

VRC Metal Systems and Advanced Manufacturing Technologies

May 26th, 2022

Aaron Nardi (Chief Technology Officer)
VRC Metal Systems LLC

Outline of Talk

- VRC Company Introduction
 - Equipment
 - Materials and Process Development
 - Applications
 - Other Technology Development
-

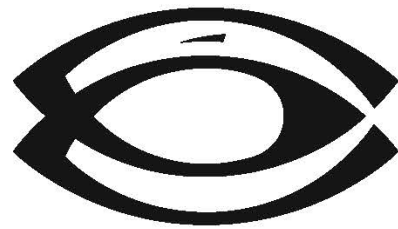
Outline of Talk

- VRC Company Introduction
 - Equipment
 - Materials and Process Development
 - Applications
 - Other Technology Development
-

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



QUALITY IN
AEROSPACE

AS9100D

NSAI Certified

Working with our Government partners



Working with our Commercial partners



Working with our Research partners



VRC Facilities

- ★ Current
- ★ Coming Soon

VRC Puget Sound Region:
Process Development
Full Production
CNC Part Machining



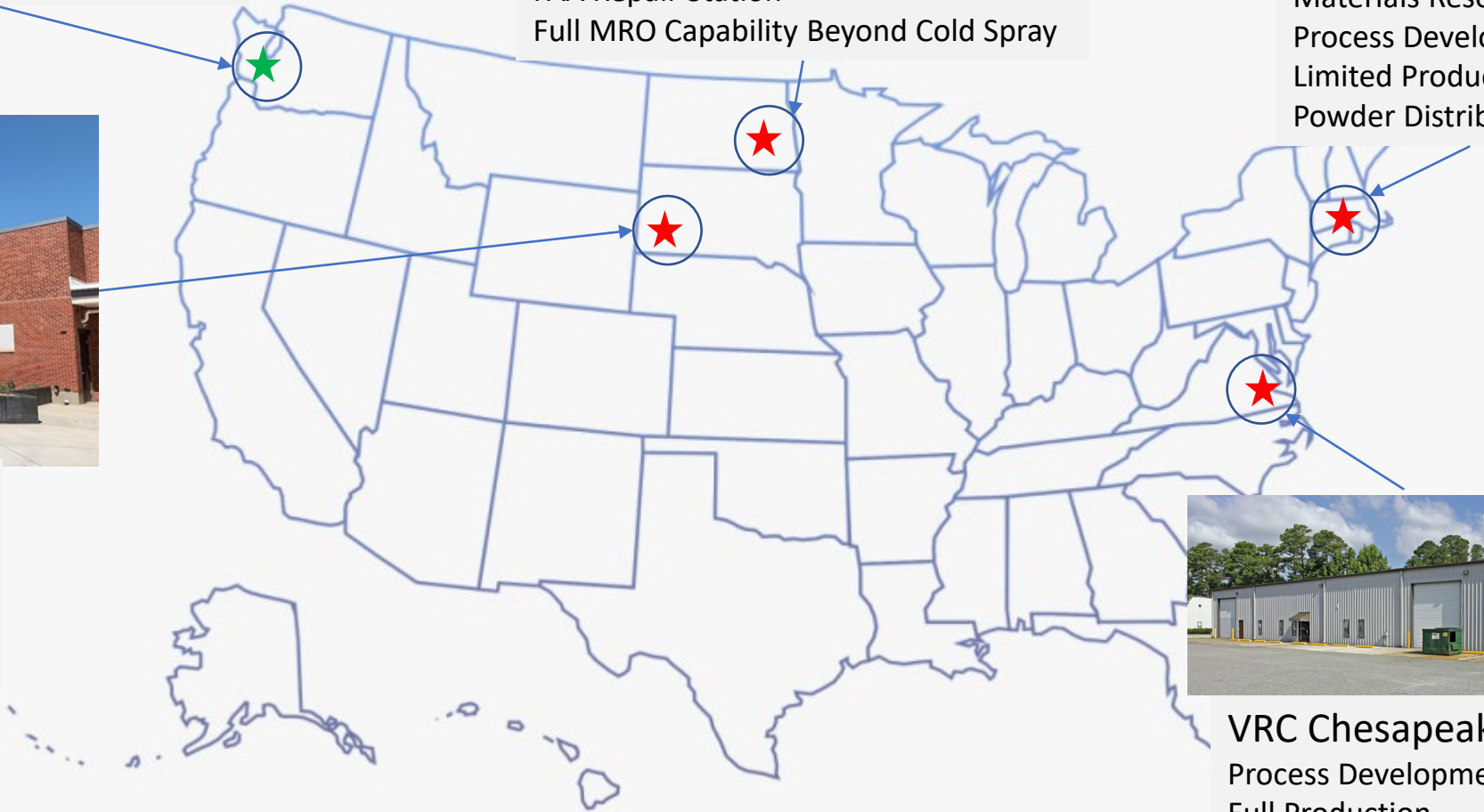
Mid-America Aero:
Process Development
Full Production
FAA Repair Station
Full MRO Capability Beyond Cold Spray



VRC Northeast:
Materials Research
Process Development
Limited Production
Powder Distribution



VRC HQ:
Engineering
System Production
Process Development
Limited Production



VRC Chesapeake:
Process Development
Full Production
CNC Part Machining



VRC – Full Service Cold Spray Provider



System Engineering & Manufacturing



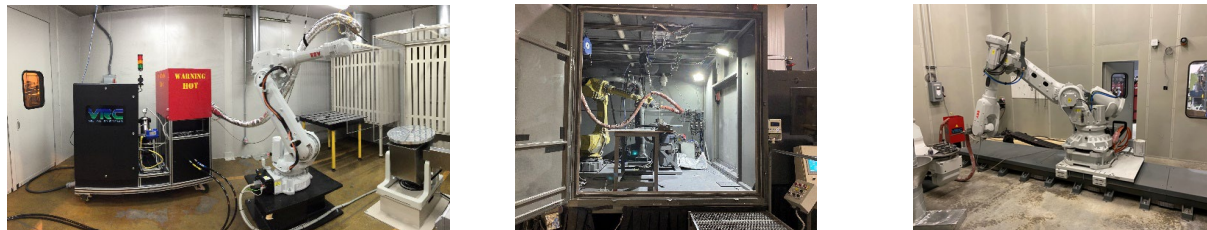
Cold Spray R&D/ Applications Development



Consumables Sales and Prototypes



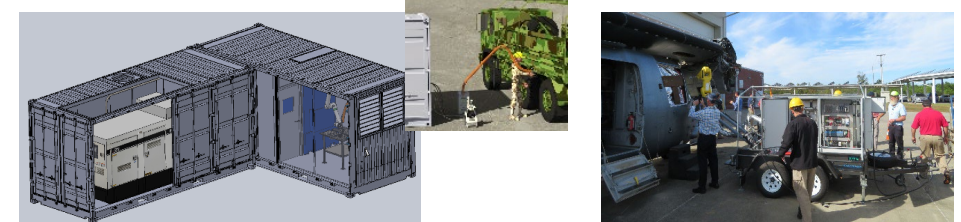
Automation/Booth Integration



Fee for Service Work



On-site Repair/Modification



Cold Spray Operations Support

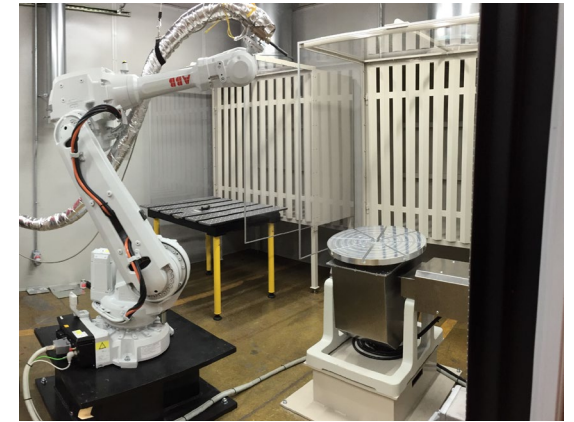


Outline of Talk

- VRC Company Introduction
 - Equipment and Consumables
 - Materials and Process Development
 - Applications
 - Other Technology Development
-

