Welcome to the JTEG Monthly Teleconference

Topic: Cold Spray Technologies Used for Repair

Greg Kilchenstein – ODASD(MPP)
Joint Technologies Exchange Group (JTEG)

- Provide a forum for the exchange of information on new technology, processes, and equipment developments.

- Collect, analyze and disseminate depot maintenance requirements for new technology, processes, and equipment.

- Advocate for new technology or equipment with cross-service potential to increase efficiency.

- Facilitate joint service technology development.
Introduction and Definition of Cold Spray

Greg Kilchenstein
Introduction to Cold Spray Action Team

Vic Champagne – Director, ARL
Center for Cold Spray
Overview of Cold Spray Technology for DoD and the Commercial Sector

Vic Champagne – Director, ARL Center for Cold Spray
Victor Champagne, Technical Team Leader
Innovative Materials & Processing Team
US Army Research Laboratory
ATTN: RDRL-WMM-C, BLDG 4600
Aberdeen Proving Ground, MD 21005-5069
Office Phone: 410-306-0822, Fax: 410-306-0829
Email: victor.k.champagne.civ@mail.mil
High explosive ammunition creating an opening in a double reinforced concrete wall through which infantry can pass.
ARL Staff and Level of Education

Scientists and Engineers: 305
Technicians: 92
Administrative: 28
Total Civilian Personnel: 425

Post Doctorates: 18
Guest Researchers: 10
Military: 6
On-Site Contractors: 195

PhDs: 47%
Masters: 31%
Bachelors: 22%
Admin: 6%

47% Engineers
22% Technicians
25% Scientists
6% Admin
ARL Center for Cold Spray

**ADVANTAGES**

- Low Temperature Process
  - Below Melting Point of Metals
  - No Combustion Fuels, Gases
  - Results in Highly Conductive Deposits
- Solid State Bonding
  - Mechanical Mixing of Particles and Substrate
  - Similar to Explosive Bonding
  - Plastic Deformation of Particles
  - Disrupt Oxide Films
  - Compressive Residual Stresses
- High Density Deposits
  - Form Thick Coatings at High Deposition Rates
  - Low Oxide and Porosity Content (<1%)
  - Form Free-Standing Structures

**APPLICATIONS**

- Corrosion Resistant Coatings (Zn, Al)
- Dimensional Restoration and Repair
  - Ni, Stainless Steel, Titanium, Aluminum
- Wear Resistant Coatings
  - CrC-NiCr, WC-Co, WCu
- EMI Shielding
- Portable Units for Field Repair

**Stationary Cold Spray System**

- Sheet Gas Flow Rate: 50-100 CFM
- Operating Temperature: 2000-2500°F
- Processing Zones: 30-50 in²
- Particle Velocity: 500-1500 ft/s

**Modeling of Cold Spray Process Parameters**

- 20 Million Copper Particles
- 25 mm Substrates
- 450 mm, 600 G M, Gau

**Advantages**

- High density deposits
- Low oxide and porosity content
- Form free-standing structures

**Applications**

- Corrosion resistant coatings (Zn, Al)
- Dimensional restoration and repair (Ni, stainless steel, titanium, aluminum)
- Wear resistant coatings (CrC-NiCr, WC-Co, WCu)
- EMI shielding
- Portable units for field repair

**Advantages**

- Low temperature process
- Below melting point of metals
- No combustion fuels, gases
- Results in highly conductive deposits

**Applications**

- Corrosion resistant coatings (Zn, Al)
- Dimensional restoration and repair (Ni, stainless steel, titanium, aluminum)
- Wear resistant coatings (CrC-NiCr, WC-Co, WCu)
- EMI shielding
- Portable units for field repair
ARL Center for Cold Spray

- World Class Research and Development Facility Recognized Internationally as the most well equipped and sophisticated cold spray R&D facility in the world
- ARL Center for Cold Spray est. 2000 (15 dedicated employees, 13 CS systems)
- Cold Spray Action Team (CSAT) (largest cold spray workshop/meeting/conference)
- CSAT LINK: http://coldsprayteam.com/
- Work with over 120 companies, as well as DOD, DOE, Foreign Countries
- Aerospace, automotive, petrochemical, medical & electronics applications
- Developed 1st Cold Spray Process Specification (MIL-STD-3021)
- Patent pending on first Hybrid Cold Spray System, “VRC Gen III”
- ESTCP Program of the Year Award in December
  http://www.serdp-estcp.org/News-and-Events/In-the-Spotlight/Cold-Spray-Technology-for-Aircraft-Component-Repair
- FOX News Report 2013
  http://www.foxnews.com/tech/2013/01/03/can-cold-green-supersonic-spray-save-black-hawk/

The direct link is: http://www.arl.army.mil/www/default.cfm?page=369
Unique solid-state materials consolidation process which utilizes high velocity particles impinging upon a substrate to build up coatings and/or free-standing structures without the use of combustion fuels.

- Stationary Robot Controlled Systems for precision and or high volume
- Portable Hand-held Systems for field repair and mobility

- Feed stock typically ranges from 1 to 50 μm diameter
- Particle ductility is crucial
- Gas temperature ranges from R.T. to 1,000°C and pressures from 300 - 725psi
- No melting of particles
- Negligible oxidation
- No decomposition or phase changes of deposited particles or substrate
Particle/Substrate Interaction*

*from H. Assadi, www.modares.ac.ir/eng/ha10003/CGS.htm
Mechanical Mixing at Interface

EDS X-ray Mapping showing mechanical mixing between coating material and substrate

copper

aluminum
Advantages of Cold Spray

- **Low Temperature Process**
  - particles “peen” the surface and develop compressive stresses (beneficial for fatigue)
  - Bonding mechanism similar to explosive cladding (mechanical mixing & metallurgical bond)
  - Conducive for thermally sensitive substrates (i.e. magnesium, composites)

- **Strength/Hardness**
  - High strength/hardness (often greater than comparable wrought materials)

- **Density**
  - 100% consolidation possible with many materials, equal to theoretical
  - little to no porosity or inherent defects (i.e. oxides), good electrical/thermal conductivity

- **Wide Selection of Commercially Available Powders/Materials**
  - metals, oxides, hydrides, polymers, nanostructured materials

- **Versatility**
  - graded structures and coatings (lengthwise and/or through thickness)
  - complex geometries
  - free-form fabrication of parts

