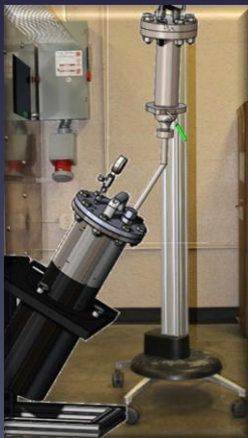
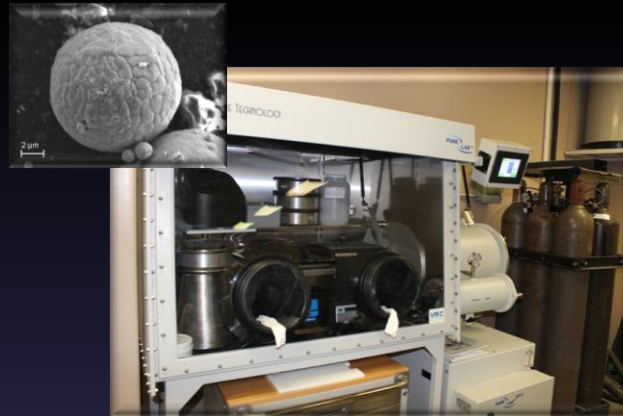


“Advancements of CS Powder Feeders and Processing”

Rob Hrabe
VRC Metal Systems, LLC
H.F. Webster Engineering Services

- VRC Overview
- Powder Processing and Delivery Overview
- Powder
- Powder Processing
- Delivery
- Powder Feeder



VRC Gen 3 Cold Spray System

Hand-held or Robotic Operation – 1000 psi



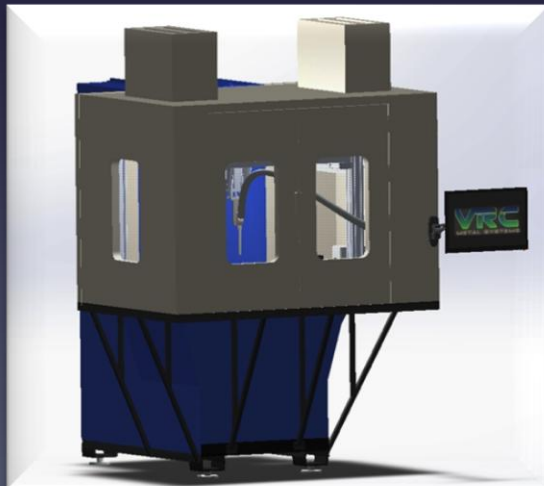
Cold Spray Booth & Motion System

Traditional Sound Booth and External Dust Collection



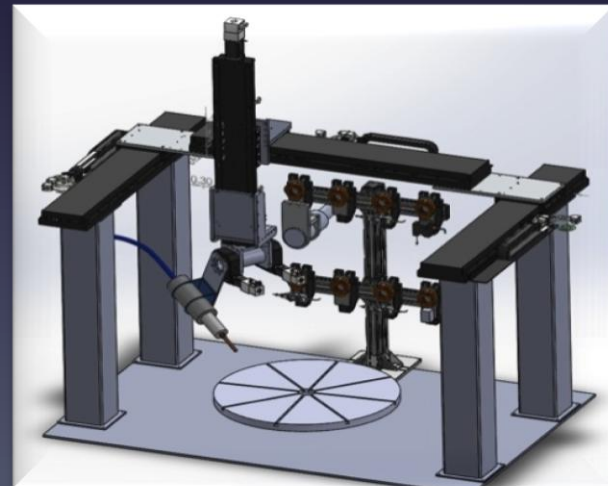
VRC Cold Spray Development Booth

Sound Damping/Dust Collection/4-Axis Motion



VRC Cold Spray Additive Manufacturing System

Multi-Axis Reconfigurable Manufacturing Center



9 Key Differentiators

1. Highest Pressure System on the Market – 1000 psi (70 bar)
2. Patent - Hand-Held Capable
 - US 20140117109 A1
3. Highly Maneuverable Light Weight Gun - < 7 lbs (3 kg)
4. Patented Heater
 - WO 2014178937 A1
5. Licensed Powder Feeder
 - United Technologies Research Center
 - Tumbles powder for better mixing
6. Mobile with Extended Reach
 - Removable Heater – Extend > 50 ft
7. Modular Design with Flexible Architecture
8. Gas Mixing – He & N₂ (or Air)
9. Continuous Process Monitoring and Data Record

