

CSAT 2016

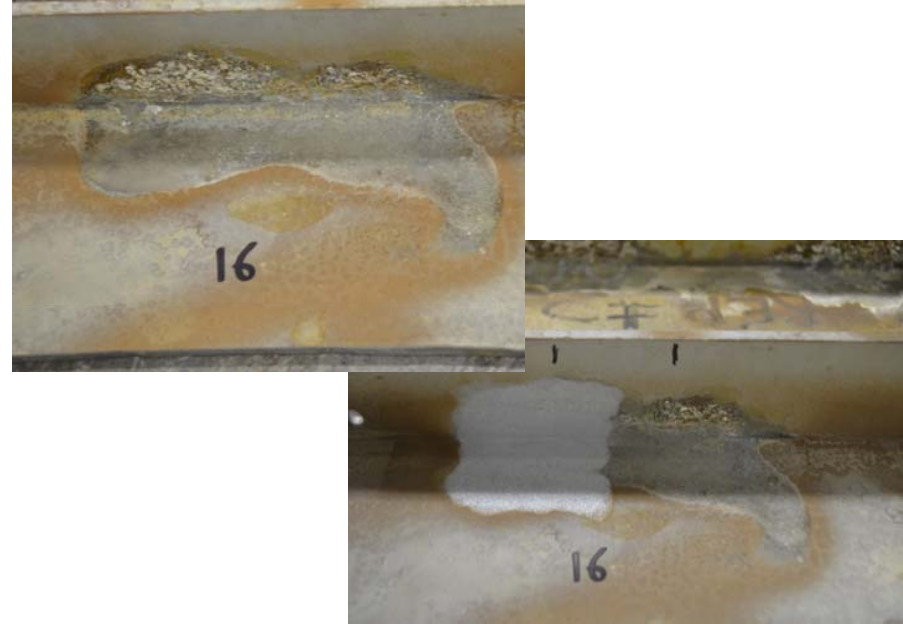
SBIR AF131-190 Phase II Cold Spray Repair for Dimensional Restoration

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Outline

- ES3 Cold Spray Efforts (Past & Present)
- Project Overview
- SBIR Phase I Testing
- SBIR Phase II Testing
- Design Enhancements – Phase II
- Metallurgical Testing
- Suggested Powders for Down-Selection
- What's Next
- Questions

ES3 Cold Spray Efforts

USN Cold Spray Repair Development (2007)

- This effort is to perform engineering analysis of portable cold spray technology and develop repair procedures necessary to establish field repairs for gearbox cases that would ordinarily require depot replacement.
- Initial field repair application focus is the AH-1W Combining Gearboxes (magnesium casting), AH-1W and UH-1N Main Transmission Housings (aluminum and magnesium castings).
- US Navy and US Army POCs
 - Kevin Conner , Robert Kestler, Carl Sauer
 - Vic Champaign



H1 C-Box Housing – Typical Damaged



H1 C-Box Housing – Cold Spray Repair

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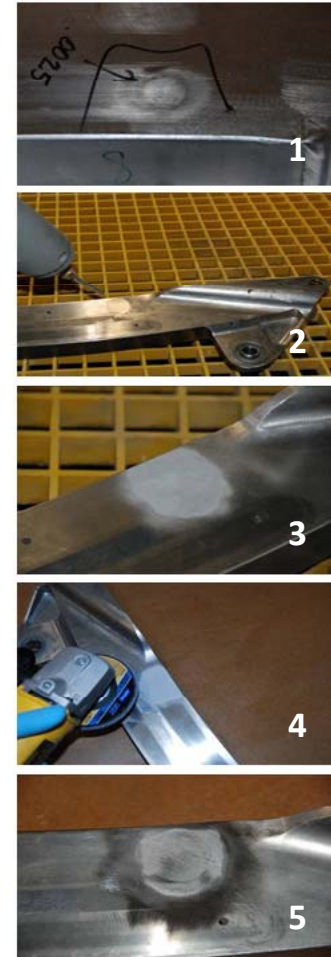