- **Ease of Production**
  - fully automated/robotically controlled turnkey system
  - no harmful fuels or extraordinary safety equipment
  - minimal material waste-high deposit efficiency (i.e. 80W-20Cu 94%, 6061 Al 100%)
  - deposition rates reported up to 40 kg/hr and higher (CP Titanium)
- Corrosion Damage Repair and Dimensional Restoration
- High Conductive and Wear Resistant Coatings
- Production of Exotic Materials Not Capable By Conventional Ingot Metallurgy
- Erosion Resistant Coatings
- Near Net Fabrication of Components
- Aerospace Specialty Coatings
- Conformable Antennas
- Selective Galvanizing
- Aircraft Skin Repair
- Heat Sinks and Power Modules
- Cladding
ESTCP Program 06-E-PP3-031 “Supersonic Particle Deposition Technology for Repair of Magnesium Aircraft Components”

Fleet Readiness Center East
Marine Corps Air Station Cherry Point, NC 28533

ARL

Penn State

Sikorsky
A United Technologies Company

Australian Government
Department of Defence
Defence Science and Technology Organisation

U.S. Army Aviation and Missile
Life Cycle Management Command (AMCOM)
Main, Intermediate and Tail Gearboxes for UH-60

- Parts are large and expensive (up to $800K/housing)
- Long lead times

- Magnesium is susceptible to wear and corrosion

- Army & Navy rotorcraft & Air Force fighters have Mg gearboxes & other parts that are unserviceable
  * 20-23 parts per aircraft
  * 4,550 rotorcraft in Army & Navy
  * 20% of fleet affected

"This is a critical safety and readiness issue"
(Major General Nickolas Justice, Commanding General, AMRDEC)
Problem
UH-60 Sump - Magnesium Housing

Corrosion sites

ROI
Unit Cost: $11K
Annual Demand Rate: 85
Repair Cost: $880
Investment: $60K
%ROI: 16707%
Annual Savings
$860K

Before

After

Repaired Sump
Wrought 5083  UTS=45,000 psi
CS-5083  UTS=50,000 psi
CS-Nano-5083  UTS=75,000 psi

**Key**

T4, T451- Solution heat-treated and naturally aged to a substantially stable condition. Temper -T451 applies to products stress-relieved by stretching. 

T6, T651- Solution heat-treated and then artificially aged, Temper -T651 applies to products stress-relieved by stretching. 

<table>
<thead>
<tr>
<th>6061 Condition</th>
<th>Source</th>
<th>UTS, ksi</th>
<th>YS, ksi</th>
<th>%EL</th>
</tr>
</thead>
<tbody>
<tr>
<td>annealed</td>
<td>1</td>
<td>18</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>T4, T451</td>
<td>2</td>
<td>30</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>T6, T651</td>
<td>2</td>
<td>42</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>cold sprayed</td>
<td>3</td>
<td>49.3</td>
<td>42.5</td>
<td>7</td>
</tr>
</tbody>
</table>

1 Matweb
2 Alcoa.com
3 Microtensile Test by Aaron Nardi at UTRC of ARL Cold Spray Block
• AZ91C-T6 and EV31-T6 failed with a relatively clean break at coating the interface.

7 out of 12 ZE41A-T5 samples failed within the Mg.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Average (ksi)</th>
<th>Stdev (ksi)</th>
<th>95% Confidence (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZE41A-T5</td>
<td>20.4</td>
<td>0.8</td>
<td>19.9, 20.8</td>
</tr>
<tr>
<td>AZ91C-T6</td>
<td>19.0</td>
<td>2.5</td>
<td>17.5, 20.5</td>
</tr>
<tr>
<td>EV31-T6</td>
<td>22.1</td>
<td>2.8</td>
<td>20.5, 23.7</td>
</tr>
</tbody>
</table>
Overview of Accomplishments

2008 Defense Standardization Program Achievement Award

Sikorsky is proceeding with the sump repair for the H-60 platform
• Approval obtained for Overhaul Repair Instruction (ORI) SS8491 (2011)

FRC-East cold spray system is installed and set up under ARL ESTCP Program
Cold Spray Coating Parameters Optimized at ARL for CP-Al & 6061Al
DEMVAl successfully completed at FRE-East (2011)

2012 Defense Standardization Program Achievement Award
Presented to members of the Cold Spray Team for ESTCP Program 06-E-PP3-031 “Supersonic Particle Deposition Technology for Repair of Magnesium Aircraft Components” (2012)

Cold Spray has been approved through MAB, AED and PO-UH-60 for UH-60 Sump Repair
Maintenance Engineering Order (MEO)T-7631 (2012)

2013 Mantech Award for Implementation of old Spray at MidAmerica, Webster, MA
Mantech Demonstration Site (Currently Performing CS on Production and Fielded Parts) (2013)
1. Maintenance Engineering Order (MEO) T7631 UH-60 Sump Repair
   • Army Aviation & Missile Research, Development & Engineering Center (AMRDEC)
   • Program Office -UH-60 Blackhawk- Rios Merritt
   • Corpus Christi Army Depot-SAFR Program Office-Mark Velazquez

2. Overhaul Repair Instruction (ORI) SS8491 UH-60 Sump Repair
   • Sikorsky Aircraft Company-Technology Integration-Bill Harris and Eric Hansen

3. Engineering Technical Assistance Request (ETAR) E12-00248 FEB Panel
   • Ellsworth Air Force Base-B-1 Chief Engineer Jeff Vaughn

4. Engineering Technical Assistance Request (ETAR) E09-00065 HydroTube
   • Ellsworth Air Force base

**Cold Spray Transition Locations**

- Corpus Christi Army Depot
- Fort Hood
- Anniston Army Depot
- Ellsworth AFB
- Hill AFB
- Tinker AFB
- Fleet Readiness Center (FRE-East)
- MidAmerica,/MOOG-Webster, MA and Fargo, ND

"Storage, Analysis, Failure Evaluation and Reclamation" (SAFR) at CCAD
Non-Structural Cold Spray Repair Processes

- **Army & Navy Approved Cold Spray Repair Processes**
  - F/A-18E/F AMAD Main Housing (hydraulic pad restoration)
  - F/A-18E/F AMAD Main Housing (gear failure repair)
  - F/A-18E/F AMAD Hydraulic Gearshaft (seal surface repair)
  - H-1 Mixer Gearbox (external chafing repair)
  - AH-64 Intermediate Gear Support (top & outer land repair)
  - UH-60 Sump (MEO T7631A packing seal surface repair)
  - UH-60 Intermediate Gearbox (MEO B1089 ctr, input, output hsgs)
  - UH-60 Tail Rotor Gearbox (MEO B1090 ctr, input, output hsgs)
  - UH-60 Accessory Gearbox (MEO B1091 cover & housing)
  - UH-60 Input Module (MEO B1092 ctr, input, output hsgs)