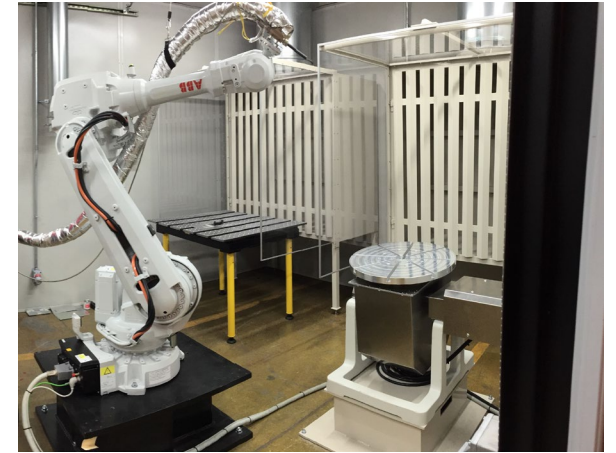
VRC Dragonfly Cold Spray System

- 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



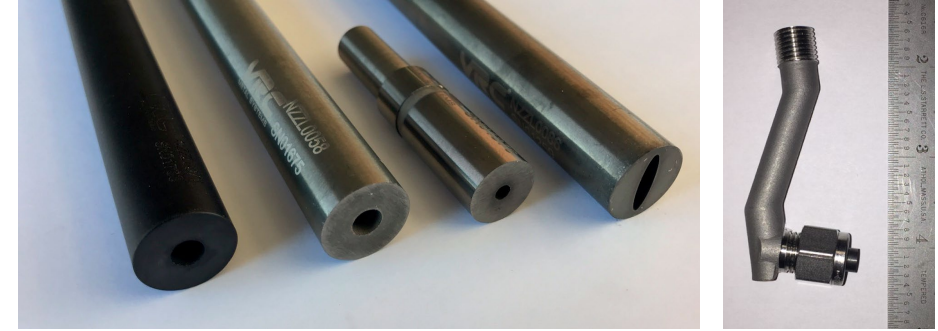
VRC Gen IV Cold Spray System

- 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 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



