Coating System Specification Approach to Non-Chromium Coatings

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MATERIALS AND MANUFACTURING DIRECTORATE

OCTOBER 2019

Outline

- BLUF: Hexavalent Chromium Issue
- Hierarchy of Controls
- Non-Cr Coatings Are…
- Salt Spray Conundrum
- Path Forward
- Summary

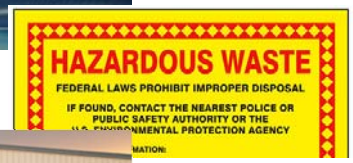
Bottom Line Up-Front: The Hexavalent Chromium Issue

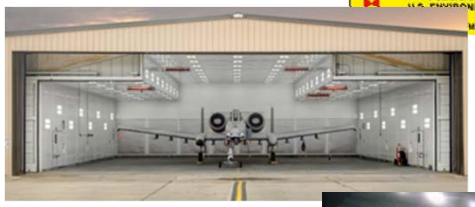
Coatings systems contain hexavalent chromium (Cr^{6+})

Cr^{6+} is highly carcinogenic

Standard Polyurethane Topcoat
Hexavalent Chromium Pigmented Epoxy Primer
Standard Cr-Free Pretreatment
Aerospace Aluminum Substrate

Old Way of Looking At Coatings





Technology Development

Reduce HazMat

Improved Facilities

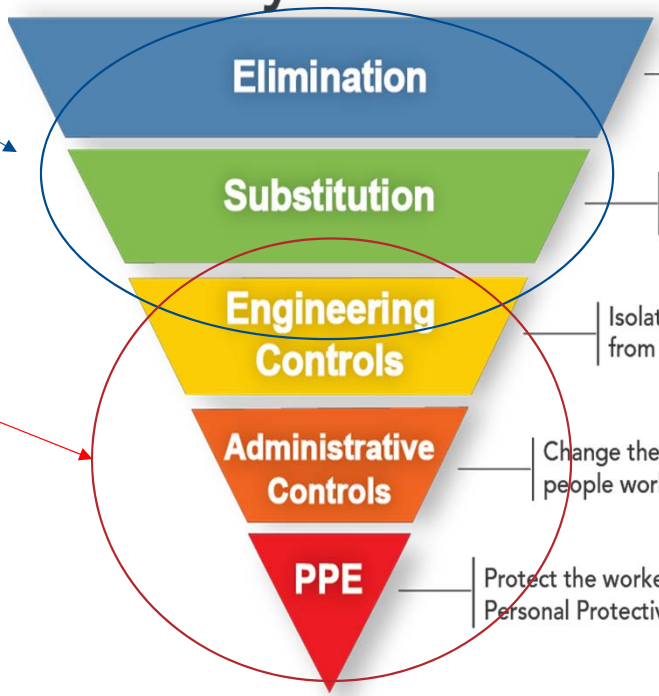
Shift Rotation

Standard Method

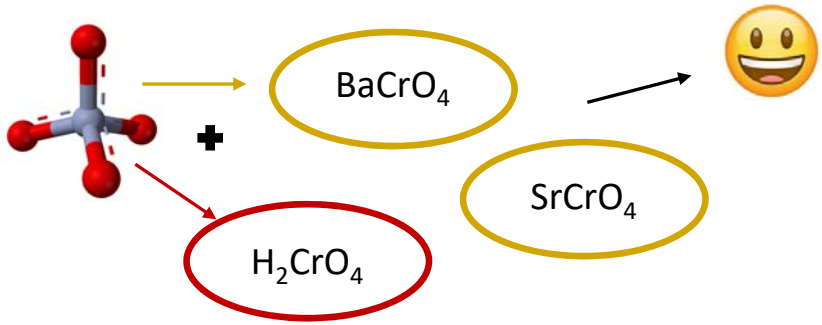
Most Effective

Less Effective

Hierarchy of Controls



Technology Development: Non-Chromium Coatings



Standard Polyurethane Topcoat
Non-Chromium Pigmented Epoxy Primer
Standard or Altenrate Cr-Free Pretreatment
Aerospace Aluminum Substrate