- **Power Transfer Module - PTM**
  - 10 Magnesium Castings
- **Transmission**
  - 13 Magnesium Castings

$7M+ Annual savings with increased component availability (above parts)
$80M+ present value savings (above repairs only)
Potential $100M annual savings based on Sikorsky trade study (Helo parts)
Candidate Parts
Magnesium & Aluminum Housings

- UH-60 Sump Corrosion sites
- F-15 AMAD wear sites
- SSN 21 TD-63 Actuator Body wear sites
- F-16 Air Inlet wear sites

Before After

F-18 AMAD Mechanical Damage

Before After
Fielded SH-60 Seahawk with Cold Spray Mg Repair Operating Since August, 2009 - Australian Navy
ARL/JSF/DSTO Collaboration

Fielded B-1 Bomber with Cold Spray Ti Repair Operating Since September 2009 - Tinker AFB
ARL/Tinker AFB/HF Webster Collaboration

Three Fielded Blackhawk Medvac Units with Cold Spray Al Repair Operating Since August, 2009
ARL/AMCOM/Ft. Hood Collaboration

Two Expeditionary Fighting Vehicles with Cold Spray Mg Repair Fielded and Operating Since September, 2008

- Power Transfer Module - PTM
  - 10 Magnesium Castings
- Transmission
  - 13 Magnesium Castings
OSD Mantech Objectives

Transition cold spray repair technology into production

- Create a production ready supply chain that will cost effectively deliver magnesium transmission housings and other high cost, high failure rate components repaired with cold spray technology
- Reclaim parts that are unserviceable due to corrosion, wear, chafing, or other damage
- Develop automated, flexible, and repeatable repair process for production implementation of cold spray

End Product: Transformational Repair System
Technical Progress
Motion System Assembly and Test in Progress

Moveable Tool Changer
Allows tools to be kept in clean environment

Facilities Requirements Definition Completed

Final Motion System Configuration

Z – axis, pitch & yaw on Gantry

X & Y – axes & roll on table

Improved Accuracy

Reduced Motion requirement for Cold Spray Gun

Distribution Statement D: Distribution authorized to the Department of Defense and approved U.S. DoD contractors functioning as technical advisors to the Government team. Other requests for this document shall be referred to (your organization and address listed here).
Gen III HP Hybrid Cold Spray System

- Hybrid
  -- Hand Held or
  -- Robotically controlled
- Mobile/portable system
- Feed system
  -- Clog resistance
  -- Flexible
  -- 8 to 20’ reach
    --- Greater for some applications
- High Pressure - 500 – 1000 psi
- High Flow rate
  -- up to 35 SCFM gas
  -- 2 to 10 kg/hr deposition
- 16-45KW resistance heater(s)
  -- up to 900 deg C
- High pressure powder feeder
  -- weight loss option
- Data feedback & recording of critical parameters
- N & He mixing option available
- Wide Range of materials possible
  -- Ti, Cu, Al 2024/7075, Ni, 316 SS
Additive Manufacturing

Current state of the art: parts require machining to final dimension

- CAD/CAM

- Integrate CAD/CAM to produce complex geometries, minimize machining and eliminate material waste

- Using CAD/CAM reproduce a shaped charge line (above) eliminating dimensional machining

- Demonstrate production of a 6061 Al part

- Conventional Cold Spray
  - New powders and processes are required.
  - Upgrade conventional CS systems for near-net fabrication.
  - Has demonstrated potential as a means of producing near-net shape complex components.

Future goals

- Integrate CAD/CAM to produce complex geometries, minimize machining and eliminate material waste
- Using CAD/CAM reproduce a shaped charge line (above) eliminating dimensional machining
- Demonstrate production of a 6061 Al part
Navy Cold Spray

Fred Lancaster - NAVAIR Materials Engineering Division
Timothy Eden, Ph.D. - Head of the Materials Processing Division – Penn St. ARL
Objective

The US Navy has the need to perform dimensional restoration of metallic components caused by corrosion, restoration of material due to wear or damage, and the ability to easily and rapidly repair structures in place on Naval Aircraft.

The objective is to develop a metallization process that can be used to facilitate repairs on naval aviation assets at all levels of maintenance.

Naval S&T Focus Areas:
- Affordability ✓
- Maintainability ✓
- Reliability

Naval S&T Objectives:
- Platform Affordability ✓
- Availability ✓
# Current & Future Projects

### Aircraft Component & Transition(s) Timeline

<table>
<thead>
<tr>
<th>Yr-10</th>
<th>Yr-11</th>
<th>Yr-12</th>
<th>Yr-13</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aircraft Component &amp; Transition(s) Timeline</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair of Cad &amp; Al Coatings (OSD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimensional Repair/Aerospace Powder Spec (DLA)</td>
<td></td>
<td></td>
<td>Repair of IVD (DLA)</td>
</tr>
<tr>
<td><strong>UH-1N/AH-1W RING GEAR High Pressure (Section 219) FRC-E</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>F-18 E/F/G AMAD Transmission Housing High Pressure Fretting/Dim Rep (Section 219) FRC-SW</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>UH-1N/AH-1W COMBINING GEARBOX HOUSING REPAIR – PORTABLE (TIPS) FRC-E</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSU-ARL Repairability, F-18 (REPTECH)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Repair of Cad Alt to Brush Plate (DLA)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H-60 Gearbox repairs – Australian Navy/USN/US Army/SAC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H-53 MGB Pad Mounts (POM15)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>F-18 EMI REPAIR – PORTABLE (TBD)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>UH-1N/AH-1W SUPPORT CASE PAD MOUNT – PORTABLE (TBD)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>UH-1N/AH-1W CAD ALTERNATIVE ELECTRICAL CONNECTORS – PORTABLE (TBD)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Key

- **Corrosion**
- **Dimensional/Non-structural**
- **Structural (Repair within struct limits)**

**1/7/2014**
Part Repair Approval

Pre-Section 219 Timeframe (5 Years)
FY-05 FY-06 FY-07 FY-08 FY-09

Section 219 Timeframe (2 years)
FY-10 FY-11 FY-12+

Army Collaboration (Demval, Testing, Information Exchange, Project Teamming, DOD Vision)

Initiate Army Contact

Cold spray specifications for process Approved Aerospace Powder Spec Pending

2 process approved/local
6 parts to date back in service
8 parts pending back in service
2 new process pending/local approval
3 parts OEM approved (SAC) for rework

Army Collaboration (Demval, Testing, Information Exchange, Project Teamming, DOD Vision)

4 Low pressure CS units Operational All FRC’s w/ capability
Technical staff trained @ all sites
1 site high pressure capable

Part Repair Approval

MIL-STD-3021 Cold Spray Spec

Part Repair Approval

4 Low pressure CS units Operational All FRC’s w/ capability
Technical staff trained @ all sites
1 site high pressure capable

Specifications

2 process approved/local
6 parts to date back in service
8 parts pending back in service
2 new process pending/local approval
3 parts OEM approved (SAC) for rework

Cold spray specifications for process Approved Aerospace Powder Spec Pending

NAVAIR Cold Spray Timeline
Australian DSTO has adapted a robotic cold spray metallization system for Mobile Repair

Advantage: Ability to apply CS portably at High Pressures for structural applications or precise repair.

