## AVT-373 Research Workshop on
## "Emerging Technologies for Proactive Corrosion Maintenance"

# Developing Hexavalent Chromate Free Coating Systems and Implementation Considerations Regarding the USAF T-38 Talon

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U.S. AIR FORCE

SwRI
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# Overview

- **T-38 Talon – overview of aircraft**
- **Hexavalent Chromium - Environmental and health hazard**
- **Developing a new coatings standard → MIL-PRF-32239B**
  - History and evolution
- **MIL-PRF-32239B → Qualification for chromium-free systems**
- **T-38 selection of an appropriate system**
- **T-38 considerations surrounding the new system**
- **Lessons learned**
- **Conclusions and Recommendations**

*The views expressed in this article are those of the author and coauthors and do not necessarily reflect the official policy or position of the United States Air Force Academy, the Air Force, the Department of Defense, or the U.S. Government.*

# T-38 Talon

- **T-38 Talon**
  - Premier training jet / USAF
  - NATO – ENJJPT syllabus
  - Two seater
  - Two turbojet engines
- **First supersonic trainer**
  - Fielded in 1961
- **Utilization**
  - USAF
  - US Navy
  - NASA
  - NATO
- **Paint → ~ 8 year cycle / paint as needed**

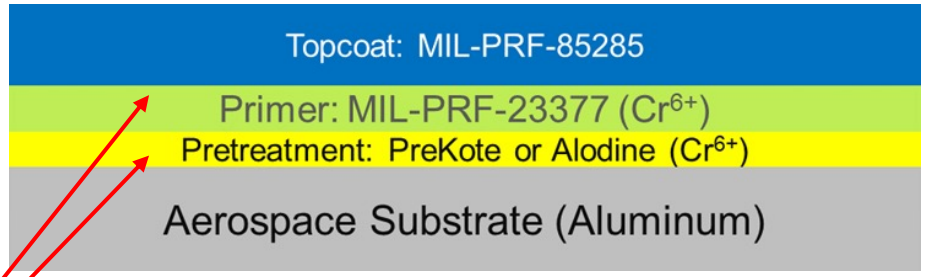
Photo taken by: USAF

*Reference: Northrop T-38 Talon - Wikipedia*

# Hexavalent Chromium

- **Hexavalent Chromium / Chromium (VI) or "$Cr^{6+}$"**
  - ➢ Excellent for corrosion prevention
    - Aerospace - used since World War II
  - ➢ Bad for human health
  - ➢ Known carcinogen
  - ➢ Highly transmittable
  - ➢ Ground water contaminant
- **USAF directive to replace**
- **$Cr^{6+}$ is prevalent in**
  - ➢ Primers, pretreatments → *Alodine prevalent!!!*
- **$Cr^{6+}$ not in topcoat → *accurate for current and new systems***

