

# VRC Metal Systems and Advanced Manufacturing Technologies

Contact Information:

Aaron Nardi – CTO VRC Metal Systems LLC

[aaron.nardi@vrcmetalsystems.com](mailto:aaron.nardi@vrcmetalsystems.com)

860-841-8337

Web Pages:

<https://coldspray.com>

<https://vrcmetalsystems.com>

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# About VRC Metal Systems, LLC



- Leader in the U.S. Cold Spray market with a focus on high pressure applications
- Founded in 2013 to commercialize R&D in high pressure hand operated cold spray ARL-SDSM&T
- Headquartered in Box Elder, SD, with locations across the US
- Today VRC Metal Systems LLC is focused on advanced manufacturing technologies including Cold Spray deposition, Cold Spray additive manufacturing, and Wire Arc Additive Manufacturing



## Working with our Government partners



## Working with our Commercial partners



## Working with our Research partners



# VRC Facilities

★ Current

★ Coming Soon



**VRC HQ:**  
Engineering  
System Production  
Process Development  
Limited Production



**Mid-America Aero:**  
Process Development  
Full Production  
FAA Repair Station  
Full MRO Capability Beyond Cold Spray



**VRC Northeast:**  
Materials Research  
Process Development  
Limited Production  
Powder Distribution



**VRC San Diego:**  
Process Development  
Full Production  
CNC Part Machining



**VRC Chesapeake:**  
Process Development  
Full Production  
CNC Part Machining



# VRC – Full Service Cold Spray Provider



## System Engineering & Manufacturing



## Cold Spray R&D/ Applications Development



## Consumables Sales and Prototypes



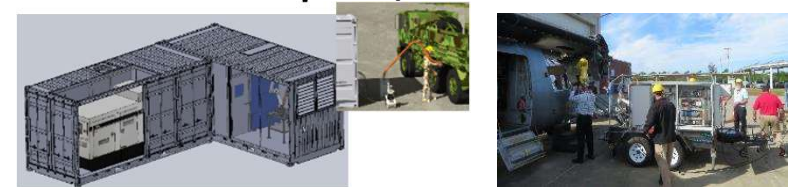
## Automation/Booth Integration



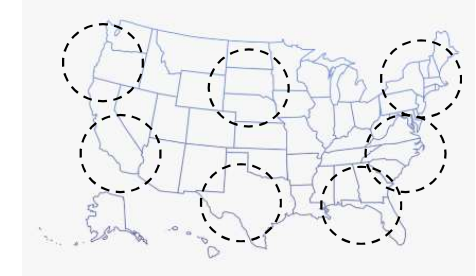
## Fee for Service Work



## On-site Repair/Modification



## Cold Spray Operations or Regional Support



# The Cold Spray Process

## Cold Spray Description:

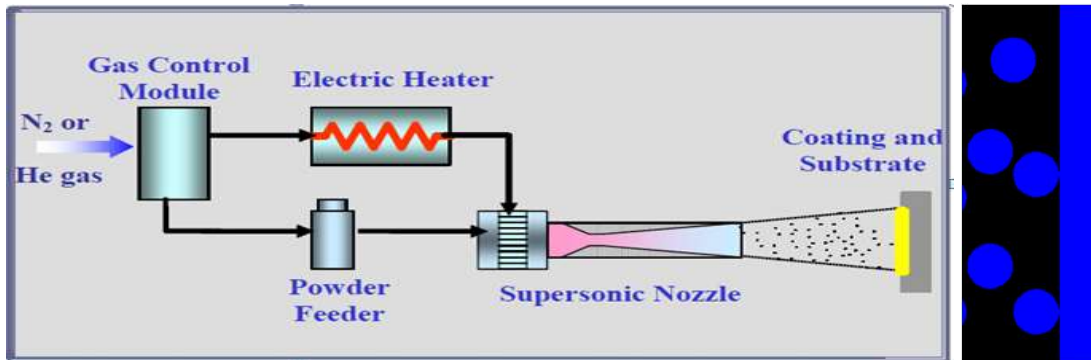
Process using compressed gas to accelerate powder material, through a supersonic nozzle, resulting in consolidation through high velocity particle impact and severe plastic deformation (Ballistic Cold Welding)