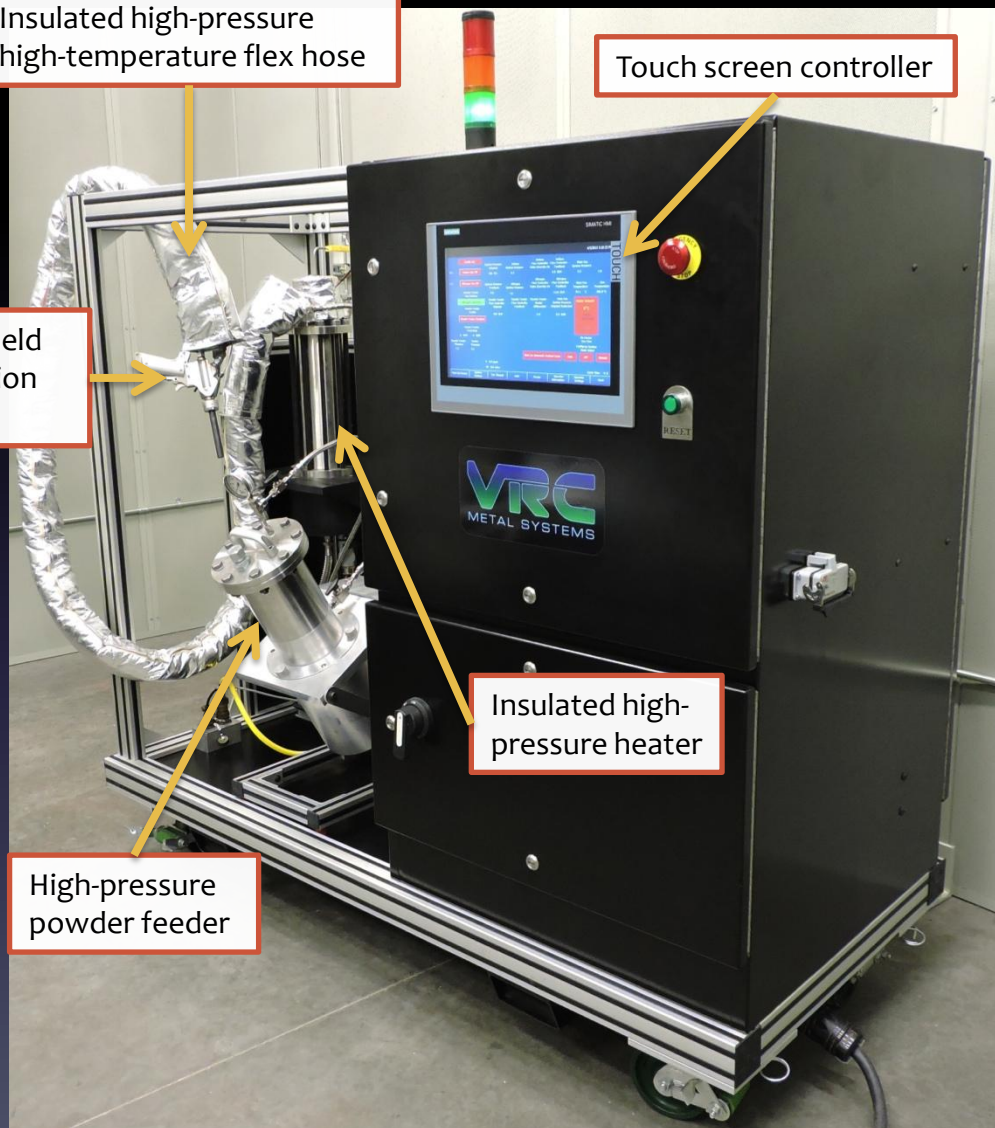
Insulated high-pressure high-temperature flex hose

Touch screen controller

Hand-held operation mode

Insulated high-pressure heater

High-pressure powder feeder





Powder Processing Development Team



For our next round of cold spray products...

