HCAT
SPONSORED BY ESTCP ★ JG-PP ★ PEWG
HARD CHROME ALTERNATIVES TEAM

Status of Chromium Replacement for Aviation Applications

Solvent Substitution Workshop, December 02

Keith Legg, Rowan Technology Group
Bruce Sartwell, NRL

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Summary

- HCAT team approach
- Landing gear status
  - Reports
  - Implementation
- Propeller hubs
  - Reports
  - Implementation
- Other HCAT projects
- Workshop on P2 for advanced aircraft
- Lessons learned

P-3 MLG HVOF WC-Co (NADEP JAX)

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HCAT approach

- Broad team of industry and DoD organizations, US and Canada
- Initial focus is replacement of hard chrome for aircraft
- Becoming involved with Cd and repair technologies

HCAT projects do not just produce technical reports, but result in actual implementation of new technologies at multiple DoD repair depots and manufacturers.

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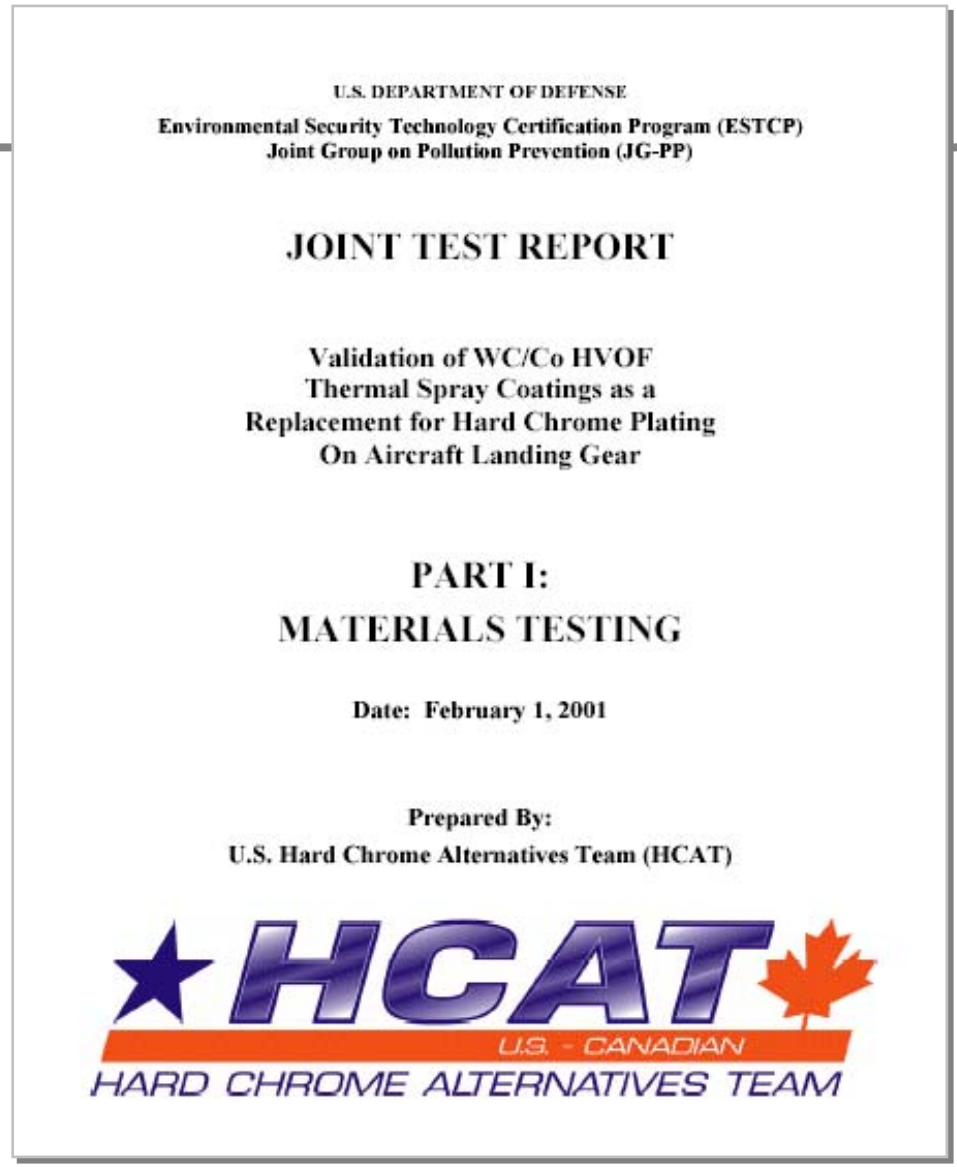
Landing gear JTR

