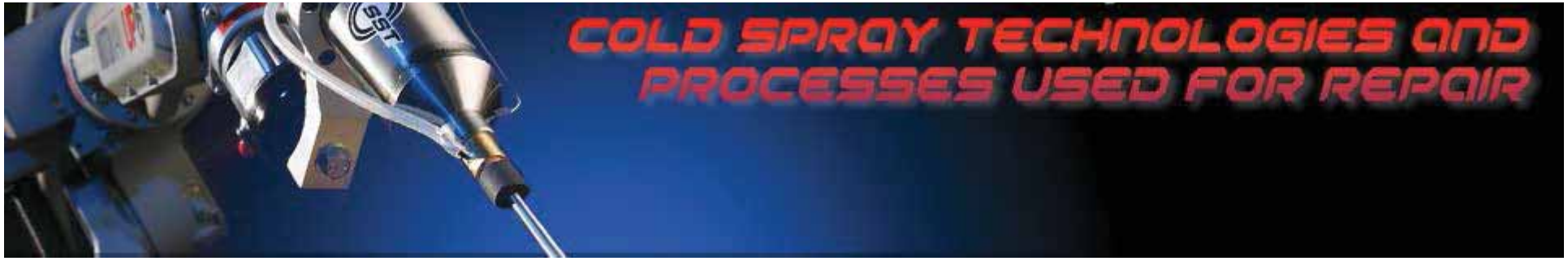
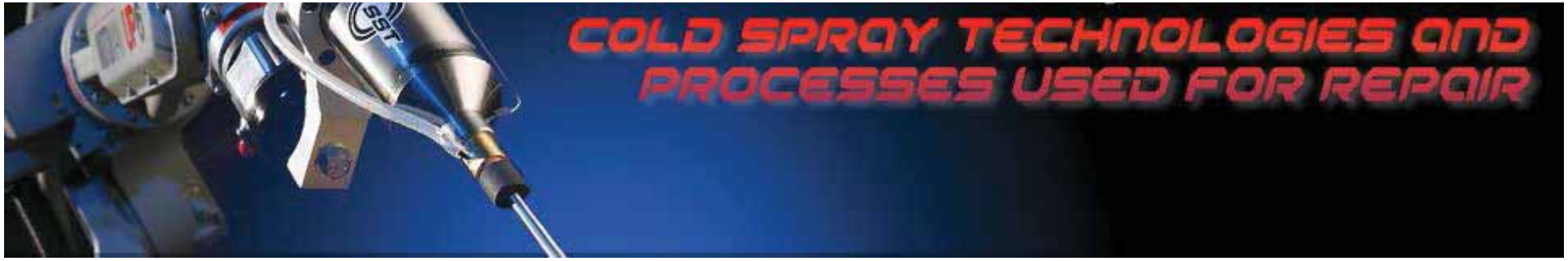


Welcome to the JTEG Monthly Teleconference

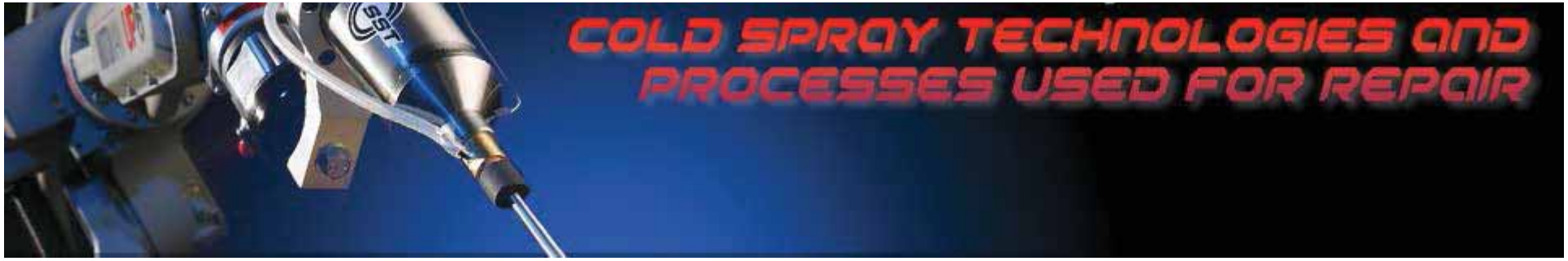
Topic: Cold Spray Technologies Used for Repair

Greg Kilchenstein – ODASD(MPP)



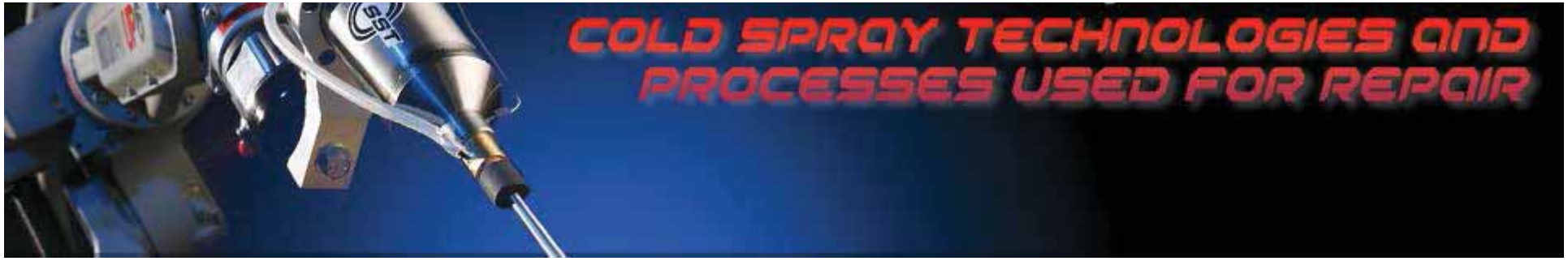
Joint Technologies Exchange Group (JTEG)

- 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.



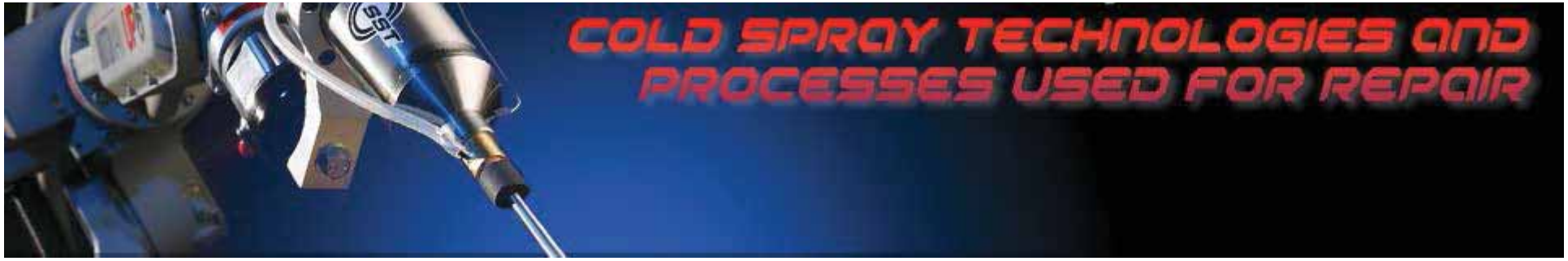
Introduction and Definition of Cold Spray

Greg Kilchenstein



Introduction to Cold Spray Action Team

Vic Champagne – Director, ARL
Center for Cold Spray

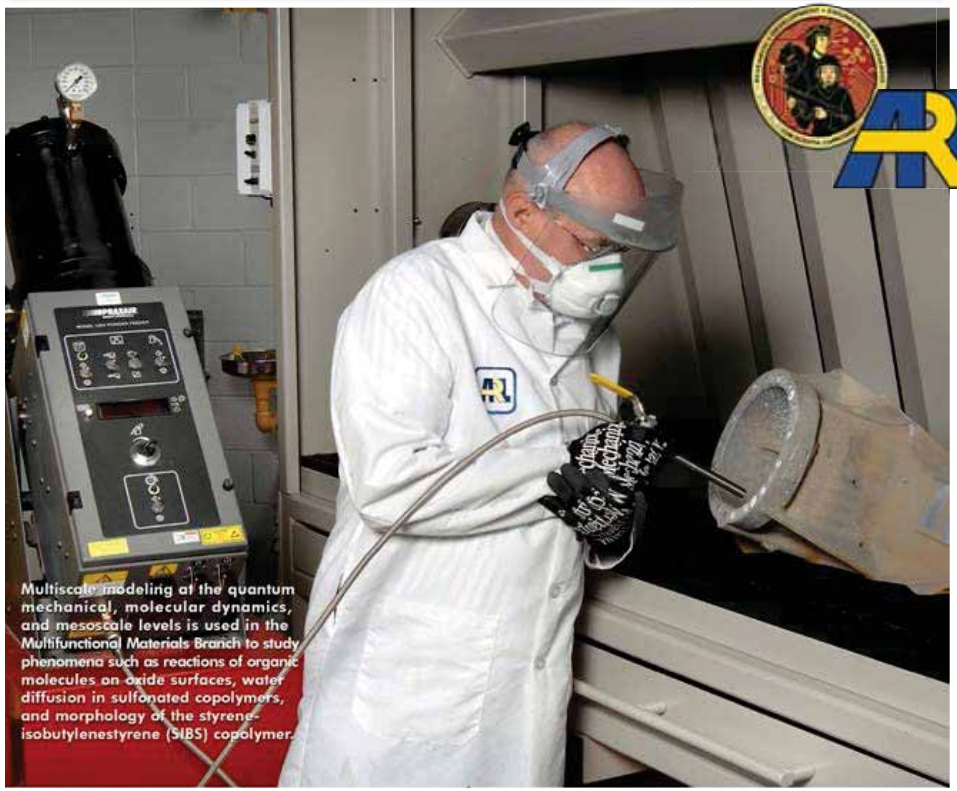


Overview of Cold Spray Technology for DoD and the Commercial Sector

Vic Champagne – Director, ARL
Center for Cold Spray

ARL Cold Spray Applications Development

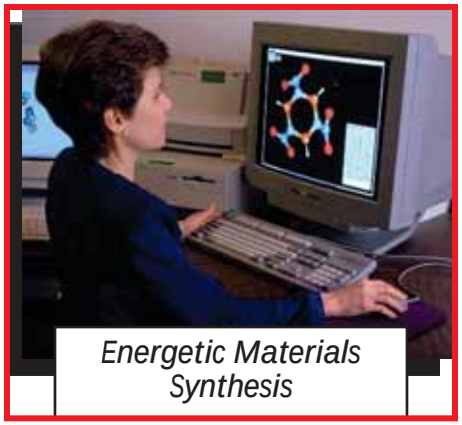
Victor Champagne, Technical Team Leader
Innovative Materials & Processing Team
US Army Research Laboratory
ATTN: RDRL-WMM-C, BLDG 4600
Aberdeen Proving Ground, MD 21005-5069
Office Phone: 410-306-0822, Fax: 410-306-0829
Email: victor.k.champagne.civ@mail.mil



Multiscale modeling at the quantum mechanical, molecular dynamics, and mesoscale levels is used in the Multifunctional Materials Branch to study phenomena such as reactions of organic molecules on oxide surfaces, water diffusion in sulfonated copolymers, and morphology of the styrene-isobutylenestyrene (SIBS) copolymer.

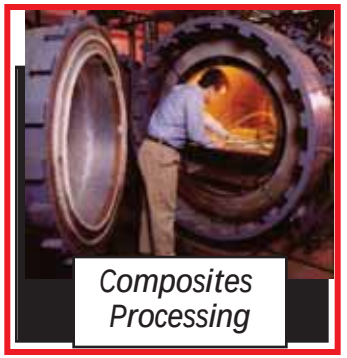
US Army Research Laboratory (ARL)

Weapons and Materials Research Directorate at APG



Energetic Materials Synthesis

- Composites
- Polymers
- Metals
- Ceramics
- Materials Processing
- Energetic Materials
- Smart Munitions
- Impact Physics



Composites Processing

Specialty Coatings

Sputter Deposition

Impact Physics Tension Hopkinson Bar

Scanning Electron Microscopy

Mechanical Properties of Energetic Materials

Cold Spray

Smart Munitions

US Army Research Laboratory

Weapons and Materials Research Directorate

Watertown Arsenal Circa 1865

ARL 21st Century

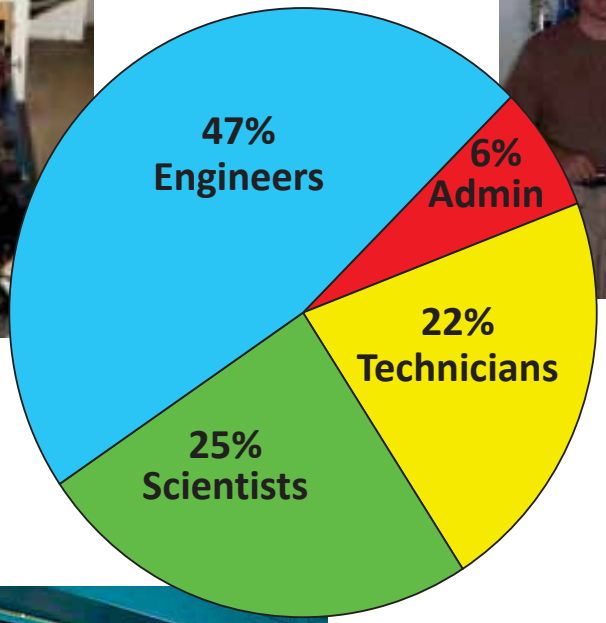
Tank Urban Survivability Kit

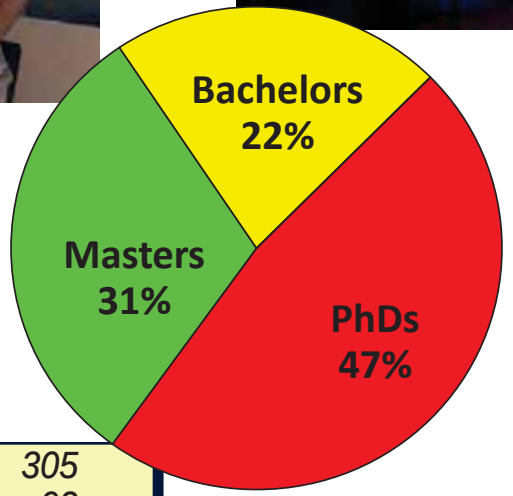
Semi-Autonomous Mobility

High explosive ammunition creating an opening in a double reinforced concrete wall through which infantry can pass.

Armor Upgrade for HMMWV

ARL Staff and Level of Education

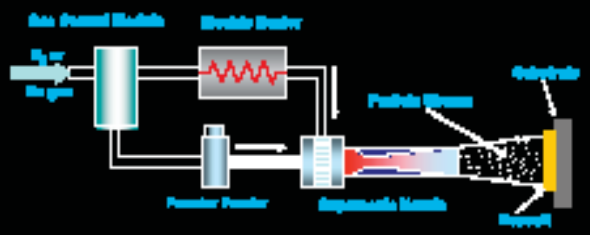




Scientists and Engineers		*305*
Technicians		*92*
Administrative	*28*	
Total Civilian Personnel		*425*
Post Doctorates		*18*
Guest Researchers		*10*
Military		*6*
On-Site Contractors		*195*

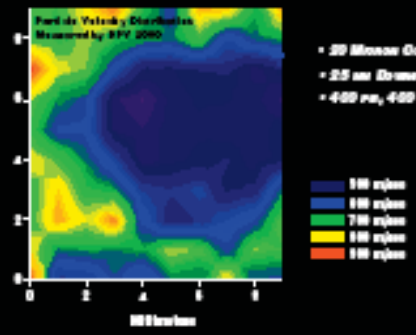
ARL Center for Cold Spray

ENHANCING THE PERFORMANCE OF MATERIALS AND COMPONENTS



Cold Spray System Configuration

Stationary Cold Spray System



Modeling of Cold Spray Process Parameters

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

EMI Shielding for HMMWV Shelter by Cold Spray

Comparison of Cold Spray and Thermal Spray

Applied EMI Shielding on the HMMWV Shelter

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)

The direct link is: http://www.arl.army.mil/www/default.cfm?page=369

- 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

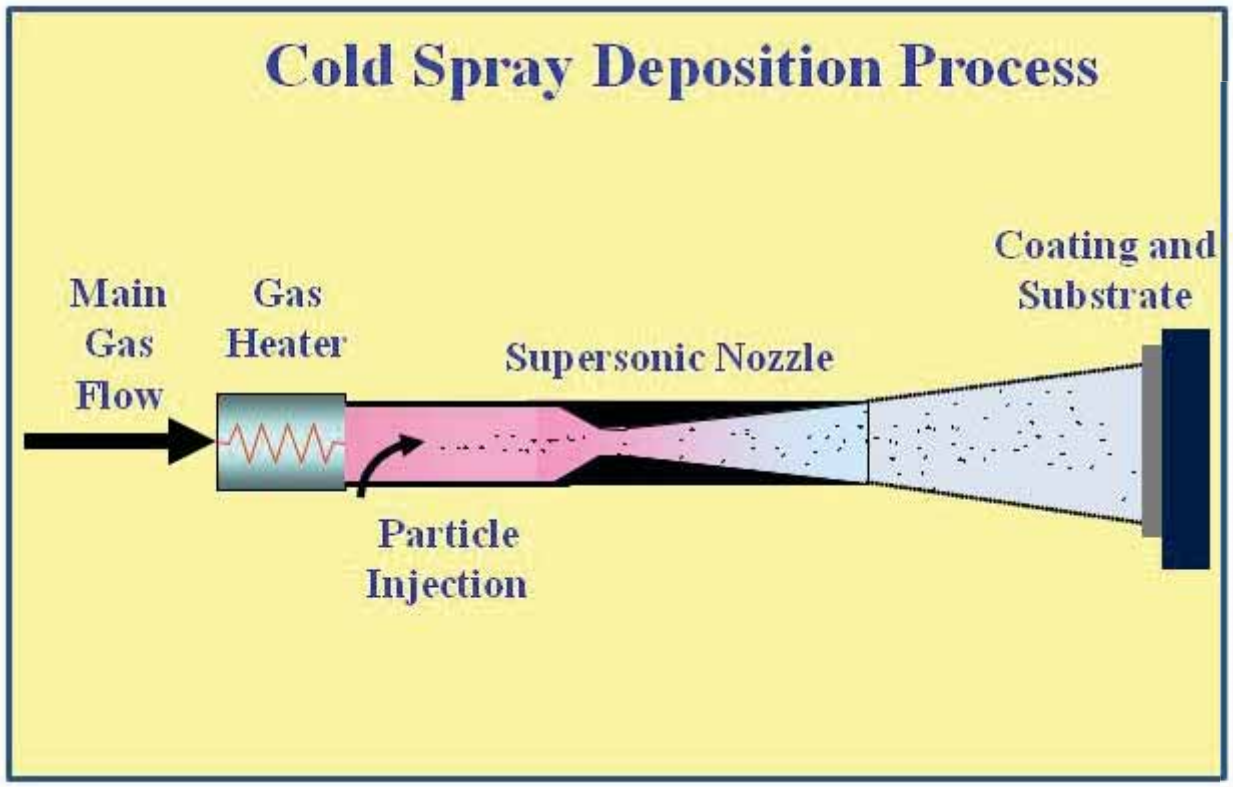
FOX News Report 2013

http://www.foxnews.com/tech/2013/01/03/can-cold-green-supersonic-spray-save-black-hawk/

The Cold Spray Process

➢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

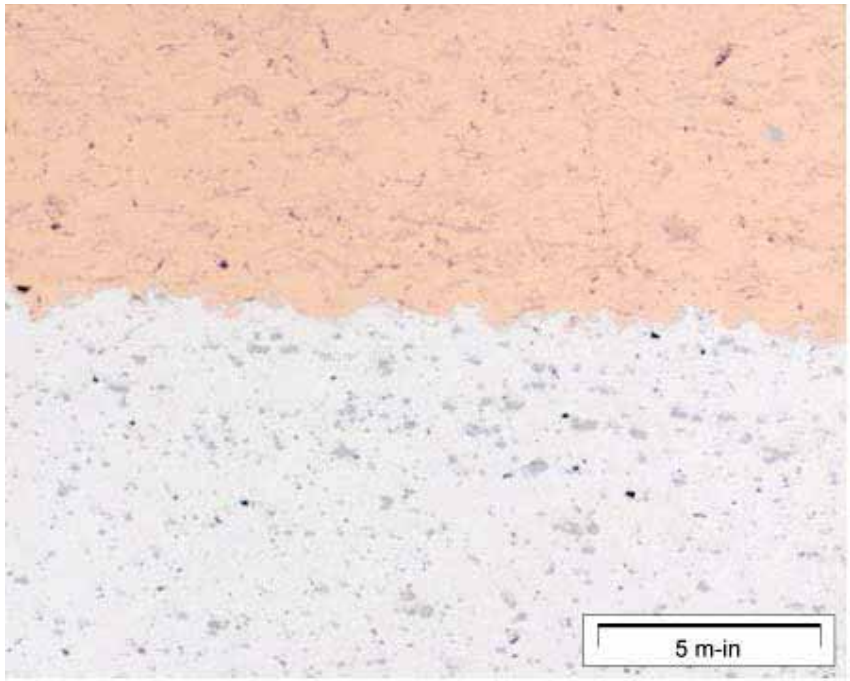


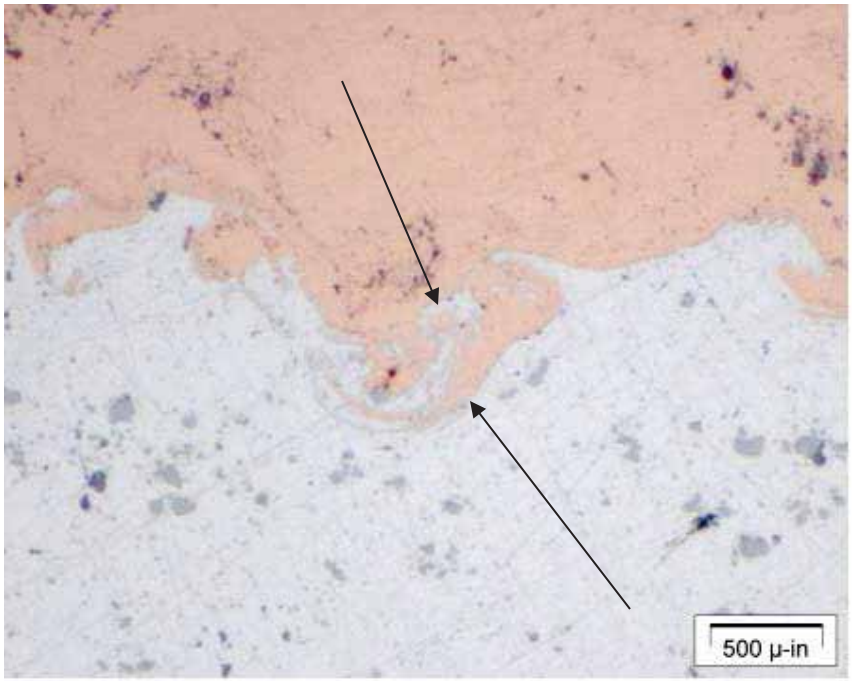
- **Feed stock typically ranges from 1 to 50 µm diameter**
- **Particle ductility is crucial**
- **Gas temperature ranges from R.T. to 1,000°C and pressures from 300 - 725psi**
- **No melting of particles**
- **Negligible oxidation**
- **No decomposition or phase changes of deposited particles or substrate**