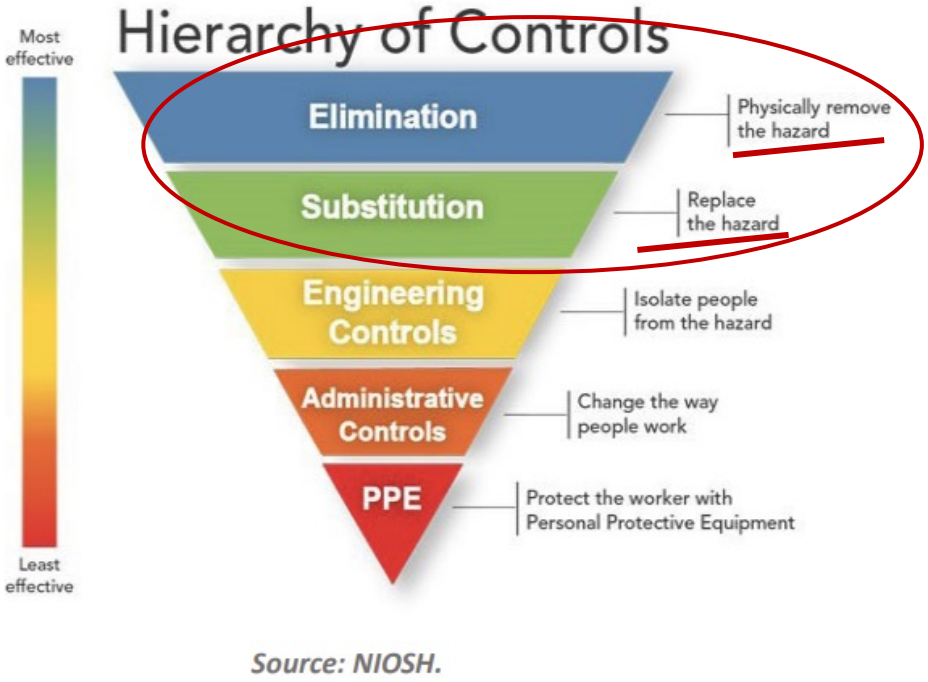
***Current T-38 OML Coating System***




*(Note: "PreKote" is an adhesion promoter -no corrosion inhibitors and no $Cr^{6+}$)*

# Health and Environmental Protection

- **PPE**
  - ➢ Quick and easy
    - Worker / PPE availability / etc.
- **Administrative**
  - ➢ Training and participation
    - Highly dependent
- **Engineering Controls**
  - ➢ Time, costly, effective
  - ➢ Hazard still present
- **Substitution and Elimination**
  - ➢ Top choice!

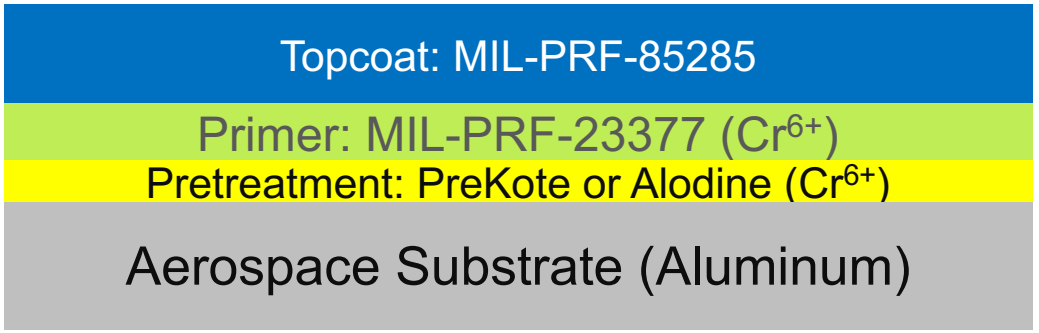



*Source: NIOSH.*

*Image reference: https://www.osha.gov/sites/default/files/Hierarchy_of_Controls_02.01.23_form_508_2.pdf*

- **Current Hexavalent Chromium Coating System**
  - Pretreatment:
    - PreKote: Adhesion promotor → no $Cr^{6+}$
    - Alodine: Conversion coat → YES $Cr^{6+}$
  - Primer: MIL-PRF-23377 (Type I, Class C2) → YES $Cr^{6+}$ ( non-chrome available)
  - Topcoat (MIL-PRF-85285) → no chromates

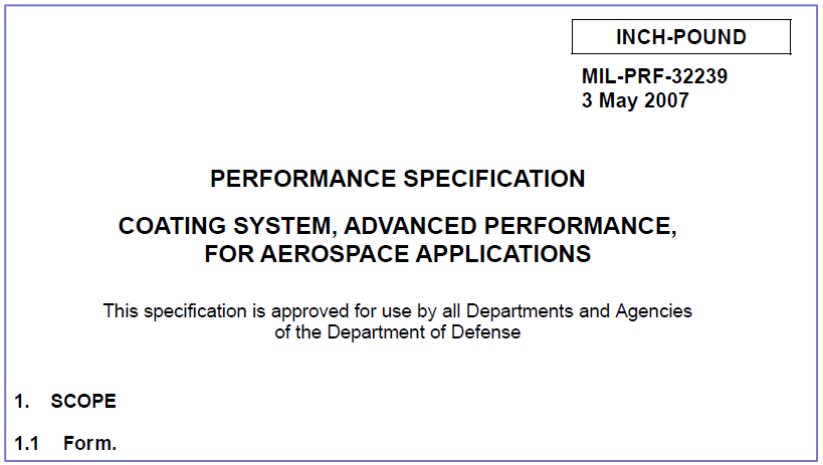

- **Need non-chromium: Effective "drop-in" replacement**
  - Works with current equipment
  - Available
  - Stable performance specification
  - Easy = better