- **Materials part of LG JTR Part 1: Materials Testing complete**
  - **Complete DRAFT version including Wear and Process Optimization**
  - **400+ pages**
    - **200 real report**
    - **200 print outs of all data**
  - **Excel files of all raw data included**
  - **Does not cover integrity or rig testing as that not in JTP Part 1**
    - **This will be covered in later report when work complete**



U.S. DEPARTMENT OF DEFENSE

Environmental Security Technology Certification Program (ESTCP)
Joint Group on Pollution Prevention (JG-PP)

JOINT TEST REPORT

Validation of WC/Co HVOF
Thermal Spray Coatings as a
Replacement for Hard Chrome Plating
On Aircraft Landing Gear

PART I:
MATERIALS TESTING

Date: February 1, 2001

Prepared By:
U.S. Hard Chrome Alternatives Team (HCAT)

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Summary of JTR

- **Fatigue**
  - Often better than EHC
  - HVOF delamination at high load
    - This is the only serious issue for most users
  - Passes acceptance criteria
- **Corrosion**
  - Not as good as EHC
  - Fails acceptance criteria
  - However, tests were against "superchrome"
    - Would have passed in comparison with "normal" EHC
  - Note: HVOF corrodes by Co dissolution
- **Wear**
  - Less wear of coated rod
  - More wear of uncoated bushing
  - Passes acceptance criteria
- **Impact**
  - WC-Co and WC-CoCr both better than EHC
  - Passes acceptance criteria
- **Hydrogen embrittlement/SCC (data taken by Boeing Seattle)**
  - **Chrome stinks!!**
    - Environmental embrittlement failure in <10 minutes
    - HVOF coatings last 1 - 2 orders of magnitude longer
    - HE happens after EHC when improperly baked out
  - Difference due to open circuit potential
  - HVOF does not cause HE
  - Passes acceptance criteria
  - Note: this is different from PAX RSL tests