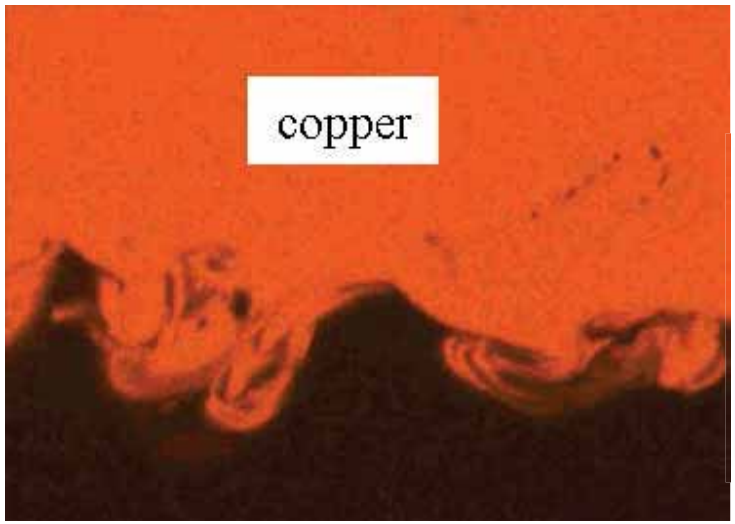
Particle/Substrate Interaction*

*from H. Assadi, www.modares.ac.ir/eng/ha10003/CGS.htm

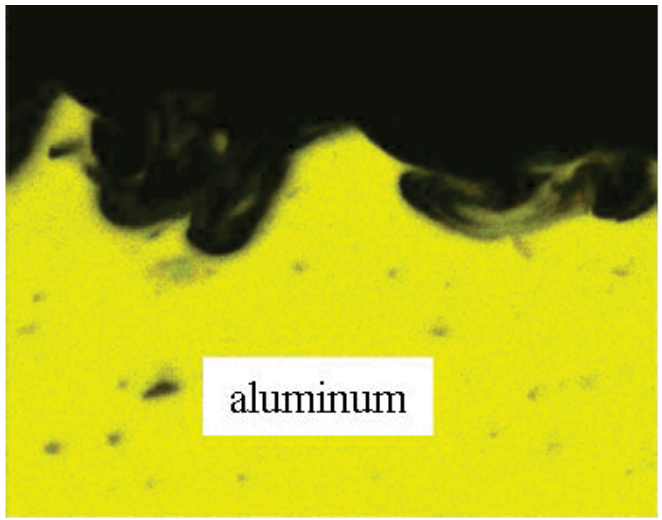
Mechanical Mixing at Interface







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

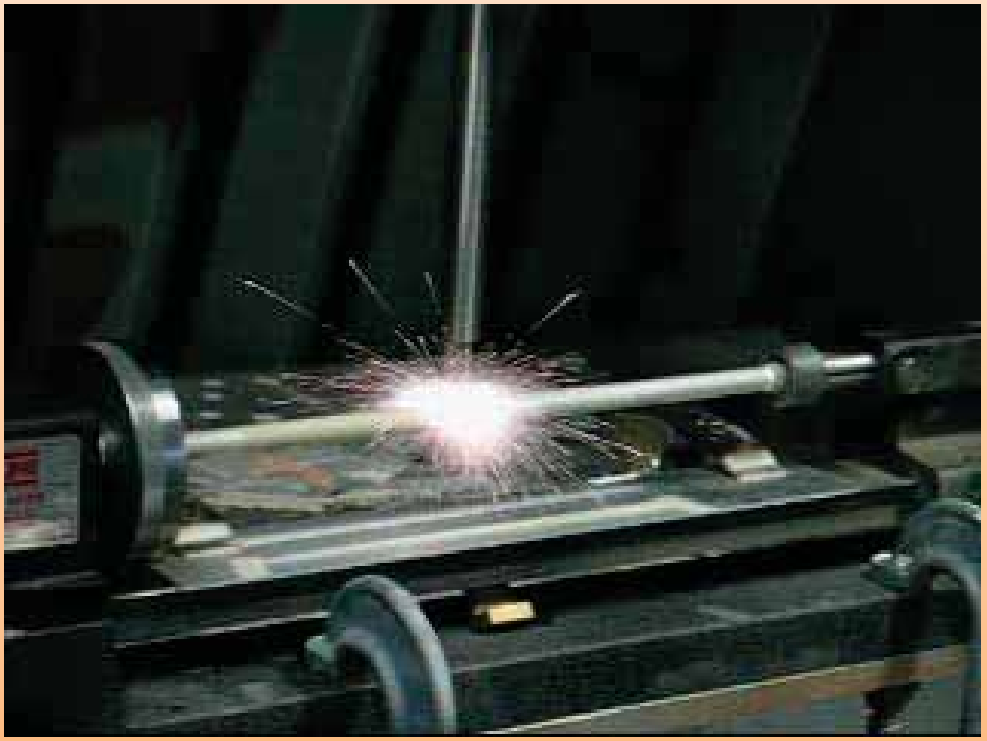


Advantages of Cold Spray

- **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)

Commercial & DoD Applications Development at ARL

- 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"

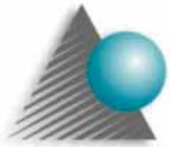
Fleet Readiness Center East

Marine Corps Air Station Cherry Point, NC 28533

JOHNS HOPKINS UNIVERSITY

PENNSTATE ARL

Sikorsky
A United Technologies Company



ROWAN TECHNOLOGY GROUP

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

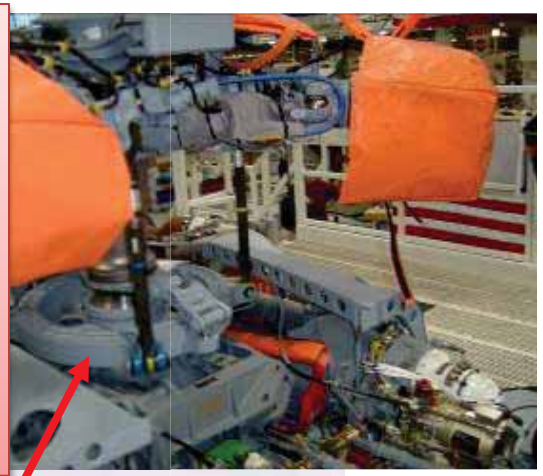
•Magnesium is susceptible to wear and corrosion

•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**



•Parts are large and expensive (up to $800K/housing)

•Long lead times

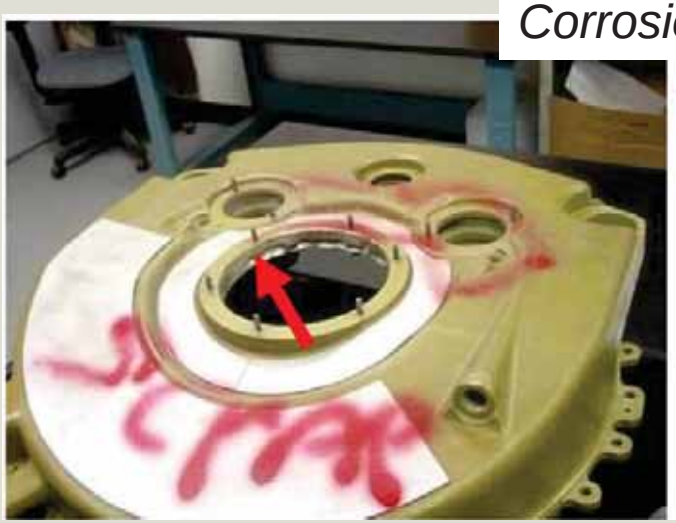
"this is a critical safety and readiness issue"

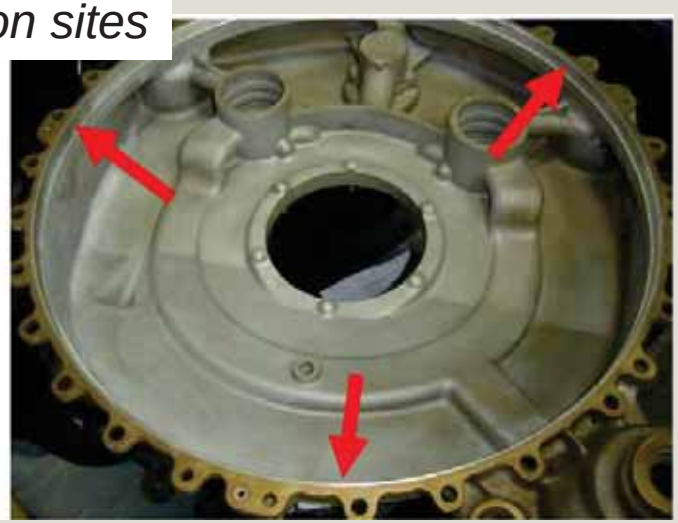
(Major General Nickolas Justice, Commanding General, AMRDEC)

Problem

UH-60 Sump - Magnesium Housing

Corrosion sites





ROI

Unit Cost: $11K

Annual Demand Rate: 85

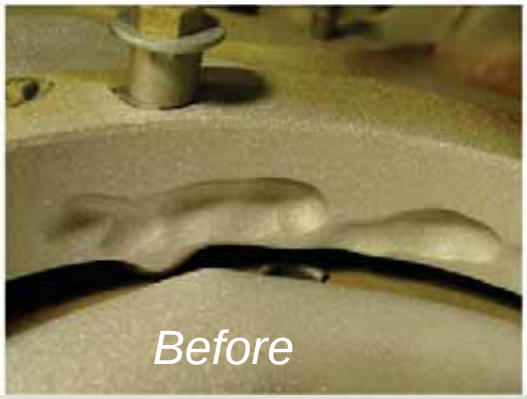
Repair Cost: $880

Investment:$60K

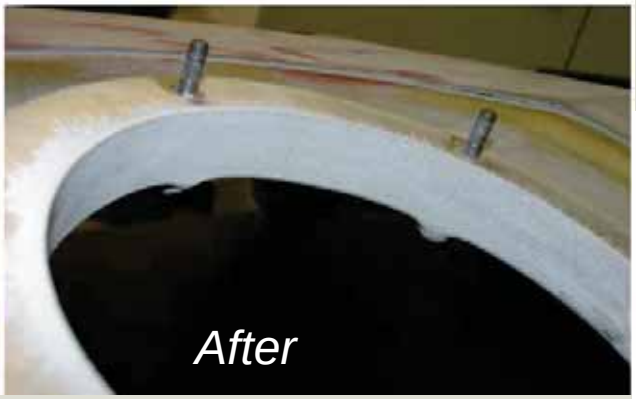
%ROI:16707%

Annual Savings

$860K



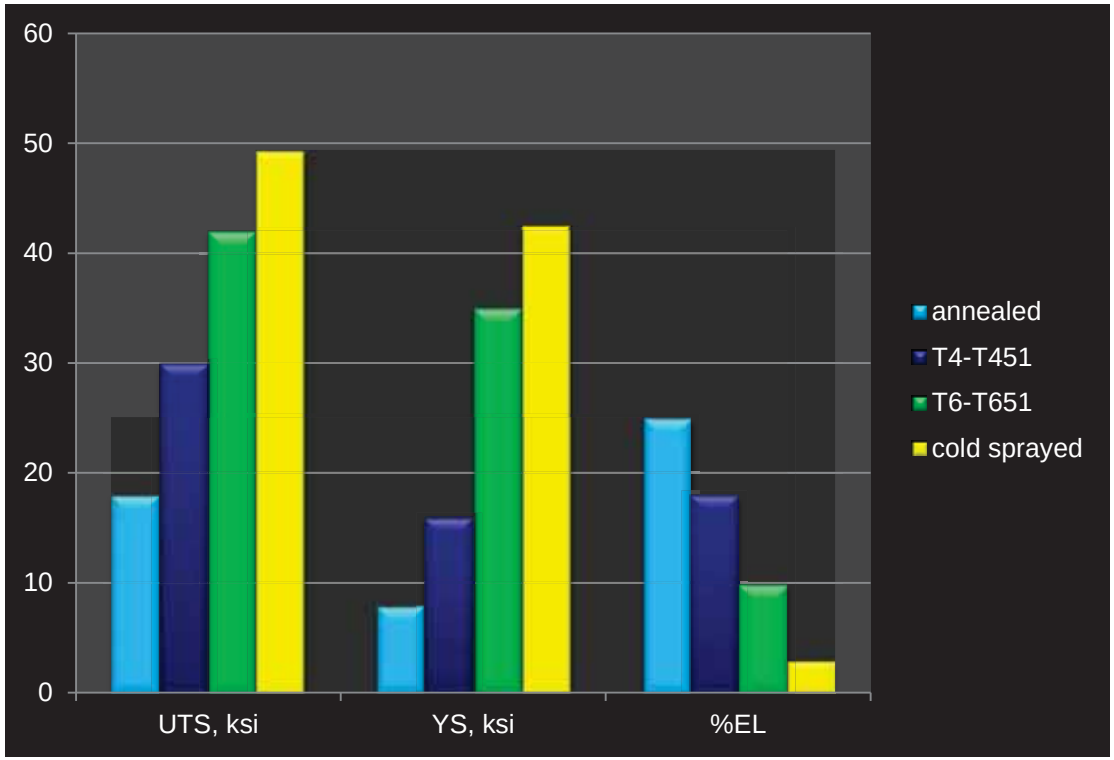
Before



After

Repaired Sump

Wrought versus Cold Spray 6061



6061 Condition	Source	UTS, ksi	YS, ksi	%EL
annealed	1	18	8	25
T4, T451	2	30	16	18
T6, T651	2	42	35	10
cold sprayed	3	49.3	42.5	7

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. [2]

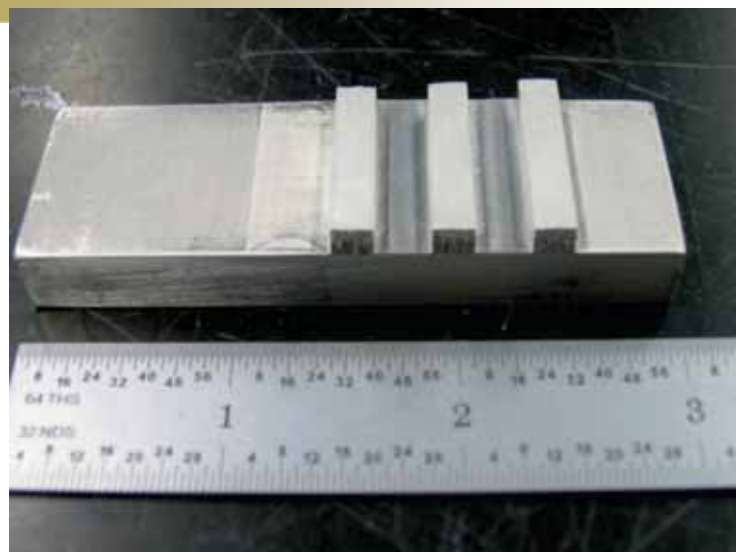
T6, T651- Solution heat-treated and then artificially aged, Temper -T651 applies to products stress-relieved by stretching.[2]

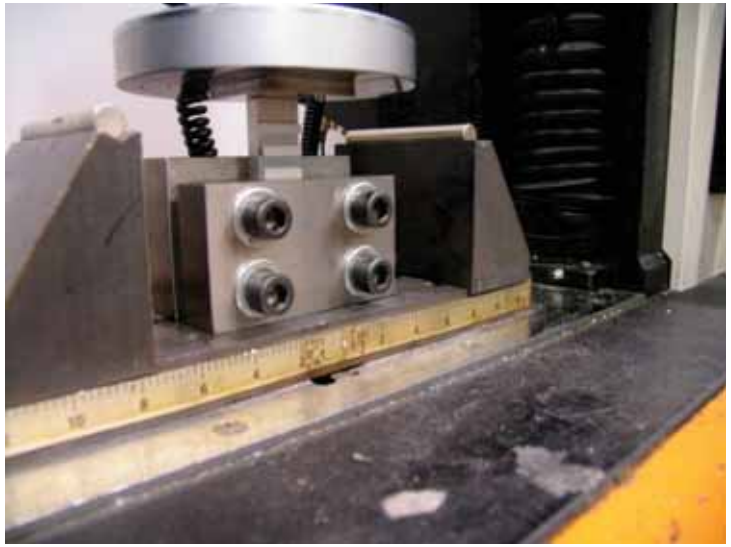
[1] Matweb

[2] Alcoa.com

[3] Microtensile Test by Aaron Nardi at UTRC of ARL Cold Spray Block

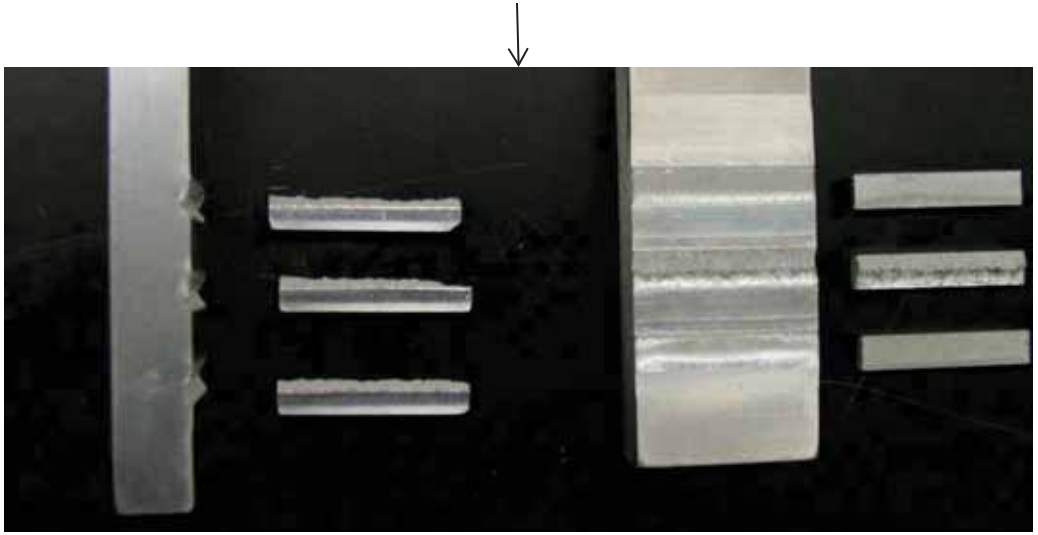
6061 Triple Lug Shear





Alloy	Average (ksi)	Stdev (ksi)	95% Confidence (ksi)
ZE41A-T5	20.4	0.8	19.9, 20.8
AZ91C-T6	19.0	2.5	17.5, 20.5
EV31-T6	22.1	2.8	20.5, 23.7

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



Overview of Accomplishments

2008 Defense Standardization Program Achievement Award

Presented to members of the Cold Spray Team for the development of a military process specification, "MIL-STD-3021, titled Materials Deposition, Cold Spray" (2008)

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 OSD Mantech Demonstration Site (Currently Performing CS on Production and Fielded Parts (2013)