HF Webster and VRC have partnered with

ARL, UTRC, MOOG, and SDSM&T

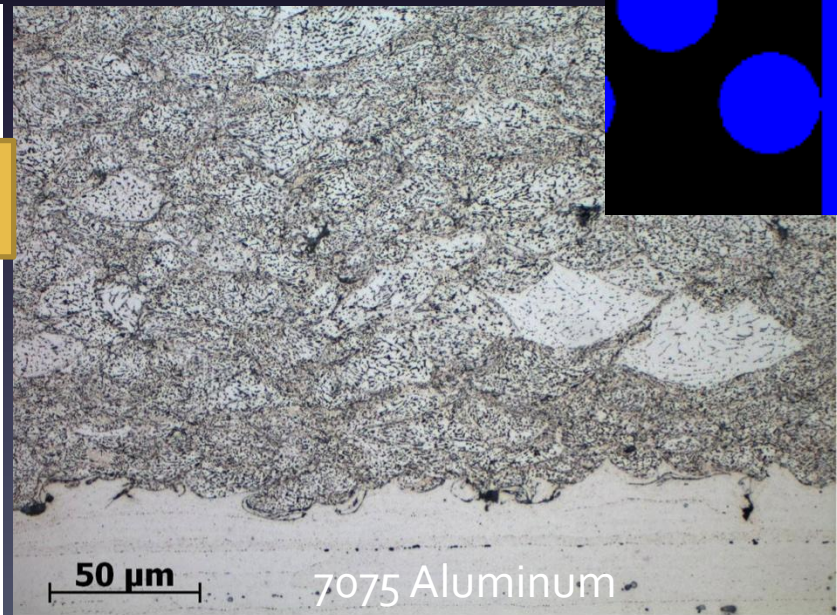
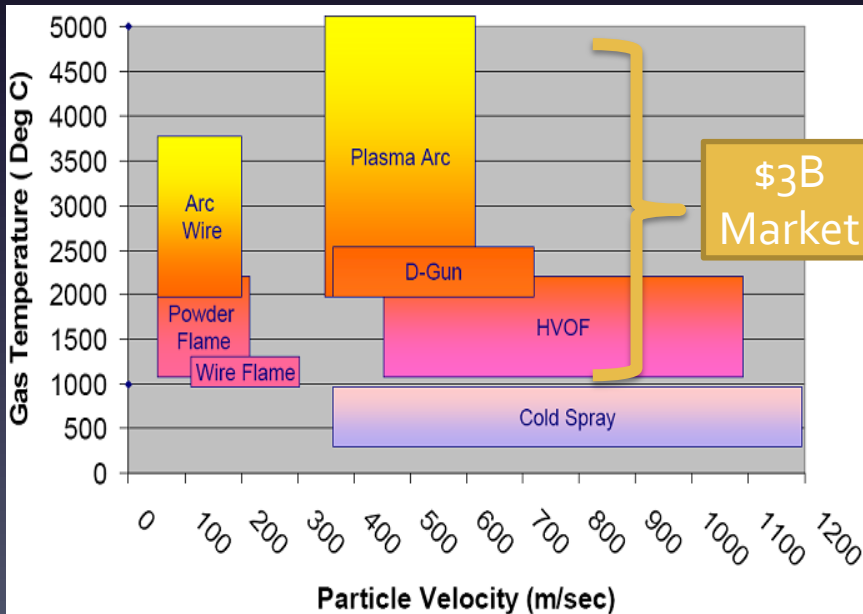
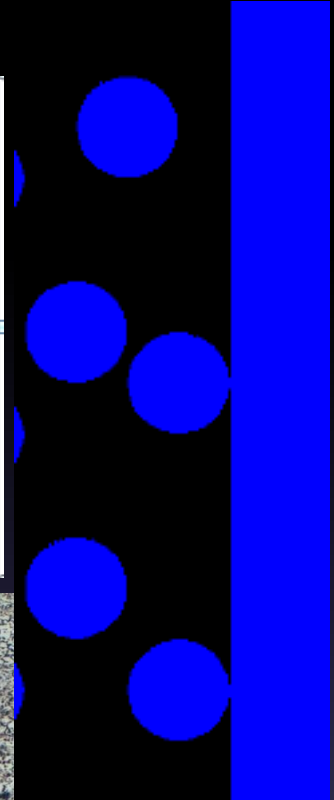
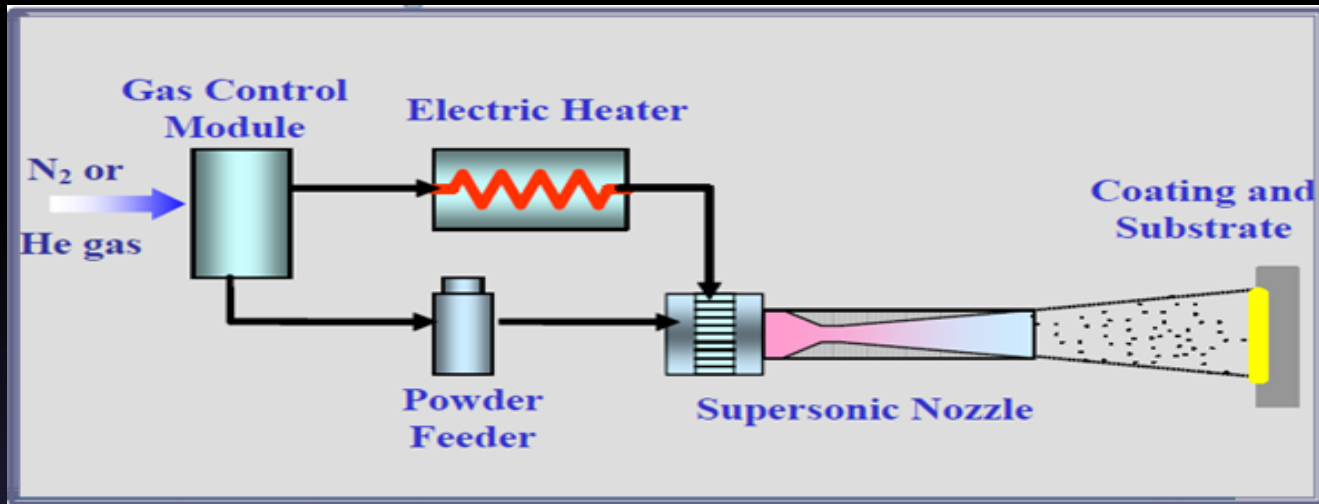
to develop **reliable powder processing techniques and equipment** for repeatable high strength coatings.



