Risk Management Approach & Progress in Cd and Cr^{6+} Elimination

11/18/2014

Presented to:
ASETS Defense

Presented by:
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NAVAIR

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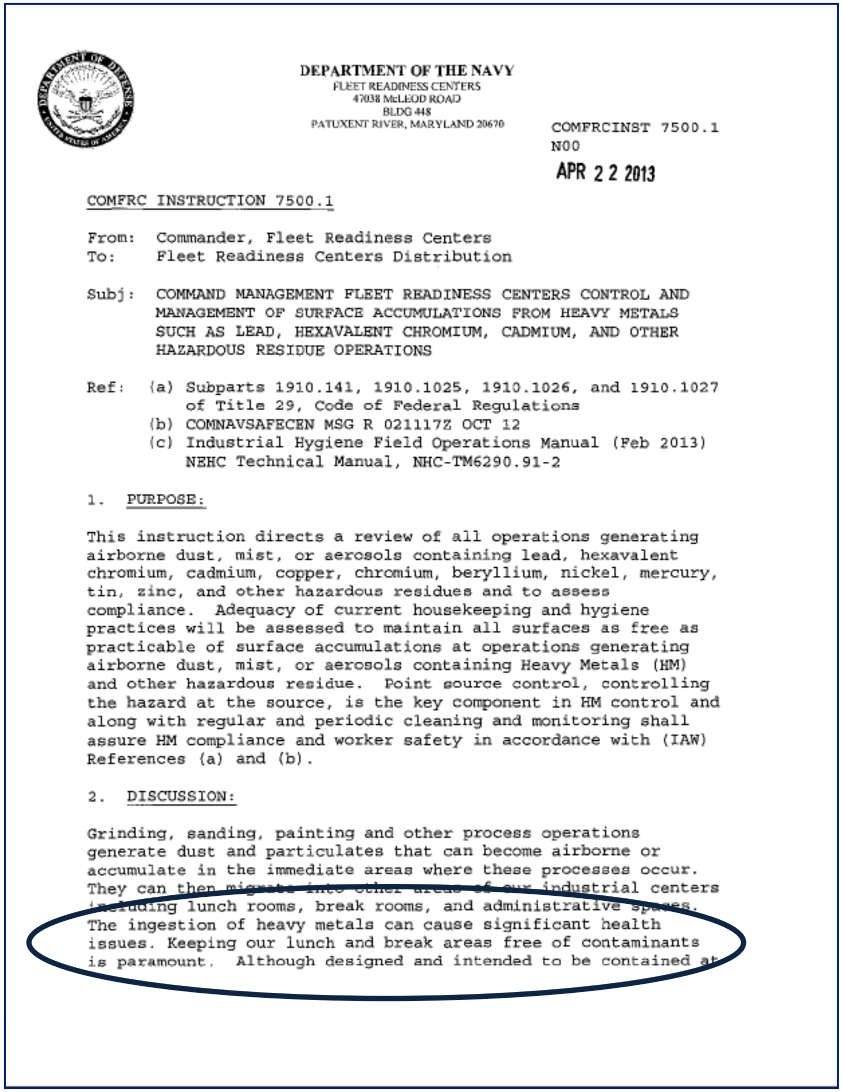
Agenda

- Drivers for Alternatives
- Risk Management Approach for RDT&E and Transition
- Status of Alternatives
- Plan Forward

Current Drivers

- Acquisition
  - Hexavalent chromium DFAR clause
  - Government, OEM and subcontractor policies and regulations
- Sustainment
  - Commander, Fleet Readiness Centers (COMFRC) initiative instigated by COMFRC Instruction 7500.1, “Command Management FRC Control and Management of Surface Accumulation from Heavy Metals such as Lead, Hexavalent Chromium, Cadmium and other Hazardous Residue Operations,” April 22, 2013
  - Fleet input on impact of isocyanates, hexavalent chromium and material flammability during ship board aircraft, weapons and support equipment maintenance
  - National and local policies and regulations



DEPARTMENT OF THE NAVY
FLEET READINESS CENTERS
47038 McLEOD ROAD
BLDG 448
PATUXENT RIVER, MARYLAND 20670

COMFRCINST 7500.1
N00
APR 22 2013

COMFRC INSTRUCTION 7500.1

From: Commander, Fleet Readiness Centers
To: Fleet Readiness Centers Distribution

