PennState
Applied Research Laboratory

Portable Cold Spray Repair
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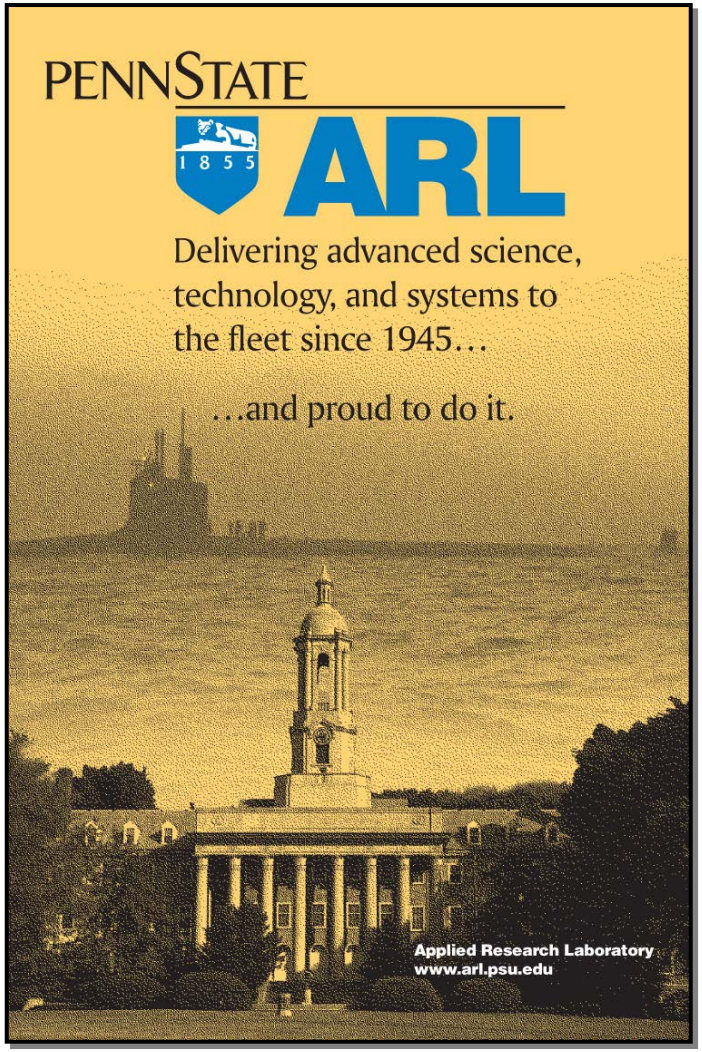
Timothy J. Eden, Ph.D.
Head of the Materials Processing Division, Applied Research Laboratory
The Pennsylvania State University
P:814.865.5880
email: tje1@arl.psu.edu