H1 C-Box Housing – Cold Spray Repair

ES3 Cold Spray Efforts

USAF Cold Spray Repair Development

- **C-5 Slat Track Cold Spray Repair (2009):**
 - Initial repair application focus on use cold spray as non-structural application for local dimensional restoration of worn spots on titanium slat tracks to return contour prior to application of the HVOF WC-Co-Cr coating.
- **C-5 Crew Entry Door Ladder Anti-Skid (2015):**
 - Development of a permanent anti-slip alternative, (cold spray process to apply material onto aluminum ladder steps) that will be meet or exceed the performance of #610 anti-slip tape (MIL-PRF-24667C, Type IV).
- **USAF POCs**
 - Clay Elliott, Frank Zahiri



Slat Track – Cold Spray Repair



Project Overview

- **SBIR Topic AF131-190, Dimensional Restoration of Aircraft Components Damaged by Corrosion**
 - To resolve issues with aircraft components damaged by corrosion in hidden and/or hard to access locations by providing a capability for on-site dimensional restoration of damage awhile providing improved corrosion protection.
 - **USAF SBIR POCs**
 - **WR-ALC:**
 - Dave Ellicks, AFMC AFRL/RXSSR
 - Clay Elliott, WR-ALC/WLSEB
 - **OC-ALC:**
 - Kelli Gonsalves, AFMC AFSC/ENSI
 - Chris Mance, AFMC AFSC/ENSI
 - **ES3 utilizing Centerline SST system for current evaluation and will evaluate other cold spray systems in future Phases**
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SBIR Phase I Testing

SBIR Phase I Feasibility study objectives:

- Identify candidate parts within the USAF at WR-ALC, OO-ALC and OC-ALC
- Develop a portable cold spray coating process for removal of corrosion product and restoration/repair of 2XXX and 7XXX aluminum substrates;
- Develop a nozzle/spray applicator for cold spray equipment for applications in limited, hard to access locations
- Demonstrate and validate the cold spray repair process on a representative aircraft component. The cold spray application will be IAW MIL-STD-3021.



SBIR Phase I Testing

Cold Spray Equipment:

- **Centerline SST Series P – Portable Cold Spray System**
 - Pressure: 250 PSI (17 Bar) – *Low to Mid Pressure*
 - Temperature: 550 °C
 - Carrier Gas: Air, Nitrogen, or Helium
- **Integrated Thermach AT-1200 Volumetric Pressurized Powder Feeder**
 - 500 PSI (34.5 bar) maximum pressure
 - Canister volume of 464 cu. in. (7603 ml)



SBIR Phase I Testing

ES3 and Centerline designed and manufactured prototype nozzle and equipment enhancements as needed to the existing Cold Spray equipment to facilitate reaching limited access areas, small working environments, etc.

Due to budget restraints, the prototypes manufactured during Phase I for limited access operations were limited to:

- Nozzle extension for longer reach applications from the spray applicator.
- Orbital Nozzle and 90 Degree design for angled spraying and internal diameter/access hole spraying.
- Flex hose for additional maneuvering into limited access applications.



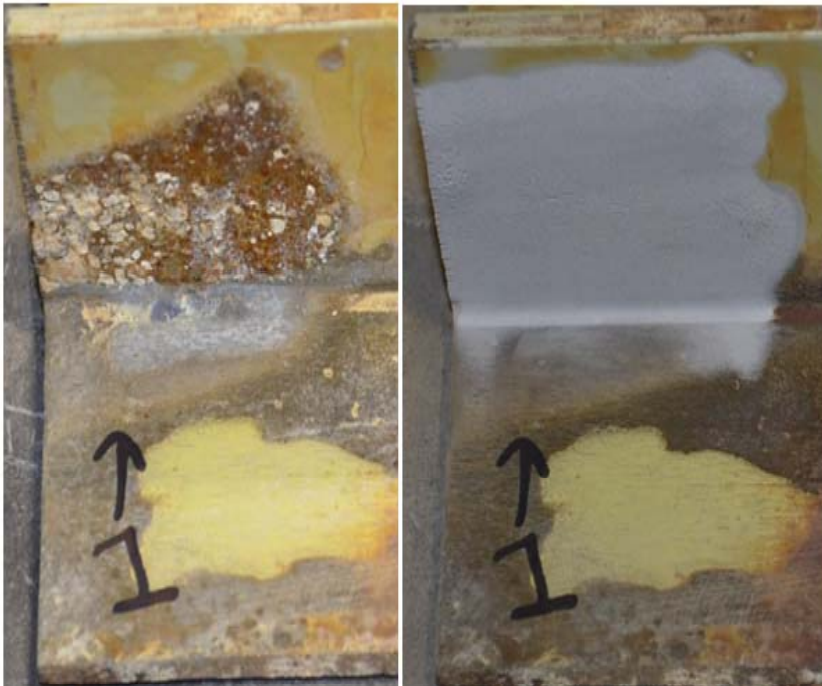
SBIR Phase I Testing

SBIR Phase I Feasibility study results:

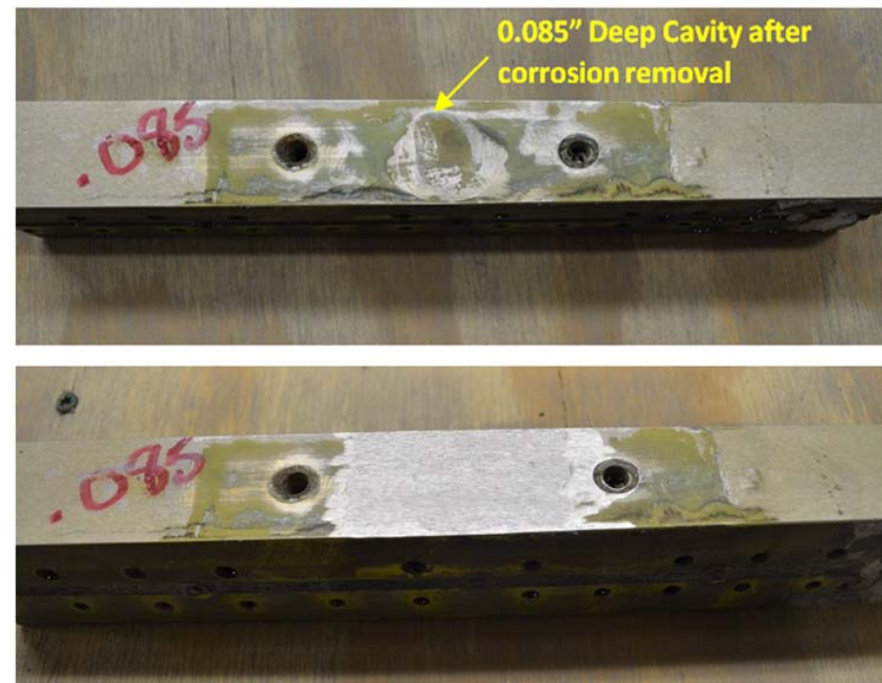
- **Candidate Part Identification**
 - A Dozen Parts Identified (Aluminum and Magnesium substrates)
- **Equipment Enhancements / Nozzle Designs**
 - Nozzle Design Approved and manufactured
- **Parameter Development & Metallurgical Lab Testing**
 - Initial cold spray application on test samples completed.
 - Metallurgical Testing successfully completed.
- **Dem/Val the cold spray repair process on a representative section of aircraft structure completed using parameters developed from metallurgical testing**



SBIR Phase I Testing



Cold Spray Application on 7075 Aluminum Aircraft Components



Cold Spray Application on F-16 Wing Trailing Edge Spar For Dimensional Restoration



SBIR Phase II Testing

Phase II will include design enhancement to the portable cold spray system and expands substrate materials to include 7XXX, 6XXX, 2XXX Al, and Magnesium. Phase II of tasks consist of :

