Portable Cold Spray Repair
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Established in 1945 by the Navy post WW II

Technology Areas
- Undersea Weapons
- Undersea Vehicles/UUV’s
- Hydrodynamics and Structures
- Acoustics & Quieting
- Comms and Information
- Power and Energy
- Navigation
- Materials/ Manufacturing

Largest Interdisciplinary Research Unit at Penn State – 1148 faculty/engineers, staff, students

Designated a University Affiliated Research Center (UARC) by DoD in 1996

Institute for Manufacturing and Sustainment (iMAST)
- Repair Technology (REPTECH)

Metric: Was technology transitioned?
ONR Defense University Research Instrumentation Program DURIP

VRC Gen III Cold Spray System - Paladin
- Max Gas Pressure 6.9 bar
- Max Gas Temp at gun 750°C
- Max Heater Powder 45 kw
- Deposition rate 7 kg/hr
- Data logging and storage

HAAS VF-3 CNC Mill
- Rotary Table
- Pallet Changer
- Dimensional probe and tool setter

Fully Integrated ABB Robot
- SolidWorks
- SolidCam
- Robot Programming Software

Touch Probe - Renishaw OMP40-2 Optical Transmission Probe
Additive-Subtractive Cold Spray Based Manufacturing Station
Technology Development

- Puget Sound Naval Shipyard (PSNS) and the Trident Refit Facility Facility Bangor (TRF) identified a number of candidate components for Cold Spray Repair
  - Repair of corrosion damage and material restoration
- Four components were selected
  - Hydraulic Actuators/Controllers (Al-6061)
  - Electric Motor End Bell Bore Repair (Steel and Cast Iron)
  - Seawater Valves (70/30 CuNi)
  - Seawater Pump Components (Bronze)
- Develop, qualify and transition repairs
- Navy Repair Procedures for repairs
  - General Cold Spray Procedure
  - Specific Repair UIPI – Universal Industrial Process Instruction
- Navy wide teleconference to provide updates
  - Provide updates on Cold Spray Technology
  - Master list of components being repaired
  - Forum for discussion
Cold Spray Repair

- Repairs have been developed using high pressure Cold Spray systems
- TD-63 Al-6061-T6 Actuator Body
- Corrosion Damage to Inner Bore
- Formed team to leverage capabilities
  - PSNS & IMF
  - ARL/Penn State
  - Army Research Laboratory
  - VRC Metals
  - UTRC
  - Moog
- Developed Repair process – mock-up
- Worked with the Navy to develop acceptance requirements
- TD-63 and TD-16, the Al-6061 T6 have been repaired and granted limited use status
Material
- Bronze C90300 Bronze Repair
- Damage to surfaces that hold the shaft
  - Corrosion / Pitting

Repair
- Remove Damage Material
- Roughen Surface
- Apply Cold Spray
- Machine to final dimensions

Acceptance of Cold Spray Repair 12-16-15:
DFS technically reviewed and approved by SEA 05Z4, SEA 05P2, and SEA 05V1
- Programmatically approved by PMS312E
  Concurred in by SEA 08
- Major temporary approval for unrestricted operations until 30-April-2019 (FY18 DPIA3) at which time pump inspections will be performed
Motor End Bell Housing Repair

- Steel housing wears causing vibration in the motor
- Replace copper plating with longer lasting solution
  - Machine worn area to remove damage
  - Restore surface to original dimension
  - Replace Copper Plating
- Develop repair process

Adhesion Strength

- \( \text{Cu} \) 8.5 ksi
- \( \text{Ni} \) >11 ksi
- \( \text{NiCr-Cr}_3\text{C}_2 \) >11 ksi 42 HRC

- Coating Parameters Established
- Process demonstrated on steel rings
- Can be machined with conventional tools
- Coating Final mock-up for UIPI
Objectives:

- Develop high pressure portable/hatchable Cold Spray systems that can be used onboard a ship, in the field or in a shop environment
- Three coordinated programs
  - NAVSEA Intermediate Maintenance Facility, Bangor
    - RIF - Hand Held Capable High-Pressure Cold Spray Repair
      - Man Portable system that can be transported through a ship or submarine
    - Phase II SBIR - Cold Spray Repair Process Development and Implementation on Navy Components
      - Portable for shop, field or pier repairs
  - ARL/PSU - iMAST
    - Hatchable Cold Spray for Naval Shipyard and Marine Corps Depots
      - Develop supporting technology
      - Support validation testing and implementation
      - Coordinate with NAVSEA and Marine Corps
Supporting Technologies

- Higher temperature, more flexible hoses
- Quick disconnects
- Motion Control
- In-process Quality Control
- Operator Feedback

Operator Environment

- Portable/Reconfigurable Dust Collection
- Gas Ventilation and Monitoring
- Personal Protection Equipment
- Safety Protocols

Standards and Procedures

Transition Applications
Adhesion Results for Hand Held Application Data for Al-6061 on Al-6061
VRC Gen III Max
ASTM C633 Results – Hand Held
• He – 10181 ± 654 psi
• N2 - 6875 ± 1055 psi
Dependent on
• Powder Treatment
• Surface Preparation
• Spray pattern
O-ring Groove Repair

- **Substrate**
  - 70/30 CuNi

- **Deposition**
  - Nitrogen
  - Inconel-Cr$_3$C$_2$
  - Cu116-Cr$_3$C$_2$

- **Testing**
- **Corrosion**
  - Salt Fog
  - Crevice
  - Galvanic Potential

- **Adhesion**

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Sprayed and Machined

Upper ringed – repaired
Lower ringed – not repaired
100 hrs ASTM B117 Salt Fog

Damage to simulate damage during use
Prototype Glove Box
- Sound dampening material
- Flow/temperature testing
- Powder removal vs flowrate
- Work envelope
- Testing for particle containment
- Flexible/reconfigurable

Hand Held Repair using modified grip in the portable glove box

Prototype II Glove Box
Repair of Al-6063 Doors: Problem Pitting Corrosion on Sealing Surfaces

- Al-6061
  - He
  - N₂
- Robotic and Hand Held Repairs
- Find curvature of the door
- Machine damaged areas
  - Limited material removal
  - Blend deep pits
- Apply Al-6061
- Machine
- Blend any areas that need additional material
- Apply Al-6061
- Machine
- Hand Finish
Hatchable Cold Spray System
• Designed
• Testing Phase
System Testing
• Portable Glovebox
• Portable Dust Collector
• Hatchable Cold Spray
• Sensors
  • Particle Sensors
  • Sensors
• Approval Process Developed
• Hand Held Data
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