# Path Forward to Non-Chromium Coatings

**New Technology**

**Qualification**



INCH-POUND
MIL-PRF-32239
3 May 2007

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

1.1 Form.

**MIL-PRF-32239 Established as performance specification to qualify new non-chromium systems**

**Authorization**

**TRANSITION**

# Starting Point: Baseline Specification

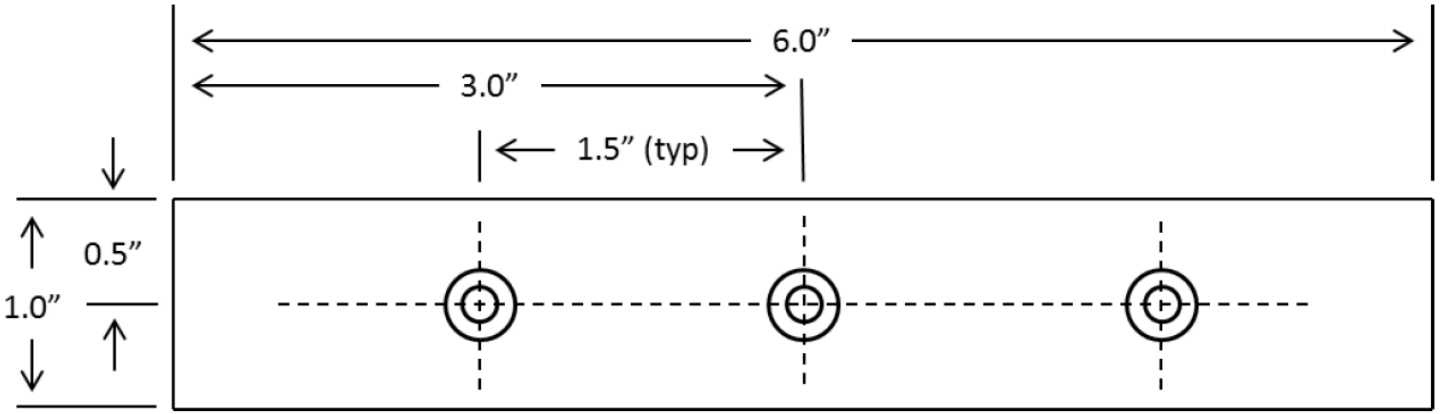
- **Society for Automotive Engineers (SAE) International Aerospace Material Specification (AMS)**
  - AMS3095A "Paint: High Gloss For Airline Exterior Systems"
  - Commercial aircraft specification → *USAF baseline*
  - Some tests and pass/fail criteria in the AMS specification
    - Only appropriate for commercial aircraft
      - Matching exact gloss coating colors
      - Requirements for flexibility
    - Qualification requirements less stringent than military requirements
  - Used as baseline criteria for MIL-PRF-32239 "Coating System, Advanced Performance, for Aerospace Applications"

# New Performance Specification

- **AMS3095A → Baseline specification for**
- **DoD"MIL-PRF-32239"**
  - Specification to develop non-chromium replacement systems
    - "As good or better" than current (chromium) coating systems
  - "Salt spray" data did not consistently represent real world
  - Testing of pretreatments and primers without hexavalent chromium led to inconsistent results
  - Inconsistencies in salt spray results (re: false positive and false negative performance in salt spray testing versus real world
  - Chromium does not work will with other corrosion inhibiting technologies
  - Need for revisions to MIL-PRF-32239