- **Nozzle and equipment upgrades (as required)**
 - **Parameter Optimization**
 - **Non-structural Test Program**
 - **Corrosion testing (ASTM B117, ASTM G85, and beach exposure)**
 - **Structural Test Program**
 - **Axial Fatigue and Tensile testing**
 - **Triple lug shear testing**
 - **Lap Joint shear testing**
 - **Dem/Val on Aircraft Components & Technique sheet development**
 - **Draft USAF Process Specification**
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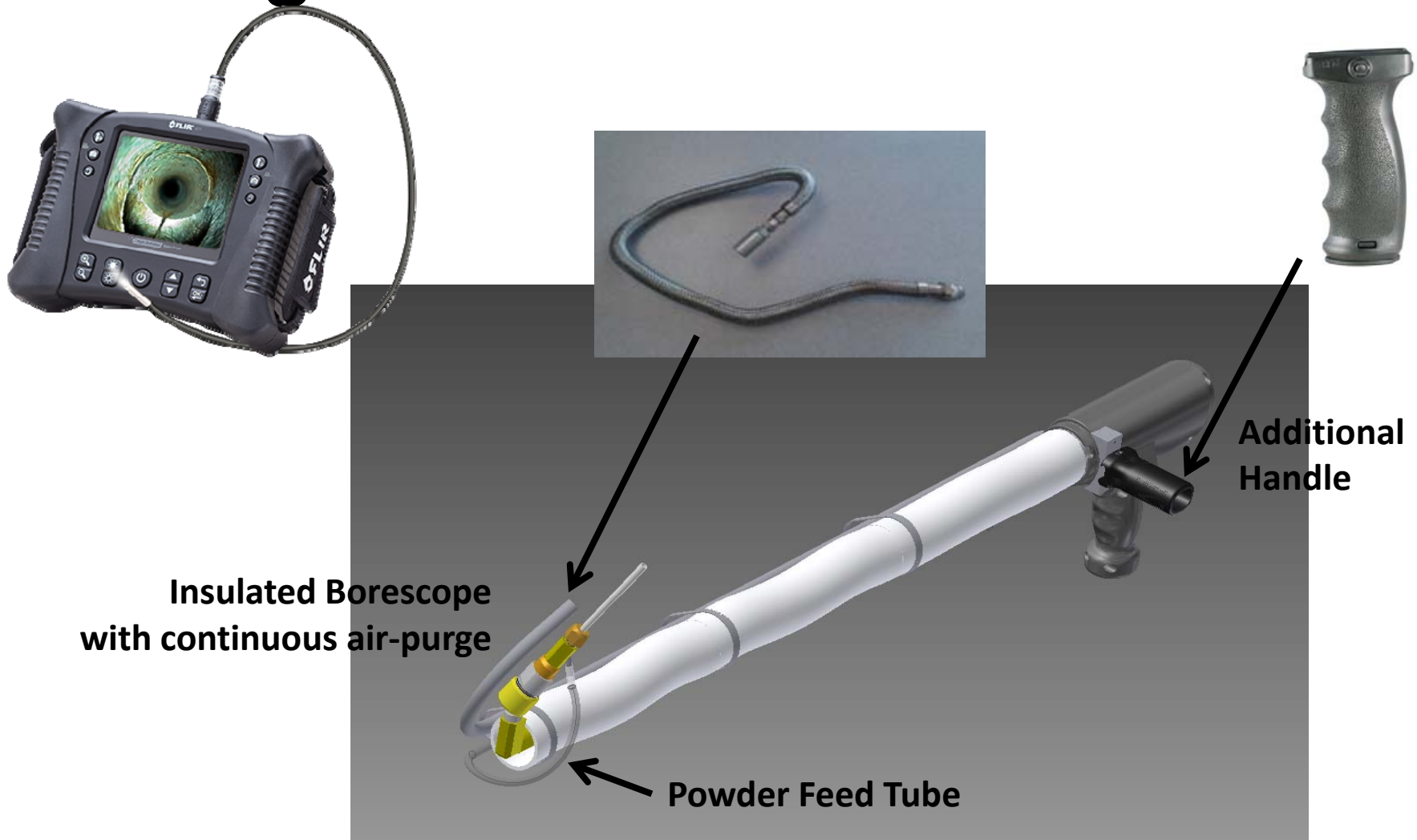


Design Enhancements – Phase II

In Phase II, ES3 continues to evaluate further enhancement to these nozzle designs as needed for additional applications identified during Phase I, and/or for safety and usability enhancement. Equipment enhancements may include, but is not limited to:

- Potential heater source enhancements or insulation to ensure powder stays heated for proper coating bond strengths and build-up and protect user from heated component.**
 - Boroscope “(or similar camera type)” attachment for nozzle extension for out of sight spray application.**
 - Additional handle for safety and maneuverability.**
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Design Enhancements – Phase II