New Way of Looking At Coatings

Mg^{2+} Li^{+} Al^{3+} Cr^{3+}

$BaSO_4$ $Y^{+/-}$

ZrO

Pr_6O_{11}

Replacement

Non-Cr = Elements that are not Cr

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	* 72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	* 104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
			* 58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
			* 90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

Military Specifications - Aircraft

Standard Polyurethane Topcoat

Mix & Match

NOT MEASUREMENT SENSITIVE

MIL-PRF-85285E
12 January 2012
SUPERSEDING
MIL-PRF-85285D
w/AMENDMENT 3
2 February 2009

MIL-PRF-85285

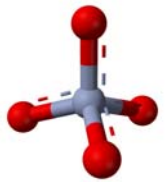
PERFORMANCE SPECIFICATION

COATING: POLYURETHANE, AIRCRAFT AND SUPPORT EQUIPMENT

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the requirements for polyurethane coating with a maximum volatile organic compound (VOC) and maximum volatile organic hazardous air pollutants (VOHAPs). The coating is furnished in kit form.



H_2CrO_4

Class C: Hexavalent Chromium Pigmented Epoxy Primer

Class N: Engineering Approval Only, Tested over Cr Pretreatments

NOT MEASUREMENT SENSITIVE

MIL-PRF-23377K
7 June 2012
SUPERSEDING
MIL-PRF-23377J
W/AMENDMENT 2
10 April 2007

MIL-PRF-23377

PERFORMANCE SPECIFICATION

PRIMER COATINGS: EPOXY, HIGH-SOLIDS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the requirements for corrosion inhibiting, chemical and solvent resistant, solvent-borne, high-solids epoxy primer coatings that have a maximum volatile organic compound (VOC) content of 340 grams per liter (g/L)(2.8 pounds per gallon [lb/gal]) as supplied by the manufacturer.

Standard Pretreatment Usually Cr6+, Some Cr3+, *One Rare Earth Non-Cr (2018)

INCH-POUND

MIL-DTL-81706B
w/AMENDMENT 1
2 May 2006
SUPERSEDING
MIL-DTL-81706B
25 October 2004

MIL-DTL-81706

DETAIL SPECIFICATION

CHEMICAL CONVERSION MATERIALS
FOR COATING ALUMINUM AND ALUMINUM ALLOYS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers chemical conversion materials used in the formation of coatings by the reaction of the material with the surfaces of aluminum and aluminum alloys.

Key Materials Properties – Previous DoD Approach

Mix & Match

Standard Pretreatment
Usually Cr6+, Some Cr3+,
***One Rare Earth Non-Cr** (2018)*

Adhesion

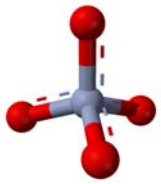
Corrosion Resistance

Class C: Hexavalent Chromium Pigmented Epoxy Primer

Class N: Engineering Approval Only, Tested over Cr Pretreatments

Adhesion **Aircraft Fluids** **Solvents**

Corrosion Resistance **Flexibility**



H_2CrO_4

Standard Polyurethane Topcoat

Ultraviolet Light **Aircraft Fluids**

Adhesion **Flexibility** **Soiling**

Humidity **Solvents**

Key Materials Properties – AFRL Approach

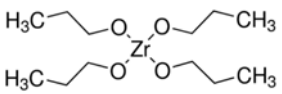
Paired

Chromium-Free Pretreatment

Adhesion

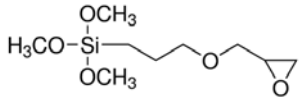
Corrosion Resistance

Pr_6O_{11} ZrO



Zirconium N-propoxide

Henkel Bonderite 5200



Glycidyl 3-(trimethoxysilyl)propyl ether

3M AC-131

$Y^{+/-}$

Effective as a System Not Mix & Match

Hexavalent Chromium Free Primer

Adhesion **Aircraft Fluids** **Solvents**

Corrosion Resistance **Flexibility**

Al^{3+} Cr^{3+}

Aluminum Rich Primer

Pr_6O_{11} $Y^{+/-}$

PPG (Deft)

