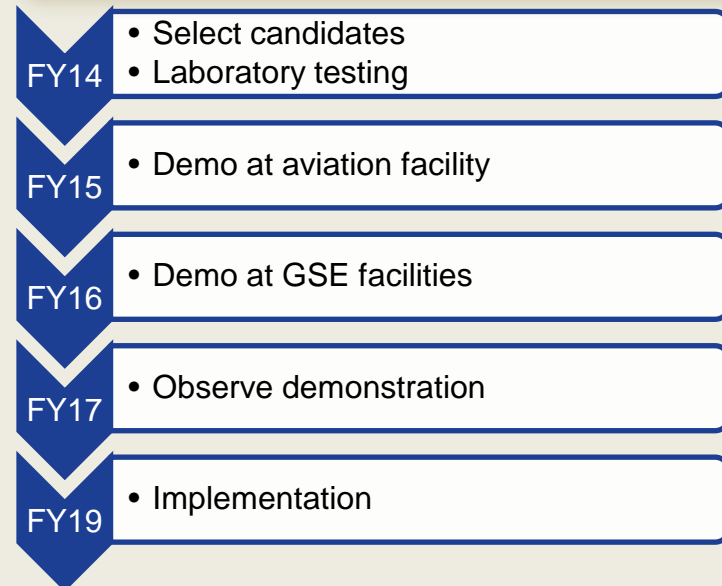


- **Objective:** Eliminate Cr(VI) from electroplated hard chrome (EHC) processes
- **Magnitude of impact:**
 - Eliminate 5 tons of chromic acid used in in EHC in Army depot operations (ANAD, CCAD, Rock Island Arsenal)
- **Intended end product:** Cr(VI)-free Non-Line of Sight (NLOS) plating process that 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



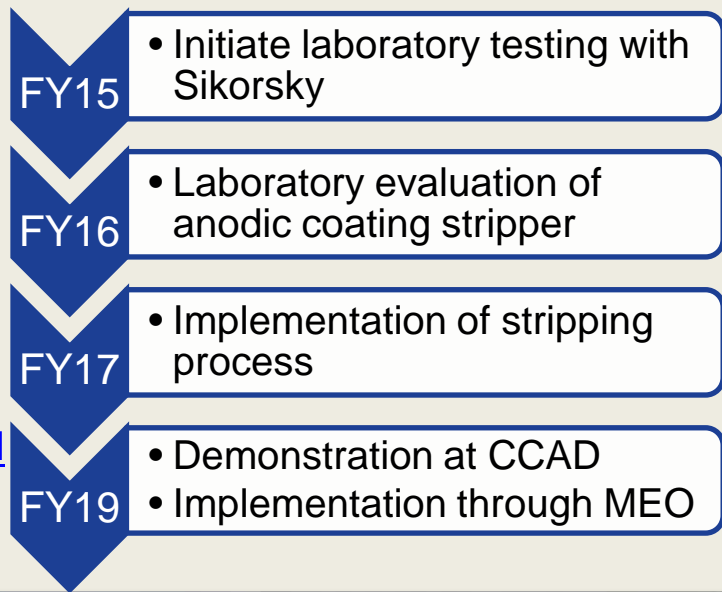


- **Objective:** Eliminate Cr(VI) in conversion coatings (CC)
- **Magnitude of impact:**
 - Eliminate 12K pounds of Cr(VI) in AI CC
 - LEAD: 20K lbs/year of Cr(VI) CC solution disposal
 - Savings of over \$2.4M in chromate waste disposal
 - Consolidated ferrous and non-ferrous pretreatment line
- **Intended 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 AI 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.



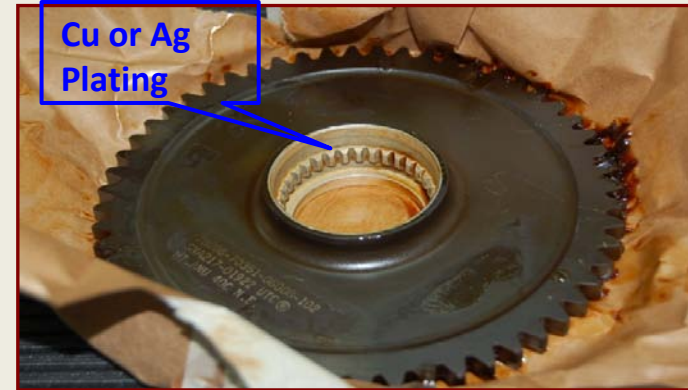


- **Objective:** Eliminate Cr(VI) in aluminum anodizing, stripping and sealing
- **Magnitude of impact:**
 - CCAD anodize and anodize stripping baths use:
 - Anodize: 2300 gallon tank with 1500 lbs. chromic acid, added as needed (500 lbs. added in 2010-2011)
 - Stripping: 1 process line, 2050 lbs of 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





- **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



Small Spur Gear, P/N 70351-08088-102

FY15

- Establish Pilot Process at CCAD
- Evaluate CS

FY16

- Demonstrate Plating/Strike
- Laboratory testing

FY17

- Implement Plating/Strike
- Demonstrate Stripping

FY18

- Implement Cr(VI)-Free Stripping



U.S. ARMY
RDECOM

Cold Spray – Large Caliber Gun Barrel Coatings and Donor Tubes, TMR 13-01

- **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

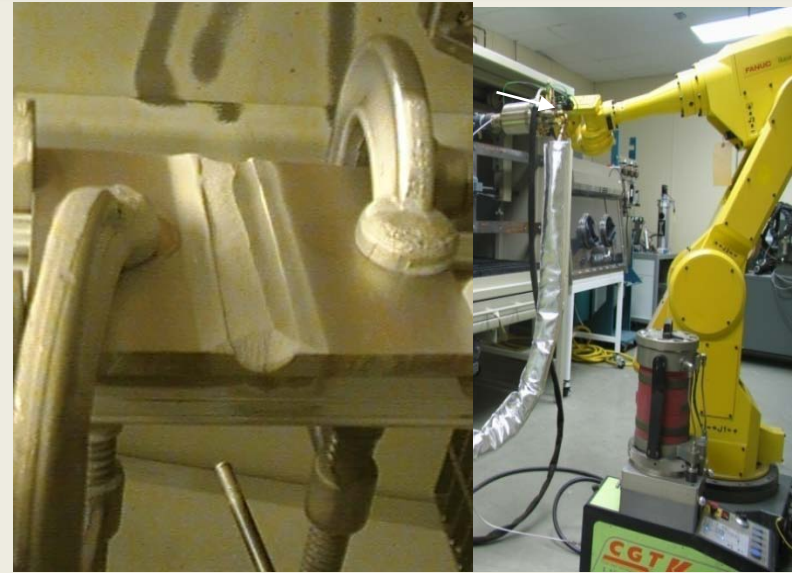
- Optimize ID nozzle
- Powder development

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



U.S. ARMY
RDECOM

Example: Potential Impact of Projects at
CCAD Plating Shop (Building 340)

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



U.S. ARMY
RDECOM

Are the Alternatives More Sustainable?

- 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