Official Approval Documents and Transition

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

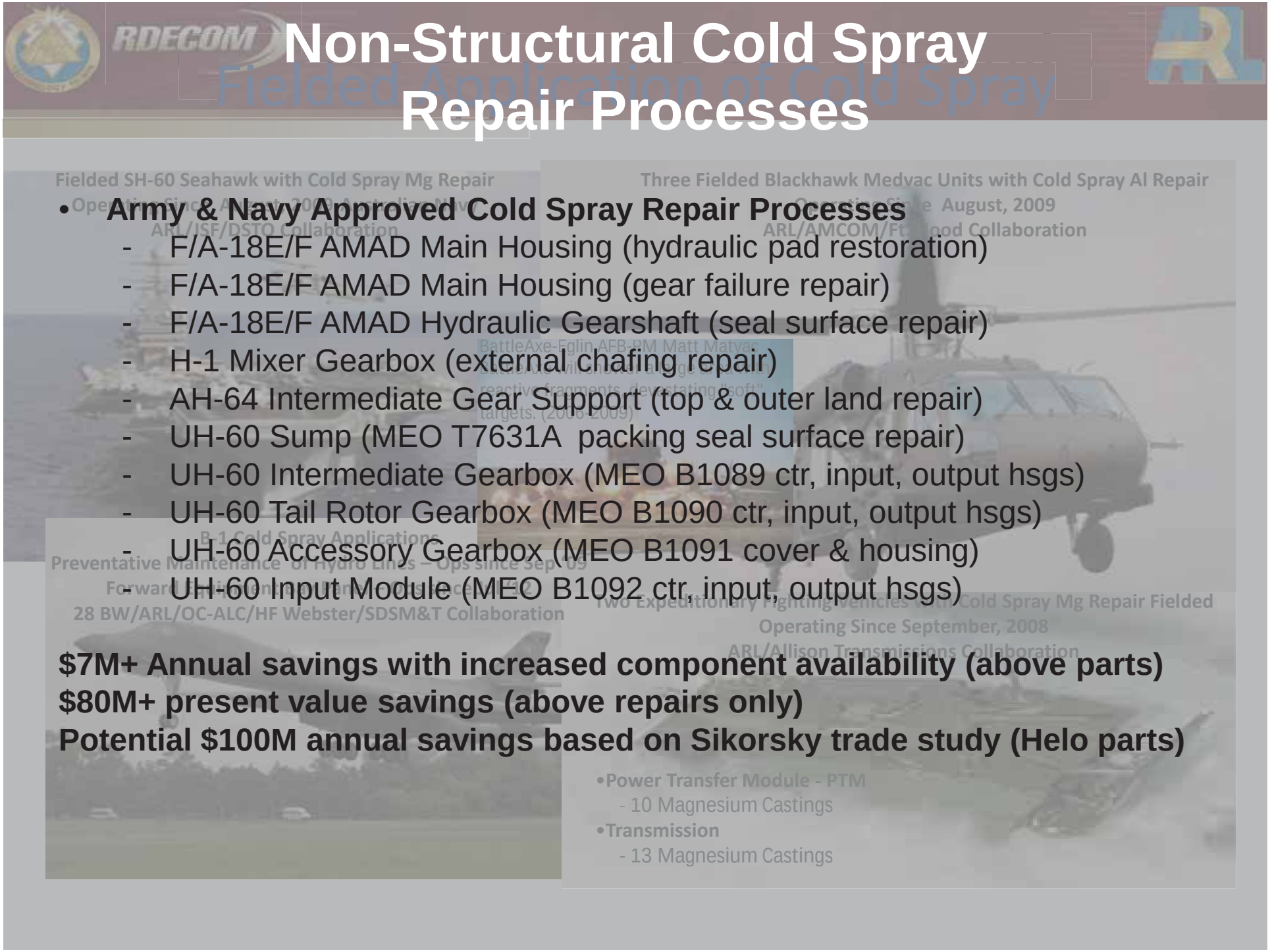
- Ellsworth Air Force base

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

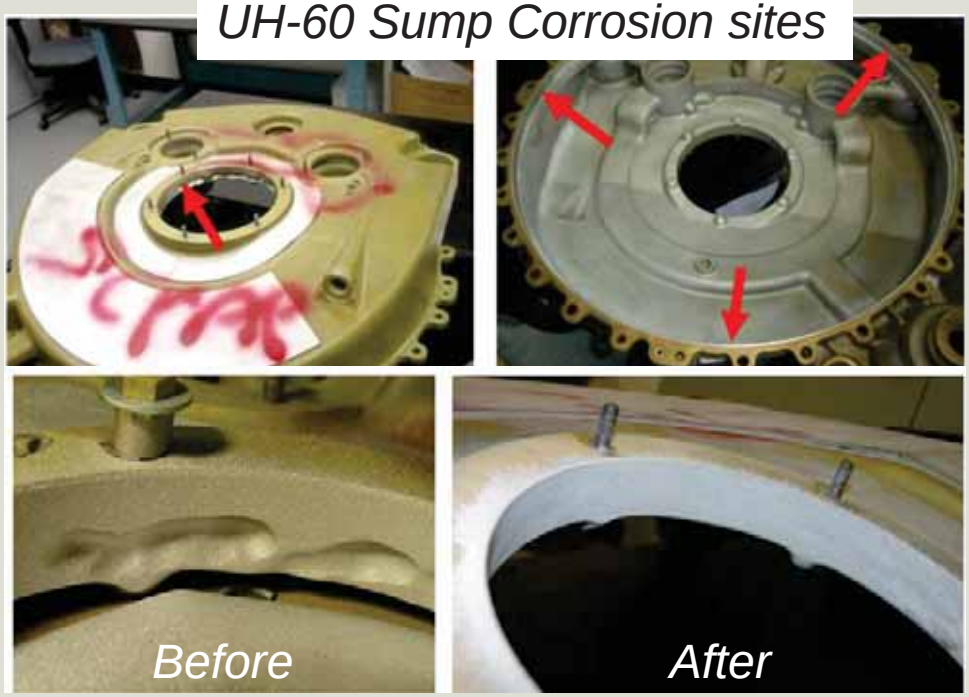


- **Army & Navy Approved Cold Spray Repair Processes**
  - F/A-18E/F AMAD Main Housing (hydraulic pad restoration)
  - F/A-18E/F AMAD Main Housing (gear failure repair)
  - F/A-18E/F AMAD Hydraulic Gearshaft (seal surface repair)
  - H-1 Mixer Gearbox (external chafing repair)
  - AH-64 Intermediate 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)

$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)

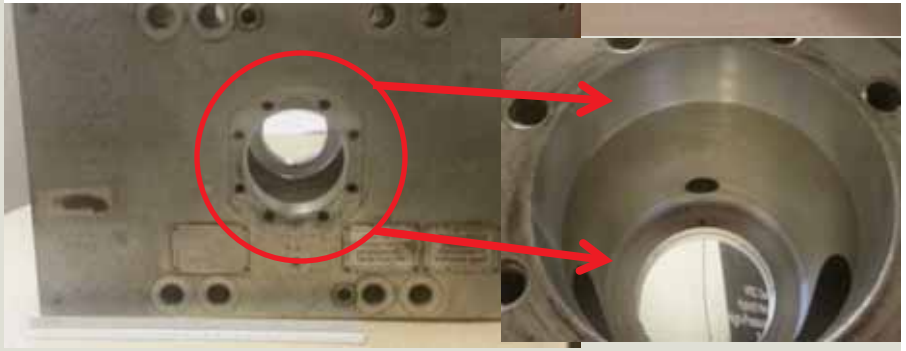
Candidate Parts
Magnesium & Aluminum Housings

UH-60 Sump Corrosion sites

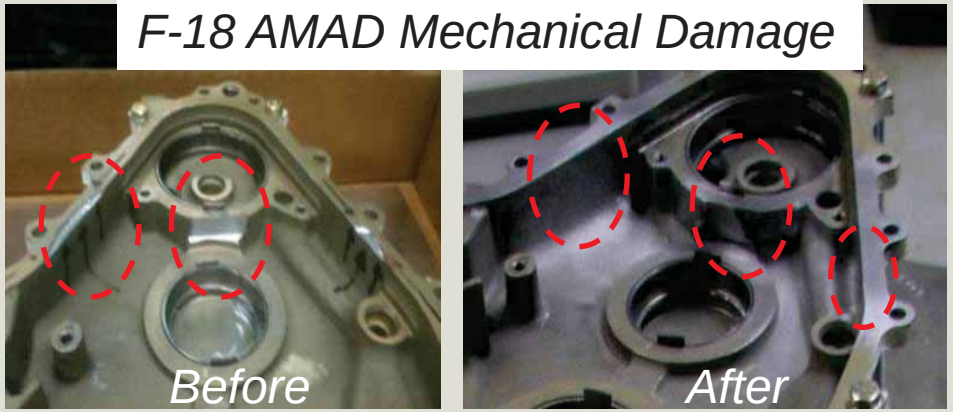


F-15 AMAD wear sites

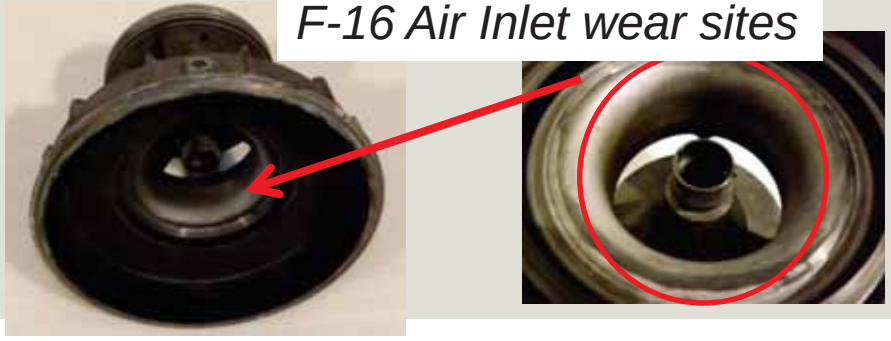
SSN 21 TD-63 Actuator Body wear sites



F-18 AMAD Mechanical Damage



F-16 Air Inlet wear sites



from Prototype to the Field

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

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

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

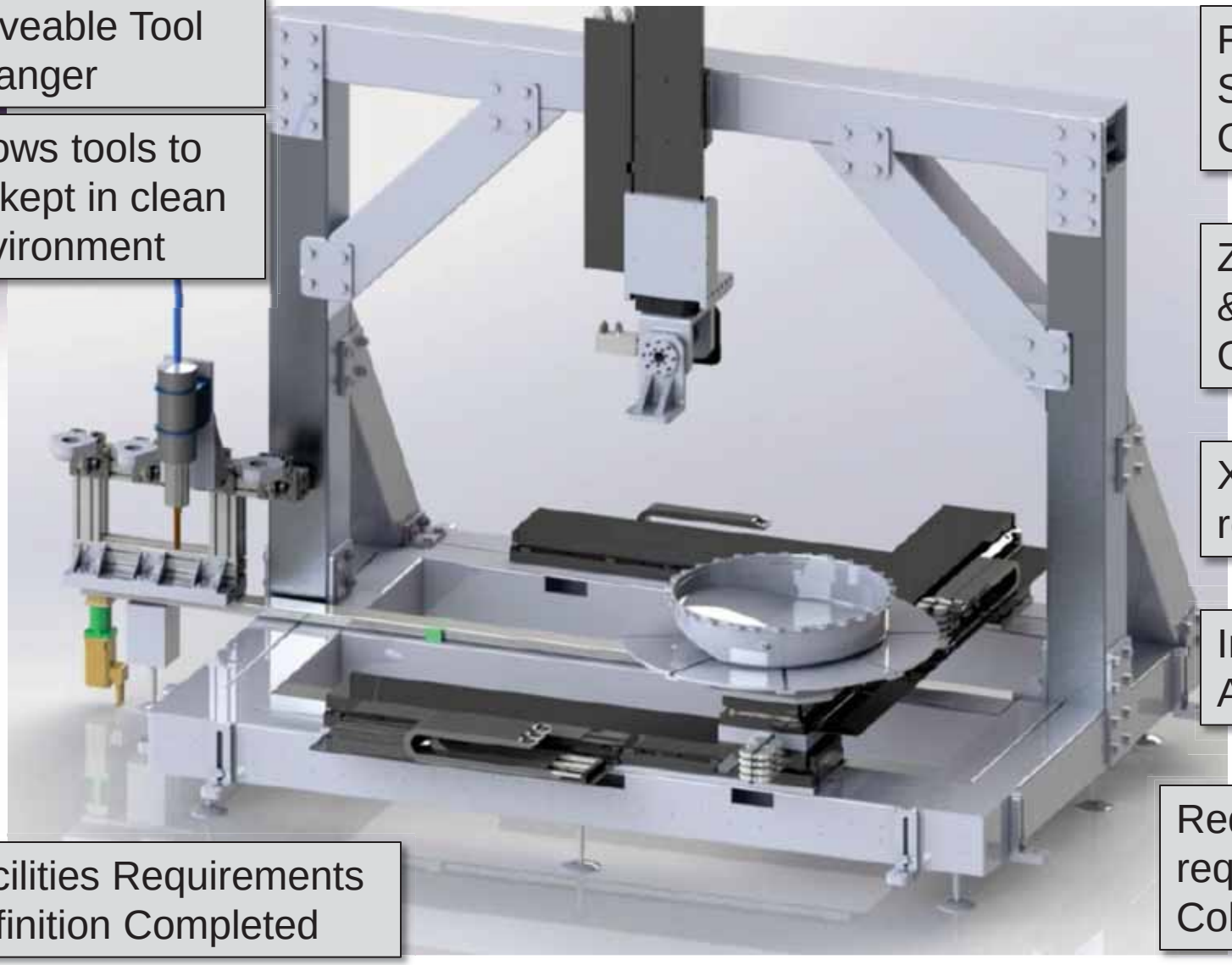
Distribution Statement D: Distribution authorized to the Department of Defense and approved U.S. DoD contractors functioning as technical advisors to the Government team. Other requests for this document shall be referred to the U.S. Army Research Laboratory, Aberdeen Proving Ground, MD 21005-5069.

Technical Progress

Motion System Assembly and Test in Progress

Moveable Tool Changer

Allows tools to be kept in clean environment



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

Facilities Requirements Definition Completed

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 the U.S. Army Research Laboratory, Aberdeen Proving Ground, MD 21005-5069.

Gen III HP Hybrid Cold Spray System

VRC METAL SYSTEMS

Aluminum Skid
55”L x 33”W x 58” H

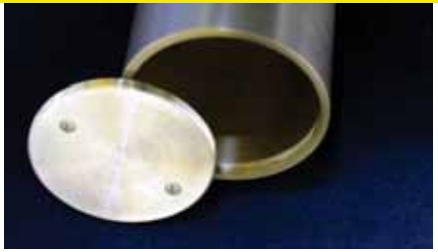
Portable Gas Supply
32”L x 23”W x 78H

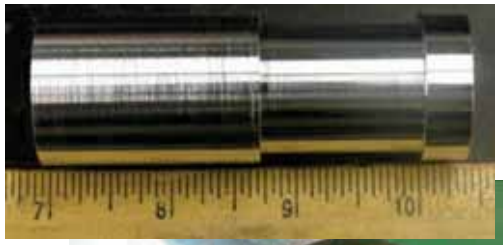
Compact Gun
Access small spaces

- **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

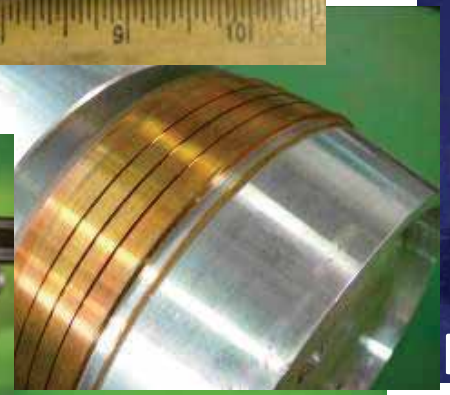
Current state of the art: parts require machining to final dimension





fine machined threads

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



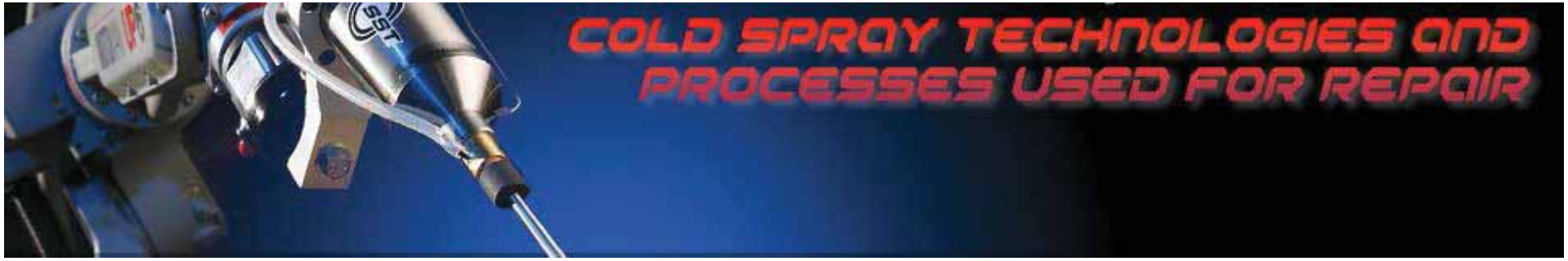
Future goals

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

CAD\CAM

- 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

NAVAIR Cold Spray Initiative Update

Cold Spray Forum January 7 DCO

Presented to:
NAVAIR Session

Presented by:
Frederick A. Lancaster AIR 4.3.4 S&T Lead

January 2014

NAVAIR

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.

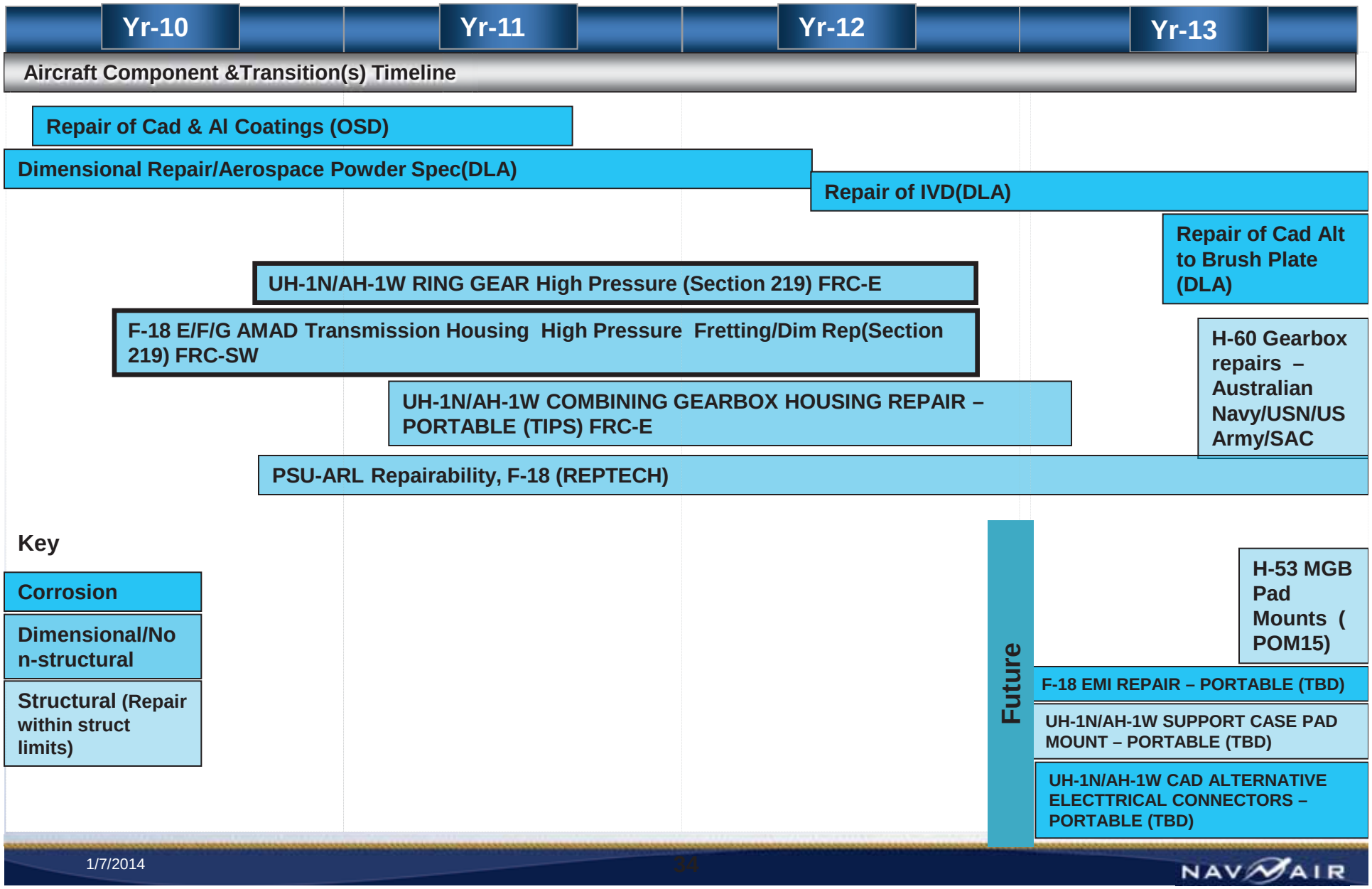
Naval S&T Focus Areas:

- Affordability √
- Maintainability √
- Reliability

Naval S&T Objectives:

- Platform Affordability √
- Availability √

Current & Future Projects



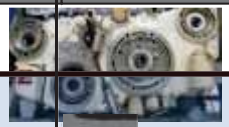
NAVAIR Cold Spray Timeline

Pre-Section 219 Timeframe (5 Years)

Section 219 Timeframe (2 years)

FY-05 | FY-06 | FY-07 | FY-08 | FY-09 | FY-10 | FY-11 | FY-12+

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



Part Repair Approval

Initiate Army Contact

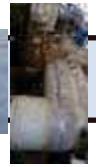
Army Collaboration (Demval, Testing, Information Exchange, Project Teaming, DOD Vision)

Pax River

SME

SME Trained Modeling

SME

FRC-East

SME Trained


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

FRC-SE

SME Trained

FRC-SW

SME Trained

Cold spray specifications for process Approved Aerospace Powder Spec Pending

MIL-STD-3021 Cold Spray Spec

MIL-PRF-XXXX Aerospace Powder Spec

Specifications

Future: Field/FRC Deployable Robotic Systems

Australian DSTO has adapted a robotic cold spray metallization system for Mobile Repair

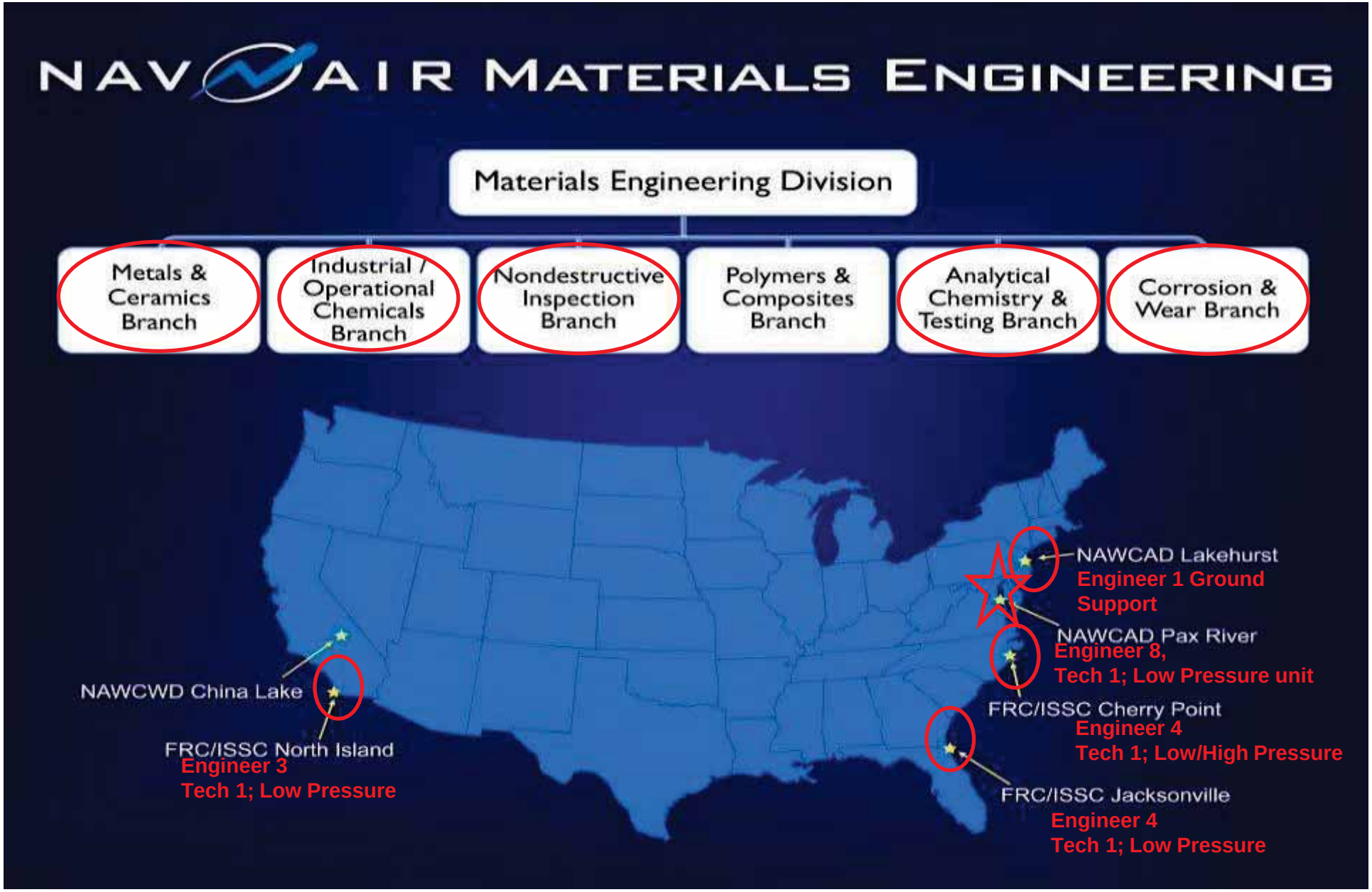
Advantage: Ability to apply CS portably at High Pressures for structural applications or precise repair.