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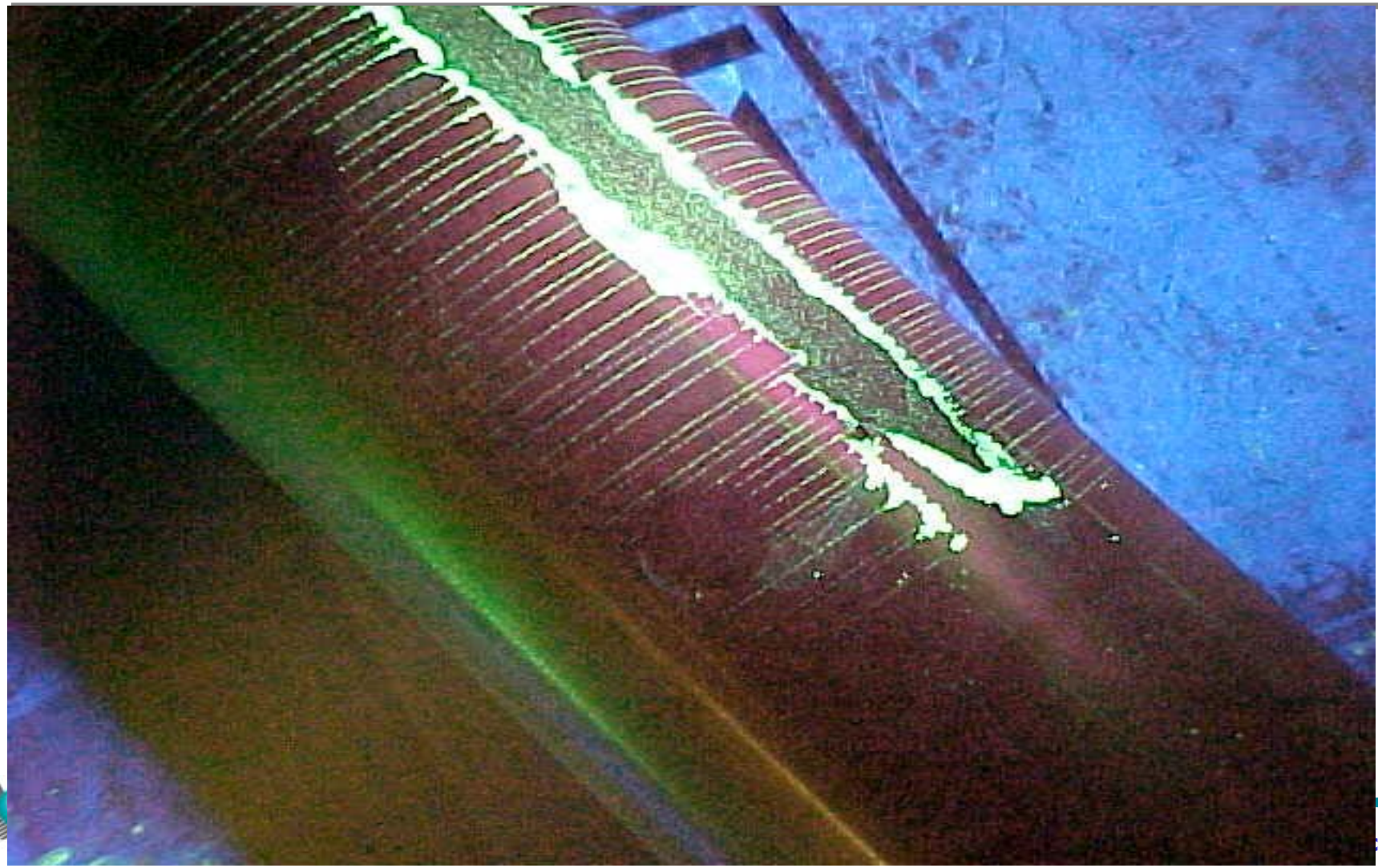
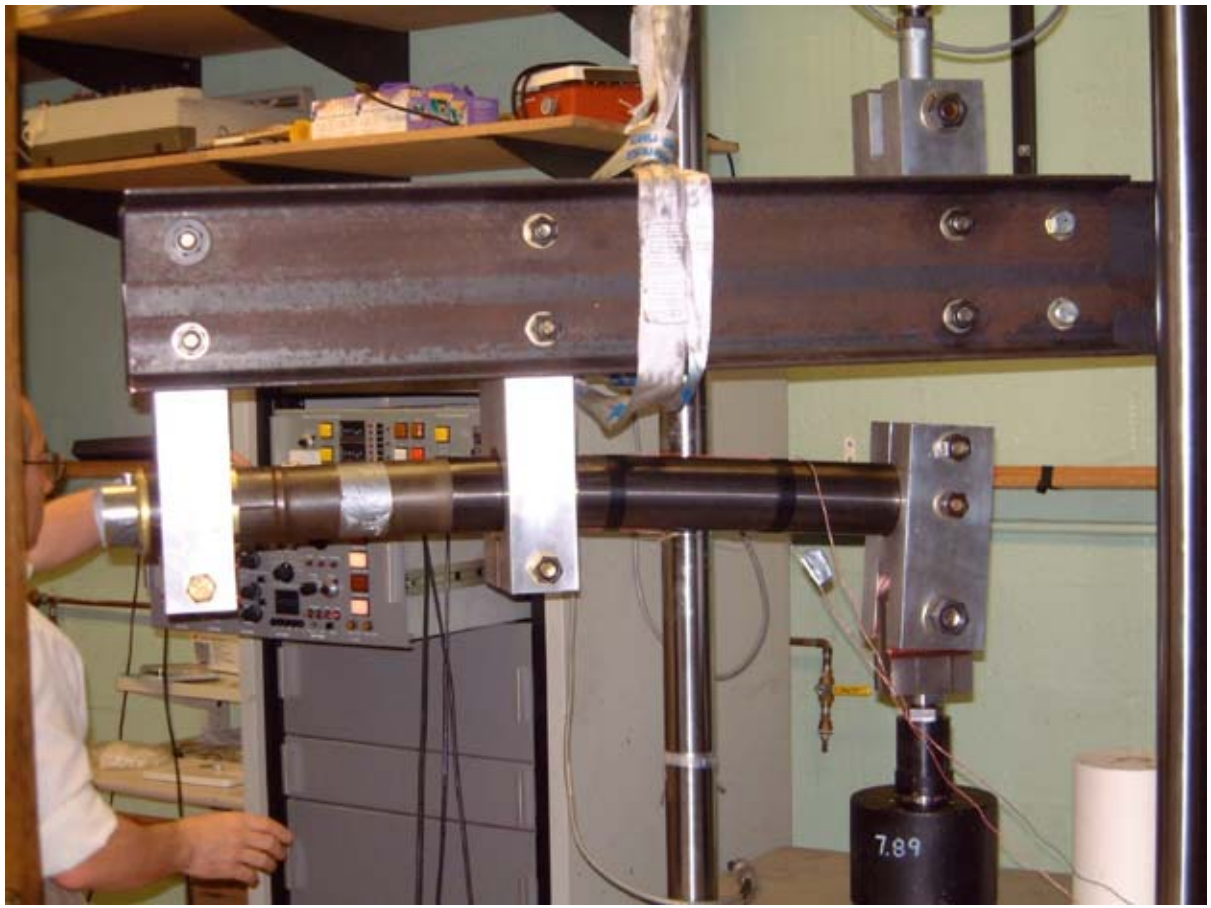
Coating Integrity – Hill/ALGLE
0.015" WC-Co FPI