## Typical Materials:

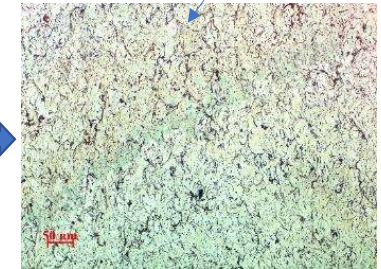
- Pure and alloyed metals, metal blends, metal-ceramic blends, polymers, polymer blends

## Basic Cold Spray System:

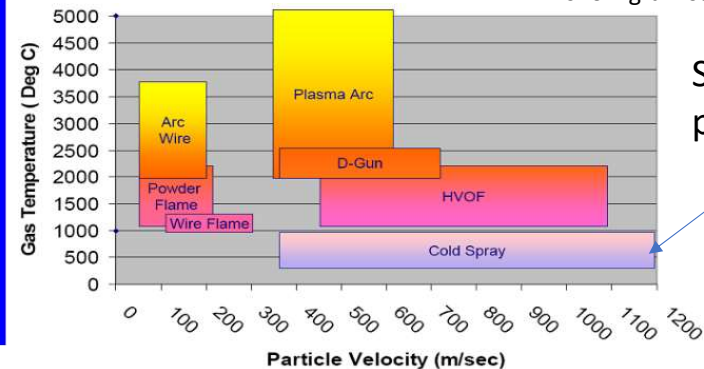
- Control System – Controls system components
- Gas Heater – increases gas temperature to (typically 200-800°C)
- Powder Feeder – feeds powder into the gas stream (typically 1-5 kg/hr)
- Applicator – mixes heated gas and powder/gas streams
- Nozzle – expands gas to supersonic velocities



CP Nickel

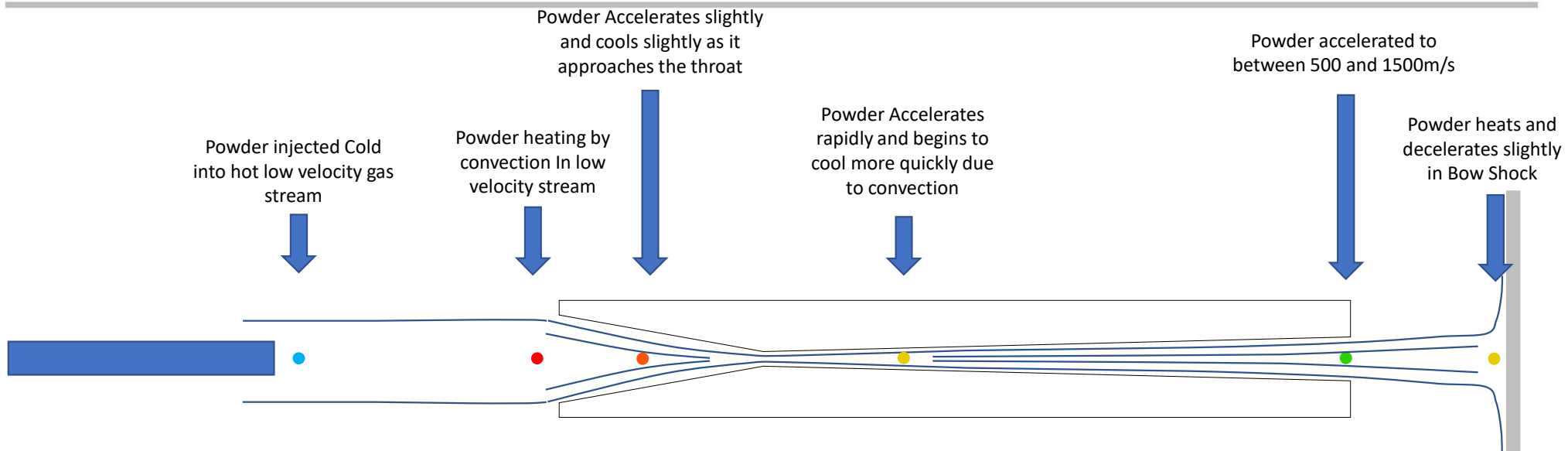


CP Nickel etched to show grain structure



Solid-state processing

# Process Physics: Particle Acceleration / Heating



## Pre-chamber Region

Cold powder carrying gas and hot gas mix over this length and equilibrate heating the particle at the same time. A pre-chamber length of between 2.5 and 4 inches is typically sufficient for the typical fine powders used in Cold Spray to heat to the mixed gas temperature. Sometimes longer lengths are required to fully heat powders

## Converging Region

Gas begins to cool slightly as the gas accelerates through the converging section achieving Mach 1 at the throat. The velocity of the gas at Mach 1 is dependent on gas composition and temperature.