Mg^{2+} Li^{+}

AkzoNobel

$BaSO_4$

Hentzen

Standard Polyurethane Topcoat

Ultraviolet Light **Aircraft Fluids**

Adhesion **Flexibility** **Soiling**

Humidity **Solvents**

The “Salt Spray” Conundrum

Standard Pretreatment
Usually Cr6+, Some Cr3+,
***One Rare Earth Non-Cr (2018)**

Class C: Hexavalent Chromium Pigmented Epoxy Primer

Class N: Engineering Approval Only, Tested over Cr Pretreatments

Corrosion Resistance → H_2CrO_4 ← **Corrosion Resistance**

336 hours

INCH-POUND

MIL-DTL-81706B
w/AMENDMENT 1
2 May 2006
SUPERSEDING
MIL-DTL-81706B
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MIL-DTL-81706

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Pretreatment only

2000 hours

NOT MEASUREMENT SENSITIVE

MIL-PRF-23377K
7 June 2012
SUPERSEDING
MIL-PRF-23377J
W/AMENDMENT 2
10 April 2007

MIL-PRF-23377

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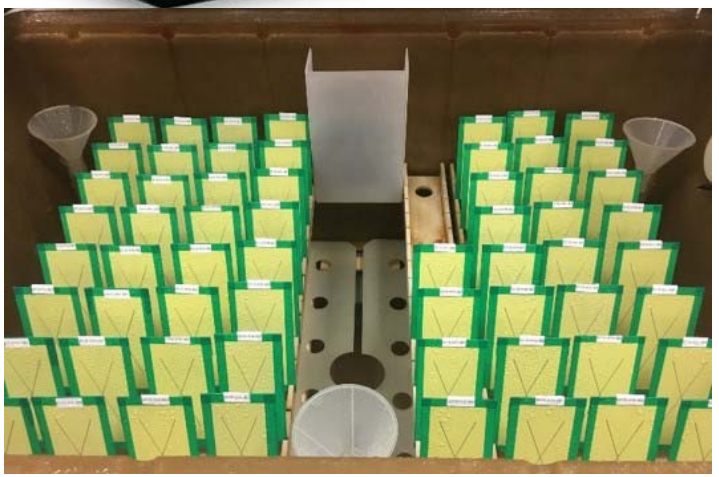
With and Without Topcoat

Exposure Cabinet



The “Salt Spray” Conundrum

Chromium-Free Pretreatment

Chromium Free Primer

Corrosion Resistance

Corrosion Resistance

Zero Cr

336 hours

INCH-POUND

MIL-DTL-81706B
w/AMENDMENT 1
2 May 2006
SUPERSEDING
MIL-DTL-81706B
25 October 2004

MIL-DTL-81706

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7 June 2012
SUPERSEDING
MIL-PRF-23377J
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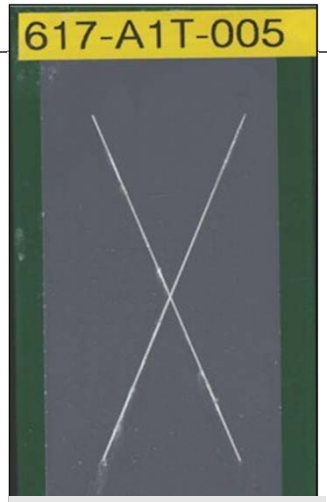
With and Without Topcoat