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.

*Rosebank Engineering presentation "TSS Cold Spray Conference 2010-Cold Spray application in Australian Aerospace Industries-Neil Matthews" DSTO Project

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)

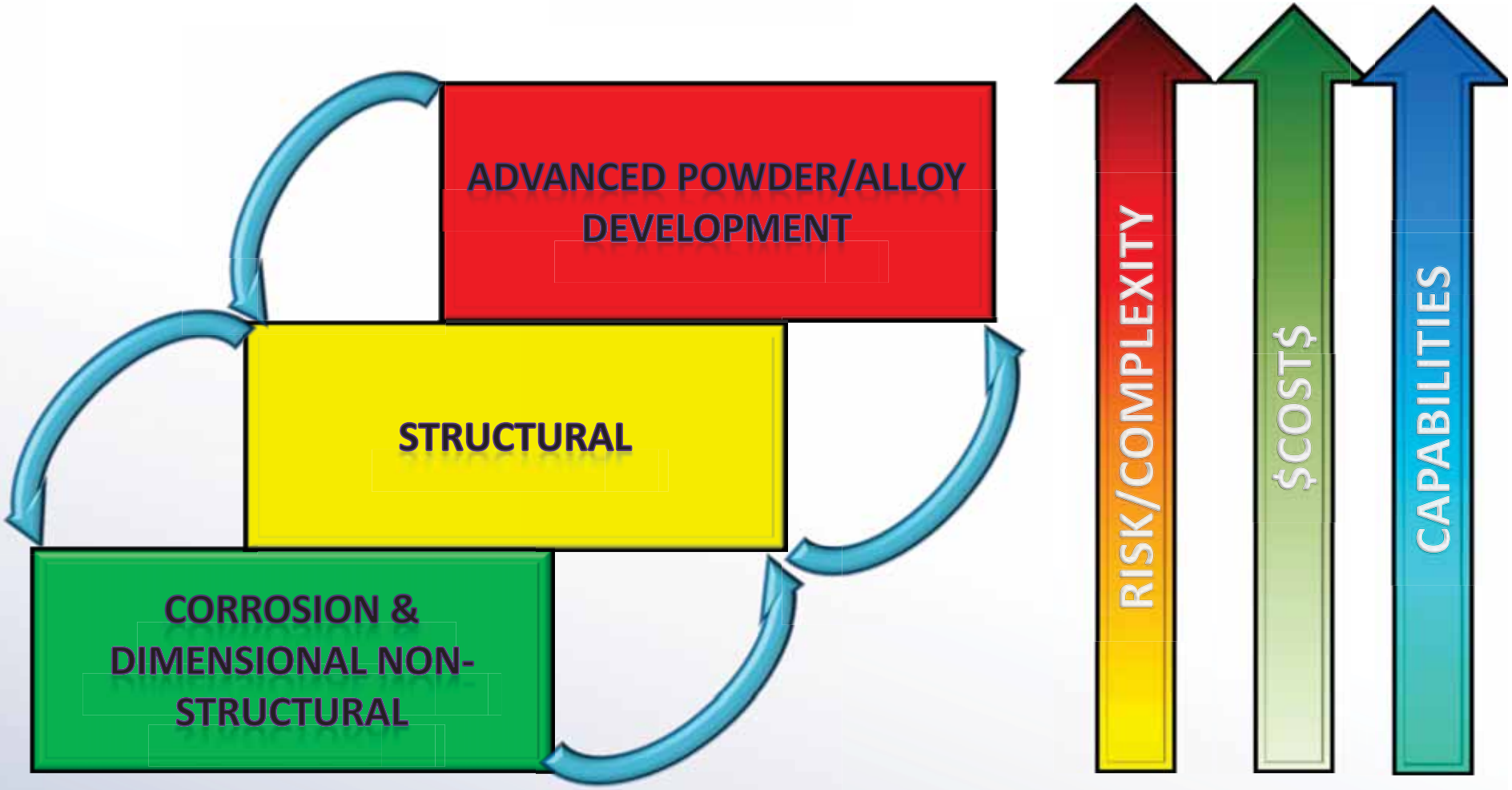
S&T Analysis

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



Approach

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

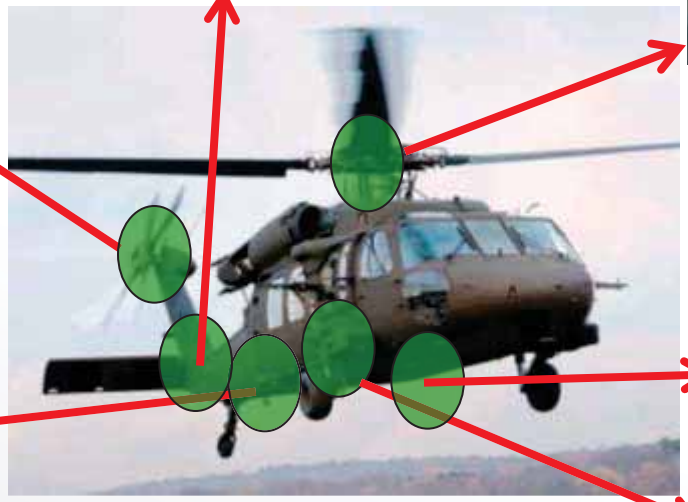
PLATFORM SPECIFIC

Cold Spray Candidate Parts
Targeted Repair Facility: FRC-East Cherry Point

Cold Spray Candidate H-60 Seahawk Applications

Fold Point Bushings/Canted Bulkhead

Cold Spray to main module sump and Flight (forward bridge) control pad



Lift Hook/Hoist

*Rosebank Engineering presentation "TSS Cold Spray Conference 2010-Cold Spray application in Australian Aerospace Industries-Neil Matthews" DSTO Project

NAVAIR

H-60 Sump – Approved by SAC
Dimensional/Non-Structural

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

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

H-60 TAILGEARBOX
Corrosion/Dimensional Non-Structural

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.

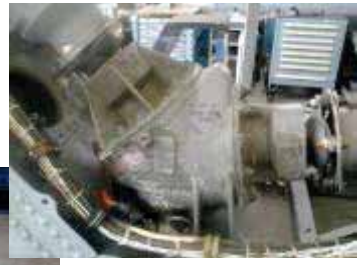
Potential Repair:

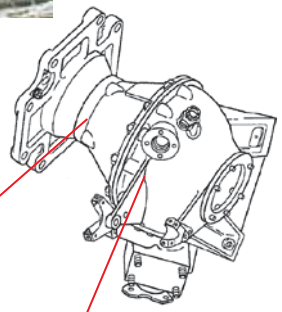
Apply cold spray after blending to fill repair area.

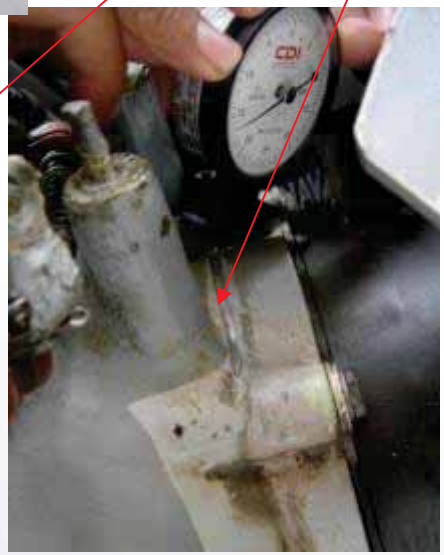
- **Provides sacrificial layer to prevent further contact with magnesium housing.**

- **Apply cold spray prior to chaffing to prevent corrosion from starting.**

Tail Transfer Box







H-60 INPUT MODULE
Corrosion/Dimensional Non-Structural

Input Module info:

Part numbers: 70351-08001-044, -045, -046, -048, -049, and -050.

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.

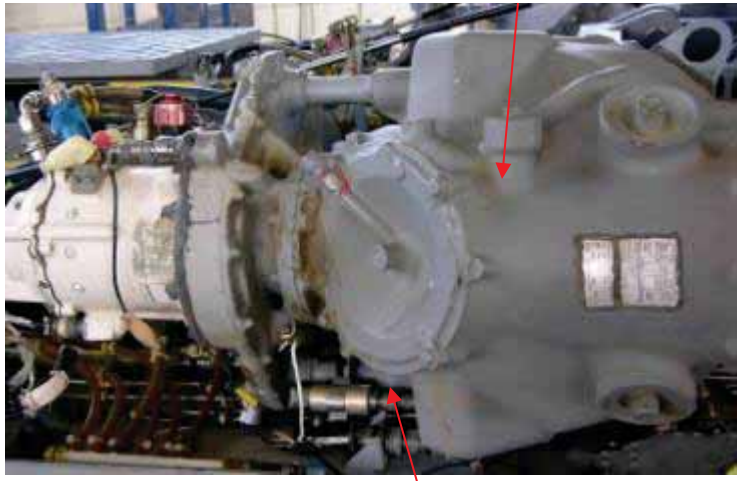
- Limit is generic for entire center housing.
- Unable to determine wall thickness at O-level to develop individual repairs.

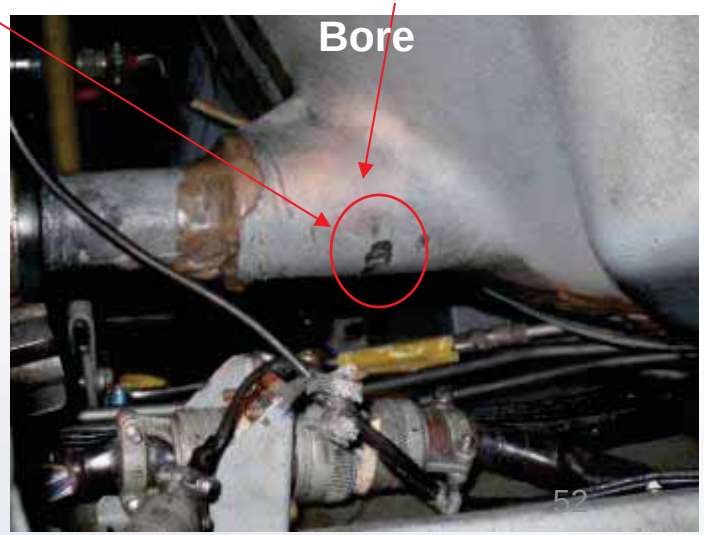
Potential Repair:

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.





H-60 MAIN GEARBOX Structural

Main Gearbox info:

Part numbers: 70351-38100-042, -044, and -046 thru -050.

Housings are ZE41A magnesium.

Problem:

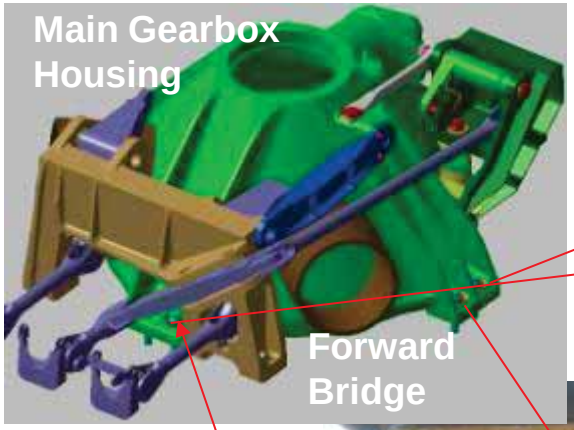
Forward Bridge attaches to Main Gearbox.

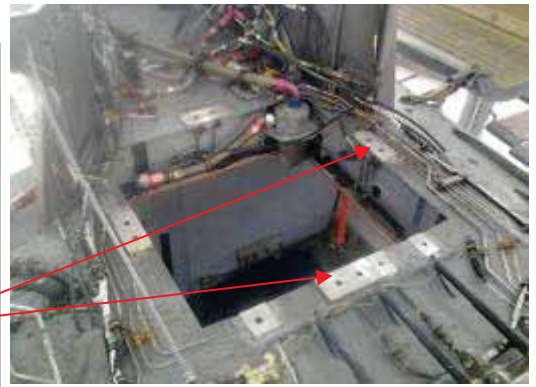
Dissimilar metals (Mg Housing, cad-plated steel bushings, steel dowel pins, aluminum support) lead to galvanic corrosion of Main Gearbox Housing.

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)

H53 Gearbox	Housing	Part Number
Main	Main	65391-11602-044
	Rear Cover	65391-11662-042
Nose	Center	65355-12048-043
		65355-12051-043
	Input	65355-12026-041
	Output	65355-12002-043
	Front Cover	65355-12056-041
		65355-12091-041
Tail	Horn	65395-07001-043

Structural/Dimensional

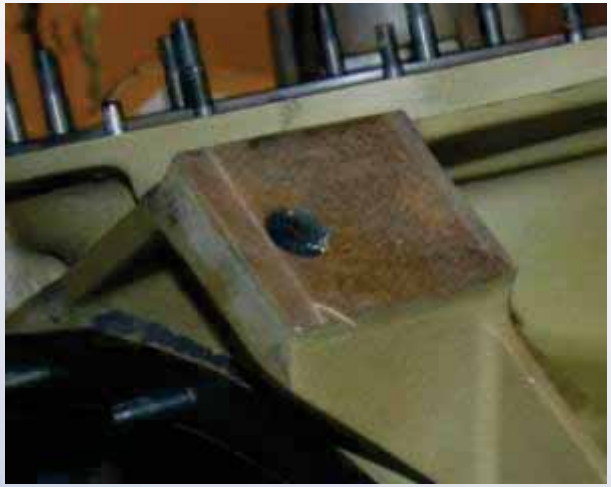
H53 Main GEARBOX

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.

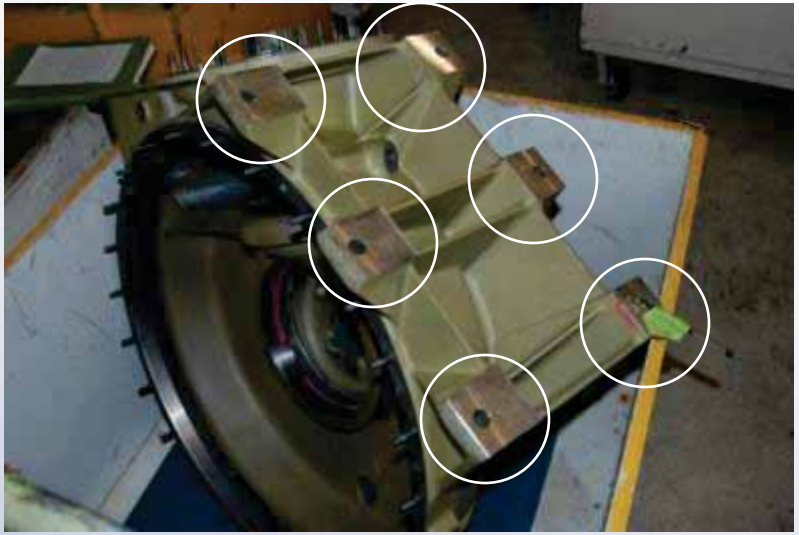
FRC EAST Update

TGB output housing

Corrosion of pilot bore

FRC EAST Update

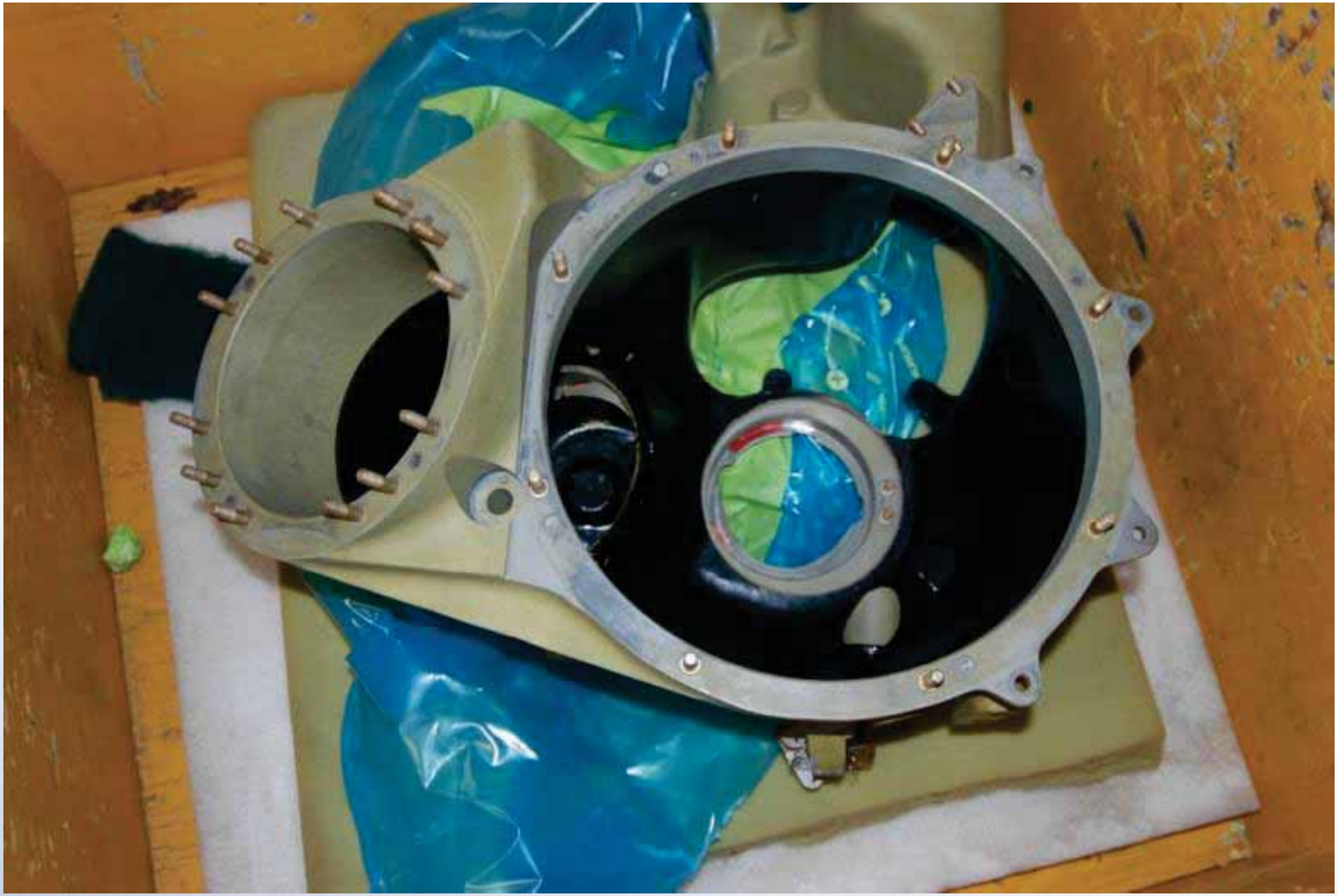
H53 TAIL GEARBOX



MOUNTING FEET LOCATIONS

NAVAIR

FRC EAST Update
H53 NOSE GEARBOX



NAVAIR

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

NAVAIR

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.