The logo for MOOG, consisting of the word 'MOOG' in a large, bold, dark red serif font.



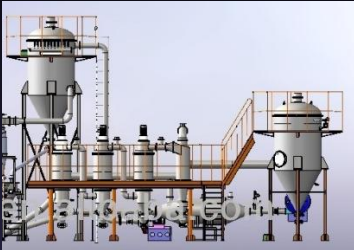
Cold Spray – A Metal Working Process



Powder Delivery Chain

Production

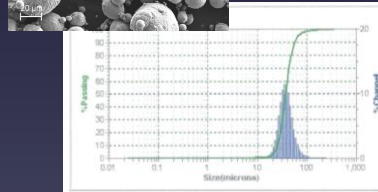
- Process
- Quality
- Certification



Chemical and Physical Characteristics of Valimet Spherical Aluminum Powder Specifications										
	H-2	H-3	H-5	H-10	H-15	H-30	H-50	H-60	H-95	
Aluminum, wt. %, min.	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7	
Valine, wt. %, max.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
Oil & Grease, wt. %, max.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
Iron, wt. %, max.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
APS (Fisher) min.	2.0	3.0	4.5	8.0	14.0	20.0				
APS (Fisher) max.	3.0	4.5	7.0	12.0	18.0	30.0				
Sieve Analysis										
-40, wt. %										100
-100, wt. %, min.										95.0
-200, wt. %										10.0
-325, wt. %										15.0
90%	7.5	10.5	15.0	22.0	40.0	58.0	92.0	101.0	160.0	
50%	3.5	4.5	8.0	12.0	20.0	31.0	55.0	70.0	108.0	
10%	1.8	2.0	4.0	6.0	9.0	15.0	30.0	44.0	73.0	

Processing

- Characterization
- Quality Control
- Preparation



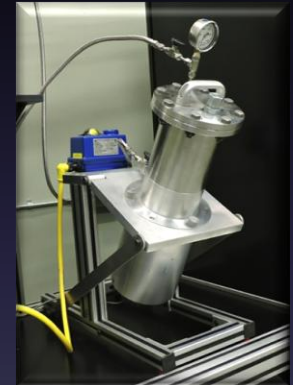
Delivery

- Packaging
- Loading
- Efficiency



Feeding

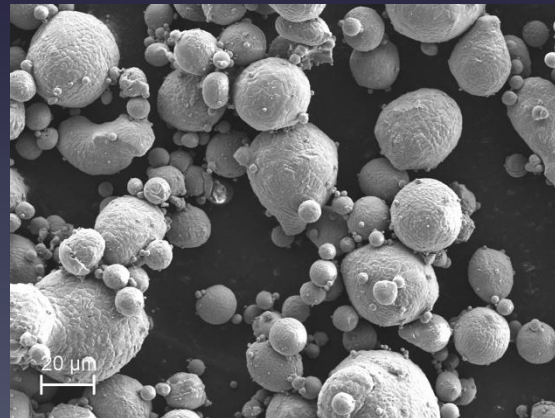
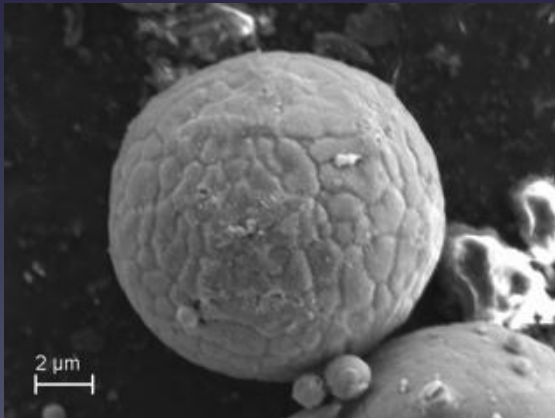
- Control
- Consistency
- Efficiency