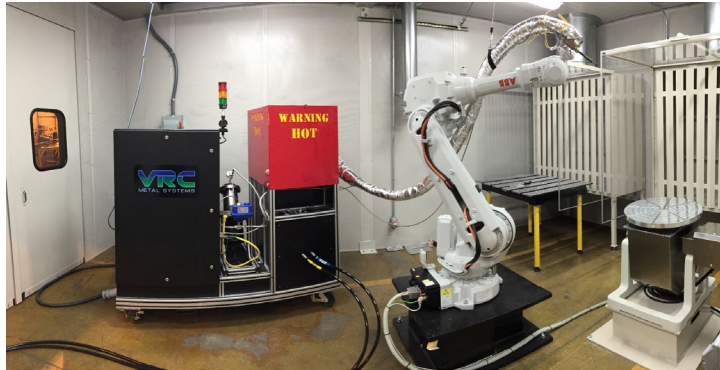
Feedstock Development

- 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

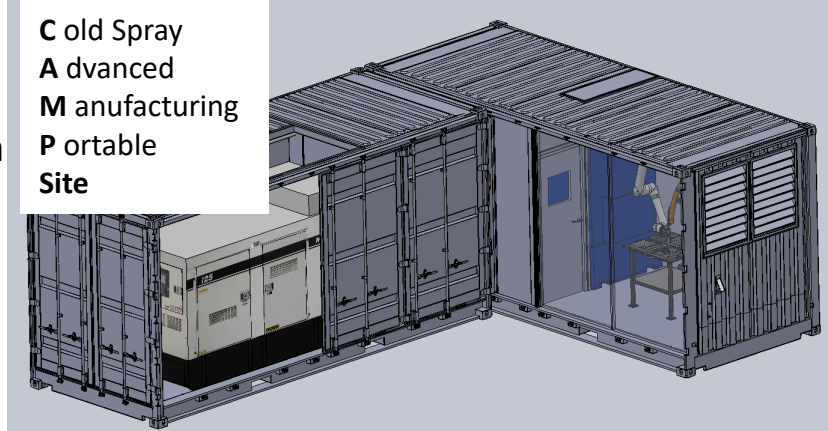
Conventional Booth



- 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
Site



Cold Spray Manufacturing Cell



- Cold Spray Booth
- Helium Recovery
- Machining Center

- Cold Spray System
- Dust Collection
- Robot

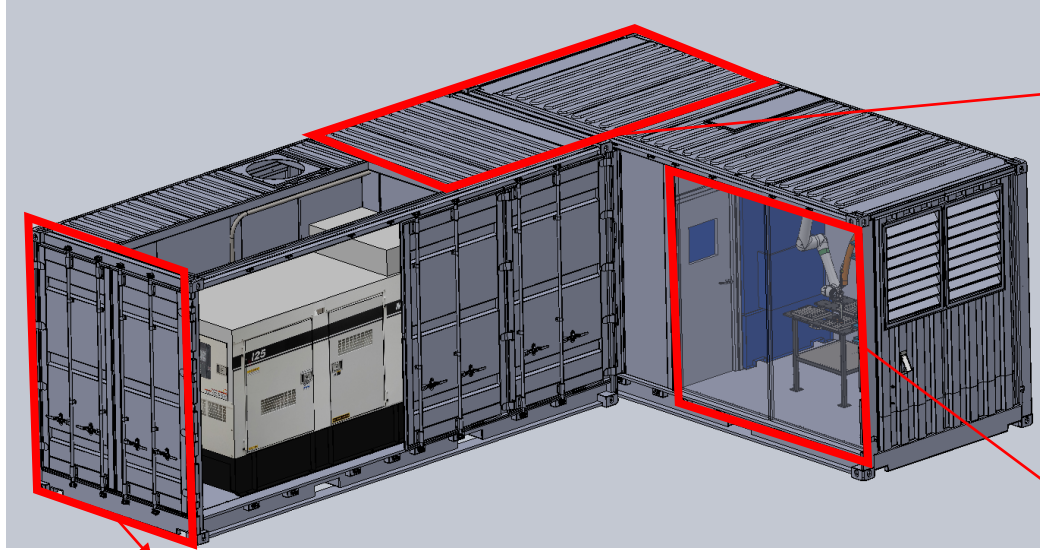
Together
ahead. **RUAG**

Portable Trailer Based System Integration



OSD Prototype Mobile AM Facility

- C.A.M.P. Site

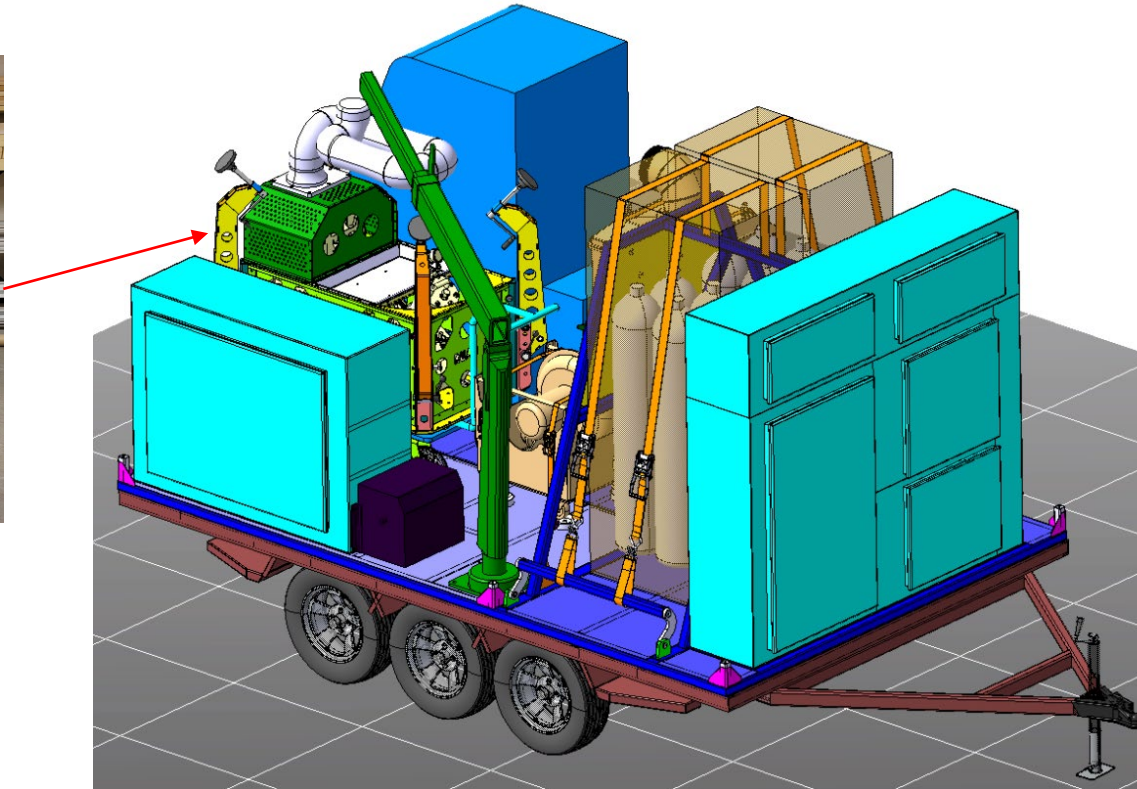
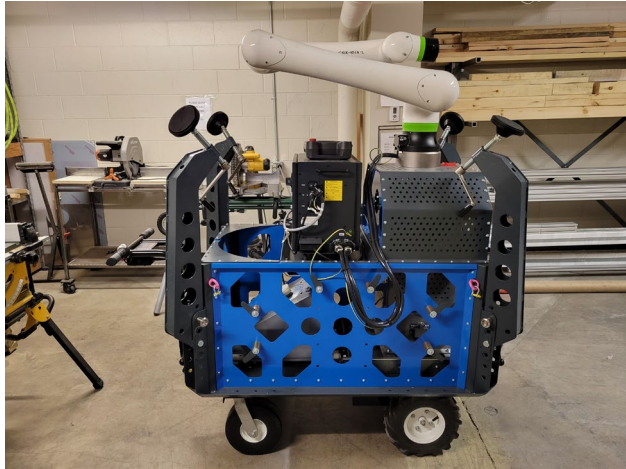


C old Spray
A dvanced
M anufacturing
P ortable
S ite



OSD Prototype Mobile Repair Platform

Brolga 2



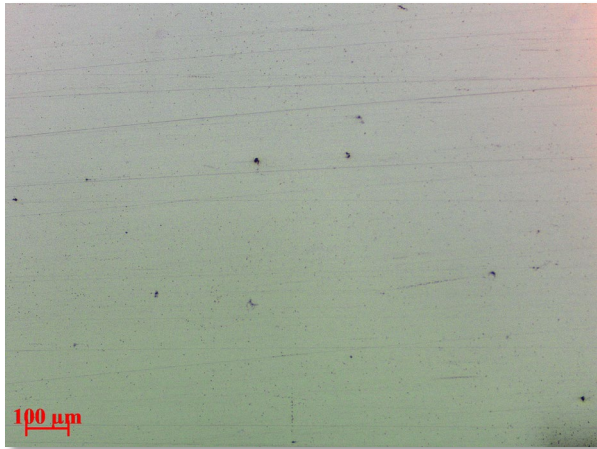
Together
ahead. **RUAG**



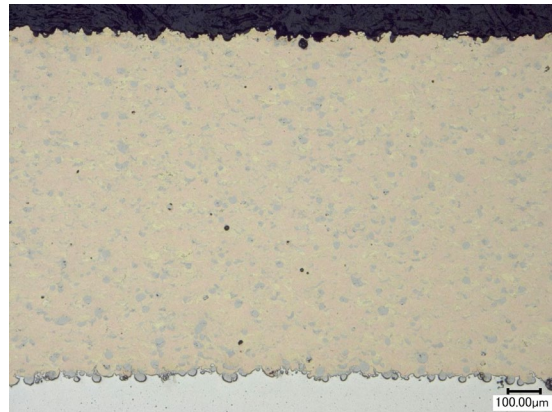
Outline of Talk

- VRC Company Introduction
 - Equipment and Consumables
 - Materials and Process Development
 - Applications
 - Other Technology Development
-

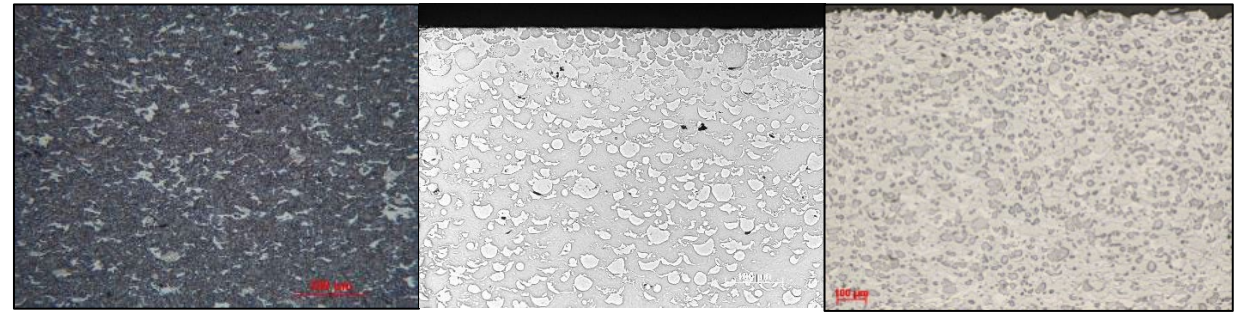
Material Solutions for a Variety of Applications



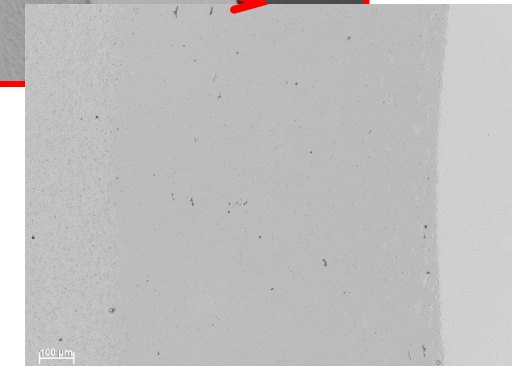
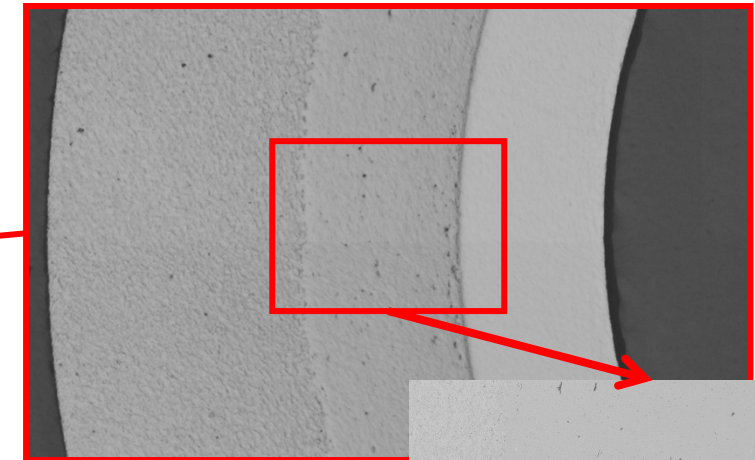
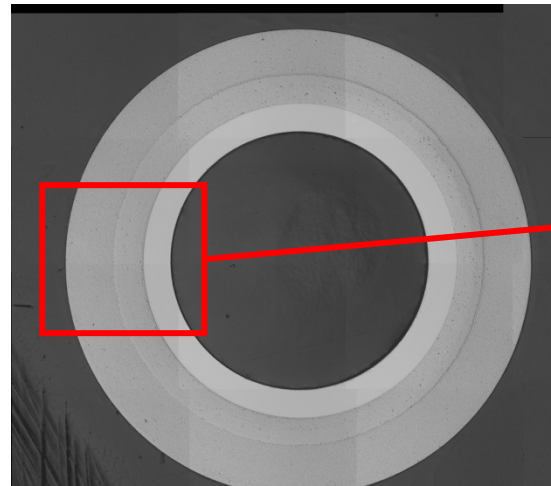
Pure Metals and Alloys