Subj: COMMAND MANAGEMENT FLEET READINESS CENTERS CONTROL AND MANAGEMENT OF SURFACE ACCUMULATIONS FROM HEAVY METALS SUCH AS LEAD, HEXAVALENT CHROMIUM, CADMIUM, AND OTHER HAZARDOUS RESIDUE OPERATIONS

Ref: (a) Subparts 1910.141, 1910.1025, 1910.1026, and 1910.1027 of Title 29, Code of Federal Regulations
(b) COMNAVSAFECEN MSG R 021117Z OCT 12
(c) Industrial Hygiene Field Operations Manual (Feb 2013) NEHC Technical Manual, NHC-TM6290.91-2

1. PURPOSE:

This instruction directs a review of all operations generating airborne dust, mist, or aerosols containing lead, hexavalent chromium, cadmium, copper, chromium, beryllium, nickel, mercury, tin, zinc, and other hazardous residues and to assess compliance. Adequacy of current housekeeping and hygiene practices will be assessed to maintain all surfaces as free as practicable of surface accumulations at operations generating airborne dust, mist, or aerosols containing Heavy Metals (HM) and other hazardous residue. Point source control, controlling the hazard at the source, is the key component in HM control and along with regular and periodic cleaning and monitoring shall assure HM compliance and worker safety in accordance with (IAW) References (a) and (b).

2. DISCUSSION:

Grinding, sanding, painting and other process operations generate dust and particulates that can become airborne or accumulate in the immediate areas where these processes occur. They can then migrate into other areas of our industrial centers including lunch rooms, break rooms, and administrative spaces. The ingestion of heavy metals can cause significant health issues. Keeping our lunch and break areas free of contaminants is paramount. Although designed and intended to be contained at

Users

All pictures courtesy of U.S. Navy, from www.navy.mil

Risk Management Approach

June 2011 EC-434-000-004

EC – 434 – 000 – 004

RISK MITIGATION FOR NON-CHROMATE COATINGS SYSTEMS

NAVAIR

17 June 2011

AIR VEHICLE ENGINEERING (AVE) DEPARTMENT
NAVAL AIR SYSTEMS COMMAND

Distribution: **Initiated By: AIR-4.3.4**

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May 2011 EC-434-000-004

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Risk Management example-Primers

The following risk analysis matrix provides a tool to assist in determining a risk category as it relates to safety and readiness as a function of expected performance and impact due to failure of a non-chromate technology. It does not address costs associated with regulatory compliance or complete life-cycle impact. While these additional factors are important drivers for making implementation decisions, the safety and readiness of the war-fighter is considered paramount.

Risk Analysis for Implementation of Non-Chromate Technology

Probability of Failure for Non-Chromate Technology vs. Chromate*	Impact of Non-Chromate Technology Failure			
	Mishap, Replacement	Reduced Service Life, High Repair Costs	Increased Maintenance Activities	Negligible
High				
Medium				
Low				
Same as Chromate				

* Probability of failure of non-chromate technology based on sufficient laboratory testing, comparison to current chromate technology for a particular application, and AIR-4.3.4 endorsement.

High Risk	Critical Application Areas should be avoided until test data supports lowering risk level. Ex. Critical Safety Items (CSI), susceptible to stress corrosion cracking (SCC), high cost for repair, inaccessible areas, etc. **
Medium Risk	Application Areas that need careful consideration and review based on test data. Ex. outer-mold-line, inner-mold line, faying surfaces, direct to metal, metal-to-composite contact, etc. **
Low Risk	Non-Critical Application Areas suitable for Dem-Val/Implementation based on test data. Ex. composites without metallic contact, fiberglass, low impact - low cost components

** Note: Factors such as platform/component operational environment and inspection intervals must be considered and may justify adjustment to the risk analysis level. Ex. Trainer aircraft operate in a less severe environment than ship based aircraft.

Mitigation strategies, such as more frequent inspection intervals or increased usage of corrosion preventative compounds (CPCs), may be used to lower risk in medium to high risk categories.