## Diverging Region

Gas is expanded rapidly reducing the dynamic temperature of the gas while the velocity increases quickly. The particle drag is high in this region accelerating the particles to high velocities. Increasing the length of this section increases the velocity that can be achieved but also reducing its temperature. Typical expanding lengths range from 4-7 inches.

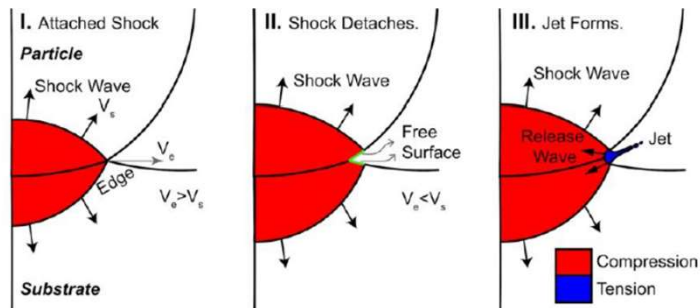
## Exit and Bow Shock Region

Gas dynamic in this region depend on expansion ratio of the nozzle (over-expanded / under-expanded). Bow shock is typically present at the substrate surface due to gas deceleration and direction change increasing gas temperature and pressure rapidly.

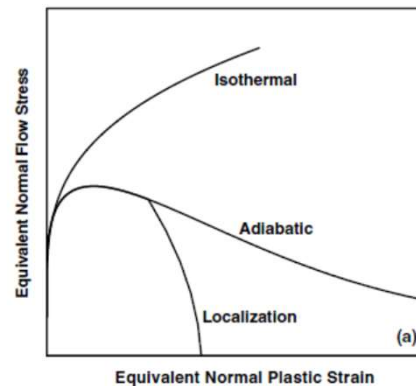
# Process Physics: Particle Impact/Bonding

## Bonding is a multistep process

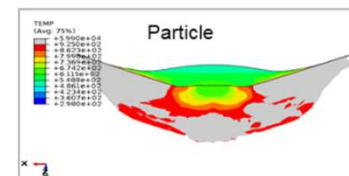
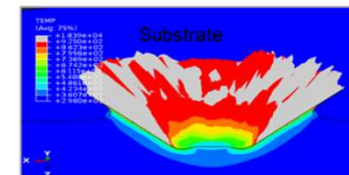
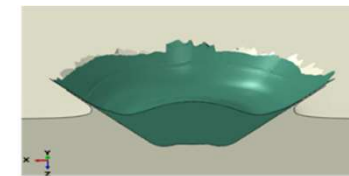
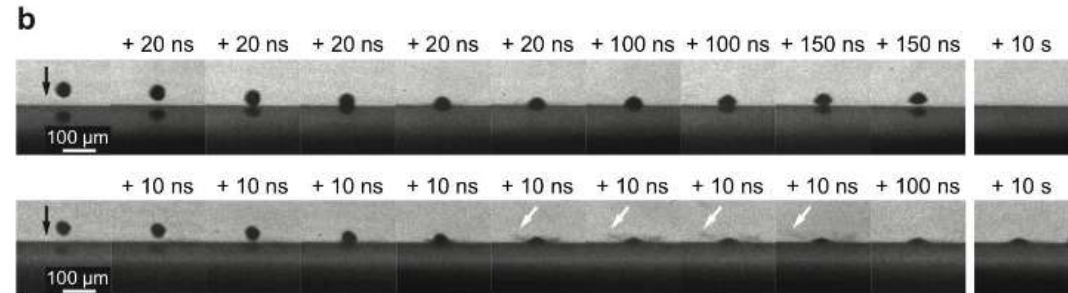
1. Impact with surface
2. Shock wave propagates from impact location toward edge of impact ejecting material
3. Plastic flow of material localizes due to adiabatic heating of the interface
4. Strain localization and heating causes shear instability creating high levels of plastic flow at the interface



Hassani Theory



Assadi Theory





# VRC Dragonfly Cold Spray System



- For entry level users and when high levels of portability are required
- Simplified user interface with preloaded recipes
- UL Listed and CE Certified
- Specifications
  - 1000 psi (69 bar)
  - 700°C at the applicator
  - Helium, Nitrogen, and Air Capable
  - 1 gas system
  - Hand Operated or robotically controlled
  - Compatible with all applicators and nozzles