Lubricious Bronze



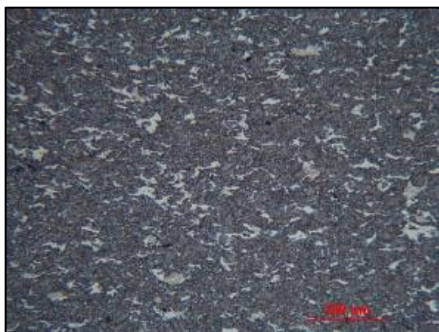
Metal Carbide Wear and General Repair Deposits



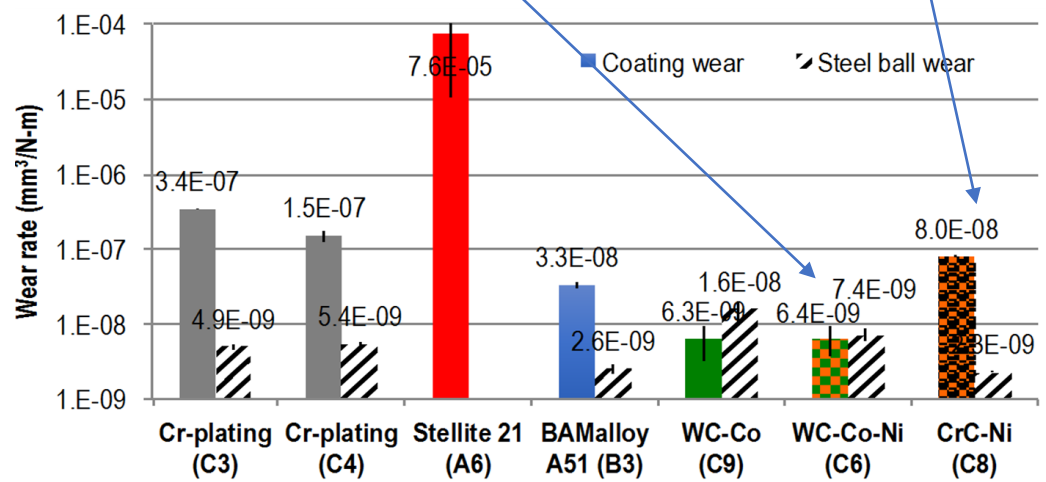
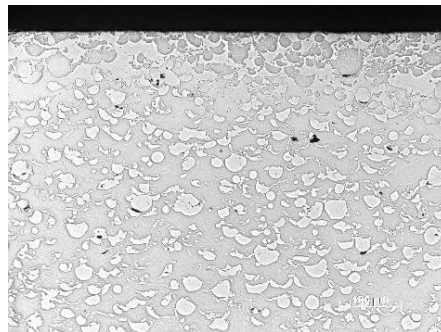
Multi-Material Layered Structures including Refractory Metals Like Chrome, Niobium, and Tantalum