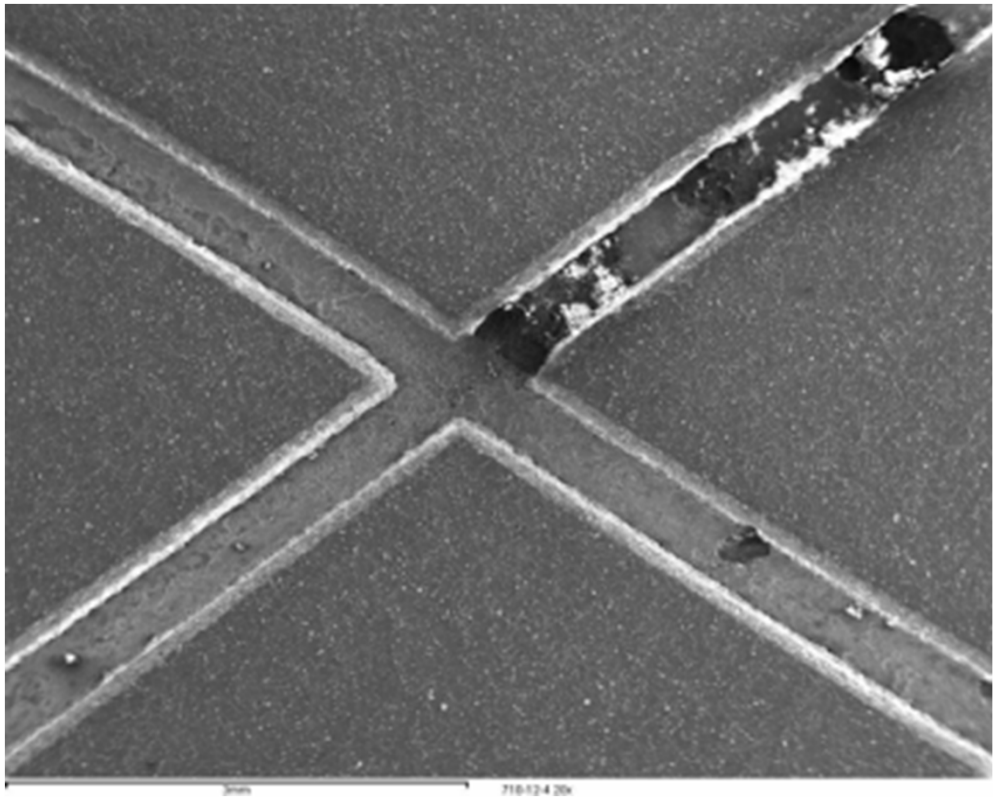


Exposure Cabinet
“**Passed**”

Outdoor
Exposure Testing
“**Failed**”