# VRC Raptor Cold Spray System



- General purpose cold spray system designed for stationary or portable use
- Dust and water-tight enclosure
- UL Listed and CE Certified
- Specifications
  - 1000 psi (69 bar)
  - 700°C at the applicator
  - Helium, Nitrogen, and Air Capable
  - 2 gas system
  - Hand Operated or robotically controlled
  - Compatible with all applicators and nozzles



# VRC Gen IV Cold Spray System



- Designed as a stationary system for production and research
- Designed for UL Listing and CE Certification
- Specifications
  - 1000 psi (69 bar)
  - 900°C at the applicator (robotic operation)
  - Internally shielded heater and applicator to reduce skin temperatures below 250°C at all operating conditions
  - 700°C at applicator (with handheld adapter)
  - Helium, Nitrogen, and Air Capable
  - Hand Operated or robotically controlled
  - 2 gas system with full gas mixing
  - Compatible with current applicators and nozzles
  - 2 Powder feeders standard with up to 4 possible
  - Added DAQ for external sensors



# VRC Cold Spray Systems



VRC Metal Systems Comparison

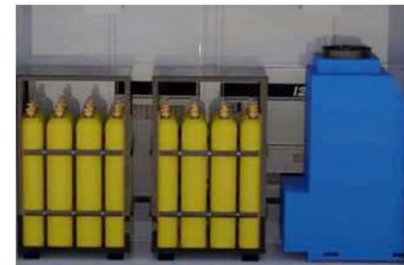
	Gen III	Raptor	Dragonfly	Gen IV
<b>1000 psi Max Pressure</b>	Y	Y	Y	Y
<b>Hand Spray Capability</b>	Y	Y	Y	Y
<b>Compatible with Legacy Nozzle and Applicators</b>	Y	Y	Y	Y
<b>Compatible with Applicator Heater</b>		Y		Y
<b>Multi-powder feeder standard</b>				Y
<b>Multi-gas unit</b>	Y	Y		Y
<b>Gas Blending</b>				Y
<b>Integration with Robotics</b>	Y	Y		Y
<b>Enclosure</b>	Standard Electrical	Dust/Water Tight	Ruggedized impact resistant	Standard Electrical
<b>DAQ</b>	System Sensors + external TC's	System Sensors + external TC's	System Sensors	system sensors + any external sensor
<b>Portability</b>	wheels	wheels, crane, fork, tow	Hand	N/A



# VRC Auxiliary Hardware



- Complete suite of nozzles: PBI, WC, Internal Diameter, Wide Area, and more.
- Portable glove box spray enclosures with optional robotics
- Portable Wet-Type dust collection for collection of hazardous dust and code compliance
- High Pressure Gas Supply Air / Nitrogen
- Helium Recovery Systems



# Feedstock Development

- Powders used in Cold Spray are developed to take advantage of and enhance the severe plastic deformation from impact
- A wide variety of processing techniques have been developed to process powders and achieved the desired outcome