Goal: A system that artisan teams can deploy and repair aircraft in the field

Worked with RAN under a Coalition Warfare project to further develop this technology for structural applications. Currently awarded an OSD Corrosion effort to further collaboration & demonstration of portable repairs.
NAVAIR Workforce Development
Current Navy Cold Spray Capabilities

NAVAIR Facilities
- FRC-East. 2 high & 1 low pressure
- Pax River, low pressure portable
- FRC Southeast (Jax), low pressure portable
- FRC Southwest (NI), low pressure portable

NAVSEA
- NSWCCD Inovati since 2004
- Keyport?

NPS
- Low Pressure cabinet
Partnerships / Collaborations

Direct collaboration with
- AIR 4.4.2.3 Power & Propulsion
- AIR 4.3.3.2 Structures
- AIR 4.3.4.2 NDI (Pax & FRC-SW)
- Penn State ARL (REPTECH)
- PMA 265, PMA 299
- FRC East, Southeast, Southwest
- Sikorsky Aircraft, Boeing Aircraft
- Australian DSTO
- NSWC Carderock & US Naval Postgrad

Partnerships with
- USMC Corrosion Program
- NSWC Carderock Materials
  - Engineer/Scientist Rotation
- NRL Code 35
- US Naval Postgrad School, Monterey
- Army Research Lab
- Proposed Annual NAVAIR/NAVSEA/USMC Cold Spray Meeting

• TIPS: H-1 Combining Gearbox Repair
• DLA: IVD Aluminum Repair
• SBIR: Low pressure repairs, two small businesses & academia
• AERMIP: Low Pressure Portable Metallization FRC-SE
• REPTECH- PSU ARL Portable Repair and Restoration of Aluminum and Magnesium Components
• OSD Mantech-2012 Cold Spray Repair & Rebuild Technology (automated)
• ONR SBA (NSWC Carderock/NPS) Single Particle Impact Study
Technology Assessment
Target Material Applications Air Vehicles

- **Aluminum alloys used for naval aviation applications**
  - 7075-T73651 Plate,
  - 7075-T76511 Extruded,
  - 7075-T6 sheet/clad skin,
  - 2024-T3 – sheet/cladskin,
  - A356-T61 Cast,

- **Steel alloys used for naval aviation applications**
  - AISI 4130 & AISI 4340,
  - Stainless Steel PH13-8Mo,
  - High Strength Steels (landing gear, arresting hooks),
  - 300M,
  - Aermet 100,
  - AF1410

- **Magnesium alloys (AZ-91, ZE41A)**
- **Titanium (Ti6-4)**
S&T Analysis

Issues for all materials of interest to the Navy/NAVAIR

- Process parameters
  - Repair limitations
- Coating optimization
  - Powder
  - Surface preparation
  - Spray parameters
- Coating bond strength
- Coating cohesion
- Post-coating preparation
  - Sealing
  - Welding
  - Machining
- Microstructural characterization
  - Metallurgical bond
  - Dislocation density
  - Coating formation
- Mechanical properties
  (comparison to existing technology)
  - Residual stress
- Fatigue
- Corrosion
- Evaluation/Development of NDT
- Significance of Flaws
- Specifications and Requirements
  - Fitness for service acceptance criteria & logistics
- In-service repair
- Safety/Environmental concerns
- Application based cost benefit analysis
- Modeling, process & materials
- Logistics constraints
  - Material
  - Equipment

Need to tie fundamental understanding of process parameters/operating envelope to coating properties
Hierarchy of Cold Spray Application Projects

- Advanced Powder/Alloy Development
- Structural
- Corrosion & Dimensional Non-Structural

RISK/COMPLEXITY

$COST$

CAPABILITIES
Establish Procedure(s)

- Develop Process(es) & Equipment
  - NRL, ARL, NSWC-Carderock, Industry, Academia

- Certify Testing & Results (laboratory)
  - Physical Tests
  - Corrosion Tests
  - Non-destructive

- Develop Process Certification Procedures/Methods

- System/Process Functional Tests
  - Apply to aircraft
  - Flight Test
FY12 Progress

Key Milestones Achieved

- All depots operational & workforce trained
- DT/OT for AMAD Fretting Corrosion Repair
  - Parts released back into fleet
- DT for AMAD internal damage rebuild repair

FRC-East System Upgrade

- Auxiliary heater installed on CGT Unit.

FY13 Progress

Key Milestones Achieved

- Continued flight time for AMAD repairs
- Upgrade of CGT-4000 @ FRC-E w/ 47kW heater
- OSD Corrosion Office sponsorship for continued working relation with Australian DSTO.
  - (overall, slow due to sequestration)
FY14 Expectations

Future:

- F-18
  - Radar Racks, AMAD Gear Hard Chrome Alt, Wing/spar fastener hole repair
    - Fund with direct PMA funding for Materials, DLA, Reptech
    - 20 F-18 Radar Racks est $220K each tot $4.4M
  - IVD Repair: DLA funded effort

- H-60
  - Canted bulkhead repair
  - Gearbox repair (SAC & Australian DSTO)

- V-22
  - V-22 Sills est $80K+ each sending back to CP.
  - FRC independent teams can now perform repairs

- Roll CS into FNC FY 16 for “Repairable Coatings” or do we want a focuses Navy & Marine Corps FNC?
- Refine portable repair process (field and depot – roll up to the airframe)

- Further Navy & Marine Corps Collaborative projects
  - Collaborative engineer rotation set-up with NSWC Carderock
Summary

• Responsive to fleet needs with solutions that keep fleet assets affordable & maintainable