Application	Impact of Primer Failure	Probability of Primer Failure	Overall Risk
Support Equipment	Negligible	Low	Low
Aircraft Exterior-Type I (gloss)	Increased maintenance	Low	Low
Aircraft Exterior-Type II (flat)	Increased maintenance	Medium	Medium
Aircraft Interior-Structural	Reduced service life	Medium	High
Aircraft Interior-Non-Structural	Increased maintenance	Medium	Medium
Aircraft Interior-Components: Avionics Rack	Increased maintenance	Low	Low
Aircraft Exterior-Components: Landing Gear	Mishap, replacement	Medium	High
Weapon Interior	Mishap, replacement	Low	High

Status of Cr^{6+} Alternatives

Cr^{6+} DFAR applications

Hexavalent Chromium Alternative Status

M&P Area	Sub Area	MRL	TRL	Consequence of Material Failure	NAVAIR R&D	Authorization Letter	NAVAIR Implemented	Documentation	Available by 2015?	Gaps
Primer- General Use	Support Equipment	9	9	Low	yes- focused on next generation NC primer with improved corrosion performance on steel and aluminum	N/A	yes	NAVAIR 17-1-125 General Series manual	yes	Improved performance on mixed metals- aluminum & steel
	Aircraft Exterior- Type I	9	8	Low	yes- field tests recently completed with fleet E-2 aircraft; positive results	pending field test report	pending authorization	Planned authorization letter and local process specification changes	potentially	
	Aircraft Exterior- Type II (low IR reflectance)	9	7	Low/Medium	yes- field testing underway on mulitple rotary platforms; planned for F/A-18	no	no	N/A	potentially	Need sufficient field data on aircraft in operating environment; Type II NC primers have reduced performance compared to Type I NC primers
	Aircraft Interior- Type I	4	4	Medium/High	yes- new products being developed and assessed in the lab; initial field testing planned on legacy a/c for FY15 and 16	no	no	N/A	no	Current NC products used on exterior applications have lower performance than chromated products. For interior use, risk is medium to high based on role of primer to inhibit stress corrosion cracking, corrosion fatigue and pitting corrosion on structural aluminum.
Primer- Adhesive Bonding		9	4	High	yes- SERDP project underway to investigate mechanisms of primer	no	no	N/A	potentially	Unfilled bond primer performing well in SERDP effort/lab assessments; needs field testing/validation in operating environment on a/c
Sealing		9	6/9	Range per application	yes- alternatives being assessed against each other and controls	no	yes- in some low risk, inspectable applications	multiple military and commercial specifications; NAVAIR 01-1A-509 General Series manual	potentially- low risk applications	Comparative data needed to develop a sealant guidance document which details where NC products may be used as well as which types
Integral Fuel Tank Coating		3	3	High	yes- joint with Air Force; focused on DIEGME resistance	no	no	AMS-C-27725C	no- no NC products qualified to specification and no current prospects	Developmental products have reduced performance and have not been assessed on aircraft
Hard Chromium Plating		9	7/9	High	yes- cobalt phosphorous (CoP) process and coating demonstration and validation being led by FRC-SE	yes- HVOF tungsten carbide cobalt/cobalt-chromium (WC-Co/WC-CoCr); no- CoP	yes- HVOF WC-Co/WC-CoCr	FRC local process specifications	yes for HVOF coatings (WC-Co/CoCr); potentially for CoP	CoP- need high temperature part maskant and additional field testing of coating