# MIL-PRF-32239 → MIL-PRF-32239A

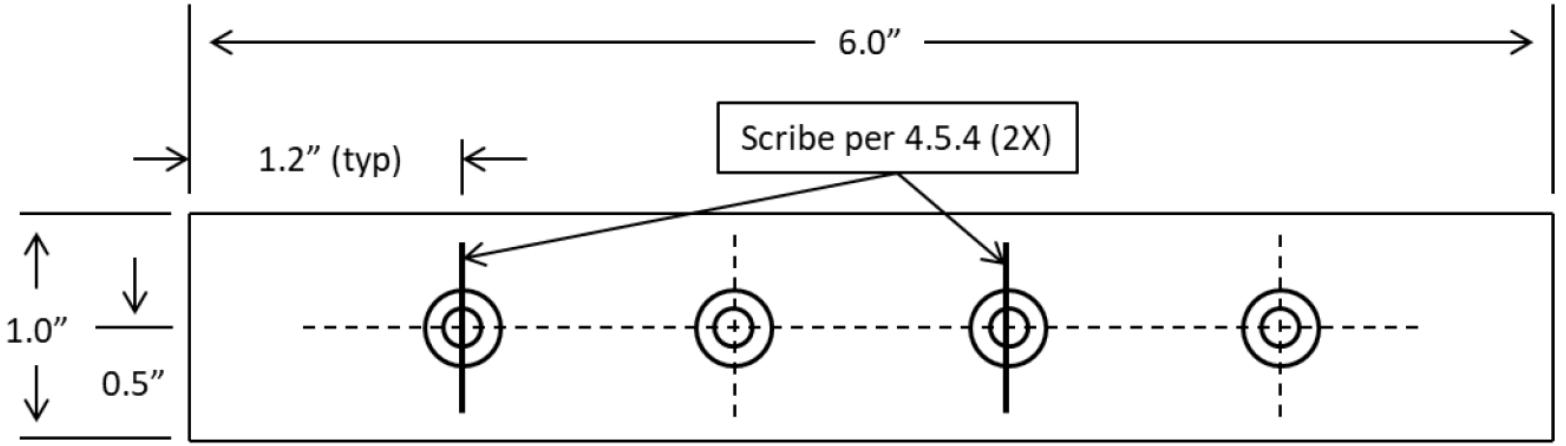
- **MIL-PRF-32239A**
  - ➢ New test parameters for "real world" → beach exposure
  - ➢ New standardized test coupon
    - Scribed fastener coupons and unscribed fastener coupons
    - Galvanic couple and real world atmospheric exposure




  - ➢ Latest variation → stable → reproducible → closer to reality

# MIL-PRF-32239A → MIL-PRF-32239B

- **MIL-PRF-32239B**
  - Engineering team at AFRL determined that the same amount of data could be collected by using half as many samples
  - Scribed and unscribed fasteners on *same* test coupon
    - Reduces number of samples




  - Latest → stable → efficient → reproducible → closer to reality

# MIL-PRF-32239B → Lessons Learned (1 of 2)

- **Cannot mix and match systems without characterization**
- **Performance of <u>each system must be verified</u>, even with <u>minor changes</u> to the system**
  - Different manufacturers of MIL-PRF-85285 Type IV topcoat
    - *Each must be qualified to MIL-PRF-32239B*
  - Performance specifications do not dictate chemistry
- **Basic laboratory materials performance tests provide value**
  - "Exposure effects" followed by flexibility testing is now incorporated into the new performance specification
  - MIL-PRF-32239B

# MIL-PRF-32239B → Lessons Learned (2 of 2)

- **ASTM B 117 Corrosion Resistance Test can give false positives and false negatives**
  - B 117 testing passed, failed on-wing
  - B 117 testing failed, passed on outdoor exposure
  - Good on-wing small aircraft, but not on large aircraft
    - Full characterization required
- **Baseline corrosion resistance performance better characterized with galvanic coupled corrosion testing, this was added to MIL-PRF-32229**

# New Systems

- **Specific pretreatment, primer and topcoat for each "System"**
  - ➢ *Must stay within the specific qualified system*