• Establishing for NAVAIR a solid base to grow from
  – Material & Process Protocols
  – Capabilities
    – Processes
    – Manpower
  – Logistics
PLATFORM SPECIFIC
Cold Spray Candidate Parts
Targeted Repair Facility: FRC-East Cherry Point
Cold Spray Candidate H-60 Seahawk Applications

- Cold Spray TRGB feet application
- Cold Spray to main module sump and Flight (forward bridge) control pad
- Fold Point Bushings/Canted Bulkhead
- Cold Spray to IGB feet for corrosion protection and geometry restoration
- Lift Hook/Hoist
- Cold Spray to Pylon Fairing

*Rosebank Engineering presentation “TSS Cold Spray Conference 2010-Cold Spray application in Australian Aerospace Industries-Neil Matthews” DSTO Project*
H-60 Sump – Approved by SAC
Dimensional/Non-Structural

Total Replacement Cost Savings estimated to be $935,000.00/ year

Substrates: ZE41A & AZ91C Magnesium
Coating Material: CP-Aluminum and/or 6061 Al
ORI issued by SAC to use Cold Spray as an alternative to the present thermal spray process
Tail Gearbox info:
Part numbers: 70358-26600-042 thru - 046.

Housings are ZE41A magnesium.

Problem:
Contact between cowlings and Tail Gearbox causes chaffing and corrosion on output housing.
O-level damage limit is 0.040 inch.
  - Damage occurs in output bearing support area, so increased repair depth is limited.

Potential Repair:
Apply cold spray after blending to fill repair area.
  - Provides sacrificial layer to prevent further contact with magnesium housing.

• Apply cold spray prior to chaffing to prevent corrosion from starting.
H-60 INPUT MODULE
Corrosion/Dimensional Non-Structural

Input Module info:
2 per aircraft.
Housings are ZE41A magnesium.

Problem:
Chip detector zapper is secured to transfer tube between Input and Accessory Modules.
Contact between zapper and Input Module causes chaffing and corrosion of transfer tube bore on center housing.

Bore is lightly loaded, but O-level damage limit is 0.040 inch.
- Limit is generic for entire center housing.
- Unable to determine wall thickness at O-level to develop individual repairs.

Potential Repair:
Apply cold spray after blending to fill repair area.
- Provides sacrificial layer to prevent further contact with magnesium housing.
Apply cold spray prior to chaffing to prevent corrosion from starting.
Main Gearbox info:
Part numbers: 70351-38100-042, -044, and -046 thru -050.
Housings are ZE41A magnesium.
Problem:
Forward Bridge attaches to Main Gearbox.
Dissimilar metals (Mg Housing, cad-plated steel bushings, steel dowel pins, aluminum support) lead to galvanic corrosion of Main Gearbox Housing.
Potential Repair:
Apply cold spray to mount pad prior to Gearbox installation.
  - Original design included 0.030 inch thick insulator between Bridge and Housing.
  - Insulator did not work and is no longer installed, leaving gap for application of cold spray.
FRC EAST Update

Cold Spray Candidate Parts
Targeted Repair Facility: FRC-East Cherry Point
## Structural/Non-Dimensional Parts under Consideration – (SAC ORI for Two)

<table>
<thead>
<tr>
<th>H53 Gearbox</th>
<th>Housing</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main</td>
<td>Main</td>
<td>65391-11602-044</td>
</tr>
<tr>
<td></td>
<td>Rear Cover</td>
<td>65391-11662-042</td>
</tr>
<tr>
<td>Nose</td>
<td>Center</td>
<td>65355-12048-043</td>
</tr>
<tr>
<td></td>
<td>Input</td>
<td>65355-12026-041</td>
</tr>
<tr>
<td></td>
<td>Output</td>
<td>65355-12002-043</td>
</tr>
<tr>
<td></td>
<td>Front Cover</td>
<td>65355-12056-041</td>
</tr>
<tr>
<td></td>
<td>Tail</td>
<td>65395-07001-043</td>
</tr>
</tbody>
</table>

1/7/2014
Structural/Dimensional

H53 Main GEARBOX
Part Numbers 65391-11602-044
/65070-35542-045
Magnesium casting
Cost New $313,800
5 housings repaired per year

Shim Replacement
Cold Spray will replace glued shims on bottom of mounting feet.
FRC EAST Update

TGB output housing

Corrosion of pilot bore
FRC EAST Update

H53 TAIL GEARBOX

MOUNTING FEET LOCATIONS
FRC EAST Update
H53 NOSE GEARBOX
FRC EAST Update

H53 MAIN GEARBOX

- Exterior
  - Mounting Feet
  - Flanges
- Interior
  - Scalloped diameter
    - 12 inches from large opening
    - 1 to 2 inches wide
FRC EAST Update

Boeing Servo Cylinder

2014-T6 housing
410 SS bushing pressed in hole and pinned
FRC EAST Update

T62T-40 Housing

ID Journal in left picture
OD Inner and outer side of flange radii
FRC EAST Update

H-1 COMBINING GEARBOX
H-1 Combining Gearbox Chaffing Repair via Low Pressure Cold Spray

Proposed by: COMNAVAIRSYSCOM/PMA-276, FRC-E/H1-FST.1

OPERATIONAL NEED

Objective: To implement low pressure cold spray repair on the H-1 combining gearboxes to restore housing integrity after suffering chaffing damage to the magnesium housing. Damage often exceeds damage allowance.

Value to Naval Warfighter:
- Reduced operational costs, avoids AVDL expense
- Increased gearbox availability
- Readiness levels improved

Gap or Sea Power 21 Area: System Safety and Availability; System Safety and Affordability

Impact if Not Addressed:
- $1 M+/year fleet cost, $1.5M+/year depot cost
- Degraded aircraft readiness, production constraint for UH-1Y and AH-1Z

PROPOSED SOLUTION

The Technology:
- Gearbox repair via cold spray application of aluminum
- GWOT funded program provided initial process verification

Similar/Related Projects:
- ESTCP Proposal 06-E-PP3-031 cold spray effort
- Section 219 in work to establish F-18 AMAD repair

TRL: Current: 6, Projected at end (FY12) 8

Major goals/Schedule by Fiscal year:
- Process development and qualification FY11/FY12
- NAVAIR approval (seminal event), FY 12
- Training package development, equipment purchase, FY13
- Transition to AH-1W program FY13

BUSINESS CASE

Key Metrics:
- Payback of total investment within 2 years
- ROI doubles as UH-1Y/AH-1Z are fielded.
- ROI increases $1.5 M if leveraged to AH-1W Transmission
  - 11 salvageable cases at CCAD ($1 M)
- Potential leveraging of technology to H-60 Airframe and MGB