Introduction to the Applied Research Laboratory



- **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?**

ARL/PSU – High Pressure System

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**

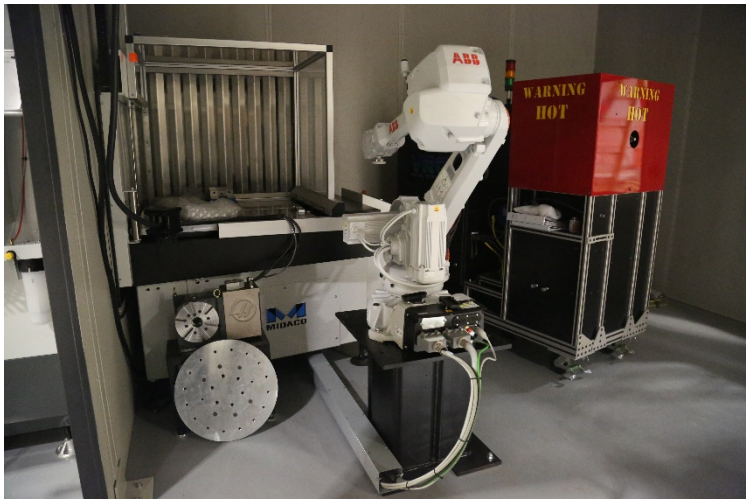
HAAS VF-3 CNC Mill

- **Rotary Table**
- **Pallet Changer**
- **Dimensional probe and tool setter**

Fully Integrated ABB Robot

- **SolidWorks**
- **SolidCam**
- **Robot Programing Software**

Touch Probe - Renishaw OMP40-2 Optical Transmission Probe



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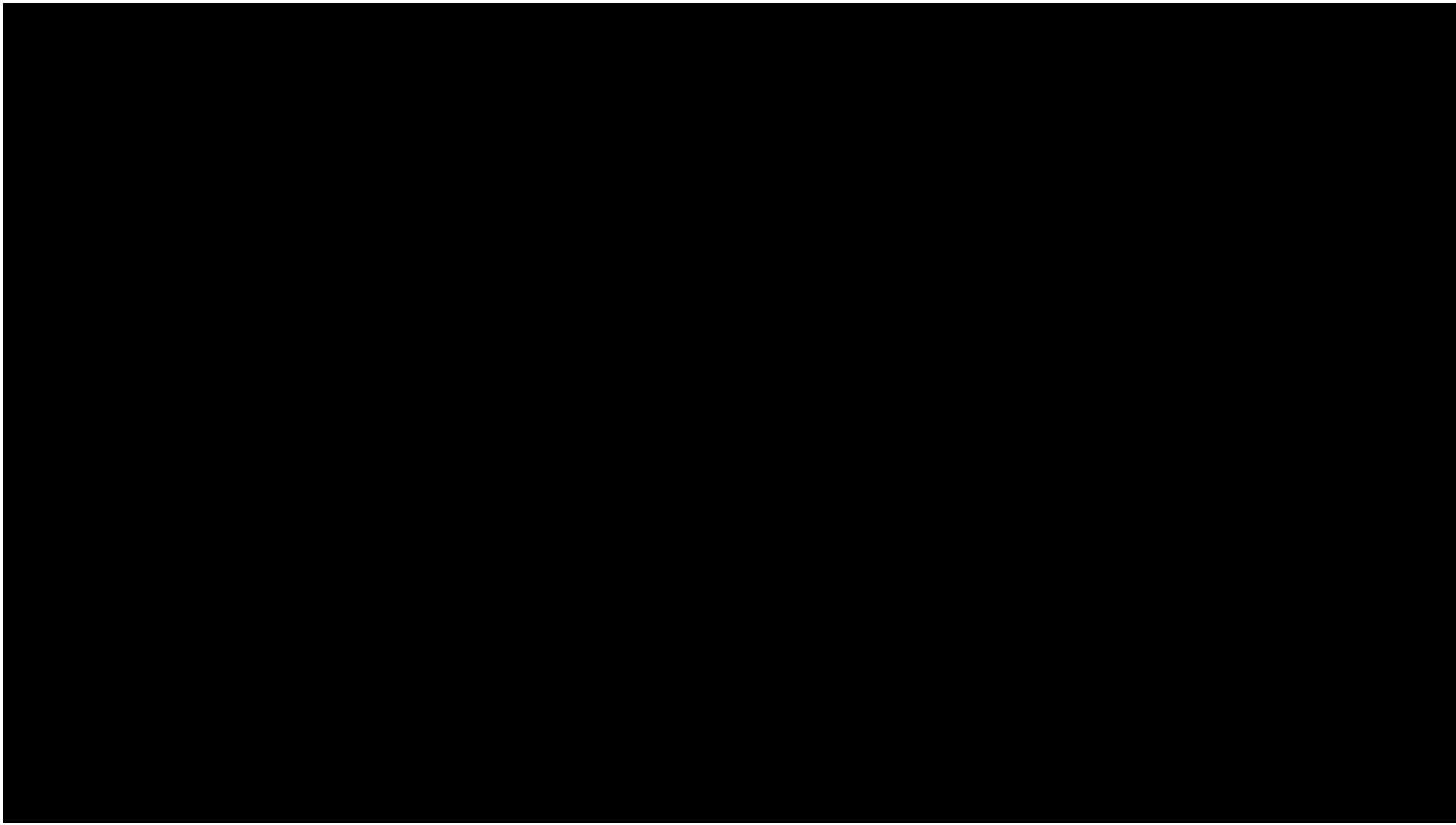
Additive-Subtractive Cold Spray Based Manufacturing Station



Technology Development

- Puget Sound Naval Shipyard (PSNS) and the Trident Refit Facility Facilty 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