| System | Pretreatment – Chromate free | Primer – Chromate free | Topcoat |
|---|---|---|---|
| Coating System 1 | PreKote® | AERODUR 2100 | 99GY001 |
| Coating System 2 | PreKote® | AERODUR 2100 | AERODUR 5000 |
| Coating System 3 | AC-131 | AERODUR 2100 | AERODUR 5000 |
| Coating System 4 | DesoGel® EAP9 | CA7236 | CA9311 |
| Coating System 5 | AC-131 | AERODUR 2118 | CA9311 |
| Coating System 6 | AC-131 | AERODUR 2118 | AERODUR 5000 |
| Coating System 7 | PreKote® | AERODUR 2118 | CA9311 |
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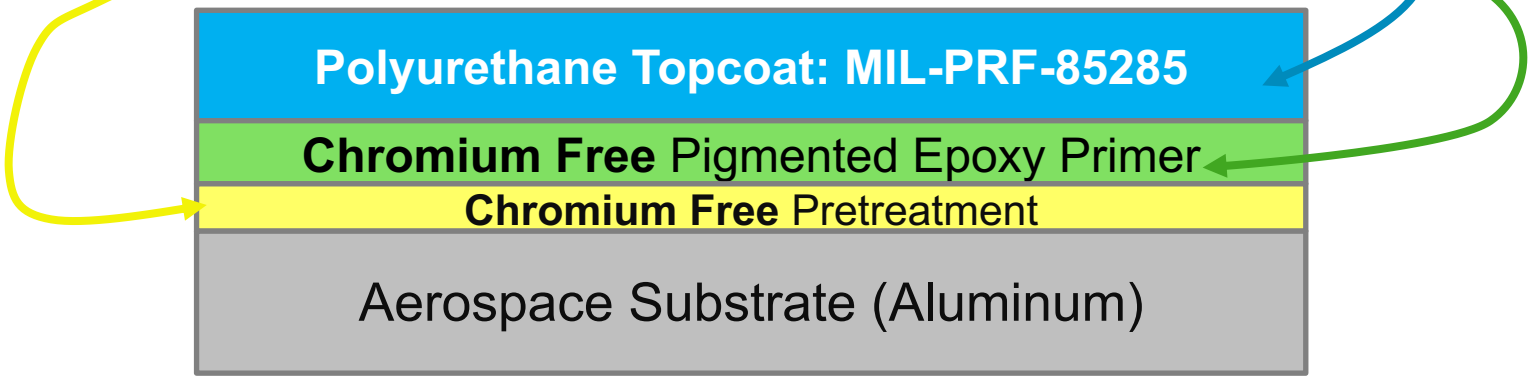
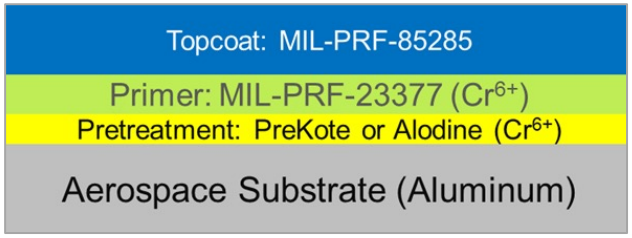


# Chromium vs. Non-Chromium System

## CURRENT ($Cr^{6+}$) SYSTEM

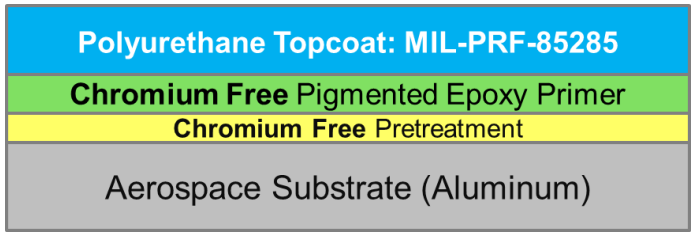
- **Mix and match** *(versatile)*
  - Any pretreatment
  - MIL-PRF-23377 *(any primer)*

    *Type and Class*
    - Type I – Standard pigments
    - Type II – Low infrared
    - Class C1 – Barium chromate based
    - Class C2 – Strontium chromate based
    - Class N – Non-chromate based
  - MIL-PRF-85285
    - Any topcoat




## NEW (non-$Cr^{6+}$) SYSTEM

- **System Specific**
  - MIL-PRF-32239B
    - Qualified system
  - Stay within the given system
  - NO mix and match *(rigid)*
- **Potential availability concerns**



# T-38: Chromium Free System Initial Choice

- **MIL-PRF-32239B systems evaluated**
  - Reduce hazards to personnel
  - Minimal disruption to operating units and maintenance bases
  - Relative continuity
  - Initial choice
    - Current system uses PreKote and same topcoat
    - System 2 → compatible with previous coating system
  - Presented to T-38 Corrosion Prevention Advisory Board (CPAB)
    - CPAB discussed → Alternative presented
      - Due to new USAF trainer jet