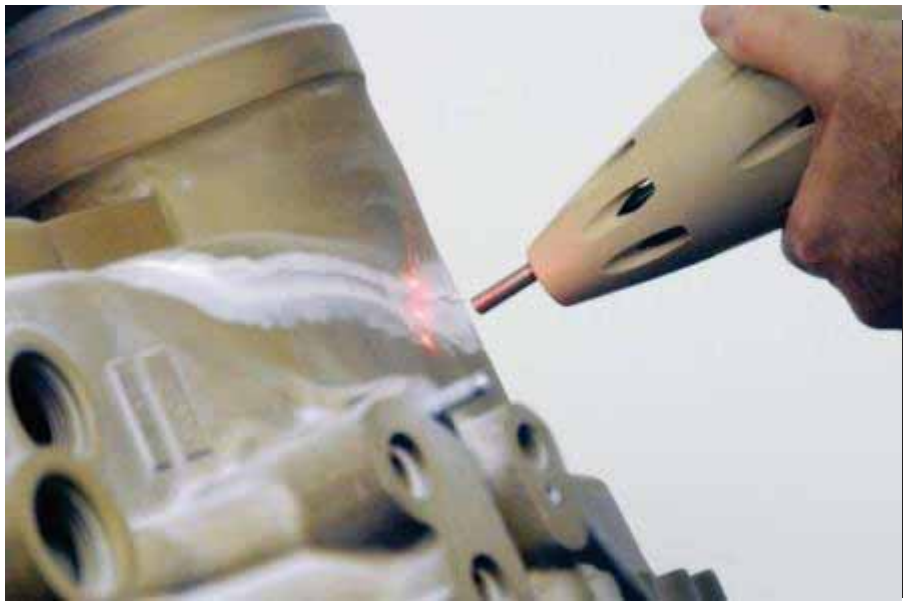
Value to Naval Warfighter:

- 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,

NAVAIR

H-1 Combining Gearbox Chaffing Repair via Cold Spray

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

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

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

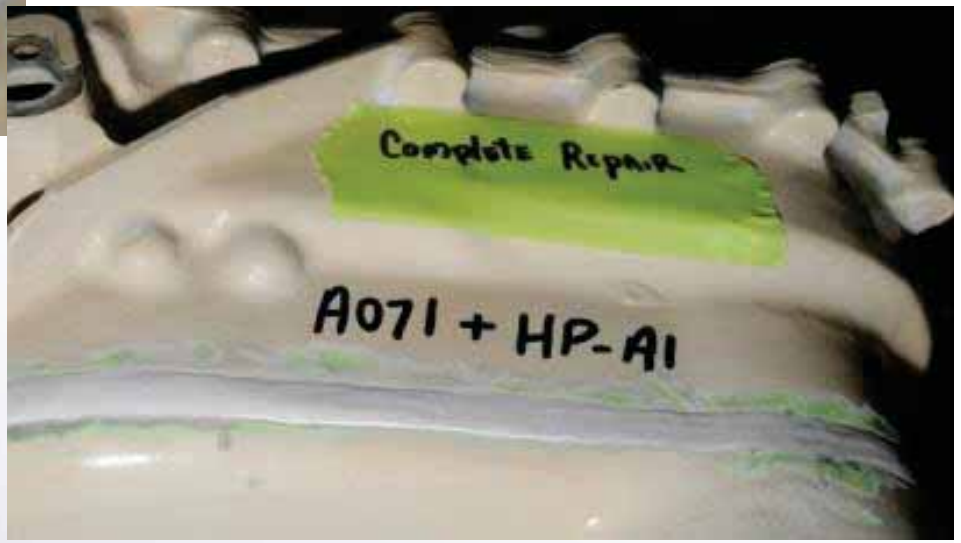
TECHNOLOGY TRANSITION PROGRAMMATICS

Source	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	Total
Transition Funding ($M)									
ONR TIPS PE 0203761N	$1.100	$0.700	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$1.800
Sub-Total	$1,100	$0.700	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$1.800
Integration Funding ($M)									
PoR-276 & PE 0206131M	$0.000	$0.000	$0.100	$0.000	$0.000	$0.100	$0.000	$0.000	$0.200
Sub-Total	$0.000	$0.000	$0.100	$0.000	$0.000	$0.100	$0.000	$0.000	$0.200
Procurement Funding ($M) and Quantity to be Procured/Deployed									
PoR-276 & PE 0206131M	$0.000	$0.000	$0.400	$0.000	$0.000	$0.200	$0.000	$0.000	$0.600
QTY	xx	xx	2	xx	xx	2	xx	xx	4
Sub-Total	$0.000	$0.000	$0.400	$0.000	$0.000	$0.200	$0.000	$0.000	$0.600
TOTAL	$1,100	$0.700	$0.500	$0.000	$0.000	$0.300	$0.000	$0.000	$2.600

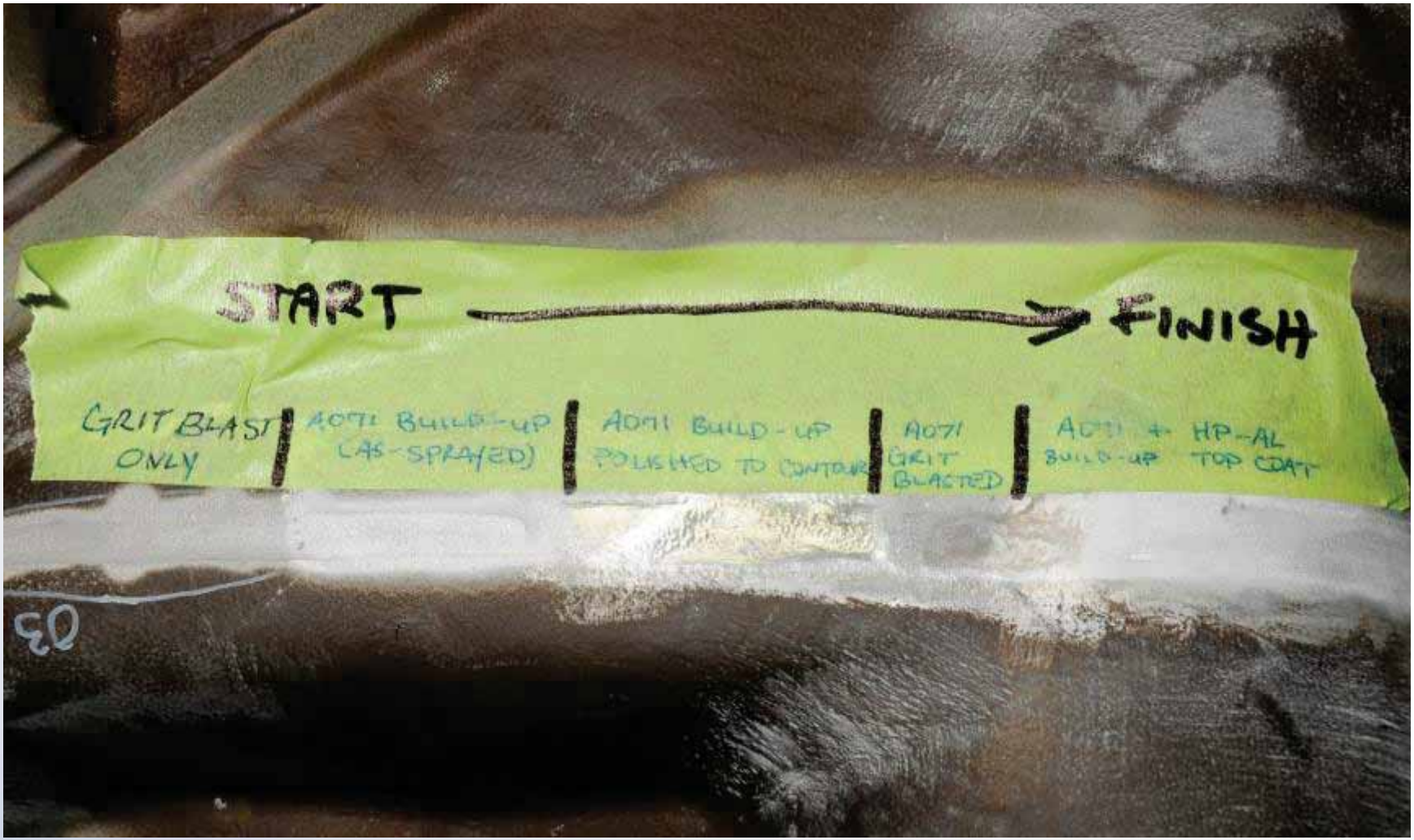
Organization	Milestone/Task	FY11	FY12	FY13	FY14	Total
PMS-276	Project Administration	$0.100				$0.100
ARL (Aberdeen).	Adhesion Testing, Powder & Equipment Evaluations	$1.000	$0.000			$1.100
ARL (Aberdeen).	Process Parameter Development		$0.500			$0.500
ARL (Aberdeen).	Training Package Validation		$0.100			$0.100
NAVAIR	Process Review and Approval		$0.100			$0.100
	Total Transition Funding ($M)	$1.100	$0.700			$1.700

NAVAIR

FRC EAST Update



FRC EAST Update

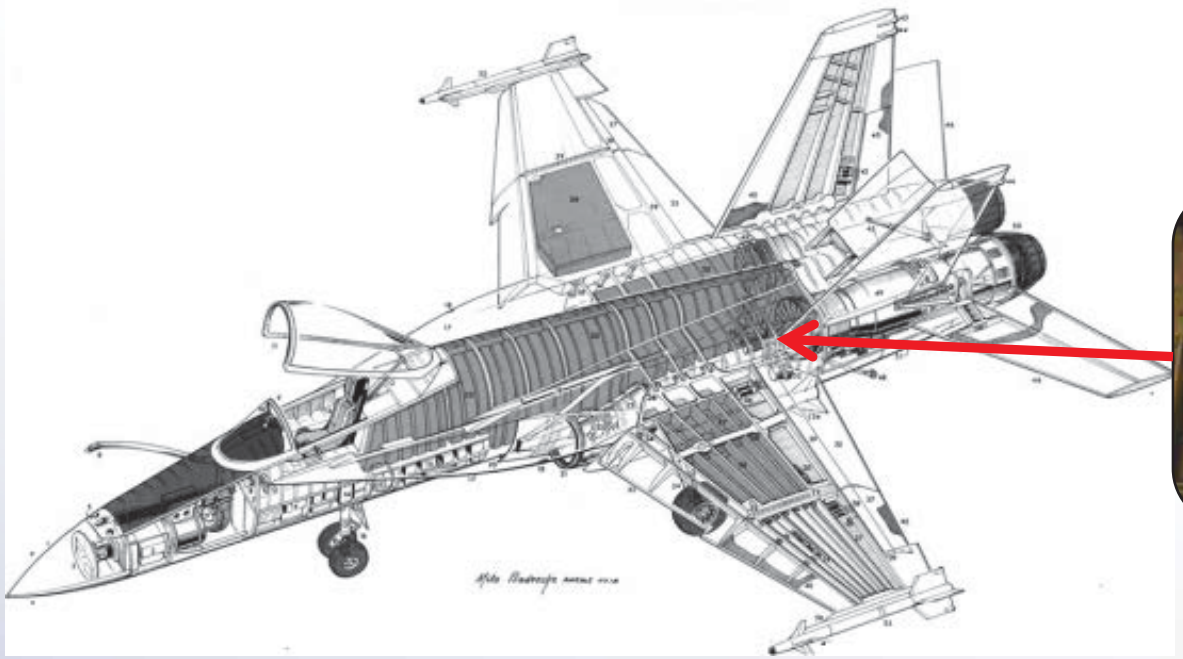


FRC-SouthWest & FRC SouthEast Updates

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

Objective

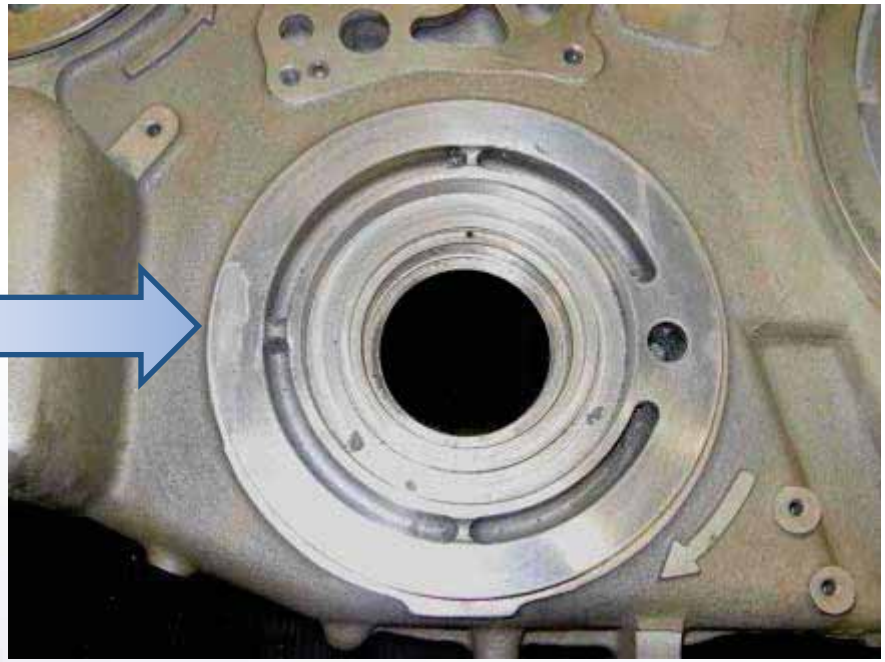
Objective: Repair both fretting corrosion and internal dimensional damage to the AMAD Gearbox



F-18 AMAD Gearbox Repair Fretting Corrosion: Repaired Back in Fleet FRC-SW

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.

Gearbox Damaged



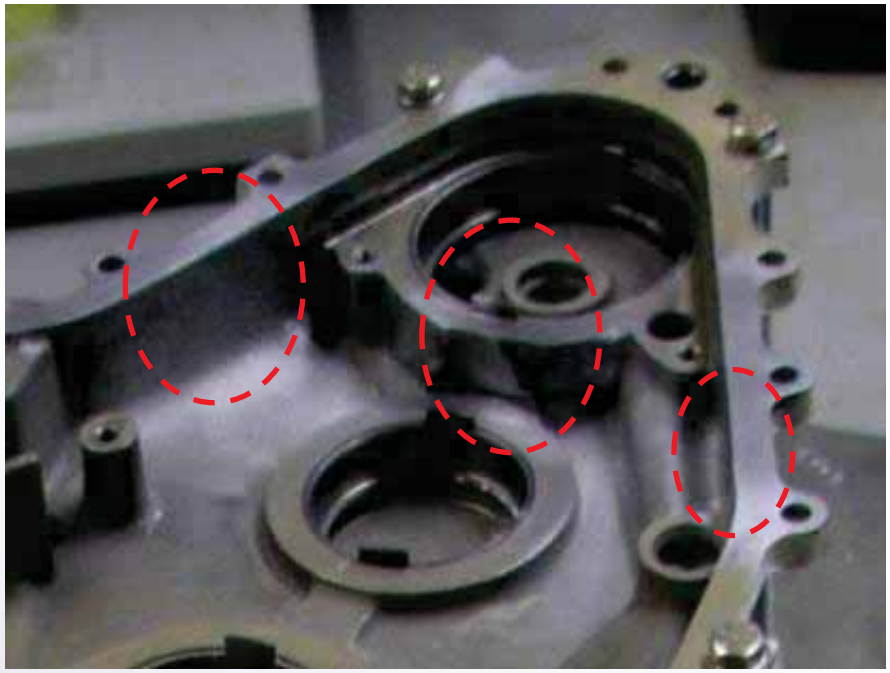
Gearbox CS Repaired

F-18 AMAD Dimensional Gearbox Repair FRC-SW

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

Gearbox Damaged



Gearbox CS Repaired

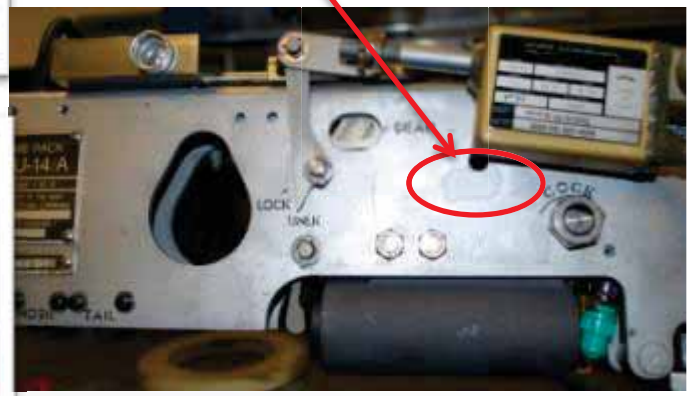
F/A-18 Bomb Rack Repair FRC-SE

- 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.

Repair area



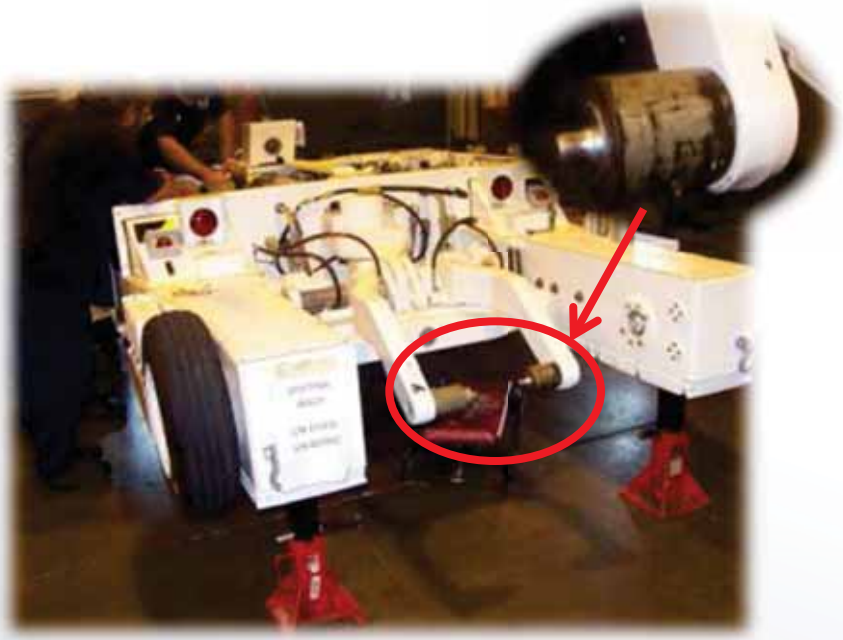
Currently in Supply as of Dec 10 2012

NAVAIR

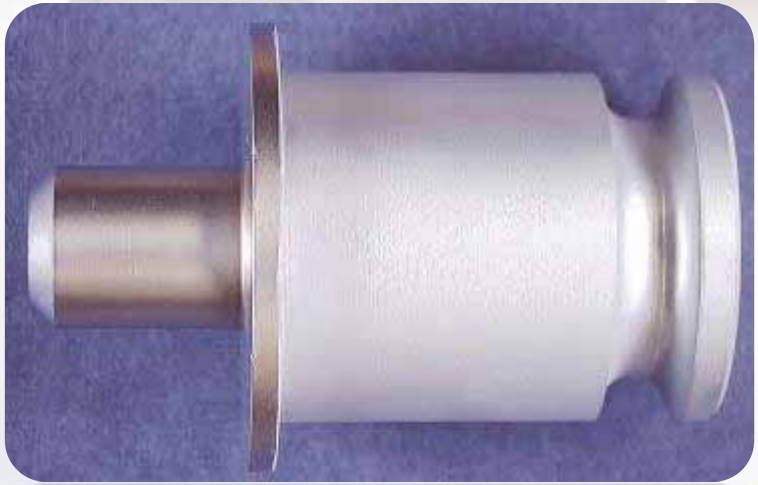
OTHER APPLICATIONS

Spotting Dolly Axel Pin FRC-SE

- **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”)

IVD Aluminum Repair & Cadmium Plate Repair New Start

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.

iMAST Overview

- **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

Materials and Manufacturing

Mission and Organization

MISSION

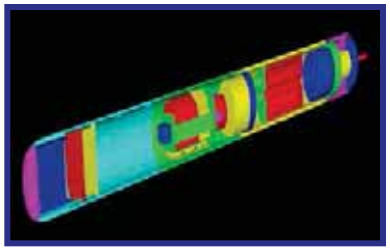
To be the preeminent source of innovative technologies-materials, process, manufacturing, and design technologies for affordable, high performance DoD platform structures and systems.

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

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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**

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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**

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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

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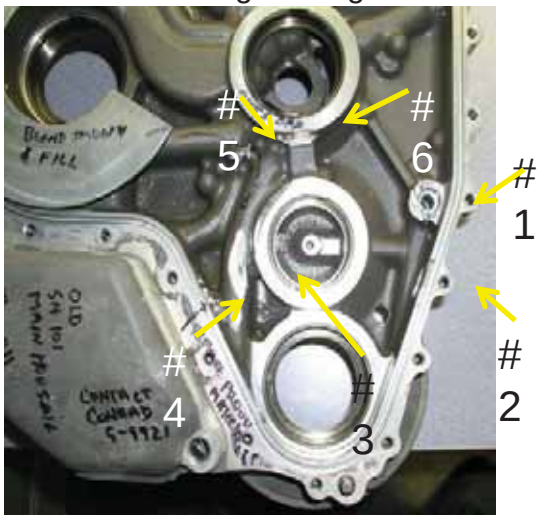
F-18A AMAD Gearbox Housing

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

Fretting Damage



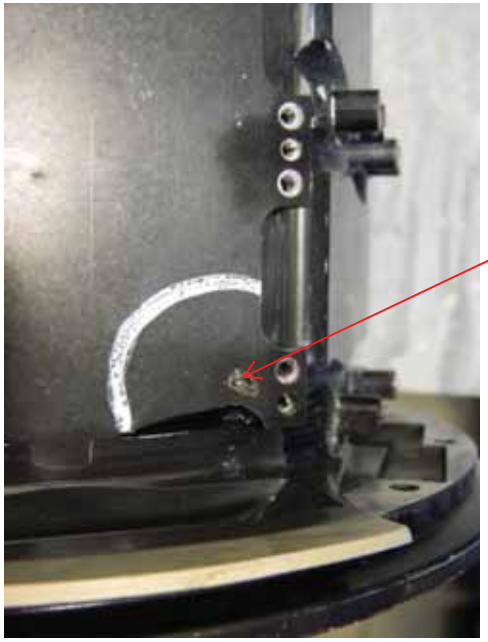
#1 Material removed for oil port
#2 Material removed for sealing surface
#3 Material removed from wall of oil passage
#4 Gear impact damage
#5 Cracked oil passage
#6 Material removed

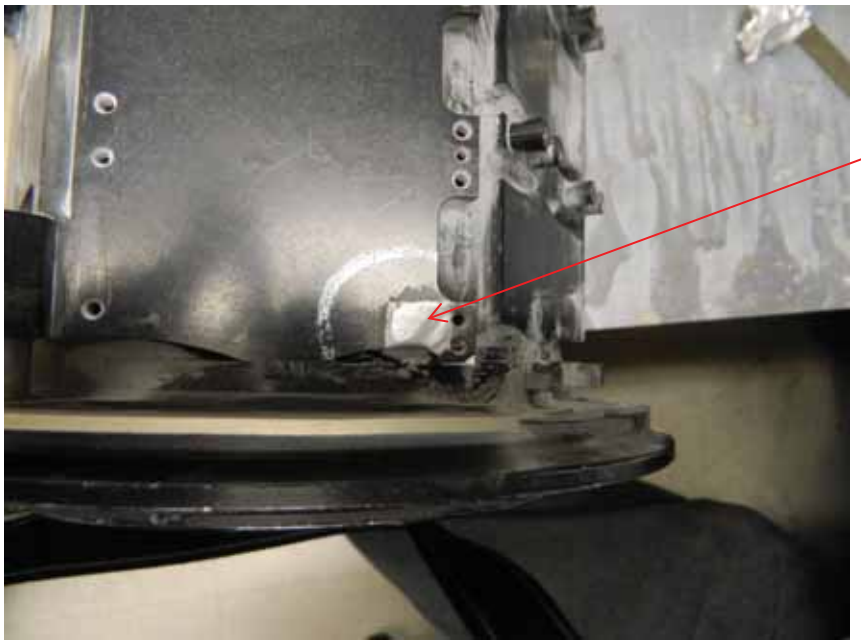
Additional Repairs

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**





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Repair Example

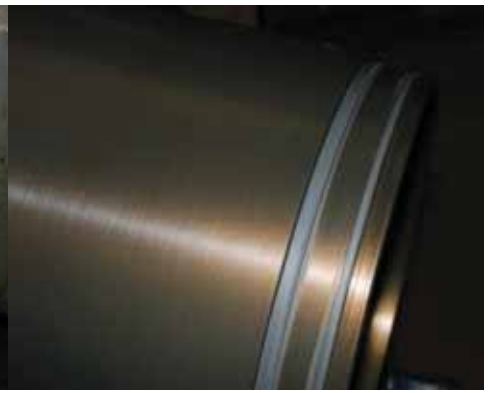
Material Restoration of Al-7175 Component for Undersea Applications