Outdoor Exposure Testing

The “Salt Spray” Conundrum

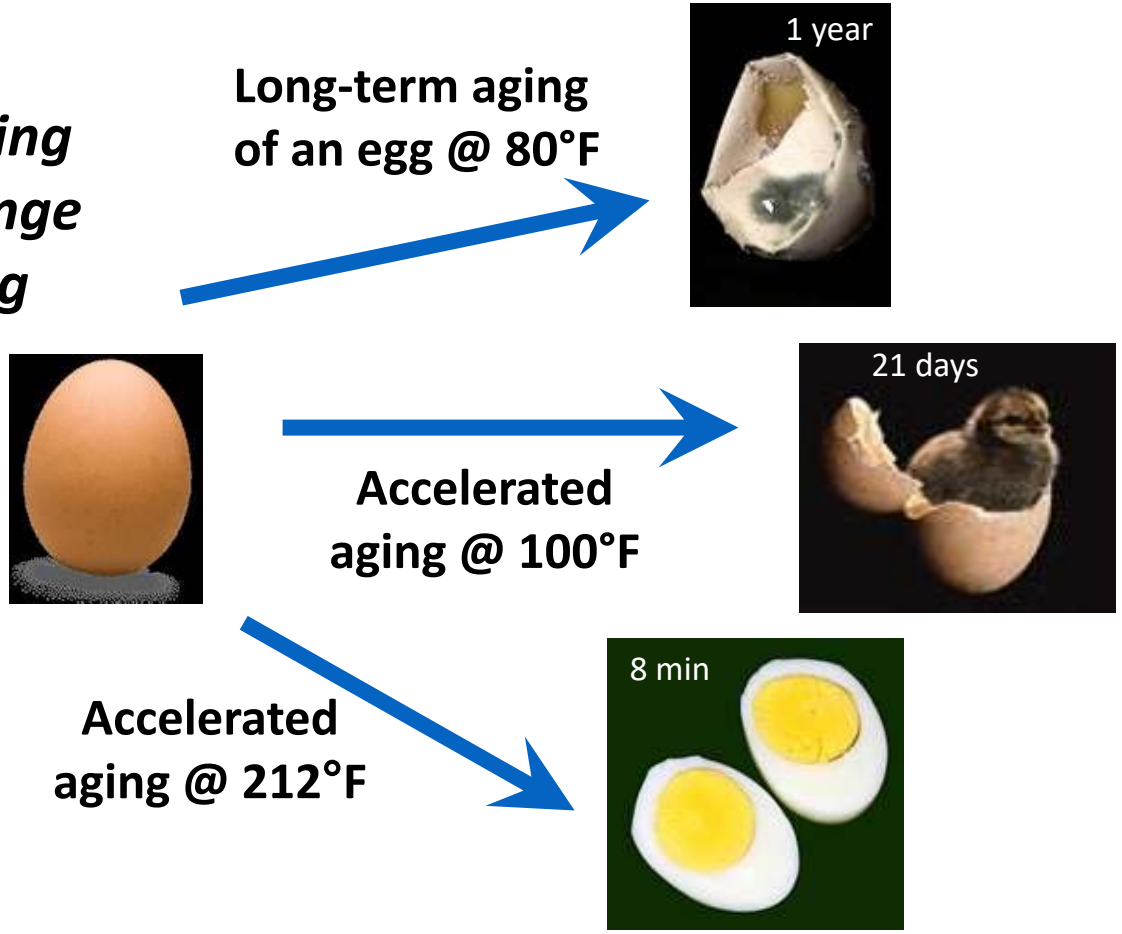


Corrosion Mechanism in Salt Spray Cabinet Testing

Corrosion Mechanism in Outdoor Exposure Testing

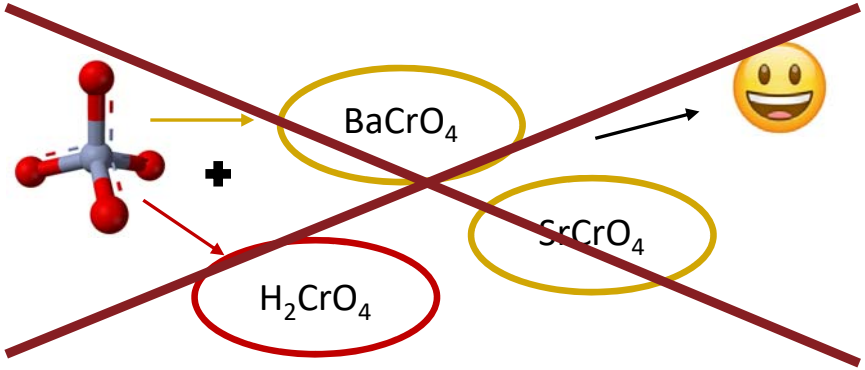
The “Salt Spray” Conundrum

Accelerated aging should not change the target aging mechanism!



Slide courtesy Dr. Greg Schoeppner AFLCMC/EZFS.