Ni-CrC and Ni-WC Materials for Wear and Impact

WC01



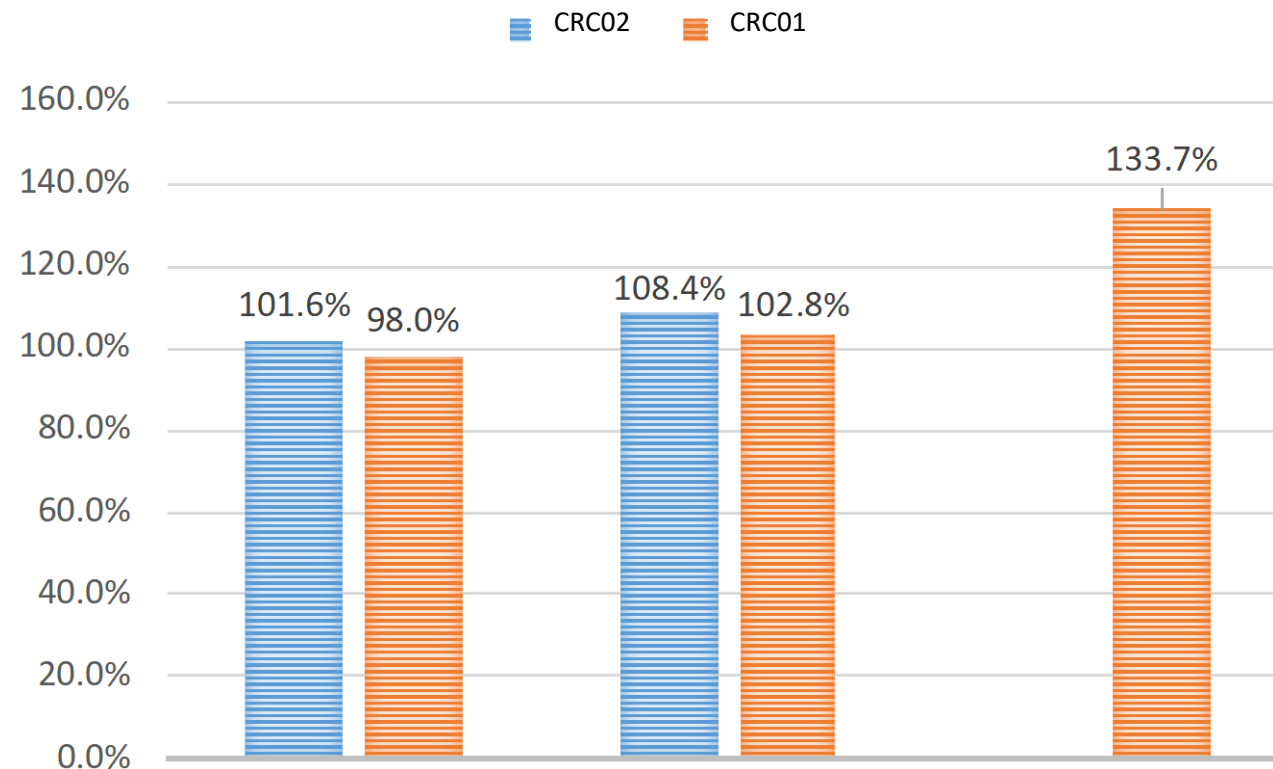
CRC01



**ASTM G133 Ball-on-flat
Reciprocating Wear Testing**

Cold Sprayed Materials

Cold Spray Ballistic Results vs. HHS V50 Baseline



AP-N2



AP-He

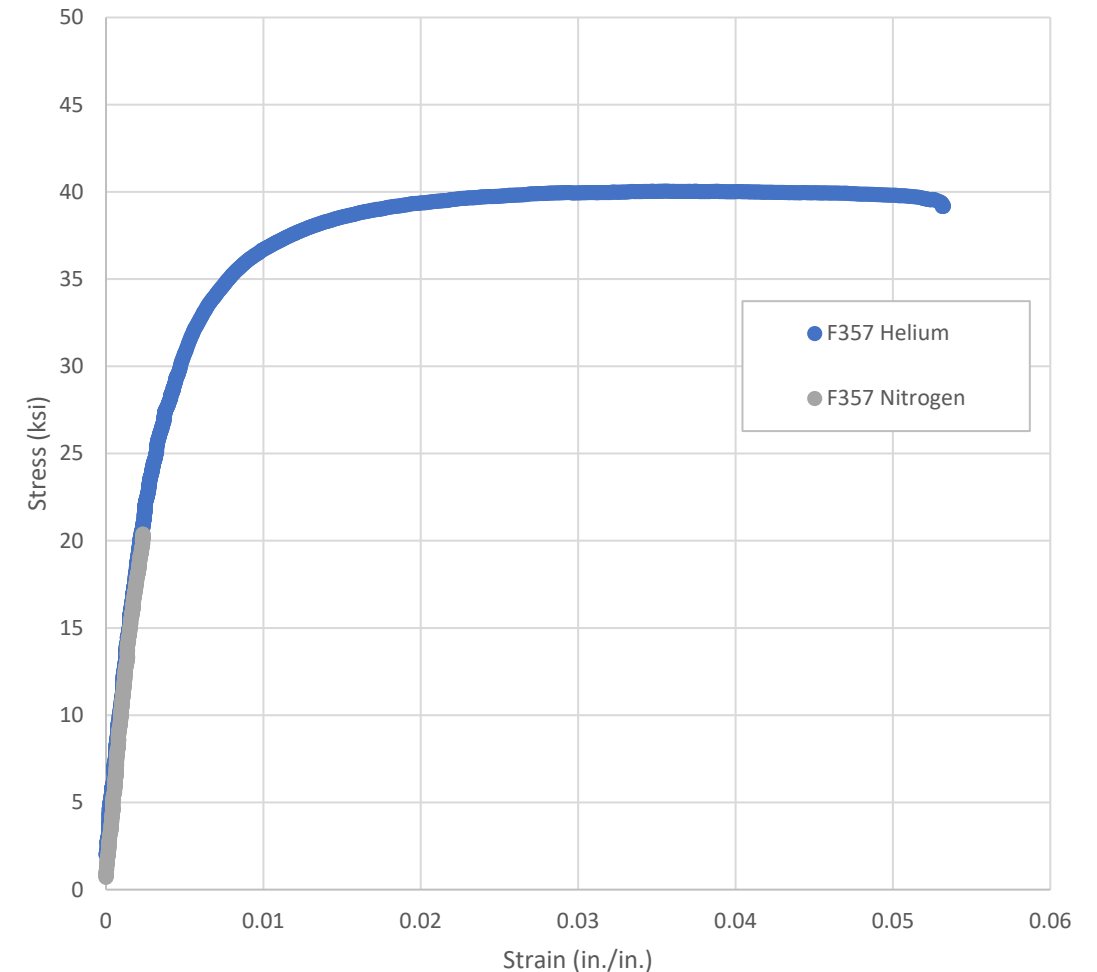


FSP-N2

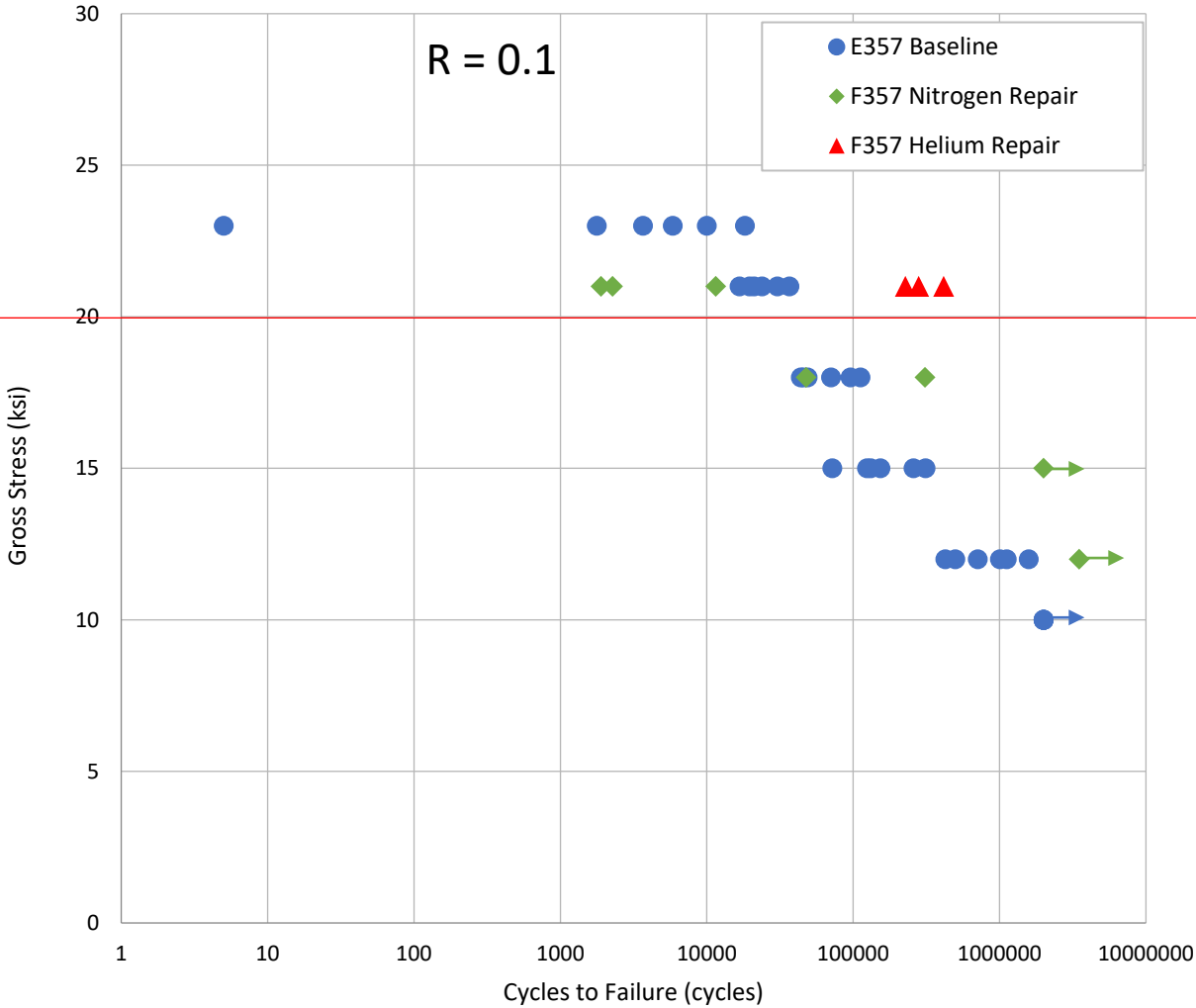
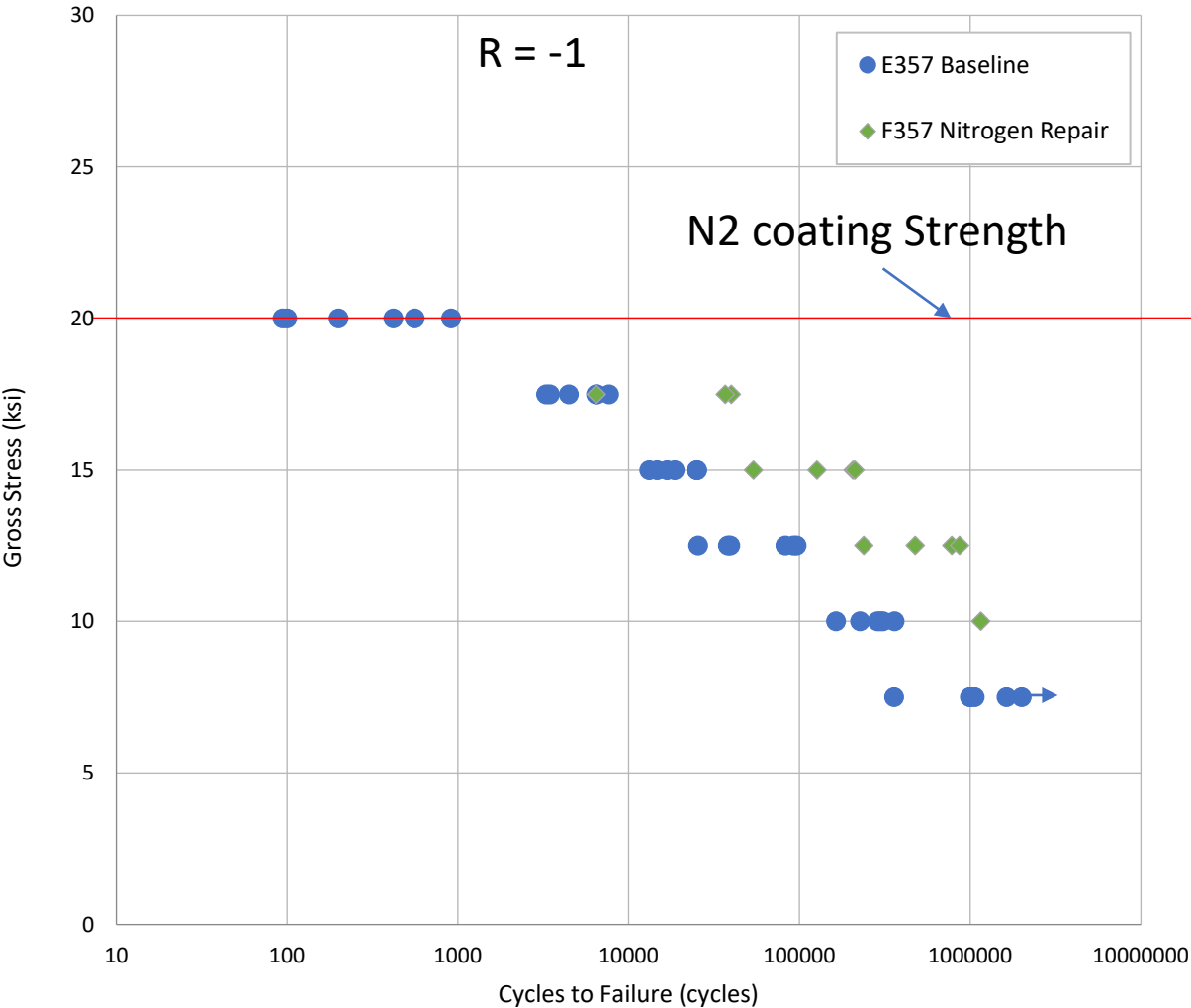
Cold Sprayed F357 Structural Repair