Coating integrity issue – Hill/ALGLE bend tests



- Coatings can spall at high stress (near yield)
  - Failure strain lower for thicker and more brittle coatings
- Important issue for carrier-based aircraft
  - Not a problem for most land-based aircraft

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Corrosion issues

- **Corrosion results highly variable**
  - **Canadian HCAT – HVOF much better than EHC**
  - **Beach exposure – HVOF much better than EHC**
  - **JTR tests – HVOF not as good as EHC**
    - **Turned out used "superchrome" baseline**
  - **Lesson – use the "real" baseline for most users**
- **Embrittlement**
  - **F-519 notch test – HVOF much better than EHC**
  - **NAVAIR Rising Step Load (RSL) – HVOF somewhat worse than EHC**
  - **Lesson – depends on choice of test method and baseline**
    - **What is the "right" method?**
    - **What corresponds best with real-world performance?**

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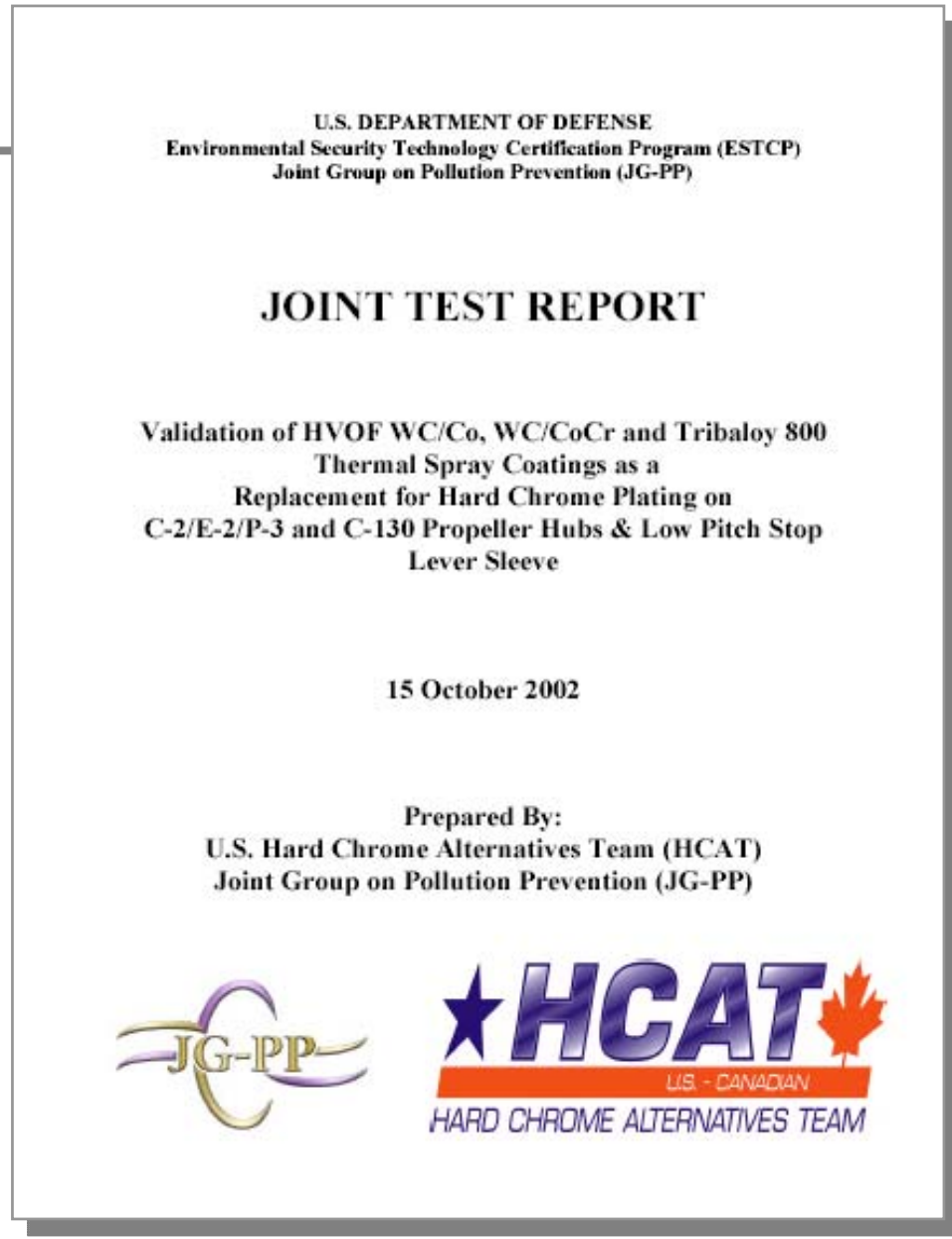
Propeller hubs – Hamilton Sundstrand and NADEP Cherry Point