Proposed Funding ($M):
FY11: $1.100  FY12: $0.700  Total: $1.800

Partners:
- Co-developing with the Army Research Lab (Aberdeen), ES3

Transition Sponsor: PMA 276, Jerry Nueslein
POC Contact Info: Robert Kestler.
### Transition Summary

- Establish process parameters, FY11-FY12
- NAVAIR approval of adhesion, FY12 (seminal event) (Nov 2012)
- Establish I-level/FRC repair capability, FY13
- Publish process in NAVAIR Manuals, FY13
- Train FRC artisans FY13
- Expand capability to fwd deployed activities, FY16

### Technical and Business Readiness

- In service repair, at the I-level
- Minimizes aircraft down time
- Reduce depot-level backlog and costs
- Increased gearbox availability
- Reduces competition for UH-1Y/AH-1Z material
- Sufficient adhesion is the technical risk/hurdle
- US Army has approved an AH-64 cold spray repair

### Technology Transition Programmatics

<table>
<thead>
<tr>
<th>Source</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition Funding ($M)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ONR TIPS PE 0203761N</td>
<td>$1.100</td>
<td>$0.700</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$1.800</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$1.100</td>
<td>$0.700</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$1.800</td>
</tr>
<tr>
<td>Integration Funding ($M)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PoR-276 &amp; PE 0206131M</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.100</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.100</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.200</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.100</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.100</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.200</td>
</tr>
<tr>
<td>Procurement Funding ($M) and Quantity to be Procured/Deployed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PoR-276 &amp; PE 0206131M</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.400</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.200</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.600</td>
</tr>
<tr>
<td>QTY</td>
<td>xx</td>
<td>xx</td>
<td>2</td>
<td>xx</td>
<td>xx</td>
<td>2</td>
<td>xx</td>
<td>xx</td>
<td>4</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.400</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.200</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.600</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$1.100</td>
<td>$0.700</td>
<td>$0.500</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$0.300</td>
<td>$0.000</td>
<td>$0.000</td>
<td>$2.600</td>
</tr>
</tbody>
</table>

### Milestone/Task

- PMS-276: Project Administration
  - FY11: $0.100
  - FY12: $0.100
  - Total: $0.200
- ARL (Aberdeen): Adhesion Testing, Powder & Equipment Evaluations
  - FY11: $1.000
  - FY12: $0.000
  - Total: $1.000
- ARL (Aberdeen): Process Parameter Development
  - FY11: $0.000
  - FY12: $0.500
  - Total: $0.500
- ARL (Aberdeen): Training Package Validation
  - FY11: $0.000
  - FY12: $0.100
  - Total: $0.100
- NAVAIR: Process Review and Approval
  - FY11: $0.000
  - FY12: $0.100
  - Total: $0.100

**Total Transition Funding ($M):** $1.100 $0.700 $1.700
FRC EAST Update

[Images of mechanical parts with labels 'HP-A1 ONLY', 'Complete Repair', 'A071 + HP-A1']
FRC EAST Update
FRC-SouthWest & FRC SouthEast Updates

Cold Spray Candidate Parts
Targeted Repair Facilities: FRC Southwest North Island & FRC Southeast Jacksonville
Objective

**Objective:** Repair both fretting corrosion and internal dimensional damage to the AMAD Gearbox
The need to perform dimensional restoration of cast A357 aluminum components caused by fretting corrosion damage. Repaired to dimensional tolerances. Mechanical, thermal cycling & test stand test complete – savings $85K - 6 returned to date to fleet.
The need to perform dimensional structural restoration of cast A357 aluminum components caused by damage.

Interior damage caused by gear spin-out repaired to dimensional tolerances, mechanical, thermal cycling & test stand test complete – savings $85K
F/A-18 Bomb Rack Repair FRC-SE

- F/A-18 Bomb Rack BRU-14/A, Subject area was solvent cleaned using Bioact 105 Wipe
  - Cold Spray-Al was applied until achieving an average of 0.0007” (0.7 mils)
  - Glass bead burnishing was performed after cold spray to give it a more seamless look and verify adhesion of coating.
F/A-18 Bomb Rack Repair FRC-SE

- F/A-18 Bomb Rack Subject part proceeded to be built and sold (In-Stock).
  - Once this part goes on A/C we will monitor it for corrosion.

Currently in Supply as of Dec 10 2012
Spotting Dolly Axel Pin for GSE:

Axel Pin was nCoP plated; during plating, the contact points did not exhibit full coverage. Therefore, the axel pin was coated with Cold Spray to provide additional corrosion protection.

- Thickness: 0.5 mil – 1 mil (0.0005” – 0.001”)average
Cold Spray Pin – FRC-SE

AVG. Thickness: 0.5 mil – 1 mil (0.0005” – 0.001”)

76
Purpose: Develop a qualified rework/spot repair for IVD aluminum using Low Pressure hand held Cold Spray.

- Working with Boeing St. Louis on OEM qualification
- Various F-18 Components @ Jax & NI are processed in IVD Chamber
  - Obtaining part numbers/part descriptions

- Will work to qualify it for Alumiplate ®repair & general high density aluminum coating for corrosion prevention on HSS & other substrates.

- Concurrently working a similar/concurrent application for cadmium plate repair using LP CS.
• Institute for Manufacturing and Sustainment Technologies (iMAST)
• Applied Research Laboratory, Penn State University
• Established February 1995 as one of the Navy ManTech Centers of Excellence
• Projects identified by ARL PIs, DoD and Industry
• Development and transition of new manufacturing processes and equipment
• Two Categories
  • **ManTech**: Weapon system affordability based
    • Metric: Dollars saved per hull or weapons system
  • **RepTech**: Availability and life cycle cost
    • Metric: ROI in O&M dollars
    • Repair, overhaul and sustainment functions
    • Target fielded weapon systems
    • Naval depots, shipyards, Marine Corps logistics bases, intermediate maintenance activities and contractor facilities performing overhaul and maintenance of fleet hardware.

Areas of Focus:
Air Vehicle Technology
Ground Combat & Combat Service Vehicle Technology
Naval Surface Platform Technology
Naval Sub-Surface Platform
MISSION
To be the preeminent source of innovative technologies-materials, process, manufacturing, and design technologies for affordable, high performance DoD platform structures and systems.