Cold Spray Repair

Material

- **Bronze C90300 Bronze Repair**

Damage to surfaces that hold the shaft

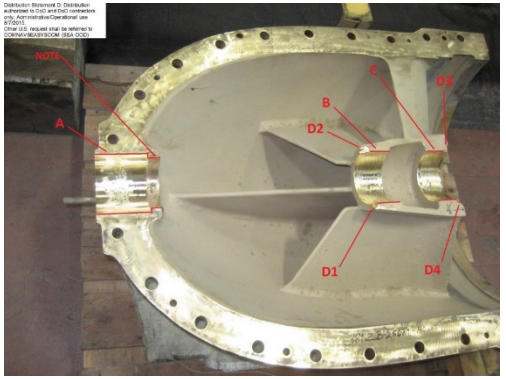
- **Corrosion / Pitting**

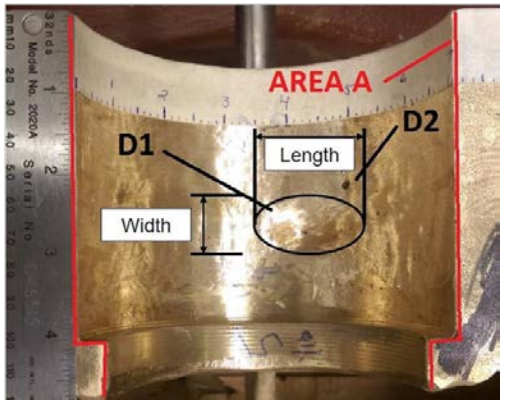
Repair

- **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**





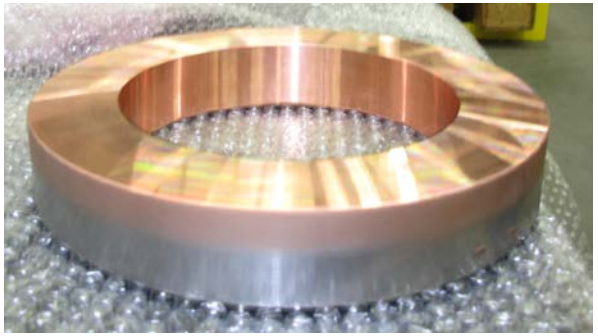
Copper Plating Replacement

Motor End Bell Housing Repair

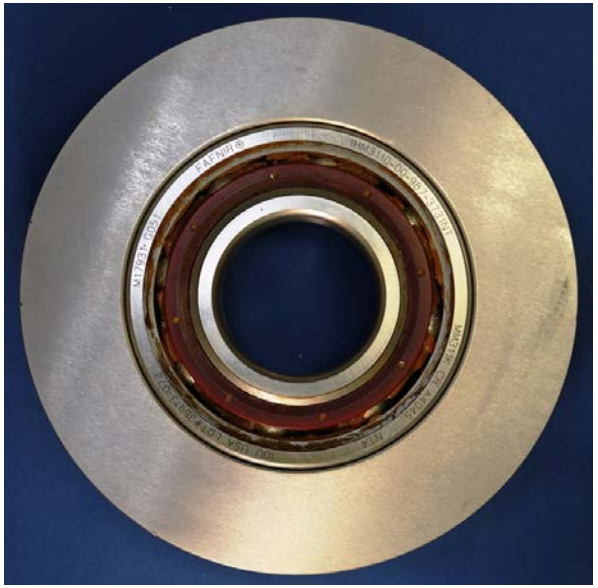
- **Steel housing wears causing vibration in the motor**
- **Replace copper plating with longer lasting solution**
  - **Machine worn area to remove damage**
  - **Restore surface to original dimension**
  - **Replace Copper Plating**
  - **Develop repair process**

	Adhesion Strength
• Cu	8.5 ksi
• Ni	>11 ksi
• NiCr-Cr_3C_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**