- Report by Hamilton Sundstrand and NADEP Cherry Point
- 100+ pages
  - Wear testing
  - Fatigue
  - Corrosion
  - Rig tests on actual parts



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Environmental Security Technology Certification Program (ESTCP)
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JOINT TEST REPORT

Validation of HVOF WC/Co, WC/CoCr and Tribaloy 800 Thermal Spray Coatings as a Replacement for Hard Chrome Plating on C-2/E-2/P-3 and C-130 Propeller Hubs & Low Pitch Stop Lever Sleeve

15 October 2002

Prepared By:
U.S. Hard Chrome Alternatives Team (HCAT)
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JG-PP

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Propeller Hubs JTR

- HVOF WC-Co in general better performance than HVOF T400
- Wear
  - HVOF much better than EHC
- Fatigue
  - HVOF better than EHC
- Corrosion
  - Ni (best) > HVOF >EHC
  - HVOF viable Ni alt.
- Rig tests
  - HVOF less wear on coated and counterface
  - Toxicity Characteristics Leaching Procedure (TCLP) – powder not haz waste

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Other core HCAT projects

- GTEs (under way)
  - Run by PEWG
  - Variety of HVOF and plasma spray coatings
  - Variety of steels, inconel substrates
  - Includes full scale engine tests with coated seals and shafts
    - Initial TF-33 engine test data look very good – almost no wear
- Hydraulic actuators (under way)
  - Surface finish especially important (superfinish)
  - Testing several seal systems
  - Rig tests
    - Speed, stroke, temperature profiles
- Helicopter dynamic components
  - Not yet begun

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Implementation of HVOF

- **Military**
  - **OO-ALC landing gear**
    - **F-16 tension struts, axles**
    - **C-5 pitch cylinders, ball screws, gudgeon pins**
    - **KC-135 axles**
  - **NADEP-CP, H-S**
    - **E-2C, C-2, P-3, and C-130: tailshaft, low pitch stop lever sleeve, rocker land.**
    - **Navy P-3 and Air Force C-130**
  - **F-35 (JSF)**
    - **HVOF baseline for CTOL**
    - **Convergent nozzle acts.**
  - **CF-18 steering covers, piston heads, MLG hexagon repair**
  - **C-17 NLG shelf test**
- **Commercial**
  - **Boeing - >100 spot HVOF uses**
  - **B767-400 HVOF on landing gear**
  - **Airbus 380 spec'd for HVOF WC-CoCr**
  - **Boeing permits HVOF for repair to 0.010"**
  - **Delta using HVOF landing gear repair in own maintenance shop**
  - **Messier-Dowty installing HVOF for landing gear**

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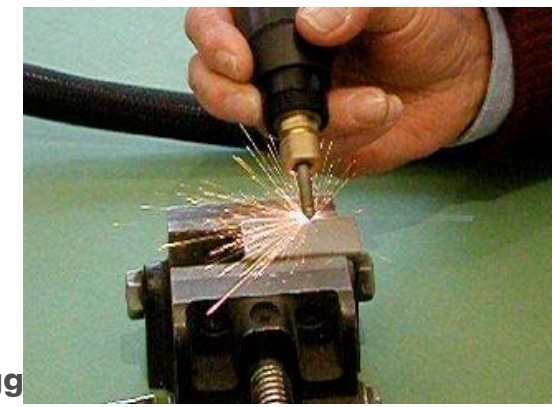
Other HCAT team projects