Status of Cr^{6+} Alternatives

Remaining applications

Hexavalent Chromium Alternative Status

M&P Area	Sub Area	MRL	TRL	Consequence of Material Failure	NAVAIR R&D	Authorization Letter	NAVAIR Implemented	Documentation	Available by 2015?	Gaps
Conversion Coating- Aluminum	Avionics/Electrical- Class 3	9	7	Medium	yes- joint service/OEM/NASA effort to validate coatings for Class 3 applications	no	no	Products currently qualified to MIL-DTL-81706 Type II, Class 3	potentially	OEM would need to generate data for electrical applications to ensure electrical properties are satisfactory with coating in place
	General Use- Class 1A	9	7/9	Medium	yes- demonstration and validation underway with NC conversion coating in combination with NC primer	yes- using chromated primer	yes- FRC-E exterior a/c re-furbishment; spray process	Authorization letter and local process specification	yes- for use under chromated primer; potentially- for use under NC primer on exterior	Only two H-46 a/c in field test with full NC system. Need additional a/c tested in operating environment. Planned follow on assessment with E-2/C-2 aircraft.
Conversion Coating- Magnesium		9	8	Low	none currently	no	no	NAWCAD Tech Report	potentially	Data available to authorize; low demand from FRC made this low priority
Conversion Coating- Titanium		9	8	Low	none currently	no	no	NAWCAD Tech Report	potentially	Data available to authorize; low demand from FRC made this low priority
Anodizing- Aluminum	Unsealed	9	9	High	For Type IIB- completing fatigue testing for planned NAVAIR-wide authorization	yes- for IC, II and III	yes- all three FRCs currently use Type IC, II and III processes	MIL-A-8625 and FRC local process specifications	yes	Type IIB in late stage R&D for potential use as Type IC alternative
	Sealing Type II and III	9	8	Medium		yes	no	Authorization letter and local process specification	yes	FRC-SE planning to implement as part of an FY15/16 CIP program
	Sealing Type IC	9	8	Medium		yes	no	Authorization letter and local process specification	yes	
	Sealing Type IIB	9	8	Medium	Yes- final fatigue data for IIB	yes	no	Authorization letter and local process specification	yes	FRC-SE planning to implement as part of an FY15/16 CIP program
Anodizing-Magnesium		9	9	Medium	none currently	yes- Keranite and Tagnite	yes- selected parts via OEMs/new production	Authorization letters	yes	
Passivation for cadmium coatings		7	5	Low	none currently	no	no	Limited lab test data; promising	potentially	Low prioirty in the past as users were focused on cadmium alternatives; could be validated for current cadmium needs at FRCs
Passivation for aluminum coatings		9	7	Low	yes- field testing ongoing	no	no	Laboratory data positive; pending results of field tests	potentially	
Passivation for zinc-nickel coatings		9	7	Low	yes- as part of zinc-nickel demonstration and validation effort at FRC-SE	no	no	Final dem/val report pending stress corrosion cracking and corrosion fatigue testing	potentially	Comparative data for zinc-nickel compared to cadmium: stress corrosion cracking, corrosion fatigue, as well as field testing in relevant operating environment
Passivation for phosphate coatings		9	7	Low	yes- field testing coordinated with the Army Research Laboratory on Army steel components	no	no	ESTCP project reports	potentially	Army work focused on passivation of zinc phosphate. Others use manganese phosphate as well. Validation of performance needed in Navy operating environment
Passivation for black oxide coatings		3	3	Low	none currently	no	no	N/A	no	
Cleaners		9	9	Low	N/A	N/A	yes- 20+ years ago	FRC local process specifications	yes	
Deoxidizers		9	9	Low	N/A	N/A	yes- 20+ years ago, except for some uses	FRC local process specifications	yes	Need NC alternative for aluminum spot weld deoxidation