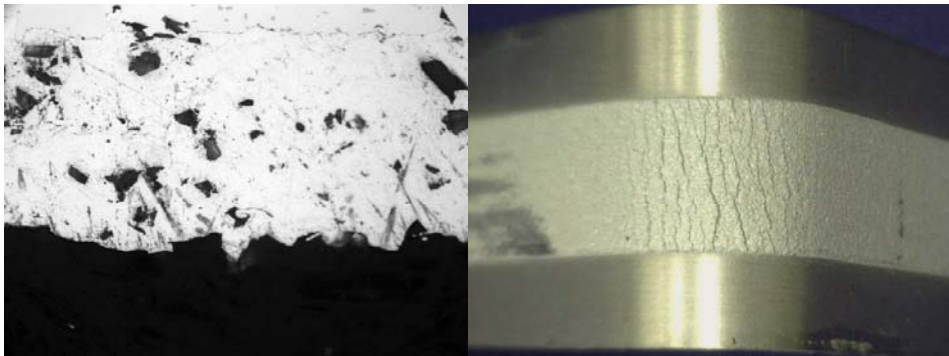
Metallurgical Testing

- Further testing for parameter optimization was recommended in Phase II with more testing at additional pressure/heat ranges, stand-off distance constraints; as well evaluate duplex coatings utilizing the A0050 or A0071 as a bond/build-up coating and high purity Aluminum as a top coat for added corrosion protection.
- A0050 was already proven to have better deposition rate than A0071 for aluminum substrate in Phase II

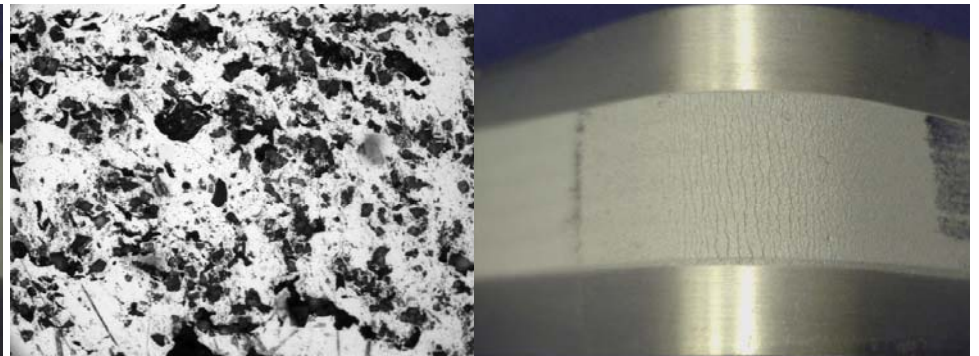
MATERIAL	POWDER			
	A0050	A0071	A0050+HP	A0071+HP
AL 2024-T3	1	0	1	0
AL 7075-T6	1	0	1	0
AL 6061-T6	1	0	1	0
ZE41A	1	1	1	1
TOTAL NUMBER OF METLAB	10			

Metallurgical Testing

A0071



A0050



- Both A0071 and A0050 should good hardness, porosity, and bond strength. However, deposition rate for A0050 is twice that of A0071.
- Bond strength is reduced to from 6000-8000 PSI to 3500 PSI with HP aluminum.

Non-Structural Testing

Corrosion testing

- ASTM B117
- Beach exposure
- ASTM G85



Cold Spray Corrosion Samples in Corrosion Chamber@ ES3 Facility



Cold Spray Corrosion Samples @ Duck, NC atmospheric exposure test facility



Structural Testing

Coupon Manufacture on-going for:

- **Axial Fatigue and Tensile testing**
- **Triple lug shear testing**
- **Lap Joint shear testing**



What's Next

- **Down Selection of Powder(s) for cold spray repair**
 - **Complete manufacture and Install of Design Enhancements**
 - **Complete cold spray application on remaining non-structural coupons and continue testing**
 - **ASTM B117, ASTM G85, and Beachfront Exposure**
 - **Continue ASTM B117, and Beachfront Testing**
 - **Complete manufacture of structural coupons.**
 - **Start developing tooling and fixturing for dem/val parts**
 - **Evaluate other Cold Spray systems, including High Pressure systems**
 - **Evaluate other substrates and applicable coatings for those substrates.**
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Questions

ES3 POCs

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