Path Forward to Non-Chromium Coatings



Non-Cr = Elements that are not Cr

New Way of Looking At Coatings

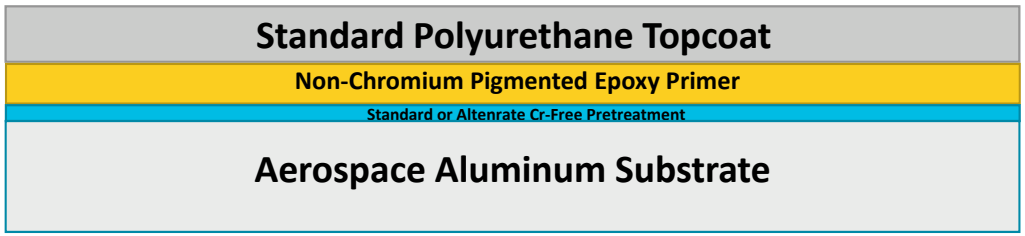
Mg^{2+} Li^{+} Al^{3+} Cr^{3+}

$BaSO_4$ $Y^{+/-}$

ZrO

Pr_6O_{11}

Replacement



Military System Specification with Outdoor Exposure Testing

Corrosion Community Seeking Improvements to Corrosion Resistance Performance Prediction

Path Forward to Non-Chromium Coatings

New Technology + **Qualification** + **Authorization** = **Transition**

Non-Cr = Elements that are not Cr

Mg^{2+} Li^{+} Al^{3+} Cr^{3+}

$BaSO_4$ $Y^{+/-}$

ZrO

Pr_6O_{11}

MIL-PRF-32239

INCH-POUND
MIL-PRF-32239B
29 APR 2019
SUPERSEDING
MIL-PRF-32239A
1 OCT 2014

PERFORMANCE SPECIFICATION

COATING SYSTEM, ADVANCED PERFORMANCE, FOR AEROSPACE APPLICATIONS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

QPL-32239

DEPARTMENT OF THE AIR FORCE
AIR FORCE RESEARCH LABORATORY
WRIGHT-PATTERSON AIR FORCE BASE OHIO

22 June 2018

MEMORANDUM FOR 309 EMXG/MXDER
ATTENTION: MR. WAYNE PATTERSON
5832 H. Avenue, Bldg 843
Hill AFB UT 84056

FROM: AFRL/RXT
2977 Hobson Way
Wright-Patterson AFB OH 45433

SUBJECT: Qualification of Non-Chrome Coating Systems to the Next Revision of MIL-PRF-32239, "Coating System, Advanced Performance for Aerospace Applications"

1. This memorandum is to inform you that the following coating system in Table 1 has met the qualification requirements and will be listed on the qualified products list (QPL) for the next revision of MIL-PRF-32239, Coating System, Advanced Performance, for Aerospace Applications.

Table 1. Qualified to MIL-PRF-32239 for full use in aerospace applications

Coating System	Pretreatment		Primer		Topcoat	
	Manufacturer	Product Identification	Manufacturer	Product Identification	Manufacturer	Product Identification
1	Pantheon	ProKote	AkzoNobel Aerospace Coatings	Aerodur 2100/9004	PPG Industries	CA9321 (w/66-gloss)

2. The following coating systems in Table 2 have met requirements sufficient for Air Ground Equipment (AGE)

6 Systems

DEPARTMENT OF THE AIR FORCE
Headquarters Air Force Life Cycle Management Center (AFMC)
Engineering Directorate
Wright-Patterson AFB OH 45433-7101

AC-18-03
19 NOV 2018

AIRWORTHINESS CIRCULAR
Non-Chromium Coating Systems for Aircraft Outer Moldlines

1. **PURPOSE:**
This Airworthiness Circular (AC) provides information about the use of non-chromium (non-Cr) coating systems on aircraft outer moldlines.

2. **SCOPE:**
This AC is applicable to all USAF air systems, including those operated by the Air National Guard and USAF Reserve.