- **ID plasma spray**
  - Replace EHC in IDs and other difficult locations
  - Plasma spray
    - T400
    - WC-Co
    - WC-Co self fluxing alloy
  - Works well and efficiently for >2.5" or 3"
  - Property/performance tests under way
- **Electrospark Alloying for repair (HCAT/PEWG)**
  - Also called Electrospark Deposition (ESA, ESD)
  - Dry analog of brush plating
  - Qualified by Rolls Royce Aero for >20 GTE repairs
  - Dem/val for GTEs, shafts on ships and subs, vehicles



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HARD CHROME ALTERNATIVES TEAM





Meeting Summary:

Materials Substitution for Pollution Prevention in Advanced Aircraft - Technology Exchange

BWI Airport Marriott, Baltimore, September 4, 5, 2002

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Major findings - Chrome plating alternatives

- If you use Cr^{6+}, use a fume suppressant
  - Initial pitting problems overcome
- HVOF method of choice for ODs and shallow IDs
  - Issues
    - Spalling at high strain
    - Seal wear and surface finish
    - Co leaching on corrosion
    - NDI through coating
    - Some concerns over reliability/repeatability from vendors
- IDs
  - Electroless and electroplated Ni - only qualified coating
    - Issues
      - inconsistent stress
    - Under evaluation in AFRL NLOS program
  - SERDP ID programs
    - Nanograin electroplate
    - ESD
    - Miniature plasma spray
- Trivalent chrome (under development)
  - Solves Cr^{6+} air emissions
  - Same grinding waste and wastewater issues from rinsing and stripping

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Major findings - Cd plating alternatives
High strength and low strength components

- **Avoid high strength steels**
  - A successful approach for some new programs
    - Ti landing gear
      - lower strength, larger volume
    - Stainless steel fasteners (engines), Ti fasteners (OML)
    - 15-5 PH stainless
      - most new actuators
  - New high strength stainless for LG (Cartech, QuesTek) under development/test
    - SERDP - OO-ALC, QuesTek
    - DUST - Boeing, OO-ALC
- **IVD Aluminum**
  - Qualified, widely used
  - Depot use growing
  - ID sputtering available, not yet qualified
  - Issues:
    - Dissolution in alkaline cleaners
    - Cost
    - Non-uniformity, especially in threads
    - Repair (OEM and depot)
- **Acid Zn-Ni, Alkaline Zn-Ni**
  - Qualified for low strength (acid)
  - Issues
    - Embrittlement (esp alkaline)
    - Ni strike for some materials

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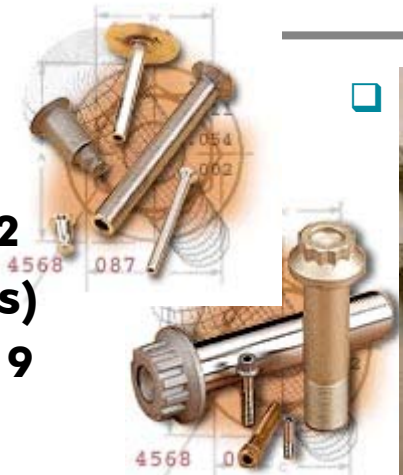
Major findings - Cad plating alternatives Fasteners and Connectors

- **Fasteners**
  - **Ti (OML)**
    - **used on F-22**
  - **Stainless (GTEs)**
    - **used in F-119**
  - **IVD Al on HSS**
    - **used on F-15, F-16 inlets**
  - **Sn-Zn**



- **Connectors**
  - **No really good options**
  - **Ni-plated polyimide composites**
    - **used on F-22**
  - **Alumiplate**
    - **Issues**
      - **solderability**
      - **inadequate electrical conduction**
      - **insufficient production capacity**
      - **sole source**

With all Cd alternatives:
How do you repair them?
- **Brush Zn-Ni works**
  - **embrittlement concerns**

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Lessons learned – how can we best field new environmental technologies?

- Up front
  - Good analysis of what makes most sense
- MUST improve readiness and performance, reduce cost
  - Environmentally better just does not cut it
    - Especially with a long-running war against terrorism to fight
  - How bad is current tech?
- Strong involvement of stakeholders at all stages
  - Close integration of development with user
- Risks and rewards
  - Decision makers need both risks and rewards
    - Better sharing of responsibility and reward between decision makers and depot personnel
  - Need a champion who sees both risk and gain
- Strong technical team assistance to lower risk, get faster implementation

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