- 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

Coating set-up

Al-7075 Coating

Re-machining



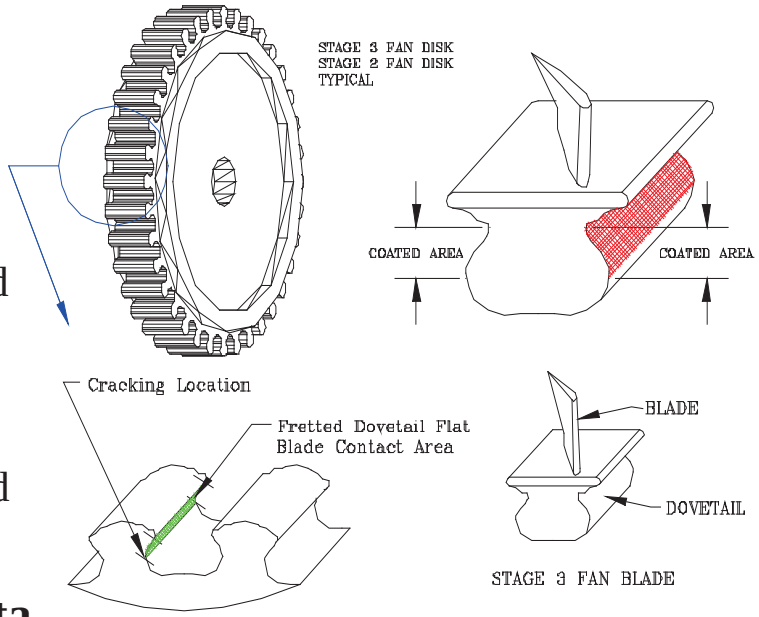
Anodized and Pressure Tested

Self-Lubricating Coatings

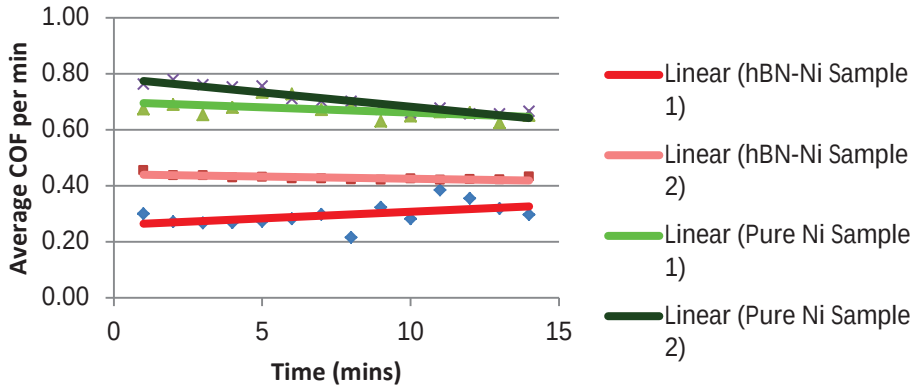
Objective: Develop a composite coating that contains a solid lubricant that has improved wear properties.

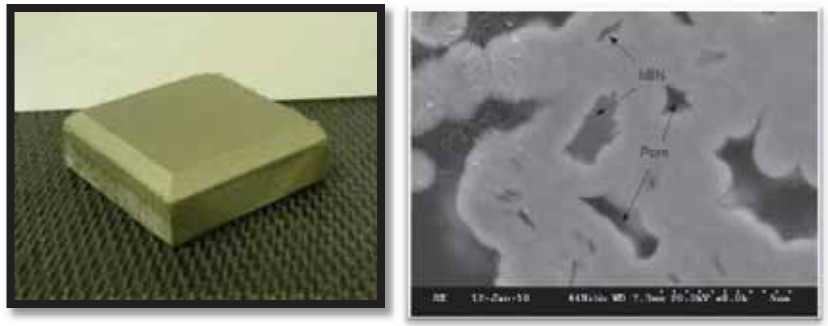
Solution: Develop method to encapsulate solid hBN in Nickel and apply a coating with the encapsulated particles using the Cold Spray Process.

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



Coefficient of Friction Data



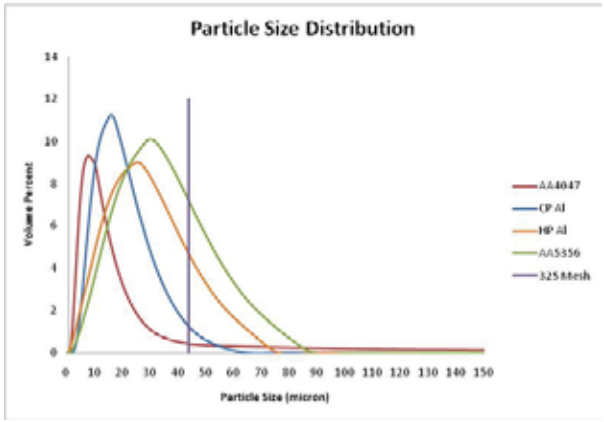


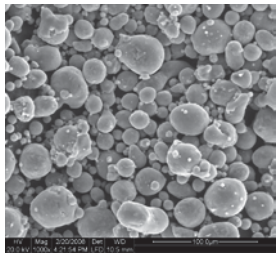
Cold Spray Coating with solid lubricant

Process Development/Evaluation/Characterization

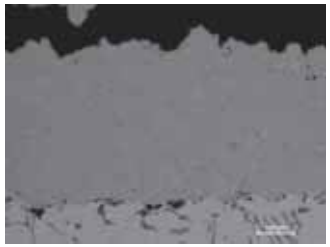
Initial Set-up

- 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

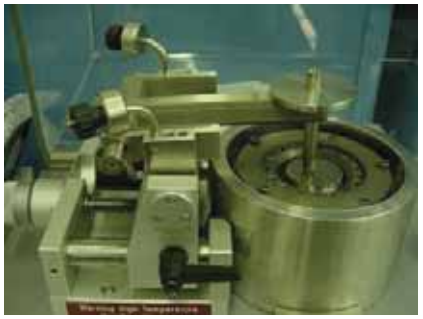




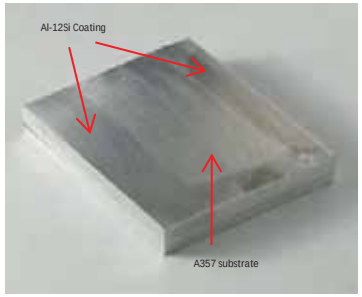
SEM of Al-12Si



Al-12Si Centerline (He) - 100x



CSEM High Temperature Tribology, Wear and Analyses



Thermocycle Testing (500 cycles at -40°F to 250°F)

Materials Characterization

Corrosion Test Capabilities

- 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

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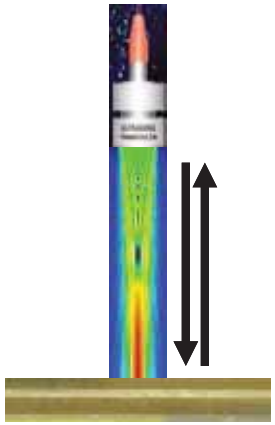
Plate Inspection

CP-Al on Al6061 using Centerline

Test Plate

Cold Sprayed/Machined Plate

Dye Penetrant



Pulse-Echo Configuration

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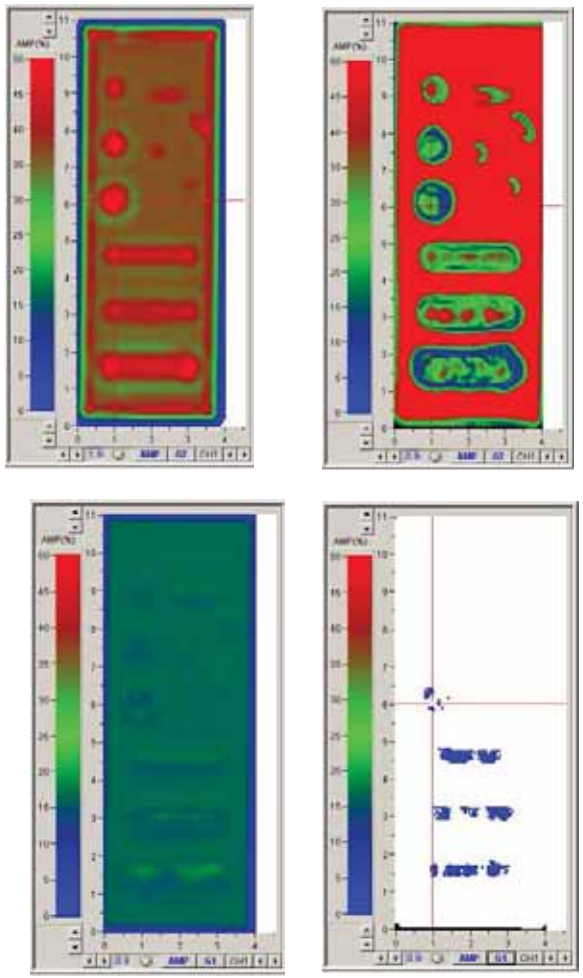
UT Inspection



1 MHz 10 MHz

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

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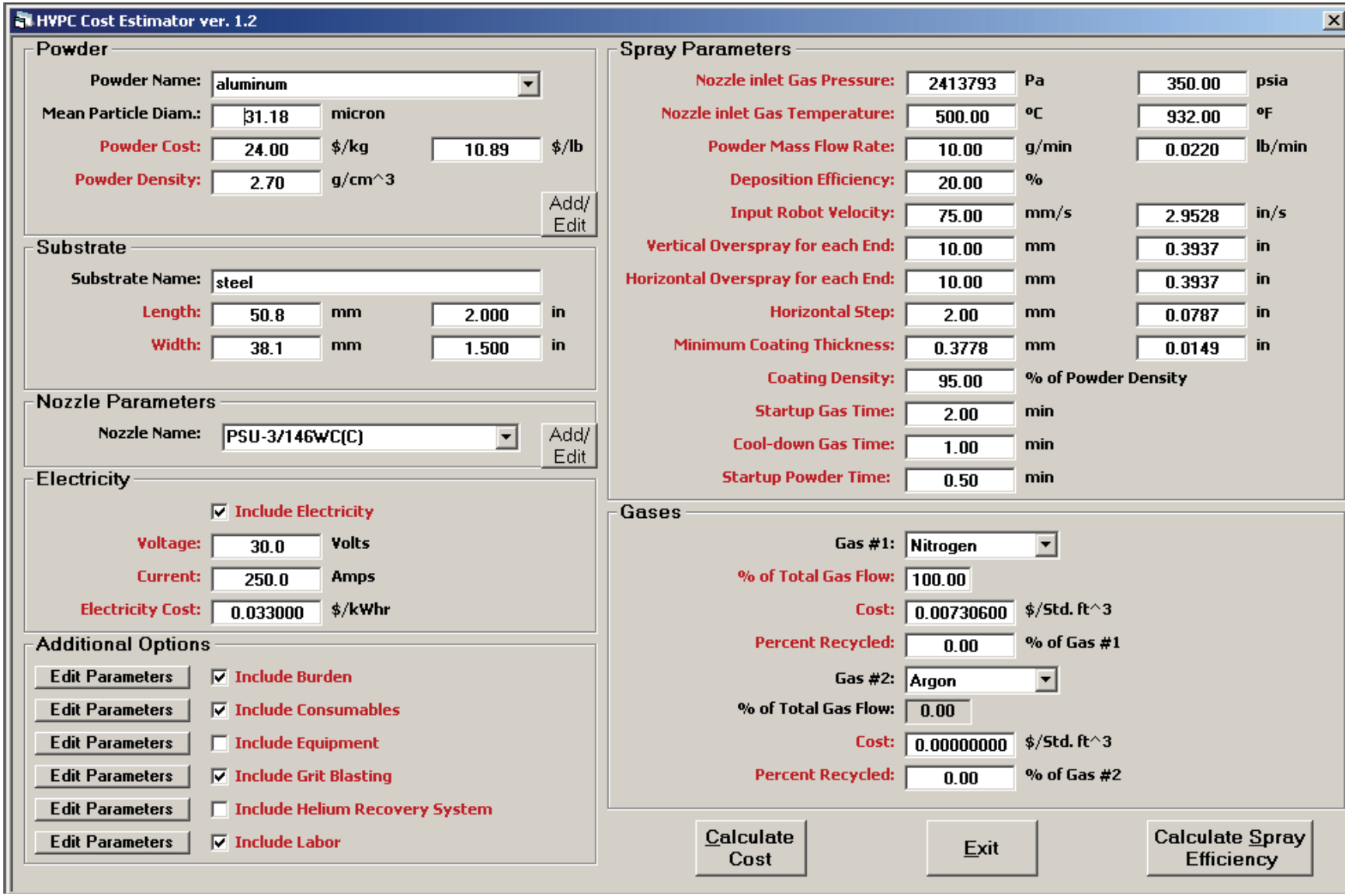
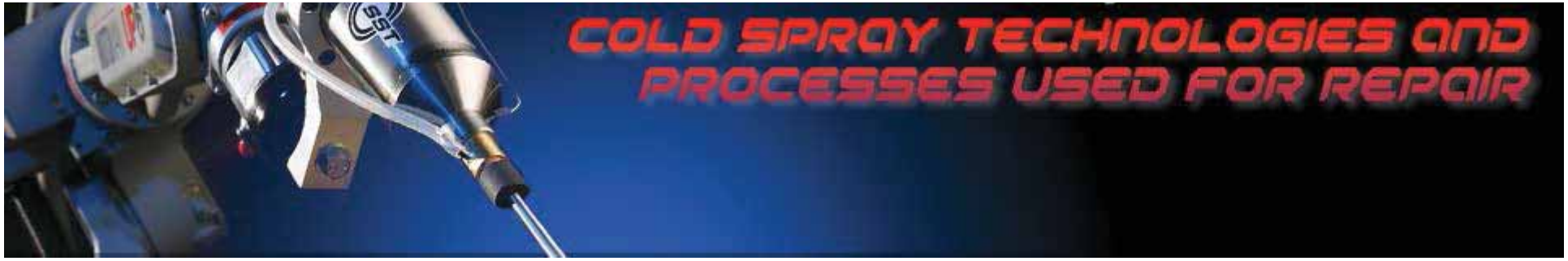
Cost Modeling



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

UNCLASSIFIED

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

UNCLASSIFIED

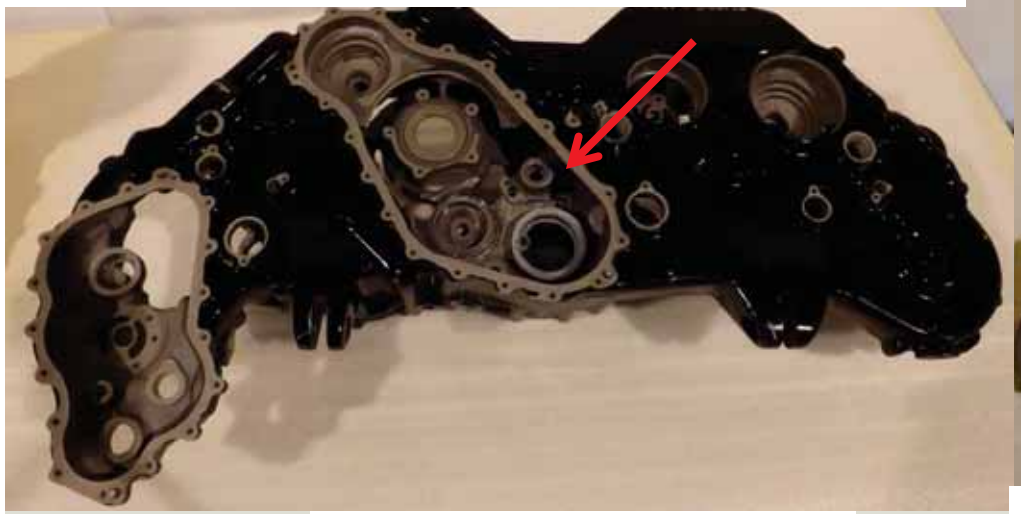
Cold Spray Collaboration

Working Group Led by AFMC/A4UE

CSAF Support

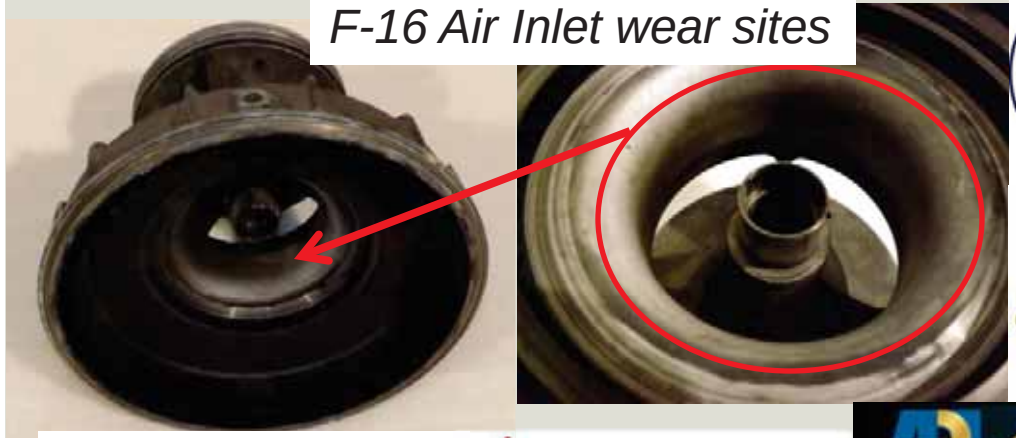
Air Force Applications
Magnesium & Aluminum Housings