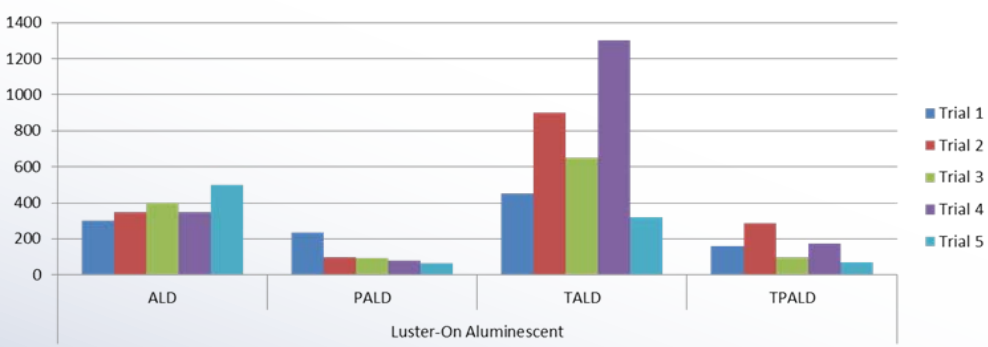
Status of NC Alternatives

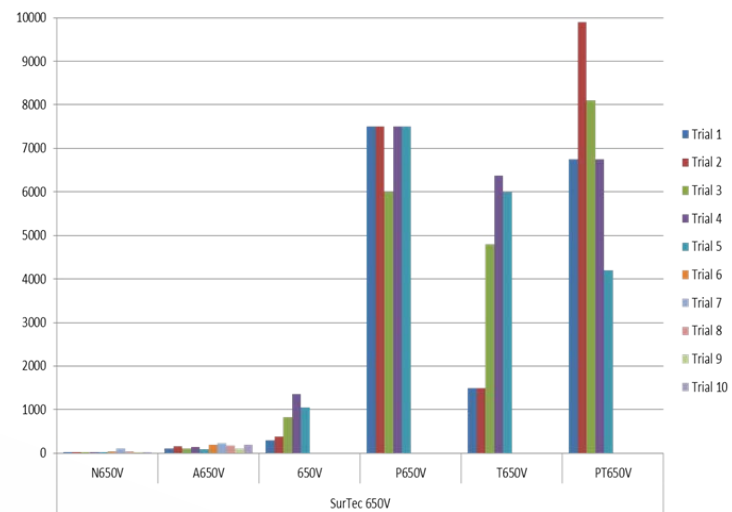
NC Conversion Coating R&D

- 1) Type II (TCP) immersion process improvement: focusing on effect of time, temperature and pH of rinse tanks pre- and post-TCP.
- 2) Surtec 650V optimization: focusing on effect of concentration, temperature, immersion time, pH. Optimized conditions validated by NASA.
  - FRC validation: immersion process
    - Based on data from the lab Surtec 650V optimization, an 1800-gallon tank will be demonstrated at FRC-SW (North Island)
    - Tank in place and charged in February 2014
    - Corrosion testing ongoing for painted coupons: 650V vs chromate control; Class N and C primers
- 3) eTCP lab assessment and scale up for immersion (and possibly spray and touch up)
  - Additives which will lead to improved deposited coating color for QA at FRCs
  - New NESDI-funded effort in FY15. Small scale assessment underway at FRC-SE & Pax
- 4) Spray applied Type IIs:
  - Cherry Point using Alodine T5900 since 2007
  - New NISE-funded effort in FY15 to assess multiple qualified products for North Island

Type II Process Optimization

- Investigating effect of pH, temperature, and immersion time of rinses before and after Type II/TCP immersion tank
- Assessed multiple products so far- Surtec 650 & 650V, Metalast TCP/HF, and Luster On Aluminescent: "standard TCPs" acting similarly, 650V not
- Plans: scale up to 80 gallon process line; assess Metalast TCP/HF-EPA and Henkel products; further study 650V
- Information shared with other potential users- two organizations have validated effect of pH





Surtec 650V Optimization

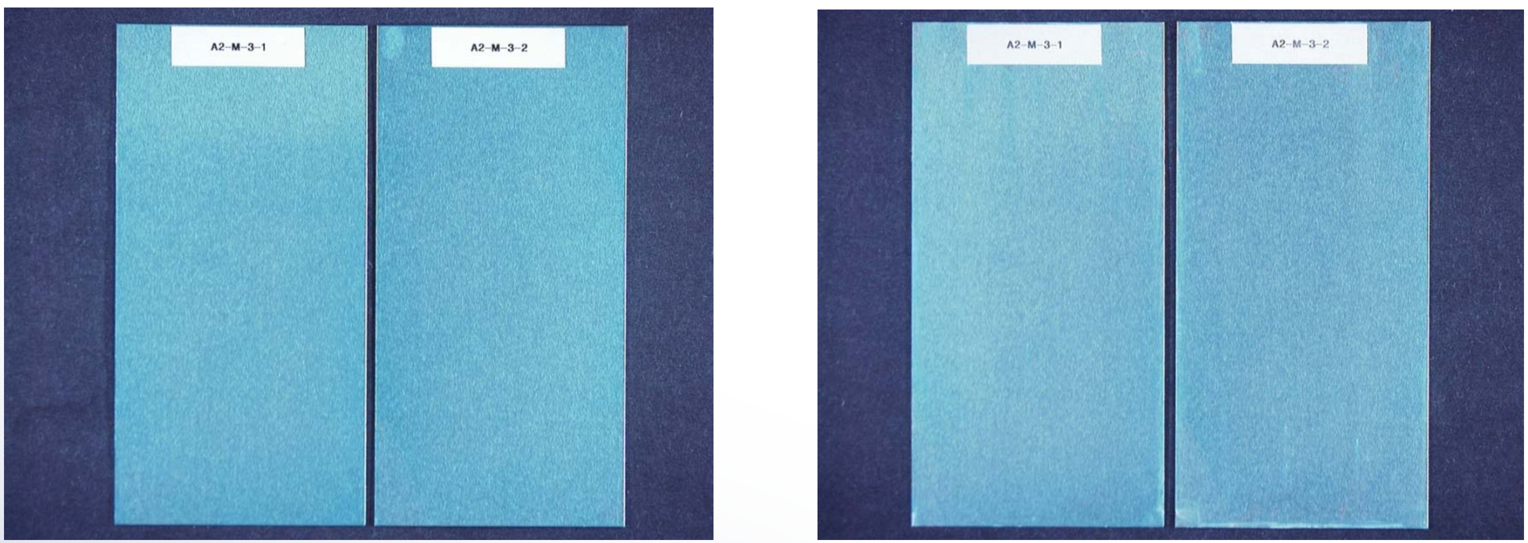
- Assessing lab optimized process parameters for Surtec 650V at FRC-SW (North Island) in 1800-gallon tank using FRC artisans and existing process
- Decision point- similar performance compared to chromate control