- Cold Spray coating strength and ductility comparison to substrate

<i>Material</i>	<i>Gas</i>	<i>Spray Direction</i>	<i>UTS avg. (ksi)</i>	<i>YS avg. (ksi)</i>	<i>EL% avg.</i>
Cast E357	N/A	N/A	37.1	33.6	6%
F357	Nitrogen	Longitudinal	20.9	20.2	0.05%
F357	Nitrogen	Traverse	16.5	16.3	0.04%
F357	Helium	Longitudinal	43.2	34.1	3.49%
F357	Helium	Traverse	39.9	30.6	4.86%



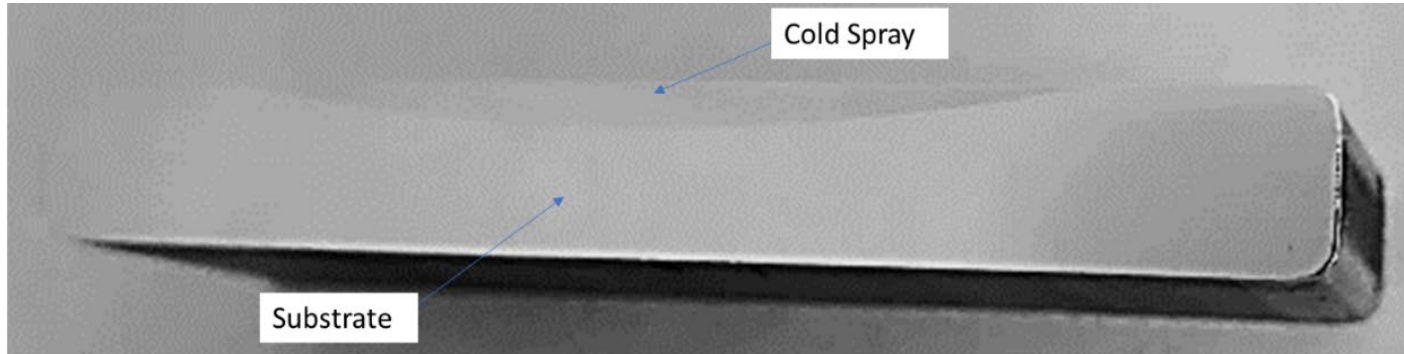
Cold Sprayed F357 Structural Repair



Cold Sprayed 7050 Structural Repair

- GOAL: Repair blends in 7050 wrought alloys without fatigue debit
- SOLUTION: CS to fill using Aluminum Alloy 7050

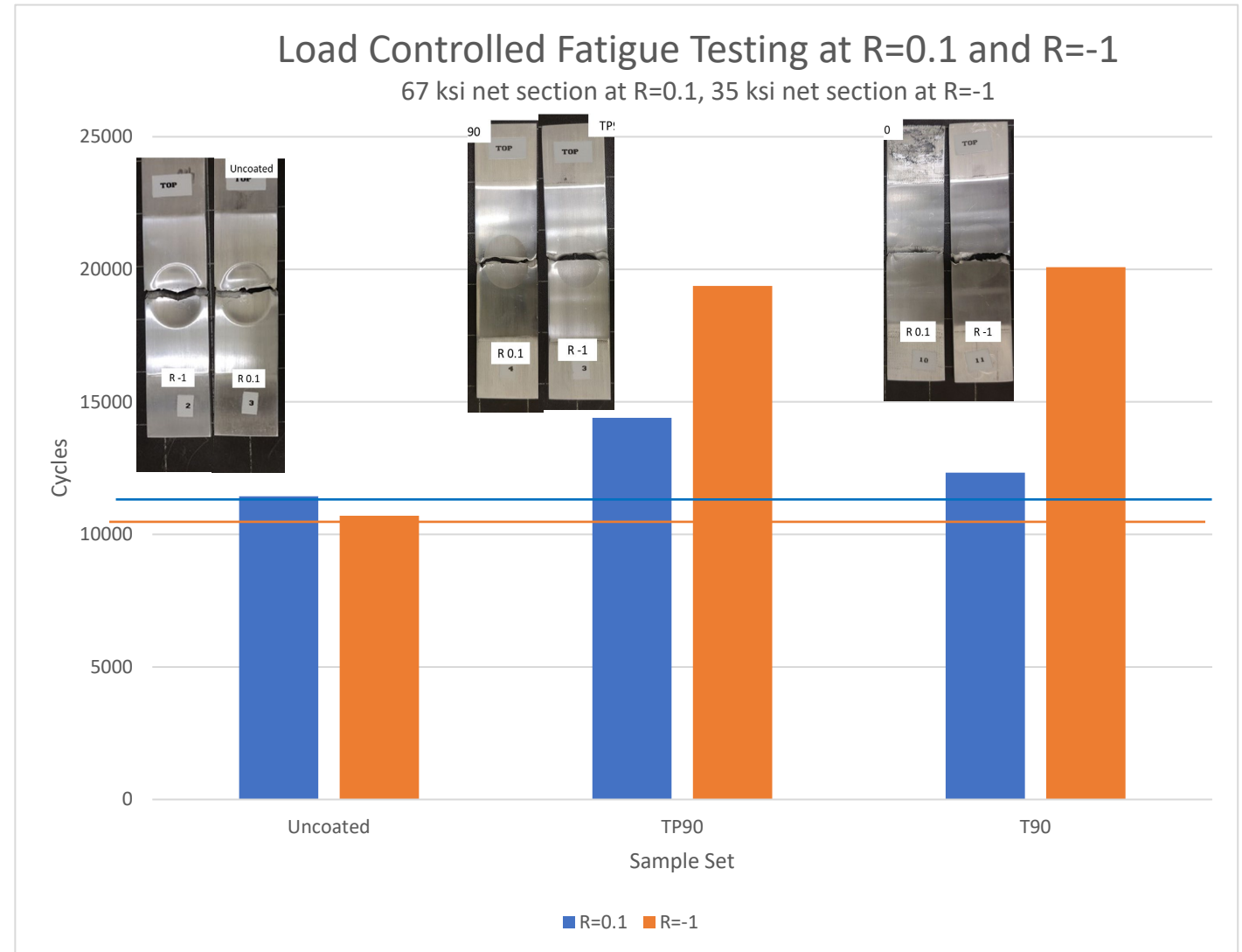
	Cold Sprayed 7050	Wrought 7050
Tensile Strength:	53 ksi	75 ksi
Yield Strength:	41 ksi	65 ksi
Elongation:	3.5 %	16 %



Is as-deposited 7050 Al suitable for structural repair of higher strength wrought 7050?