F-16 Accessory Drive Gearbox Wear sites



F-15 AMAD wear sites

F-16 Air Inlet wear sites



A-10 Fuel Valve Hsg corrosion

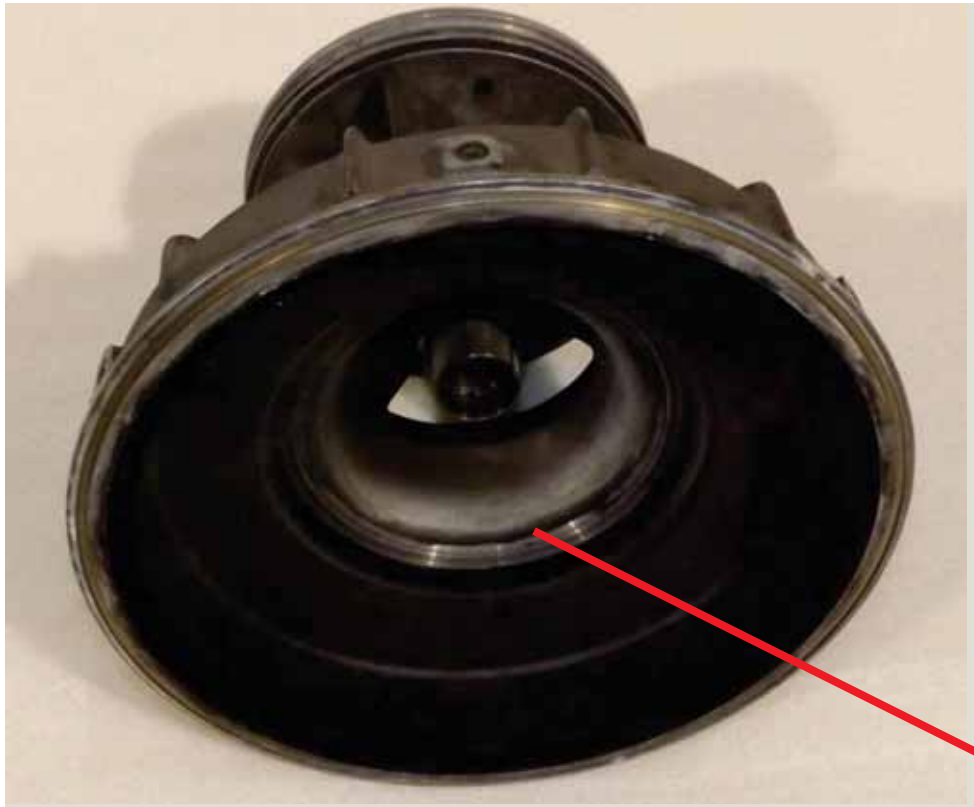
MOOG

HF WEBSTER ENGINEERING SERVICES

R3S Repair, Refurbish, and Return to Service

Problem

F-16 Air Inlet Housing



Mostly Aircraft Availability Issue

Annual Savings: ~$26K

Prototypes developed & cold sprayed

Testing in work

First Article in work

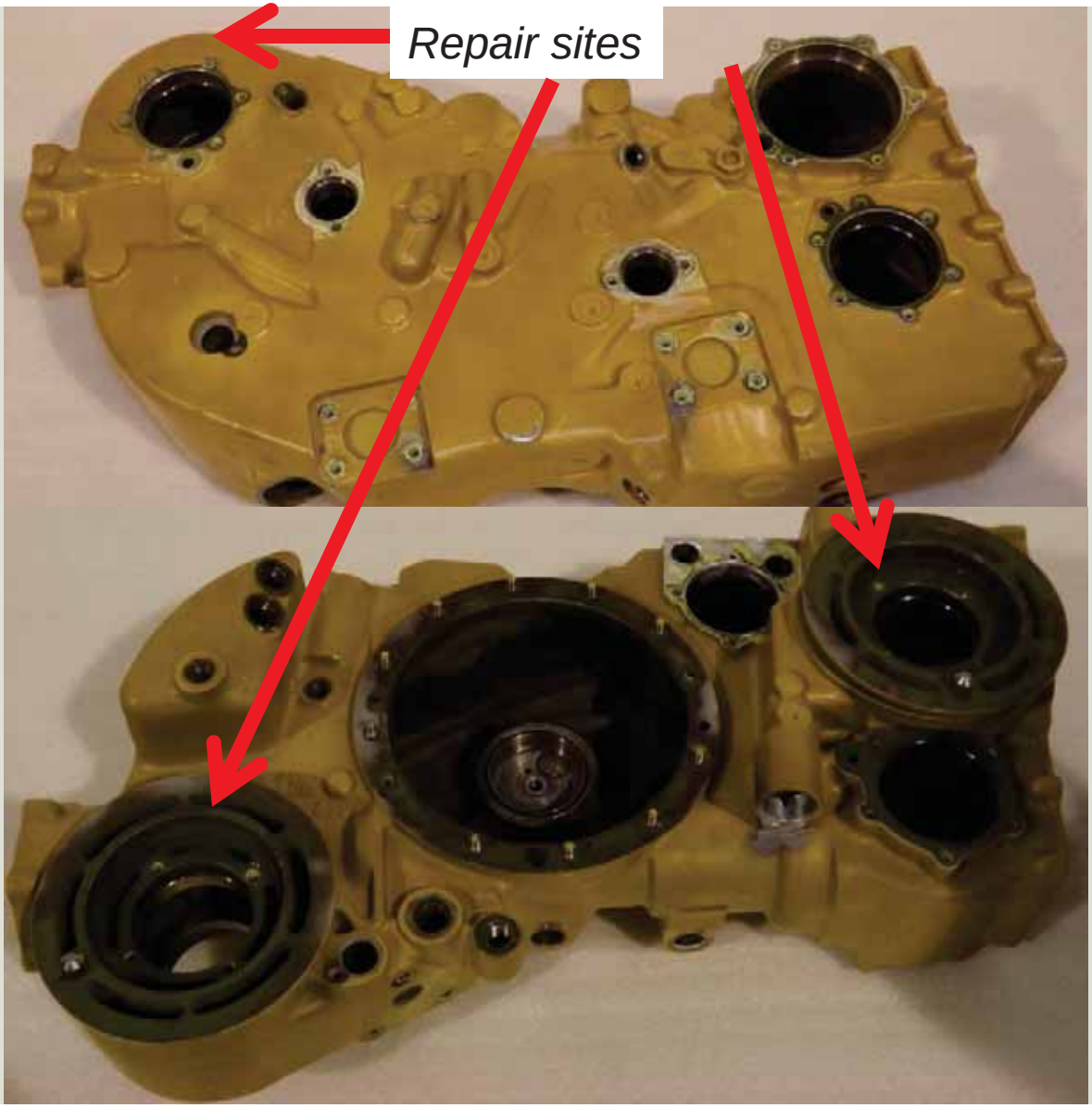
Repaired Sump

Nominated by

AFMC Gen Wolfenbarger Staff

Problem

F-15 AMAD - Magnesium Housing



Nominated by AFMC

Gen Wolfenbarger Staff

Spares availability problem

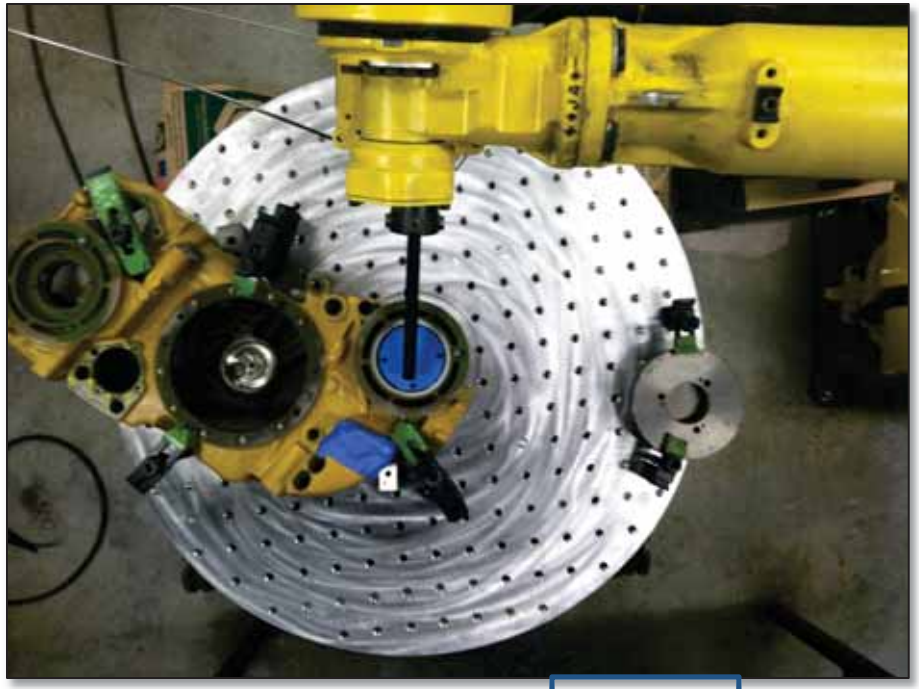
High Cost/High Demand

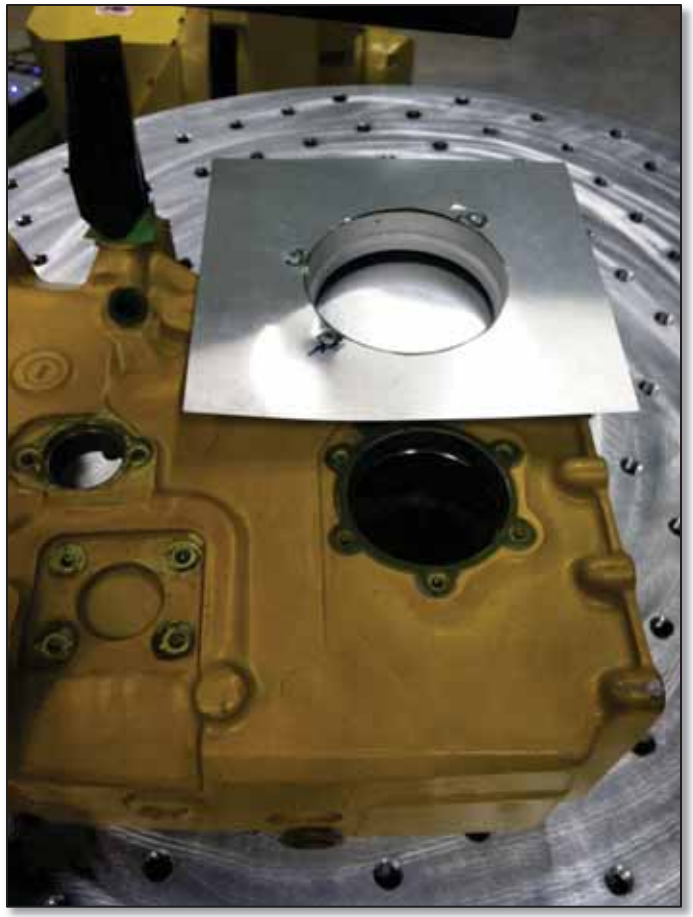
Test Article Cold Sprayed

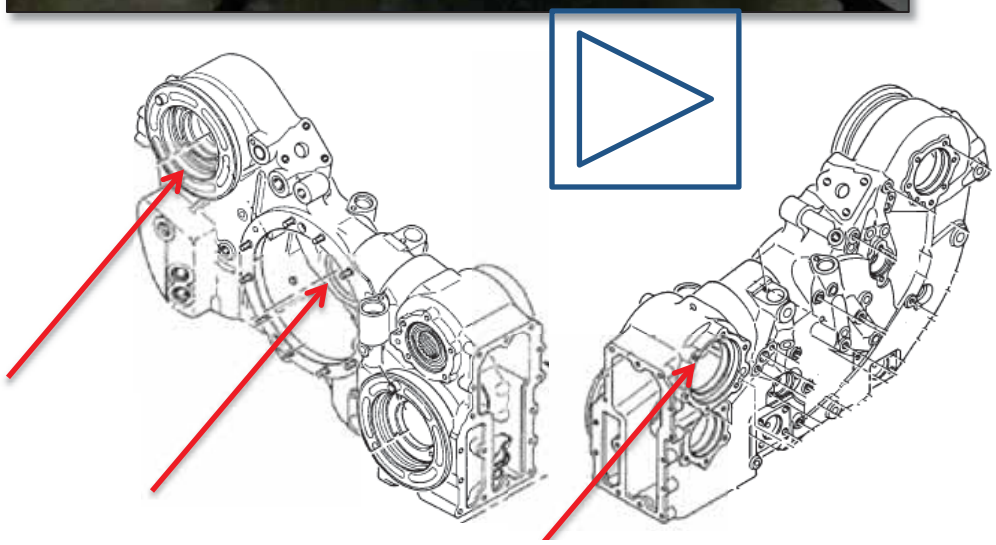
Annual Savings ~ $472K

%ROI: 8086%

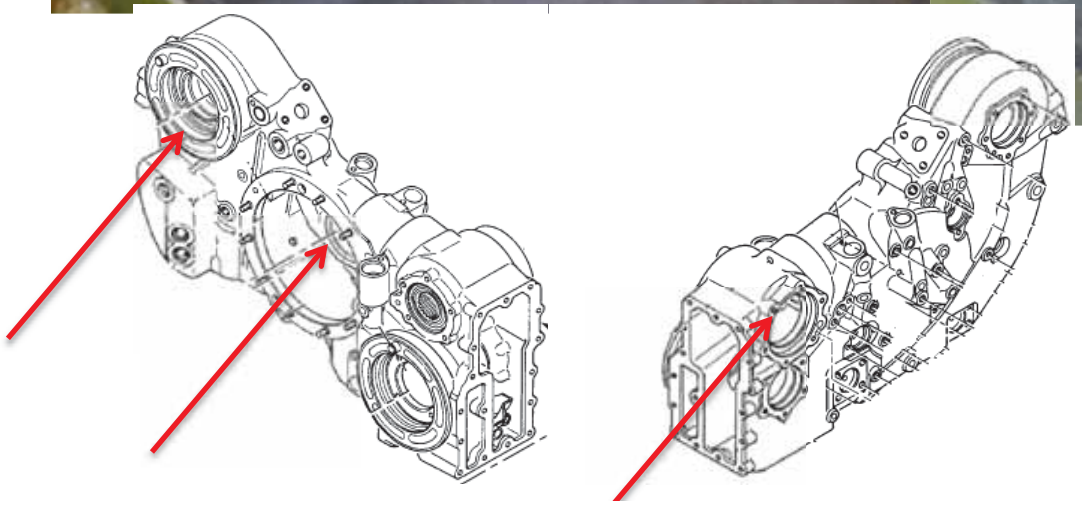
F-15 AMAD: Masking





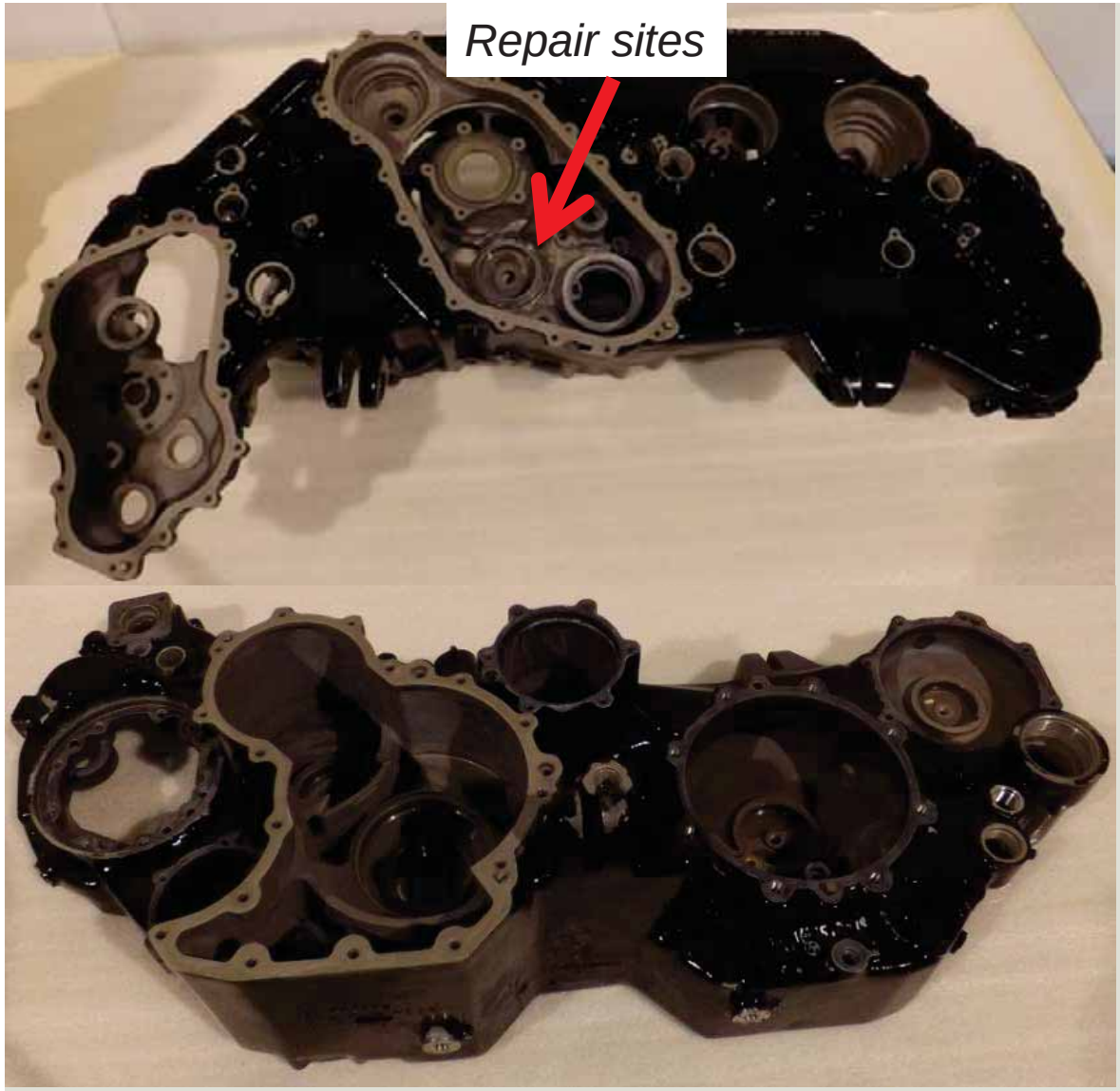


F-15 AMAD: Bore Repair



Problem

F-16 ADG- Magnesium Housing



Nominated by AFMC

Gen Wolfenbarger Staff

Spares availability problem

High Cost/High Demand

%ROI: 6337%

Annual Savings ~$317K

Automation Development

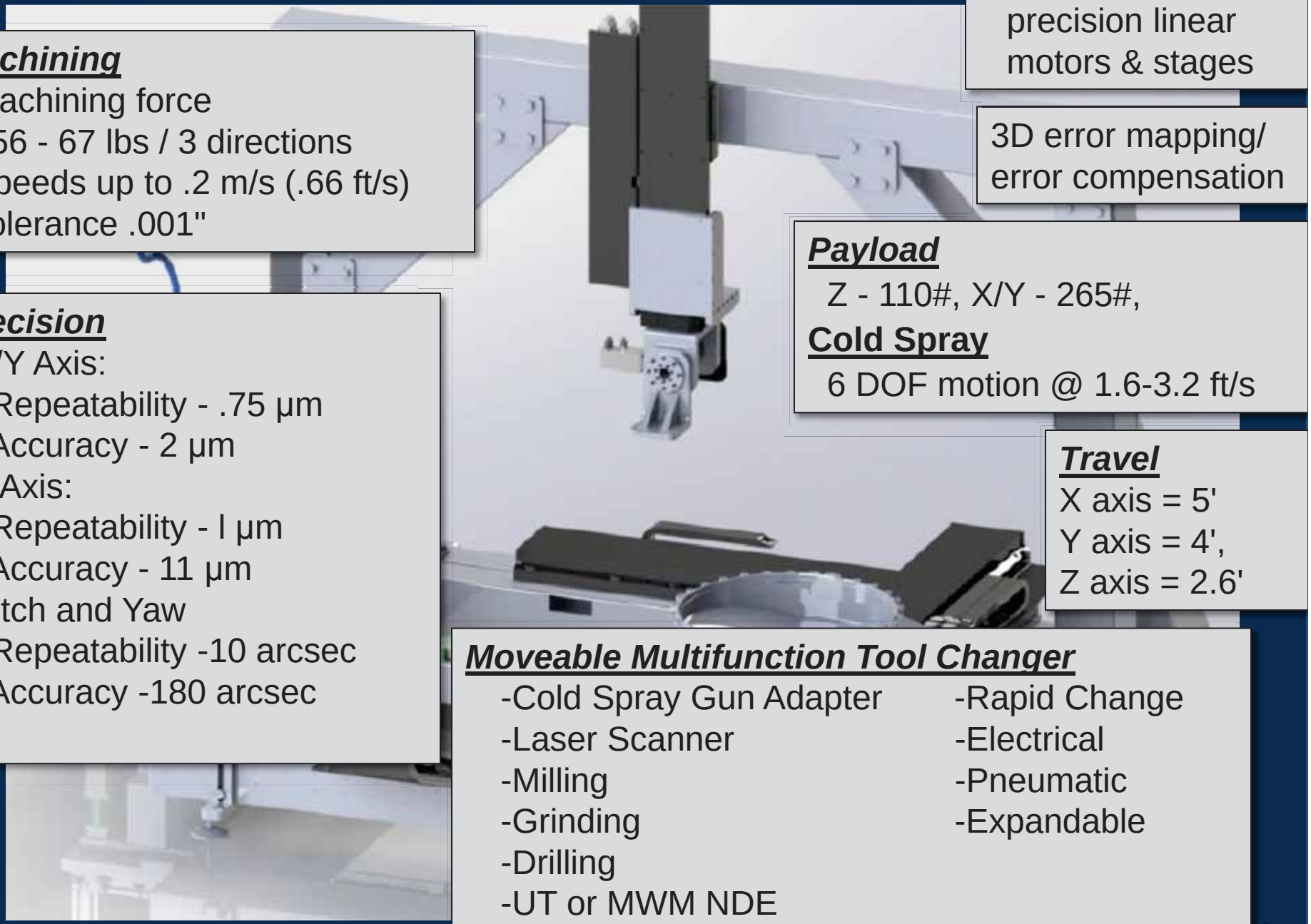
Transition cold spray repair technology into production

- 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

6 Degree of Freedom Modular Motion System



Aerotech high precision linear motors & stages

3D error mapping/ error compensation

Machining

Machining force
56 - 67 lbs / 3 directions
Speeds up to .2 m/s (.66 ft/s)
Tolerance .001"

Payload

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

Cold Spray

6 DOF motion @ 1.6-3.2 ft/s

Precision

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

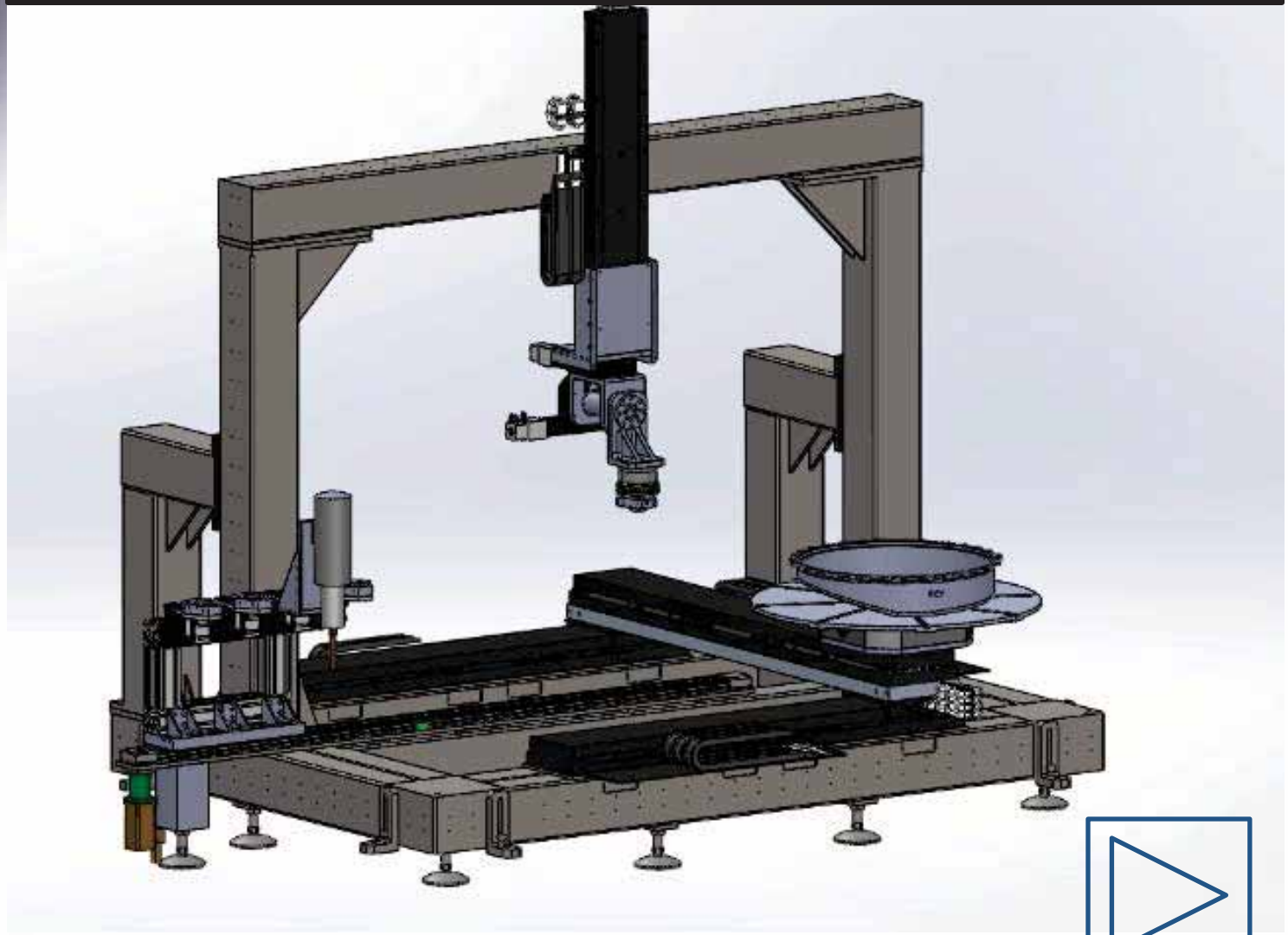
Travel

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

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

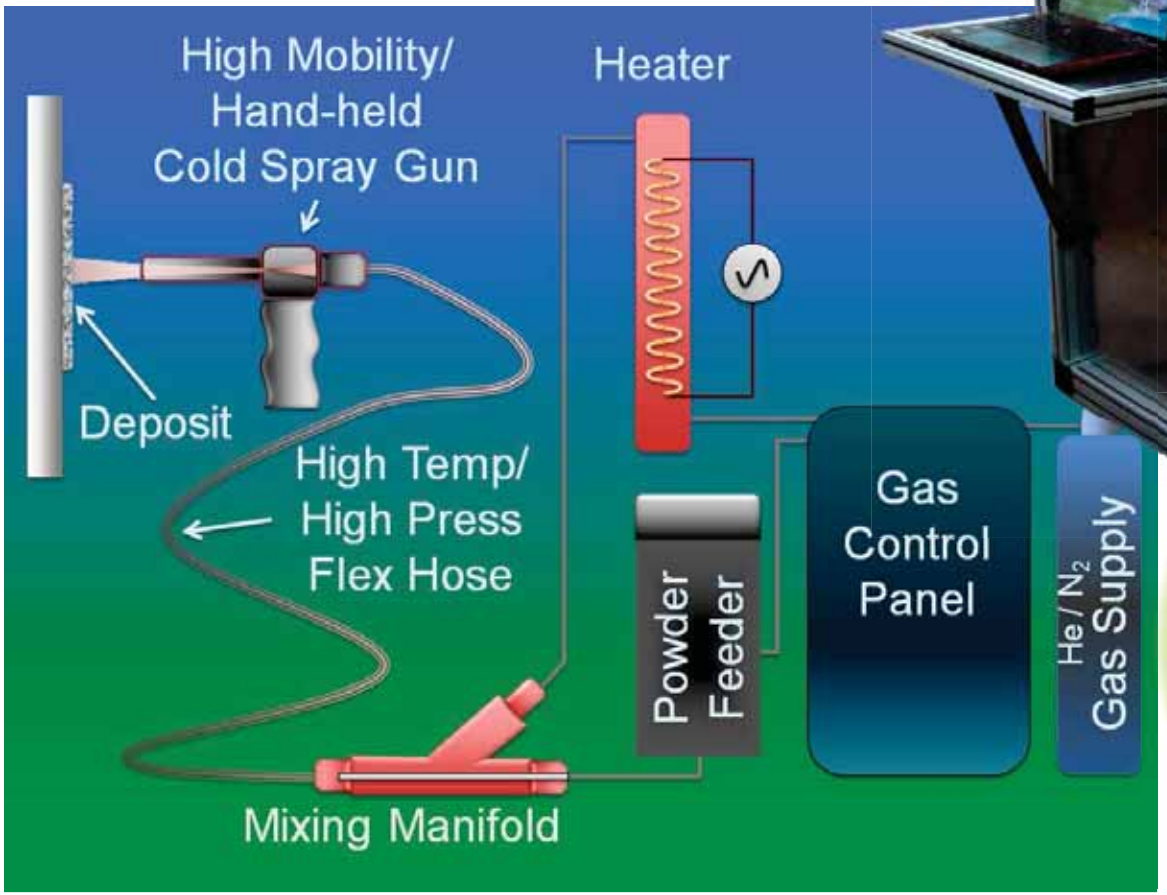
- **Standard Operating System reduces process development costs and allows for distributed repair operations**
- **Improved Quality and Repeatability of Repair**
- **Large workspace up to ~ 5’ x 4’ x 2.6’**
- **Processing of small and large parts**
- **All-in-one system reduces time to repair, difficulty, & 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