Bottom Line: The quality of the coating depends on controlling the process

Powder Characterization

- Essential Powder Testing
 - Micro or Nano Hardness Measurement
 - SEM Images
 - Microtrack – Particle Size Analysis



Understanding Powders

- **Particle Size**
 - Affects Particle Velocity and Temperature
- **Size Distribution**
 - Affects the range of velocities and temperatures of impacting particles
 - Very Fine Particles $< 5 \mu\text{m}$ can promote nozzle clogging or coating defects
- **Shape**
 - Affects Particle Velocity
- **Density**
 - Porous Powders may contribute to voids/pores in coating
- **Hardness**
 - Affects Critical Velocity – Can usually be changed by heat pre-treatments

Powder Modifications

- **Powder Classification**

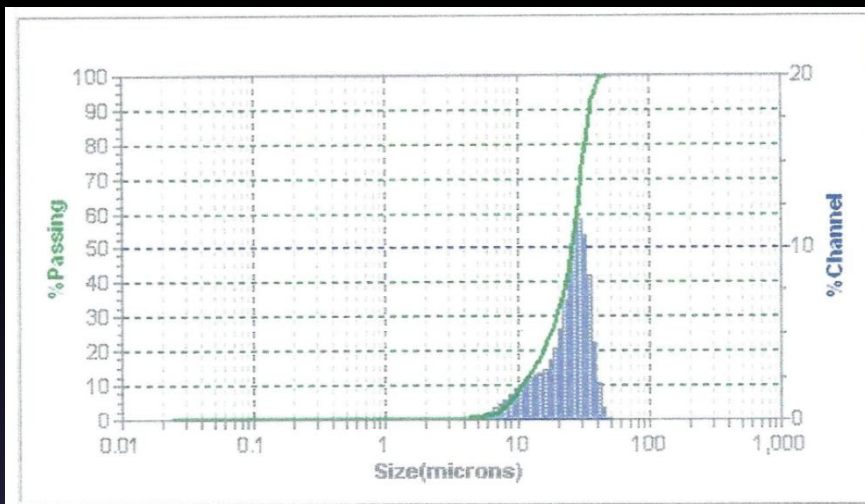
- Cut Request from Vendor
- Manual or Automatic Sieving of Powder on Site
- Gas Classification - Elutriation

- **Heat Treatment**

- Removes adsorbed water vapor above 100°C
- Can be used to anneal, age, or stress relieve powders
- At high temperatures and reducing environments powders can be degassed or depassivated.

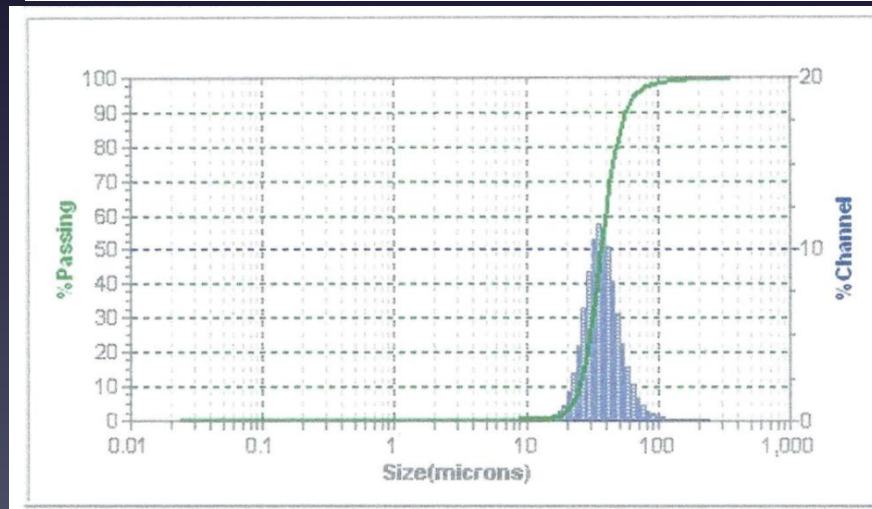
Powder Classification

2024 Aluminum Powder
Prior To Sizing



Summary		Percentiles		Size Percent	
Data Item	Value	%Tile	Size(um)	Size(um)	%Tile
MV(um):	24.72	10.00	11.09		
MN(um):	8.88	20.00	15.70		
MA(um):	19.81	30.00	20.11		
CS:	3.03E-01	40.00	23.34		
SD:	10.02	50.00	25.90		
Mz:	24.50	60.00	28.09		
SDg:	9.50	70.00	30.27		
Ski:	-0.18188	80.00	32.71		
Kg:	24.71	90.00	35.86		
		95.00	38.43		