Cold Sprayed 7050 Structural Repair

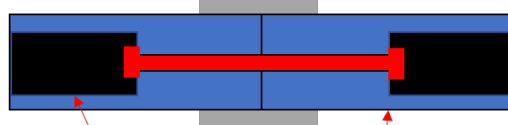
- R=0.1 tension-tension and R=-1 fully reversed fatigue
- R=0.1 → 67 ksi net section
- R=0.1 → 35 ksi net section
- *Cold Spray increased fatigue life under very high stress LCF conditions!!*
- Cold Spray repairs carry load



Cold Sprayed 7050 Structural Repair

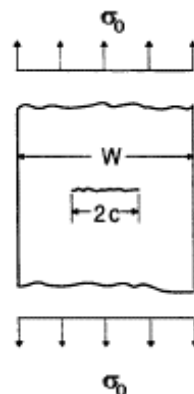
Supplemental Testing

- Originally developed in Germany for evaluation of Thermal Spray Coatings
- Combined strength and toughness
- Result from TCT test reported as stress intensity factor

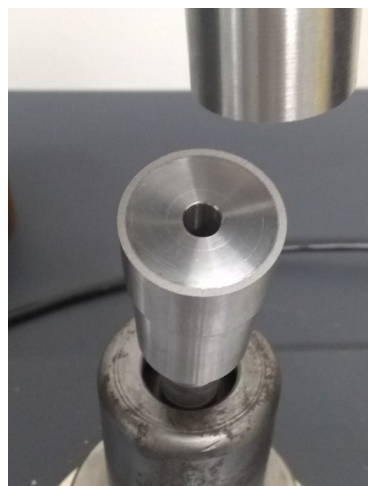


Threaded 0.75 inch
threads

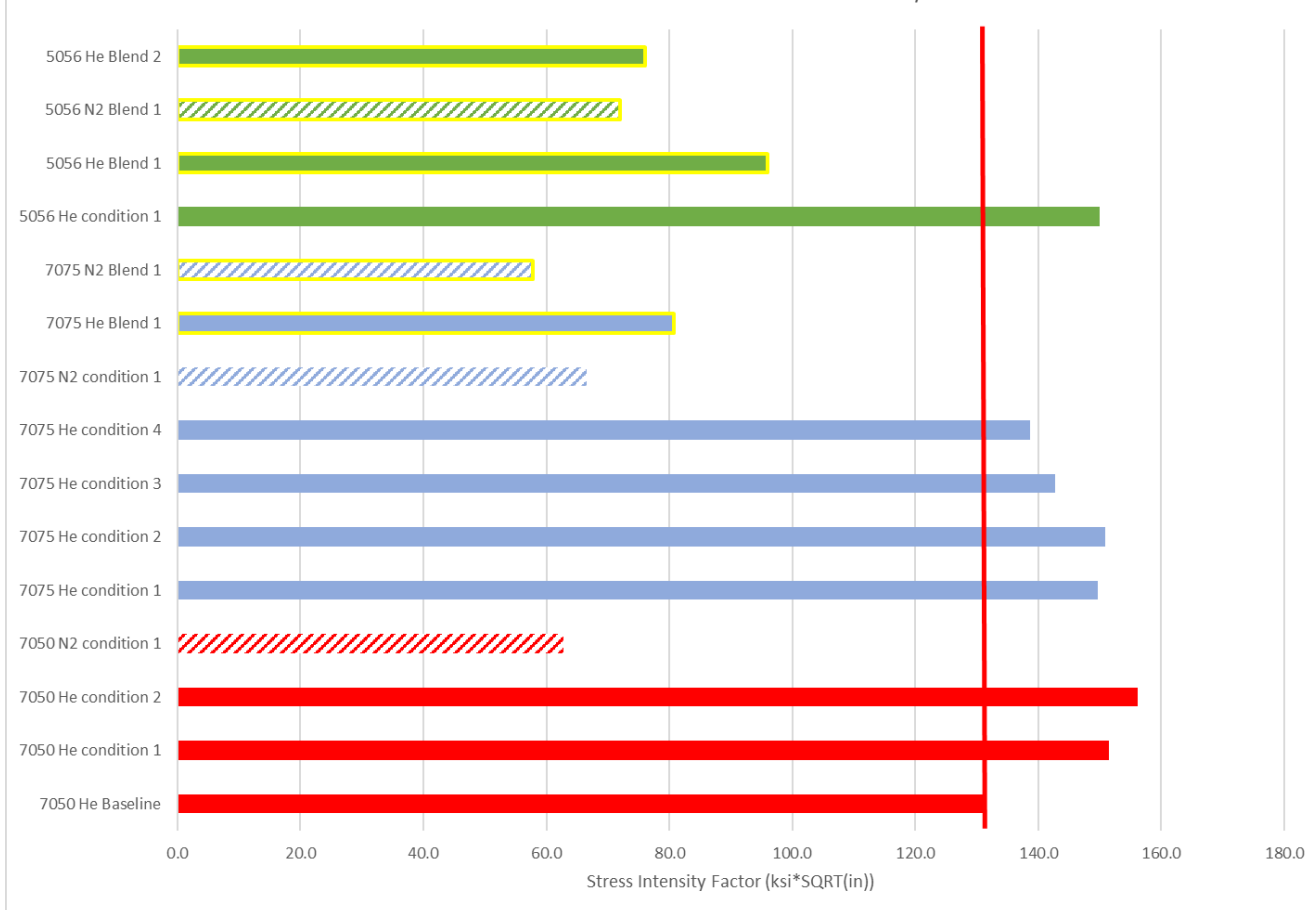
2- 1 inch diameter 2
inch long pins



$$K_0 = F_0 \sigma_0 \sqrt{\pi a}$$
$$F_0 = \left[\sec \left(\frac{\pi a}{W} \right) \right]^{1/2}$$



TCT Test Results for Baseline 7050 and Alternate Materials/Processes

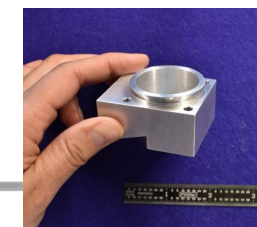
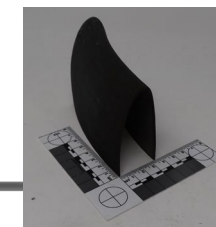
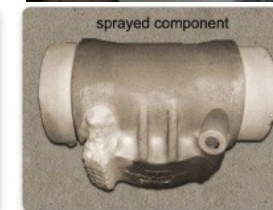
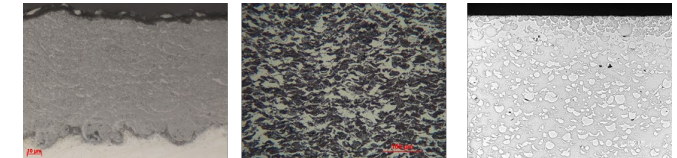
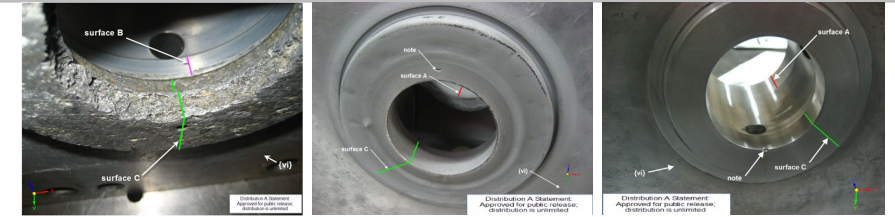


Outline of Talk

- VRC Company Introduction
 - Equipment and Consumables
 - Materials and Process Development
 - Applications
 - Other Technology Development
-