# Cold Spray Integration Solutions

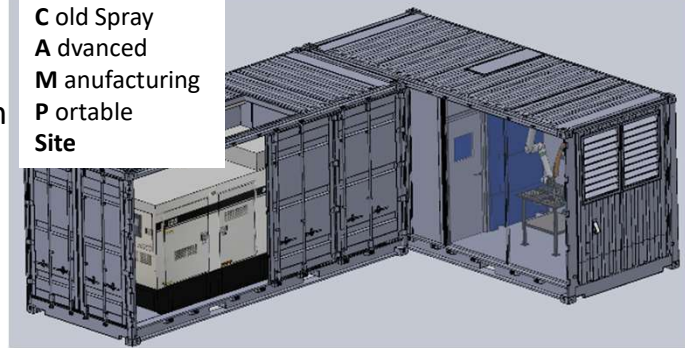
### Conventional Booth



- Cold Spray system
- Robot
- Spray Hood
- Dust Collection

- Cold Spray system
- Robot
- Dust Collection
- Generator
- Air Compressor

C old Spray  
A dvanced  
M anufacturing  
P ortable  
S ite



### Cold Spray Manufacturing Cell



- Cold Spray Booth
- Helium Recovery
- Machining Center

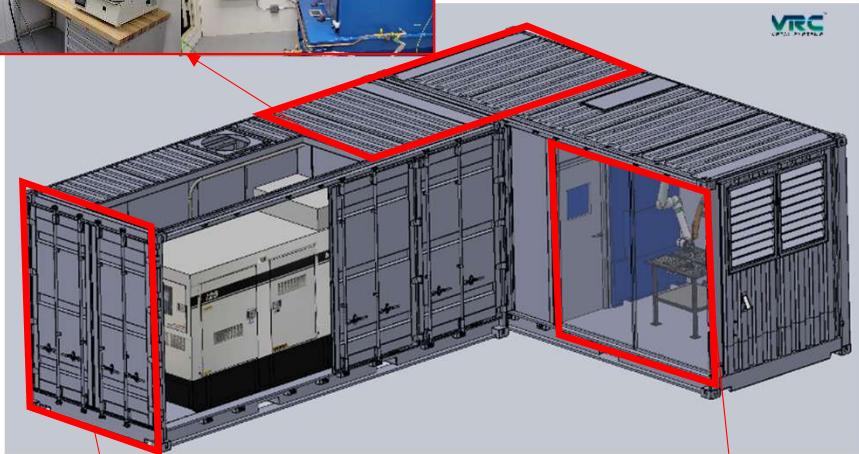
- Cold Spray System
- Dust Collection
- Robot

Together  
ahead. **RUAG**

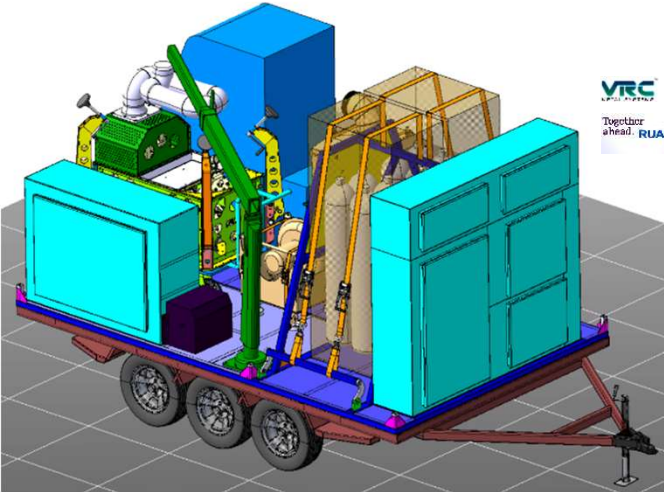
### Portable Trailer Based System Integration



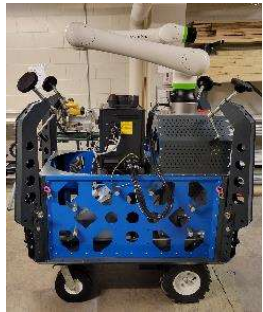
# Cold Spray Operations at the Point of Use



## Brolga 2



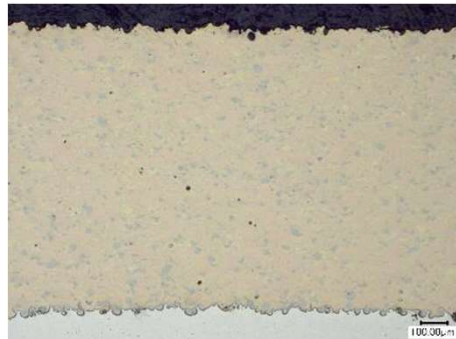
**C**old Spray  
**A**dvanced  
**M**anufacturing  
**P**ortable  
**SITE™**



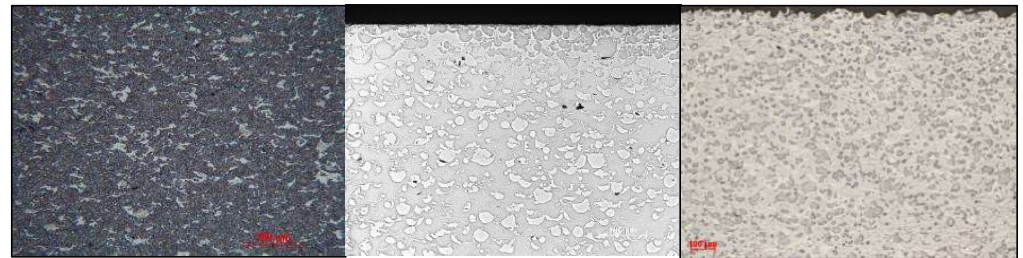
# Material Solutions for a Variety of Applications