2024 Aluminum Powder
After Sizing



Summary		Percentiles		Size Percent	
Data Item	Value	%Tile	Size(um)	Size(um)	%Tile
MV(um):	42.1	10.00	25.47		
MN(um):	20.27	20.00	29.09		
MA(um):	35.38	30.00	31.94		
CS:	1.70E-01	40.00	34.56		
SD:	11.83	50.00	37.25		
Mz:	38.83	60.00	40.22		
SDg:	12.87	70.00	43.76		
Ski:	0.2791	80.00	48.71		
Kg:	43.87	90.00	57.57		
		95.00	68.41		

Other Considerations

- **Ball Milling**

- Can be used to affect particle morphology
- Can also add cold work to a powder



- **Mixing**

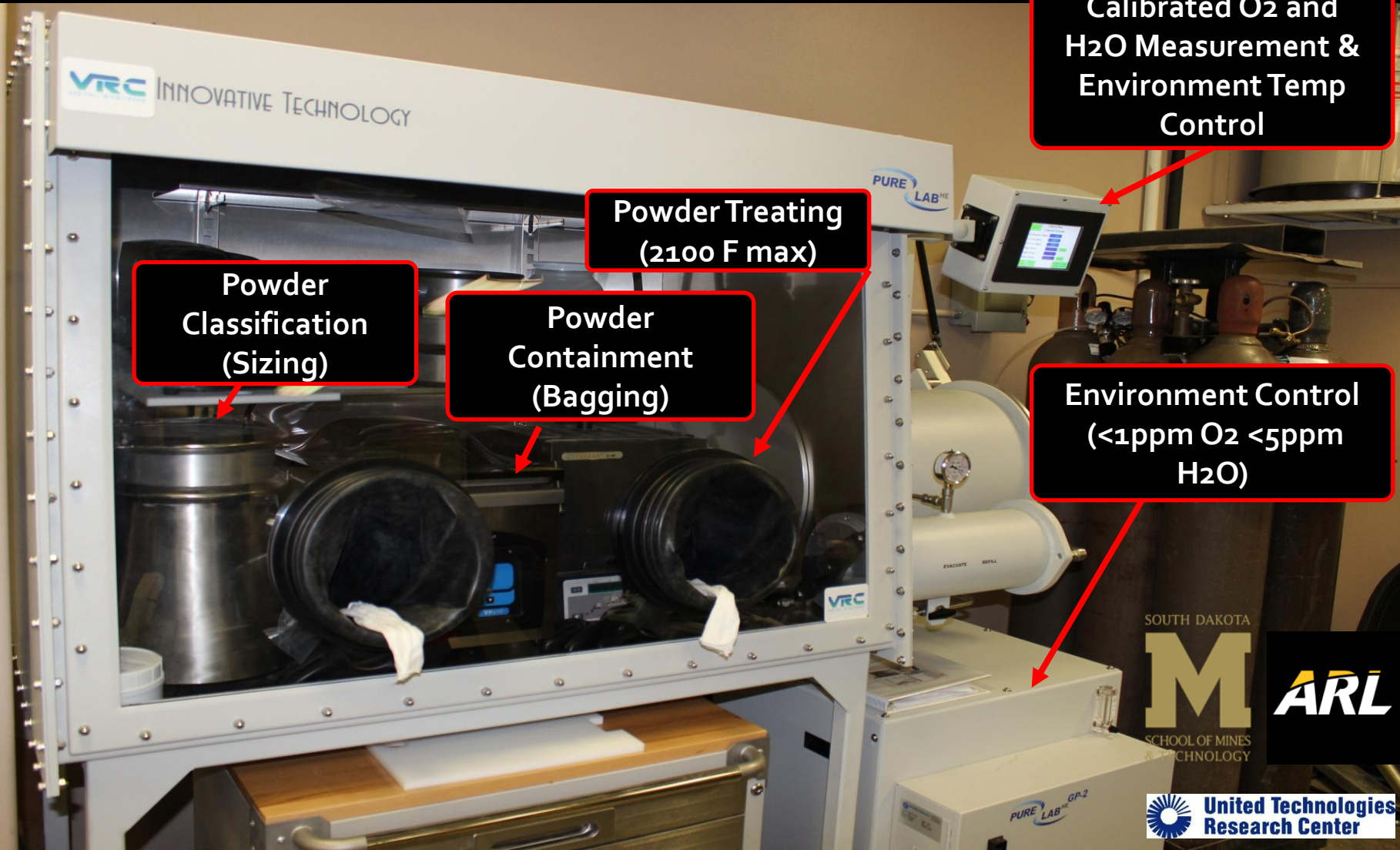
- Emulate Alloy
- Improve Properties – Wear Resistance, Corrosion Resistance, Adhesion, etc