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



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

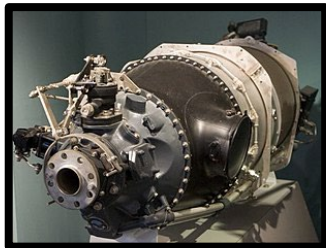
PT6 Housings

H-46 Components

AW-139 Upper Scissor Lever

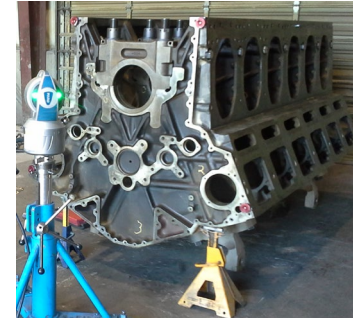
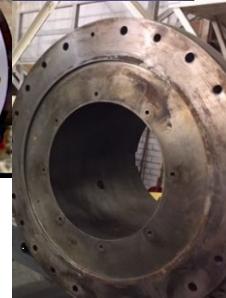
S-76 Components

Landing Gear Components



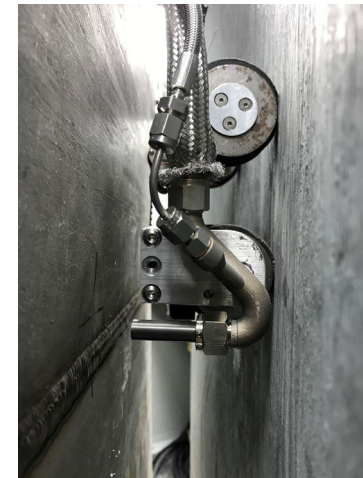
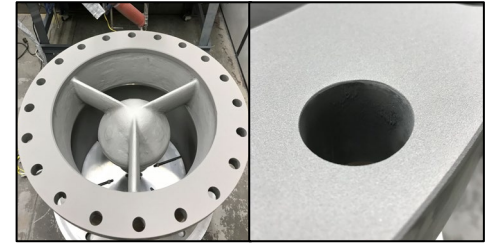
Applications in Heavy Industrial

- Pipeline damage, corrosion, and leaks
- Sealing and Mating Surfaces
 - Ex. Flange refacing
- Wear Resistant Coatings
- Casting Repair
- Supporting Equipment
 - Ex. Centrifugal & Axial Compressors and Pumps
- Downhole parts



Applications in Energy Sector

- Stress Corrosion Cracking prevention on Stainless Steel in nuclear secondary systems
- General Corrosion prevention in nuclear secondary systems
- Specialty coatings for fuel rods in nuclear
- Mobile repair of large water and fuel rod storage containers
- On-Site cavitation repair of hydro-power components



Outline of Talk

- VRC Company Introduction
 - Equipment and Consumables
 - Materials and Process Development
 - Applications
 - Other Technology Development
-

Wire Arc Additive Manufacturing (WAAM) of Titanium (C.P. Grade 2)

Application & Issues

- ❑ Titanium (C.P. Grade 2) is used in the Department of Navy for pumps, impellers, and valves.
- Limited availability of large titanium parts.
- Lead times.
- Supply chain gaps in USA;
Large Titanium casting foundries are extinct in USA.

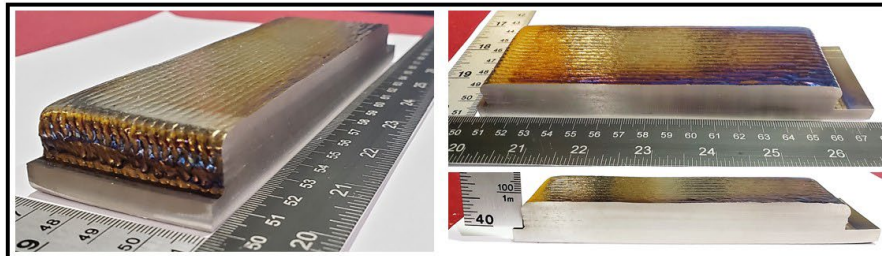
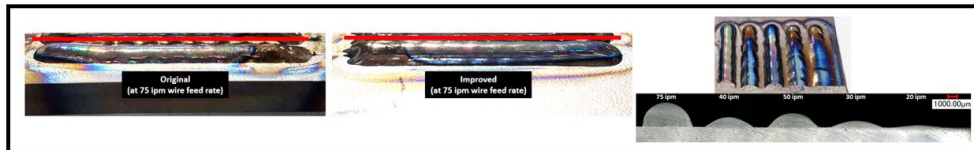
Approach & Advantages

- Develop the Wire Arc Additive Manufacturing Process for Titanium Deposition.



- ✓ High deposition rate additive manufacturing (AM) process.
- ✓ Medium feature resolution.
- ✓ Ideal for manufacturing large parts, at the point of need.
- ✓ Efficient process; almost 100% deposition efficiency.

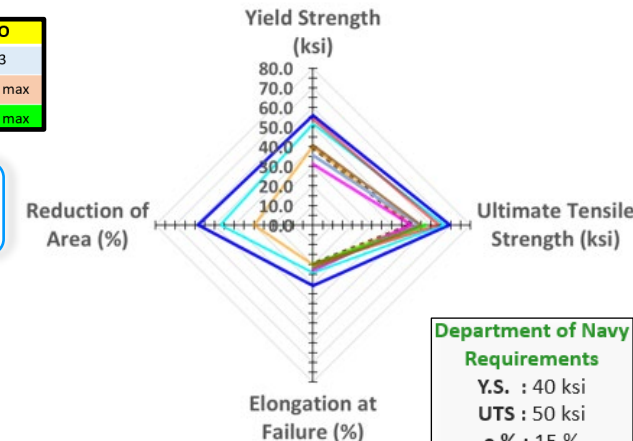
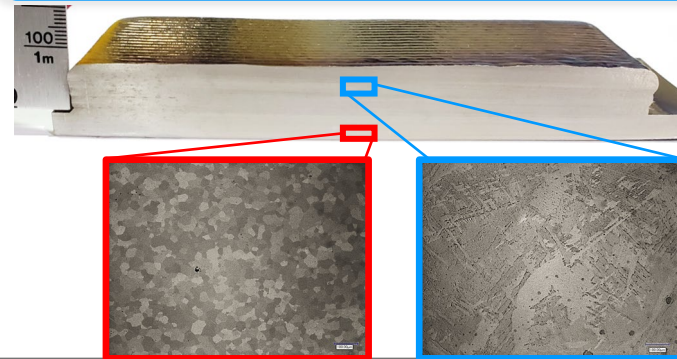
WAAM Titanium (C.P. Grade 2) – Process Development



WAAM Titanium (C.P. Grade 2) – Chemistry, Structure & Properties

Titanium C.P. (Grade 2) Chemistry	C	Fe	H	N	O
VRC (w.t.%)	0.01	0.05	0.0017	<0.001	0.003
ASTM Requirements (w.t.%)	0.10 max	0.30 max	0.015 max	0.03 max	0.25 max
Department of Navy Requirements (w.t.%)	-	-	-	-	0.25 max

Fully Dense WAAM Titanium Deposit with Superior Mechanical Properties, within Chemistry Requirements.



- VRC - Longitudinal Samples
- VRC - Transverse Samples
- ASTM Grade 2 (American C.P. Titanium Grade 2 - URN50400) - min
- Commercially pure alpha titanium Grade 2 for bars and billets (ASTM B348-78)
- DIN 3.7035 (German equivalent to ASTM C.P. Titanium Grade 2)
- JIS Class 2 - min (Japanese equivalent to ASTM C.P. Titanium Grade 2)
- GOST BT1-0 - min (Russian equivalent to ASTM C.P. Titanium Grade 2)
- GB TA2 (Chinese equivalent to ASTM C.P. Titanium Grade 2)
- BS 25-35t/in2 (British equivalent to ASTM C.P. Titanium Grade 2) - min

Thank you

- Resources for Further Information

- Contact Information – aaron.nardi@vrcmetalsystems.com
- Web Pages
 - <https://coldspray.com>
 - <https://vrcmetalsystems.com>