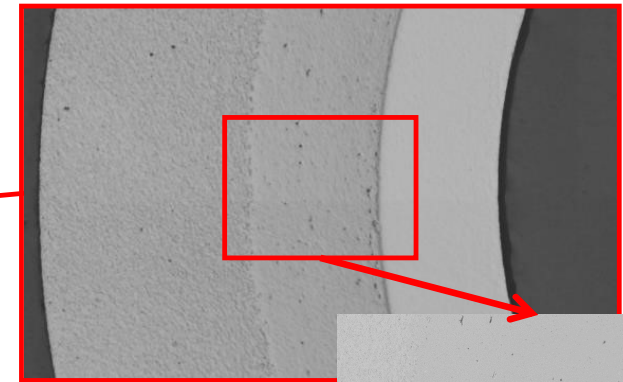
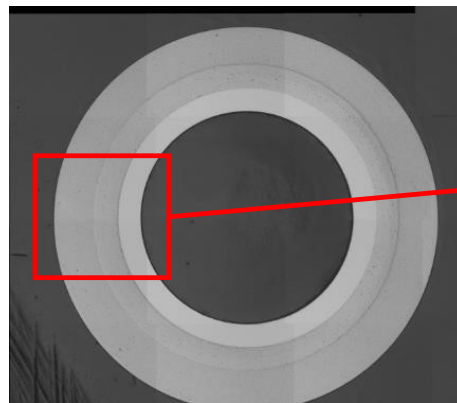
Pure Metals and Alloys



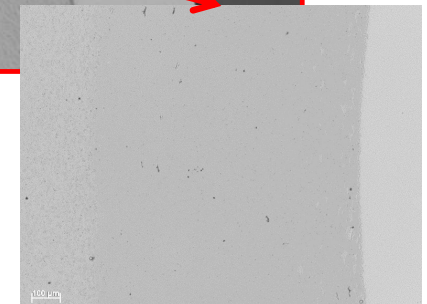
Lubricious Bronze



Metal Carbide Wear and General Repair Deposits

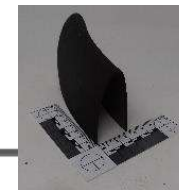
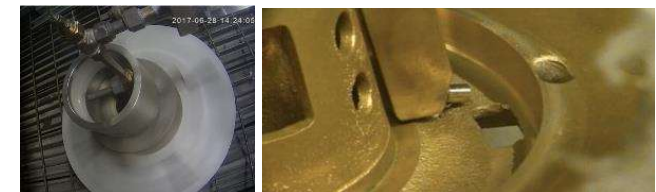
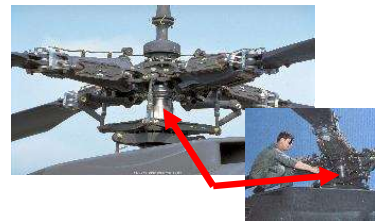


Multi-Material Layered Structures including Refractory Metals Like Chrome, Niobium, and Tantalum



# Typical Cold Spray Applications

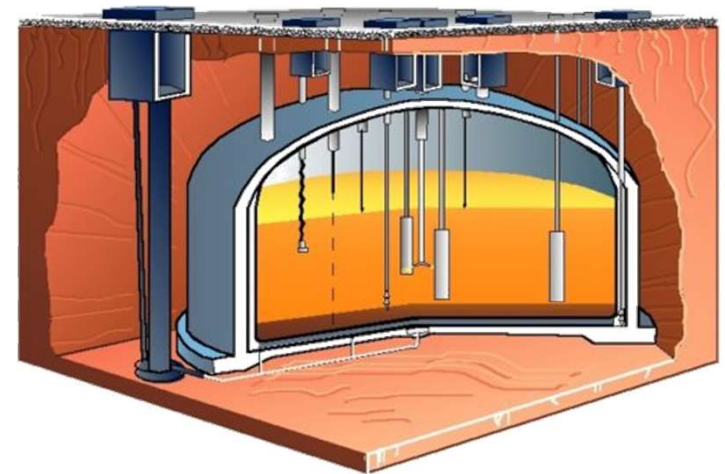
- Corrosion repair and mitigation
- Wear repair and mitigation
- Other surface enhancements
  - Appearance, Conductivity, Anti-microbial, extreme temps
- Feature addition for damaged parts
- Additive manufacturing of new parts