1800-gallon Surtec 650V tank (l) and rinse tank (r)

Manual rinsing step

eTCP

- Color change: an important quality control and aesthetic requirement which has been impeding implementation at our FRCs and other users
- Initial results very promising for an additive from Metalast. Other additives to be investigated
- NESDI dem/val effort funded for FY15-17: focus on immersion process
- Other efforts planned to investigate performance in spray and touch-up (wipe and pen) on aluminum as well as effect on magnesium, anodized aluminum, high purity aluminum coatings, and other applications



Metalast additive in Metalast TCP-HF/EPA on 2024-T3, as coated (left) and after 336 hours ASTM B117 (right)

Advanced Topcoat System

- Main fleet/FRC needs- NC primer and non-isocyanate topcoat
- Featured effort to address these needs:
  - New ONR FNC project, "Advanced Topcoat Systems," is planned to start in FY16 and last through FY19
  - Focus on two products: aviation (Navy and USMC) and ground vehicles (USMC)
  - Aviation product is planned to field test advanced coating systems with no Hazmats on targeted lists, reduced flammability and reduced VOCs/HAPs
  - Plan includes re-baselining primer and topcoat spec requirements for chromate and non-chromated classes and types, and potentially MIL-PRF-81706/5541 and MIL-A-8625

ONR Program Code 35

Advanced Topcoat System (ATS)

AT A GLANCE

WHAT IS IT?

A Primer/Topcoat System that provides reduced toxicity to enable shipboard maintenance of aviation and amphibious platforms with high-performance structural protection.

HOW DOES IT WORK?

- New topcoat resin chemistry to address maintenance operation restrictions associated with toxic isocyanate materials.
- Novel metal-rich primers for improved protection of dissimilar material interfaces; weight reduction versus current zinc-rich pigments.

WHAT WILL IT ACCOMPLISH?

Enhanced corrosion protection

- 25% reduction in corrosion and coating maintenance costs for Naval Aviation
- 35% reduction in maintenance cost for USMC Ground Vehicles

Provide improved functional performance and reduced toxicity

- Reduction in health and environmental issues by elimination of toxic isocyanates
- Increase in exterior color stability, gloss retention, flexibility and erosion resistance for AV
- Increase in retention of chemical warfare agent resistance, and mar/impact resistance for GV
- Reduction in flammability by increasing flash point to 140°F; VOCs to 100 g/l

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The Advanced Topcoat System (ATS) Future Naval Capability (FNC) Product is developing protective coating systems with substantially improved corrosion inhibition and reduced environmental, safety and health (ESOH) impacts for Navy and Marine Corps aviation weapon systems and Marine Corps ground and amphibious weapon systems. To achieve this, the ATS program is developing and integrating two technologies: a state-of-the-art topcoat system for aviation (AV) and ground and amphibious vehicles (GV). Performance advancements are focused on increased corrosion performance and optimizing coating deposition, adhesion (AV/GV) and chemical agent resistance (GV).

The ATS products are responding to higher performance corrosion requirements with reduced ESOH impact as expressed by the Fleet. In addition to substantially reducing the impact of corrosion, the ATS products will reduce the use of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) as well as have reduced flammability. All of these improvements will improve the quality of the workplace for maintenance personnel.

By improving coating system performance, ATS will ensure that the Navy and Marine Corps reduce the impact of maintenance activities world-wide while employing SOTA protection schemes which enhance survivability over extended maintenance intervals. The ATS products enable increased Sailor/Marine operational health and safety, and eliminates restrictions on CPC maintenance that lead to additional costs and reduced readiness; improved durability and survivability delivers increased A_o.