Materials Processing
- Material Design and Characterization
- Process Development
- Advanced Coatings

Advanced Composites
- Marine, Land, and Aerospace Systems
  - Design and Analysis
  - Materials Char./Qual.
  - Process Optimization
  - NDE, Repair

Manufacturing Systems
- Automated Conceptual Design/Trade Space Exploration
- Simulation and Modeling for Manufacturing
- Shearography, Spectrometry, Inspection, NDT
- Environmental Technology

Laser Processing
- Laser Physics
- Process Technology
- System Integration

Systems Operation & Automation
- Condition Based Maintenance
- Sense and Respond Logistics
- Integrated Health Management

MAJOR PROGRAMS
iMAST, Drivetrain Technology Center, DTRA University Partnership, Laser Processing Consortium
Navy ManTech Cold Spray Overview

- Work with DoD and OEMs to identify projects and then develop the Program Plan and the Technology Transition Plan

- A focus of iMAST is to further develop emerging technologies for specific DoD applications, develop repair/manufacturing solutions and then transition the process to the DoD and/or industry

- Works with all branches of the DoD on cold spray and other related repair/manufacturing technologies

- ARL has the DARPA funded Center for Innovative Metal Processing through Direct Digital Deposition (CIMP-3D)
  - Demonstration facility for additive manufacturing using metal deposition
Navy ManTech Cold Spray Overview

• ARL Cold Spray Projects
  • Successfully completed three ManTech/RepTech programs
    • AAV Enhanced Appliqué Armor Kit Product Improvement / Marines
    • Corrosion Coating for High Hard Steel Armor
    • Corrosion Resistant Coatings for Magnesium Transmission Gearboxes for SH60 / NAVAIR – Leveraged with ESTCP Supersonic Particle Deposition Technology for Repair of Magnesium Aircraft Components
    • Portable Cold Spray Repair and Restoration of Aluminum and Magnesium Components/ NAVAIR – Pax River, FRC-SW, E, SE
  • New Start
    • Cold Spray Proof of Procedure for Navy Shipboard Components / Puget Sound Naval Ship Yard
  • Supported several Phase I and Phase II SBIRs
  • Supports several industry partners in the development and application of cold spray technology
AAV ARMOR

- Develop a corrosion resistant coating to extend the life of the AAV appliqué armor.
  - Corrosion Resistant
  - Impact Resistant
  - <40% of the cost of new armor
  - Compare performance to Wire-arc Thermal Spray
- Two sets of coating armor
- One year deployment
- Significantly reduced corrosion
- Demonstrated Impact Resistance
- Met Cost Requirements

Armor after extended use

Armor with Cold Spray Coating under CARC after extended use
No approved repair process
Number of different repairs required
• Fretting
• Impact
• Material Removal
• Sealing surfaces
Repair Requirements
• Hardness
• Machinability
• Corrosion/Wear Resistance
• Adhesion Strength
• Low thermal input

A357.0-T61
Al-7-0.03Ti
HVN 113 VHN
σ_u >45ksi
σ_y >36ksi

#1 Material removed for oil port
#2 Material removed for sealing surface
#3 Material removed from wall of oil passage
#4 Gear impact damage
#5 Cracked oil passage
#6 Material removed
F/A-18 A-D Generator Control Unit Tube Flange
Attaches to the AMAD

Repairs at North Island – Jan 29th - Feb 1st 2013
Tube flange – Al6061 with arc pitting corrosion
• Repaired 7 tubes flanges
• Cost $25K

Arc Pit
Repair
Material Restoration of Al-7175 Component for Undersea Applications

• Joint/sealing surface was out of tolerance after machining
• Al-7075 coating was applied using Cold Spray
• Component was re-machined to required dimensional tolerance and hard anodized
• Components were assembled and pressured tested in a simulated deep sea pressure chamber and tested in the field
• Components have been in operation as part of a test program for over two years
• Cold Spray repair of two components were completed 3 weeks after initial request
• Component repair completed in 4 weeks
**Objective:** Develop a composite coating that contains a solid lubricant that has improved wear properties.

**Solution:** Develop method to encapsulate solid hBN in Nickel and apply a coating with the encapsulated particles using the Cold Spray Process.

**Results:** Coatings have been produced Bond strength (> 11 ksi) and a reduced coefficient of friction.

**Coefficient of Friction Data**

![Graph showing coefficient of friction data](image)
Initial Set-up
- Type of repair
  - Dimensional
  - Structural
- Powder Selection
  - Material Compatibility
  - Hardness
  - CTE Match
  - Size and morphology
- Powder testing
  - Size Distribution
  - Morphology
- Surface Preparation
  - Material removal
  - Bead blasting
  - Surface roughness
- Cold Spray System Evaluation
- Process parameters
  - Modeling – initial parameters
  - Process Gas – Type, Pressure, Temperature
  - Nozzle
  - Traverse rate
  - Cost
- Coating Properties
  - Adhesion / Bond Strength
  - Corrosion
  - Wear
  - Thermal Affects
• Cyclic Corrosion Chamber
  • Equipment: Singleton CCT-10
  • Purpose: Accelerated testing (weeks, months) in a simulated aggressive corrosive environment
  • Capabilities: ASTM B117, GM 9540P, SAE J2334, others
• Alternate Immersion Chamber
  • Equipment: Customized automated immersion tank
  • Purpose: Accelerated testing (weeks) of stress corrosion cracking
  • Capabilities: ASTM G44
• Electrochemical (DC & AC)
  • Equipment: Gamry PC4 Potentiostat, EG&G 273A Potentiostat (for high current applications)
  • Purpose: Rapid testing (hours) to obtain corrosion resistance information
  • Capabilities: Electrochemical polarization, corrosion rate, galvanic corrosion, pitting resistance, Electrochemical Impedance Spectroscopy (EIS)
• Related Equipment
  • High impedance voltmeter (Z=10^{13} \Omega)
  • Conductivity/pH meter
  • Crevice corrosion test cells
  • Micro probe reference electrodes (50 micron)
  • Stress Corrosion Cracking
Plate Inspection

CP-Al on Al6061 using Centerline

Test Plate

Cold Sprayed/Machined Plate

Dye Penetrant

Pulse-Echo Configuration
UT Inspection

Ultrasonic Parameters:
- Spike pulse excitation
- Pulse-echo signal transmission
- 0.050 inch step & scan increment
- Scans performed with 1, 2, 5, and 10 MHz planar transducers
- C-Scan (amplitude) imaging created from selected time windows (gates) within the voltage-time ultrasonic response

Results:
- Image all internal features
- No voids detected
- Backwall echo thresholding not usable for volumetric inspection due to internal geometry and material density variations
- Hand (contact) UT practical but mid-volume gate thresholding required for void (pore) detection
Navy Cold Spray