# Hanford Site Tank Repair

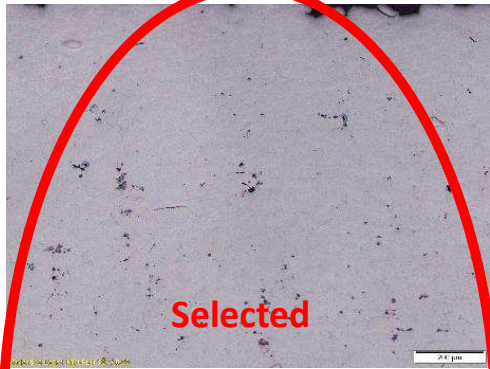
## Problem Statement

- Hazardous waste tanks are sustaining corrosion from prolonged exposure to waste fluids and existing defects in the welded structure.
  - Wall thinning, pitting, potential perforations
  - No welding or other high temperature techniques
  - Access limited
- Acceptable Repair Solution Development
  - No thermal degradation
  - Has compressive residual stresses
  - Replaces lost material and increases wall thickness
  - Can be done in-situ
- Coating Acceptance Criteria
  - Adhesion Greater than 48 MPa
  - Porosity less than 2%
  - Hardness Greater than 250 HV
  - Inspectable using Ultrasonic Measurements



# Hanford Site Tank Repair

## Material Downselect



### Mild Steel (He)

- DE: 64%
- Adhesion: 61 MPa
- Porosity: 0.17%
- Hardness: 276 HV



### 316L SS Blend

- DE: 23%
- Adhesion: 61 MPa
- Porosity: 0.90%
- Hardness: 345 HV



### 410L SS Blend

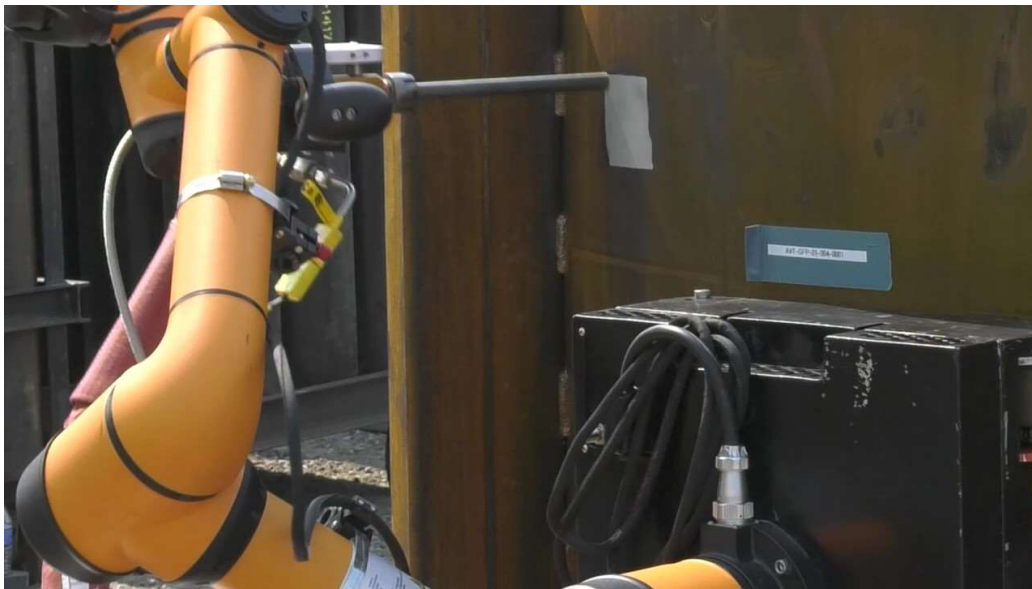
- DE: 27%
- Adhesion: 57 MPa
- Porosity: 0.80%
- Hardness: 322 HV

\*A36 Substrate Hardness: 147 HV

# Hanford Site Tank Repair



## Field Demonstration at Hanford Using VRC Dragonfly



Parameter	Pre-Witness Coupon	Post-Witness Coupon
Adhesion	45 Mpa	57 Mpa
Porosity	0.26 %	0.32 %
Hardness	235 HV	245 HV

### Coatings on Mockup UT-Inspection

Sample	Pre-Thickness	Post-Thickness	Coating Thickness
TW3	0.383 in.	0.450 in.	0.067 in.
IB1	0.080 in.	0.150 in.	0.070 in.
TW1	0.383 in.	0.442 in.	0.059 in.
TW2	0.385 in.	0.448 in.	0.063 in.