Key Technologies:

Non-isocyanate topcoats, with CARC option for the USMC; lower VOCs, HAPs and flammability (AV and GV) – to address ship-board maintenance capability gap.

Aluminum-rich primer, with capability for use on aluminum and steel; lower VOCs, HAPs and flammability; larger range of applied thickness (AV and GV) – to address improved galvanic corrosion protection gap.

Research Challenges and Opportunities:

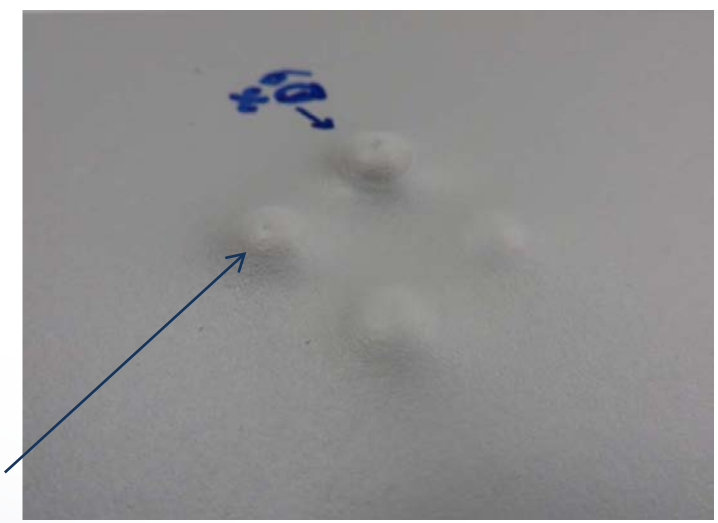
- Topcoat – novel, iso-cyanate free polymers/catalysts
- Single (1K) and two component (2K) formulations
- Primer – novel galvanic protection pigments / inhibitors

OFFICE OF NAVAL RESEARCH www.onr.navy.mil

Non-Isocyanate Topcoat

- Started as an ONR Swampworks project: objective is to develop aviation-type topcoat based on siloxane topcoat technology developed by the Naval Research Lab for ships
- Initial work focused on touch up (MIL-PRF-81352). Good weathering, chemical resistance and paint properties were rapidly developed, including 1K and 2K compositions.
- Better-than-expected progress. Plan is now three phased:
  - Touch up- gloss white & flat gray (MIL-PRF-81352)- FY15, initial field test
  - Support equipment- gloss white (MIL-PRF-85285 Type II)- FY15, initial field test
  - General use- gloss white & flat gray (MIL-PRF-85285 Types I and IV)- FY16/17, initial field test
- Flexibility is key challenge- mature lab products meet flex requirements for touch up and support equipment (Type II) applications for both gloss white and flat gray.
- For general aircraft use (Type I and IV), lab products are achieving 20-40% impact flex but need optimization for all properties

¼" mandrel bend at room temperature



GE Impact results with pass at 40%

Al-Rich Primer

- Focus on exceeding performance of state-of-the art primers on aluminum (MIL-PRF-23377 Class C), mixed metals (MIL-DTL-53022 Type IV) and grit-blasted steel (zinc-rich primers)
- NAVAIR patented technology; licenses in place for U.S. and foreign markets
- Optimization of epoxy-based system continues while leading compositions are assessed in lab, on beach (KSC) and lead-the-fleet demos

Active aluminum alloy pigment

Status of Cadmium Alternatives

Coating/Process	Advantage	Disadvantage	LS Components	HS Components	Connectors	Fasteners
Electroplated cadmium	easy, sunk cost	it's cadmium, requires post-bake	yes	yes	yes	yes
Vacuum cadmium	no post bake	it's cadmium, line-of-sight	yes	yes	yes	yes
IVD aluminum	mature process, no post bake	expensive process, HRE issues	yes	yes	yes	no
Alkaline zinc-nickel	it's not cadmium, low cost process	limited application due to HE	yes	no	yes	no
Stylus cadmium	sunk cost, established	it's cadmium, artisan required	yes	yes	NA	NA
AlumiPlate	excellent corrosion protection, non-LOS process	process, sole source	yes	yes	yes	yes
IZ-C17+ zinc-nickel	low cost process	requires post-bake, in dem/val	yes	yes	yes	yes
Cold spray aluminum	novel process to apply aluminum, alloying ability	line-of-sight	yes	yes	no	no
DVD aluminum	dense coating, alloying ability, good throwing power, no post-bake	expensive process, TRL ~4	yes	yes	maybe	maybe