Goal is Cr Replacement

Standard Polyurethane Topcoat

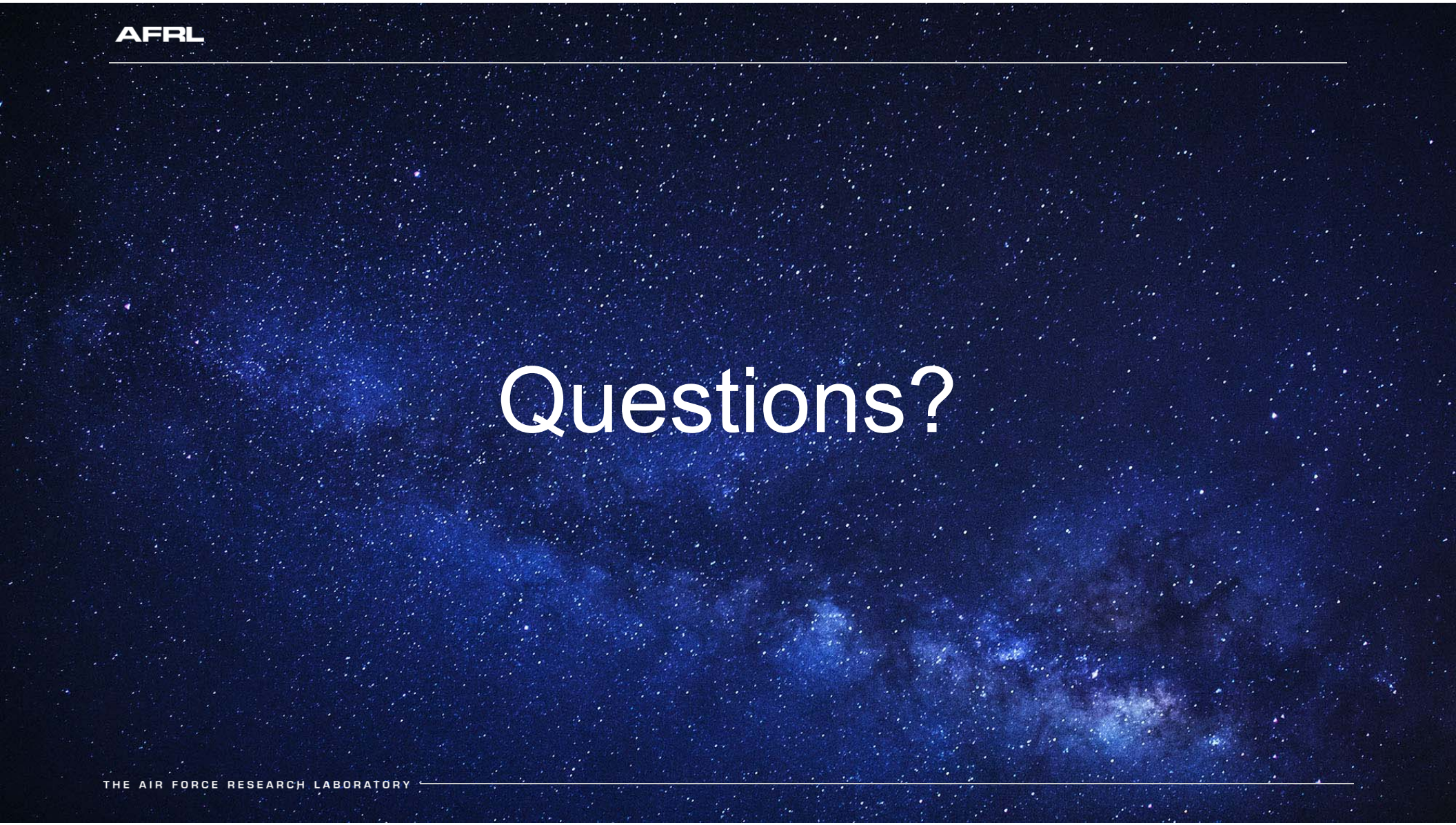
Non-Chromium Pigmented Epoxy Primer

Standard or Altenrate Cr-Free Pretreatment

Aerospace Aluminum Substrate

Summary

- BLUF: Hexavalent Chromium Issue ---- Well Understood
- Hierarchy of Controls ---- Replacement
- Non-Cr Coatings Are ---- Everything that isn't Cr
- Salt Spray Conundrum ---- Acceleration does not always give the right answer
- Path Forward ---- Military System Specification


AFRL
Questions?
THE AIR FORCE RESEARCH LABORATORY