# Thin Wall Repair Development

## Simulated Thin Wall Repair of Steel Pipe



Simulated thin wall damage



Damage blended out



Surface Grit Blasted

Surface repaired to bring wall thickness back above min wall requirement



Manual Cold Spray operation using 410SS based repair material

# Planetary Gear Shaft for Earth Moving Equipment

- 4 feet Long
- 2 foot base diameter
- 970 lbs
- A bearing seized and the inner race galled the carrier.



<https://mining.komatsu/en-au/surface-mining/electric-rope-shovels>

**Galling damage. This was machined out prior to cold spray.**

**As Received**



**After cold spray repair**



**Deposit material: 410SS-carbide blend.**

**Post-Machined**



**Part was still in service 30 months later, normal replacement interval is 24 months.**

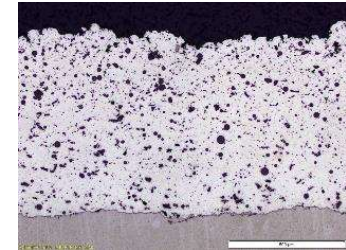
# Corrosion Protection and Repair

## Storage Tanks and Mixing Chambers

- Steel tanks are subject to corrosion
  - Repair corrosion damage
  - Coat to prevent further corrosion
  - Protect welds from localized corrosion
- Common repairs needed
  - Spot repair of corrosion
  - Increasing wall thickness
  - Sealing small leaks



High density barrier coatings of nickel or stainless steel



Aluminum based galvanic protection



NZZL0060

747-787 m/s Depending on feed rate ( $\pm 100$  m/s)



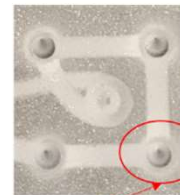
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745-748 m/s Depending on feed rate ( $\pm 87$  m/s)

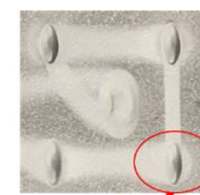


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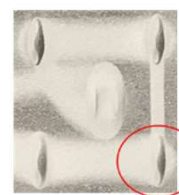
751-756 m/s Depending on feed rate ( $\pm 96$  m/s)



8.6mm Spread at 40mm standoff



13mm Spread at 40mm standoff



15mm Spread at 40mm standoff

# Military and Commercial Aerospace



PennState

AH-64 Static Mast Support  
AH-64 Intermediate Gear Support

Bell AH-1 Elevator Horns  
H-53 Main Transmission  
H-53 Nose Gearbox  
H-60 Sump

UH-60 Main Gearbox Housing  
T-700 Front Frame  
T-700 Shafts

B-1 Hydrotubes  
B-1 FEB Panels  
B-52 CSD Housing  
F-15 AMAD

F-15 CSD Housing  
F-15 Electrical Housing  
F-16 ADG

F-18 AMAD  
KC-135 IDG Housings  
CH47 Case & Rotor  
S-64 Components

S-92 Sump & Hydro Hsgs  
PT6 Housings  
H-46 Components  
AW-139 Upper Scissor Lever  
S-76 Components  
Landing Gear Components



# Military Maritime



PennState



Platform	Application	Substrate
Ballistic Missile Submarine	Hydraulic Actuator	Ductile CastIron
Nimitz Class Aircraft Carrier	AC CW Pump Motor Shaft	Stainless Steel 410
Moored Training Ship	MSW Hull Valve Upper Stem	KMONEL
Nimitz Class Aircraft Carrier	Seawater Check Valve Disk	CUNI 7030
Ballistic Missile Submarine	Hydraulic Actuator End Cap	Aluminum 6061
Nuclear Submarine	Regulating Valve Body	Bronze
Nuclear Submarine	Hydraulic Actuator Body	Aluminum 6061
Nimitz Class Aircraft Carrier	Gearbox Flange	Carbon Steel
Nuclear Submarine	Operating Rod	KMONEL
Nuclear Submarine	Regulating Valve Body	Bronze
Nuclear Submarine	Hydraulic Actuator Body	Aluminum 6061
Nuclear Submarine	Valve Stem	Stainless Steel410
Nimitz Class Aircraft Carrier	Pump Shaft	KMONEL