Copper Coated Steel Ring



NiCr-Cr_3C_2 Coated Steel Ring with bearing installed

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**

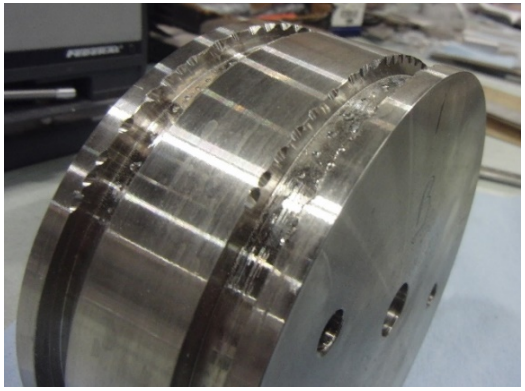
Al-6061 Substrate

Coated and Machined

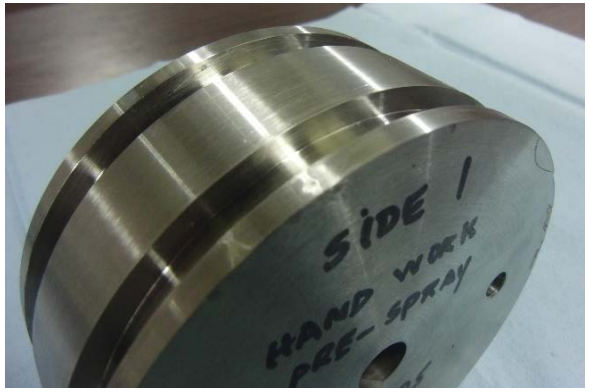
After 689 hrs in B117

O-ring Groove Repair

- Substrate
  - 70/30 CuNi
- Deposition
  - Nitrogen
  - Inconel-Cr_3C_2
  - Cu116-Cr_3C_2
- Testing
- Corrosion
  - Salt Fog
  - Crevice
  - Galvanic Potential
- Adhesion



Damage to simulate damage during use



Sprayed and Machined

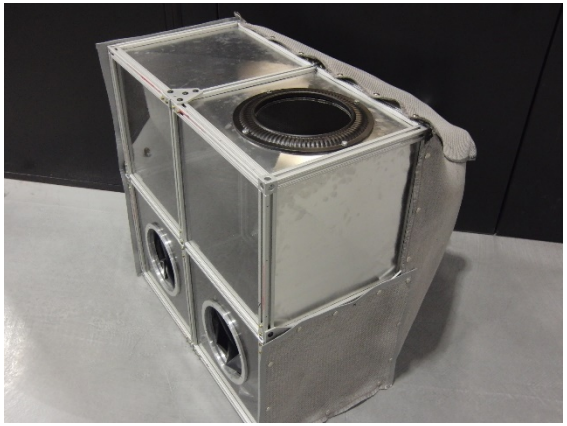
Upper ringed – repaired
Lower ringed – not repaired
100 hrs ASTM B117 Salt Fog

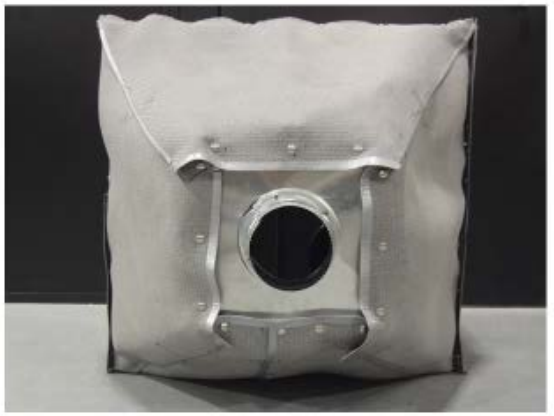
Letterkenny Patriot Missile System Door Repair

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



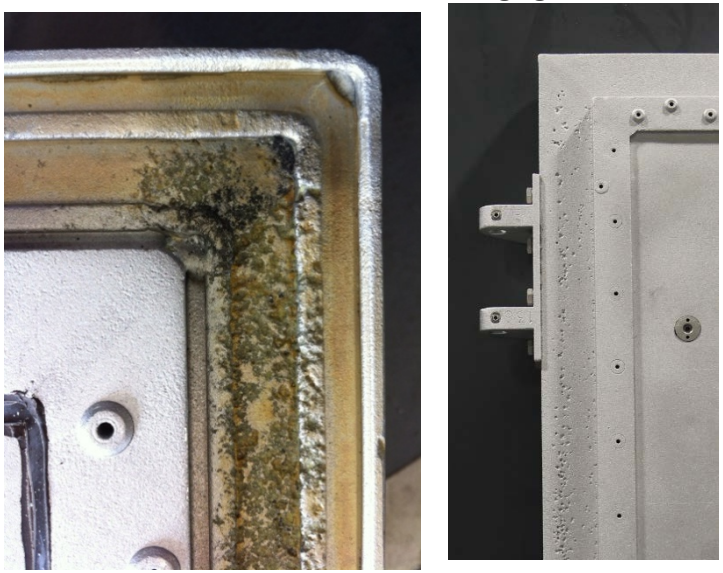


Prototype II Glove Box

Repair of Al-6063 Doors: Problem Pitting Corrosion on Sealing Surfaces

- Al-6061
  - He
  - N_2
- 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

EMI and sealing gaskets



Pitting Corrosion

Summary

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**

Acknowledgements

NAVSEA O4X
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VRC Metal Systems