Fred Lancaster - NAVAIR Materials Engineering Division
Timothy Eden, Ph.D. - Head of the Materials Processing Division – Penn St. ARL
Air Force Advances in Cold Spray

Rob Hrabe - H.F. Engineering Services, Chief Executive Officer
Mr Brian James – 28th Bomb Wing Air Force Engineering Technical Services
Air Force Advances in Cold Spray

Brian L. James
28 MXG/AFETS
7 Jan 2013
Overview

• Air Force Cold Spray Applications
  • Mg & Aluminum Housings

• Automation Systems
  • OSD Mantech Cold Spray Repair and Rebuild Technology

• Portable/Hand Held Equipment Development

• Air Force Portable/Hand Held Cold Spray Applications
Air Force Applications
Magnesium & Aluminum Housings

F-16 Accessory Drive Gearbox Wear sites

F-15 AMAD wear sites

F-16 Air Inlet wear sites

A-10 Fuel Valve Hsg corrosion

MOOG
HF Webster
Engineering Services
Problem
F-16 Air Inlet Housing

Mostly Aircraft Availability Issue
Annual Savings: ~$26K
Prototypes developed & cold sprayed
Testing in work
First Article in work

Nominated by
AFMC Gen Wolfenbarger Staff
Problem
F-15 AMAD - Magnesium Housing

Nominated by AFMC
Gen Wolfenbarger Staff
Spares availability problem
High Cost/High Demand
Test Article Cold Sprayed
Annual Savings ~ $472K
%ROI: 8086%
F-15 AMAD: Masking
F-15 AMAD: Bore Repair
Problem
F-16 ADG- Magnesium Housing

Repair sites

Nominated by AFMC
Gen Wolfenbarger Staff
Spares availability problem
High Cost/High Demand
%ROI: 6337%
Annual Savings ~$317K
Automation Development

Transition cold spray repair technology into production

- Create a production ready supply chain that will cost effectively deliver magnesium transmission housings and other high cost, high failure rate components repaired with cold spray technology
- Reclaim unserviceable parts - corrosion, wear, chafing, other damage
- Develop automated, flexible, and repeatable repair process for production implementation of cold spray
- Lower logistics cost, higher on-wing time, less Operational-level and Periodic Depot Maintenance, Improved Readiness.
- Benefits wide range of weapons systems – all services

End Product: Transformational Repair System
6 Degree of Freedom Modular Motion System
**Machining**
Machining force
56 - 67 lbs / 3 directions
Speeds up to 0.2 m/s (.66 ft/s)
Tolerance .001"

**Precision**
X/Y Axis:
  - Repeatability - .75 μm
  - Accuracy - 2 μm
Z Axis:
  - Repeatability - 1 μm
  - Accuracy - 11 μm
Pitch and Yaw
  - Repeatability -10 arcsec
  - Accuracy -180 arcsec

**Payload**
Z - 110#, X/Y - 265#

**Cold Spray**
6 DOF motion @ 1.6-3.2 ft/s

**Travel**
X axis = 5'
Y axis = 4'
Z axis = 2.6'

**Moveable Multifunction Tool Changer**
- Cold Spray Gun Adapter
- Laser Scanner
- Milling
- Grinding
- Drilling
- UT or MWM NDE
- Rapid Change
- Electrical
- Pneumatic
- Expandable

Aerotech high precision linear motors & stages
3D error mapping/error compensation
6 Axis CAD to Motion Animation
Benefits
Cold Spray Automation

- Flexibility to adapt to multiple part variations/types
- Minimize/eliminate setup time between operations
- Multiple operations at a single station
- High accuracy for scanning, machining, and NDI operations +/- .001"
- Open architecture that will allow for adaptation to future repair requirements and/or future expansion
- Intelligent repair/manufacturing that requires minimal “artisan” ability and maximizes repeatability
- Minimize new part startup/engineering time
- Eliminate long delays in repair development and qualification
- This program will improve the long lead times and lack of available spare parts.
- Overall reduce cost of repair development and production

Rethink the way we do repair
Benefits
Automation System

- Standard Operating System reduces process development costs and allows for distributed repair operations
- Improved Quality and Repeatability of Repair
- Large workspace up to ~ 5’ x 4’ x 2.6’
- Processing of small and large parts
- All-in-one system reduces time to repair, difficulty, & cost
- True CAD to motion planning – ease of design to production
- Solid Works environment
- Customizable MMI/Flexible I/O’s
- CAD to CAM Path Planning

Rethink the way we do repair
Hybrid Portable Hand Held High Pressure Cold Spray System

Commercialization Partner Licensed Through ARL

Portable Aluminum Skid
Portable Gas Supply
Compact Gun Access small spaces
Video of the cold spray process:
Problem
B-1 Forward Equipment Bay (FEB) Panels

28th MXG Initiative
Panels no longer manufactured
A/C availability problem
%ROI: 5807%
Annual Savings ~ $840K
Applicable to nearly all military aircraft

8 panels per aircraft
Four panels per side, Lt and Rt sides
Problem
B-1 Lt Upper Aft FEB Panel

Chafing Wear on Operational Panel

Before

After
#1 Maintenance manhour driver on B-1, similar on most aircraft
ROI primarily based on lost flight hours and reduced maintenance manhours
Estimated at least 1800 Mission Capable (MC) hours ~75 days improvement per year
Equates to $78M annually in lost training and maintenance costs*
* Based on AFIT Study, "Total Cost Comparison of B-1B Non-mission Capable (NMC) Drivers using Finite Source with Spares Queueing, Maj Dan Diehl, 2012

### Problem

**Hydraulic Tubing Chafing**

- **Chafing Points Wear Tested**
  - Spoiler Actuator line
  - Main Landing Gear Line
  - Nose Landing Gear Accumulator Line
Candidate Parts
Chafing - Aircraft Skin Panels & Hydro Tubes

Chafing Wear on Operational Panel

- Main Landing Gear Line
- Nose Landing Gear Accumulator Line

Chafing Point Wear Tested

8 panels per aircraft
Four panels per side
Lt and Rt sides

CS Repaired June 2012
1+ Year, 155 Flight Hours

CS Applied Jan 2011 (2 A/C)
~3 Years 4151 Combined Flt Hrs

CS Applied Mar 2009
4+ Years, 2202 Flight Hours
Questions?

Mr. Brian L. James, GS–12
Air Force Engineering and Technical Services

Rob Hrabe
H. F. Webster Engineering Services
Q & A

Ray Langlais
Review New Actions

Ray Langlais
Thank You

Cold Spray Action Team Website
http://coldsprayteam.com/index.html