# T-38 Chromium-Free Final Choice

- **Corrosion Prevention Advisory Board discussed**
  - Air Education Training Center (AETC) *(key stakeholders)*
  - Replacement for T-38 → T-7 Red Hawk
  - T-7 will be using System 4
  - For continuity and future compatibility
    - System 4 → Selected for T-38
      - System 4 topcoat is "matte" finish → T-38 uses a "gloss" finish
    - AFRL already qualifying (MIL-PRF-32239B) System 4 for "gloss" finish
    - AFRL added System 8 as a qualified system early 2023
  - T-38 implementing Systems 4 *and* System 8

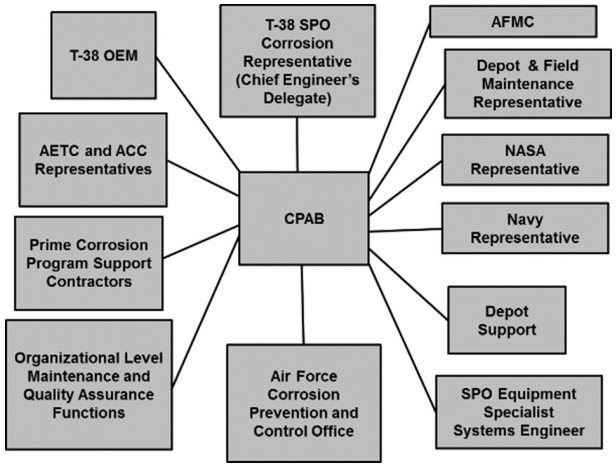
| System | Pretreatment – Chromate free | Primer – Chromate free | Topcoat |
|---|---|---|---|
| Coating System 4 | DesoGel® EAP9 | CA7236 | CA9311 |
| Coating System 8 | DesoGel® EAP9 | CA7236 | CA9800 |

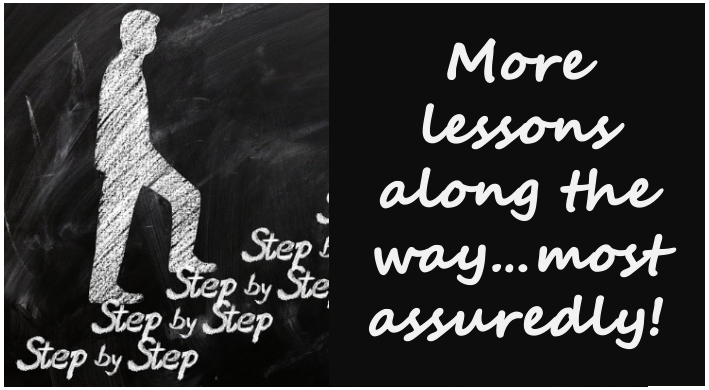
# Fielding Chromium Free System

- **Successful reduction and ultimate elimination of hazards and exposure to personnel**
- **Successful application/durability of robust coatings to prevent corrosion of the T-38 and other USAF trainer aircraft**
- **Appropriate training of personnel and demonstrations from suppliers**
  - Working with manufacturers to train units
- **Assuring availability of products in supply chain and ability to procure**
  - Working with manufacturers for consistent and seamless supply
- ***CURRENTLY*** **- Working stepwise implementation**

# Lessons Learned

- **Chromium free systems require diligence**
- **Workout *logistics* → the supply chain is critical**
  - ➢ Choices limited within the system
    - NO last minute substitutions
- **Stepwise implementation advised**
  - ➢ Helps to reveal potential missteps
  - ➢ Work out logistics - availability and supply
- **Communicate and collaborate**
  - ➢ CPAB, talk *with* field units / maintenance
- **Work with maintenance and field units**
  - ➢ Program Office isolated/insulated



# Conclusions and Recommendations

- **Chromium replacements can be as good or better**
- **Qualify every system to a standard**
- **Modify performance specification or standard appropriately**
  - May require complicating testing
  - May increase cost
  - May increase time
- **Choose multiple systems if possible**
  - Systems 5 & 6 similar, different topcoats
  - Systems 3 & 6 similar, different primers
- **Work with maintainers and users as well as manufacturers**
- **Stepwise implementation**

| System | Pretreatment – Chromate free | Primer – Chromate free | Topcoat |
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- **SMSgt Matt Dowden (AFCPCO)**
- **Rob Madsen (AFCPCO)**
- **Air Force Corrosion Prevention Control Office**
- **T-38 CPAB**

***Sincere thanks to all!!!***

# Any questions?

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# Any answers?

*Thank you for your time!*