- **Quality Control**

- Packaging and Handling



Powder Treatment Equipment at VRC



Powder Loading Equipment at VRC

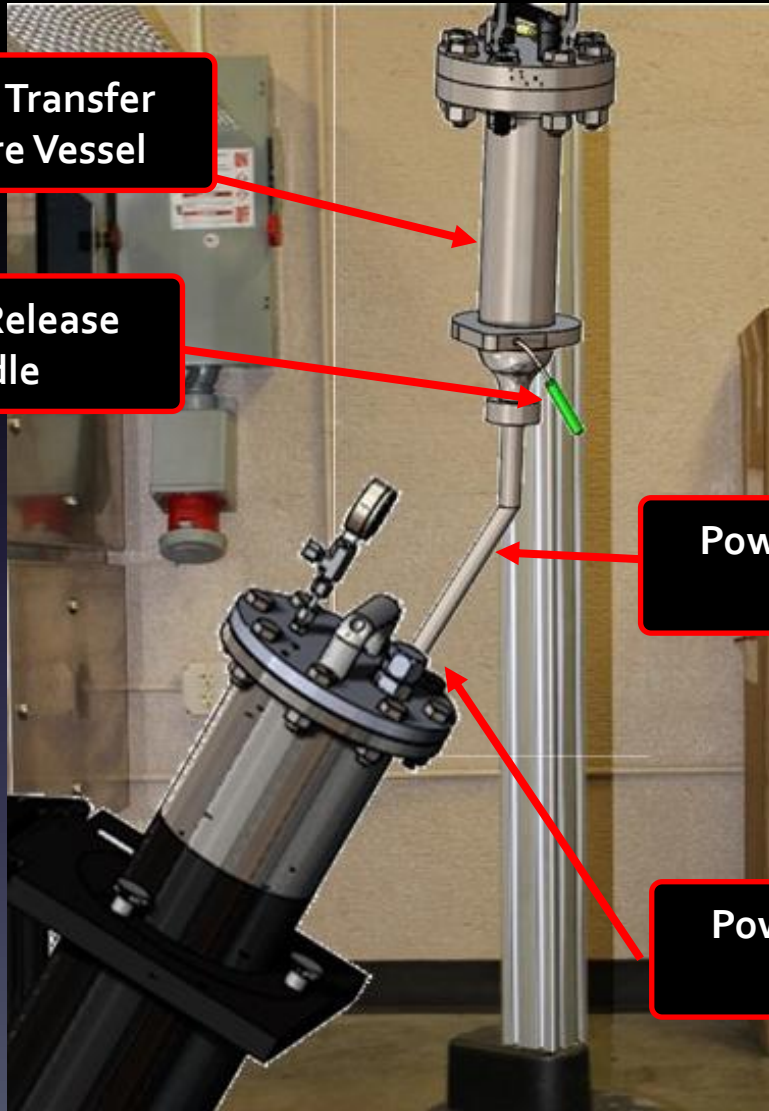
Powder Transfer
Pressure Vessel

Powder Release
Handle

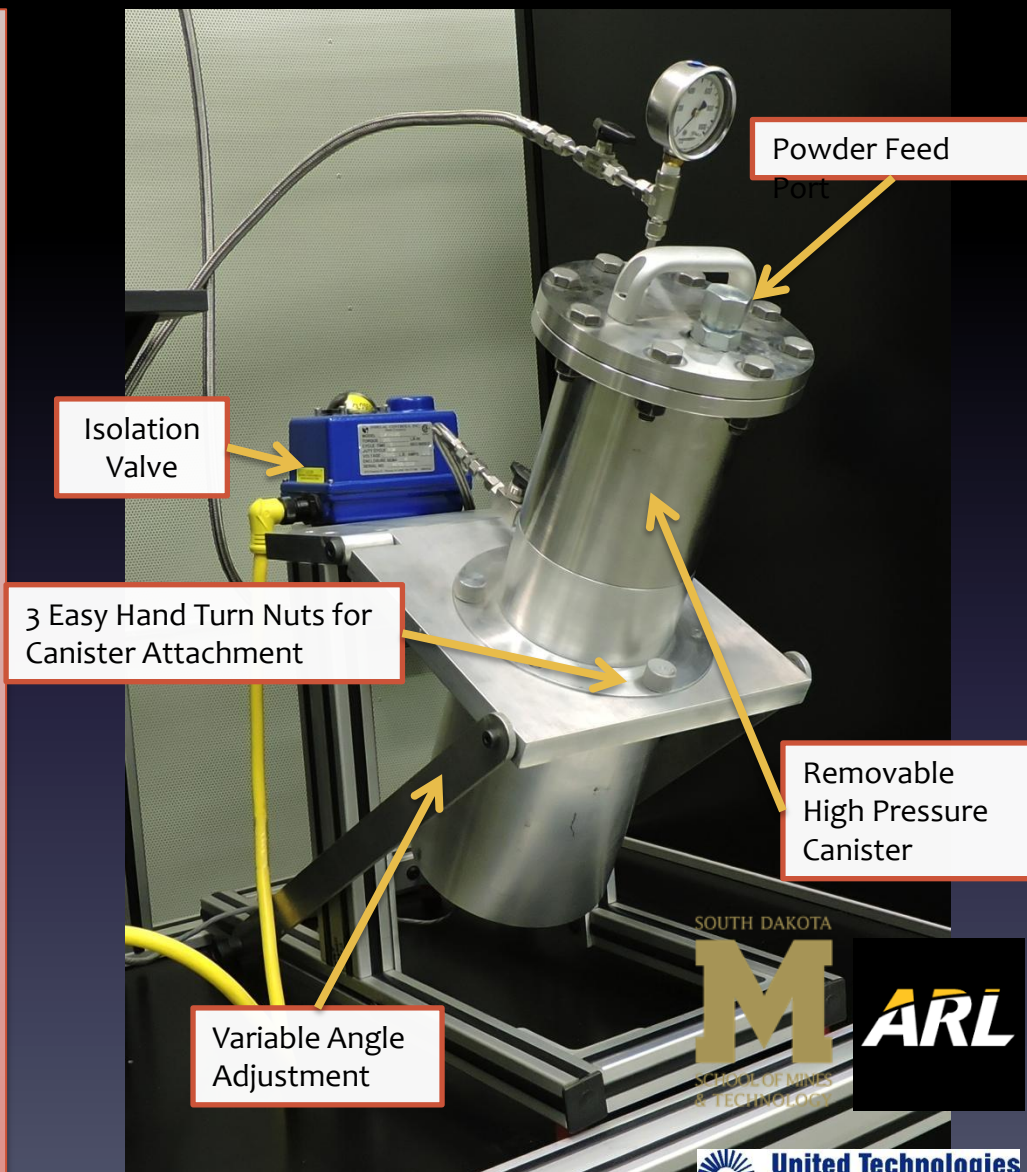
Processed Powder
Packaging

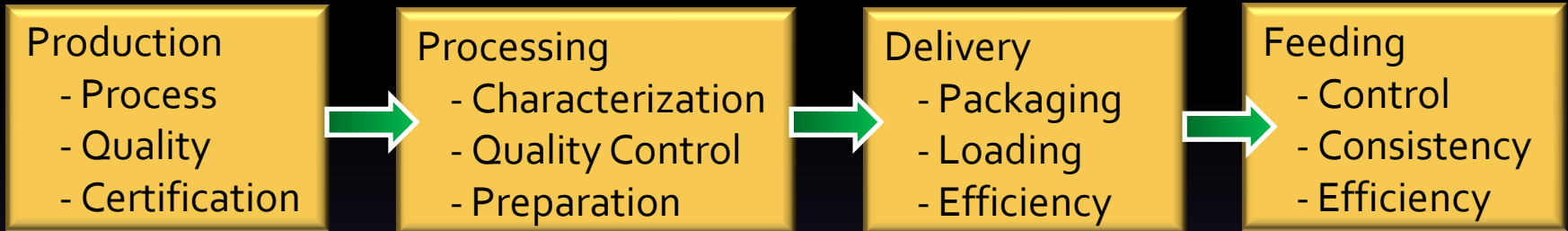
Powder Transfer
Tube

Powder Transfer
Port



1. Ultra-High Pressure
 - 1000 psi (70 bar)
2. Removable Light Weight Canister for Easy Cleaning
 - < 22 lbs (10 kg)
3. Powder Feeder Tumbles Powder
 - Mixes powder while running to avoid separation
4. Powder Feed Port
 - Add powder while running or to avoid air exposure
5. Licensed Powder Feeder
 - United Technologies Research Center
 - Tumbles powder for better mixing
6. Powder Feed Isolation Valve
7. Variable Speed Control with Closed Loop Feedback
8. Weight Loss Option Available





End Product: Consistent High Quality Cold Spray Coatings



“MAKING METALS WORK”

www.vrcmetalsystems.com