VRC METAL SYSTEMS

Commercialization Partner
Licensed Through ARL

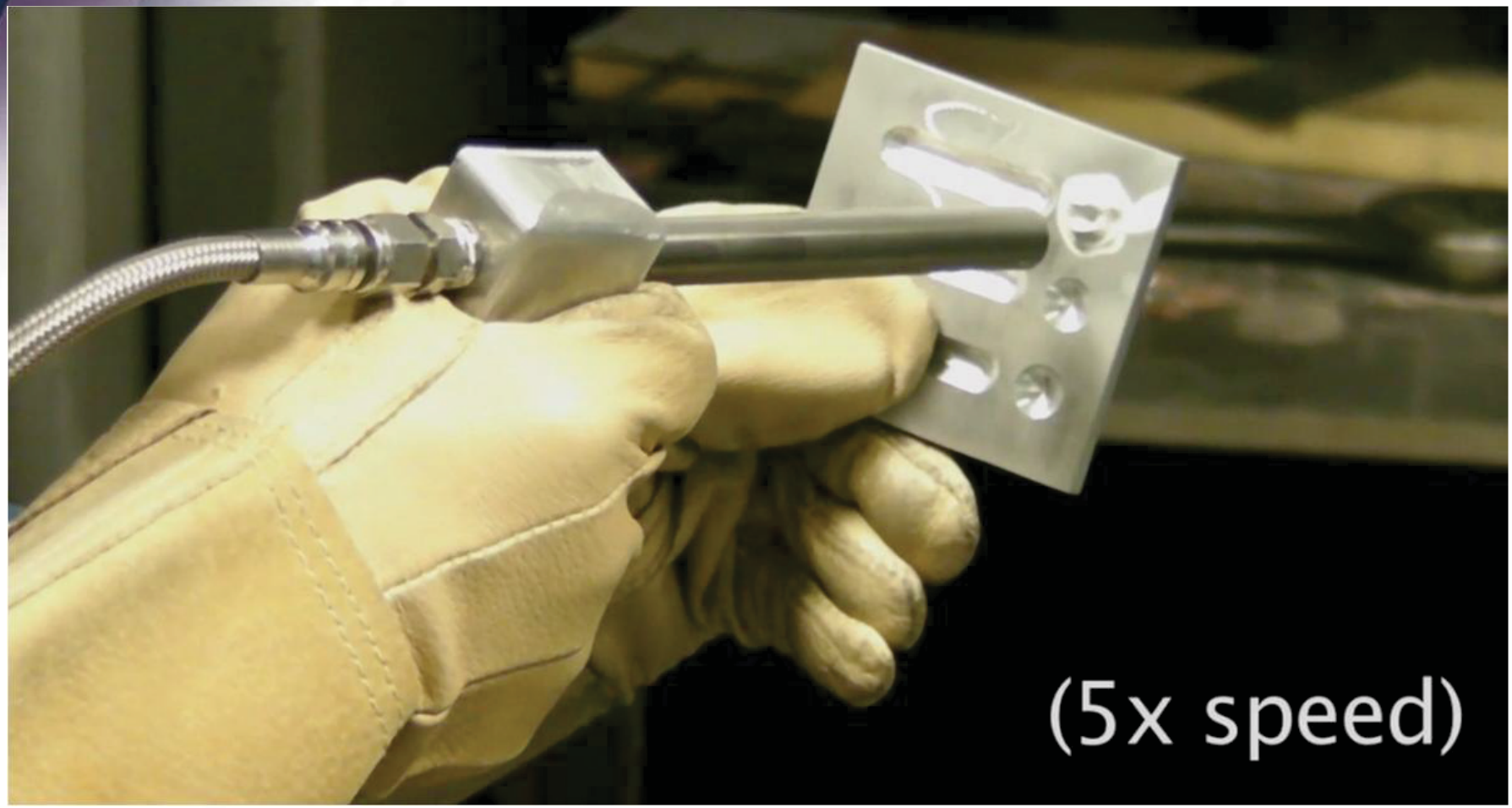


Portable Aluminum Skid

Portable Gas Supply

Compact Gun
Access small spaces

Video of the cold spray process:



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Problem

B-1 Forward Equipment Bay (FEB) Panels

28th MXG Initiative

Panels no longer manufactured

A/C availability problem

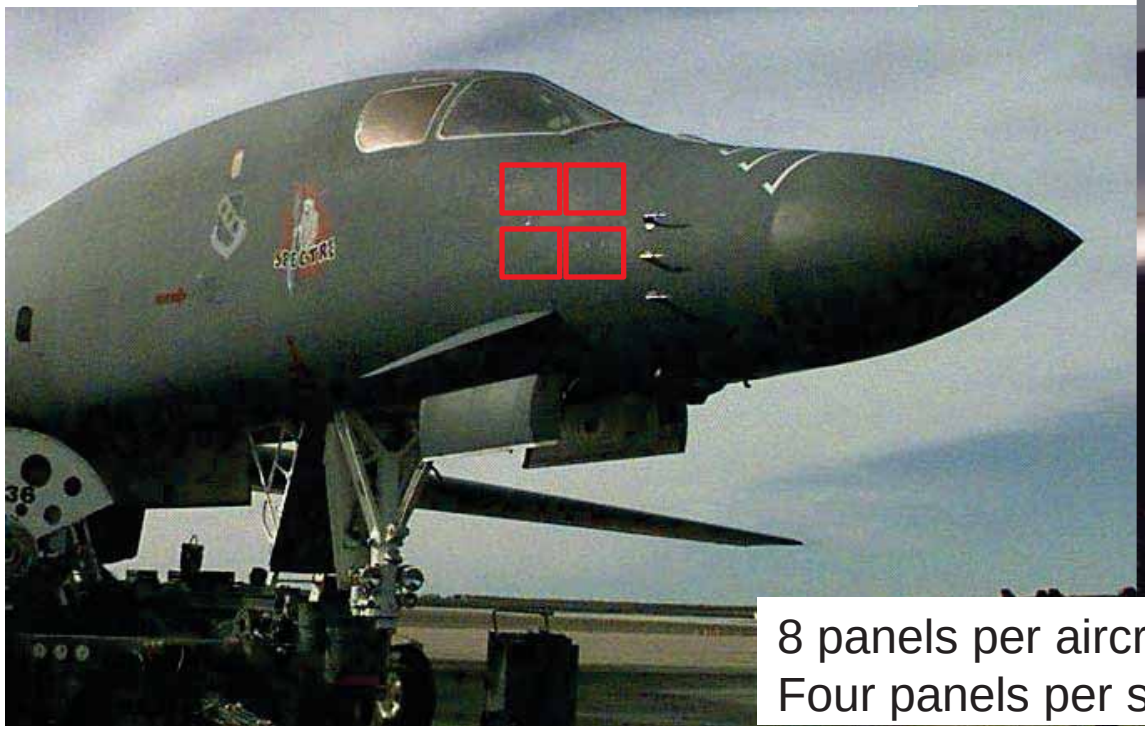
%ROI: 5807%

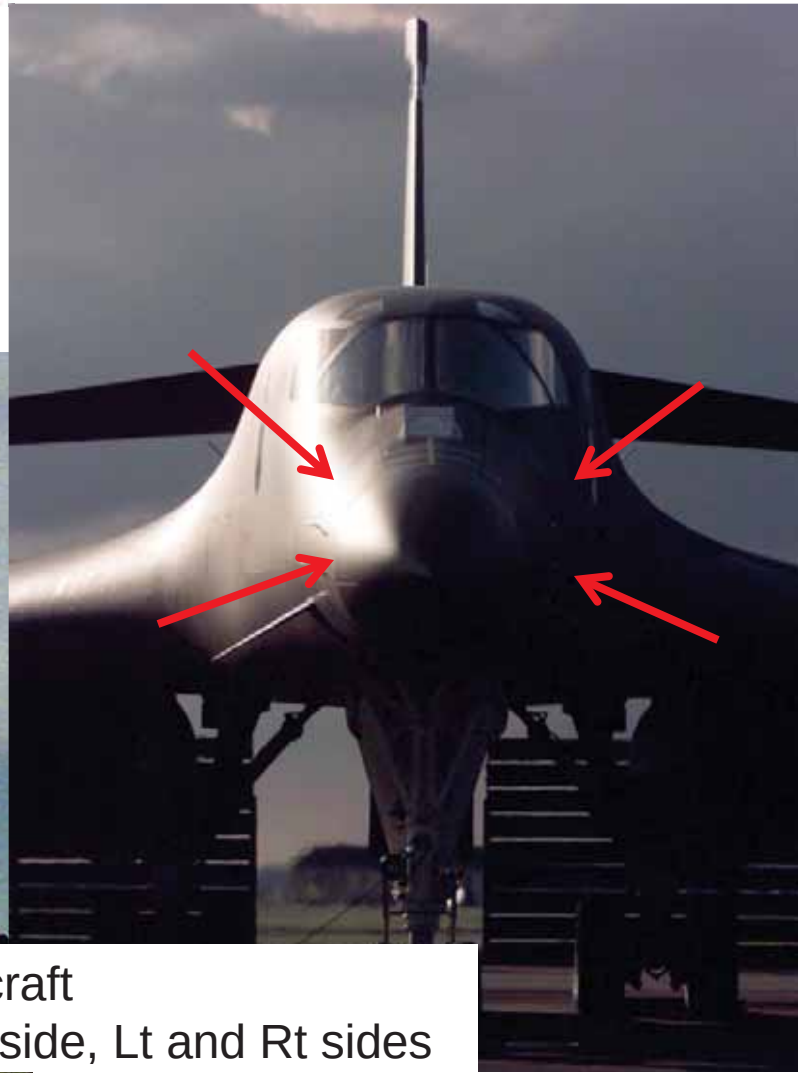
Annual Savings ~ $840K

Applicable to nearly all military aircraft

HF WEBSTER
ENGINEERING SERVICES

R3S
Repair, Refurbish, and Return to Service





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

Problem

B-1 Lt Upper Aft FEB Panel

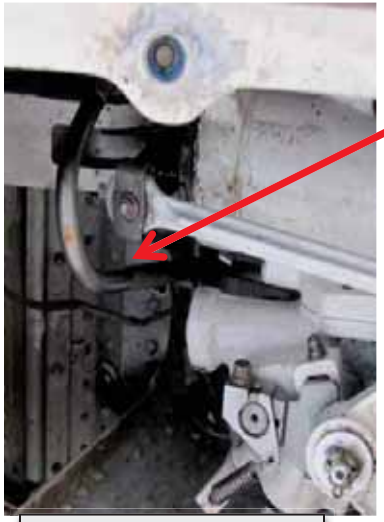
Problem

Hydraulic Tubing Chafing

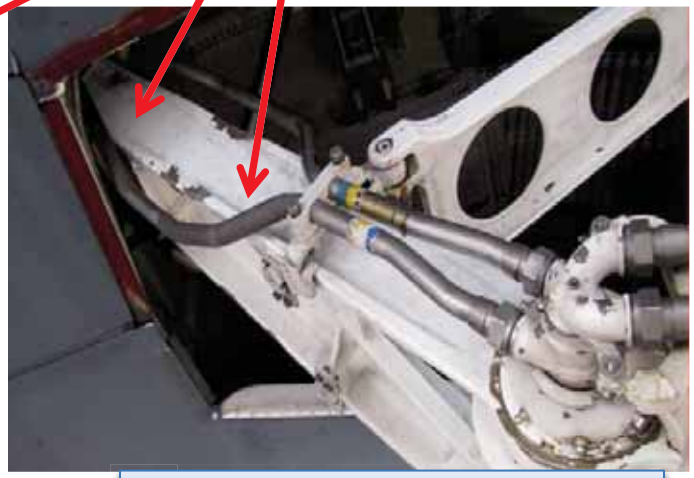
- ❑ #1 Maintenance manhour driver on B-1, similar on most aircraft
- ❑ ROI primarily based on lost flight hours and reduced maintenance manhours
- ❑ Estimated at least1800 Mission Capable (MC) hours ~75 days improvement per year
- ❑Equates to $78M annually in lost training and maintenance costs*

* 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

Chafing Points Wear Tested



Spoiler Actuator line



Main Landing Gear Line

Nose Landing Gear Accumulator Line

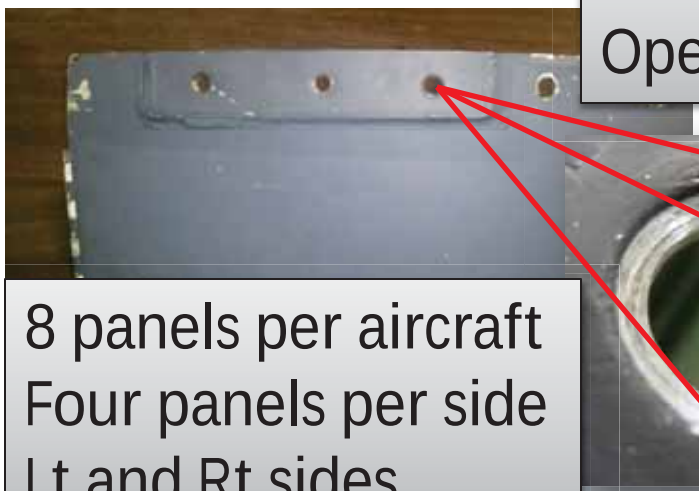
Repair, Refurbish, and Return to Service

HF WEBSTER ENGINEERING SERVICES

Candidate Parts

Chafing - Aircraft Skin Panels & Hydro Tubes

Chafing Wear on Operational Panel



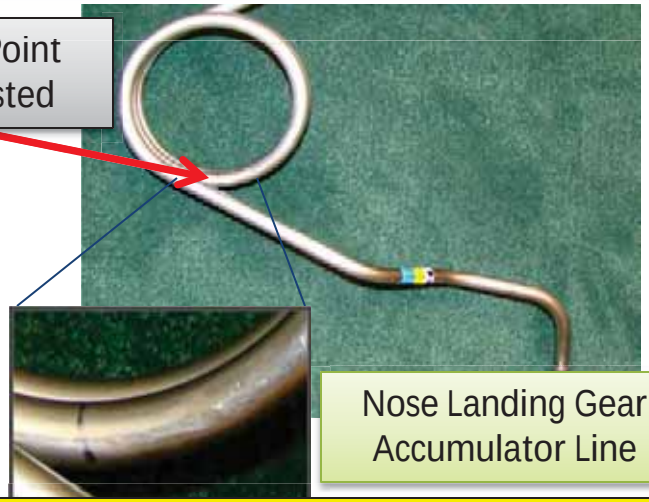
Chafing Point Wear Tested

Main Landing Gear Line

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

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

Chafing Point Wear Tested



Nose Landing Gear Accumulator Line

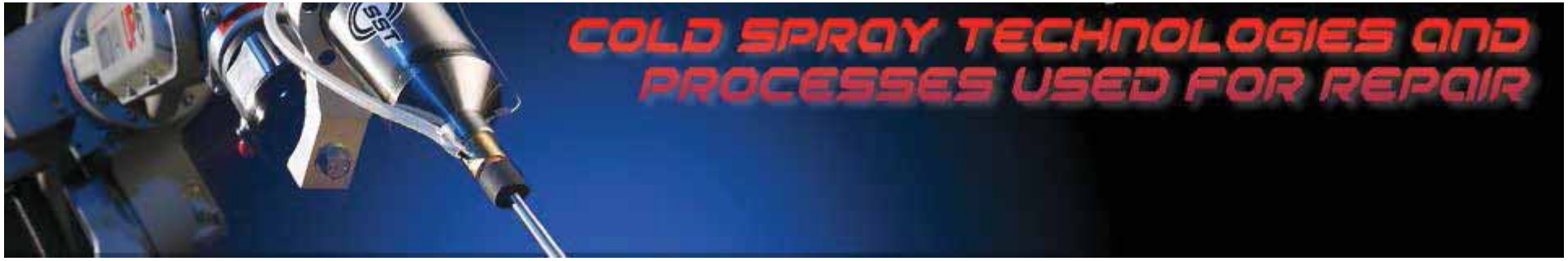
CS Repaired June 2012
1+ Year, 155 Flight Hours

CS Applied Mar 2009
4+ Years, 2202 Flight Hours

Questions?

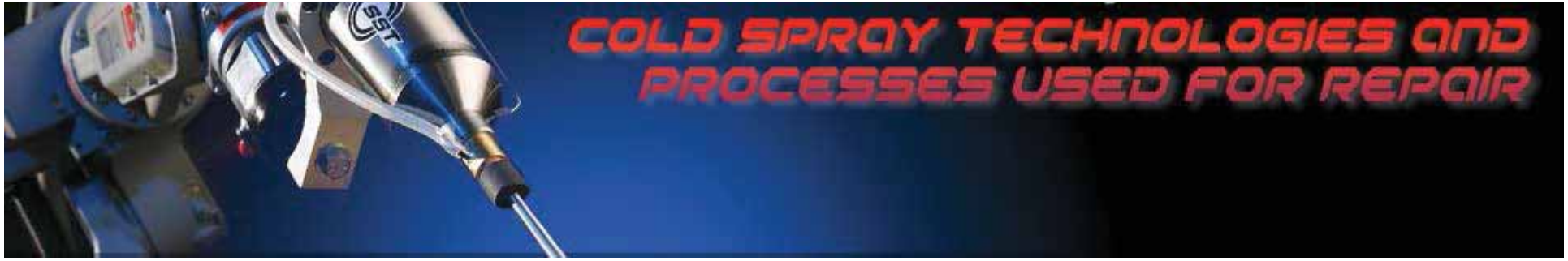
Mr. Brian L. James, GS-12
Air Force Engineering and Technical Services

Rob Hrabe
H. F. Webster Engineering Services



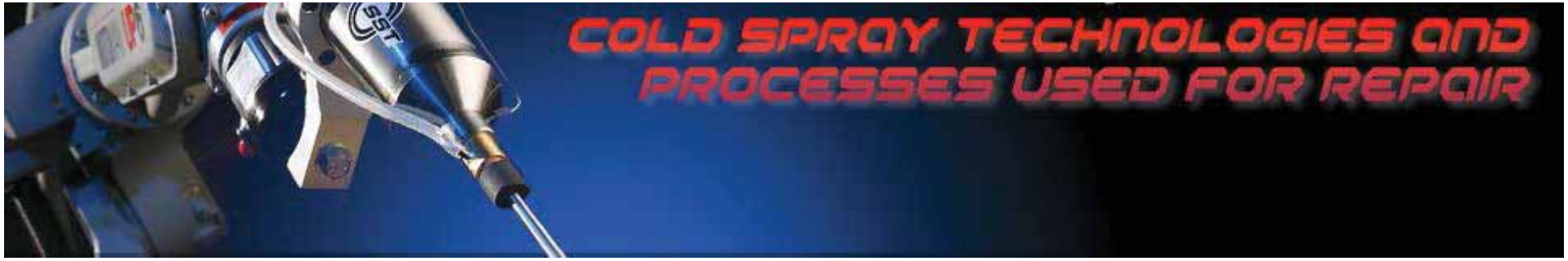
Q & A

Ray Langlais



Review New Actions

Ray Langlais



Thank You

Cold Spray Action Team Website

http://coldsprayteam.com/index.html