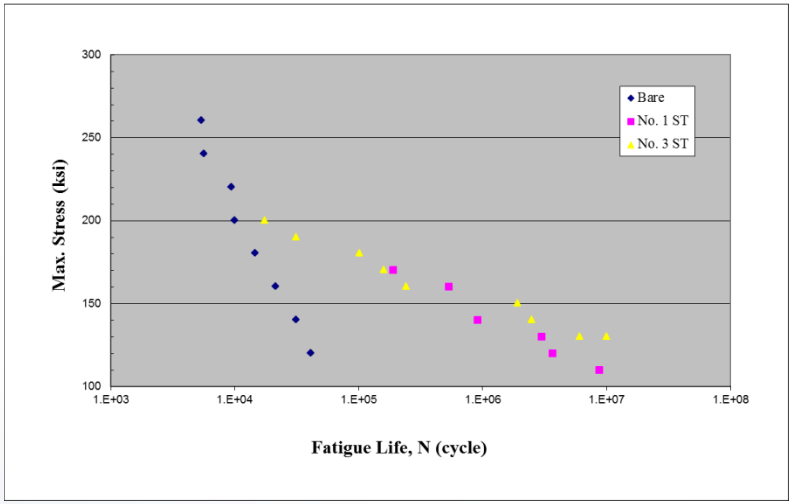
In use

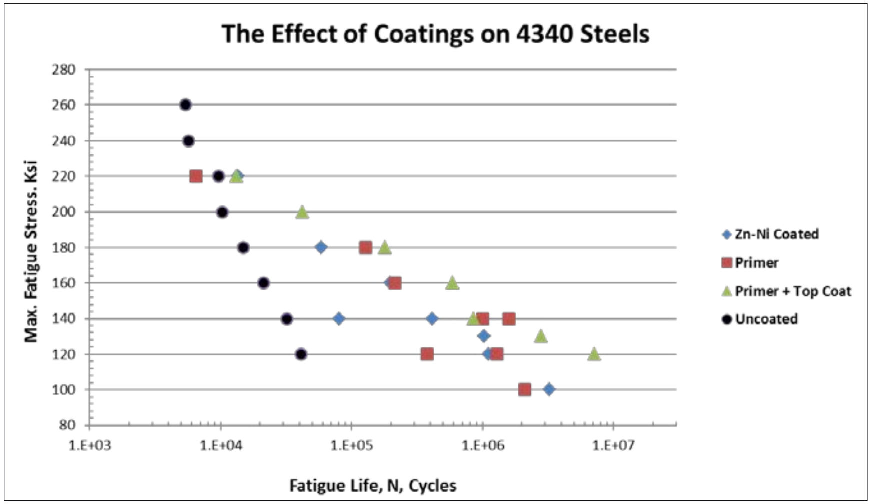
R&D

Focusing on two alternative metals/alloys, aluminum and zinc-nickel. This reduces the number of galvanic interactions possible and lowers the cost of testing, validation and implementation.

Zinc-Nickel Electroplating

- Leading low cost FRC alternative
- Dem/val underway at FRC-SE (Jacksonville)
- Building on Air Force, Boeing, and other work
- Key data: SCC and corrosion fatigue performance- as-coated, with currently used water-reducible chromated primer, and with primer and gloss white topcoat





Corrosion fatigue performance of cadmium (with Cr6+ passivation) (left) and Zn-Ni (with Cr3+ passivation) (right) on 4340 steel

For the cadmium data, blue points are uncoated, pink points are cadmium with chromated primer (MIL-PRF-85582 Type I), and yellow points are cadmium, chromated primer and gloss white topcoat (MIL-PRF-85285 Type I).

Five Year Plan

- Prioritize R&D investments and transition targets based on drivers: DFAR clause, ship-board aircraft maintenance needs and new COMFRC initiative
- Continue leveraging sponsors to greatest extent possible and coordinate where possible with sister services and organizations, OEMs, universities and suppliers
- Expand growing relationship with the Naval Research Lab to maximize use of skills, capabilities, and facilities
- Look for additional "crossover" opportunities like the polysiloxane topcoat technology
- Continue chipping away at highest priorities using our risk management approach in acquisition and sustainment